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Supply Side Management in Micro Hydro using Battery Bank: A case study of Pinthali Microhydro plant, Kavre, Nepal

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 "Supply Side Management in Micro Hydro using Battery Bank: A case study of Pinthali Microhydro Plant, Kavre, Nepal'' submitted by Amit Subedi, 073/MSES/552 in partial fulfilment of the requirements for the degree of Master of Science in Energy System Planning and Management.

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ABSTRACT

Geographical difficulties and slow development of power generation, transmission and distribution, related activities have made many remote areas not assessable to national grids in Nepal. Electricity demand is increasing day by day in urban as well as rural areas but instant extension of national grid seems difficult in many remote places of Nepal. Thousands of Micro hydropower are being installed throughout the country where extension of grid is difficult. This paper presents the introduction of battery bank for the supply side management in the micro hydropower plants. Surplus power during off load time is stored in a battery instead of wasting in dump load. The system is designed in Matlab Simulink where system containing Electronic Load Controller(ELC), Battery Management System(BMS), three phase ac/dc converter were used. Synchronous Generator which generates constant power feeds the load, battery and dump load according to requirement. Battery uses the power for charging during off load hour and supplies deficit power during peak hour. Case study of Pinthali microhydro power of capacity 8.1 KW was carried out for load survey to calculate excess power. Simulated system successfully distributed the power to the load when load demand was higher than generation through the battery.

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LIST OF ABBREVIATION

AEPC	Alternative Energy Promotion Center
Ah	Ampere-hours
CBS	Central Bureau of Statistic
DoD	Depth of Discharge
EMF	Electromotive Force
ELC	Electronic Load Controller
GHG	Green House Gas
GoN	Government of Nepal
kW	kilo Watt
kWh	kilo Watt hour
LDC	Load Dispatch Center
LF	Load Factor
MHPS	Micro Hydropower Plant System
MHVE	Microhydro Village Electrification
MW	Mega-Watt
NEA	Nepal Electricity Authority
NRs	Nepali Rupees
PPA	Power Purchase Agreement
REDP	Rural Energy Development Programme
RET	Renewable Energy Technology
SG	Synchronous Generator
SoC	State of Charge
SS	Sub Station
SSM	Supply Side Management
TV	Television
USD	United States Dollar
VAT	Value Added Tax

CHAPTER ONE: INTRODUCTION

1.1 Background

Electricity supply in the rural areas of Nepal remains as one of the most challenging issues due to the high infrastructure cost and losses, lack of road, and poor returns compounded by constrained government budgets resulting from the geographical profile of Nepal (Banerjee, 2011). Microhydro power (MHP) has history of about five decades in Nepal which comprises of installed capacity of about 23 MW and it has benefitted about 250,000 households around the country basically in rural areas where extension of grid is difficult (Acharya, 2016). The efficient use of microhydro can lead to advancement in the lifestyle and economic status of the people. Microhydro power are isolated system which are generally not connected in the grid and is suitable for sparsely distributed population like villages where cost of investment of extension of grid is expensive. Per capita income of Nepalese people is US\$ 1034 per year and per capita electricity consumption is 245 kWh per year which is very low than average value (World Bank, 2020). This shows that either new plants need to be installed or existing plants should be upgraded.

Instalment of new plant for the generation of electricity involves investment of huge amount of capital. Generally, Microhydro power consists of ELC for dumping of excess power during of peak hours and these power are dissipated in the form of heat energy in most of the cases. Due to gradual increase in consumer power demand, during peak time demand becomes higher than supply. In addition, if new generator is to be installed in existing plant for the capacity upgrade will also involves big capital. Plant use factor of the Microhydro power becomes low due to dissipation of large amount of power in dump load through ELC. Thus dumped power can be stored during off peak time and can be utilized later for maintaining reliable supply through Microhydro power. As battery is the power storing device, it can be used for the supply management in any Micro Hydro Plant.

Over the last few decades, there has been a growing realisation in developing countries that Microhydro power have an important role to play in the economic development of remote rural areas (Fraenkel, 1991). So need for reliable renewable energy which would include micro hydro in rural areas is necessary.

In the developing country like Nepal, Microhydro power is one of the best source of renewable energy for rural electrification. Microhydro power are isolated system which are generally not connected in the grid and is suitable for sparsely distributed population like villages where cost of investment of extension of grid is expensive considering the existing political and economic situation of Nepal and analysing various available natural resources in the country, only those commercial energy sources which are economically, environmentally and socio-politically justifiable should be promoted. Micro hydro power is the best alternative source of energy for the rural villages of Nepal which are not connected in national grid network as source of fuel for the production of electricity is water which is available in most of the places with required head and discharge. Implementation of Microhydro power brings improvement in the lifestyle of the people along with improved health and education facilities. In economic aspect it is beneficial to both developer and consumer. As economic activities increases, it also contributes in the national economy. We need to assess the possible advantages that could be gained after installing the plant so that we can know the socio-economic contribution of the plant and reason to develop it in required place. Hydropower technology is the process of obtaining electrical power by using the head and discharge of the moving water. Flowing water at designed head and discharge runs through penstock pipe and hits the turbine blades which results in motion of the shaft. Rotating shaft is coupled with generator and it causes generator shaft to rotate. Then generator converts energy of rotating shaft i.e. mechanical energy inti electrical energy. Thus obtained power is distributed to the consumer in suitable ratings. Big hydropower requires big space along with dams and reservoirs but microhydro are simple in construction and operation. Generally, an isolated micro hydropower system is designed to operate without any interference with main grid. The main advantage of using Microhydro power is that is doesn’t use any types of fuel and meets demand of the consumer with continuous supply.

Several studies have been carried out for the performance improvement of the Microhydro power and also main study focuses on the impact of Microhydro power on social and economic aspects. Economic aspect shows the good improvement in the lifestyle of the local people as usage of power improves health, education, communication and other basic requirement of people. Electrical power is also fruitful in establishing new source of income to the locals. So for the long run of the Microhydro power financial status also plays important role.

Usage of battery bank for the management of evening load on the Microhydro power would be a new area of interest for increasing reliability sustainability and efficiency of Microhydro power.

1.2 Problem Statement

Large number of Microhydro power are being installed in remote areas for the supplement of electrical power. As size of Microhydro power is small power production of relatively small as compared to big hydropower. Due to low power production consumer are restricted to use limited power appliances. Small increase in consumer load my bring drop in voltage and frequency of the system. Main issue regarding Microhydro power is about the flickering effect seen during evening time due to power deficit. On other hand surplus power are either dumped on ELC or used in to dumped on water heater which is a total waste of energy.

This issue brings low reliability of the Microhydro power hindering the sustainability of the Microhydro power. Amount of Capital is invested on Microhydro power and deliverance of unreliable power may bring question on sustainability of Microhydro power.

Microhydro power generates power from running water which is available throughout the day. Basically power demand is high on evening time as almost all lighting loads are being operated but during day time Microhydro power are almost useless for those loads and power demand is very small.

Use of battery bank would store surplus power during day time for charging and it gets discharged during power deficit which would increase reliability and efficiency of micro hydro. This will support the sustainability of Microhydro power.

1.3 Need and Importance

Electrical power is one of the most important need in present context. Many sources are available for generation of electricity to operate modern equipment that requires electricity. Electricity sources may be renewable and non-renewable, non-renewable sources may cause serious effect in climate and may cause different hazard to human life. In this aspect most of the people living in poverty line are seriously affected. Due to this reason renewable sources such as wind, solar, hydropower's are in choice nowadays. As Nepal has huge potential in hydropower i.e. about 83,000 MW (Shrestha, 1996). About 6000 of rivers/rivulets flows through steep mountains and hills giving the required head for energy production (H. Sharma, R. Awal, 2013). Huge investment is required for the extraction of power through big hydropower. Also most of the villages in Nepal are diversely scattered and this will also increase the cost of transmission and distribution line through grid.

Microhydro power is the good option to facilitate the rural population through electrification which are diversely scattered. This may be good isolated source of power and is reliable and economic. As flowing water doesn't cost any money and system involved in Microhydro power is simple and user friendly. Operation of Microhydro power can also be done by operator with simple knowledge of the system.

Most of the power generated by Microhydro power is used for lighting purpose. With certain time frame, the load of the consumer may gradually increase but generating capacity is constant. So at the peak time demand may be greater than generation and at this case we have to add new source of generation or increase the capacity of existing source. Addition of new source of generation causes huge source of investment. So we can increase the capacity of existing system by adding battery as a source of supply during peak time. We can use surplus power available during off peak time to charge the battery and can use same stored power in peak time.

The incorporation of battery bank on the Microhydro power also results on the improved load factor of the plant. Load factor is the ratio of total power used to total power available. So improved load factor will certainly aid better use of electric power on the Microhydro power.

1.4 Scope of study

In this research, we have used Matlab and Simulink software for the modelling and analysing the output power from the microhydro plant. For development of model in the software we should have knowledge of the microhydro plant parameters such as power generating capacity, types of generator, types of turbine and other relevant parameters.

For development of model we have considered the Pinthali microhydro power which has synchronous generator of 8.1 kW. We have ELC and added battery bank in the system. We have consumer load varying up to 10 kW i.e. about 20% excess of the existing power generating capacity. ELC has capacity to dissipate all the power of the plant if load and battery doesn't use any power. For battery we have used solar tubular and is capable to supply deficit power for two hours. Battery capacity is chosen in a such a way that it doesn't discharge beyond 50%. Hybrid AC/DC converter is kept which charges battery in DC and supply ac to the system. Charing of the battery is monitored by buck converter where DC link voltage and DC bus voltage are compared.

1.5 Limitations of study

Only active power is considered for our study as there is no significant flow of reactive power in microhydro power. Almost all loads are resistive in nature so reactive power is not considered for our study. Also software based model doesn't consider losses that occurs in real practice resulting in more efficient system. Also data taken from case study was a direct questionnaire with the consumer. No tools were used in measuring the energy consumption pattern of the consumer. Random sampling was done where out of 142 households only 105 houses were surveyed. Only one Microhydro power is considered for the case study and results may be different for financial analysis for different microhydro power. Price of the component was taken from Kathmandu district rate which may vary on near future and may lead to change in the analysed results.

1.6 Objectives

The main objective of the thesis is:

- To develop an analytical model for usage of battery bank for the supply side enhancement of micro hydro plants.

The main objectives will be accomplished with the following auxiliary objectives:

1. To study about power storage possibility to fulfil peak demand in microhydro plant by simulating the battery bank based model using Matlab software.
2. To analyse the energy consumption pattern of the microhydro benefitted consumer through case study.
3. To make cost analysis and financial analysis of the battery based system.

CHAPTER TWO: LITERATURE REVIEW

2.1 Supply side management

Supply-side management (SSM) refers to actions taken to confirm the generation, transmission and distribution of energy square measure conducted expeditiously. This has become particularly vital with the liberation of the electricity trade in several countries, wherever the economical use of accessible energy sources becomes essential to stay competitive.

SSM is employed primarily with regard to electricity however it also can be applied to actions regarding the availability of different energy resources like fossil fuels and renewables. Utility firms might check out suggests that of modifying their load profile to permit their least economical generating instrumentality to be used as very little as potential (compared with high potency instrumentality that ought to be accustomed the maximum). They will improve maintenance and management of existing instrumentality, or upgrade instrumentality with progressive technologies.

Energy users can usually focus their efforts on demand-side management (DSM) however some can contemplate the provision aspect too (Shiwakoti, 2019). As an example, they'll investigate on-site generation various together with cogeneration or contemplate diversifying to alternative fuel sources (such as fossil fuel, solar, wind, biofuels).

For associate electricity system, effective SSM can increase the potency with that the end-users are provided, permitting the utility company to defer major cost, which could preferably be needed for increasing their capability in growing markets. SSM makes put in generating capability ready to give electricity at lower value (permitting lower costs to be offered to consumers) and reduces environmental emissions per unit of end-use electricity provided.

SSM may contribute to up the dependableness of a provide system. With the present trend of freeing the provision trade, it's turning into additional necessary to begin supply-side management wherever the provider, user and therefore the setting all win. Within the case of SSM applied to biomass, the advantage of upper potency within the provide chain is that the reduction in resources required to fulfill a particular demand. This helps cut back the danger of deforestation and therefore avoids not solely a loss of energy provide however potential environmental harm.

In brief, an electrical utility may embark on SSM to:

- Ensure reliable convenience of energy at the minimum economic value ultimately increasing its profits;
- Provide most value to its customers by reducing energy prices;
- Meet increasing electricity demand without incurring in unnecessary major capital investments in new generating capacity;
- Minimize environmental impact.

2.1 Case area

Many microhydro plants are being installed throughout the country with varying capacity. For the research purpose we have taken Pinthali microhydro plant as it is near from the Kathmandu valley i.e. about 70 km east located in Kavrepalanchowk district. Nearest town of the plant is Dhulikhel which is about one and half hour ride on bus. As it is nearer to the Kathmandu valley people have average living standard here.

Pinthali village 142 households being benefitted from the microhydro plant residing on typical village lifestyle. For education one primary school is being established by government and economic activities involves animal husbandry and agriculture such as corn and wheat farms. Irrigation facilities is available here which was initiated by single women Beli Lama in 2016 B.S. Status of women is also comparatively good here and each and every child goes to school. Economic status is stable in overall and people are educated and self-reliant. People are ahead in terms of developmental activities and are friendly and welcoming in this village.

The major profession of the villagers is farming beside some of the villagers are involved in professional farming of ‘Bodhichitta’ which has handsome market price. Some of the youth population are migrated to capital Kathmandu for the economic activities. Also some youth are in foreign employment to uplift the economic status of their families. As almost all the villagers are from Tamang community, Buddhism was followed as a main religion in the village.

Figure 2. 1 Pinthali village

Figure 2. 2 Satellite view of Pinthali village

(Source: Google Maps)

In 2001, the village became one of the first in the district to turn on its electric bulbs. Microhydro power of capacity 8.1 kW was installed in the village. Installment of microhydro plant played important role in the improvement of the lifestyle of the local people. Lighting the electric bulb was still the dream for large population of the country then. Initially consumers were totally using lighting load and performance of microhydro power was very reliable. Chances of outage was low and performance of microhydro was very good. With increase in the advancement of technologies people started using additional equipment which consume electrical power. Additional load includes charging of phones, charging of lights, television and even few numbers of refrigerator in the cold stores.

With the increment on the load the performance of microhydro power was slowly degraded as load on peak time started to exceed the installed capacity of the microhydro power. Voltage level falls significantly on the peak hours due to overload and sometime outage occurs which decreases the reliability of the plant.

2.3 Battery theory

A battery is an assortment of one or more number of cell that go below chemical reactions to make flow of electrons among circuits. There's lot of analysis and advancement occurring in battery technology, and as a result, breakthrough technologies square measure being old and used round the world presently. Batteries came in to play than to the requirement to the requirement to store generated electricity. As a decent amount of energy was being generated, it had been vital to store the energy thus it may be used once generation is down or once there's a requirement to power standalone devices that cannot be unbroken bound to the availability from the mains. Here it ought to be noted that solely DC may be keep within the batteries, AC current can't be keep.

Types of Batteries

Batteries typically is classified into completely different classes and kinds, starting from chemical composition, size, kind issue and use cases, however below all those square measure two major battery types;

1. Primary Batteries

Primary batteries are batteries that can't be recharged one depleted. Primary batteries are manufactured from chemistry cells whose chemistry reaction can't be reversed.

