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LIST OF ABBREVIATIONS

AEPC	: Alternative Energy Promotion Center
NRREP	: National Rural and Renewable Energy Program
CESC	: Clean Energy Support Center
VDC	: Village Development Committee
ROR	: Run off River
MOE	: Ministry of Energy
DOED	: Department of Electricity Development
NEA	: Nepal Electrical Authority
INPS	: Integrated Nepal Power System
RET	: Renewable Energy Technology
RERL	: Renewable Energy for Rural Livelihood Programme
IOE	: Institute of Engineering
REDP	: Rural Energy Development Programme
DEES	: District Energy and Environment Section
DDC	: District Development Committee
DEF	: District Energy Fund
DEEMC	: District Energy and Environment Management Committee
RESC	: Renewable Energy Service Center
K2U2MGWC	: Kalung Khola Urja Upatyaka Mini Grid Working Committee
PPA	: Power Purchase Agreement
MHP	: Micro Hydro Plant
UNDP	: United Nationals Development Program
ELC	: Electronic Load Controller
IPP	: Independent Power Producer
ONAN	: Oil Natural Air Natural
AVR	: Automatic Voltage Regulator
MCB	: Miniature Circuit Breaker
MCCB	: Moulded Case Circuit Breaker
LA	: Lightning Arrester
CT	: Current Transformer
NO	: Normally Open
NC	: Normally Close
DC	: Direct Current
AC	: Alternative Current
AS	: Automatic Synchronizer
MHFG	: Micro Hydro Functional Group
LV	: Low Voltage
HV	: High Voltage
LT	: Low Tension
HT	: High Tension
kW	: Kilo Watt
kWHr	: Kilo Watt Hour
PF	: Power Factor
HP	: Horse Power

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ACKNOWLEDGEMENTS

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We can’t remain without thanking to all the working committee members of Mini Grid, field supporting staffs and Micro Hydro functional groups. We would like to acknowledge the operators of MHPs in all the sites.

Last but not the least the special thanks goes to the people of Sarkuwa, Dameak, Paiyauthanthap, Rangkhani VDC for their cooperation during the data collection and stay of our team over there.

The Study Team
ECoCoDE Nepal (P.) Ltd.

EXECUTIVE SUMMARY

With the main focus "To improve the living standard of rural women and men, increase employment of women and men as well as productivity, reduce dependency on traditional energy and attain sustainable development through integrating the alternative energy with the socio-economic activities of women and men in rural communities", AEPC executing five years period National Rural and Renewable Energy Programme (NRREP) from mid-July 2012 to mid-July 2017. Community Electrification Sub-component of NRREP is one of the major components responsible for coordination and implementation of community electrification activities throughout the country in demand driven and public-partnership approach. One of the activities to meet the above defined output was to "Put in place quality and technical standards, including grid connection specification and standard power purchase agreements". One of the sub activities to contribute to above activity was to conduct "Techno- socio-economic study in Baglung Mini Grid .The main rational behind the concept was to aggregate the power output of small sized MHPs so that sizeable amount of power may be available in the locally formed Mini Grid. With aggregated power there would have been better possibility of small and cottage industries and other end uses which will contribute in enhancing the overall plant factor of all the connected plants. This will promote more and more economic activities in the area with better income generation for the villagers. Another important aspect of forming Baglung Mini Grid was to avoid the situation of local people abandoning micro hydro plants once NEA grid line approaches their villages. With cumulative capacity which was to be more than 100kW it was, there was strong possibility that NEA may agree to connect the so formed Mini Grid to its national grid which is not very far from the nearest plant. To address issues of isolated plant, REDP/UNDP/AEPC has started a pilot project to connect 6 MHPs total power capacity of 107 kW of Baglung district through 8 km long 11 kV transmission line forming Mini Grid which is now operated and managed by local community named Urja Upatyaka Mini Grid Co-Operative.

Being a new practice, there are several difficulties in Baglung Mini Grid such as Technical, Managerial, Economical and Social issues which must be solved for its long term sustainability. The outcome of this project is to dig out such difficulties along with Technical, Social, Economical benefits to communities so that it is become easier to replicate another Mini Grid project in future.

CHAPTER 1: INTRODUCTION

1.1 Background

Nepal is small country sandwiched in between India and China with total population of about 26.5 Million. Nepal is rich in hydropower with 83,000 MW theoretical and 42133 MW technically and financially viable potential. Average rainfall in the country is about 1500 mm per year out of which 80% falls in monsoon season (mid of June to early of September). Till now only 740 MW of power is generated along with 53.5 MW thermal plants which is less than 1% of total theoretical potential. INPS system is predominantly Run of River (ROR) type only with 92 MW of which are storage projects with system needing additional storage projects. In the fiscal year 2011/12 the peak demand of INPS was 1026 MW and actual supply was only 578 MW which includes 121 MW imported from India. In this fiscal year the total energy demand has been 5195 GWh out of which only 80.4% could be supplied. The peak demand growth is about 8.5% and energy growth is 10% in our country. The system loss in Nepal is as high as about 26%. In the last fiscal year only a total of 12MW was commissioned whereas the annual required additional power was about 100 MW. About 55% populations have access to electricity and per capita annual consumption of electricity is around 91 KWHr. Over the last 4 years there have been several electricity deficits, including painful load shedding. Ministry of Energy (MOE) and Department of Electricity Development (DOED) under MOE oversee the electricity development in Nepal. Nepal Electrical Authority (NEA) is fully owned by Government and is responsible for Generation, Transmission and Distribution of electrical power.

