INVESTMENT GRADE ENERGY AUDIT REPORT

Agra Nagar Nigam, Uttar Pradesh

Submitted by

Energy Efficiency Services Limited

Submitted To

Agra Nagar Nigam

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ACKNOWLEDGMENT

We are sincerely thankful to the Ministry of Urban Development, Government of India for including energy audits to achieve energy efficiency under the reforms of Atal Mission for Rejuvenation and Urban Transformation (AMRUT). We are also extremely thankful to the "Department of Urban Development, Government of Uttar Pradesh" for taking up the reform on priority basis with Energy Efficiency Services Limited (EESL) and signing the agreement on 09th Feb 2017 for preparation of Investment Grade Energy Audit (IGEA) reports for its AMRUT Mission and Smart Mission for Cities & Towns. We acknowledge the support and guidance provided by the following Central and State Government officials:

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- Shri R K Mishra, Director of Urban Local Bodies, Department of Urban Development, Govt. of Uttar Pradesh, Lucknow
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- Shri Shrkishan D. Bhattad (EA-5460)
- Shri Prashant Deshpande (EM-4793)

On Behalf of Energy Efficiency Services Limited

Mr. Tarun Tayal, Regional Manager, EESL - UP

Executive Summary

Background of the Project

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) was launched by Prime Minister of India in June 2015 with the objective of providing basic services (e.g. water supply, sewerage, urban transport) to households and build amenities in cities which will improve the quality of life for all.

To facilitate market transformation and replicate Municipal Energy Efficiency Programme on a large scale in India, Ministry of Urban Development (MoUD), Government of India signed a Memorandum of Understanding (MoU) with Energy Efficiency Services Limited (EESL), a joint venture under Ministry of Power, Government of India on 28th September 2016 under AMRUT. This will enable replacement of inefficient pump sets in Public Water Works & Sewerage Systems (PWW&SS) with energy efficient pump sets with no upfront cost to the Municipal Bodies. The investment will be recovered in form of fixed annuity.

Energy audit and optimizing energy consumption are mandatory reforms under AMRUT. EESL and "Department of Urban Development, Government of Uttar Pradesh" have jointly entered into an agreement on 9th February, 2017 in order to provide an overarching framework to facilitate engagement between State Government and various ULBs (covered under AMRUT) of Uttar Pradesh. Under this agreement, EESL is undertaking the project to replace old inefficient pump sets by energy efficient pump sets in Agra City of Uttar Pradesh.

Description of Facilities

Agra is located on the banks of the Yamuna River. Water for Agra is drawn from Yamuna River at following locations:

- Jeoni Mandi
- Sikandara

There are 4 Water treatment plants which supply treated water to Agra city. There are 3 nos water treatment plant of 90 MLD, 20 MLD & 10 MLD capacities at Jeoni Mandi and 1 nos water treatment plant of 144 MLD at Sikandara. Clear water from Water Treatment Plants is distributed through different Water Distribution Zonal Pumping Stations divided among three zones. Description of facility and water pumping stations of Agra is provided in table below:

Description of facility and water storage capacity

S. No	Facility Name & Location	Source of water	Number of pumps	MLD Capacity	Type of Storage	Number of Reservoir/Clarifier	No. of OHT
1	Old Intake Well	River	3	225 MLD (From Jeoni Mandi Water Treatment Plant)	Intake well	0	0
2	New Intake Well	River	3		Intake well	0	0
3	New Jal Nigam Intake Well	River	3		Intake well	0	0
4	HT Plant (Golkamra)	Jeoni Mandi WTP	3		Clear Water	1	0

S. No	Facility Name & Location	Source of water	Number of pumps	MLD Capacity	Type of Storage	Number of Reservoir/Clarifier	No. of OHT
5	Synchronous Plant	Jeoni Mandi WTP	2		Clear Water	1	0
6	8 VT Plant	Jeoni Mandi WTP	7		Clear Water	1	0
7	Flowmore plant	Jeoni Mandi WTP	5		Clear Water	1	0
8	Sanjay Place ZPS	Sikandra WTP	10	6.9 MLD	Clear Water	1	0
9	Kotwali ZPS	Jeoni Mandi WTP	5	3.15MLD	Clear Water	1	1
10	Surya Nagar ZPS	Sikandra WTP	5	3.49 MLD	Clear Water	1	0
11	Mathura Road ZPS	Sikandra WTP	4	3.63MLD	Clear Water	2	0
12	Trans Yamuna	Jeoni Mandi WTP	2	0.8MLD	Clear Water	1	0
13	Lawyer's Colony ZPS	Sikandra WTP	4	1.03MLD	Clear Water	1	2
14	Nirbhay Nagar ZPS	Sikandra WTP	2	0.4MLD	Clear Water	1	0
15	Lohamandi ZPS	Sikandra WTP	5	5.73MLD	Clear Water	2	1
16	Keshavkunj ZPS (Bodla ZPS)	Sikandra WTP	5	3.8MLD	Clear Water	1	0
17	Shahganj Phase-1 ZPS	Sikandra WTP	8	8.5MLD	Clear Water	2	1
18	Shahganj Phase-2	Sikandra WTP	5	4.54MLD	Clear Water	1	0
19	Kedar Nagar	Sikandra WTP	3	0.605 MLD	Clear Water	1	1
20	Tajganj ZPS	Jeoni Mandi WTP	6	3.55MLD	Clear Water	2	0
21	Rakabganj ZPS	Jeoni Mandi WTP	5	5.05MLD	Clear Water	2	1
22	Navlakha ZPS	Jeoni Mandi WTP	4	7.95MLD	Clear Water	1	0
23	Chhipitola Booster	Jeoni Mandi WTP	2	1.5MLD	Clear Water	0	1
24	Red Fort Booster	Jeoni Mandi WTP	1	NA	Clear Water	0	0

Summary of Performance Evaluation of Pumpsets

Based on the measurement and analysis carried out during the energy audit, the pump and pump set efficiencies for all pumping stations have been estimated. The summary of results is provided in the table below.

Pump range and Efficiency evaluation metrics:

Sr. no	Pump type	Pump capacity range (kW)	Weighted average pump efficiency (%)	Weighted average pump set efficiency (%)
8 VT Plant, Water Works, Jeoni Mandi				
1	VT	> 200 kW	39.98%	35.41%
Flowmore plant				
1	VT	150-200 kW	87.13%	83.09%
Old Intake Well, Jeoni Mandi				
1	VT	150-200 kW	37.36%	35.12%
New Intake Well, Jeoni Mandi				
1	VT	150-200 kW	45.29%	42.57%
New Jal Nigam Intake well, Jeoni Mandi				
1	VT	125-149 kW	36.90%	34.50%
Sanjay Place				
1	VT	31-45 kW	39.89%	36.30%
2	VT	61-90 kW	46.85%	42.87%
Kotwali ZPS				
1	VT	16-30 kW	66.48%	59.83%
2	VT	31-45 kW	20.01%	18.21%
Surya Nagar ZPS				
1	VT	16-30 kW	25.27%	22.74%
2	VT	31-45 kW	27.34%	24.88%
3	VT	91-125 kW	58.87%	54.75%
Mathura Road ZPS				
1	VT	31-45 kW	38.76%	35.28%
Trans Yamuna ZPS				
1	VT	16-30 kW	20.11%	18.10%
2	VT	31-45 kW	29.44%	26.79%
Lawyer's Colony ZPS				
1	VT	31-45 kW	47.39%	43.12%
Nirbhay Nagar ZPS				
1	VT	16-30 kW	78.98%	71.87%
Lohamandi ZPS				
1	VT	31-45 kW	NA	32.21%
2	VT	61-90 kW	55.40%	49.97%
Keshavkunj ZPS (Bodla ZPS)				
1	VT	31-45 kW	35.40%	41.38%
Shahganj Phase-1 ZPS				
1	VT	Up to 15 kW	37.67%	33.91%
2	VT	31-45 kW	44.51%	40.50%
3	VT	61-90 kW	18.99%	17.38%
4	VT	91-125 kW	42.43%	39.67%
Shahganj Phase-2				
1	VT	31-45 kW	43.43%	39.52%
2	VT	61-90 kW	56.77%	51.54%
Kedar Nagar				
1	VT	16-30 kW	65.89%	59.30%
Rakabganj ZPS				
1	VT	61-90 kW	40.34%	37.04%
Navlakha ZPS				
1	HSC	61-90 kW	73.38%	70.29%
2	HSC	125-149 kW	59.19%	56.70%
Chhipitola Booster				
1	HSC	16-30 kW	41.67%	37.51%

Performance Indicators

Along with estimation of efficiency of pump sets, performance indicators such as specific energy consumption was also evaluated for pumps in Agra. Details of performance indicators and other operating parameters is provided in the table below:

Performance Indicators of pump sets of 8 VT Plant:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
8 VT Plant	Pump-5	6&7 in parallel and 5 have separate pipe	21.77	200	1255	6,267	7,865,623	1,254,300	0.159	39.98%	37.18%
8 VT Plant	Pump-6		18.3	173	1281	2,550	3,267,546	441,212	0.135	39.47%	36.91%
8 VT Plant	Pump-7		19.9	217	1287	2,761	3,552,021	599,114	0.169	34.36%	32.13%
	Total			**590**	**3,823**	**11,578**	**6,819,567**	**2,294,626**			

Performance Indicators of pump sets of Flow More Plant:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Flow More Plant	Pump-3 200 kW	P2-200 kW - separate line, P3-200 kW and P2-93 kW in parallel	35	168	1,465	1,122	1,643,453	188,533	0.115	87.18%	83.09%

Performance Indicators of pump sets of Old Intake Well:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Old Intake Well	Pump-6	Not fixed depends on inlet source	13.17	230	2,249	4,775	10,737,383	1,096,579	0.102	37.36%	35.12%

Performance Indicators of pump sets of New Intake Well:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
New Intake Well	Pump-1	2W + 1SB	11.05	105	1,015	6,311	6,408,023	661,671	0.103	31%	29.14%
New Intake Well	Pump-2		12.05	134	2,079	6,679	13,887,971	892,321	0.064	54.33%	51.07%
New Intake Well	Pump-3		12.05	150	2,166	1,146	2,481,803	171,488	0.069	50.52%	47.49%
	Total			**388**	**5,261**	**14,136**	**22,777,797**	**1,725,480**			

Performance Indicators of pump sets of New Jal Nigam Intake Well:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
New Jal Nigam	Pump-2	1 working	12.06	96	1,113	4,091	4,553,116	391,767	0.086	40.82%	38.17%

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Intake well											
New Jal Nigam Intake well	Pump-3		12.01	115	1,080	3,583	3,870,126	410,544	0.106	32.98%	30.83%
	Total			**211**	**2,193**	**7,674**	**8,423,242**	**802,311**			

Performance Indicators of pump sets of Sanjay Place Pumping Station:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Sanjay Place, Maithan Side	Pump-1	1,2,5 in parallel. Pumps 3, 4 under breakdown	26.46	78	596	1,328	791,083	104,104	0.132	59.83%	54.75%
Sanjay Place, Maithan Side	Pump-2		25.06	61	522	1,278	666,643	78,380	0.118	63.43%	58.04%
Sanjay Place, Maithan Side	pump-5		20.79	38	292	1,330	388,913	50,853	0.131	47.57%	43.29%
Sanjay Place, Hariparv at Side	Pump-1	1,2,4 in parallel; separate	10.05	34	359	1,339	480,673	45,823	0.095	31.36%	28.72%

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Sanjay Place, Hariparv at Side	Pump-2	line from pump 5	14.19	36	343	1,150	394,074	41,270	0.105	40.54%	36.89%
Sanjay Place, Hariparv at Side	Pump-3		14.75	70	615	-	-	-	0.114	38.54%	35.26%
Sanjay Place, Hariparv at Side	Pump-4		13.29	61	574	1,339	767,863	81,414	0.106	37.31%	34.14%
Sanjay Place, Hariparv at Side	Pump-5(0)		51.8	44	99	1,341	133,308	58,471	0.439	35.15%	32.16%
	Total			**422**	**3,400**	**9,105**	**3,622,557**	**460,315**			

Performance Indicators of pump sets of Kotwali ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Kotwali ZPS	Pump-1	1, 2 in parallel - direct distribution. 4 for ESR filling.	5.79	28	232	702	163,004	19,565	0.12	14.44%	13.14%
Kotwali ZPS	Pump-2		6.49	32	424	702	297,601	22,607	0.076	25.58%	23.28%
Kotwali ZPS	Pump-4		31.89	27	186	1,625	302,157	43,862	0.145	66.48%	59.83%
	Total			**87**	**842**	**3,029**	**762,762**	**86,034**			

Performance Indicators of pump sets of Surya Nagar ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Surya Nagar ZPS	Pump-1	1, 3 & 4 or 2, 3 & 4 in parallel for direct distribution	12.42	14	111	392	43,336	5,565	0.128	29.27%	26.34%
Surya Nagar ZPS	Pump-2		10.89	21	136	549	74,518	11,543	0.155	21.27%	19.14%
Surya Nagar ZPS	Pump-3		11.02	36	297	510	151,368	18,260	0.121	27.34%	24.88%
Surya Nagar ZPS	Pump-4		21.48	121	1,132	930	1,053,372	112,565	0.107	58.87%	54.75%
	Total			**192**	**1,675**	**2,381**	**1,322,594**	**147,933**			

Performance Indicators of pump sets of Mathura Road ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Mathura Road ZPS	Pump-2	2, 3, 4 in parallel for direct distribution.	16.34	41	408	1,076	439,148	44,532	0.101	48.21%	43.87%
Mathura Road ZPS	Pump-3		15.19	28	150	726	108,725	20,033	0.184	24.67%	22.45%
Mathura Road ZPS	Pump-4		14.6	34	336	1,076	361,850	36,425	0.101	43.41%	39.51%
	Total			**103**	**894**	**2,878**	**909,723**	**100,990**			

Performance Indicators of pump sets of Trans Yamuna ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Trans Yamuna ZPS	Pump-1	Only no. 1 operates.	9.43	35	367	913	334,735	32,096	0.096	29.44%	26.79%
Trans Yamuna ZPS	Pump-2		5.37	14	179	-	-	-	0.081	20.11%	18.10%
	Total			**50**	**546**	**913**	**334,735**	**32,096**			

Performance Indicators of pump sets of Lawyers Colony ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Lawyer's Colony ZPS	Pump-1 (Lawyer's Colony)	2 in parallel for Lawyers' Colony, pump 1 for Dayal bagh	28.47	35	232	3,912	907,838	136,019	0.15	56.87%	51.75%
Lawyer's Colony ZPS	Pump-2 (Lawyer's Colony)		28.01	35	119	3,914	464,766	137,864	0.297	28.26%	25.71%
Lawyer's Colony ZPS	Pump-1 (Dayal Bagh ESR)		23.31	20	165	596	98,552	12,051	0.122	57.04%	51.91%
	Total			**90**	**516**	**8,422**	**1,471,156**	**285,934**			

Performance Indicators of pump sets of Nirbhay Nagar ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Nirbhay Nagar ZPS	Pump-1	Both in parallel	28.85	28	224	558	124,775	15,439	0.124	69.78%	63.50%
Nirbhay Nagar ZPS	Pump-2		31.32	21	199	557	110,658	11,760	0.106	88.18%	80.25%
	Total			**49**	**422**	**1,115**	**235,433**	**27,199**			

Performance Indicators of pump sets of Lohamandi ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Lohamandi ZPS	Pump-1 (Direct distribution)	1,3 in parallel - ESR filling; 1,2,4 in parallel for direct supply, 5 has separate pipe	15.2	53	580	616	357,692	32,591	0.091	49.66%	45.44%
Lohamandi ZPS	Pump-1 (ESR filling)		16.95	52	507	365	185,006	19,012	0.103	49.08%	44.91%
Lohamandi ZPS	Pump-2		22.57	73	665	612	407,301	44,845	0.11	61.01%	55.82%
Lohamandi ZPS	Pump-3		15.5	19	142	364	51,651	6,769	0.131	35.40%	32.21%
Lohamandi ZPS	Pump-4		17.23	72	945	919	868,293	66,033	0.076	67.45%	61.71%
Lohamandi ZPS	Pump-5		20.71	69	654	929	607,544	63,799	0.105	58.70%	53.71%
	Total			**337**	**3,493**	**3,805**	**2,477,487**	**233,049**			

Performance Indicators of pump sets of Keshavkunj ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Keshavkunj ZPS (Bodla ZPS)	Pump-1	1,2,3,4 in parallel for direct distribution	13	42	366	641	234,816	26,653	0.114	34.27%	31.19%
Keshavkunj ZPS (Bodla ZPS)	Pump-3		17.58	35	340	641	218,028	22,484	0.103	51.03%	46.43%
Keshavkunj ZPS (Bodla ZPS)	Pump-4		14.68	36	422	569	240,445	20,673	0.086	51.11%	46.51%
	Total			**230**	**2,195**	**2,492**	**1,375,908**	**144,930**			

Performance Indicators of pump sets of Shahganj Phase 1 ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Shahganj Phase-1 ZPS	Pump-1	1,2,4,5 for direct supply. One working in Subhash Park section.	11.79	65	352	807	283,989	52,489	0.185	18.99%	17.38%
Shahganj Phase-1 ZPS	Pump-2		12.61	34	396	807	319,811	27,123	0.085	44.51%	40.50%
Shahganj Phase-1 ZPS	Pump-4		13	114	1,440	807	1,162,656	91,933	0.079	47.89%	44.77%
Shahganj Phase-1 ZPS	Pump-5		14.2	63	559	807	451,444	50,506	0.112	36.97%	34.57%
Shahganj Phase-1 ZPS	Pump-2 (Subhash Park)		5.88	11	265	2,091	553,733	23,640	0.043	41.65%	37.49%

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Shahganj Phase-1 ZPS	Pump-3 (Subhash Park)		5.2	12	263	1,306	342,807	15,998	0.047	33.69%	30.33%
	Total			**299**	**3,274**	**6,625**	**3,114,440**	**261,689**			

Performance Indicators of pump sets of Shahganj Phase 2 ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Shahganj Phase-2	Pump-1	1,2,3,4 in parallel. Separate line for 5.	18.97	34	335	602	201,972	20,661	0.102	55.49%	50.49%
Shahganj Phase-2	Pump-2		10.13	38	393	602	236,381	22,855	0.097	31.36%	28.54%
Shahganj Phase-2	Pump-3		23.67	69	553	602	332,940	41,308	0.124	56.77%	51.95%
Shahganj Phase-2	Pump-4		21.33	68	729	602	438,855	41,199	0.094	67.63%	61.88%
Shahganj Phase-2	Pump-5		22.47	66	439	3,682	1,617,204	242,519	0.15	44.59%	40.80%
	Total			**275**	**2,449**	**6,090**	**2,827,352**	**368,542**			

Performance Indicators of pump sets of Kedar Nagar ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Kedar Nagar	Pump-1		29.36	26	204	726	148,395	19,086	0.129	69.08%	62.17%

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Kedar Nagar	Pump-2	Only 1 pump operates	28.84	26	190	1,312	248,861	34,635	0.139	62.70%	56.43%
	Total			**53**	**394**	**2,038**	**397,256**	**53,721**			

Performance Indicators of pump sets of Rakabganj ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Rakabganj ZPS	Pump-2	2, 4 in parallel. Separate line for 5.	5.07	77	792	700	554,761	53,741	0.097	15.17%	14.26%
Rakabganj ZPS	Pump-4		22.06	67	529	764	404,598	51,112	0.126	51.98%	47.56%
Rakabganj ZPS	Pump-5		18.07	70	704	864	608,370	60,742	0.1	53.88%	49.30%
	Total			**250**	**2,323**	**2,483**	**1,613,872**	**171,159**			

Performance Indicators of pump sets of Navlakha ZPS:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Navlakha ZPS	Pump-2	2&4 in parallel operation but have separate pipe	31.47	137	995	767	763,662	105,393	0.138	64.82%	62.10%
Navlakha ZPS	Pump-3		35.57	148	784	2,998	2,349,557	443,586	0.189	53.56%	51.31%
Navlakha ZPS	Pump-4		35.57	63	460	327	150,557	20,748	0.138	73.38%	70.29%
	Total			**348**	**2,239**	**4,092**	**3,263,776**	**569,727**			

Performance Indicators of pump sets of Chhipitola Booster:

Location	Pump Reference	Operating Pattern	Total head (m)	Measured power consumption (kW)	Pumping quantity (m^3/hour)	Estimated annual operating hours (hour/annum)	Estimated quantity pumped per annum (KL)	Estimated annual power consumption (kWh/annum)	Estimated SEC (kW/kL)	Pump efficiency (%)	Pump set efficiency (%)
Chhipitola Booster	Pump-1	1 working	19.29	18	119	332	39,526	6,078	0.154	37.96%	34.16%
Chhipitola Booster	Pump-2		18.29	11	90	1,623	146,220	17,830	0.122	45.39%	40.85%
	Total			**29**	**209**	**1,955**	**185,746**	**23,908**			

Summary of Project Cost Benefit Analysis

The energy saving has been calculated on the basis of energy audit activity conducted at the pumping stations. Consequently, feasibility of individual projects has been discussed with ULB officials and different pump manufactures. The energy saving of this project has been calculated on the basis of the technical information shared by the manufacturers (for the recommended equipment) and operating information shared by pumping station personnel. The estimated energy saving is provided in the table below:

Summary of Energy efficiency measures identified during the audit

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
	Pumping System				
1	Replacement of Pump-5 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	645,356	19.92	51.31	5
2	Replacement of Pump-6 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	193,443	19.92	15.38	16
3	Replacement of Pump-7 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	330,890	19.92	26.31	9
4	Replacement of Pump-6 at Old Intake Well, Jeoni Mandi with energy efficient pump set	541,292	28.62	43.03	8
5	Replacement of Pump-1 at New Intake Well, Jeoni Mandi with energy efficient pump set	327,674	20.97	26.05	10
6	Replacement of Pump-2 at New Intake Well, Jeoni Mandi with energy efficient pump set	115,611	35.90	9.19	47
7	Replacement of Pump-2 at New Jal Nigam Intake well, Jeoni Mandi with energy efficient pump set	175,275	20.97	13.93	18
8	Replacement of Pump-3 at New Jal Nigam Intake well, Jeoni Mandi with energy efficient pump set	220,904	20.97	17.56	14

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
9	Replacement of Pump-5 at Sanjay Place, Maithan Side. with energy efficient pump set	16,828	8.73	1.34	78
10	Replacement of Pump-1 at Sanjay Place, Hariparvat Side. with energy efficient pump set	19,532	10.92	1.55	84
11	Replacement of Pump-4 at Sanjay Place, Hariparvat Side. with energy efficient pump set	38,445	17.15	3.06	67
12	Replacement of Pump-5(0) at Sanjay Place, Hariparvat Side. with energy efficient pump set	32,014	8.18	2.55	39
13	Replacement of Pump-1 at Kotwali ZPS with energy efficient pump set	12,405	5.75	0.99	70
14	Replacement of Pump-2 at Mathura Road ZPS with energy efficient pump set	19,447	10.86	1.55	84
15	Replacement of Pump-3 at Mathura Road ZPS with energy efficient pump set	13,637	6.39	1.08	71
16	Replacement of Pump-1 at Trans Yamuna ZPS with energy efficient pump set	16,341	8.80	1.30	81
17	Replacement of Pump-1(Lawyer's Colony) at Lawyer's Colony ZPS with energy efficient pump set	35,946	8.73	2.86	37
18	Replacement of Pump-2(Lawyer's Colony) at Lawyer's Colony ZPS with energy efficient pump set	86,044	8.20	6.84	14
19	Replacement of Pump-1 at Shahganj Phase-1 ZPS with energy efficient pump set	37,113	9.42	2.95	38
20	Replacement of Pump-5 at Shahganj Phase-2 with energy efficient pump set	109,617	12.11	8.71	17
21	Replacement of Pump-2 at Rakabganj ZPS with energy efficient pump set	31,695	14.52	2.52	69

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
22	Replacement of Pump-3 at Navlakha ZPS with energy efficient pump set	154,038	9.07	12.25	9
23	Replacement of Pump-2 at Chhipitola Booster with energy efficient pump set	7,119	2.50	0.57	53
	Subtotal	**3,180,667**	**328.53**	**252.86**	**16**
	Auxiliary loads				
24	Installation of APFC panel at Sanjay Place	-	6.49	9.76	8
25	Installation of APFC panel at Kotwali ZPS	-	1.73	2.07	10
26	Installation of APFC panel at Surya Nagar ZPS	-	2.88	4.07	9
27	Installation of APFC panel at Mathura Road ZPS	-	1.73	3.48	6
28	Installation of APFC panel at Trans Yamuna ZPS	-	1.01	0.19	63
29	Installation of APFC panel at Lawyer's Colony ZPS	-	1.95	3.42	7
30	Installation of APFC panel at Nirbhay Nagar ZPS	-	1.01	0.15	82
31	Installation of APFC panel at Lohamandi ZPS	-	3.61	6.14	7
32	Installation of APFC panel at Keshavkunj (Bodla) ZPS	-	5.19	1.39	45
33	Installation of APFC panel at Shahganj Phase-1 ZPS	-	5.77	16.44	4
34	Installation of APFC panel at Shahganj Phase-2	-	4.33	5.53	9
35	Installation of APFC panel at Kedar Nagar	-	1.01	1.19	10
36	Installation of APFC panel at Tajganj ZPS	-	6.13	3.08	24

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
37	Installation of APFC panel at Rakabganj ZPS	-	3.61	5.14	8
38	Installation of APFC panel at Navlakha ZPS	-	3.24	6.75	6
39	Installation of capacitor at Chhipitola Booster	-	0.18	0.25	9
40	Installation of capacitor at Red Fort Booster	-	0.05	0.04	17
	Subtotal	-	**49.91**	**69.09**	**9**
41	Replacement of existing lighting equipment at Old Intake Well with LED lamps	525.6	0.03	0.04	10
42	Replacement of existing lighting equipment at New Intake Well with LED lamps	411.72	0.02	0.03	6
43	Replacement of existing lighting equipment at New Jal Nigam Intake Well with LED lamps	2,312.64	0.10	0.18	7
44	Replacement of existing lighting equipment at Synchronous with LED lamps	192.72	0.01	0.02	7
45	Replacement of existing lighting equipment at Flowmore Plant with LED lamps	1,020.54	0.03	0.08	5
46	Replacement of existing lighting equipment at 8 VT Plant with LED lamps	617.58	0.03	0.05	6
47	Replacement of existing lighting equipment at Sanjay Place with LED lamps	1,787.04	0.32	0.14	27

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
48	Replacement of existing lighting equipment at Kotwali ZPS with LED lamps	1,300.86	0.18	0.10	21
49	Replacement of existing lighting equipment at Surya Nagar ZPS with LED lamps	4,673.46	0.71	0.37	23
50	Replacement of existing lighting equipment at Mathura Road ZPS with LED lamps	44,67.6	0.89	0.36	30
51	Replacement of existing lighting equipment at Trans Yamuna ZPS with LED lamps	227.76	0.02	0.02	12
52	Replacement of existing lighting equipment at Lawyer's Colony ZPS with LED lamps	502.24	0.10	0.04	29
53	Replacement of existing lighting equipment at Nirbhay Nagar ZPS with LED lamps	1,419.12	0.29	0.11	31
54	Replacement of existing lighting equipment at Lohamandi ZPS with LED lamps	487.64	0.03	0.04	8
55	Replacement of existing lighting equipment at Keshavkunj ZPS with LED lamps	459.9	0.04	0.04	14
56	Replacement of existing lighting equipment at Shahganj-1 ZPS with LED lamps	1949.1	0.30	0.15	23
57	Replacement of existing lighting equipment at Shahganj Phase-2 ZPS with LED lamps	398.58	0.03	0.03	10
58	Replacement of existing lighting equipment at Kedar Nagar with LED lamps	889.14	0.08	0.07	13
59	Replacement of existing lighting equipment at Tajganj ZPS with LED lamps	779.64	0.11	0.06	20
60	Replacement of existing lighting equipment at Navlakha ZPS with LED lamps	2409	0.54	0.19	34

Sl. No.	Energy Efficiency Measures (EEM)	Annual Energy Savings (kWh/annum)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)
61	Replacement of existing lighting equipment at Chhipi Tola ZPS with LED lamps	551.88	0.02	0.04	5
62	Replacement of existing lighting equipment at Red Fort Booster with LED lamps	718.32	0.01	0.06	2
	Subtotal	**28,102**	**3.85**	**2.23**	**21**
TOTAL		**3,208,769**	**332.39**	**255.10**	**16**

Under maintenance pump sets, which were not repaired during energy audit period, were not taken up for measurement, analysis and subsequent implementation in this report.

Implementation of the energy efficiency measures on pumping system may result in annual energy savings of 3,180,667 kWh per year which is 44.27% of the existing electricity consumption. This energy saving is equivalent to 273.5 toe and results in reduction 2608.07 tCO_2 per year.

Apart from pumping system, opportunities for electricity and cost savings were identified in auxiliary systems such as lighting and reactive power compensation system. ULB may implement recommendation identified for auxiliary systems which may result in annual energy savings of 28,102 kWh per year.

Project Financials and proposed Business Model

Total Project cost (CAPEX)

The following are the key components considered while arriving at the total project cost:

i. Cost of pump, motor and other accessories (like NRV and gate valve), discovered through a transparent bidding process;

ii. Cost of dismantling, installation and commissioning including testing charges, discovered through a transparent bidding process;

iii. Project Establishment and Supervision charges of EESL at 5 % of total cost of equipment including installation;

iv. Cost of preparation of IGEA, as per actual tendered cost, plus EESL's service charge at 15%;

v. All applicable goods and services tax as on actual basis; and

vi. Capitalized interest during the Project Implementation Period.

Details of project capital cost is provided in the table below:

Project Capital Cost

Capital Cost Related assumption	Unit	Value
Number of Pumps	*No.*	23
Total Cost of Equipment including installation, commissioning and testing	*INR lakhs*	328.53
Cost of pump including motor	*INR lakhs*	260.92
Cost of NRV	*INR lakhs*	20.57
Cost of Gate valve	*INR lakhs*	23.29
Cost of Web based dashboard	*INR lakhs*	1.77
Installation and Commissioning Cost including testing charges	*INR lakhs*	21.99
EESL's administrative and establishment charge	*%*	5.0%
Cost of preparation of IGEA report including EESL service charges and applicable GST	*INR lakhs*	22.04
Total Project Cost w/o Capitalized interest	*INR lakhs*	367.00
Commissioning Details		
Total Months for Commissioning	*Months*	9
Capitalized interest	*INR lakhs*	20.57
Total Project Cost	*INR lakhs*	387.58

Operating Costs (OPEX)

The following are the key components considered while arriving at the operating cost for the project

i. Project Establishment and Supervision charges of EESL at 4% of total project cost, with annual escalation of 5%; and

ii. Actual incurred Repair & Maintenance charges, discovered through a transparent bidding process.

Details about project operating cost is provided in the table below.

Project Operating Cost

Operational Details	Unit	Value
EESL's administrative and establishment charges	%	4%

Financing Terms and other tax related assumptions

The following are the key financial assumptions used in developing the model. Financing terms and tax related assumptions are provided in the table below:

Parameters	Unit	Value
Term of the project	*years*	7
Financing Details		
Debt Percentage	%	70%
Cost of Debt	%	11%
Equity Percentage	%	30%
Cost of Equity (post- tax)	%	16%
Tax Details		
Corporate Tax	**%**	34.61%
Goods and Services Tax	%	18%

Output - Annuity Payment to EESL

Based on the cost parameters and assumptions mentioned above, the annuity payment to EESL was computed. Details of annuity payment to EESL are provided in the table below.

Annuity payment to EESL

Year	Unit	1	2	3	4	5	6	7	Total
Calculations of annuity payment									
Total Debt to be repaid	*INR lakh*	67.00	62.74	58.48	54.21	49.95	45.69	41.42	379.48
Principal Repayment	*INR lakh*	38.76	38.76	38.76	38.76	38.76	38.76	38.76	271.30
Interest	*INR lakh*	28.24	23.98	19.72	15.45	11.19	6.93	2.66	108.18
Total Equity Repayments	*INR lakh*	43.54	39.47	35.41	31.34	27.28	23.21	19.15	219.40
Recovery of equity investment	*INR lakh*	16.61	16.61	16.61	16.61	16.61	16.61	16.61	116.27
Return on equity	*INR lakh*	26.93	22.86	18.80	14.73	10.67	6.60	2.54	103.13
R&M Charges	*INR lakh*	0.00	6.57	8.21	9.86	11.50	13.14	13.14	62.42
EESL's administrative and establishment charge	*INR lakh*	15.50	16.28	17.09	17.95	18.84	19.79	20.78	126.23
Annuity Payment to EESL	*INR lakh*	126.04	125.06	119.19	113.36	107.57	101.83	94.49	787.53
Goods and Services Tax on annuity payment	*INR lakh*	22.69	22.51	21.45	20.40	19.36	18.33	17.01	141.76
Annuity Payment to EESL incl. all applicable taxes	*INR lakh*	148.73	147.57	140.64	133.76	126.93	120.16	111.50	929.29
ULB Savings									
Total Savings	*INR lakh*	252.86	260.42	268.01	275.63	283.25	290.84	298.37	1929.38
Profit to ULB	*INR lakh*	104.13	112.85	127.37	141.87	156.31	170.68	186.88	1000.09
% of savings with ULBs	%								**51.83%**

Sensitivity analysis

The sensitivity analysis has been conducted to determine the impact of change in capital cost and change in savings on the percentage of monetary share of accrued savings retained by the ULB. Project sensitivity analysis is provided in the table below.

Project sensitivity analysis

Change in Capital Cost	% savings retained by the utility
-10%	56.27%
-5%	54.05%
0%	51.83%
5%	49.62%
10%	47.40%
Change in Interest(ROE, Interest, D/E ratio)	**% savings retained by the utility**
-10%	46.48%
-5%	49.30%
0%	51.83%
5%	54.13%
10%	56.21%

Key facts of IGEA

Particular	Unit	Value
Total number of pump sets as per LOA	Nos.	103
Total number of pump sets under maintenance	Nos.	21
Total number of pump sets where measurement was not possible	Nos.	17
Total number of pump sets audited	Nos.	65
Total numbers of pumps sets considered for replacement	Nos.	23
Estimated present annual energy consumption (for 23 pump sets)	kWh	7,184,344
Estimated annual energy consumption with proposed EEPS (for 23 pump sets)	kWh	4,003,677
Percentage energy saving potential	%	44.27%
Total project cost (including IGEA cost and capitalized interest)	Rs. Lakhs	387.58

Pre – implementation annual energy consumption (baseline) and post implementation annual energy consumption will be estimated based proposed Measurement and Verification (M & V methodology).

Pumps not considered for replacement:

Of the 65 pump sets audited, 42 are not being considered for replacement. Of the 42, 8 nos. were observed to be operating at efficiencies above 60% as given in table below. These pumps have limited scope for savings and long payback periods.

Sr No	Location	Pump no.	Pump set efficiency	Annual operating hours
1	Flowmore plant	Pump 3 - 200 kW	83.09%	1,122

Sr No	Location	Pump no.	Pump set efficiency	Annual operating hours
2	Nirbhay Nagar	Pump 1	63.50%	558
3	Nirbhay Nagar	Pump 2	80.25%	557
4	Lohamandi	Pump 4	61.71%	919
5	Shahganj Phase-2	Pump 4	61.88%	602
6	Kedar Nagar	Pump 1	62.17%	726
7	Navlakha	Pump 2	62.10%	767
8	Navlakha	Pump 4	70.29%	327

In case of the remaining 34 pumps, their operating hours were found to be relatively less. Majority of the pumps in the Zonal Pumping Stations operate for less than 4 hours a day. As a result of limited operating hours, their payback period was found to be high.

Rated and operating parameters of pump sets to be installed under this project along with other accessories are provided in the table below:

Key facts of pump sets to be replaced under this project

Pump Identification				Rated parameters			Operating parameters (individual operation)				Accessories to be installed		
Pump house	Pump Reference	Pump type	Fluid handled	Flow (m3/hour)	Head (m)	Motor rating (kW)	Flow (m3/hour)	Total head (m)	Actual power consumption (kW)	Pump set efficiency (%)	NRV to be installed (Yes/No)	Gate valve to be installed (Yes/No)	Apparatus for Web based dashboard (Yes/No)
8 VT Plant													
8 VT Plant, Water Works, Jeoni Mandi	Pump-5	Vertical turbine	Water	1226	53	260	1255	22	200	37.18%	Yes	Yes	Yes
8 VT Plant, Water Works, Jeoni Mandi	Pump-6	Vertical turbine	Water	1212	47	220	1281	18	173	36.91%	Yes	Yes	Yes
8 VT Plant, Water Works, Jeoni Mandi	Pump-7	Vertical turbine	Water	1212	47	220	1287	20	217	32.13%	Yes	Yes	Yes
Old Intake Well													
Old Intake Well, Jeoni Mandi	Pump-6	Vertical turbine	Water	3180	15	185	2249	13	230	35.12%	No	No	Yes
New intake Well													
New Intake Well, Jeoni Mandi	Pump-1	Vertical turbine	Water	2460	16	150	1015	11	105	29.14%	Yes	Yes	Yes
New Intake Well, Jeoni Mandi	Pump-2	Vertical turbine	Water	3180	16	180	2079	12	134	51.07%	Yes	Yes	Yes
New Jal Nigam intake Well													
New Jal Nigam Intake well, Jeoni Mandi	Pump-2	Vertical turbine	Water	1950	16	132	1113	12	96	38.17%	Yes	Yes	Yes
New Jal Nigam Intake well, Jeoni Mandi	Pump-3	Vertical turbine	Water	1950	16	132	1080	12	115	30.83%	Yes	Yes	Yes

Pump Identification				Rated parameters			Operating parameters (individual operation)				Accessories to be installed		
Pump house	Pump Reference	Pump type	Fluid handled	Flow (m3/hour)	Head (m)	Motor rating (kW)	Flow (m3/hour)	Total head (m)	Actual power consumption (kW)	Pump set efficiency (%)	NRV to be installed (Yes/No)	Gate valve to be installed (Yes/No)	Apparatus for Web based dashboard (Yes/No)
Sanjay Place													
Sanjay Place, Maithan Side.	Pump-5	Vertical turbine	Water	324	30	37	292	21	38	43.29%	Yes	Yes	Yes
Sanjay Place, Hariparvat Side.	Pump-1	Vertical turbine	Water	300	35	37	359	10	34	28.72%	Yes	Yes	Yes
Sanjay Place, Hariparvat Side.	Pump-4	Vertical turbine	Water	648	30	75	574	13	61	34.14%	Yes	Yes	Yes
Sanjay Place, Hariparvat Side.	Pump-5(0)	Vertical turbine	Water	NA	NA	67	99	52	44	32.16%	Yes	Yes	Yes
Kotwali													
Kotwali ZPS	Pump-1	Vertical turbine	Water	324	30	37	232	6	28	13.14%	Yes	Yes	Yes
Mathura Road													
Mathura Road ZPS	Pump-2	Vertical turbine	Water	300	35	37	408	16	41	43.87%	Yes	Yes	Yes
Mathura Road ZPS	Pump-3	Vertical turbine	Water	300	35	37	150	15	28	22.45%	Yes	Yes	Yes
Trans Yamuna													
Trans Yamuna ZPS	Pump-1	Vertical turbine	Water	300	32	37	367	9	35	26.79%	No	No	Yes
Lawyers' Colony													
Lawyer's Colony ZPS	Pump-1 (Lawyer's Colony)	Vertical turbine	Water	270	34	37	232	28	35	51.75%	Yes	Yes	Yes

Pump Identification				Rated parameters			Operating parameters (individual operation)				Accessories to be installed		
Pump house	Pump Reference	Pump type	Fluid handled	Flow (m3/hour)	Head (m)	Motor rating (kW)	Flow (m3/hour)	Total head (m)	Actual power consumption (kW)	Pump set efficiency (%)	NRV to be installed (Yes/No)	Gate valve to be installed (Yes/No)	Apparatus for Web based dashboard (Yes/No)
Lawyer's Colony ZPS	Pump-2 (Lawyer's Colony)	Vertical turbine	Water	270	34	37	119	28	35	25.71%	Yes	Yes	Yes
Shahganj Phase-1													
Shahganj Phase-1 ZPS	Pump-1	Vertical turbine	Water	600	32	75	352	12	65	17.38%	Yes	Yes	Yes
Shahganj Phase-2													
Shahganj Phase-2	Pump-5	Vertical turbine	Water	600	31	75	439	22	66	40.80%	Yes	Yes	Yes
Rakabganj													
Rakabganj ZPS	Pump-2	Vertical turbine	Water	648	30	75	792	5	77	14.26%	Yes	Yes	Yes
Navlakha													
Navlakha ZPS	Pump-3	HSC	Water	1200	35	160	784	36	148	51.31%	Yes	Yes	Yes
Chhipitola Booster													
Chhipitola Booster	Pump-2	HSC	Water	140	30	20	90	18	11	40.85%	Yes	Yes	Yes

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ABBREVIATIONS

ANN	Agra Nagar Nigam
AMRUT	Atal Mission Rejuvenation and Urban Transformation
APFC	Automatic Power Factor Control
ATS	Autotransformer starter
BEP	Best Efficiency Point
BPS	Booster Pumping Stations
CEA	Certified Energy Auditor
DRA	DRA Consultants Limited
DSM	Demand Side Management
DVVNL	Dakshinanchal Vidyut Vitaran Nigam Limited
EC	Energy Conservation
EE	Energy Efficiency
EEM	Energy Efficiency Measure
EEPS	Energy Efficient Pump Set
EESL	Energy Efficiency Services Limited
FY	Financial Year
HT	High Tension
HSC	Horizontal Split Casing
IGEA	Investment Grade Energy Audit
kVA	Kilo Volt Ampere
kW	Kilowatt
kWh	kilowatt Hour
LED	Light Emitting Diode
LT	Low Tension
MEEP	Municipal Energy Efficiency Programme
MoUD	Ministry of Urban Development
MoU	Memorandum of Understanding
OHT	Over Head Tank
O&M	Operation and Maintenance
PF	Power Factor
PS	Pumping Station
PWW&SS	Public Water Works & Sewerage Systems
RPM	Rotations Per Minute
R&M	Repair & Maintenance
ROE	Return on Equity
SEC	Specific Energy Consumption
SHPSC	State level High Powered Steering Committee
SLTC	State Level Technical Committee
SPS	Sewerage Pumping Station
STP	Sewerage Treatment Plant
TOE	Tonne of oil equivalent
ULB	Urban Local Body
UM	Under Maintenance
VFD	Variable Frequency Drive
WTP	Water Treatment Plant
ZPS	Zonal Pumping Station

1 Introduction

1.1 Background of the Project

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) was launched by Prime Minister of India in June 2015 with the objective of providing basic services (e.g. water supply, sewerage, urban transport) to households and build amenities in cities which will improve the quality of life for all.

To facilitate market transformation and replicate Municipal Energy Efficiency Programme on a large scale in India, MoUD, Government of India signed a MoU with Energy Efficiency Services Limited (EESL), a joint venture under Ministry of Power, Government of India on 28th September, 2016 under AMRUT. This will enable replacement of inefficient pumpsets in Public Water Works & Sewerage Water Systems with energy efficient pumpsets at no upfront cost to the Municipal Bodies. The investment will be recovered in form of fixed annuity.

Energy audit and optimizing energy consumption are mandatory reforms under AMRUT. EESL "Department of Urban Development, Government of Uttar Pradesh" have jointly entered into an agreement on 9th February, 2017 in order to provide an overarching framework to facilitate engagement between state government and various ULBs (covered under AMRUT) of Uttar Pradesh. Under this agreement, EESL is undertaking the project to replace old inefficient pumpsets by energy efficient pumpsets in Agra City of Uttar Pradesh.

According to MoUD, energy auditsfor improving energy use is one of the mandated reforms under the AMRUT and this initiative would help the cities significantly. “This will substantially reduce costs of operation of water supply schemes and public lighting that will ultimately benefit the citizens. EESL willbe promotinguse of energy efficiency programmes across the country and will ensure supply of latest technologiesunder these municipal programmes".

Energy cost accounts for 40 to 60 % of cost only for water supply in urban areas and energy efficiency interventions can reduce this cost by 20 to 40 %, depending on the type and age of pumpsetsbeing used for bulk water supply. By becoming energy efficient, ULBs can reap annually up to 4,800 MU and Rs.3,200 Crores besides avoiding the need for 3,300 MW of power.

Necessary interventions would be undertaken by EESL without any financial burden on ULB as cost of the proposed Municipal Energy Efficiency Programmes would be borne out of annuity. MoU states that performance contracting offers a mechanism for ULB to finance these projects without upfront investment.

As per the MoU, EESL will develop overall strategy for taking up energy efficiency projects in urban areas by implementation of energy efficient pumpsets in public water works and sewage systems.

EESL will provide or arrange project funding for implementation as required and will procure energy efficient equipment and materials in a transparent manner besides ensuring repair and maintenance services for the goods replaced and installed by it.EESL is in the process of implementing energy efficient pumps for 500 cities under AMRUT scheme of Government of India. After the agreement between “Department of Urban Development, Government of Uttar Pradesh” and EESL was signed successfully on 09th February 2017, EESL initiated an open tendering process for hiring Energy Auditing Agency through competitive bidding. Based on the bidding evaluation, M/s DRA Consultants Ltd. (DRA) was selected for doing the energy audit for Agra city.EESL has engaged DRA for preparation of (IGEA) reports for Public Water Works and Sewerage Systems (PWW&SS) with an objective to replace inefficient pump sets with efficient ones vide its work order Ref:.: EESL/06/2016-17/Energy Audit/Uttar Pradesh/01-61/LOA-1617379/10258 dated 28th March 2017.

1.2 Stakeholders Involved

There are many stakeholders involved in AMRUT. Their roles and responsibilities are already defined by the MoUD and other technical committee. Generally, the MoUD, EESL and ULB have major role to execute under AMRUT.

MoUD: The MoUD committee may co-opt any representative from any Government Department or organization as Member or invite any expert to participate in its deliberations. Key roles of MoUD include:

i. Allocation and release of funds to the States/UTs/Mission Directorate.
ii. Overall monitoring and supervision of the Mission.
iii. Advise to the State/UT/implementing agencies on innovative ways for resource mobilization, private financing and land leveraging.
iv. Confirm appointment of organizations, institutions or agencies for third party monitoring.

Department of Urban Development: “Department of Urban Development, Government of Uttar Pradesh” was setup to ensure the proper implementation and monitoring of the centrally assisted programme. DUD provides technical support to districts/towns to achieve their targets and also help in monitoring the state training plan. They also provide guidance and supervise the programme implementation through visits to the project sites.

ULB: At the City level, the ULB will be responsible for implementation of the Mission. The Municipal Commissioner will ensure timely preparation of all the required documents.The ULBs will ensure city level approvals of IGEA and bid documents and forward these to the State level Technical Committee (SLTC)/ State level High Powered Steering committee (SHPSC) for approvals. The ULB will also be responsible for building coordination and collaboration among stakeholders for timely completion of projects without escalation of project cost.

SLTC: SLTC may co-opt member(s) from other State Government Departments/Government organizations and may also invite experts in the field to participate in its deliberations.

EESL: Ministry of Power has set up Energy Efficiency Services Limited (EESL), a Joint Venture of NTPC Limited, PFC, REC and POWERGRID to facilitate implementation of energy efficiency projects. It will promote energy efficiency programmes across the country and will ensure supply of energy efficient equipment under this municipal programme. Necessary interventions would be undertaken by EESL without any financial burden on ULBs as cost of the proposed Municipal Energy Efficiency Programmes would be borne out of annuity payments. EESL has been doing various Energy Efficient Programmes, list of same is provided below:

1. Domestic Appliances Programme (LED Bulbs, LED Tube lights, Fans, etc.)
2. Street Lighting National Programme
3. Agricultural Demand Side Management
4. Municipal Energy Efficiency Programme
5. Atal JyotiYojana(Solar LED Street Lights)

Energy Auditing Agency - DRA: EESL has engagedDRA for preparation of IGEA reports for public water works in Agra, Uttar Pradeshwith an objective to replace inefficient pump sets with energy efficient ones. DRA had conducted energy audit activity at Agra and had made IGEA with financial projections for AgraULB.

Pump Suppliers and Manufacturers: EESL has selectively taken on-board range of pump manufacturers and enquired with themregarding the necessary specifications of the products which can be used in line with the defined criteria according to EESL. All these manufacturers are rated manufacturers and comply with the quality and standards of their products.

1.3 Objective of the IGEA

Energy costs account for 40 to 60% of cost for water supply in urban areas and energy efficiency interventions can reduce this cost by 20 to 40 %, depending on the type and age of pumpsets being used for Public Water Works and Sewerage Systems (PWW&SS). The MoUD with support from EESL has designed framework project for Energy Efficiency in cities of India while giving priority to AMRUT and smart cities. The objective of this project and IGEA report is to provide maximum information for creating baseline and analysis of current energy and utilization of Public water works systems.

Thisproject is to be co-implemented by EESL and the objectives of this project are as under:

- To create increased demand for EE investments by adopting a ULB approach to facilitate the development of customized EE products and financing solutions in ULB.
- To raise the quality of EE investment proposals from a technical and commercial perspective.
- To expand the use of existing guarantees mechanisms for better risk management by EESL to catalyze additional commercial finance for energy efficiency.
- To establish a monitoring and evaluation system for the targeted ULB.

Scope of Work of Detailed Energy Audit

The general scope of work for detailed energy audits under IGEA as per Schedule 'A' is as follows:

- Discussion with Key personnel and Site visits of the facility
  - Initial discussions with Key personnel such as Commissioner, Chief Officer, Electrical/Mechanical engineer and pump operators to explain the objectives of the project,benefits of energy efficiency, and the approach that will be followed in Energy Audit.
  - Purpose of these discussion will be to ensure that key personnel of ULB have adequate understanding of the project.
  - Visiting all the facilities within the scope of project by identified agency to ascertain the availability of data and system complexity.
  - Identified agency will formulate a data collection strategy.
- Data Collection
  - Current energy usage (month wise) for all forms of energy for the last three years (quantity and cost)
  - Mapping of process
  - ULB and pumping station profile including name of station, years in operation, total water quantity pumped in last three years
  - List of major pumping equipment and specifications
- Analysis
  - Energy cost and trend analysis
  - Energy quantities and trend analysis
  - Specific consumption and trend analysis
  - Pumping costs trend analysis
  - Scope and potential for improvement in energy efficiency
- Detailed process mapping to identify major areas of energy use
- To identify all areas for energy saving (with or without investment) in the following areas:
  - Electrical: Power factor management, transformer loading, power quality tests, motor load studies, lighting load, electrical metering, monitoring and control system
  - Water usage and pumping efficiencies (including water receipt, storage, distribution, utilization, etc.), pump specifications, break down maintenance
- Classify parameters related to EE Enhancements such as estimated quantum of energy saving, investment required, time frame for implementation, payback period and to classify the same in order of priority
- Undertake detailed financial analysis of the investments required for EE enhancements
- Design "Energy Monitoring System" for effective monitoring and analysis of energy consumption, energy efficiency.

- Correlate monthly pumping quantity data with electricity consumption for a period of last three years of normal operation for individual sections of the overall pumping station
- Recommend a time bound action plan for implementation
- The broad content of the IGEA report should be as follows:
    - **Executive summary:** Provides brief description of the facilities covered, measures evaluated, analysis methodology, results and a summary table presenting the cost and savings estimates for each recommended measure. It also includes a summary of the recommended measures and costs as well as the financial indicators of the Project.
    - **Background:** Background about the ULB and the project.
    - **Facility Description:** Details of the existing facilities targeted, such as water treatment & supply systems, sewage treatment and handling systems.
    - **Energy Scenario:** Energy consumption details of all facilities included in the audit and their energy sources.
    - **Baseline parameters and Adjustments:** Methodology followed in establishing the baseline parameters and criteria.
    - **Data Collection**: List the various types of data collected and their sources.
    - **System mapping**: Describe the methodology followed for system mapping and include the maps and process flow diagrams in the report.
    - **List of Potential EEMs:** A list of all identified measures with estimates of the savings and payback periods on investments, and a summary of the selected EEMs chosen for further development.

1.4 Methodology adopted for Energy Audit

A detailed energy audit was conducted at all the pumping stations falling under Agra Nagar Nigamfrom 1st to 28th May 2017. The energy audit team of DRA comprised of BEE certified energy auditors/managersand pump experts. During the field visit, adequatenumber of portable energy audit instruments were used to carry out measurements of pumpsets efficiency parameters. In addition to this, design and operational data was collected from logbooks, equipment manuals and pump manufacturers. Discussions were held with various technical and operating staffs of the ULBto understand the system and pumpsets operations and requirements completely. The energy audit study mainly focused on the evaluation of operational efficiency/performance of the pumpsets already installed in the premise from the energy conservation point of view.

The methodology planned for accomplishing the above scope of work was divided into three phases as detailed below:

Phase 1: Inception

- Conduct kick-off meeting
- Pilot visit to a few sites to ascertain the availability of data, measurements points and system complexity
- Discussed and finalized the methodology for data collection as per job card.

Phase 2: Detailed energy audit

- Initial meeting with concerned staff of ULBat each site to brief them regarding the project
- Walk-through of the site along with pumping station/site personnel to understand the site conditions and equipment involved

- Assessment of data availability (historical data/technical data sheets of major equipment/maintenance practices/cost details/electricity bills, etc.) and placing request for required data
- Finalization of measurement points and support required from ULB staff
- Conducting measurements and data collectionwith support from ULBstaff
    - Energy auditing instruments used during project are listed below:
        - Power analyser: For electrical parameters(V, A, kW, kVA, kWh, kVAh, PF, Hz and THD)
        - Ultrasonic flow meter: For water flow measurement
        - Ultrasonic thickness gauge: For pipeline thickness measurement
        - Digital pressure gauges: For suction and discharge pressure measurement
        - Lux meter: For lighting intensity measurement
    - Filling& signing of job cards
    - Parallel activities of noting observations on the following:
        - SLD (Site Layout Diagram) & PID
        - Operation &Maintenance practices
        - Instrumentation in place and
        - Existing practices to monitor energy consumption.

Phase 3: Analysis and IGEA report preparation

- Compilation and analysis of data collected from site
- Performance assessment of the equipment
- Conceptualization and development of energy cost reduction projects
- Cost benefit analysis
- Review of adequacy of instrumentation for energy efficiency monitoring and
- Submission of IGEA report to ULB/ SLTC for approval.

2 Interaction with Facilities/ Key Personnel

The energy auditing team interacted for work proceeding and reporting with stakeholders for efficient information exchange. The kick-off meeting was held at Agra Jal Sansthan, General Manager's Office, near Water Works Chouraha, Jeoni Mandi, Agra, on 3rd April, 2017 for discussing the data/information required, methodology to be followed and support required from the ULB.The ULB appointed its staff to provide support and information during energy audit. DRA has provided day wise reporting to appointed staff of ULB regarding work status. Based on the work experience with ULB, inception report was submitted to EESL.

During the kick-off meeting and pre-site visit on 3rd April, 2017 following points were discussed:

- Support from the ULB will be given to the DRA team for conducting energy audit
- Energy audit will be conducted by DRA team in presence of EESL personnel and nodal official of ULB.
- Observations will be discussed with the appointed official of ULB and EESL
- DRA can communicate with ULB official regarding scheduling of sites for audit
- Support will be provided by ULB to obtain various data to create baseline of energy consumption, quantity of water pumped, etc.
- The letter of site activity conducted should be collected by DRA after finishing the site work
- DRA will regularly report the ULB official by informing the status of work and work schedule
- The site work completion letter should contain the information of pumps measured and those under maintenance
- DRA will report the status of work on a daily basis to project-coordinator of EESL
- DRA will submit the job card to EESL after completion of site work
- Signature of authorized personnel should be obtained on the job card in case of non-availability of data

EESL also appointed theirstaff to monitor audit works and to provide support and guidance for better quality of work flow. The appointed staff from EESL have been trained for the information exchange and toprovide maximum support for the site to be ready for energy audit. The appointed staff of EESL held periodicdiscussionwith DRA team members regarding the observation of energy audit and feasibility of EE projects at ULB.

2.1 Interaction with Pump Manufacturers

Some of the reputed pump manufacturers were selectively contacted regarding the costing and feasibility of different pumpsets. The discussion with pumpset manufacturers included the following points:

- Technical Feasibility of the suggested energy efficiency measures were discussed with the vendors.
- Commercial terms of EEM such as cost of equipment, auxiliary systems, and installation cost etc.were discussed with the vendors for assessing financial viability of EEM.

3 Project area and Facility description

3.1 General information about the city

Agra formerly known as Akbarabad is a city on the banks of the river Yamuna in the Northern state of Uttar Pradesh, India, 363 km west of state capital, Lucknow and 200 km south from national capital New Delhi. The modern city of Agra was founded in the 16th century by Sikandar Lodhi, who was a king of the Lodhi dynasty. It is one of the most populous cities in Uttar Pradesh and the 19th most populous in India. Agra district population grew by 21% in the decade 2001-11 and 31% in the decade 1991-2001. On the basis of landmass, Agra is the third largest city in the state of Uttar Pradesh. Agra is famous for its Historical monuments like Taj Mahal, Agra Fort, Sikandra, Fatehpur Sikri, etc. As per the previous Census, the population of Agra city is provided in the table 1.

Table 1: Population of Agra city[1]

Census Year	Population (Nos.)
2001	1,275,134
2011	1,585,704

3.2 Accessibility to city from Metro cities & State capital

Rail

Agra Cantonment and Agra Fort are two major railway stations in Agra. Agra is located around 200 km south of Delhi and is on the south-bound railway line from Delhi, as a result of which it is well-connected to Delhi and other metro cities such as Mumbai, Chennai, Bengaluru and Hyderabad. An east-west railway line through Agra Fort station provides connectivity to Jaipur.

Road

Agra is well connected by road to national capital New Delhi and other nearby major cities in Uttar Pradesh, as well as to Jaipur and other nearby districts in Rajasthan.

Air

Agra Airport (Kheria Airport) is about 12.5 km from city center.

[1] Source:https://www.citypopulation.de/php/india-uttarpradesh.php?adm2id=0915

3.3 Pumping Stations in the Agra city

Agra is located on the banks of the Yamuna River. Water for Agra is drawn from Yamuna River at following locations:

- Jeoni Mandi
- Sikandara

There are 4 Water treatment plants which supply treated water to Agra city. There are 3 nos water treatment plant of 90 MLD, 20 MLD & 10 MLD capacities at Jeoni Mandi and 1 nos water treatment plant of 144 MLD at Sikandara. Clear water from Water Treatment Plants is distributed through different Water Distribution Zonal Pumping Stations divided among three zones.

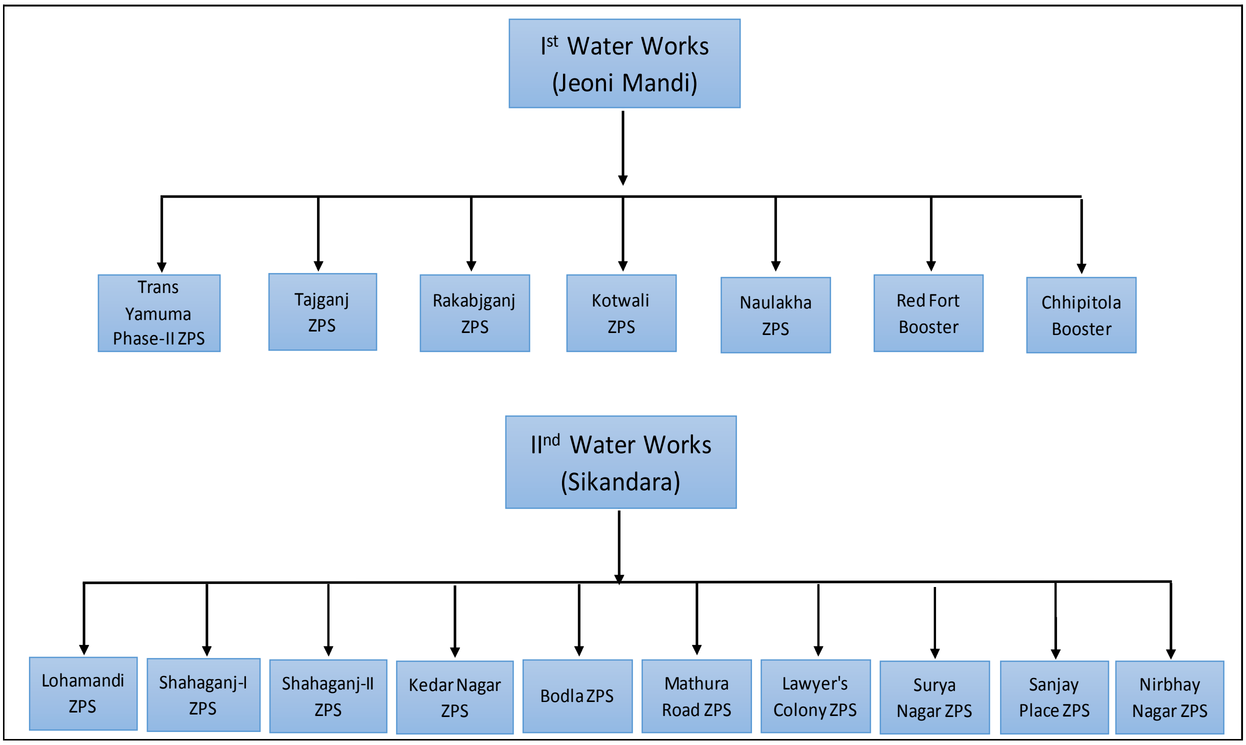


Figure 1 Water distribution system in Agra

The details of the water pumping stations are provided in the table below.

Table 2: Details of pumping stations

S. No	Name& Location of pump house	Capacity (MLD)	Type of the facility (Raw water/ WTP/Booster)	Source of water	Distribution/ Delivery area
1	Old Intake Well	225 MLD (From Jeoni Mandi Water Treatment Plant)	Raw water	River	Jeoni Mandi WTP
2	New Intake Well		Raw water	River	Jeoni Mandi WTP

S. No	Name& Location of pump house	Capacity (MLD)	Type of the facility (Raw water/ WTP/Booster)	Source of water	Distribution/ Delivery area
3	New Jal Nigam Intake Well		Raw water	River	Jeoni Mandi WTP
4	HT Plant (Golkamra)		WTP	Jeoni Mandi WTP	ZPS
5	Synchronous Plant		WTP	Jeoni Mandi WTP	ZPS
6	8 VT Plant		WTP	Jeoni Mandi WTP	ZPS
7	Flowmore plant		WTP	Jeoni Mandi WTP	ZPS, ESR
8	Sanjay Place ZPS	6.9 ML	Booster	Sikandra WTP	Hariparvat Rectangular, Mandi Syed Khan, Sanjay Place market
9	Kotwali ZPS	3.15ML	Booster	Jeoni Mandi WTP	Distribution, Moti Katra ESR
10	Surya Nagar ZPS	3.49 ML	Booster	Sikandra WTP	Direct distribution
11	Mathura Road ZPS	3.63ML	Booster	Sikandra WTP	Direct distribution
12	Trans Yamuna	0.8ML	Booster	Jeoni Mandi WTP	Trans Yamuna
13	Lawyer's Colony ZPS	1.03ML	Booster	Sikandra WTP	Lawyers' Colony ESR, Dayalbagh ESR
14	Nirbhay Nagar ZPS	0.4ML	Booster	Sikandra WTP	Nirbhay nagar ESR
15	Lohamandi ZPS	5.73ML	Booster	Sikandra WTP	Lohamandi ESR, direct distribution
16	Keshavkunj ZPS (Bodla ZPS)	3.8ML	Booster	Sikandra WTP	Keshavkunj ESR
17	Shahganj Phase-1 ZPS	8.5ML	Booster	Sikandra WTP	Subhash Park ESR, Rui ki Mandi, Police Lines
18	Shahganj Phase-2	4.54ML	Booster	Sikandra WTP	Direct distribution

S. No	Name& Location of pump house	Capacity (MLD)	Type of the facility (Raw water/ WTP/Booster)	Source of water	Distribution/ Delivery area
19	Kedar Nagar	0.605 ML	Booster	Sikandra WTP	Kedar Nagar/Shahganj-III
20	Tajganj ZPS	3.55ML	Booster	Jeoni Mandi WTP	Direct distribution
21	Rakabganj ZPS	5.05ML	Booster	Jeoni Mandi WTP	Rakabganj ESR/direct distribution
22	Navlakha ZPS	7.95ML	Booster	Jeoni Mandi WTP	Direct distribution
23	Chhipitola Booster	1.5ML	Booster	Jeoni Mandi WTP	Chhipitola ESR
24	Red Fort Booster		Booster	Jeoni Mandi WTP	Direct distribution

3.4 Historical Energy Consumption Data

Historical data about water pumped and energy consumption of Agra Nagar Nigam is provided below:

Table 3: Historical water pumped and energy consumption data for last three years

Description	Water flow (kL /Annum)	Energy consumption (kWh/Annum)	Specific energy consumption (kWh/kL)
Apr-2014 to Mar-2015	Not available	15,087,926	Not available
Apr-2015 to Mar-2016	Not available	15,295,692	Not available
Apr-2016 to Mar-2017	Not available	14,655,697	Not available

3.5 Power Failure Data

The power failure data was not available with ULB.

Table 4: Historical power failure data

Description	Power failure in Hours
March -16	Not available
April -16	Not available
May -16	Not available
June – 16	Not available
July -16	Not available

Description	Power failure in Hours
August – 16	Not available
September – 16	Not available
October – 16	Not available
November – 16	Not available
December -16	Not available
January -17	Not available
February -17	Not available
Average	Not available
Total	Not available

3.6 Rainfall and Climate data

Rainfall and climate data of Agra is provided in table 5.

Table 5: Rainfall and Climate data of Agra City[2]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Temp (°C)	27	31	37	42	45	44	38	35	37	38	33	29
Avg. Temp (°C)	22	25	32	38	41	41	35	32	34	33	28	23
Min Temp (°C)	14	16	23	30	34	34	30	37	28	26	21	16
Avg. Rain (mm)	0	0.4	14.2	0.4	17.3	50.92	381.31	337.41	30.18	0.4	0	0
Avg. rainy days	0	2	7	2	15	10	29	28	15	1	0	0

3.7 GroundWater Profile

In present scenario, complete water demand of Agra city is being met through water of Yamuna River and ULB is not using ground as a source of water. Data regarding net ground water availability of Agra district and allocation of different users is provided in table 6.

Table 6: Ground Water Profile[3]

Assessment Unit/ District	Net Annual Ground Water Availability (ha m)	Existing Gross Ground Water Draft for irrigation (ha m)	Existing Gross Ground Water Draft for domestic and industrial water supply (ha m)	Existing Gross Ground Water Draft for All uses (ha m)	Allocation for domestic, and industrial requirement supply up to next 25 years (ha m)	Net Ground Water Availability for future irrigation development (ha m)
Agra	82214.01	87857.93	5693.02	93550.95	9316.51	5191.97

[2]https://www.worldweatheronline.com/agra-weather-averages/uttar-pradesh/in.aspx
[3]Groundwater Year Book 2015-16 for Uttar Pradesh by Central Ground Water Board (CGWB)

3.8 Reservoir Levels at Different Seasons

The data regarding the water level of the reservoir for different seasons was not available with ULB

Table 7: Reservoir levels at different seasons[4]

Different seasons	Reservoir level
Summer	Not available
Winter	Not available
Monsoon	Not available

3.9 Water Cost Estimation

During energy audit, data regarding various operation and maintenance expenses borne by ULB was collected for estimating water cost. Details of expenditure by ULB during last year and estimated water cost is provided in the table 8.

Table 8: Water cost estimation

Particular	Units	Values
Energy Cost (Electricity)	Rs. Lakhs	1,673
Repair & maintenance	Rs. Lakhs	29.39
Operation (man power & raw materials)	Rs. Lakhs	161.44
Miscellaneous cost (Cost of major replacement)	Rs. Lakhs	430.55
Total Cost	Rs. Lakhs	2,293.95
Annual water pumped to city (estimated)	kL	82,853,541
Water cost	Rs./kL	2.77

[4]http://www.cgwrd.in/r-data/cat_view/1-reservoir-data/28-archive-2015.html

4 Pumping Stations Performance Evaluation

Agra gets drinking water supply from Yamuna River.Water is lifted at raw water pump stations and supplied to Jeoni Mandi and Sikandra WTPs. Treated water is then further supplied to pumping stations divided into three different zones, from where it is pumped directly into distribution or into overhead tanks. Details of pumping stations, layout and results of performance assessment are provided in subsequent sections of this chapter.

4.1 Connected load at pumping stations

Details of connected load of pumping stationsareas given below:

Table 9: Connected load details for pumping stations

Sr. no.	Location	Connected load - pump motors (kW)	Connected load – Auxiliaries (kW)	Total connected load (kW)
1	Old Intake Well	428	0.52	428.52
2	New Intake Well	515	0.38	515.38
3	New Jal Nigam Intake Well	396	0.74	396.74
4	Golkamra HT plant	980		980
5	Synchronous Plant	335	0.04	335.04
6	Flowmore Plant	768	0.695	768.695
7	8 VT Plant	1476	0.845	1476.845
8	Sanjay Place	590	2.046	592.046
9	Kotwali ZPS	102.5	0.905	103.405
10	Surya Nagar ZPS	227	4.333	231.333
11	Mathura Road ZPS	186	1.7	187.7
12	Trans Yamuna ZPS	54		54
13	Lawyer's Colony ZPS	148	0.36	148.36
14	Nirbhay Nagar ZPS	52	0.558	52.558
15	Lohamandi ZPS	337	0.5	337.5
16	Keshavkunj ZPS (Bodla ZPS)	221	0.395	221.395
17	Shahganj Phase-1 ZPS	409	0.917	409.917

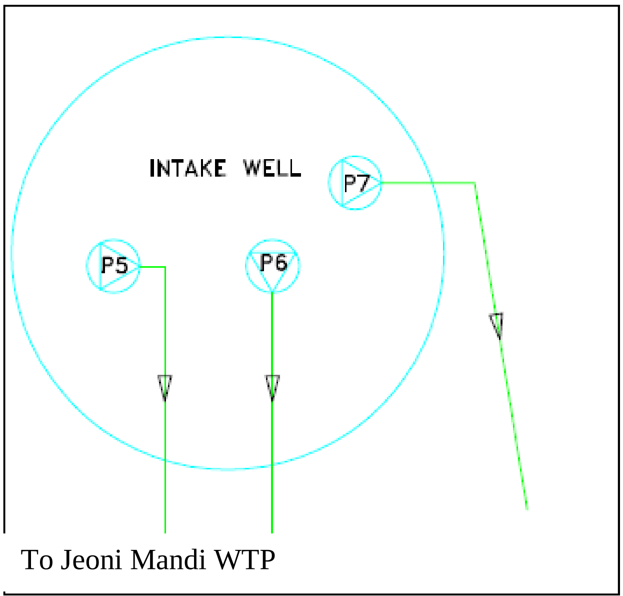
Sr. no.	Location	Connected load - pump motors (kW)	Connected load – Auxiliaries (kW)	Total connected load (kW)
18	Shahganj Phase-2	299	0.255	299.255
19	Kedar Nagar	90	1.165	91.165
20	Tajganj ZPS	312	0.3	312.3
21	Rakabganj ZPS	337	0.228	337.228
22	Navlakha ZPS	395	1.038	396.038
23	Chhipitola Booster	35	0.14	35.14
24	Red Fort Booster	7.5	0.1	7.6
Total		**5278**	**15.78**	**5293.78**

4.2 Old Intake Well, Jeoni Mandi

4.2.1 Overview of existing systems

The Old Intake Well lifts raw water from the Yamuna and feeds it to the Jeoni Mandi WTP. There are 3 VT pumps installed here.

Figure 2 Plant Layout for Old Intake Well



4.2.2 Electricity Supply

The Old Intake Well is a part of Jeoni Mandi scheme which receives HT supply from Torrent Power at 11 kV. Supply for the motors at Old Intake Well is stepped down throung a 315 kVA and a 630 kVA transformer to 415V. Single line diagram for Old Intake Well is provided below.

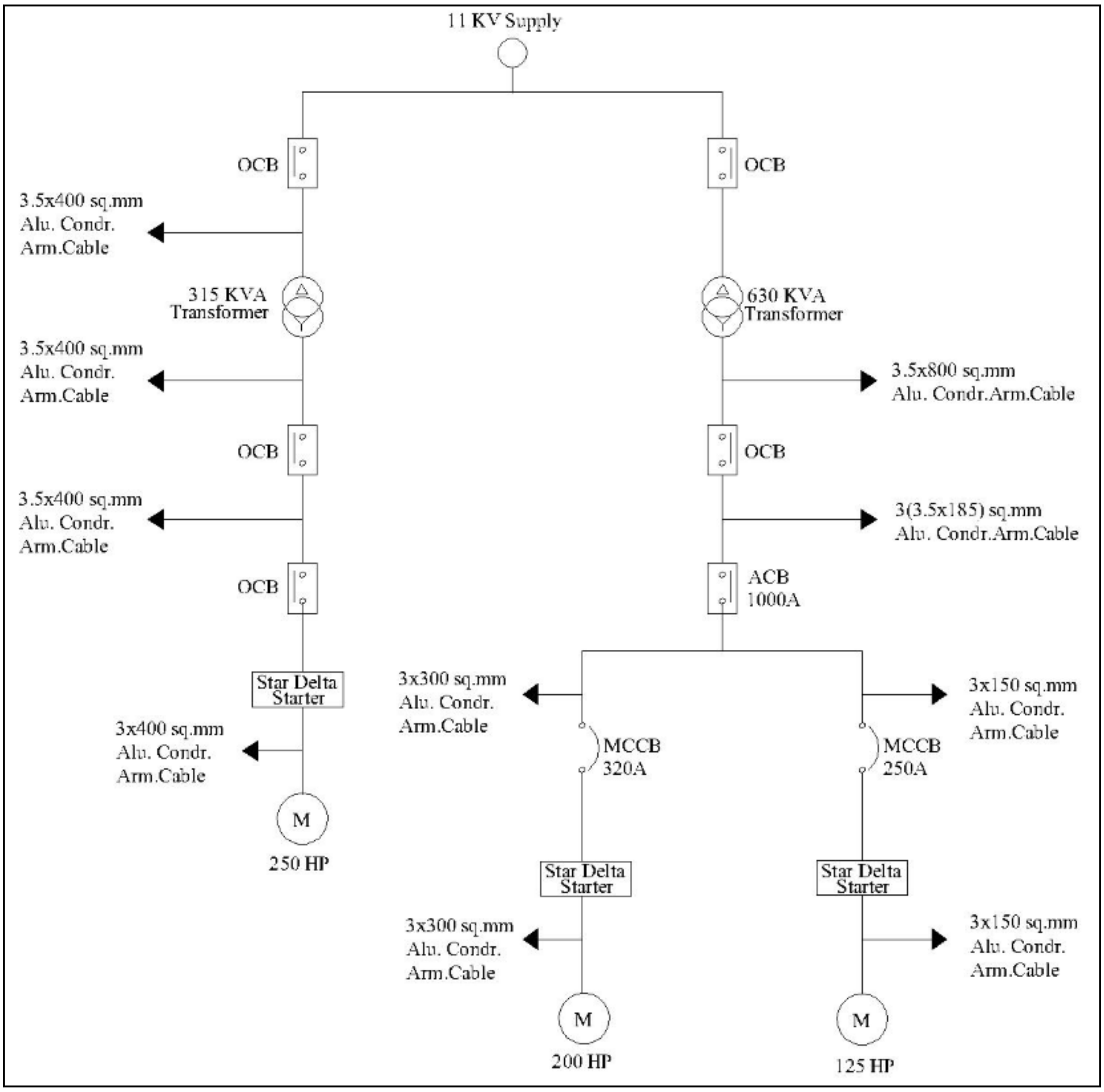


Figure 3 Single line diagram for the Old Intake Well

4.2.3 Tariff Structure

The Old Intake Well is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 10: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Jeoni Mandi Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.2.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the tablebelow. Average power factor recorded ws found to be 0.804.

Table 11: Energy cost and energy consumption detail for Jeoni Mandi

Period of energy bill	Energy consumption (kWh/Annum)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./Annum)
Apr-14 to Mar-15	12,159,218		100,587,661
Apr-15 to Mar-16	11,881,609	-2.3%	112,728,987
Apr-16 to Mar-17	11,023,036	-7.2%	113,563,575

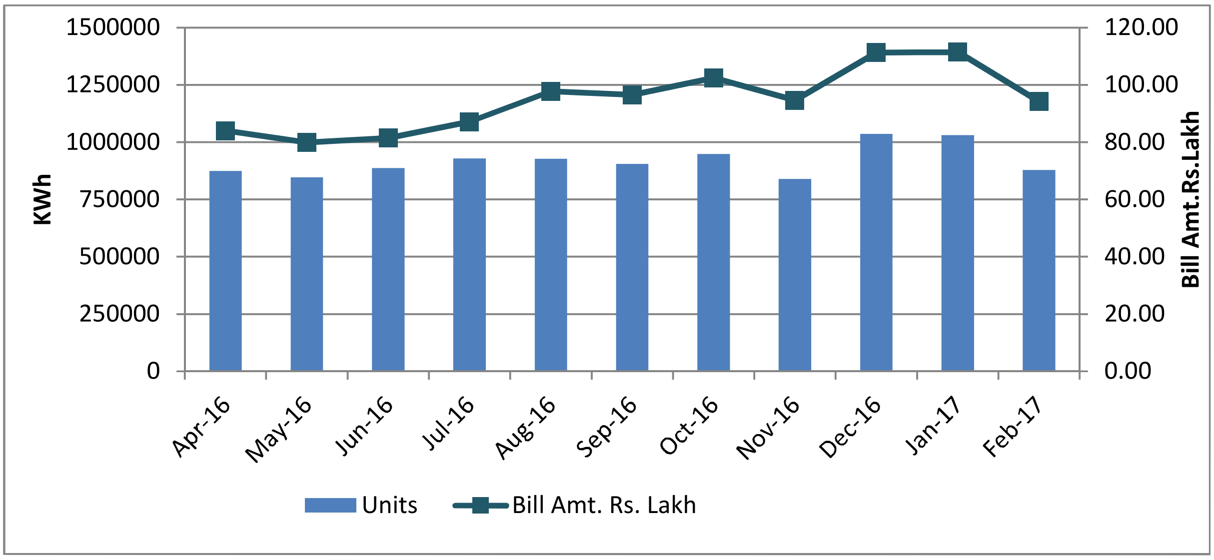


Figure 4 Monthly electricity consumption and electricity bill for Jeoni Mandi

4.2.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT side for recording variation of electrical parameters. Details about transformers installed at Old Intake Well is provided in below table.

Table 12: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer-1	Transformer-1 (315 kVA, 11/0.433 kV)	Pump set 1
Main Incomer-2	Transformer-2 (630 kVA, 11/0.433 kV)	Pump sets 2, 3

Transformer -1 :

Voltage Profile:

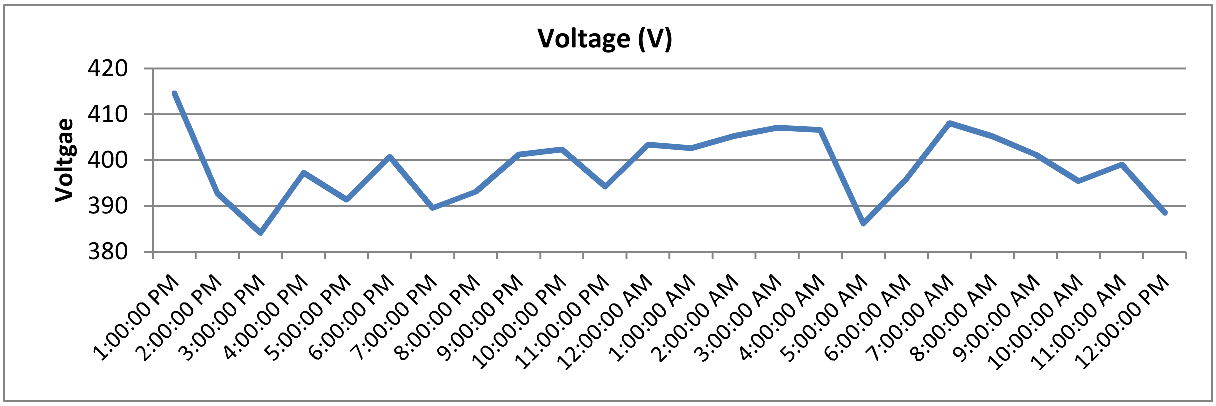


Figure 5 Voltage Variation of Transformer-1

- The voltage is found to vary widely between 384 and 415V, averaging around 399V.

Power consumption and Apparent power Profile:

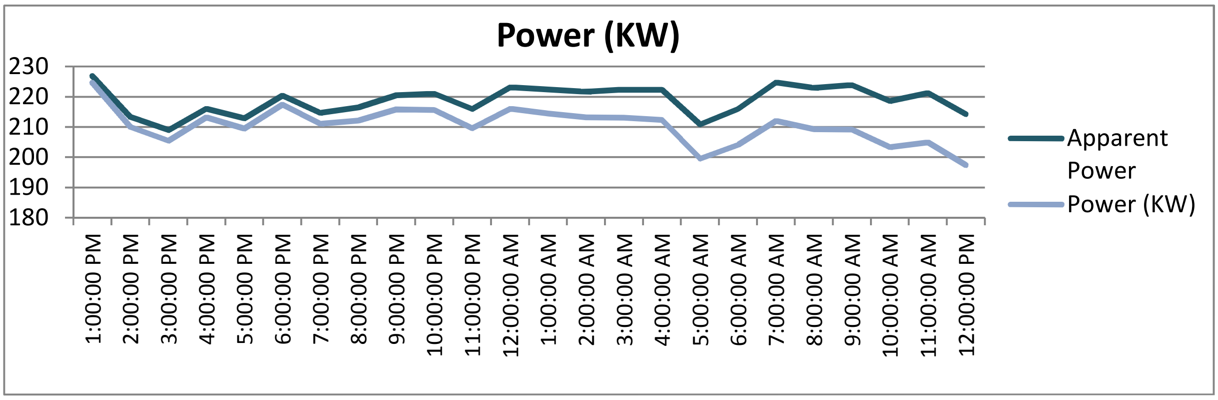


Figure 6 Power consumption variation at Transformer-1

- The power consumption is found to vary between 195 and 224 kW, averaging around 210.5 kW.
- The apparent power is found to vary between 208 and 227 kVA, averaging around 218.8 kVA.

Power factor profile

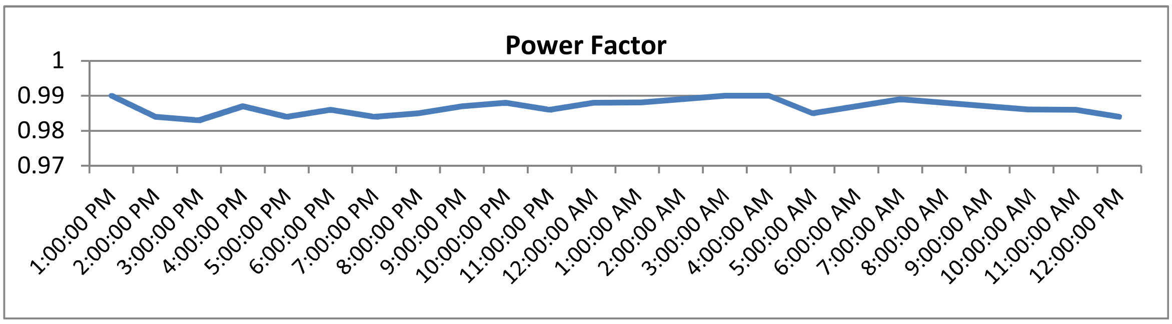


Figure 7 Power factor variation profile on Transformer-1

- The power factor is found to be well-maintained at above 0.98.

Frequency Profile:

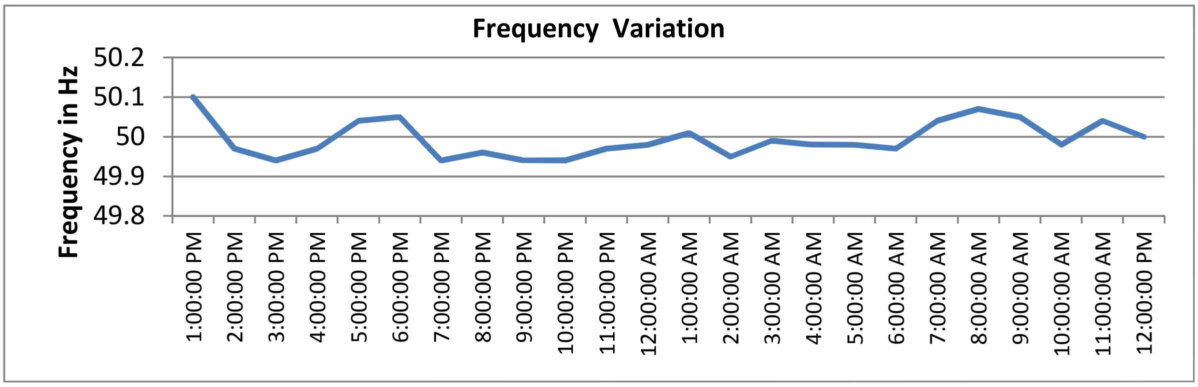


Figure 8 Frequency variation on Transformer-1

- The frequency is found to vary between 49.94 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

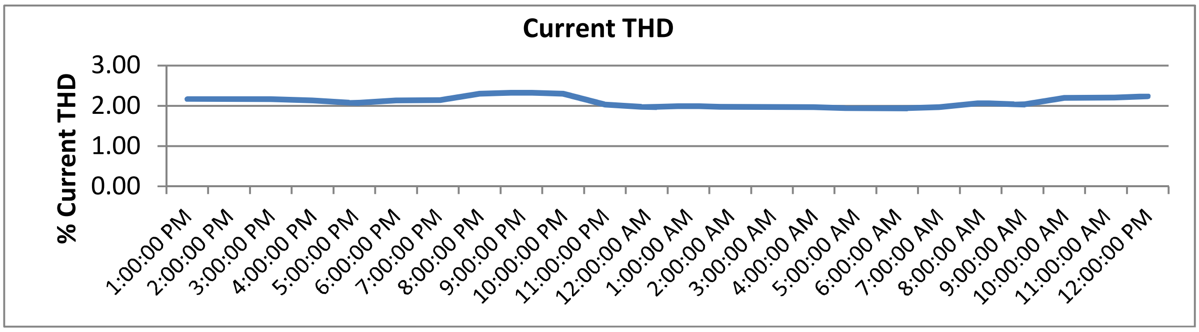


Figure 9 Variation of THD in current on Transformer-1

- The current THD is found to vary between 1.9 and 2.3%, averaging around 2.1%.

***Total Harmonics distortion - Voltage*:**

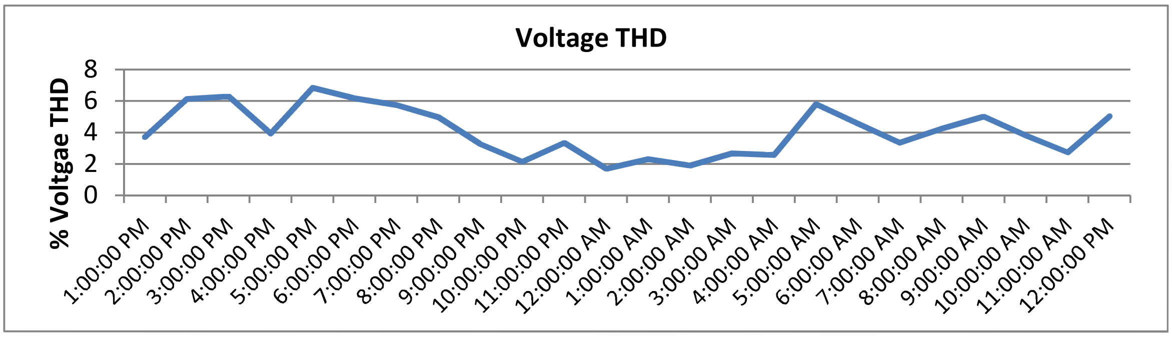


Figure 10Variation in THD - voltage on Transformer-1

- The voltage THD was found to vary between 1.8% to a high value of around 7%, averaging around 4.1%.

***Transformer loading*:**

Based on the 24 hour logging done during energy audit, transformer loading was calculated and same is provided below.

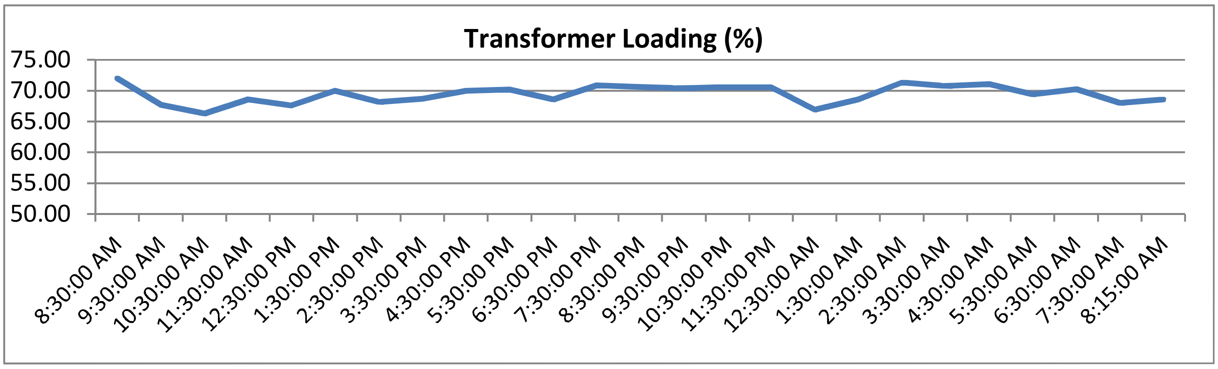


Figure 11Transformer-1 loading

- Transformer-1 loading was observed to be in the 65%-72% range.

4.2.6 Pumping Station System Mapping

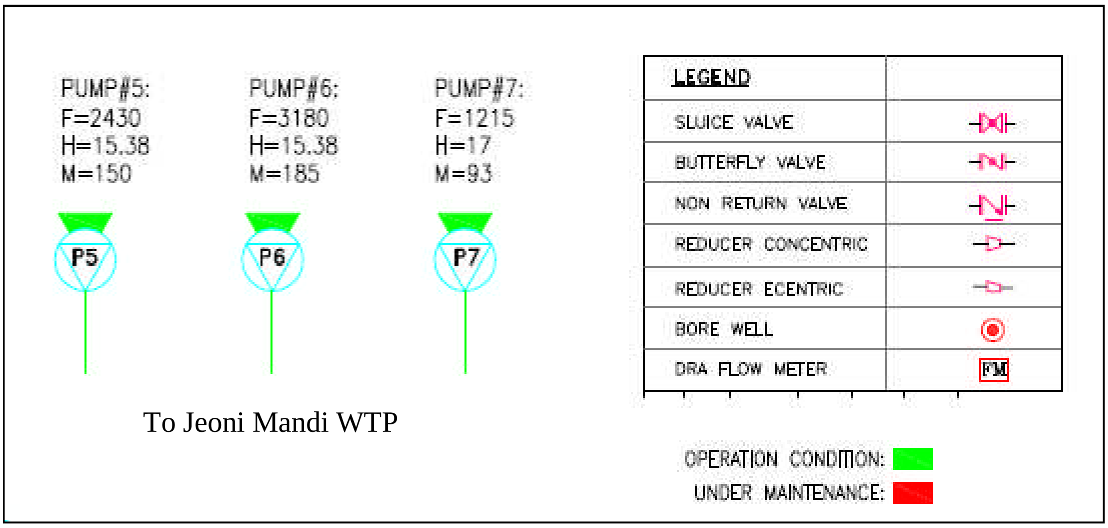


Figure 12: P & ID diagram for Old Intake Well

4.2.7 Pumps Performance Evaluation

As per the methodology described in section –1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 13: General details of Old Intake Well

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	Old intake well
Classification (WTP,PS, SPS, STP)	Raw Water Pumping station
Pumps installed	3
No. of pumps in operation	3
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the Old Intake Well to showcase the actual situation are provided below.

Figure 13: Photographs of Old Intake Well

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 14: Performance Evaluation of pumps at Old Intake Well

Parameters	Unit	Old Intake Well, Jeoni Mandi
Rated Parameters		**Pump-6**
Pump make		Flowmore
Motor make		Kirloskar
Pump type		VT
Motor serial no.		3890339-1
Pump serial no.		1220101K1C
Rated flow	m^3/h	3180
Rated head	m	15.38
Rated motor	kW	185
Measured parameters		
Total suction head	m	-8.17
Total discharge head	m	5

Parameters	Unit	Old Intake Well, Jeoni Mandi
Average flow delivered	m^3/h	2248.67
Motor input power	kW	229.65
Frequency	Hz	50.00
Speed	RPM	742.03
Total head developed	m	13.17
Head utilization	%	86%
Flow utilization	%	71%
Hydraulic power	kW	80.65
Motor input power	kW	229.65
Calculated pumpset efficiency	%	35.12%
Rated motor efficiency	%	94%
Calculated pump efficiency	%	37.36%
Specific energy consumption	kWh/m^3	0.102

Key Observations:

- Pump set no. 6 was observed to be operating at a pump set efficiency of 35.12%.
- Flow measurement was not possible for pump nos. 5 and 7 due to site constraints.
- Heavy leakage was observed from column pipe.Discharge pipes of pump nos. 5 and 7 were found to be highly corroded.

4.2.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 15: Other electrical equipment at Old Intake Well - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	Two
Capacity (kVA)	315 kVA, 630 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 16: Other electrical equipment at Old Intake Well - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Old Intake Well	CFL	2	0.065	12
	Tube light	1	0.04	24

Table 17: Other electrical equipment at Old Intake Well

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Room cooler	1	0.35	24

4.2.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Old Intake Well is provided in below table.

Table 18: Estimated annual energy consumption and water supply for Old Intake Well

Name of section	Name of the pump	Operating pattern	Annual operating hours (hours/Annum)	Weighted average power consumption (kW)	Total power consumption per year (kWh/Annum)
Old Intake Well	Pump-1	Not fixed, depends on inlet sourcs	1,493	134.6	200,996
	Pump-2		4,775	229.65	1,096,579
	Pump-3		4,625	74.08	342,617
	Total		**10,893**	**438.33**	**1,640,192**

4.3 New Intake Well, Jeoni Mandi

4.3.1 Overview of existing systems

The New Intake Well lifts raw water from the Yamuna and feeds it to the Jeoni Mandi WTP. There are three VT pumps installed, operating in a 2W+1S arrangement.

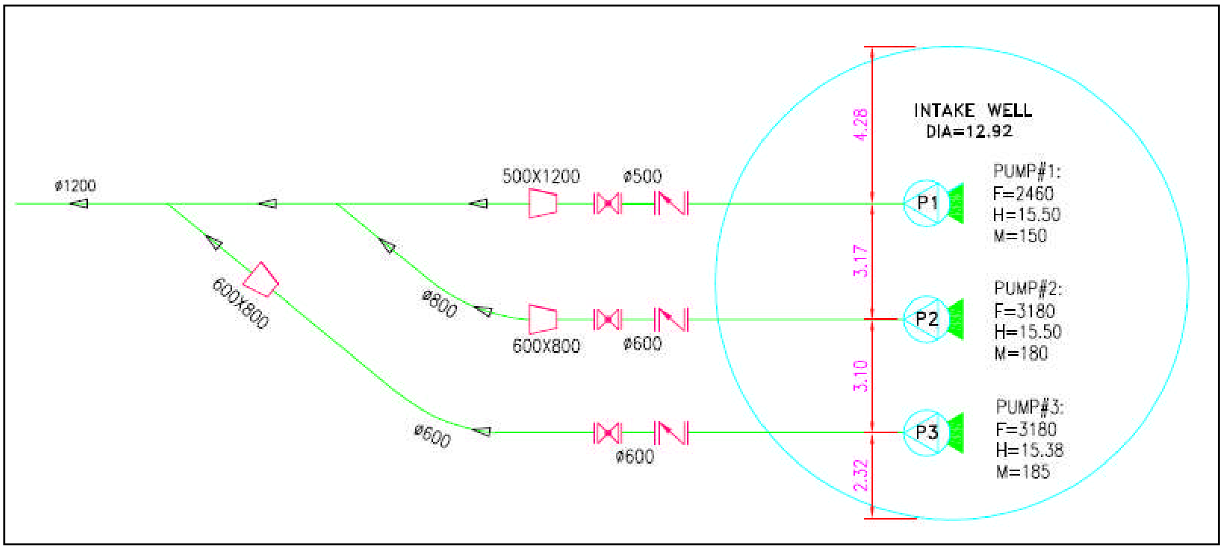


Figure 14 Plant Layout for New Intake Well

4.3.2 Electricity Supply

The New Intake Well is a part of Jeoni Mandi scheme which receives HT supply from Torrent Power at 11 kV. Supply for the motors at Old Intake Well is stepped down through a 1000 kVA transformer to 415V. Single line diagram for New Intake Well is provided below.