2. Secondary Batteries

Secondary batteries square measure batteries with chemistry cells whose chemical reactions are often reversed by applying a particular voltage to the battery within the reversed direction. Additionally, named as reversible batteries, secondary cells in contrast to primary cells are often recharged once the energy on the battery has been worn-out. They're usually employed in high drain applications and alternative situations wherever it'll be either too overpriced or impossible to use single charge batteries. tiny capability secondary batteries square measure accustomed power transportable electronic devices like mobile phones, and alternative gadgets and appliances whereas heavy batteries square measure employed in powering various electrical vehicles and alternative high drain applications like load levelling in electricity generation. They're additionally used as standalone power sources aboard Inverters to produce electricity. Though the initial value of exploit reversible batteries is often a full heap on top of that of primary batteries however they're the foremost efficient over the semi-permanent.

The following are the different types of rechargeable batteries that are commonly used.

- Lithium-ion(Li-ion)
- Nickel Cadmium(Ni-Cd)
- Nickel-Metal Hydride(Ni-MH)
- Lead-Acid

- **Selecting the right battery for your application**

Battery life affects the productive preparation of devices that need long battery life and albeit many power management techniques area unit being adopted to create the battery last longer, a compatible battery should still be elite to attain the required outcome. Below are some factors to consider when selecting the right type of battery for your project.

1. Energy Density: The energy density is that the total quantity of energy that may be keep per unit mass or volume. This determines however long your device stays on before it wants a recharge.

2. Power Density: Maximum rate of energy discharge per unit mass or volume. Low power: laptop computer, i-pod. High power: power tools.

3. Safety: It is vital to contemplate the temperature at that the device you're building can work. At high temperatures, bound battery elements can breakdown and might endure exoergic reactions. High temperatures usually reduces the performance of most batteries.

4. Life cycle durability: The stability of energy density and power density of electric battery with perennial athletics (charging and discharging) is required for the long battery life required by most applications.

5. Cost: Cost is a vital a part of any engineering choices you'll be creating. It's necessary that value the cost of the battery alternative is in proportion to with its performance and cannot increase the general cost of the project abnormally.

- **Lead-Acid Batteries**

Lead-acid batteries square measure an inexpensive reliable power workhorse employed in heavy-duty applications. They're typically terribly giant and since of their weight, they're forever employed in non-portable applications like solar-panel energy storage, vehicle ignition and lights, backup power and cargo levelling in power generation/distribution. The lead-acid is that the oldest form of reversible battery and still terribly relevant and necessary into today's world. Lead-acid batteries have terribly low energy to volume and energy to weight magnitude relations however it's a comparatively giant power to weight ratio and as a result, will offer vast surge currents once required. These attributes aboard its low value create these batteries engaging to be used in many high current applications like powering automobile starter motors and for storage in backup power provides.

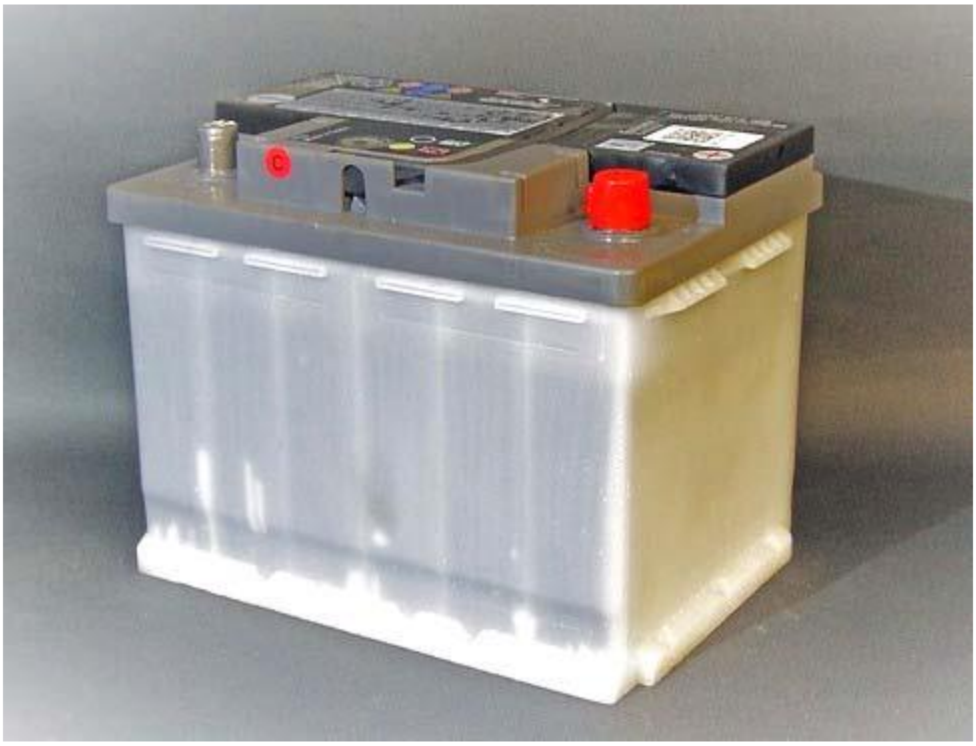

Figure 2. 3 Lead acid battery

(Source: Google photos)

2.4 Previous research

There are many benefits of Microhydro power in terms of minimized cost for transmission and distribution of electric power. Microhydro power generally supplies power to the local load and transmission of power to long distance is not required. This will also preserve rural and urban areas which may have be deteriorated for transmission of the power (Ibrahim, 2012).

Battery based microhydro plant was found technically feasible for the usage of power in the communication channel in remote areas. Battery based system could be a good option for the place where grid is not possible to be expanded in near future. Central energy station could be a good option for the places where grid energy seems difficult to be expanded in near future. As microhydro power is generated from water resources, all the villages may not have sufficient water resources. To meet the peak demand to operate lights, television, radio and charging the appliance, we can use energy storing devices to store power during day and peak hours can use such accumulated power to meet the need (Hermann, 2006).

Water resources may be limited in some places so it must be utilized properly and effectively. We should focus on the high plant use factor in the planning stage. Use of low priority loads like ELC to use generated power for water heating can be cut off and power can be used in other priority loads (Fraenkel, 1991).

There are many challenges for the development of Microhydro power in Nepal (Banerjee, 2011). He also added the benefits of micro hydro power in socio-economic aspect of rural areas despite reliable and efficient power supply is also a problem. He also focused on advancement of Microhydro power with new technology.

Hybrid renewable energy system can be used in optimized way through different optimization techniques and operational strategy. Renewable energy resources are always a good option to satisfy electrification requirement of the rural areas. In addition we can integrate more than one source of generation to make a hybrid system which will reduce the cost of investment and also reduce the price of generation of energy in long term (Somano, 2017).

Per unit cost of electricity generation in microhydro was found to be 3 cents in Pakistan whereas 10 cents in Tajikistan. Cost of electricity generation can be reduced by coping with new technology, cost effective generators and turbine etc. Per unit electricity cost is determined from life cycle coat and annual operating cost along with revenue generated from the plant in any of the renewable energy resources (Abid, 2014).

It should also be noted that power production by microhydro power can be 24 hours a day but it is used by producer to produce power for about 6 hours only. Here, potential of the energy production is lost which also indicates loss of energy. Community are not using it to make money as it could give so it is difficult to cover investment of the plant. Also income of the people is low in such areas and low plant factor is wasted opportunity to overcome low income problem and to increase productivity of the plant (Banerjee, 2011).

NEA has brought many guidelines and upgrades to make electrical power generation, transmission and distribution at least cost nut AEPC is backward in this term as it has not brought such cost effective guidelines. It doesn't clarify what is the purpose of plant and it just empowers rural community to meet simple needs rather focusing in the productivity (Benjamin K. Sovacool, 2010).

This shows low productivity of plant and also a loss of probable energy that could be generated. This will also affect the financial issues of the plant as payback of the plant will be harder to obtain. If microhydro is unable to meet the peak load, battery may be an option to store power and supply at peak time. Most of the houses uses lighting loads and some of the energy efficient appliances and sometimes is fulfilled by solar and wind power also. Use of battery bank doesn't require additional discharge and is also an efficient system. This will make maximum use of power available from the plant. (Buyer, 2004).

During the day time, the electrical power for the main appliances is not used often (R.Shreedhar, 2015). Therefore, other activities such as ironing cloths, battery charging and any other economic activity can be undertaken using the generated electricity. He showed the scope of waste energy to be utilized properly in Microhydro power.

2.5 Scenario of Microhydro power in Nepal

Microhydro power has a long prevailing history in the context of Nepal. Several plans and policies have been formulated and implemented from the national level to promote the micro-hydro as a solution itself or a tool to address various demands of the rural community. The effort and initiatives from the government has been listed below.

Table 4.3. 1 Initiative from Government

Source: (World Bank, 2015)

S.N	Years	Plan	Description
1.	1975-1980	5th development plan	Committed to develop microhydro sector
2.	1980-1985	6th development plan	The Agricultural Development Bank Limited (ADBL) launched the “Rural Electrification Project” and started promoting electricity generation from MHPs by providing 50 to 75 percent subsidy on the cost of the electromechanical equipment
3.	1985-1990	7th development plan	The GoN recognized the importance of alternative energy technologies and promoted it as a tool for developing the agriculture sector and small-scale industries as well as conservation of forest resources
4.	1992-1997	8th development plan	Special priority to the energy sector with an emphasis on reducing the gap between urban and rural areas. The AEPC was established during this period as a body of the GoN and the Rural Energy Development Program (REDP) was initiated with support from the United Nations Development Project (UNDP) and the World Bank.
5.	1997-2002	9th development plan	Emphasized the need of developing alternative energy for economic development & environmental protection with clear policy formulation directives and targets
6.	2002- 2007	10th development plan	Set clear targets for alternative energy and aimed to increase the rural population’s access to energy from 7 percent to 12. Percent 9.8 MW (2MW from Pico and 7.8 MW from micro-hydro) in 59 districts. 3.5% of total electricity supplied from MH
7.	2007-2010	11th development plan	Aimed to increase this access by another 5 percent. Installation of Mini/micro hydro power of 10 MW in 54 districts of Nepal. Set up Energy and Environment Unit in all 75 districts to coordinate RET activities. Promotion of Micro/mini hydro CDM projects.
8.	2010-2013	12th development plan	Promoted the development of MHPs under the leadership of local government & aimed to increase rural energy access by an additional 7 percent.

9.	2013-2016	13th development plan	Aimed to enhance the capacity of local bodies to plan, implement, promote, monitor and evaluate RETs and increase rural population's access to energy by an additional 7 percent.
10.	2016-2020	14th development plan	In addition to the prevalent plans, research to assess the possibility of connecting MHP to the National grid or the inter-connection of the micro hydro plants

Similarly, other various policies have been formulated in order to make the smooth delivery mechanism.

- As per water resource act, microhydro power can use water mills and water grinders without a license. (Water Resource Act, 1992)
- There is no requirement of obtaining licence for generation, transmission and distribution electrical power which are rated up to 1000 kW and for conducting necessary survey thereof as long as they are registered with district Water Resource Committee. (Electricity Act, 1992)
- The Hydropower Development Policy enlists its objective to generate electricity at low cost by utilizing the water resources available in the country. To tie-up electrification with the economic activities. And to render support to the development of rural economy by extending the rural electrification by operating small and mini hydropower projects at the local level (Hydropower Development Policy, 2001)
- The rural energy policy encourages community based energy development initiatives, promotes private sector for supply of the RETs, creates Rural energy funds for subsidy mobilization and emphasizes mandatory participation of the local bodies such as RSC, VDC and DDC to assist (Planning, technical, social mobilization) the community User Group /MHP company (Rural Energy Policy, 2006) .
- The Renewable Energy Subsidy Policy provides subsidy for off grid community/cooperative/Private/Public private partnership owned mini/micro hydropower from 10 kW to 1000 kW on the basis of actual power generation or consumption by consumers within the local distribution. Apart from this the subsidy is also provided for the productive energy use, additional subsidy to the targeted beneficiary groups for the wire connections (Renewable Energy Subsidy Policy, 2016). In order to reduce the dependency on the subsidy the policy addresses the credit

provision. An institutional credit mechanism has been created to provide both a credit-line and credit guarantee scheme under CREF which disburses both soft loan and subsidy. The policy further addresses institutional arrangement, Monitoring & Evaluation, disaster affected projects and subsidy delivery mechanism to effectively implement these policies (Renewable Energy Subsidy Policy, 2016).

- The GoN has provision to separate budget to provide electrification to the rural community which are deprived of national grid electricity. The National Planning Commission (NPC) is the advisory body responsible for formulation, resource allocation, implementation, and monitoring and evaluation of development plans.

Similarly, many guidelines and policies are being developed from the GoN and also from the AEPC regarding the microhydro power along with rural electrification to facilitate electricity supply to the rural community.

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter presents the methods and processes carried out to answer the research question. To carry out the research, a number of steps are to be used to achieve the final target of the research. Research methodology is just a steps and guidelines that is followed throughout the research for addressing the issues of the research and finding best possible solution to the issue for betterment.

The following is the framework for the conduction of research. This represent the structure of the study to find the answer of the research question. This consists of issues identification on need of battery based system for an effective running of existing microhydro plant, supply side management, research question, data collection, analytical model development, simulation setup, result, conclusion and recommendation. To develop this model, energy consumption data of each appliance are collected from users. The following is the framework for the conduction of research. This represent the structure of the study to find the answer of the research question. This consists of issues identification on the battery based model for an effective supply side management, research question, data collection, model development, simulation setup, result, conclusion and recommendation.

Figure 3. 1 Research Framework

The study involves the following methodologies:

3.1 Literature review

Review of the research articles, journals websites books and other relevant material gives us ideas about the studies that has been made previously on the related field this review will give us what should we do to make our research effective and how to make sequential steps for the research completion. We should study different theories to put our research in right way. The modifications on the past microhydro power structures, the implementation of the new technologies and their limitations should be studied first. What methodologies have previous researchers used should be considered and we should develop the methodology from those studies.

An extensive literature review was carried out on the issues related to usage of battery bank in microhydro power supply side management and other aspects of microhydro plants.

At first the necessary theories and relevant literatures are studied and then the necessary resources to complete the research are to be finalized. The resources may be the data, model development approach and software selection.

Different models required for giving right way to this research work are to be studied first. The study of Matlab and Simulink model for the model development of battery based system was also studied. Limitation and difficulties in previous studies are to be understood before preceding to next phase of the study.

3.2 Analytical Model Development for Microhydro Powered Battery Bank.

This stage includes the study of model for battery charging on microhydro power. Once the necessary literatures on different theories for developing models are reviewed, the analytical model was developed. And this model helps in understanding how battery bank helps to fulfil peak load by use of surplus power for charging. Based on the solutions of analytical model, battery based system will be designed that best satisfy the model.

3.3 Modelling and Simulation using Matlab and Result Analysis

Once the theoretical design for the battery bank is being made, the model in Matlab and Simulink software was created as per the key data and information obtained from theoretical approach. The various flow parameters such as active and reactive power as well as phase angle and power output, efficiency of the plant, other performances curves, etc. will be observed using the simulation data and the results will be analysed with the theoretical model.

The results obtained from the simulation will be validated with the results obtained from analytical solutions.

3.4 Data collection and analysis

The target population for this research problem consists of the total individual electricity consumer those who purchased the electricity service from the Pinthali microhydro power.
The data collection and analysis algorithm is as follows;

1. Questionnaire design
2. Identify the load and their usage pattern for the users
3. Calculate the daily, electricity consumption of consumer n as per the answer received from consumers.
4. Find the recent daily energy consumption of consumer n from microhydro power for one year.
5. Find the average energy consumption by microhydro power benefitted consumers.
6. Determine the deviation of surveyed energy consumption and actual energy consumption.
7. Finalize the data for the research

Finally, the result will be analysed and study will be carried out in the Microhydro power. Pinthali Microhydro power of capacity 8.1 kW is selected for this purpose. This includes study of analytical results and its possibility of implication on microhydro power.
The sample was considered when there's no more than 10% deviation in actual energy consumption of recent month and the energy consumption in survey data. Out of 142 consumers, 105 samples taken and they stay within deviation limit.

