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ELECTRICAL ENERGY AUDITING AND ENHANCHMENT OF POWER SYSTEM AT BASBARI WATER TREATMENT PLANT, KATHMANDU

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Abstract

The water treatment plant (WTP) employs a variety of electrical machines and utilities, making it an intensive energy consumption plant. In this study, an energy audit was conducted on the Basbari WTP in Kathmandu, Nepal to identify the hotspots that consume most of the energy in the plant and recommend solutions for energy-efficient operation. A power quality analyzer was used to analyze the energy consumption patterns of electrical parameters and the TOD meter load survey data is taken from the electricity authority. The study found that transmission pumps and backwash/makeup pumps consume 77% and 6% of the energy, respectively. Efficient utilization of pump motors could result in an annual cost savings of NRS 109,681.12 from transmission pumps, backwash pumps, and make pumps. The payback period for light replacement and installation of a capacitor bank is 2.16 years and 1.95 years, respectively.

Keywords: *Energy Consumption, Maximum Demand, Specific Energy Consumption, Energy Audit, Energy*

1 Introduction

A water treatment plant is a facility that processes raw water from natural sources, and converts it into clean, safe drinking water. The purpose of water treatment is to remove contaminants, such as bacteria, viruses, chemicals, and other impurities, that can cause illness or damage to infrastructure. Water treatment plants play a critical role in ensuring that communities have access to safe and reliable drinking water. It also helps to protect public health by removing harmful pollutants and minimizing the risk of waterborne diseases. Kathmandu Upatyaka Khanepani Limited (KUKL) is an independent water utility government agency and it has been established under the Company Act of 2063. It is being operated under the public-private partnership model and running several WTP within the Kathmandu Valley for the delivery and production of drinking water. Basbari water treatment plant is operated under maharajgung branch, KUKL. The treatment of water at maharajgung branch dependent on two water treatment facilities and thirty deep tubular well. Energy consumption in any plant is determined by inspection survey known as Energy Audit [1]. It identifies opportunity to improve efficiency and determine where, when, why and how energy is used in the system [2]. It contains report on technical recommendations for improving energy efficiency by verification, monitoring and analysis of use energy with the application of a cost-benefit analysis and a strategy to lower energy consumption. On the other hand, it helps to identifies maximum energy saving areas by breaking down the total energy consumption into all its components and also provides base from which extent of energy saving can be calculated.

Basbari WTP has employed several electrical power consuming machines and the plant is running for the last two decades. Also, the technical status and performance of the equipment/machineries are largely unknown and so the aim of the study is to conduct energy audit to identify the hotspots consuming most of machines, plant overall operating efficiency and recommend necessary action to run more efficiently.

1.1 Need of Energy Audit

Energy, materials, and labor expenses are significant components of a company's operating costs. To reduce costs and increase profitability, it is important to optimize these expenses. One way to achieve cost reduction is by conducting an energy audit, which can help identify areas of waste and inefficiency. The primary goal of an energy audit is to reduce energy consumption per unit cost of product, which can significantly lower operation costs or increase product output. Furthermore, an energy audit can serve as a framework for any organization to effectively manage its energy consumption and costs. By optimizing energy usage, companies can reduce their environmental impact and enhance their sustainability efforts. [1]

1.2 Water Purification Procedure

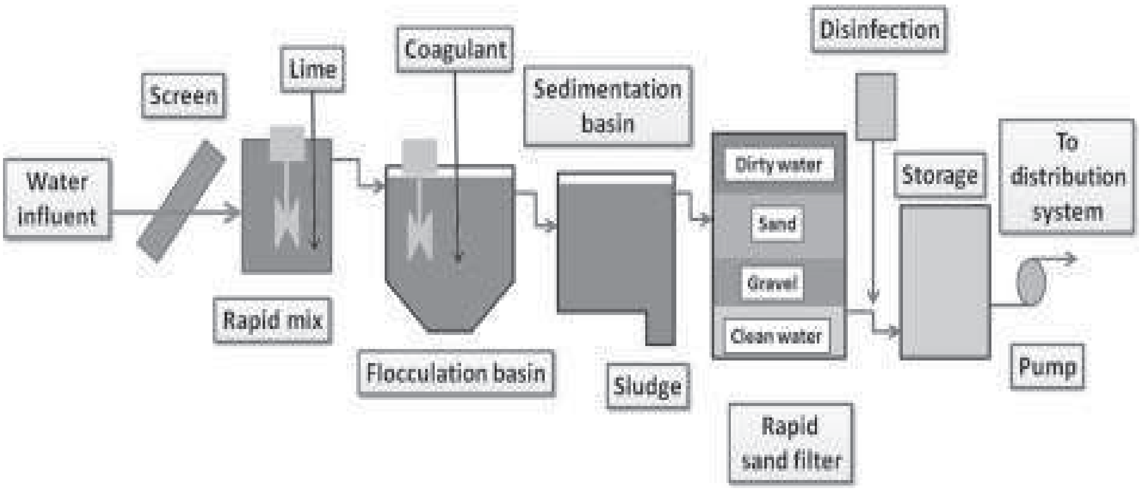


Figure 1: Water Purification Procedure [3]