In addition to INPS there are several isolated micro hydro projects totaling about 23 MW along with 12MW solar energy and 20 kW wind power which contributes less than 10 % of total electrification. With the objective of developing and promoting renewable energy technologies which focus in rural areas of Nepal, AEPC under then Ministry of Environment Science and Technology was established in 1996. After establishment, AEPC has been implementing several renewable energy programs in Nepal. From July, 16, 2012 AEPC is executing a five year period National Rural and Renewable Energy Programme (NRREP) which has single programme modality. Over past four decades, around 2500 micro-hydro plants (ranging from 5kW to 100kW including Peltric Sets) have been installed in Nepal providing electricity to over 200,000 household in rural Nepal. Central or regional grid is supposed to provide long term reliable electricity facility. However, grid extension for rural electrification is often unfeasible and highly costly. Renewable Energy Technologies (RET's) such as micro hydro can be one of the effective solutions to provide lighting to the rural communities. To address the constraints of meeting the peak hour demand by isolated micro hydro and bringing the utilization factor and growing demand into consideration, formulation of mini-grid can be an appropriate option to connect these isolated micro hydro plants in a local grid. Alternative Energy Promotion Center (AEPC) is now testing these new approaches to rural electrification that connects two or more plants in a locally distributed system known as Mini Grid. Alternative Energy Promotion Center (AEPC) and Nepal Electricity Authority (NEA) are the two nodal agencies involved in off-grid and on-grid rural electrification in Nepal. In case of on-grid rural electrification, national grid is expanded to rural areas whereas several alternative energy technologies such as wind, micro hydropower, solar PV are installed in rural areas as isolated system in off-grid rural electrification. This report presents Techno–Socio and Economic study of Mini-Grid which is implemented in the Baglung District for the first time in Nepal as the pilot project, where six micro-hydropower plants previously running in isolation mode with sizes ranging from 9 kW to 26 kW are connected to a local grid, forming a Mini-Grid power system of 11 kV with total grid power of 107 kW in an islanding mode. This is the first pilot project initiated in Nepal by Renewable Energy for Rural Livelihood Programme (RERL) / AEPC.

1.2 Objective of the study

Assess the current technical-social-economic situation and management modality prevailing in the Mini Grid area and come up with recommendation for improving the existing situation regarding these aspects as well as to document the best practices which could be replicated in future Mini Grids.

1.3 Scope of the study

The scope of the work varies from technical aspect study to socio economic analysis of the project. As the installation of micro hydro in the rural area increases, people are not only benefited from the lighting purpose but the small scale enterprises will start to establish. Problem like unsafe drinking water will be eliminated by using electric power for water pumping .Today our country is facing daily load shedding of 12 to 14 hours, so the concept of mini grid formation by connecting a number of micro hydro plant in vicinity will gear up in near future in rest 45 percent land of Nepal which is yet to be electrified by national grid line. With the connection of Mini Grid to national grid and making contribution of micro hydro in the national interest of minimizing load shedding will increase day by day and hopefully some work will be performed in policy formulation. With this broad scope of this mini grid project, the following scope of study will be covered in this task.

- ✓ Technical evaluation of various equipments used in Mini Grid system.
- ✓ Evaluation of problem related to mini grid operation.
- ✓ Management model of mini grid operation.
- ✓ Plant factor calculation of micro hydro connected to mini grid.
- ✓ Socio economic impact of mini grid.
- ✓ Problems associated with mini grid construction.
- ✓ Conclusion and recommendation of the task.

1.4 Methodology

In order to fulfill the objective of the ToR, our team performed various works in sequential manner. Following are the major step to complete the work.

I. Desk study:

Various information of Baglung Mini grid regarding to technical, managerial, social and economical aspects were collected and studied, questionnaires for communities, Functional

Group, plant operator, staffs of Co-Operative were made and completely prepared for field visit.

II. Field visit:

During this stage study team made the field visit of Urja Upatyaka Mini Grid site. Lots of technical test and experiments were made; individual households survey was done, Interaction with management committee of Co-Operative, Micro Hydro functional groups, plant operators, staffs of Co-Operatives was performed and various required data were collected. During this stage detail study in following topics was made.

- ✓ Technical study:
- ✓ Management study:
- ✓ Socio-Economic study.

III. Office work:

Data collected during field visit were analyzed, various group discussions were made among team members and other experts in related fields, drawings were prepared and final report was made.

1.5 Reporting

I. Inception Report

At the beginning, within one week of after the signing of the contract agreement, 3 copies hard copies plus one soft copy of draft inception report was prepared and were submitted to the AEPC/NRREP for comments and suggestions.

I. Draft Final Report

After completing various studies, a draft report was prepared and three hard copies plus one soft copy of such report was submitted to AEPC/NRREP for comments and suggestions.

II. Final Report

After having subsequent comments and feedback from the various experts, a final report is prepared incorporating all the comments and feedback in the draft final report. The drawings, calculations or designs were changed accordingly. Only then a final report was prepared and submitted to the client, within 1 week of receipt of comments on the draft final report. Final report consists of three copies in hard plus one soft copy. The final report includes the original photographs of the project site. The team leader and other professionals of the team will visit the client to explain or make clear some points, calculations, drawings as require.

1.6 Chapter outline

The final report presents the outcomes of study in the following manner.

CHAPTER I: INTRODUCTION

This chapter provides an introduction and presentation of the final report.

CHAPTER II: MINI GRID

It introduces the concept, origin and history of Baglung Mini Grid. It also presents fact/data sheets/salient features of all generating stations within Mini Grid. Equipment specification, single line diagram and modes of operations are also the contents of this chapter.

CHAPTER III: TECHNICAL STUDY

Describes the technical system adopted in Baglung Mini Grid. It also includes technical impact and issues of the existing systems.

CHAPTER IV: MANAGEMENT STUDY

Outline the current management modality of Mini Grid. Duties, responsibilities of both business groups, method of Grid operation, and difficulties of current management system are another part of this chapter.

CHAPTER V: SOCIO-ECONOMIC STUDY

This chapter describes the socio-economical behavior of Mini Grid and its sub-components. Demand side aspects, Energy consumption, Generation scenario of Mini Grid along with financial and economic impacts are presented within this chapter.

CHAPTER VI: CONCLUSIONS AND RECOMMANDATIONS

This chapter presents the outcomes and recommendation of the study.

ANNEXES

It presents various drawings, diagrams, photo gallery etc. as required.