Out of 105 samples there's the participation of different consumer class so as to represent proportionate stratified sampling as per the ratio of the population group. The sample size holds the 95% confidence level with 4.2% margin of error as per determined by the Slovin's formula. A number of research studies use the so-called Slovin's (or sometimes Sloven's) formula for obtaining the sample size. For n number of the sample size, Slovin's formula is given by (Yemane, 1967)

$$n = \frac{N}{1+Ne^2} \qquad \text{Equation 1}$$

where N is the population size and e is the margin of error, which holds true for all 95% confidence level.

3.5 Simulation setup

Once the theoretical model and the required data are available, battery based system can be determined using Simulink model. For the simulation, collected data will be used and kept in Matlab. This setup will give a clear idea of how supply side can be managed using the battery bank in conventional microhydro power.

3.6 Sizing of battery

Battery needs proper rating according to the need when it needs to be used. Size of battery is directly linked with the financial issues. If battery is kept below the requirement it may get discharged up to lower value which reduces the battery life. In other hand oversizing may result in increased investment.

Battery size in kWh,

$$E_{batt}(kWh) = \frac{(1+ageing\ factor)*\frac{kWh}{day}}{\eta_{inverter}*DoD} \qquad \text{Equation 2}$$

Here, ageing factor is the reduced performance of the battery after being used for continuous time,

$\eta_{inverter}$= inverter efficiency,

DoD= Depth of Discharge

Battery capacity in Ah,

$$E_{cap}(Ah) = \frac{E_{batt}*1000}{V} \qquad \text{Equation 3}$$

Here, E_{batt} is the kWh rating of the battery

V is the voltage rating of the battery

3.7 Financial analysis of the battery based system

A financial analysis is must before investing capital in the proposed project. Therefore, a financial analysis was done in order to know its financial feasibility. In this research, two key indicators of financial decision were considered to check whether the investing on the battery based microhydro power would be beneficial to utility as well as to consumer. The considered financial indicators were payback period and net present value of the proposed scheme.

Discounted payback period (DPP) $= \dfrac{\ln\left(\left(\dfrac{1}{1-\frac{I*r}{A}}\right)^{-1}\right)}{\ln(1+r)}$ Equation 4

Where, I= initial investment

A=Annual return

r = Discount rate

NPV= -I+ $\dfrac{F1}{(1+r)}$+……………………. + $\dfrac{Fn}{(1+r))^{n}}$ Equation 5

Where, I= initial investment

F=Future values

r = interest rate

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Basic Design

Microhydro powers are simple in construction with few of the major components involved such as turbine, synchronous generator, electronic load controller with consumer load. Supply of power may be less than power demand by load during peak time. For addressing this issue, we have added the battery in the existing microhydro power. After addition of battery in our system, we have new model with additional power source to supply power in peak time. Our new model has Pelton turbine, synchronous generator of 8.1 kW, battery and electronic load controller. As we have load varying up to 10 kW, we have battery system to supply power up to 2 hours. This will be obtained without decreasing the depth of discharge of battery beyond 50%. Also hybrid inverter is included in design for charging of battery and supply of power to the system.

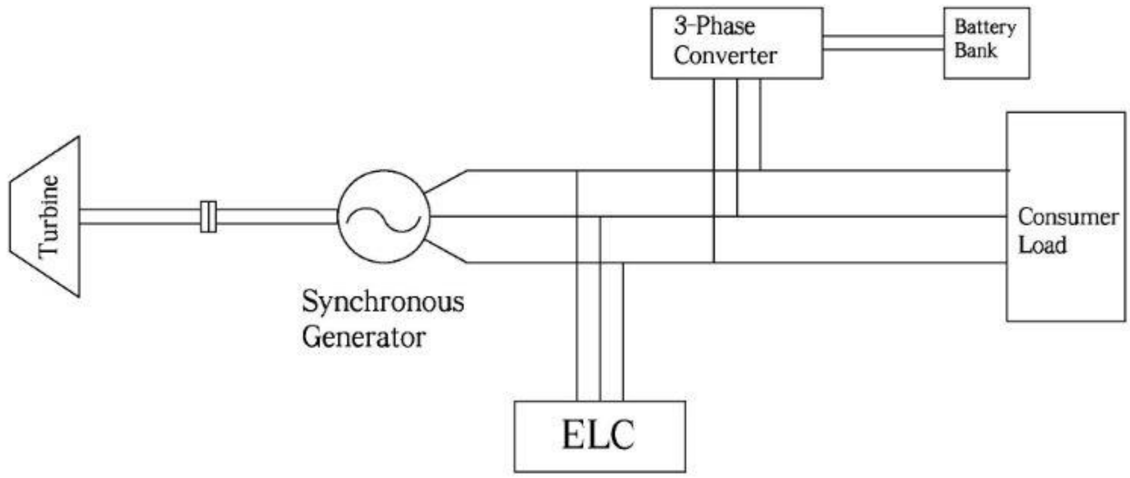

Figure 4. 1 Block diagram of Microhydro with battery storage

Load draws only active power only as there is no inductive load so total load is considered active in nature. There is the use of thyristors in the electronic load controller which are kept anti-parallel. By varying the firing angle of the thyristors we can dissipate desired power in to the ELC. So our model consists of Pelton turbine, synchronous generator, electronic load controller and consumer load. Modified model consists of battery in addition to the existing plant.

4.2 Analysis of existing load demand

The load profile of the model consisting of 142 users was found uneven, there appeared peak for two slots of time in a day. On the other time the demand is so less than that of peak loads. This load profile results a higher peak value with lower average value of power demand. The system has been peaking in the evening and morning hour at which the residential works concentrate. The figure below shows that the demand profile of all seasons are uneven with multiple peaking and formation of valleys in a day.

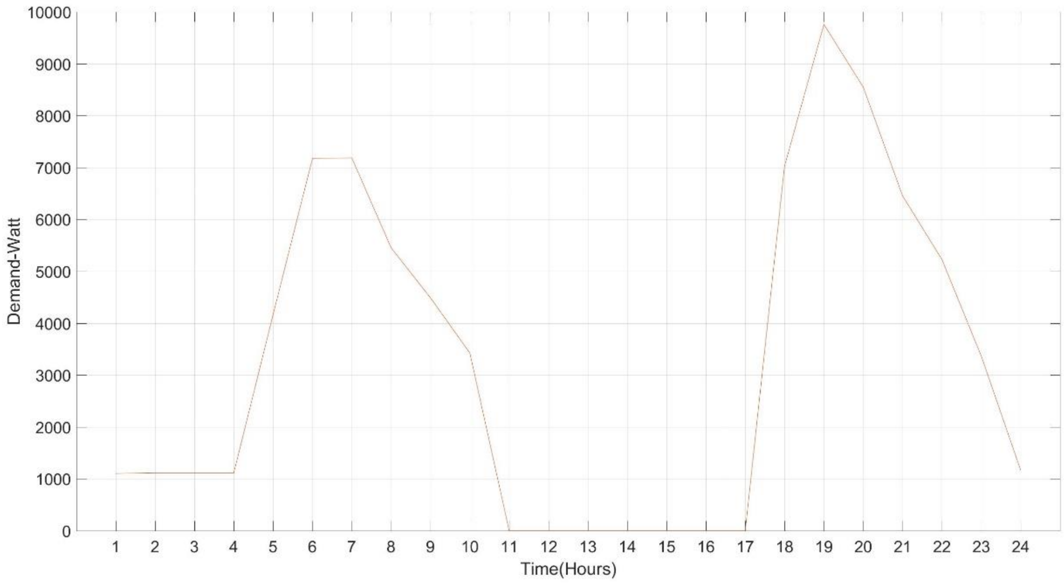

Figure 4. 2 Load curve of consumers

Consumers were using basically small loads as power generated by microhydro power wouldn't support running of higher wattage appliances. High percentage of load was lighting loads as it was essential need of the local people. In addition, people used electricity for phone charging, light charging, television and few number of refrigerators.

Figure below shows the pie chart showing the energy consumption by the appliances of the end user. Five loads i.e. lighting, refrigerator, television, phone charging and light charging are taken for our study. Lighting is the major source of load followed by phone charging, refrigerator, television and light charging. The percentage of the energy consumed by each appliance is given below:

Table 4.3. 2 Daily energy consumed by each appliance

S.N	Appliances	Energy consumed(kWh)
1.	Lighting	26.031
2.	Refrigerator	9.960
3.	Television	5.314
4.	Phone Charging	13.620
5.	Light Charging	2.670
	Total	57.595

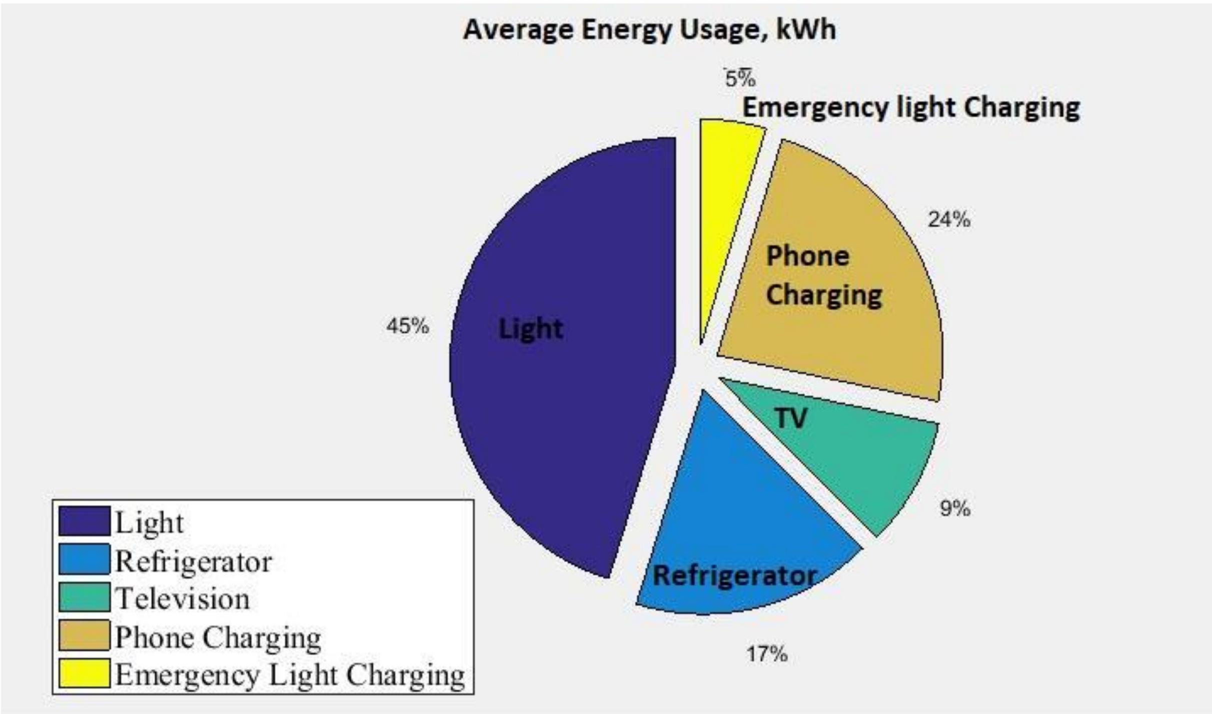

Figure 4. 3 Pie chart of energy consumed by appliances

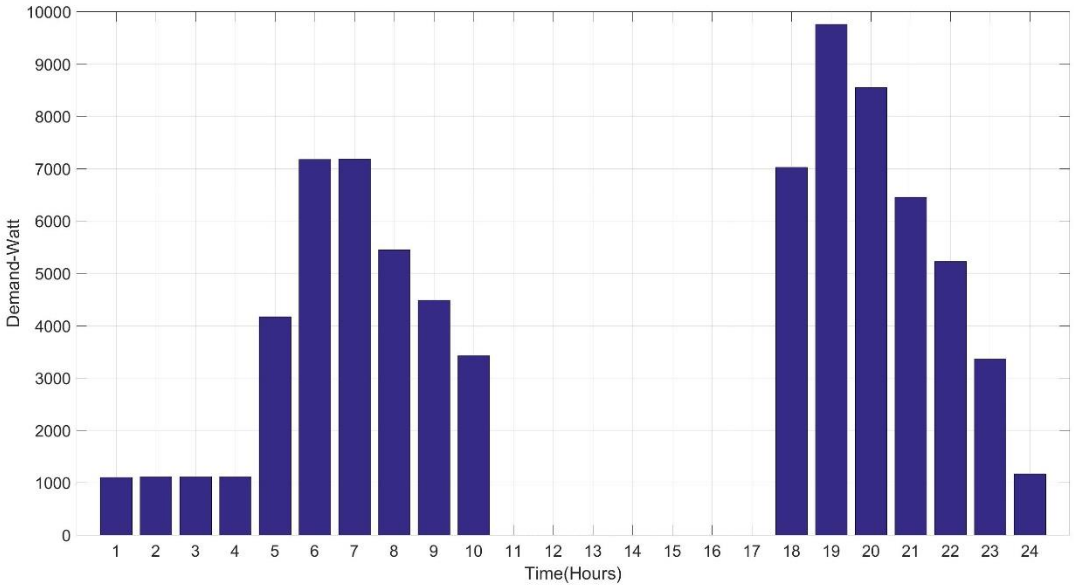

Figure 4. 4 Load bar of consumer demand

Figure above shows the wattage demand of the appliances in different time of the day. Microhydro power is kept closed from 10 am to 5 pm and water is used in irrigation and for grinding of cereals. Load gets higher value at the morning and evening time and peak load is recorded at 7pm on evening. Following data were obtained from the load assessment:

Table 4.3. 3 Load assessment findings

S.N	Name	Value
1.	Total consumers	142
2.	Load factor	0.3326
3.	Average load	3.245 kW
4.	Peak load	9.757 kW

From the load assessment and load curve calculation of the 142 consumers some conclusion was drawn. Load factor of 0.3326 was obtained which shows the ratio of average load to the peak load. Higher the value of load factor more efficient the plant is. Average load of 3.245kW was obtained and peak load of 9.757kW was noted which was above the generating capacity of the plant.

4.2 Operational mode

We have considered different modes for our study. The first priority of the power goes to the consumer load. Then if power remains it is used by battery. Finally, if power is left from usage by both then it is dissipated in ELC.

Surplus power = Power generated by source – Power used by load

Deficit power = Power used by load - Power generated by source

First mode: Surplus power is available after feeding load and battery is fully charged. So this power will be dissipated in ELC.

Second mode: Surplus power is available after feeding the load and battery in charging condition. Here, ELC doesn't get any power to dissipate. We have power available for load and battery only.

Third mode: Power demand by load is greater than power generated by source. So demand will be met by addition of the power from battery into the system.

4.3 Controlling Units

4.3.1 Electronic Load Controller

With variation in the consumer load, there is variation in the frequency of power generation. Frequency and load is inversely related as increase in one quantity indicates fall in another quantity and vice-versa. Frequency of the system needs to be maintained constant to insure quality power to the consumer. Chances of fluctuation increases with changing load which need to be governed properly. Control system involved will generate error signal upon deviation of frequency from standard value. To maintain the frequency of the system in standard value ELC plays a vital role. When firing angle of the thyristors changes the power dissipated through the ELC also changes.

We need to choose the proper resistance of the ELC. The value must be able to dissipate the full power generation capacity of the plant when none of the priority load uses the generated power.

Rating of the resistance for ELC is given by,

$$R_{dump} = \frac{V_l^2}{K*Pgen} \qquad \text{Equation 6}$$

Where, V_l= line voltage

P_{gen}= Generated power in plant

K = secondary load multiplication factor (Gyawali, 2015).