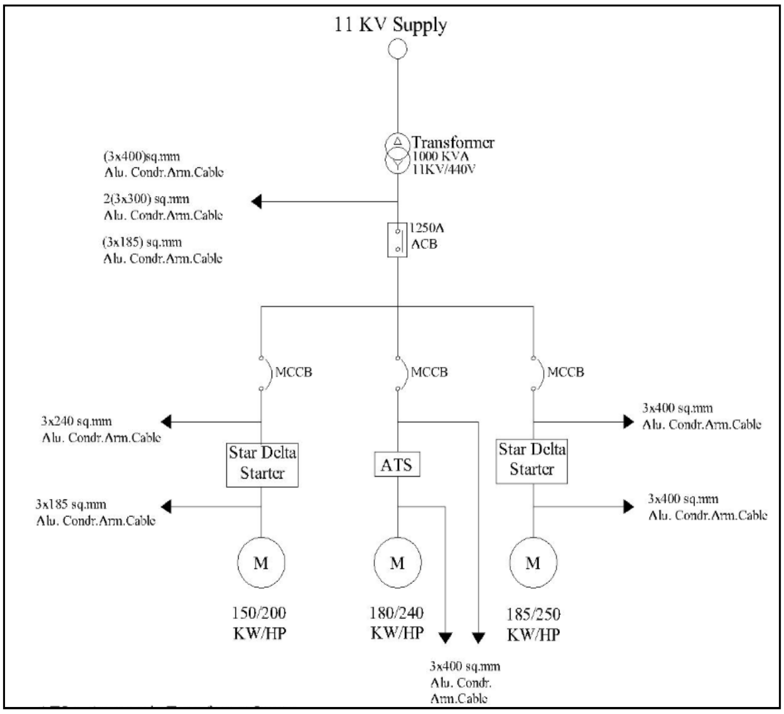


Figure 15 Single line diagram for the New Intake Well

4.3.3 Tariff Structure

The New Intake Well is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.3.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.3.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at New Intake Well is provided in below table.

Table 19: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer-1	Transformer-1 (1000) kVA, 11/0.44 kV)	All 3 pump sets

Voltage Profile:

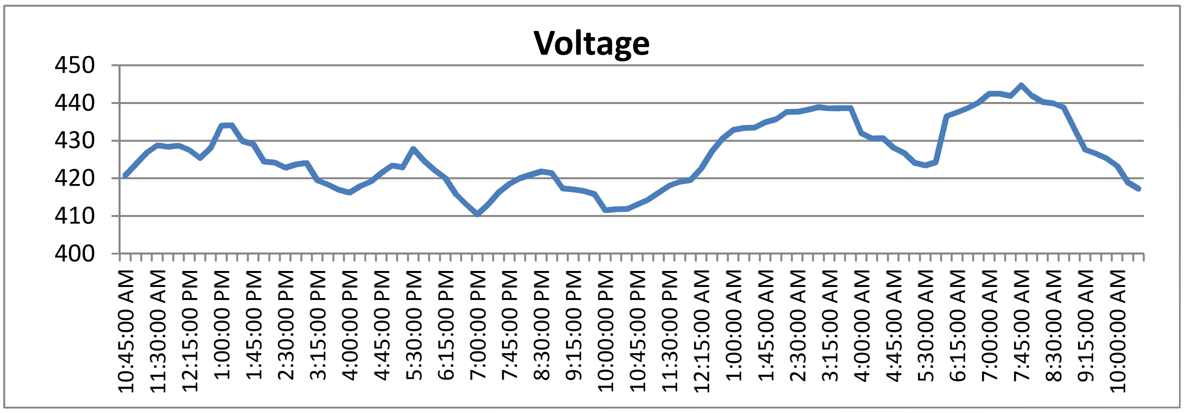


Figure 16 Voltage Variation at New Intake Well

- The voltage is observed to vary between 410V and 445V, with an average of 426.3V.

Power consumption and Apparent power Profile

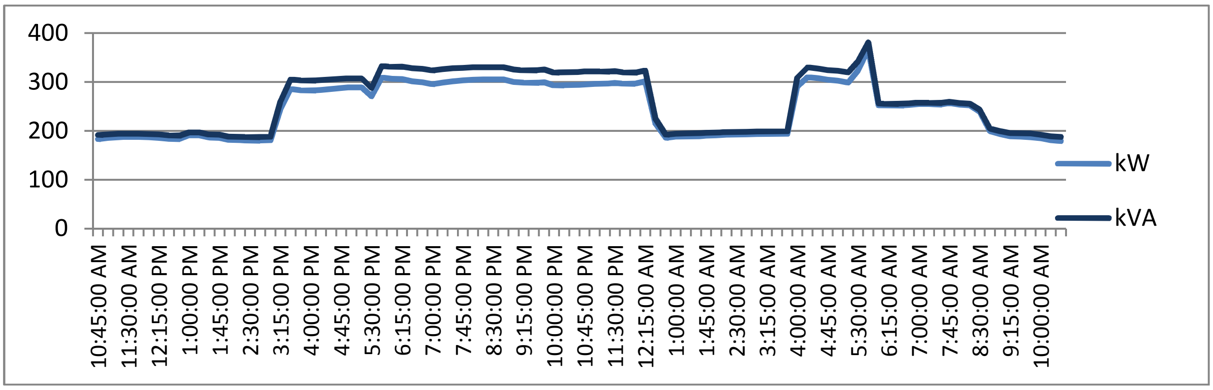


Figure 17 Power consumption variation at New Intake Well

- The New Intake Well is in operation throughout the 24 hours. The pump motors are rated 150 kW, 180 kW and 185 kW. The observed kW consumption is either in the 170-190 kW range or the 280-310 kW rangeas per the number of pumps in operation.
- The kVA consumption is found to be either in the 180-200 kVA range or the 300-330 kVA range as per the number of pumps in operation.

Power factor profile

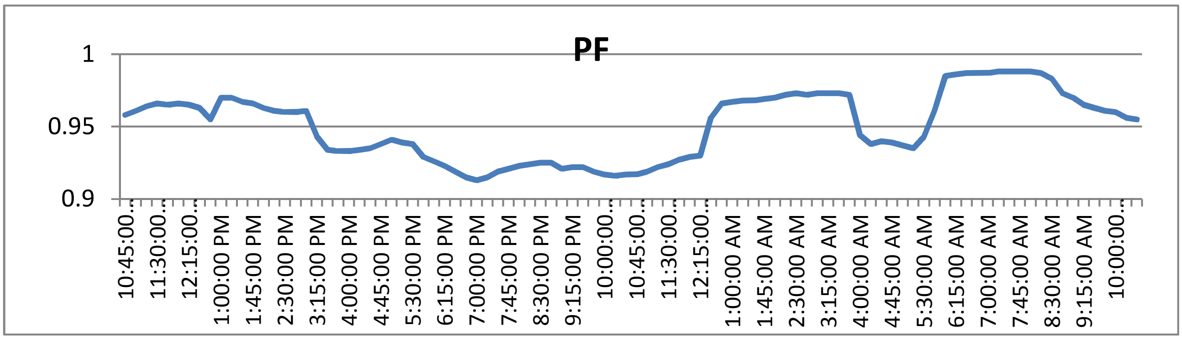


Figure 18 Power factor variation profile at New Intake Well

- The power factor is found to be maintained above 0.9, with the highest recorded being around 0.99.

Frequency Profile:

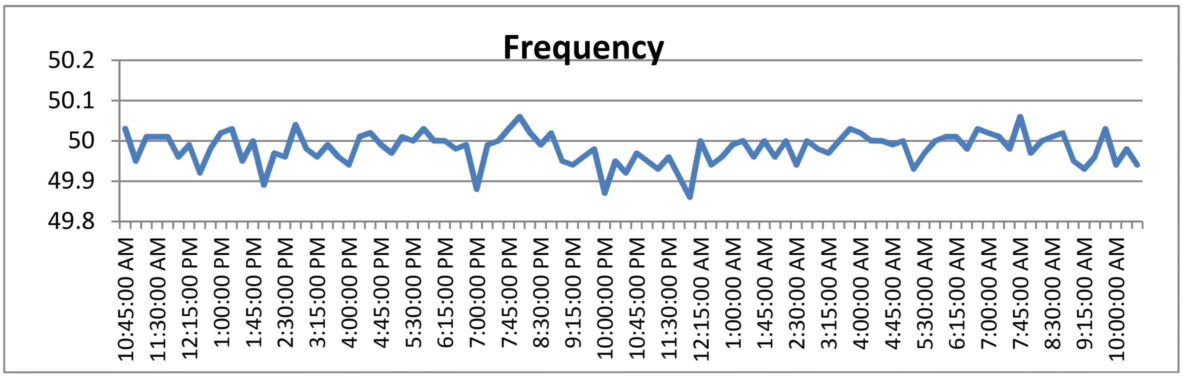


Figure 19 Frequency variation at New Intake Well

- The frequency was observed to vary between 49.85 and 50.05 Hz.

Total Harmonics distortion (THD) - Current:

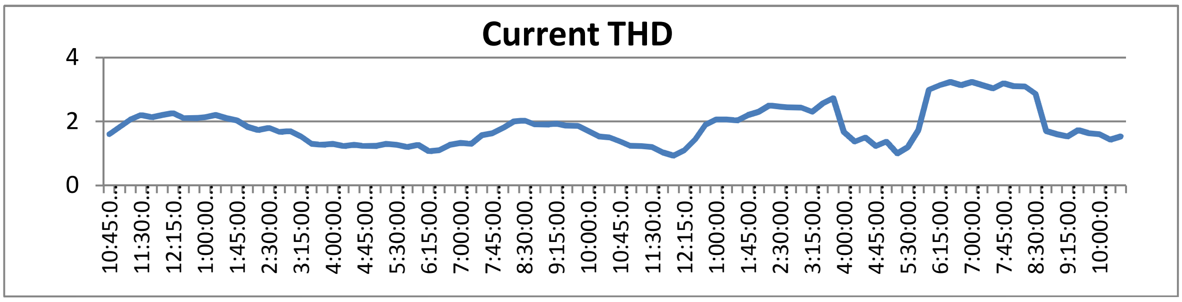


Figure 20 Variation of THD in current at New Intake Well

- The current THD was found to vary between 0.9% and 3.4%, averaging around 1.85%.

Total Harmonics distortion - Voltage:

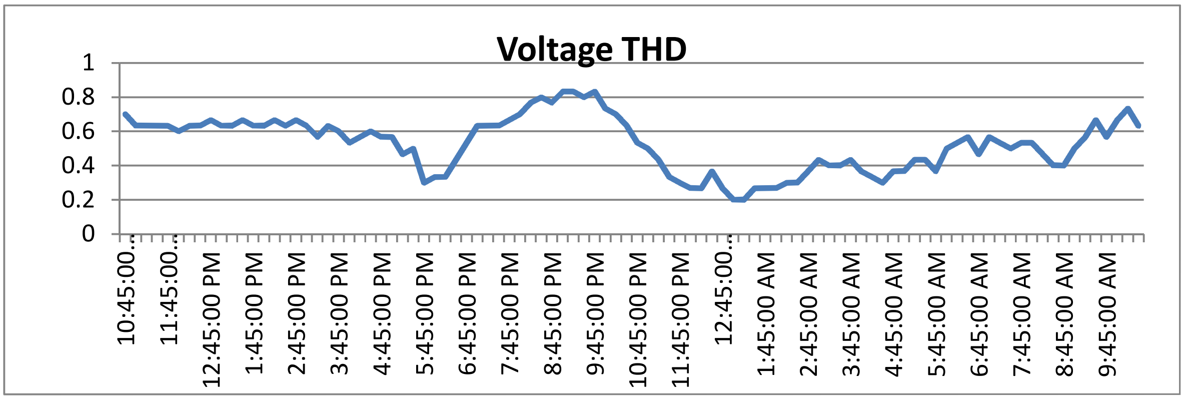
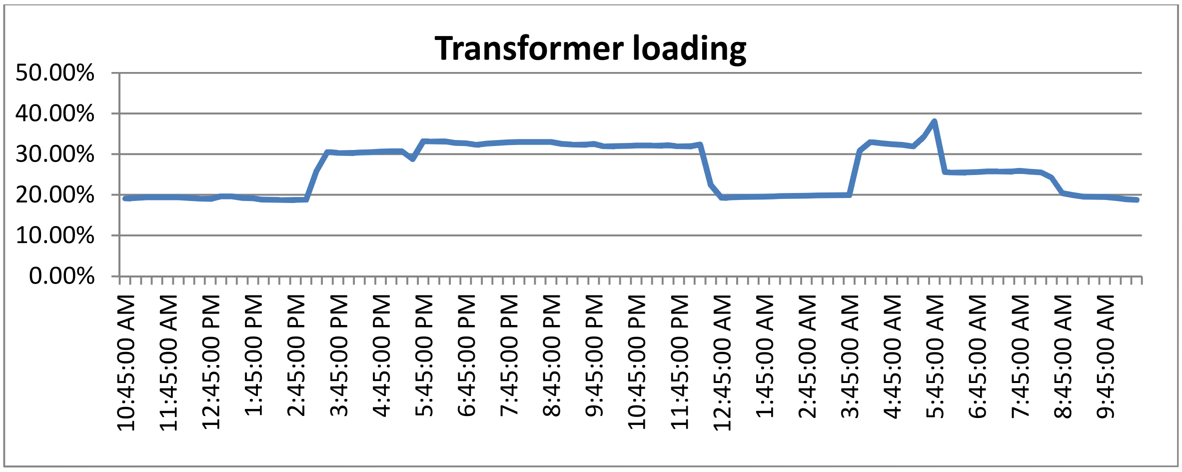


Figure 21 Variation in THD - voltage at New Intake Well

- The voltage THD was found to be less than 1%.

Transformer loading:

Based on the kVA measurement during energy audit, transformer loading was calculated and same is provided below.



- Depending on the number of pumps in operation, transformer loading was found to be in the 19-20% or 31-33% range.

4.3.6 Pumping Station System Mapping

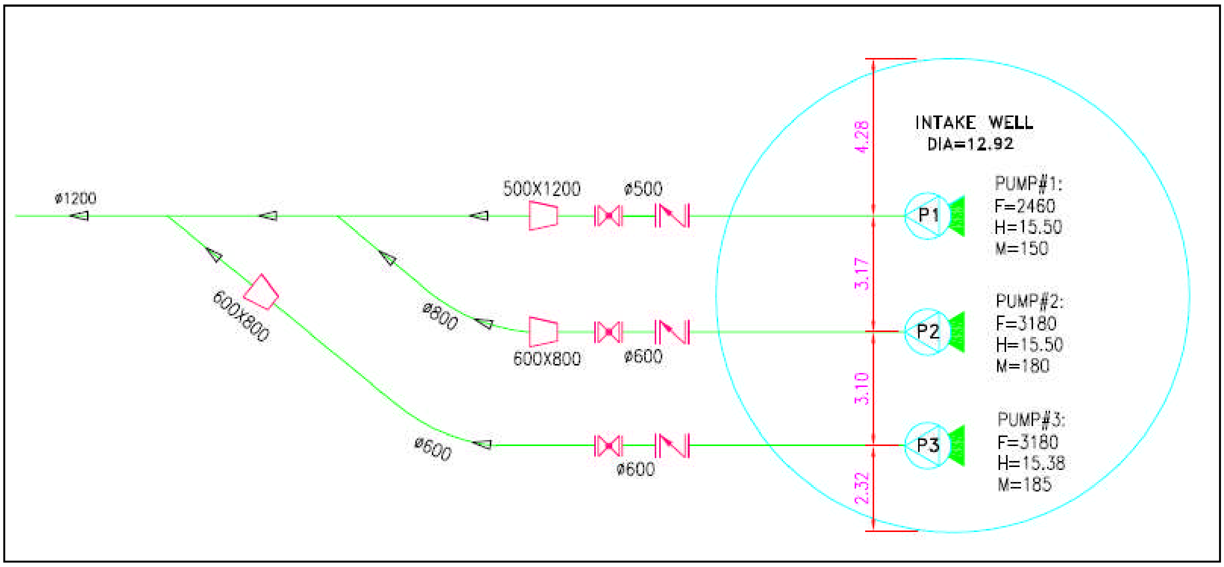


Figure 22P & ID diagram for New Intake Well

4.3.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB.

Table 20: General details of New Intake Well

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	Newintake well
Classification (WTP,PS, SPS, STP)	Raw Water Pumping station
Pumps installed	3
No. of pumps in operation	3
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the New Intake Well to showcase the actual situation are provided below.

Intake well structure	Pumping machinery installed
	

Figure 23: Photographs of New Intake Well

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 21: Performance Evaluation of pumps at New Intake Well

Parameters	Unit	New Intake Well, Jeoni Mandi	New Intake Well, Jeoni Mandi	New Intake Well, Jeoni Mandi
		Pump-1	Pump-2	Pump-3
Pump make		Kirloskar	Kirloskar	Flowmore
Motor make		Marathon	Marathon	Marathon
Pump type		VT	VT VT	
Motor serial no.		155523200001	155123230001	7309304-1
Pump serial no.		1502815003	152H215001	NA
Rated flow	m^3/h	2460	3180	3180

Parameters	Unit	New Intake Well, Jeoni Mandi	New Intake Well, Jeoni Mandi	New Intake Well, Jeoni Mandi
		Pump-1	Pump-2	Pump-3
Rated head	m	15.5	15.5	15.38
Rated motor	kW	150	180	185
Parameters measured				
Total suction head	m	-6.05	-6.05	-6.05
Total discharge head	m	5	6	6
Average flow delivered	m^3/h	1015.33	2079.33	2166.00
Motor input power	kW	104.84	133.60	149.67
Frequency	Hz	50.01	50.08	50.02
Speed	RPM	988.13	746.83	729.70
Performance evaluation				
Total head developed	m	11.05	12.05	12.05
Head utilization	%	71%	78%	78%
Flow utilization	%	41%	65%	68%
Hydraulic power	kW	30.55	68.24	71.08
Motor input power	kW	104.84	133.60	149.67
Calculated pumpset efficiency	%	29.14%	51.07%	47.49%
Rated motor efficiency	%	94.0%	94.0%	94.0%
Calculated pump efficiency	%	31%%	54.33%	50.52%
Specific energy consumption	kWh/m^3	0.103	0.064	0.069

Key Observations:

- Pump set nos. 1, 2 and 3 were observed to be operating at pump set efficiencies of 29.14%, 51.07% and 47.49% respectively. The observed head was less than 80% of the rated head, and the observed discharge was found to be significantly less than the rated discharge.

4.3.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 22: Other electrical equipment at New Intake Well- Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	1000 kVA

Parameters	Details
Primary/Secondary voltages	11 kV/440 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 23: Other electrical equipment at New Intake Well - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
New Intake Well	CFL	2	0.065	12

Table 24: Other electrical equipment at New Intake Well – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Room cooler	1	0.25	24

4.3.9 Total Energy Consumption Estimation For Pump sets & Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for New Intake Well is provided in below table.

Table 25: Estimated energy consumption for New Intake Well

Name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
New Intake Well	Pump-1	2W + 1SB	6,311	104.84	661,671
New Intake Well	Pump-2		6,679	133.60	892,321
New Intake Well	Pump-3		1,146	149.67	171,488
	Total		**14,136**	**388.11**	**1,725,480**

4.4 New Jal Nigam Intake Well, Jeoni Mandi

4.4.1 Overview of existing systems

The New Jal Nigam Intake well lifts raw water from the Yamuna and feeds it to the Jeoni Mandi WTP. There are three VT pumps installed, of which one was in breakdown condition and the others are operated in 1W+1SB arrangement.

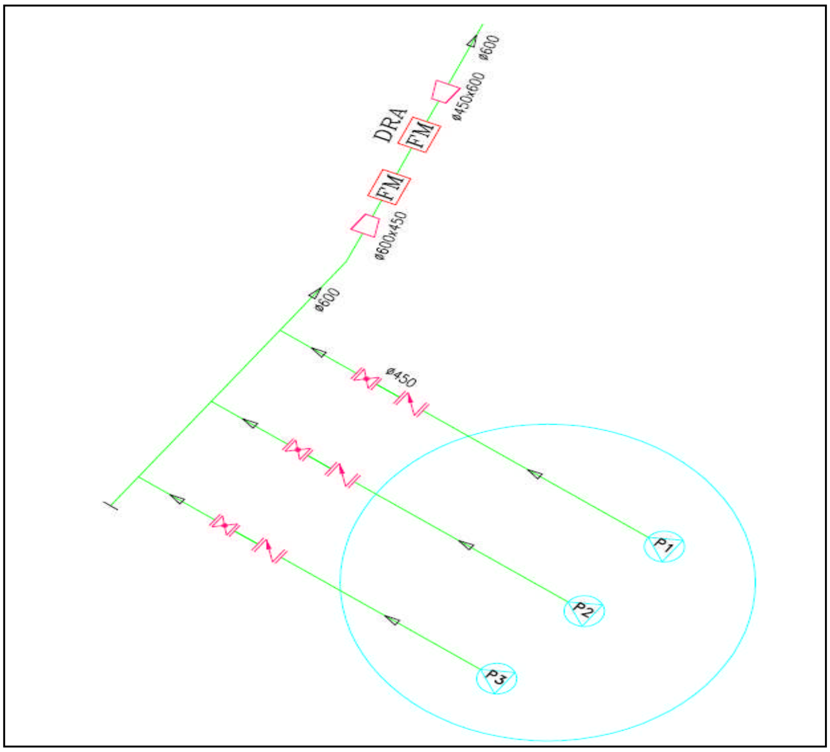


Figure 24 Plant Layout for New Jal Nigam Intake Well

4.4.2 Electricity Supply

New Jal Nigam intake well is part of Jeoni Mandi scheme. The intake well receives power at 11 kV, which is stepped down through a 500 kVA transformer to feed the motors at 415V.

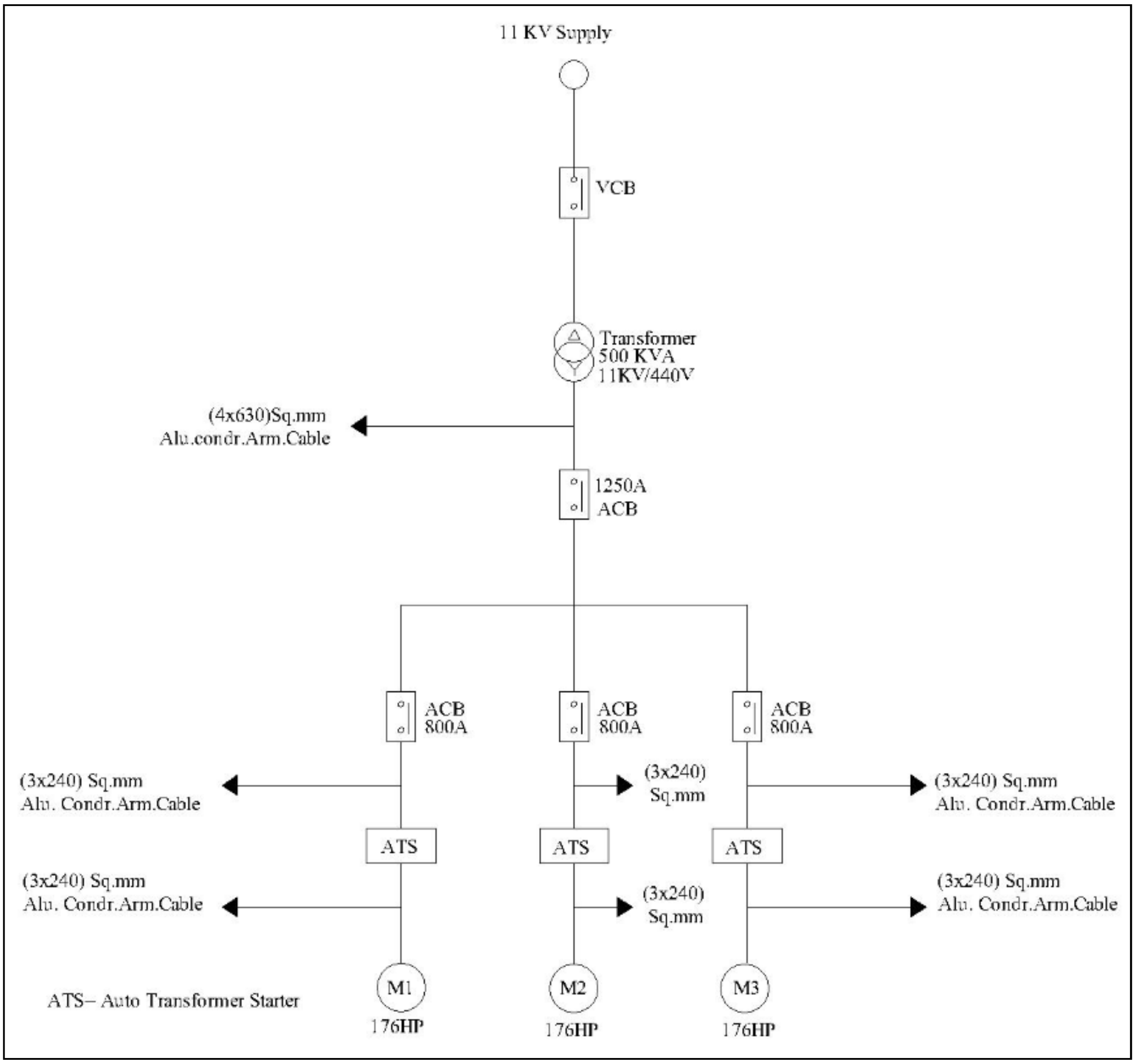


Figure 25 Single line diagram for the New Jal Nigam Intake Well

4.4.3 Tariff Structure

The New Jal Nigam Intake Well is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.4.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.4.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at New Jal Nigam Intake Well is provided below.

Table 26: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer-1	Transformer-1 (500) kVA, 11/0.44 kV)	All 3 pump sets

Voltage Profile:

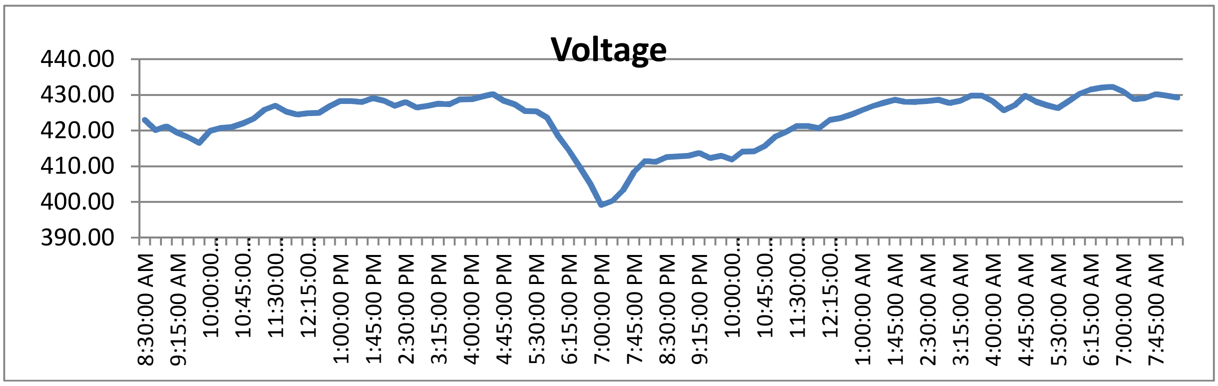


Figure 26: Voltage Variation at New Jal Nigam Intake Well

- Wide variation was observed in the voltage, varying between 399 and 430V and averaging around 423V.

Power consumption and Apparent power Profile:

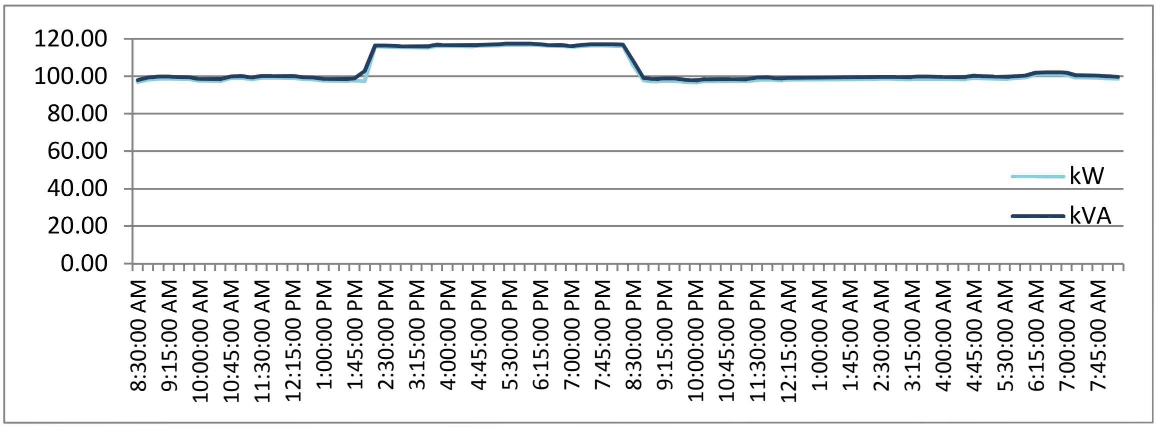


Figure 27: Power consumption variation at New Jal Nigam Intake Well

- The two functioning pumps are operated in 1W+1SB arrangement. The power consumption was found to be either around 96-100 kW or 114-116 kW.
- The apparent power consumption was found to be either 98-105 kVAor115-118 kVA.

Power factor profile

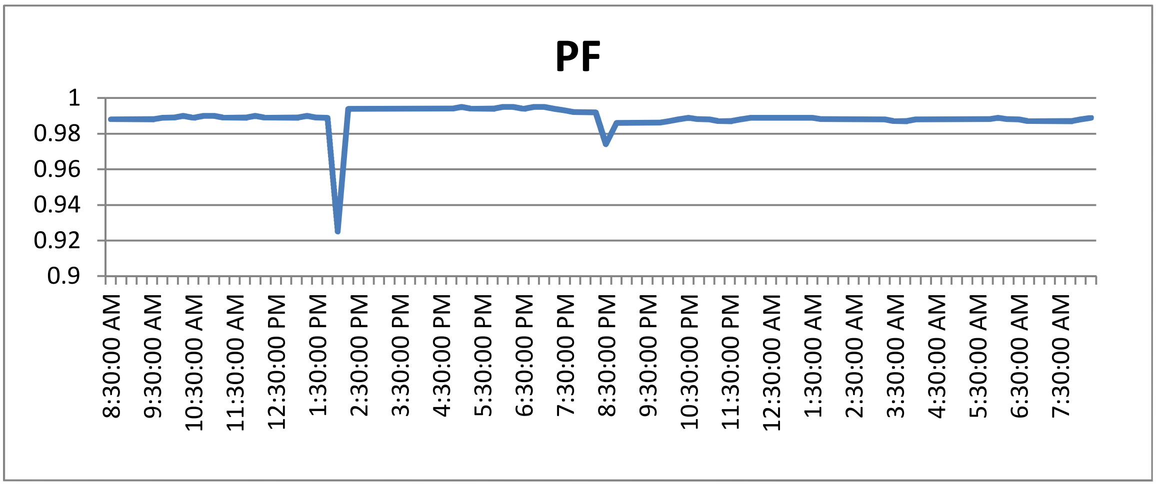


Figure 28: Power factor variation profile at New Jal Nigam Intake Well

- The power factor was found to be consistently maintained around 0.99. The spikes correspond to the time period between switching off of one pump motor and switching on another.

Frequency Profile:

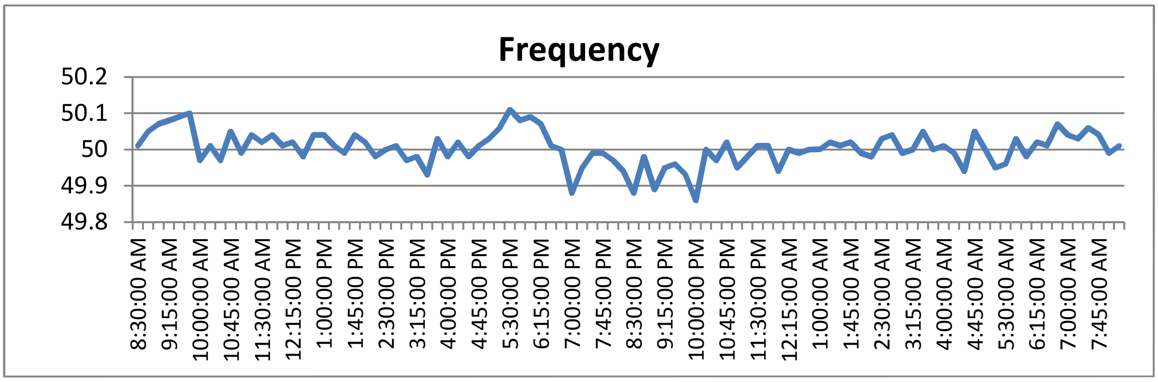


Figure 29: Frequency variation at New Jal Nigam Intake Well

- The frequency was found to vary between 49.85 and 50.12 Hz.

Total Harmonics distortion (THD) - Current:

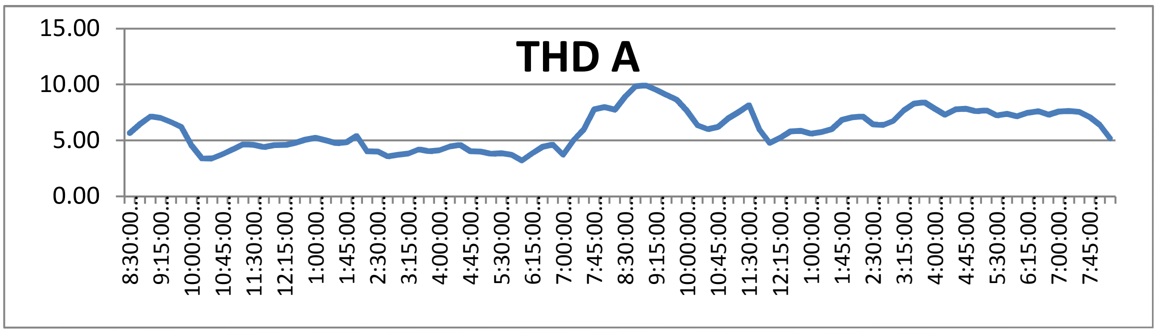


Figure 30: Variation of THD in current at New Jal Nigam Intake Well

- The current THD was observed to be as high as around 10% on some instances, while the minimum was around 3.4%. Overall, the average current THD was around 6%.

Total Harmonics distortion - Voltage:

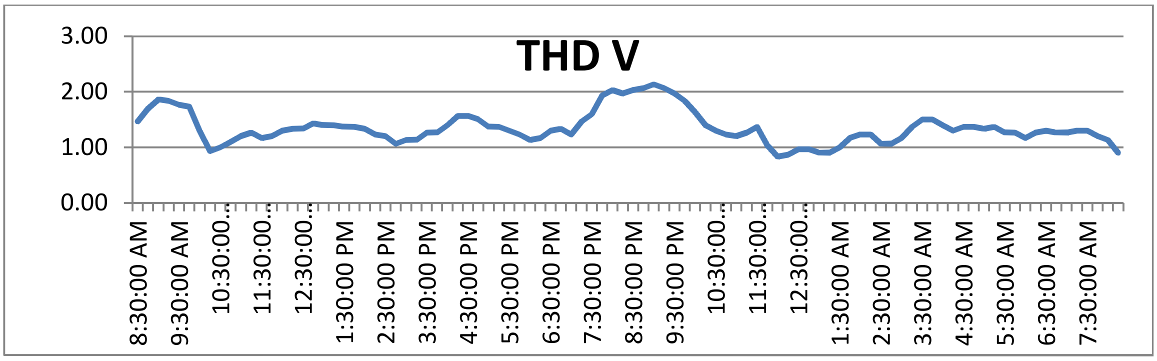


Figure 31: Variation in THD - voltage at New Jal Nigam Intake Well

- The voltage THD was found to vary between 0.8% and 2.2%.

Transformer loading:

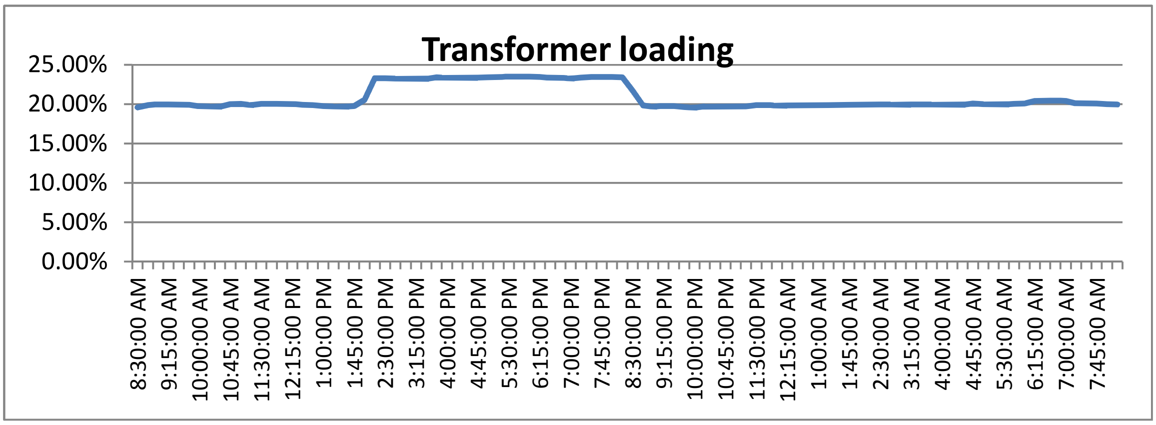


Figure 32: Transformer loadingat New Jal Nigam Intake Well

- The transformer at New Jal Nigam intake well is rated 500 kVA. The loading was observed to be either around 20% or around 23% depending on the pump motor in operation.

4.4.6 Pumping Station System Mapping

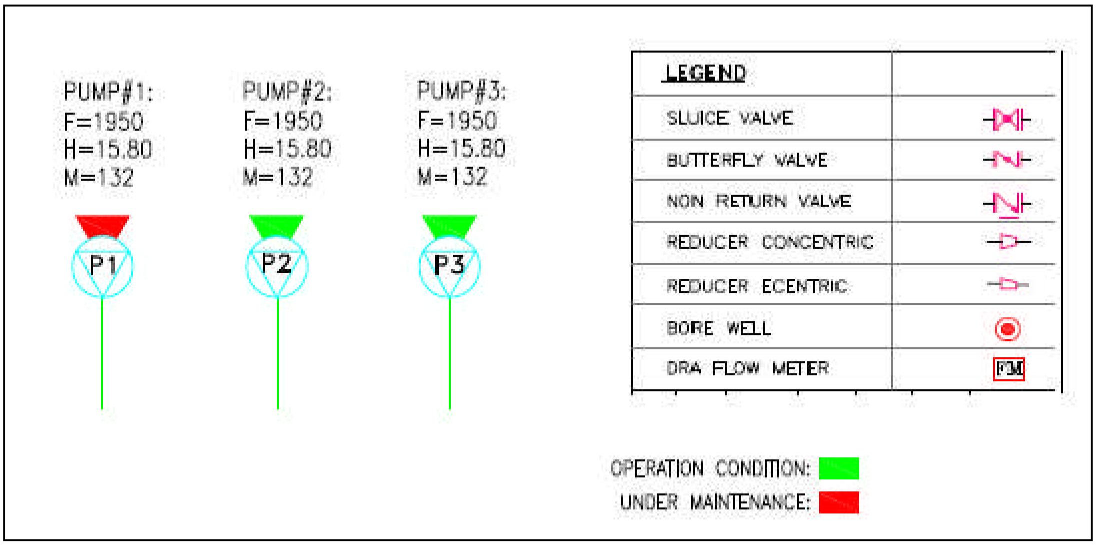


Figure 33: P & ID diagram for New Jal Nigam Intake Well

4.4.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 27: General details of New Intake Well

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	New Jal Nigam intake well
Classification (WTP,PS, SPS, STP)	Raw Water Pumping station
Pumps installed	3
No. of pumps in operation	2
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the Old Intake Well to showcase the actual situation are provided below.

Intake well structure	Pumping machinery installed
	

Figure 34: Photographs of New Jal Nigam Intake Well

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 28: Performance Evaluation of pumps at New Jal Nigam Intake Well

	Unit	New Jal Nigam Intake well, Jeoni Mandi	New Jal Nigam Intake well, Jeoni Mandi
Parameters		Pump-2	Pump-3
Pump make		WPIL Limited	WPIL Limited
Motor make		Kirloskar	Kirloskar
Pump type		VT	VT
Motor serial no.		SL10028-01	SL10028-01
Pump serial no.		30147	20X1AU
Rated flow	m^3/h	1950	1950
Rated head	m	15.8	15.8
Rated motor	kW	132	132
Parameters measured			
Total suction head	m	-8.06	-8.01
Total discharge head	m	4	4
Average flow delivered	m^3/h	1113.00	1080.00
Motor input power	kW	95.77	114.57
Frequency	Hz	49.96	49.97
Speed	RPM	1485.00	1483.33
Performance evaluation			

Parameters	Unit	New Jal Nigam Intake well, Jeoni Mandi Pump-2	New Jal Nigam Intake well, Jeoni Mandi Pump-3
Total head developed	M	12.06	12.01
Head utilization	%	76%	76%
Flow utilization	%	57%	55%
Hydraulic power	kW	36.55	35.32
Motor input power	kW	95.77	114.57
Calculated pumpset efficiency	%	38.17%	30.83%
Rated motor efficiency	%	93.5%	93.5%
Calculated pump efficiency	%	40.82%	32.98%
Specific energy consumption	kWh/m^3	0.086	0.106

Key Observations:

- Pumps 2 and 3 were observed to be operating at pump set efficiencies of 38.17% and 30.83% respectively. The operating head was found to be below 80% of the rated head and the measured discharge was found to be significantly less than the rated discharge.
- Pump no. 1 was in breakdown condition at the time of audit.

4.4.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 29: Other electrical equipment at New Jal Nigam Intake Well- Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	500 kVA
Primary/Secondary voltages	11 kV/440 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 30: Other electrical equipment at New Jal Nigam Intake Well - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
New Jal Nigam Intake Well	Tubelight	6	0.08	24
	CFL	2	0.065	12

Table 31: Other electrical equipment at New Jal Nigam Intake Well

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Exhaust fan	1	0.25	24

4.4.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for New Jal Nigam Intake Well is provided in below table.

Table 32: Estimated energy consumption for New Jal Nigam Intake Well

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
New Jal Nigam Intake well	Pump-2	1 working	4091	95.77	391767
New Jal Nigam Intake well	Pump-3		3583	114.57	410544
	Total		**7,674**	**210.34**	**802,311**

4.5 HT Plant (Golkamra Pumping Station)

4.5.1 Overview of existing systems

The Golkamra plant has three pumps having HT motors. One pump set is in breakdown condition and the remaining two are operated in 1W+1SB system. The common outlet of the Golkamra plant and the common outlet of the Synchronous plant are connected. The Golkamra plant supplies treated water to Zonal Pumping Stations.

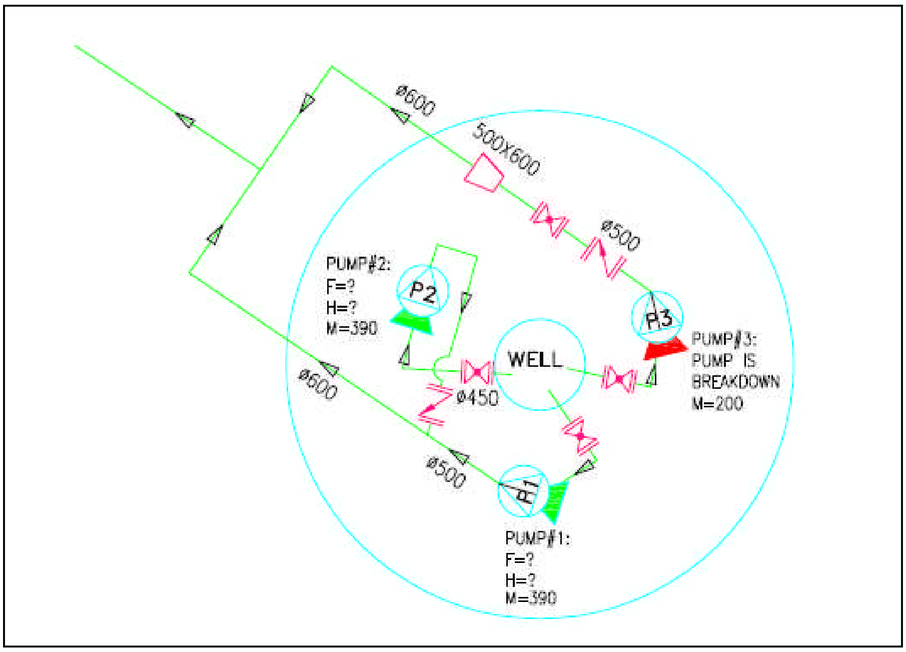


Figure 35 Plant Layout for Golkamra Pump House

4.5.2 Electricity Supply

The Golkamra plant is a part of the Jeoni Mandi scheme. Supply to the plant is at 11 kV, from which it is stepped down to 3.3 kV for supply to the pump motors.

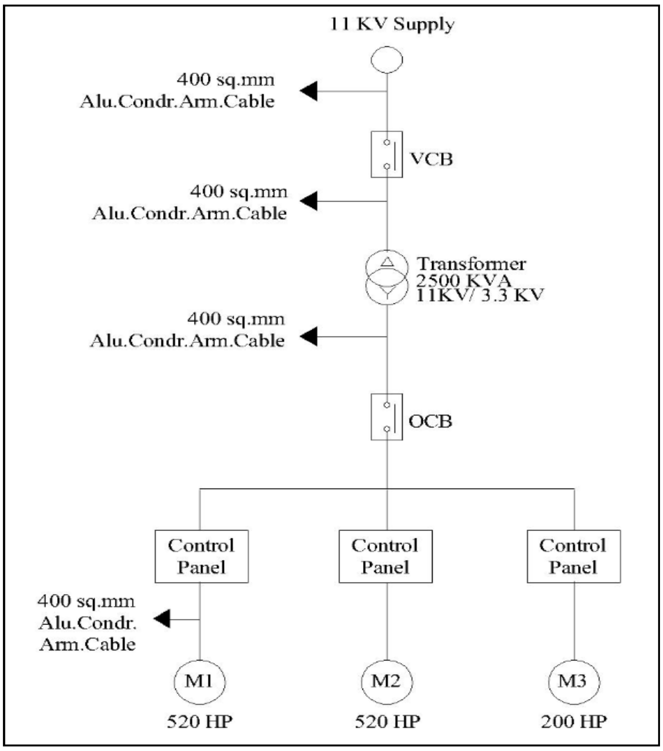


Figure 36 Single line diagram for the Golkamra Pump House

4.5.3 Tariff Structure

The HT (Golkamra) pump house is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.5.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.5.5 Energy Consumption Pattern at Pumping Station

Details about transformers installed at Golkamra Pump House is provided in below table.

Table 33: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer-1	Transformer-1 (2500) kVA, 11/3.3 kV)	All 3 pump sets

As per information provided, the transformer was originally rated 5000 kVA, 11/6.6 kV but was repaired and redesigned to the present kVA capacity and voltage ratio. Electrical measurements were not possible at Gol Kamra due to site constraints.

4.5.6 Pumping Station System Mapping

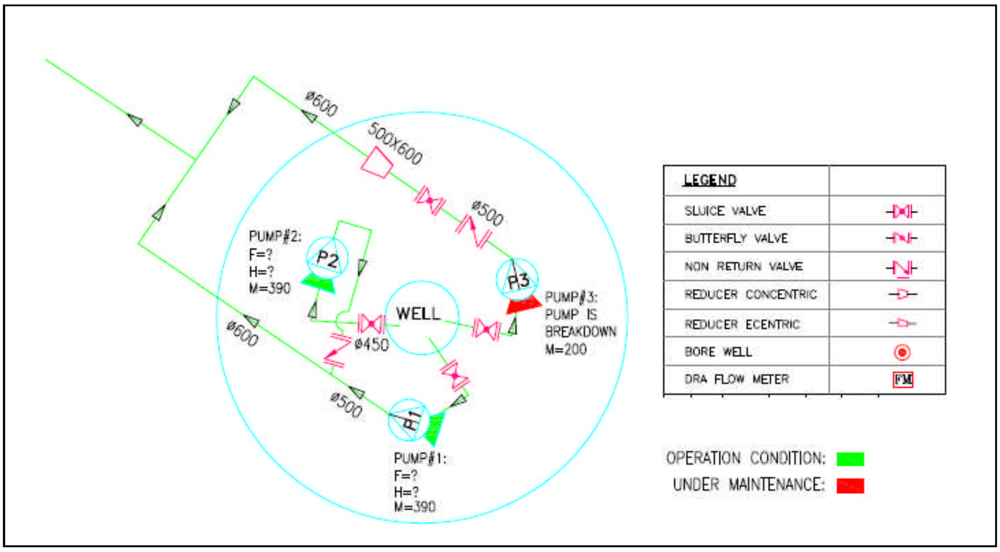


Figure 37: P & ID diagram for Gol Kamra pump house

4.5.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 34: General details of Golkamra plant

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	Golkamra plant
Classification (WTP,PS, SPS, STP)	Clear Water Pumping station
Pumps installed	3
No. of pumps in operation	2
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the Golkamra plant to showcase the actual situation are provided below.

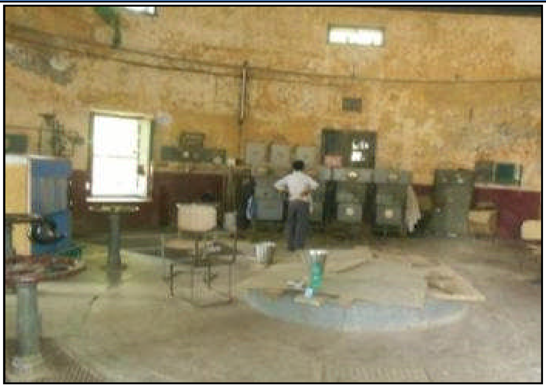
Pumping machinery installed	Panel room
	

Figure 38 Photographs of Gol Kamra pump house

The operational pumps at Gol Kamra pump house could not be tested due to site constraints.

Key Observations:

- Pump set no. 3 was in breakdown condition.
- Heavy leakage was observed on the pump floor.
- SLV and NRV are installed and working but in poor condition and highly corroded.

4.5.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 35: Other electrical equipment at HT Plant (Golkamra Pumping Station) - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	2500 kVA
Primary/Secondary voltages	11 kV/3.3kV
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

No other auxiliary loads installed at Golkamra plant.

4.5.9 Total Energy Consumption Estimation For Pump sets & Pumping Stations

Measurements were not possible at Gol Kamra pump house due to site constraints. Thus, total energy consumption could not be determined.

4.6 Synchronous Pumping Station – Jeoni Mandi

4.6.1 Overview of existing systems

The Synchronous Plant has three pump sets of which one is in breakdown condition. The remaining two, one having HT motor and one having LT motor, are operated in 1W+1SB combination. Its common header joins the common header from the Golkamra plant.

4.6.2 Electricity Supply

The Synchronous Plant is a part of the Jeoni mandi scheme. The 210 kW pump receives HT supply while the remaining two receive LT supply.

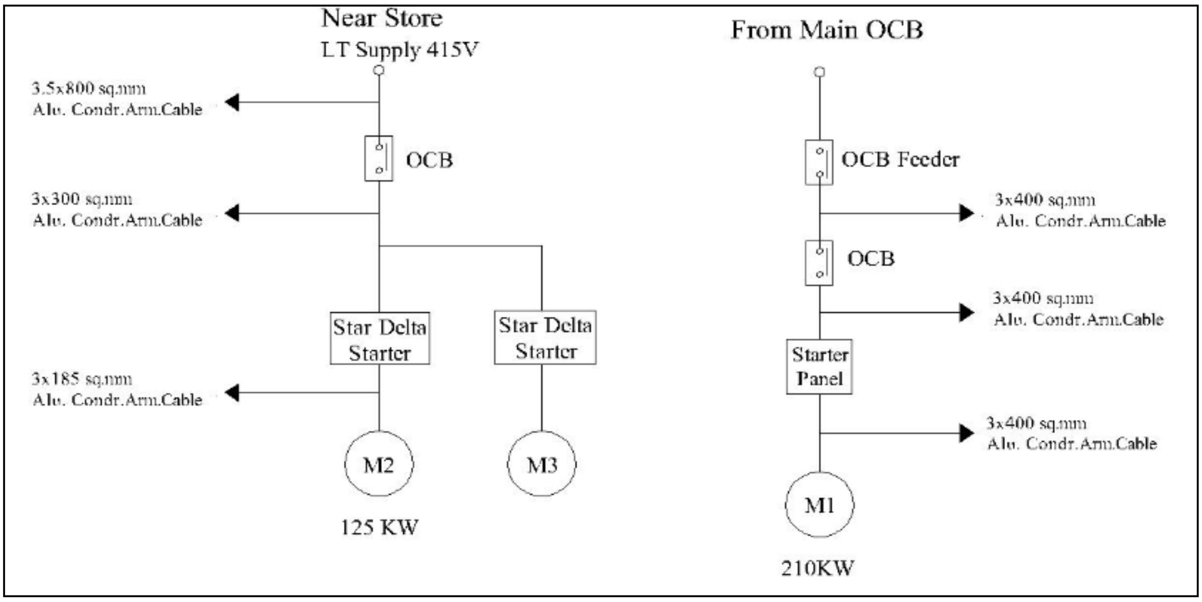


Figure 39: Single line diagram for the Synchronous Pump House

4.6.3 Tariff Structure

The Synchronous Pumping Station is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.6.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.6.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on LT incomer for recording variation of electrical parameters. Given below are measurements for the 125 kW motor incomer.

Voltage Profile:

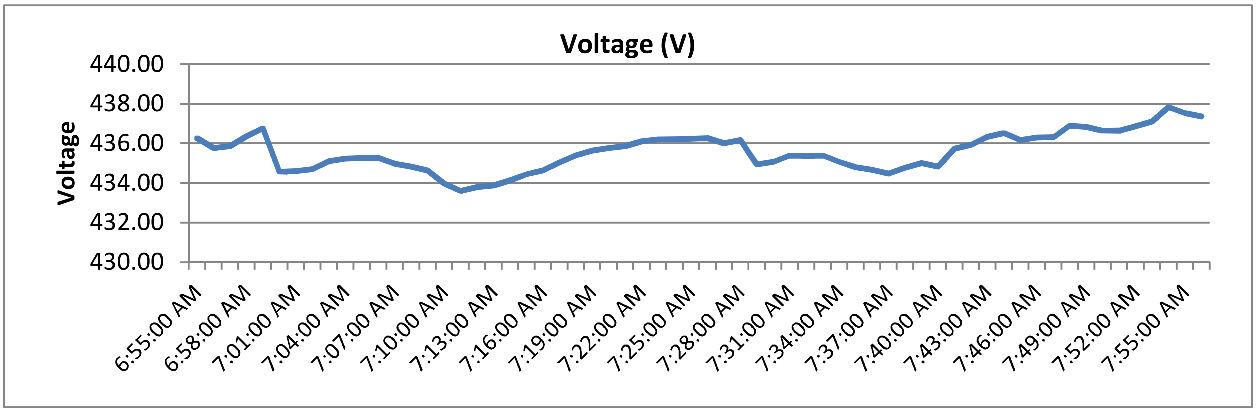


Figure 40: Voltage Variation at Synchronous Plant

- The voltage is observed to vary between 433 and 438V.

Power consumption and Apparent power Profile:

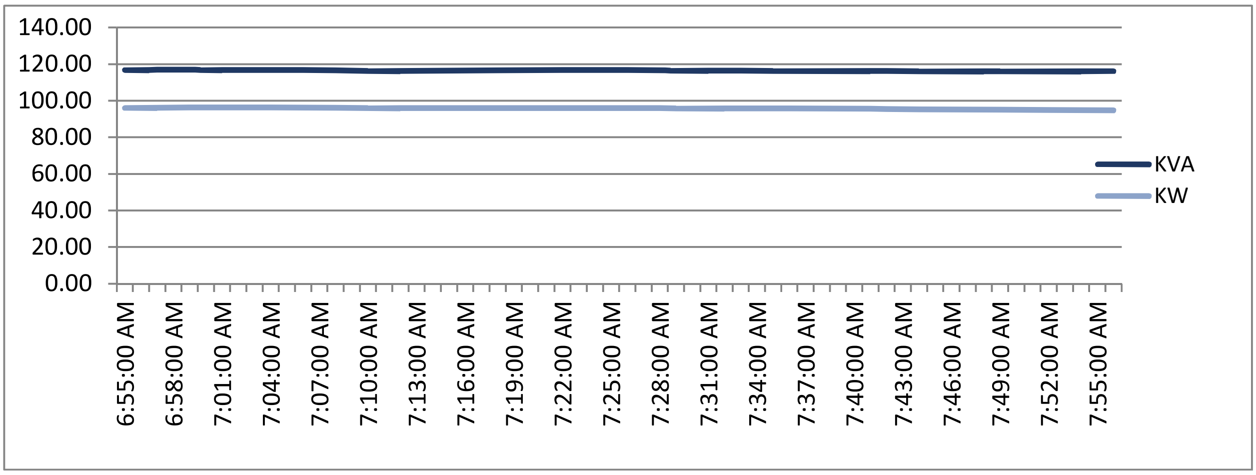


Figure 41: Power consumption variation at Synchronous Plant

- The power consumption is observed to be around 95-96 kW.
- Apparent power is found to be around 115-117 kVA.

Power factor profile

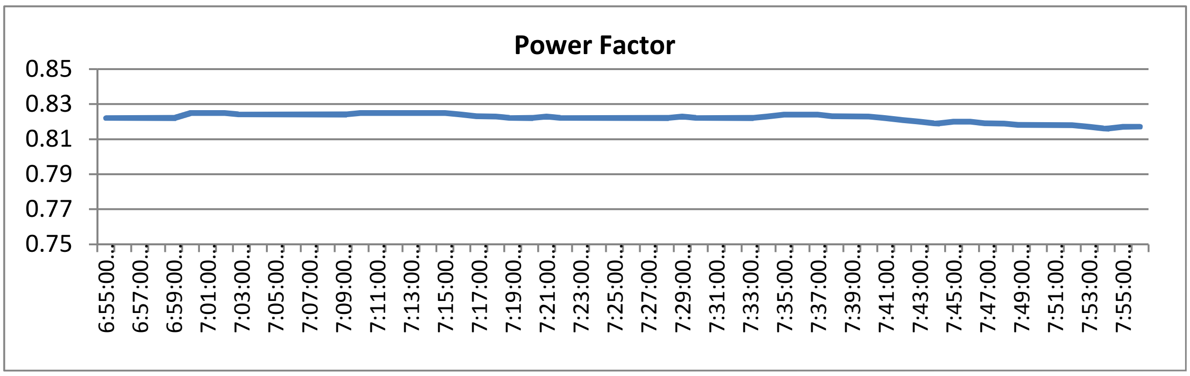


Figure 42: Power factor variation profile at Synchronous Plant

- The power factor was found to be low at around 0.82-0.83.

Frequency Profile:

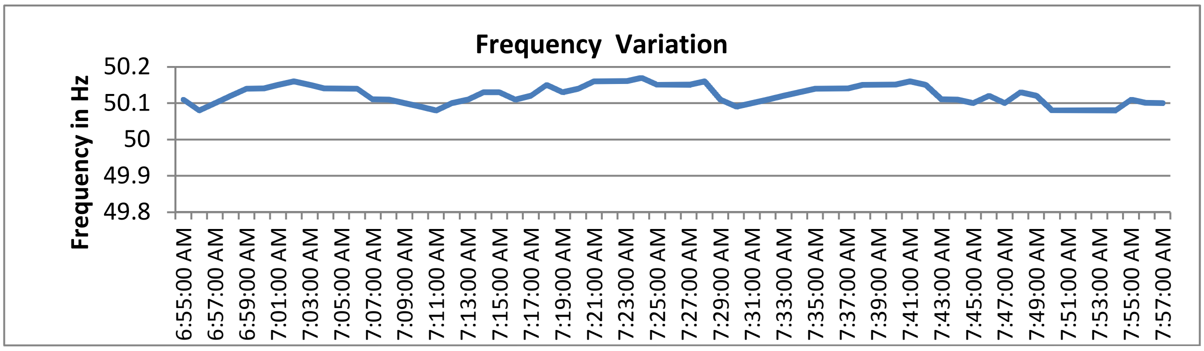


Figure 43: Frequency variation at Synchronous Plant

- The average frequency is found to be more than 50 Hz. Frequency was observed to vary between 50.08 and 50.17 Hz

Total Harmonics distortion (THD) - Current:

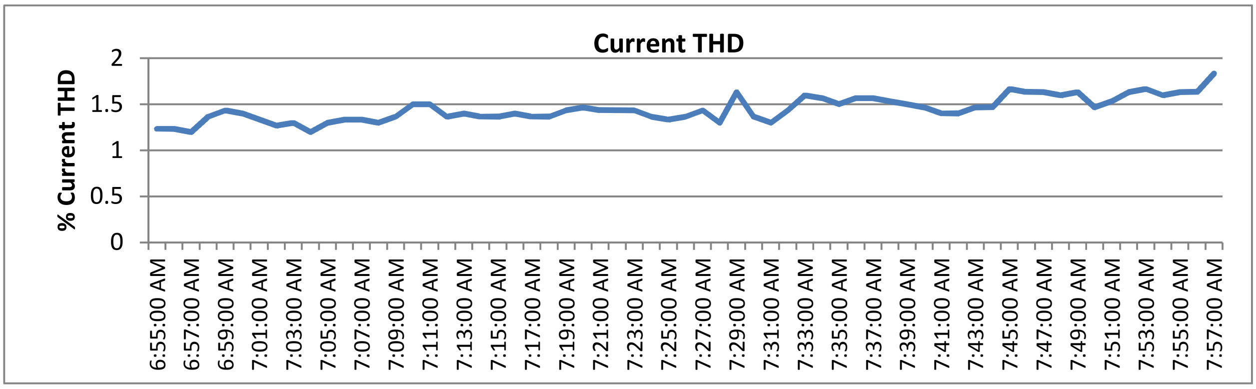


Figure 44: Variation of THD in current at Synchronous Plant

- The current THD is found to vary between 1.2 and 1.8%, averaging around 1.44%.

Total Harmonics distortion - Voltage:

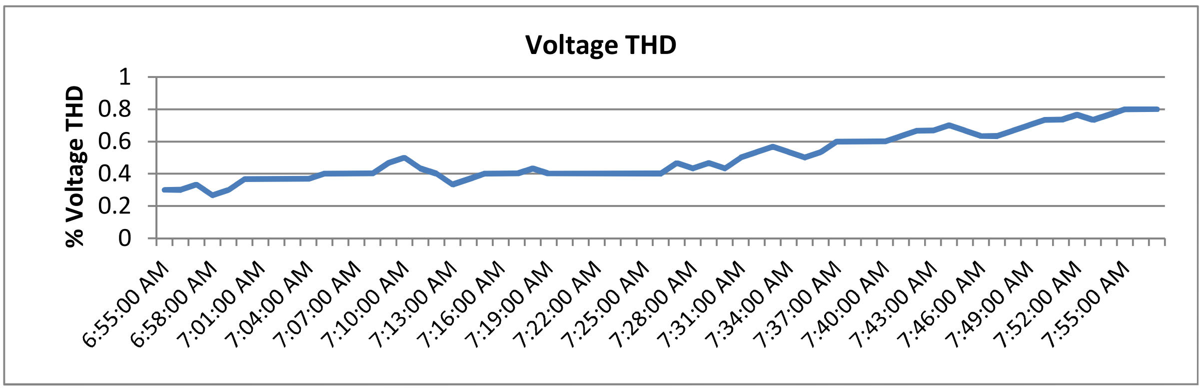


Figure 45: Variation in THD - voltage at Synchronous Plant

- Voltage THD is observed to be less than 1%.

4.6.6 Pumping Station System Mapping

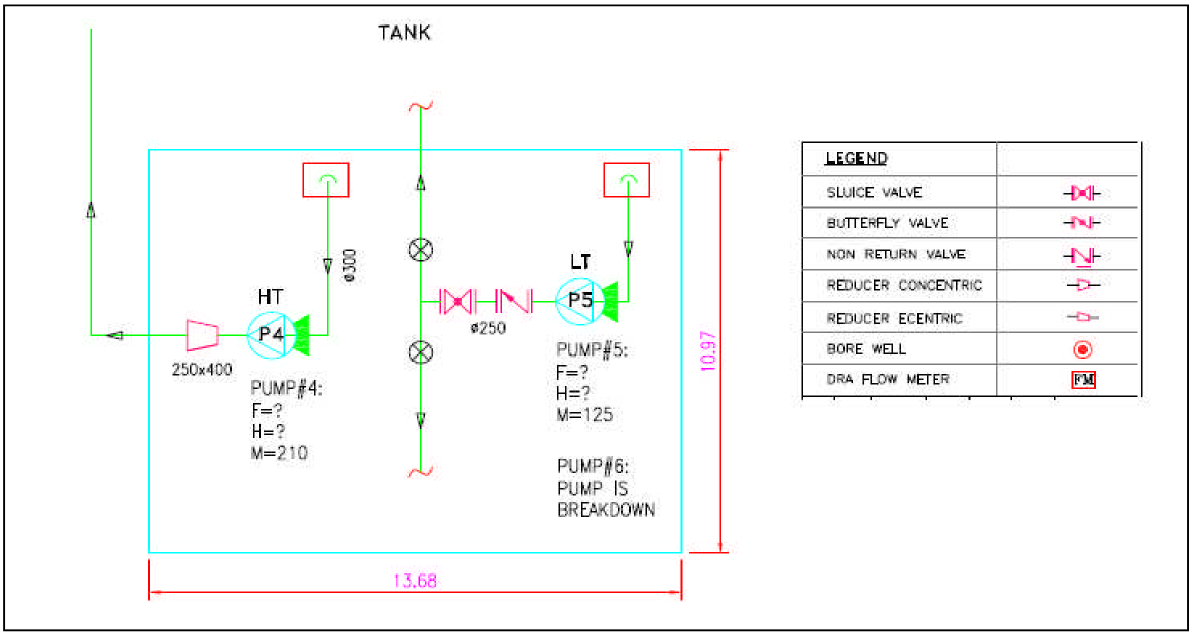


Figure 46: P & ID diagram for WTP-3

4.6.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 36: General details of Golkamra plant

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	Synchronous plant
Classification (WTP,PS, SPS, STP)	Clear Water Pumping station
Pumps installed	3
No. of pumps in operation	2
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the Synchronous plant to showcase the actual situation are provided below.

Pumping machinery installed	Pump house structure
	

Figure 47: Photographs of Synchronous pump house

Pumps installed at Synchronous Plant could not be tested due to site constraints.

Key Observations:

- NRV and SLV are installed on the pumps and in working condition but are in poor condition.

4.6.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 37: Other electrical equipment at Synchronous Pumping Station – Jeoni Mandi

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hoursper day
Synchronous plant	Tubelight	1	0.04	24

4.6.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

Measurements were not possible at Synchronous pump house due to site constraints. Thus, total energy consumption could not be determined.

4.7 8 VT Plant, Jeoni Mandi Water Works

4.7.1 Overview of existing systems

The 8 VT Plant receives treated water from the Jeoni Mandi WTP. 8 VT pumps are installed here, of which three were in breakdown condition and two are used in emergency.

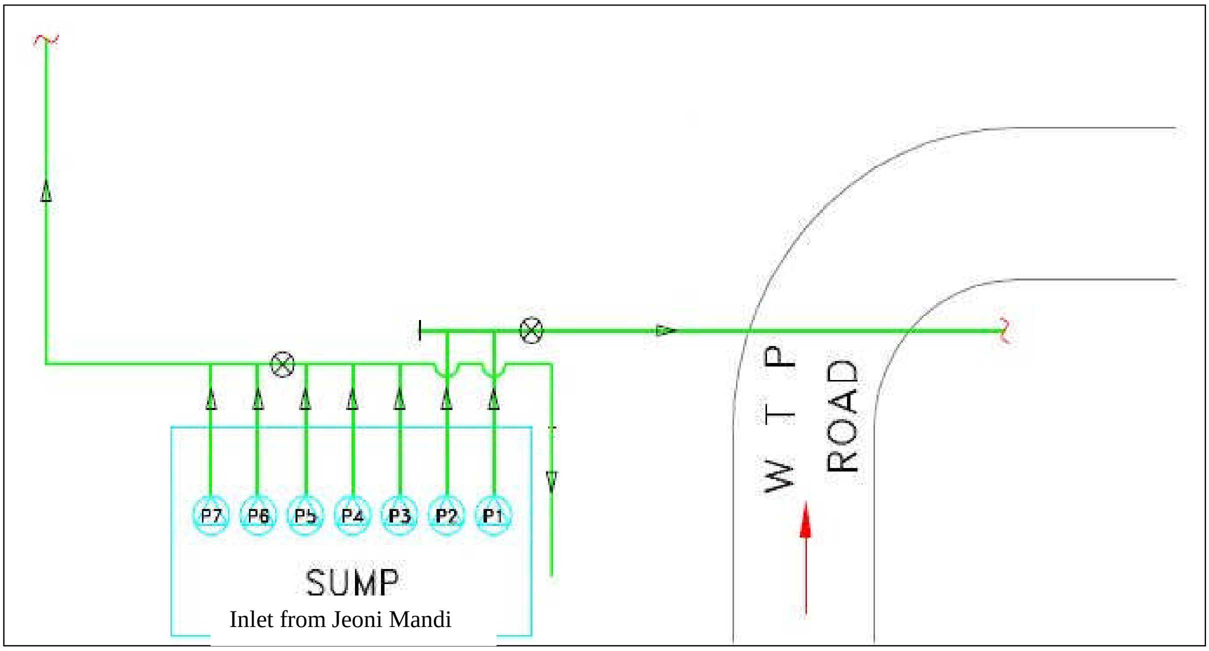


Figure 48: Plant Layout for 8 VT Pump House

4.7.2 Electricity Supply

The 8 VT Plant is a part of Jeoni Mandi scheme. The plant receives supply at 11 kV, which is stepped down through 2 nos. transformers to feed motors at 415V. A bus coupler is provided between the busbars fed by the two transformers.

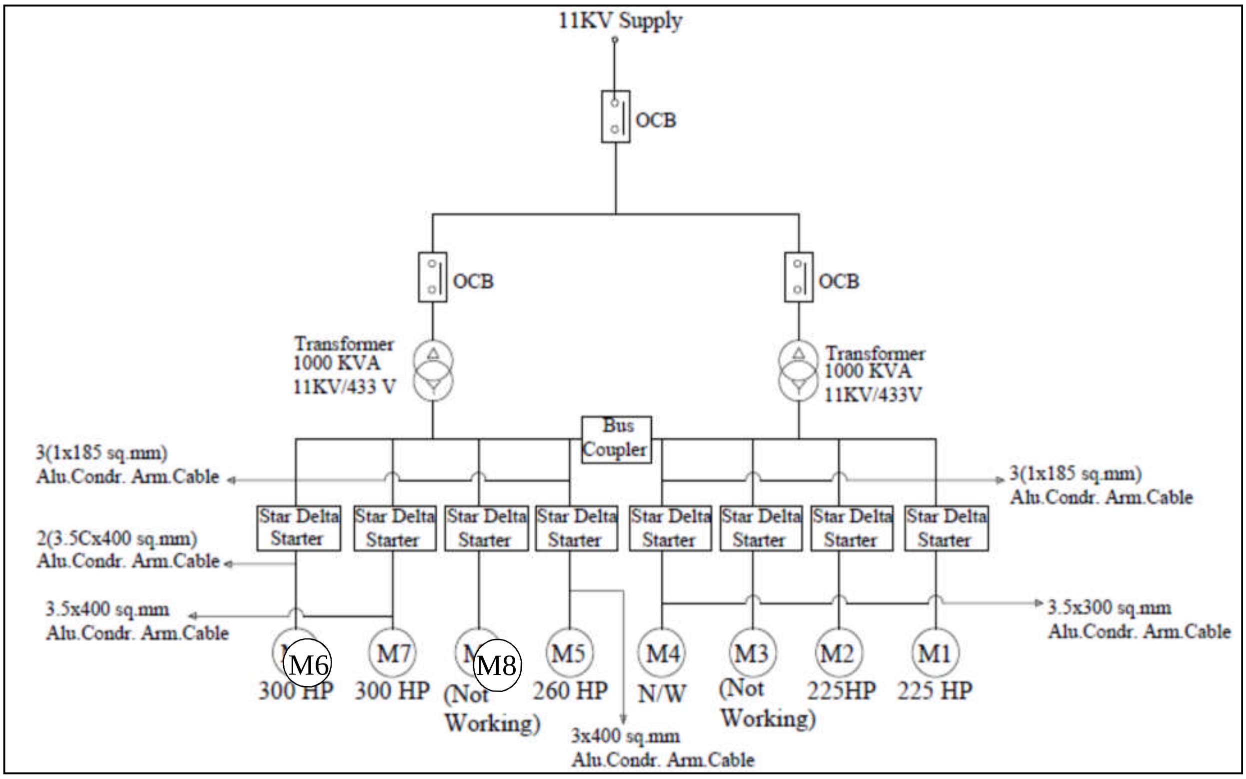


Figure 49: Single line diagram for the 8 VT Pump House

4.7.3 Tariff Structure

The 8 VT Plant is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.7.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.7.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at 8 VT Pump House is provided in below table.

Table 38: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Incomer-1	Transformer-1 (1000) kVA, 11/0.433 kV)	Pumps 1-4
Incomer-2	Transformer-2 (1000) kVA, 11/0.433 kV)	Pumps 5-8

Transformer -1 :

Voltage Profile:

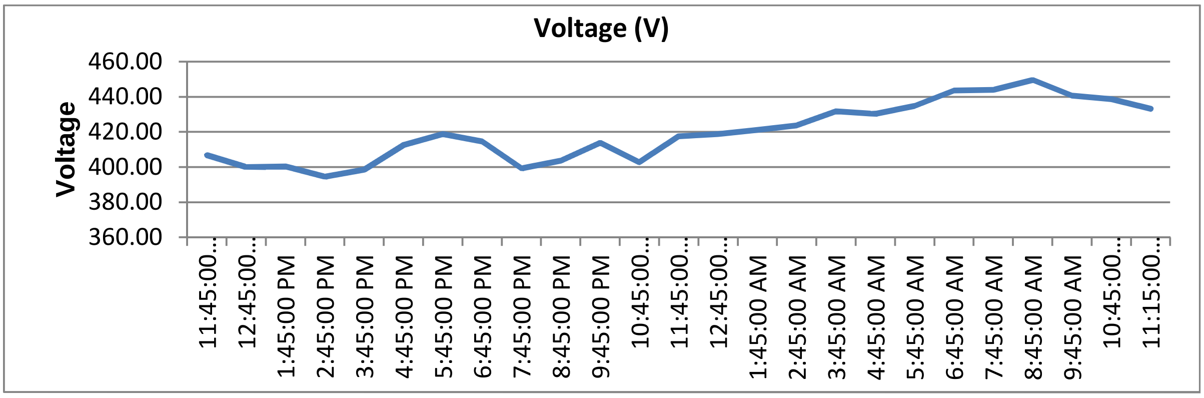


Figure 50: Voltage Variation

- Voltage was found to vary over a large range between 390 and 450V, averaging around 419.5V.

Power consumption and Apparent power Profile:

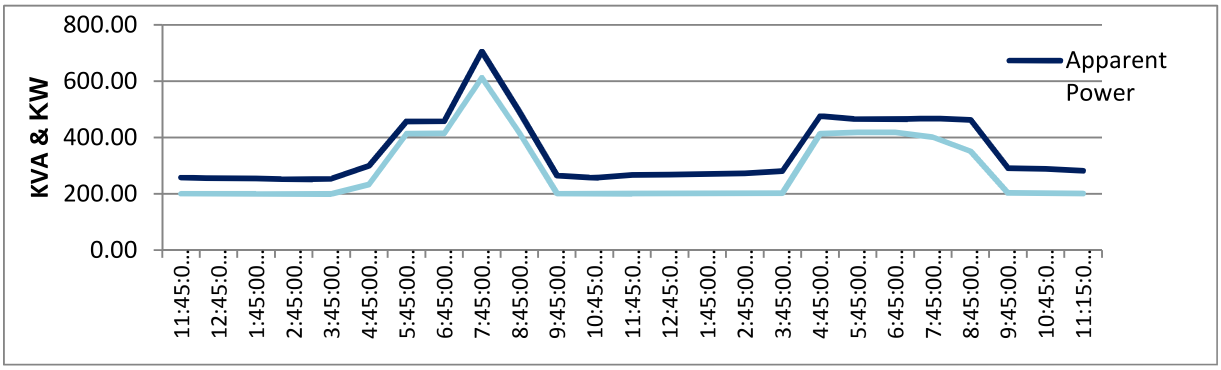


Figure 51: Power consumption variation

- The kW consumption is observed to be around 200/400/600 kW, corresponding to operation of 1/2/3 pumps.
- Apparent power is observedtobe around 250/460/700 kVA.

Power factor profile

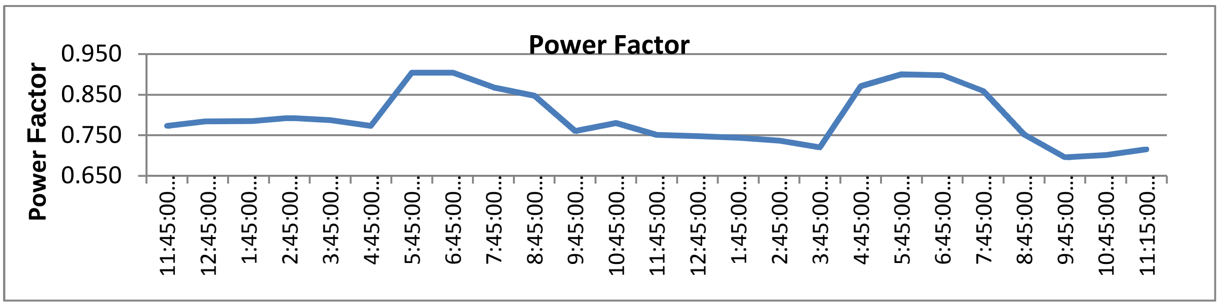


Figure 52: Power factor variation

- Power factor was found to show wide variation, falling as low as 0.7 and occasionally rising to around 0.9. The average PF was low at around 0.794.

Frequency Profile:

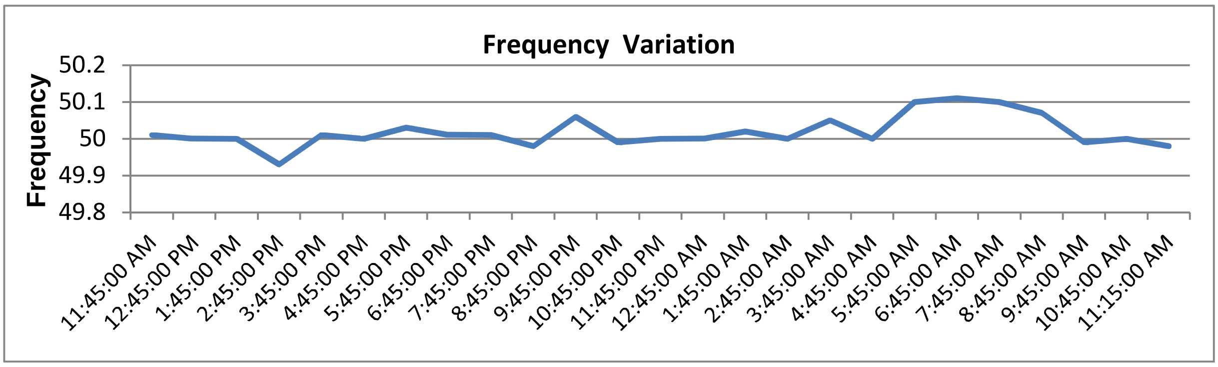


Figure 53: Frequency variation

- The frequency is observed to vary between 49.93 and 50.11 Hz.

Total Harmonics distortion (THD) - Current:

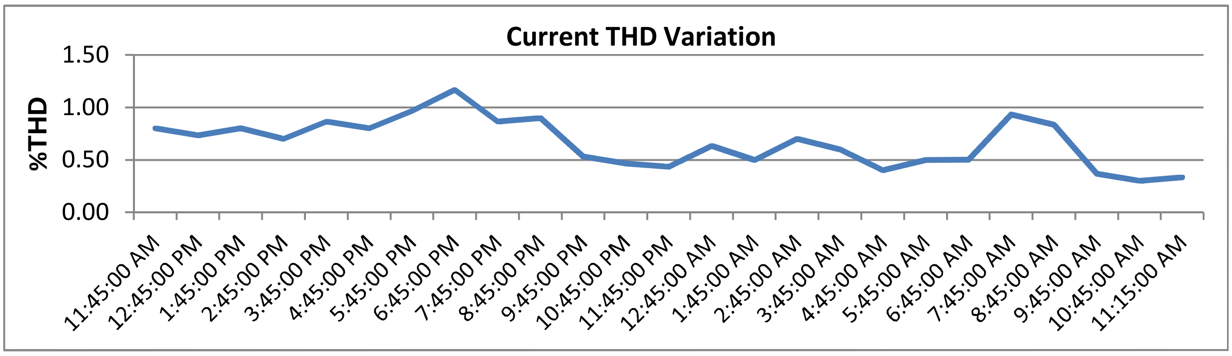


Figure 54: Variation of THD in current

- The THD in current is found to show variation between 0.3% and 1.2%, averaging 0.67%.

Total Harmonics distortion - Voltage:

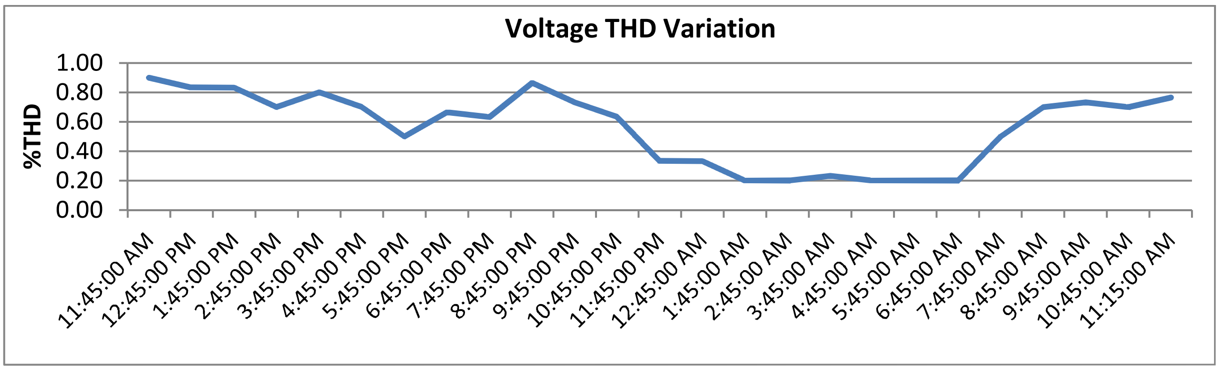


Figure 55: Variation in THD – voltage

- The voltage THD is found to be less than 1%.

Common measurement – pumps 6,7:

Voltage Profile:

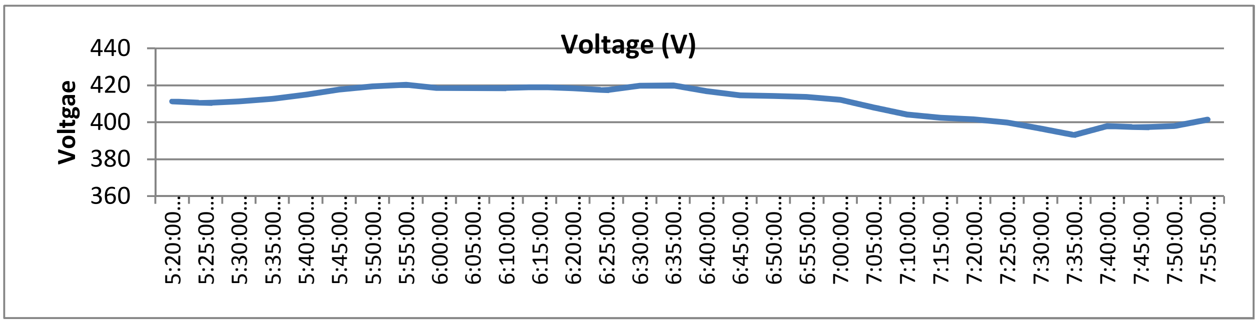


Figure 56: Voltage Variation profile

- The voltage was observed to vary between 390 and 420V, averaging 410.5V.

Power consumption and Apparent power Profile:

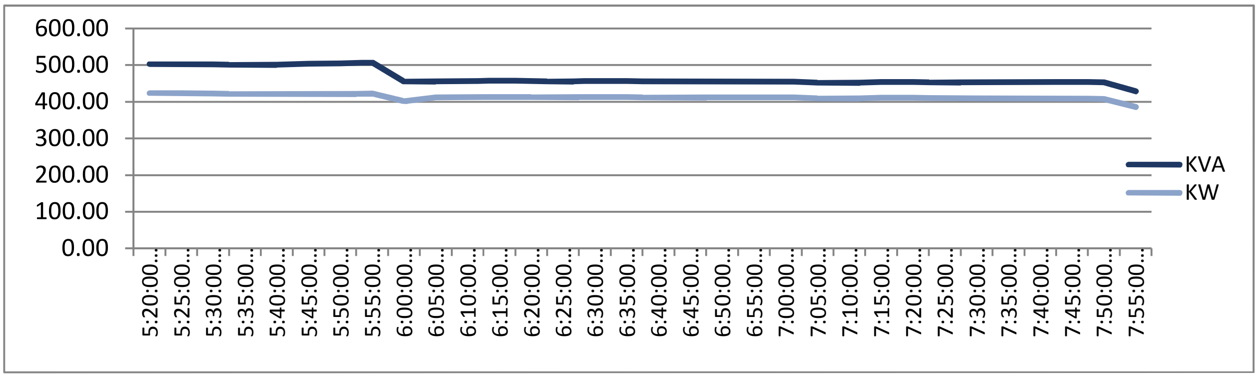


Figure 57: Power consumption variation

- Power consumption was found to vary between 390 and 425 kW, averaging 413 kW.
- Apparent power was found to vary between 425 and 510 kVA, averaging 466 kVA.

Power factor profile

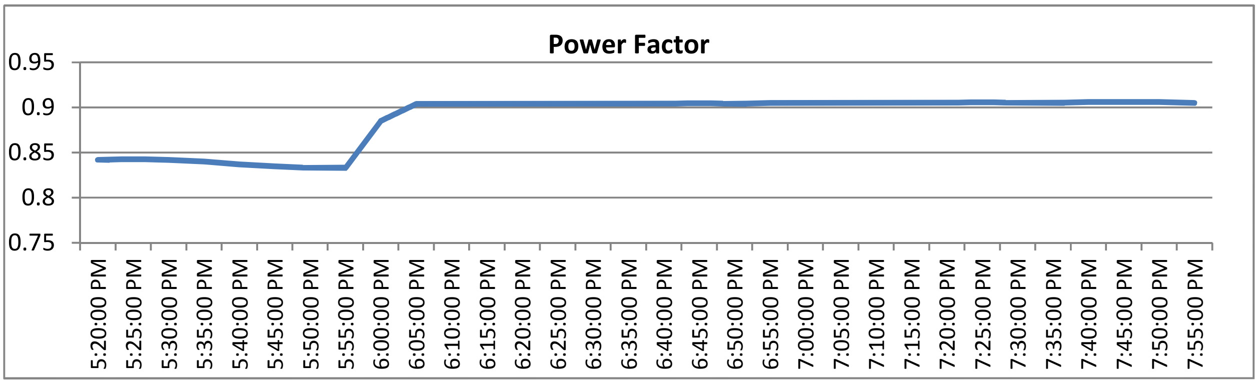


Figure 58: Power Factor variation

- Power factor was initially observed to be just below 0.85, before rising to around 0.9. The average PF over the entire duration was 0.887.

Frequency Profile:

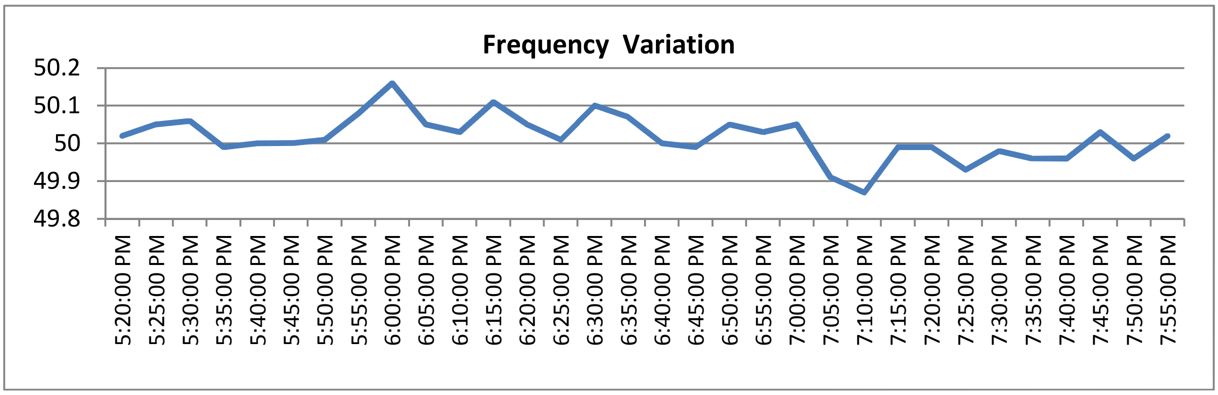


Figure 59: Frequency variation

- Frequency was mostly found to vary between 49.9 and 50.1 Hz, though low and high values of 49.85 Hz and 50.15 Hz were observed.

Total Harmonics distortion - Current:

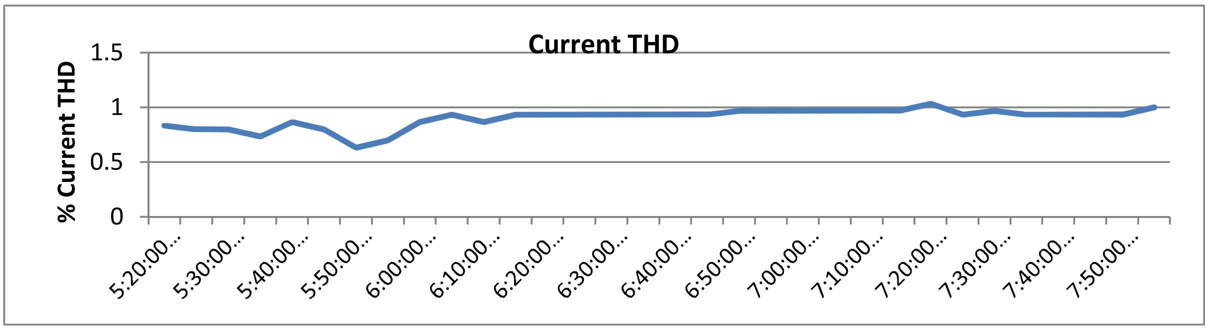


Figure 60: Variation in THD - current

- The current THD was observed to be less than 1% except some occasional peaks of around 1.05%.

Total Harmonics distortion - Voltage:

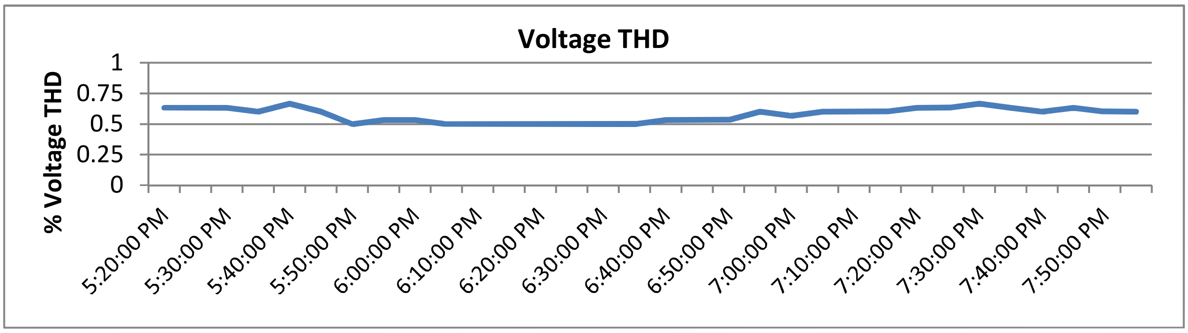


Figure 61: Variation in THD – voltage

- The voltage THD was found to be less than 0.75%.

Transformer loading:

Based on the 24 hour logging done during energy audit, transformer loading was calculated and same is provided below.

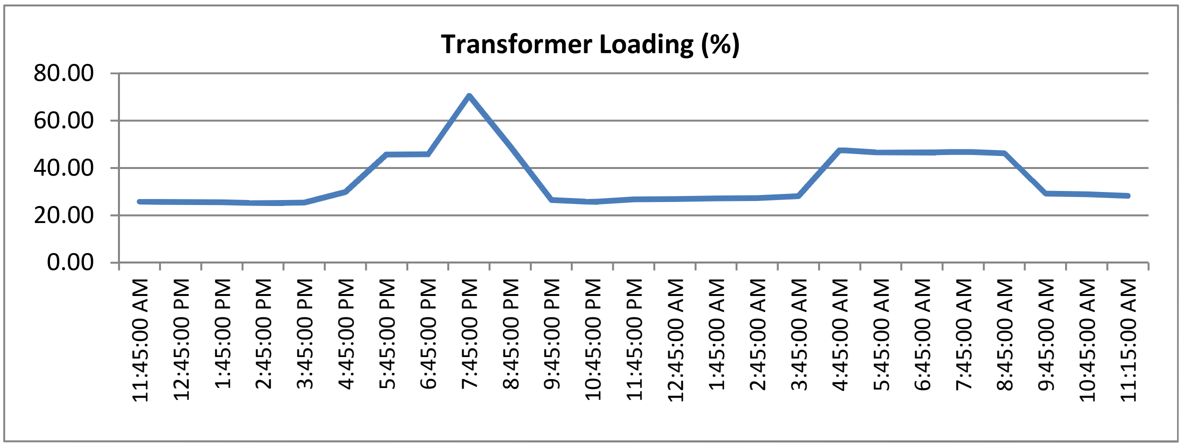


Figure 62 Transformer loading

- Based on the number of pumps in operation, the transformer loading is found to be 25-28%/47-50%/65-70%.

4.7.6 Pumping Station System Mapping

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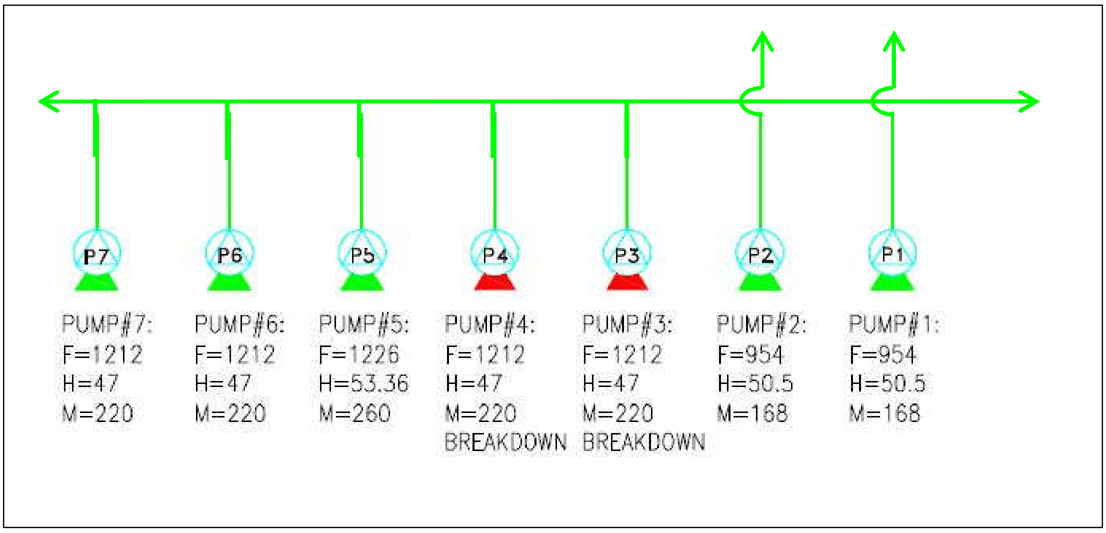


Figure 63: P & ID diagram for 8 VT Plant

4.7.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection

- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 39: General details of Golkamra plant

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	8 VT plant
Classification (WTP,PS, SPS, STP)	Clear Water Pumping station
Pumps installed	7
No. of pumps in operation	3
No. of pumps under maintenance	4
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the 8 VT plant to showcase the actual situation are provided below.