Figure 1 illustrates the use of high mixing rates to combine chemicals rapidly with water. The addition of chemicals such as aluminum sulfate (alum) is necessary to neutralize the electrical charge of the particles and to encourage them to combine into larger particles known as flocs, which can be more easily separated. As the flocs become heavier, they gradually settle to the bottom of the water supply during sedimentation. Prior to settling, the clear water above passes through filters composed of materials such as sand, gravel, and charcoal, which contain pores of varying sizes. These filters are designed to remove small particles such as dust, parasites, bacteria, viruses, and chemicals that were not settled during sedimentation. [4]

According to a published journal on the assessment of electrical energy consumption, proper utilization of energy through methods such as installing capacitor banks to improve power factor and implementing solar plants resulted in 11.5% savings, which equates to approximately 4 lakhs per month. In addition, the use of PLC and SCADA technology can help minimize losses, and computer buses should be protected to avoid future problems [5]. However, the advancements in AI, Block chain 3.0, 5G, and Digital Twins are crucial in expediting research progress towards the practical application of energy saving field. [6]

The pumping system is the highest energy-consuming device in water treatment plants, and reducing consumption can be achieved through process energy audits specific to the type of facility. The level of audits includes walking surveys, energy surveys and analysis, and detailed audits. Firstly, a walking survey and energy survey are conducted, and then a detailed energy audit is required. In addition to these, energy bills, drawings, flow diagrams, previous energy audits, and pump blower curves are also required.

$$Pw = \frac{wRT_1}{550ne}\left[\left(\frac{p_2}{p_1}\right)^{0.283} - 1\right] \text{.................} \ 1$$

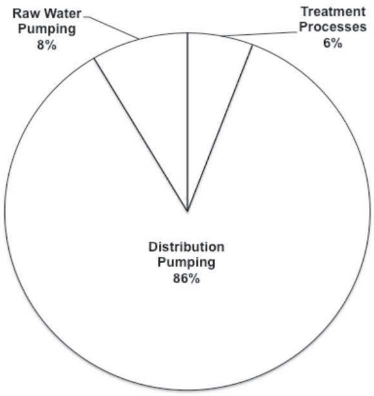


Figure 2: Consumption Pattern Trend

Pw = Blower power (hp), w = flow air weight (lb/s), T_1 = inlet temperature, °R, e = efficiency

p_1 = inlet pressure, (lbf/in^2) p_2 = outlet pressure, (lbf/in^2), the value of n is 0.283

$$Pump\ hp = \frac{flow*head}{3960*pump\ efficiency} \text{.................} \ 2$$

$$motor\ hp = \frac{pump\ hp}{motor\ efficiency} \text{.................} \ 3$$

While calculating the energy efficiency measures, the life cycle analysis cost analysis should be considered. LCCA consists of total cost of energy efficiency. Total cost includes capital cost, O&M costs and disposal costs. [7]

The Plan-Do-Check-Act process also works for energy management systems. Firstly, data from buildings, treatment plants, and plant utilities are collected. Secondly, capital investments and operational improvements are made in energy efficiency program management. Energy audits are not free but have fast paybacks. The parameters affecting energy audits in the WTP are raw water quality, lighting, pumping, and power factor.

$$Transformer\ efficiency = \frac{kW}{kW + no\ load\ loss + (\%loading)^2 * load\ loss} \text{.................} \ 4$$

The recommendation of reducing the energy bills are power factor improvement by installing capacitors, the pumps and motors should properly size to optimize efficiency, the power should be balanced so that it should (3-5)% of motor input power, balance the system to minimize flow and reduce pump power requirements and repair leakage of pipelines [8]

There are nine water treatment plants and several waste treatment plants in the Kathmandu Valley. The operation and maintenance of water treatment plants are highly preferred, whereas operation of sewerage plants is still inappropriate. To improve the system performance, issues of economics, technicalities, and social aspects should be resolved.

The improvement of the drive should increase energy efficiency, lower the cost of operation, and reduce environmental hazards. The different methods and materials of energy audits include initial process analysis, future audit direction, measurement and data collection, and energy analysis. The benefits of energy audits include energy saving, cost saving, emission reduction, and process organization improvement. [9]

1.3 Energy Management System

Energy conservation can be achieved by reducing energy consumption. An energy audit asks questions about when, why, where, and how energy consumption in utilities is shown in Figure 3. Detailed energy auditing involves three types of steps. In the first step, planning, checklists, inspecting energy bills, and usage of energy in the plants are assessed. In the second step, data measurement, energy analysis, savings potential, and cost-benefit analysis are performed. In the third step, a report with recommendations and an action plan is provided. Techniques for improving performance include using separate usage meters, reducing peak demand, scheduling usage at specific times, and using demand controllers.[10]