CHAPTER 2: MINIGRID

2.1 Concept of Origin of Mini Grid

After being feeling the need of developing modality for technical, financial and managerial aspects to connect Micro Hydro with National Grid, first to stop MHPs being defunct due to availability of grid electricity and next to generate additional revenue to community by selling electricity generated from MH during excess generation period and purchase electricity from grid during deficit period thus balancing the electricity demand and supply making long term sustainability of MHPs, this study was invisaged. To avoid unpredictable future health of MHPs AEPC/REDP had initiated for the feasibility assessment of connecting MH with national grind. In 2001, in order to testify the feasibility connecting MH with national grid AEPC/REDP had supported Institute of Engineering (IOE), Electrical department to conduct R & D that had successfully connected its MH used for teaching purpose built in the lab with the national grid. According to this report MH having capacity greater than 10 kW are feasible, technically and economically for the interconnection with grid. IOE had performed detailed feasibility study in those issues and the findings were validated by experimental work. After getting successful result from grid connection, interconnection of two or more similar MHs situated in close vicinity came forward. In general isolated MH has lower plant factor of around 25 %, because of lighting predominantly is the main requirement of rural people. Other shortcoming of isolated MHs are: limited Capacity of Generation to meet the future load growth, less reliability to supply electricity during regular maintenance, low quality electricity, difficulty in providing round the clock supply for plants that share water for other important purposes like irrigation, drinking water etc. Although the connection of multiple end uses seem to be possible and increase the utilization factor, it is somehow difficult to achieve the target due to constraints of a single generating unit. With the objective of addressing such shortfall of isolated MHs, in 2005, AEPC/REDP conceived an innovative idea of piloting Mini Grid by synchronizing a number of similar nearby MHPs, for which a feasibility of grid connection of MHP was proposed. Accordingly, the MECC Consultancy (P) Ltd. was sub-contracted to conduct pre-feasibility study in three districts, Kavre, Sindhuplachowk and Baglung. Among the three potential sites, the site in Baglung was found the most appropriate. Consequently, REDP undertook the “Detailed Feasibility Study for the Mini Grid Project in “Urja Upatyaka of Baglung” in September 2007. According to the report total cost of Mini Grid is Rs. 15,000,000.00 (US$ 190,000) and payback period is 6.5 years. Net present worth at 4% discount rate of interest is Rs.5, 239,136.00 and Internal Rate of Return (IRR) of 8.76%. The targeted objectives of Baglung Mini Grid can be summarizes as: *[reference AEPC/RERL report]*

- **OPTIMIZATION OF ELECTRICITY GENERATION.**
  - ✓ Balancing the surplus electricity of one or more MHs with the deficit electricity of other one or more MHs.
  - ✓ Creating opportunity to establish bigger size end uses at a time requiring more electricity (up to 50 kW) than quantity generated from normal MH of 10 to 30 kW.

- ✓ Operating all plant at their full generation capacity round the clock without requiring of dumping of additional power into the ballast as in normal MH in order to keep frequency within acceptable range.
- ✓ Carrying out the vital maintenance activity in any or few plants with beneficiary households still getting electricity to meet their minimum households lighting requirement.

➢ **CONNECTION OF MINI-GRID WITH NATIONAL GRID.**

- ✓ Offering sizable capacity (Both load and Generation) to NEA for encouraging to connect the Mini-Grid with the national grid.

➢ **ACHIEVEMENT OF SYSTEM SUSTAINABILITY.**

- ✓ Increasing revenue for MHs from the increased uses/ sales of electricity.
- ✓ Shifting from power based tariff to energy based tariff system for disciplined use of electricity.
- ✓ Promoting better inter scheme co-ordination and sense of togetherness.
- ✓ Earning additional revenue from selling day time and night time excess electricity to national grid.
- ✓ Purching electricity from national grid in case of severe power shortages in the Mini Grid system especially in the dry month period.
- ✓ Requiring no closure of individual MH in case of national grid comes in the area in the immediate future.

2.2 Rural Electrification in Baglung District

Baglung, one of the districts of Dhaulagiri Zone, lies in the western region of Nepal. The district covers an area of 1,784 km², total households, 61,482 and has a population of 268,613. It has 59 Village Development Committees and one Municipality. It has many rivers and streams and so, many suspension bridges. Baglung is also known as the district of suspension bridges. The district has been declared as model district of decentralized rural energy system "URJA JILLA" by 12th District Council in 2004(24th Baisakh 2061). Baglung is also the zonal headquarters of Dhaulagiri Zone. The Major Institutions at the District Level are DDC: DEES, DEEC, DEEMC, DEF, SO and RESC. Total Achievement in the field of RETs & End can be summarizes as:

S.N.	Description	Quantity	Power/Size	Beneficiaries HHS	Remarks
1	Renewable Energy Technology				
1.1	Micro-Hydro(MHDS/MHVEP/MHP/MHS)	86	2,478 kW	23,485	Completed
1.2	Micro-Hydro (MHDS/MHVEP/MHP/MHS)	9	912 kW	6216	Under construction
1.3	Peltric Set	16	49kW	580	Completed
1.4	Solar Home System(SHS)	4324		4324	Completed
1.5	Improved Cooking Stove(ICS)	32242		32242	Completed
1.6	Metallic ICS	253		253	Completed
1.7	Institutional ICS	14		14	Completed
2	Electrification from NEA Grid			25558	
2	End use Promotion	377		23425	Completed

Table 1: Achievement in the field of RET in Baglung district

Figure shows the electrification scenario of Baglung District. 39 % of total populations are electrified through Micro and Pico Hydro. 42 % are electrified through NEA Grid whereas 19% of total populations are still un–electrified.

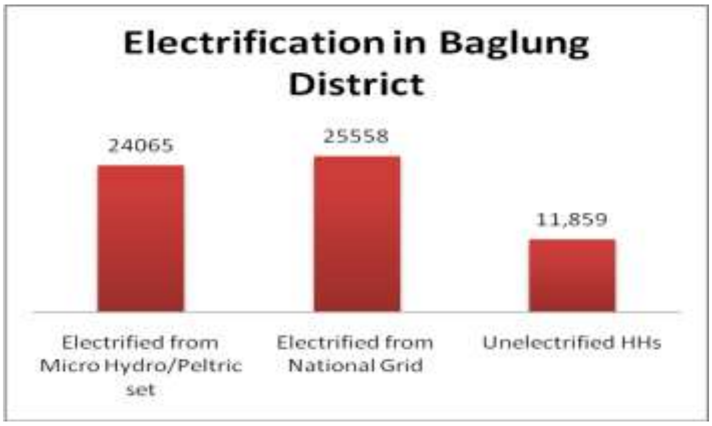


Figure 1: Rural Electrification in Baglung District [Source: DDC: DEES, Baglung]