Pumping machinery installed	Pump house structure
	

Figure 64: Photographs of 8 VT Plant

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 40: Performance Evaluation of pumps at 8 VT Plant

Parameters Rated Parameters	Unit	8 VT Plant Pump-5	8 VT Plant Pump-6	8 VT Plant Pump-7
Pump make		WPIL	Jyoti	Jyoti
Motor make		GEC	Jyoti	Jyoti
Pump type		VT	VT	VT
Motor serial no.		1314707-1	121410	121581
Pump serial no.		3456	9433	9434

Parameters	Unit	8 VT Plant Pump-5	8 VT Plant Pump-6	8 VT Plant Pump-7
Rated flow	m^3/h	1226	1212	1212
Rated head	m	53.36	47	47
Rated motor	kW	260	220	220
Parameters measured				
Total suction head	m	-1.77	-2.30	-1.90
Total discharge head	m	20	16	18
Average flow delivered	m^3/h	1255.00	1281.33	1286.67
Motor input power	kW	200.13	173.02	217.02
Frequency	Hz	49.96	49.94	49.93
Speed	RPM	1477.33	1481.33	1477.00
Performance evaluation				
Total head developed	m	21.77	18.30	19.90
Head utilization	%	41%	39%	42%
Flow utilization	%	102%	106%	106%
Hydraulic power	kW	74.40	63.86	69.73
Motor input power	kW	200.13	173.02	217.02
Calculated pumpset efficiency	%	37.18%	36.91%	32.13%
Rated motor efficiency	%	93.0%	93.5%	93.5%
Calculated pump efficiency	%	39.98%	39.47%	34.36%
Specific energy consumption	kWh/m^3	0.159	0.135	0.169

Table 41: Parallel pumping at 8 VT Plant

Parameters	Unit	8 VT Plant Pumps 6,7
Total suction head	m	-3.08
Total discharge head	m	20
Total flow m^3/h	m^3/h	2535.67
Motor input power	kW	414.89
Performance evaluation		
Total head developed	m	23.08
Head utilization	%	49%
Flow utilization	%	105%
Hydraulic power developed by pump	kW	159.35
Motor input kW	kW	414.89
Calculated overall efficiency	%	38.41%
Motor efficiency	%	93%

Parameters	Unit	8 VT Plant Pumps 6,7
Calculated pump efficiency	%	41.3%
Specific energy consumption	kWh/m³	163.62

Key Observations:

- Pump nos. 5, 6 and 7 were all observed to be operating at pump set efficiencies in the 32%-38% range. The observed discharge was close to the rated discharge, but the observed head was found to be significantly less than the rated head.
- Combined efficiency of pump sets 6 and 7 during parallel pumping was found to be 38.41%.
- Pumps 3 and 4 were in breakdown condition at the time of audit.
- Heavy leakage was observed from joint between pump outlet pipe and common header.

4.7.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 42: Other electrical equipment at 8 VT Plant, Jeoni Mandi Water Works - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	Two
Capacity (kVA)	1000 kVA, 1000 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	

Table 43: Other electrical equipment at 8 VT Pump House - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
8 VT plant	CFL	3	0.065	12

Table 44: Other electrical equipment at 8 VT Pump House

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Other loads	Air Cooler	1	0.250	24
	Exhaust Fan	2	0.200	10

4.7.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for 8 VT Plant is provided in below table.

Table 45: Estimatedenergy consumption for 8 VT Plant

Name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
8 VT Plant	Pump-5	6&7 in parallel and 5 have separate pipe	6267	200.13	1254300
8 VT Plant	Pump-6		2550	173.02	441212
8 VT Plant	Pump-7		2761	217.02	599114
	Total		**11,578**	**590.17**	**2,294,626**

4.8 Flowmore Plant

4.8.1 Overview of existing systems

The Flowmore plant receives treated water from the Jeoni Mandi WTP and then pumps it to zonal pumping stations or to Kamla Nagar area. Five VT pumps are installed here, of which two were in breakdown condition.

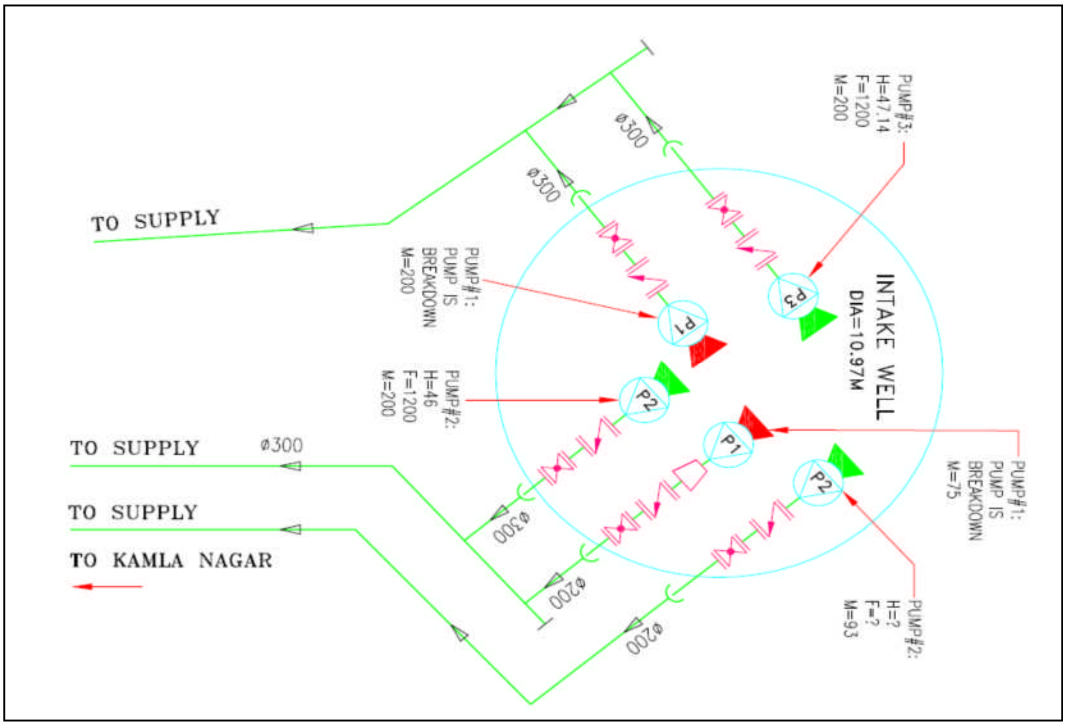


Figure 65: Plant Layout for Flowmore Plant

4.8.2 Electricity Supply

The Flowmore plant is a part of the Jeoni mandi water works connection. It receives power at 11 kV, which is stepped down through transformer for feeding motors at 415V.

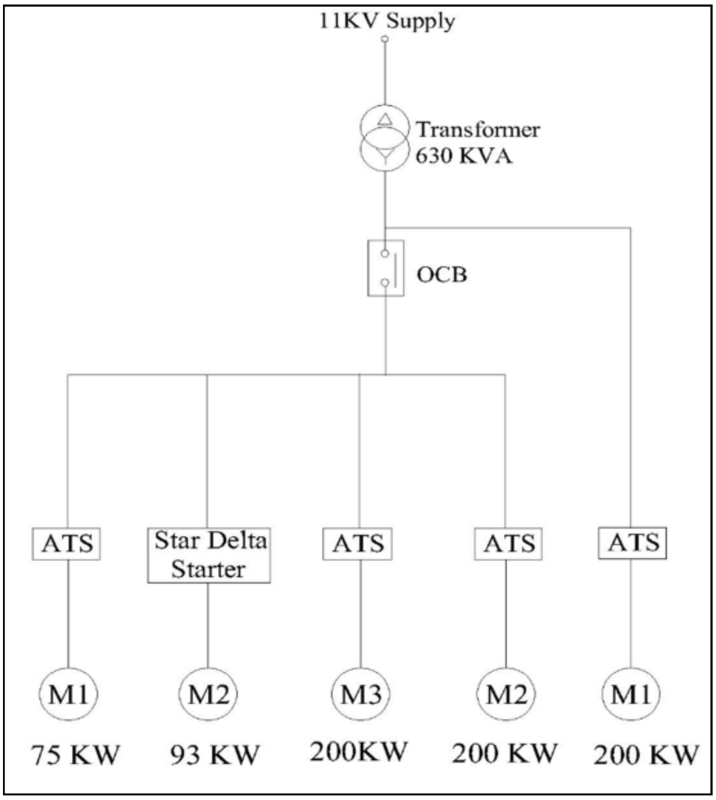


Figure 66: Single line diagram for Flowmore Plant

4.8.3 Tariff Structure

The Flowmore plant is covered under Jeoni Mandi scheme electrical connection which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL. Tariff details are covered in section 4.2.3.

4.8.4 Electricity Bill Analysis

The three intake wells (Old, New and New Jal Nigam), the Jeoni Mandi water treatment plants and 4 nos clear water pump houses (HT Golkamra, Synchronous, Flowmore and 8 VT) are all covered under a single electrical connection by the name of Jeoni Mandi. Analysis of this bill is covered in section 4.2.4.

4.8.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at 8 VT Plant is provided in below table.

Table 46: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Incomer-1	Transformer-1 (630) kVA, 11/0.433 kV)	All 5 pump sets

Voltage Profile:

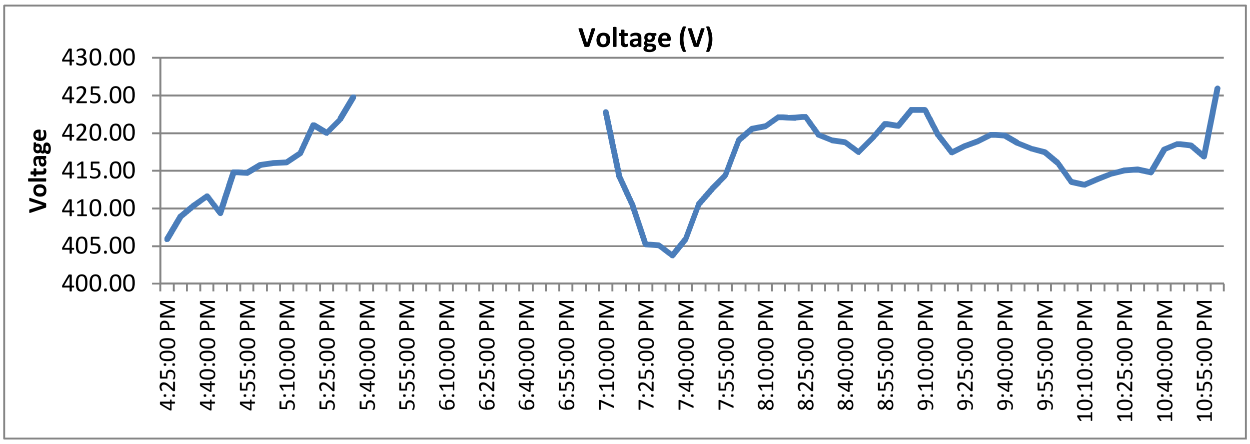


Figure 67: Voltage Variation of Transformer-1

- Power cut occurred at 7:45, lasted for around 1 hour 15 minutes.
- The voltage was found to vary between 404 and 425V, averaging around 423V.

Power consumption and Apparent power Profile:

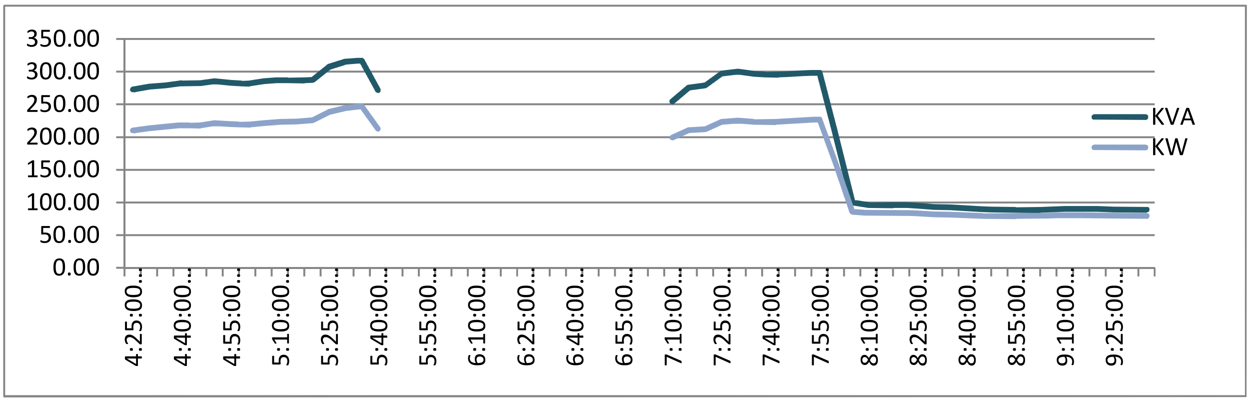


Figure 68: Power consumption variation at Transformer-1

- The power consumption was observed to be in the 75-90 kW/210-230 kW range as per the number of pumps in operation.
- The apparent power was observed to be in the 85-100 kVA/270-300 kVA range as per the number of pumps in operation.

Power factor profile

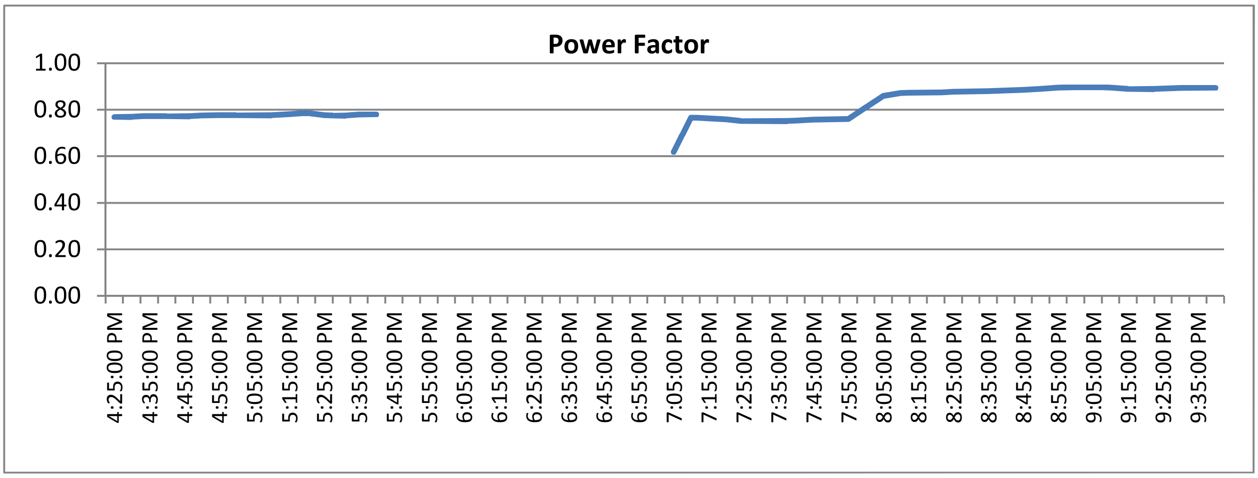


Figure 69: Power factor variation profile on Transformer-1

- Power factor was found to be less than 0.8 during operation of two pumps, and improved to close to 0.9 during operation of single pump having lower motor kW.

Frequency Profile:

During energy audit, frequency was recorded for 24 hours at the transformer secondary side at the main LT panel of the Transformer. Variation in frequency for the recorded 24 hour period is provided in figure 10

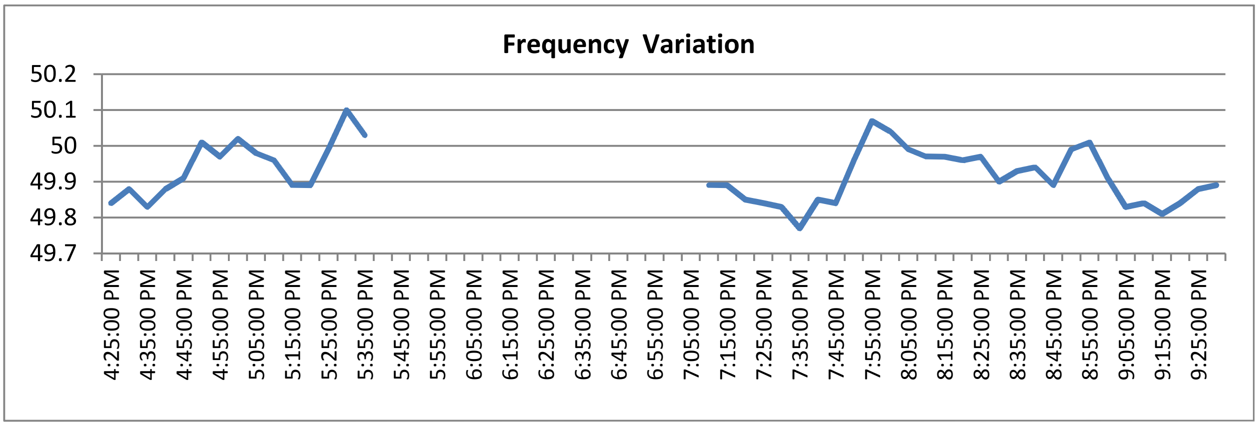


Figure 70: Frequency variation on Transformer-1

- The frequency was found to approach or drop below 49.8 Hz on some occasions, while maximum recorded frequency was 50.1 Hz.

Total Harmonics distortion (THD) - Current:

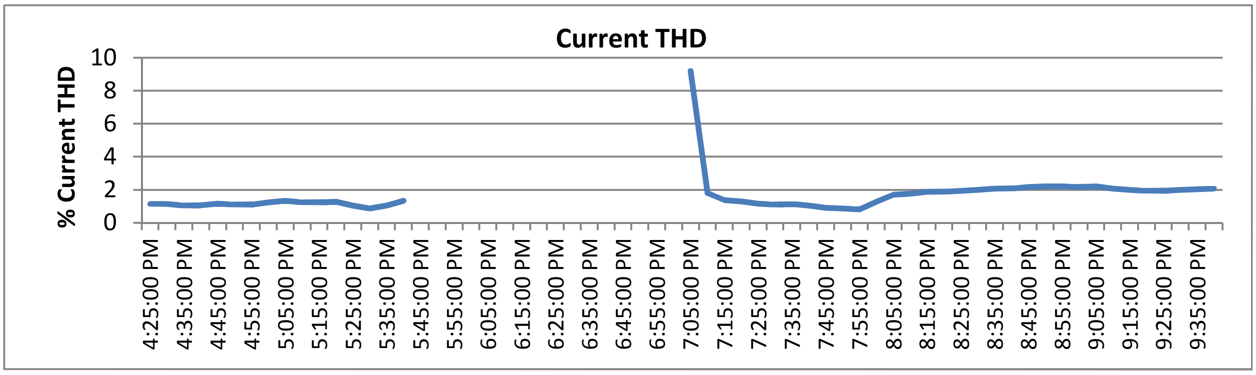


Figure 71: Variation of THD in current on Transformer-1

- With the exception of a spike observed during restart after power cut, the current THD was observed to be in the 1%-2% range with an average of 1.74%.

Total Harmonics distortion - Voltage:

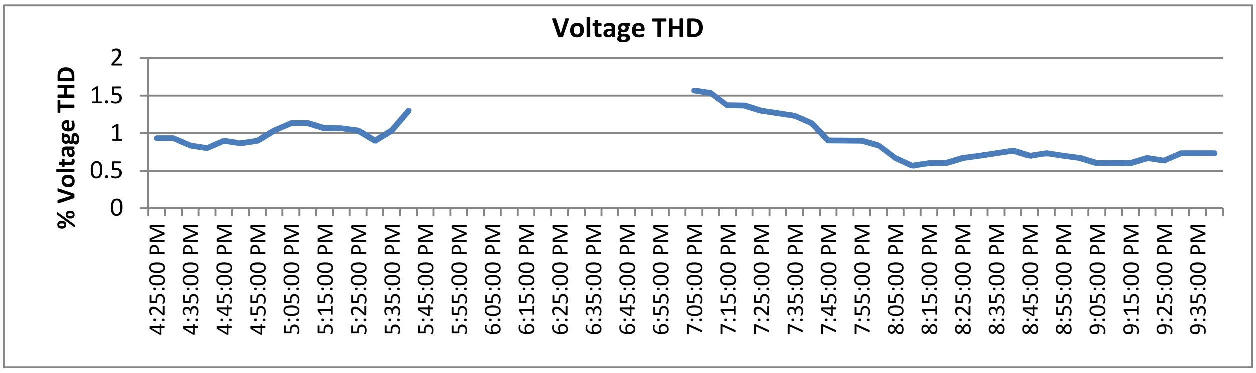


Figure 72: Variation in THD - voltage on Transformer-1

- The voltage THD was found to vary between 0.5 and 1.6%, averaging around 0.83%.

Morning supply: 2 pumps running

Voltage Profile:

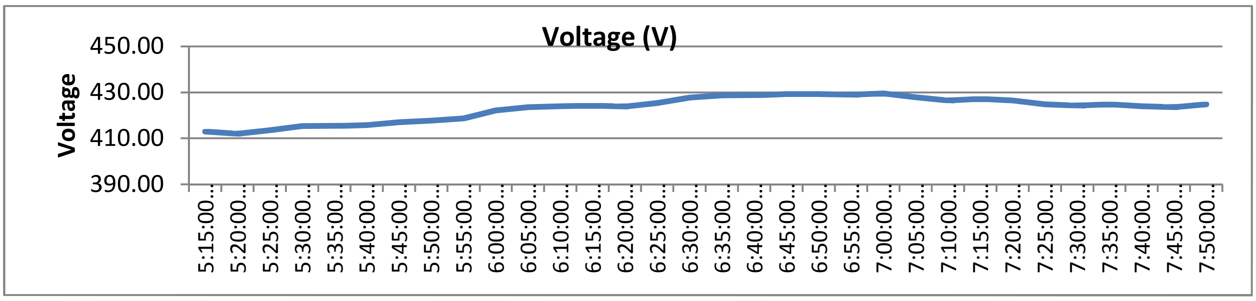


Figure 73: Voltage Variation profile

- The voltage was found to vary between 412 and 430V, averaging 423V.

Power consumption and Apparent power Profile:

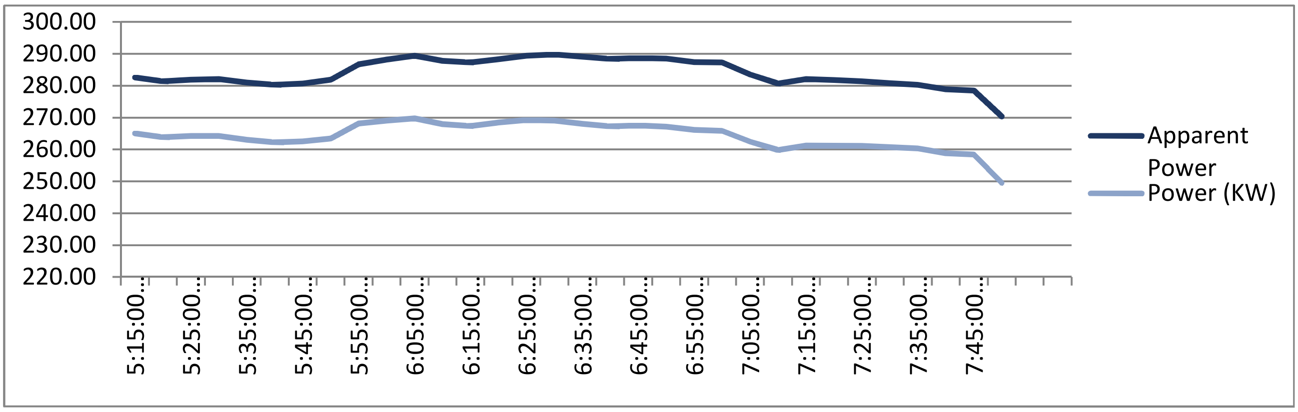


Figure 74: Power consumption variation

- The power consumption was observed to be around 260-270 kW.
- The apparent power was observed to be around 280-290 kVA.

Power factor profile

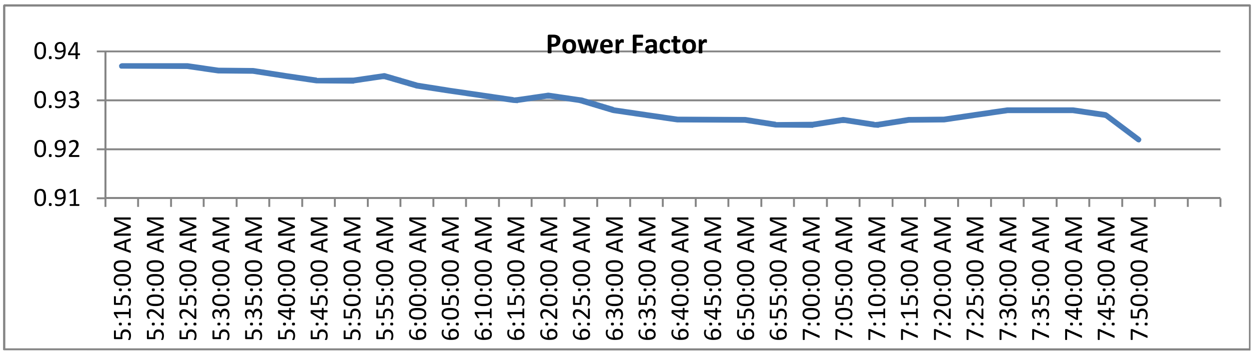


Figure 75 Power Factor variation

- The power factor is found to be maintained above 0.92.

Frequency Profile:

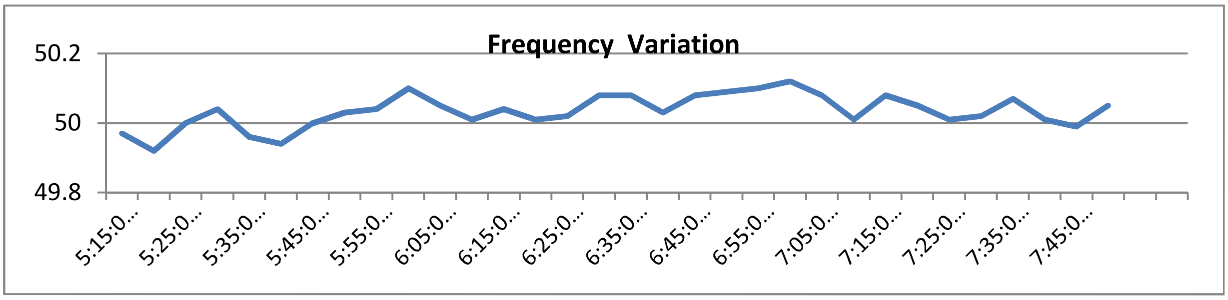


Figure 76: Frequency variation

Frequency is found to vary between 49.94 and 50.12 Hz.

Total Harmonics distortion - Current:

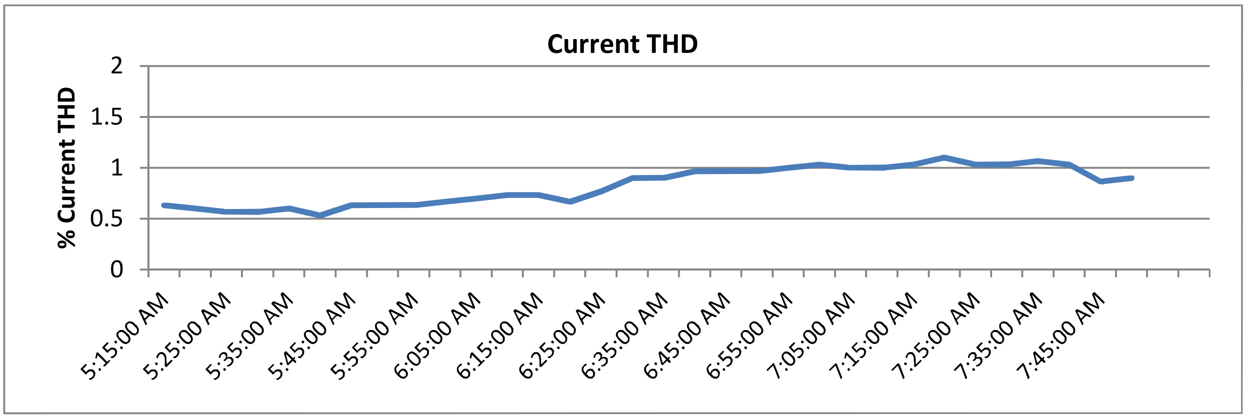


Figure 77: Variation in THD - current

- The current THD was found to be in the 0.5-1.1% range, averaging 0.83%.

Total Harmonics distortion - Voltage:

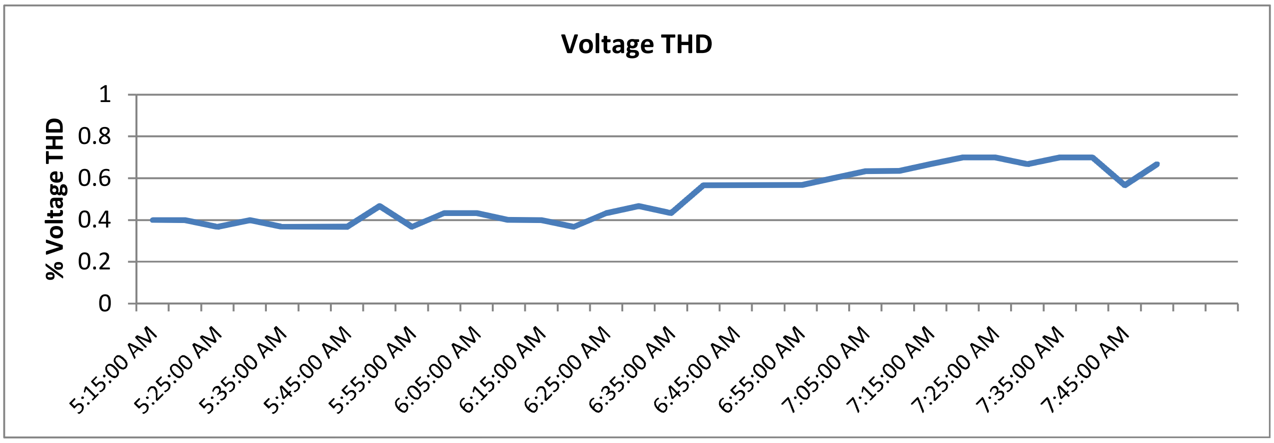


Figure 78: Variation in THD - voltage

- The voltage THD was found to be less than 0.8%.

Transformer loading:

Based on the kVA measurement during energy audit, average transformer loading was calculated and same is provided below.

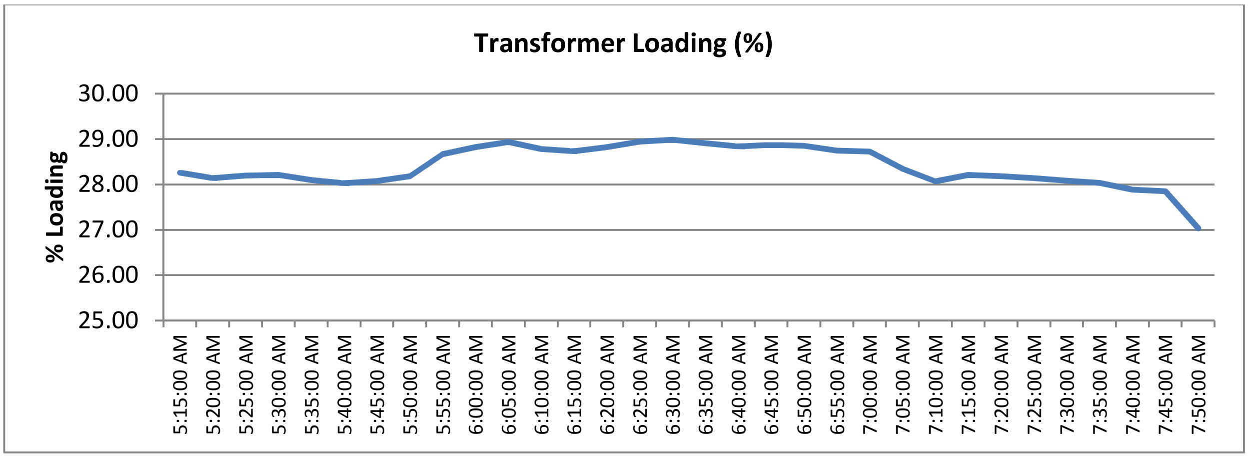


Figure 79 Transformer loading

- The transformer loading is observed to be around 27-29% with two pumps in operation.

4.8.6 Pumping Station System Mapping

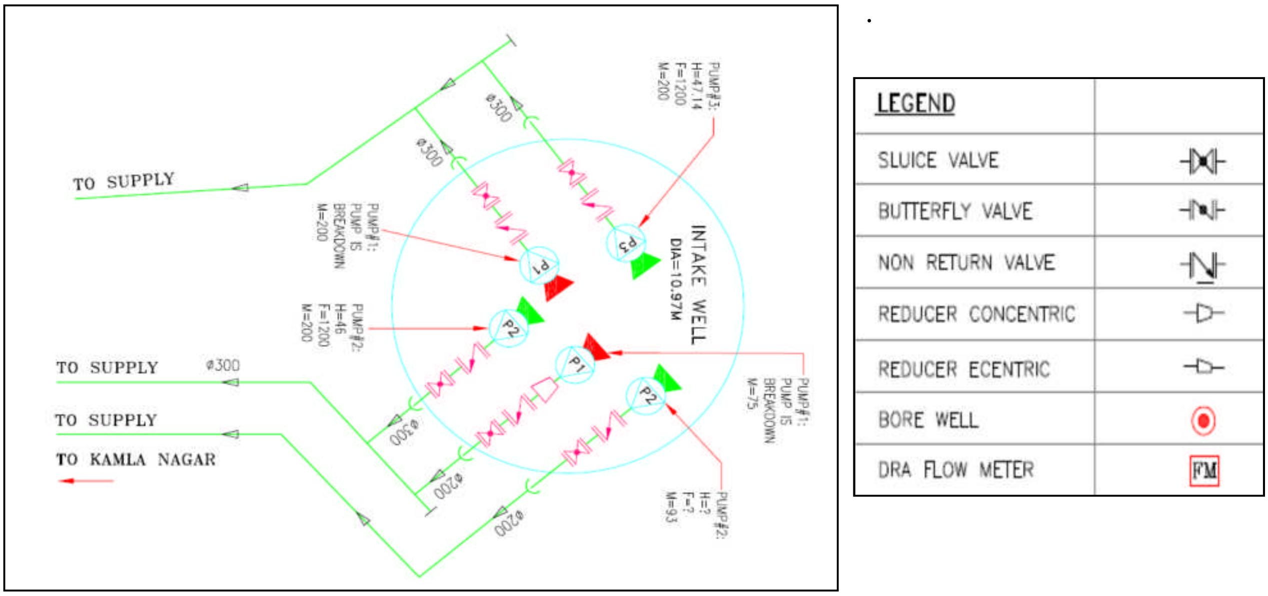


Figure 80: P & ID diagram for Flowmore Plant

4.8.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 47: General details of Flowmore plant

Data	Value / Details
Name of site	Jeoni Mandi
Name of Sub-section	Flowmore plant
Classification (WTP,PS, SPS, STP)	Clear Water Pumping station
Pumps installed	5
No. of pumps in operation	3
No. of pumps under maintenance	2
Other Details	
Basis of pump operation	Level of reservoir tank of Jeoni Mandi WTP
VFD installed (Yes/No)	No

Photographs captured at the Flowmore plant to showcase the actual situation are provided below.

Pumping machinery installed	Pump house structure
	

Figure 81: Photographs of Flowmore Plant

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 48: Performance Evaluation of pumps at Flowmore Plant

Parameters Parameters	Unit	Flow More Plant Pump-3 200 kW
Pump make		WPIL
Motor make		Alstom
Pump type		VT
Motor serial no.		265622000001
Pump serial no.		3403
Rated flow	m^3/h	1200
Rated head	m	47.14
Rated motor	kW	200
Parameters measured		

Parameters	Unit	Flow More Plant Pump-3 200 kW
Total suction head	m	0.00
Total discharge head	m	35
Average flow delivered	m^3/h	1465.33
Motor input power	kW	168.10
Frequency	Hz	49.95
Speed	RPM	1489.67
Performance evaluation		
Total head developed	m	35.00
Head utilization	%	74%
Flow utilization	%	122%
Hydraulic power	kW	139.67
Motor input power	kW	168.10
Calculated pumpset efficiency	%	83.09%
Rated motor efficiency	%	95.3%
Calculated pump efficiency	%	87.18%
Specific energy consumption	kWh/m^3	0.115

Key Observations:

- Pump 1 (200 kW) and pump 1 (75 kW) were in breakdown condition.
- Individual flow measurement was not possiblefor pump 2 (200 kW) and pump 2 (93 kW).
- Pump 3 was found to be operating at a pump set efficiency of 83.09%.

4.8.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 49: Other electrical equipment at Flowmore Pump House - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	630 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	

Table 50: Other electrical equipment at Flowmore Pump House – lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Flowmore plant	Tubelight	2	0.04	12
	CFL	3	0.075	12

Table 51: Other electrical equipment at Flowmore Pump House

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Cooler	1	0.28	24
	Exhaust Fan	1	0.11	8

4.8.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Flowmore Plant is provided in below table.

Table 52: Estimated energy consumption for Flowmore Plant

Name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Flow More Plant	Pump-2 200 kW	Pump 2-200 kW - separate line, P3-200 kW and P2-93 kW in parallel	1,578	164.65	259,873
Flow More Plant	Pump-3 200 kW		1,122	168.10	188,533
Flow More Plant	Pump-2 93 kW		2,318	60.52	140,265
	Total		**5,018**	**393.27**	**588,671**

4.9 Sanjay Palace ZPS

4.9.1 Overview of existing systems

The Sanjay Palace ZPS receives treated water from the Sikandra WTP. The water is then pumped to Hari Parvat, Maithan, and Sanjay Market areas through different sets of pumps. A total of ten VT pumps are installed here, of which 4 supply to Hari Parvat area, 5 to Maithan area and 1 to Sanjay Market area.

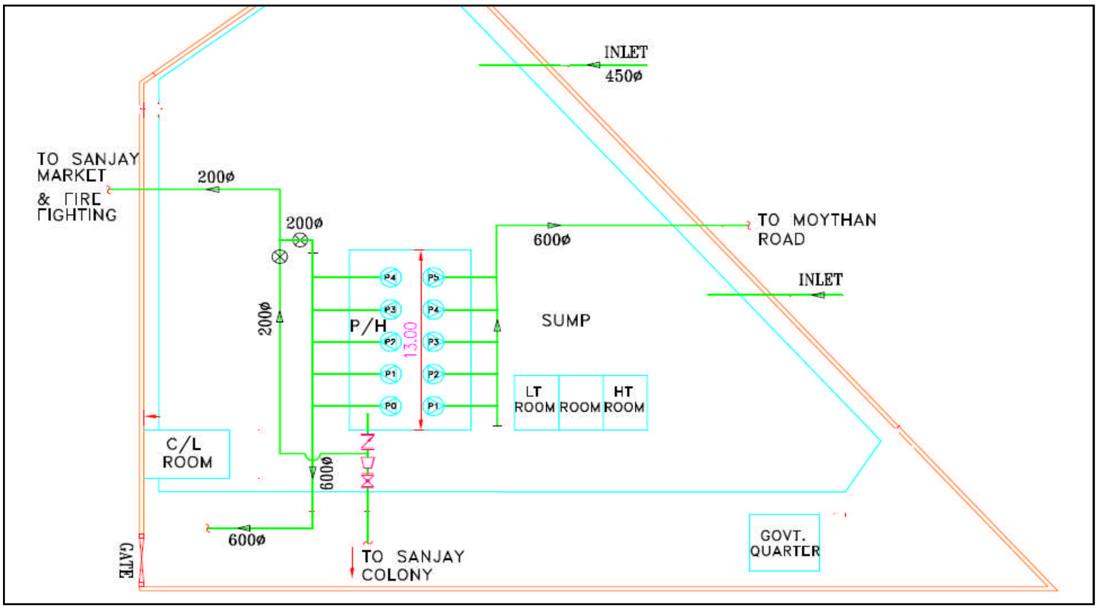


Figure 82: Plant Layout for Sanjay Palace ZPS

4.9.2 Electricity Supply

Sanjay Place ZPS receives supply at 11 kV from Torrent Power. This is stepped down to 415V via a 630kVA transformer to feed the motors.

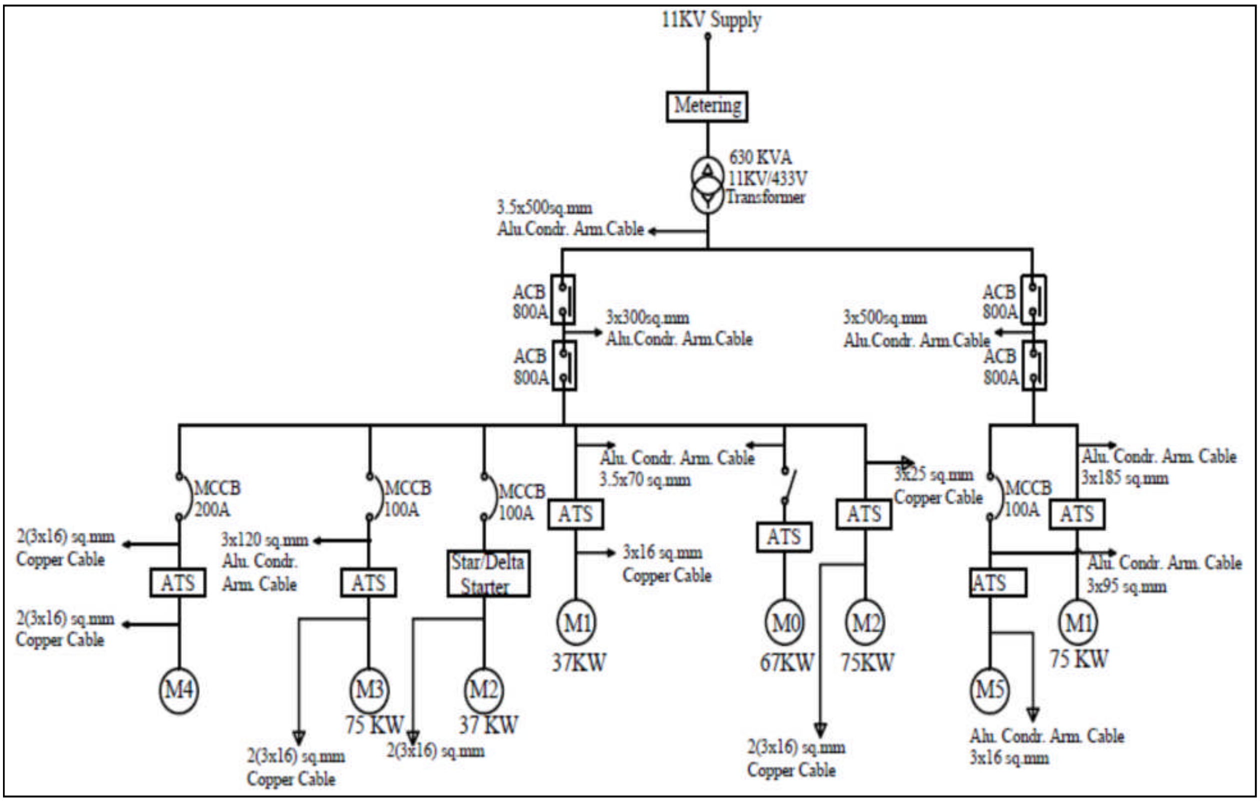


Figure 83 Single line diagram for the Sanjay Palace ZPS

4.9.3 Tariff Structure

The electrical connection for Sanjay Place ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 53: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Sanjay Place Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.9.4 Electricity Bill Analysis

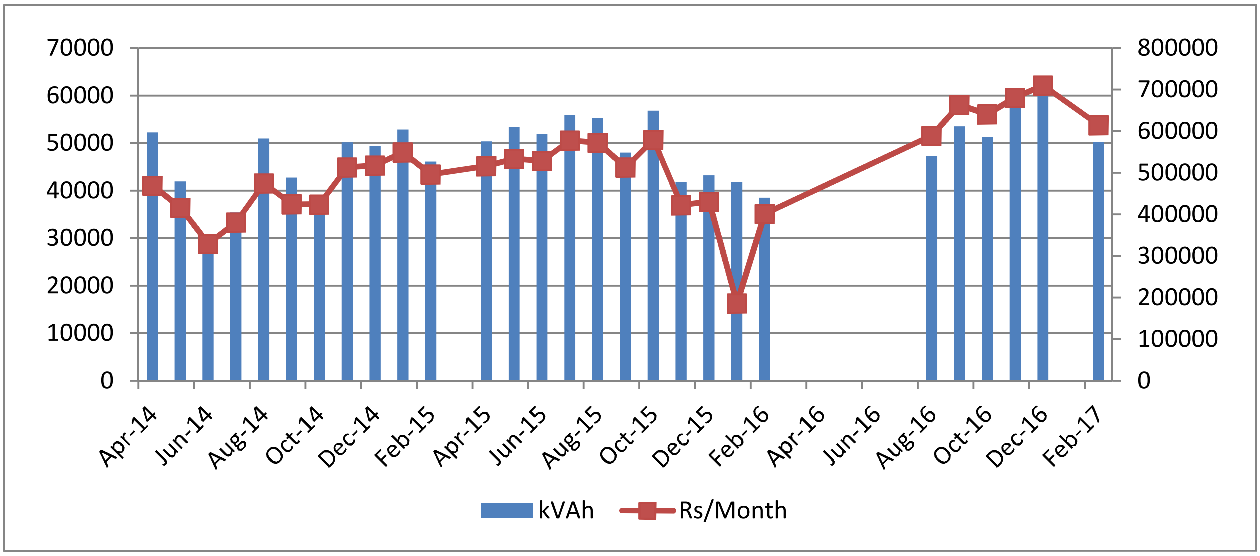
During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

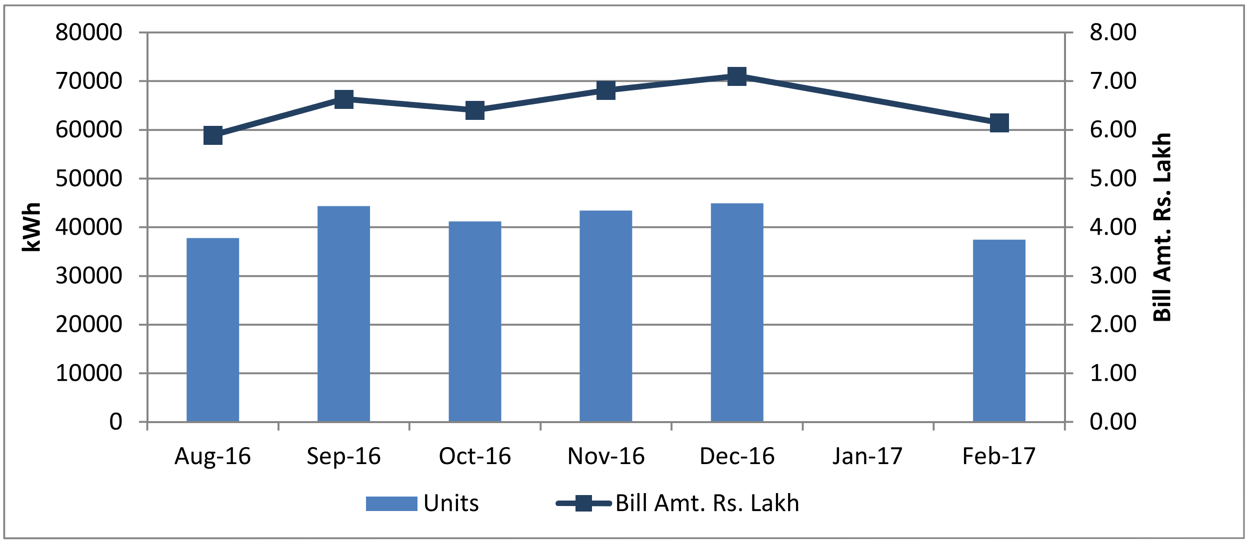
Table 54: Energy cost and energy consumption detail for Sanjay Palace ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	452,991		5,452,074
Apr-15 to Mar-16	495,281	9.3%	5,742,409
Apr-16 to Mar-17	498,408	0.6%	7,800,011

The recorded power factor at Sanjay Place ZPS was around 0.83-0.84. As billing is done on kVAh basis, improving the measured power factor to unity will reduce the kVAH consumption and thus the electricity cost paid per month. Monthly consumption and bill amount for available bills from Apr 2014 to March 2017 is given in the graph below.

Figure 84: Monthly electricity consumption and electricity bill for Sanjay Palace ZPS





4.9.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on secondary side of transformer for recording variation of electrical parameters. Details about transformers installed at Sanjay Palace ZPS is provided in below table.

Table 55: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer-1	Transformer-1 (630) kVA, 11/0.433 kV)	All 10 pump sets

A single transformer handles the entire load of the Sanjay Place pumping station.

Voltage Profile:

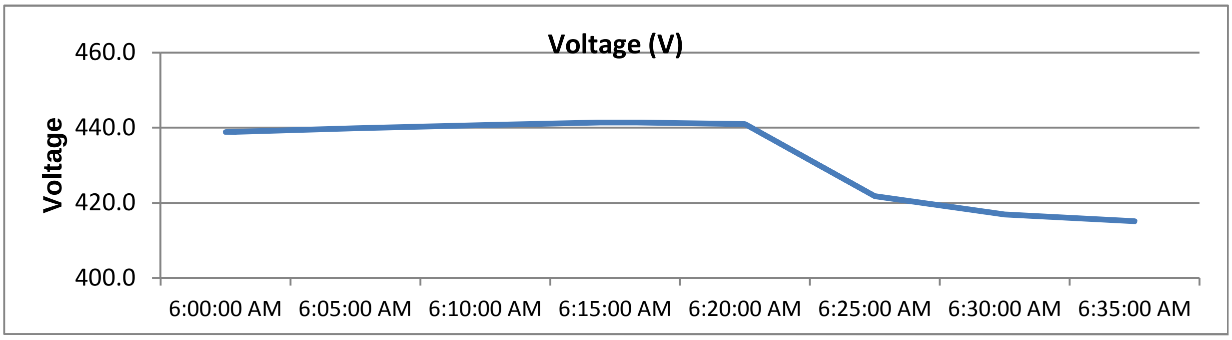


Figure 85 Voltage Variation

- The voltage variation at main incomer is observed to be in the 415-440V range, averaging 432V.

Power consumption and Apparent power Profile:

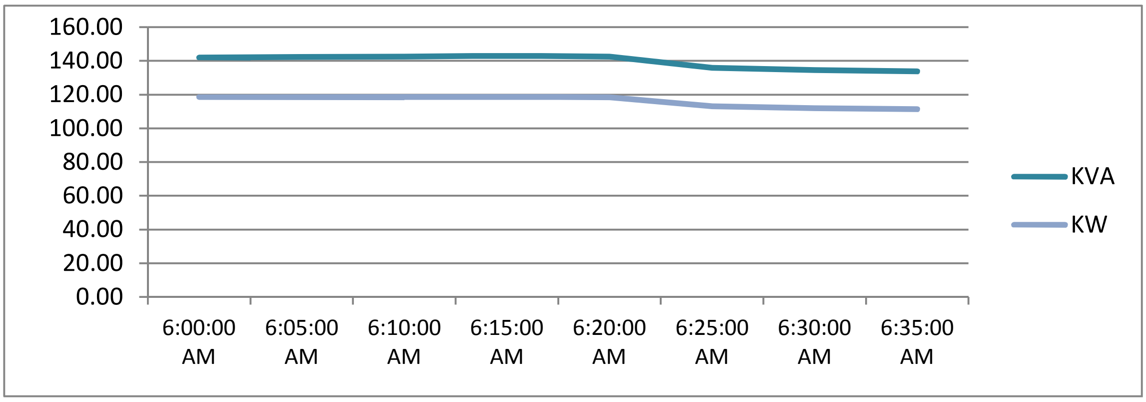


Figure 86 Power consumption variation

- Power consumption at main incomer during the measurement period was found to be around 110-120 kW.
- kVA consumption recorded at main incomer during measurement period was found to be around 130-145 kVA.

Power factor profile

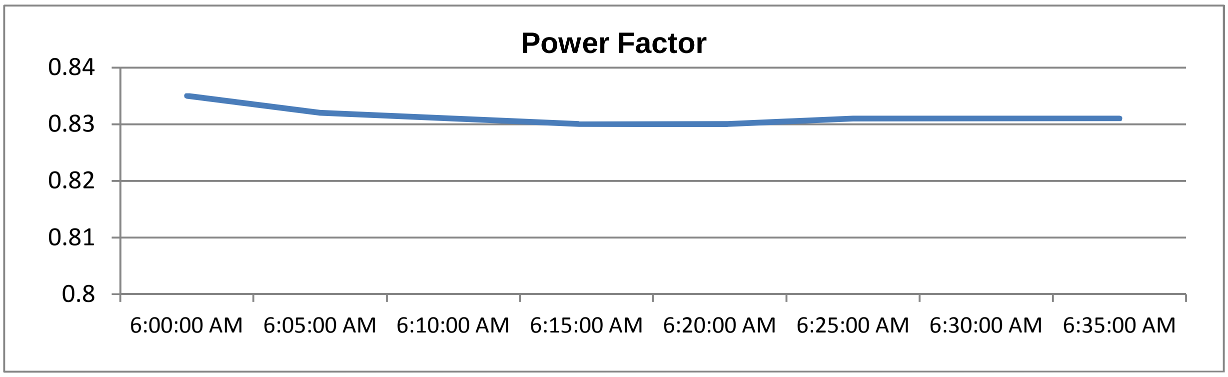


Figure 87: Power factor variation profile

- The power factor was consistently found to be around 0.83-0.84.

Frequency Profile:

During energy audit, frequency was recorded for 24 hours at the transformer secondary side at the main LT panel of the Transformer. Variation in frequency for the recorded 24 hour period is provided in figure 10

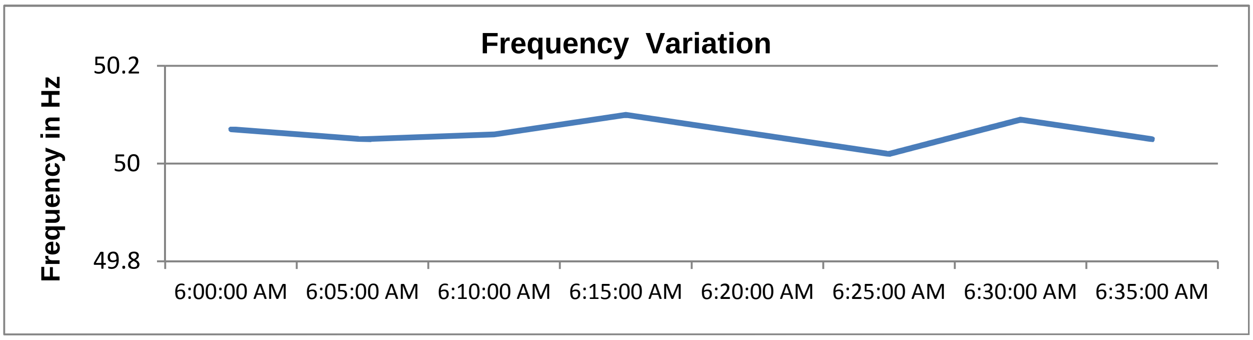


Figure 88 Frequency variation

- The frequency measured at Transformer LT side was found to be between 50 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

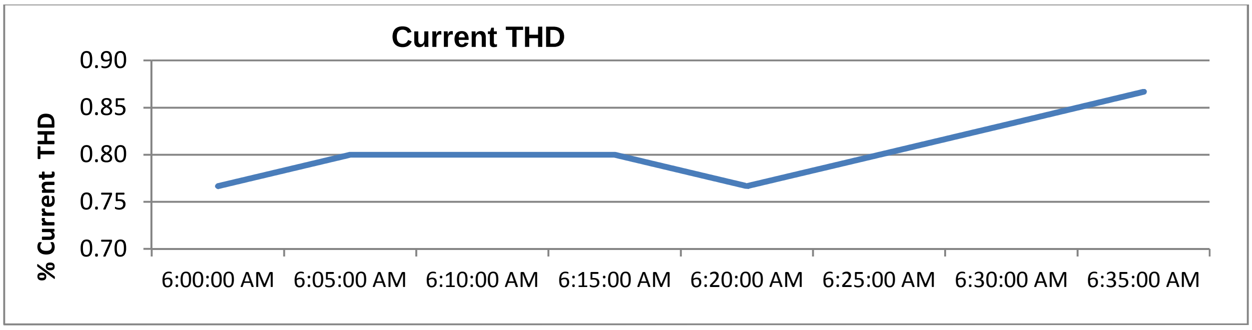


Figure 89 Variation of THD in current

- The current THD was found to be less than 1%.

Total Harmonics distortion - Voltage:

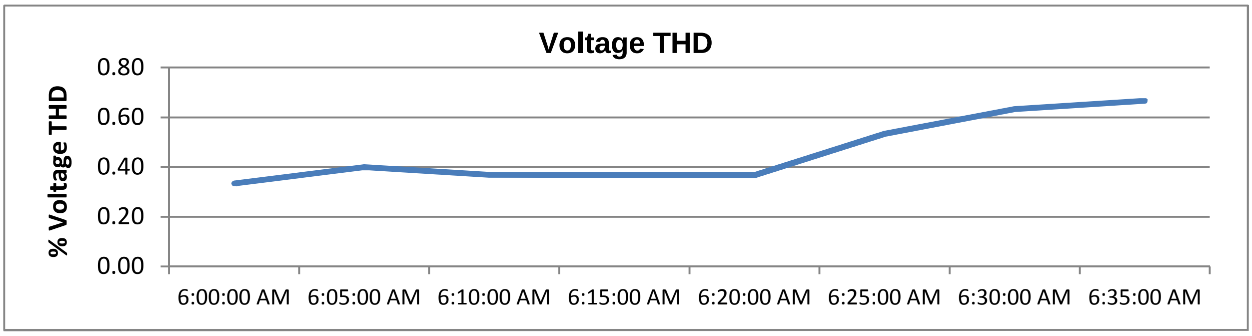


Figure 90: Variation in THD - voltage

- The voltage THD was found to be less than 0.75%.

Incomer – Hari Parvat side:

Voltage Profile:

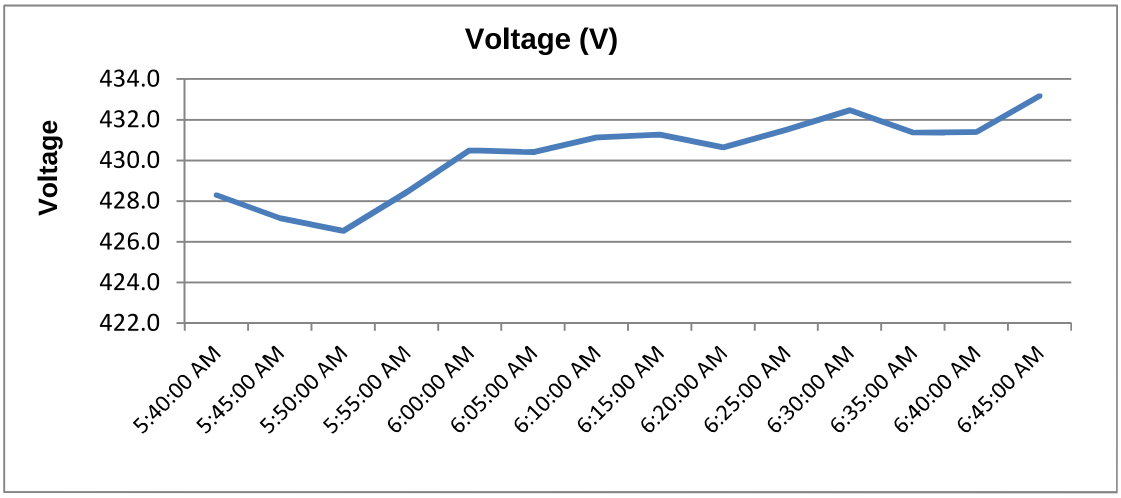


Figure 91: Voltage Variation profile at Hariparvat side incomer

- The voltage recorded at Hariparvat side incomer was found to vary between 426 and 433V.

Power consumption and Apparent power Profile:

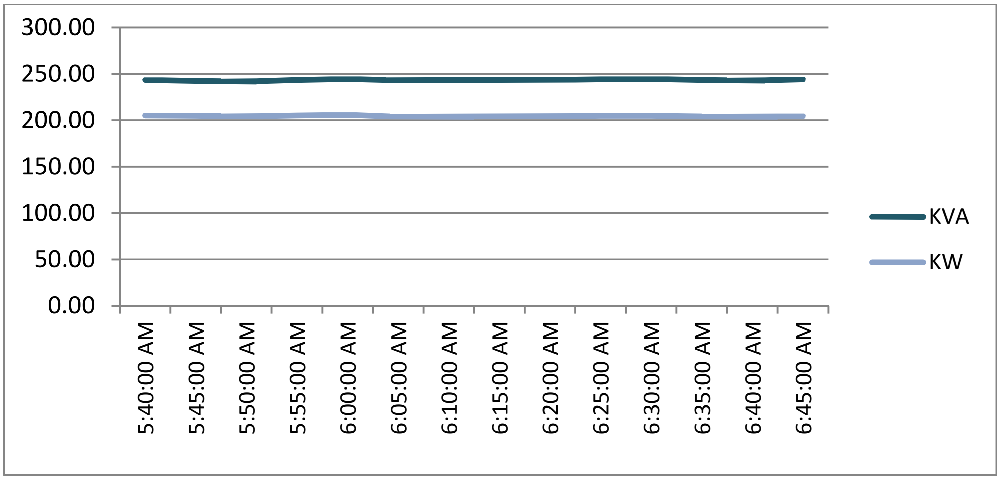


Figure 92: Power consumption variation at Hariparvat side incomer

- Power consumption recorded at Hariparvat side incomer was found to be around 200-210 kW.
- kVA consumption recorded at Hariparvat side incomer was found to be around 240-250 kVA.

Power factor profile

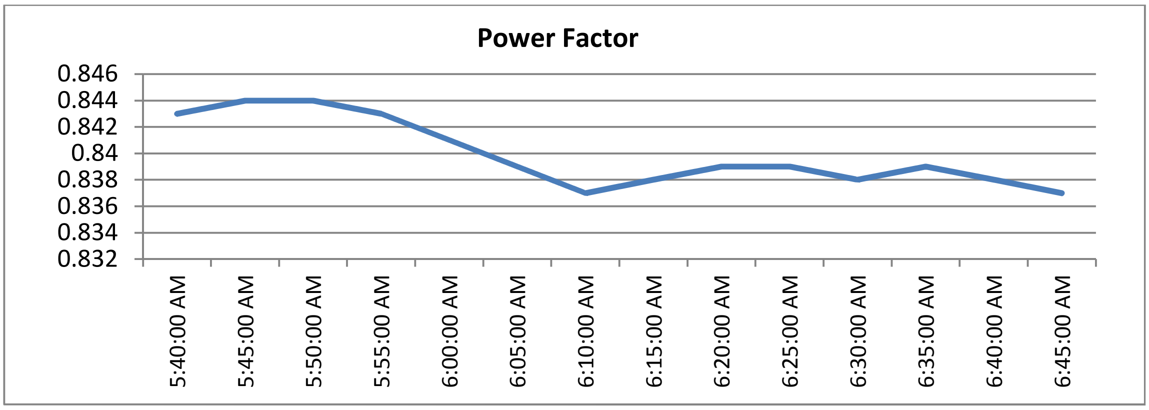


Figure 93: Power Factor variation at Hariparvat side incomer

- The recorded power factor was found to be consistently in the 0.837-0.845 range.

Frequency Profile:

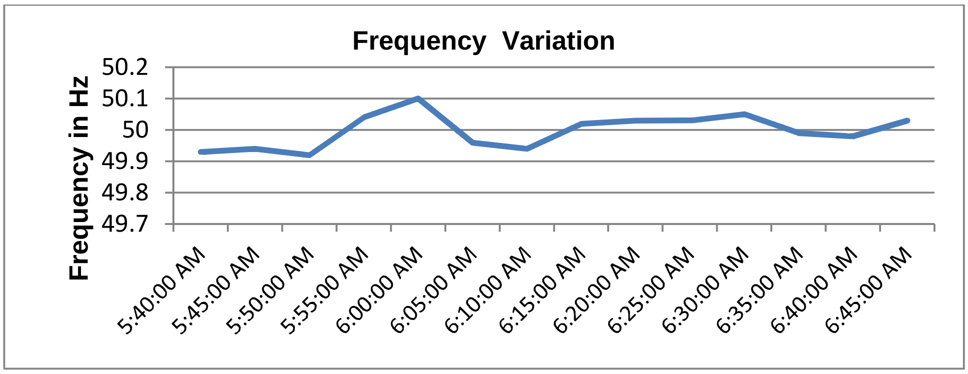


Figure 94: Frequency variation at Hariparvat side incomer

- The recorded frequency was found to be in the 49.9-50.1 Hz range.

Total Harmonics distortion - Current:

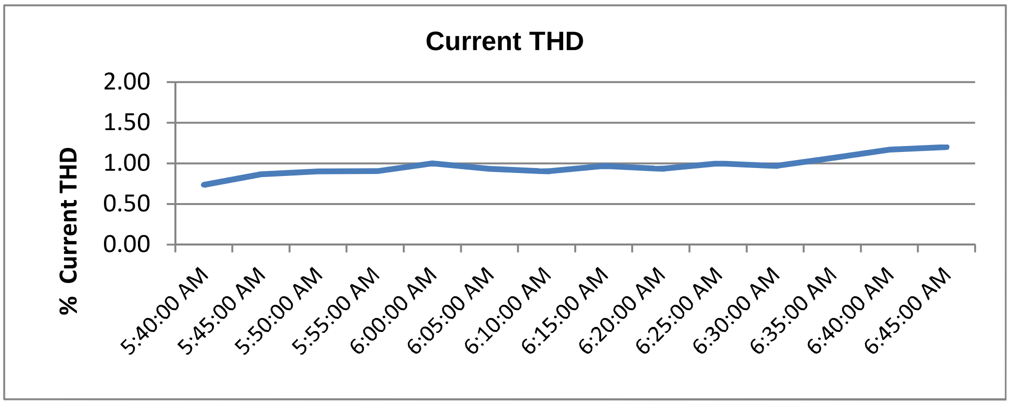


Figure 95: Variation in THD - current at Hariparvat side incomer

- The current THD was found to be in the 0.7%-1.2% range.

Total Harmonics distortion - Voltage:

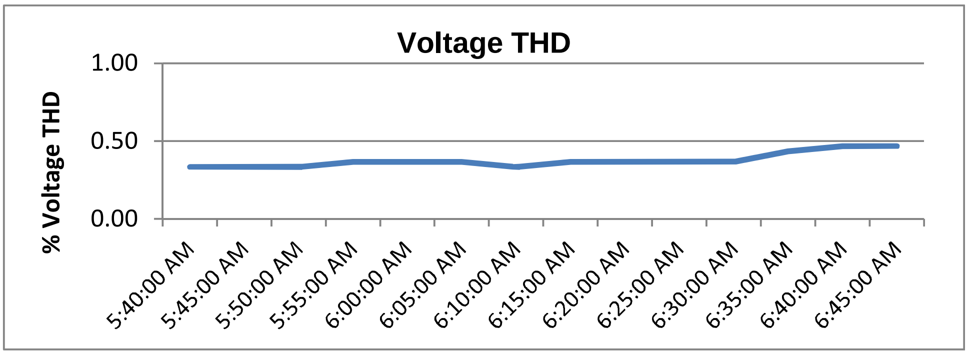


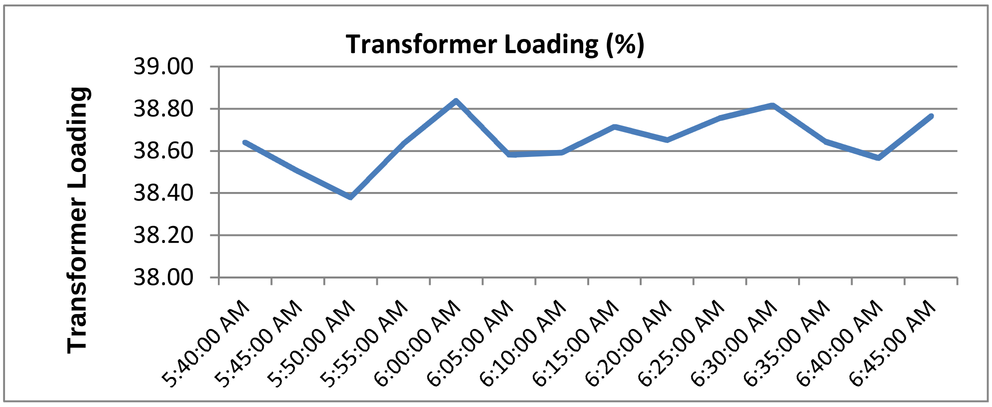
Figure 96: Variation in THD - voltage at Hariparvat side incomer

- The voltage THD was found to be less than 0.5%.

Transformer loading:

Based on the 24 hour logging done during energy audit, average transformer loading was calculated and same is provided in the table 56.

Table 56: Transformer loading analysis



- Energy consumption at the Hariparvat side incomer during the measurement period causes around 38-39% transformer loading.

4.9.6 Pumping Station System Mapping

Ten pumps are installed in Sanjay Place ZPS, divided into Hariparvat side supply and Maithan side supply.

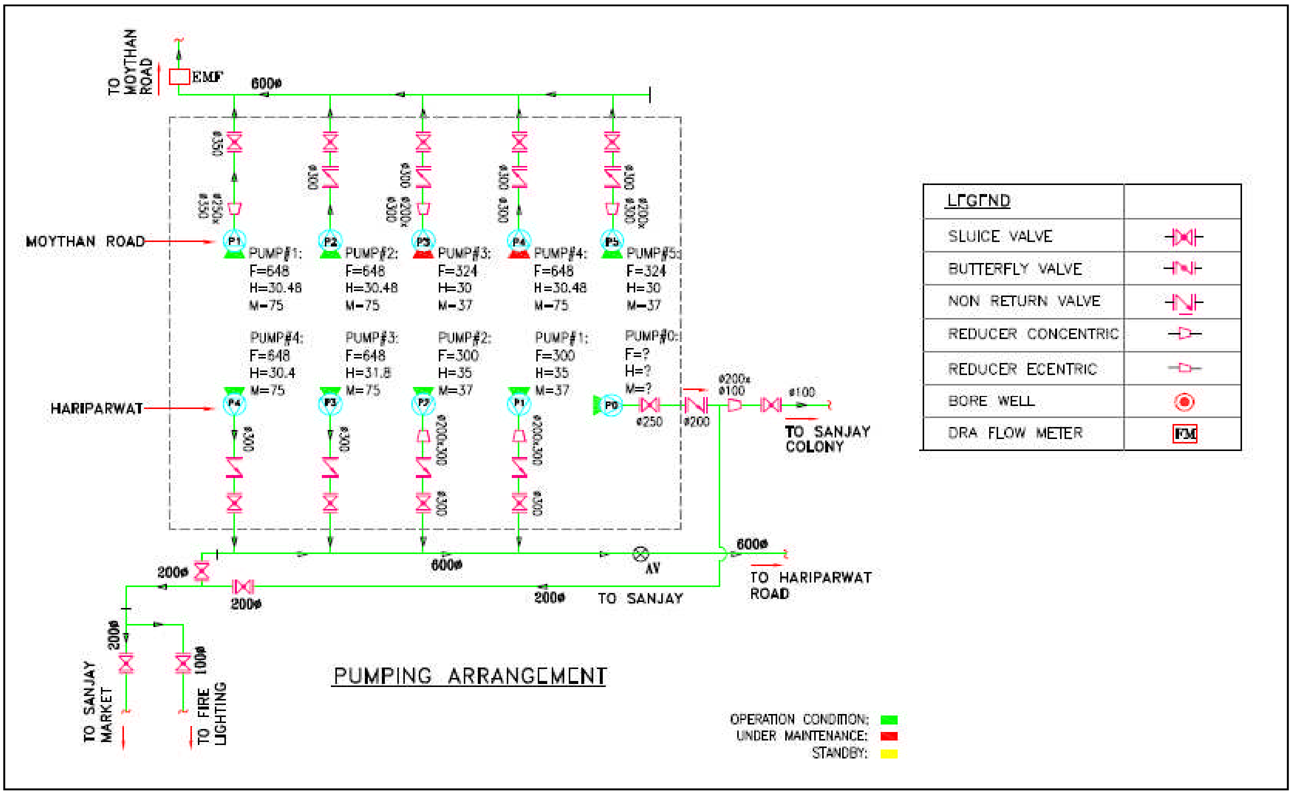


Figure 97: P & ID diagram for Sanjay Palace ZPS

4.9.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 57: General details of Sanjay Place pump house

Data	Value / Details
Name of site	Sanjay Place
Name of Sub-section	Maithan side supply, Hariparvat side supply
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	10
No. of pumps in operation	8
No. of pumps under maintenance	2
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Sanjay Place ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 98: Photographs of Sanjay Palace ZPS – Maithan Side

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 58: Performance Evaluation of pumps at Sanjay Palace ZPS – Maithan Side

Parameters	Unit	Sanjay Place, Maithan Side.	Sanjay Place, Maithan Side.	Sanjay Place, Maithan Side.
Parameters		Pump-1	Pump-2	pump-5
Pump make		Johnson	Jyoti	Jyoti
Motor make		Kirloskar	Kirloskar	Jyoti
Pump type		VT	VT	VT
Motor serial no.		NA	131826	NA
Pump serial no.		NA	N26023	NA
Rated flow	m^3/h	648	648	324
Rated head	m	30.48	30.48	30
Rated motor	kW	75	75	37
Parameters measured				
Total suction head	m	-6.46	-5.06	-4.79
Total discharge head	m	20	20	16
Average flow delivered	m^3/h	595.83	521.60	292.40
Motor input power	kW	78.41	61.33	38.23
Frequency	Hz	49.96	50.07	49.98
Speed	RPM	1477.33	1478.33	1464.00
Performance evaluation				
Total head developed	m	26.46	25.06	20.79
Head utilization	%	87%	82%	69%
Flow utilization	%	92%	80%	90%
Hydraulic power	kW	42.93	35.59	16.55
Motor input power	kW	78.41	61.33	38.23
Calculated pumpset efficiency	%	54.75%	58.04%	43.29%
Rated motor efficiency	%	91.5%	91.5%	91.0%
Calculated pump efficiency	%	59.84%	63.43%	47.57%
Specific energy consumption	kWh/m^3	0.132	0.118	0.131

Table 59: Performance Evaluation of pumps at Sanjay Palace ZPS – Hariparvat Side

	Unit	Sanjay Place, Hariparvat Side.	Sanjay Place, Hariparvat Side.	Sanjay Place, Hariparvat Side.	Sanjay Place, Hariparvat Side.	Sanjay Place, Hariparvat Side.
Parameters		Pump-1	Pump-2	Pump-3	Pump-4	Pump-5(0)
Pump make		Jyoti	Johnson	Kirloskar	Jyoti	NA

Parameters	Unit	Sanjay Place, Hariparvat Side. Pump-1	Sanjay Place, Hariparvat Side. Pump-2	Sanjay Place, Hariparvat Side. Pump-3	Sanjay Place, Hariparvat Side. Pump-4	Sanjay Place, Hariparvat Side. Pump-5(0)
Motor make		Jyoti	Jyoti	Kirloskar	Kirloskar	Jyoti
Pump type		VT	VT	VT	VT	VT
Motor serial no.		NA	2800460-3	2800970-7	NA	NA
Pump serial no.		NA	NA	NA	26021	NA
Rated flow	**m^3/h**	300	300	648	648	300
Rated head m	**m**	35	35	31.8	30.4	35
Rated motor kW	**kW**	37	37	75	75	67
Parameters measured						
Total suction head	**m**	-6.05	-6.19	-4.75	-5.29	-4.80
Total discharge head	**m**	4	8	10	8	47
Average flow delivered	**m^3/h**	359.07	342.70	615.33	573.60	99.43
Motor input power	**kW**	34.23	35.89	70.11	60.82	43.61
Frequency	**Hz**	50.13	49.96	50.05	49.98	49.67
Speed	**RPM**	1485.67	1463.00	1475.00	1476.33	1486.33
Performance evaluation						
Observed head m	**m**	10.05	14.19	14.75	13.29	51.80
Head utilization	**%**	29%	41%	46%	44%	148%
Flow utilization	**%**	120%	114%	95%	89%	33%
Hydraulic power kW		9.83	13.24	24.72	20.76	14.03
Motor input power	**kW**	34.23	35.89	70.11	60.82	43.61
Calculated pumpset efficiency		28.72%	36.89%	35.26%	34.14%	32.16%
Rated motor efficiency		91%	91%	91.5%	91.5%	91.5%
Calculated pump efficiency		31.56%	40.54%	38.54%	37.31%	35.15%
Specific energy consumption	**kWh/m^3**	0.095	0.105	0.114	0.106	0.439

Table 60: Parallel pumping at Sanjay Palace ZPS

Location		Sanjay Place (Maithan Side)	Sanjay Place (Hariparvat Side)	Sanjay Place (Hariparvat Side)
Parameters measured		**1,2,5 Maithan**	**1,2,4 Haripravat**	**1,2,3 Hariparvat**
Total suction head	m	-3.79	-3.99	-5.02
Total discharge head	m	18	10	10
Total flow	m^3/h	1641.33	1293.00	1312.00
Motor input power	kW	177.65	141.96	143.52

Location		Sanjay Place (Maithan Side)	Sanjay Place (Hariparvat Side)	Sanjay Place (Hariparvat Side)
Parameters measured		1,2,5 Maithan	1,2,4 Hariparvat	1,2,3 Hariparvat
Performance evaluation				
Total head developed	m	21.79	13.99	15.02
Head utilization		71%	40%	43%
Flow utilization		101%	104%	105%
Hydraulic power developed by pump	kW	97.40	49.25	53.67
Motor input kW	kW	177.65	141.96	143.52
Calculated overall efficiency		54.83%	34.69%	37.39%
Motor efficiency		91%	91%	91%
Calculated pump efficiency		60.25%	38.12%	41.08%
Specific energy consumption	kWh/m^3	108.24	109.79	109.39

Key Observations:

- All pump sets at Hariparvat side were found to be operating at poor pump set efficiencies in the 28%-37% range.Pumps 1-4 were found to be operating at head significantly less than rated head. Pump 5 was operating at higher head than rated, and at significantly less than rated discharge.
- In parallel pumping at Hariparvat side, the combination of pumps 1,2,3 was found to have a marginally higher efficiency of 37.39% compared to the 34.69% for the pumps 1,2,4 combination. Overall the efficiencies of both combinations were found to be poor.
- Pumps 3 and 4 at Maithan side were in breakdown condition and hence were not tested.
- Pumps nos. 1, 2 and 5 on the Maithan side were operating at pump set efficiencies of 52.75%, 58.04%, 43.25% respectively. Pumps 1 and 2 were operating closer to their rated head compared to pump no. 5, but both operating head and operating discharge were found to be less than rated for all these pumps.
- In parallel pumping at Maithan side, the three operational pumps were running in parallel and the combined efficiency was found to be 54.83%.

4.9.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 61: Other electrical equipment at Sanjay Place ZPS- Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	630 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header

Parameters	Details
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 62: Other electrical equipment at Sanjay Place ZPS - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Sanjay Place ZPS	Tubelight	6	0.036	12
	HPSV	3	0.16	12

Table 63: Other electrical equipment at Sanjay Place ZPS

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Exhaust fan	4	0.15	6
	Motor (chlorine)	4	0.75	4

4.9.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Sanjay Palace ZPS is provided in below table.

Table 64: Estimated energy consumption for Sanjay Palace ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Sanjay Place, Maithan Side.	Pump-1	1,2,5 in parallel. Pumps 3,4 under breakdown	1,328	78.41	104,104
Sanjay Place, Maithan Side.	Pump-2		1,278	61.33	78,380
Sanjay Place, Maithan Side.	pump-5		1,330	38.23	50,853
Sanjay Place, Hariparvat Side.	Pump-1	1,2,4 in parallel; separate line from pump 5	1,339	34.23	45,823
Sanjay Place, Hariparvat Side.	Pump-2		1,150	35.89	41,270
Sanjay Place, Hariparvat Side.	Pump-3		0	70.11	0
Sanjay Place, Hariparvat Side.	Pump-4		1,339	60.82	81,414
Sanjay Place, Hariparvat Side.	Pump-5(0)		1,341	43.61	58,471
	Total		**9,105**	**423**	**460,315**

4.10 Kotwali ZPS

4.10.1 Overview of existing systems

Kotwali ZPS receives treated water from Jeoni Mandi WTP. Five pumps are installed here, of which one was discarded and one was under maintenance at the time of audit. ESR filling and direct distribution are performed through dedicated sets of pumps and pipe lines.

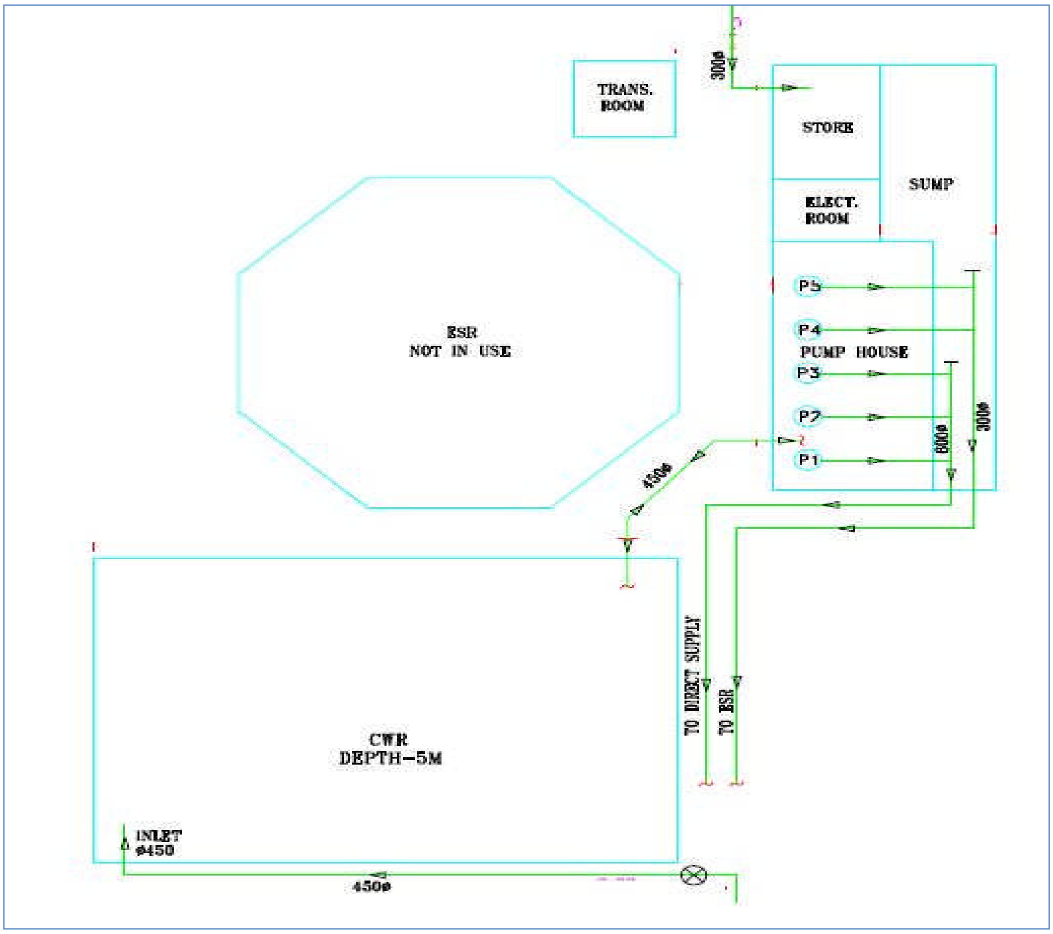
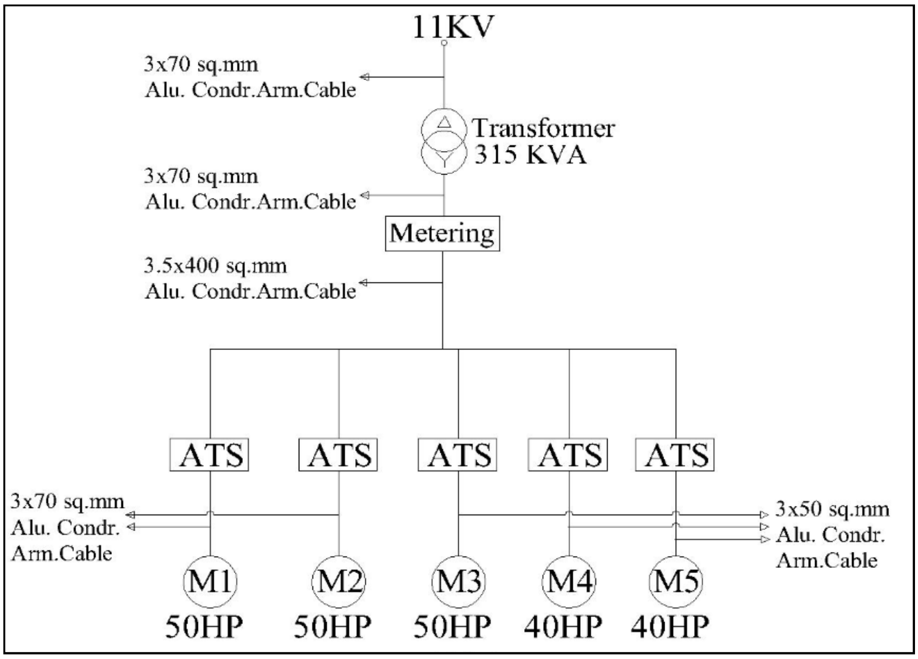


Figure 99: Plant Layout for Kotwali ZPS

4.10.2 Electricity Supply

Kotwali ZPS receives supply at 11 kV from Torrent Power. This is stepped down to 415V via a 315 kVA transformer to feed the motors.

Figure 100: Single line diagram for the Kotwali ZPS



4.10.3 Tariff Structure

The electrical connection for Kotwali ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 65: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Kotwali ZPS	
	Energy Meter-1 (HT)	Energy Meter-2 (LT)
Meter serial number	NA	NA
Power supply	11 kV line	NA
Energy charges	Rs. 7.155 Per kVAh	NA
Fixed/demand charge	Rs. 290/kW	NA
(Basis : DVVNL Tariff Order for FY 2016-17)		

4.10.4 Electricity Bill Analysis

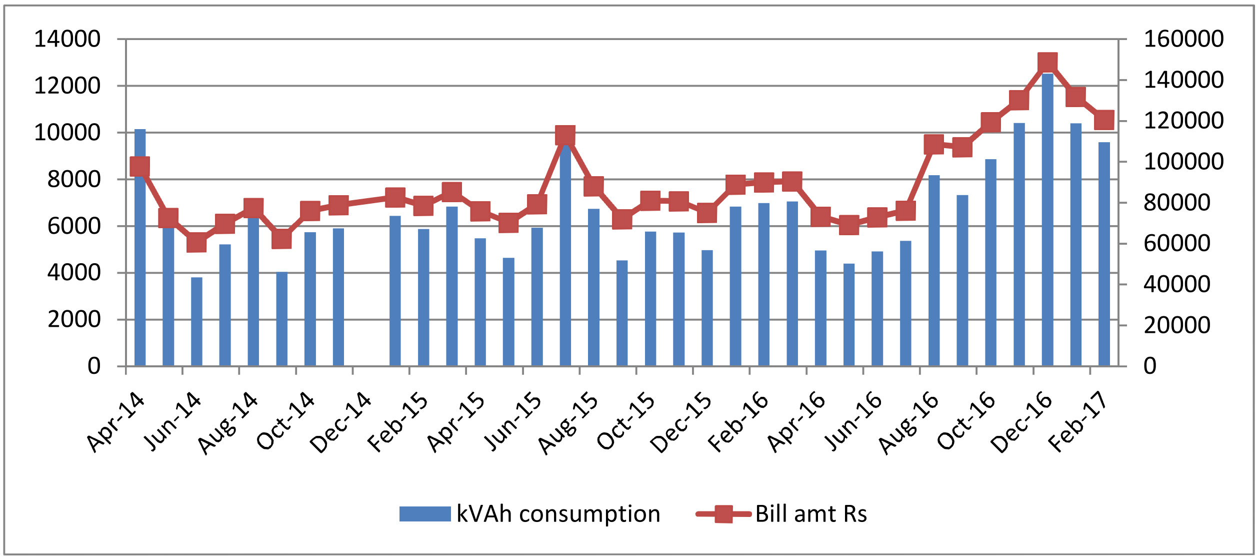
During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

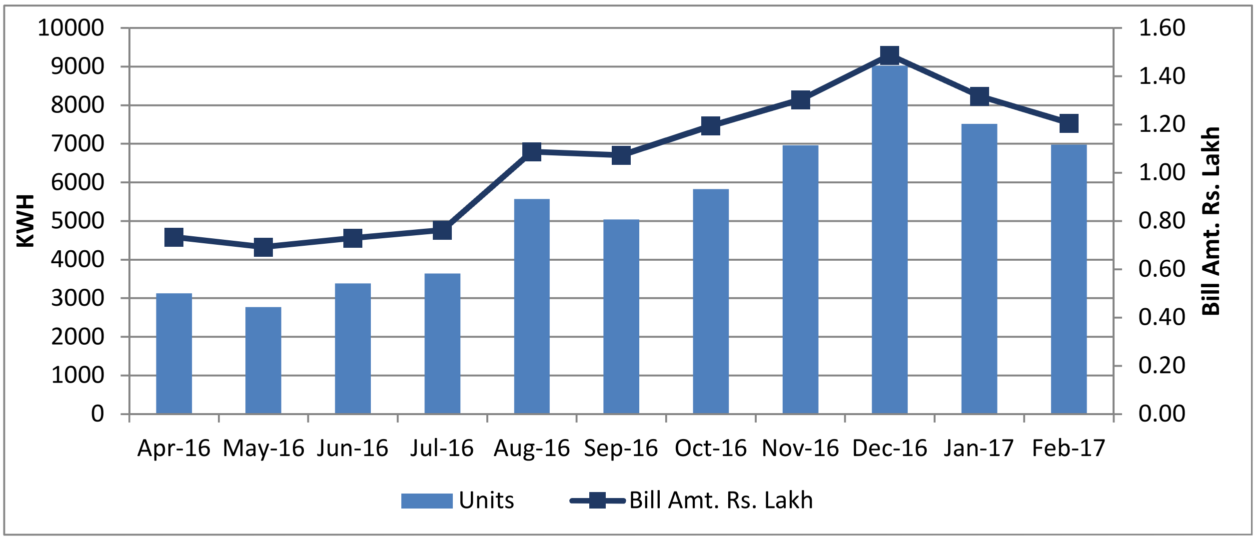
Table 66: Energy cost and energy consumption detail for Kotwali ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	49,580		919,295
Apr-15 to Mar-16	57,543	16.1%	1,096,616
Apr-16 to Mar-17	65,267	13.4%	1,263,831

The power factor recorded at the incomer was found to be around 0.91.

Figure 101: Monthly electricity consumption and electricity bill for Kotwali ZPS





4.10.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT sidefor recording variation of electrical parameters. Details about transformers installed at Kotwali ZPS is provided in below table.

Table 67: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 315 kVA, 11/0.433 kV)	All 5 pump sets

Voltage Profile:

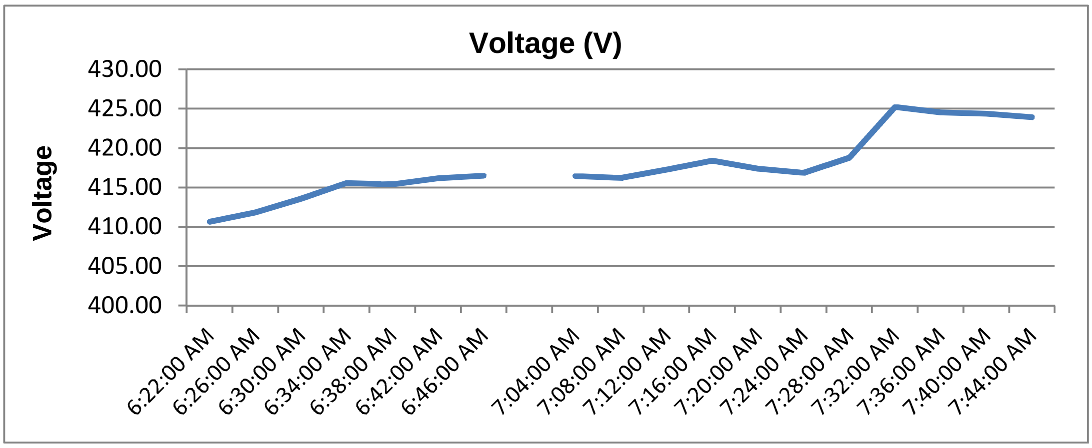


Figure 102: Voltage Variation at Kotwali LT incomer

- A power cut occurred during the measurement.
- The voltage measured at the Kotwali LT incomer was found to be in the 410-425V range.

Power consumption and Apparent power Profile:

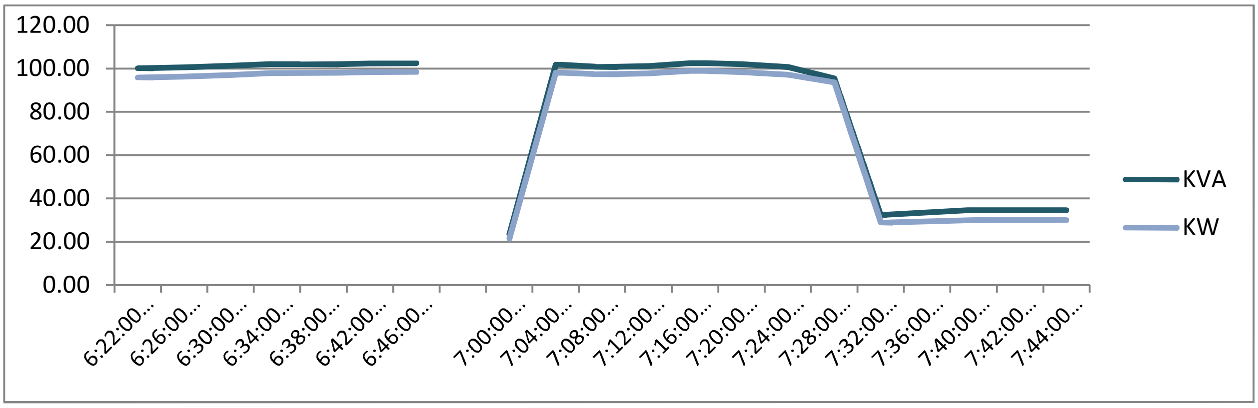


Figure 103: Power consumption variation at Kotwali LT incomer

- Power consumption corresponding to parallel operation of three pumps was observed to be around 95 kW. For operation of single pump, it was found to be around 30 kW.
- kVA consumption during operation of three pumps was found to be around 100-105 kVA, while during operation of single pump it was found to be around 35 kVA.

Power factor profile

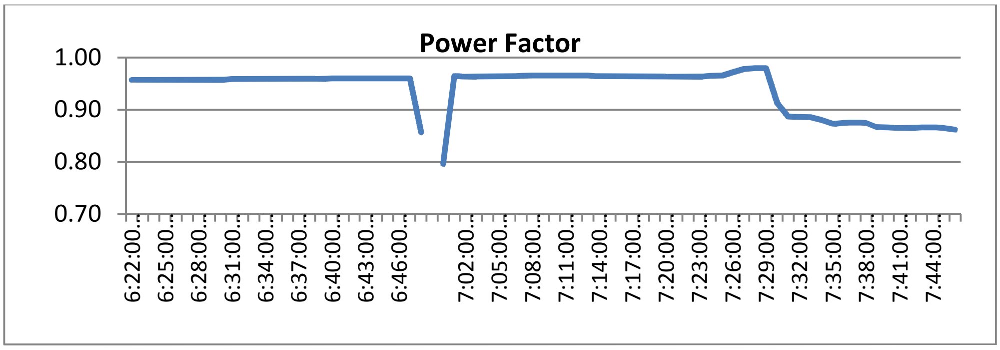


Figure 104: Power factor variation profile at Kotwali LT incomer

- The power factor was found to be over 0.95 during operation of three pumps, reducing to around 0.86-0.88 during operation of single pump.