With firing angle α, power dissipation in ELC is given by,

$$P_{drop} = \frac{Vs^2}{R_{dump}} \left\{ \frac{1}{\pi}(\pi - \alpha) + \frac{\sin 2\alpha}{2} \right\} \quad \text{Equation 7}$$

During high power demand by load, ELC dissipates no power and is obtained by firing ELC at 180°.

4.4 Simulation results

Battery based Microhydro system was tested on the Matlab and Simulink and many results were drawn. Simulation results shows improved performance of Microhydro power after implementation of Microhydro powered batteries.

Mode 1

When battery is fully charged and power generated by microhydro power is greater than power demanded by load, excess power will be dissipated on the ELC.

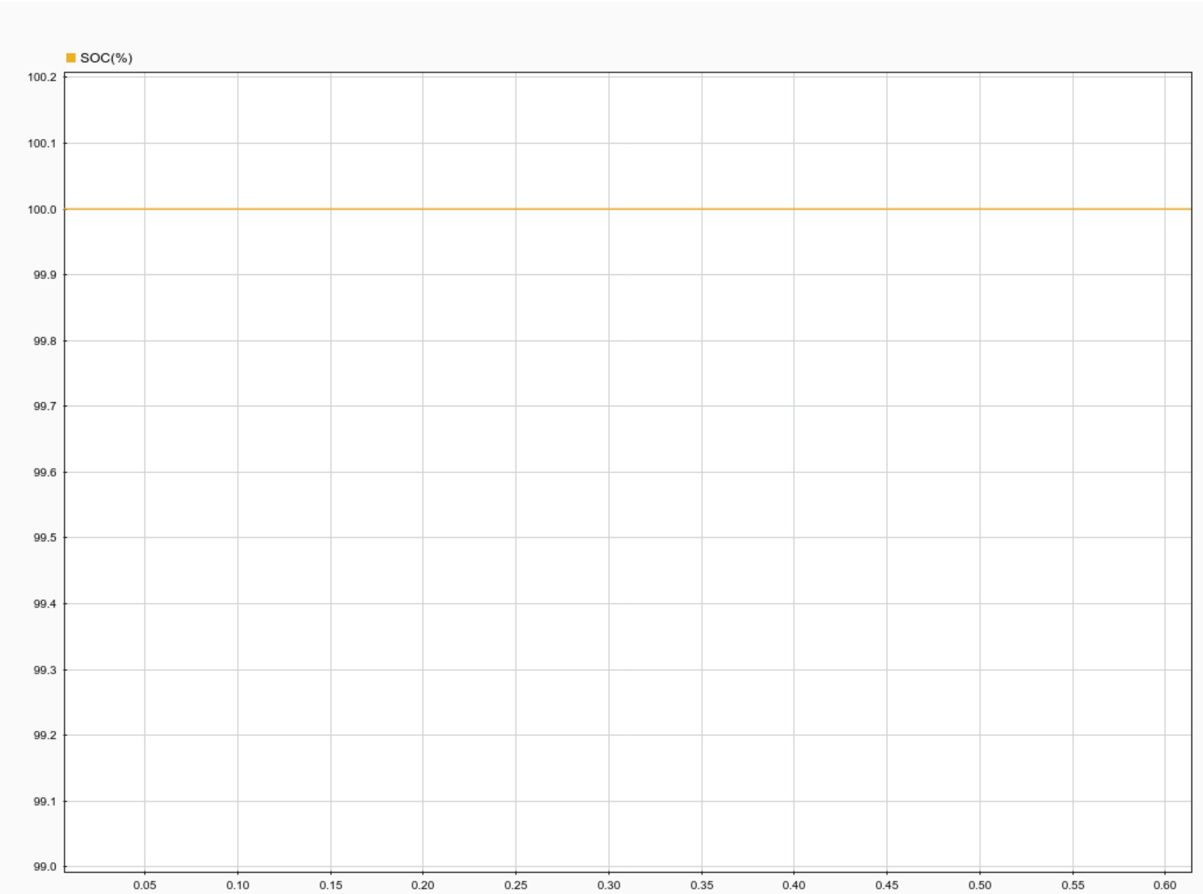

Figure 4. 5 State of Charge of battery after fully charged

Figure 4. 5 shows the status of battery after being fully charged. State of charged is maintained at 100%. After battery is fully charged the excess power will be dumped by ELC.

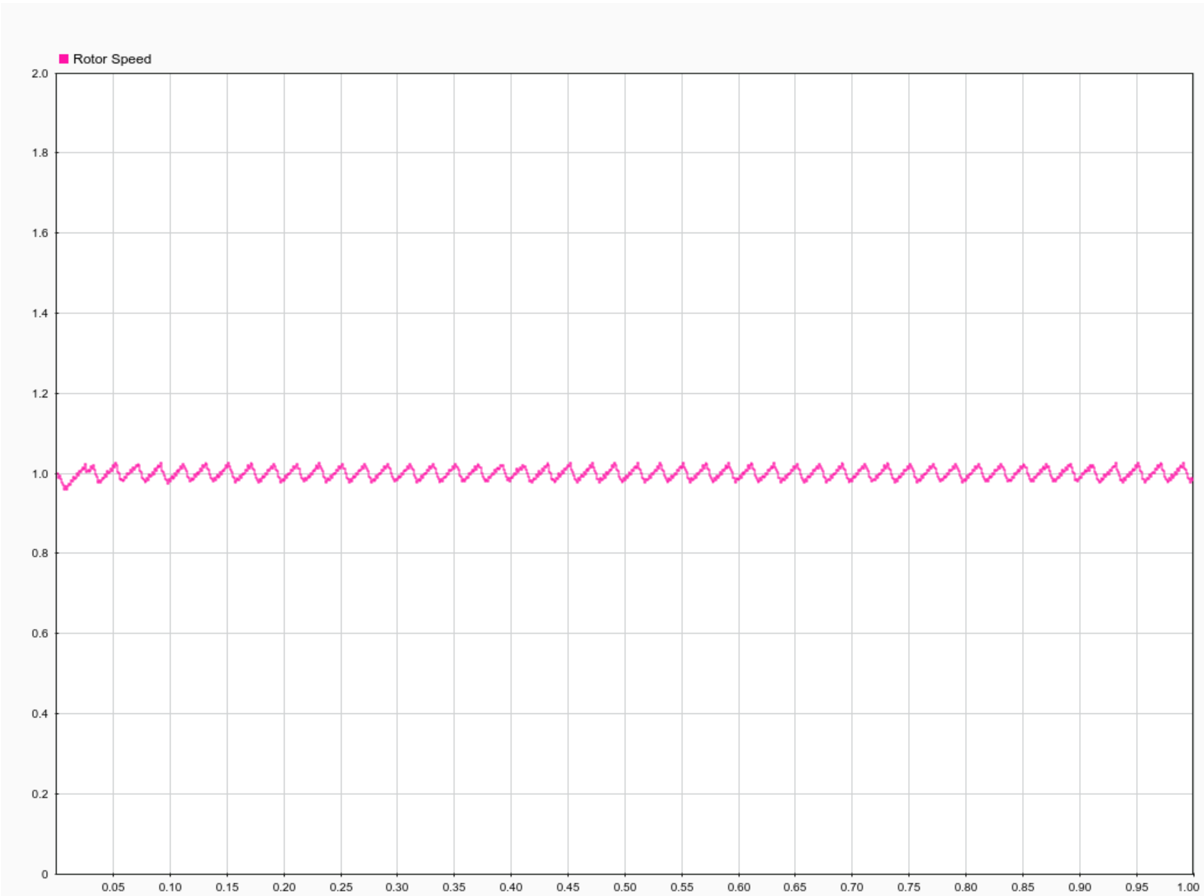

Figure 4. 6 Rotor speed when battery is fully charged

Rotor speed indicates the speed of rotor of synchronous generator. It is represented in per unit system as 1 indicates the rated synchronous speed. Figure 4. 6 shows the speed of rotor when battery is being fully charged. Rotor speed is maintained in the range of 1 p.u, which indicates that our synchronous machine is running in rated speed.

ELC is an electronic device with thyristors which can be fired with certain firing angle to dump the excess power generated by source for the load frequency control. It is basically used in conventional microhydro plants and is useful in consuming power when consumer doesn't use the generated power by the plant. Figure 4. 7 shows the firing angle of the ELC when battery is fully charged. Under this condition some of the power is consumed by user and battery doesn't use power as it is fully charged. So, ELC is most important component of the microhydro plant for its efficient operation.

Figure 4. 7 shows the firing angle of ELC when the battery is fully charged. When thyristors is fired at zero degree then it will be ready for full conduction i.e. it can take load equivalent to its capacity and it can dump maximum load. With increase in firing angle the load dissipation capacity of the ELC decreases and we can make ELC to dump no load at firing angle of 180°. Load dissipation capacity of the ELC can be varied by changing the firing angle of thyristors and when battery is fully charged and load doesn't consume generated power fully then it is dissipated by ELC by firing it with suitable angle.

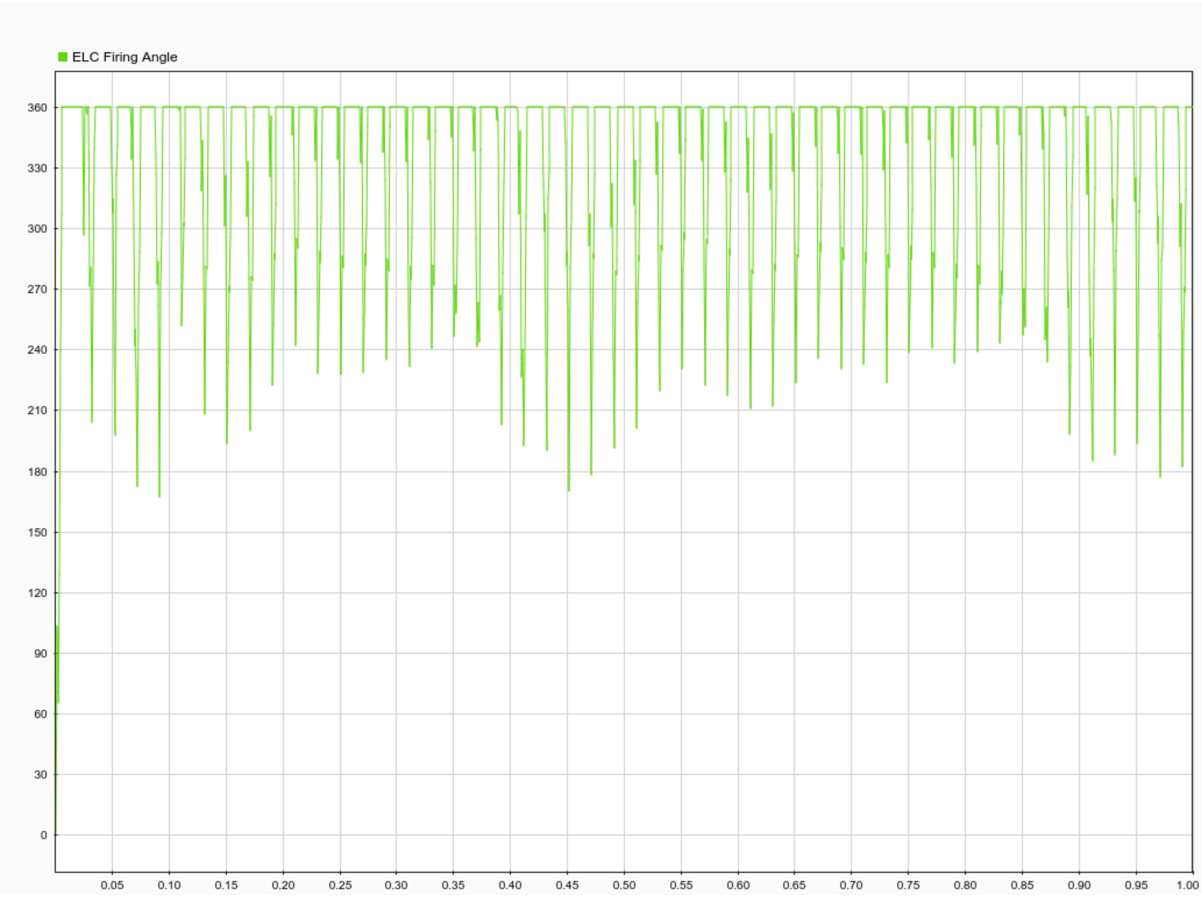

Figure 4. 7 Firing angle of ELC when battery is fully charged

As battery if fully charged in mode 1, the generated power will be fully delivered to the load but load doesn't consume the full of the generated power. So we need ELC to dump the excess power in the figure 4. 8 three curve are shown. The blue curve on the positive side denotes the generation on the power from the plant and green line on the other side denotes the power consumed by load. Purple line denotes the power utilized by battery for the charging which is approximately zero as it is fully charged.

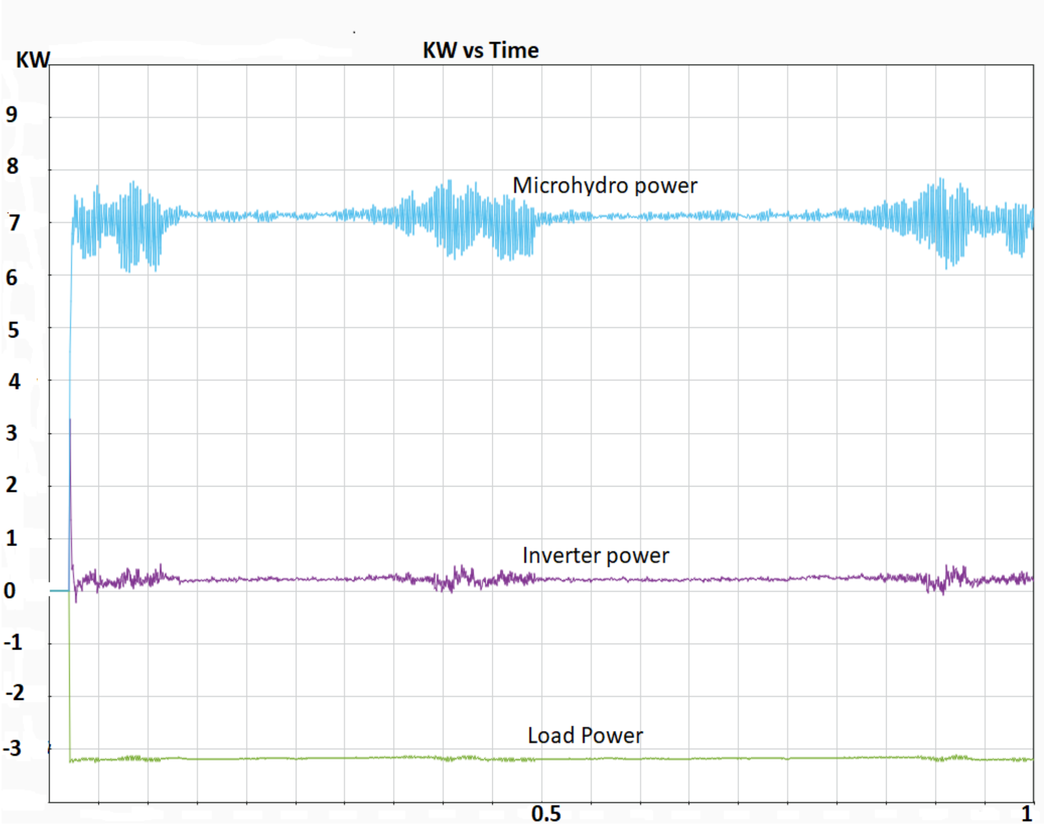

Figure 4. 8 Power generation and distribution after battery is fully charged

In this case of 3 kW load consumes the power from the main source i.e. microhydro. As power generated by source is greater than the power demanded by the load, there is excess power in the system. In this mode battery is already fully charged and excess power needs to be dumped by the ELC. So, antiparallel thyristors are fired with a certain firing angle to dump the excess power from the system.

