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

by

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A THESIS

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APPROVAL PAGE

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Electrical Energy Auditing and Enhancement of Power System at Basbari Water Treatment Plant, Kathmandu"** submitted by Dipesh Dhakal, in partial fulfilment of the requirements for the degree of Master of Science in Energy system planning and management.

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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 data 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.

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LIST OF ACRONYMS

AD	Anno Domini
AC	Alternating Current
BAU	Business as Usual
BBWTP	Basbari Water Treatment Plant
CT	Current Transformer
DC	Direct Current
DG	Diesel Generator
HP	Horse Power
HVAC	High Voltage Alternating Current
kVA	Kilo Volt Ampere
kVAR	Kilo Volt Ampere Reactive
kW	Kilo Watt
kWh	Kilo Watt Hour
KUKL	Kathmandu Upatyaka Khanepani Limited
LCCA	Life Cycle Cost Analysis
LED	Light Emitting Diode
MCB	Miniature Circuit Breaker
MCCB	Molded Case Circuit Breaker
MDB	Main Distribution Board
MLD	Million Littre per Day
mWh	Mega Watt hour
NEA	Nepal Electricity Authority
NG	Nepal Government
NPR	Nepalese Rupees
NPV	Net Present Value

O&M	Operation and Maintenance
PF	Power Factor
PH	Potential of Hydrogen
PLC	Programmable Logic Controller
RSF	Rapid Sand Filter
SCADA	Supervisory Control and Data Acquisition
TIA	Tribhuvan International Airport
TOD	Time of Day
VFD	Variable frequency drive
WTP	Water Treatment Plant

CHAPTER 1: INTRODUCTION

1.1 Background

The history of piped water supply systems in Nepal dates back to 1895 A.D., when Bir Sumsher commissioned the first Bir Dhara system in Kathmandu, which was a type of water distribution network. This initiative also led to the establishment of the Pani Goshwara Adda, an office responsible for overseeing and providing piped water supplies, as well as the deployment of a limited number of private and communal standpipes in specific regions across Kathmandu. The Sundarijal water treatment plant was the first systematic water treatment plant, built to treat the tailrace water of the Sundarijal hydropower station (640 KW). The hydropower and water treatment plant were constructed with Indian aid assistance during the regime of Chandra Sumser. The components of the water treatment plant include a distribution chamber, flocculation, sedimentation, chlorination, and clear water tanks. The first Nepali hydropower of Pharphing (500 KW) has been utilized for water supply, along with other sources such as the Nagargun system, Shivapuri, and deep tube wells. [1]

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 [2]. It identifies opportunity to improve efficiency and determine where, when, why and how energy is used in the system [3]. 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.

1.2 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. There are two types of energy audit, preliminary and detail energy audit.

1.3 Preliminary Audit

The process of conducting a preliminary energy audit is highly efficient and enables the assessment of energy consumption in any project or plant. Its effectiveness lies in its ability to accurately estimate the potential for energy savings and identify the areas that require improvement with the least amount of effort. Additionally, this audit method aids in identifying low-cost or no-cost measures that can result in immediate improvements or savings. A preliminary energy audit establishes a reference point that can be used to monitor progress over time, and it highlights areas that require further detailed analysis or measurement. This audit method primarily utilizes existing or readily obtainable data to generate results.

1.4 Detailed Energy Audit

Executing a detailed energy audit typically involves ten steps, which are divided into three phases: pre-audit, audit, and post-audit. The first two steps fall under the pre-audit phase, while the next seven steps are part of the audit phase. The final step is the post-audit phase.

- This includes a walk-through audit, where an auditor inspects the facility to assess its energy consumption and identify areas of potential improvement.
- Conduct the meeting with all divisional heads
- Data collection, process flow diagram, and energy utility diagram
- Surveying and Monitoring
- Execution of detailed trials and experiments on selected energy guzzlers
- Energy consumption analysis
- Identifying and developing energy conservation plan
- Analysis of costs and benefits
- Reporting to and presenting to upper management
- Application and Follow-up

A comprehensive energy audit assesses all major energy-using systems and provides a detailed energy project implementation plan for a water distribution and treatment facility. This audit method offers the most precise assessment of energy conservation and expenses, encompassing thorough calculations of energy cost savings, project expenses, and the interdependent impacts of all initiatives. It takes into account the energy use of all major equipment, such as pumps, electrical motors, transformers, and lighting systems.

The energy balance is a key element in a comprehensive energy audit. This involves calculating energy use, taking an inventory of energy-using systems, and making assumptions about current operating conditions. This estimated use is then compared to utility bill charges.

By using energy more efficiently, Nepalese industries have the potential to cut production costs significantly. Energy is used to operate machines and produce goods or services, making it a crucial aspect of business operations. However, energy awareness is lacking in organizations like KUKL, and it's necessary to quantify energy consumption to attract management's attention to energy savings. Nepal's industries have yet to realize the benefits of energy audits, which can lead to increased profit with lower energy consumption.

Reducing the use of petroleum products and fossil fuels can lead to even greater long-term savings, both environmentally and financially. KUKL has a significant potential for energy audits, especially given its growth and high energy consumption.

1.5 Electricity Load Management and Power Factor Improvement

Load management is a crucial factor in optimizing power plant capacity and minimizing peak demand. Effective load management is necessary to control maximum demand and can be achieved through load generation curves, load rescheduling, shedding of unused loads, and product storage. Reactive power compensation and captive power generation during peak loads are also essential for efficient load management.

Improving the power factor is another crucial aspect of energy efficiency. To achieve energy efficiency, it can be helpful to use devices such as synchronous condensers, phase advancers, and capacitor banks to distribute the load. After improving the power factor, there is a reduction in losses, cable size, motor size, and transformer size, as well as an increase in voltage regulation and efficiency.

Electricity appliances like motors, pumps, ventilation systems (HVAC), lighting systems, diesel generators, fans, and blowers also play a vital role in energy efficiency. Therefore, it is important to consider their energy consumption and efficiency in load management and power factor improvement strategies.

1.6 Water Treatment Process

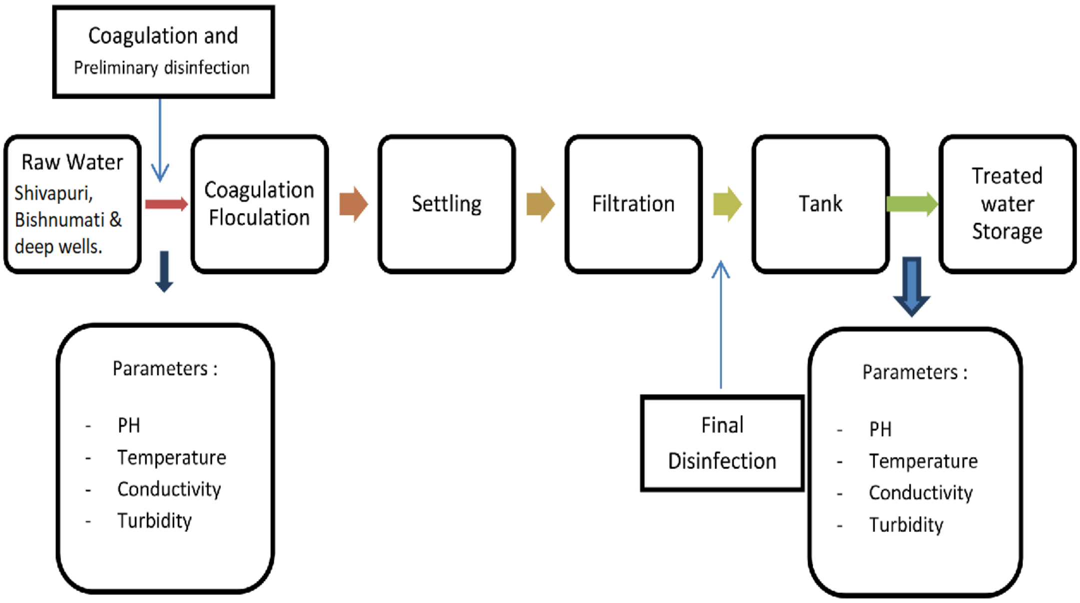

Figure 1: Water Treatment Process [4]

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. [5]

1.7 Problem Statement

The Basbari water treatment plant located in the maharajgung branch was constructed with the aid of international donors and has an average production capacity of 11.66 MLD. The monthly average energy tariff cost for this branch is approximately NRs. 90,548.72, and tariff has decreased since 2077 Shrawan due to NG reducing the demand charge. However, due to the aging of the machines, the plant is not running efficiently, and energy auditing is needed to identify energy-saving potentials. The company is currently facing losses while operating the industry and could benefit from implementing energy-saving measures.

The purpose of conducting an energy audit is to assess the amount of energy used and identify ways to decrease consumption, increase energy efficiency, or generate energy. In water supply systems, performing energy audits is a critical step towards improving their energy efficiency. These audits can concentrate on a single electrical component, such as a pump, or a group of assets, like a water treatment plant. They can also evaluate the hydraulic energy consumption across the entire system. The energy audit of electrical assets involves examining individual assets or sets of assets that use electricity or utilize renewable energy sources. Energy audits are not frequently performed in water utilities in Nepal, so it is essential to conduct such audits and implement energy-saving measures in other industries as well.

1.8 Objective

1.8.1 Main Objective

The main objective of this research is to assess the electricity consumption of a water treatment plant and identify opportunities to save energy costs.

1.8.2 Specific Objective

- To identify the energy-consuming equipment currently in use, determine the actual monthly energy demand, and evaluate the monthly energy tariff for the water treatment plant.
- To perform a comprehensive energy audit of the water treatment plant.
- To conduct areas where annual energy savings can be achieved and calculate the amount of energy that can be saved annually.
- To determine the payback period using an efficient method.
- Finding the electricity consumption per unit water.

1.9 Limitation of Study

The aim of this research is to gain an understanding of the energy consumption within water treatment plants and identify opportunities for energy savings in water usage. Due to time and resource limitations, this study could not cover all areas in the field of water and energy management. The majority of the analysis was conducted using primary data collection, with some supplementary information gathered through interviews with plant engineers and operators and a limited amount of secondary data.

The cost of chemicals, manpower and repair/maintenance was not factored into the calculations.

KUKL only pays the energy charges, while the government provides subsidies on demand charges. However, when calculating the payback periods of capacitor banks, demand charges are also included. The reason for including demand charges is to recover the subsidies provided to KUKL from the government through NEA.

CHAPTER 2: LITERATURE REVIEW

A literature review is carried through reading various papers associated with process of water treatment, methods of energy auditing in water treatment plants, energy conservation & energy saving potentials of treatment plants and cost benefit analysis of WTP.