Frequency Profile:

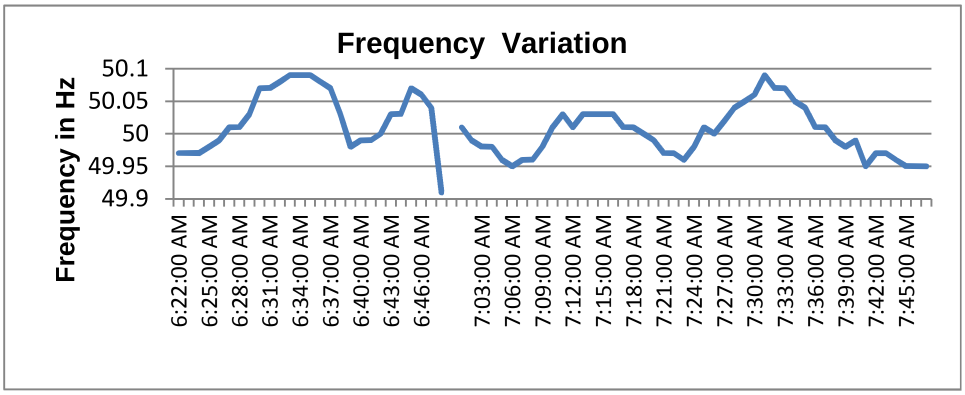


Figure 105 Frequency variation at Kotwali LT incomer

- Frequency was observed to vary between 49.9 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

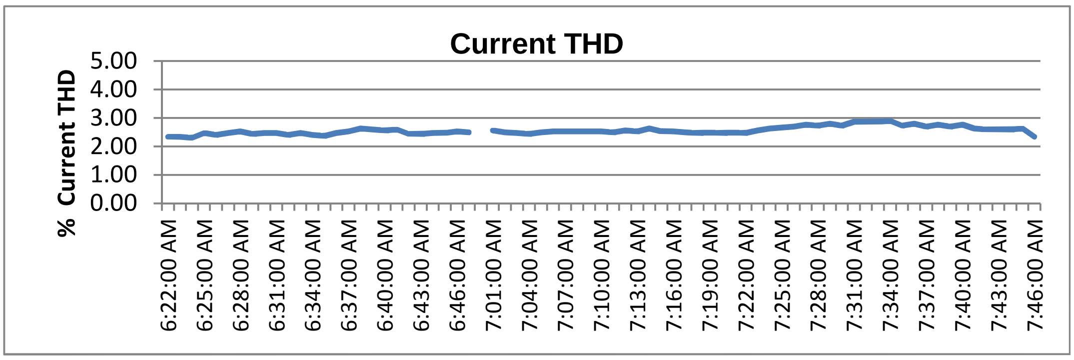


Figure 106: Variation of THD in current at Kotwali LT incomer

- The current THD was observed to be around 2.2-3%.

Total Harmonics distortion - Voltage:

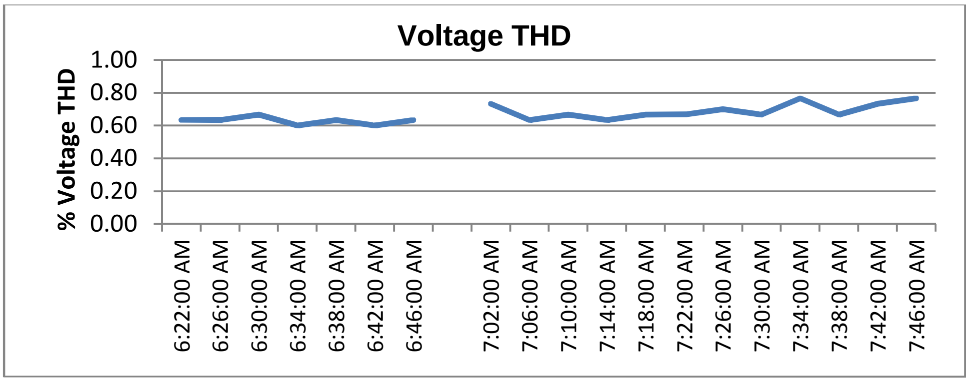


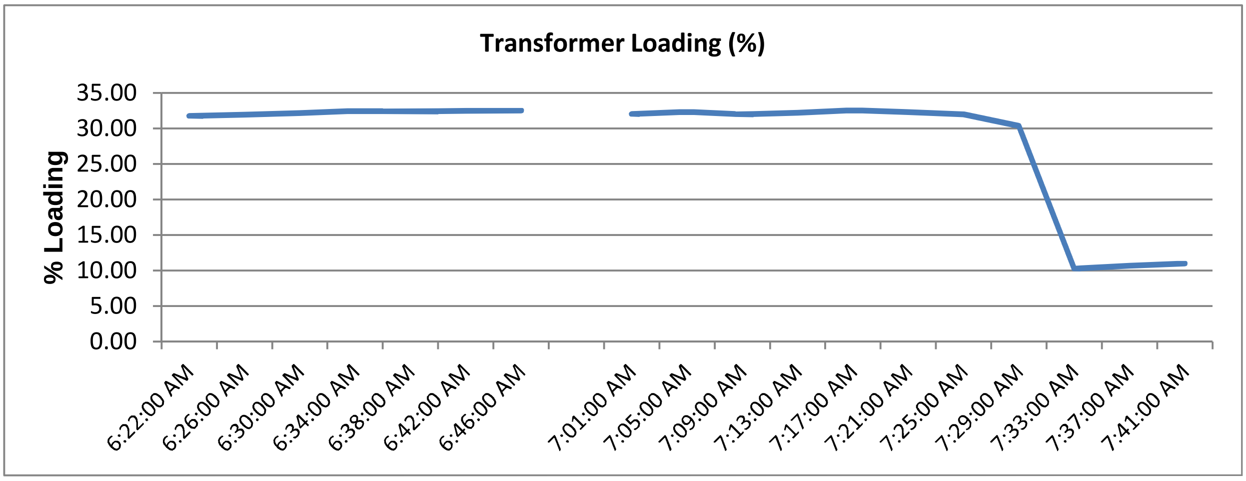
Figure 107: Variation in THD - voltage at Kotwali LT incomer

- The voltage THD was found to be less than 1%.

Transformer loading:

A 315 kVA transformer is installed at Kotwali ZPS. Transformer loading was determined based on kVA consumption and same is provided below.

Table 68: Transformer loading analysis



- Typically, three pumps are operated at Kotwali ZPS. During such operation, transformer loading was observed to be in the 30%-35% range.
- The loading dropped to around 10% during operation of single pump.

4.10.6 Pumping Station System Mapping

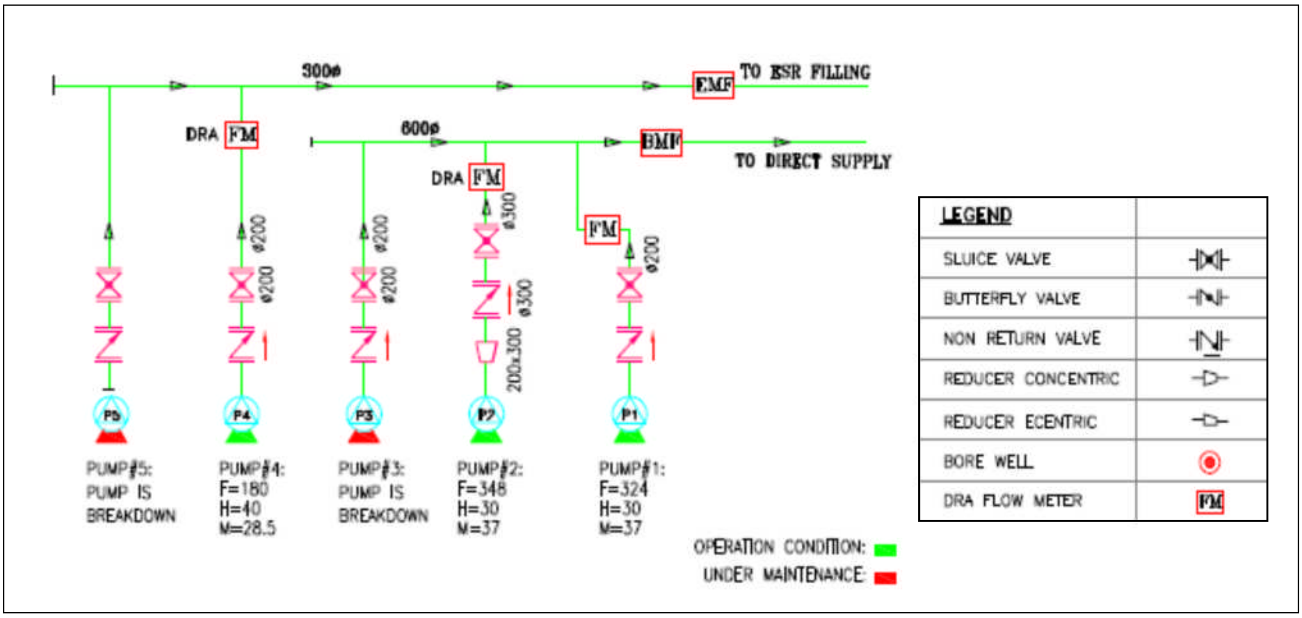


Figure 108: P & ID diagram for Kotwali ZPS

4.10.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 69: General details of Sanjay Place pump house

Data	Value / Details
Name of site	Kottwali ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	3
No. of pumps under maintenance	2
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Kotwali ZPS to showcase the actual situation are provided below.

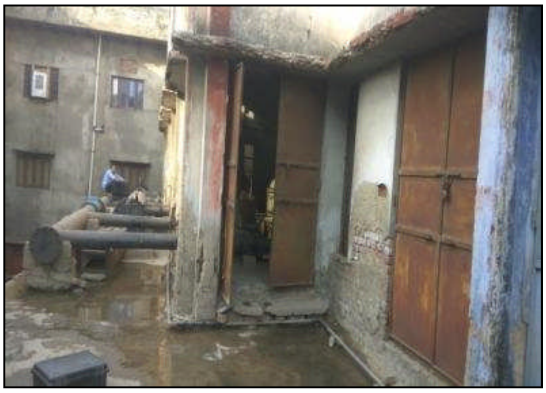
View of pump house	Pumps installed
	

Figure 109: Photographs of Kotwali ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 70: Performance Evaluation of pumps at Kotwali ZPS

	Unit	Kotwali ZPS	Kotwali ZPS	Kotwali ZPS
Parameters		Pump-1	Pump-2	Pump-4
Pump make		Jyoti	Jyoti	Jyoti
Motor make		Jyoti	Jyoti	Jyoti
Pump type		VT	VT	NA
Motor serial no.		NA	M0999258	NA
Pump serial no.		NA	NA	275DMFD200
Rated flow	m^3/h	324	348	180
Rated head	m	30	30	40
Rated motor	kW	37	37	28.5
Parameters measured				
Total suction head	m	-3.79	-4.49	-4.89
Total discharge head	m	2	2	27
Average flow delivered	m^3/h	232.20	423.93	186.00
Motor input power	kW	27.87	32.20	27.00
Frequency	Hz	50.01	49.98	50.00
Speed	RPM	1491.33	1480.67	1457.67
Performance evaluation				
Total head developed	m	5.79	6.49	31.89

Parameters	Unit	Kotwali ZPS Pump-1	Kotwali ZPS Pump-2	Kotwali ZPS Pump-4
Head utilization	%	19%	22%	80%
Flow utilization	%	72%	122%	103%
Hydraulic power kW	kW	3.66	7.50	16.15
Motor input power	kW	27.87	32.20	27.00
Calculated pumpset efficiency	%	13.14%	23.28%	59.83%
Rated motor efficiency	%	91%	90%	90%
Calculated pump efficiency	%	14.44%	25.58%	66.48%
Specific energy consumption	kWh/m³	0.120	0.076	0.145

Table 71: Parallel pumping at Kotwali ZPS

Location		Kotwali ZPS
Parameters measured		**1,2**
Total suction head	m	-4.51
Total discharge head	m	2
Total flow m3/h	m³/h	663.60
Motor input power	kW	48.51
Performance evaluation		
Total head developed	m	6.51
Head utilization		22%
Flow utilization		99%
Hydraulic power developed by pump	kW	11.76
Motor input kW	kW	48.51
Calculated overall efficiency		24.25%
Motor efficiency		91%
Calculated pump efficiency		26.64%
Specific energy consumption	kWh/m³	73.09

Key Observations:

- Common header of pump nos. 1,2,3 is used for supplying water directly into distribution network. Common header of pumps 4,5 is used for ESR filling.
- Pumps 1 and 2 were observed to be operating at very poor pump set efficiencies of 13.14% and 23.3%. Both were observed to be operating significantly below their rated head. The combined efficiency of the two during their parallel operation was also found to be quite low at 24.25%.

- Pump set efficiency of pump 4 was found to be 59.83%, and its operating head was found to be more than 75% of the rated head.
- Pump no. 5 is discarded and pump no. 3 was under maintenance at the time of audit.
- NRV of pump no. 1 & 2 are not working.

4.10.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 72: Other electrical equipment at Kotwali ZPS- Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	315 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 73: Other electrical equipment at Kotwali ZPS - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Kotwali ZPS	CFL	3	0.085	12
	Metal Halide	1	0.25	12

Table 74: Other electrical equipment at Kotwali ZPS

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Exhaust fan	2	0.2	12

4.10.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Kotwali ZPS is provided in below table.

Table 75: Estimated energy consumption for Kotwali ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Kotwali ZPS	Pump-1	1,2 in parallel - direct distribution. 4 for ESR filling.	702	27.87	19,565
Kotwali ZPS	Pump-2		702	32.20	22,607
Kotwali ZPS	Pump-4		1,625	27.00	43,862
	Total		**3,029**	**87.07**	**86,034**

4.11 Suryanagar ZPS

4.11.1 Overview of existing systems

Suryanagar ZPS receives treated water from Sikandra WTP. There are five pumps here, operated in 3W+2SB combination. Water is supplied directly into distribution.

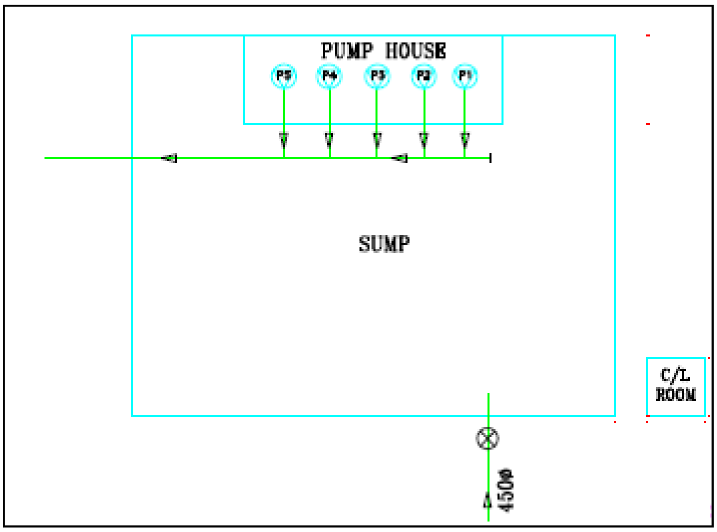


Figure 110: Plant Layout for Suryanagar ZPS

4.11.2 Electricity Supply

Suryanagar ZPS receives supply at 11 kV from Torrent Power. This is stepped down to 415V via a 315 kVA transformer to feed the motors.

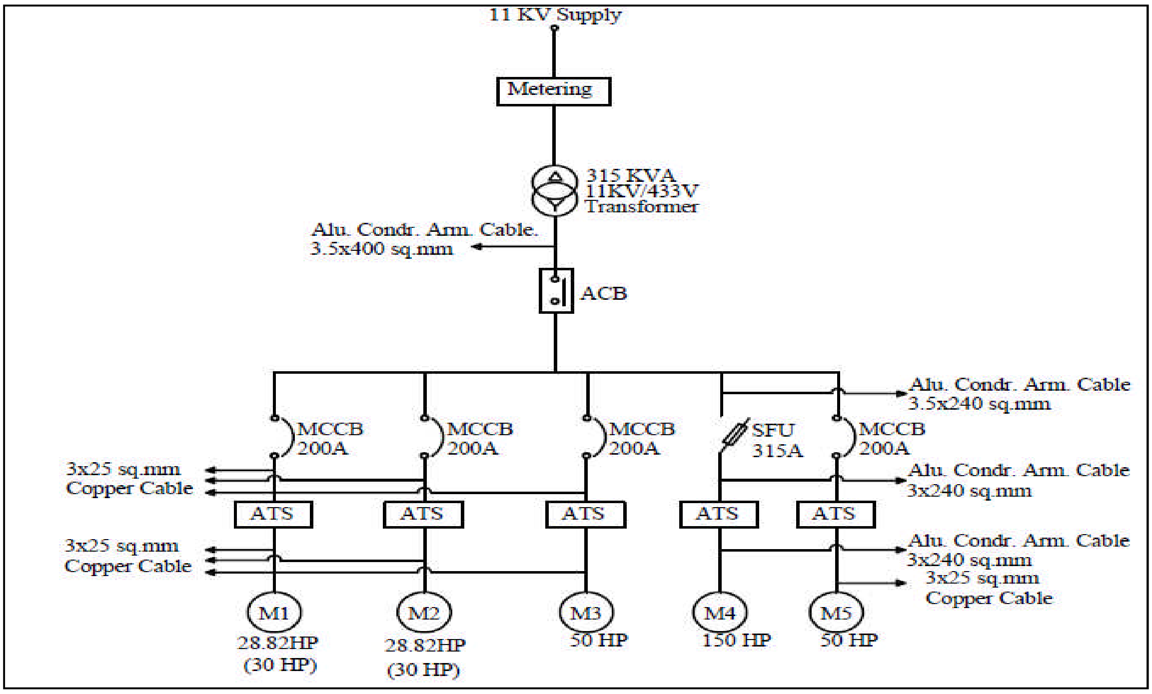


Figure 111: Single line diagram for the Suryanagar ZPS

4.11.3 Tariff Structure

The electrical connection for Suryanagar ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 76: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Suryanagar ZPS Energy Meter-1 (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.11.4 Electricity Bill Analysis

During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

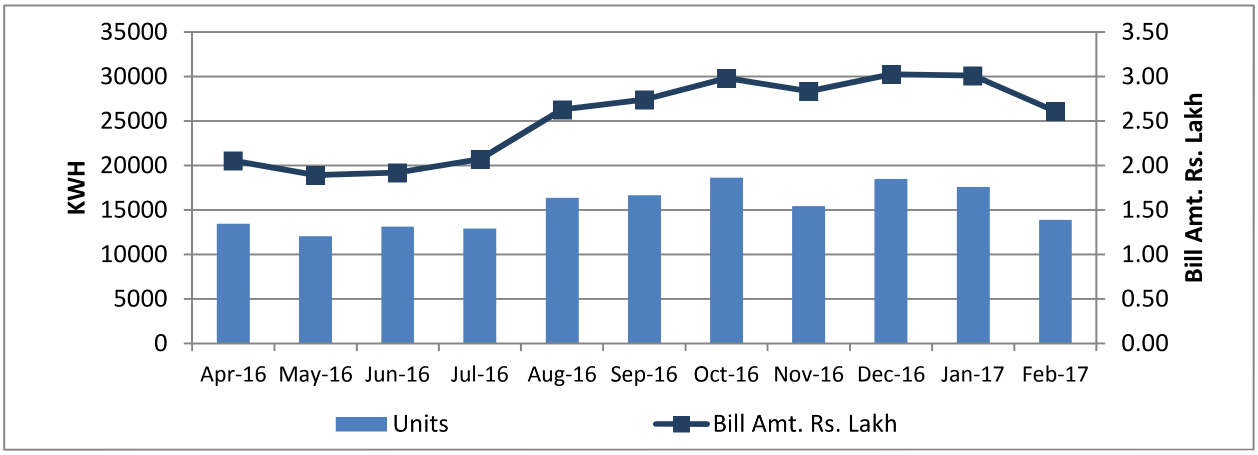
Table 77: Energy cost and energy consumption detail for Suryanagar ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	213,312		3,522,001

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-15 to Mar-16	220,121	3.2%	4,377,994
Apr-16 to Mar-17	184,041	-16.4%	3,030,225

The power factor recorded at the incomer was found to be in the 0.89-0.9 range. It was observed that the recorded demand has exceeded the contract demand by a very high margin of around 50% throughout 2016-17. As a result of recorded demand exceeding contract demand, 'Excess demand charges' have been levied in addition to the regular demand charges.

Figure 112: Monthly electricity consumption and electricity bill for Suryanagar ZPS



4.11.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT side for recording variation of electrical parameters. Details about transformers installed at Suryanagar ZPS is provided in below table.

Table 78: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 315 kVA, 11/0.433 kV)	All 5 pump sets

Pumps 1, 3, 4 in operation:

Voltage Profile:

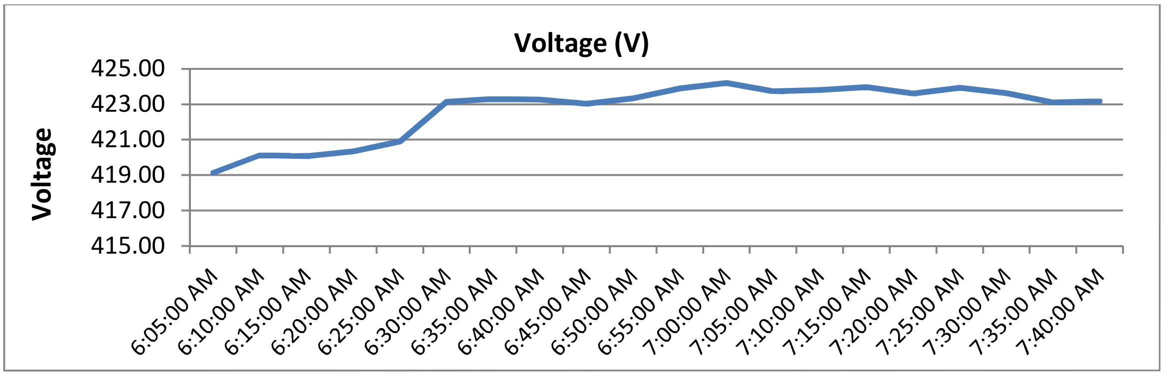


Figure 113: Voltage Variation during parallel operation of pumps 1,3,4

- The voltage during parallel operation of pumps 1,3,4 was observed to be in the 419-423V range.

Power consumption and Apparent power Profile:

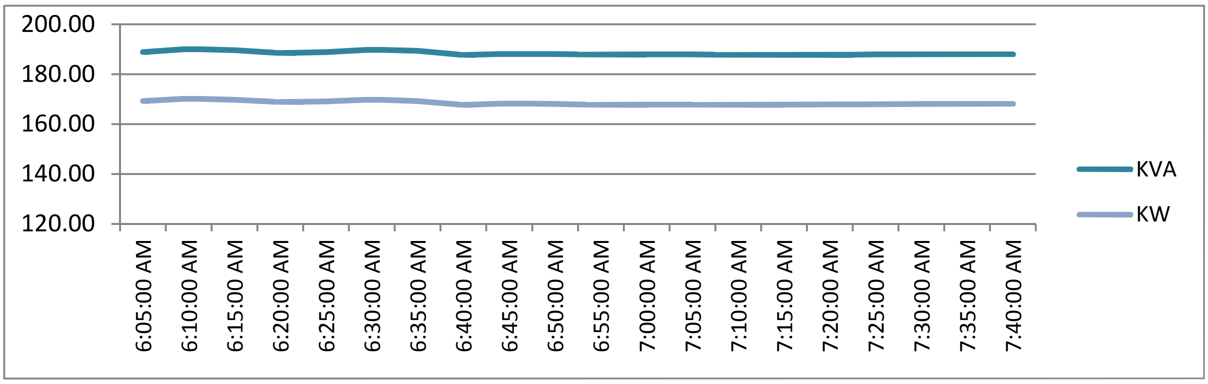


Figure 114: Power consumption during parallel operation of pumps 1,3,4

- Power consumption in parallel operation of pumps 1,3,4 was observed to be around 165-170 kW.
- Apparent power in parallel operation of pumps 1,3,4 was observed to be around 185-190 kVA.

Power factor profile

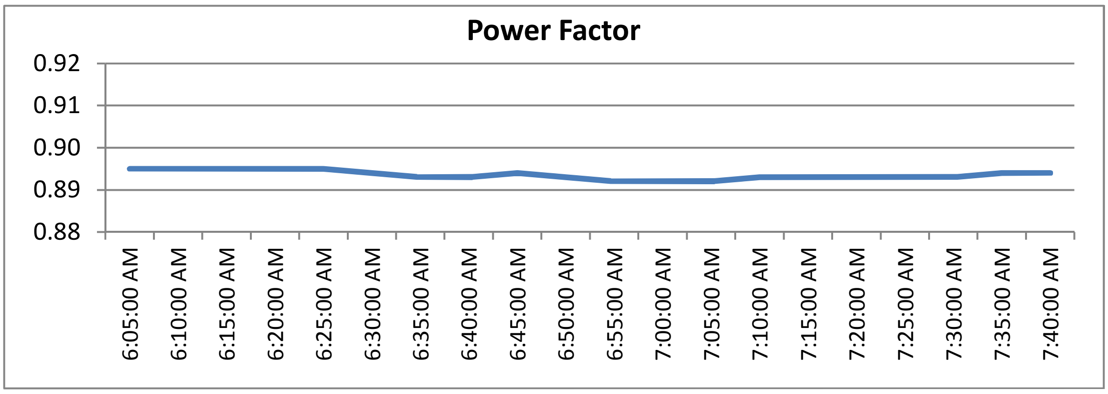


Figure 115: Power factor variation during parallel operation of pumps 1,3,4

- Power factor was found to be in the 0.89-0.9 range.

Frequency Profile:

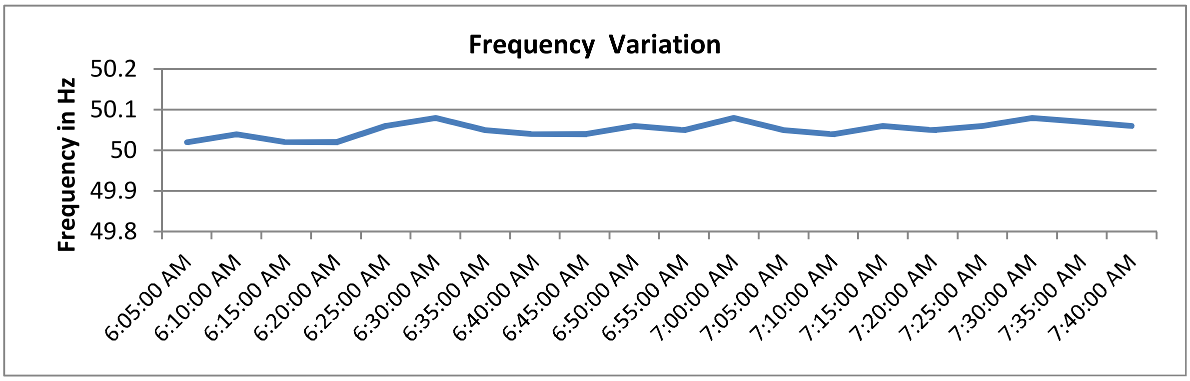


Figure 116: Frequency variation during parallel operation of pumps 1,3,4

- The frequency measured was found to vary between 50 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

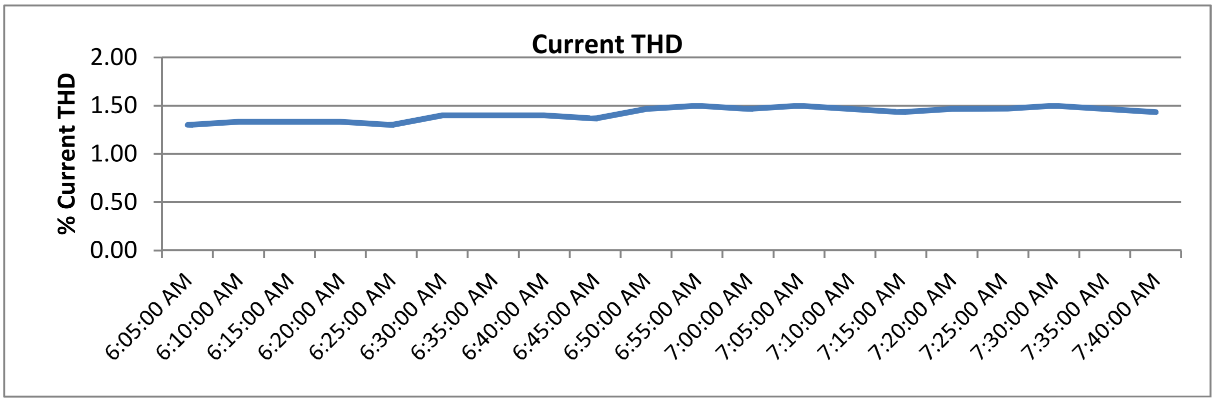


Figure 117: Variation of THD in current during parallel operation of pumps 1,3,4

- The current THD was found to be around 1.2-1.5%.

Total Harmonics distortion - Voltage:

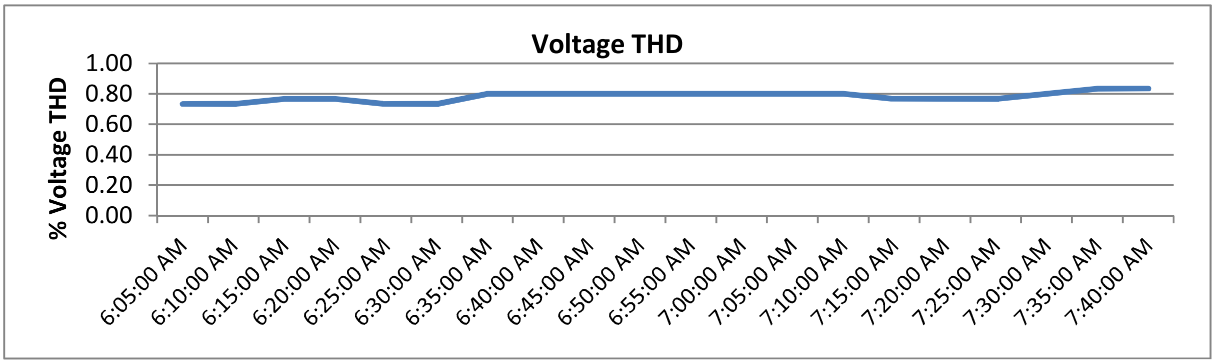


Figure 118: Variation in THD - voltage during parallel operation of pumps 1,3,4

- The voltage THD was found to be less than 1%.

Pumps 2, 3, 4 in operation:

Voltage Profile:

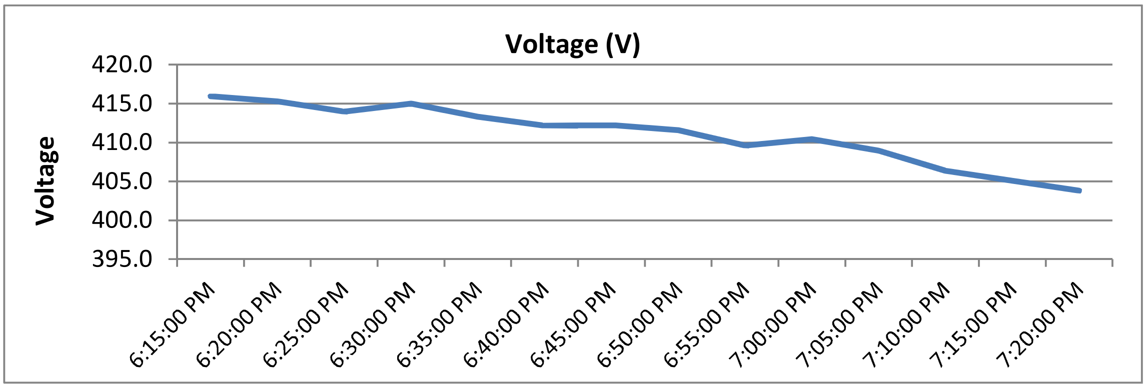


Figure 119: Voltage Variation during parallel operation of pumps 2,3,4

- The voltage was found to vary between 403V and 418V, averaging 411V.

Power consumption and Apparent power Profile:

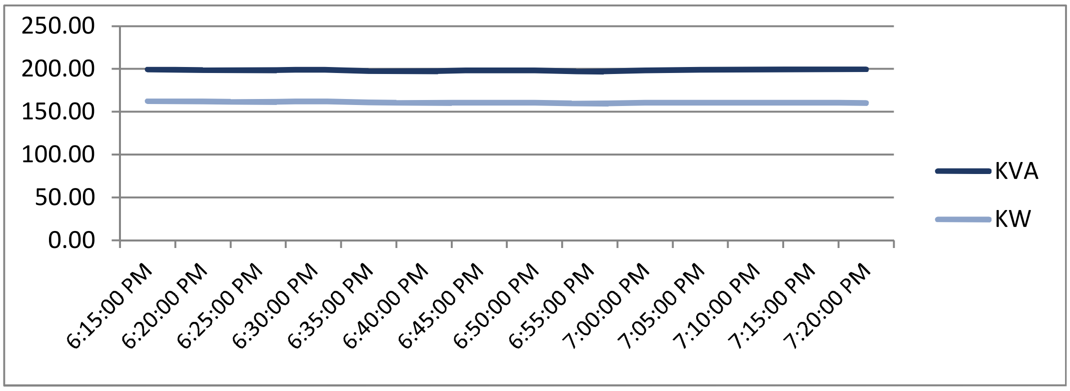


Figure 120: Power consumption during parallel operation of pumps 2,3,4

- Power consumption during parallel operation of pumps 2,3,4 was found to be around 160 kW.
- Apparent powerduring parallel operation of pumps 2,3,4 was found to be around 200 kVA.

Power factor profile

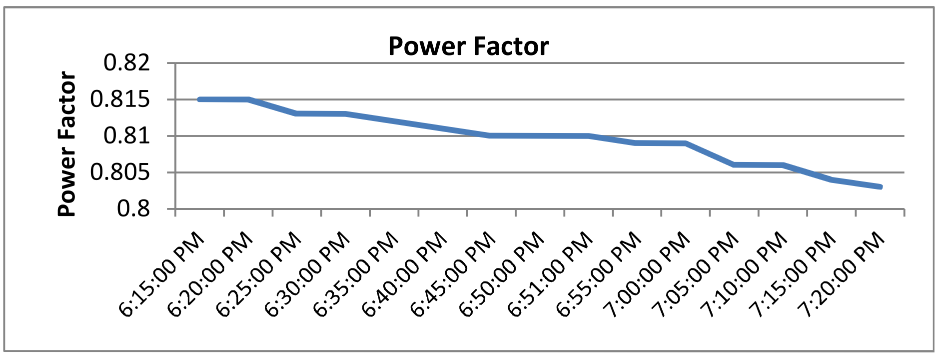


Figure 121: Power factor variation during parallel operation of pumps 2,3,4

- Power factor was found to vary between 0.8 and 0.815.

Frequency Profile:

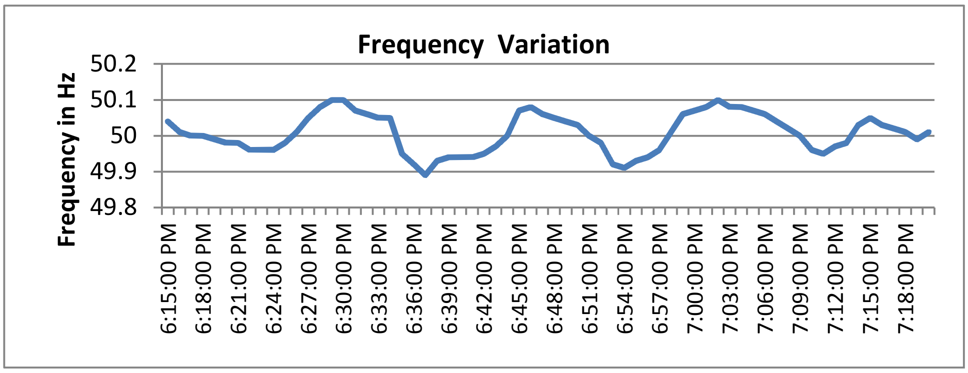


Figure 122: Frequency variation during parallel operation of pumps 2,3,4

- The frequency was found to vary between 49.9 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

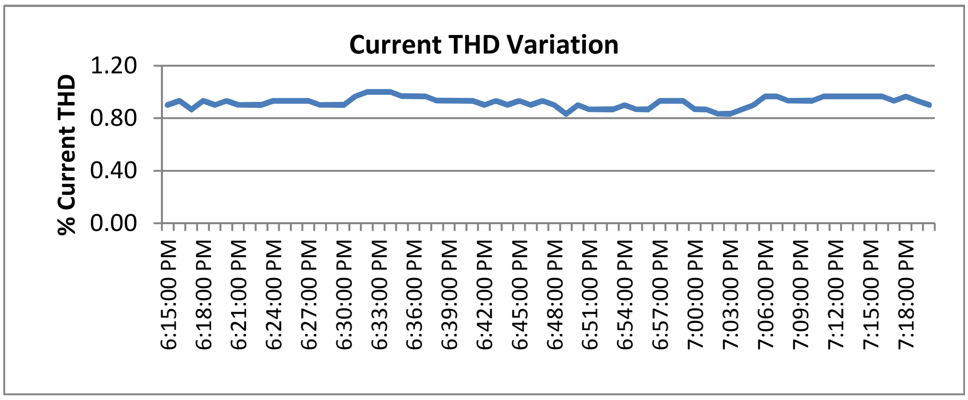


Figure 123: Variation of THD in current during parallel operation of pumps 2,3,4

- The current THD was observed to be around 1%.

Total Harmonics distortion - Voltage:

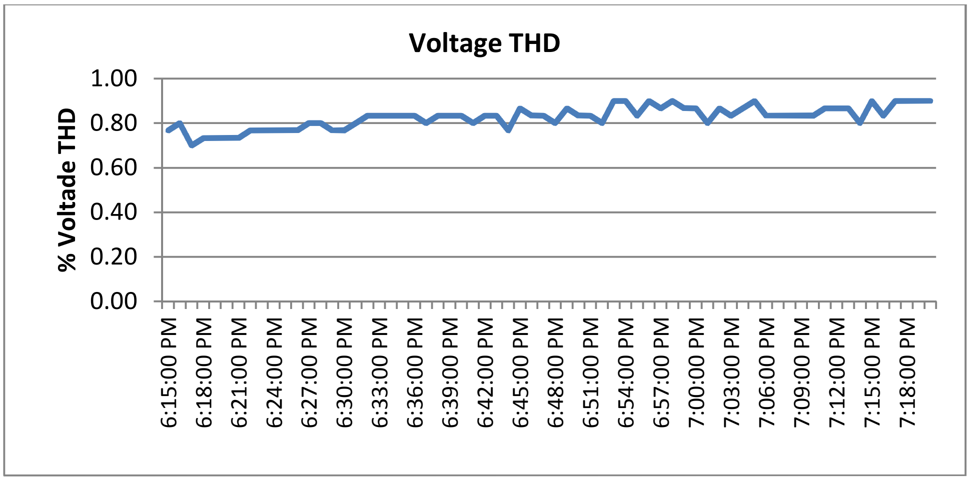


Figure 124: Variation in THD - voltage during parallel operation of pumps 2,3,4

- The voltage THD was found to be less than 1%.

Transformer loading:

Figure 125: Transformer loadingduring parallel operation of pumps 2,3,4

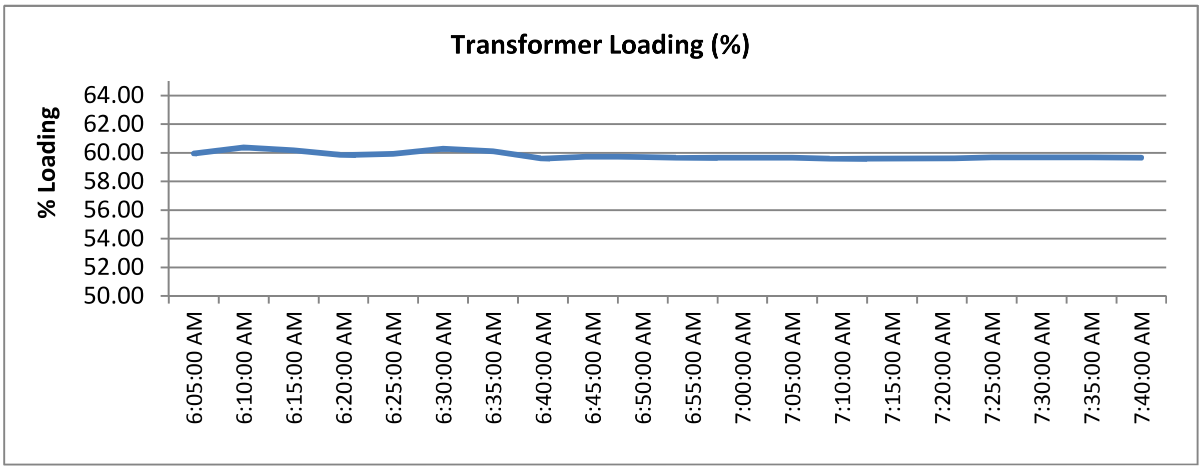
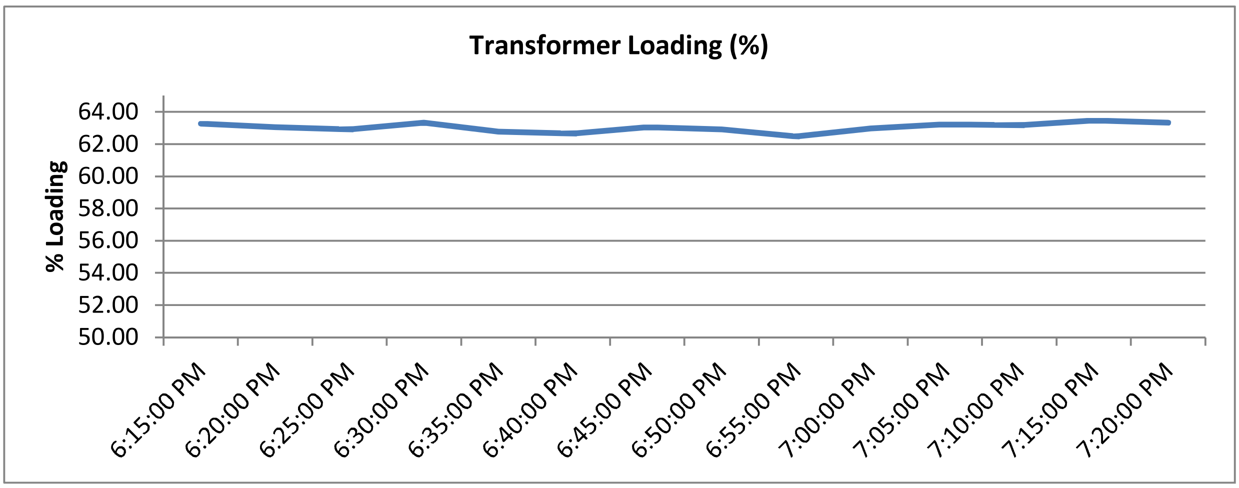


Figure 126: Transformer loadingduring parallel operation of pumps 1,3,4



- During both the pump operating combinations (pumps 2,3,4 and pumps 1,3,4), the transformer loading was observed to be in the 60-65% range.

4.11.6 Pumping Station System Mapping

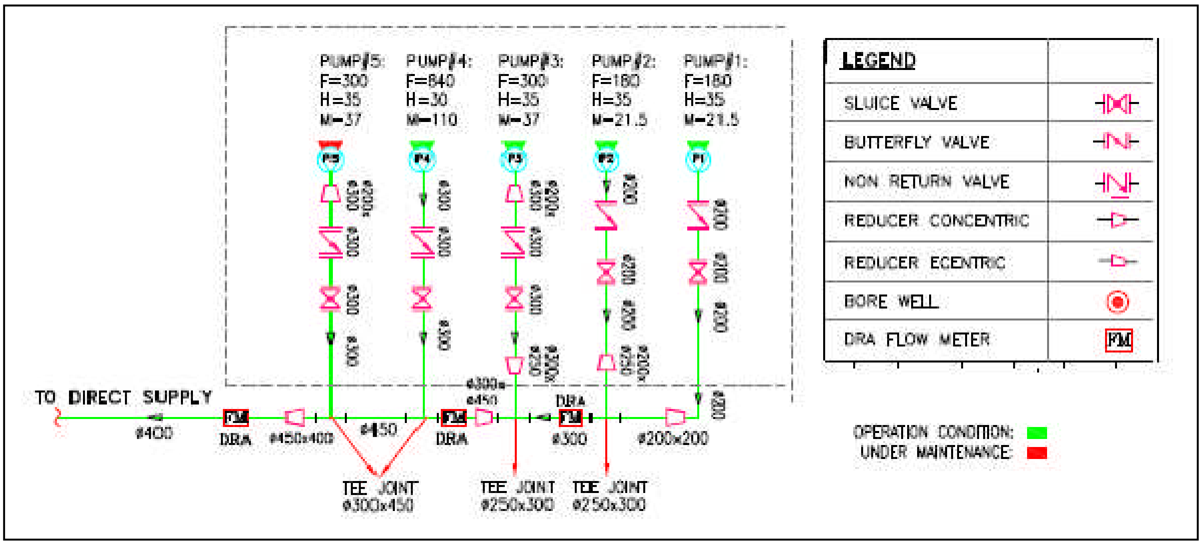


Figure 127P & ID diagram for Suryanagar ZPS

4.11.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 79: General details of Suryanagar ZPS

Data	Value / Details
Name of site	Suryanagar ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	4
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Suryanagar ZPS to showcase the actual situation are provided below.

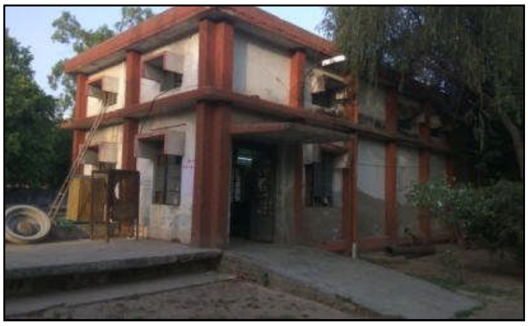
View of pump house	Pumps installed
	

Figure 128: Photographs of Suryanagar ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 80: Performance Evaluation of pumps at Suryanagar ZPS

Parameters	Unit	Surya Nagar ZPS Pump-1	Surya Nagar ZPS Pump-2	Surya Nagar ZPS Pump-3	Surya Nagar ZPS Pump-4
Pump make		Jyoti	Jyoti	Jyoti	Fairbanks
Motor make		Jyoti	Jyoti	Jyoti	Kirloskar
Pump type		VT	VT	VT	VT
Motor serial no.		M09991602	M09991600	M09991577	23704038-1
Pump serial no.		NA	NA	NA	99.11.01.218
Rated flow	m^3/h	180	180	300	840
Rated head	m	35	35	35	30
Rated motor	kW	21.5	21.5	37	110
Parameters measured					
Total suction head	m	-3.42	-1.89	-2.02	-3.48
Total discharge head	m	9	9	9	18
Average flow delivered	m^3/h	110.53	135.73	296.90	1132.33
Motor input power	kW	14.19	21.03	35.82	121.00
Frequency	Hz	50.19	50.09	50.04	50.01
Speed	RPM	1484.33	1474.00	1485.33	1483.67
Performance evaluation					
Observed head m	m	12.42	10.89	11.02	21.48
Head utilization	%	35%	31%	31%	72%

Parameters	Unit	Surya Nagar ZPS Pump-1	Surya Nagar ZPS Pump-2	Surya Nagar ZPS Pump-3	Surya Nagar ZPS Pump-4
Flow utilization	%	61%	75%	99%	135%
Hydraulic power	kW	3.74	4.02	8.91	66.25
Motor input power	kW	14.19	21.03	35.82	121.00
Calculated pumpset efficiency		26.34%	19.14%	24.88%	54.75%
Rated motor efficiency		90.0%	90.0%	91.0%	93.0%
Calculated pump efficiency		29.27%	21.27%	27.34%	58.87%
Specific energy consumption	kWh/m³	0.128	0.155	0.121	0.107

Table 81: Parallel pumping at Suryanagar ZPS

Location		Surya Nagar	Surya Nagar
Parameters measured		**1,3,4**	**2,3,4**
Total suction head	m	-2.12	-2.29
Total discharge head	m	9.333333	10
Total flow	m³/h	1315.67	1286.33
Motor input power	kW	167.71	161.17
Performance evaluation			
Total head developed	m	11.45	12.29
Head utilization		33%	35%
Flow utilization		100%	97%
Hydraulic power developed by pump	kW	41.04	43.04
Motor input kW	kW	167.71	161.17
Calculated overall efficiency		24.47%	26.71%
Motor efficiency		90.00%	90.00%
Calculated pump efficiency		27.19%	29.67%
Specific energy consumption	kWh/m³	127.47	125.29

Key Observations:

- Pump no. 5 was in breakdown condition.
- Pump set efficiencies of pumps 1, 2 and 3 were observed to be quite poor at 26.34%, 19.14% and 24.88%. All of them were found to be operating significantly below their rated head.
- Pump set efficiency of pump no. 4 was found to be 54.75%, and the operating head of the pump was much higher compared to pumps 1, 2 and 3.

- In parallel pumping, the combinations of pumps 1,3,4 and pumps 2,3,4 were found to give low combined efficiencies around 24-26%, operating significantly below the rated head of the pumps.

4.11.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 82: Other auxiliary equipment at Suryanagar ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	315 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 83: Other electrical equipment at Suryanagar ZPS - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
	Tubelight	6	0.04	12
	Tubelight	6	0.036	12
Suryanagar ZPS	CFL	5	0.085	12
	Sodium vapour	5	0.15	12
	Metal Halide	1	0.25	12

Table 84: Other electrical equipment at Suryanagar ZPS – Auxiliary pumps and others

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary Pumps and Other loads	Exhaust fan	2	0.085	10
	Ceiling fan	8	0.07	8
	Cooler	7	0.035	8
	Computer	1	0.08	8

4.11.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Suryanagar ZPS is provided in below table.

Table 85: Estimated annual energy consumption and water supply for Suryanagar ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Surya Nagar ZPS	Pump-1	1,3&4 or 2,3&4 in parallel for direct distribution	392	14.19	5,565
Surya Nagar ZPS	Pump-2		549	21.03	11,543
Surya Nagar ZPS	Pump-3		510	35.82	18,260
Surya Nagar ZPS	Pump-4		930	121.00	112,565
	Total		**2,381**	**192.04**	**147,933**

4.12 Mathura Road ZPS

4.12.1 Overview of existing systems

Mathura Road ZPS receives clear water from the Sikandra WTP. Four pumps are installed here, of which three are operated. Water is pumped directly into distribution network.

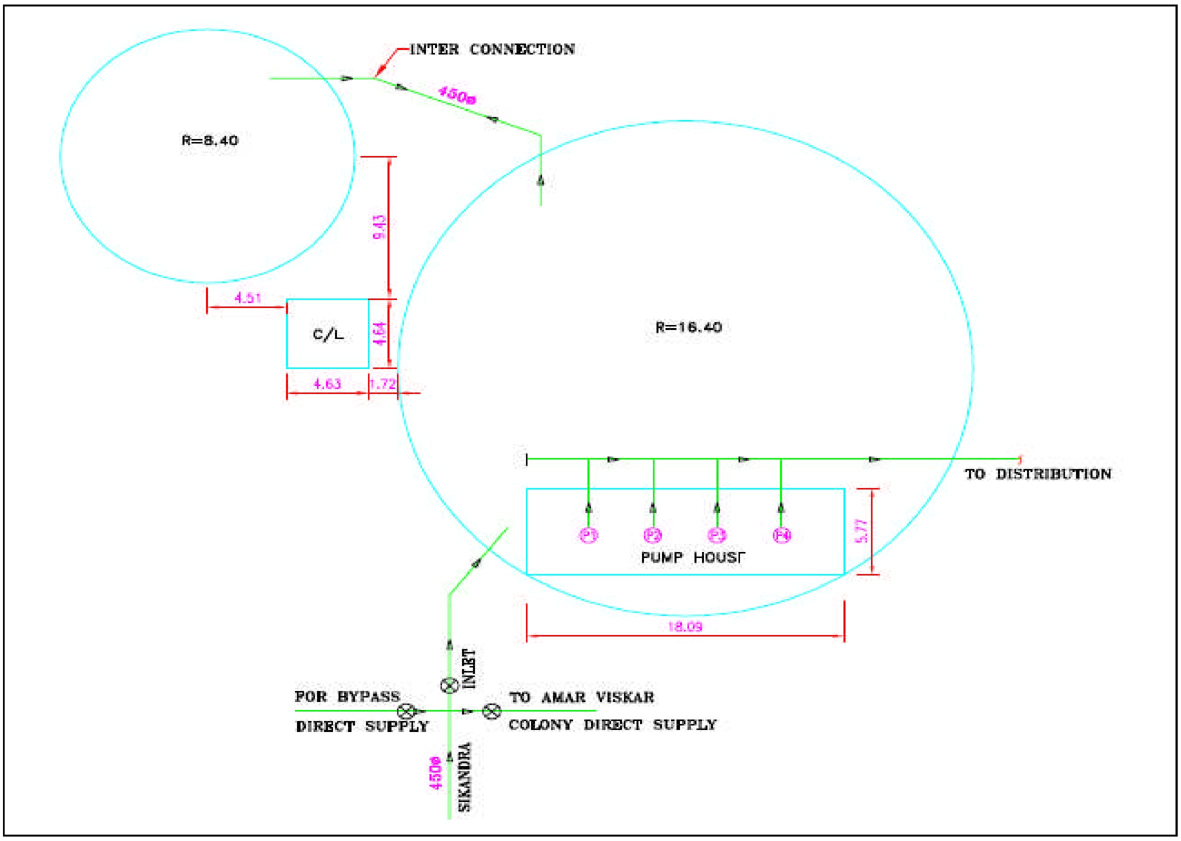
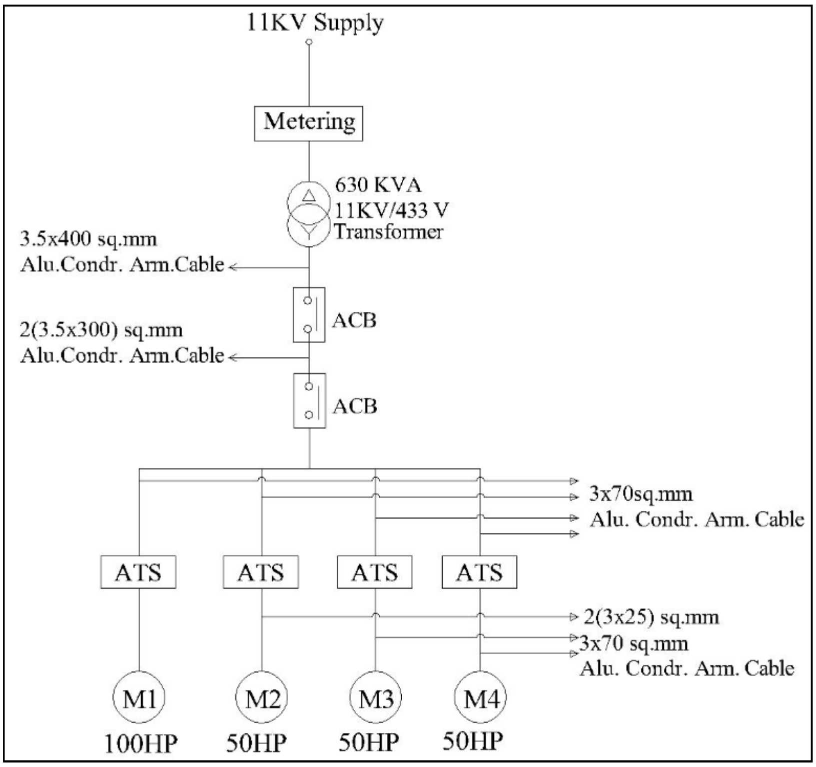


Figure 129: Plant Layout for Mathura Road ZPS

4.12.2 Electricity Supply

Mathura Road ZPS receives supply at 11 kV from Torrent Power. This is stepped down to 415V via a 630 kVA transformer to feed the motors.

Figure 130Single line diagram for the Mathura Road ZPS



4.12.3 Tariff Structure

The electrical connection for Mathura Road ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 86: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Mathura Road Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.12.4 Electricity Bill Analysis

During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

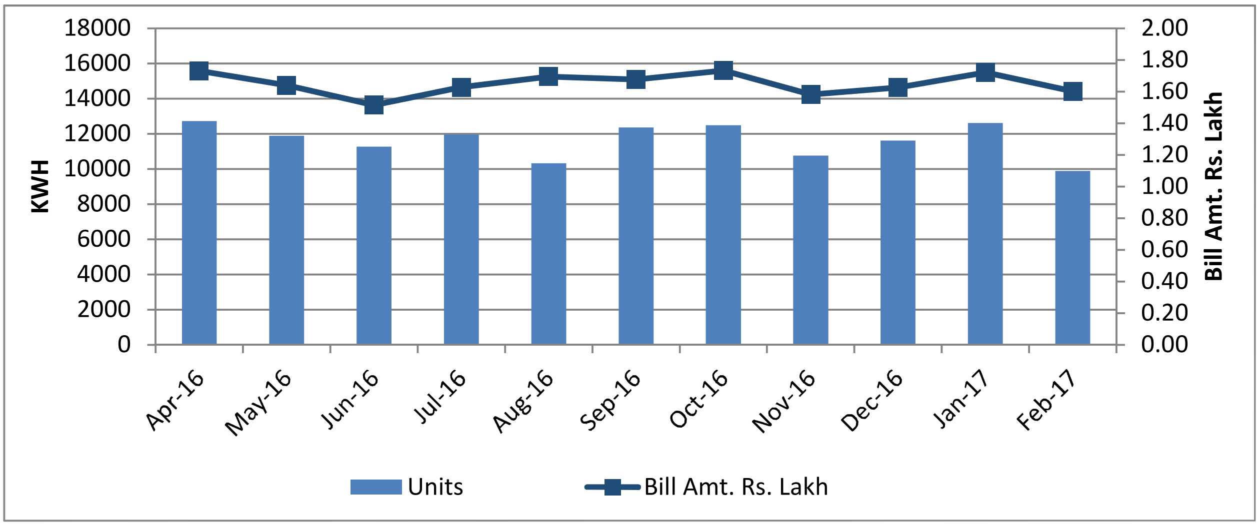
Table 87: Energy cost and energy consumption detail for Mathura Road ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	142,766		2,154,764
Apr-15 to Mar-16	161,926	13.4%	2,226,949
Apr-16 to Mar-17	139,480	-13.9%	1,979,458

The power factor recorded on the incomer was found to be low, around 0.76-0.77. The billing is kVAh-based, hence improving the power factor will result in reduced kVAh consumption for same kWh requirement, thus leading to reduction in monthly bill amount.

The recorded demand has been observed to consistently exceed the contract demand throughout 2016-17. As a result of this, 'Excess demand charges' have been levied in addition to the normal demand charges every month.

Figure 131: Monthly electricity consumption and electricity bill for Mathura Road ZPS



4.12.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at Mathura Road ZPS is provided in below table.

Table 88: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 630 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

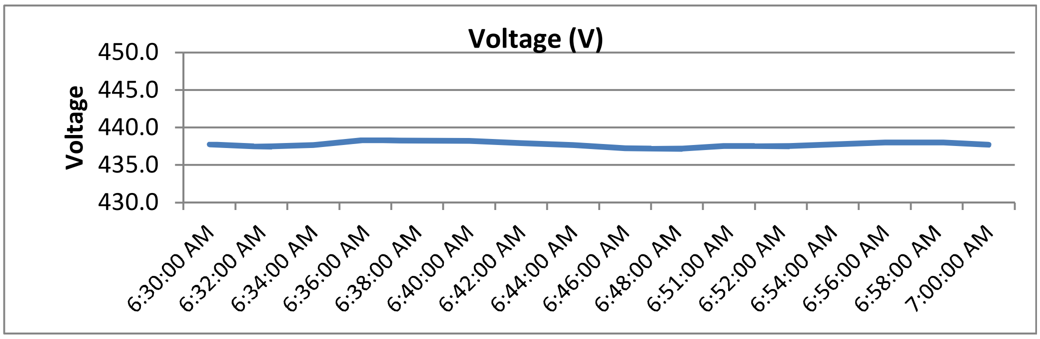


Figure 132: Voltage Variation of Transformer-1

- The voltage was found be fairly consistent around 437-439V.

Power consumption and Apparent power Profile:

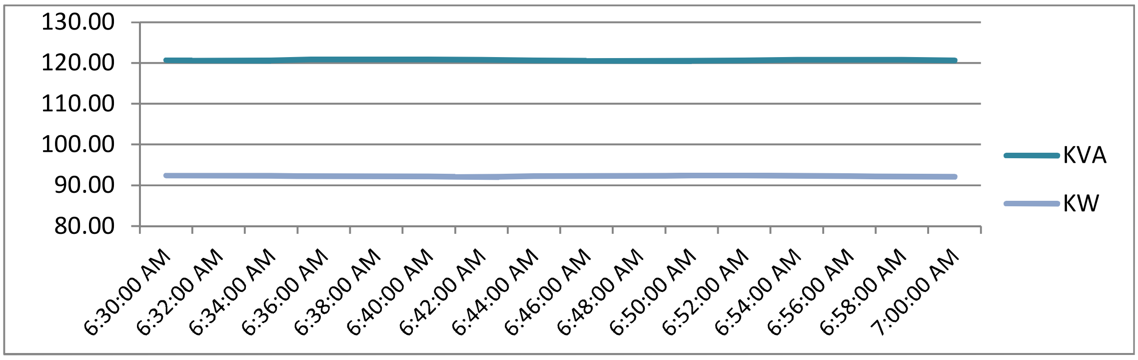


Figure 133: Power consumption variation at Transformer-1

- During parallel operation of three pumps, power consumption was found to be around the 90-95 kW range.
- The apparent power was found to be around 120 kVA.

Power factor profile

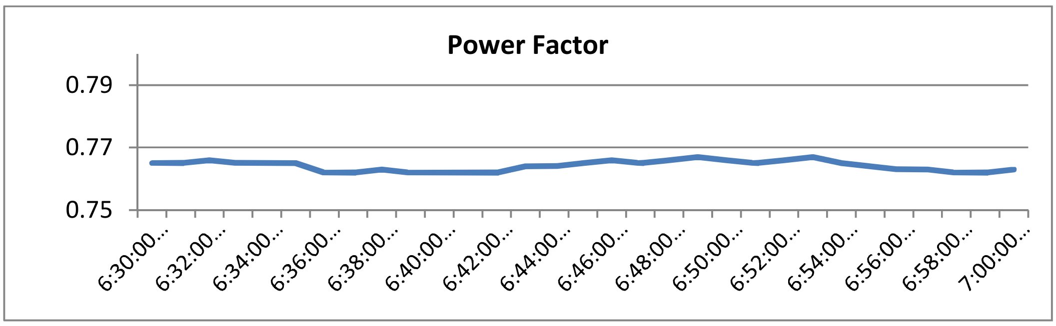


Figure 134 Power factor variation profile on Transformer-1

- The power factor measured on main incomer was found to be low, around 0.76-0.77.

Frequency Profile:

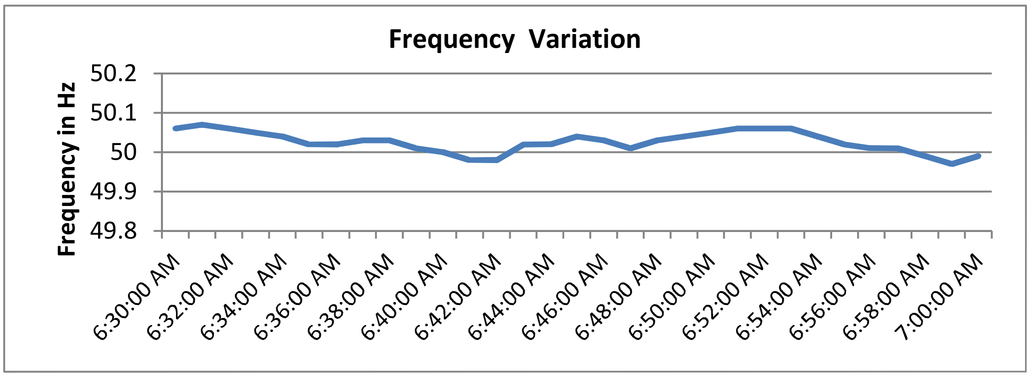


Figure 135: Frequency variation on Transformer-1

- The frequency was found to vary between 49.95 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

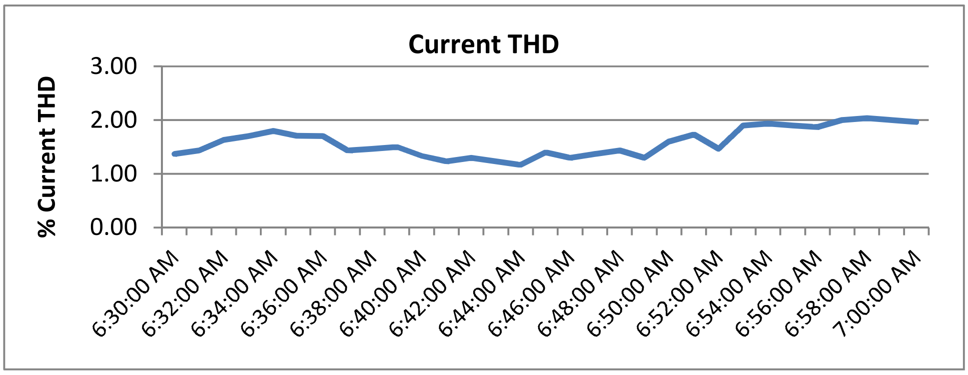


Figure 136: Variation of THD in current on Transformer-1

- The current THD was observed to be around 1.3-2%.

Total Harmonics distortion - Voltage:

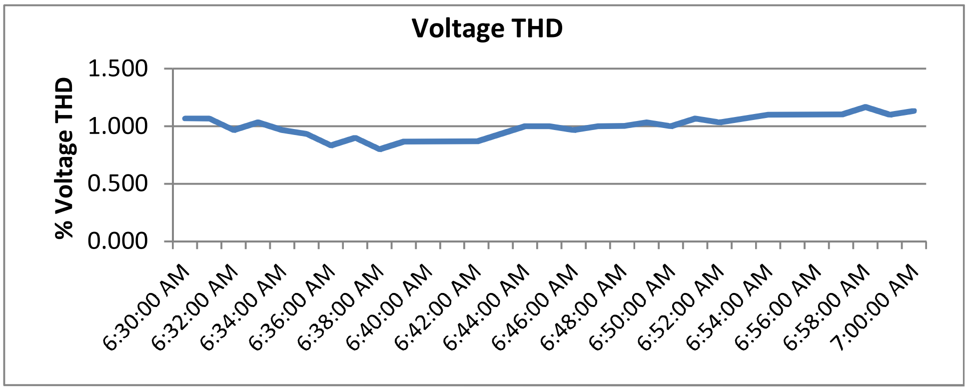


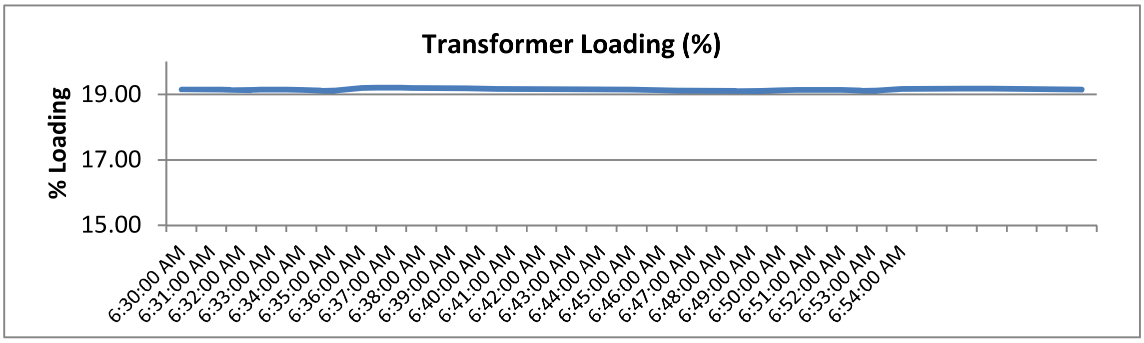
Figure 137: Variation in THD - voltage on Transformer-1

- The voltage THD was observed to be around 0.8-1.2%.

Transformer loading:

A 630 kVA transformer is installed at Mathura Road ZPS.Transformer loading was calculated based on the recorded kVA at the transformer LT side.

Table 89: Transformer loading analysis



- The transformer loading is found to be quite low, around 19-20%.

4.12.6 Pumping Station System Mapping

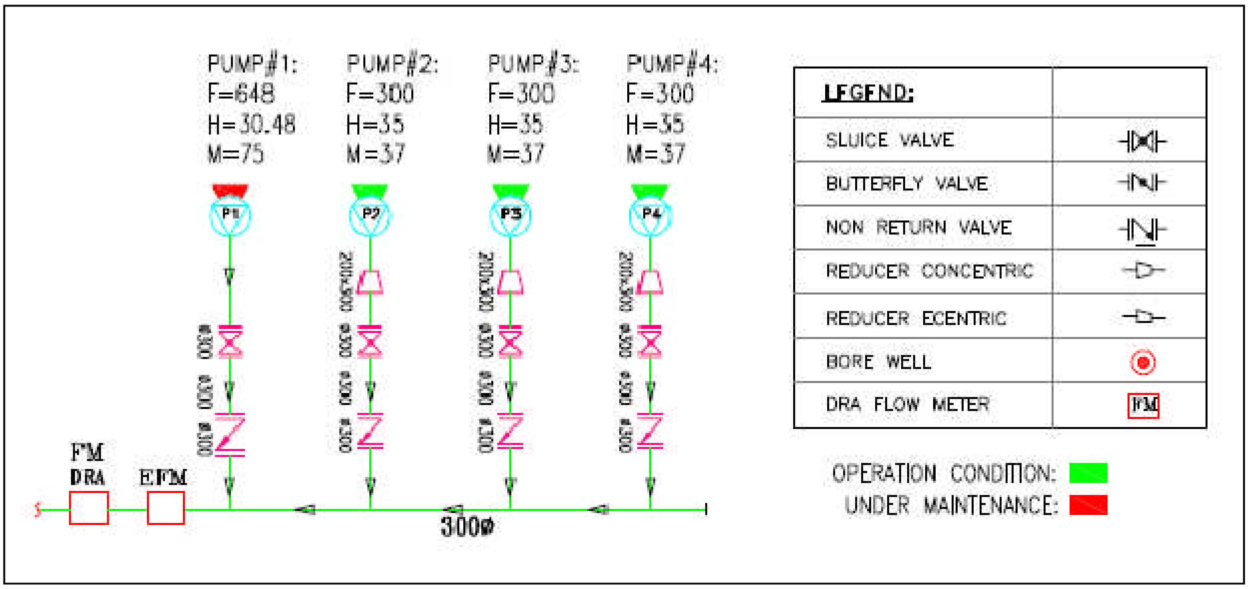


Figure 138: P & ID diagram for Mathura Road ZPS

4.12.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection

- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 90: General details of Mathura Road ZPS

Data	Value / Details
Name of site	Mathura Road ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	4
No. of pumps in operation	3
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Mathura Road ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 139: Photographs of Mathura Road ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 91: Performance Evaluation of pumps at Mathura Road ZPS

	Unit	Mathura Road ZPS	Mathura Road ZPS	Mathura Road ZPS
Parameters		Pump-2	Pump-3	Pump-4
Pump make		Jyoti	Jyoti	Jyoti
Motor make		Jyoti	Jyoti	Jyoti
Pump type		VT	VT	VT
Motor serial no.		M09991576	M09991586	M09991589
Pump serial no.		NA	NA	NA

Parameters	Unit	Mathura Road ZPS Pump-2	Mathura Road ZPS Pump-3	Mathura Road ZPS Pump-4
Rated flow	m^3/h	300	300	300
Rated head	m	35	35	35
Rated motor	kW	37	37	37
Parameters measured				
Total suction head	m	-4.34	-5.19	-3.60
Total discharge head	m	12	10	11
Average flow delivered	m^3/h	408.10	149.80	336.27
Motor input power	kW	41.38	27.60	33.85
Frequency	Hz	50.07	50.09	50.04
Speed	RPM	1475.00	1478.00	1472.67
Performance evaluation				
Total head developed	m	16.34	15.19	14.60
Head utilization	%	47%	43%	42%
Flow utilization	%	136%	50%	112%
Hydraulic power kW	kW	18.16	6.20	13.37
Motor input power	kW	41.38	27.60	33.85
Calculated pumpset efficiency	%	43.87%	22.45%	39.51%
Rated motor efficiency	%	91%	91%	91%
Calculated pump efficiency	%	48.21%	24.67%	43.41%
Specific energy consumption	kWh/m^3	0.101	0.184	0.101

Table 92: Parallel pumping at Mathura Road ZPS

Location	Unit	Mathura Road ZPS
Parameters measured		**2,3,4**
Total suction head	m	-4.40
Total discharge head	m	10
Total flow	m^3/h	973.80

Location	Unit	Mathura Road ZPS
Parameters measured		**2,3,4**
Motor input power	kW	83.03
Performance evaluation		
Total head developed	m	14.40
Head utilization	%	41%
Flow utilization	%	78%
Hydraulic power developed by pump	kW	38.20
Motor input kW	kW	83.03
Calculated overall efficiency	%	46.00%
Motor efficiency	%	91%
Calculated pump efficiency	%	50.55%
Specific energy consumption	kWh/m^3	85.27

Key Observations:

- Pump no. 1 has been discarded.
- Pump set efficiencies of pumps 2,3 and 4 were found to be 43.87%, 22.45% and 39.51% respectively. All three were operating below their rated head. With all three running in parallel, the combined efficiency was found to be 46%, with the operating head still significantly below the rated head of the pumps.
- NRVs of all pumps are not in working condition.
- Heavy leakage was observed from the common outlet.

4.12.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 93: Other auxiliary equipment at Mathura Road ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	One
Capacity (kVA)	630 kVA
Primary/Secondary voltages	11 kV/433 V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 94: Other electrical equipment at Mathura Road ZPS - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Mathura Road	HPSV	4	0.25	12
	Metal Halide	1	0.25	12
	Metal Halide	3	0.15	12

4.12.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Mathura Road ZPS is provided in below table.

Table 95: Estimated energy consumption for Mathura Road ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Mathura Road ZPS	Pump-2	2,3,4 in parallel for direct distribution.	1,076	41.38	44,532
Mathura Road ZPS	Pump-3		726	27.60	20,033
Mathura Road ZPS	Pump-4		1,076	33.85	36,425
	Total		**2,878**	**102.83**	**100,990**

4.13 Trans Yamuna ZPS

4.13.1 Overview of existing systems

Trans Yamuna ZPS receives treated water from Jeoni Mandi WTP. Water is pumped directly into distribution for supply to Trans Yamuna phase-2 area. Two pumps are installed here, of which one has not been in operation for several months.

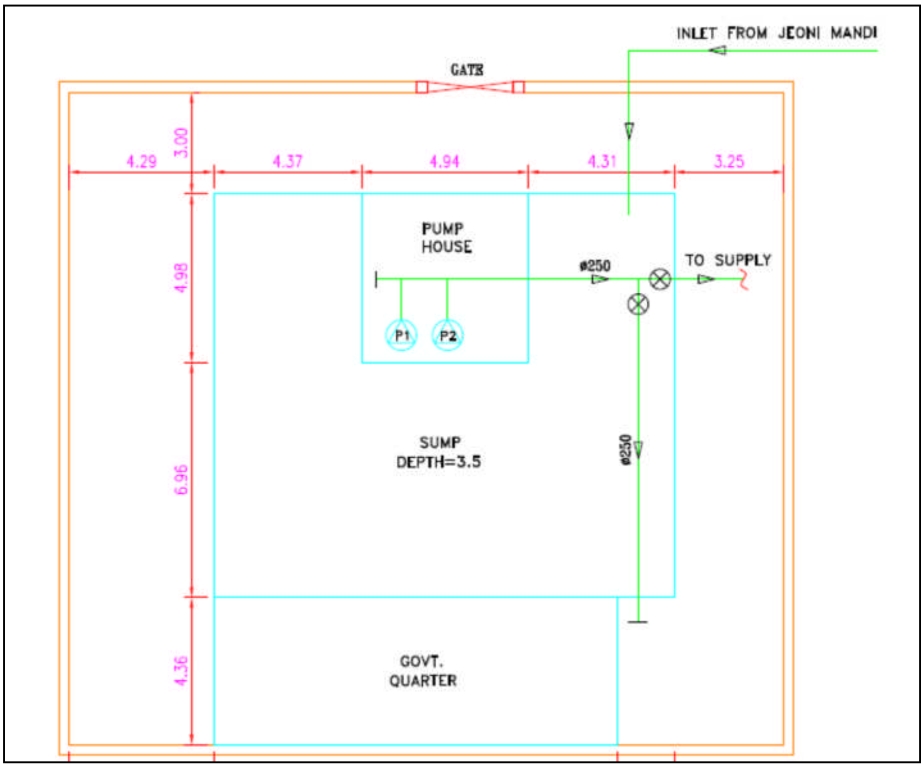


Figure 140: Plant Layout for Trans Yamuna ZPS

4.13.2 Electricity Supply

Trans Yamuna receives supply at 440V from Torrent Power,

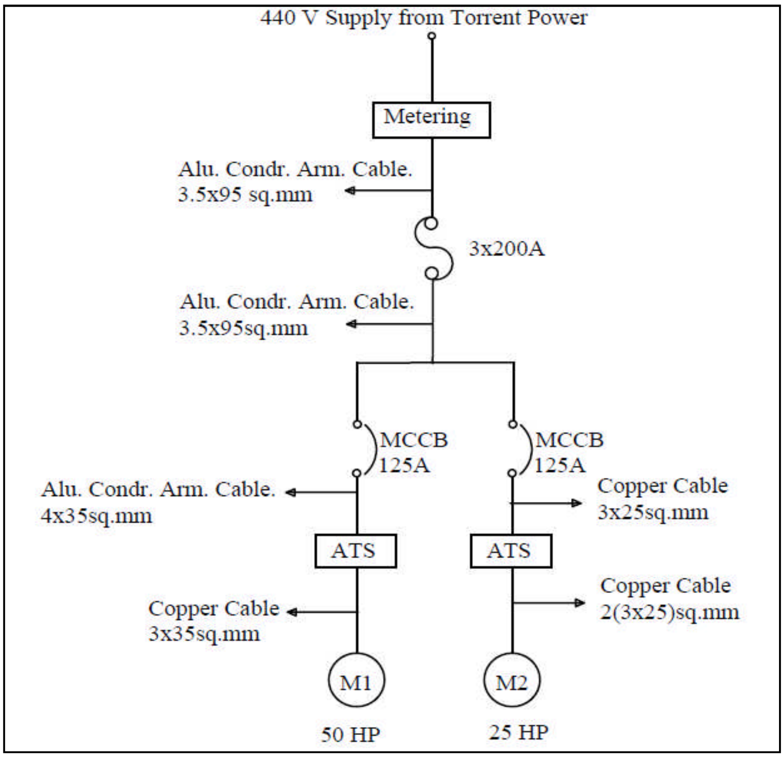


Figure 141 Single line diagram for the Trans Yamuna ZPS

4.13.3 Tariff Structure

The electrical connection for Trans Yamuna ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 96: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Trans Yamuna Energy Meter (LT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.13.4 Electricity Bill Analysis

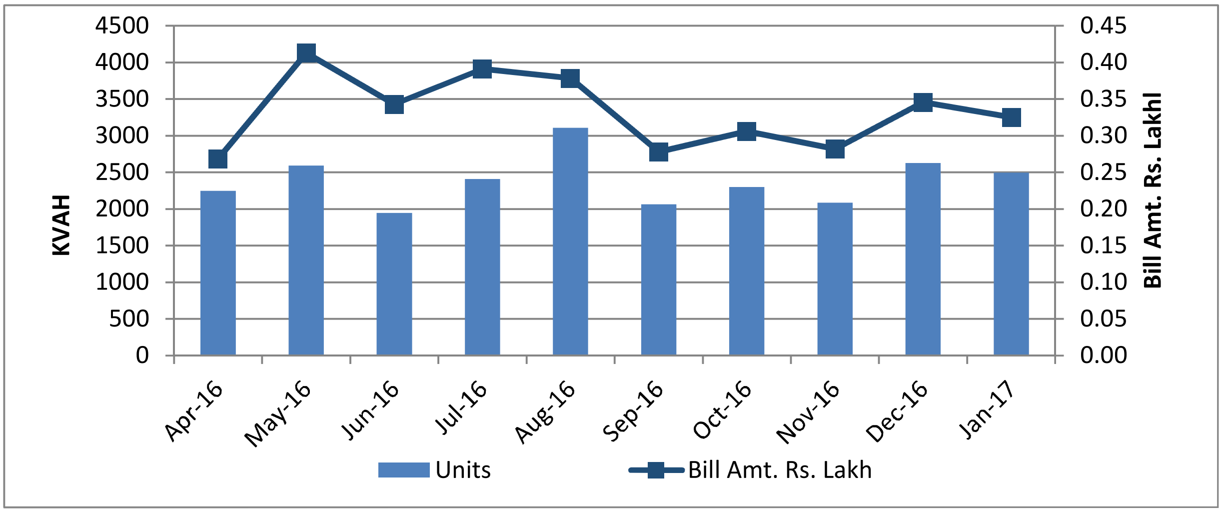
During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

Table 97: Energy cost and energy consumption detail for Trans Yamuna ZPS

Period of energy bill	Energy consumption (kVAH/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	25,735		297,926
Apr-15 to Mar-16	27,153	5.5%	330,340
Apr-16 to Mar-17	25,698	-5.4%	399,818

The power factor recorded on the incomer was observed to be around 0.88. As the billing is kVAh-based, improving the power factor will reduce the electricity bill amount paid every month.

Figure 142: Monthly electricity consumption and electricity bill for Trans Yamuna ZPS



4.13.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on main LT incomer of pump house. The recorded parameters are given below:

Voltage Profile:

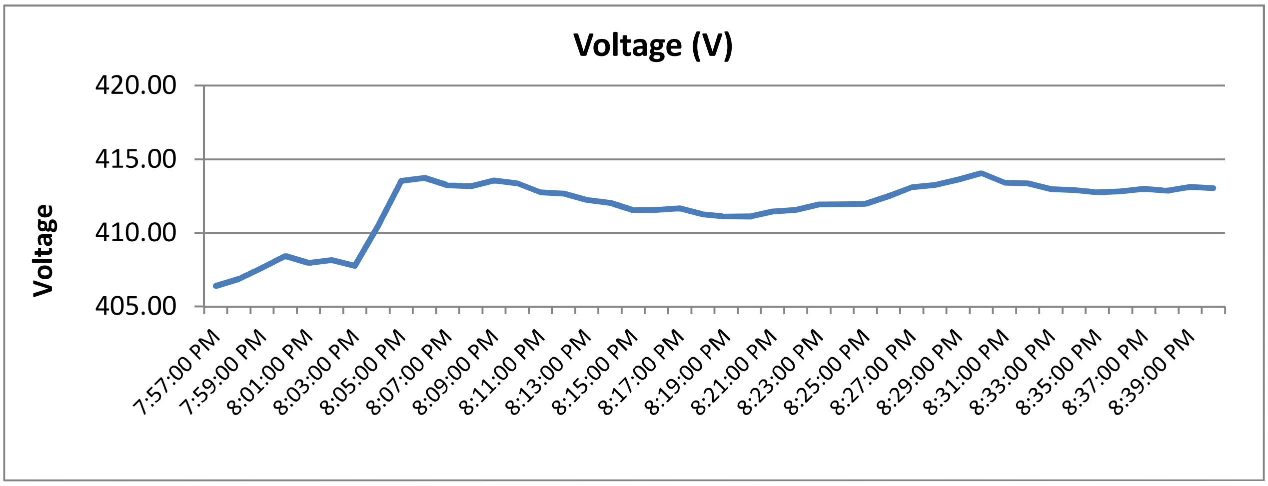


Figure 143: Voltage Variation at Trans Yamuna ZPS

- The voltage was found to vary between 406 and 414V.

Power consumption and Apparent power Profile:

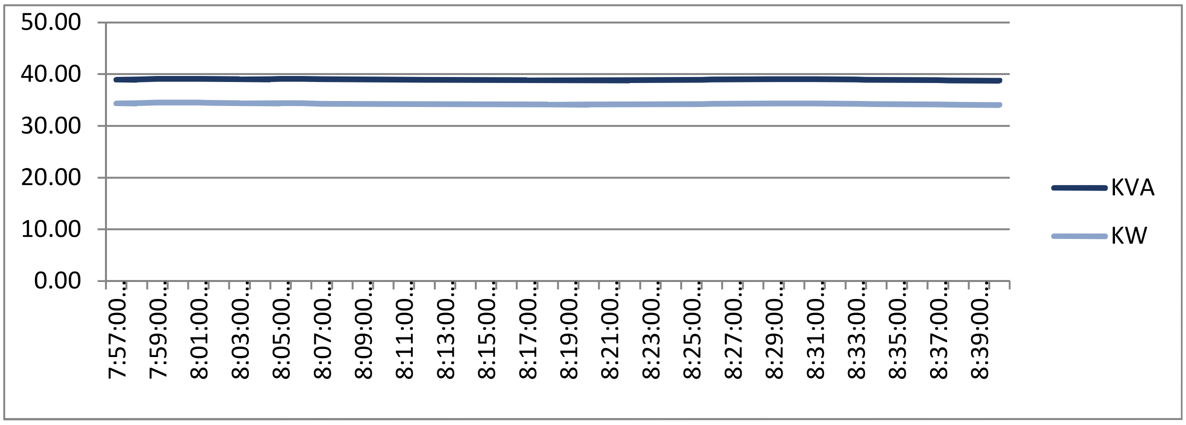


Figure 144: Power consumption variation at Trans Yamuna ZPS

- The power consumption was observed to be around 35 kW, corresponding to operation of the pump having motor rated 37 kW.
- The apparent power was found to be around 39 kVA.

Power factor profile

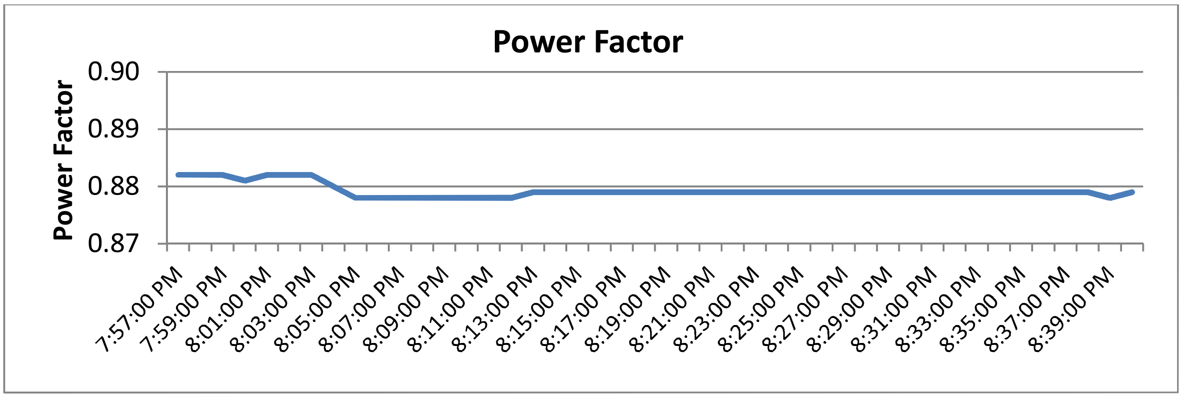


Figure 145: Power factor variation profile at Trans Yamuna ZPS

- The power factor was observed to be around 0.88.

Frequency Profile:

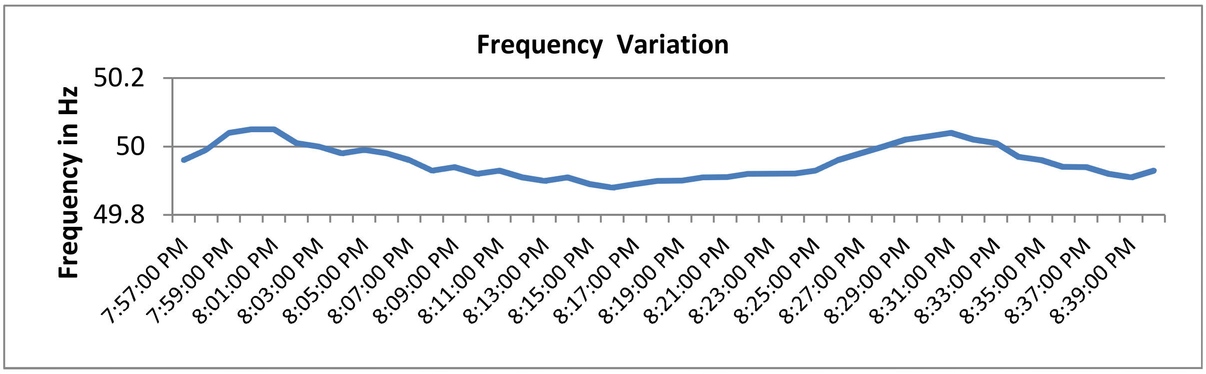


Figure 146: Frequency variation at Trans Yamuna ZPS

- The frequency was found to vary between 49.85-50.05 Hz.

Total Harmonics distortion (THD) - Current:

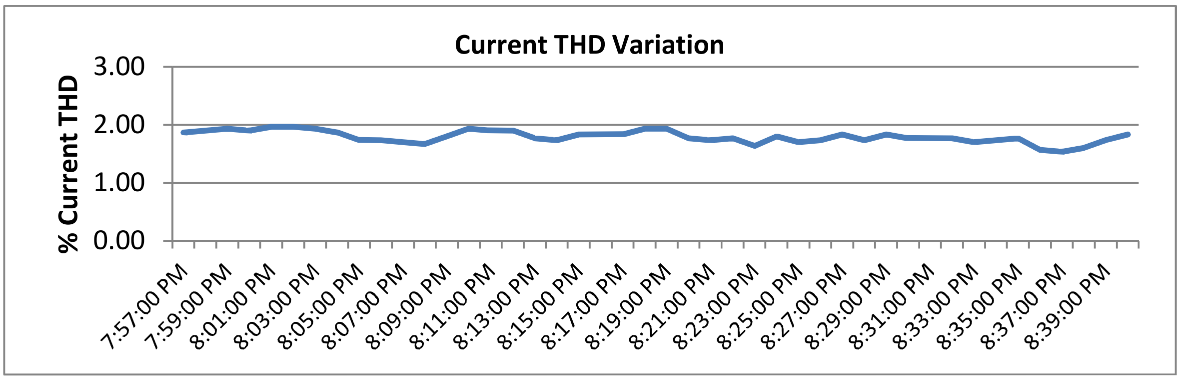


Figure 147: Variation of THD in current at Trans Yamuna ZPS

- Current THD was found to be around 1.5-2%.

Total Harmonics distortion - Voltage:

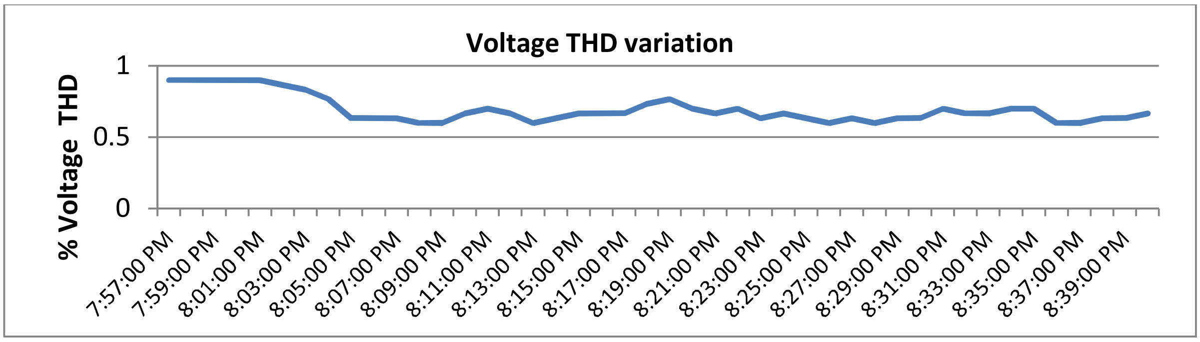


Figure 148: Variation in THD - voltage at Trans Yamuna ZPS

- Voltage THD was observed to be less than 1%.

4.13.6 Pumping Station System Mapping

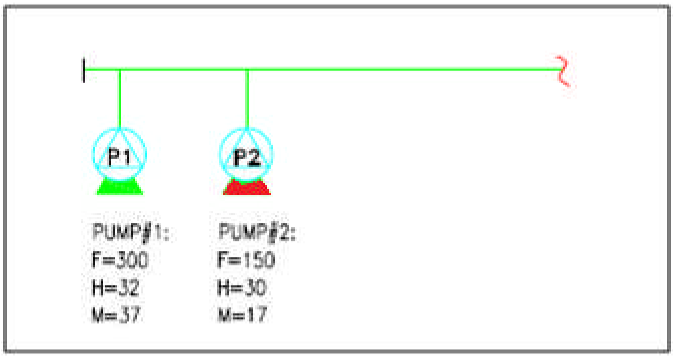


Figure 149: P & ID diagram for Trans Yamuna ZPS

4.13.7 Pumps Performance Evaluation

As per the methodology described in section – 1,4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 98: General details of Trans Yamuna ZPS

Data	Value / Details
Name of site	Trans Yamuna ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	2
No. of pumps in operation	2
No. of pumps under maintenance	0
Other Details	

Data	Value / Details
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Trans Yamuna ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 150: Photographs of Trans Yamuna ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 99: Performance Evaluation of pumps at Trans Yamuna ZPS

	Unit	Trans Yamuna ZPS	Trans Yamuna ZPS
Parameters		Pump-1	Pump-2
Pump make		Kirloskar	Jyoti
Motor make		Jyoti	NA
Pump type		VT	VT
Motor serial no.		M05150064	2800657-1
Pump serial no.		BHR-3	250T2B401
Rated flow	m^3/h	300	150
Rated head	m	32	30
Rated motor	kW	37	17
Parameters measured			
Total suction head	m	-2.77	-3.37
Total discharge head	m	6.6	2
Average flow delivered	m^3/h	366.83	179.33
Motor input power	kW	35.17	14.48
Frequency	Hz	49.97	49.97
Speed	RPM	1474.33	1468.33
Performance evaluation			

	Unit	Trans Yamuna ZPS	Trans Yamuna ZPS
Parameters		Pump-1	Pump-2
Total head developed	m	9.43	5.37
Head utilization	%	29%	18%
Flow utilization	%	122%	120%
Hydraulic power kW	kW	9.42	2.62
Motor input power	kW	35.17	14.48
Calculated pumpset efficiency	%	26.79%	18.10%
Rated motor efficiency	%	91.0%	90%
Calculated pump efficiency	%	29.44%	20.11%
Specific energy consumption	kWh/m^3	0.096	0.081

Key Observations:

- Pump no. 2 was not in operation for several months at the time of audit.
- Pumps 1 and 2 were found to be operating at pump set efficiencies of 26.79% and 18.1% respectively.Operating head of both pumps was found to be significantly less than the rated head, while discharge was found to be higher than rated discharge.

4.13.8 Auxiliaries In Pumping Stations

Table 100: Other auxiliary equipment at Trans Yamuna ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	0
Capacity (kVA)	
Primary/Secondary voltages	
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

No other auxiliary loads are installed at Trans Yamuna.

4.13.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Trans Yamuna ZPS is provided in below table.

Table 101: Estimated energy consumption for Trans Yamuna ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Trans Yamuna ZPS	Pump-1	Only no. 1 operates.	913	35.17	32096
Trans Yamuna ZPS	Pump-2		0	14.48	0

4.14 Lawyers Colony ZPS

4.14.1 Overview of existing systems

Lawyers' Colony ZPS receives clear water from Sikandra WTP. Water is pumped from here to Lawyers' Colony area and to Dayal Bagh ESR through separate sets of (1W+1SB) pumps and dedicated pipe lines.