Mode 2

In this mode, power demand by load is less than generated power by the source and battery is on charging process. Load will take the power needed from the main source and battery will take the power required for the charging. Remaining power after being used by load and battery will be consumed by the ELC.

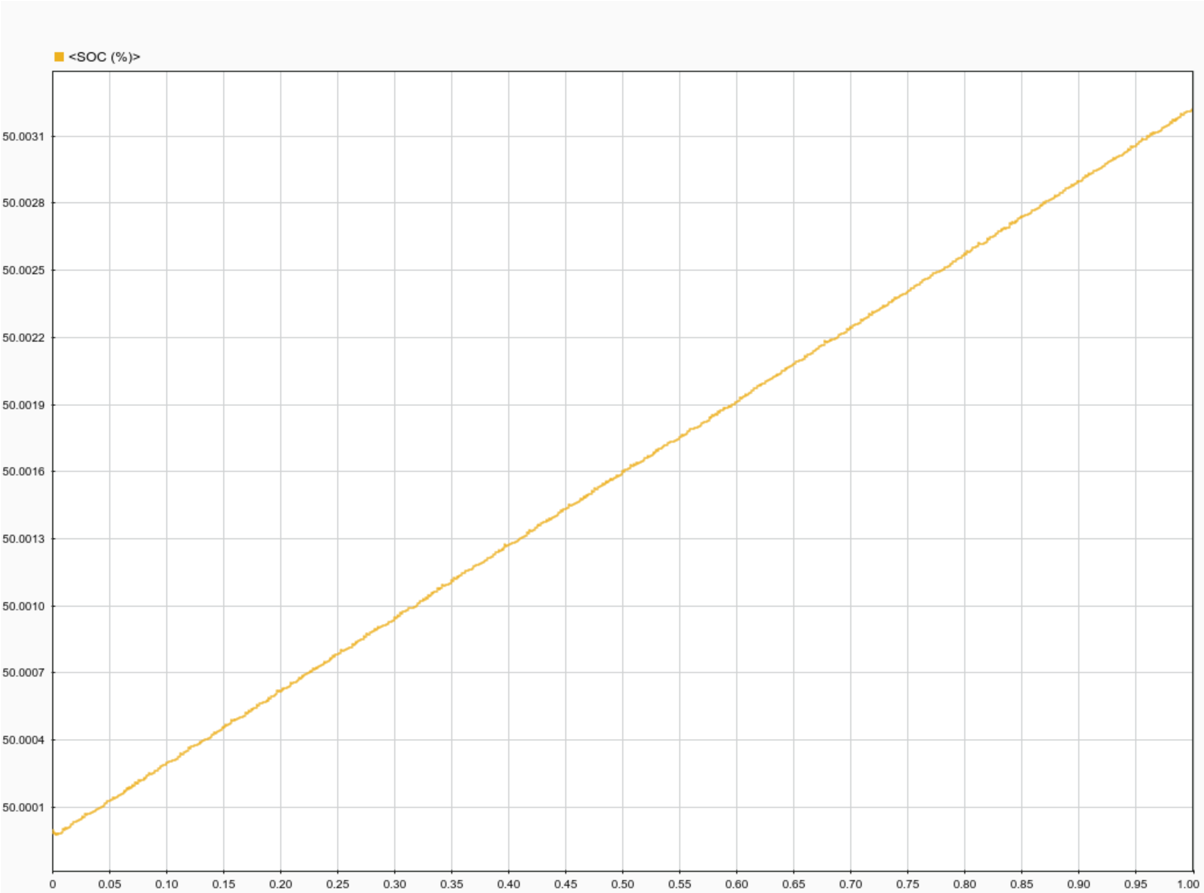

Figure 4. 9 State of charge on charging condition of battery

During underload condition and battery is on charging condition, the state of charge slowly increases with respect to time. Depth of discharge of battery is 50%, the state of charge of battery will start to increase from 50%.

The rotor speed of the synchronous machine is shown in the figure 4. 10 which is maintained in the range of 1 p.u. Due to loads like consumer load and battery charging load connected to a source, there will be slight fluctuation in the rotor speed which lies within tolerable range.

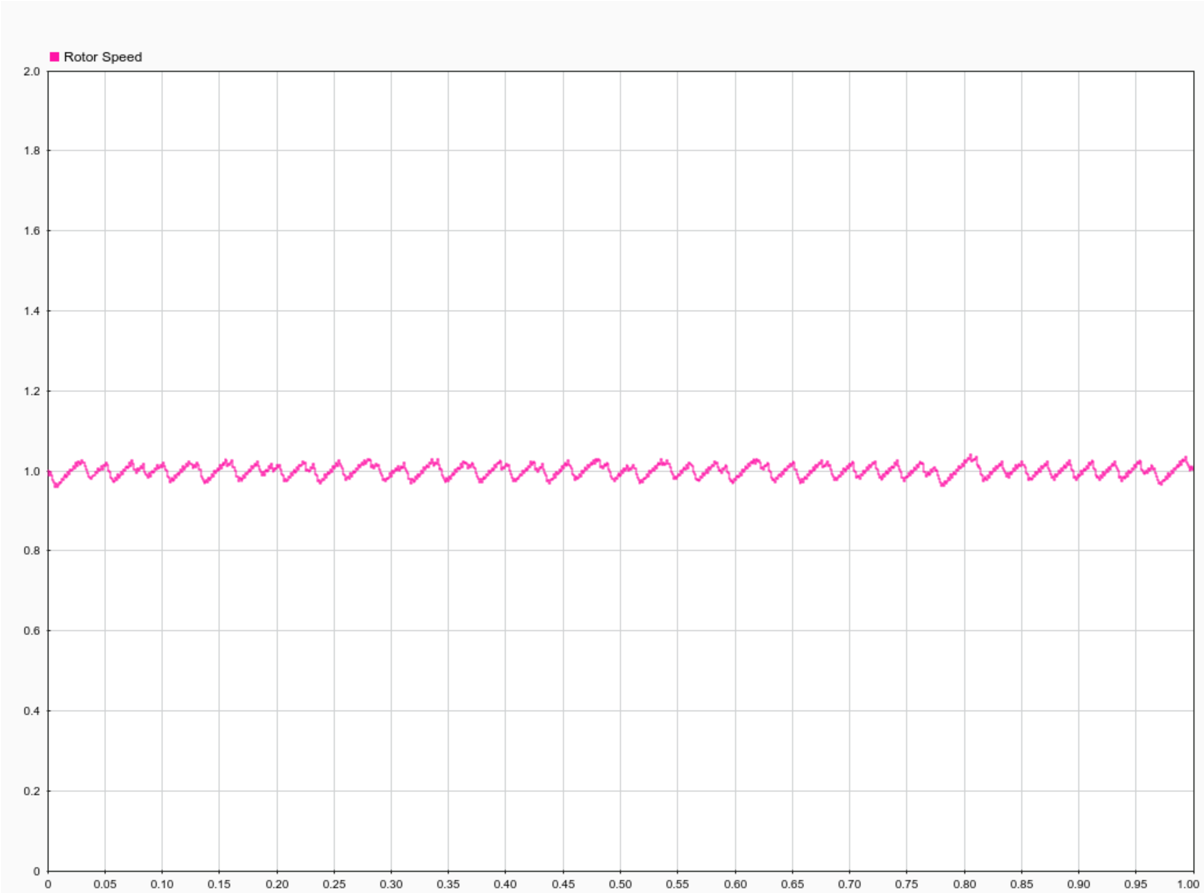

Figure 4. 10 Rotor speed on underload condition

During underload condition, demand of the consumer load is lower than the power generated and excess power is utilized by battery. Again the power remained after power utilized will be dumped by the ELC. The firing angle characteristic is shown in figure 4. 11, where thyristors is fired at different angle for dumping the excess power.

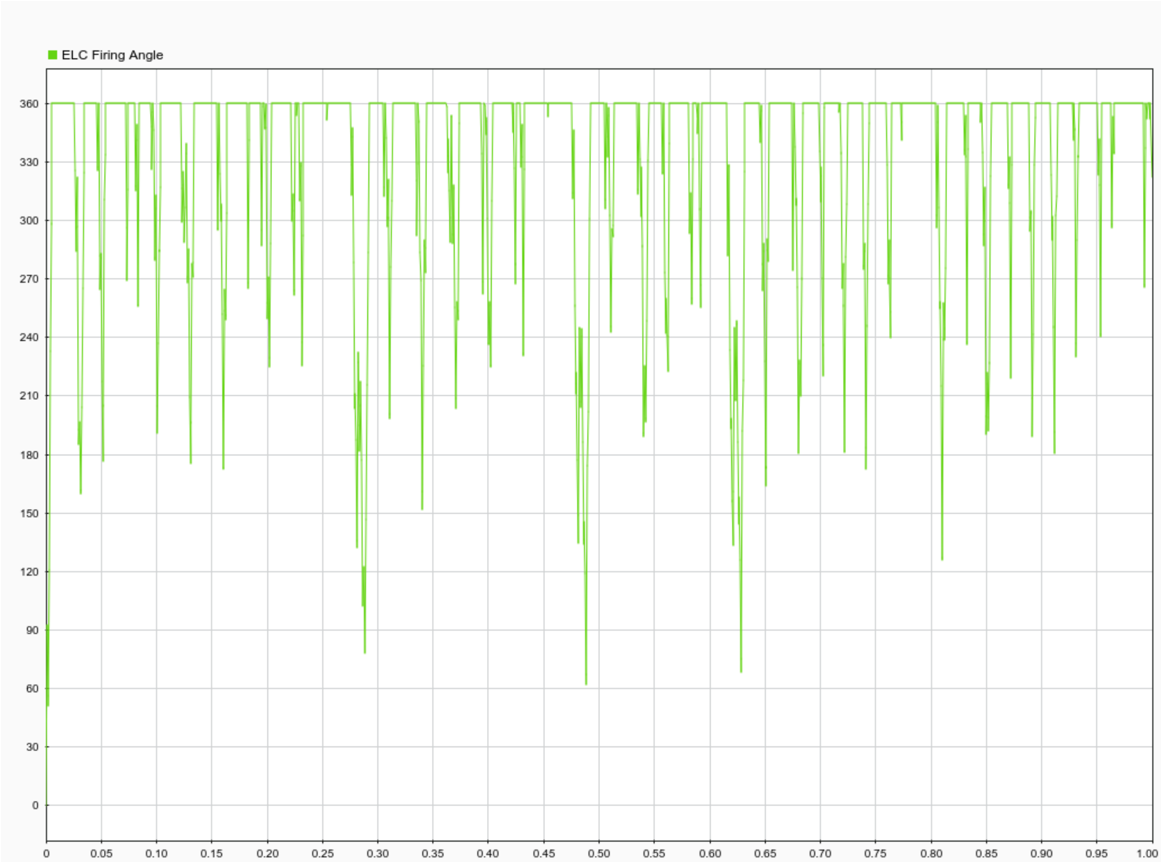

Figure 4. 11 Firing characteristic on underload condition

Figure 4. 12 shows the graph of power generation and distribution. Upper curve on positive part with blue color denotes the power generated by the main source. Curve on the negative part is the power consumed by consumer load and battery for charging. In this mode battery gets charged from the excess power from the source and further excess load is dumped by the ELC.

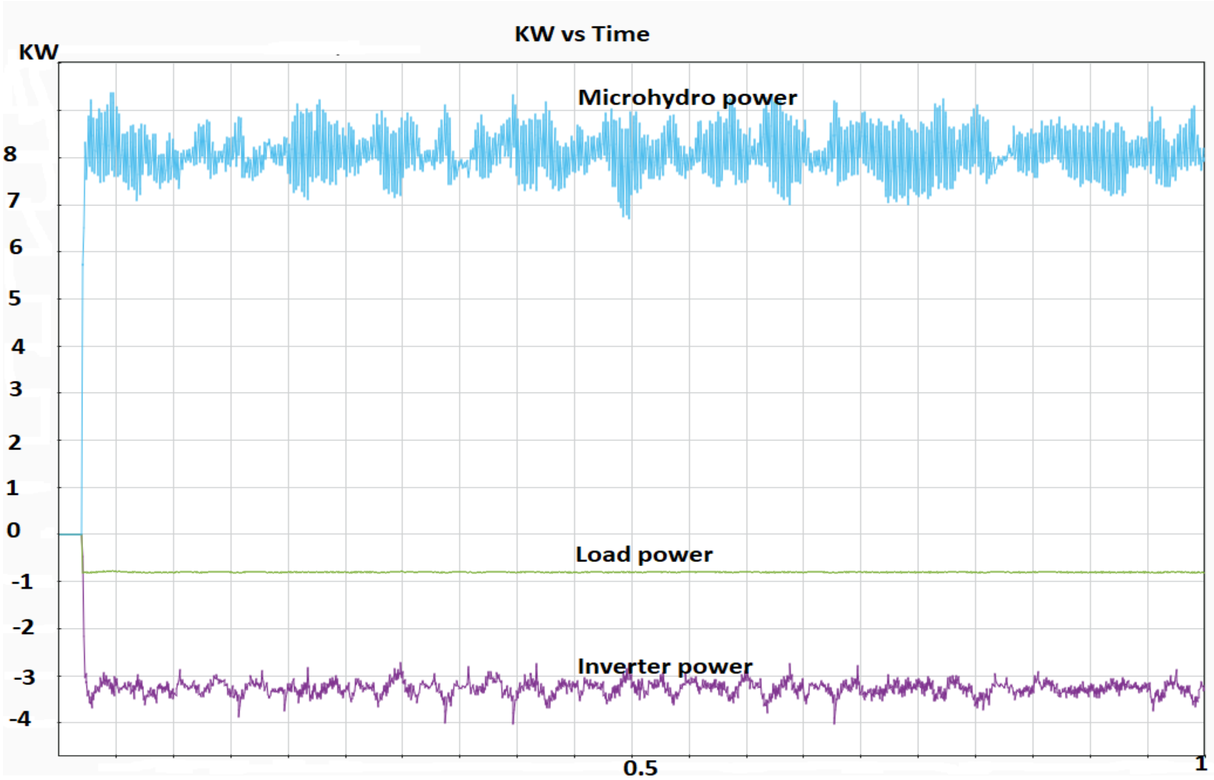

Figure 4. 12 Power generation and distribution during underload condition

Mode 3

In this mode the system runs in the overload condition. The power demand by the load is greater than the power generated by the plant. In this case the deficit power to the load is supplied by the auxiliary source i.e. from battery. Plant will be running in the full capacity in this condition and tends to under speed due to demand of high power from the load. As auxiliary source adds up the power in the system, again rotor speed tends to fluctuate. In this way rotor speed tends to settle with respect to the time.

The state of charge of battery slowly decreases when it supplies power to the load. Figure 4.13 shows the state of charge of battery in overload condition of the microhydro.