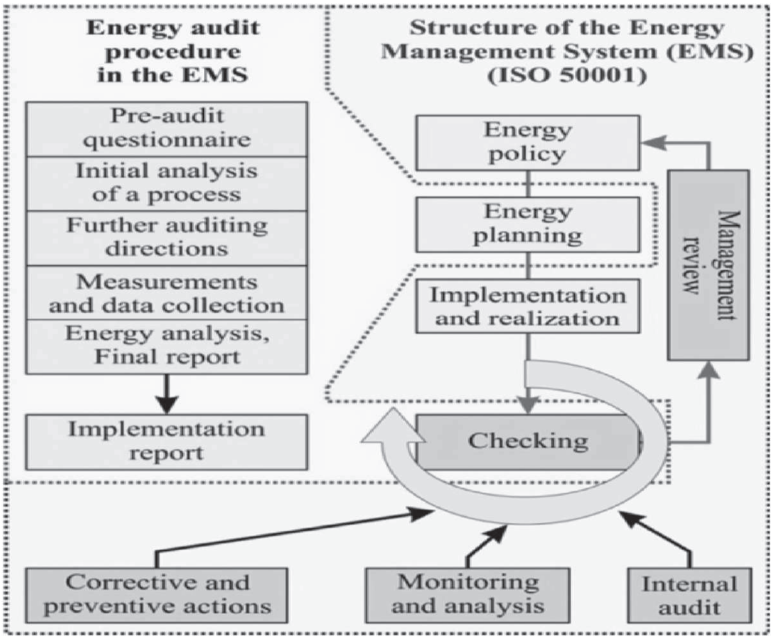


Figure 3: Energy audit procedures [10]

According to research published on the electrical power system at TIA in Kathmandu, Nepal, enhancements to the electrical power system can be achieved by reducing reactive loads, which has eventually improved the power factor. The methodology used a business-as-usual (BAU) scenario and methods to forecast electrical parameters, resulting in a savings of 507,407.8 kWh per year. [11]

According to research published on a five-star hotel in Nagpur, the conservation of electrical energy is achieved by identifying energy-saving potentials. The findings can aid in implementing an energy-efficient project to improve efficiency. Additionally, the research explores the harmonics of current and voltage. The third harmonics of current and voltage were measured at below fifteen percent and five percent, respectively. [12]

Energy Management is done by

- Conducting a thorough review of existing literature to establish a theoretical framework for energy management.
- Finding out the energy conservation opportunities based on energy audit.
- Qualitative and Quantitative analysis.

The recommendation and conclusion are

- Implementation of energy management through institutional capacity building.
- At the pulp and paper industry, most of the state of art technologies use 25% to 38% less energy than a mix of process current used.

As a result of the study, nineteen energy-saving proposals have been suggested, which are categorized based on their cost and potential return as low, medium, and high. Implementing these proposals will lead to an annual savings of INR 12,124,152, with an investment of INR 8,885,000. [13]

An exhaustive examination of efforts to improve energy efficiency in centrifugal pumping systems should include VFD control, load shifting, optimizing pump system efficiency, and specific energy-based control methods. The findings of the paper suggest replacing inefficient motors, replacing oversized components, optimizing the piping system, operating the pump near the best efficiency point, and using VFDs. [14]

The research study on strategizing demand side management in the residential sector of Nepal shows that the development of a structure through the Leap model software forecasting on energy consumption sectors, analysis of various scenarios, and its effects on electricity planning are essential. An exhaustive examination of efforts to improve energy efficiency in the centrifugal pumping system indicates that per capita electricity consumption would rise to 369 kWh if the sector becomes more dependent on electricity, requiring a generation capacity eight times greater than the present value. The study suggests that if solar power is used, 165 MW would be needed to meet 30% of the lighting load by the end of the study period. [15]

The aim of the case study conducted on an educational institution (IMCO, Sohar, Oman) was to identify and implement energy-saving measures in order to reduce the institution's electricity consumption. Through an analysis of the institution's energy consumption patterns, the study identified areas where energy-saving measures could be implemented. The study found that two strategies were implemented: first, replacing traditional fluorescent lamps with LED lights, and second, installing window solar films that are able to control solar heat. [16]

The findings of this study revealed that lighting usage patterns differed across all of the investigated lecture rooms, with 31% of the lighting load wasted and 13% of the lighting load misused by building users recorded. Furthermore, the lighting performance of the lecture room obtained met the MS 1525:2007 lighting with an average illuminance level (300-500 lux) is recommended for working interiors such as classrooms. [17]

2 Methodology

The research methods used include data gathering and energy audits. The initial phase involved site visits, followed by data collection about energy-consuming devices and areas where energy savings could be achieved. The research also involved analyzing efficient techniques and evaluating the costs of the most effective methods.

2.1 General Information

(1) Facility Name:	Basbari Water Treatment Plant, Maharajgung Branch
(2) Facility type:	Surface and Groundwater treatment plant
(3) Establishment:	2004
(4) Water Source:	Surface water from Shivapuri and Bishnumati and ground water from Gonggabu and Basbari Deep tube wells
(5) Capacity:	21 MLD (Design)
(6) Access:	500 m (1 minutes' drive) from Maharajgung, Ring Road
(7) Objective:	Removal of turbidity, organic matter, bacteria and other harmful matter from raw water in order to provide pure water.