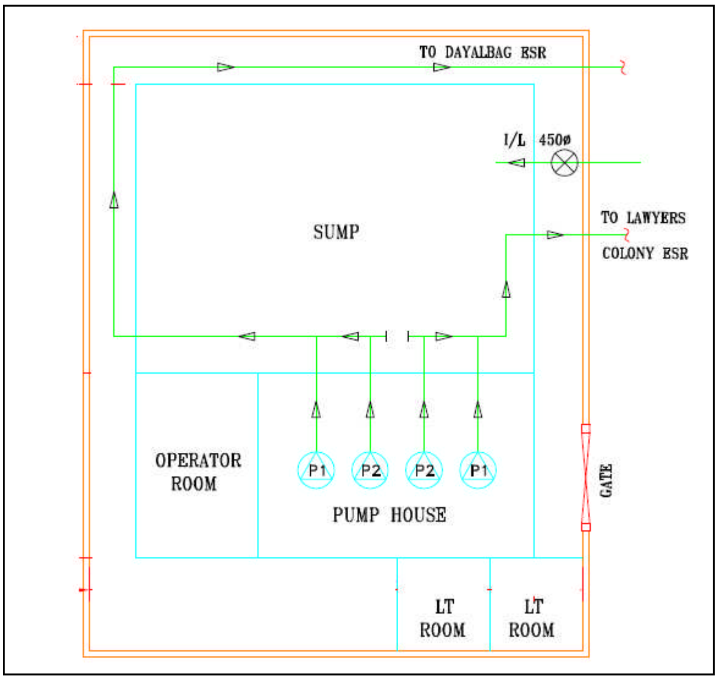


Figure 151 Plant Layout for Lawyers' Colony ZPS

4.14.2 Electricity Supply

Lawyers Colony ZPS receives power supply at 440V from Torrent Power.

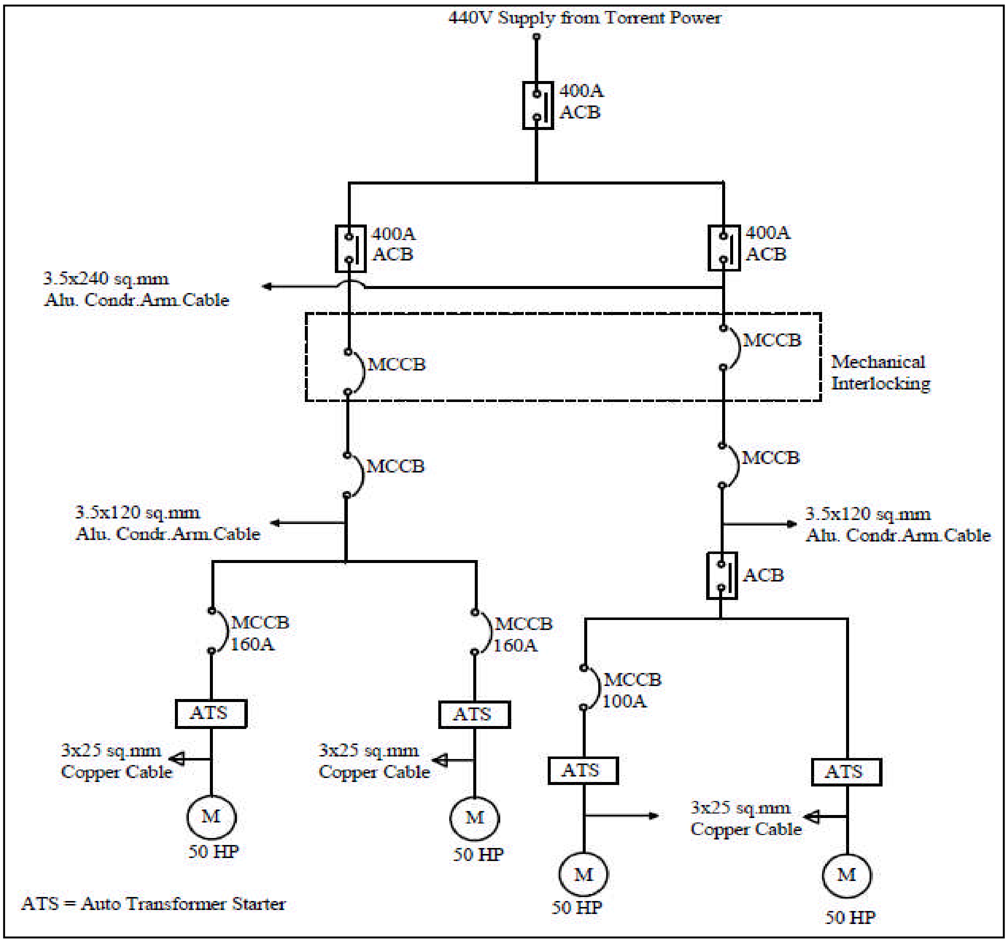


Figure 152 Single line diagram for the Lawyers' Colony ZPS

4.14.3 Tariff Structure

The electrical connection for Lawyers Colony ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 102: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Lawyers Colony Energy Meter (LT)
Meter serial number	NA
Power supply	0.44 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.14.4 Electricity Bill Analysis

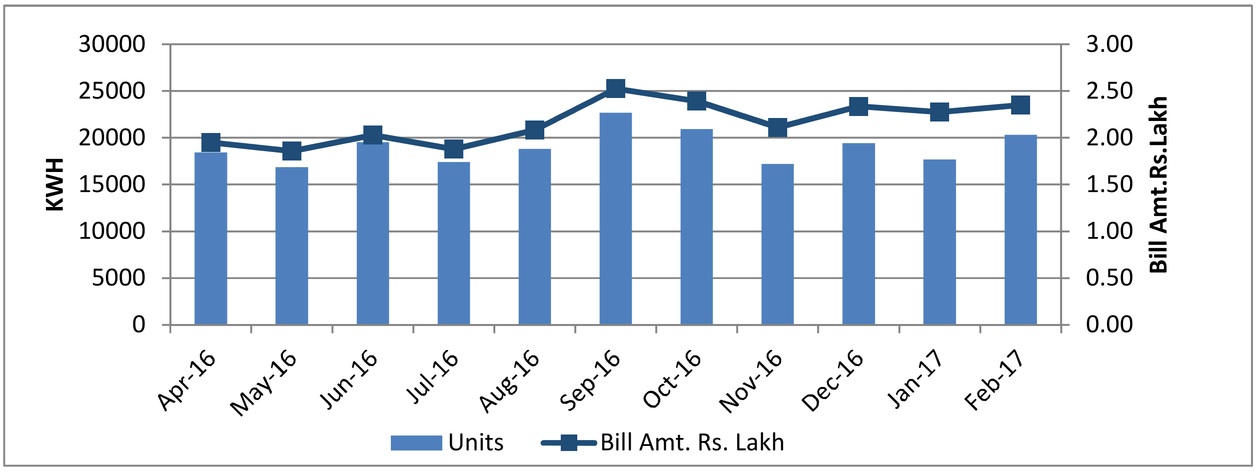
During energy audit, electricity bill data was collected from the ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year are provided in the table below.

Table 103: Energy cost and energy consumption detail for Lawyers' Colony ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	235,975		2,304,019
Apr-15 to Mar-16	228,024	-3.4%	2,380,794
Apr-16 to Mar-17	228,386	0.2%	2,595,256

The power factor recorded on the incomer was found to be around 0.84. As the billing is kVAh-based, improving the power factor will lead to reduction in bill amount paid every month.

Figure 153: Monthly electricity consumption and electricity bill for Lawyers' Colony ZPS



4.14.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed onLT incomer for recording variation of electrical parameters. The recorded parameters are given below.

Voltage Profile:

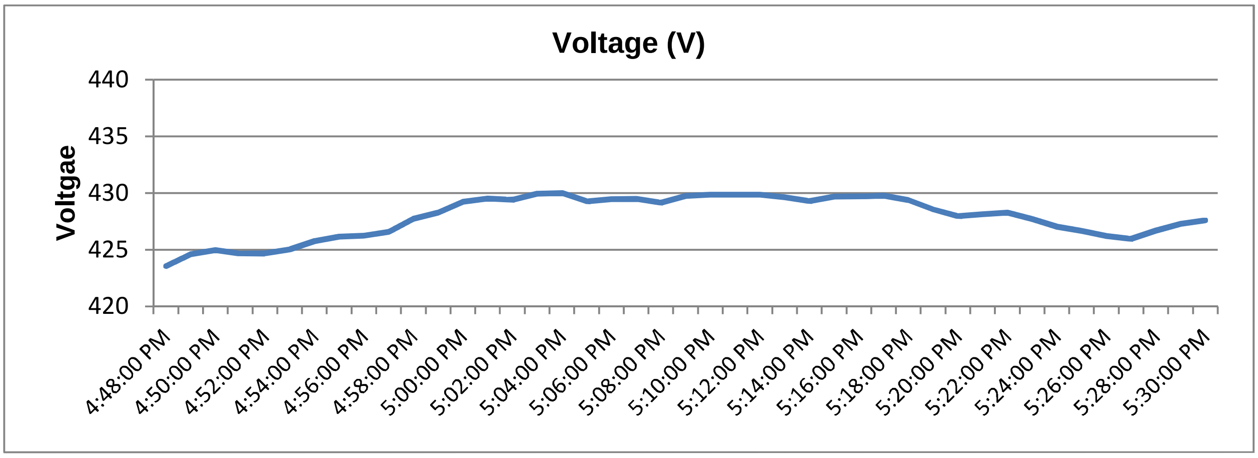


Figure 154: Voltage Variation at Lawyers' Colony ZPS

- The recorded voltage was found to vary between 423 and 430V.

Power consumption and Apparent power Profile:

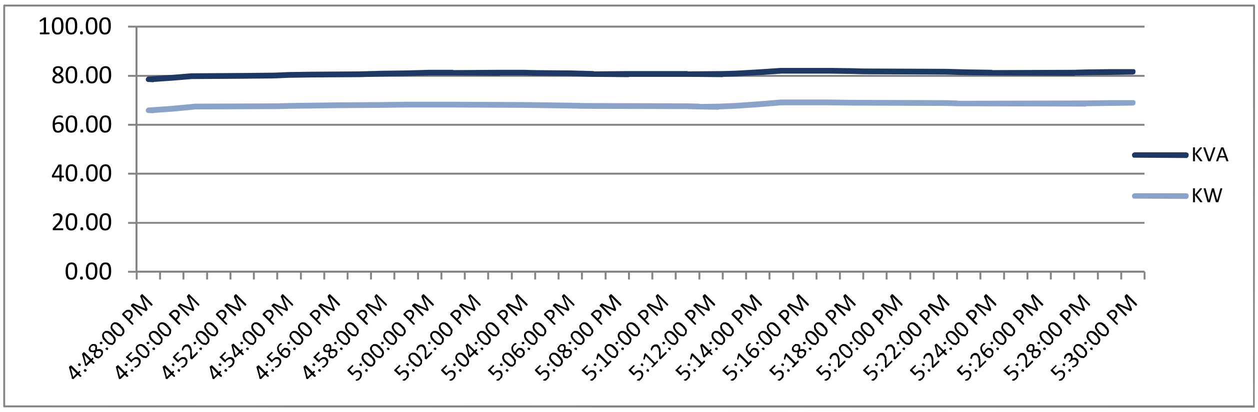


Figure 155: Power consumption variation at Lawyers' Colony ZPS

- The power consumption during parallel operation of two pumps was found to be around 65-70 kW.
- The apparent power during parallel operation of two pumps was found to be around 78-83 kVA.

Power factor profile

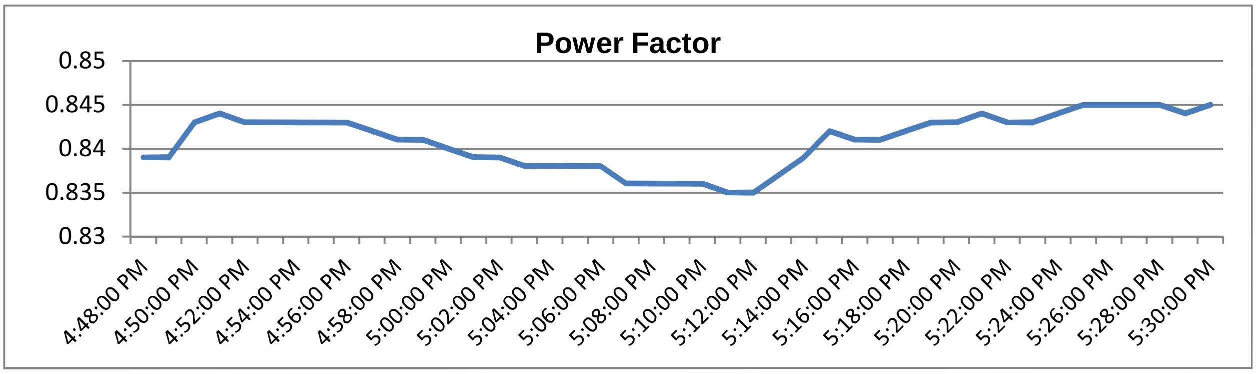


Figure 156: Power factor variation profile at Lawyers' Colony ZPS

- The power factor was found to be in the 0.835-0.845 range.

Frequency Profile:

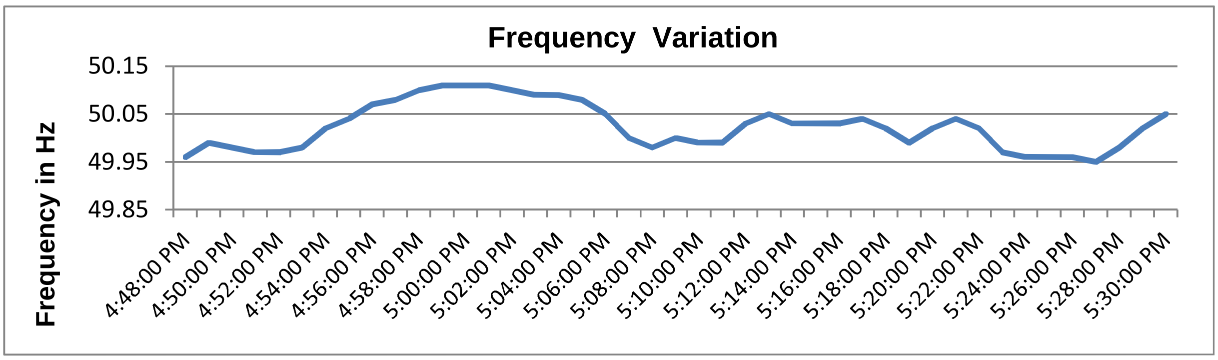


Figure 157: Frequency variation at Lawyers' Colony ZPS

- The frequency was found to vary between 49.95 and 50.11 Hz.

Total Harmonics distortion (THD) - Current:

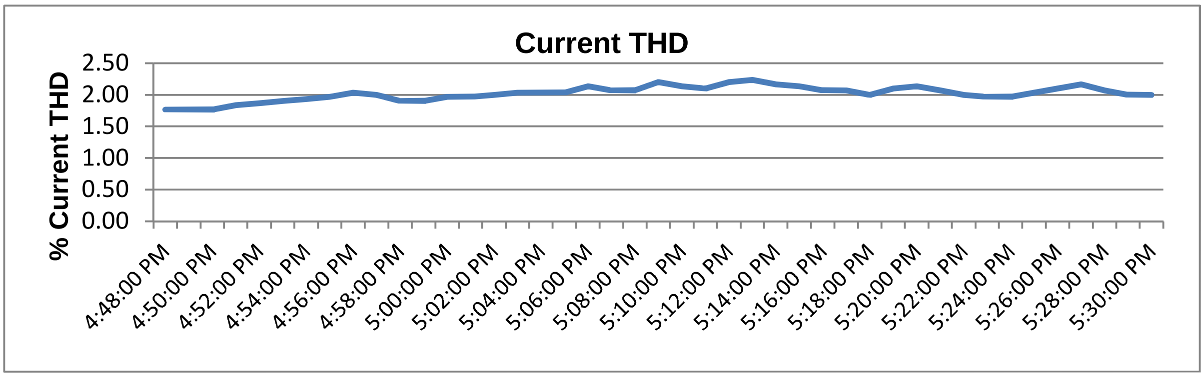


Figure 158Variation of THD in current at Lawyers' Colony ZPS

- The current THD was found to be around 1.7-2.4%.

Total Harmonics distortion - Voltage:

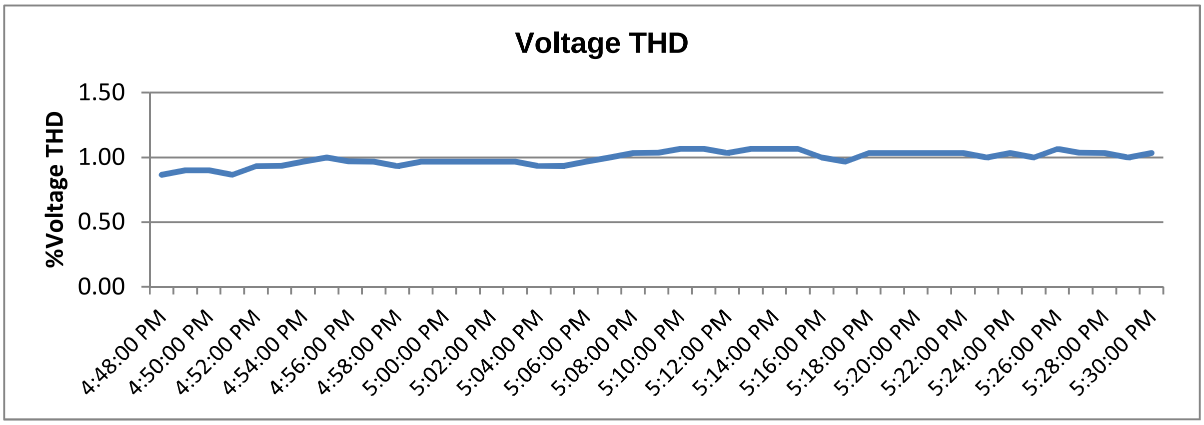


Figure 159: Variation in THD - voltage at Lawyers' Colony ZPS

- The voltage THD was found to be close to 1%.

4.14.6 Pumping Station System Mapping

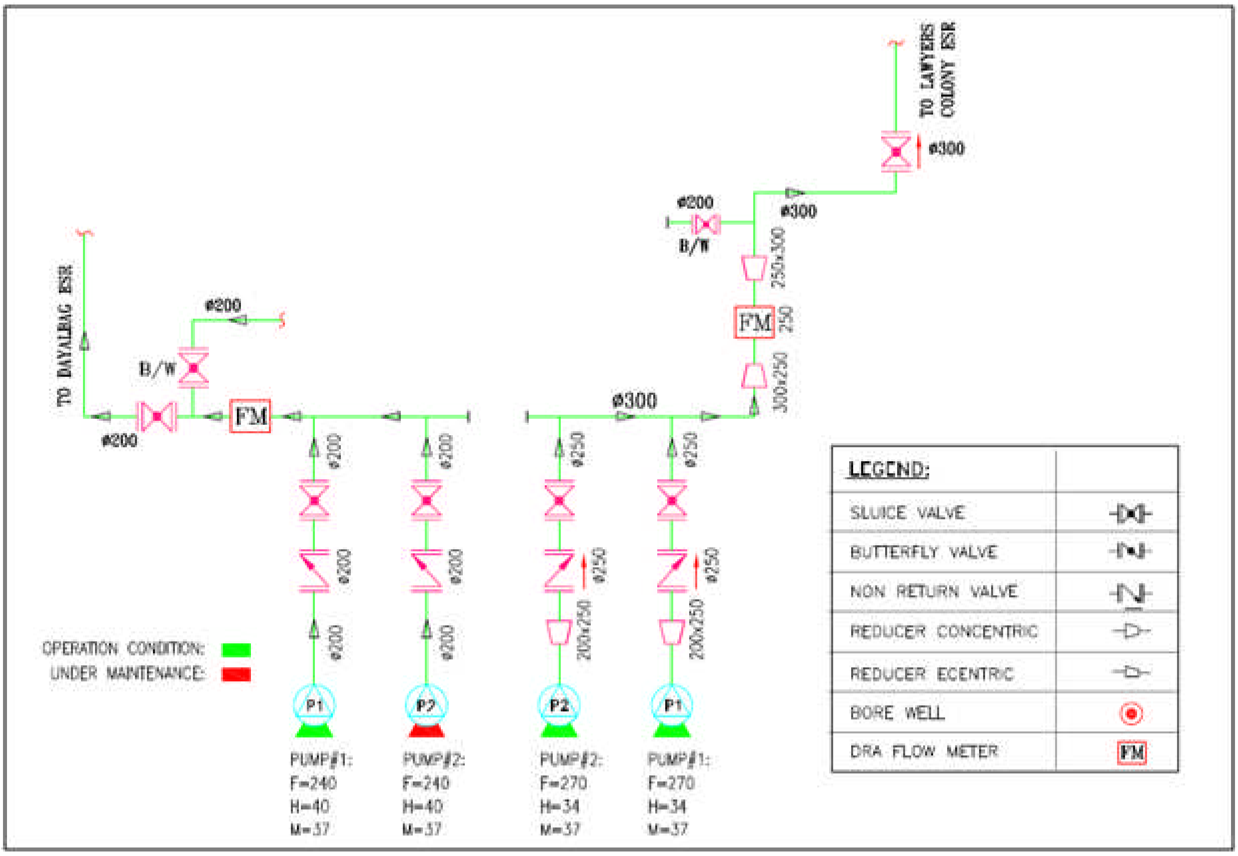


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Figure 160: P & ID diagram for Lawyers' Colony ZPS

4.14.7 Pumps Performance Evaluation

As per the methodology described in section – 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 104: General details of Lawyers Colony ZPS

Data	Value / Details
Name of site	Lawyers Colony ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	4
No. of pumps in operation	3
No. of pumps under maintenance	1

Data	Value / Details
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Lawyers Colony ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 161: Photographs of Lawyers' Colony ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 105: Performance Evaluation of pumps at Lawyers' Colony ZPS

	Unit	Lawyer's Colony ZPS	Lawyer's Colony ZPS	Lawyer's Colony ZPS
Parameters		Pump-1(Lawyer's Colony)	Pump-2(Lawyer's Colony)	Pump-1(Dayal Bagh ESR)
Pump make		Flowmore	Flowmore	WPIL
Motor make		Jyoti	Jyoti	Jyoti
Pump type		VT	VT	VT
Motor serial no.		M1991899	M11991910	M03091440
Pump serial no.		634016999-F	634020999-F	NA
Rated flow	m^3/h	270	270	240
Rated head	m	34	34	40
Rated motor	kW	37	37	37
Parameters measured				
Total suction head	m	-2.47	-2.01	-4.31
Total discharge head	m	26	26	19
Average flow delivered	m^3/h	232.07	118.73	165.30
Motor input power	kW	34.77	35.22	20.21

	Unit	Lawyer's Colony ZPS	Lawyer's Colony ZPS	Lawyer's Colony ZPS
Parameters		Pump-1(Lawyer's Colony)	Pump-2(Lawyer's Colony)	Pump-1(Dayal Bagh ESR)
Frequency	Hz	48.68	49.96	49.96
Speed	RPM	1474.67	1477.67	1476.00
Performance evaluation				
Total head developed	m	28.47	28.01	23.31
Head utilization	%	84%	82%	58%
Flow utilization	%	86%	44%	69%
Hydraulic power kW		17.99	9.06	10.49
Motor input power	kW	34.77	35.22	20.21
Calculated pumpset efficiency		51.75%	25.71%	51.91%
Rated motor efficiency		91.0%	91.0%	91.0%
Calculated pump efficiency		56.87%	28.26%	57.04%
Specific energy consumption	kWh/m^3	0.150	0.297	0.122

Table 106: Parallel pumping at Lawyers' Colony ZPS

Location	**Unit**	**Lawyer's Colony ZPS**
Parameters measured		**1,2**
Total suction head	m	-3.37
Total discharge head	m	27
Total flow	m^3/h	398.33
Motor input power	kW	65.12
Performance evaluation		
Total head developed	m	30.37
Head utilization		89%
Flow utilization		74%
Hydraulic power developed by pump	kW	32.95
Motor input kW	kW	65.12
Calculated overall efficiency		50.60%
Motor efficiency		91.00%
Calculated pump efficiency		55.60%
Specific energy consumption	kWh/m^3	163.48

Key Observations:

- Two dedicated pumps each and dedicated pipelines are provided for supply to Lawyers' Colony and Dayal Bagh.
- Pump no. 2 for Dayal Bagh supply was not in operation.
- Pump set efficiencies for pumps 1 and 2 for Lawyers' Colony were found to be 51.75% and 25.71% respectively, and both head and discharge of both the pumps were found to be less than the rated values. During parallel operation of these two pumps, the combined efficiency was 50.6% and both pumps were operating closer to the rated head.
- The pump set efficiency of pump-1 for Dayal Bagh ESR was found to be 51.91%, and the pump was operating significantly below its rated head.
- NRV of both pumps for Lawyer's colony ESR is not working.

4.14.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 107: Other auxiliary equipment at Lwyers Colony ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	0
Capacity (kVA)	
Primary/Secondary voltages	
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 108: Other electrical equipment at Lawyer's Colony ZPS - Lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Lawyers Colony	Tubelight	1	0.04	8
	Metal Halide	1	0.25	8

Table 109: Other electrical equipment at Lawyer's Colony ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Stand Fan	1	0.07	10

4.14.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Lawyers' Colony ZPS is provided in below table.

Table 110: Estimated annual energy consumption and water supply for Lawyers' Colony ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Lawyer's Colony ZPS	Pump-1(Lawyer's Colony)	2 in parallel for Lawyers' Colony, pump 1 for Dayal bagh	3,912	34.77	136,019
Lawyer's Colony ZPS	Pump-2(Lawyer's Colony)		3,914	35.22	137,864
Lawyer's Colony ZPS	Pump-1(Dayal Bagh ESR)		596	20.21	12,051
	Total		**8422**	**90.2**	**285934**

4.15 Nirbhay Nagar ZPS

4.15.1 Overview of existing systems

Nirbhay Nagar ZPS receives treated water from Sikandra WTP. Two pumps are installed here and they are run in parallel. Water is supplied directly into distribution network. ESR has been constructed but is not in use.

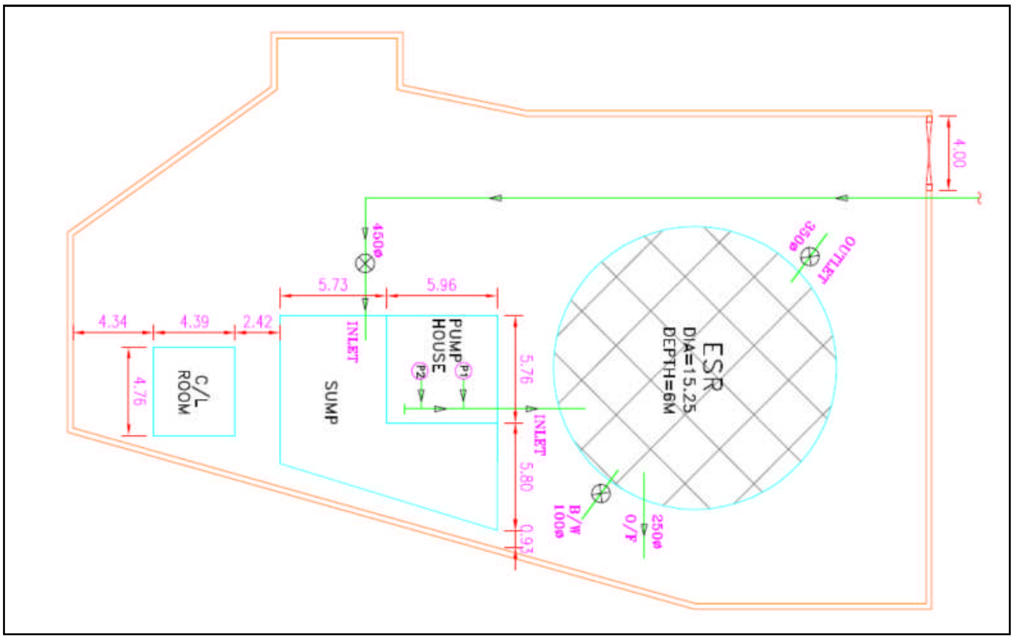

Figure 162: Plant Layout for Nirbhay Nagar ZPS

4.15.2 Electricity Supply

Nirbhay Nagar receives supply at 440V from Torrent Power.

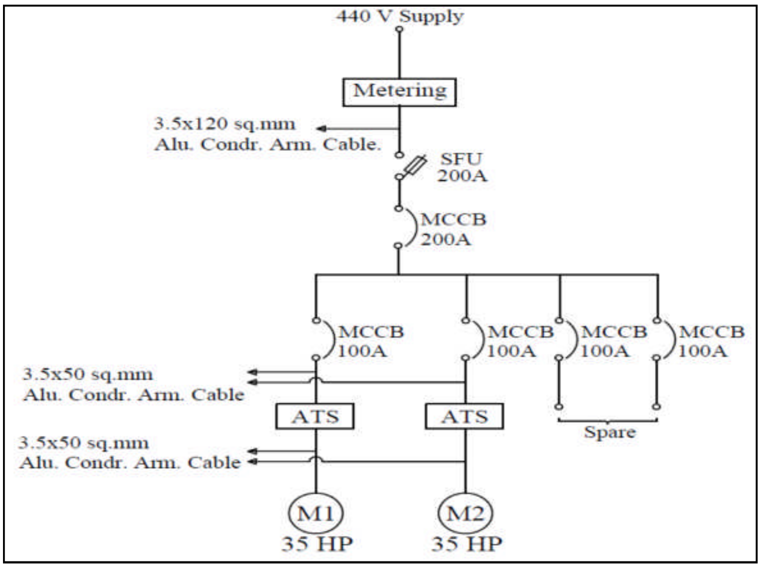

Figure 163: Single line diagram for the Nirbhay Nagar ZPS

4.15.3 Tariff Structure

The electrical connection for Nirbhay Nagar ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 111: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Nirbhay Nagar Energy Meter (LT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.15.4 Electricity Bill Analysis

Table 112: Energy cost and energy consumption detail for Nirbhay Nagar ZPS

Period of energy bill	Energy consumption (kVAH/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to mar-15	Not available		Not available
Apr-15 to Mar-16	14,719		319,670
Apr-16 to Mar-17	11,241	-23.6%	342,241

The power factor recorded on the incomer was observed to be around 0.857-0.875. As the billing is kVAh-based, improving the power factor will lead to reduction in electricity bill amount paid every month.

4.15.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on main LT incomer for recording variation of electrical parameters. The recorded parameters are as given below.

Voltage Profile:

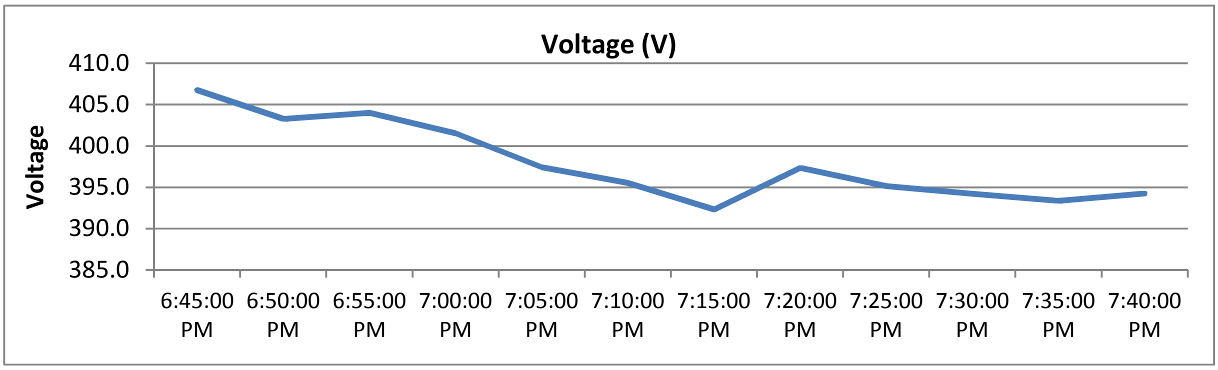

Figure 164: Voltage Variation at Nirbhay Nagar

- The voltage was found to vary between 392 and 408V.

Power consumption and Apparent power Profile:

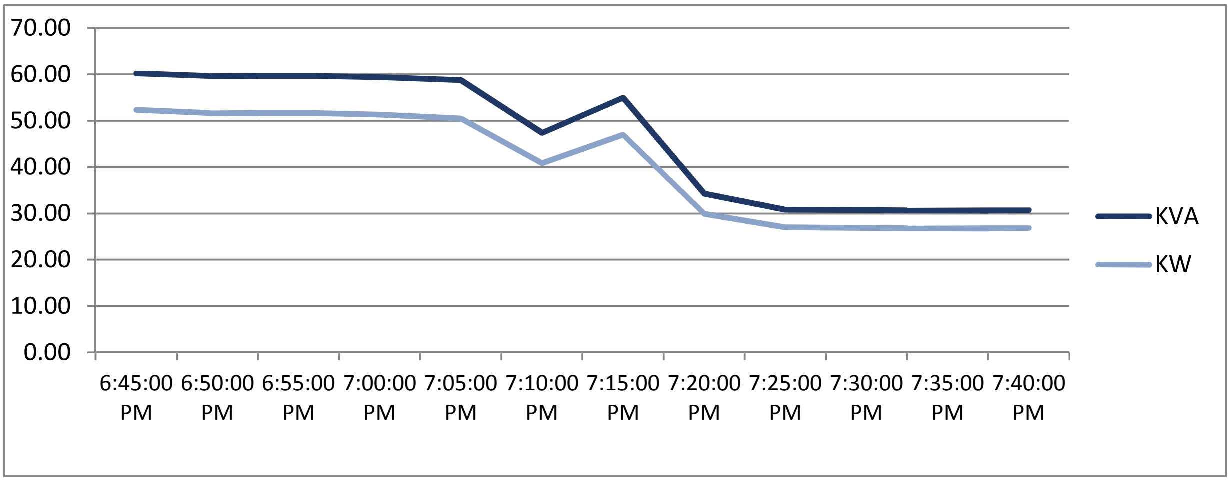

Figure 165: Power consumption variation at Nirbhay Nagar

- Power consumption during operation of two pumps was found to be around 50-55 kW. After tripping of one pump around 7:20, only one pump was in operation and power consumption was found to be around 26 kW.
- Apparent power was found to be around 59-61 kVA during operation of two pumps and around 30 kVA during operation of single pump.

Power factor profile

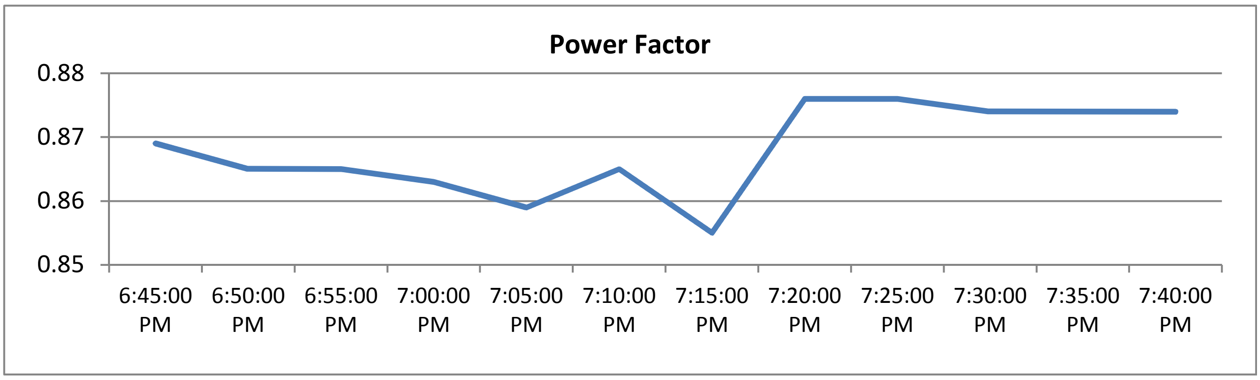

Figure 166 Power factor variation profile at Nirbhay Nagar

- Power factor was found to vary between 0.857 and 0.875, and was found to improve marginally during operation of single pump.

Frequency Profile:

During energy audit, frequency was recorded for 24 hours at the transformer secondary side at the main LT panel of the Transformer. Variation in frequency for the recorded 24 hour period is provided in figure 10

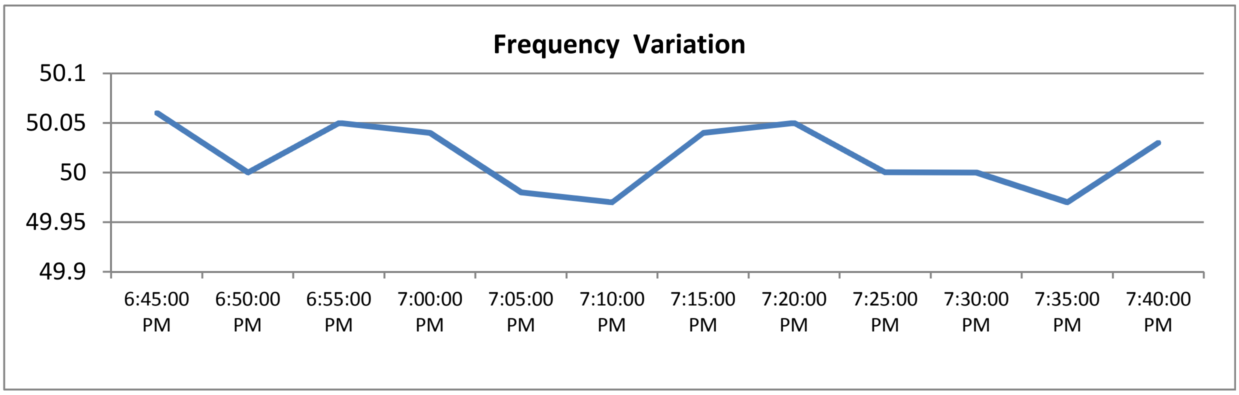

Figure 167: Frequency variation at Nirbhay Nagar

- Frequency was observed to vary between 49.96 and 50.07 Hz.

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Total Harmonics distortion (THD) - Current:

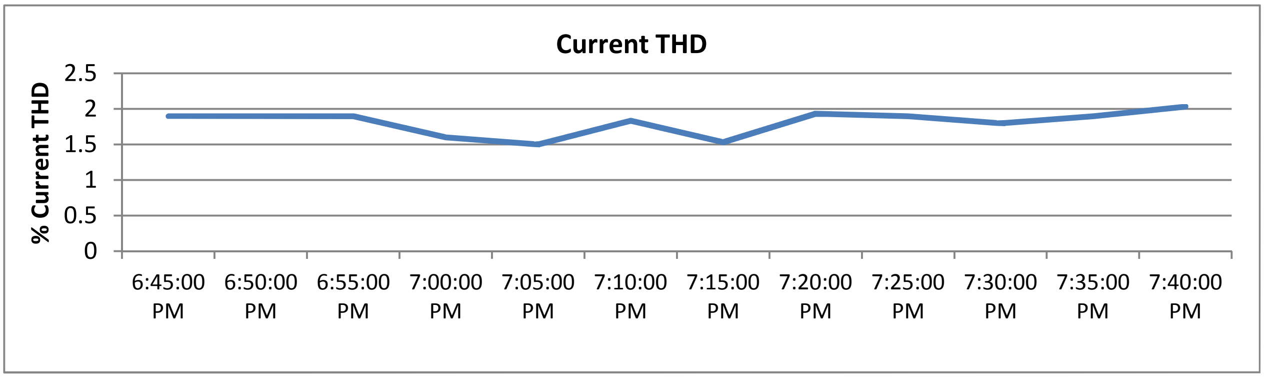


Figure 168: Variation of THD in current at Nirbhay Nagar

- The current THD was observed to be around 1.5-2%.

Total Harmonics distortion - Voltage:

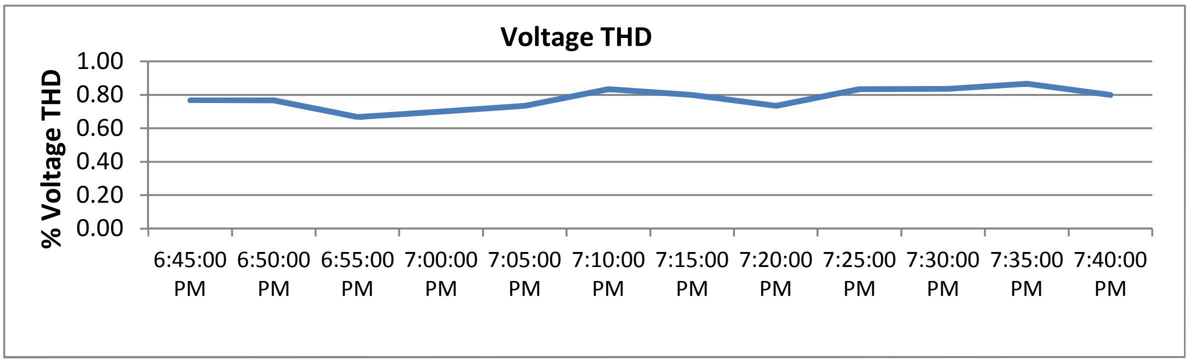


Figure 169: Variation in THD - voltage at Nirbhay Nagar

- The voltage THD was found to be less than 1%.

4.15.6 Pumping Station System Mapping

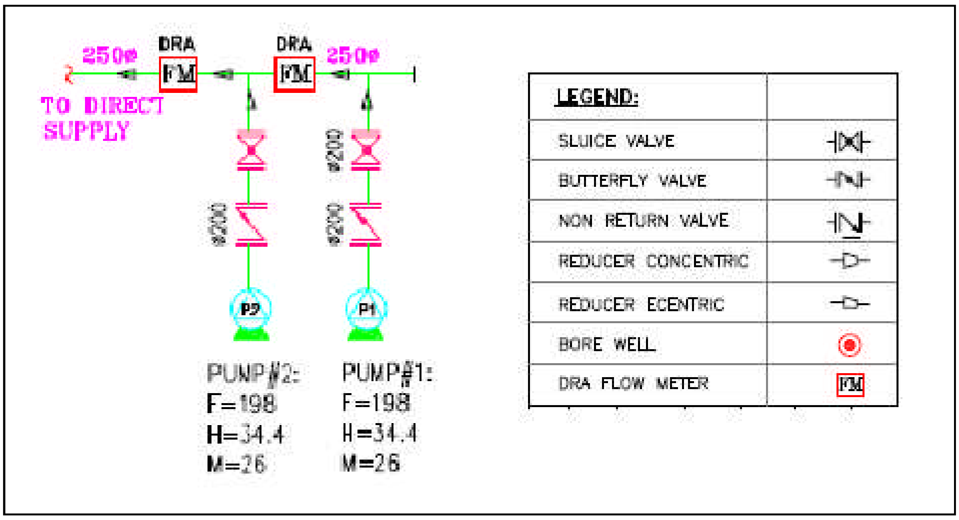


Figure 170: P & ID diagram for Nirbhay Nagar ZPS

4.15.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 113: General details of Nirbhay Nagar ZPS

Data	Value / Details
Name of site	Nirbhay Nagar ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	2
No. of pumps in operation	2
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Nirbhaynagar ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 171: Photographs of Nirbhay Nagar ZPS

The performance evaluation of the pumps was done based on the measurement done during energy audit. Results of performance evaluation of pumps are given below.

Table 114: Performance Evaluation of pumps at Nirbhay Nagar ZPS

	Unit	Nirbhay Nagar ZPS	Nirbhay Nagar ZPS
Parameters		Pump-1	Pump-2
Pump make		WPIL	WPIL
Motor make		Jyoti	Jyoti
Pump type		VT	VT
Motor serial no.		M0592	NA
Pump serial no.		IA4-341	IA4-341
Rated flow	m^3/h	198	198
Rated head	m	34.4	34.4
Rated motor	kW	26	26
Parameters measured			
Total suction head	m	-1.85	-3.32
Total discharge head	m	27	28
Average flow delivered	m^3/h	223.60	198.60
Motor input power	kW	27.67	21.11
Frequency	Hz	50.02	50.08
Speed	RPM	1478.33	1478.33
Performance evaluation			
Total head developed	m	28.85	31.32
Head utilization	%	84%	91%
Flow utilization	%	113%	100%

	Unit	Nirbhay Nagar ZPS	Nirbhay Nagar ZPS
Parameters		Pump-1	Pump-2
Hydraulic power	kW	17.57	16.94
Motor input power	kW	27.67	21.11
Calculated pumpset efficiency		63.50%	80.25%
Rated motor efficiency		91.0%	91.0%
Calculated pump efficiency		69.78%	88.18%
Specific energy consumption	kWh/m³	0.124	0.106

Table 115: Parallel pumping at Nirbhay Nagar ZPS

Location		Nirbhay Nagar ZPS
Parameters measured		**1,2**
Total suction head	m	-2.75
Total discharge head	m	27
Total flow	m³/h	256.47
Motor input power	kW	35.47
Performance evaluation		
Total head developed	m	29.75
Head utilization		86%
Flow utilization		65%
Hydraulic power developed by pump	kW	20.78
Motor input kW	kW	35.47
Calculated overall efficiency		58.58%
Motor efficiency		91.00%
Calculated pump efficiency		64.37%
Specific energy consumption	kWh/m³	138.30

Key Observations:

- Pumps 1 and 2 were operating at pump set efficiencies of 63.5% and 80.25%. Operating head of both pumps was found to be higher than 80% of the rated head.
- SLV of both pumps were in good working condition but were reported to have minor jamming problem.NRV of pump no. 1 was not in working condition.

4.15.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 116: Other auxiliary equipment at Nirbhay Nagar ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	0
Capacity (kVA)	
Primary/Secondary voltages	
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 117: Other electrical equipment at Nirbhay Nagar ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Nirbhay Nagar	Tubelight	3	0.036	12
	Metal Halide	3	0.15	12

4.15.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Nirbhay Nagar ZPS is provided in below table.

Table 118: Estimated energy consumption for Nirbhay Nagar ZPS

Name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Nirbhay Nagar ZPS	Pump-1	Both in parallel	558	27.67	15,439
Nirbhay Nagar ZPS	Pump-2		557	21.11	11,760
	Total		**1,115**	**48.78**	**27,199**

4.16 Lohamandi ZPS

4.16.1 Overview of existing systems

Lohamandi Zonal Pumping Station receives clear water from the Sikandra WTP. Water is pumped from here into distribution as well as for ESR filling.

4.16.2 Electricity Supply

Lohamandi ZPS receives supply at 11 kV from Torrent Power. This is stepped down via a transformer to 440 V for feeding the motors.

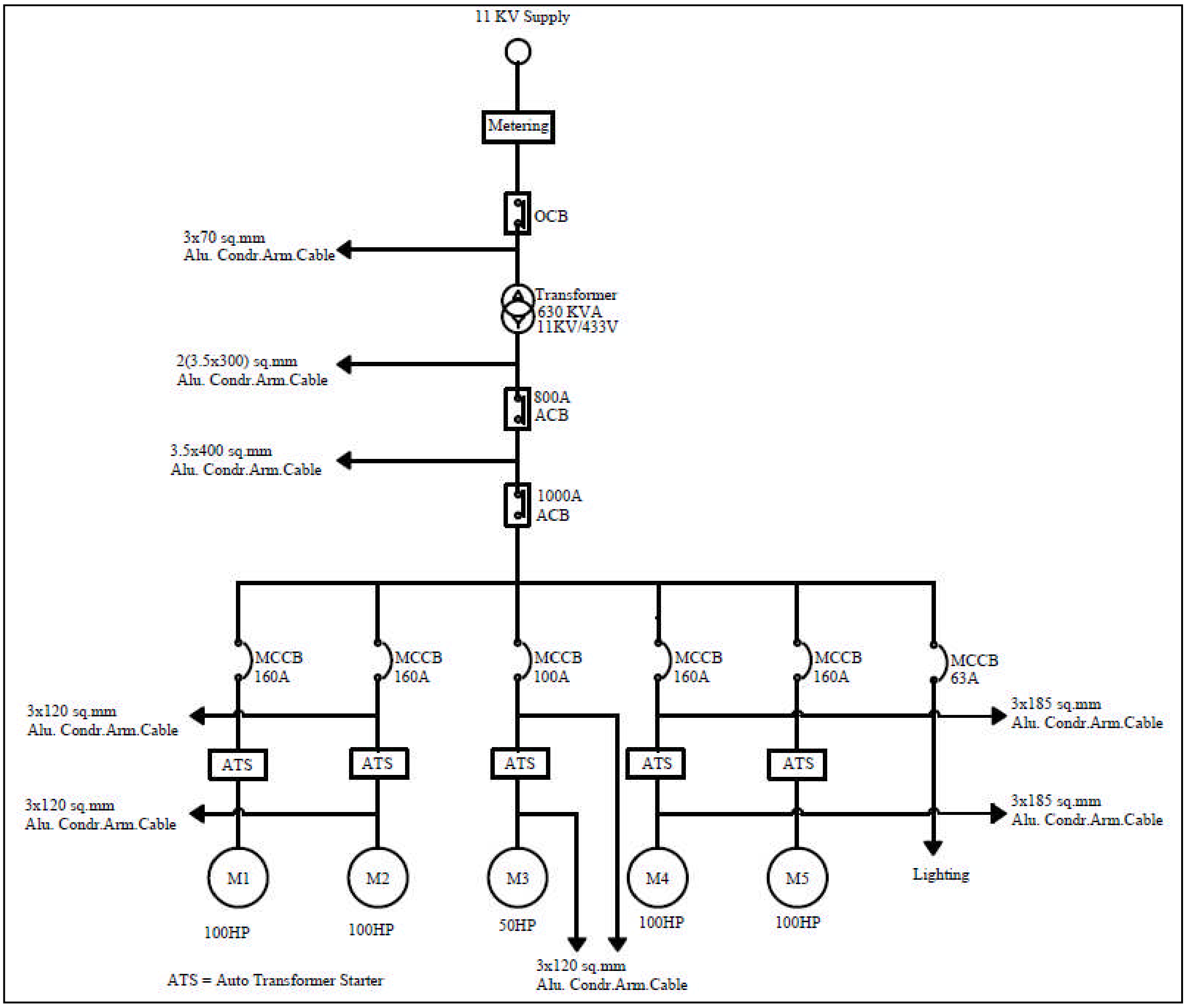


Figure 172: Single line diagram for the Lohamandi ZPS

4.16.3 Tariff Structure

The electrical connection for Lohamandi ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 119: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Loha Mandi Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.16.4 Electricity Bill Analysis

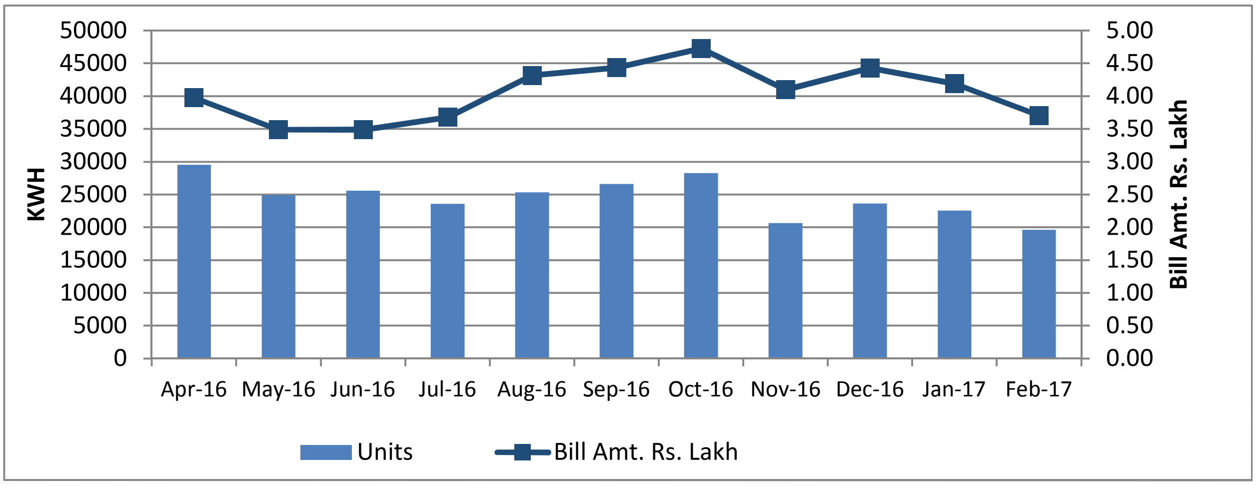
Table 120: Energy cost and energy consumption detail for Lohamandi ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	342,597		5,165,863
Apr-15 to Mar-16	393,314	14.8%	5,332,586
Apr-16 to Mar-17	294,912	-25.0%	4,857,207

The power factor recorded on the main incomer was observed to be around 0.83. As the billing is kVAh-based, improving the power factor will lead to reduction in the electricity bill amount paid every month.

It is observed that the recorded demand has often been more than twice the contract demand. As a result of exceeding the contract demand, 'Excess demand charges' have been levied in addition to the regular demand charges.

Figure 173: Monthly electricity consumption and electricity bill for Lohamandi ZPS



4.16.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT sideat pumping station for recording variation of electrical parameters. Details about transformers installed at Lohamandi ZPS is provided in below table.

Table 121: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 630 kVA, 11/0.433 kV)	All pump sets

ESR Supply:

Voltage Profile:

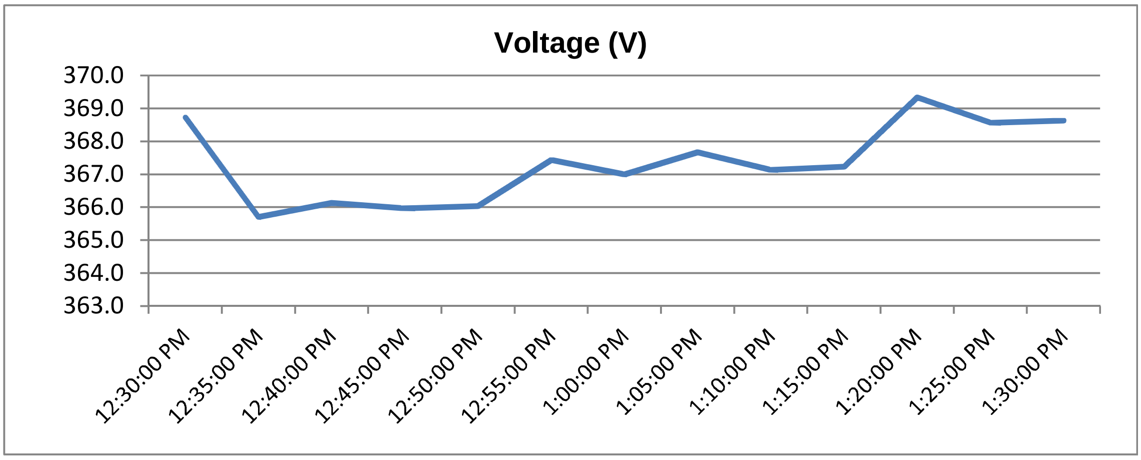


Figure 174: Voltage Variation during ESR filling

- The voltage was observed to be quite low, around the 365-370V range.

Power consumption and Apparent power Profile:

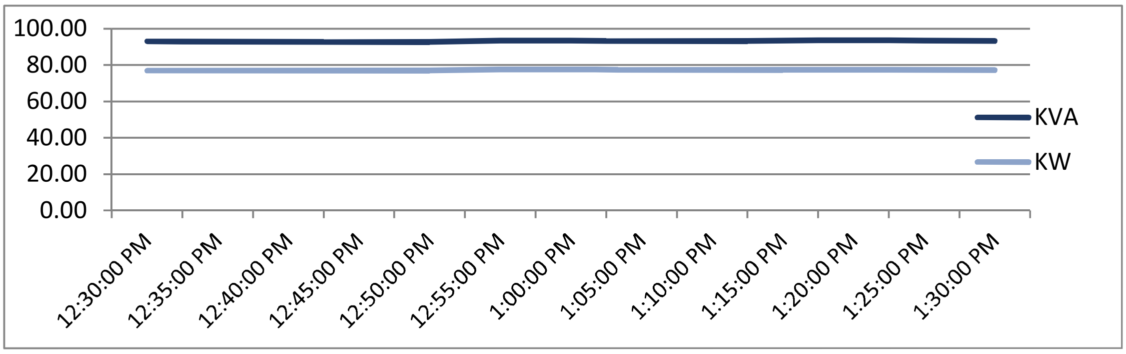


Figure 175: Power consumption variation during ESR filling

- Power consumption during ESR filling is found to be consistently around 76-80 kW.
- Apparent power during ESR filling is found to be consistently around 90-94 kVA.

Power factor profile

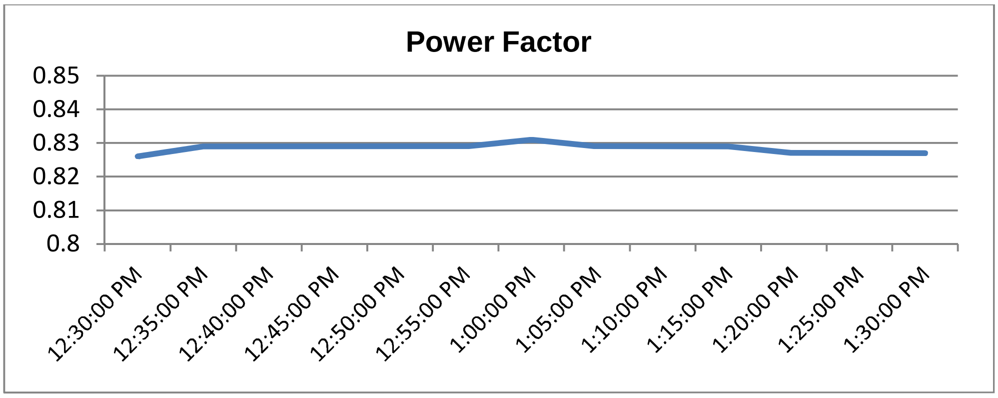


Figure 176: Power factor variation profile during ESR filling

- Power factor during ESR filling is observed to be around 0.825-0.83.

Frequency Profile:

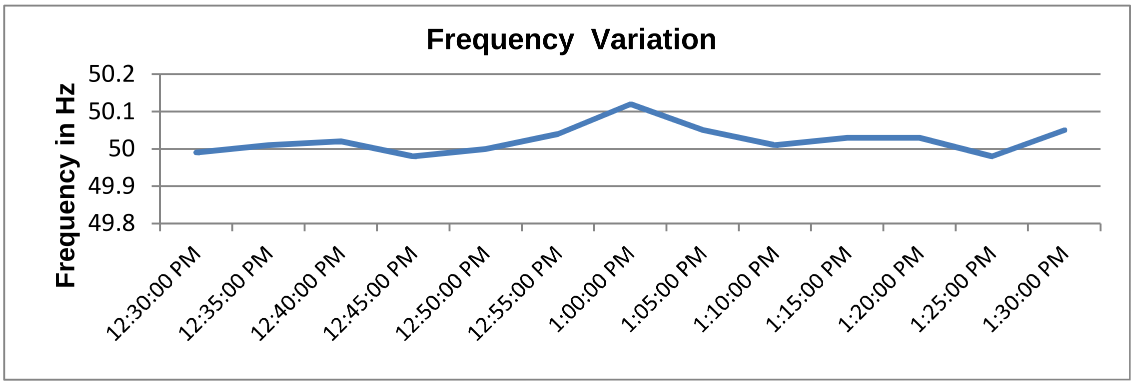


Figure 177: Frequency variation during ESR filling

- The frequency was found to vary between 49.96 and 50.13 Hz.

Total Harmonics distortion (THD) - Current:

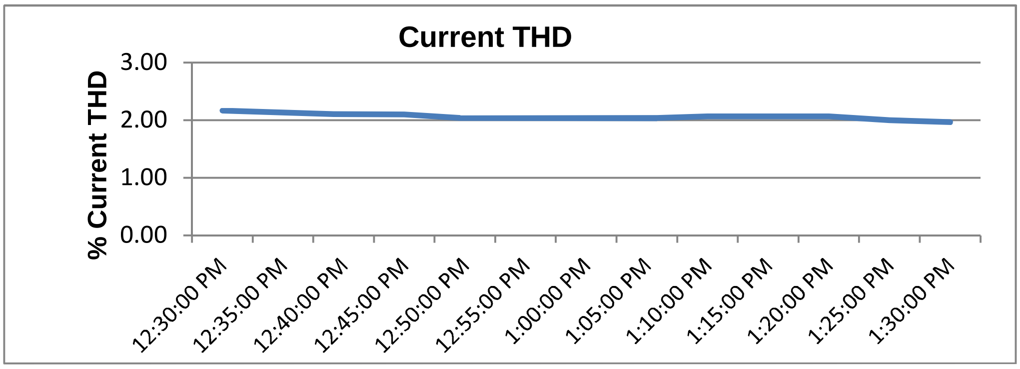


Figure 178: Variation of THD in current during ESR filling

- The current THD is observed to be around 1.9-2.2%.

Total Harmonics distortion - Voltage:

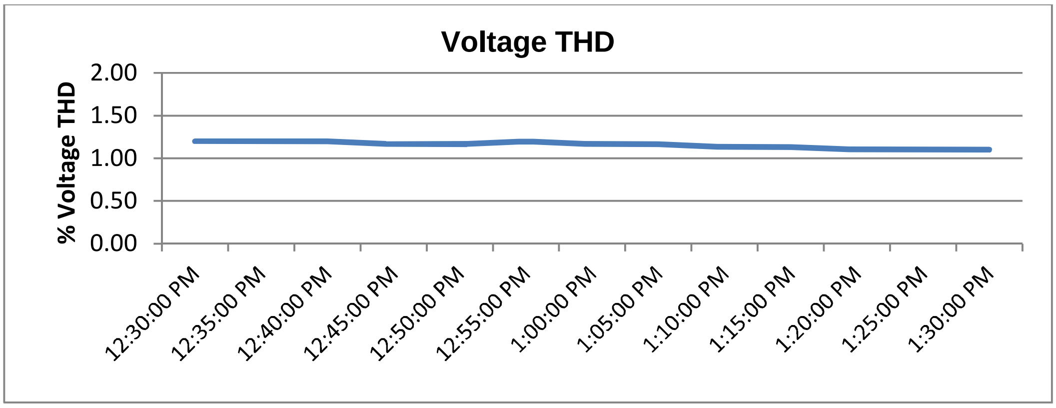


Figure 179: Variation in THD - voltage during ESR filling

- The voltage THD is observed to be around 1.1-1.3%.

Direct distribution - morning:

Voltage Profile:

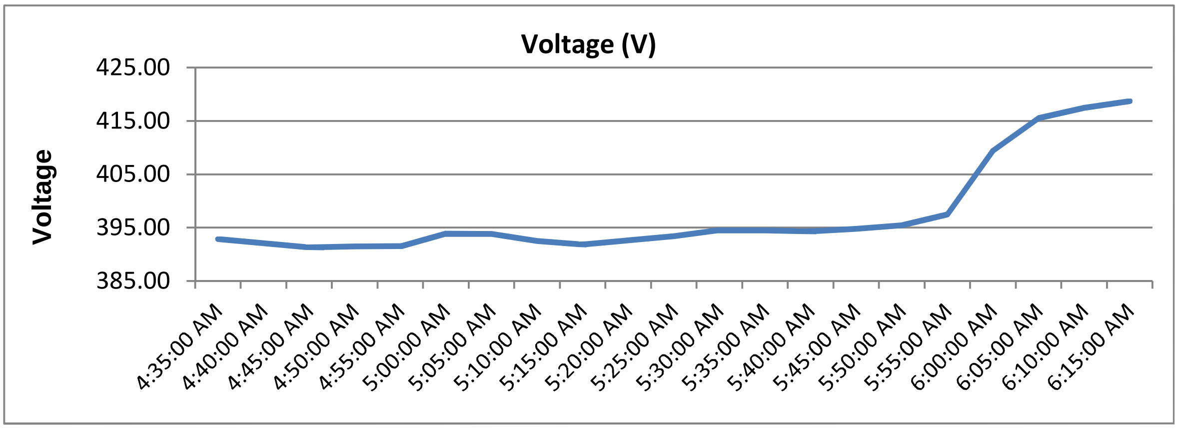


Figure 180: Voltage Variation profile during direct distribution

- The voltage was found to vary between 390 and 420V, averaging 397.6V. It was found to be much higher when a single pump was running, i.e. after 6:05, than during operation of 4 pumps.

Power consumption and Apparent power Profile:

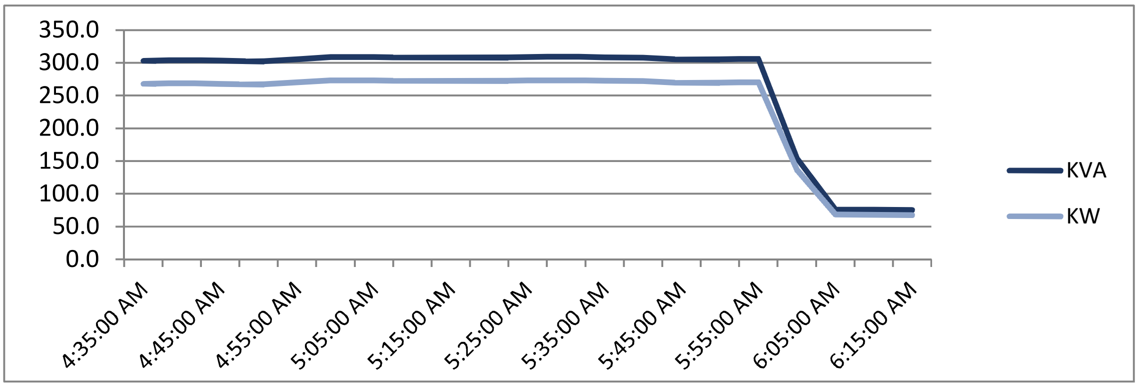


Figure 181: Power consumption variation during direct distribution

- The power consumption was observed to be around 270 kW during parallel operation of 4 pumps, whereas it was around 70 kW during operation of single pump.
- Apparent power recorded during parallel pumpingwas around 300-310 kVA, while it was around 75 kVA during operation of single pump.

Power factor profile

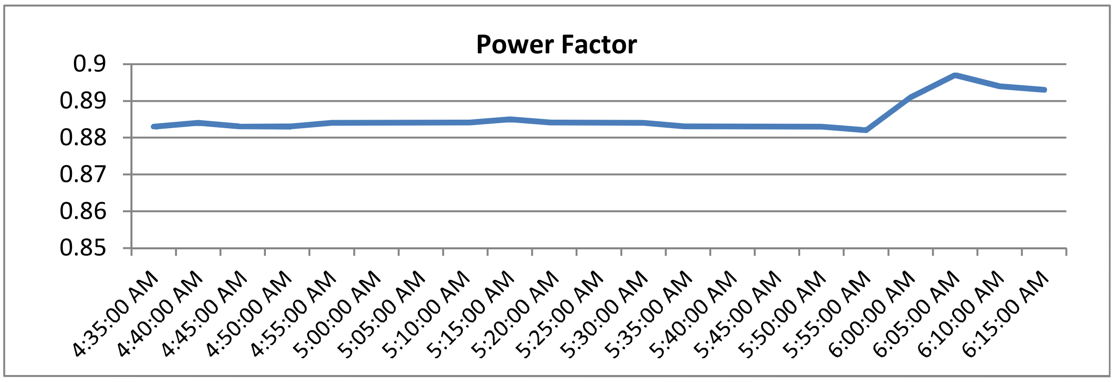


Figure 182: Power Factor variation during direct distribution

- Power factor during parallel pumping was observed to be around 0.88-0.885. Improvement to 0.895 was observed during running of single pump.

Frequency Profile:

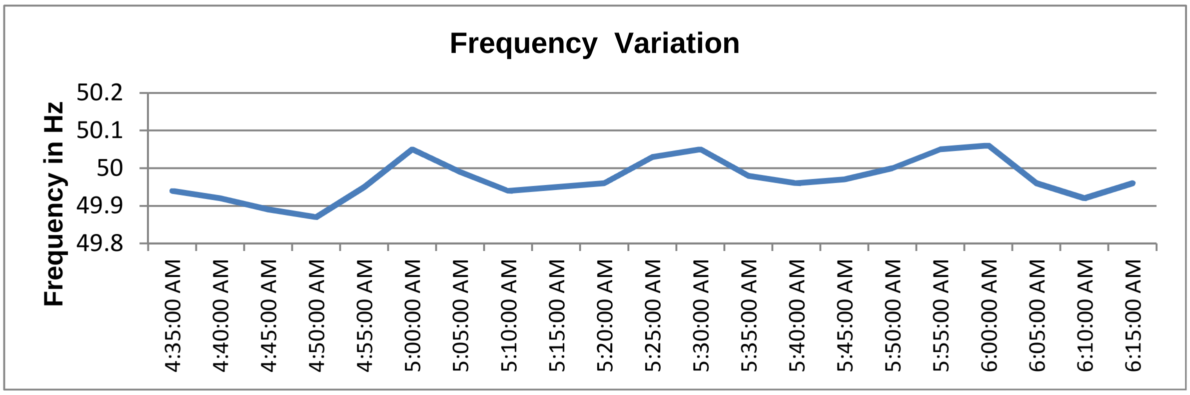


Figure 183: Frequency variation during direct distribution

- The frequency was found to vary between 49.85 and 50.05 Hz.

Total Harmonics distortion - Current:

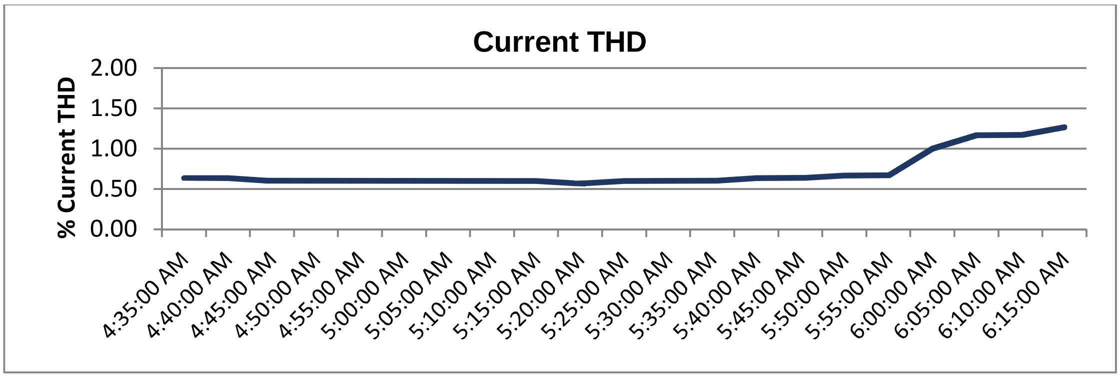


Figure 184: Variation in THD - current during direct distribution

- The current THD was around 0.6-0.7% during parallel pumping and increased to around 1.3% during solo operation.

Total Harmonics distortion - Voltage:

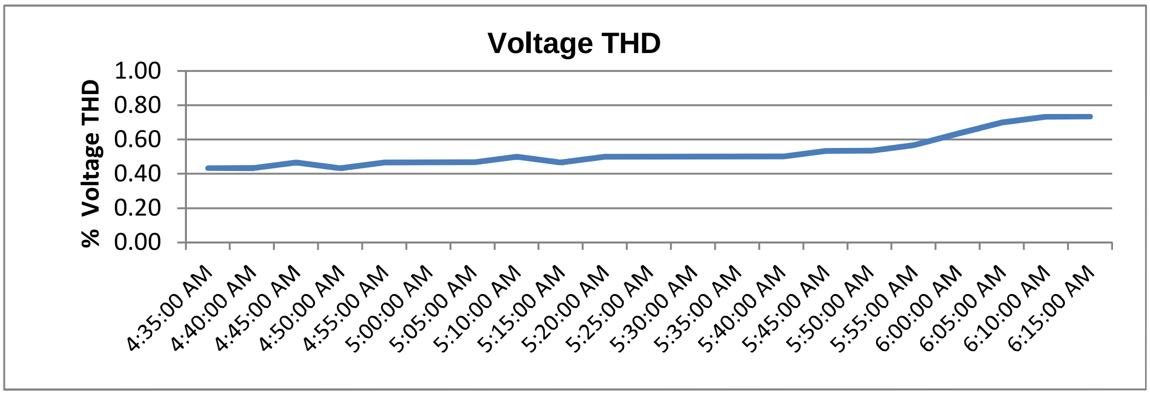


Figure 185: Variation in THD - voltage during direct distribution

- The voltage THD was found to be less than 1%.

Transformer loading:

Based on the kVA measurement done during energy audit, average transformer loading was calculated and same is given below.

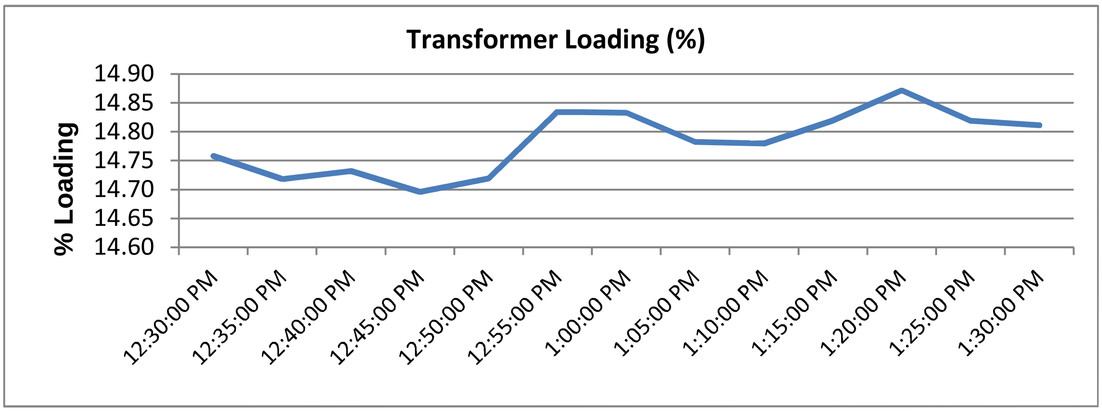


Figure 186: Transformer loading during ESR filling

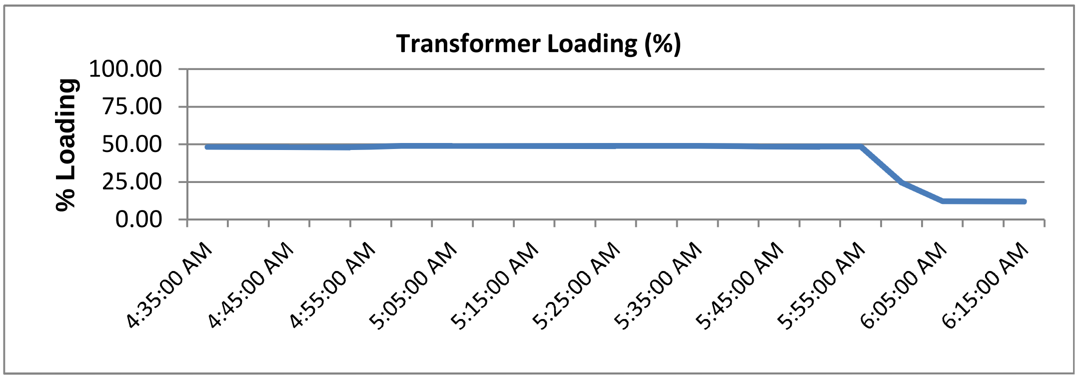


Figure 187: Transformer loadingduring direct distribution

- Transformer loading during operation of four pumps during direct distribution, as is typically done here, is observed to be close to 50%.
- With two pumps in operation during ESR filling, the transformer loading is low at around 15%.

4.16.6 Pumping Station System Mapping

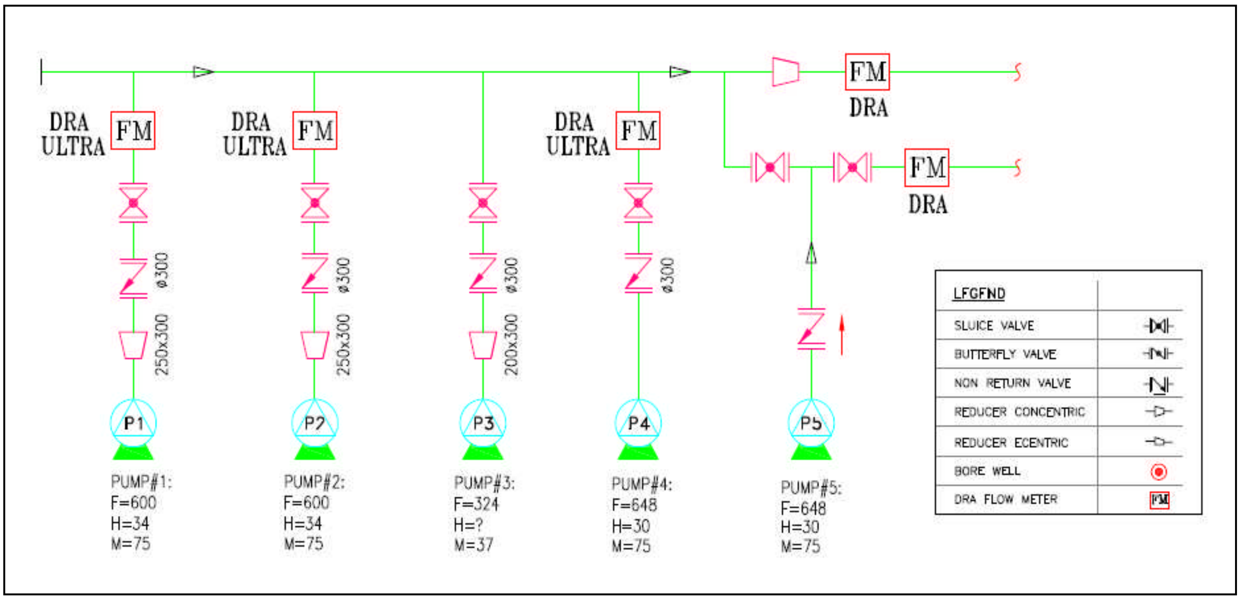


Figure 188: P & ID diagram for Lohamandi ZPS

4.16.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices

- Verification of Job card by the authorized representative of ULB

Table 122: General details of Lohamandi ZPS

Data	Value / Details
Name of site	Lohamandi ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	5
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Lohamandi ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 189: Photographs of Lohamandi ZPS

Table 123: Performance Evaluation of pumps at Lohamandi ZPS

	Unit	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS
Parameters		Pump-1 (Direct distribution)	Pump-1 (ESR filling)	Pump-2	Pump-3	Pump-4	Pump-5
Pump make		Jyoti	Jyoti	Kirloskar	Jyoti	Fairbanks	Jyoti
Motor make		Jyoti	Jyoti	Kirloskar	Jyoti	Kirloskar	Jyoti
Pump type		VT	VT	VT	VT	VT	VT
Motor serial no.		M05150078	M05150079	29707056-2	NA	29704035-2	13822
Pump serial no.		BHR-5	BHR-	NA	NA	16H	NA
Rated flow	m^3/h	600	600	600	324	648	648
Rated head	m	34	34	34		30	30
Rated motor	kW	75	75	75	37	75	75
Parameters measured							

	Unit	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS	Lohamandi ZPS
Parameters		Pump-1 (Direct distribution)	Pump-1 (ESR filling)	Pump-2	Pump-3	Pump-4	Pump-5
Total suction head	m	-1.20	-0.95	-2.57	-0.50	-3.23	-2.71
Total discharge head	m	14	16	20	15	14	18
Average flow delivered	m^3/h	580.43	506.87	665.43	141.83	944.57	653.80
Motor input power	kW	52.89	52.09	73.27	18.59	71.83	68.66
Frequency	Hz	49.94	49.98	49.85	50.01	49.99	49.97
Speed	RPM	1493.00	1477.33	1486.00	1473.33	1474.00	1475.33
Performance evaluation							
Total head developed	m	15.20	16.95	22.57	15.50	17.23	20.71
Head utilization	%	45%	50%	66%	--	57%	69%
Flow utilization	%	97%	84%	111%	44%	146%	101%
Hydraulic power kW	kW	24.03	23.39	40.90	5.99	44.33	36.87
Motor input power	kW	52.89	52.09	73.27	18.59	71.83	68.66
Calculated pumpset efficiency	%	45.44%	44.91%	55.82%	32.21%	61.71%	53.71%
Rated motor efficiency	%	91.5%	91.5%	91.5%	91%	91.5%	91.5%
Calculated pump efficiency	%	49.66%	49.08%	61.01%	35.40%	67.45%	58.70%
Specific energy consumption	kWh/m^3	0.091	0.103	0.110	0.131	0.076	0.105

Table 124: Parallel pumping at Lohamandi ZPS

Location	Unit	Lohamandi ZPS	Lohamandi ZPS
Parameters measured		**1,3**	**1,2,4,5**
Total suction head	m	-1.84	-2.50
Total discharge head	m	15	17
Total flow	m^3/h	658.93	2155.67
Motor input power	kW	87.18	202.09
Performance evaluation			
Total head developed	m	16.84	19.50
Head utilization	%	50%	57%

Location	Unit	Lohamandi ZPS	Lohamandi ZPS
Flow utilization	%	71%	86%
Hydraulic power developed by pump	kW	30.21	114.50
Motor input kW	kW	87.18	202.09
Calculated overall efficiency	%	34.66%	56.66%
Motor efficiency	%	91%	91%
Calculated pump efficiency	%	38.08%	62.26%
Specific energy consumption	kWh/m^3	132.30	93.75

Key Observations:

- Pump 5 has a separate delivery line from the remaining pumps. Pumps 1 and 3 are used for ESR filling. Pumps 1,2 and 4 are used for direct distribution.
- Pump set efficiency of pump 1 is found to be 45.44% during use for direct distribution and 44.91% during use for ESR filling. Its operating head is found to be significantly less than the rated head in both cases.
- Pump set efficiencies of pump set nos. 2, 3, 4 and 5 are observed to be 55.82%, 32.21%, 61.71% and 53.71% respectively. All pumps were found to be operating well below their rated head.
- In parallel operation of pumps 1,3 for ESR filling, the overall efficiency was found to be 34.66% while it was found to be 56.66% in parallel operation of pumps 1, 2, 4, 5 for direct distribution.
- NRV of pump no. 4 is not working.

4.16.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 125: Other auxiliary equipment at Lohamandi ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	630
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 126: Other electrical equipment at Lohamandi ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Lohamandi	Bulb	1	0.1	12

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
	Tubelight	2	0.04	8

Table 127: Other electrical equipment at Lohamandi ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Cooler	1	0.25	8
	Ceiling Fan	1	0.07	8

4.16.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Lohamandi ZPS is provided in below table.

Table 128: Estimated energy consumption for Lohamandi ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Lohamandi ZPS	Pump-1 (Direct distribution)	1,3 in parallel - ESR filling; 1,2,4 in parallel for direct supply, 5 has separate pipe	616	52.89	32,591
Lohamandi ZPS	Pump-1 (ESR filling)		365	52.09	19,012
Lohamandi ZPS	Pump-2		612	73.27	44,845
Lohamandi ZPS	Pump-3		364	18.59	6,769
Lohamandi ZPS	Pump-4		919	71.83	66,033
Lohamandi ZPS	Pump-5		929	68.66	63,799
	Total		**3805**	**337.33**	**233,049**

4.17 Keshavkunj (Bodla) ZPS

4.17.1 Overview of existing systems

Keshavkunj ZPS receives treated water from Sikandra WTP. Water is pumped directly into distribution. ESR is constructed but is not in use.

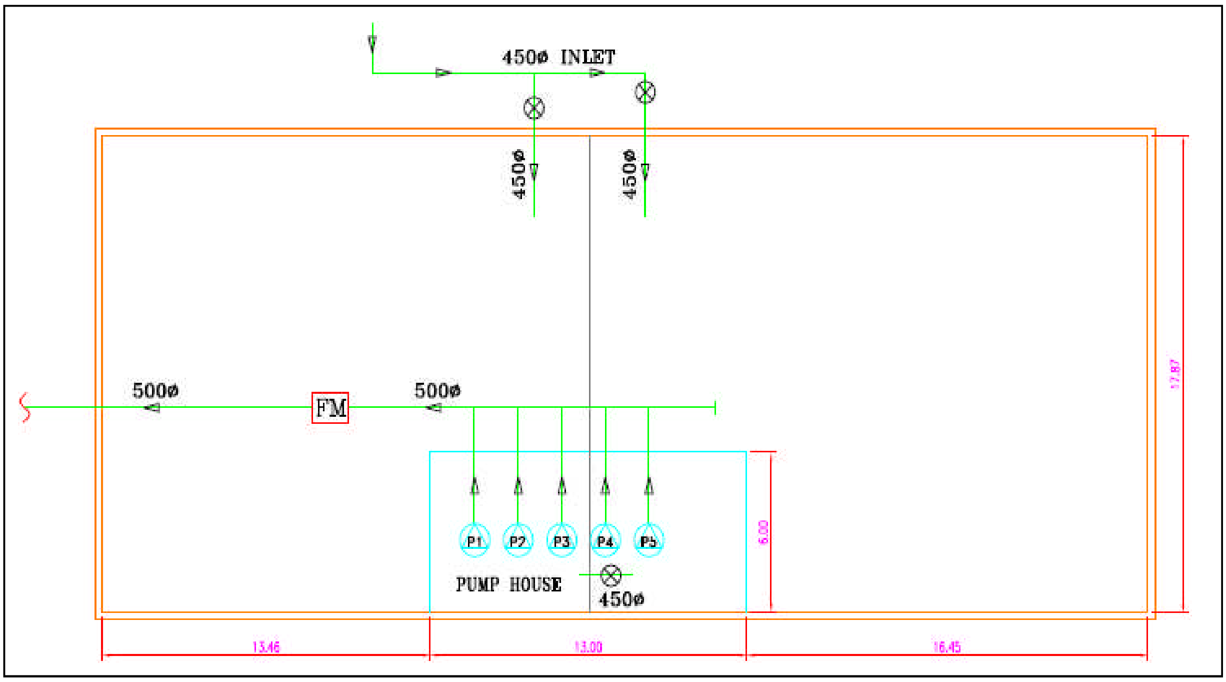


Figure 190: Plant Layout for Keshavkunj ZPS

4.17.2 Electricity Supply

Keshavkunj ZPS receives supply from Torrent Power at 11 kV. This is stepped down to 440V by a transformer to feed the motors.

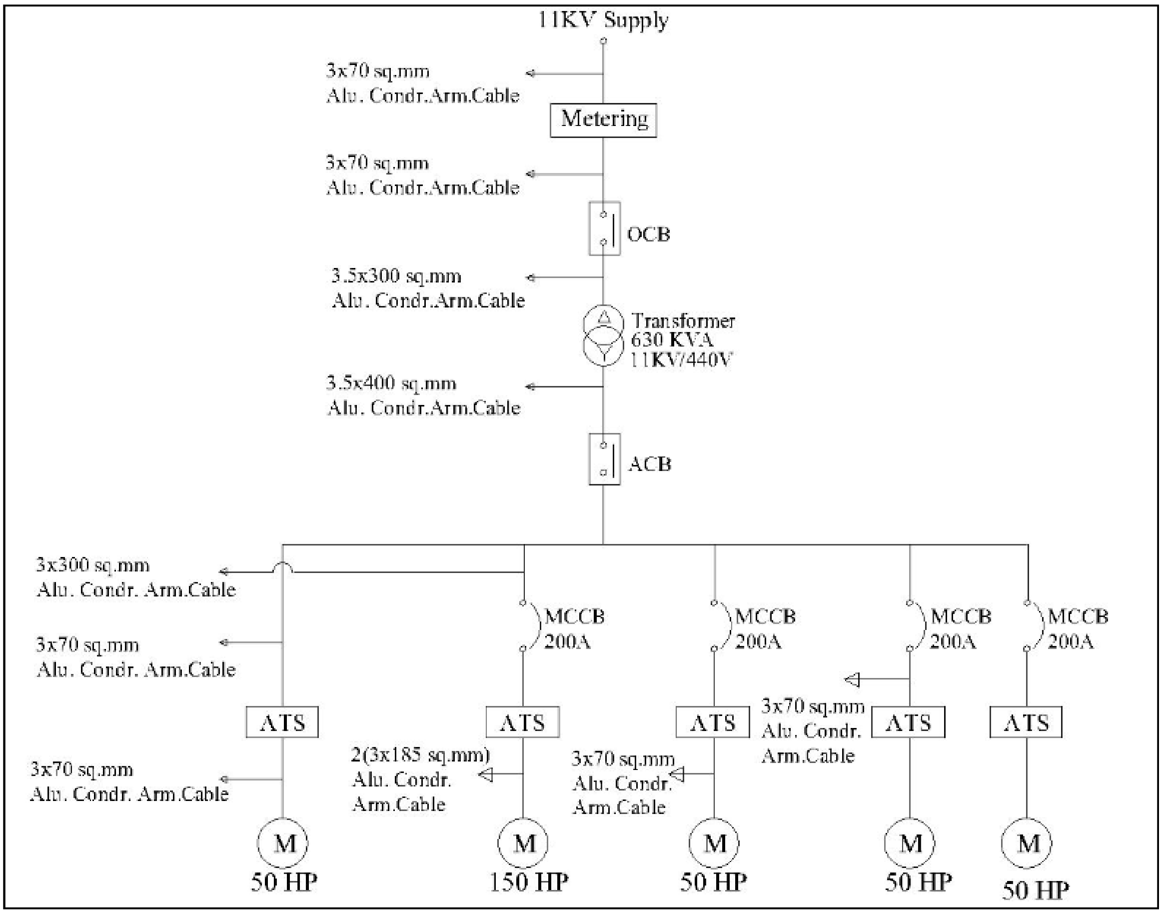


Figure 191: Single line diagram for the Keshavkunj ZPS

4.17.3 Tariff Structure

The electrical connection for Keshavkunj ZPS which is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 129: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Jeoni Mandi	
	Energy Meter-1 (HT)	Energy Meter-2 (LT)
Meter serial number	NA	NA
Power supply	11 kV line	NA
Energy charges	Rs. 7.155 Per kVAh	NA
Fixed/demand charge	Rs. 290/kW	NA
(Basis : DVVNL Tariff Order for FY 2016-17)		

4.17.4 Electricity Bill Analysis

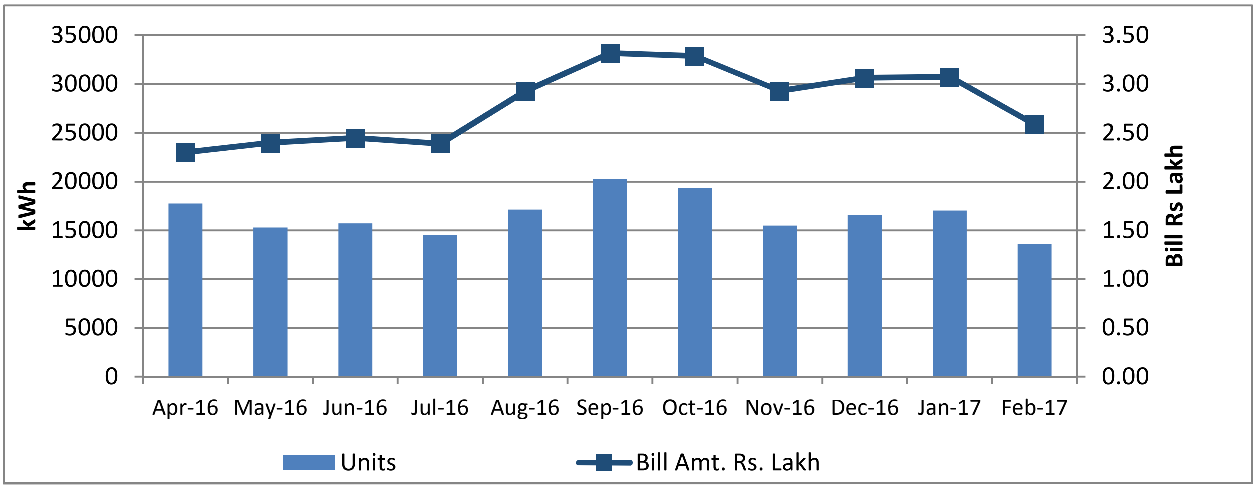
Table 130: Energy cost and energy consumption detail for Keshavkunj ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	189,628		2,652,581
Apr-15 to Mar-16	240,890	27.0%	3,220,476
Apr-16 to Mar-17	199,257	-17.3%	3,351,374

The power factor recorded on the incomer was observed to be around 0.89-0.9. As the billing is kVAh-based, improving he power factor will lead to reduction in the bill amount paid every month.

It is observed that recorded demand has regularly exceeded contract demand. As a result, 'Excess demand charges' have been levied every month in addition to regular demand charges.

Figure 192: Monthly electricity consumption and electricity bill for Keshavkunj ZPS



4.17.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT sidefor recording variation of electrical parameters. Details about transformers installed at Keshavkunj ZPS is provided in below table.

Table 131: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 630 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

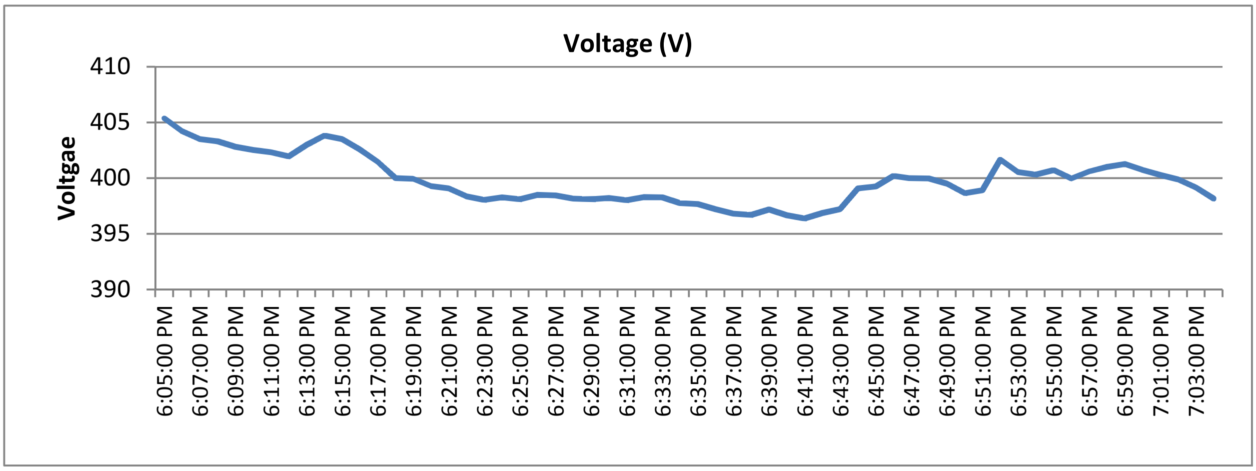


Figure 193: Voltage Variation at Keshavkunj (Bodla) ZPS

- The voltage is found to vary between 396 and 406V. The observed voltage is marginally below the rated 415V.

Power consumption and Apparent power Profile:

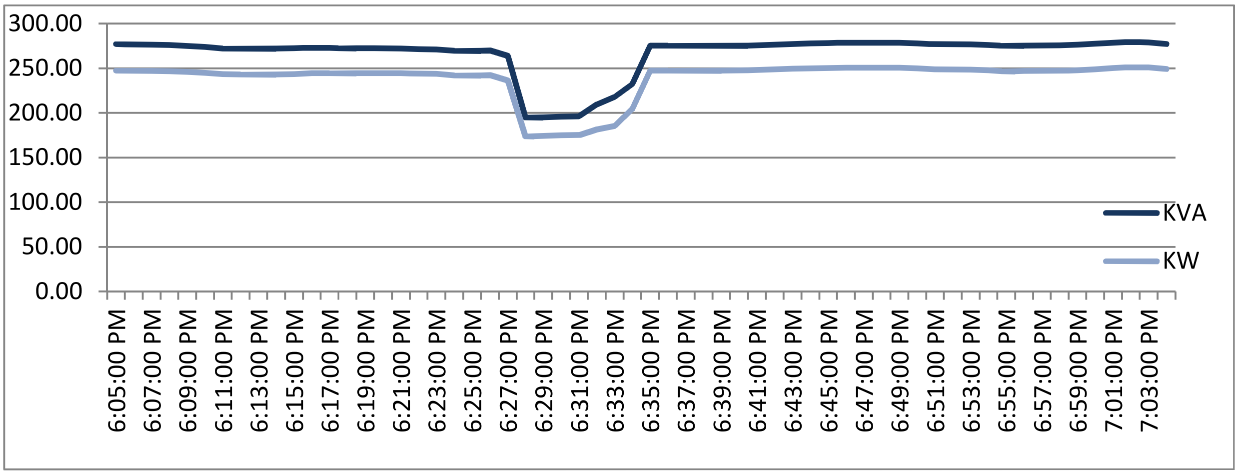


Figure 194: Power consumption variation at Keshavkunj (Bodla) ZPS

- Power consumption observed during parallel running of four pumps was around 240-250 kW.
- Apparent power during parallel running of four pumps was around 260-280 kVA.