2.1 Process of Water Treatment Plant

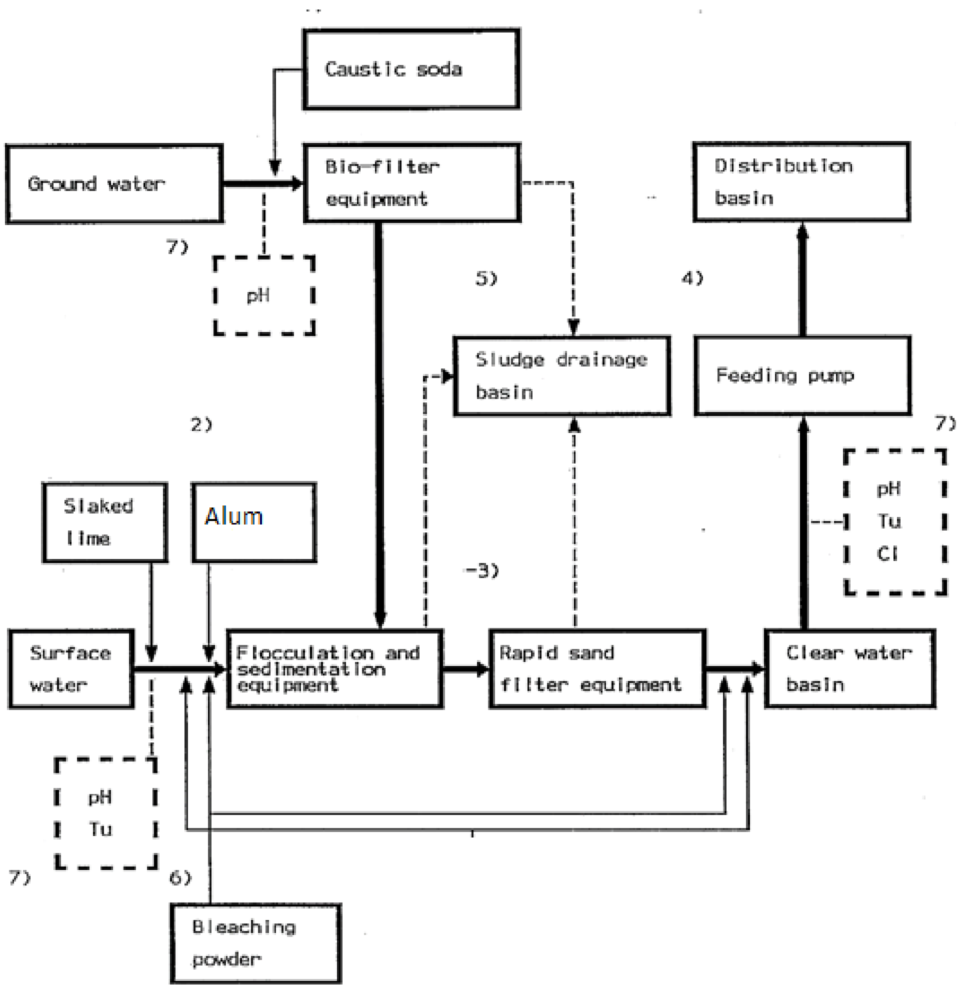

Figure 2: Basbari Water Treatment Plant Process Flow Diagram

Figure 2 describes the process of the Basbari water treatment plant, which has the facility to treat both groundwater and surface water. Bio-filters are used only for groundwater to filter biological components, and a blower is used in the bio-filter. The water from the bio-filter and surface water meet at the inlet distribution chamber, where the water is pre-treated with bleaching powder and alum. Then, the water goes to the flocculation chamber, sedimentation, and filter bed. The backwash pump, which is highly consuming, and the make-up pump are used during the backwashing process. After the filtration process, the water goes to the clear water tank. Then, three transmission pumps carry water from the clear water tank to the distribution tank, and one transmission pump carries water for local supply.

2.2 Electricity Billing

Two-part tariffs are calculated for electricity billing by utilities for small, medium and large-scale industries. The two-part tariff consists of active power and apparent power, and active power is kWh charges whereas apparent power is maximum demand charge. In Nepal, the Nepal Electricity Authority is responsible for revenue collection and consumer services. The tariff structure of the TOD meter for community based water utility is as seen below.

S.N	Consumer category	Demand charge per KVA (NRs.)	Peak hour (5 pm -11 pm) per unit(NRs.)	Off-peak hour (11 pm - 5 am) Per unit (NRs.)	Normal hour (5 am - 5 pm) per unit (NRs.)	Remarks
1	For 11 kV	0	6.3	3.4	4.7	Wet season
2	For11KV	0	6.3	4.7	4.7	Dry season

Table 1: Nepal Electricity Authority Tariff Structure of Time of Day Meter.

2.3 Energy Conservation and Energy Consumption

Energy consumption should controlled by efficient device, proper utilization of electrical energy. Energy consumption is also called the energy used by human civilization.

2.3.1 Energy Audit and Water Treatment Plant

Energy conservation can achieved by reduced in energy consumption. Energy audit ask the questionnaire of when, why, where, when and how energy consumption in appliances. Detail energy audit is an actual method in which three types of steps are involved. In the first step planning, checklist, inspect energy bill and usage of energy in the plants. In the second step data measurement, energy analysis, saving potential and cost benefit analysis is done. At the third step making report with recommendation and action plan is given. The techniques for improving performance includes separate usage meter, reduce peak demand, time scheduling and demand controller.

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 [6]. 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. [7]

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. 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. [8]

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

P_w = 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

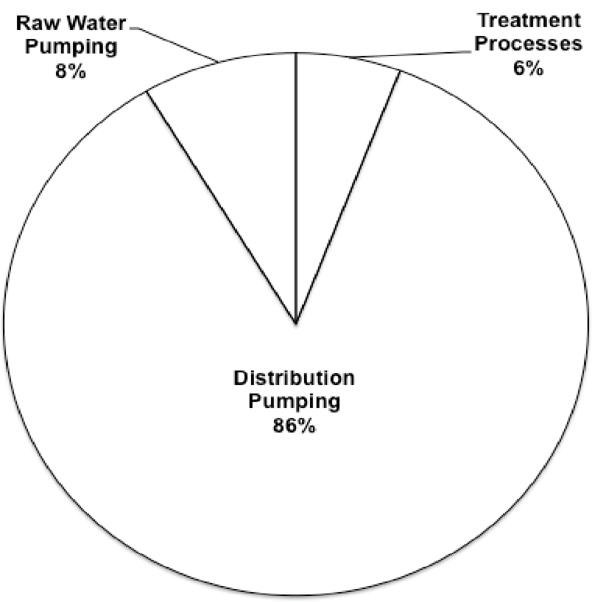

Figure 3: Typical Consumption for Water Treatment Plant.

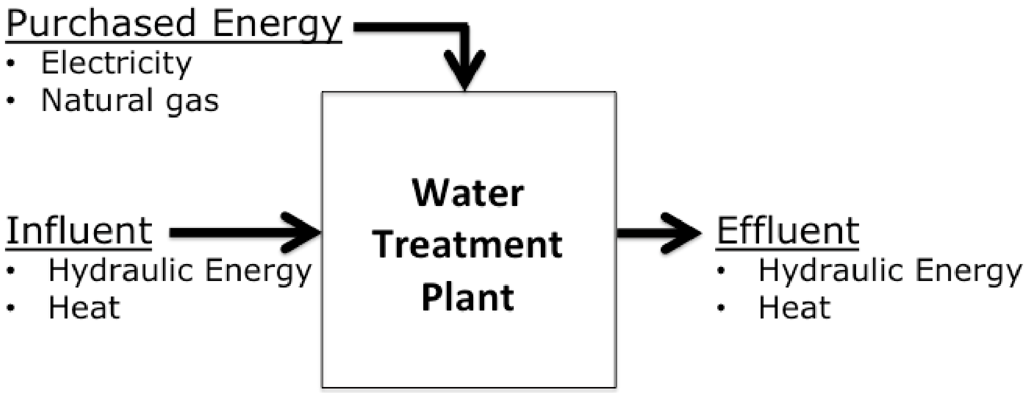

Figure 4: Water Treatment Plant Energy Balance.

$$Pump\ hp = \frac{flow*head}{3960*pump\ efficiency} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$motor\ hp = \frac{pump\ hp}{motor\ efficiency} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

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.

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

The recommendation of reducing the energy bills are power factor improvement by installing capacitors, the pumps and motors should properly size to optimize efficiency, a voltage imbalance can cause a 3–5% reduction in motor input power, balance the system to minimize flow and reduce pump power requirements and repair leakage of pipelines [9]

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. [10]

2.3.2 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 5. 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. [11]

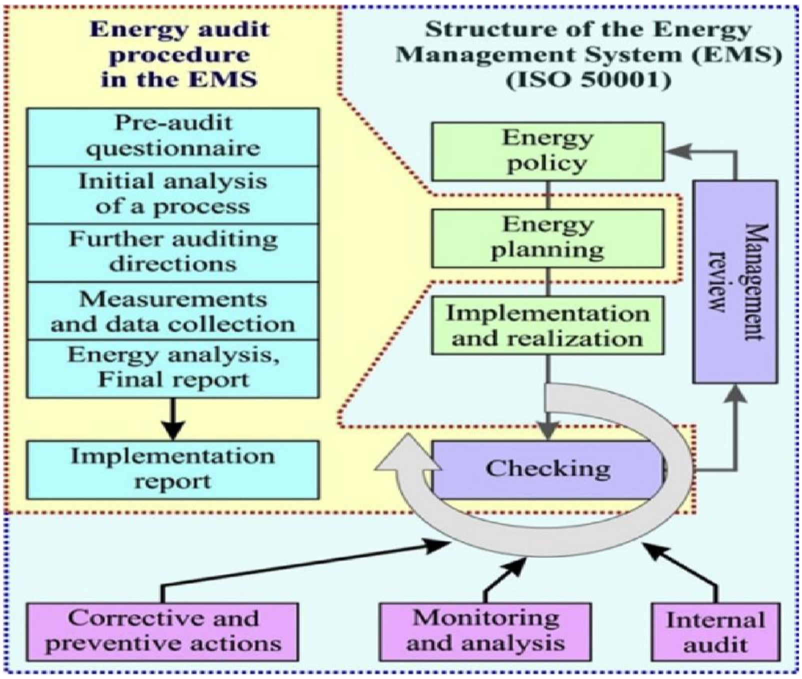

Figure 5: Energy Audit Procedures

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. [12]

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. [13]

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. [14]

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. [15]

2.3.3 Demand Side Management

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. [16]

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. [17]

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. [18]

2.3.4 Motors

Industries mainly consist of motor loads, which convert electrical energy into mechanical energy. The most commonly used types of industrial electric motors are induction motors, DC motors, and synchronous motors. AC motors are generally preferred over DC motors due to their lower cost and better speed control with the use of a Variable Frequency Drive (VFD). The cost of copper required for DC motors is higher, while AC motors require more iron, which is less expensive than copper. Additionally, torque production of AC motors is higher than that of DC motors.

The efficiency of motors plays a vital role in energy saving. As the efficiency of a motor increases, power consumption reduces. However, the efficiency of a motor is affected by various losses, including fixed losses such as frictional and windage losses, and variable losses such as copper losses. These losses should be minimized to increase the efficiency of the motor. Energy-efficient motors are designed to increase efficiency by using lower loss silicon steel, longer core thick wire, thinner laminations, and small air gaps, copper bars instead of aluminum, superior bearings, and good ventilation fans.

Energy-efficient motors cover a wide range of ratings, and their full-load efficiency is higher. They are designed following standard guidelines and procedures such as IS 1231. Although the cost of an energy-efficient motor is slightly higher, it pays back in reduced operating costs. Due to limitations related to voltage, frequency, and speed, energy-efficient motors must be carefully selected to achieve maximum benefits.

Energy efficiency of motors can be achieved through power factor correction using capacitors, synchronous condensers, and phase shifters. Proper rewinding of motors is also important, as improper rewinding can reduce the efficiency of the motor.

2.4 Financial Analysis Methods used in Energy Audit

When it comes to analyzing the costs and benefits of electrical instruments, the most commonly used methods are NPV, IRR, and payback analysis. Payback analysis helps estimate how long it will take to recover the initial investment, but it has a limitation in that it doesn't provide insight into the period after the initial investment is recovered. Despite this limitation, payback analysis is frequently used in energy auditing.

In energy auditing, the most common financial analysis tool is the simple payback method. However, for large projects, it may not be the most suitable tool. A sensitivity analysis should be performed in such cases to identify the effects of changing assumptions, such as operating hours, projected activity levels, energy inflation, and interdependencies, on the project's financial viability. The analysis should also consider dependent projects that are closely linked to the project being evaluated.

CHAPTER 3: RESEARCH 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.

3.1 Overview

The energy consumption of a water treatment plant is determined by conducting a detailed energy audit using energy measuring instruments. Analytical analysis of energy consumption and financial data is performed using Microsoft Excel. The theoretical framework of the research methodology is then plotted in Figure 6

3.1.1 Walk through Audit

- Determine the working hours of pumps and other loads
- Identify connected loads by interviews with supervisor and inspection of pumps
- Measure the discharge of water
- Collection of twenty-three months bill
- Identified hotspots as transmission pump, backwash pump and make-up pump
- Time required for walk through audit is 2 to 3 days.