2.3 Historical Background

For the proper construction, operation, management and utilization of Mini Grid, 17 members "Kalung Khola Urja Upatyaka Mini Grid Working Committee" (K2U2MGWC) was formed in 065/9/24. The working committee was formed by the representatives of every Micro Hydro that are connected to Mini Grid. The members of committee were selected from the method of election. An agreement had been made between working committee and DEES Baglung at 2066 after which the field level work was stated. After purching of locally available material from various suppliers, construction of 11 kV, 8 kM long transmission line had been completed within 2067. In the way of searching appropriate designer and installer to complete the Mini Grid in Baglung, in 2009, an Indian company Y-tek controls was selected to carry out the study, design and Installation of control panel for all MHs within Mini Grid area which had prior experiences in design, Installation and commissioning of Mini Grid projects. After some preparation, installation of control panel was started at the beginning of 2067 and despite of long unanticipated delays and uncertainty, the project was finally completed in the mid of 2068. 11 members, first Urja Upatyaka Mini Grid Co-operative management committee were formed after the registration of Mini Grid into Co-Operative at Division Co-Operative office Baglung. To operate Mini Grid in IPP modality, Mini Grid Co–Operative made Power purchase Agreements (PPA) with each MHP. After preparation for office management, nomination of staffs, completion of installation of single and three phase energy meters, Mini Grid was commercially operated with IPP modality from beginning of 2069. During this interval Mini Grid was formally inaugurated by Ministry of Environment, Science & Technology, Mr. Tatad in the year 2068. Now the Mini Grid Co-Operative is managing by second Management committee which was formed by the general house of Co-Operative members held in the year 2068. The project cost is around 200000 USD which was funded by the United Nations Development Programme (UNDP) and the project is implemented by the Rural Energy Development Programme (REDP) and community. The project cost expenditure of project can be summarized in the following chart. Major portion of the project cost includes the cost of electromechanical equipments. It includes cost of the control panel, 11 kV transmission line material, ACSR conductor, steel tubular poles, cost of Transformer, transportation and customs clearance. Only 14% of total cost was spent for Detail feasibility study, Human resource, capacity building, Institutional and operational cost. Technical and managerial support was provided by DEES Baglung with the establishment of office at Mini Grid site to emphasis for the better implementation of the project.

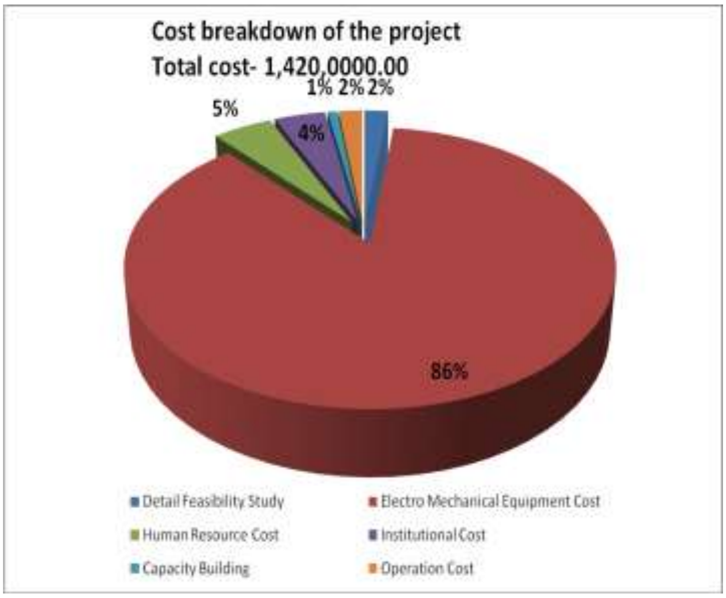


Table 2: Project cost break down [*Source: AEPC/RERL presentation*]

2.4 System Overview of Mini Grid

Urja Upatyaka Mini Grid was established in the eastern-southern belt of Baglung District, a 12-hours walk on step dirty road from Baglung, the district headquarter. It includes 6 Micro Hydro plants (i.e. Upper Kalung Khola (12 kW), Kalung Khola (22 kW), Urja Khola I (26 kW), Urja Khola II (9kW), Urjakhola IV (14 kW) & Theulakhola MHP (24 kW), originated from same source of stream) located in Rangkhani, Paiyauthanthap, Sarkuwa and Dameak VDV having total power output of the system is 107 kW, interconnected by means of 8 kM long , 11 kV transmission line with 1178 households (HHs) as beneficiary. All of these plants were built in between 2056 to 2068 and are supported REDP. Microprocessor based grid synchronizable Electronic load Controller (ELC) is the core technology used in mini grid project.

All of MHP and Mini Grid were operated in IPP model in which six MHP are treated as Independent Power producer (IPP). MHP sell the electricity to the Mini grid in fixed Power Purchase Agreement (PPA) rate and Grid sell the electricity to the consumer according to its tariff rate. Micro hydro functional group would be responsible for the generation of electricity and Mini Grid is responsible for the transmission and distribution of electricity. There are 2 operators in each MHP and manager as required. All the plants operate according to the operational schedule prepared by Mini Grid according to the loading status. Mini Grid is registered under the Co-Operative rules of Nepal government in Division Co-Operative office, Baglung. Mini Grid Co-operative management committee will be responsible for the operation of Mini Grid. It provides services to the consumer by establishment of office at center of grid. There are three staffs i.e. Technical manager, Accountant & Technician who performs the regular duty at office. Mini Grid is planned advance to the next phase of its development, in which it is planned to interconnect with the nearby 33kV national grid at Kushmi Sera bazaar also it is planned to develop an additional plant of capacity 40kW to provide service for remaining un-electrified households within the scope of it. Besides Mini Grid, a number of Pico hydro provides service for many villages of this area.