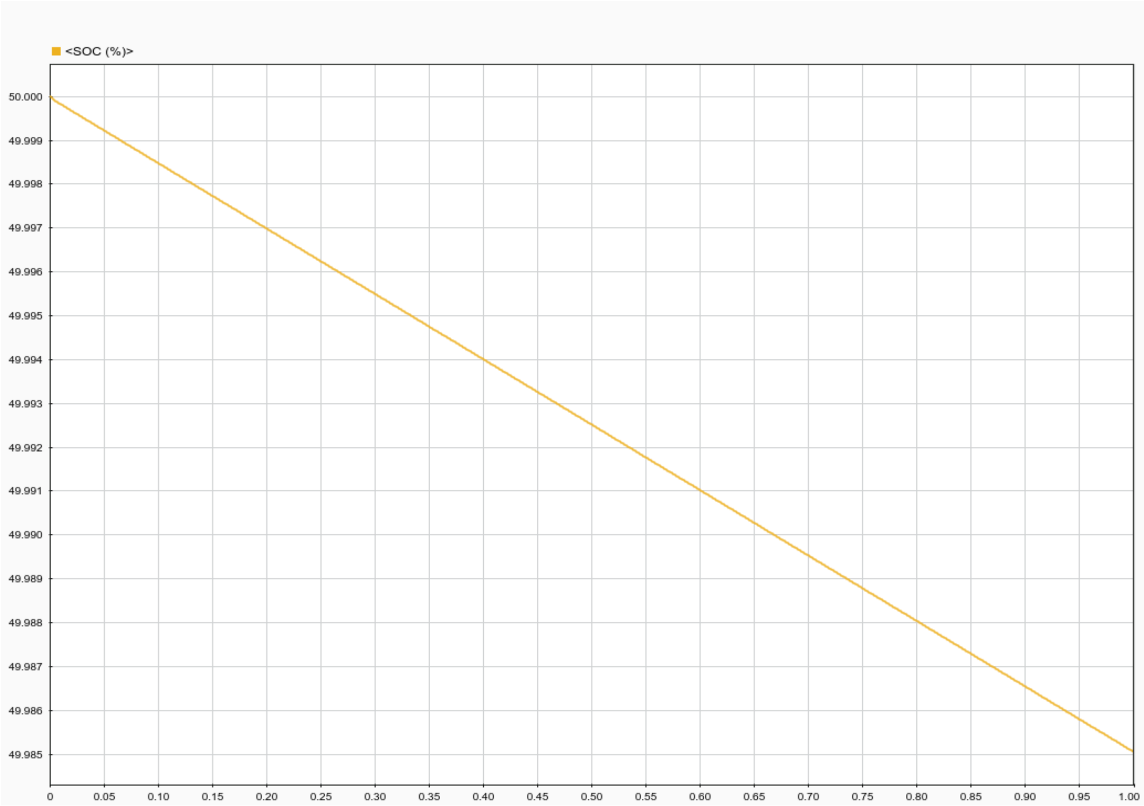

Figure 4. 13 State of charge of battery during overload condition

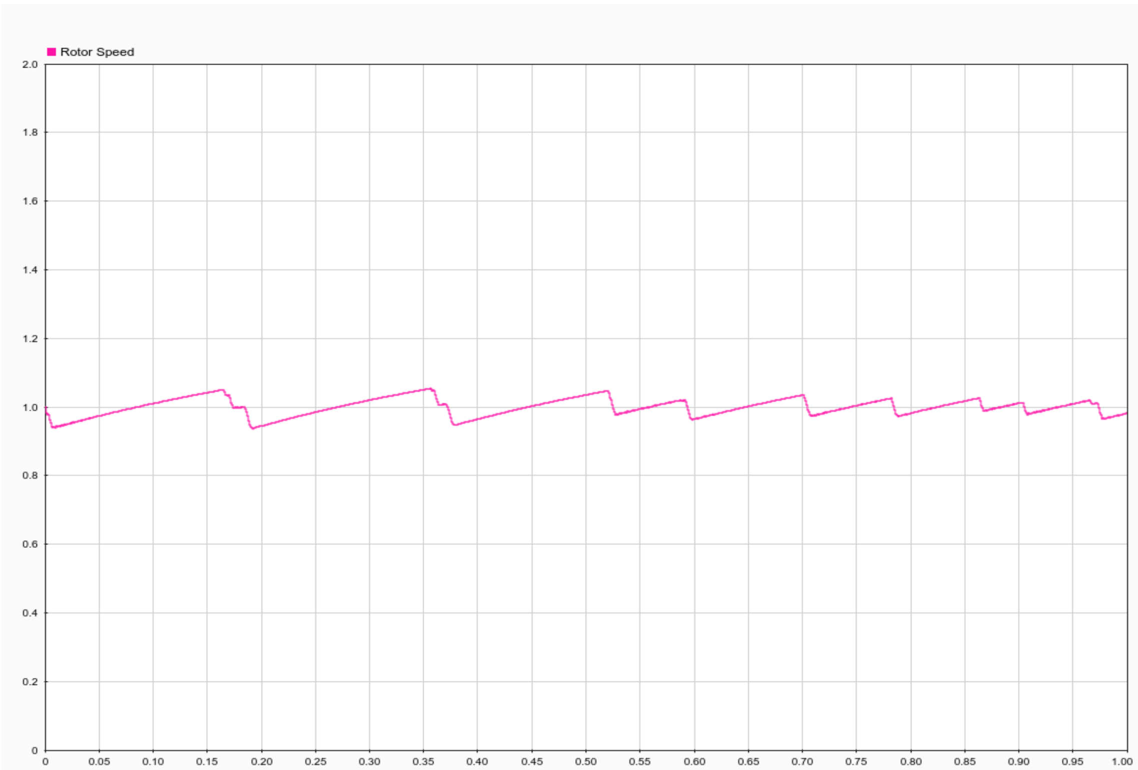

Figure 4. 14 Rotor speed under overload condition

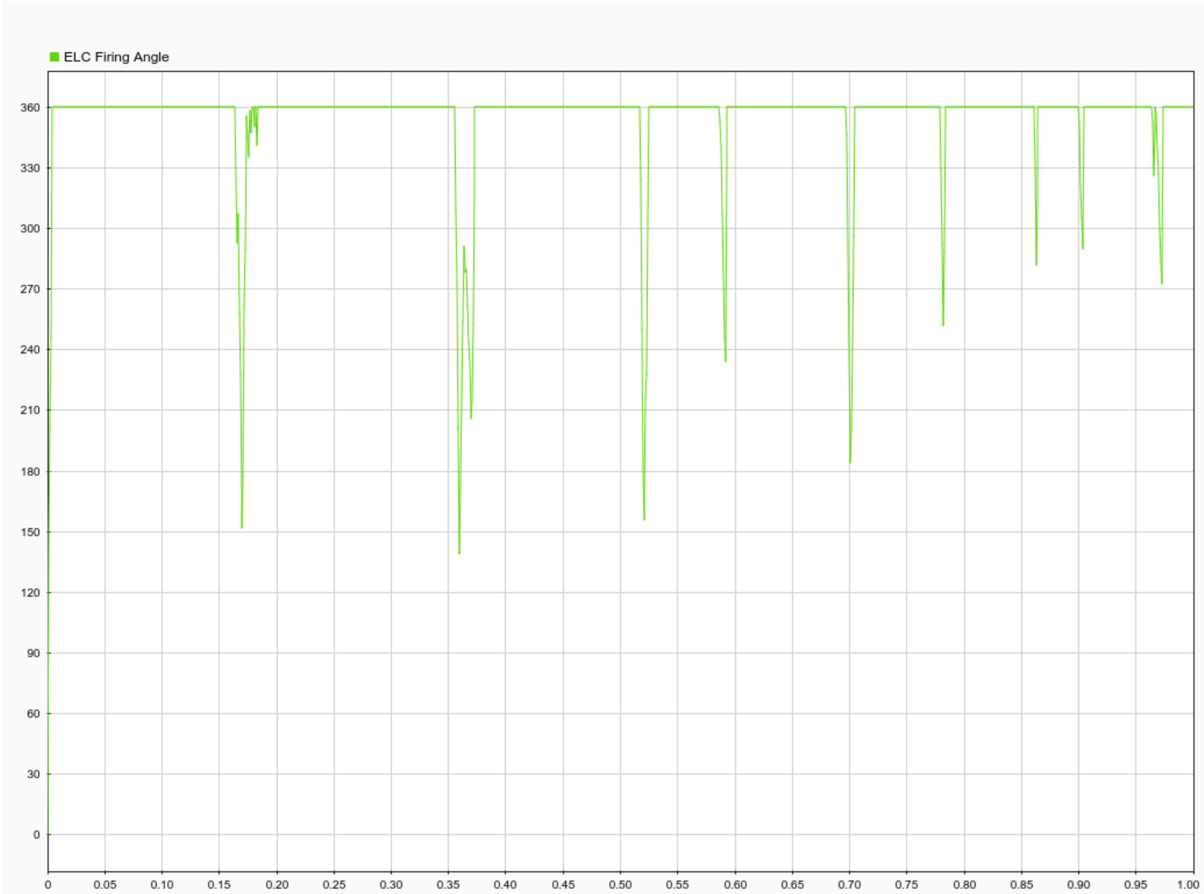

Figure 4. 15 Firing angle characteristic at overload condition

Figure 4. 15 shows the firing angle of ELC in overload condition. ELC is fired at different firing angles as per requirement of the system. In this case no power is dump by the ELC as requirement of load is higher.

When demand exceeds the supply then voltage tends to drop in the consumer side but generation voltage is always constant despite minor fluctuation in rotor speed. In this case, DC link voltage tends to drop as load demand more power. As soon as voltage starts to fall system is switched in the overload mode and battery starts to supply the power to the system.

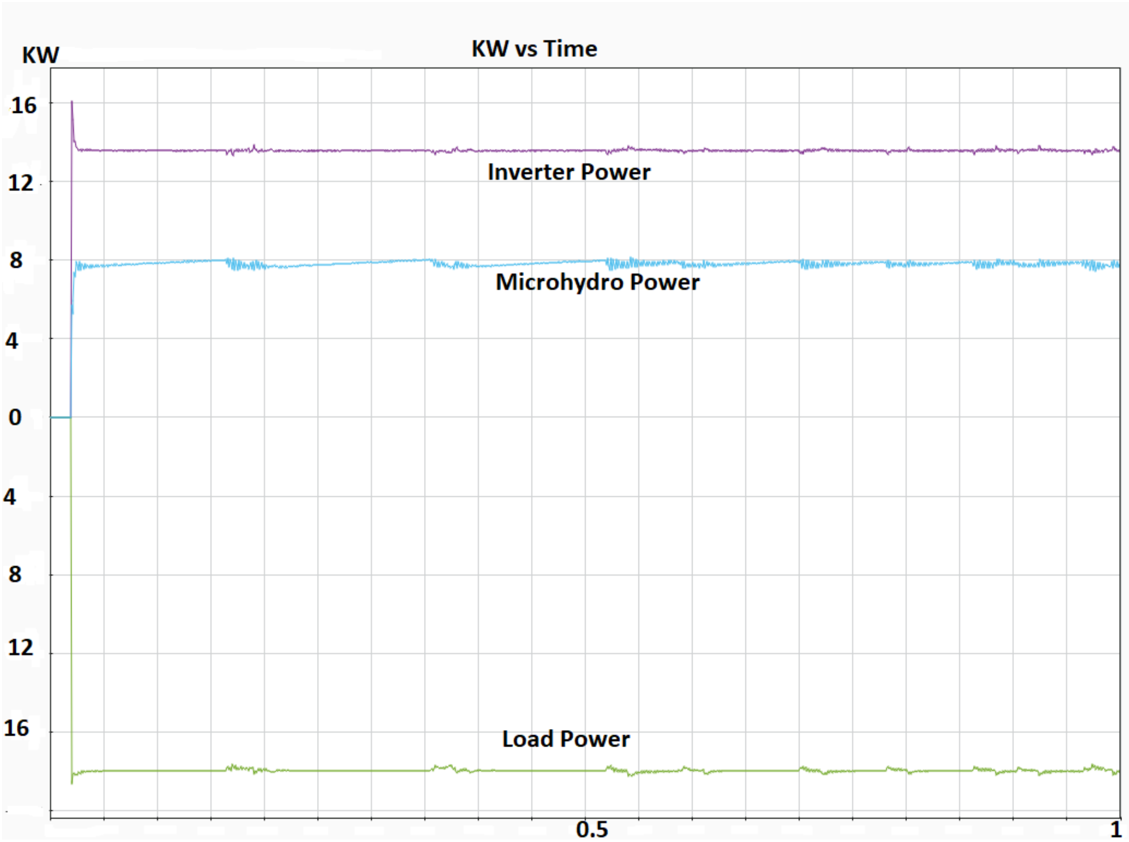

Figure 4. 16 Power generation and distribution during overload

4.5 Mode Switching

System operates in the different modes on the basis of the power consumed by battery, consumer load and ELC. When battery is charged completely we have one mode of operation whereas when battery is in charging condition we have another mode of operation. Also when load demand is higher than generated power, we have another operational mode. In this way we have to switch the operation according to the mode.

For transition of mode DC link voltage is compared to dc bus voltage. DC link voltage is maintained at 800V. DC link voltage is compared with dc bus voltage and reference signal is obtained from the comparison. Thus obtained reference signal triggers the different modes of operation of the inverter.

Table 4.3. 4 Mode transition

S.N	DC Link Voltage	DC Bus Voltage	Mode
1.	800V	800V	1 (Fully charged)
2.	800V	<800V	2 (Charging)
3.	800V	>800V	3 (Discharging)

A 8.1 kW generator generates the power and supplies to the load of 3kW, if battery is fully charged then system will operate in mode 1. And DC link voltage and DC bus voltage is maintained at 800V. The excess of load is dumped by the ELC. If DC link voltage is less than DC bus voltage, then system will operate in mode 2 i.e. the battery will continue to charge and if excess power is left it will be dumped by the ELC.

Finally, if DC link Voltage is higher than DC bus voltage then the system will operate in mode 3 i.e. battery supplies the power to the load and battery will start to discharge. In this way different modes of operation are obtained from comparison of DC link voltage and DC bus voltage.

4.6 Battery sizing and Costing

For the incorporation of battery in the existing microhydro plant, sizing of the battery is important. The size of battery should be chosen in such a way that it covers the excess load in the system. Power deficit in the peak load time is covered by the battery bank.

For the sizing of the battery we have to consider different factors such as depth of discharge(DoD), battery ageing, operating temperature, inverter efficiency etc. We have used the operating temperature of 25 °C, and battery ageing factor is considered 15% (Angel A. Bayod-Rujula, 2013). Hence capacity of battery needs to be increased by 15%.

For the Pinthali microhydro plant we have generated capacity of 8.1 kW, so synchronous generator constantly generates the power of 8.1 kW. When power demand by load is less then power generated power is used for battery charging and further excess power will be dumped in ELC. In case of power demand by load is greater than the power generated it is supplied by battery bank to the system. From our load survey we have noted the peak demand of 9.575 kW which is approximately 20% greater than the generated capacity of the plant.

Generated power =8.1 kW

Peak power = 9.575 kW

Deficit power on peak time= 1.475 kW

Inverter efficiency= 90%

Depth of discharge= 50%

System is designed in such a way that if can feed the peak load for 2 hours,

So total kilowatt-hour energy that battery can supply in a day is calculated,

i.e. 1.475kW * 2 hours= 3 kWh/day

As we know,

Battery size in kWh,

$$E_{batt}(kWh) = \frac{(1+ageing\ factor)*\frac{kWh}{day}}{\eta_{inverter}*DoD}$$

Battery capacity in Ah,

$$E_{cap}(Ah) = \frac{E_{batt}*1000}{V}$$

The ampere-hour rating gives the capacity of the battery. This capacity of battery for the required voltage level is met by connecting the battery in either series or in parallel connection.

Table 4.3. 5 Different parameters for battery sizing

S.N	Parameter	Calculated Rating	Design Rating
1.	KWh Battery size	7.66 kWh	-
2.	Ah Battery size	639 Ah	700 Ah
3.	Battery voltage	-	12 V
4.	Inverter size	1.84 kVA	2 kVA

Calculate value of the different component may not be available in the market so rating of the component is so chosen that it is available in the market easily.