3.1.2 Midway Audit

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

3.1.3 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.

3.1.4 Electricity Bills

The period of Electricity bills are from 2077 Bhadra to 2079 Ashar

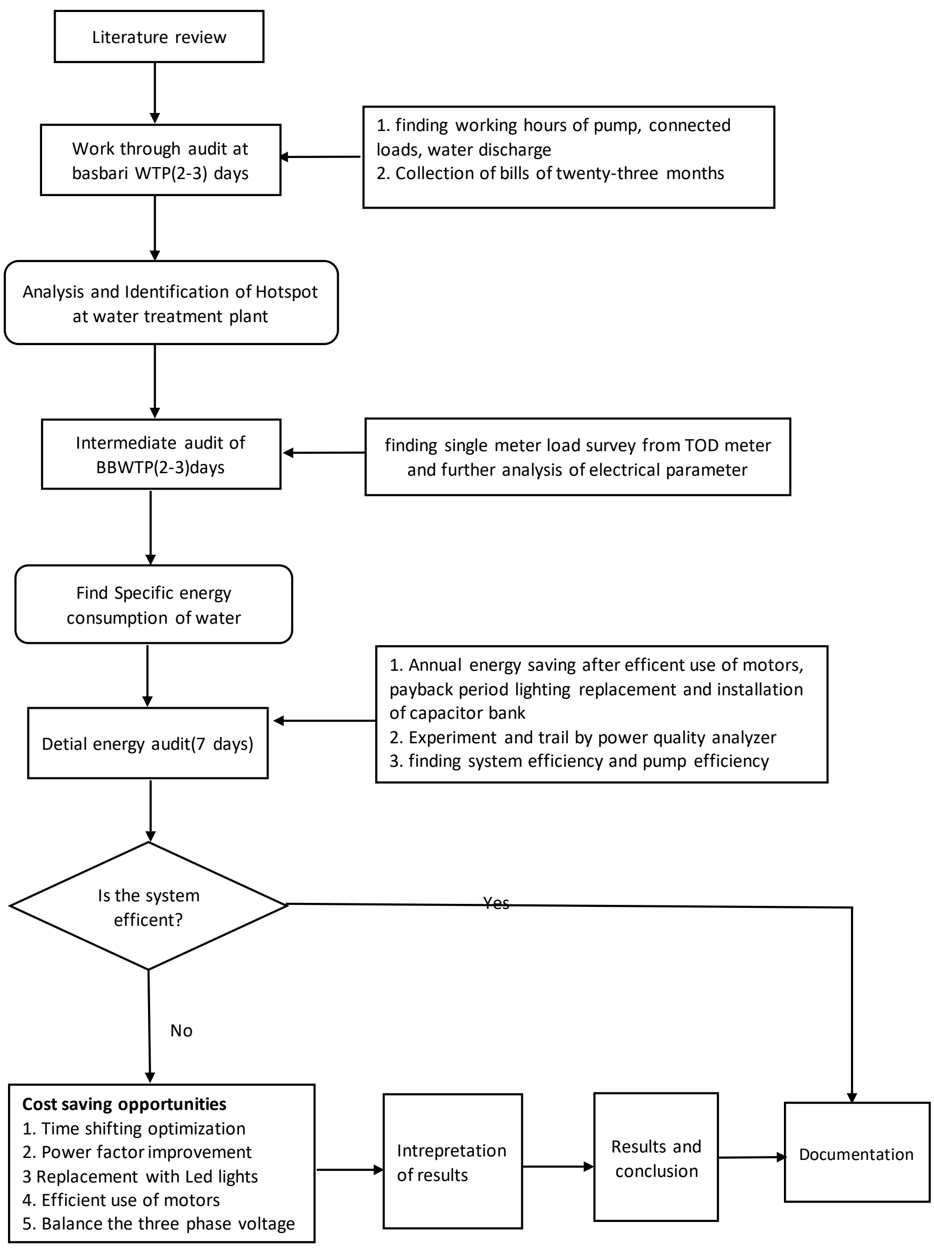

Figure 6: Theoretical Framework of Research Methodology

3.2 Experimental Setup

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 7: Power Analyzer Setup

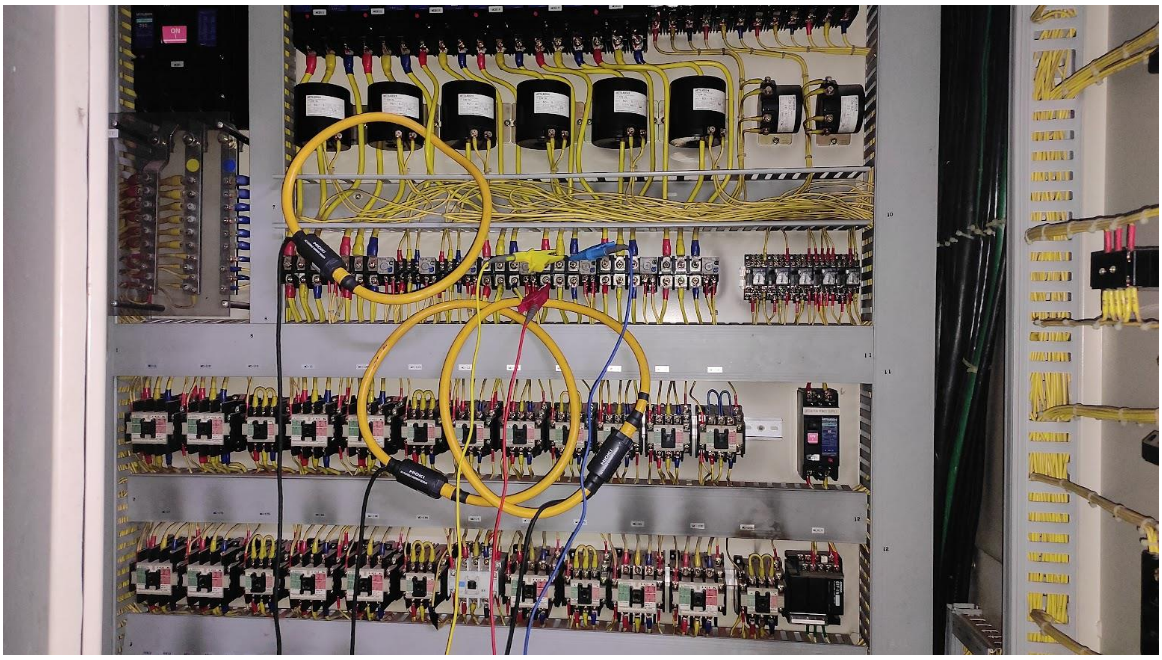

Figure 8: CTs and Voltage Probe Connected at Panel Board

3.3 Electrical Energy Consumption, Energy Saving and Economic Analysis

To find the energy consumption with given power (P) and time (t) then equation becomes

$$E = P * t \ldots\ldots\ldots\ldots\ldots\ldots 5$$

Monthly energy cost can be determine by

$$E_{mc} = E_m * C_{kWh} + E_{max} * C_{kVA} \text{.................} 6$$

Whereas E_{mc} represents total monthly bill, E_m is total energy consumption, C_{kWh} is average cost of per unit consumption, E_{max} is maximum demand and C_{kVA} is cost of demand charge per kVA per month.

Annual energy cost saving should be find from the equation given below.

$$E_{saving} = (E_{mcold}-E_{mcnew})*12 \text{................} 7$$

Where E_{saving} is total energy saving, E_{mcold} is energy used before efficient method and E_{mcnew} is energy used after efficient method.

Load factor is given by,

$$L.F = \frac{Actual\ load}{Approved\ load} \text{.................} 8$$

Relation between power-factor (cosβ), KVA and kW is,

$$kW = kVA * \cos\beta \text{.................} 9$$

$$kVAR = P * (\tan\beta_1 - \tan\beta_2) \text{.................} 10$$

Where kVAR is the reactive power required for power factor improvement, P is active power and β_1 and β_2 are phase angles before and after implementation of capacitor banks.

3.4 Site Selection

This treatment plant 500 m from Maharajgung ring road near to Gangalal hidyarog kendra Kathmandu. It is located at co-ordinates of 27°44'51.15"N, 85°20'42.94"E in Bagmati province. The geographical map of Basbari water treatment plant is shown in Figure 9

Figure 9: Basbari Water Treatment Plant Location

3.4.1 Basbari Water Treatment Plant

Kathmandu Upatyaka Khanepani Limited (KUKL) is a water supply and sanitation operator within Kathmandu valley. It was founded in 2004 and is responsible for managing water supply and wastewater services in the region. KUKL is a public company established under the Company Act, with the majority of shares owned by municipalities (50%) and the government (30%), and the remaining shares owned by private sector representative bodies (15%) and the employees' trust (5%). KUKL operates three major water treatment plants, Mahankalchaur Kathmandu, Basbari Kathmandu, Melamchi WTP, and Bode Bhaktapur water treatment plant, as well as several medium and small-sized facilities such as Old Sunderijal, Saibu, Panipokhari, Takhel, and Bhatapur Basbari water treatment plant.

The Kathmandu valley water supply system has twenty-six existing water treatment plants, with 20 in operating condition and a total treatment capacity of about 117 MLD. Six of the WTPs are comparatively larger (with treatment capacities greater than 10 MLD) and treat water from surface or ground sources, or both. The rest are mostly smaller facilities, with the majority being for treatment of groundwater and attached to individual tube wells located throughout the Kathmandu valley. The Basbari water treatment plant was constructed to remove turbidity, organic matter, bacteria, and other harmful materials from raw water. Its maximum production is 21 MLD (during the wet season) and minimum production is 2 to 2.5 MLD (during the dry season). The capacity of the bio-filter is 17.6 MLD, and the capacity of the flocculation, sedimentation, and filter is 21 MLD. Currently, it is managed by the Maharajgunj Branch Office.

3.4.2 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, Banyatar 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.

CHAPTER 4: RESULTS AND DISCUSSION

First plan and organize & work through survey in the water treatment plant. In the detail phase audit, data is collected, process flow and energy utility data is prepared and then recommendation and cost benefit analysis is done. Energy consumption is measured through power analyzer, data logger, clamp meter, multi-meter and power factor meter etc.

4.1 Electrical Single Line Diagram and Overall Power Factor Correction

4.1.1 Electrical Single 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 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. The plant is protected by lighting arrestor, DO fuse and grounding arrangements. The use of change over switch is switching between diesel generator and grid supply. There is separate supply system for control switches, lighting arrangements, pump supply and condenser supply.