2.2 Methodology framework

With an energy measurement tool and a detailed energy audit, one may determine the energy usage at a water treatment facility. Analytical work has been done in Microsoft Excel for both energy use and financial analysis. Research methodology's theoretical foundation shown in Figure 4 Firstly identification of need of energy analysis of water then after literature review is done. After review the literature, findings of research gap between case study and existing research.

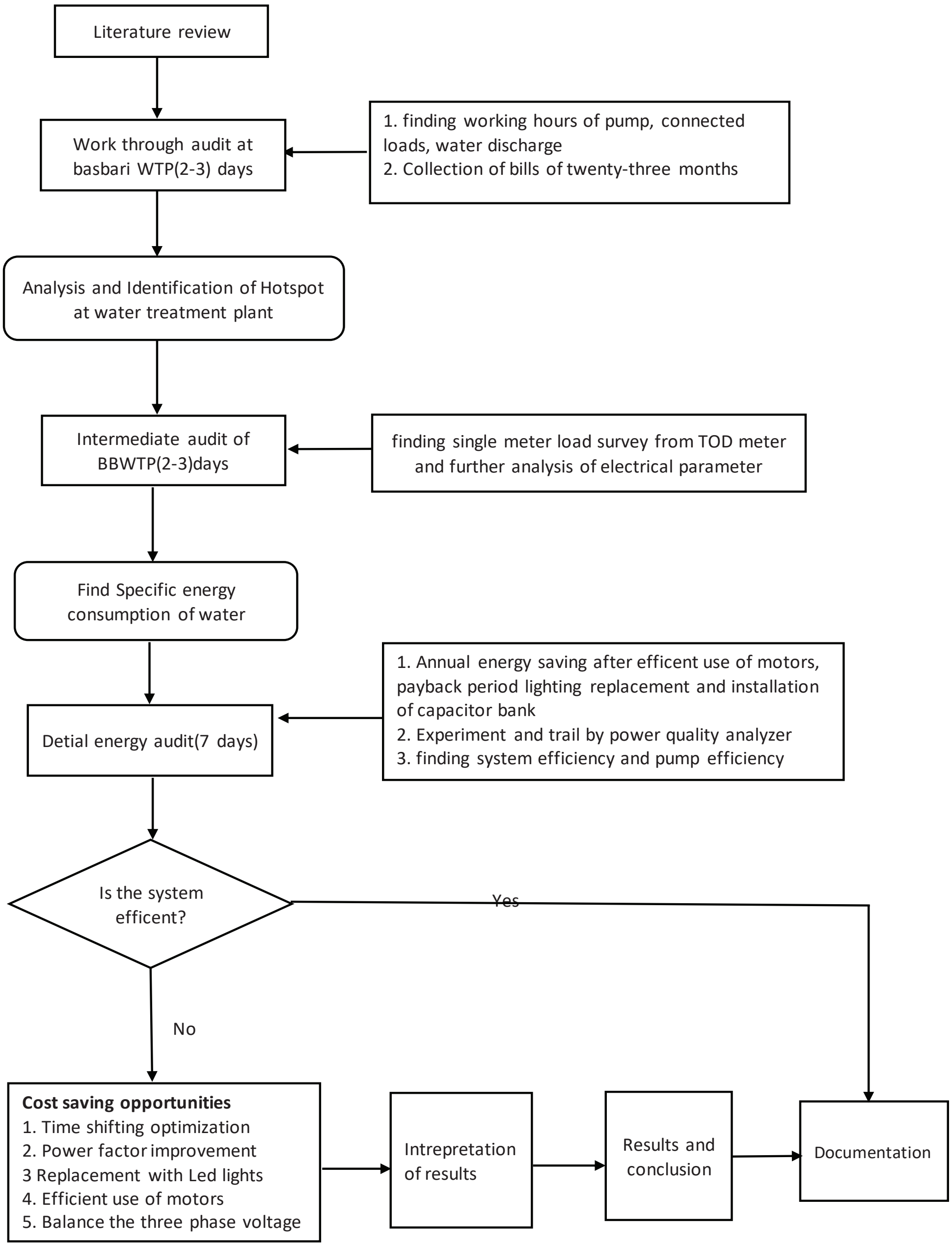


Figure 4: Theoretical Framework of Research Methodology

2.2.1 Walk through audit

- Working hours of pump and others load
- Identify connected loads by interviews with supervisor and inspection of pumps
- Measure the flow meter of water
- Collection of twenty-three months bills
- Identified hotspots as transmission pump, backwash pump and make-up pump
- Time required for walk through audit is 2 to 3 days.

2.2.2 Midway audit

- Collection of voltage, current, average power factor, kWh consumption in each time slots from single meter load survey and further analysis of using above data.
- Specific energy consumption
- Time required for half-way audit is 2 to 3 days

2.2.3 Detail audit

- With the help of power quality analyzer record several average power factor and validate with NEA TOD meter survey, measured active power, system efficiency and pump efficiency.
- Finding the annual saving if the motors are running efficiently.
- Calculation of payback period of replacement with led light and installation of capacitor bank. (Assumption of the study is considering demand charge because NEA claims the money from NG.)
- Time required to experiment and analyzing data required date seven days.