Power factor profile

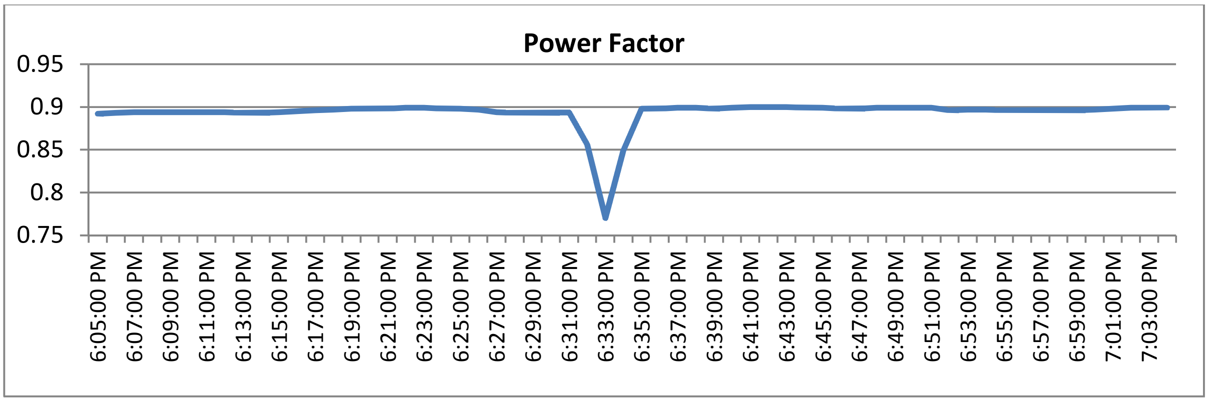


Figure 195: Power factor variation profile at Keshavkunj (Bodla) ZPS

- Power factor observed during parallel running of four pumps was around 0.89-0.9.

Frequency Profile:

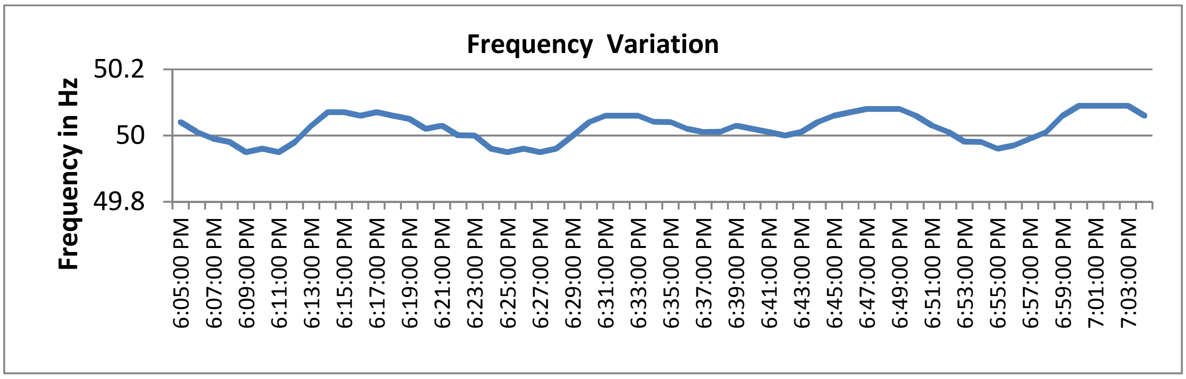


Figure 196 Frequency variation at Keshavkunj (Bodla) ZPS

- The frequency was found to vary between 49.94 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

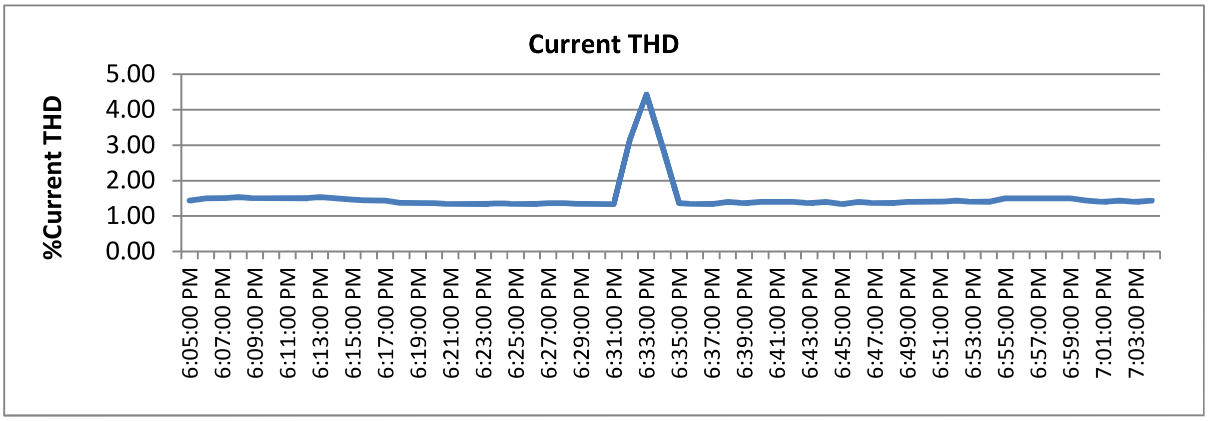


Figure 197: Variation of THD in current at Keshavkunj (Bodla) ZPS

- The current THD during operation of four pumps was around 1.5%.

Total Harmonics distortion - Voltage:

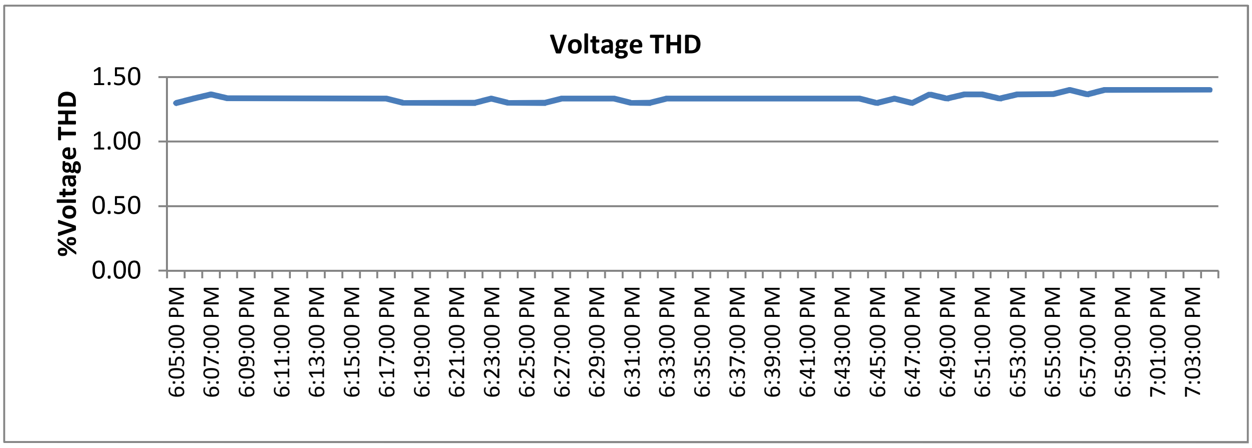


Figure 198: Variation in THD - voltage at Keshavkunj (Bodla) ZPS

- The voltage THD was consistently found to be around 1.3-1.4%.

Transformer loading:

Based on the kVA measurement done during energy audit, average transformer loading was calculated and same is provided below.

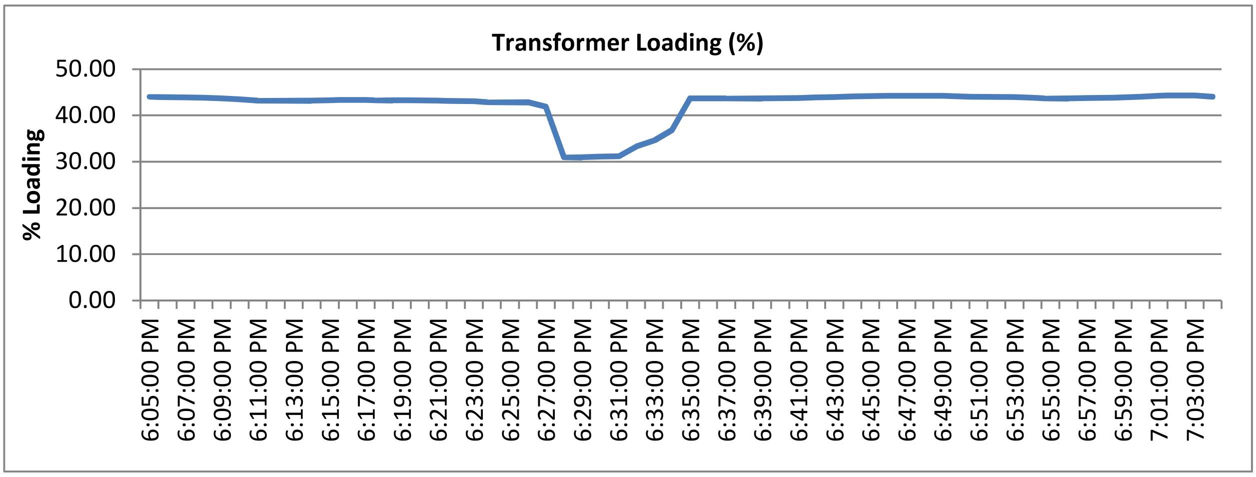


Figure 199: Variation in THD - voltage at Keshavkunj (Bodla) ZPS

- Transformer loading during operation of four pumps was found to be around 42-45%.

4.17.6 Pumping Station System Mapping

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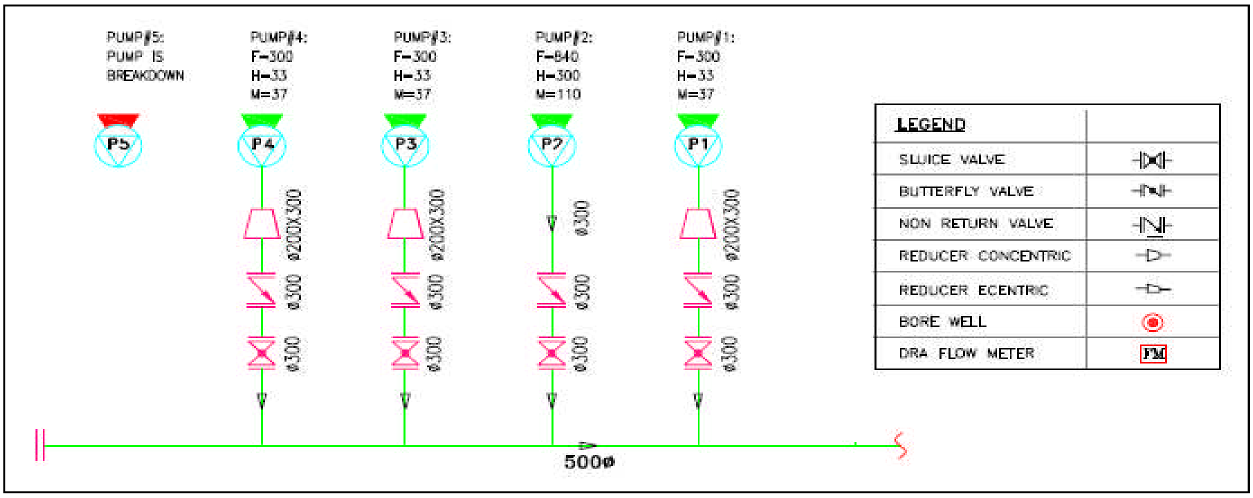


Figure 200: P & ID diagram for Keshavkunj ZPS

4.17.7 Pumps Performance Evaluation

As per the methodology described in section – 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 132: General details of Keshavkunj ZPS

Data	Value / Details
Name of site	Keshavkunj ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	4
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Keshavkunj ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed

Figure 201 Photographs of Keshavkunj ZPS

Table 133: Performance Evaluation of pumps at Keshavkunj ZPS

	Unit	Keshavkunj ZPS (Bodla ZPS)	Keshavkunj ZPS (Bodla ZPS)	Keshavkunj ZPS (Bodla ZPS)
Parameters		Pump-1	Pump-3	Pump-4
Pump make		Kirloskar	Kirloskar	Kirloskar
Motor make		Jyoti	Jyoti	Kirloskar
Pump type		VT	VT	VT
Motor serial no.		NA	NA	M09991593
Pump serial no.		NA	153A413005	BHR-3
Rated flow	m^3/h	300	300	300
Rated head	m	33	33	33
Rated motor	kW	37	37	37
Parameters measured				
Total suction head	m	-3.00	-3.58	-2.68
Total discharge head	m	10	14	12
Average flow delivered	m^3/h	366.47	340.27	422.47
Motor input power	kW	41.60	35.09	36.32
Frequency	Hz	49.96	50.04	50.06
Speed	RPM	1478.33	1474.00	1479.00
Performance evaluation				
Total head developed	m	13.00	12.33	9.43
Head utilization	%	39%	37%	29%
Flow utilization	%	122%	113%	141%
Hydraulic power kW		12.97	11.43	10.85
Motor input power	kW	41.60	35.09	36.32

Parameters	Unit	Keshavkunj ZPS (Bodla ZPS) Pump-1	Keshavkunj ZPS (Bodla ZPS) Pump-3	Keshavkunj ZPS (Bodla ZPS) Pump-4
Calculated pumpset efficiency		31.19%	46.43%	46.51%
Rated motor efficiency		91%	91%	91%
Calculated pump efficiency		34.27%	51.03%	51.11%
Specific energy consumption	kWh/m^3	0.114	0.103	0.086

Table 134: Parallel pumping at Keshavkunj ZPS

Location	Unit	Keshavkunj ZPS (Bodla ZPS)
Parameters measured		**1,2,3,4**
Total suction head	m	-2.68
Total discharge head	m	4
Total flow	m^3/h	2423.27
Motor input power	kW	247.90
Performance evaluation		
Total head developed	m	6.68
Head utilization		20%
Flow utilization		139%
Hydraulic power developed by pump	kW	44.11
Motor input kW	kW	247.90
Calculated overall efficiency		17.79%
Motor efficiency		91%
Calculated pump efficiency		19.55%
Specific energy consumption	kWh/m^3	102.30

Key Observations:

- Pump set efficiencies of pumps 1,3 and 4 were found to be 31.19%, 32.57% and 29.88% respectively. All three were found to be operating significantly below their rated head. During parallel operation of pumps 1-4, the combined efficiency was found to be quite poor at 17.79%, and the operating head was significantly less than the rated head of the pumps.
- Pump no. 5 has been discarded.
- Sump was found to be in poor condition.

4.17.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 135: Other auxiliary equipment at Keshavkunj ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	630
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 136: Other electrical equipment at Keshavkunj ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Keshavkunj	CFL	3	0.065	12

Table 137: Other electrical equipment at Keshavkunj ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Exhaust Fan	1	0.2	24

4.17.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Keshavkunj (Bodla) ZPS is provided in below table.

Table 138: Estimated annual water supply and energy consumption for Keshavkunj (Bodla) ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Keshavkunj ZPS (Bodla ZPS)	Pump-1	1,2,3,4 in parallel for direct distribution	641	41.60	26,653
Keshavkunj ZPS (Bodla ZPS)	Pump-2		641	117.24	75,120

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Keshavkunj ZPS (Bodla ZPS)	Pump-3		641	35.09	22,484
Keshavkunj ZPS (Bodla ZPS)	Pump-4		569	36.32	20,673
	Total		**2,492**	**230.25**	**144,930**

4.18 Shahganj Phase-1 ZPS

4.18.1 Overview of existing systems

Shahganj Phase-1 Zonal Pumping station receives clear water from Sikandra WTP. Water is supplied from here to Shahganj and Subhash Park areas through dedicated sets of pumps.

4.18.2 Electricity Supply

Shahganj Phase-1 ZPS receives supply from Torrent Power at 11 kV. A 1000 kVA transformer steps down this voltage for supply to motors.

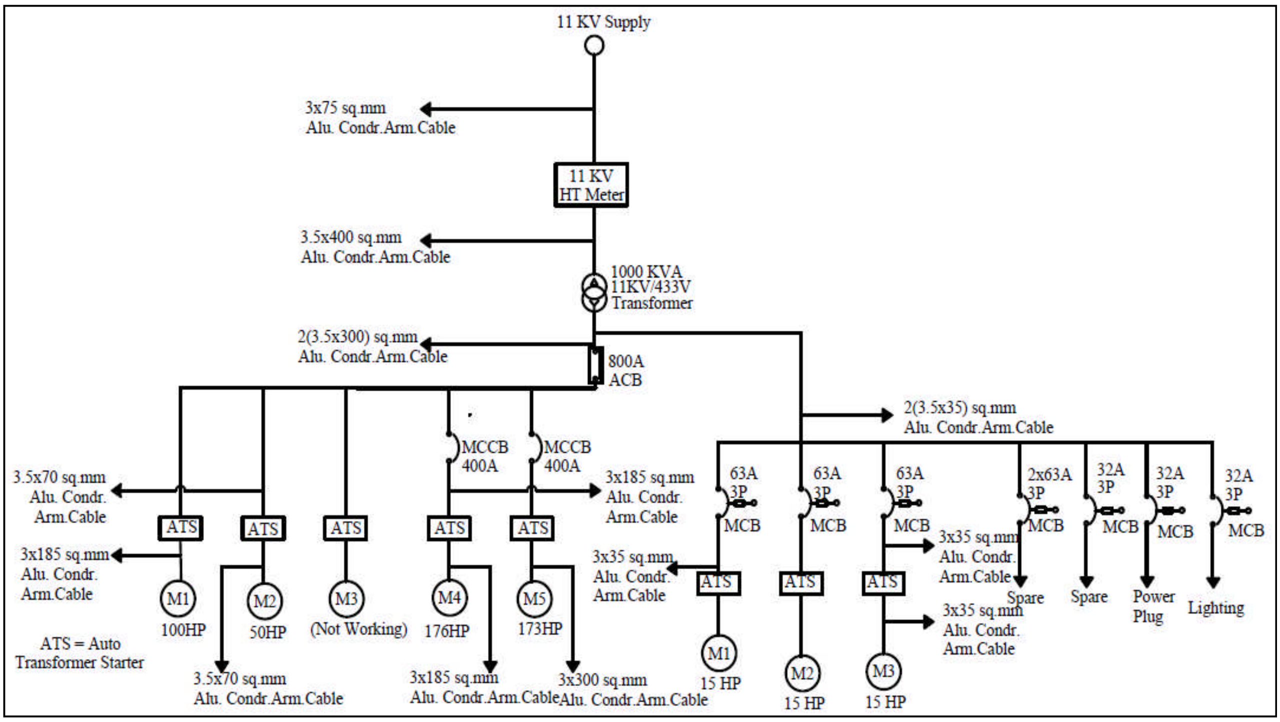


Figure 202: Single line diagram for the Shahganj Phase-1 ZPS

4.18.3 Tariff Structure

The electrical connection for Shahganj Phase-1 is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 139: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Shahganj Phase-1 Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.18.4 Electricity Bill Analysis

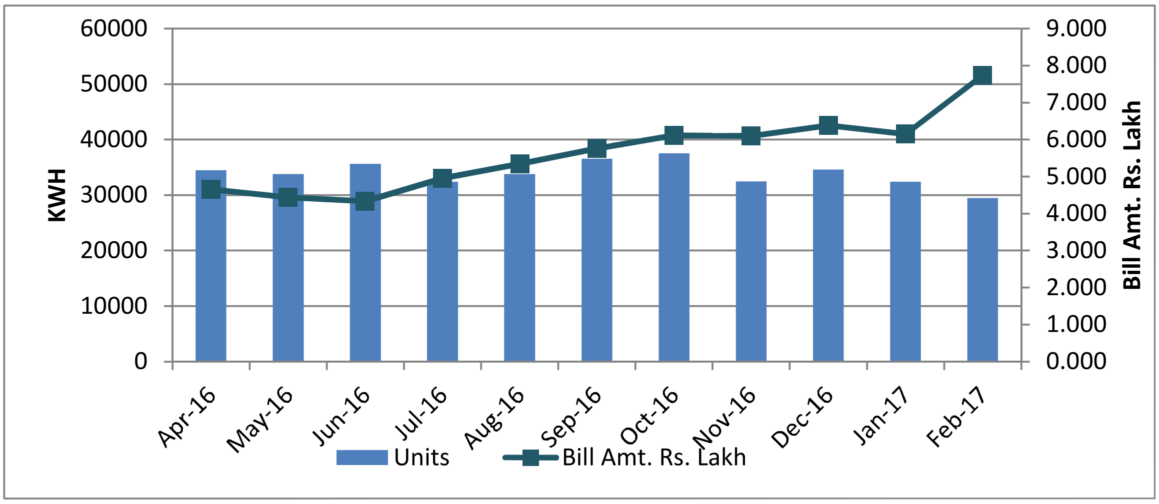
Table 140: Energy cost and energy consumption detail for Shahganj Phase-1 ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	Not available		Not available
Apr-15 to Mar-16	Not available	-	Not available
Apr-16 to Mar-17	407,053	-	6,761,008

The power factor recorded on the incomer was observed to be around 0.85-0.89. As the billing is kVAh-based, improving the power factor will lead to reduction in bill amount paid every month.

The recorded demand was observed to exceed the contract demand by a significant margin every month throughout 2016-17. As a result of exceeding the contract demand, 'Excess demand charges' have been levied in addition to the regular demand charges. Savings can be achieved by avoiding these charges by revision of contract demand to closely match the actual load requirement.

Figure 203: Monthly electricity consumption and electricity bill for Shahganj Phase-1 ZPS



4.18.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT sidefor recording variation of electrical parameters. Details about transformers installed at Shahganj Phase-1 ZPS is provided in below table.

Table 141: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 1000 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

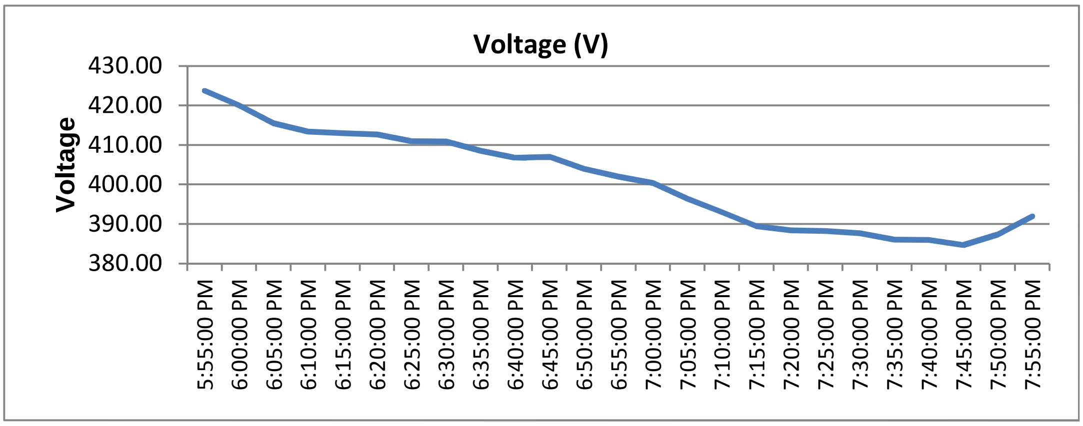


Figure 204: Voltage Variation at Shahganj Phase-1

- The voltage was observed to show wide variation between 385V and 425V, averaging 401V.

Power consumption and Apparent power Profile:

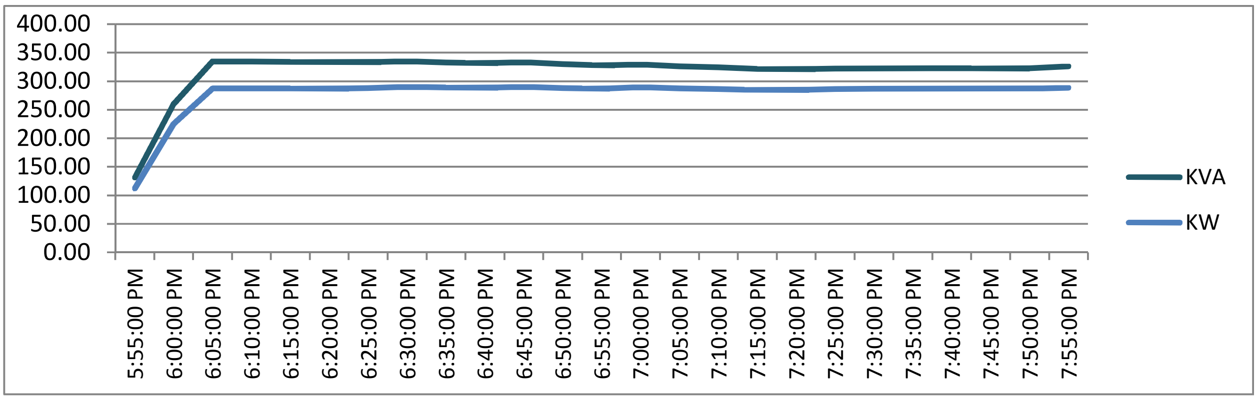


Figure 205: Power consumption variation at Shahganj Phase-1

- The power consumption with four pumps running was found to be around 285-290 kW.
- The apparent power with four pumps running was found to be around 320-340 kVA.

Power factor profile

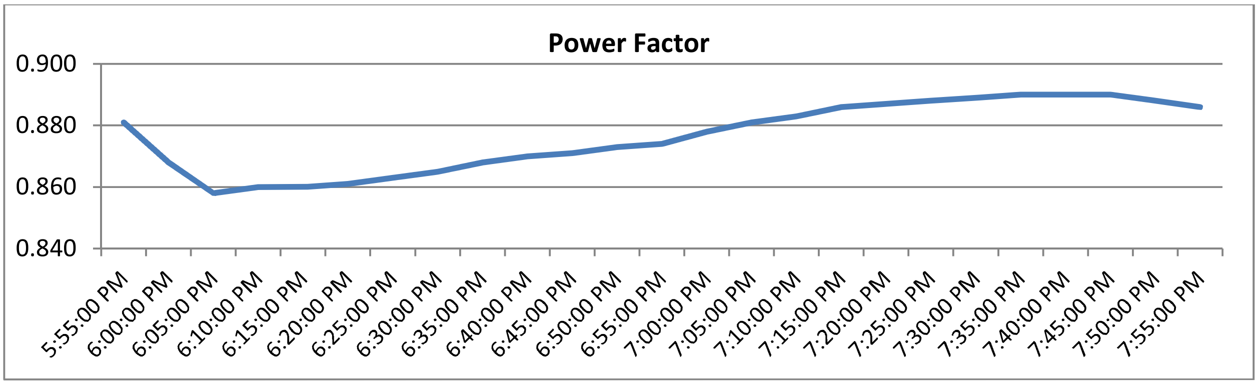


Figure 206: Power factor variation profile at Shahganj Phase-1

- The power factor was found to vary between 0.857 and 0.89.

Frequency Profile:

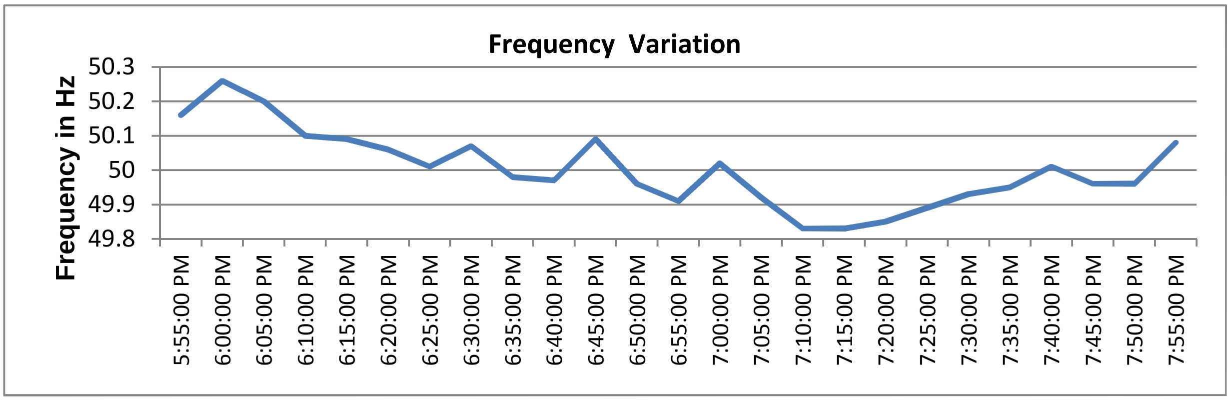


Figure 207: Frequency variation at Shahganj Phase-1

- The frequency was found to vary between 49.8 and 50.3 Hz.

Total Harmonics distortion (THD) - Current:

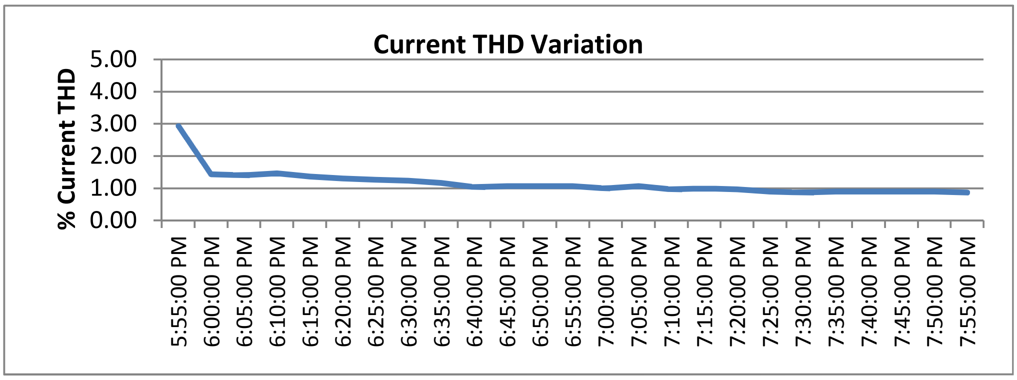


Figure 208: Variation of THD in current at Shahganj Phase-1

- During operation of four pumps, current THD was found to be in the 1-1.5% range.

Total Harmonics distortion - Voltage:

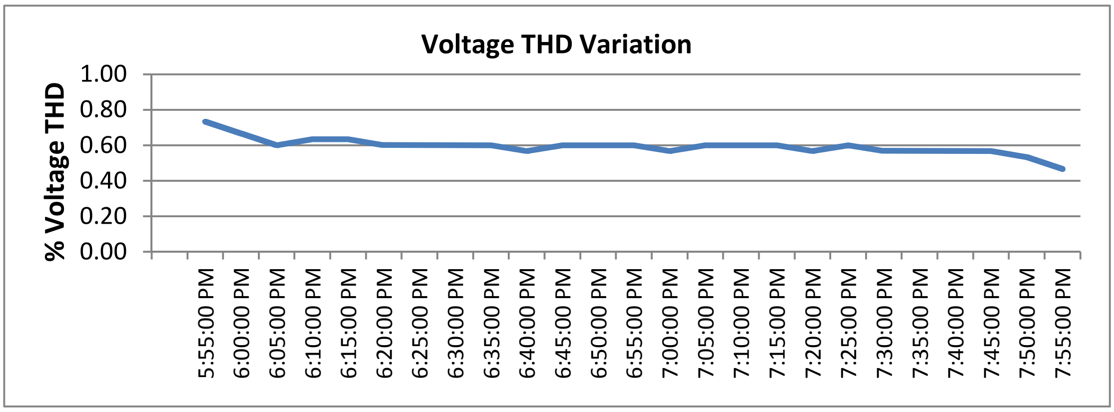
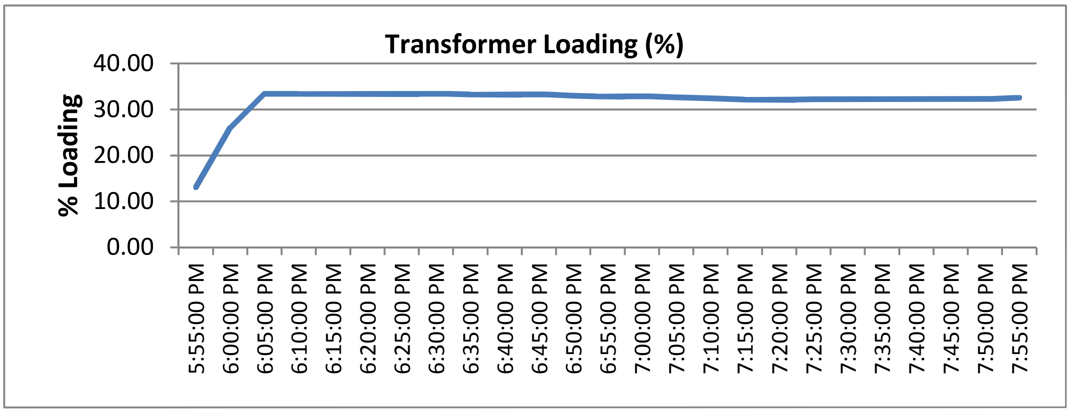


Figure 209: Variation in THD - voltage at Shahganj Phase-1

- The voltage THD was found to be less than 1%.

Transformer loading:

Based on the kVA measurement done during energy audit, average transformer loading at Shahganj Phase-1 ZPS was calculated.Transformer details and loading are given below.



- Transformer loading during operation of four pumps was estimated to be around 32-34%.

4.18.6 Pumping Station System Mapping

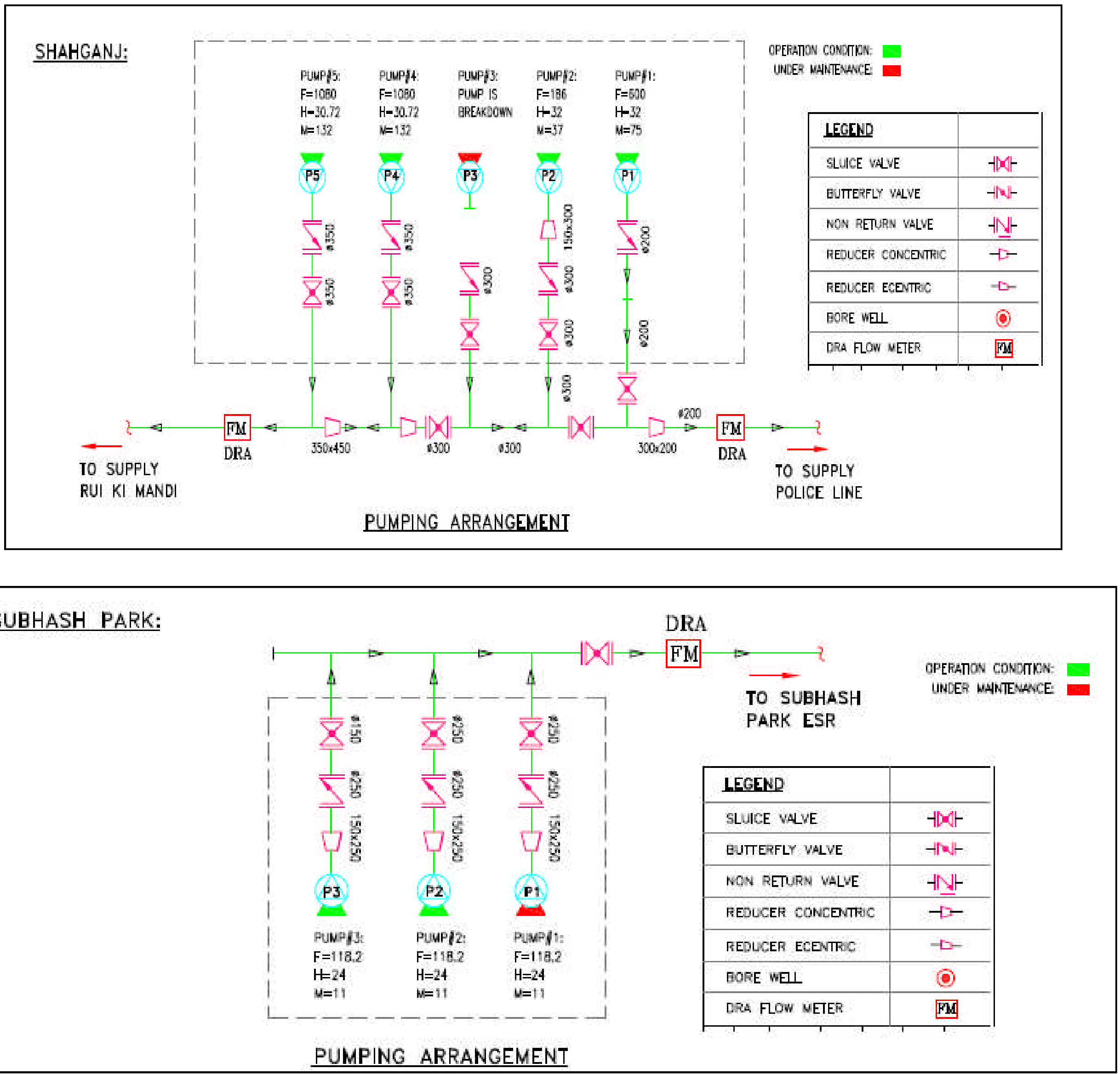


Figure 210: P & ID diagram for Shahganj Phase-1 ZPS

4.18.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 142: General details of Shahganj Phase-1 ZPS

Data	Value / Details
Name of site	Shahganj Phase-1 ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	8
No. of pumps in operation	6
No. of pumps under maintenance	2
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Shahganj Phase-1 ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 211: Photographs of Shahganj Phase-1 ZPS

Table 143: Performance Evaluation of pumps at Shahganj Phase-1 ZPS

	Unit	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS
Parameters		Pump-1	Pump-2	Pump-4	Pump-5	Pump-2 (Subhash Park)	Pump-3 (Subhash Park)
Pump make		Kirloskar	Jyoti	Jyoti	Kirloskar	Chandra	Chandra
Motor make		Kirloskar	Jyoti	Jyoti	Jyoti	Jyoti	Jyoti
Pump type		VT	VT	VT	VT	VT	VT
Motor serial no.		29805110-2	NA	NA	NA	NA	NA
Pump serial no.		NA	NA	NA	NA	C283W	C283W
Rated flow	m^3/h	600	186	1080	1080	118.2	118.2
Rated head	m	32	32	30.72	30.77	24	24
Rated motor	kW	75	37	132	132	11	11

Parameters	Unit	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS	Shahganj Phase-1 ZPS
		Pump-1	Pump-2	Pump-4	Pump-5	Pump-2 (Subhash Park)	Pump-3 (Subhash Park)
Parameters measured							
Total suction head	m	-1.79	-2.61	-3.00	-2.20	-3.88	-3.20
Total discharge head	m	10	10	10	12	2	2
Average flow delivered	m^3/h	351.73	396.10	1440.00	559.13	264.77	262.57
Motor input power	kW	65.01	33.59	113.86	62.55	11.30	12.25
Frequency	Hz	49.98	50.00	50.04	50.00	50.04	50.12
Speed	RPM	1480.67	1476.00	1473.33	1464.00	1463.33	1469.67
Performance evaluation							
Total head developed	m	11.79	12.61	13.00	14.20	5.88	5.20
Head utilization	%	37%	39%	42%	46%	24%	22%
Flow utilization	%	59%	213%	133%	52%	224%	222%
Hydraulic power kW	kW	11.30	13.61	50.98	21.62	4.24	3.72
Motor input power	kW	65.01	33.59	113.86	62.55	11.30	12.25
Calculated pumpset efficiency	%	17.38%	40.50%	44.77%	34.57%	37.49%	30.33%
Rated motor efficiency	%	91.5%	91.0%	93.5%	93.5%	90.0%	90.0%
Calculated pump efficiency	%	18.99%	44.51%	47.89%	36.97%	41.65%	33.69%
Specific energy consumption	kWh/m^3	0.185	0.085	0.079	0.112	0.043	0.047

Table 144: Parallel pumping at Shahganj Phase-1 ZPS

Location	Unit	Shahganj Phase-1 ZPS
Parameters measured		**1,2,4,5**
Total suction head	m	-4.07
Total discharge head	m	8
Total flow	m^3/h	2822.40

Location	Unit	Shahganj Phase-1 ZPS
Parameters measured		**1,2,4,5**
Motor input power	kW	288.51
Performance evaluation		
Total head developed	m	12.07
Head utilization		38%
Flow utilization		96%
Hydraulic power developed by pump	kW	92.75
Motor input kW	kW	288.51
Calculated overall efficiency		32.15%
Motor efficiency		91%
Calculated pump efficiency		35.33%
Specific energy consumption	kWh/m^3	102.22

Key Observations:

- Pump no. 3 and Subhash park supply pump no. 1 were in breakdown condition at the time of audit.
- Pump 1 was operating at a low pump set efficiency of 17.38%. Pumps 2, 4 and 5 wer operating at pump set efficiencies of 40.5%, 44.77% and 34.57% respectively. All pumps were found to be operating significantly below their rated head.
- Combined efficiency during parallel operation of pumps 1,2,4,5 was found to be 32.15%, and the operating head was significantly less than the rated head.
- The Subhash Park supply pumps 2 and 3 were operating at pump set efficiencies of 37.49% and 30.33% respectively. Operating head was found to be significantly less than the rated head.

4.18.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 145: Other auxiliary equipment at Shahganj Phase-1 ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	1000
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 146: Other electrical equipment at Shahganj Phase-1 ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Shahganj-1	CFL	1	0.085	12
	Metal Halide	2	0.15	12
	Tubelight	12	0.036	12

Table 147: Other electrical equipment at Shahganj Phase-1 ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Exhaust Fan	1	0.1	24

4.18.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Shahganj Phase-1 ZPS is provided in below table.

Table 148: Estimated energy consumption for Shahganj Phase-1 ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Shahganj Phase-1 ZPS	Pump-1	1,2,4,5 for direct supply. One working in Subhash Park section.	807	65.01	52,489
Shahganj Phase-1 ZPS	Pump-2		807	33.59	27,123
Shahganj Phase-1 ZPS	Pump-4		807	113.86	91,933
Shahganj Phase-1 ZPS	Pump-5		807	62.55	50,506
Shahganj Phase-1 ZPS	Pump-2 (Subhash Park)		2,091	11.30	23,640
Shahganj Phase-1 ZPS	Pump-3 (Subhash Park)		1,306	12.25	15,998
	Total		**6,625**	**298.56**	**261,689**

4.19 Shahganj Phase-2 ZPS

4.19.1 Overview of existing systems

Five pumps are installed at Shahganj Phase-2 ZPS, of which pump no. 5 is dedicated for supply to BSF area.

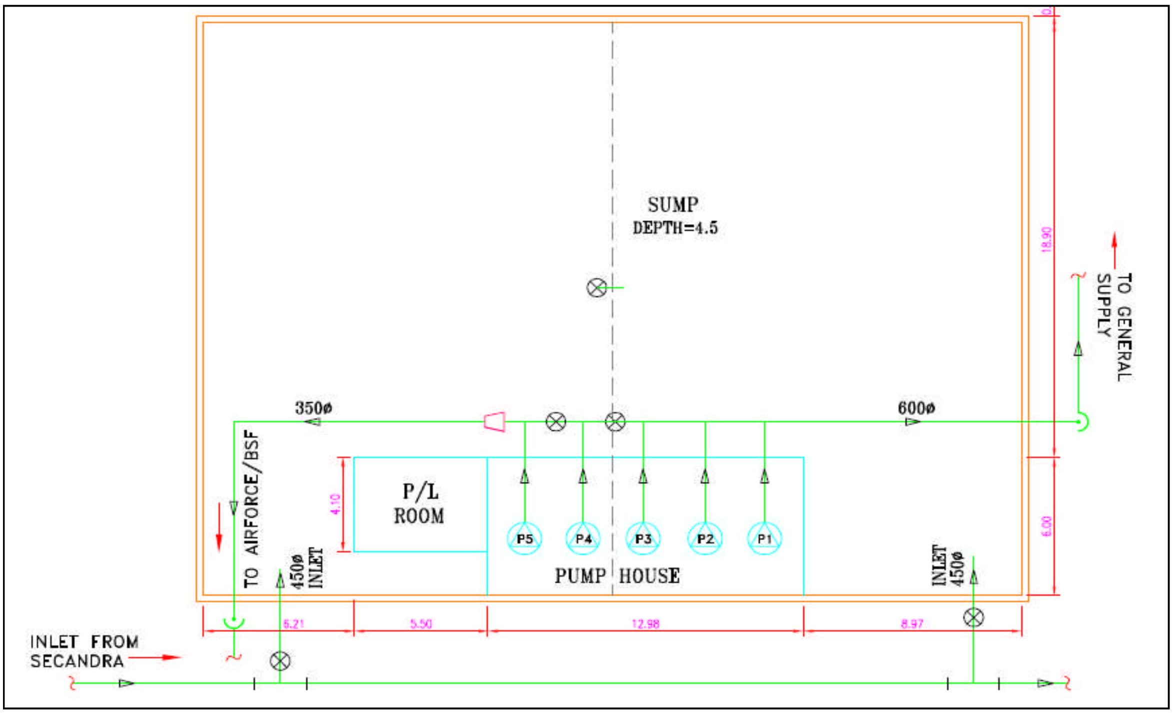


Figure 212Plant Layout for Shahganj Phase-2 ZPS

4.19.2 Electricity Supply

Shahganj Phase-2 ZPS receives supply at 11 kV from Torrent Power. This is stepped down to 440V for feeding the motors.

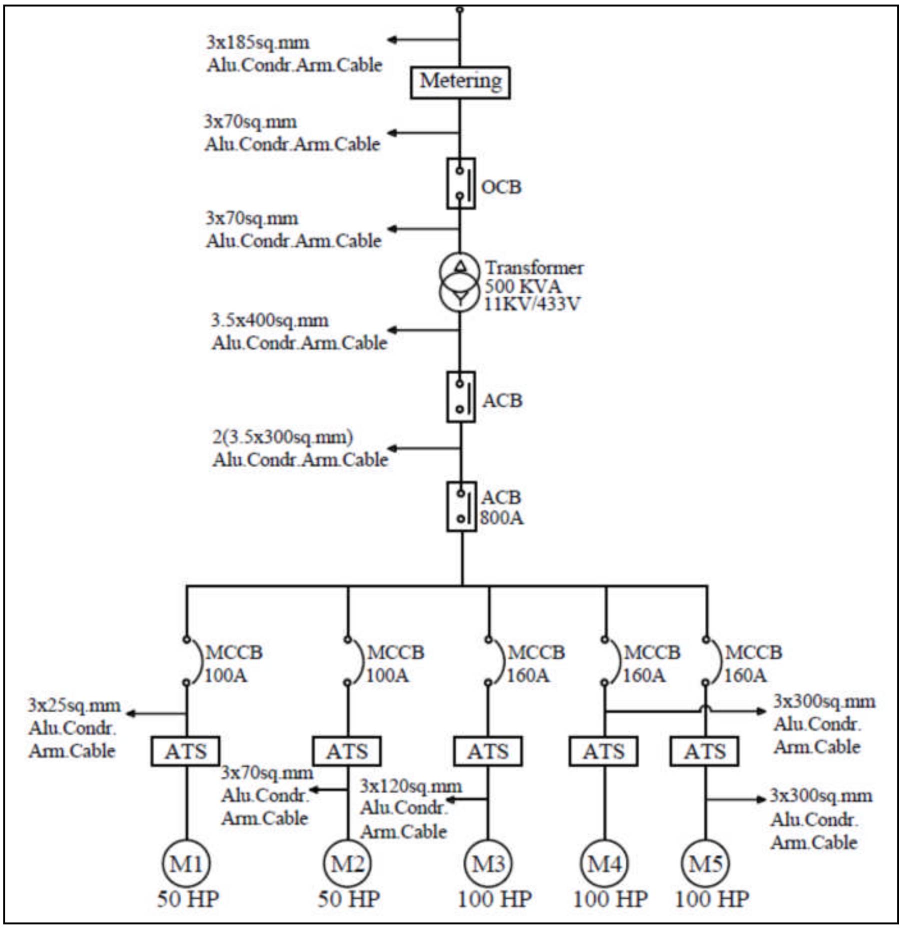


Figure 213: Single line diagram for the Shahganj Phase-2 ZPS

4.19.3 Tariff Structure

The electrical connection for Shahganj Phase-2 ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 149: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Shahganj Phase-2 Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

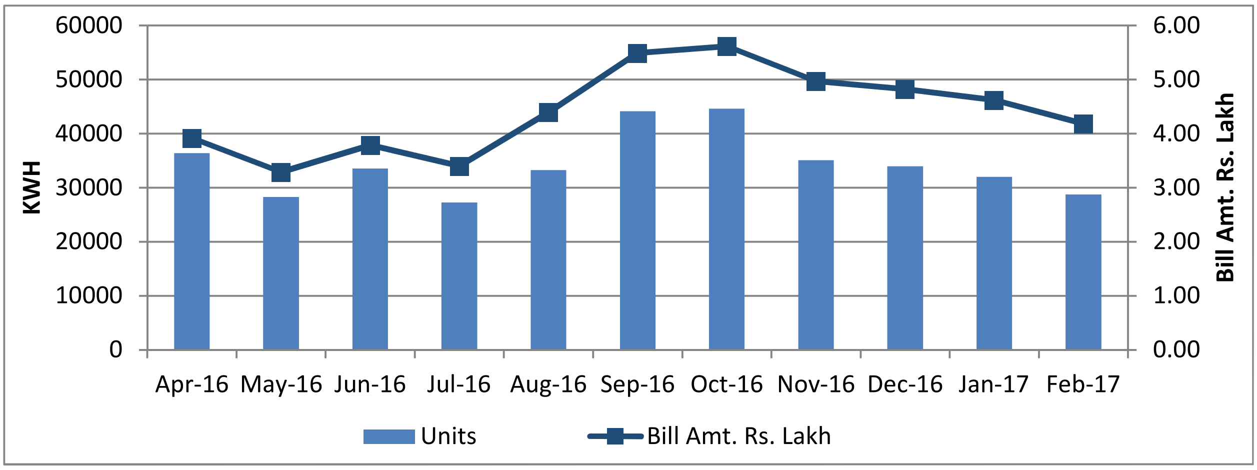
4.19.4 Electricity Bill Analysis

Table 150: Energy cost and energy consumption detail for Shahganj Phase-2 ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	410,335		3,809,768
Apr-15 to Mar-16	514,460	25.4%	5,572,602
Apr-16 to Mar-17	411,608	-20.0%	5,291,114

- It is observed that the recorded demand has consistently exceeded the contract demand. As a result, 'Excess demand charges' have been levied in addition to the regular demand charges every month. These charges can be avoided and savings can be achieved by revision of contract demand to a value more closely matched to actual load requirement.

Figure 214: Monthly electricity consumption and electricity bill for Shahganj Phase-2 ZPS



4.19.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at Shahganj Phase-2 ZPS is provided in below table.

Table 151: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 500 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

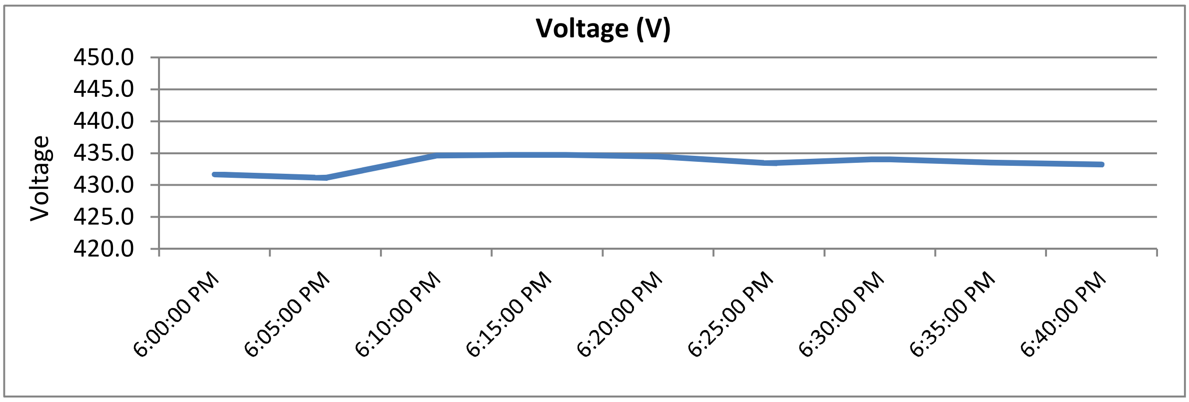


Figure 215 Voltage Variation at Shahganj Phase-2

- The recorded voltage is observed to be consistent around the 430-435V range.

Power consumption and Apparent power Profile:

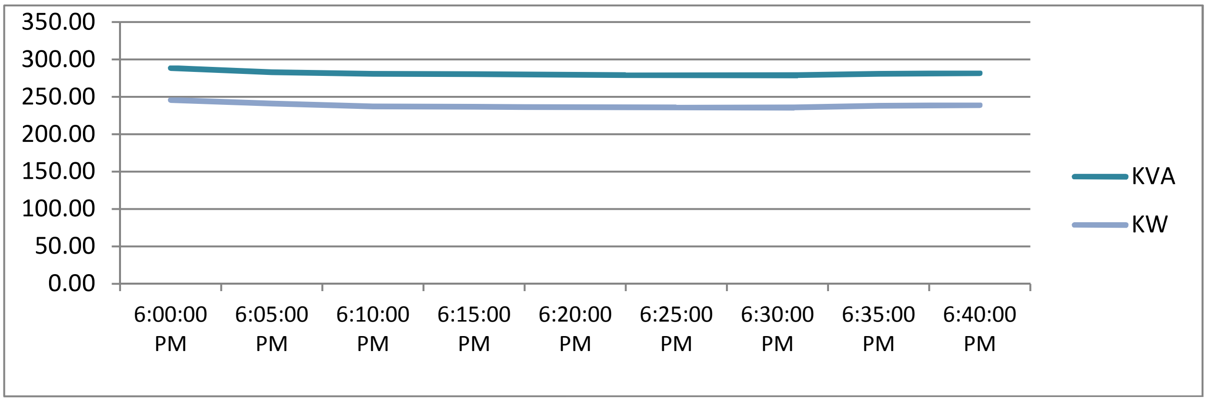


Figure 216: Power consumption variation at Shahganj Phase-2

- Power consumption during operation of four pumps is observed to be around 235-250 kW.
- Apparent power during operation of four pumps is observed to be around 275-290 kVA.

Power factor profile

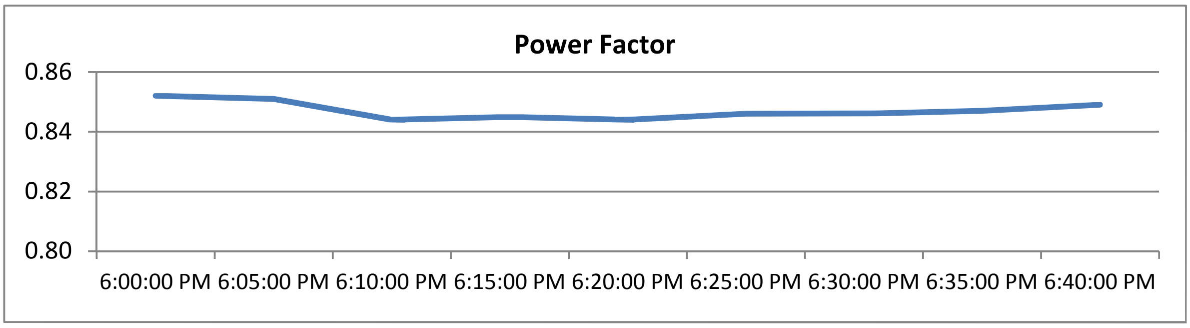


Figure 217: Power factor variation profile at Shahganj Phase-2

- The power factor on incomer is found to be around 0.84-0.85.

Frequency Profile:

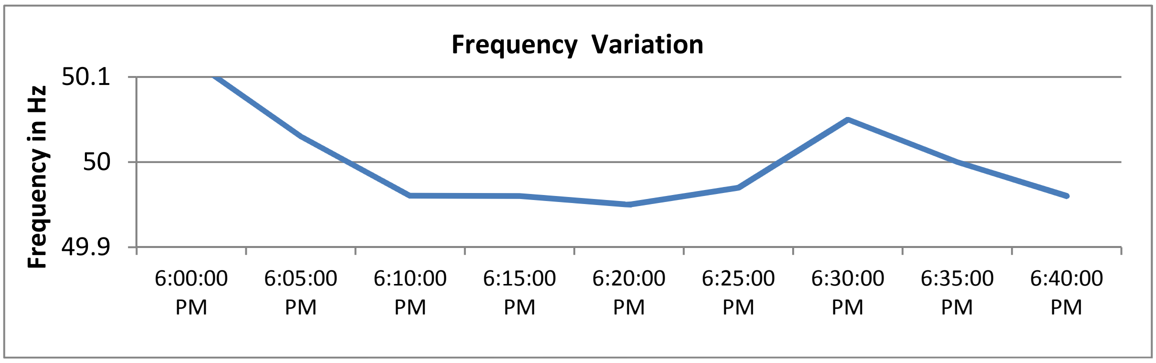


Figure 218: Frequency variation at Shahganj Phase-2

- Frequency is found to vary between 49.9 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

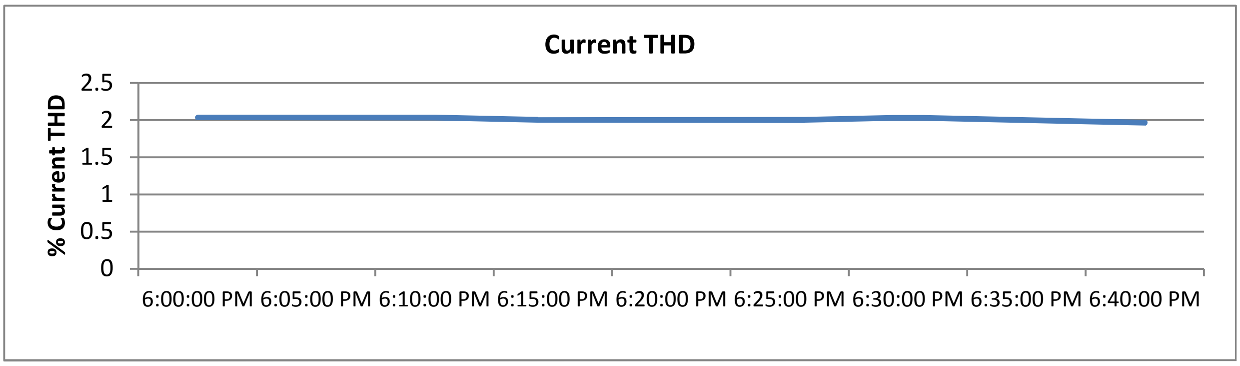


Figure 219: Variation of THD in current at Shahganj Phase-2

- The current THD is found to be around 2%.

Total Harmonics distortion - Voltage:

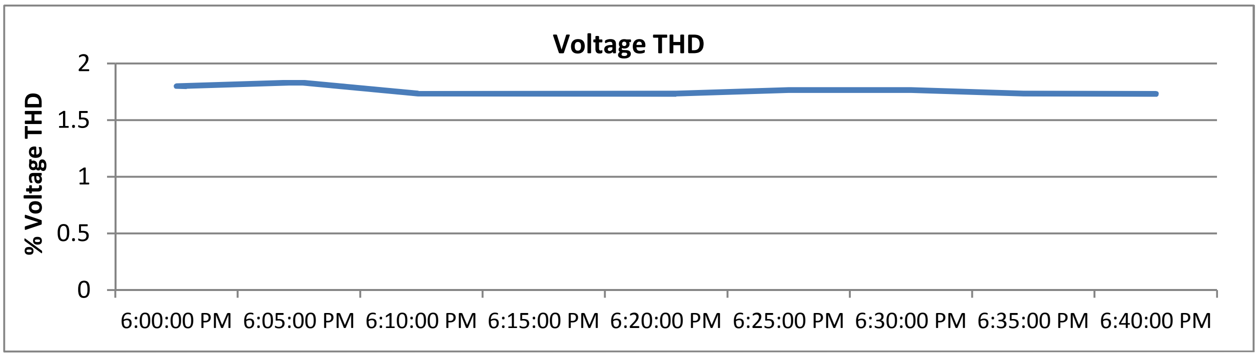


Figure 220: Variation in THD - voltage at Shahganj Phase-2

- The voltage THD is found to be around 1.7-1.8%.

Transformer loading:

Transformer loading at Shahganj Phase-2 was estimated from the measured kVA consumption on the transformer LT side. Transformer loading is as given below.

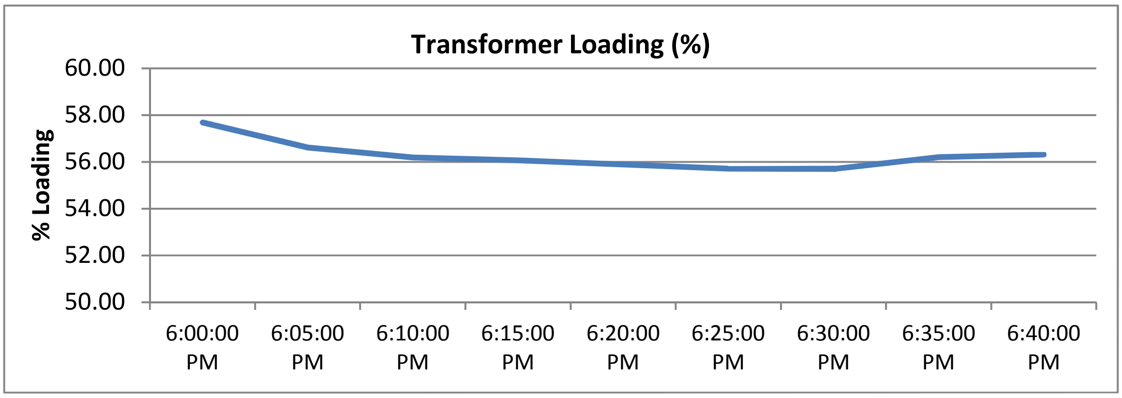


Figure 221: Transformer loading

- Measurement is performed for the pump running pattern usually followed at the pump station. As per measured kVA, transformer loading is found to be around 55-58%.

4.19.6 Pumping Station System Mapping

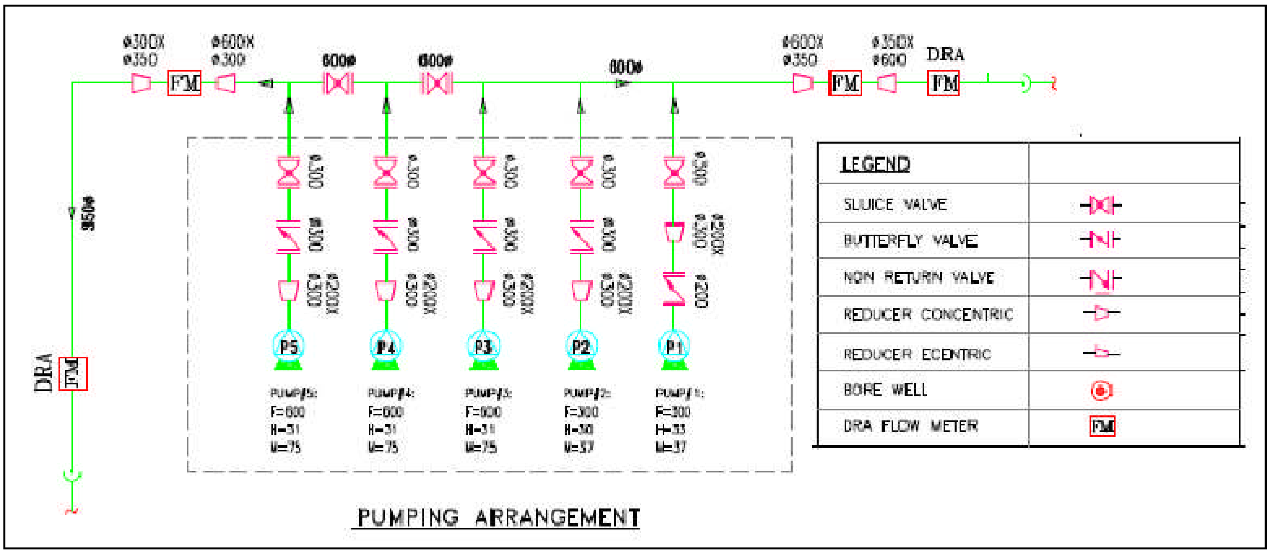


Figure 222: P & ID diagram for Shahganj Phase-2 ZPS

4.19.7 Pumps Performance Evaluation

As per the methodology described in section - 0, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection

- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 152: General details of Shahganj Phase-2 ZPS

Data	Value / Details
Name of site	Shahganj Phase-2 ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	5
No. of pumps under maintenance	-
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Shahganj Phase-2 ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 223: Photographs of Shahganj Phase-2 ZPS

Table 153: Performance Evaluation of pumps at Shahganj Phase-2 ZPS

	Unit	Shahganj Phase-2	Shahganj Phase-2	Shahganj Phase-2	Shahganj Phase-2	Shahganj Phase-2
Parameters		Pump-1	Pump-2	Pump-3	Pump-4	Pump-5
Pump make		Kirloskar	Jyoti	Jyoti	Jyoti	Jyoti
Motor make		Kirloskar	Jyoti	Jyoti	Jyoti	Jyoti
Pump type		VT	VT	VT	VT	VT
Motor serial no.		2800705-2	M08140331	M12140621	131880	NA
Pump serial no.		153A413003	N-31737	N-31798	N-311162	N-31101
Rated flow	m^3/h	300	300	600	600	600
Rated head	m	33	30	31	31	31

Parameters	Unit	Shahganj Phase-2 Pump-1	Shahganj Phase-2 Pump-2	Shahganj Phase-2 Pump-3	Shahganj Phase-2 Pump-4	Shahganj Phase-2 Pump-5
Rated motor	kW	37	37	75	75	75
Parameters measured						
Total suction head	m	-2.97	-2.80	-3.67	-3.33	-2.47
Total discharge head	m	16	7.33	20	18	20
Average flow delivered	m^3/h	335.37	392.50	552.83	728.70	439.27
Motor input power	kW	34.31	37.95	68.59	68.41	65.87
Frequency	Hz	50.05	50.01	49.9575	50.03	50.01
Speed	RPM	1474.33	1475.33	1477.00	1485.00	1463.67
Performance evaluation						
Total head developed	M	18.97	10.13	23.67	21.33	22.47
Head utilization	%	57%	34%	76%	69%	72%
Flow utilization	%	112%	131%	92%	121%	73%
Hydraulic power kW	kW	17.32	10.83	35.63	42.34	26.88
Motor input power	kW	34.31	37.95	68.59	68.41	65.87
Calculated pumpset efficiency	%	50.49%	28.54%	51.95%	61.88%	40.80%
Rated motor efficiency	%	91.0%	91.0%	91.5%	91.5%	91.5%
Calculated pump efficiency	%	55.49%	31.36%	56.77%	67.63%	44.59%
Specific energy consumption	kWh/m^3	0.102	0.097	0.124	0.094	0.150

Table 154: Parallel pumping at Shahganj Phase-2 ZPS

Location		Shahganj Phase-2 ZPS
Parameters measured		**1,2,3,4**
Total suction head	m	-2.73
Total discharge head	m	12
Total flow	m^3/h	2253.33
Motor input power	kW	240.34

Performance evaluation		
Total head developed	m	14.73
Head utilization		45%
Flow utilization		125%
Hydraulic power developed by pump	kW	90.41
Motor input kW	kW	240.34
Calculated overall efficiency		37.62%
Motor efficiency		91%
Calculated pump efficiency		41.34%
Specific energy consumption	kWh/m^3	106.66

Key Observations:

- Pumps 1-4 are connected to a common header. Pump 5 has a separate line and is used for supplying to separate area.
- Pump set efficiencies of pumps 1,2,3 and 4 were found to be 50.49%, 28.54%, 51.95% and 61.88% respectively. The operating head of all four pumps was found to be less than the rated head, with pumps 3 and 4 operating at 65% of rated head or above, pump 2 operating at a significantly lower head compared to the others. In parallel operation of pumps 1-4, the combined efficiency was observed to be 37.62%, and the operating head was found to be significantly lower than the rated head.
- Pump set efficiency of pump 5 was found to be 40.8%. Its operating head was found to be higher than 70% of the rated head.

4.19.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 155: Other auxiliary equipment at Shahganj Phase-2 ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	500
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 156: Other electrical equipment at Shahganj Phase-2 ZPS – lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Shahganj Phase-2	CFL	1	0.085	12
	Bulb	1	0.06	12

Table 157: Other electrical equipment at Shahganj Phase-2 ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
1	Fan	1	0.11	24

4.19.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Shahganj Phase-2 ZPS is provided in below table.

Table 158: Estimated energy consumption for Shahganj Phase-2 ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Shahganj Phase-2	Pump-1	1,2,3,4 in parallel. Separate line for 5.	602	34.31	20,661
Shahganj Phase-2	Pump-2		602	37.95	22,855
Shahganj Phase-2	Pump-3		602	68.59	41,308
Shahganj Phase-2	Pump-4		602	68.41	41,199
Shahganj Phase-2	Pump-5		3,682	65.87	242,519
	Total		**6,090**	**275.13**	**368,542**

4.20 Kedar Nagar Pumping Station

4.20.1 Overview of existing systems

Kedar Nagar ZPS receives clear water from Sikandra WTP. Three pumps are installed, of which one was in breakdown condition. ESR filling and direct distribution are performed at different times.

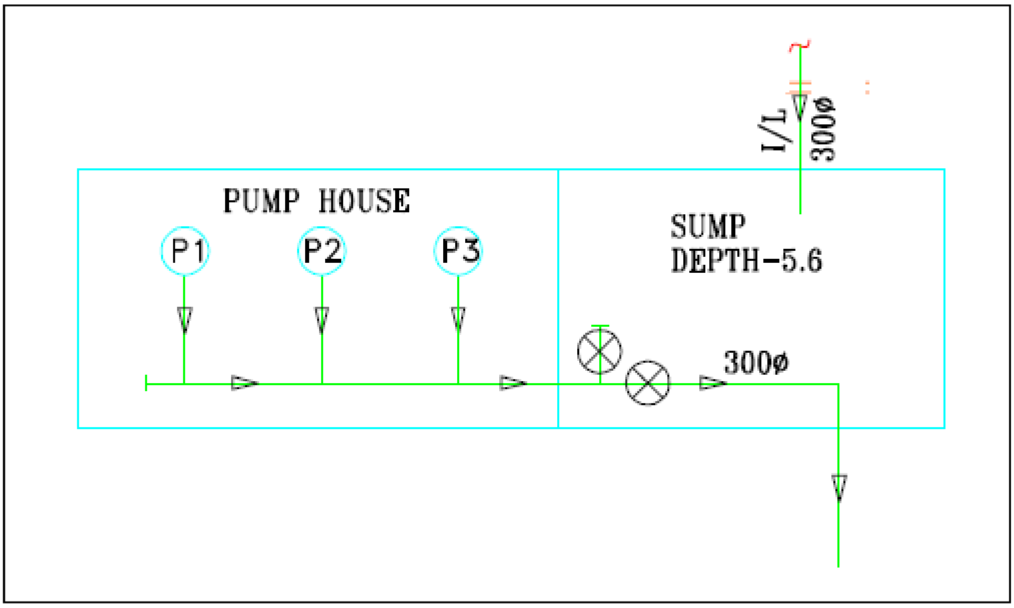


Figure 224: Plant Layout for Kedar Nagar ZPS

4.20.2 Electricity Supply

Kedar Nagar receives supply from Torrent Power at 11 kV. This is stepped down to 440V through a 100 kVA transformer to feed the motors.

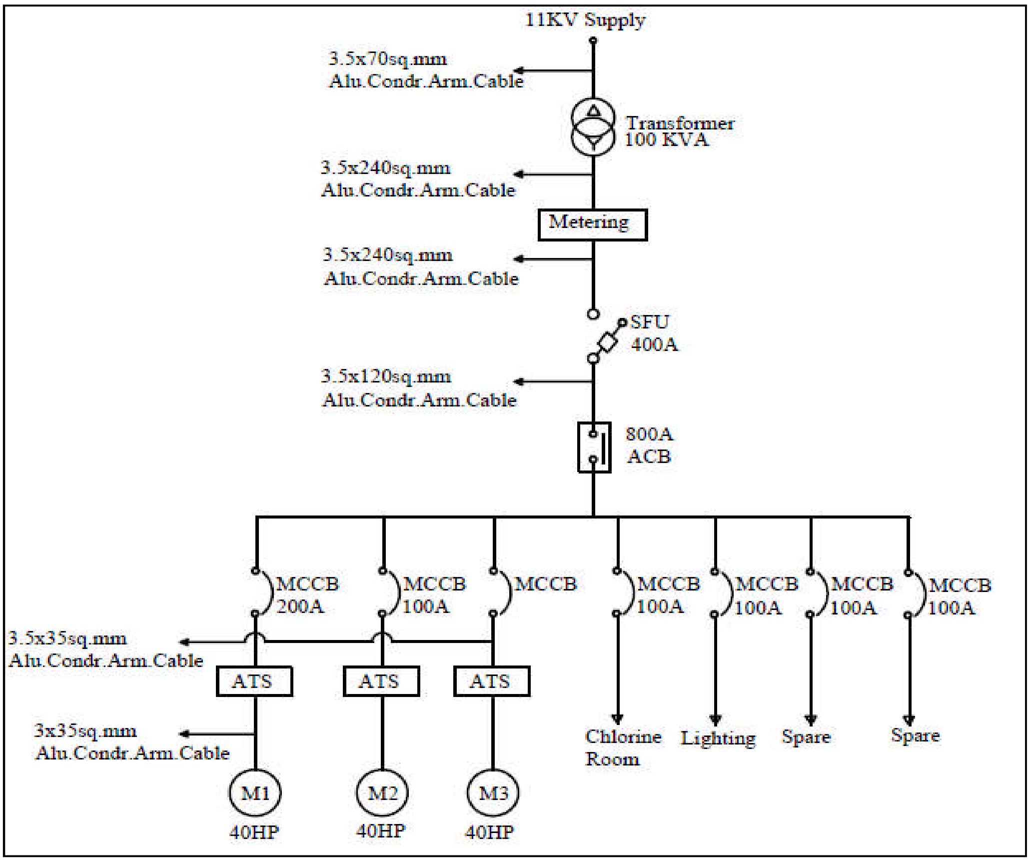


Figure 225: Single line diagram for the Kedar Nagar ZPS

4.20.3 Tariff Structure

The electrical connection for Kedar Nagar ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 159: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Kedar Nagar Energy Meter-1 (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

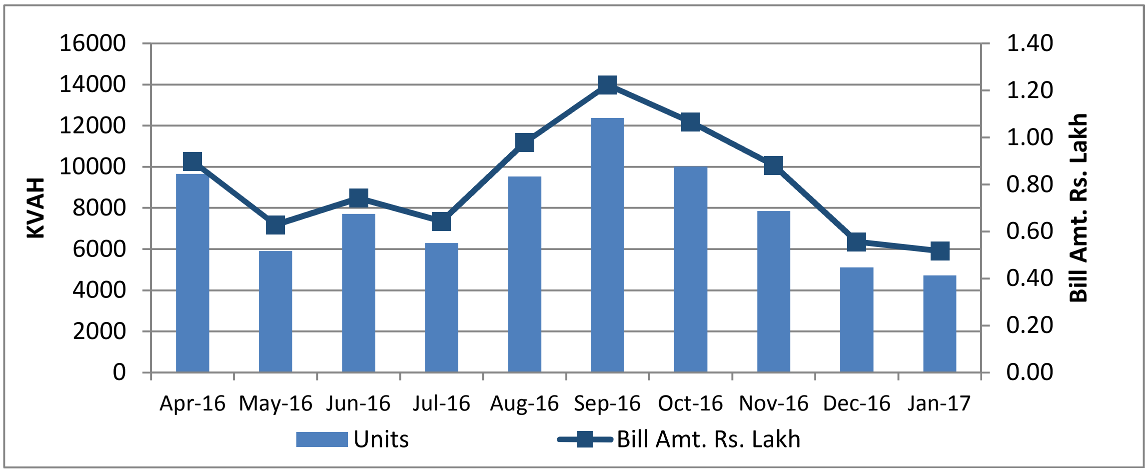
4.20.4 Electricity Bill Analysis

Table 160: Energy cost and energy consumption detail for Kedar Nagar ZPS

Period of energy bill	Energy consumption (KWH/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	72,157		748,110

Period of energy bill	Energy consumption (KWH/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-15 to Mar-16	102,529	42.1%	1,110,504
Apr-16 to Mar-17	77,546	-24.4%	975,791

Figure 226: Monthly electricity consumption and electricity bill for Kedar Nagar ZPS



4.20.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on main LT incomer for recording variation of electrical parameters. Two pumps are operated in 1W+1SB arrangement at Kedar Nagar; the two pumps were run one by one during the measurement.

Table 161: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 100 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

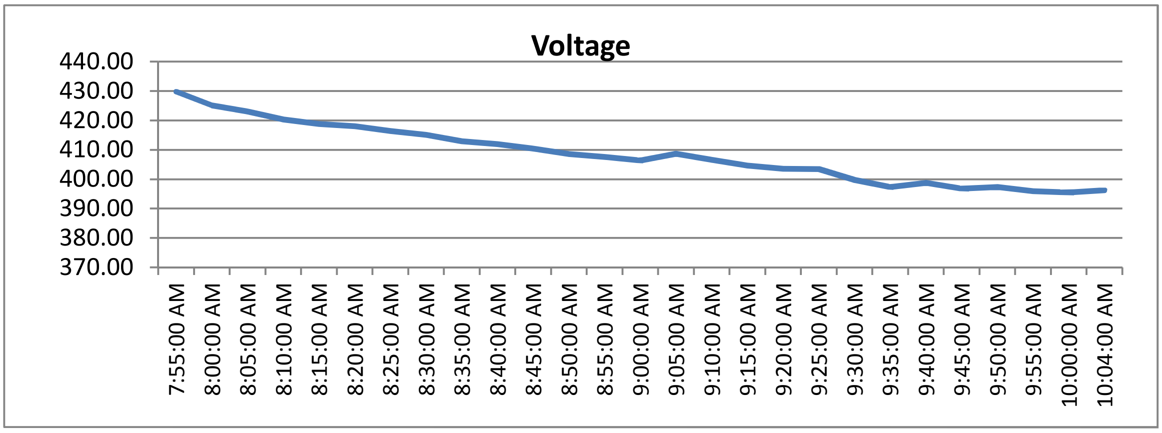


Figure 227: Voltage Variation at Kedar Nagar ZPS

- The voltage was found to decline steadily from 430V to around 395V. The average voltage was 408.5V

Power consumption and Apparent power Profile:

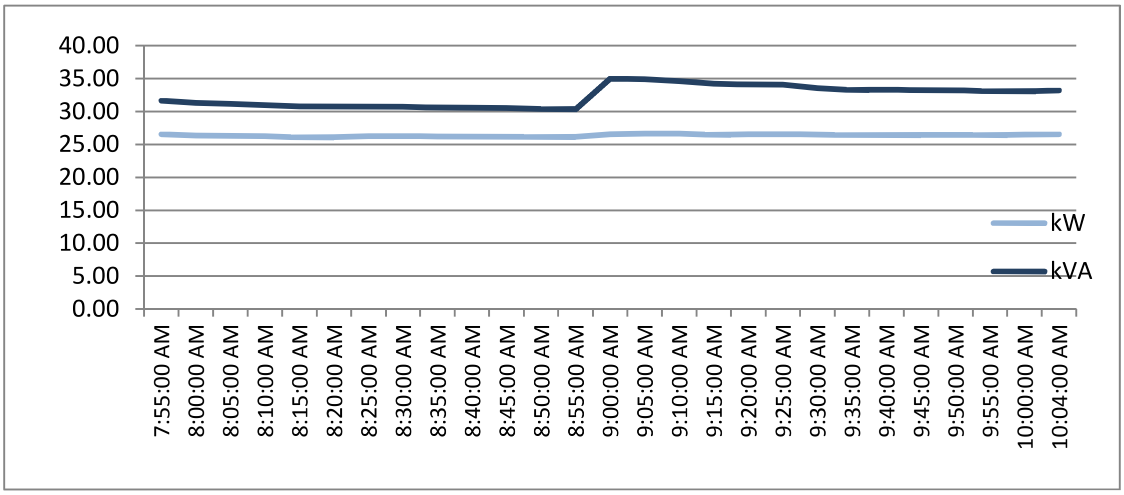


Figure 228: Power consumption variation at Kedar Nagar ZPS

- The power consumption was found to be around 26.5 kW throughout the recording.
- The apparent power consumption was found to be around 30-31 kVA during operation of first pump and around 34-35 kVA during operation of second pump.

Power factor profile

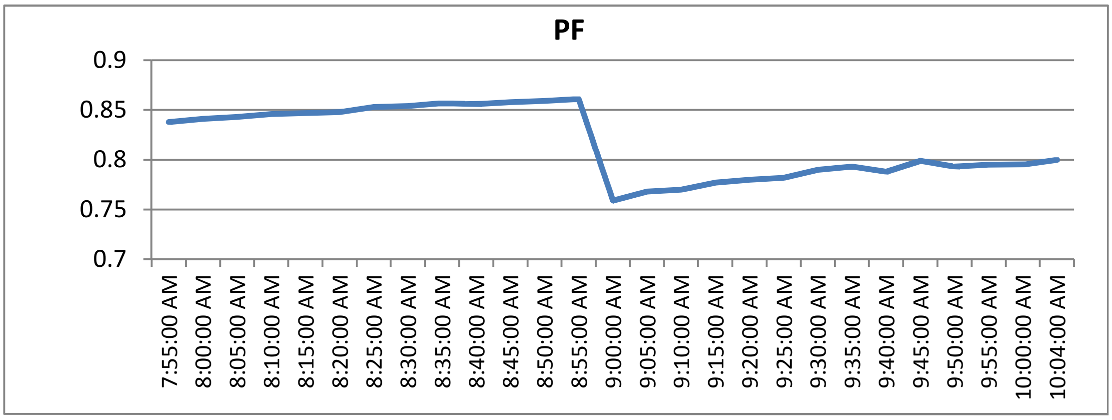


Figure 229: Power factor variation profile at Kedar Nagar ZPS

- The power factor was around 0.84-0.86 during operation of first pump, reducing to the 0.75-0.8 range during operation of the second pump.

Frequency Profile:

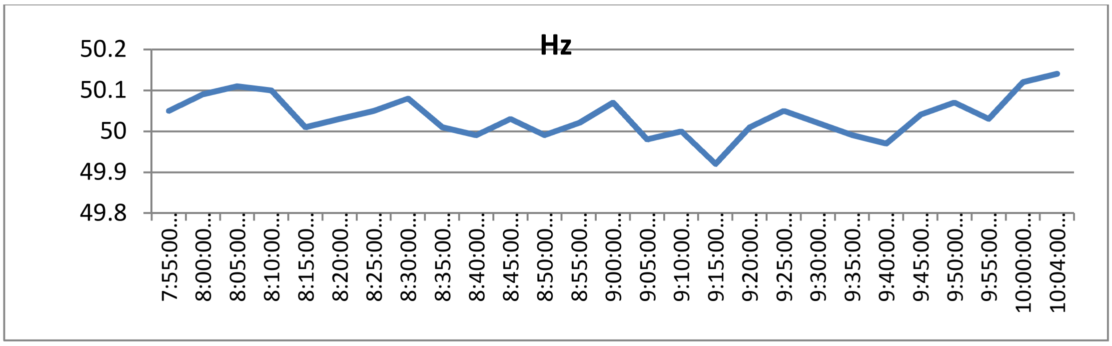


Figure 230: Frequency variation at Kedar Nagar ZPS

- The frequency was found to vary between 49.91 and 50.11 Hz, averaging 50.04 Hz.

Total Harmonics distortion (THD) - Current:

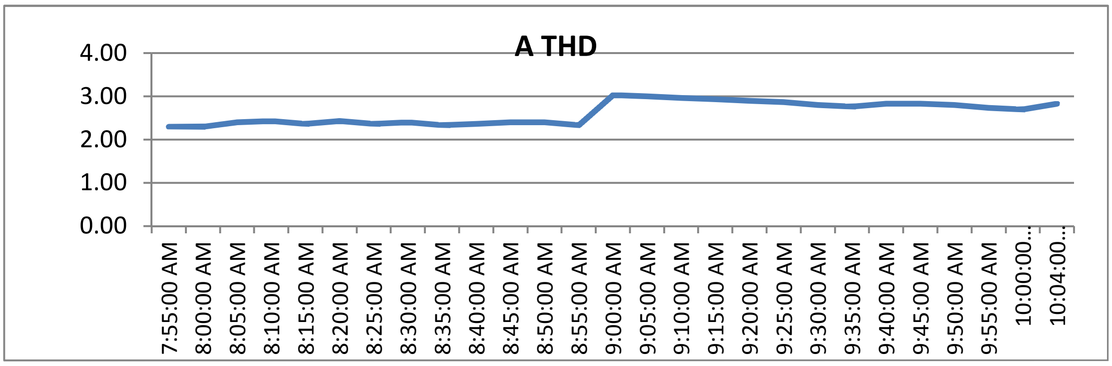


Figure 231: Variation of THD in current at Kedar Nagar ZPS

- The current THD during operation of first pump was around 2.3-2.5%, rising to around 2.9-3% during operation of second pump.

Total Harmonics distortion - Voltage:

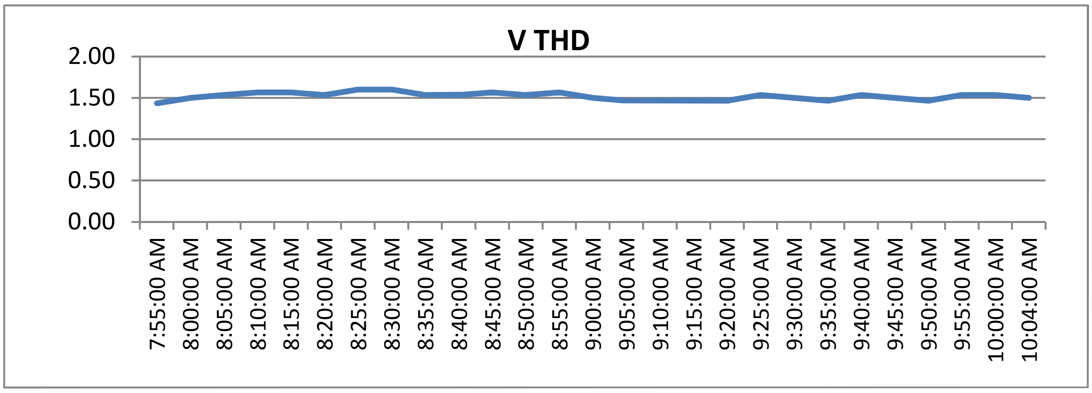


Figure 232: Variation in THD - voltage at Kedar Nagar ZPS

- The voltage THD was found to be around 1.4-1.6%.

4.20.6 Pumping Station System Mapping

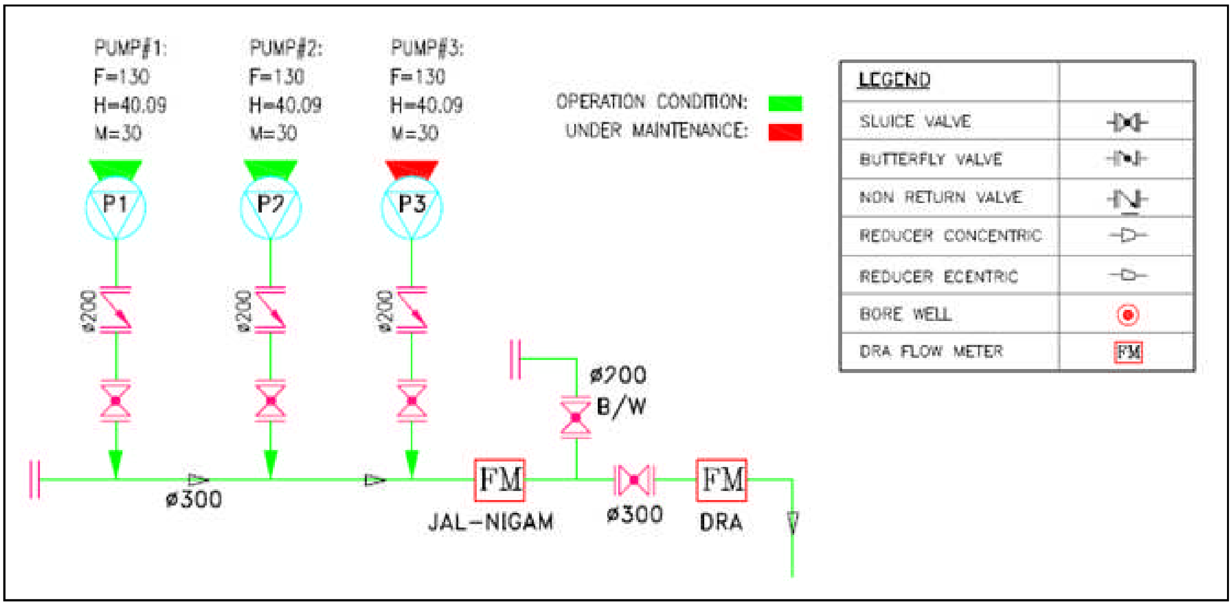


Figure 233P & ID diagram for Kedar Nagar ZPS

4.20.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 162: General details of Kedar Nagar ZPS

Data	Value / Details
Name of site	Kedar Nagar ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	3
No. of pumps in operation	2
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Kedarnagar ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 234 Photographs of Kedar Nagar ZPS

Table 163: Performance Evaluation of pumps at Kedar Nagar ZPS

	Unit	Kedar Nagar	Kedar Nagar
Parameters		Pump-1	Pump-2
Pump make		WPIL	WPIL
Motor make		Jyoti	Jyoti
Pump type		VT	VT
Motor serial no.		NA	M01010043
Pump serial no.		4-1200	4-1200
Rated flow	m^3/h	130	130
Rated head	M	40.09	40.09
Rated motor	kW	30	30
Parameters measured			
Total suction head	M	-3.36	-2.84
Total discharge head	M	26	26
Average flow delivered	m^3/h	204.33	189.67
Motor input power	kW	26.28	26.40
Frequency	Hz	50.03	50.02
Speed	RPM	1477.67	1480.67
Performance evaluation			
Total head developed	M	29.36	28.84
Head utilization	%	73%	72%
Flow utilization	%	157%	146%
Hydraulic power kW	kW	16.34	14.89

Parameters	Unit	Kedar Nagar Pump-1	Kedar Nagar Pump-2
Motor input power	kW	26.28	26.40
Calculated pumpset efficiency	%	62.17%	56.43%
Rated motor efficiency	%	90.0%	90.0%
Calculated pump efficiency	%	69.08%	62.70%
Specific energy consumption	kWh/m³	0.129	0.139

Key Observations:

- Pump no. 3 was in breakdown condition for around 1 year at the time of audit.
- Pump set efficiencies of pumps 1 and 2 were observed to be 62.17% and 56.43% respectively. Both pumps were observed to be operating at around 70% of the rated head.
- There is heavy leakage from delivery sluice valve of pump no. 1.

4.20.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 164: Other auxiliary equipment at Kedar Nagar ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	500
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 165: Other electrical equipment at Kedar Nagar ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Kedar Nagar	Tubelight	7	0.04	12
	CFL	1	0.085	12

Table 166: Other electrical equipment at Kedar Nagar ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Exhaust Fan	4	0.2	6

4.20.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Kedar Nagar ZPS is provided in below table.

Table 167: Estimated annual energy consumption and water supply for Kedar Nagar ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Kedar Nagar	Pump-1	Only 1 pump operates	726	26.28	19,086
Kedar Nagar	Pump-2		1,312	26.40	34,635
	Total		**2,038**	**52.68**	**53,721**

4.21 Tajganj ZPS

4.21.1 Overview of existing systems

Tajganj ZPS receives treated water from the Jeoni Mandi WTP. A total of six pumps are installed here and water is supplied into distribution.

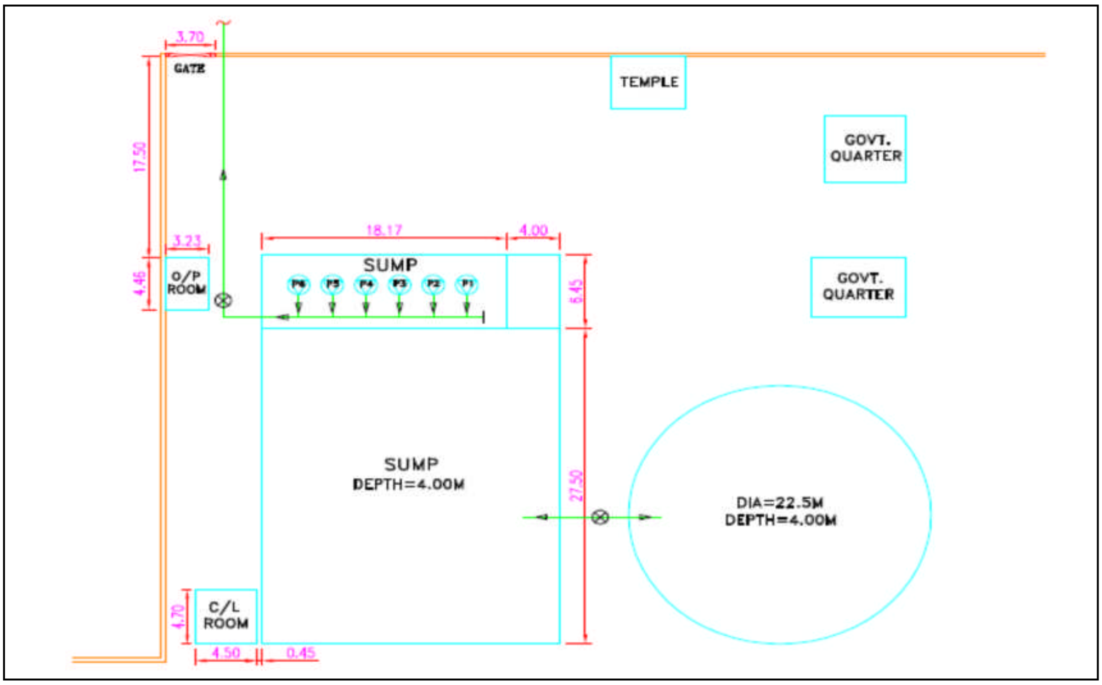


Figure 235 Plant Layout for Tajganj ZPS

4.21.2 Electricity Supply

Tajganj receives supply at 11 kV level from Torrent Power. This is stepped down to 440V level through a 500 kVA transformer to feed the motors.