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	

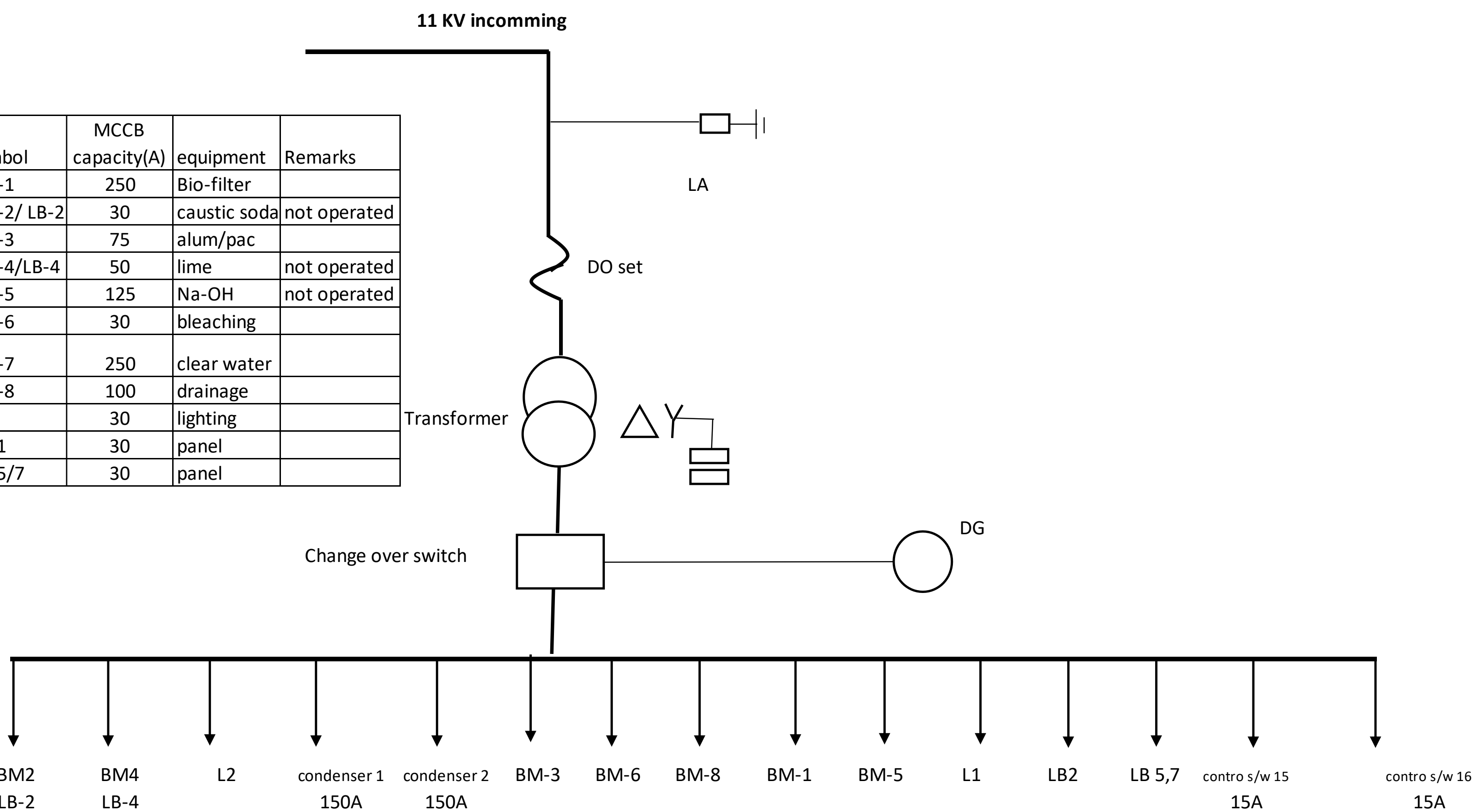

Figure 10: Single Line Diagram of Basbari Water Treatment Plant

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 2: Load Profile of Basbari Water Treatment Plant

4.1.2 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 ranges from 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.

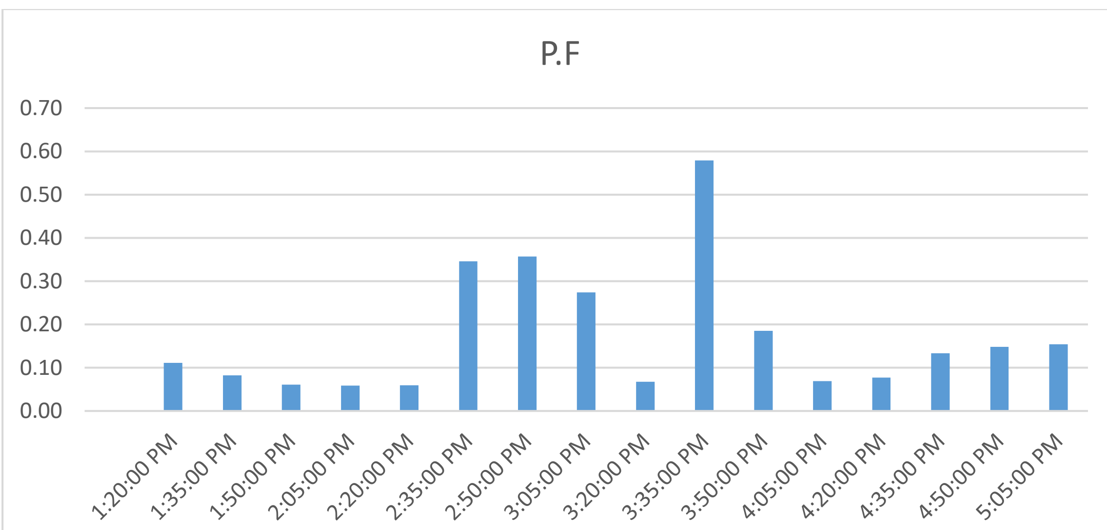

Figure 11: Power Factor of Basbari Water Treatment Plant on 28 January 2022

4.2 Load Analysis of Water Treatment Plant

Total connected load inside plant found as below during survey.

S.N	Pumps/Motors	No of pumps	Capacity	Total connected load
1	Transmission pumps	4	18.5	74
2	Backwash pumps	2	22	44
3	Make up pumps	2	7.5	15
4	Auto Pressure pumps	2	5.5+3.75	9.25
5	De watering pumps	1	0.75	0.75
6	Blower	3	22	66
7	Submersible pumps	1	7.5	7.5
8	Alum/ PAC Feed motor	2	0.75	1.5
9	Grinder Pump	1	11.2	11.2
10	Alum circulate pump	2	1.5	3
11	Lime pump	4	1.5	6
12	Drainage pumps	2	11.2	22.4
13	Pre chlorination pumps	1	0.75	0.75
14	TX Chlorination pump reset	2	1.1	2.2
15	TX Chlorination pump reset	1	0.75	0.75
16	Mixer pump Bleaching	2	1.5	3
17	Golfutar pump supply	1	7.5	7.5
18	Water for Bleaching	1	0.75	0.75
19	Incubator	2	0.25	0.5
20	Tube lights	100	0.009	0.9
21	Street light	12	0.04	0.48
22	Return pump	1	11.2	11.2
24	Fan	8	0.06	0.48
25	Refrigerator	1	0.15	0.15
26	Distilled water machine	1	0.1	0.1
27	Heater	6	1.5	9

Table 3: Total Connected Load

It is possible that the bio filter may have lower energy consumption compared to other types of water treatment systems, especially if the local area is receiving groundwater directly. However, it's important to note that the connected load of the bio filter may still be high due to the need for pumps, motors, and other equipment that are required to operate the system. Currently, the NAOH equipment is not in use, and make-up pumps need to 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. Since the water has a nearly precise pH level and does not 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 shift the chemical solution, and fifteen minutes for dosing. The soiled Quick Sand Filter is cleaned using the backwash pumps, and both the surface wash unit sets and make-up pump unit sets operate simultaneously. The backwash drain water is collected in a drainage basin and then, using a recovery pump, the water is collected again in the RSF.

The clear water transmission pump is the primary and constant load of the plant, running for almost 6 hours during the dry season and a total of 42 hours during the wet season. The following are the details for all connected loads:

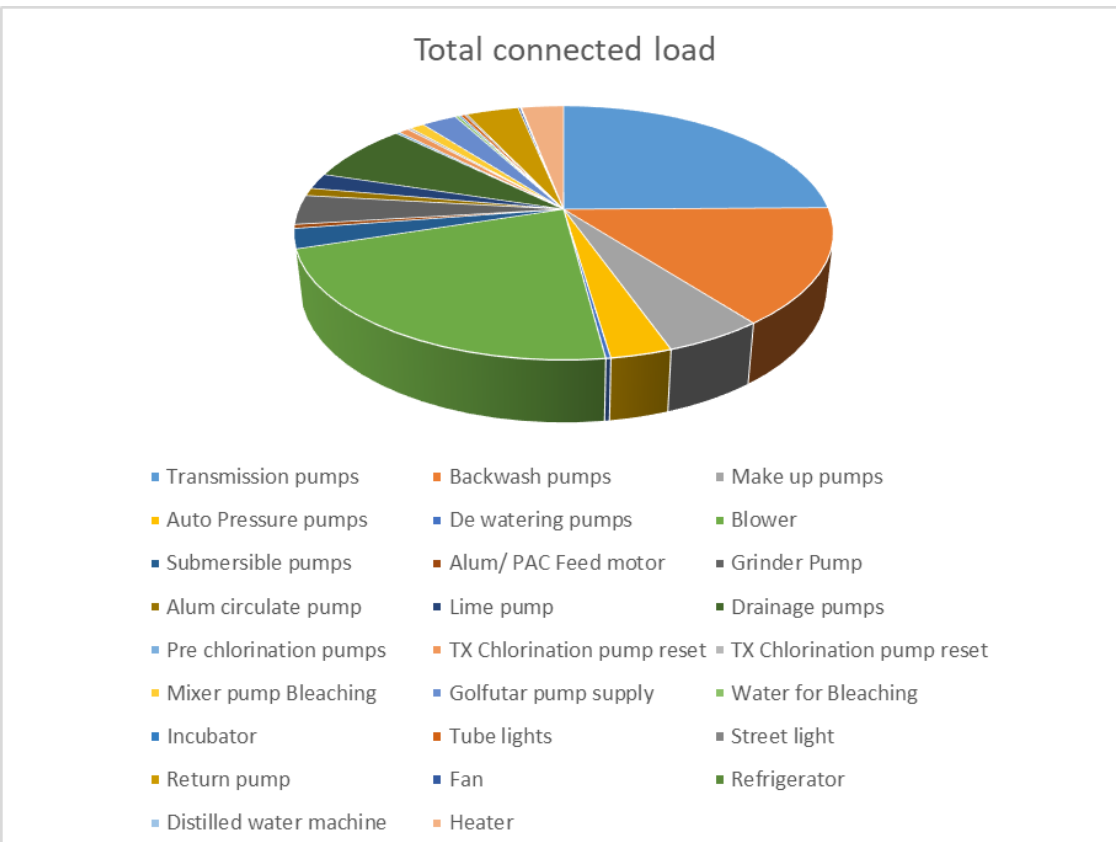

Figure 12: Total Connected Loads

4.3 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.

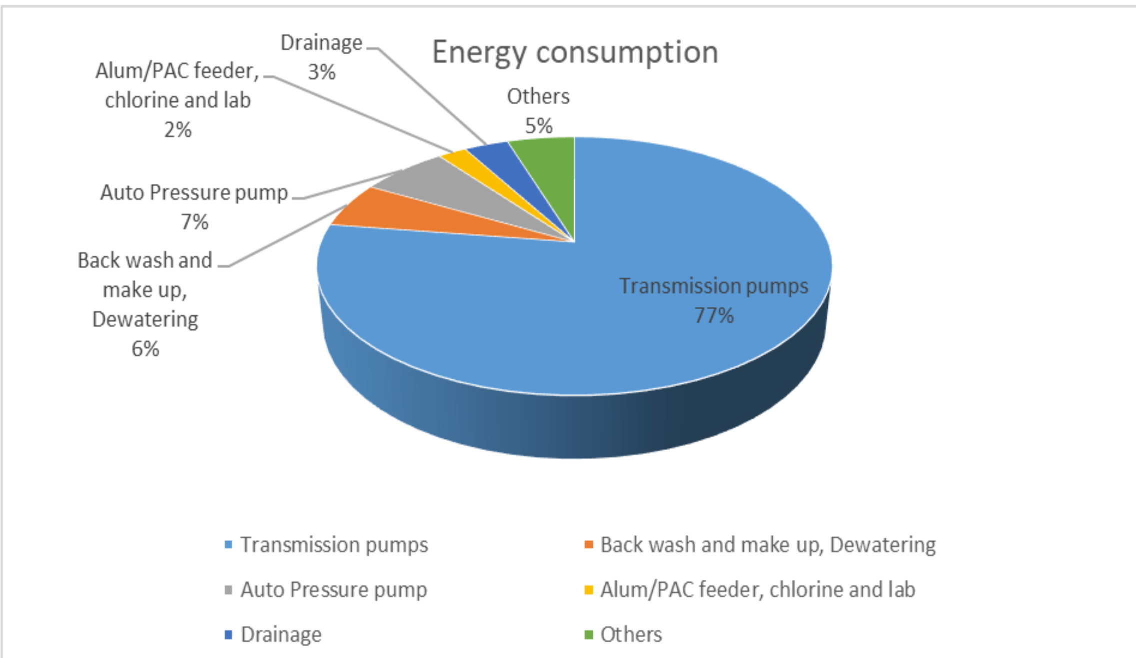

Figure 13: Daily Energy Consumption Pattern

4.4 Specific Energy Consumption

Specific energy consumption on the June 18 2022 (Ashar 04 2079) is found as:

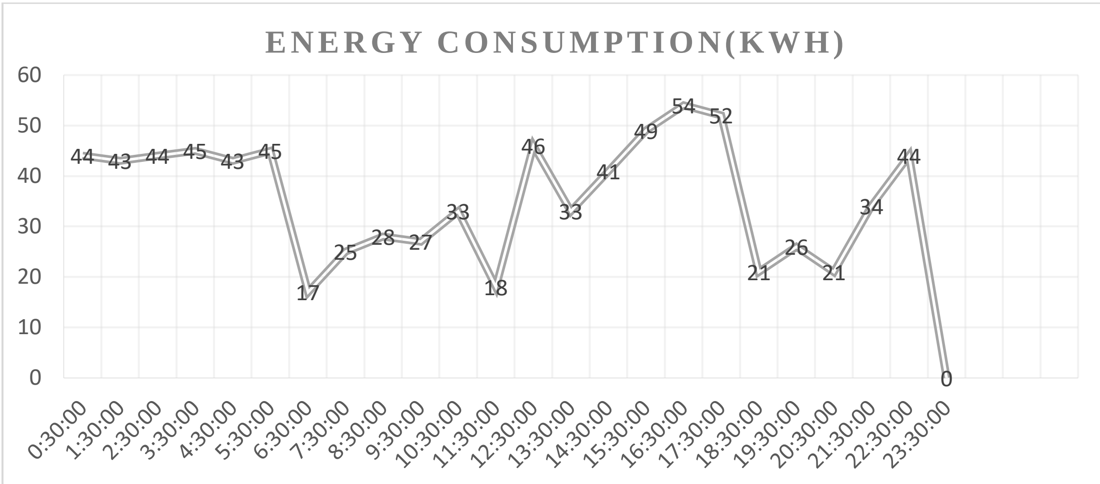

Figure 14: Energy Consumption in BWTP

The water treatment plant (WTP) consumes a total of 876 kWh of energy over the course of 24 hours (June 18 2022), while supplying 8000 cubic meters of water during the same time period. The specific energy consumption of the WTP is determined by dividing the total energy consumption by the total volume of water supplied, resulting in a specific energy consumption of 0.1095 kWh per cubic meter of water. The plant experiences higher energy consumption at 5 pm, while consumption decreases at 7 am. This pattern is due to the usage of pumps and motors at the plant, which can vary throughout the day.

Specific energy consumption is high from magh to baisak whereas specific energy consumption is low at month from shrawan to kartik. Remaining 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.

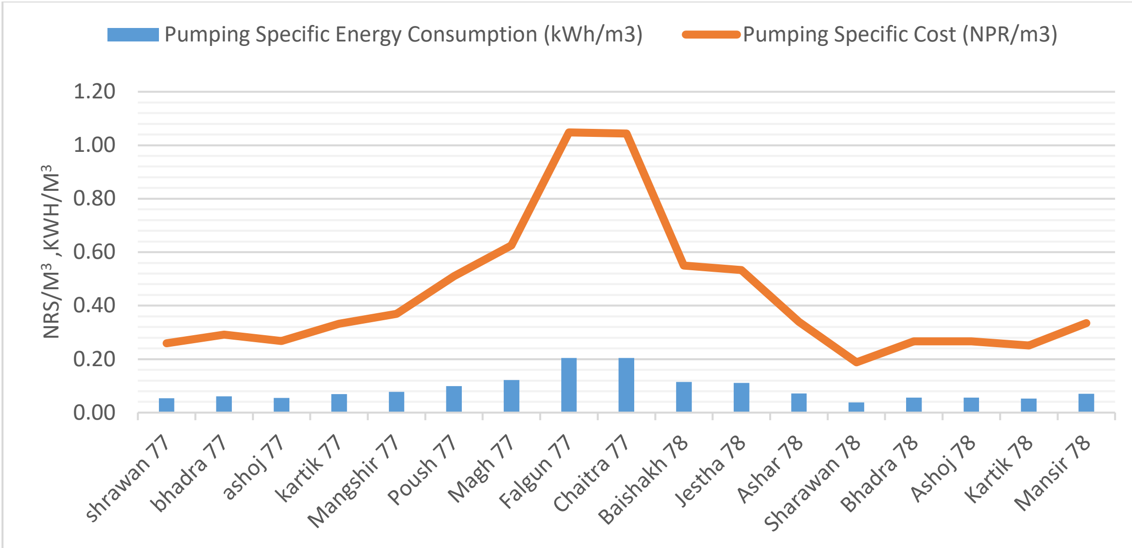

Figure 15: Specific Energy Consumption

4.5 Voltage Variation:

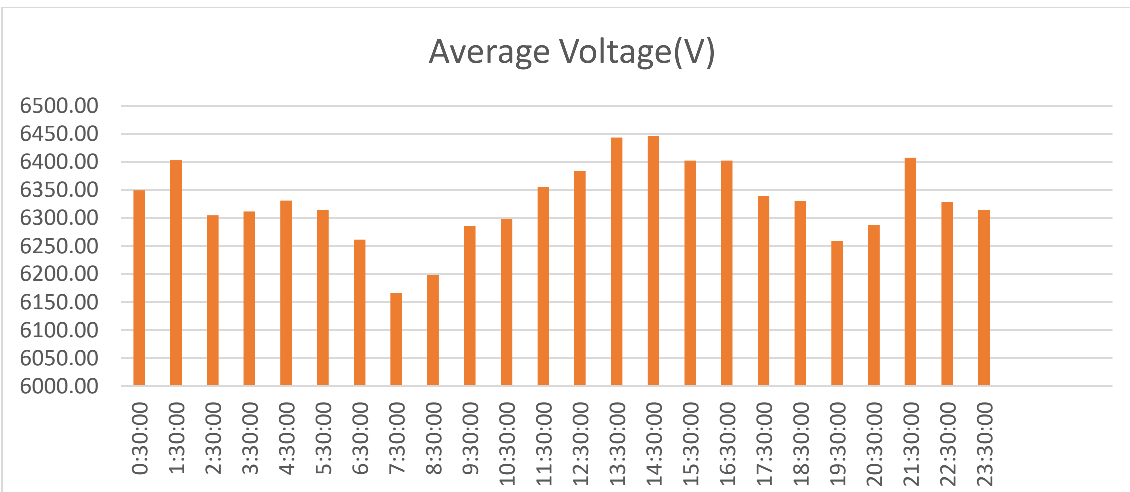

Figure 16: Voltage Variation in Basbari Water Treatment Plant

The voltage variation and energy consumption patterns have same but the current variation and energy consumption patterns have different. The product of current and voltage is proportional to energy consumption. 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.

4.6 Current Variation:

Current Variation not only depends on active power but also depends on the reactive power also.

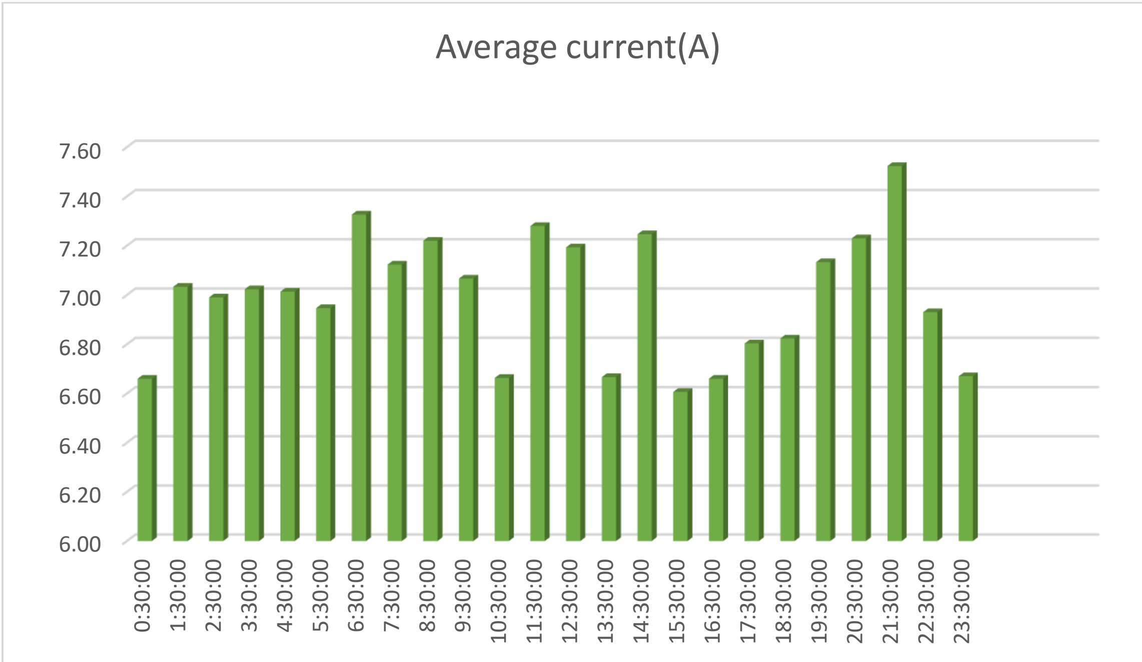

Figure 17: Current Variation

4.7 Energy Consumption Analysis

Monthly energy bill of last 23 months is collected and energy consumption analysis is done as below:

4.7.1 Energy Consumption in Fiscal Year 2078/2079:

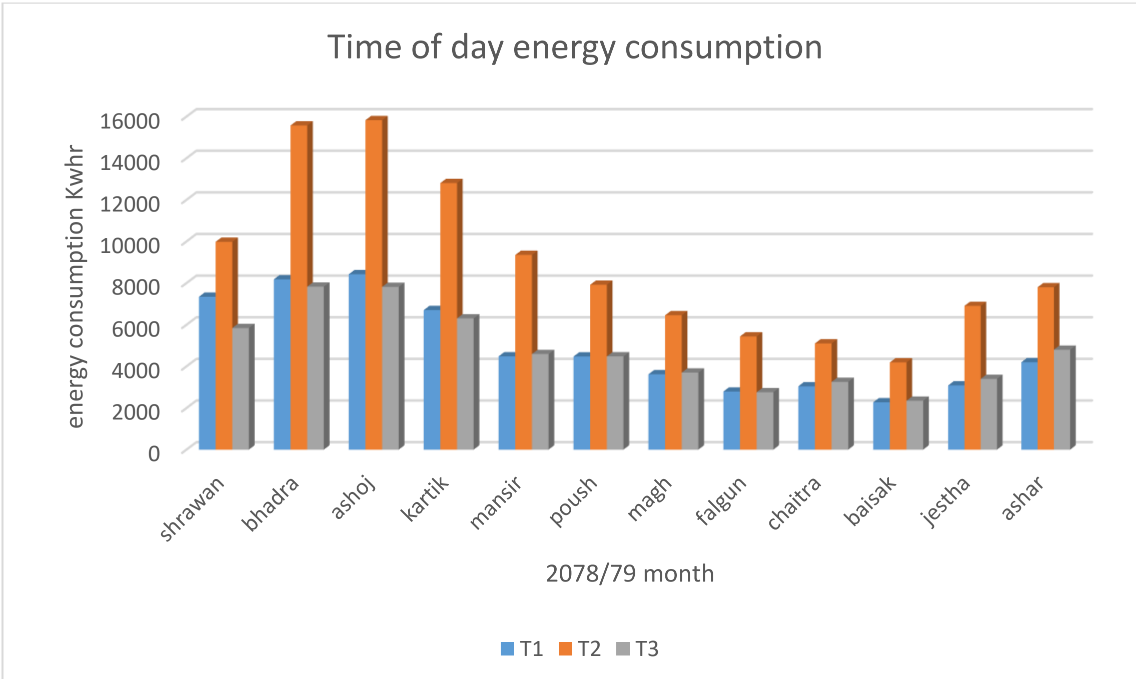

Figure 18: Monthly Energy Consumption at Year 2078/79

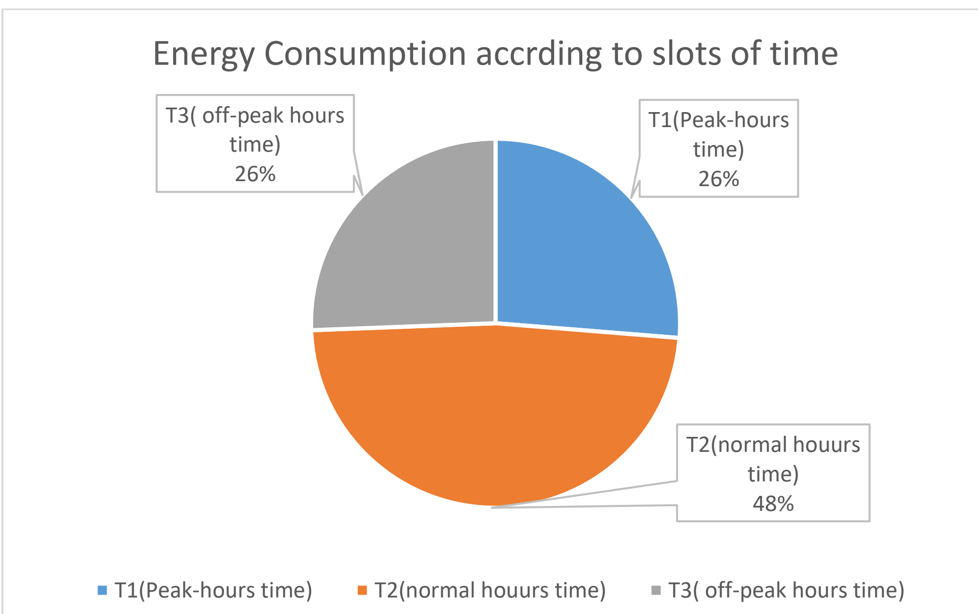

Figure 19: Energy Consumption throughout the Year 2078/79

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, with a small amount of power consumed during off-peak hours and peak hours. The energy consumption during normal hours, peak hours, and off-peak hours is 48%, 26%, and 26%, respectively.

4.7.2 Energy Consumption in Fiscal Year 2077/2078:

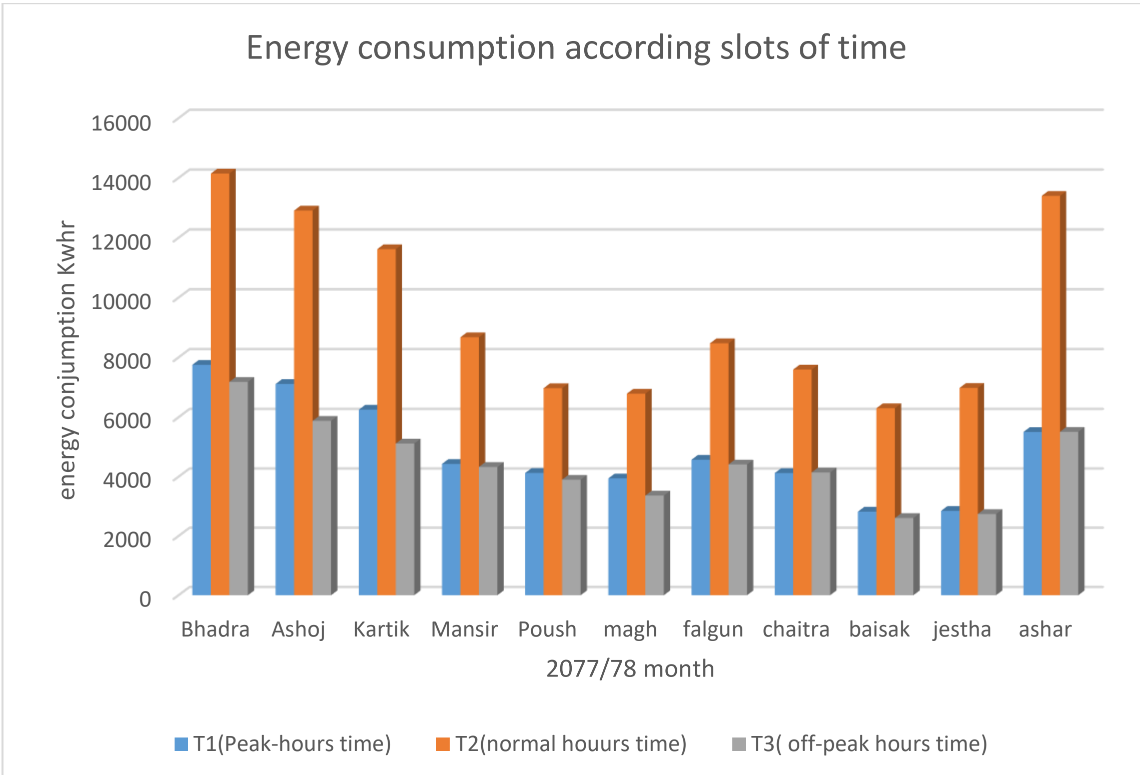

Figure 20: Monthly Energy Consumption at Year 2077/78

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, with a small amount of power consumed during off-peak hours and peak hours. The energy consumption during normal hours, peak hours, and off-peak hours is 50%, 26%, and 24%, respectively.

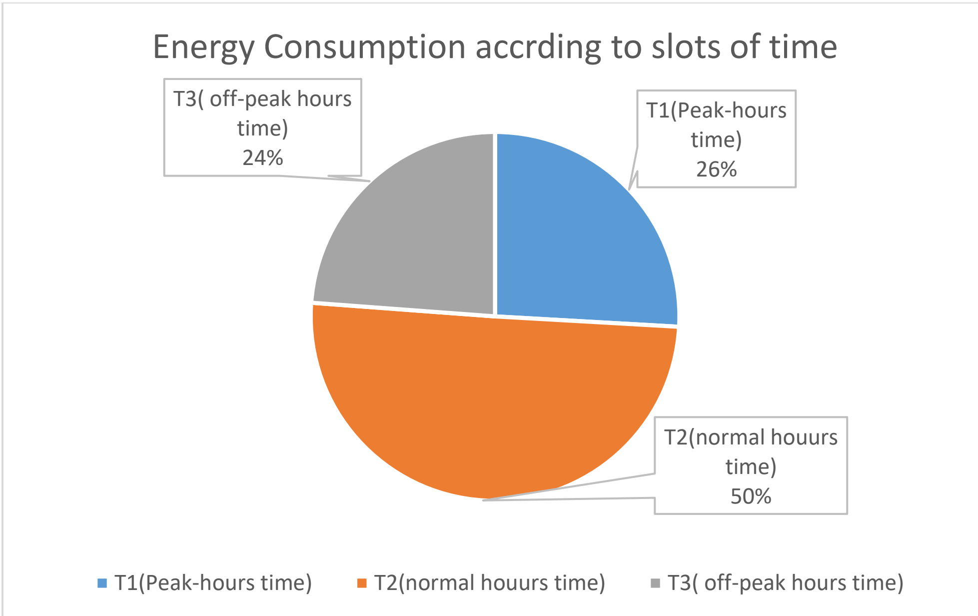

Figure 21: Energy Consumption throughout the Year 2077/78.

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 to Kartik.

4.8 Maximum KVA Demand Analysis:

At the monthly bill of Nepal Electricity Authority Maximum recorded demand data also available at time slots basis. For the analysis 23 months data are taken for the thesis works.

4.8.1 Maximum KVA Demand at Fiscal Year 2078/79

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 for the thesis works. 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.

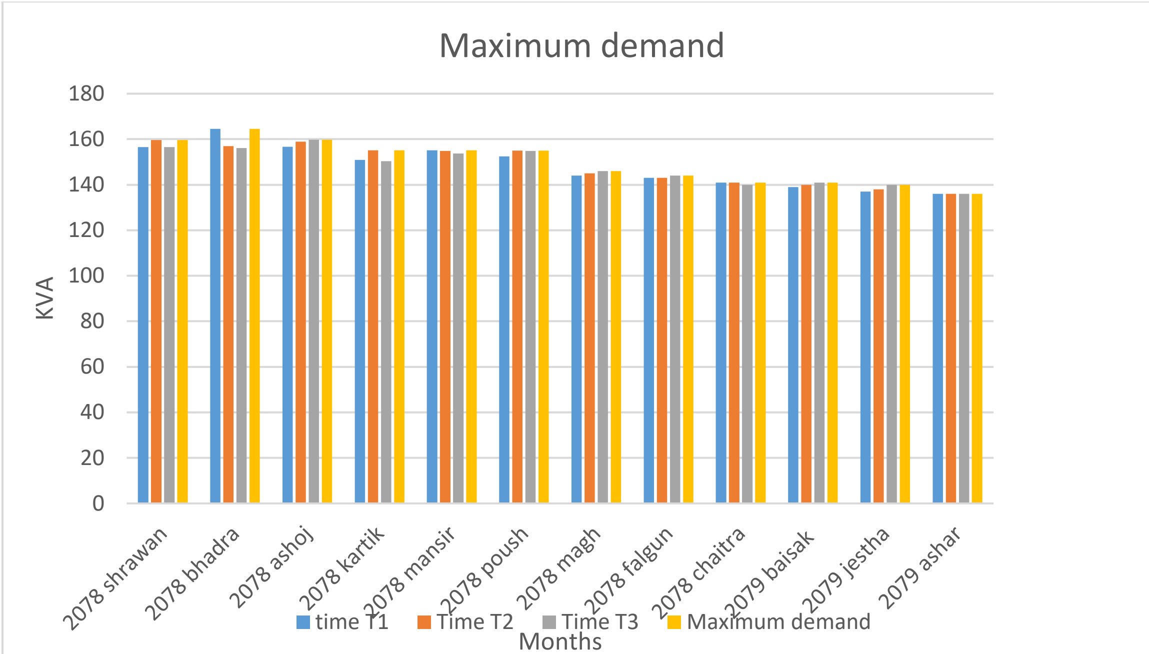

Figure 22: KVA Demand at Year 2078/79

4.8.2 Maximum KVA Demand at Fiscal Year 2077/78

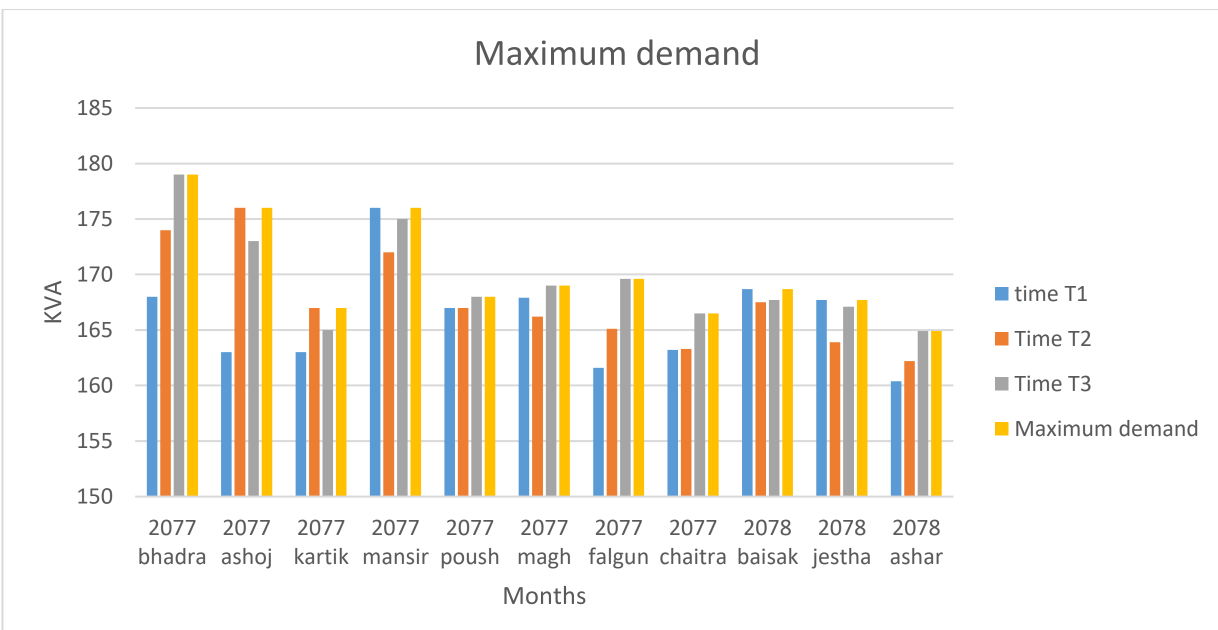

Figure 23: KVA Demand at 2077/78

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 to 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