For the incorporation of battery based system in the microhydro plant we need to install hybrid inverter and set of battery required. As we are using the inverter that fits with 12 V battery in our design which is a standard voltage level available in the market, we need to incorporate the battery of 12 V and 100 Ah in parallel.

Rating of battery in Ah= 100

Rating of battery in Voltage= 12 V

Number of batteries required= 7

Price of each battery for 100 Ah, 12 V= NRs 17,000 *(Source: Kathmandu District Rate)*

Since district rate price is exclusive of installation cost, transportation cost and VAT, we should include the additional cost. We have addition of 13% VAT, 5% transportation cost and 5% installation cost. *(Source: Kathmandu District Rate)*

Total cost of battery sized 100 Ah, 12 V with installation= NRs 21,180

Cost of 2 kVA grid interactive inverter= NRs 48,600

Cost of inverter after VAT, transportation and installation cost= NRs 60,550

Table 4.3. 6 Costing for battery based system

S.N.	Items	Rating	Rate(NRs)	Quantity	Total cost(NRs)
1.	Battery (solar tubular)	100 Ah	21,180	7	148,260
2.	Inverter	2000 VA	60,550	1	60,550
	Total				208,810

Hence, NRs 208,810 is required costing for the instalment of battery based system in the Pinthali microhydro plant to fulfil the deficit power during peak hour.

The addition of battery bank in the microhydro plant doesn’t add up any additional income in the microhydro plant but addition of the system would add up the capacity of the plant in peak hours. The battery bank is able to supply up to 3 kWh of energy per day which could be monetized according to the electricity standard rates for the purchase of power from power producer. Nepal Electricity Authority (NEA) which is solely responsible for the transmission and distribution of electrical power in the country has standard rates for the generated power.

Table 4.3. 7 Cost of electricity generated by battery

S.N.	Season	Rate (NRS/kWh)	kWh/Day	Annual cost of energy(NRS)
1.	Wet (Baishakh- Mangsir)	4.8	3	3,456
2.	Dry (Poush- Chaitra)	8.4	3	3,024
	Total			6,480

So, total energy costing NRs 6,480 is supplied by battery bank in one year. Cost of electricity generated is NRs 4.8 in wet month and NRs 8.4 in dry month.

(Source: Nepal Electricity Authority).

For financial analysis of the system only NPV could be calculated. Discounted payback period couldn't be calculated as return is very small as compared to the investment. Discount rate is considered 10% for our financial analysis. Discounted payback is obtained in infinity time as high initial investment couldn't be compensated by small revenue from the investment.

Life of the battery is generally considered 5 years for solar tubular battery, so we can calculate the net present value of the project after 5 years.

Table 4.3. 8 NPV of the battery based design

Year	Investment (NRs)	Annual Return (NRs)	NPV of Return (NRs)	NPV (NRs)
0	-208810	0	0.0	-208810
1		6480	5890.9	-202919.1
2		6480	5355.4	-197563.7
3		6480	4868.5	-192695.2
4		6480	4425.9	-188269.3
5		6480	4023.6	-184245.7

Here, the NPV value is NRs -184245.7, which is for the project life cycle of five years. When NPV value is negative, we reject the project from the financial aspects.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In existing microhydro plant, we added the battery system using Matlab and Simulink software and was found technically sound. We analyzed the successful power flow from the study conducted. Also the use of battery based system improves the load factor of the plant. The productivity of power was improved and this will certainly support on sustainability, reliability and efficiency of Microhydro plants. Following conclusion can be drawn from the study;

- Microhydro power produces the constant power as it is equipped with synchronous generator. The power demand by the load varies as consumption pattern of the consumer differs from each other and load also varies with respect to time. During off peak time power is dumped in the ELC as generated power is not fully consumed by load but on the other hand there is power deficit in the peak time. So power can be stored in the battery during off peak hours and can be delivered to load on peak hours.

- Case study of the consumer of the Pinthali village was conducted where 105 house hold out of 142 households were surveyed. Total load and load consumption time and pattern was questioned to a consumer and load curve was calculated from the surveyed data. Some conclusion was drawn from those data like, load factor was found to be 0.3326, average load was found as 3.245 kW and peak load was calculated to be 9.757 kW. Peak load was noticed on 7pm on the evening.

- Cost analysis done for the instalment of battery based microhydro system for the supplement of additional power during peak hour showed the cost of investment of NRs 208,810. Peak load exceeds the generated load by 1.475 kW and system was designed to supply the deficit power which include total cost of battery and inverter inclusive of installation cost, VAT and transportation cost. Financial analysis of the system was not found feasible. Discounted payback period of the project was not found as financial benefit earned from the project is very low as compared to the initial investment. Annual cost of electricity generated was only NRs 6,480. In addition, net present value for the project is negative which implies that project is financially infeasible. Installation of microhydro is done for the improving the socio-economic aspect of the local people. It is not used for purpose earning the profit in our context.

Installation of the battery based system definitely provide the quality power to the consumer by meeting the demand in the peak hours.

5.2 Recommendations

Implementation of battery based system doesn't add up significant revenue from the plant looking from the financial aspects. Several studies conducted from socio-economic aspect has proved that microhydro has significant role in uplifting the lifestyle of the people. Pinthali is one of example to adopt dyadic interface between microhydro and irrigation which in overall has provided significant benefits to the people. There is no doubt that we can obtain quality power after implementation of battery based system. This also assist in increasing the capacity of plant in peak hours and adding load to the system in off peak hours.

Addition of battery based system in present context seems infeasible from the financial aspect. Decrease in discount rate with improved life of battery and reduced cost in near future may make system feasible from those aspects also. In addition, other studies can also be done with battery alternatives. Power added by battery can be monetized from consumer end as to increase existing tariff rate which would increase the revenue of the plant in overall. This would make system to achieve its payback in required time.

Study of microhydro power whose capacity is comparatively big than Pinthali microhydro power can be made. Also non-profit sectors whose motive is to uplift the socio-economic status and to improve quality of living of the rural community despite of seeking the financial benefits of the plant can get involved in the project.

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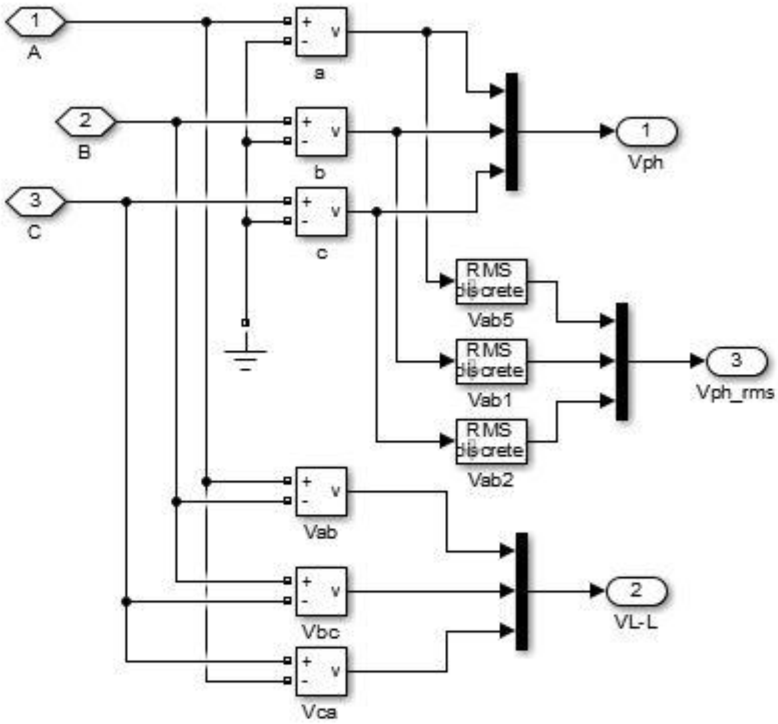
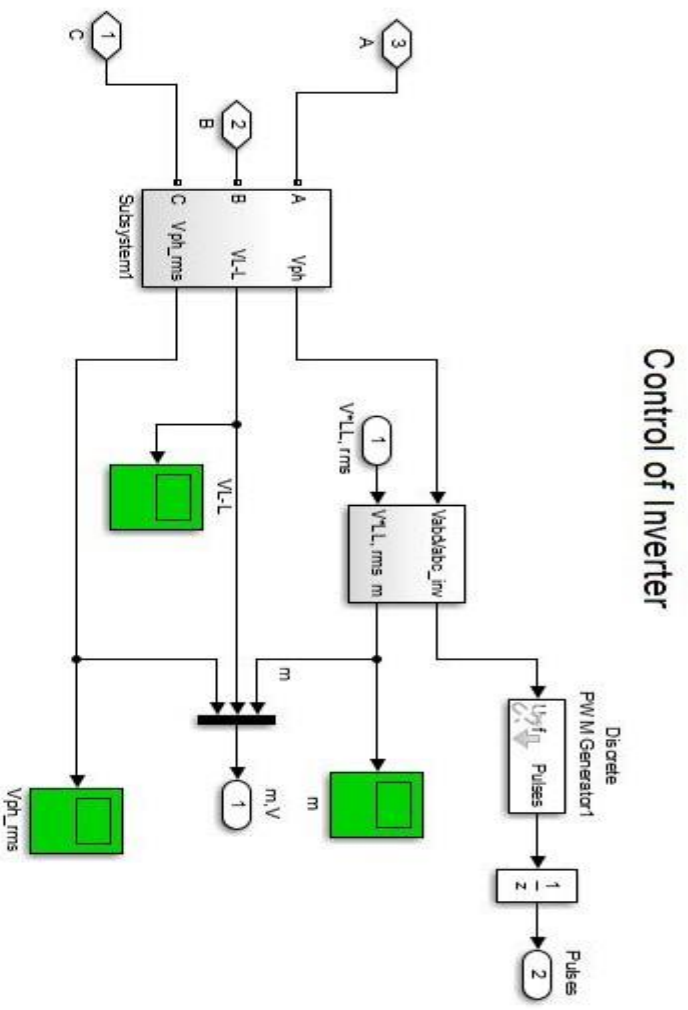
APPENDICES