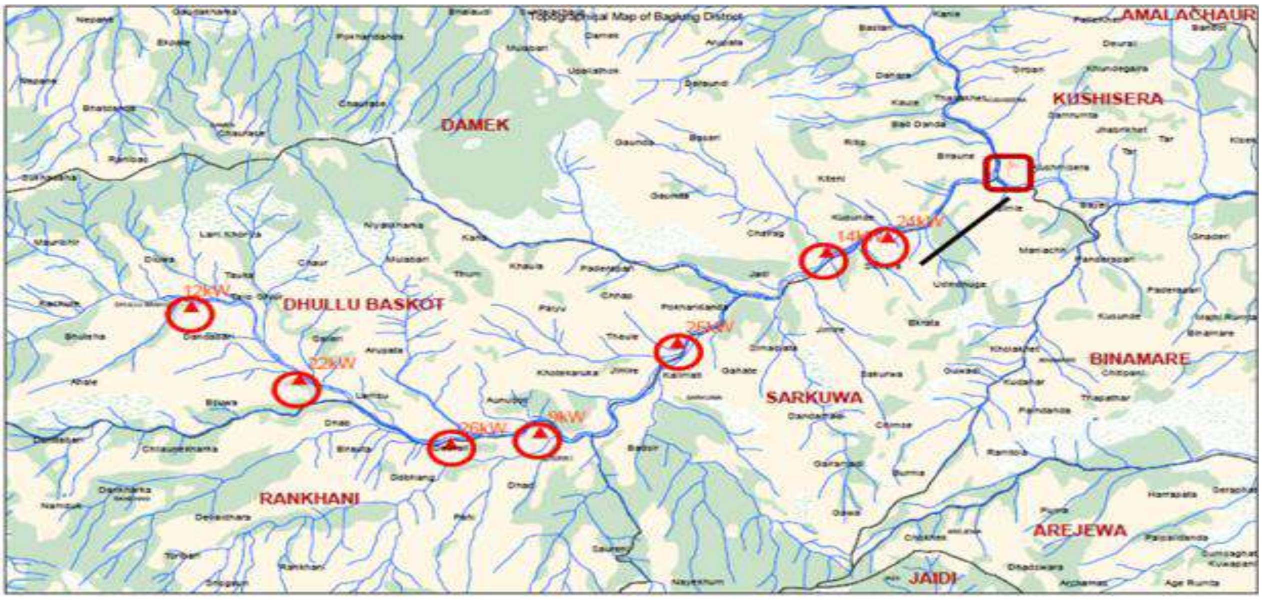


Figure 2: Topographical map of Urja Upatyaka Mini Grid [AEPC/RERL presentation]

Topographical map shows the location of the micro-hydropower plants. The circular block represents the individual micro hydro power stations whereas the rectangular block is the nearby33/11 kV central grid (NEA) substation. The substation is located at Kushmishera which is just around 0.6km from the mini-grid, near the Theula Khola MHS. It is 25 km south-east from Baglung Bazar, the district headquarter of Baglung District. Baglung Bazar lies approximately 275 km west of Kathmandu.

Each of the generating unit generates power at distribution voltage i.e. 400 V and power station constitutes of turbine generator sets, frequency controlling unit, voltage regulating unit, synchronizing unit, measurement unit, switchgear and protection unit, bus bar arrangement & 11 kV line connecting 0.4/11 kV transformer unit. Six channels Microcontroller based digital ELC, having droop facility along with ballast heater regulates the frequency of the system. Automatic voltage regulator with droop facility suitable for parallel operation having panel mounting voltage adjustment facility controls the system voltage. Synchronizing unit facilitates the interconnection of MHP with other generator which can be done in both automatic and manual mode. Separate measurement system was provided for generation and local load measurement. Protection system consists of Relaying system i.e. Voltage restrained OC relay, Over / Under frequency relay, Phase unbalance relay, O/U voltage relay, Reverse power relay, Over current relay & Master trip relay. These relay protect the generator during abnormal condition of operation. Panel mounting bus bar arrangement facilitates power importing and exporting modes of operation through transformer with Mini Grid.

2.5 Generating stations fact sheets/ Salient features

Table 3: Salient Features of Upper Kalung Khola Generating Station

Naming	Detailing	Description
Unit description	Location	Paiyauthanthap-9 ,Bijua
	Capacity(kW)	12
	Head(m)	57
	Discharge(lps)	45
	Cannel length(m)	345
	Type of Turbine	Cross flow
	Type of Drive	V- belt
	Generator Capacity	25kVA,
	generator Type	Brush less type, Synchronous, 3-phase
	Rated voltage & Current	415 V, 35 Amp
	Excitation V & I	25 V, 2.2 Amp
	Make	Kerala Electrical and Allied Engineering Co.Ltd.
	Ballast capacity	15 kW, 6 element
	Ballast Type	Water immersion
	Date of establishment	2062
	Earthing mechanism	Separate System and body earthing
Dedicated Feeder	Service area	Paiyauthanthap ward no. 1 & 9
	No of households	114
	Line Length	1200 m, 3-phase & 1000 m 1-phase
	Conductor	Weasel
	Steel pole	108 nos
	Lightning Arrester	12 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 kA, Distribution class
	Isolator	11 kV,100 Amp
	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	30 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	130 W
	Full load loss	800 W
	Tappings	±2*2.5% on HT, No Load tap changer
	Cooling	ONAN
	Type	Outdoor

	Earthing mechanism	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable16 mm sq, 4core, 3-ph 4 wire
	LT Conductor length	15 m
End use	Agro-processing Mills	2 (5 HP each)
	Poultry	2
	Computer / Print	2 / 1 nos
Social	Secondary School	1 nos
Organization	Lower primary	1 nos

Table 4: Salient features of Kalung Khola Generating Station

Naming	Particular	Description
Unit description	Location	Paiyauthanthap-4,Lamsu
	Capacity(kW)	22
	Head(m)	56
	Discharge(lps)	70
	Cannel length(m)	550
	Type of Turbine	Double jet peloton
	Type of Drive	Flat belt
	Generator Capacity	40kVA,
	generator Type	Brush type, Synchronous, 3-phase
	Rated voltage & Current	415 V, 55.6 Amp
	Excitation V & I	285 V, 4.3 Amp
	Make	Kirloskar Electrical and Allied Engineering Co. Ltd.
	Ballast capacity	30 kW, 6 element
	Ballast Type	Water immersion
	Date of establishment	2054
	Earthing mechanism	No system and body earthing
Dedicated Feeder	Service area	Paiyauthanthap ward no. 3, 4,5, & 6
	No of households	232
	Line Length	2000 m, 3-phase & 1000 m 1-phase
	Conductor	Squirrel
	Steel pole	101 nos
	wooden pole	30 nos
	Lightning Arrester	5 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 kA, Distribution class
	Isolator	11 kV,100 Amp

	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	50 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	170 W
	Full load loss	1050 W
	Tappings	±2*2.5% on HT, No Load tap changer
	Cooling	ONAN
	Type	Outdoor
	Earthing mechanics	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable35 mm sq, 3.5core, 3-ph 4 wire
	LT Conductor length	20 m
End use	Agro-processing Mills	4(7.5 HP each)
	Poultry	1
	Computer / Print	7 / 3 nos
	Saw mill	1,3-Phase & 1, 1-Phase
Social	Higher sec. School	1 nos
Organization	Lower Sec. School	1 nos
	Lower primary	1 nos
	Health post	1 nos
	Medical Clinic	1 nos