4.9 Comparison of Energy Consumption

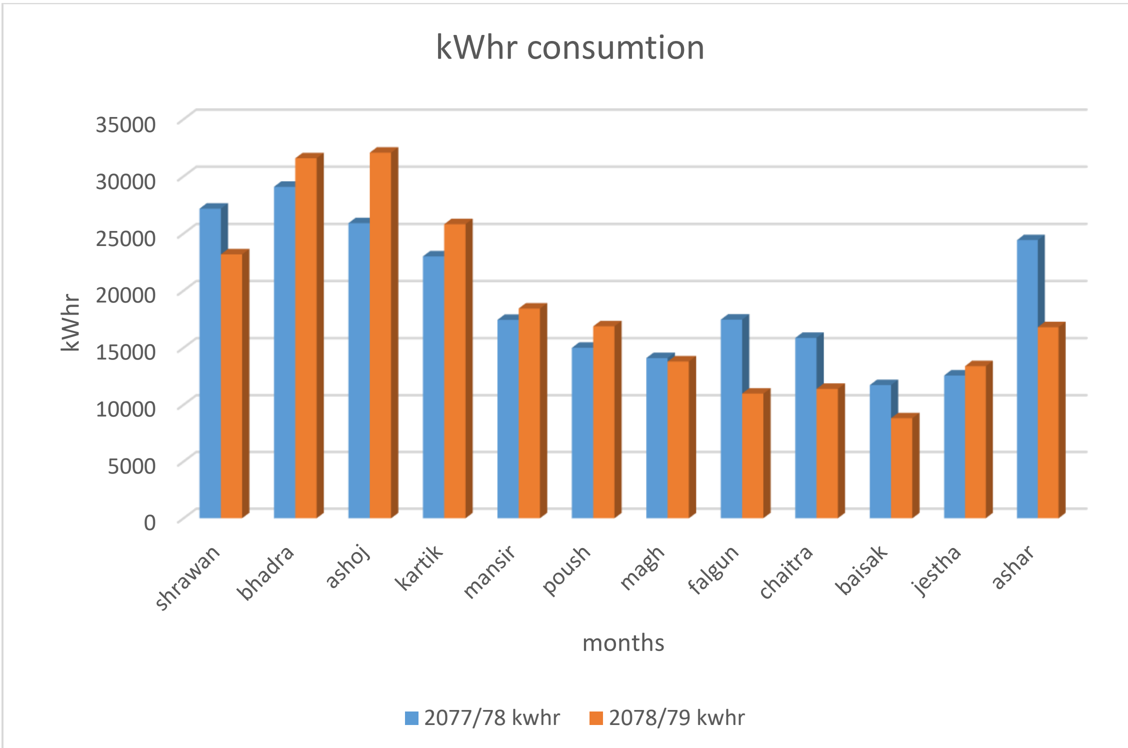

Figure 24: Monthly Energy Consumption during 2077/78 and 2078/79

According to the data gathered in 2077/78, the average monthly energy consumption was found to be 19.47 MWh, while the yearly energy consumption was calculated to be 233.74 MWh. In 2078/79, the average monthly energy consumption decreased to 18.59 MWh, resulting in a yearly energy consumption of 223.13 MWh.

The reason for the decrease in energy consumption can be attributed to the operation of the Melamchi Water Supply System. This system provides a reliable source of water supply, which has reduced the need for energy-intensive water treatment processes. As a result, the overall energy consumption of the water treatment plant has decreased, leading to lower energy costs and a more sustainable operation.

4.10 Tariff

As per the decision made by the Nepal Government, the electricity utility provides a subsidy to the water utility for the demand charge. However, later on, the electricity utility claims compensation from the Nepal government to cover their costs.

It is worth noting that the tariff paid by the water utility varies throughout the year, with the highest tariff paid during the month of bhadra and the lowest tariff paid during the month of baisak. This fluctuation in the tariff is likely due to changes in demand and supply of electricity during different times of the year.

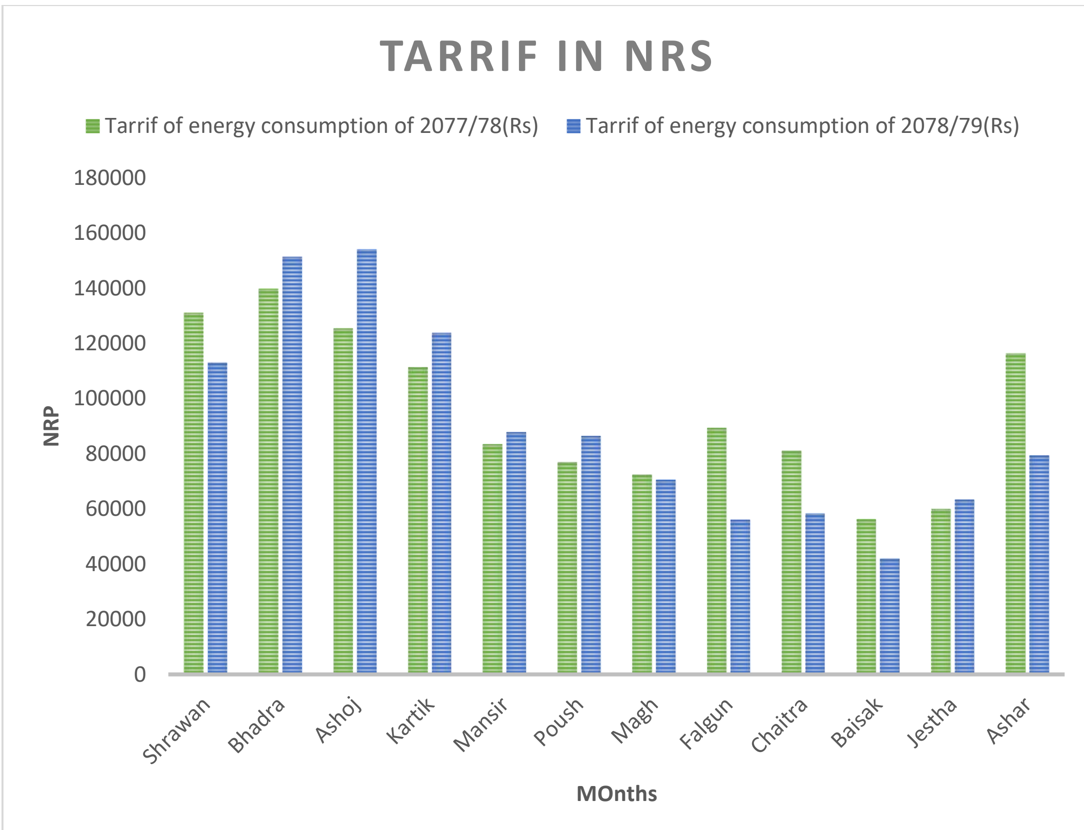

Figure 25: Monthly Energy Bill Comparison between 2077/78 and 2078/79

4.11 Energy Efficiency Analysis

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 4: Measured Active Power, Hydraulic Power and Efficiency Table.

Pump	3 star Pump efficiency	Power consumption by efficient pump (KW)	Operating Hours	Annual Energy Saving (KW)	Annual Cost Saving
Pump 1 - Gravity Tank	101.86	13.04	3.00	2856.13	14052.14
Pump 2 - Gravity Tank	103.55	13.00	6.20	5883.80	28948.30
Pump 3 - Gravity Tank	99.16	13.65	6.00	5977.24	29408.02
Pump 4 - Gravity Tank	94.22	14.25	6.00	6241.50	30708.18
Back Wash - Pump 1	56.01	14.45	0.92	970.46	4774.67
Back Wash - Pump 2	58.86	13.75	0.00	0.00	0.00
Makeup Water - Pump 1	94.33	5.42	0.92	363.78	1789.81
Makeup Water - Pump 2	91.87	5.25	0.00	0.00	0.00
Total				22292.91	109681.12

Table 5: Annual Cost Saving

It can be found that the pumps with low measured active power have high efficiency, while the backwash pump has lower efficiency compared to the other pumps. 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 109681.12 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.

4.12 Cost Benefits Analysis

Parameter	Unit	Value
Present Approved Load	kVA	500
Transformer Capacity	kVA	500
Maximum kVA Recorded	kVA	179
Demand Charge	NPR/kVA	150
Present Power Factor	φ	0.58
Active Load	kW	103.82
Proposed Power Factor	φ	0.98
Capacitor Bank Required	kVAR	124.73
Demand Saving	kVA	73.06
Annual Demand Charge Saving	NPR	131,510.20
Investment for Capacitor and APFC	NPR	268,179.82
Annual Energy consumption based on TOD meter reading	kWh	233,743
Avg. Energy Charge	NPR/kWh	4.92
Savings in Tr & distr. Loss	kWh	1,168.72
Cost savings from energy	NPR	5,750.08
Annual Monetary savings	NPR	137,260.28
Payback Period	Years	1.95

Table 6: Payback Period Calculation of Capacitor Bank

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.

Replacement of the Tube lights		
Parameter	**Unit**	**Values**
Tube lights operating for 24 hours	No.	15
Tube lights operating for 10 hours	No.	39
Energy consumption by existing lights (@40W)	kWh/day	30
Energy consumption by new lights (@18W)	kWh/day	13.5
Annual Energy Saving	kWh/day	6022.5
Weighted cost of Energy	NPR/kWh	4.89
Annual Monetary Savings	NPR	29,450.03
Investment	NPR	64,000.00
Payback period	Years	2.16

Table 7: Payback Period Calculation of Replacement of Lights

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 2.16 years.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The plant operates under low power factor, which should vary from 0.06 to 0.58. 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 lakhs annually. The connected load of the water transmission system is the twenty-five percentage, 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 to 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 maximum demand varies from 164.9kVA to 179kVA at the fiscal year 2077/78, but the maximum demand variation is 136kVA to 164.9 kVA at the fiscal year 2078/79. 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 specific energy 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.

5.2 Recommendation

- 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.)
- Time shifting optimization should be done in order to decrease the cost of energy usage.