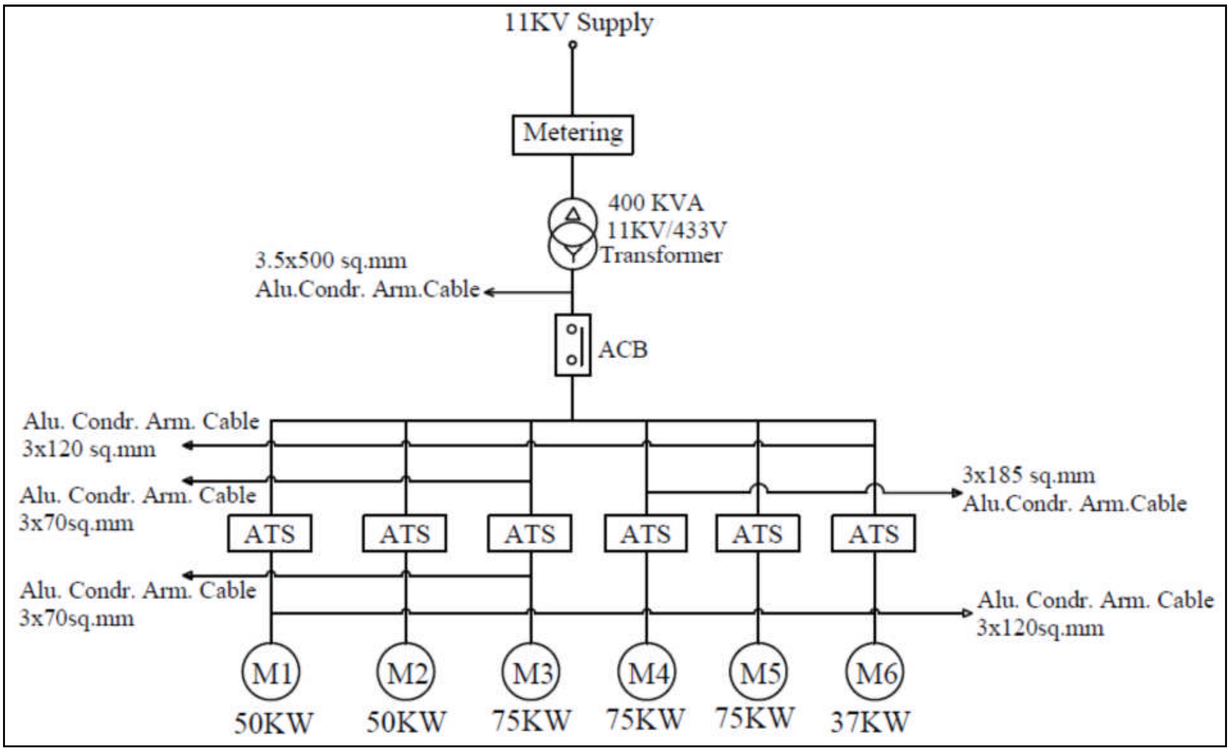


Figure 236 Single line diagram for the Tajganj ZPS

4.21.3 Tariff Structure

The electrical connection for Tajganj ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 168: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Tajganj Energy Meter (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

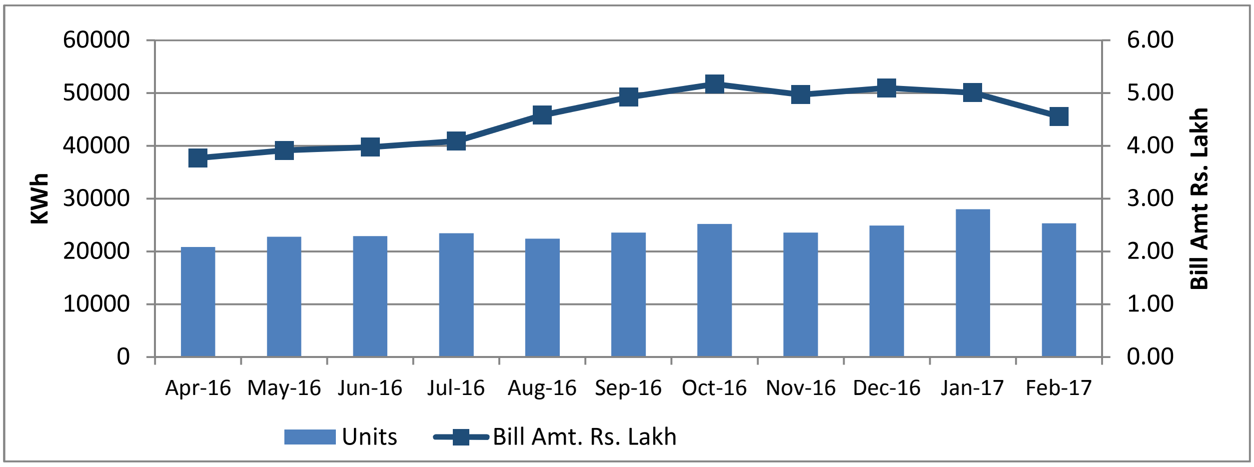
4.21.4 Electricity Bill Analysis

Table 169: Energy cost and energy consumption detail for Tajganj ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Feb-15	Not Available	NA	Not Available
Apr-15 to Feb-16	Not Available	NA	Not Available
Apr-16 to Feb-17	286,791	NA	5,456,352

- It is observed that the recorded demand has consistently exceeded the contract demand – it has been consistently observed to be more than thrice the contract demand. As a result, 'Excess demand charges' have been levied in addition to the regular demand charges every month.

Figure 237: Monthly electricity consumption and electricity bill for Tajganj ZPS



4.21.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at Tajganj ZPS is provided in below table.

Table 170: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 400 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

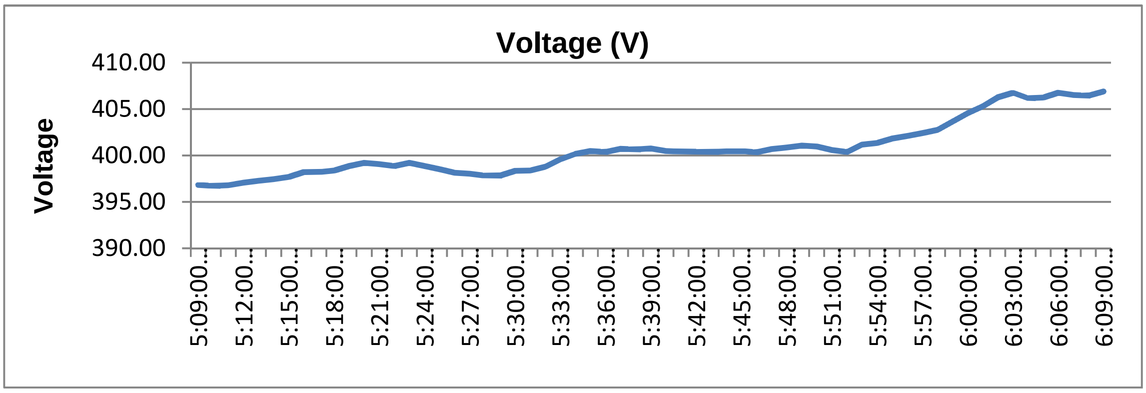


Figure 238: Voltage Variation at Tajganj ZPS

- The recorded voltage was observed to vary between 396V and 407V.

Power consumption and Apparent power Profile:

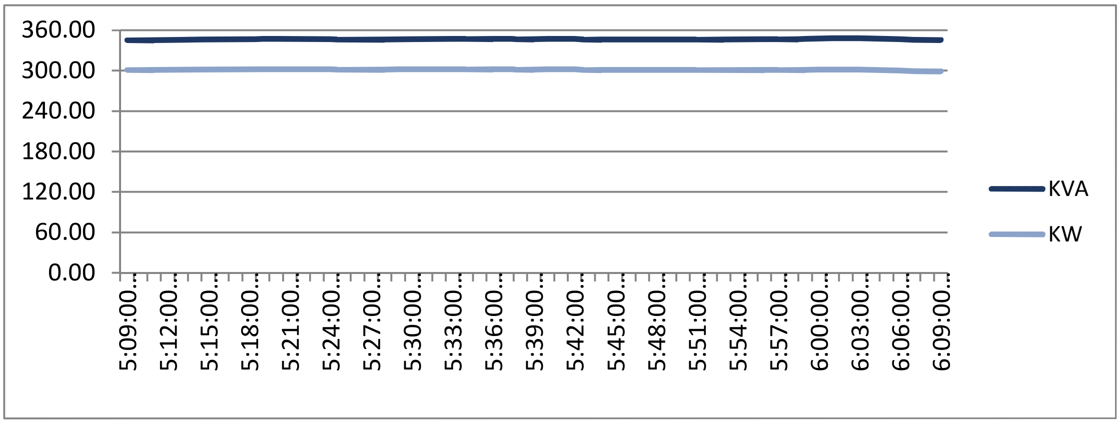


Figure 239: Power consumption variation at Tajganj ZPS

- The power consumption observed with five pumps in operation was around 300 kW.
- The apparent power observed with five pumps in operation was around 340-350 kVA.

Power factor profile

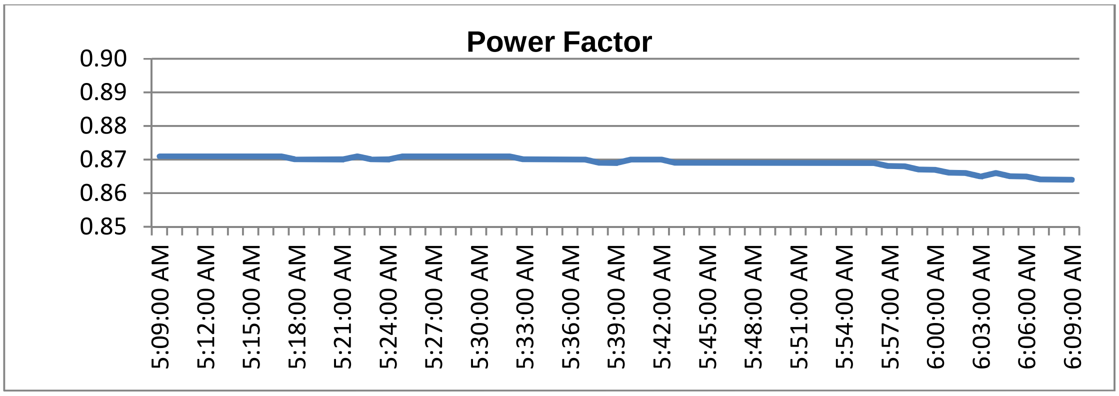


Figure 240: Power factor variation profile at Tajganj ZPS

- The power factor was observed to be around 0.86-0.87.

Frequency Profile:

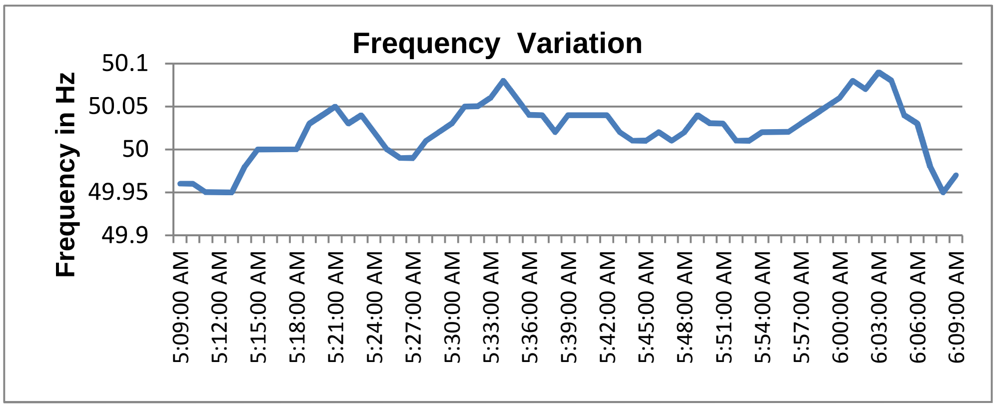


Figure 241: Frequency variation at Tajganj ZPS

- The frequency was observed to vary between 49.95 and 50.1 Hz.

Total Harmonics distortion (THD) - Current:

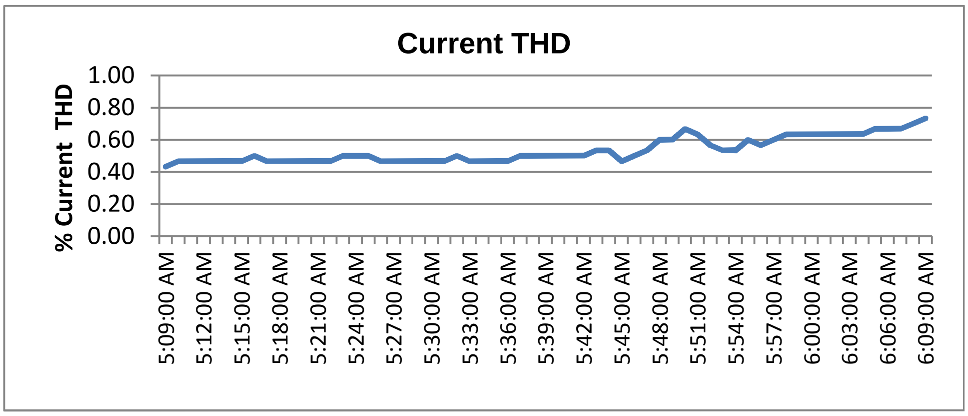


Figure 242: Variation of THD in current at Tajganj ZPS

- The current THD was found to be less than 1%.

Total Harmonics distortion - Voltage:

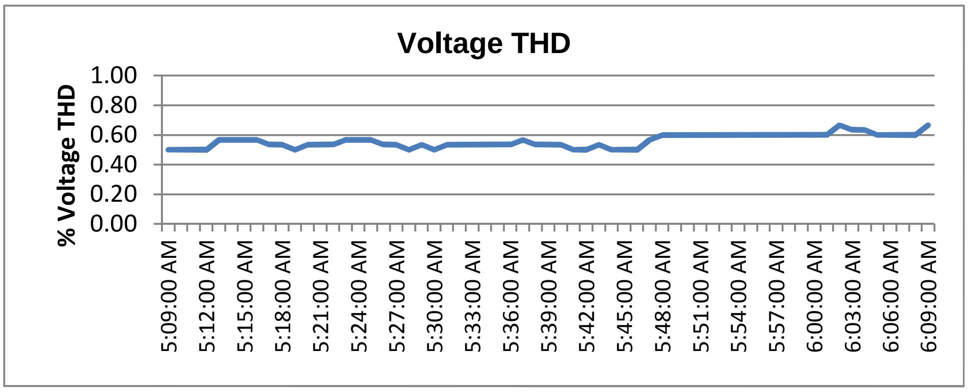


Figure 243: Variation in THD - voltage at Tajganj ZPS

- The voltage THD was found to be less than 1%.

Transformer loading:

Based on the kVA measured during energy audit, average transformer loading of the 400 kVA transformer was calculated and same is provided below.

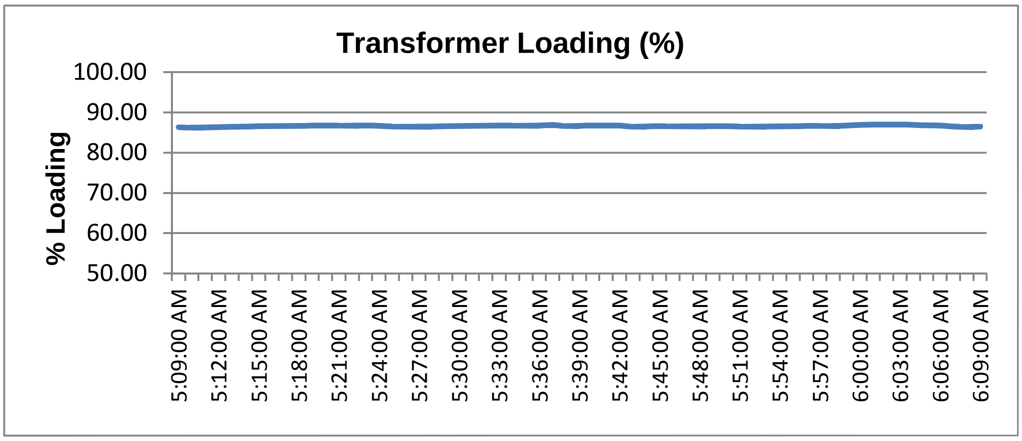


Figure 244: Transformer loadingat Tajganj ZPS

- The transformer loading is found to be around 85-87% during operation of five pumps.

4.21.6 Pumping Station System Mapping

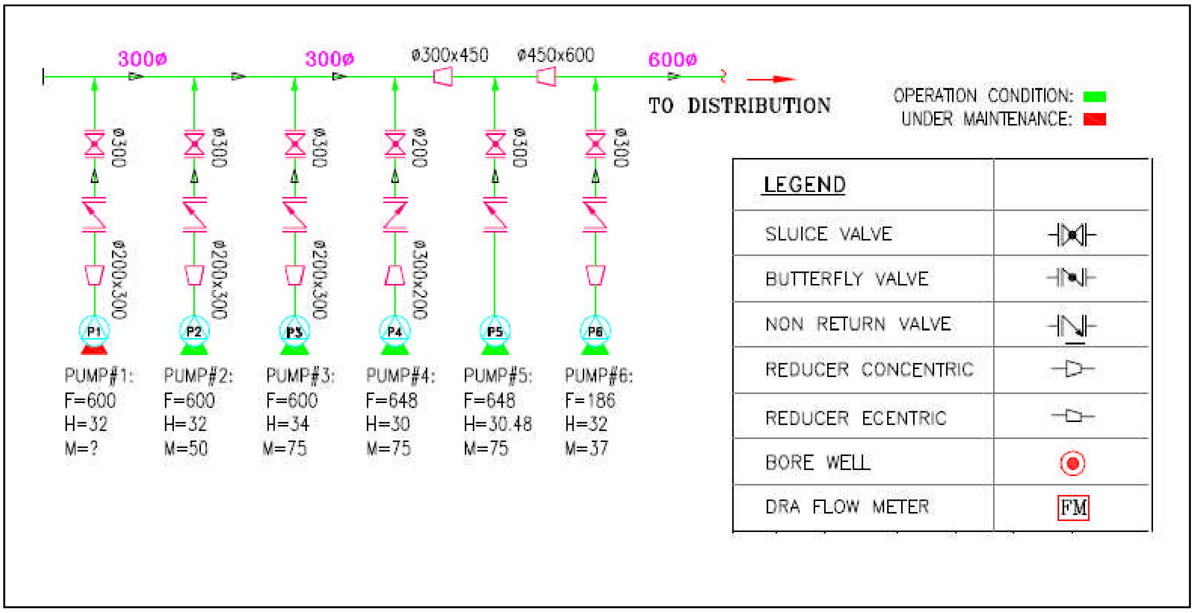


Figure 245: P & ID diagram for Tajganj ZPS

4.21.7 Pumps Performance Evaluation

As per the methodology described in section - 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 171: General details of Tajganj ZPS

Data	Value / Details
Name of site	Tajganj ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	6
No. of pumps in operation	5
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Tajganj ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed

Figure 246: Photographs of Tajganj ZPS

Flow measurement for individual pumps was not possible due to site constraints.

Table 172: Parallel pumping at Tajganj ZPS

Location		Tajganj ZPS
Parameters measured		2,3,4,5,6
Total suction head	m	-2.97
Total discharge head	m	13
Total flow	m^3/h	2942.33
Motor input power	kW	280.77
Performance evaluation		
Total head developed	m	15.97
Head utilization		47%
Flow utilization		110%
Hydraulic power developed by pump	kW	127.94
Motor input kW	kW	280.77
Calculated overall efficiency		45.57%
Motor efficiency		91.5%
Calculated pump efficiency		49.8%
Specific energy consumption	kWh/m^3	95.42

Key Observations:

- The combined efficiency during parallel pumping was observed to be 45.57%. The operating head of the pumps was found to be much less than the rated head.

4.21.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 173: Other auxiliary equipment at Tajganj ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	400
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 174: Other electrical equipment at Tajganj ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Tajganj	Tubelight	2	0.004	24
	Sodium Vapour	1	0.15	12

Table 175: Other electrical equipment at Tajganj ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Ceiling Fan	1	0.07	8

4.21.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Tajganj ZPS is provided in below table.

Table 176: Estimated annual energy consumption for Tajganj ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Tajganj ZPS	Pump-2	2,3,4,5&6 in parallel for direct distribution. 1 is under breakdown	687	46.38	31,854
Tajganj ZPS	Pump-3		738	70.70	52,205
Tajganj ZPS	Pump-4		741	73.44	54,404
Tajganj ZPS	Pump-5		741	70.72	52,392
	Total		**2,907**	**261.24**	**190,855**

4.22 Rakabganj ZPS

4.22.1 Overview of existing systems

Rakabganj ZPS receives treated water from Jeoni Mandi WTP. Five pumps are installed here. Both direct distribution and ESR filling are performed at different times.

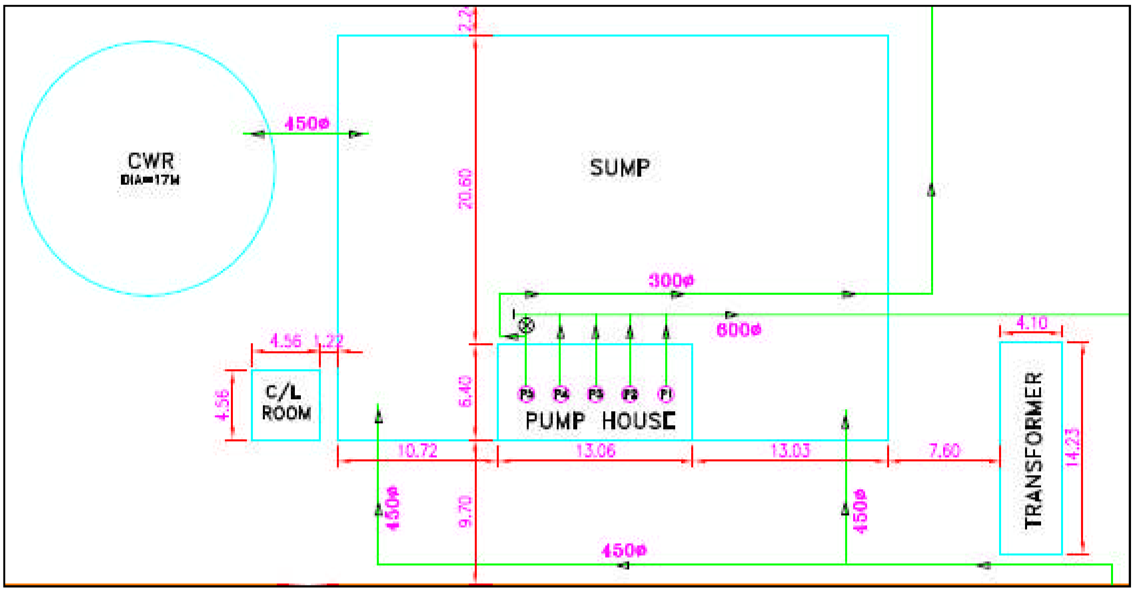


Figure 247: Plant Layout for Rakabganj ZPS

4.22.2 Electricity Supply

Rakabganj ZPS receives supply at 11 kV from Torrent Power. This is stepped down via a 315 kVA transformer to 440V level to feed the motors.

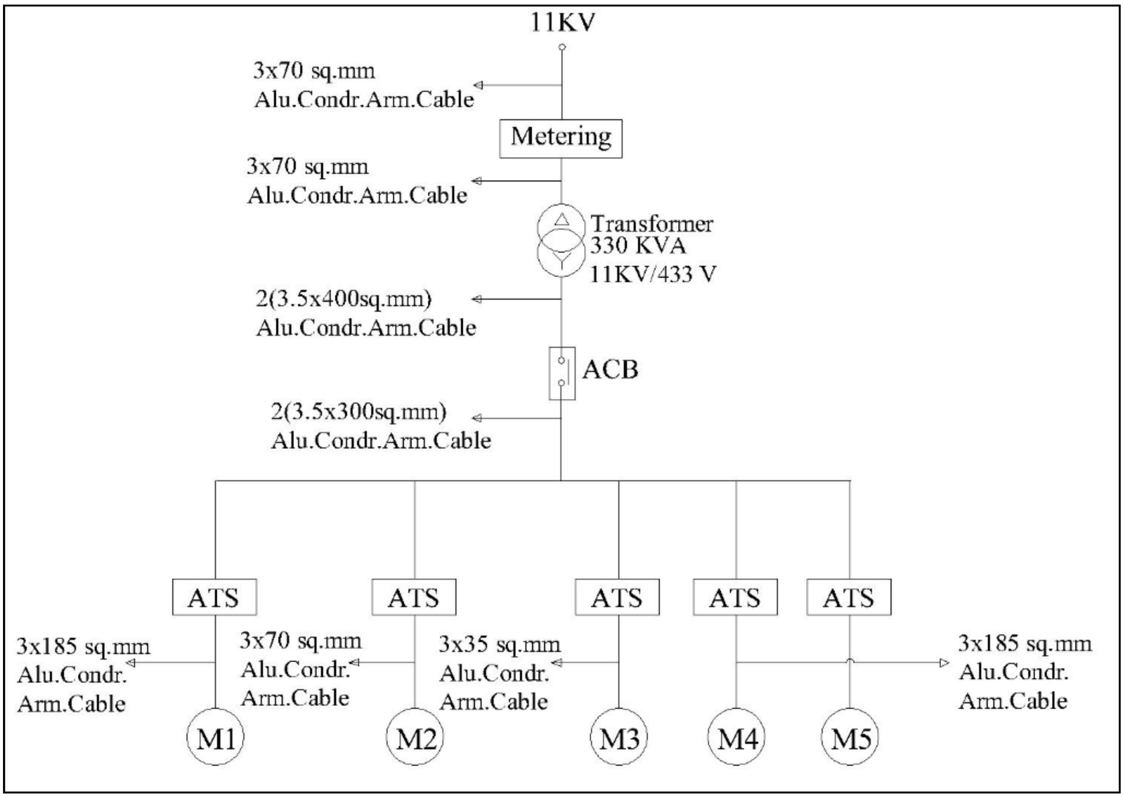


Figure 248: Single line diagram for the Rakabganj ZPS

4.22.3 Tariff Structure

The electrical connection for Rakabganj ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 177: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Rakabganj Energy Meter-1 (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

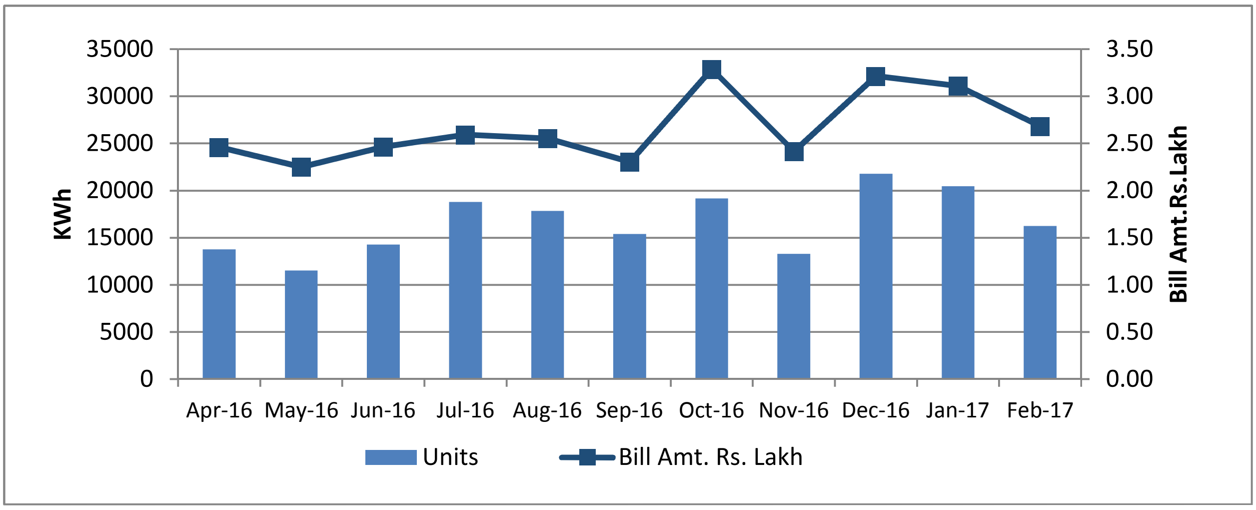
4.22.4 Electricity Bill Analysis

Table 178: Energy cost and energy consumption detail for Rakabganj ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase from previous year	Energy cost (Rs./y)
Apr-14 to Mar-15	184,246		2,663,607
Apr-15 to Mar-16	196,523	6.7%	3,735,095
Apr-16 to Mar-17	199,119	1.3%	3,200,320

- The power factor is consistently observed to be poor at less than 0.8. Improving the power factor will lead to reduction in kVA demand as well as kVAh consumption, leading to savings.

Figure 249: Monthly electricity consumption and electricity bill for Rakabganj ZPS



4.22.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on transformer LT sidefor recording variation of electrical parameters. Details about transformers installed at Rakabganj ZPS is provided in below table.

Table 179: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 400 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

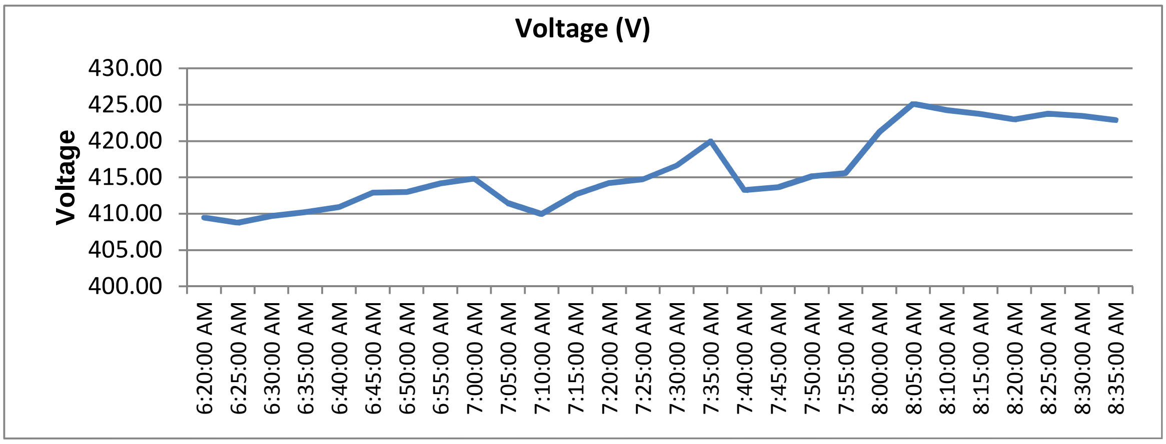


Figure 250: Voltage Variation at Rakabganj

- The recorded voltage was found to vary between 408 and 425V.

Power consumption and Apparent power Profile:

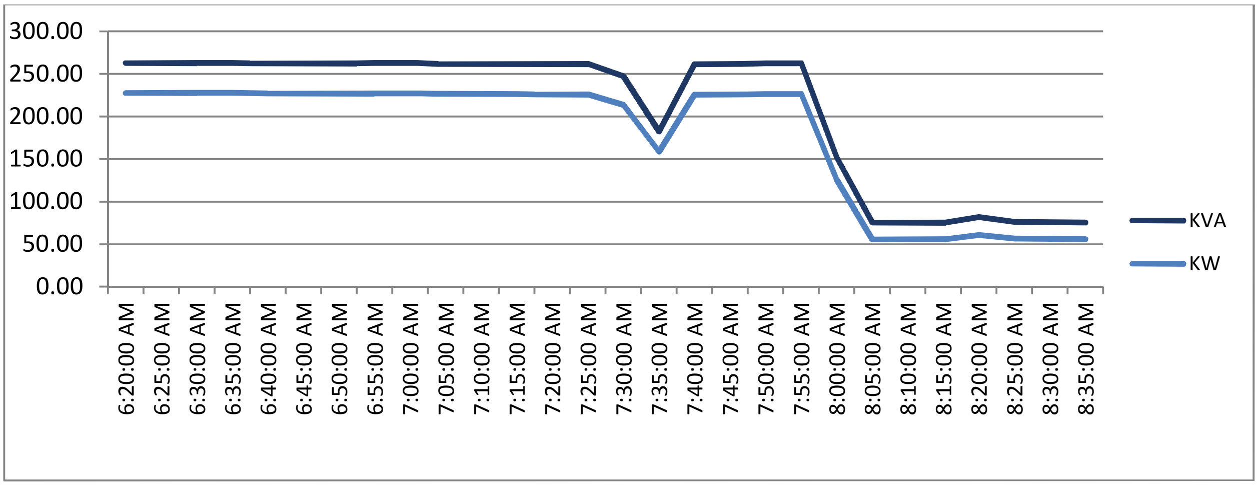


Figure 251: Power consumption variation at Rakabganj

- Power consumption during operation of three pumps was found to be around 220-230 kW. During operation of single pump (8:05 onwards), the consumption was found to be around 55-60kW.
- Apparent power during operation of three pumps was found to be around 260-270 kVA. During operation of single pump (8:05 onwards), the consumption was found to be around 75-80kVA.

Power factor profile

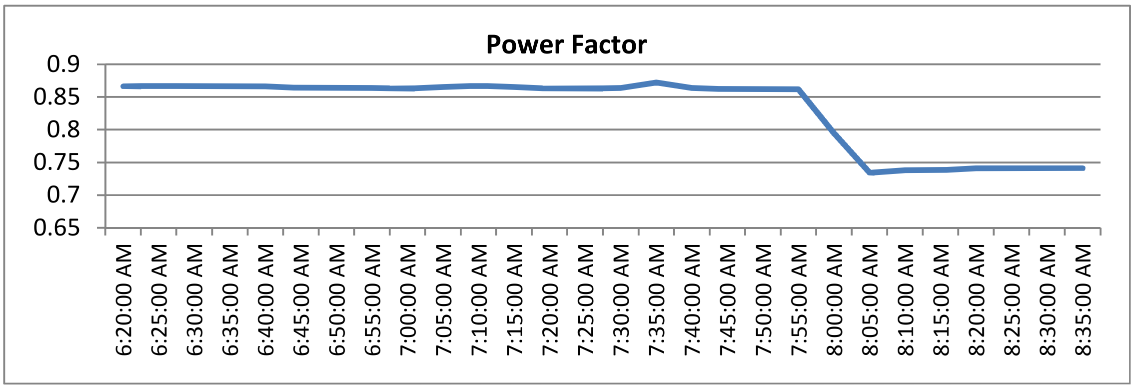


Figure 252: Power factor variation profile at Rakabganj

- The power factor was observed to be around 0.86-0.87 with three pumps in operation, dropping to below 0.75 during operation o single pump.

Frequency Profile:

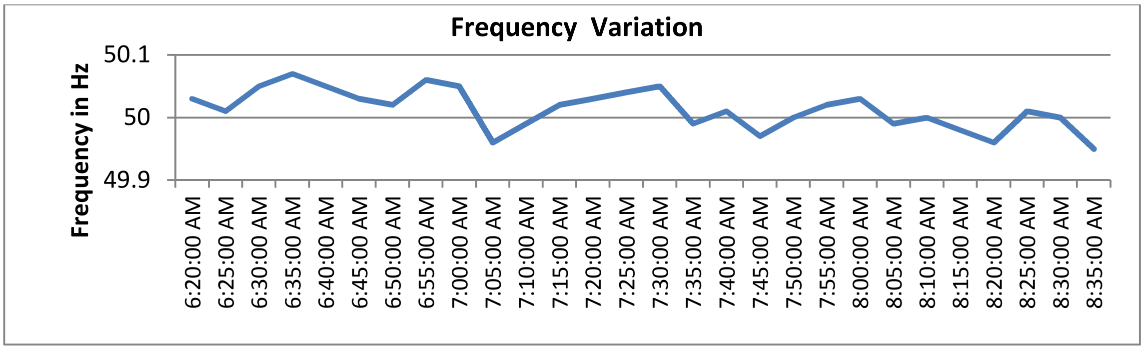


Figure 253: Frequency variation at Rakabganj

- The frequency was observed to vary between 49.95 and 50.07 Hz.

Total Harmonics distortion (THD) - Current:

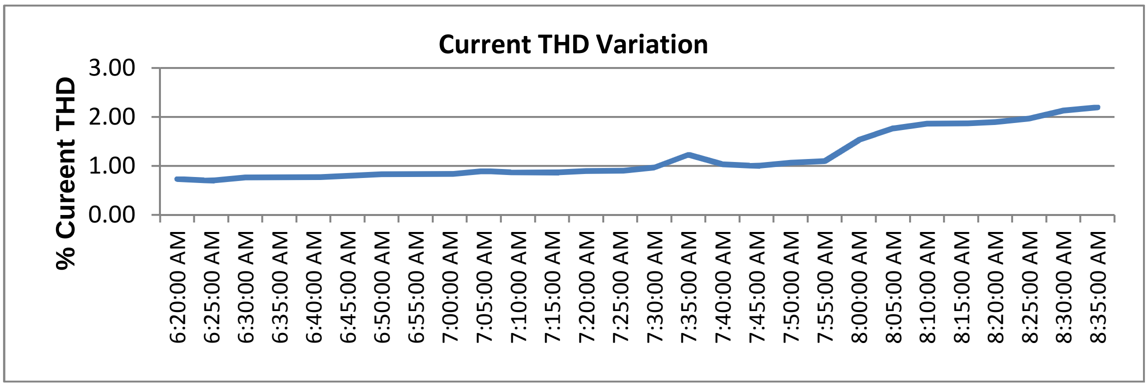


Figure 254: Variation of THD in current at Rakabganj

- The current THD was found to be around 0.7-1.3% during parallel operation of three pumps. It was observed to rise from around 1.6% to around 2.2% during operation of single pump.

Total Harmonics distortion - Voltage:

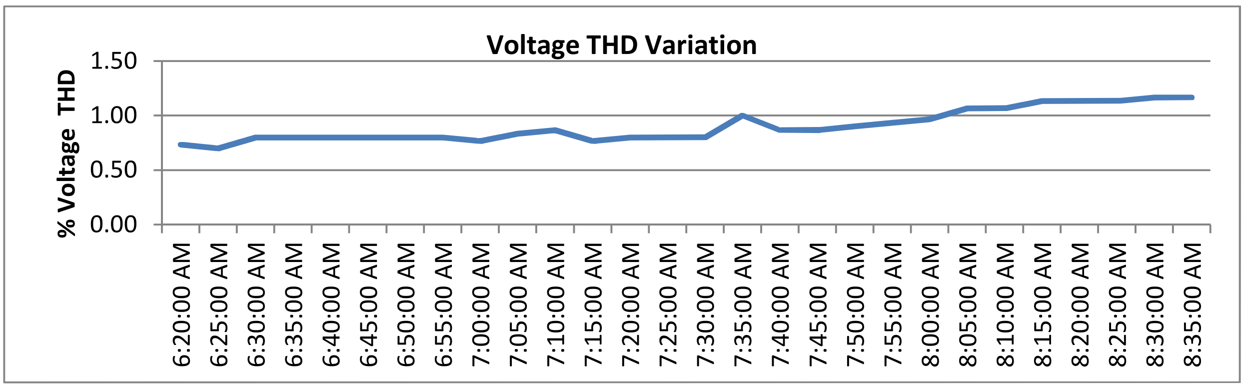


Figure 255: Variation in THD - voltage at Rakabganj

- Voltage THD was observed to be less than 1% during operation of three pumps, rising to around 1.2% during operation of single pump.

Transformer loading:

Based on the kVA measurement done during energy audit, average transformer loading for the 315 kVA transformer was calculated and same is provided below.

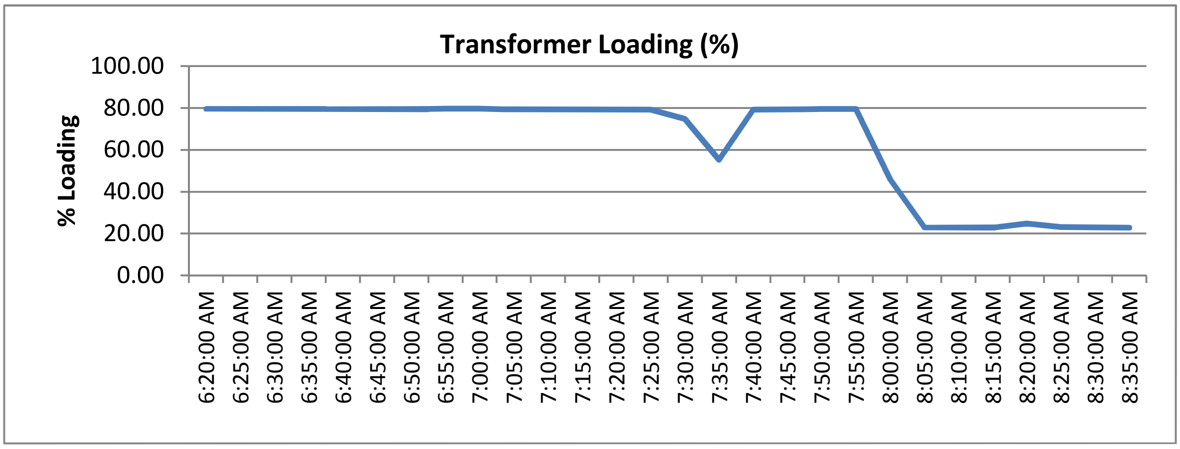


Figure 256: Transformer loadingat Rakabganj

- Loading on transformer is found to be close to 80% during operation of three pumps.

4.22.6 Pumping Station System Mapping

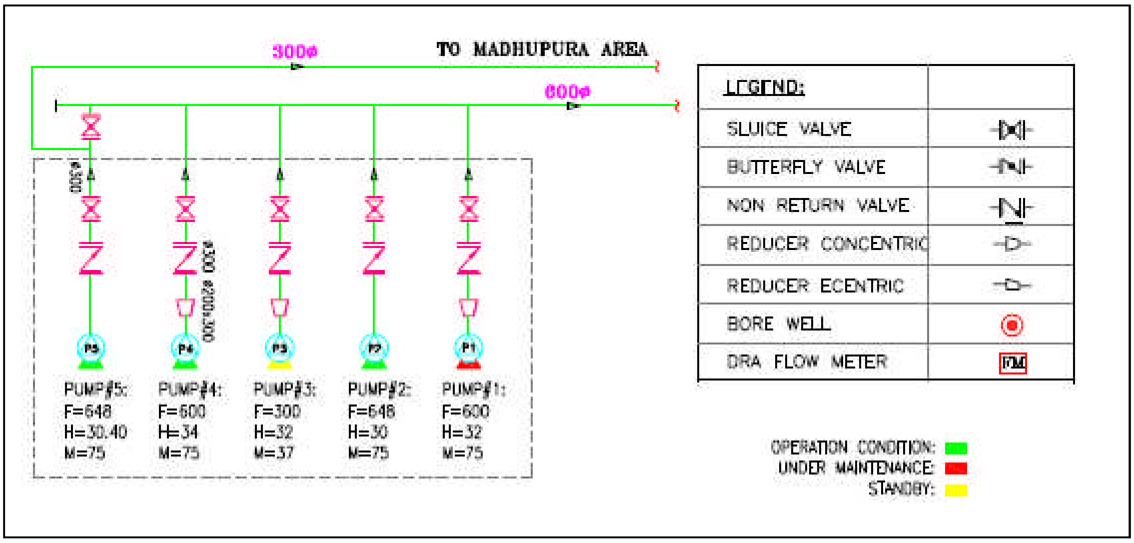


Figure 257: P & ID diagram for Rakabganj

4.22.7 Pumps Performance Evaluation

As per the methodology described in section – 1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 180: General details of Rakabganj ZPS

Data	Value / Details
Name of site	Rakabganj ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	5
No. of pumps in operation	4
No. of pumps under maintenance	1
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Rakabganj ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 258: Photographs of Rakabganj ZPS

Table 181: Performance Evaluation of pumps at Rakabganj

	Unit	Rakabganj ZPS	Rakabganj ZPS	Rakabganj ZPS
Parameters		Pump-2	Pump-4	Pump-5
Pump make		Fairbanks	Kirloskar	Jyoti
Motor make		Kirloskar	Jyoti	Jyoti
Pump type		VT	VT	VT
Motor serial no.		29704035-4	M05150078	NA
Pump serial no.		16H	BHR3	B400D2F
Rated flow	m^3/h	648	600	648
Rated head	m	30	34	30.4

Parameters	Unit	Rakabganj ZPS Pump-2	Rakabganj ZPS Pump-4	Rakabganj ZPS Pump-5
Rated motor	kW	75	75	75
Parameters measured				
Total suction head	m	-3.07	-4.06	-2.07
Total discharge head	m	2	18	16
Average flow delivered	m^3/h	792.00	529.37	704.47
Motor input power	kW	76.72	66.87	70.34
Frequency	Hz	49.92	49.96	50.04
Speed	RPM	1473.33	1488.00	1475.33
Performance evaluation				
Total head developed	m	5.07	22.06	18.07
Head utilization	%	17%	65%	59%
Flow utilization	%	122%	88%	109%
Hydraulic power kW	kW	10.94	31.81	34.67
Motor input power	kW	76.72	66.87	70.34
Calculated pumpset efficiency	%	14.26%	47.56%	49.30%
Rated motor efficiency	%	94.0%	91.5%	91.5%
Calculated pump efficiency	%	15.17%	51.98%	53.88%
Specific energy consumption	kWh/m^3	0.097	0.126	0.100

Key Observations:

- Pump set efficiency of pump no. 2 was found to be 14.26%, with the pump operating significantly below the rated head. Pumps 4 and 5 were observed to have pump set efficiencies of 47.56% and 49.3%, and operating head of both was less than 70% of the rated head.
- Top of sump had collapsed and at present, temporary arrangement for covering of sump has been made using nets and corrugated plastic sheets.
- NRV of pump no. 2 was not in working condition.

4.22.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 182: Other auxiliary equipment at Rakabganj ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	315
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 183: Other electrical equipment at Old Rakabganj ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Rakabganj	CFL	2	0.014	24

Table 184: Other electrical equipment at Rakabganj ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Exhaust Fan	1	0.2	24

4.22.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Rakabganj ZPS is provided in below table.

Table 185: Estimated energy consumption for Rakabganj ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Rakabganj ZPS	Pump-2	2,4 in parallel. Separate line for 5.	700	76.72	53,741
Rakabganj ZPS	Pump-3		155	35.89	5,564
Rakabganj ZPS	Pump-4		764	66.87	51,112
Rakabganj ZPS	Pump-5		864	70.34	60,742
	Total		**2,483**	**249.82**	**171,159**

4.23 Navlakha ZPS

4.23.1 Overview of existing systems

Navlakha ZPS receives treated water from Jeoni Mandi WTP. Water is supplied from here to MES, Cantonment and Bindu Colony areas at different times. Pump no. 1 is dedicated for supply to MES, and its billing is also done by MES.

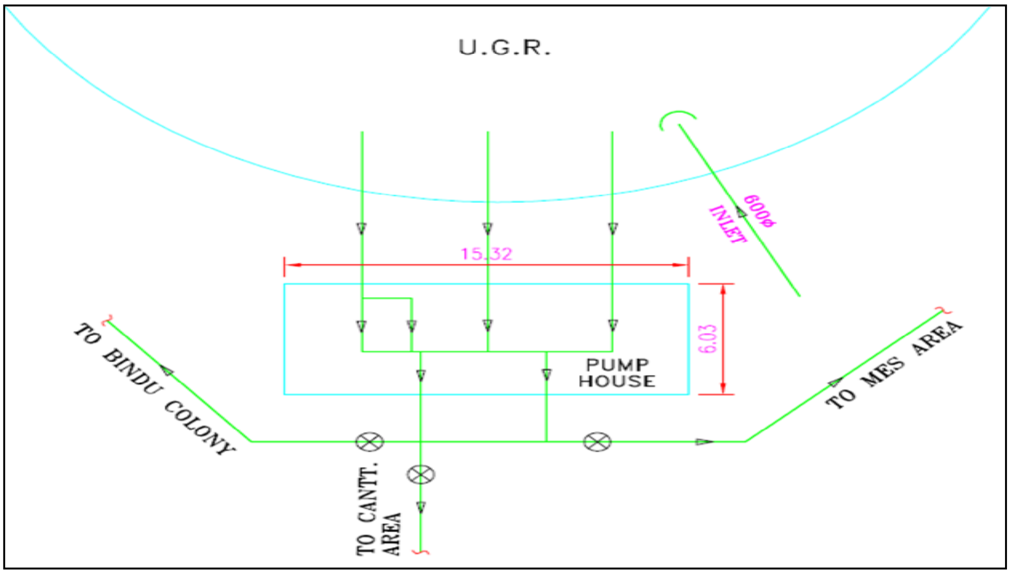


Figure 259: Plant Layout for Navlakha ZPS

4.23.2 Electricity Supply

Navlakha ZPS receives supply at 11 kV level from Torrent Power.This is stepped down to 433V level via a 315 kVA transformer to feed the motors.

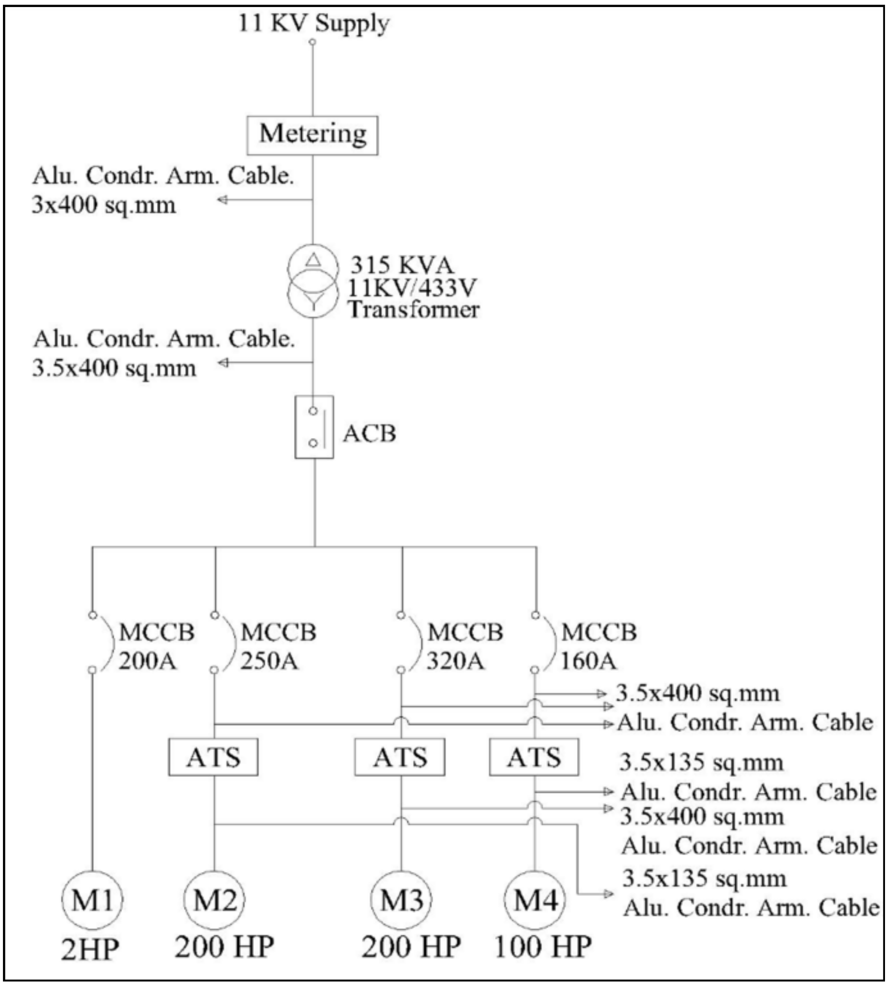


Figure 260 Single line diagram for the Navlakha ZPS

4.23.3 Tariff Structure

The electrical connection for Navlakha ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 186: Tariff structure (From DVVNL FY 2016-17 Tariff order)

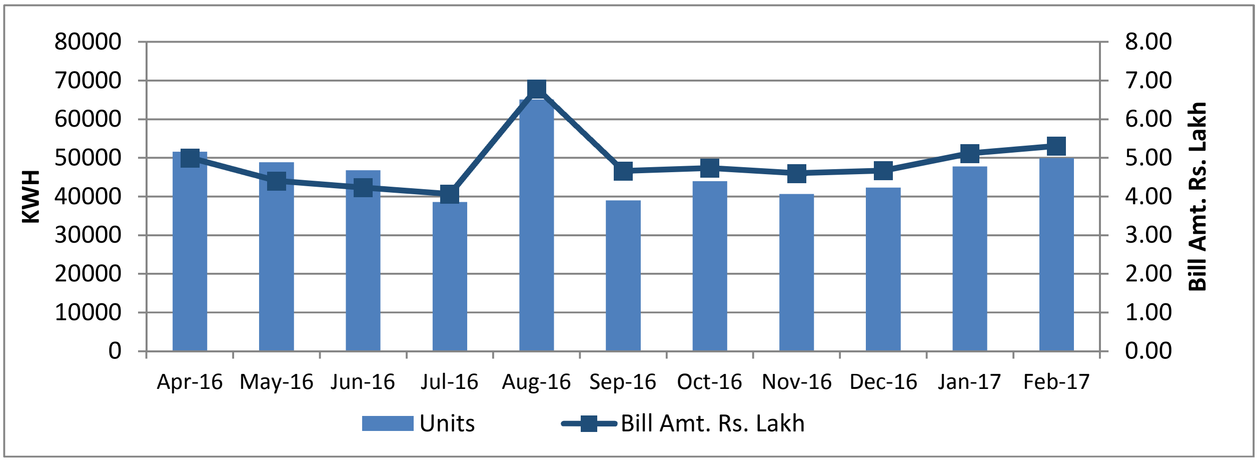
Description	Navlakha ZPS Energy Meter-1 (HT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.23.4 Electricity Bill Analysis

Table 187: Energy cost and energy consumption detail for Navlakha ZPS

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	575,612		5,195,923
Apr-15 to Mar-16	729,693	26.8%	7,933,405
Apr-16 to Mar-17	561,593	-23.0%	5,848,279

Figure 261: Monthly electricity consumption and electricity bill for Navlakha ZPS



4.23.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed ontransformer LT side for recording variation of electrical parameters. Details about transformers installed at Navlakha ZPS is provided in below table.

Table 188: Details of Transformers

Main Incomers	Details of Transformer	Connected load
Main Incomer	Transformer-1 315 kVA, 11/0.433 kV)	All pump sets

Voltage Profile:

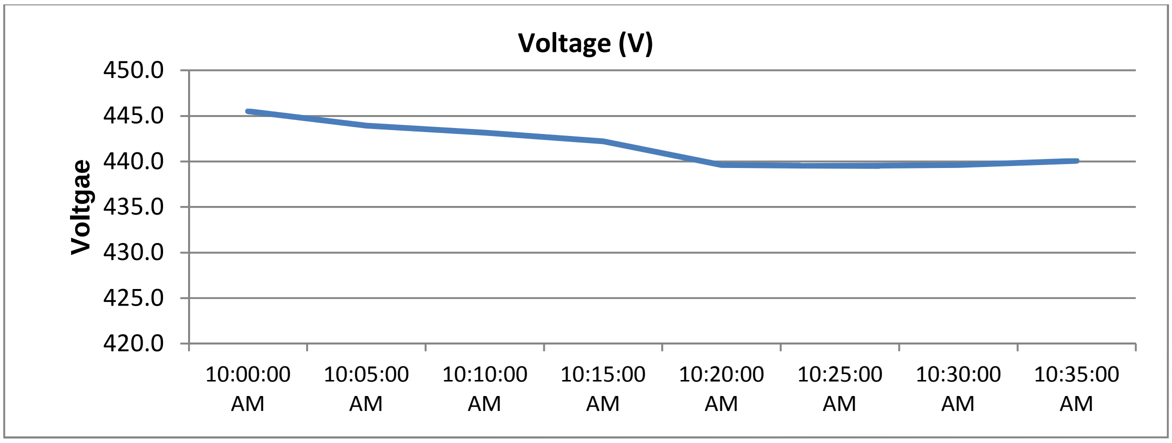


Figure 262: Voltage Variation at Navlakha ZPS

- The recorded voltage was observed to vary between 439 and 446V.

Power consumption and Apparent power Profile:

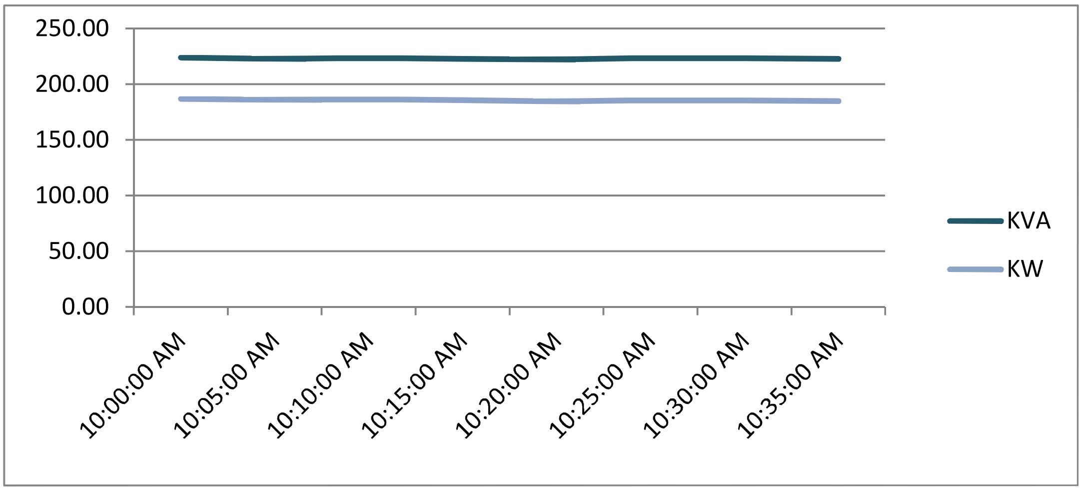


Figure 263: Power consumption variation at Navlakha ZPS

- Power consumption during operation of two pumps was observed to be around 185-190 kW.
- Apparent power during operation of two pumps was observed to be around 220-230 kVA.

Power factor profile

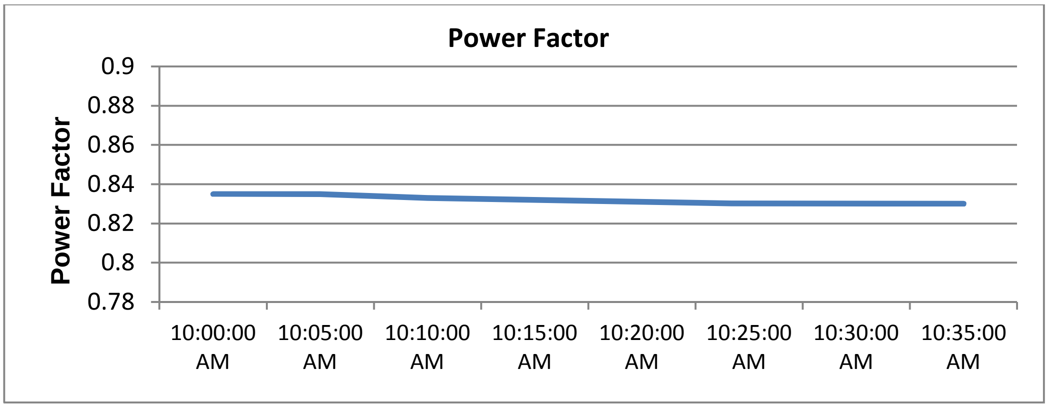


Figure 264: Power factor variation profile at Navlakha ZPS

- The observed power factor was found to be around 0.83-0.84.

Frequency Profile:

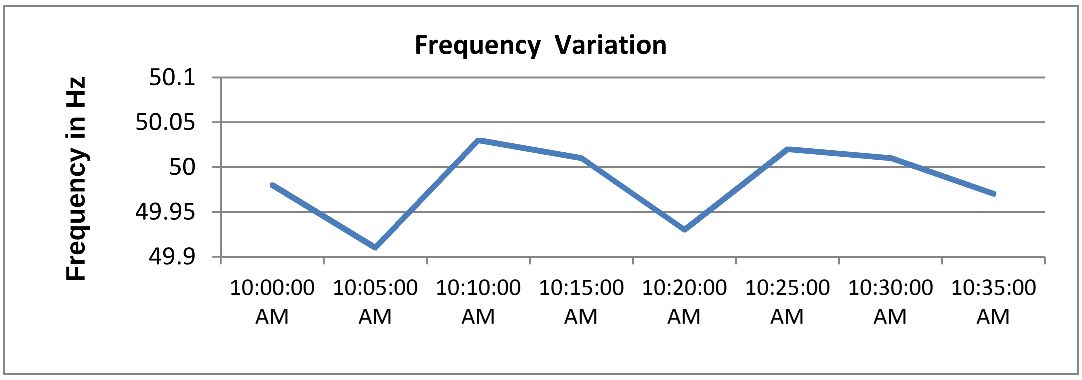


Figure 265: Frequency variation at Navlakha ZPS

- The frequency was observed to vary between 49.9 and 50.03 Hz.

Total Harmonics distortion (THD) - Current:

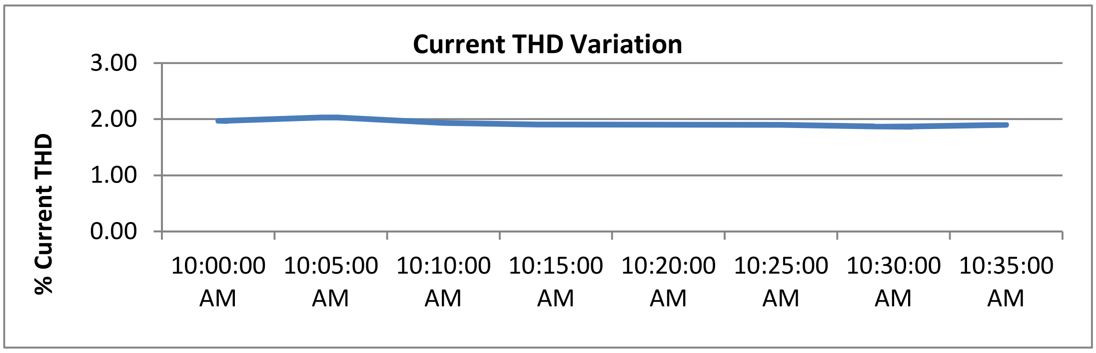


Figure 266: Variation of THD in current at Navlakha ZPS

- The observed current THD was around 1.9-2%.

Total Harmonics distortion - Voltage:

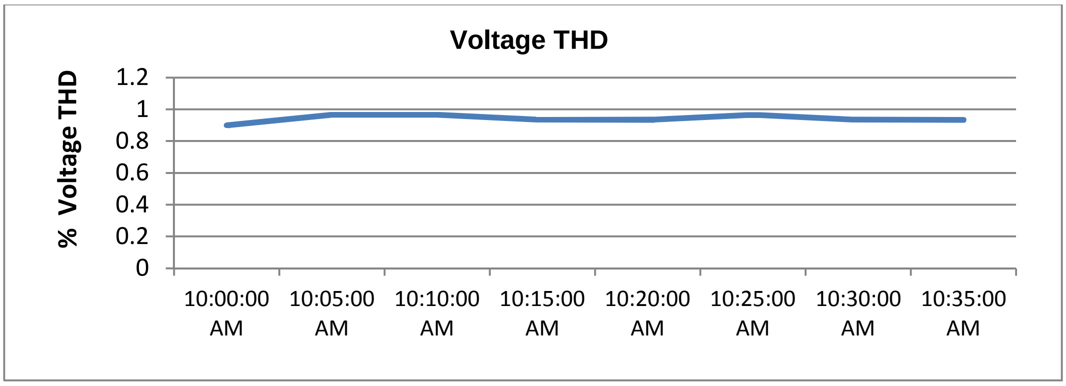


Figure 267: Variation in THD - voltage at Navlakha ZPS

- The observed voltage THD was around 0.9-1%.

Transformer loading:

Based on the kVA measurement done during energy audit, average transformer loading for the 315 kVA transformer was calculated and same is provided below.

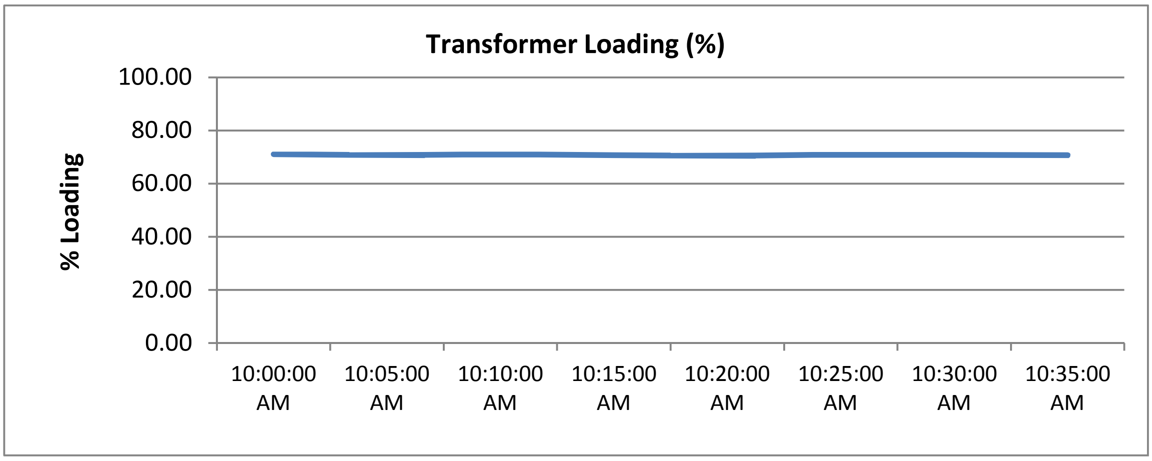


Figure 268: Transformer loadingat Navlakha ZPS

- Transformer loading during operation of two pumps was found to be around 70%.

4.23.6 Pumping Station System Mapping

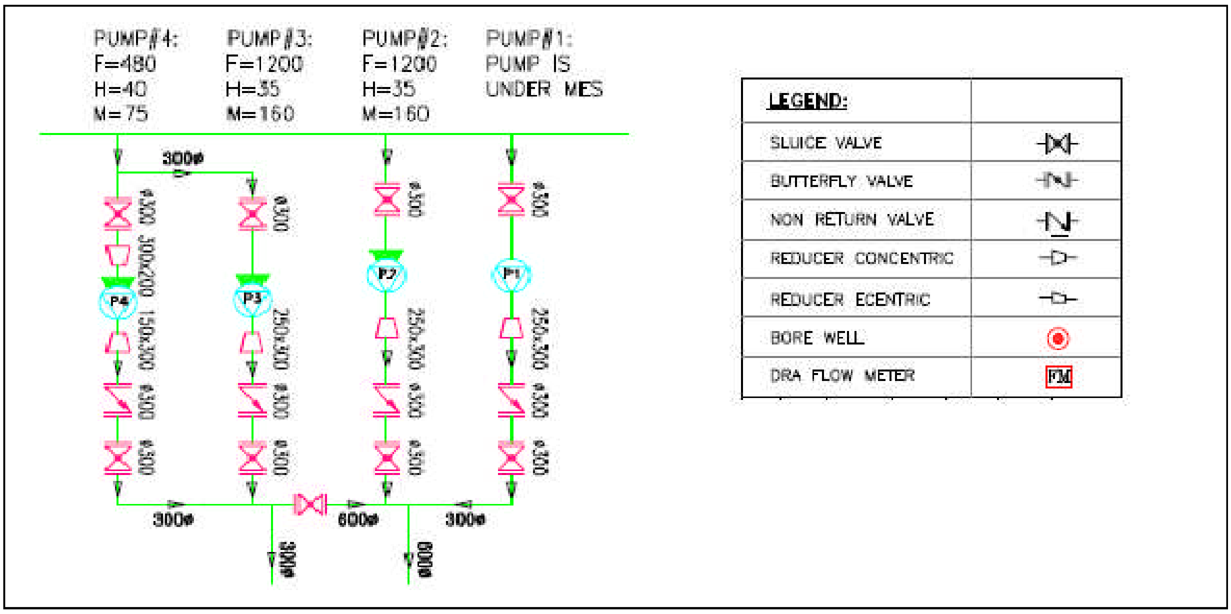


Figure 269 P & ID diagram for Navlakha ZPS

4.23.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 189: General details of Navlakha ZPS

Data	Value / Details
Name of site	Navlakha ZPS
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Zonal Pumping station/Water distribution station
Pumps installed	4
No. of pumps in operation	4
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Navlakha ZPS to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 270 Photographs of Navlakha ZPS

Table 190: Performance Evaluation of pumps at Navlakha ZPS

Parameters	Unit	Navlakha ZPS Pump-2	Navlakha ZPS Pump-3	Navlakha ZPS Pump-4
Pump make		Kirloskar	Kirloskar	Mather & Platt
Motor make		Crompton Greaves	Crompton Greaves	Jyoti
Pump type		HSC	HSC	HSC
Motor serial no.		NA	NA	1067
Pump serial no.		NA	NA	6/8-BLE
Rated flow	m^3/h	1200	1200	480
Rated head	m	35	35	40
Rated motor	kW	160	160	75
Parameters measured				
Total suction head	m	2.53	1.43	0.43
Total discharge head	m	34	37	36
Average flow delivered	m^3/h	995.17	783.63	460.43
Motor input power	kW	137.34	147.95	63.45
Frequency	Hz	50.05	49.98	50.04
Speed	RPM	1472.00	1487.00	1487.33
Performance evaluation				
Total head developed	m	31.47	35.57	35.57
Head utilization	%	90%	102%	89%
Flow utilization	%	83%	65%	96%
Hydraulic power kW	kW	85.29	75.91	44.60
Motor input power	kW	137.34	147.95	63.45
Calculated pumpset efficiency	%	62.10%	51.31%	70.29%

Parameters	Unit	Navlakha ZPS Pump-2	Navlakha ZPS Pump-3	Navlakha ZPS Pump-4
Rated motor efficiency	%	95.8%	95.8%	95.8%
Calculated pump efficiency	%	64.82%	53.56%	73.38%
Specific energy consumption	kWh/m³	138.01	188.80	137.80

Table 191: Parallel pumping at Navlakha ZPS

Location		Navlakha ZPS
Parameters measured		**2,4**
Total suction head	m	1.80
Total discharge head	m	34
Total flow	m^3/h	1467.93
Motor input power	kW	185.74
Performance evaluation		
Total head developed	m	32.20
Head utilization		81%
Flow utilization		87%
Hydraulic power developed by pump	kW	128.74
Motor input kW	kW	185.74
Calculated overall efficiency		69.31%
Motor efficiency		95.8%
Calculated pump efficiency		72.35%
Specific energy consumption	kWh/m^3	126.53

Key Observations:

- Water is supplied to MES, Cantonment and Bindu Colony areas at different times. Pump no. 1 is dedicated for supply to MES.
- The pump set efficiencies of pumps 2, 3 and 4 were found to be 62.10%, 51.31% and 70.29% respectively. The operating head of all three was found to be more than 80% of their rated head.
- The overall efficiency during parallel operation of pump nos. 2 and 4 was found to be 69.31%.
- NRV of all pumps is not in working condition. All valves were found to be jammed and leakage from them was observed.

4.23.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 192: Other auxiliary equipment at Navlakha ZPS - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	1
Capacity (kVA)	315
Primary/Secondary voltages	11kV/440V
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 193: Other electrical equipment at Navlakha ZPS - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
Navlakha	CFL	1	0.028	12
	Sodium Vapour	3	0.15	12
	Sodium Vapour (Pole)	3	0.15	12

Table 194: Other electrical equipment at Navlakha ZPS – auxiliary pumps and other loads

Others	Type of Equipment	No. of fittings	Rating (kW)	Average Operating hours per day
Auxiliary pumps and other loads	Exhaust	1	0.11	24

4.23.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Navlakha ZPS is provided in below table.

Table 195: Estimated annual energy consumption and water supply for Navlakha ZPS

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Navlakha ZPS	Pump-2	2&4 in parallel operation but have separate pipe	767	137.34	105,393
Navlakha ZPS	Pump-3		2,998	147.95	443,586
Navlakha ZPS	Pump-4		327	63.45	20,748
	Total		**4,092**	**348.74**	**569,727**

4.24 Chhipitola Booster

4.24.1 Overview of existing systems

Chhipitola pump station is used for in-line boosting of treated water from Jeoni Mandi WTP. It is used for feeding Chhipitola ESR. Two pumps are installed.

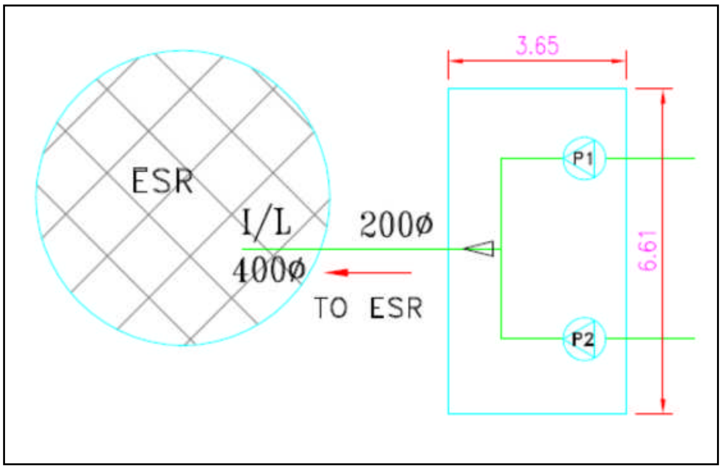


Figure 271: Plant Layout for Chhipitola Booster

4.24.2 Electricity Supply

Chhipitola booster receives supply at 440V from Torrent Power.

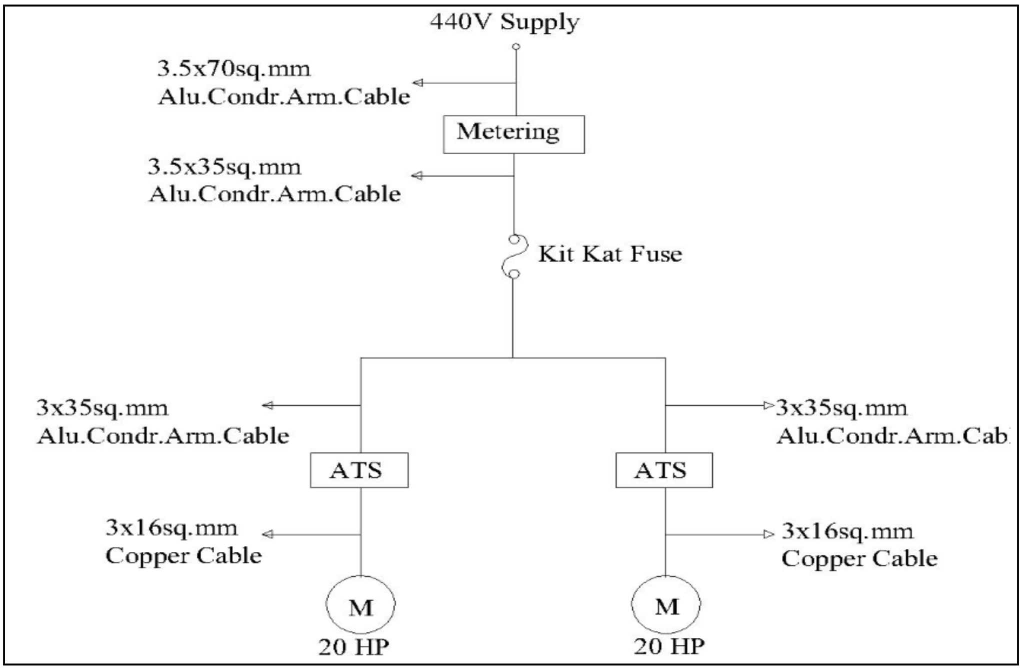


Figure 272: Single line diagram for the Chhipitola Booster

4.24.3 Tariff Structure

The electrical connection for Chhipitola ZPS is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 196: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Chhipitola Energy Meter (LT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

4.24.4 Electricity Bill Analysis

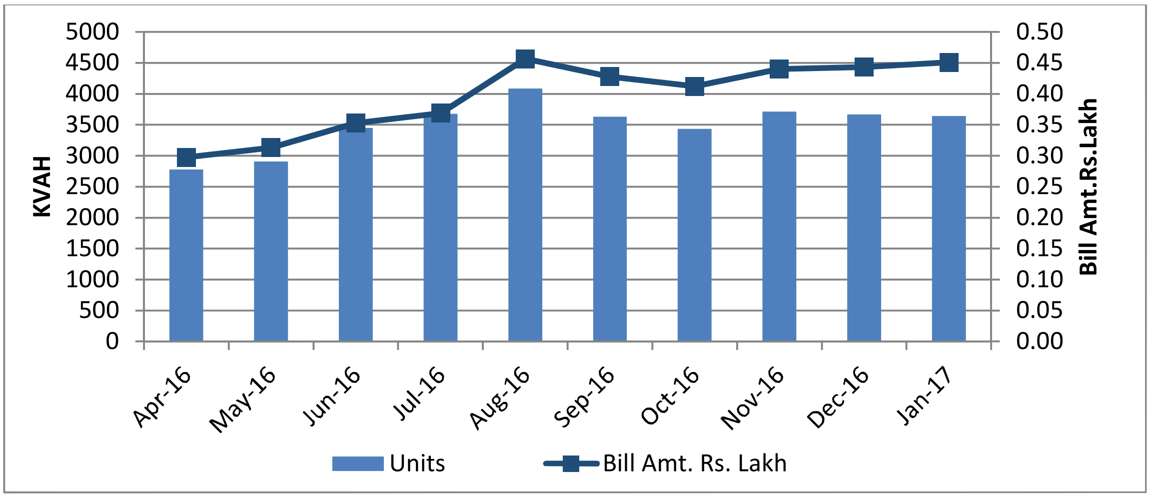
During energy audit, electricity bill data for last 3 years was collected from Municipal Corporation. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year is provided in below table.

Table 197: Energy cost and energy consumption detail for Chhipitola Booster

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	33,775		347,573
Apr-15 to Mar-16	31,906	-5.5%	375,842
Apr-16 to Mar-17	38,074	19.3%	475,609

- It is observed that the recorded demand has consistently exceeded the contract demand. As a result, ‘Excess demand charges’ have been levied in addition to the regular demand charges every month.

Figure 273: Monthly electricity consumption and electricity bill for Chhipitola Booster



4.24.5 Energy Consumption Pattern at Pumping Station

During energy audit, three phase power analyzer was installed on LT incomerfor recording variation of electrical parameters.

Pump 1 in operation:

Voltage Profile:

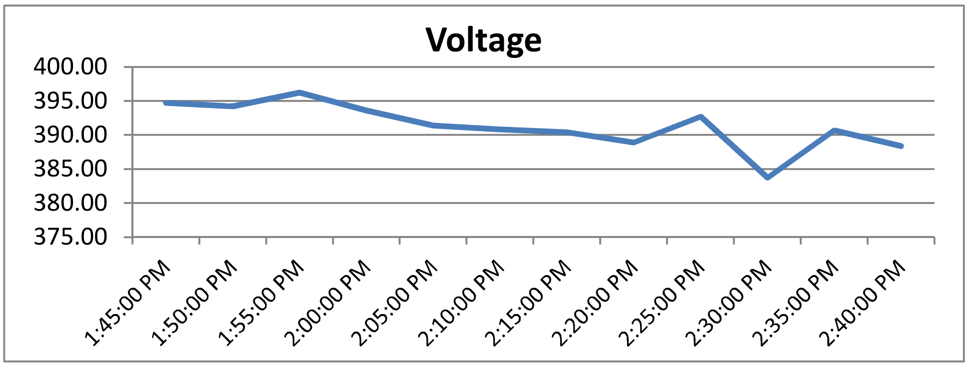


Figure 274: Voltage Variation during operation of pump-1

- Voltage is found to vary between 384 and 396V.

Power consumption and Apparent power Profile:

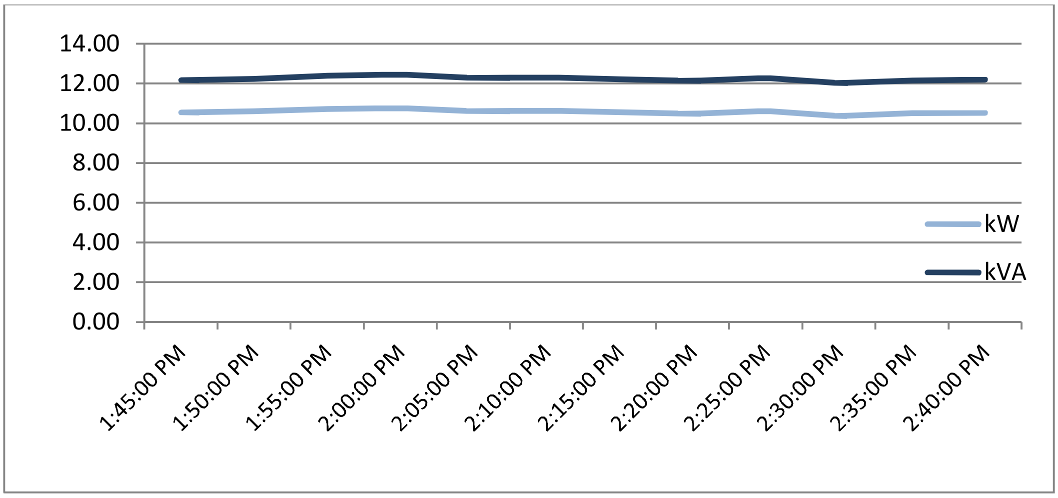


Figure 275: Power consumption variation during operation of pump-1

- Power consumption is observed to be around 10.4-10.7 kW.
- Apparent power is observed to be around 12-12.5 kVA.

Power factor profile

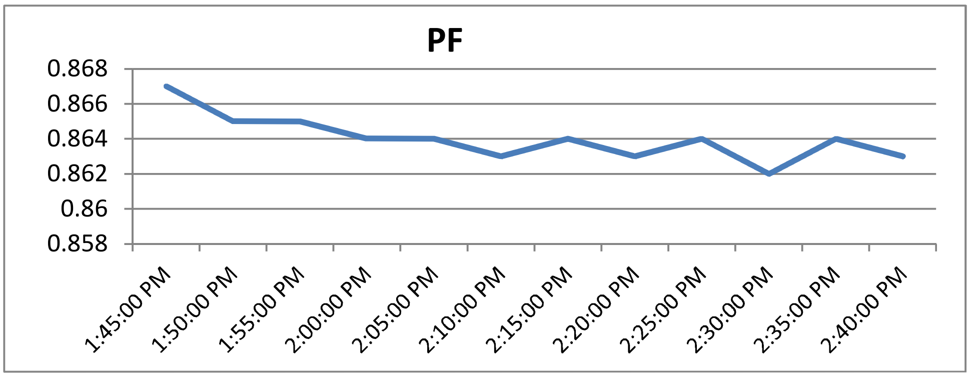


Figure 276: Power factor variation profile during operation of pump-1

- Power factor is found to be around 0.86-0.87.

Frequency Profile:

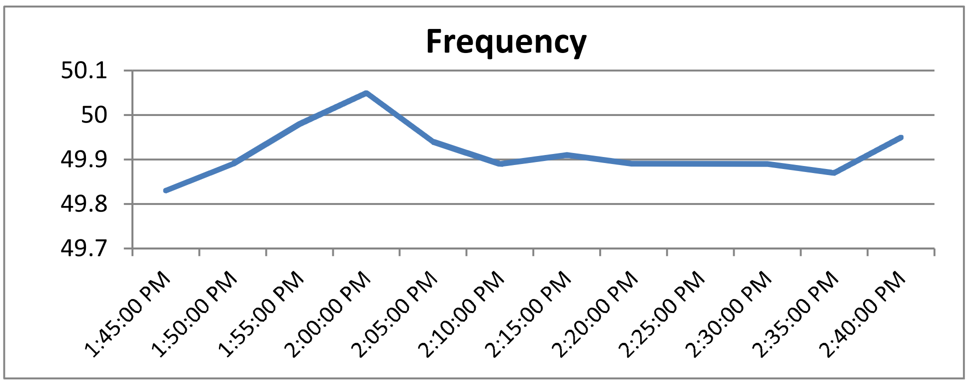


Figure 277: Frequency variation during operation of pump-1

- The frequency was found to vary between 49.82 and 50.05 Hz.

Total Harmonics distortion (THD) - Current:

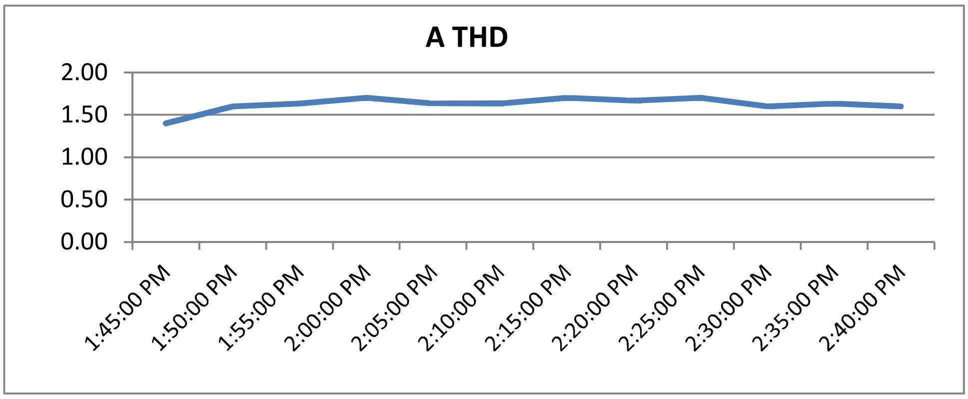


Figure 278: Variation of THD in current during operation of pump-1

- The current THD is observed to be around 1.6%.

Total Harmonics distortion - Voltage:

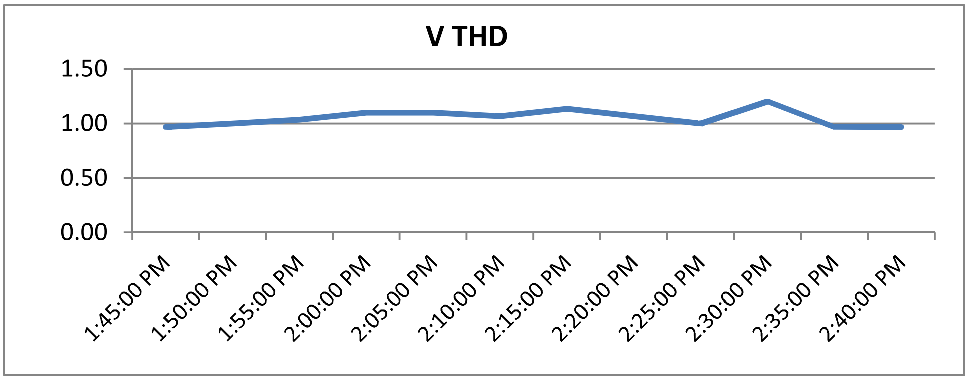


Figure 279: Variation in THD - voltage during operation of pump-1

- Voltage THD is observed to be around 1-1.3%.

Pump 2 in operation:

Voltage Profile:

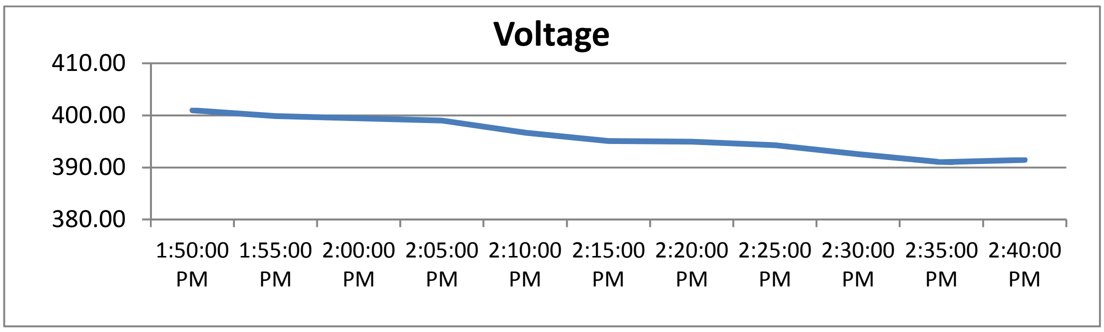


Figure 280: Voltage Variation during operation of pump-2

- Voltage is found to vary between 391 and 401V.

Power consumption and Apparent power Profile:

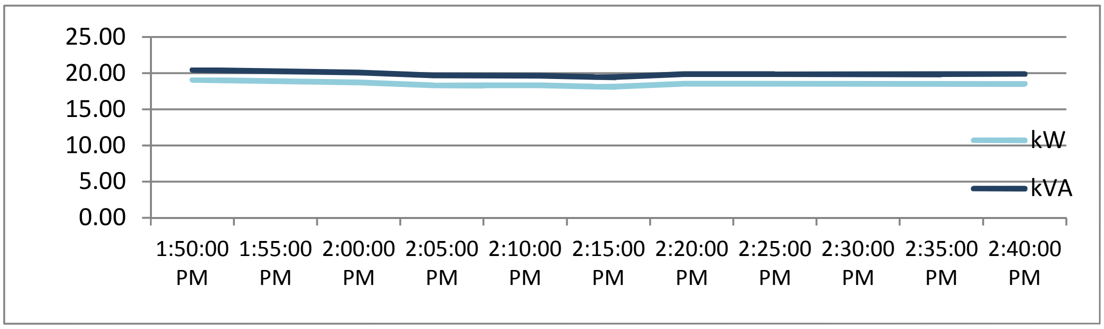


Figure 281: Power consumption variation during operation of pump-2

- Power consumption is found to be around 18.5-19 kW.
- Apparent power is found to be around 19.5-20.5 kVA.

Power factor profile

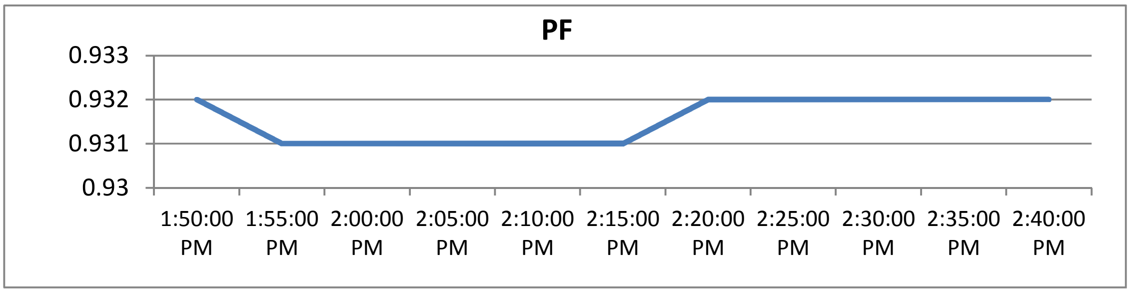


Figure 282: Power factor variation profile during operation of pump-2

- Power factor is found to be around 0.931-0.932.

Frequency Profile:

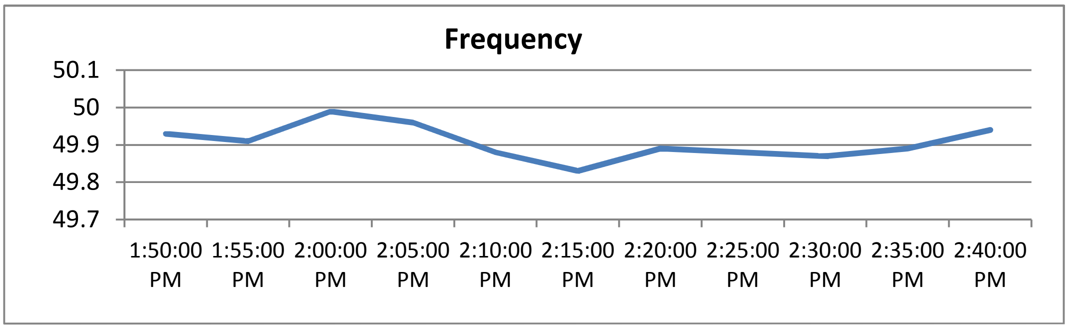


Figure 283: Frequency variation during operation of pump-2

- The frequency is found to be less than 50 Hz, with minimum recorded around 49.82 Hz.

Total Harmonics distortion (THD) - Current:

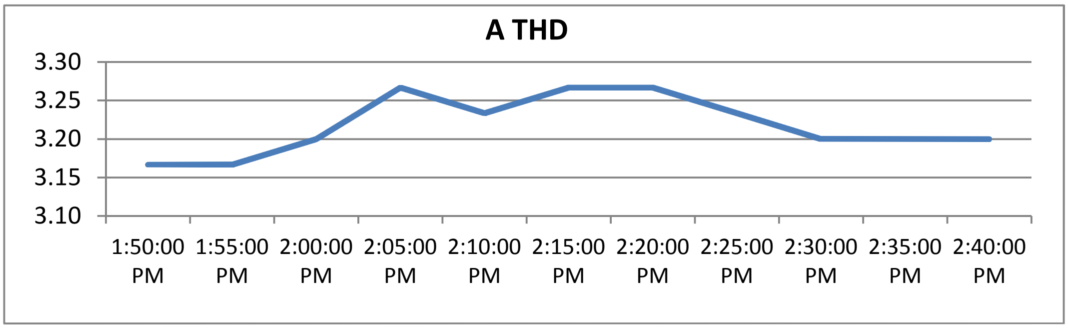


Figure 284 Variation of THD in current during operation of pump-2

- THD in current is found to be around 3.15-3.3%.

Total Harmonics distortion - Voltage:

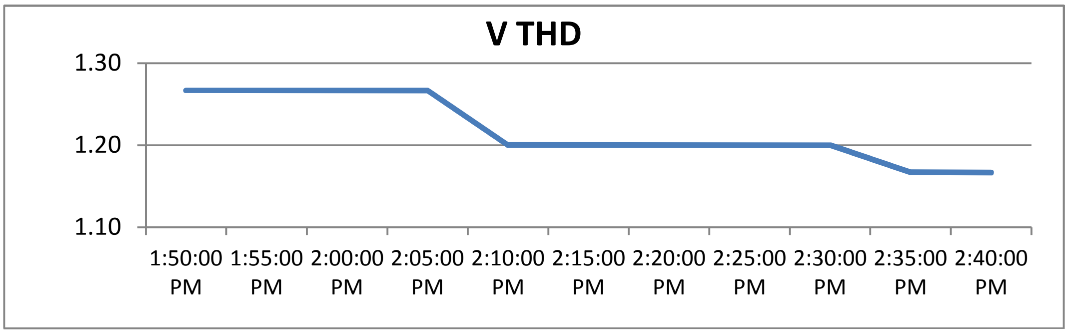


Figure 285 Variation in THD - voltage during operation of pump-2

- Voltage THD is found to be around 1.15-1.3%.

4.24.6 Pumping Station System Mapping

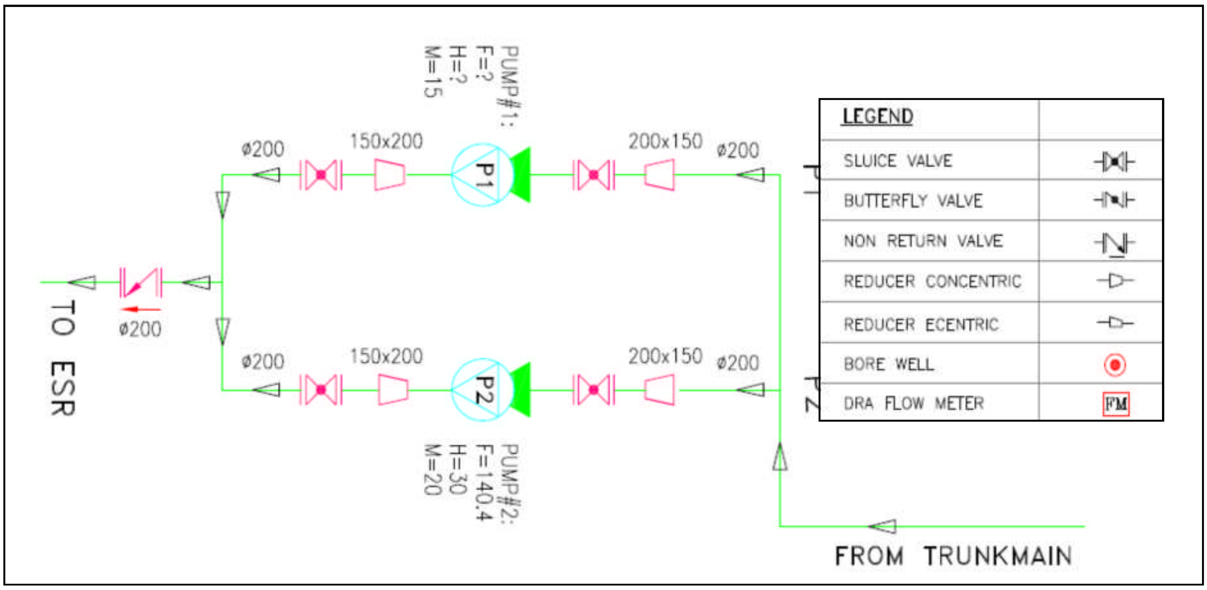


Figure 286: P & ID diagram for Chhipitola boostes

4.24.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices
- Verification of Job card by the authorized representative of ULB

Table 198: General details of Chhipitola booster

Data	Value / Details
Name of site	Chhipitola booster
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Booster station
Pumps installed	2
No. of pumps in operation	2
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Chhipitola booster to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 287: Photographs of Chhipitola booster

Table 199: Performance Evaluation of pumps at Chhipitola booster

Parameters	Unit	Chhipitola Booster Pump-1	Chhipitola Booster Pump-2
Pump make		NA	Jyoti
Motor make		NA	Kirloskar
Pump type		HSC	HSC
Motor serial no.		NA	NA
Pump serial no.		NA	21089D
Rated flow	m^3/h		140.4
Rated head	m		30
Rated motor	kW	15	20
Parameters measured			
Total suction head	m	-5.29	-5.29
Total discharge head	m	14	13
Average flow delivered	m^3/h	119.10	90.10
Motor input power	kW	18.31	10.99
Frequency	Hz	49.90	49.82
Speed	RPM	1452.67	1415.67
Performance evaluation			
Total head developed	m	19.29	18.29
Head utilization	%	--	61%
Flow utilization	%	--	64%
Hydraulic power kW	kW	6.26	4.49
Motor input power	kW	18.31	10.99
Calculated pumpset efficiency	%	34.16%	40.85%

Parameters	Unit	Chhipitola Booster Pump-1	Chhipitola Booster Pump-2
Rated motor efficiency	%	90%	90%
Calculated pump efficiency	%	37.96%	45.38%
Specific energy consumption	kWh/m³	153.76	121.94

Key Observations:

- The pump set efficiencies of pumps 1 and 2 were found to be 34.16% and 40.85% respectively.