2.2.4 Electricity bills

The period of Electricity bills are from 2077 bhadra to 2079 ashar

2.3 Experimental set up

To execute the results from the BBWTP some devices set up are done. Power analyzer is the device that is used to extract parameters from the plant. CTs, Voltage probe is connected to taken all parameter from the plant.

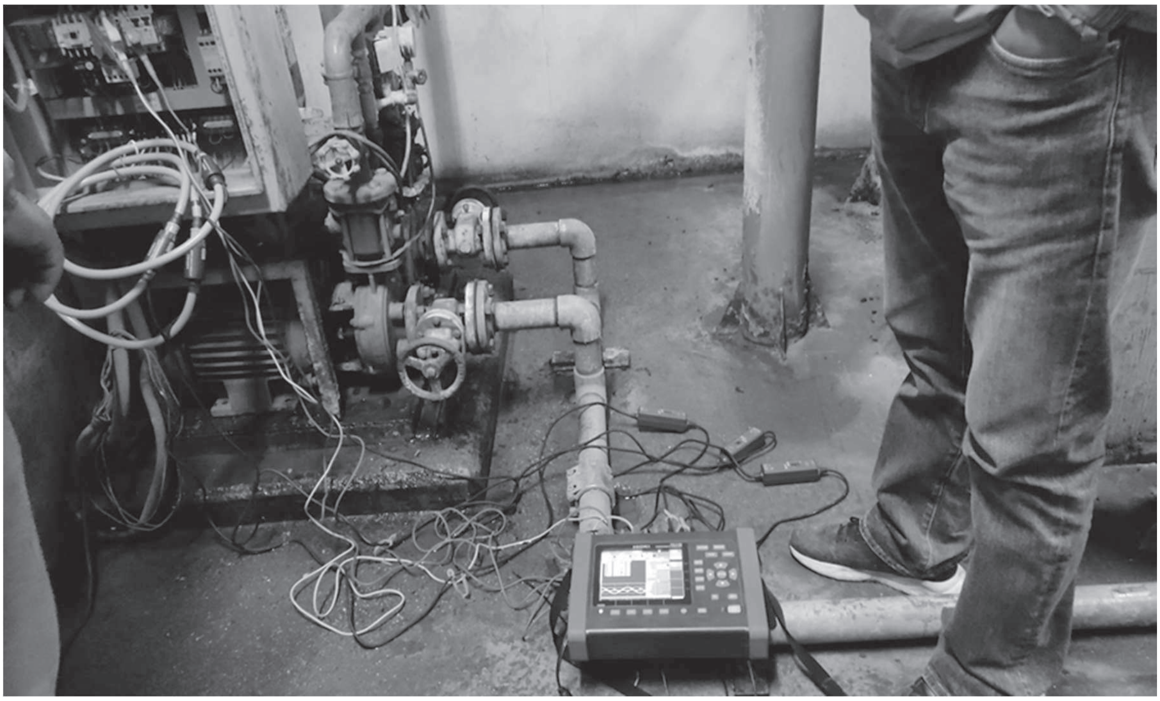


Figure 5: Power Analyzer Set up

3 Results and Discussions

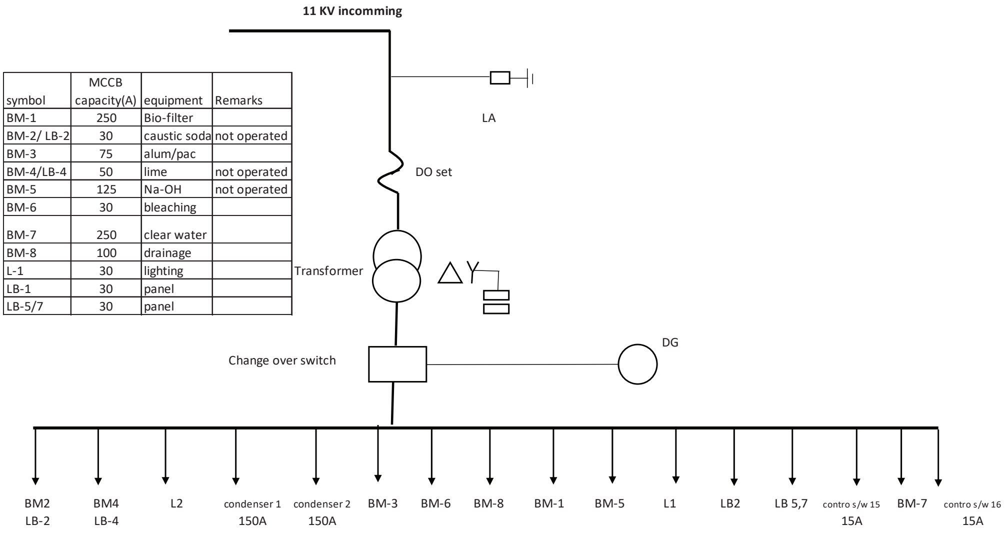
3.1 Power Line Diagram

In the power line diagram, the 11KV incoming line is connected to the NEA grid and a TOD meter is installed at the high voltage side. The line then passes through a 500KVA dry transformer and a 400KVA diesel generator backup system. The power is distributed from the main distribution board to different sub-distribution areas, including the bio-filter, caustic soda preparation area, alum PAC feeding system, Lime preparation area, Na-OH preparation, bleaching, clear water, drainage, lighting, and other panels.