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APPENDICES

2078/79 electricity consumption	T1(Peak-hours time)	T2(normal hours time)	T3(off-peak hours time)
Shrawan	7347	9982	5842
Bhadra	8182	15573	7827
Ashoj	8427	15829	7816
Kartik	6703	12807	6305
Mansir	4482	9354	4593
Poush	4473	7923	4479
magh	3621	6456	3702
falgun	2790	5438	2756
chaitra	3042	5103	3252
baisak	2272	4192	2349
jestha	3085	6904	3397
ashar	4200	7800	4800
Total	58624	107361	57118

Table 8: Electricity Consumption of Fiscal Year 2078/79

2077/78 electricity consumption	T1(Peak-hours time)	T2(normal houurs time)	T3(off-peak hours time)
Bhadra	7753	14148	7182
Ashoj	7113	12909	5880
Kartik	6253	11619	5122
Mansir	4431	8675	4330
Poush	4127	6972	3899
magh	3944	6789	3365
falgun	4573	8473	4414
chaitra	4123	7596	4145
baisak	2823	6303	2607
jestha	2848	6981	2743
ashar	5506	13402	5512
Total	53494	103867	49199

Table 9: Electricity Consumption of Fiscal Year 2077/78

Months	2077/78 kWhr	2078/79 kWhr	Tarrif of energy consumption of 2077/78(Rs)	Tarrif of energy consumption of 2078/79(Rs)
Shrawan	27173	23173	131100.84	113071.74
Bhadra	29085	31583	139765.38	151356.54
Ashoj	25903	32074	125478.54	154069.02
Kartik	22995	25815	111423.72	123861.42
Mansir	17437	18431	83414.4	87821.46
Poush	14998	16877	77098.2	86474.94
Magh	14098	13799	72575.4	70554.9
Falgun	17462	10985	89388.54	56046.34
Chaitra	15865	11398	81163.56	58435.92
Baisak	11733	8815	56273.2	42010.62
Jestha	12574	13388	60087.06	63441.84
Ashar	24420	16800	116420.88	79440
Total	**233743**	**223138**	**1144189.72**	**1086584.74**

Table 10: Tariff of Electricity Consumption

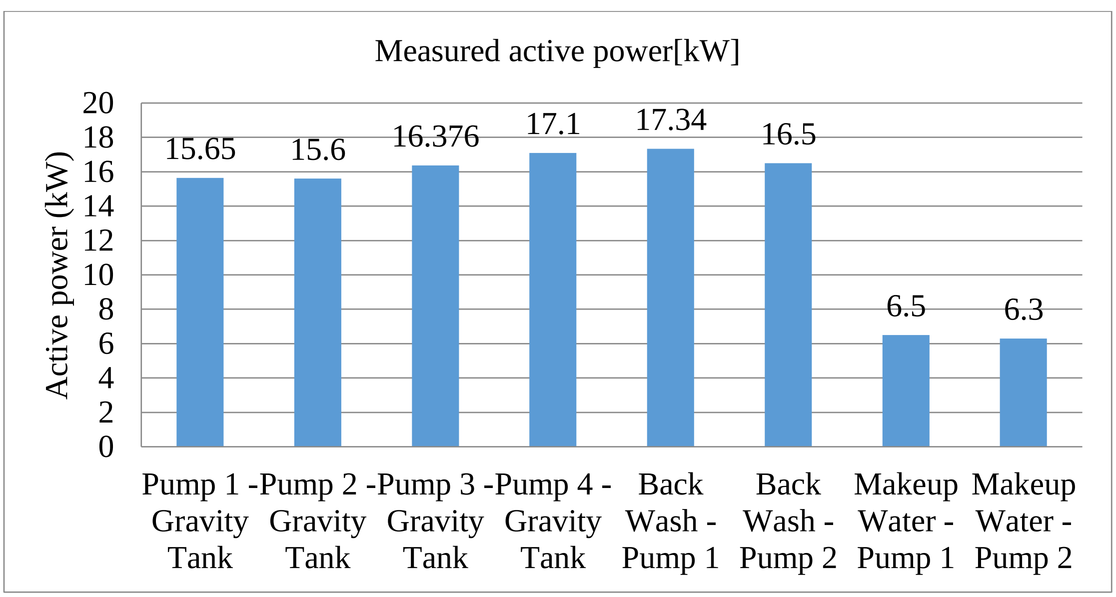

Figure 26: Measured Active Power of Different Pumps

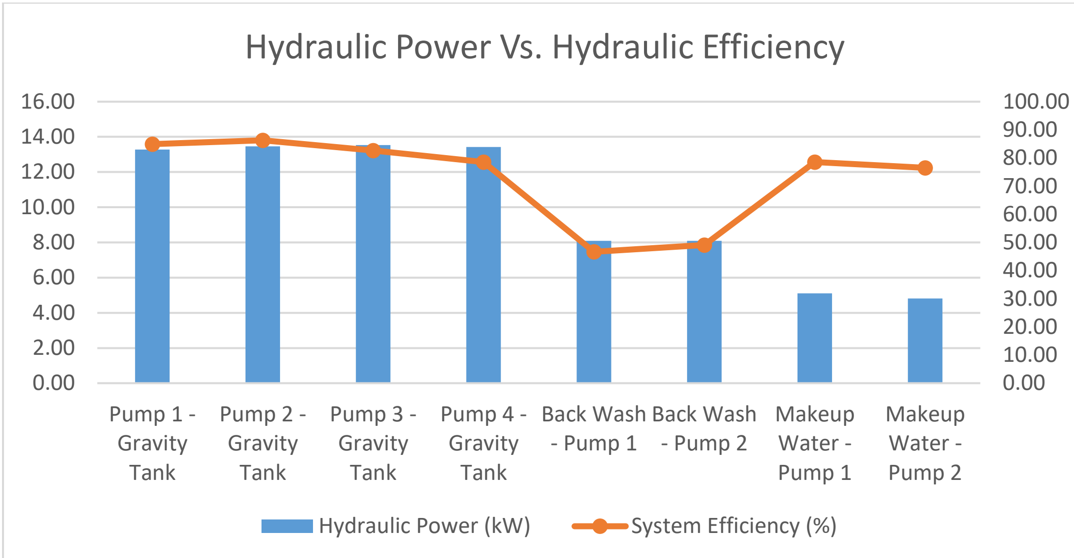

Figure 27: Hydraulic Power vs System Efficiency

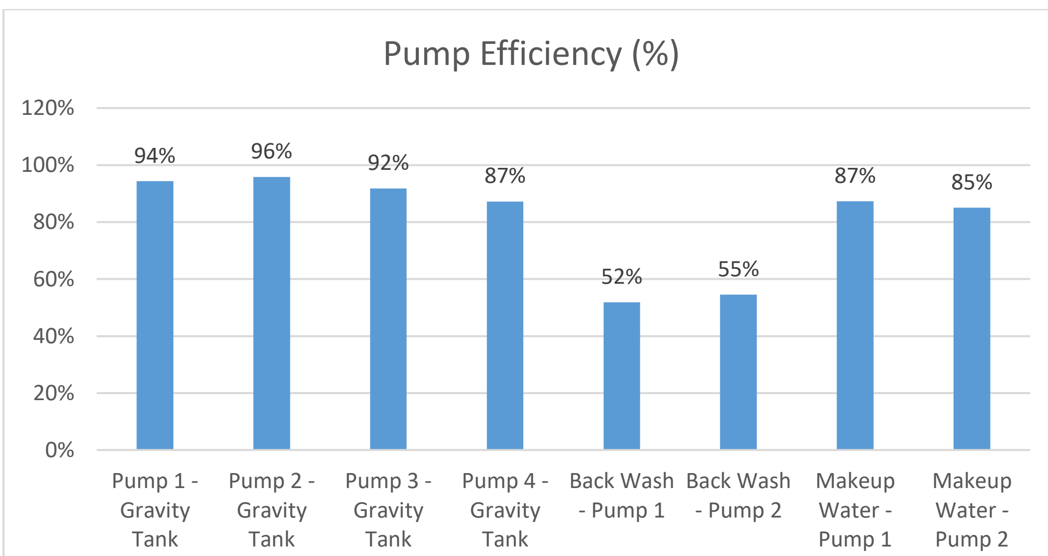

Figure 28: Pump Efficiency

maximum demand reading				
month	Time T1	Time T2	Time T3	Maximum demand
2077 bhadra	168	174	179	179
2077 ashoj	163	176	173	176
2077 kartik	163	167	165	167
2077 mansir	176	172	175	176
2077 poush	167	167	168	168
2077 magh	167.9	166.2	169	169
2077 falgun	161.6	165.1	169.6	169.6
2077 chaitra	163.2	163.3	166.5	166.5
2078 baisak	168.7	167.5	167.7	168.7
2078 jestha	167.7	163.9	167.1	167.7
2078 ashar	160.4	162.2	164.9	164.9
2078 shrawan	156.5	159.6	156.5	159.6
2078 bhadra	164.5	156.9	156.1	164.5
2078 ashoj	156.7	158.9	159.8	159.8
2078 kartik	150.9	155.1	150.4	155.1
2078 mansir	155.1	154.9	153.7	155.1
2078 poush	152.4	155	154.8	155
2078 magh	144	145	146	146
2078 falgun	143	143	144	144
2078 chaitra	141	141	140	141
2079 baisak	139	140	141	141
2079 jestha	137	138	140	140
2079 ashar	136	136	136	136

Table 11: Maximum Demand Recording

NO.	The real time clock	L1 voltage	L2 voltage	L3 voltage (V)	Average Voltage(V)	L1 Current	L2 Current (A)	L3 Current (A)	Average current(A)	Total average power factor	Active(kWh)	Difference in Kwhr
1	0:30:00	6350	6358	6340	6349.33	5.68	6.88	7.42	6.66	0.3176	4522805	44
2	1:30:00	6396	6418	6396	6403.33	5.87	7.19	8.04	7.03	0.3188	4522849	43
3	2:30:00	6302	6318	6294	6304.67	5.88	7.15	7.94	6.99	0.3203	4522892	44
4	3:30:00	6306	6328	6302	6312	5.9	7.12	8.05	7.02	0.322	4522936	45
5	4:30:00	6326	6346	6322	6331.33	5.91	7.1	8.03	7.01	0.3236	4522981	43
6	5:30:00	6312	6334	6298	6314.67	5.91	7.03	7.9	6.95	0.3244	4523024	45
7	6:30:00	6260	6278	6246	6261.33	6.5	7.25	8.23	7.33	0.3256	4523069	17
8	7:30:00	6174	6184	6142	6166.67	6.6	7.06	7.71	7.12	0.3189	4523086	25
9	8:30:00	6208	6214	6174	6198.67	6.38	7.28	8	7.22	0.3145	4523111	28
10	9:30:00	6290	6300	6266	6285.33	6.37	7.02	7.81	7.07	0.3104	4523139	27
11	10:30:00	6304	6314	6278	6298.67	5.8	6.75	7.44	6.66	0.3076	4523166	33
12	11:30:00	6360	6370	6336	6355.33	6.53	7.24	8.07	7.28	0.3061	4523199	18
13	12:30:00	6386	6400	6366	6384	6.38	7.11	8.09	7.19	0.3007	4523217	46
14	13:30:00	6448	6458	6426	6444	5.71	6.92	7.37	6.67	0.3035	4523263	33
15	14:30:00	6448	6462	6430	6446.67	6.39	7.16	8.19	7.25	0.3025	4523296	41
16	15:30:00	6404	6416	6388	6402.67	5.77	6.84	7.21	6.61	0.3052	4523337	49
17	16:30:00	6404	6416	6388	6402.67	5.75	6.86	7.37	6.66	0.3076	4523386	54
18	17:30:00	6340	6354	6324	6339.33	5.87	7.13	7.41	6.8	0.3113	4523440	52
19	18:30:00	6334	6344	6314	6330.67	6.03	6.96	7.48	6.82	0.3141	4523492	21
20	19:30:00	6272	6276	6228	6258.67	6.45	7.07	7.88	7.13	0.3098	4523513	26
21	20:30:00	6302	6304	6258	6288	6.46	7.25	7.98	7.23	0.3067	4523539	21
22	21:30:00	6414	6422	6388	6408	6.68	7.47	8.42	7.52	0.3032	4523560	34
23	22:30:00	6328	6340	6318	6328.67	5.93	7.14	7.72	6.93	0.3033	4523594	44
24	23:30:00	6312	6326	6306	6314.67	5.78	6.86	7.37	6.67	0.3046	4523638	

Table 12: TOD Meter Reading