Table 5 : Salient features of Urja Khola I Generating Station

Naming	Particular	Description
Unit	Location	Rangkhani-1, Rumta
description	Capacity(kW)	26
	Head(m)	54
	Discharge(lps)	100
	Cannel length(m)	625
	Type of Turbine	Cross flow
	Type of Drive	Flat belt
	Generator Capacity	50kVA,
	generator Type	Brush less , Synchronous, 3-phase
	Rated voltage & Current	415 V, 70 Amp
	Excitation V & I	33 V, 2.9 Amp
	Make	Kerala Electrical and Allied Engineering Co.Ltd.
	Ballast capacity	30 kW, 6 element

	Ballast Type	Water immersion
	Date of establishment	2057
	Earthing mechanism	Separate system and body earthing (Plate)
Dedicated Feeder	Service area	Rangkhani ward no. 1, 4, & 5
	No of households	267
	Line Length	4500 m, 3-phase & 800 m 1-phase
	Conductor	1000m –Dog, 3500m- Weasel & 800m Squirrel
	Steel pole	115nos
	wooden pole	40nos
	Lightning Arrester	11 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 kA, Distribution class
	Isolator	11 kV,100 Amp
	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	50 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	170 W
	Full load loss	1050 W
	Tappings	±2*2.5% on HT, No Load tap changer
	Cooling	ONAN
	Type	Outdoor
	Earthing mechanism	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable 35 mm sq, 3.5core, 3-ph 4 wire
	LT Conductor length	18 m
End use	Agro-processing Mills	3(7.5 HP each)
	Poultry	7
	Computer / Print	27/ 5 nos
	Internet cyber	1 nos
	Electronic shop	2 nos
	Saw mill	1, 1-Phase
Social institution	Higher sec. School	1 nos
	Primary School	1 nos
	Lower primary School	1 nos
	Boarding School (Primary)	1 nos
	Health post	1 nos
	Vet nary shop	1 nos

	Medical Clinic	1 nos

Table 6: Salient features of Urja Khola II Generating Station

Naming	Particular	Description
Unit description	Location	Rangkhani-1, Chicapani
	Capacity(kW)	9
	Head(m)	17
	Discharge(lps)	110
	Cannel length(m)	195
	Type of Turbine	Cross flow
	Type of Drive	V- belt
	Generator Capacity	20kVA,
	generator Type	Brush less , Synchronous, 3-phase
	Rated voltage & Current	415 V, Amp
	Excitation V & I	26 V, 2.7 Amp
	Make	BHEL Electric Machine Ltd.
	Ballast capacity	15 kW, 6 element
	Ballast Type	Water immersion
	Date of establishment	2062
	Earthing mechanism	Separate system and body earthing (Plate)
Dedicated Feeder	Service area	Rangkhani Ward no 6 & 7
	No of households	165
	Line Length	1500 m, 3-phase & 500 m 1-phase
	Conductor	Weasel
	Steel pole	45 nos
	wooden pole	6 nos
	Lightning Arrester	3 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 kA, Distribution class
	Isolator	11 kV,100 Amp
	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	30 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	130 W
	Full load loss	800 W
	Tappings	±2*2.5% on HT, No Load tap changer

	Cooling	ONAN
	Type	Outdoor
	Earthing mechanism	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable16 mm sq, 4 core, 3-ph 4 wire
	LT Conductor length	20 m
End use	Agro-processing Mills	2 (5 HP each)
	Poultry	6
	Computer / Print	32 / 2 nos
	Photo Studio	1 nos
	Saw mill	1, 1-Phase
Social	Higher sec. School	1 nos
institution	Primary School	1 nos

Table 7: Salient features of Urja Khola IV Generating Station

Naming	Particular	Description
Unit	Location	Dameak, Zadi
description	Capacity(kW)	14
	Head(m)	16
	Discharge(lps)	164
	Cannel length(m)	250
	Type of Turbine	Cross flow
	Type of Drive	Flat belt
	Generator Capacity	30kVA,
	generator Type	Brush less , Synchronous, 3-phase
	Rated voltage & Current	415 V, 42 Amp
	Excitation V & I	26 V, 2.3 Amp
	Make	Kerala Electrical and Allied Engineering Co.Ltd.
	Ballast capacity	18 kW, 6 element
	Ballast Type	Water immersion
	Date of establishment	2068
	Earthing mechanism	Separate system and body earthing (Plate)
Dedicated	Service area	Sarkuwa ward no. 1, 2, 3 & 4
Feeder	No of households	124
	Line Length	3000 m, 3-phase & 1000 m 1-phase
	Conductor	Weasel
	Steel pole	70 nos
	Concrete pole	7 nos

	Lightning Arrester	8 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 KA, Distribution class
	Isolator	11 kV,100 Amp
	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	30 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	130 W
	Full load loss	800 W
	Tapings	±2*2.5% on HT, No Load tap changer
	Cooling	ONAN
	Type	Outdoor
	Earthing mechanics	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable16 mm sq, 4core, 3-ph 4 wire
	LT Conductor length	15 m
	HT Conductor	Weasel
	Ht Conductor length	50 m
End use	Agro-processing Mills	2(10 HP & 5 HP)
	Saw mill	1, 3-Phase & 1, 1-Phase
Social institution	Higher sec. School	No
	Lower Sec. School	No
	Lower primary	1 nos

Table 8: Salient Features of Theula Khola Generating Station

Naming	Particular	Description
Unit description	Location	Sarkuwa-9 Rumti
	Capacity(kW)	24
	Head(m)	50
	Discharge(lps)	150
	Cannel length(m)	550
	Type of Turbine	Cross flow
	Type of Drive	Flat belt
	Generator Capacity	50kVA,
	generator Type	Brush less , Synchronous, 3-phase
	Rated voltage & Current	415 V, 69.6 Amp
	Excitation V & I	63 V, 2 Amp