However, the caustic soda system, lime system, and Na-OH system are not currently operational. A vacuum circuit breaker is connected at the MDB, while MCCBs ranging from 30A to 250A are connected at the SDB. The starter systems for pump motors include star-delta starting systems and auto-transformer starting systems.

Date	Time	Phase Voltage in Volts			Line Voltage in Volts			Line Current in Amps		
		U1N	U2N	U3N	U12	U23	U31	A1	A2	A3
1/28/2022	1:20:00 PM	232.12 V	227.94 V	228.15 V	399.37 V	392.65 V	399.94 V	120.07 A	150.42 A	140.44 A
1/28/2022	1:35:00 PM	232.50 V	228.60 V	228.66 V	400.28 V	393.77 V	400.59 V	125.08 A	155.73 A	146.62 A
1/28/2022	1:50:00 PM	232.91 V	229.17 V	229.07 V	401.20 V	394.57 V	401.27 V	125.76 A	156.06 A	145.71 A
1/28/2022	2:05:00 PM	232.47 V	228.91 V	228.65 V	400.64 V	394.05 V	400.40 V	125.76 A	156.79 A	147.93 A
1/28/2022	2:20:00 PM	230.30 V	226.70 V	226.26 V	396.97 V	389.98 V	396.41 V	125.24 A	154.47 A	145.68 A
1/28/2022	2:35:00 PM	229.44 V	227.24 V	227.04 V	396.14 V	392.02 V	395.99 V	108.35 A	136.38 A	122.13 A
1/28/2022	2:50:00 PM	229.84 V	227.75 V	227.62 V	396.91 V	393.05 V	396.79 V	110.98 A	137.80 A	123.69 A
1/28/2022	3:05:00 PM	231.15 V	229.05 V	228.89 V	399.14 V	395.29 V	399.03 V	111.49 A	140.53 A	126.38 A
1/28/2022	3:20:00 PM	231.85 V	229.76 V	229.53 V	400.37 V	396.39 V	400.25 V	124.89 A	150.31 A	142.72 A
1/28/2022	3:35:00 PM	231.12 V	228.95 V	228.93 V	398.92 V	395.31 V	399.08 V	106.72 A	140.22 A	118.30 A
1/28/2022	3:50:00 PM	231.13 V	228.94 V	228.74 V	399.00 V	395.07 V	398.90 V	117.82 A	143.56 A	132.55 A
1/28/2022	4:05:00 PM	229.91 V	227.68 V	227.77 V	396.79 V	393.13 V	397.09 V	124.19 A	147.88 A	141.67 A
1/28/2022	4:20:00 PM	227.53 V	224.97 V	224.88 V	392.56 V	388.08 V	392.56 V	122.55 A	144.50 A	139.73 A
1/28/2022	4:35:00 PM	226.64 V	222.04 V	222.13 V	389.68 V	382.03 V	390.09 V	118.15 A	147.91 A	135.79 A
1/28/2022	4:50:00 PM	227.64 V	223.43 V	223.24 V	391.80 V	384.34 V	391.73 V	117.56 A	146.32 A	134.22 A
1/28/2022	5:05:00 PM	229.41 V	225.21 V	224.96 V	394.88 V	387.39 V	394.72 V	119.03 A	149.62 A	135.79 A

Table 1: Load Profile of Basbari Water Treatment Plant



symbol	MCCB capacity(A)	equipment	Remarks
BM-1	250	Bio-filter	
BM-2/ LB-2	30	caustic soda	not operated
BM-3	75	alum/pac	
BM-4/LB-4	50	lime	not operated
BM-5	125	Na-OH	not operated
BM-6	30	bleaching	
BM-7	250	clear water	
BM-8	100	drainage	
L-1	30	lighting	
LB-1	30	panel	
LB-5/7	30	panel	

Figure 6: Single Line Diagram of Plant

3.2 Power factor of Plant

The multiplication of voltage, current and power factor gives active power of plant. Low power factor causes high reactive power at the System. Power factor of the plant is taken the data from the TOD meter of NEA as well as validate the data through power analyzer. The power factor 0.06 to 0.58 at the plant. The plant is faced by very low power factor so it may cause unreliable operation. Currently there is no demand fee for the water supply system but electricity utility company claims the money from the government to compensate the money. It is better to install capacitor bank in the water treatment plant.

3.3 Total Connected Loads of Plant

Although the bio filter has a high connected load, it is rarely operated because the local supply goes directly from ground water without treatment. The NAOH equipment is not currently in use. The make-up pumps should operate frequently to maintain pressure for washing the filter bed.

Every day, the alum works for fifteen minutes to dissolve, fifteen minutes to shift, and fifteen minutes to dose. Only a single unit runs at once. Since the water has a virtually exact pH level and doesn't require pH adjustment, the slaked lime equipment is no longer in use. The chlorine feeding apparatus runs for thirty minutes to dissolve, fifteen minutes to switch the chemical solution, and fifteen minutes for dosing.