4.24.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 200: Other auxiliary equipment at Chhipitola booster - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	0
Capacity (kVA)	
Primary/Secondary voltages	
Instrumentation at site	
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 201: Other electrical equipment at Chhipitola Booster - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
1	Tubelight	1	0.04	24
2	Bulb	1	0.1	12

4.24.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Chhipitola booster is provided in below table.

Table 202: Estimated annual energy consumption and water supply for Chhipitola booster

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Chhipitola Booster	Pump-1	1 working	332	18.31	6,078
Chhipitola Booster	Pump-2		1,623	10.99	17,830
	Total		**1,955**	**29.3**	**23,908**

4.25 Red Fort Booster

4.25.1 Overview of existing systems

The Red Fort booster is an in-line boosting pump house which receives water from Jeoni Mandi WTP and supplies it to Red Fort area. Two pumps are installed here, of which one was not in use for several months at the time of audit. The pipeline from which the pump receives water is also used for direct distribution, during which the suction valve of the Red Fort booster pump is closed.

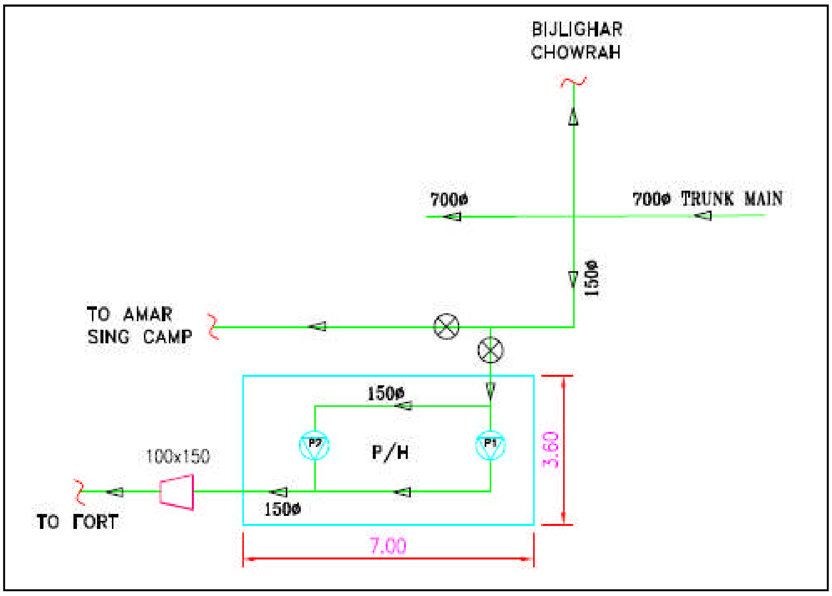


Figure 288: Plant Layout for Red Fort Booster

4.25.2 Electricity Supply

The Red Fort booster receives supply at 440V from Torrent Power.

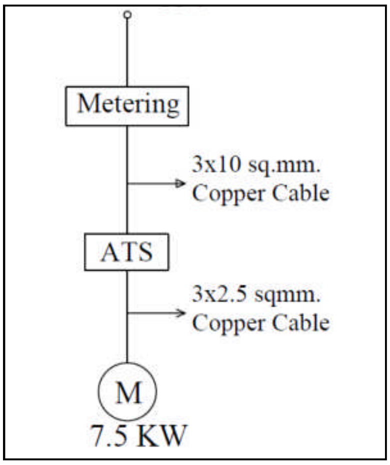


Figure 289: Single line diagram for the Red Fort Booster

4.25.3 Tariff Structure

The electrical connection for Red Fort booster is provided by Torrent Power. The connection is covered in the LMV-7 tariff category of DVVNL.

Table 203: Tariff structure (From DVVNL FY 2016-17 Tariff order)

Description	Red Fort booster Energy Meter (LT)
Meter serial number	NA
Power supply	11 kV line
Energy charges	Rs. 7.155 Per kVAh
Fixed/demand charge	Rs. 290/kW
(Basis : DVVNL Tariff Order for FY 2016-17)	

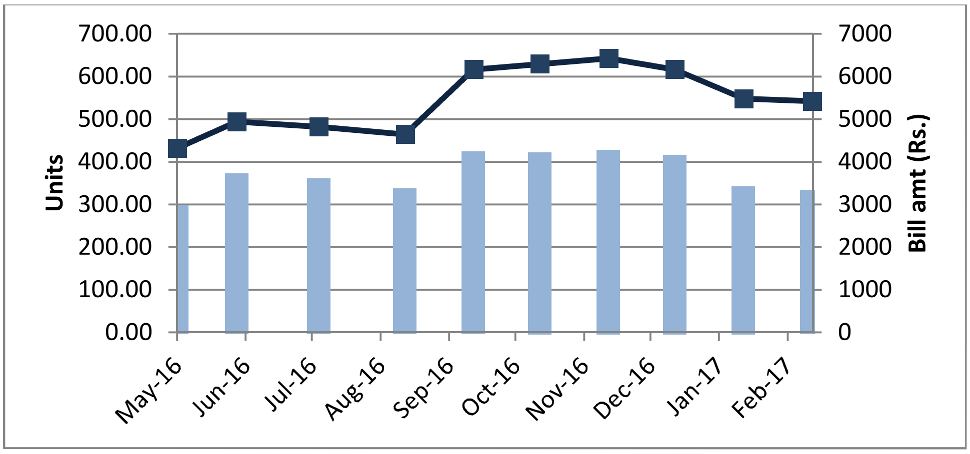
4.25.4 Electricity Bill Analysis

During energy audit, electricity bill data was collected from ULB. Details of annual electricity consumption, annual electricity cost of last 3 years along with percentage increase over previous year is provided in below table.

Table 204: Energy cost and energy consumption detail for Red Fort Booster

Period of energy bill	Energy consumption (kWh/y)	Percentage Increase of energy consumption over previous year (%)	Energy cost (Rs./y)
Apr-14 to Mar-15	Not Available	Not Available	Not Available
Apr-15 to Mar-16	Not Available	Not Available	Not Available
Apr-16 to Mar-17	4,185		65,593

Figure 290: Monthly electricity consumption and electricity bill for Red Fort Booster



4.25.5 Energy Consumption Pattern at Pumping Station

At Red Fort booster station, one pump is in operation. The voltage was found to vary between a maximum 425.1 V and a minimum 415.4 V, averaging 419.7 V. The power factor was found to be consistent from 0.881 to 0.882.

4.25.6 Pumping Station System Mapping

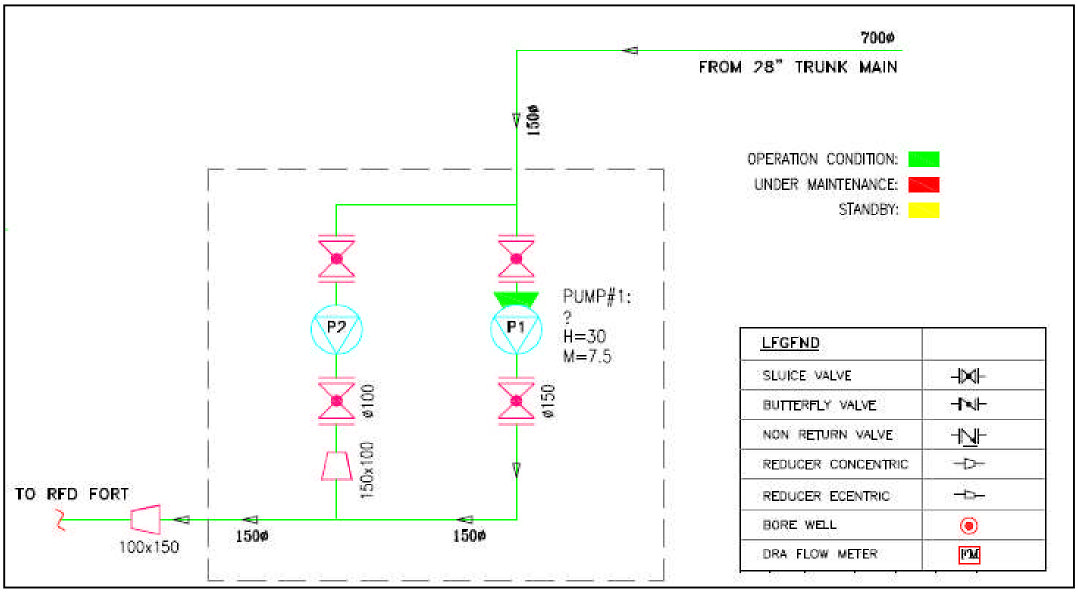


Figure 291 P & ID diagram for Red Fort booster

4.25.7 Pumps Performance Evaluation

As per the methodology described in section -1.4, the team had collected detailed information from the pumping stations. Site data collection activities included the following:

- Data collection
- System mapping including collection of inventories, name plate details
- Measurements of flow, head and power input to motor
- Interaction with the site personnel on the operating practices

- Verification of Job card by the authorized representative of ULB

Table 205: General details of Red Fort booster

Data	Value / Details
Name of site	Red Fort booster
Name of Sub-section	-
Classification (WTP,PS, SPS, STP)	Booster station
Pumps installed	1
No. of pumps in operation	1
No. of pumps under maintenance	0
Other Details	
Basis of pump operation	Inlet supply from WTP
VFD installed (Yes/No)	No

Photographs captured at Red Fort booster to showcase the actual situation are provided below.

View of pump house	Pumps installed
	

Figure 292: Photographs of Red Fort booster

Table 206: Performance Evaluation of pumps at Red Fort booster

Performance evaluation for pump 1 could not be performed because pressure measurement was not possible at site.

4.25.8 Auxiliaries In Pumping Stations

During the energy audit, auxiliary electrical load of pumping station were also studied and details of same is provided below.

Table 207: Other auxiliary equipment at Red Fort booster - Transformer & Instrumentation

Parameters	Details
Transformers details	
Number of Transformers	0
Capacity (kVA)	
Primary/Secondary voltages	
Instrumentation at site	

Parameters	Details
Suction pressure gauges	Not Available
Discharge pressure gauges	Tapping points are available on main header
Flow meter	Not available
Energy meter	For whole facility at incoming feeder (DISCOM meter only)

Table 208: Other electrical equipment at Red Fort Booster - lighting

Lighting details	Type of lamp	No. of fittings	Rating (kW)	Average Operating hours per day
1	Bulb	1	0.1	24

4.25.9 Total Energy Consumption Estimation For Pump sets& Pumping Stations

During energy audit, measurements were conducted on individual pumps and operating hours of pumps were also collected from the available log books and from operators for estimating annual energy consumption. Estimated energy consumption for Red Fort booster is provided in below table.

Table 209: Estimated energy consumption for Red Fort booster

name of section	Name of pump	Operating Pattern	Annual operating hours (hour/annum)	Weighted average power consumption (kW)	Estimated annual power consumption (kWh/annum)
Red Fort Booster	Pump-1	1 working	1716	5.18	8883

4.26 Auxiliary Loads

Sr. no.	Location	Connected load – Auxiliaries (kW)
1	Old Intake Well	0.52
2	New Intake Well	0.38
3	New Jal Nigam Intake Well	0.74
4	Golkamra HT plant	
5	Synchronous Plant	0.04
6	Flowmore Plant	0.695
7	8 VT Plant	0.845
8	Sanjay Place	2.046
9	Kotwali ZPS	0.905
10	Surya Nagar ZPS	4.333
11	Mathura Road ZPS	1.7
12	Trans Yamuna ZPS	
13	Lawyer's Colony ZPS	0.36
14	Nirbhay Nagar ZPS	0.558

Sr. no.	Location	Connected load – Auxiliaries (kW)
15	Lohamandi ZPS	0.5
16	Keshavkunj ZPS (Bodla ZPS)	0.395
17	Shahganj Phase-1 ZPS	0.917
18	Shahganj Phase-2	0.255
19	Kedar Nagar	1.165
20	Tajganj ZPS	0.3
21	Rakabganj ZPS	0.228
22	Navlakha ZPS	1.038
23	Chhipitola Booster	0.14
24	Red Fort Booster	0.1
Total		**15.785**

5 Baseline Assessment

Estimation of baseline is the key element in design and development of any energy efficiency project. It play an important role in determining the savings associated with the implementation of energy efficiency measure (EEM) and determining the techno-financial feasibility of the EEM. In case of Municipal Energy Efficiency Programme (MEEP), the baseline is affected by many parameters including the changes in the system due to addition of command area, seasonal variations, increase in population affecting the flow (Q) and the head (H).

Measurement and Verification (M&V) is the term given to the process for quantifying savings delivered by an Energy Efficiency Measure (EEM). It includes energy saving verification process involving measurements and reporting. M & V methodology followed in this project includes following measurement schedule

a. Measurement of parameters pre EEM implementation using portable instruments

b. Measurement of parameters post EEM implementation using portable instruments.

Energy savings are calculated as the difference in power drawn (in pre and post implementation scenario) multiplied by the operating hours mentioned in this report. Baseline of this project will be estimated based on pre EEM implementation measurements, conducted just before installation of new EEPS at pumping station.

5.1 Definition of possible and operating combinations

In ULBs, especially in case of pumping stations, where the pumps are connected in parallel, the pump operated in various combinations. For the purpose of this document, these combinations are defined as possible combinations. For example, for if 3 pumps are connected in parallel, there are 7 possible combinations considering three different pumps i.e.

Pump 1	Pump 1+ Pump 2	
Pump 2	Pump 2+ Pump 3	Pump 1+Pump 2+Pump 3
Pump 3	Pump 3 +Pump 1	

However, the ULB might be operating the pumps only in three combination, depending on the flow requirement, from the one discussed above. For the purpose of this document, these combinations are defined as operating combinations.

Operating Combination 1	Operating Combination 2	Operating Combination 3
Pump 1	Pump 1+ Pump 2	Pump 1+Pump 2+Pump 3

5.2 Key measurements for determining baseline or pre implementation level

To determine baseline, the following parameters would be measured during pre-implementation period (just before installation of new energy efficient pumps) for each operating combination.

i. Power Consumption, voltage, frequency (kW, Volt, hz)

Data Unit	kW, Volt, hz
Description	Voltage, frequency and power consumption of all operating combinations at site (pre and post implementation)
Source of Data	On site measurement using calibrated portable instrument (power analyzer)
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using portable power analyzer
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

ii. Flow rate (m^3/hr)

Data Unit	m^3/hr.
Description	Flow rate delivered for all operating combinations at site (pre and post implementation)
Source of Data	On site measurement using calibrated portable instruments (flow meter)
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using portable flow meter
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

iii. Head (m)

Data Unit	meters (m)
Description	Average head delivered for all operating combinations at site (pre and post implementation)
Source of Data	On site measurement using calibrated instruments
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using pressure gauge installed at both the suction and discharge side of the pump
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

5.3 Baseline

The baselines energy consumption measurement for existing water pumping station will be established using pre implementation (just before installation of new pumps) measurements on existing pumps. Most of the electric parameters would be measured instantaneously using portable instruments, while operating hours would be provided by this report.

The baseline would be:

$$\mathrm{BaselineEnergyConsumptionofapump(kWh)} = \mathrm{kW1} \times \mathrm{hoursofoperation1} + \mathrm{kW2} \times \mathrm{hoursofoperation2} + \cdots.$$

Where, 1, 2…. represent operating combination of pump

$$\text{BaselineEnergyConsumptionofaULB(kWh)} = \text{Baselineofpump1} + \text{Baselineofpump2} + \cdots.$$

Where 1, 2 … represent baseline energy consumption of pumps of ULB

Baseline of this project will be estimated based on pre-implementation measurements, conducted just before installation of new EEPS at pumping station. Table 210 provides estimated present energy consumption of pumps (in different operating combination) based on data provided in this report.

Table 210: Estimated energy consumption for Agra

Name of pumping station	Pump Reference	Power consumption (kW)	Flow rate (m³/hr.)	Frequency (Hz)	Head (m)	Voltage (V)	Hours baseline (hours)	Baseline Energy Consumption (kWh)
8 VT Plant, Water Works	Pump-5	200	1,255	50	22	407	6,267	1,254,300
8 VT Plant, Water Works	Pump-6	173	1,281	50	18	415	2,550	441,212
8 VT Plant, Water Works	Pump-7	217	1,287	50	20	418	2,761	599,114
Total		**590**	**3,823**				**11,578**	**2,294,626**
Old Intake Well	Pump-6	230	2,249	50	13	410	4,775	1,096,579
Total		**230**	**2,249**				**4,775**	**1,096,579**
New Intake Well	Pump-1	105	1,015	50	11	413	6,311	661,671
New Intake Well	Pump-2	134	2,079	50	12	419	6,679	892,321
Total		**238**	**3,095**				**12,990**	**1,553,993**
New Jal Nigam Intake well	Pump-2	96	1,113	50	12	396	4,091	391,767
New Jal Nigam Intake well	Pump-3	115	1,080	50	12	399	3,583	410,544
Total		**210**	**2,193**				**7,674**	**802,311**
Sanjay Place, Maithan side	Pump 5	38	292	50	21	437	1,330	50,853
Sanjay Place, Hariparvat Side.	Pump-1	34	359	50	10	443	1,339	45,823
Sanjay Place, Hariparvat Side.	Pump-4	61	574	50	13	418	1,339	81,414
Sanjay Place, Hariparvat Side.	Pump-5(0)	44	99	50	52	443	1,341	58,471
Total		**177**	**1,325**				**5,348**	**236,561**
Kotwali ZPS	Pump-1	28	232	50	6	422	702	19,565
Total		**28**	**232**				**702**	**19,565**
Mathura Road ZPS	Pump-2	41	408	50	16	428	1,076	44,532
Mathura Road ZPS	Pump-3	28	150	50	15	430	726	20,033
Total		**69**	**558**				**1,802**	**64,565**

Name of pumping station	Pump Reference	Power consumption	Flow rate	Frequency	Head	Voltage	Hours baseline	Baseline Energy Consumption (kWh)
		(kW)	(m^3/hr.)	(Hz)	(m)	(V)	(hours)	
Trans Yamuna ZPS	Pump-1	35	367	50	9	411	913	32,096
Total		**35**	**367**				**913**	**32,096**
Lawyer's Colony ZPS	Pump-1 (Lawyer's Colony)	35	232	49	28	406	3,912	136,019
Lawyer's Colony ZPS	Pump-2 (Lawyer's Colony)	35	119	50	28	408	3,914	137,864
Total		**70**	**351**				**7,826**	**273,883**
Shahganj Phase-1 ZPS	Pump-1	65	352	50	12	400	807	52,489
Total		**65**	**352**				**807**	**52,489**
Shahganj Phase-2	Pump-5	66	439	50	22	376	3,682	242,519
Total		**66**	**439**				**3,682**	**242,519**
Rakabganj ZPS	Pump-2	77	792	50	5	383	700	53,741
Total		**77**	**792**				**700**	**53,741**
Navlakha ZPS	Pump-3	148	784	50	36	442	2,998	443,586
Total		**148**	**784**				**2,998**	**443,586**
Chhipitola Booster	Pump-2	11	90	50	18	397	1,623	17,830
Total		**11**	**90**				**1,623**	**17,830**
TOTAL							**63,419**	**7,184,344**

Due to site constraints/operational constraints, different operating combinations of the pumps could not be tested.

6 Energy Efficiency Measures

6.1 Summary of Energy Efficiency Measures

A summary of the proposed energy efficiency measures at Pumping Stations in Agra is provided in the table below.

Table 211: Overall summary of energy conservation measures

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
Pumping System							
1	Replacement of Pump-5 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	1,254,300	645,356	19.92	51.31	5	51%
2	Replacement of Pump-6 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	441,212	193,443	19.92	15.38	16	44%
3	Replacement of Pump-7 at 8 VT Plant, Water Works, Jeoni Mandi with energy efficient pump set	599,114	330,890	19.92	26.31	9	55%
4	Replacement of Pump-6 at Old Intake Well, Jeoni Mandi with energy efficient pump set	1,096,579	541,292	28.62	43.03	8	49%
5	Replacement of Pump-1 at New Intake Well, Jeoni Mandi with energy efficient pump set	661,671	327,674	20.97	26.05	10	50%

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
6	Replacement of Pump-2 at New Intake Well, Jeoni Mandi with energy efficient pump set	892,321	115,611	35.90	9.19	47	13%
7	Replacement of Pump-2 at New Jal Nigam Intake well, Jeoni Mandi with energy efficient pump set	391,767	175,275	20.97	13.93	18	45%
8	Replacement of Pump-3 at New Jal Nigam Intake well, Jeoni Mandi with energy efficient pump set	410,544	220,904	20.97	17.56	14	54%
9	Replacement of Pump-5 at Sanjay Place, Mauthan Side. with energy efficient pump set	50,853	16,828	8.73	1.34	78	33%
10	Replacement of Pump-1 at Sanjay Place, Hariparvat Side. with energy efficient pump set	45,823	19,532	10.92	1.55	84	43%
11	Replacement of Pump-4 at Sanjay Place, Hariparvat Side. with energy efficient pump set	81,414	38,445	17.15	3.06	67	47%
12	Replacement of Pump-5(0) at Sanjay Place, Hariparvat Side. with energy efficient pump set	58,471	32,014	8.18	2.55	39	55%
13	Replacement of Pump-1 at Kotwali ZPS with energy efficient pump set	19,565	12,405	5.75	0.99	70	63%
14	Replacement of Pump-2 at Mathura Road ZPS with energy efficient pump set	44,532	19,447	10.86	1.55	84	44%
15	Replacement of Pump-3 at Mathura Road ZPS with energy efficient pump set	20,033	13,637	6.39	1.08	71	68%

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
16	Replacement of Pump-1 at Trans Yamuna ZPS with energy efficient pump set	32,096	16,341	8.80	1.30	81	51%
17	Replacement of Pump-1 (Lawyer's Colony) at Lawyer's Colony ZPS with energy efficient pump set	136,019	35,946	8.73	2.86	37	26%
18	Replacement of Pump-2 (Lawyer's Colony) at Lawyer's Colony ZPS with energy efficient pump set	137,864	86,044	8.20	6.84	14	62%
19	Replacement of Pump-1 at Shahganj Phase-1 ZPS with energy efficient pump set	52,489	37,113	9.42	2.95	38	71%
20	Replacement of Pump-5 at Shahganj Phase-2 with energy efficient pump set	242,519	109,617	12.11	8.71	17	45%
21	Replacement of Pump-2 at Rakabganj ZPS with energy efficient pump set	53,741	31,695	14.52	2.52	69	59%
22	Replacement of Pump-3 at Navlakha ZPS with energy efficient pump set	443,586	154,038	9.07	12.25	9	35%
23	Replacement of Pump-2 at Chhipitola Booster with energy efficient pump set	17,830	7,119	2.50	0.57	53	40%
	Subtotal	**7,184,344**	**3,180,667**	**328.53**	**252.86**	**16**	**44.27%**
			Auxiliary loads				
24	Installation of APFC panel at Sanjay Place	-	-	6.49	9.76	8	-

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
25	Installation of APFC panel at Kotwali ZPS	-	-	1.73	2.07	10	-
26	Installation of APFC panel at Surya Nagar ZPS	-	-	2.88	4.07	9	-
27	Installation of APFC panel at Mathura Road ZPS	-	-	1.73	3.48	6	-
28	Installation of APFC panel at Trans Yamuna ZPS	-	-	1.01	0.19	63	-
29	Installation of APFC panel at Lawyer's Colony ZPS	-	-	1.95	3.42	7	-
30	Installation of APFC panel at Nirbhay Nagar ZPS	-	-	1.01	0.15	82	-
31	Installation of APFC panel at Lohamandi ZPS	-	-	3.61	6.14	7	-
32	Installation of APFC panel at Keshavkunj (Bodla) ZPS	-	-	5.19	1.39	45	-
33	Installation of APFC panel at Shahganj Phase-1 ZPS	-	-	5.77	16.44	4	-
34	Installation of APFC panel at Shahganj Phase-2	-	-	4.33	5.53	9	-
35	Installation of APFC panel at Kedar Nagar	-	-	1.01	1.19	10	-
36	Installation of APFC panel at Tajganj ZPS	-	-	6.13	3.08	24	-
37	Installation of APFC panel at Rakabganj ZPS	-	-	3.61	5.14	8	-
38	Installation of APFC panel at Navlakha ZPS	-	-	3.24	6.75	6	-

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
39	Installation of capacitor at Chhipitola Booster	-	-	0.18	0.25	9	-
40	Installation of capacitor at Red Fort Booster	-	-	0.05	0.04	17	-
	Subtotal			**49.91**	**69.09**	**9**	
41	Replacement of existing lighting equipment at Old Intake Well with LED lamps	919.8	525.6	0.03	0.04	10	57%
42	Replacement of existing lighting equipment at New Intake Well with LED lamps	854.1	411.72	0.02	0.03	6	48%
43	Replacement of existing lighting equipment at New Jal Nigam Intake Well with LED lamps	4204.8	2312.64	0.10	0.18	7	55%
44	Replacement of existing lighting equipment at Synchronous with LED lamps	350.4	192.72	0.01	0.02	7	55%
45	Replacement of existing lighting equipment at Flowmore Plant with LED lamps	1335.9	1020.54	0.03	0.08	5	76%
46	Replacement of existing lighting equipment at 8 VT Plant with LED lamps	854.1	617.58	0.03	0.05	6	72%
47	Replacement of existing lighting equipment at Sanjay Place with LED lamps	3048.48	1787.04	0.32	0.14	27	59%
48	Replacement of existing lighting equipment at Kotwali ZPS with LED lamps	2211.9	1300.86	0.18	0.10	21	59%

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
49	Replacement of existing lighting equipment at Surya Nagar ZPS with LED lamps	7765.74	4673.46	0.71	0.37	23	60%
50	Replacement of existing lighting equipment at Mathura Road ZPS with LED lamps	7446	4467.6	0.89	0.36	30	60%
51	Replacement of existing lighting equipment at Trans Yamuna ZPS with LED lamps	306.6	227.76	0.02	0.02	12	74%
52	Replacement of existing lighting equipment at Lawyer's Colony ZPS with LED lamps	846.8	502.24	0.10	0.04	29	59%
53	Replacement of existing lighting equipment at Nirbhay Nagar ZPS with LED lamps	2444.04	1419.12	0.29	0.11	31	58%
54	Replacement of existing lighting equipment at Lohamandi ZPS with LED lamps	671.6	487.64	0.03	0.04	8	73%
55	Replacement of existing lighting equipment at Keshavkunj ZPS with LED lamps	854.1	459.9	0.04	0.04	14	54%
56	Replacement of existing lighting equipment at Shahganj-1 ZPS with LED lamps	3578.46	1949.1	0.30	0.15	23	54%
57	Replacement of existing lighting equipment at Shahganj Phase-2 ZPS with LED lamps	635.1	398.58	0.03	0.03	10	63%
58	Replacement of existing lighting equipment at Kedar Nagar with LED lamps	1598.7	889.14	0.08	0.07	13	56%

Sr. No.	Energy Efficiency Measures (EEM)	Present annual energy consumption (kWh/year)	Annual Energy Savings (kWh/year)	Investment Cost (Rs. Lakh)	Energy Cost Saving per annum (Rs. Lakh)	Payback Period (Months)	Percentage of energy saving (%)
59	Replacement of existing lighting equipment at Tajganj ZPS with LED lamps	1357.8	779.64	0.11	0.06	20	57%
60	Replacement of existing lighting equipment at Navlakha ZPS with LED lamps	4064.64	2409	0.54	0.19	34	59%
61	Replacement of existing lighting equipment at Chhipi Tola ZPS with LED lamps	788.4	551.88	0.02	0.04	5	70%
62	Replacement of existing lighting equipment at Red Fort Booster with LED lamps	876	718.32	0.01	0.06	2	82%
	Subtotal	**47013.46**	**28102.08**	**3.85**	**2.23**	**21**	60%
	TOTAL	**7,231,358**	**3,208,769**	**332.39**	**255.10**	**16**	44%

6.2 Detailed Energy Efficiency Measures

6.2.1 Replacement of old pump sets with new, efficient pump sets

Existing operating conditions: The existing pump sets in most pump stations are quite old and were observed to be operating away from their best efficiency point. A number of pump sets were in breakdown condition.

Recommendations: The present operating pump efficiency of many pump sets across pump houses is less than 55%. Therefore, it is suggested to replace existing pumps with energy efficient pump to reduce the energy consumption. A total of 23 nos. of pump sets have been identified for replacement.

Cost benefit analysis: Expected savings from the replacement of pump sets is about 3,180,667 kWh per year, which would result in a cost benefit of about Rs. 252.86 Lakh per year. Estimated investment for implementation of this measure is about Rs 328.53 Lakh, which includes cost of pump set, installation cost, cost of NRV, gate valve and cost of Web based dashboard. Simple payback period of this intervention is estimated to be about 16 months. Detailed cost benefit analysis for each pump house is given in the tables below:

Table 212: Cost benefit analysis of pump replacement at 8VT Plant

Description	Units	8 VT Plant	8 VT Plant	8 VT Plant
		Pump-5	Pump-6	Pump-7
Rated Parameters				
Flow delivered	m^3/hr.	1226	1212	1212
Head developed	M	53	47	47
Motor power consumption	kW	260	220	220
Measured Parameters				
Flow delivered	m^3/hr.	1255	1281	1287
Head developed	M	22	18	20
Motor power consumption	kW	200	173	217
Calculated efficiency of pumpset	%	37.18%	36.91%	32.13%
Proposed Parameters				
Flow of the pump	m^3/hr.	1250	1250	1250
Head of the pump	M	22	22	22
Power of the motor on existing duty point	kW	97.16	97.16	97.16
Proposed efficiency of pump set on existing duty point	%	77%	77%	77%
Operating hours of the pump	Hours	6267	2550	2761
Electricitytariff	Rs./kWh	7.95	7.95	7.95
Annual energy saving	kWh	645356	193443	330890
Annual cost saving	Rs. Lakhs	51.31	15.38	26.31
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	17.61	17.61	17.61

Description	Units	8 VT Plant Pump-5	8 VT Plant Pump-6	8 VT Plant Pump-7
Investment towards NRV replacement including GST	Rs. Lakh	1.06	1.06	1.06
Investment towards gate valve replacement including GST	Rs. Lakh	1.18	1.18	1.18
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08	0.08
Payback period	Months	5	16	9

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 213: Cost benefit analysis of pump replacement at Old and New Intake Wells

` Rated Parameters	Units	Old Intake Well Pump-6	New Intake Well Pump-1	New Intake Well Pump-2
Flow delivered	$m^3/hr.$	3180	2460	3180
Head developed	M	15	16	16
Motor power consumption	kW	185	150	180
Measured Parameters				
Flow delivered	$m^3/hr.$	2249	1015	2079
Head developed	M	13	11	12
Motor power consumption	kW	230	105	134
Calculated efficiency of pumpset	%	35.12%	29.14%	51.07%
Proposed Parameters				
Flow of the pump	$m^3/hr.$	2200	1000	2200
Head of the pump	M	15	15	15
Power of the motor on existing duty point	kW	116.29	52.92	116.29
Proposed efficiency of pump set on existing duty point	%	77%	77%	77%
Operating hours of the pump	Hours	4775	6311	6679
Electricitytariff	Rs./kWh	7.95	7.95	7.95
Annual energy saving	kWh	541292	327674	115611
Annual cost saving	Rs. Lakhs	43.03	26.05	9.19
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	28.54	16.04	28.54
Investment towards NRV replacement including GST	Rs. Lakh	0.00	2.29	3.52
Investment towards gate valve replacement including GST	Rs. Lakh	0.00	2.56	3.76
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08	0.08
Payback period	Months	8	10	47

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 214: Cost benefit analysis of pump replacement at New Jal Nigam Intake Well

Description Rated Parameters	Units	New Jal Nigam Intake well Pump-2	New Jal Nigam Intake well Pump-3
Flow delivered	m^3/hr.	1950	1950
Head developed	M	16	16
Motor power consumption	kW	132	132
Measured Parameters			
Flow delivered	m^3/hr.	1113	1080
Head developed	M	12	12
Motor power consumption	kW	96	115
Calculated efficiency of pumpset	%	38.17%	30.83%
Proposed Parameters			
Flow of the pump	m^3/hr.	1000	1000
Head of the pump	M	15	15
Power of the motor on existing duty point	kW	52.92	52.92
Proposed efficiency of pump set on existing duty point	%	77%	77%
Operating hours of the pump	Hours	4091	3583
Electricitytariff	Rs./kWh	7.95	7.95
Annual energy saving	kWh	175275	220904
Annual cost saving	Rs. Lakhs	13.93	17.56
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	16.04	16.04
Investment towards NRV replacement including GST	Rs. Lakh	2.29	2.29
Investment towards gate valve replacement including GST	Rs. Lakh	2.56	2.56
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08
Payback period	Months	18	14

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 215: Cost benefit analysis of pump replacement at Sanjay Place ZPS

Description	Units	Sanjay Place, Maithan Side. pump-5	Sanjay Place, Hariparvat Side. Pump-1	Sanjay Place, Hariparvat Side. Pump-4	Sanjay Place, Hariparvat Side. Pump-5(0)
Rated Parameters					
Flow delivered	m^3/hr.	324	300	648	*NA
Head developed	M	30	35	30	*NA

Description	Units	Sanjay Place, Maithan Side. pump-5	Sanjay Place, Hariparvat Side. Pump-1	Sanjay Place, Hariparvat Side. Pump-4	Sanjay Place, Hariparvat Side. Pump-5(0)
Motor power consumption	kW	37	37	75	67
Measured Parameters					
Flow delivered	m^3/hr.	292	359	574	99
Head developed	M	21	10	13	52
Motor power consumption	kW	38	34	61	44
Calculated efficiency of pumpset	%	43.29%	28.72%	34.14%	32.16%
Proposed Parameters					
Flow of the pump	m^3/hr.	250	350	600	100
Head of the pump	M	28	15	15	50
Power of the motor on existing duty point	kW	25.58	19.64	32.10	19.73
Proposed efficiency of pump set on existing duty point	%	75%	73%	76%	69%
Operating hours of the pump	Hours	1330	1339	1339	1341
Electricitytariff	Rs./kWh	7.95	7.95	7.95	7.95
Annual energy saving	kWh	16828	19532	38445	32014
Annual cost saving	Rs. Lakhs	1.34	1.55	3.06	2.55
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	7.41	9.59	15.82	6.86
Investment towards NRV replacement including GST	Rs. Lakh	0.59	0.59	0.59	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66	0.66	0.66	0.66
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08	0.08	0.08
Payback period	Months	78	84	67	39

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 216: Cost benefit analysis of pump replacement at Kotwali ZPS

Description	Units	Kotwali ZPS Pump-1
Rated Parameters		
Flow delivered	m^3/hr.	324
Head developed	M	30
Motor power consumption	kW	37
Measured Parameters		
Flow delivered	m^3/hr.	232
Head developed	M	6
Motor power consumption	kW	28
Calculated efficiency of pumpset	%	13.14%

Description	Units	Kotwali ZPS Pump-1
Proposed Parameters		
Flow of the pump	m^3/hr.	225
Head of the pump	M	12
Power of the motor on existing duty point	kW	10.20
Proposed efficiency of pump set on existing duty point	%	72%
Operating hours of the pump	Hours	702
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	12,405
Annual cost saving	Rs. Lakhs	0.99
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	5.05
Investment towards NRV replacement including GST	Rs. Lakh	0.27
Investment towards gate valve replacement including GST	Rs. Lakh	0.35
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	70

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 217: Cost benefit analysis of pump replacement at Mathura Road ZPS

Description	Units	Mathura Road ZPS Pump-2	Mathura Road ZPS Pump-3
Rated Parameters			
Flow delivered	m^3/hr.	300	300
Head developed	M	35	35
Motor power consumption	kW	37	37
Measured Parameters			
Flow delivered	m^3/hr.	408	150
Head developed	M	16	15
Motor power consumption	kW	41	28
Calculated efficiency of pumpset	%	43.87%	22.45%
Proposed Parameters			
Flow of the pump	m^3/hr.	350	120
Head of the pump	M	18	18
Power of the motor on existing duty point	kW	23.31	8.81
Proposed efficiency of pump set on existing duty point	%	74%	67%
Operating hours of the pump	Hours	1076	726

Description	Units	Mathura Road ZPS Pump-2	Mathura Road ZPS Pump-3
Electricitytariff	Rs./kWh	7.95	7.95
Annual energy saving	kWh	19447	13637
Annual cost saving	Rs. Lakhs	1.55	1.08
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	9.53	5.07
Investment towards NRV replacement including GST	Rs. Lakh	0.59	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66	0.66
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08
Payback period	Months	84	71

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 218: Cost benefit analysis of pump replacement at Trans Yamuna ZPS

Description	Units	Trans Yamuna ZPS Pump-1
Rated parameters		
Flow delivered	m^3/hr.	300
Head developed	M	32
Motor power consumption	kW	37
Measured Parameters		
Flow delivered	m^3/hr.	367
Head developed	M	9
Motor power consumption	kW	35
Calculated efficiency of pumpset	%	26.79%
Proposed Parameters		
Flow of the pump	m^3/hr.	300
Head of the pump	M	15
Power of the motor on existing duty point	kW	17.27
Proposed efficiency of pump set on existing duty point	%	71%
Operating hours of the pump	Hours	913
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	16341
Annual cost saving	Rs. Lakhs	1.30
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	8.72
Investment towards NRV replacement including GST	Rs. Lakh	0.00
Investment towards gate valve replacement including GST	Rs. Lakh	0.00
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08

Description	Units	Trans Yamuna ZPS Pump-1
Payback period	Months	81

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 219: Cost benefit analysis of pump replacement at Lawyers' Colony ZPS

Description Rated Parameters	Units	Lawyer's Colony ZPS Pump-1 (Lawyer's Colony)	Lawyer's Colony ZPS Pump-2 (Lawyer's Colony)
Flow delivered	m^3/hr.	270	270
Head developed	M	34	34
Motor power consumption	kW	37	37
Measured Parameters			
Flow delivered	m^3/hr.	232	119
Head developed	M	28	28
Motor power consumption	kW	35	35
Calculated efficiency of pumpset	%	51.75%	25.71%
Proposed Parameters			
Flow of the pump	m^3/hr.	250	125
Head of the pump	M	28	28
Power of the motor on existing duty point	kW	25.58	13.24
Proposed efficiency of pump set on existing duty point	%	75%	72%
Operating hours of the pump	Hours	3912	3914
Electricitytariff	Rs./kWh	7.95	7.95
Annual energy saving	kWh	35946	86044
Annual cost saving	Rs. Lakhs	2.86	6.84
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	7.41	6.87
Investment towards NRV replacement including GST	Rs. Lakh	0.59	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66	0.66
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08	0.08
Payback period	Months	37	14

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 220: Cost benefit analysis of pump replacement at Shahganj Phase-1 ZPS

Description Rated Parameters	Units	Shahganj Phase-1 ZPS Pump-1
Flow delivered	m^3/hr.	600
Head developed	M	32
Motor power consumption	kW	75
Measured Parameters		
Flow delivered	m^3/hr.	352
Head developed	M	12
Motor power consumption	kW	65
Calculated efficiency of pumpset	%	17.38%
Proposed Parameters		
Flow of the pump	m^3/hr.	350
Head of the pump	M	14
Power of the motor on existing duty point	kW	19.04
Proposed efficiency of pump set on existing duty point	%	70%
Operating hours of the pump	Hours	807
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	37113
Annual cost saving	Rs. Lakhs	2.95
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	8.72
Investment towards NRV replacement including GST	Rs. Lakh	0.27
Investment towards gate valve replacement including GST	Rs. Lakh	0.35
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	38

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 221: Cost benefit analysis of pump replacement at Shahganj Phase-2 ZPS

Description	Units	Shahganj Phase-2 Pump-5
Rated Parameters		
Flow delivered	m^3/hr.	600
Head developed	M	31
Motor power consumption	kW	75
Measured Parameters		

Description	Units	Shahganj Phase-2 Pump-5
Flow delivered	m^3/hr.	439
Head developed	M	22
Motor power consumption	kW	66
Calculated efficiency of pumpset	%	40.80%
Proposed Parameters		
Flow of the pump	m^3/hr.	400
Head of the pump	M	25
Power of the motor on existing duty point	kW	38.95
Proposed efficiency of pump set on existing duty point	%	70%
Operating hours of the pump	Hours	3682
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	99125
Annual cost saving	Rs. Lakhs	7.88
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	15.09
Investment towards NRV replacement including GST	Rs. Lakh	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	25

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 222: Cost benefit analysis of pump replacement at Rakabganj ZPS

Description	Units	Rakabganj ZPS Pump-2
Rated Parameters		
Flow delivered	m^3/hr.	648
Head developed	M	30
Motor power consumption	kW	75
Measured Parameters		
Flow delivered	m^3/hr.	792
Head developed	M	5
Motor power consumption	kW	77
Calculated efficiency of pumpset	%	14.26%
Proposed Parameters		
Flow of the pump	m^3/hr.	700
Head of the pump	M	12
Power of the motor on existing duty point	kW	31.47

Description	Units	Rakabganj ZPS Pump-2
Proposed efficiency of pump set on existing duty point	%	73%
Operating hours of the pump	Hours	700
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	31695
Annual cost saving	Rs. Lakhs	2.52
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	13.19
Investment towards NRV replacement including GST	Rs. Lakh	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	69

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 223: Cost benefit analysis of pump replacement at Navlakha ZPS

Description	Units	Navlakha ZPS Pump-3
Rated Parameters		
Flow delivered	$m^3/hr.$	1200
Head developed	M	35
Motor power consumption	kW	160
Measured Parameters		
Flow delivered	$m^3/hr.$	784
Head developed	M	36
Motor power consumption	kW	148
Calculated efficiency of pumpset	%	51.31%
Proposed Parameters		
Flow of the pump	$m^3/hr.$	800
Head of the pump	M	35
Power of the motor on existing duty point	kW	96.57
Proposed efficiency of pump set on existing duty point	%	79%
Operating hours of the pump	Hours	2998
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	154038
Annual cost saving	Rs. Lakhs	12.25
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	7.75
Investment towards NRV replacement including GST	Rs. Lakh	0.59
Investment towards gate valve replacement including GST	Rs. Lakh	0.66

Description	Units	Navlakha ZPS Pump-3
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	9

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

Table 224: Cost benefit analysis of pump replacement at Chhipitola booster

Description	Units	Chhipitola Booster Pump-2
Rated Parameters		
Flow delivered	m^3/hr.	140
Head developed	M	30
Motor power consumption	kW	20
Measured Parameters		
Flow delivered	m^3/hr.	90
Head developed	M	18
Motor power consumption	kW	11
Calculated efficiency of pumpset	%	40.85%
Proposed Parameters		
Flow of the pump	m^3/hr.	100
Head of the pump	M	18
Power of the motor on existing duty point	kW	6.60
Proposed efficiency of pump set on existing duty point	%	74%
Operating hours of the pump	Hours	1623
Electricitytariff	Rs./kWh	7.95
Annual energy saving	kWh	7119
Annual cost saving	Rs. Lakhs	0.57
Investment towards new pumpset including installation and commissioning, including GST	Rs. Lakh	2.07
Investment towards NRV replacement including GST	Rs. Lakh	0.00
Investment towards gate valve replacement including GST	Rs. Lakh	0.35
Investment towardsWeb based dashboard including GST	Rs. Lakh	0.08
Payback period	Months	53

Note: Above pumps were proposed at duty points (of existing pumps) observed during energy audit.

6.2.2 Power factor improvement through installation of APFC panels

Table 225: Cost benefit analysis of APFC installation at Sanjay Place ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.83
Average power factor from recent EB bill		0.780
Average real power	kW	320.81
Average apparent power	kVA	383.1
Annual grid electricity consumption	kWh	498408
	kVAh	639906
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	271
Annual grid electricity consumption	kWh	498408
	kVAh	639906
Annual grid electricity savings	kVAh	136464
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	9.76
Investment towards APFC panel	Rs. Lakhs	6.49
Payback period	Months	7.98

Table 226: Cost benefit analysis of APFC installation at Kotwali ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.94
Average power factor from recent EB bill		0.676
Average real power	kW	79.38
Average apparent power	kVA	83.17
Annual grid electricity consumption	kWh	65267
	kVAh	94848
Proposed System		

Parameters	Unit	Parameters
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	73
Annual grid electricity consumption	kWh	65267
	kVAh	94848
Annual grid electricity savings	kVAh	28922
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	2.07
Investment towards APFC panel	Rs. Lakhs	1.730
Payback period	Months	10.03

Table 227: Cost benefit analysis of APFC installation at Suryanagar ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.81
Average power factor from recent EB bill		0.774
Average real power	kW	161.01
Average apparent power	kVA	198.49
Annual grid electricity consumption	kWh	184041
	kVAh	242740
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	119
Annual grid electricity consumption	kWh	184041
	kVAh	242740
Annual grid electricity savings	kVAh	56841
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	4.07
Investment towards APFC panel	Rs. Lakhs	2.884

Parameters	Unit	Parameters
Payback period	Months	8.51

Table 228: Cost benefit analysis of APFC installation at Mathura Road ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.76
Average power factor from recent EB bill		0.735
Average real power	kW	92.27
Average apparent power	kVA	120.67
Annual grid electricity consumption	kWh	139480
	kVAh	189537
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	72
Annual grid electricity consumption	kWh	139480
	kVAh	189537
Annual grid electricity savings	kVAh	48647
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	3.48
Investment towards APFC panel	Rs. Lakhs	1.73
Payback period	Months	5.97

Table 229: Cost benefit analysis of APFC installation at Trans Yamuna ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.88
Average power factor from recent EB bill		0.896
Average real power	kW	34.4

Parameters	Unit	Parameters
Average apparent power	kVA	38.82
Annual grid electricity consumption	kWh	25698
	kVAh	28666
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	38
Annual grid electricity consumption	kWh	25698
	kVAh	28666
Annual grid electricity savings	kVAh	2708
Electricity tariff	Rs./kVAh	6.84
Annual monetary saving	Rs. Lakhs	0.19
Investment towards APFC panel	Rs. Lakhs	1.01
Payback period	Months	65.40

Table 230: Cost benefit analysis of APFC installation at Lawyers Colony ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.84
Average power factor from recent EB bill		0.819
Average real power	kW	68.12
Average apparent power	kVA	80.97
Annual grid electricity consumption	kWh	228386
	kVAh	278437
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	81
Annual grid electricity consumption	kWh	228386
	kVAh	278437
Annual grid electricity savings	kVAh	47744

Parameters	Unit	Parameters
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	3.42
Investment towards APFC panel	Rs. Lakhs	1.947
Payback period	Months	6.84

Table 231: Cost benefit analysis of APFC installation at Nirbhay Nagar ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.82
Average power factor from recent EB bill		0.839
Average real power	kW	46.58
Average apparent power	kVA	56.29
Annual grid electricity consumption	kWh	11241
	kVAh	13425
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	37
Annual grid electricity consumption	kWh	11241
	kVAh	13425
Annual grid electricity savings	kVAh	2070
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	0.15
Investment towards APFC panel	Rs. Lakhs	1.01
Payback period	Months	81.77

Table 232: Cost benefit analysis of APFC installation at Lohamandi ZPS

Parameters	Unit	Parameters
Present System		

Parameters	Unit	Parameters
Average power factor measured on main incomer		0.87
Average power factor from recent EB bill		0.768
Average real power	kW	221.11
Average apparent power	kVA	252.83
Annual grid electricity consumption	kWh	294912
	kVAh	383655
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	168
Annual grid electricity consumption	kWh	294912
	kVAh	383655
Annual grid electricity savings	kVAh	85764
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	6.14
Investment towards APFC panel	Rs. Lakhs	3.605
Payback period	Months	7.05

Table 233: Cost benefit analysis of APFC installation at Keshav Kunj (Bodla) ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.89
Average power factor from recent EB bill		0.903
Average real power	kW	239
Average apparent power	kVA	266.89
Annual grid electricity consumption	kWh	199257
	kVAh	220752
Proposed System		
Proposed power factor at Incomer		0.99

Parameters	Unit	Parameters
Required capacitor bank	kVAr	188
Annual grid electricity consumption	kWh	199257
	kVAh	220752
Annual grid electricity savings	kVAh	19483
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	1.39
Investment towards APFC panel	Rs. Lakhs	5.19
Payback period	Months	44.69

Table 234: Cost benefit analysis of APFC installation at Shahganj-1 ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.88
Average power factor from recent EB bill		0.651
Average real power	kW	278.05
Average apparent power	kVA	317.38
Annual grid electricity consumption	kWh	407053
	kVAh	640891
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	221
Annual grid electricity consumption	kWh	407053
	kVAh	640891
Annual grid electricity savings	kVAh	229726
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	16.44
Investment towards APFC panel	Rs. Lakhs	5.77
Payback period	Months	4.21

Table 235: Cost benefit analysis of APFC installation at Shahganj-2 ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.85
Average power factor from recent EB bill		0.835
Average real power	kW	238
Average apparent power	kVA	281.31
Annual grid electricity consumption	kWh	411608
	kVAh	493099
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	170
Annual grid electricity consumption	kWh	411608
	kVAh	493099
Annual grid electricity savings	kVAh	77333
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	5.53
Investment towards APFC panel	Rs. Lakhs	4.33
Payback period	Months	9.38

Table 236: Cost benefit analysis of APFC installation at Kedar Nagar ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.817
Average power factor from recent EB bill		0.810
Average real power	kW	26.38
Average apparent power	kVA	32.35
Annual grid electricity consumption	kWh	77546
	kVAh	95006

Parameters	Unit	Parameters
Proposed System		
Proposed power factor at Incomer	Cos ø	0.99
Required capacitor bank	kVAr	41
Annual grid electricity consumption	kWh	77546
	kVAh	95006
Annual grid electricity savings	kVAh	16677
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	1.19
Investment towards APFC panel	Rs. Lakhs	1.01
Payback period	Months	10.15

Table 237: Cost benefit analysis of APFC installation at Tajganj ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.87
Average power factor from recent EB bill		0.858
Average real power	kW	301.28
Average apparent power	kVA	346.44
Annual grid electricity consumption	kWh	286791
	kVAh	332719
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	232
Annual grid electricity consumption	kWh	286791
	kVAh	332719
Annual grid electricity savings	kVAh	43030
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	3.08
Investment towards APFC panel	Rs. Lakhs	6.129

Parameters	Unit	Parameters
Payback period	Months	23.89

Table 238: Cost benefit analysis of APFC installation at Rakabganj ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.83
Average power factor from recent EB bill		0.724
Average real power	kW	177.68
Average apparent power	kVA	208.41
Annual grid electricity consumption	kWh	199119
	kVAh	272928
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	165
Annual grid electricity consumption	kWh	199119
	kVAh	272928
Annual grid electricity savings	kVAh	71797
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	5.14
Investment towards APFC panel	Rs. Lakhs	3.61
Payback period	Months	8.42

Table 239: Cost benefit analysis of APFC installation at Navlakha ZPS

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.83
Average power factor from recent EB bill		0.847

Parameters	Unit	Parameters
Average real power	kW	175.52
Average apparent power	kVA	210.93
Annual grid electricity consumption	kWh	561593
	kVAh	661572
Proposed System		
Proposed power factor at Incomer		0.99
Required capacitor bank	kVAr	145
Annual grid electricity consumption	kWh	561593
	kVAh	661572
Annual grid electricity savings	kVAh	94306
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	6.75
Investment towards APFC panel	Rs. Lakhs	3.245
Payback period	Months	5.77

Table 240: Cost benefit analysis of capacitor installation at Chhipitola booster

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.864
Average power factor from recent EB bill		0.907
Average real power	kW	10.58
Average apparent power	kVA	12.24
Annual grid electricity consumption	kWh	38074
	kVAh	41977
Proposed System		
Proposed power factor at Incomer		0.99

Parameters	Unit	Parameters
Required Fixed Type capacitor	kVAr	17
Annual grid electricity consumption	kWh	38074
	kVAh	41977
Annual grid electricity savings	kVAh	3519
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	0.25
Investment towards ixed Type capacitor	Rs. Lakhs	0.180
Payback period	Months	8.59

Table 241: Cost benefit analysis of capacitor installation at Red Fort booster

Parameters	Unit	Parameters
Present System		
Average power factor measured on main incomer		0.882
Average power factor from recent EB bill		0.877
Average real power	kW	5.18
Average apparent power	kVA	5.87
Annual grid electricity consumption	kWh	4185
	kVAh	4773
Proposed System		
Proposed power factor at Incomer		0.99
Required Fixed Type capacitor	kVAr	5
Annual grid electricity consumption	kWh	4185
	kVAh	4773
Annual grid electricity savings	kVAh	546
Electricity tariff	Rs./kVAh	7.155
Annual monetary saving	Rs. Lakhs	0.04
Investment towards Fixed Type Capacitor	Rs. Lakhs	0.0541
Payback period	Months	16.62

6.2.3 Lighting Optimization

Sr. No.	Location	Existing lighting load			Proposed lighting load			Savings					Investment Required	Simple Payback Period in months
		Type	Rated W	Nos	Type	Rated W	Nos	Reduction in W	Operating hours per day	kWh per day	kWh per annum	Rs per annum		
1	Synchronous	Tubelight	40	1	LED Tubelight	18	1	22	24	0.528	192.72	1532.12	850	6.66
2	Flowmore Plant	Tubelight	40	2	LED Tubelight	18	2	44	12	0.528	192.72	1532.12	1700	13.31
		CFL	75	3	LED Tubelight	18	2	189	12	2.268	827.82	6581.17	700	3.10
3	8 VT Plant	CFL	65	3	LED Tubelight	18	3	141	12	1.692	617.58	4909.76	2550	6.23
4	Old Intake Well	CFL	65	2	LED Tubelight	18	3	76	12	0.912	332.88	2646.4	2550	11.56
		Tubelight	40	1	LED Tubelight	18	1	22	24	0.528	192.72	1532.12	850	6.66
5	New Intake Well	CFL	65	2	LED Tubelight	18	2	94	12	1.128	411.72	3273.17	1700	6.23
6	New Jal Nigam Intake Well	Tubelight	80	6	LED Tubelight	36	6	264	24	6.336	2312.64	18385.49	10200	6.66
7	Sanjay Place	Tubelight	36	6	LED Tubelight	18	6	108	12	1.296	473.04	3760.67	5100	16.27
		HPSV	160	3	LED	60	3	300	12	3.6	1314	10446.3	26400	30.33
8	Kotwali ZPS	CFL	85	3	LED Tubelight	18	6	147	12	1.764	643.86	5118.69	5100	11.96
		Metal Halide	250	1	LED	100	1	150	12	1.8	657	5223.15	12600	28.95
9	Surya Nagar ZPS	Tubelight	40	6	LED Tubelight	18	6	132	12	1.584	578.16	4596.37	5100	13.31
		Tubelight	36	3	LED Tubelight	18	3	54	12	0.648	236.52	1880.33	2550	16.27
		CFL	85	5	LED Tubelight	18	8	281	12	3.372	1230.78	9784.70	6800	8.34
		Sodium Vapour Lamp	150	5	LED	60	5	450	12	5.4	1971	15669.45	44000	33.70

Sr. No.	Location	Existing lighting load			Proposed lighting load			Savings					Investment Required	Simple Payback Period in months
		Type	Rated W	Nos	Type	Rated W	Nos	Reduction in W	Operating hours per day	kWh per day	kWh per annum	Rs per annum		
		Metal Halide	250	1	LED	100	1	150	12	1.8	657	5223.15	12600	28.95
10	Mathura Road ZPS	HPSV	250	4	LED	100	4	600	12	7.2	2628	20892.6	50400	28.95
		Metal Halide	250	1	LED	100	1	150	12	1.8	657	5223.15	12600	28.95
		Metal Halide	150	3	LED	60	3	270	12	3.24	1182.6	9401.67	26400	33.70
11	Trans Yamuna ZPS	Tubelight	40	1	LED Tubelight	18	1	22	6	0.132	48.18	366.17	850	27.86
		Bulb	100	1	LED Tubelight	18	1	82	6	0.492	179.58	1364.81	850	7.47
12	Lawyer's Colony ZPS	Tubelight	40	1	LED Tubelight	18	1	22	8	0.176	64.24	510.71	850	19.97
		Metal Halide	250	1	LED	100	1	150	8	1.2	438	3482.1	8800	30.33
13	Nirbhay Nagar ZPS	Tubelight	36	3	LED Tubelight	18	3	54	12	0.648	236.52	1880.33	2550	16.27
		Metal Halide	150	3	LED	60	3	270	12	3.24	1182.6	9401.67	26400	33.70
14	Kedar Nagar	Tubelight	40	7	LED Tubelight	18	7	154	12	1.848	674.52	5362.43	5950	13.31
		CFL	85	1	LED Tubelight	18	2	49	12	0.588	214.62	1706.23	1700	11.96
15	Lohamandi ZPS	Bulb	100	1	LED Tubelight	18	1	82	12	0.984	359.16	2855.32	850	3.57
		Tubelight	40	2	LED Tubelight	18	2	44	8	0.352	128.48	1021.42	1700	19.97
16	Tajganj ZPS	Tubelight	40	2	LED Tubelight	18	2	44	24	1.056	385.44	3064.25	1700	6.66
		Sodium Vapour	150	1	LED	60	1	90	12	1.08	394.2	3133.89	8800	33.70
17	Keshavkunj ZPS	CFL	65	3	LED Tubelight	18	5	105	12	1.26	459.9	3656.21	4250	13.95
18	Shahganj-1 ZPS	CFL	85	1	LED Tubelight	18	2	49	12	0.588	214.62	1706.23	1700	11.96
		Metal Halide	150	2	LED	60	2	180	12	2.16	788.4	6267.78	17600	33.70
		Tubelight	36	12	LED Tubelight	18	12	216	12	2.592	946.08	7521.34	10200	16.27

Sr. No.	Location	Existing lighting load			Proposed lighting load			Savings					Investment Required	Simple Payback Period in months
		Type	Rated W	Nos	Type	Rated W	Nos	Reduction in W	Operating hours per day	kWh per day	kWh per annum	Rs per annum		
19	Navlakha ZPS	CFL	28	1	LED Tubelight	18	1	10	12	0.12	43.8	348.21	850	29.29
		Sodium Vapour	150	3	LED	60	3	270	12	3.24	1182.6	9401.67	26400	33.70
		Sodium Vapour (Pole)	150	3	LED	60	3	270	12	3.24	1182.6	9401.67	26400	33.70
20	Shahganj Phase-2 ZPS	CFL	85	1	LED Tubelight	18	2	49	12	0.588	214.62	1706.23	1700	11.96
		Bulb	60	1	LED Tubelight	18	1	42	12	0.504	183.96	1462.48	850	6.97
21	Chhipi Tola ZPS	Tubelight	40	1	LED Tubelight	18	1	22	24	0.528	192.72	1532.12	850	6.66
		Bulb	100	1	LED Tubelight	18	1	82	12	0.984	359.16	2855.32	850	3.57
22	Red Fort Booster	Bulb	100	1	LED Tubelight	18	1	82	24	1.968	718.32	5710.64	850	1.79
Total annual											**28102**	**223331.82**	**385250**	**20.70**

7 Repair &Maintenance Measures

7.1 Present R&M and O&M expenses

Pump sets requires periodic repair and maintenance to keep themin running condition and each R & M activity has a cost associated with it. During energy audit, it was observed that need of repair and maintenance arises generally for replacement of consumables and for addressing wear and tears of components of pump set.Data regarding repair and maintenance cost for last three financial years along with other cost related with operation for each zone in Agra is given in the tables below.

Table 242: R&M expenses for Water Supply establishments in Agra

Financial Data	Units	Values
Cost of Repair & Maintenance		
Cost of Repair & Maintenance in FY2014 – 2015	Rs. Lakh	209.11
Cost of Repair & Maintenance in FY2015 – 2016	Rs. Lakh	247.22
Cost of Repair & Maintenance in FY2016- 2017	Rs. Lakh	29.39
Cost of operation		
Cost of Operation in FY2014 -2015	Rs. Lakh	41.72
Cost of Operation in FY2015-2016	Rs. Lakh	124.8
Cost of Operation in FY2016-2017	Rs. Lakh	161.44
Cost of Purchase of new pump/motors/accessories		
Cost of Purchase of new pump/motors/accessories in FY2014-2015	Rs. Lakh	331.98
Cost of Purchase of new pump/motors/accessories in FY2015- 2016	Rs. Lakh	668.46
Cost of Purchase of new pump/motors/accessories in FY2016 -2017	Rs. Lakh	430.55

In proposed scenario, repair and maintenance cost for the pumps of Agra may reduceas most of old and inefficient pumps will be replaced by new energy efficient pumps. Along with this, during project period, repair and maintenance of new pumps will be done by EESL selected manufacturer.

8 Project Financials and Business model

An IGEA Report is the process of conducting an energy audit to identify efficiency improvement opportunities, and translating the technical findings into financial terms to present it as a bankable project capable of securing a loan. Therefore it is important to conduct a detailed financial analysis for the project to ascertain the financial viability of the project.

This project would be implemented in Annuity Mode. In this mode, EESL will invest all the capital investment required for implementation of the Energy Efficiency Project. **EESL will assure a minimum energy savings of approx. 20% as compared to the existing energy consumption. Payments would not be affected if savings are higher than 20%.** Further EESL would provide Repair & Maintenance (R&M) for the replaced pump sets during the project period. The repayment to EESL (in the form of annuity) would be determined on cost plus ROE basis. Schematic of business model of this project is provided in figure 293.

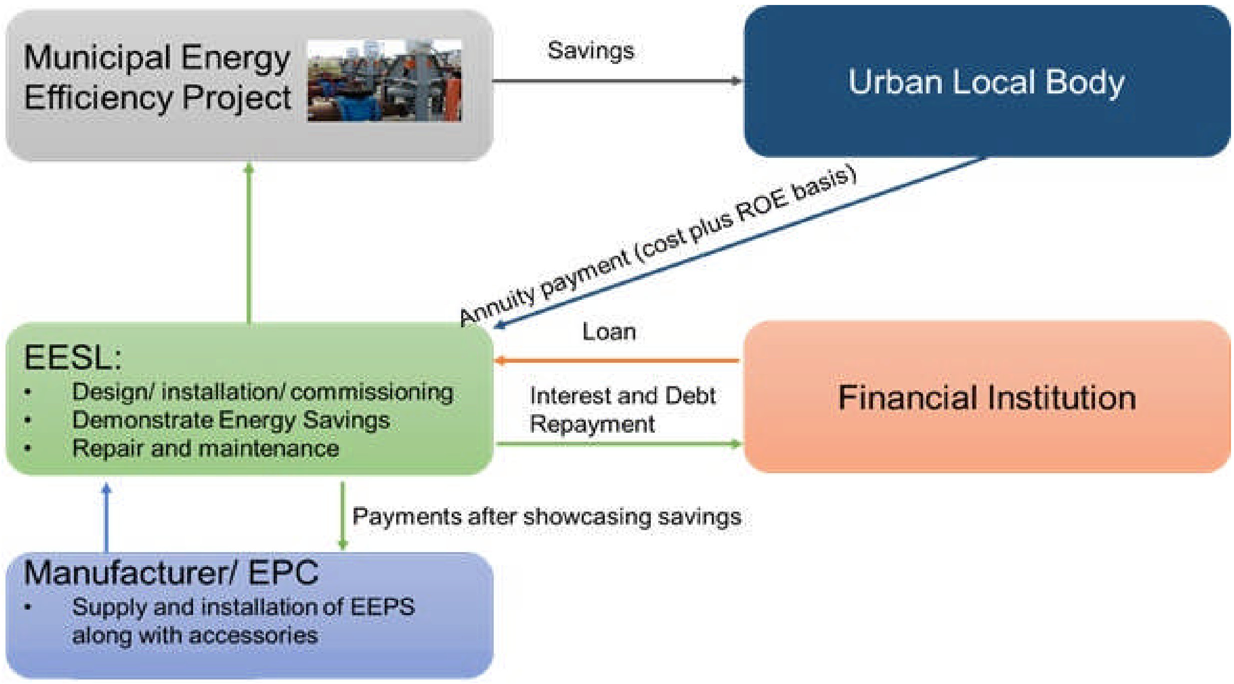


Figure 293 Schematic of business model of the project

8.1 Total Project cost (CAPEX)

The following are the key components considered while arriving at the total project cost:

- Cost of pump, motor and other accessories (like NRV and gate valve), discovered through a transparent bidding process;
- Cost of dismantling, installation and commissioning, discovered through a transparent bidding process;
- Project Establishment and Supervision charges of EESL at 5 % of total cost of equipment including installation;

- Cost of preparation of IGEA, as per actual tendered cost, plus EESL's service charge at 15%;
- All applicable taxes and duties as on actual basis; and
- Capitalized interest during the Project Implementation Period.

Table 243: Total Project Cost

Capital Cost Related assumption	Unit	Value
Number of Pumps	*No.*	23
Total Cost of Equipment including installation, commissioning and testing	*INR lakhs*	328.53
Cost of pump including motor	*INR lakhs*	260.92
Cost of NRV	*INR lakhs*	20.57
Cost of Gate valve	*INR lakhs*	23.29
Cost of Web based dashboard	*INR lakhs*	1.77
Installation and Commissioning Cost including testing charges	*INR lakhs*	21.99
EESL's administrative and establishment charge	*%*	5.0%
Cost of preparation of IGEA report including EESL service charges and applicable GST	*INR lakhs*	22.04
Total Project Cost w/o Capitalized interest	*INR lakhs*	367.00
Commissioning Details		
Total Months for Commissioning	*Months*	9
Capitalized interest	*INR lakhs*	20.57
Total Project Cost	*INR lakhs*	387.58

8.2 Operating Costs (OPEX)

The following are the key components considered while arriving at the operating cost for the project

Operational Details	Unit	Value
EESL's administrative and establishment charges	%	4%

8.3 Financing Terms and other tax related assumptions

The following are the key financial assumptions used in developing the model.Details of financing terms and tax related assumptions are provided in table 244.

Table 244: Financing terms and tax related assumptions

Parameters	Unit	Value
Term of the project	*years*	7
Financing Details		
Debt Percentage	%	70%
Cost of Debt	%	11%
Equity Percentage	%	30%
Cost of Equity (post- tax)	%	16%
Tax Details		
Corporate Tax	**%**	34.61%
Goods and Services Tax	%	18%

8.4 Output - Annuity Payment to EESL

Based on the cost parameters and assumptions mentioned above, the annuity payment to EESL was computed.

Table 245: Annuity payment to EESL

Year		1	2	3	4	5	6	7	Total
Calculations of annuity payment									
Total Debt to be repaid	*INR lakh*	67.00	62.74	58.48	54.21	49.95	45.69	41.42	379.48
Principal Repayment	*INR lakh*	38.76	38.76	38.76	38.76	38.76	38.76	38.76	271.30
Interest	*INR lakh*	28.24	23.98	19.72	15.45	11.19	6.93	2.66	108.18
Total Equity Repayments	*INR lakh*	43.54	39.47	35.41	31.34	27.28	23.21	19.15	219.40
Recovery of equity investment	*INR lakh*	16.61	16.61	16.61	16.61	16.61	16.61	16.61	116.27
Return on equity	*INR lakh*	26.93	22.86	18.80	14.73	10.67	6.60	2.54	103.13
R&M Charges	*INR lakh*	0.00	6.57	8.21	9.86	11.50	13.14	13.14	62.42
EESL's administrative and establishment charge	*INR lakh*	15.50	16.28	17.09	17.95	18.84	19.79	20.78	126.23
Annuity Payment to EESL	*INR lakh*	126.04	125.06	119.19	113.36	107.57	101.83	94.49	787.53
Goods and Services Tax on annuity payment	*INR lakh*	22.69	22.51	21.45	20.40	19.36	18.33	17.01	141.76
Annuity Payment to EESL incl. all applicable taxes	*INR lakh*	148.73	147.57	140.64	133.76	126.93	120.16	111.50	929.29
ULB Savings									
Total Savings	*INR lakh*	252.86	260.42	268.01	275.63	283.25	290.84	298.37	1929.38
Profit to ULB	*INR lakh*	104.13	112.85	127.37	141.87	156.31	170.68	186.88	1000.09
% of savings with ULBs	*%*								**51.83%**

8.5 Sensitivity analysis

The sensitivity analysis has been conducted to determine the impact of change in capital cost and change in savings on the percentage of monetary share of accrued savings retained by the ULB.

Table 246: Project Sensitivity Analysis

Change in Capital Cost	% savings retained by the utility
-10%	56.27%
-5%	54.05%
0%	51.83%
5%	49.62%
10%	47.40%
Change in Interest(ROE, Interest, D/E ratio)	**% savings retained by the utility**
-10%	46.48%
-5%	49.30%
0%	51.83%
5%	54.13%
10%	56.21%

8.6 Payment Security Mechanism

Payment default by the borrower is perceived as one of the most important risks. For projects based on ESCO model, wherein ESCO or financial institution pays the upfront capital for project implementation, the regular payment to the ESCO/financial institution is crucial to maintain a positive cash flow. There are difficulties associated with measuring energy performance accurately and equitably, and therefore the actual energy savings may be disputable, especially in circumstances where the energy baseline and stipulated factors are not well established at the pre-project stage. Apart from possible dispute on actual savings, host's bankruptcy and dismissal of a management body could also be possible reasons for non-payment. Payment security mechanism is necessary to ensure confidence of investors in an ESCO projects. The mechanism should be structured in a way which would be acceptable to ESCO/financial institution. The payment security mechanism maybe in form of irrevocable bank guarantees or letter of credit (LOC) furnished by the ESCO/financial institution.

8.6.1 Letter of credit

Letter of credit (LC) is the obligation taken by the bank to make the payment once certain criteria are met. Whereas, bank guarantee (BG) is a promise made by a bank that the liabilities of the debtor will be met in event the energy user fails to make the payment. The major difference between bank guarantee (BG) and letter of credit (LC) is that BG reduces the loss in the transaction if transaction doesn't go as planned while letter of credit ensures that transaction proceeds as planned. As the ultimate objective of the program is to improve the energy efficiency in water supply and sewage system and ensuring the success of the project, letter of credit would be preferred payment security mechanism.

Letter of credits processes payment on receipt of required documents from the service provider. Major challenges associated with letter of credit are enlisted below:

- Letter of credits are usually irrevocable agreement and hence any changes in terms of contract will be difficult to address in letter of credit.
- Getting letter of credit is difficult considering the stringent qualification criteria. Letter of credit is usually issued to companies and organization that have cash flow, asset and good credit score.
- Usually line of credit are issued with terms for paying it back, herein energy user will be using the line of credit to pay the service provider for its services. In case of energy savings line of credit could be used as an guarantee in case of default by the government entity

In the case of the AMRUT program, the state government play a critical role in implementation of the project would sign the tri partite agreement for implementation of the project. The state government shall provide an unconditional, revolving and irrevocable Letter of Credit from a scheduled and nationalized bank (other than co-operative banks) at its own cost for the entire contractperiod. The amount of letter of credit shall be equivalent to 2 times the quarterly invoice. The LC may then be drawn upon by EESL for recovery of the eligible payments, in case of defaults.

9 Key Observations and Suggestions

To achieve optimum performance and reliability, a pump must be operated close to its BEP (Best efficiency point). The BEP is the most stable operating point for a centrifugal pump. At best efficiency point, the hydrodynamic unbalanced load of the centrifugal pump is at its minimum. Basically, when a pump operates at a point that is far away from the actual BEP, it results in an overall increase in hydrodynamic unbalanced load. This in turn affects the performance, reliability and efficiency of the pump.

Observation:

- **Old Intake Well, Jeoni Mandi:** Pumping machinery, pipes and electrical equipment were found to be old, rusted and in poor condition.

Old pumping machinery and electrical equipment in bad condition

- **New Jal Nigam Intake Well, Jeoni Mandi:** Pump no. 1 was in breakdown condition.

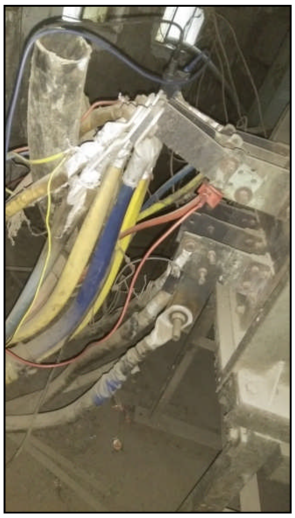
- **HT Plant Golkamra**
  - Measurements were not possible due to site constraints.
  - Pump no. 3 was in breakdown condition.

- **Synchronous Plant**
  - Measurements were not possible due to site constraints.
  - Pump no. 6 was in breakdown condition.

- **8 VT Plant**
  - Heavy leakage was observed from joint between pump outlet pipe and common header.
  - Electrical panels were found to be open and motor terminal box covers were missing. Electrical work in general was found to be in bad condition.

	
Leakage from joint between pump outlet and common header at 8 VT plant	Terminal box covers missing from motors at 8 VT plant

- **Flowmore Plant**
  - Excessive heating was observed at terminals of circuit breaker. Uncovered/open terminal boxes were observed at several points.

	  
Excessive heating at circuit breaker terminals	Open contacts at several locations such as transformer, switchgear, motor terminal box

- **Sanjay Place ZPS**
  - Water is supplied from Sanjay Place ZPS to three different areas through dedicated pumps and pipes. Five pumps supply water to Maithan area, four to Hariparvat area and one to Sanjay market.
  - Pumping machinery and pipes at Sanjay Place were observed to be old and rusted.

- **Kotwali ZPS**
  - Water is supplied to direct distribution and for ESR filling through dedicated pumps and pipelines. Three pumps (pump nos. 1-3) are connected to the pipeline used for direct distribution and two pumps (pump nos. 4, 5) to the pipeline for ESR filling.
  - Pump nos. 3 and 5 were under breakdown condition.

- **Suryanagar ZPS**
  - Pump no. 5 was in breakdown condition.

- **Mathura Road ZPS**
  - Pump no. 1 was discarded.

- **Trans Yamuna ZPS**
  - Pump no. 2 has not been in use for several months.

- **Lawyers' Colony ZPS**
  - Dedicated pump sets and pipes are installed for supply to Lawyers' Colony and Dayal Bagh areas (2 pumps each).
  - Pump no. 2 for Dayal Bagh supply was in breakdown condition.

- **Lohamandi ZPS**
  - Pump no. 3 is used for ESR supply. Pumps 2, 4 and 5 are used for direct distribution. Pump 1 is used in both direct distribution and ESR filling.

- **Keshavkunj ZPS**
  - Pump no. 5 was in breakdown condition.

- **Shahganj Phase-1 ZPS**
  - Five dedicated pumps and their pipeline are used for supply to Shahganj area. Three dedicated pumps and their separate pipeline are used for supply to Subhash Park area.
  - Pump 3 of Shahganj supply and pump 1 of Subhash Park supply were in breakdown condition.

- **Kedar Nagar ZPS**
  - Pump 3 was under maintenance.

- **Tajganj ZPS**
  - Pump 1 was in breakdown condition.
  - Individual flow measurement for the pumps was not possible due to site constraints.

- **Rakabganj ZPS**
  - Pump no. 1 was under maintenance.
  - Top of sump had collapsed and at present, temporary arrangement for covering of sump has been made using nets and corrugated plastic sheets.

- **Navlakha ZPS**
  - Pump no. 1 is used for supply to MES area and its billing is also covered by MES. The other pumps are used for supply to Cantonment area and Bindu Colony at different times.

Operation and Maintenance

There is huge lack of operation and maintenance practice has observed during energy audit. It could be reason for poor performance of pump sets. Deviation of duty point from BEP is not the only reason for reduced efficiency in pump systems, and reasons for this includes wear and tear of internal components (through erosion, cavitation, corrosion, etc.), increased friction losses in piping (due to partial blockages, corrosion, deposition of calcium carbonate), etc. They have a significant impact on pump system efficiency. Also opportunities to save energy by replacing or repairing system components are frequently overlooked. There are various other conditions that decrease the efficiency of pump some of them are given below;

- Heat generated due to packing.
- Rubbing between wear rings and maintaining impeller clearances.
- Recirculation using a bypass line from the discharge of the pump to the suction.
- Double volute design.
- Throttled discharge valve.
- Corroded internal pump passages that cause fluid turbulence.
- Obstacles, hindrances or any sort of restrictions inside the piping passages which might include a foreign particles, or dirt.
- Over lubricated bearings.

9.1 Other Observations And Limitations

Various scope and limitations of the energy efficient projects were observed when energy audit activity was conducted and the same has also been discussed with ULB officials. It is estimated that there is immense opportunity for energy saving in pumping stations in Agra.

Other observations

- It was observed during the audit that civil work and piping at some locations was in poor condition.
- It has been observed that due to the ageing of the pumps currently present in the plant premise, its efficiency and performance is badly affected as the installed pump are around 10-12 years old. It is suggested that installation of new energy efficient pump will lead to energy savings.
- The installed lighting system in the premises were also analyzed and it was suggested that the energy efficient lighting system would lead to significant amount of energy savings.
- The recorded demand at some locations was found to consistently exceed the contract demand, resulting in levying of "Excess demand charges". By appropriate revision of contract demand to closely match the actual required demand, the recorded demand will not exceed the contract demand as a result of which excess demand charges will not be applicable and savings will be achieved.

Limitations

- The installation of energy efficient systems and components should be done according to suggested EE measures.
- Another tapping in the delivery line or change in the existing water delivery network will affect the performance of the new pump.

Due to the limitations observed by the DRA team during the energy audit done, they were unable to cover some of the pumpsets in the plants visited. The following table depicts the plants where energy audit was conducted with associated number of pumpsets that were audited and reasons for the limitations observed.

Table 247: List of Pumping station audited with pumps operating status

S.No	Name of the pumping station	Number of Pumps present	Number of Pumps audited	Number of Pumps where measurement was not possible	Number of Pumps under maintenance /breakdown	Reasons for not covering the pumps
1	HT Plant (Golkamra)	3	0	0	3	Site constraints/breakdown
2	Synchronous pumping station	3	1	0	2	Site constraints/breakdown
3	8 VT Plant	8	3	0	5	Breakdown/emergency use
4	Flow More Plant	5	1	2	2	Breakdown
5	Old Intake Well, Jeoni Mandi	3	1	2	0	
6	New Intake Well, Jeoni Mandi	3	3	0	0	
7	New Jal Nigam Intake well	3	2	0	1	Breakdown
8	Sanjay Place, Maithan Side.	5	3	0	2	Breakdown
9	Sanjay Place, Hariparvat Side.	5	5	0	0	
10	Kotwali ZPS	5	3	0	2	Breakdown
11	Surya Nagar ZPS	5	4	0	1	Breakdown
12	Mathura Road ZPS	4	3	0	1	Breakdown
13	Trans Yamuna ZPS	2	2	0	0	
14	Lawyer's Colony ZPS	4	3	0	1	Breakdown
15	Nirbhay Nagar ZPS	2	2	0	0	

S.No	Name of the pumping station	Number of Pumps present	Number of Pumps audited	Number of Pumps where measurement was not possible	Number of Pumps under maintenance /breakdown	Reasons for not covering the pumps
16	Lohamandi ZPS	5	5	0	0	
17	Keshavkunj ZPS (Bodla ZPS)	5	3	1	1	Breakdown
18	Shahganj Phase-1 ZPS	8	6	0	2	Breakdown
19	Shahganj Phase-2	5	5	0	0	
20	Kedar Nagar	3	2	0	1	Breakdown
21	Tajganj ZPS	6	0	5	1	Breakdown
22	Rakabganj ZPS	5	3	1	1	Breakdown
23	Navlakha ZPS	3	3	0	0	
24	Chhipitola Booster	2	2	0	0	
25	Red Fort Booster	1	0	1	0	
Total		**103**	**65**	**12**	**26**	

10 Measurement and Verification (M&V)

Measurement and Verification (M&V) is the term given to the process for quantifying savings delivered by an Energy Efficiency Measure (EEM). It includes energy saving verification process involving measurements and reporting methodology.M & V methodology followed in this project includes following measurement schedule

- Measurement of parameters pre EEM implementation (just before installation of EEPS) for all operating combinations using portable instruments

- Measurement of parameters post EEM implementation for all operating combinations using portable instruments.

Energy savings are calculated as the difference in power drawn (in pre and post implementation scenario) multiplied by the operating hours mentioned in IGEA.

These energy savings shall be verified in accordance with M&V plan presented in the final report by EESL and as agreed upon by the ULB. The energy savings will be determined and signed by EESL, Pump Supplier and the ULB. EESL shall submit a report as per the reporting template attached to this agreement verifying the savings mentioned in the agreement.

The report shall be submitted by EESL to all the ULB within 15 days of the completion of the verification

10.1 Definition of possible and operating combinations

In ULBs, especially in case of pumping stations, where the pumps are connected in parallel, the pump operated in various combinations. For the purpose of this document, these combinations are defined as possible combinations. For example, for if 3 pumps are connected in parallel, there are 7 possible combinations considering three different pumps i.e.

Pump 1	Pump 1+ Pump 2	
Pump 2	Pump 2+ Pump 3	Pump 1+Pump 2+Pump 3
Pump 3	Pump 3 +Pump 1	

However, the ULB might be operating the pumps only in three combination, depending on the flow requirement, from the one discussed above. For the purpose of this document, these combinations are defined as operating combinations.

Operating Combination 1	Operating Combination 2	Operating Combination 3
Pump 1	Pump 1+ Pump 2	Pump 1+Pump 2+Pump 3

10.2 Flow of activities under M & V process

- First, measurements of old pump would be carried out by the supplier when new pump is ready to be installed at ULB.

- Instantaneous measurement of parameters like flow, head (both at suction and discharge) and power of old pump would be carried out for all operating combinations after stabilisation using portable meters. These parameters will be called pre implementation parameters

- Pre implementation parameters will be verified by EESL, ULB and Supplier.

- Then, old pump will be replaced by new pump and instantaneous measurements of parameters mentioned above will be carried out on new pump after stabilisation for same operating combinations. These parameters will be called post implementation parameters.

- Energy savings of a pump for each combination would be determined by multiplying the difference in instantaneous power consumption in pre and post EEM implementation scenario with corresponding operating hours mentioned in IGEA. Total savings of a pump will be the summation of energy savings in each operating combination (i.e. weighted average savings of a pump would be estimated)

- The flow and head of new pump i.e. post implementation parameters should match pre implementation parameters.

- Post implementation parameters will be verified by EESL, ULB and supplier.

- Penalty would be imposed on pump supplier if energy savings, at ULB level, are less than 20% of existing energy consumption

10.3 Pre and post implementation assessment

To determine savings, the following parameters would be measured during pre and post implementation for each operating combination,

Power Consumption, voltage, frequency (kW, Volt, hz)

Data Unit	kW, Volt, hz
Description	Voltage, frequency and power consumption of all operating combinations (pre and post implementation)
Source of Data	On site measurement using calibrated portable instrument (power analyzer)
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using portable power analyzer
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

Flow rate (m^3/hr)

Data Unit	m^3/hr
Description	Flow rate delivered for all operating combinations (pre and post implementation)
Source of Data	On site measurement using calibrated portable instruments (flow meter)
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using portable flow meter
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

Head (m)

Data Unit	meters (m)
Description	Average head delivered for all operating combinations (pre and post implementation)

Source of Data	On site measurement using calibrated instruments
Description of measurement methods and procedures to be applied	Instantaneous onsite measurement using pressure gauge installed at both the suction and discharge side of the pump
QA/QC procedures to be applied	Calibrated instrument from a NABL accredited laboratory

10.4 Correction Factors and adjustments

In case of deviation in frequency and voltage at the time of post implementation parameter measurements, following correction factors would be applied on parameters of new pump to determine actual. Adjustments factors to be used during M&V are provided in table 248.

Table 248: Adjustment factors to be used during M & V

Factor Affecting	Rationale for adjustment	Adjustment to be made
Variation in supply frequency	As per pump affinity law	$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$ $\frac{P_1}{P_2} = (\frac{N_1}{N_2})^3$ Where, Q is the flow of the meter N is the speed of the shaft P is the power drawn
Voltage Variation	As per BEE guidelines	If the post implementation voltage is 10% higher than pre implementation voltage, power consumption will increases by 0.75% If the post implementation voltage is 10% lower than pre implementation voltage, power consumption will increase by 2%

10.5 Determination of Savings

Based on this data, the energy savings would be calculated as given below:

$$\% \, savings \, (s1) = \frac{\left((kWpre1 - kWpost1) \, X \, h1\right) + \left((kWpre2 - kWpost2) \, X \, h2\right) + \, \ldots \ldots .}{(kWpre1 \, X \, h1) + (kWpre2 \, X \, h2) + \cdots \ldots}$$

Where, 1, 2…. represents parameter for different operating combinations of a pump
h1, h2 represents annual operating hours of a pump in different combinations
kW_{pre} – Instantaneous power consumption of old pump in a particular combination
kW_{post} – Instantaneous power consumption of new pump in a particular combination
s1 represents percentage savings of a pump

Further, aggregate savings at a ULB level would be determined based on weighted average savings of all pumps:

The aggregate percentage savings at ULB would be

$$aggregate\,\%\,savingsatULB = \frac{s_1 \times e_1 + \ s_2 \times e_2 + \ s_3 \times e_3 \ldots\ldots\ldots.}{e_1 + \ e_2 + \ e_3 \ldots\ldots}$$

Where, e represents energy consumption of one pump in all combination

$$e1 = kWpre1\ Xhour1 + kWpre2\ Xhour2 + \cdots \ldots\ldots\ldots$$

s1, s2, s3, s4, s5........ are percentage savings for individual pumps replaced at ULB
e1, e2, e3, e4, e5........ are annual energy consumption of each pump

11 Risk Responsibility Matrix & Risk Mitigation

To develop an effective business model, it is necessary to identify clear roles and responsibilities and the risks associated with the project development. This is useful to develop appropriate structure and plan for project financing and risk mitigation mechanism for ring fencing the risks of project investors. Some of the major risks and their mitigation mechanisms are discussed below.As established in the previous sections, the preferred mode for implementation of this project is annuity mode. Therefore the responsibility matrix has been prepared considering the preferred implementing mode. Details of financial risk and associated mitigation measures table 249.

Table 249: Financial Risk Analysis and Mitigation

Risk	Key Incidence of risk	Description	Mitigation Measure
Operational Risk: Usage risks are usually a direct consequence of use of equipment by the end users. These risks are usually beyond the control of the ESCO			
Inaccurate Baseline	ULB	Baseline for any ESCO based project is usually defined in terms of energy consumption and the performance level of the equipment. In case of pumping stations, when pumps are connected in parallel, few pumps might not be operational during baseline determination. Also, an increase or decrease in operating hours can show up as corresponding increase or decrease in "savings" unless adequate adjustments are applied	The design of the M&V protocol would include sufficient measures in form of engineering formula for baseline correction to sufficiently mitigate this risk
Operational change in the facility	ULB	Operational changes can be in terms of change in usage hours. Further in case of pumping system, the operational changes can be a result of use of higher size of pumps, increase in number of pumps connected in a parallel system, increase in required flow among others.	
Market Risk: Market risks arise due to uncertainty of market conditions. These risks can be attributed to various stakeholders and factors including suppliers of technology, maturity of technology and consumers among others.			
Availability of suppliers	EESL	Availability of suppliers and the technology are keys to development of any ESCO project. Competition in market leads to market forces optimizing the cost. This also leads to new technology innovations and product differentiation. Dependence on a single supplier also increase the project risk, where the project is dependent on capability of single vendor to supply quality products in required quantity in a pre-	EESL is mitigating the risk by ensuring the involvement of manufacturers and suppliers throughout the project lifecycle including taking inputs during IGEA preparation. Further pumping is a matured industry with many suppliers

Risk	Key Incidence of risk	Description	Mitigation Measure
		determined time frame. Ineffective competition may lead to installation of inferior quality product and also cause delay in implementation.	
Age of the technology	EESL	Mature technology are by nature stable and more dependable than new technology. The performance standards for mature technologies are also well defined. There are many inherent risks associated with new technology, these include price fluctuations, rapid technology improvements (which could lead to project being more effective later i.e. early adopters curse[5]), lesser awareness about technology shortcomings and effects.	Pumping is a matured technology with key technical parameters and fundamentals remaining relatively constant during the past century.
Financial Risk: The financial risk mainly deals with the cost escalations associated with the project. These risks if not mitigated properly affect the profitability and feasibility of the project			
Equipment Cost Escalation	ULB	The increase in equipment cost could be due to various factors including increase in cost of raw materials, changed policies and regulations. The escalated cost could result in reducing the project profitability and in worst scenarios making the project unviable.	In the annuity mode, the equipment cost considered is the cost discovered in competitive bidding. This will ensure the best possible cost for the ULB. Further, manufacturer'sbudgetary quotations are taken while developing the IGEA.
Installation and annual maintenance cost Escalation	ULB (before bidding) Technology supplier (post bidding)	Installation cost is the function of manpower cost, cost of carrying inventory and material required for installation. For a project with longer execution cycle, managing installation and annual maintenance cost can be key to success of the project. In addition to factor affecting increase in manpower cost (change in labor laws etc.), the reasons for installation and annual maintenance cost are similar to equipment cost escalation. As the selected technology supplier is contractually responsible for installation and annual maintenance at the rate mentioned in its bids. The	For the ULB the mitigation measures are same above

[5] The new technology turns old very quickly. Also rapid improvements lead to reduction in cost in near future. For example early adopters of solar technology had to pay a higher feed in tariff as compared to later adopters

Risk	Key Incidence of risk	Description	Mitigation Measure
		risk is transferred to the technology provider post bidder selection.	
M&V Costs	EESL	M&V costs tend to vary significantly depending on the extent of measurements, involvement of technical manpower, and automation required in the M&V methods and protocols adopted	M&V mechanism will be clearly defined, agreed and incorporated into project financials prior to project implementation
Time and Budget Overruns	EESL	Failure to implement a viable project in a timely manner can add costs	To be addressed by closely monitoring progress with unit
Design and construction risk: Improper design and delays in constructions are a significant risk to ESCO project.			
Delays in procurement, installation and commissioning	All stakeholders	Delay in procurement, installation and commissioning could drive up project cost. Longer project durations could also increase the probability of other regulatory and policy related risks. It is important to plan the project efficiently to minimize these risks. Projects undertaken by EESL usually require procurement of large quantity of a single product	Standardization of bidding and other contractual documents is key to minimize this risk. Additionally all the stakeholders including ULBs, state government, manufacturers and energy auditors need to be engaged since project inception
Improper selection of energy efficiency solution and integration of energy efficient solution	All stakeholders	The aim of an ESCO project is reduce energy consumption while maintaining or improving performance of the equipment. Proper selection of solution is important to achieve these objectives. Improper selection of solution could lead to non-achievement of savings as estimated. It could also lead to not meeting the performance parameters from the baseline scenario	The manufacturers and technology suppliers are engaged since the project inception including overseeing energy audit activities and selection of technology. Further the manufacturers should be encouraged to visit the facility before bidding for the project.
Performance risks: related to performance of energy efficient equipment post implementation. Poor performance could lead to reduced savings from the ESCO project. This may result in poor financial returns for the project			
Equipment performance depreciation	EESL /Technology Supplier	In many conditions the equipment performance deteriorates over the life of the project. The derating of the equipment needs to be properly modelled in the business model for the project. Incorrect assumptions could lead to severe financial implication of the project. There are two key reasons for the equipment performance depreciation. **Quality of equipment:** Equipment installed as a part of the project does not conform to quality standards set. It is also possible that the vendor supplies equipment which do not	Derating of equipment has been appropriately modelled in the financial model. The values of derating have been finalized after consultation with manufacturers. Proper quality control action plan needs to be developed as part of the bidding documents and contract.

Risk	Key Incidence of risk	Description	Mitigation Measure
		meet the technical specification set out in the bidding document. **External conditions:** These conditions include various external parameters including power quality and operating condition (flow output and pump submergence) deviating from the design parameters	Capacity building of pump operators in proper operations of the new pumps installed
Repair/maintenance and warranty risks	EESL /Technology Supplier	Repair/maintenance and warranty risks relate to faulty equipment risks. The risk also arises due to different agencies being responsible for operations and repair/maintenance. In case of this project, operation would be managed by urban utility, whereas EESL and in turn technology supplier would be responsible for the repair and maintenance. A dispute also might arise related to deviation from warranty conditions which are also not under EESL/technology supplier control. EESL offers extended warranty up to the life of the project under most of its projects. The payment to EESL is also linked to satisfactory replacement of faulty equipment and timely repairs.	Capacity building of pump operators will be taken up to facilitate proper operations and routine preventive maintenance of the new pumps installed EESL will define Comprehensive repair and maintenance requirements including spares and components inventory, as well as appropriate systems (e.g. for registering complaints and turn-around times) and will make the equipment suppliers contractually responsible for preventive maintenance requirements.
Environmental and Legal Risk			
Reduction of water level	ULB, state government and general population	In areas where ground water is supplied through submersible pumps, another important risk is reduction of water level due to over drawl of water by the farmers because of more efficient high discharge new pumps. This could result in many short and long term environmental effects. If the water table is not recharged consistently if might result in other long term effects including desertification.	Change in operation guidelines, i.e. reduction if water supply hours if the flow is increased
Utilization of old inventory in other areas	ULB and EESL	If the collected inefficient pumps are not destroyed they could be used again. This would defeat the purpose of the project and lead to over-estimation of environmental benefits associated with the project.	Proper destruction of old inventory
Health, Safety and Social risk			
Health Safety and Social risk	ULB and EESL	As principal employer EESL is responsible for these risks including: Nonpayment of minimum wages Child labor	EESL should contractually make the technology supplier and contractor adequately

Risk	Key Incidence of risk	Description	Mitigation Measure
		Insurance for workers Emergency preparedness, fire & electrical safety Safety of tools and equipment used	responsible for this risk. As principal employer of all the people working under this project, EESL should collect proper documentation.

12 Project Implementation Schedule

12.1 Execution Strategy

EESL and other stakeholders need to pay attention to project execution in order to deliver impactful projects. The efforts and money on a project that is poorly executed do not produce results on the expected lines.

Following are the project execution strategies to keep projects running efficiently and on schedule:

Define specific and measurable objectives: The well-executed project is seen as one that achieves its desired results. Those specifics should include:

- The timeline for the project- Identify milestones and deadlines that are needed to accomplish incremental progress.
- The staff and infrastructure resources necessary to complete the project. This would include full-time employees, outside contractors, part-time staff or specialized freelance support to properly execute the project.
- The cost of the project- Be sure to take into account human resources and material costs, including hardware and software or consulting fees, travel or other incremental expenses.

Plan for the unexpected: The project managers should take into account that not everything will go as planned. Being prepared for changes also means standing behind a project's goals on a broad level. As the project is being executed, project leaders should be able to explain and support what has happened in the project to date, along with: current status, what the results thus far mean to the project and its objectives, and what specific impact these results will have on the project in terms of cost reduction, broader opportunities, etc.

Measure progress through project waypoints: The process to improvement must invariably include measurement; and not just on a one-and-done basis. The different stakeholders need to measure progress along the way to see an updated view of the project so that they can respond immediately if (and when) project parameters need to be re-calibrated or changed. Measurement should be happening organically so that project leaders have visibility into the time commitment of project participants and the cost of materials and infrastructure.

12.2 Proposed schedule

The total implementation period of the EEM's as per the schedule provided by the pumping station is given in below table.

Table 250: Project Implementation Schedule

T0: Date of signing of MoU between State Government and EESL

Sr. No	Activity	T0	T0 + 30 days	T0 + 90 days	T0 + 105 days	T0 + 135 days
1	Signing of MoU between State Government and EESL					
2	Inviting tenders for hiring of agency to prepare IGEA Report					
3	Preparation of IGEA and submission to ULB					
4	Submission of IGEA to SLTC by ULB					
5	SLTC approval on IGEA					

T1: Date of signing tripartite agreement between State Government, ULB and EESL, known as effective date

Sr. No	Activity	T1	T1 + 30 days	T1 + 90 days	T1 + 255 days	T1 + 270 days
1	Signing of tripartite agreement between State Government, ULB and EESL					
2	Inviting tenders for selection of pump supplier					
3	Selection of pump supplier					
4	Installation of energy efficient pump sets at ULB					
5	Submission of M & V report to ULB by EESL					

Since the ULB has water supplying priorities; the implementation is proposed to be carried out in such a way that the operation of pumping station is not impacted.

Annexures

The Annexures have been compiled as a separate document.

List of Annexures:

1. Energy Auditor/Manager Certificate
2. Verified Job Cards
3. Calibration Certificates of Instruments
4. Electricity Bills
5. Performance Curves of new proposed pump sets
6. Budgetary Quotations from Pump Manufacturers