	Make	Kirloskar Electrical and Allied Engg. Co.Ltd.
	Ballast capacity	36 kW, 6 element
	Ballast Type	Water immersion
	Date of establishment	2056
	Earthing mechanism	Separate system and body earthing (Plate)
Dedicated	Service area	Sarkuwa Ward No 5, 6, 7, 8 & 9
Feeder	No of households	282
	Line Length	2500 m, 3-phase & 500 m 1-phase
	Conductor	Dog-500m, Rabbit-2500m
	Steel pole	120 nos
	wooden pole	15 nos
	Lightning Arrester	6 nos, (0.5 kV,1.5 kA),with plate earthing
Substation	Type	Double pole mounting, 4.5 m height
	Lightning Arrester	9 kV,10 kA, Distribution class
	Isolator	11 kV,100 Amp
	Drop out fuse	11 kV, Porcelain type, Taiwan make
Transformer	Rating	50 kVA
	Voltage	11/0.4 kV
	Vector Group	YNyn0
	No load loss	170 W
	Full load loss	1050 W
	Tapings	±2*2.5% on HT, No Load tap changer
	Cooling	ONAN
	Type	Outdoor
	Earthing mechanics	separate for HT & LA (Plate600*600*3mm, 8 SWG Copper wire), Common LT & Generator
	LT Conductor	Armored Cable35 mm sq, 3.5core, 3-ph 4 wire
	LT Conductor length	20 m
End use	Agro-processing Mills	4(2, 7.5 HP & 2, 10 HP)
	Poultry	7 nos
	Computer / Print	7 / 3 nos
	Saw mill	1,1-Phase
Social	Higher sec. School	1 nos
institution	Primary School	1 nos
	Health post	1 nos

2.6 Transmission Line

For the Power transfer and network formation, 8 Km long 3 phase 11KV single circuit transmission line has been constructed. 7 sets of isolators and D.O fuse for isolating the 11KV line from each MHP are used. The transmission line runs along Urja Khola River, which are tapped at seven different places to connect each MHP. Double pole mounted outdoor transformer along with Lighting Arrester, Isolating switch and drop out fuse are use in all tapped lines. The whole length of transmission line can be broken into three different sections by means of two sets of series drop out fuse, the purpose of which are to make the fault finding process easy, to minimizing the fault clearance time and to operate the Mini Grid in partial breakdown mode in case of longer duration problems. A numbers of Lighting Arresters are used to protect line and equipment from lighting over voltages. 11 kV Grid transmission line corridor of Mini Grid and connection scheme of each plant to Grid is shown in following single line diagram.

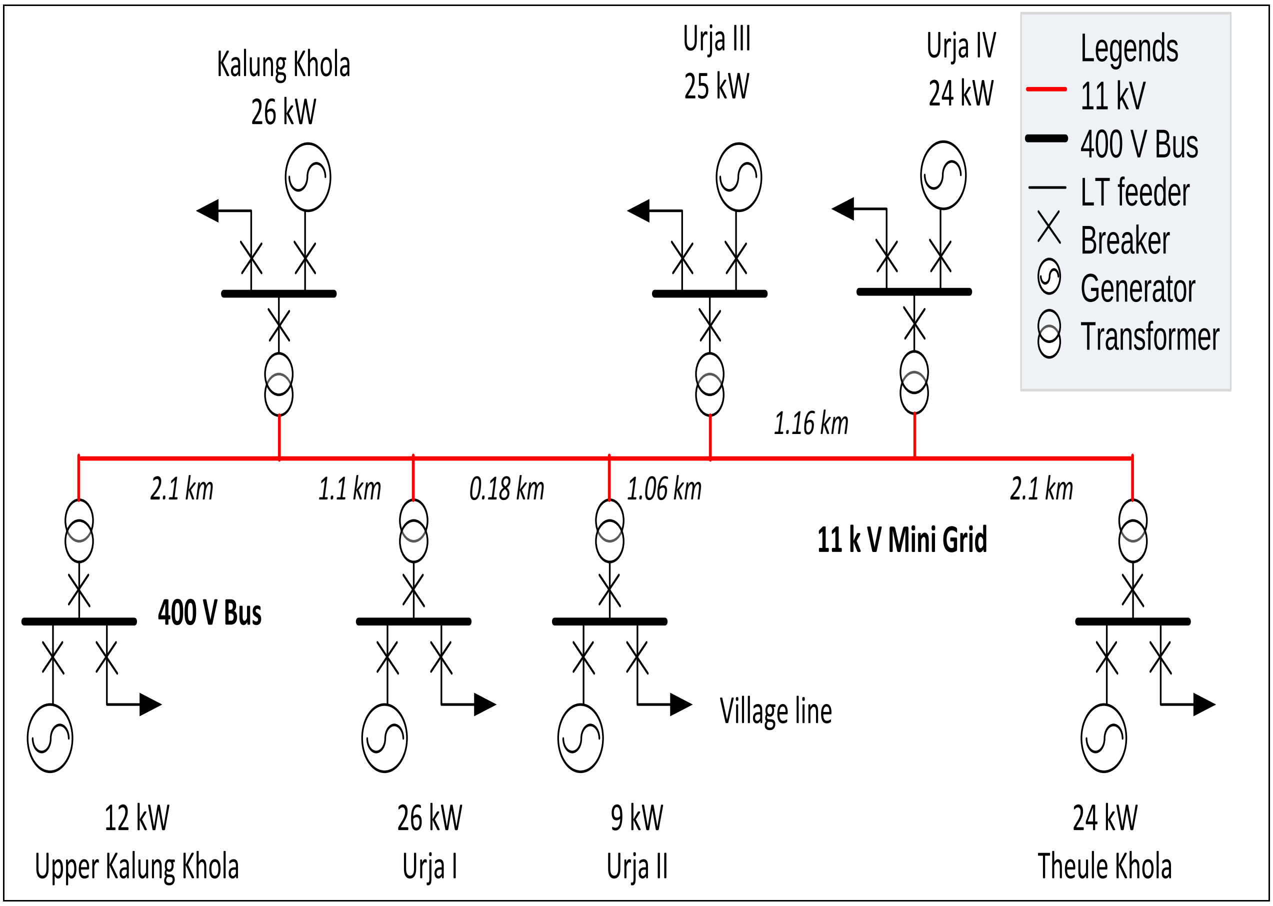


Figure 3: Profile of Mini Grid Transmission Line [*Source: RERL*]

Table 9: Salient features of Mini Grid Transmission Line

Naming	Particular	Description	Remarks
Line	Type	Weasel	
Conductor	Length	8 kM	Single length
	Configuration	Mix, Triangular & Horizontal	
	Nominal Area	30 mm sq	