The soiled Quick Sand Filter is cleaned using the backwash pumps. The surface wash unit sets and makeup pump unit sets are both in operation at once. The backwash drain water is collected in a drainage basin, and then the water is collected once again in the RSF by a recovery pump.

The clear water transmission pump is the plant's primary and constant load. It has been running for almost 6 hours during the dry season and for a total of 42 hours during the wet season.

3.4 Energy Consumption

Despite having a high connected load, air blowers only consume a small portion of the overall energy during the rainy season, since groundwater does not enter the water treatment plant. Five percent of the total energy is used for general lighting loads in the treatment plant and household loads in housing. Slaked lime is not used because the water's pH is so close to neutral. Dosing, disinfection, and lab equipment together consume two percent of the energy. Clear water transmission pumps account for seventy-seven percent of the energy usage, while backwash makeup and dewatering consume six percent, auto-pressure pumps use seven percent, and drainage systems consume three percent. Therefore, energy conservation efforts should focus on drainage, backwash, makeup, and transmission pumps, which are the primary energy consumers.

3.5 Energy Consumption Analysis

The voltage variation of the water treatment plant is 2.89% below the base level and 1.48% above the base level. As the permissible level of voltage variation is 5%, it can be concluded that the electricity authority provides stable voltage. The variation in current not only depends on active power but also on reactive power. Analysis of the fiscal year 2078/79 shows that the least energy was consumed in the month of Baisakh (8813 kWh) and the highest energy was consumed in the month of Ashoj (32072 kWh). Energy consumption is higher during normal hours and peak hours, with a small amount of power consumed during off-peak hours. The energy consumption during normal hours, peak hours, and off-peak hours is 48%, 26%, and 26%, respectively.

Similarly, the analysis of fiscal year 2077/78 shows that the least energy was consumed in the month of Baisakh (11733 kWh) and the highest energy was consumed in the month of Bhadra (29083 kWh). Energy consumption is higher during normal hours and peak hours, with a small amount of power consumed during off-peak hours. The energy consumption during normal hours, peak hours, and off-peak hours is 50%, 26%, and 24%, respectively.

Comparing the two fiscal years, it can be observed that less energy was consumed during the month of Baisakh and energy consumption was high between the months of Shrawan and Kartik.

3.6 Maximum KVA Demand Analysis

At the monthly billing of Nepal Electricity Authority, maximum recorded demand data is available on a time slot basis. For the analysis, data from 23 months was taken from the thesis work. The KVA depends on the loading of the electricity-consuming device. The in-plant load demand varies from 136 KVA to 164.5 KVA over the course of the fiscal year 2078-79's 12 months. Bhadra is a month of rising demand while Ashar is a month of falling demand. The internal water treatment plant's approved demand is 500 KVA. The load factor (LF) is 27.2% for 136 KVA demand and 32.9% for maximum demand, indicating that some water treatment plant equipment, such as the air blower, hypo, and lime pump, are not in use. The lower maximum demand occurs in the month of Ashar, and the higher maximum demand occurs in the month of Bhadra in the fiscal year 2077/78. The recorded maximum demands are 164.9 KVA and 179 KVA, respectively. The maximum demand pattern is the same in two years' comparison. The maximum demand is reduced by using capacitor banks, which directly saves the demand charge as well as the reliability of the plant.

3.7 Specific Energy Consumption

Specific energy consumption is high at magh to baisak whereas specific energy consumption is low at month from shrawan to kartik. Remains months has moderate specific energy consumption. Average specific energy consumption is 0.078 kWh per cubic meter and specific cost is NPR 0.32 per cubic meter.