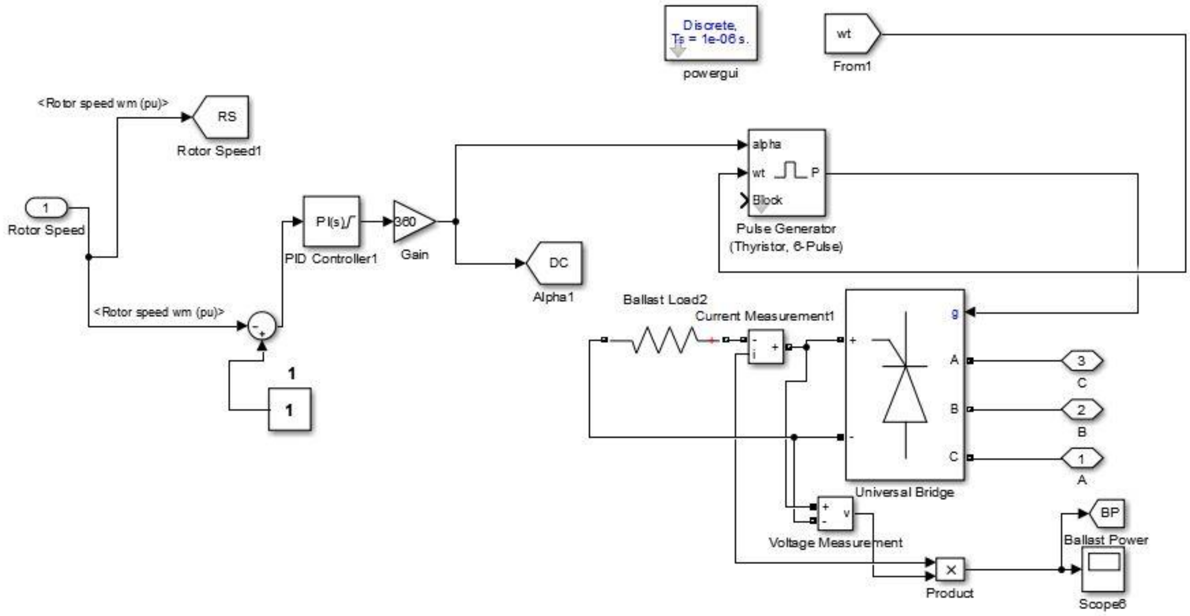
Appendix A: Subsystem of inverter



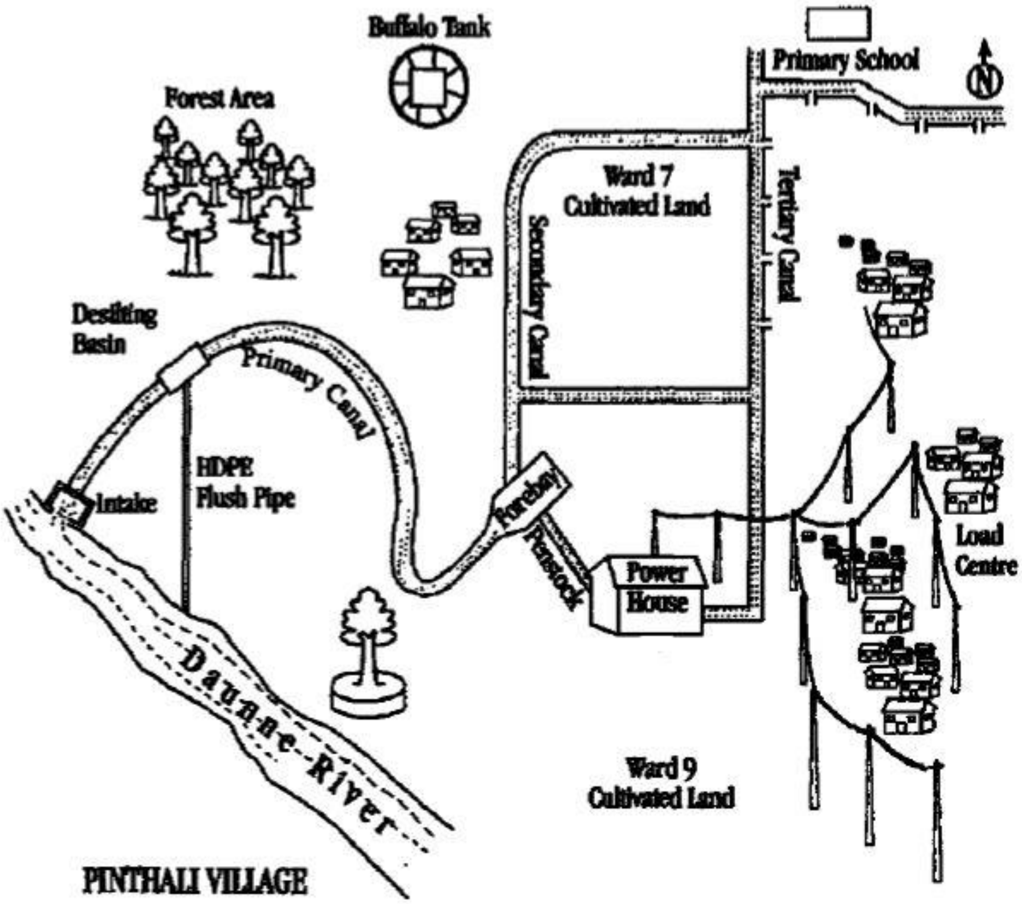
Appendix B: Control of inverter



Appendix C: Electronic Load Controller model



Appendix D: Layout of Pinthali village



Appendix E: Kathmandu district rate

काठमाण्डु जिल्लाको आ. व. २०७७/७८ को दररेट

Solar Power

सि.नं	निर्माण सामाग्रीहरुको विवरण	एकाई	मु.अ.क. बाहेकको दररेट		
			आ.व. २०७५/७६	आ.व. २०७६/७७	आ.व. २०७७/७८
१	Solar PV Module	प्रति वाट	९०.००	९०.००	९०.००
२	Solar Tubular Battery (200Ah@c20,12v)	गोटा	३२१००.००	३२१००.००	३२१००.००
३	Solar Tubular Battery (150 Ah@c20,12v)	गोटा	२४५००.००	२४५००.००	२४५००.००
४	Solar Tubular Battery (100 Ah@c20,12v)	गोटा	१७०००.००	१७०००.००	१७०००.००
५	Solar Tubular Battery (80 Ah@c20,12v)	गोटा	१६९००.००	१६९००.००	१६९००.००
६	Solar Tubular Battery (60 Ah@c20,12v)	गोटा	१२२००.००	१२२००.००	१२२००.००
७	Solar Tubular Battery (40 Ah@c20,12v)	गोटा	८०००.००	८०००.००	८०००.००
८	Solar Gel Battery (200 Ah@c20,12v)	गोटा	६६७००.००	६६७००.००	६६७००.००
९	Solar Gel Battery (150 Ah@c20,12v)	गोटा	५०२००.००	५०२००.००	५०२००.००
१०	Solar Gel Battery (100 Ah@c20,12v)	गोटा	३६१००.००	३६१००.००	३६१००.००
११	Solar Gel Battery (80 Ah@c20,12v)	गोटा	३११००.००	३११००.००	३११००.००
१२	Solar Gel Battery (75 Ah@c20,12v)	गोटा	२७६००.००	२७६००.००	२७६००.००
१३	Solar Gel Battery (40 Ah@c20,12v)	गोटा	१५८००.००	१५८००.००	१५८००.००
१४	Solar Lithinium Ion Battery (100AH@c10,12V)	गोटा	३६७००.००	३६७००.००	३६७००.००
१५	Solar Lithinium Ion Battery (80AH@c10,12V)	गोटा	३२६००.००	३२६००.००	३२६००.००
१६	Solar Lithinium Ion Battery (50AH@c10,12V)	गोटा	१८७००.००	१८७००.००	१८७००.००
१७	Charge controller (60A/24-48V)	गोटा	३२५००.००	३२५००.००	३२५००.००
१८	Charge controller 45A/12-24-48 V	गोटा	२३९००.००	२३९००.००	२३९००.००
१९	Charge controller 30A/12-24-48 V	गोटा	१९८००.००	१९८००.००	१९८००.००
२०	Charge controller 25A/12-24-48 V	गोटा	१४८००.००	१४८००.००	१४८००.००
२१	Charge controller 20a/12-24 V	गोटा	६०००.००	६०००.००	६०००.००
२२	Charge controller 15a/12-24 V	गोटा	४९००.००	४९००.००	४९००.००
२३	Charge controller 10a/12-24 V	गोटा	२७००.००	२७००.००	२७००.००
२४	Charge controller 5a/12-24 V	गोटा	१६००.००	१६००.००	१६००.००
२५	Solar dusk to down controller 20A/12Vwith driver curcit	गोटा	४५००.००	४५००.००	४५००.००
२६	Solar street light 40W- 12V DC with autodimming system	गोटा	३१६००.००	१३६००.००	१३६००.००
२७	Solar street light 30W- 12V DC with autodimming system	गोटा	२४३००.००	२४३००.००	२४३००.००
२८	Solar street light 20W- 12V DC with autodimming system	गोटा	१५३००.००	१५३००.००	१५३००.००
२९	Solar street light 100W	गोटा	४२३००.००	४२३००.००	४२३००.००
३०	Solar street light 80W	गोटा	३५८००.००	३५८००.००	३५८००.००
३१	Solar street light 60W	गोटा	२६८००.००	२६८००.००	२६८००.००
३२	Solar street light 40W	गोटा	१५१००.००	१५१००.००	१५१००.००
३३	Solar street light 30W	गोटा	१२०००.००	१२०००.००	१२०००.००
३४	Solar street light 20W	गोटा	८६००.००	८६००.००	८६००.००
३५	Solar street light 12W	गोटा	५६००.००	५६००.००	५६००.००
३६	Ms pole 6 m high with rustproof enamel paint dimension 4" for buttom 3 m 3" for top 3 m	गोटा	१७४००.००	१७४००.००	१७४००.००
३७	Ms pole 7 m high with rustproof enamel paint dimension 4" for buttom 4m 6" for top 3 m	गोटा	१९२००.००	१९२००.००	१९२००.००
३८	Ms pole 8 m high with rustproof enamel paint dimension 4" for buttom 5m 6" for top 3 m	गोटा	२१४००.००	२१४००.००	२१४००.००
३९	Ms pole 9 m high with rustproof enamel paint dimension 4" for buttom 6 m 6" for top 3 m	गोटा	२१७००.००	२१७००.००	२१७००.००
४०	7 m Hot Deep Galvanized Pole with Diameter of Pole section 4" for bottom 4.5 m and 3" for top 2.5 m	गोटा	२१४००.००	२१४००.००	२१४००.००
४१	8 m Hot Deep Galvanized Pole with Diameter of Pole section 5" for bottom 4.5 m, 4" for Middle 1.75 m and and 3" for top 1.75 m	गोटा	२४७००.००	२४७००.००	२४७००.००

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सि.नं	निर्माण सामाग्रीहरुको विवरण	एकाइ	मु.अ.क. बाहेकको दररेट		
			आ.व. २०७५/७६	आ.व. २०७६/७७	आ.व. २०७७/७८
४२	9 m Hot Deep Galvanized Pole with Diameter of Pole section 5" for bottom 5 m, 4" for Middle 2m and and 3" for top 2m	गोटा	२६९००.००	२६९००.००	२६९००.००
४३	10 m Hot Deep Galvanized Pole with Diameter of Pole section 5" for bottom 5.2 m, 4" for Middle 2.4m and and 3" for top 2.4m	गोटा	२९१००.००	२९१००.००	२९१००.००
४४	Pure sine wave inverter 250 VA /12 V	गोटा	७२००.००	७२००.००	७२००.००
४५	Pure sine wave inverter 400 VA /12 V	गोटा	१३५००.००	१३५००.००	१३५००.००
४६	Pure sine wave inverter 850 VA /12 V	गोटा	१६५००.००	१६५००.००	१६५००.००
४७	Pure sine wave inverter 1000 VA /12 V	गोटा	२२९००.००	२२९००.००	२२९००.००
४८	pure sine wave inverter 1400 VA	गोटा	२४३००.००	२४३००.००	२४३००.००
४९	Pure sine wave Solar Hybrid Inverter 850VA with inbuilt charge controller	गोटा	२०२००.००	२०२००.००	२०२००.००
५०	Pure sine wave Solar Hybrid Inverter 1000VA with inbuilt charge controller	गोटा	२४२००.००	२४२००.००	२४२००.००
५१	Pure sine wave Solar Hybrid Inverter 3KVA with 50A inbuilt charge controller	गोटा	७१५००.००	७१५००.००	७१५००.००
५२	Pure sine wave Solar Hybrid Inverter 5KVA with 50A inbuilt charge controller	गोटा	१४३०००.००	१४३०००.००	१४३०००.००
५३	Ms light Arms	सेट	२२००.००	२२००.००	२२००.००
५४	SPV mountaining frame	सेट	५८००.००	५८००.००	५८००.००
५५	Battery box	सेट	४५००.००	४५००.००	४५००.००
५६	Battery stand	सेट	४५००.००	४५००.००	४५००.००

Appendix F: Load curve calculation coding

```
clc;
clear all;
A=5; H=24;
N=105;
for i=1:105
Users(:,:,i)=xlsread('amit2.xlsx',i);
end
C=Users(2:end-1,1:H,1:N);
C(isnan(C))=0;
D=Users(2:end-1,25,1:N);
D(isnan(D))=0;
for j=1:105
for i=1:5
X_all(i,:,j)=C(i,1:24,j)*D(i,1,j);
end
end
Z=sum(sum(X_all,1),3);


figure(1)
plot(Z);
hold on

    xlabel('Time(Hours)');
    ylabel('Demand-Watt');

    set(gca,'FontSize',18);
    xlim([0 25]);
    set(gca,'XTick',[1 3 7 11 15 19 24 ]);

    saveas(gcf,'Existing Load Curve.jpg');
    grid on;
```

Appendix G: Nepal Electricity Authority power purchase rate

NEA BOARD DECISIONS ON THE POWER PURCHASE RATES AND ASSOCIATED RULES FOR PPA OF ROR/PROR/STORAGE PROJECTS EFFECTIVE FROM 2074/01/14 (April 27, 2017)

1. Rated capacity of hydropower projects to be eligible for local currency PPA = any capacity
2. Rated capacity of hydropower projects to be eligible for foreign currency PPA = above 100 MW
3. Maximum power purchase rate for energy = NEA's rate decided for ROR /PROR/Storage projects

   ROR (Posted rate with 3% simple escalations for 8 years for the capacity up to 100 MW and the base rate to be lowered for projects above 100 MW with ROE higher than 17 %)

Option	Season	Rate Rs/KWh (upto 100 MW project)	Min. Dry season Energy required
1 (Dry and wet season 6 months each)	Wet (Jestha 16 - Mangsir 15)	4.80	30 %
	Dry (Mangsir 16- Jestha 15)	8.40	
2 (Dry and wet season months 4 and 8 respectively)	Wet (Baisakh- Mangsir)	4.80	15 %
	Dry (Poush- Chaitra)	8.40	

PROR (3% simple escalations for 8 years and base rate to be lowered for projects of any rated capacity with ROE higher than 17 %)

Season	**Time of Day**	**Daily hours required to generate at rated capacity**	**Rate Rs./KWh**	**Min. Dry season Energy required**
Dry (Mangsir 16- Jestha 15)	Peak hours	1 hr to less than 2 hrs	8.50	30 %
		2 hrs to less than 3 hrs	8.80	
		3 hrs to less than 4 hrs	9.40	
		4 hrs to 6 hrs	10.55	
	Non-peak hours		8.40	
Wet (Jestha 16- Mangsir 15)	All hours		4.80	

STORAGE (3% simple escalations for 8 years and base rate to be lowered for projects of any rated capacity with ROE higher than 17 %)

Season	Rate Rs/KWh	Min. Dry season Energy required
Dry (Mangsir 16- Jestha 15)	12.40	35 %
Wet (Jestha 16- Mangsir 15)	7.10 (If wet season energy is more than 50%, this rate shall be decreased by the excess %)	

4. If dry season energy is less than 35% of annual energy, a storage project shall be considered as a PROR project for applying the power purchase rate.

5. Flat power purchase rate (example for less than 50% wet season energy : Dry season energy % *12.40 + Wet season energy % *7.10) shall be applicable for multipurpose storage projects.

6. The active storage volume of a storage project should not be less than the volume corresponding to the design discharge of 15 days and the dead storage volume should be designed not to be filled up by sediments for at least 50 years.

7. A PROR project must be capable of providing daily peaking power at rated capacity for minimum 1 hour to 6 hours at one time.

8. Despite any hours of daily peaking mentioned in PPA, power purchase rate for a PROR project in the dry season for the peaking energy shall be as per actual as approved once a year by the system operator after the project is commissioned.

9. If the energy supplied in dry season is found to be less than 30% after the ROR/PROR project comes into operation despite mentioning 30 % or more dry season energy in PPA, the annual energy supplied more than the estimated annual energy based on 30% energy in dry season shall be adjusted as a compensation in the monthly bill payment in the next year.

   Example: Suppose, annual contract energy (X) = 100 GWh

   Min. dry season energy required to be supplied = 0.3X

   Suppose, dry season energy supplied in a year (y) = 29 GWh

   Total estimated annual energy based on 30% dry season energy = y/0.3 =96.67 GWh

   Amount to be adjusted as a compensation =(Total energy supplied in a year – Total annual estimated energy based on 30% dry season energy)* Power purchase rate in the wet season of the relevant year

   However, if the developer has paid the penalty on account of not meeting the energy as per the monthly availability declaration in a fiscal year, the only one which is higher out of the above compensation amount or the penalty in a year on account of not meeting the availability declaration shall be applicable.

10. The new rates and the associated rules shall be applicable only to the projects to be concluded from Baisakh 14, 2074 onwards.

11. For foreign currency denominated PPA, NEA Board has approved the guidelines based on the above rates and associated terms and conditions.

Appendix H: Discounted Payback Calculation

Year	Investment(NRS)	Annual Return(NRS)	NPV of Return(NRS)	NPV(NRS)
1	-208810	6480	5890.909091	-214700.909
2		6480	5355.371901	-209345.537
3		6480	4868.51991	-204477.017
4		6480	4425.927191	-200051.09
5		6480	4023.570173	-196027.52
6		6480	3657.791067	-192369.729
7		6480	3325.264606	-189044.464
8		6480	3022.967824	-186021.496
9		6480	2748.152567	-183273.344
10		6480	2498.320516	-180775.023
11		6480	2271.200469	-178503.823
12		6480	2064.727699	-176439.095
13		6480	1877.025181	-174562.07
14		6480	1706.386528	-172855.683
15		6480	1551.26048	-171304.423
16		6480	1410.2368	-169894.186
17		6480	1282.033454	-168612.153
18		6480	1165.484959	-167446.668
19		6480	1059.531781	-166387.136
20		6480	963.2107096	-165423.925
21		6480	875.6460996	-164548.279
22		6480	796.0419088	-163752.237
23		6480	723.6744625	-163028.563
24		6480	657.885875	-162370.677
25		6480	598.0780682	-161772.599
26		6480	543.7073347	-161228.892
27		6480	494.2793952	-160734.612
28		6480	449.3449047	-160285.267
29		6480	408.4953679	-159876.772

30		6480	371.3594254	-159505.412
31		6480	337.5994776	-159167.813
32		6480	306.908616	-158860.904
33		6480	279.0078328	-158581.897
34		6480	253.6434843	-158328.253
35		6480	230.5849857	-158097.668
36		6480	209.6227143	-157888.045
37		6480	190.5661039	-157697.479
38		6480	173.2419127	-157524.237
39		6480	157.4926479	-157366.745
40		6480	143.1751344	-157223.57
41		6480	130.1592131	-157093.41
42		6480	118.3265574	-156975.084
43		6480	107.5695976	-156867.514
44		6480	97.79054329	-156769.724
45		6480	88.9004939	-156680.823

Appendix I: Photograph from Site

Penstock Pipe

Group discussion

Turbine generater set

Pinthali village

Site picture

Appendix J: Load survey Sample

Load survey of microhydro benefitted household of Pinthali village

Name of consumer: ……………………………………………………………………………. Address: ……………………………………………

Electricity bill per month: ………………….

S.N	Application used	Name of Appliance	Number	Wattage	Operating Time(Hours)				Remarks
					Morning	Day	Evening	Night	
1	Lights	LED							
		CFL							
		Incandescent							
2	Refrigerator								
3	Television								
4	Phone Charging								
5	Laptop Charging								
6	Light Charging								

Appendix K: Load curve calculation graph

Appliances/ time	0 AM-1 AM	1 AM-2 AM	2 AM-3 AM	3 AM-4 AM	4 AM-5 AM	5 AM - 6 AM	6 AM-7 AM	7 AM-8 AM	8 AM-9 AM	9 AM-10 AM	10 AM-11 AM	11AM -12 PM	12 PM-13 PM	13 PM-14 PM	14 PM-15 PM	15 PM-16 PM	16 PM-17 PM	17 PM-18 PM	18 PM-19 PM	19 PM-20 PM	20 PM-21 PM	21 PM-22 PM	22 PM-23 PM	23 PM-00AM	Wattage
Light																									
Refrigerator																									
TV																									
Phone Charging																									
Light Charging																									

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Appendix L: Matlab model of battery based system