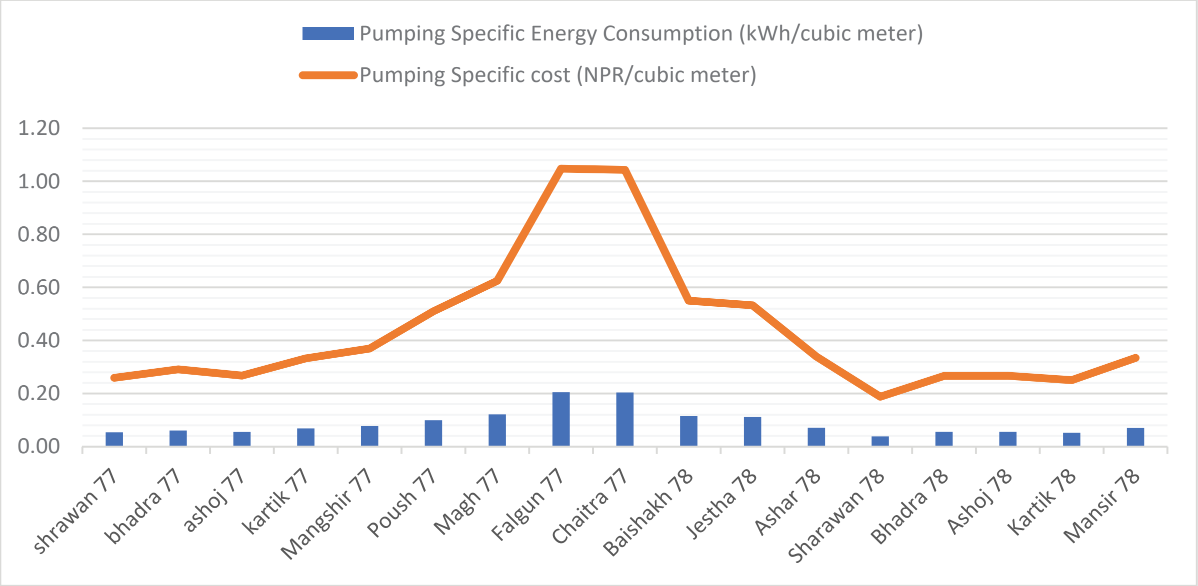


Figure 7: Specific Consumption

3.8 Energy Efficiency

It can be concluded that the pumps with low measured active power have high efficiency, while the backwash pump has lower efficiency compared to the other pumps. Pump number 2 was not operated during the experimental setup. The system efficiency varied from 46.67% to 84.88%, while pump efficiency ranged from 52% to 94%. It can be noted that system efficiency is directly proportional to pump efficiency.

Efficient utilization of pump motors could result in an annual cost savings of NRS 109,681.12 from transmission pumps, backwash pumps, and make pumps. This saving is calculated by subtracting the measured power from the power consumption of the efficient motors.

Pump Station	Measured Active Power [kW]	Flow [m^3/h]	Head (m)	Hydraulic Power (kW)	System Efficiency (%)	Pump Efficiency (%)
Pump 1 - Gravity Tank	15.65	375	13	13.28	84.88	94%
Pump 2 - Gravity Tank	15.6	380	13	13.46	86.29	96%
Pump 3 - Gravity Tank	16.376	382	13	13.53	82.64	92%
Pump 4 - Gravity Tank	17.1	379	13	13.43	78.52	87%
Back Wash - Pump 1	17.34	198	15	8.09	46.67	52%
Back Wash - Pump 2	16.5	198	15	8.09	49.05	55%
Makeup Water - Pump 1	6.5	125	15	5.11	78.61	87%
Makeup Water - Pump 2	6.3	118	15	4.82	76.56	85%

Table 2: Pump Motor Efficiency Table

3.9 Cost Benefits Analysis

The 40W tube lights have been replaced by new LED tube lights. Fifteen tube lights are on for 24 hours, and 39 tube lights are on for 10 hours per day. The old tube lights consumed 30 kWh per day, while the new LED tube lights consume 13.5 kWh per day. The cost to replace the new LED tube lights was NRS 64,000, and the annual savings after using the new LED tube lights is NRS 29,450. The simple payback for the lighting equipment is 2.17 years.

The present approved load inside the water treatment plant is 500 KVA, and the maximum recorded demand is 179 KVA. The power factor for the plant is 0.58, but it should be 0.98 after the installation of a capacitor bank. The required capacity of the capacitor bank should be 124.73 kVAR to make the power factor 0.98. The annual demand savings after the installation of the capacitor bank are 73.06 kVA, resulting in an annual demand charge savings of NRS 137,260.28. The investment for the capacitor bank is NRS 268,179.82, and the simple payback after installation is 1.95 years.

4 Suggestion and Recommendation

- Power factor enhancement by the installation of a capacitor bank results in an increase in power factor (0.98) and 73 kVA less demand at a connected load of 500 kVA, saving 1.37 lacks annually.
- For maximum efficiency, properly size to the load. In comparison to ordinary motors, high efficiency motors offer efficiency gains of 4–5%.
- Power supply three-phases should be balanced. (A voltage imbalance can cause a 3–5% reduction in motor input power.)
- To reduce water waste, fix seals and packing.
- Balance the system to decrease flows and cut back on pump power requirements.

5 Conclusion

The plant operates under low power factor, which should vary from 0.06 to 0.58. The connected load of the water transmission system is the total connected load, whereas the water transmission system consumes seventy-seven percent of the total plant's load. After analyzing twenty-three months' bills from the electricity utility, it was found that the highest energy consumption occurred from Shrawan to Mansir, while the lowest occurred between Falgun and Baisak. According to data taken by a time-of-day meter, nearly fifty percent of energy consumption occurs during normal hours, and equal power is consumed during peak and off-peak hours. Inside the water treatment facility, the highest demand varies from 179 to 164.9 KVA, which is more than the approved demand of 500 KVA for the fiscal year 2077/78, but the maximum demand variation is less in later fiscal years. Energy consumption is directly proportional to tariff, resulting in higher tariffs between Shrawan and Mansir. The specific energy consumption throughout the year is 0.078 kWh/m3, with the highest consumption occurring between Falgun and Baisak. The pumps operate at their highest efficiency during transmission and at low efficiency during backwash. The payback period for capacitor bank replacement is 1.95 years, and the payback period for LED light replacements is 2.16 years.

6 Acknowledgements

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