	Stranding	Aluminum / Steel (6/1)	
	Breaking strength	11.4 kN	
	Weight	128 kG/kM	
	Resistance	0.9 Ohm/kM	at 20 deg C.
Pole	Type	Steel Tubular Pole, Folding Type	
	Total length	11 m	
	Buried height	1.8 m	
	Pole foundation	Stone & Mud feeling	
	Weight	140 kg	
	Coating	One coating of Red Oxide Primer	
	Base Plate	5 kg	
	Folds	3 nos	
Top Section	Length	2.7 m	
	Outside diameter	88.9 mm	
	Thickness	3.25 mm	
Middle Section	Length	2.7 m	
	Outside diameter	114.3	
	Thickness	4,5 mm	
Bottom Section	Length	5.6 m	
	Outside diameter	139.7 mm	
	Thickness	4.5mm	
Pin Insulator	Type	11 kV, Porcelain made	
	Creepage Distance	230 mm	
	Make	RRI	
	Number	600	Approx
Disc Insulator	Type	11 kV, Porcelain made, Socket Type	
	Creepage Distance	280 mm	
	Mean Diameter	255 mm	
	Make	RRI	
Stay	Stay Rod	8*1500 mm	
	Stay Plate	300*300*4 mm	
	Stranding	7/16 SWG	
	Others	Bulldog Grip, Thimble, Clamp etc.	
Channel	For Pin Insulator	100*50*5*900 mm	1 nos
		100*50*5*250	1 nos
	For H Pole	100*50*5*1800 mm	2 nos
		50*50*5*1800 mm	2 nos
	For Transformer	100*50*5*1800 mm	2 nos
		100*50*5*300 mm	2 nos
	For Drop Out Fuse	50*50*5*1800 mm	1 nos
	For isolator	100*50*5*1800 mm	2 nos
Earthing	Numbers	For each LA	
	Conductor	8 SWG, copper wire	
	Plate	600*600*3 mm	

Lightning Arrester	Number	14	
	Rating	11 kV, 10 kA Distribution class	
	Make	Taiwan / Lamco India	

2.7 Equipment Specification of Control Panel

Departing from the Control Panel of normal stand alone MHS, to take care of various technical issues regarding system interconnection as synchronization, protection, Measurement and Instrumentation, Active and reactive power sharing etc, existing system consists lots of equipments the details of which can be summarized in the following section. In general for the stations having capacity greater than 15 kW and those of capacity less than 15 kW are grouped in two separate sections. All of the MHP within each section have exactly same equipment within control panel. *[Reference Y-Tek report]*

Table 10: Equipment Specification of (Kalung Khola, Urja Khola 1 & Theulakhola Stations)

Particulars	Description	Make	Qty.	Remarks
Q/V Control unit	AVR with droop facility suitable for parallel operation	Y-tek, KEL	1	
	Automatic power factor regulator	Y-tek	1	Not in Function
	Digital Potentiometer (10 K Ohm)	Y-tek	1	Not in Function
	Excitation adjusting Pot(2 K Ohm)		1	
	Voltmeter for excitation Voltage	AE	1	
	Ammeter for excitation Current	AE	1	
	Droop CT (100/5 Amp, 5 VA, 5p10 class)	HAI	1	
P/F Control Unit	Digital ELC, With droop compensation, 6 Channel	Y-tek	1	
	Driver Card	Y-tek	1	
	Electronic Load Monitor (ELM)	Y-tek	1	
	HRC fuse for Ballast Load (63 Amp)		6	
	Thristers (97 Amp, 1600 V)	Smicrone	6	
Dc Supply Unit	Battery Charge Controller	Y-tek	1	
	Supply Transformer (12-0-12,18-0-18)		one/one	
	Charging Transformer(0-36 V, 2 Amp)		1	
	Diodes (15 Amp)		2	
	Thyristors (15 Amp)		2	
	HRC Fuse (32 Amp)		3	
	Battery (12 V, 17 AH , Series connected)		2	
	DC contactor		1	
	Voltmeter for Battery Voltage (0-50 V)	AE	1	
	Dc on Key		1	
Synchronizing Unit	Automatic Synchronizer (AS-200)	Y-tek	1	

	Dual Frequency Meter(25- 100 Hz, Digital)	Y-tek	1	
	Dual Voltmeter (0-500 V)	AE	1	
	Dark Lamp		2	
	Auxiliary relay for switching (9 Contact)		6	
	Selector switch for Synchronization (Auto-Off-Manual)		1	
	Synchronization Process enable Push On Button		1	
Protection Unit	O/U Voltage Relay with adjustable setting	Y-tek	1	
	O/U Frequency Relay with adjustable setting	Y-tek	1	
	Over Current Relay	Y-tek	1	
	Voltage Restrain Over Current relay	Y-tek	1	
	Reverse power Relay	Y-tek	1	Not in Function
	Reverse power Relay	Y-tek	1	
	Phase Unbalance Relay	Y-tek	1	
	Master Trip Relay	Y-tek	1	
	Current Transformer (50/5, 5 VA, 5P10 Class)	HAI	6	
Generation Measurement Unit	kWH Meter (3 ph ,4 Wire, Digital)	AE	1	Unsatisfactory performance
	kW Meter (3 ph, 4 Wire, Analog, 0-40 kW)	AE	1	
(After Ballast)	Voltmeter with selector switch (0-500 V)	AE	1	
	Ammeter with Selector switch (0-50 Amp)	AE	1	
	Current Transformer (50/5, 5 VA, 5p10 Class)	HAI	3	
	Power factor meter (Leading/ Lagging)	AE	1	Unsatisfactory performance
Dedicate Load Measurement Unit	kWH Meter (3 ph ,4 Wire, Digital)	AE	1	Unsatisfactory performance
	kW Meter (3 ph, 4 Wire, Analog, 0-80 kW)	AE	1	
	Voltmeter with selector switch (0-500 V)	AE	1	
	Ammeter with Selector switch (0-100 Amp)	AE	1	
	Current Transformer (100/5, 5 VA, 5P10 Class)	HAI	3	
Indicators	Alarm Annunciater (16 Channel) With power on, Test & Reset point)	Y-tek	1	
	Electronic Hooter		1	
	Generation Indicators (R,Y,B) Lamp		3	
	Dedicated Load Indicators (R,Y,B) Lap		3	
	Common Bus Indicator (R,Y,B) Lamp		1	
	DC On/OFF indicator Lamp		1	
	Semaphore (Contactor On/Off) Indicator		1	
Push on Buttons	Mushroom Type Emergency Button		1	
	Contactor Turn On Button		1	
	Reset Button (Relay)		1	

	Voltage Up Button		1	
	Voltage Down Button		1	
	BFV Close Button		1	
	BFV Open Button		1	
Miscellaneous	AC Contactor (140 Amp, AC3 Duty)	L &T	1	
	MCCB with Shunt trip Coil (100 Amp)	L &T	2	
	MCB (6 Amp)	Havels	6	
	MCB (10 Amp)	Havels	1	
	MCB(2 AMP)	Havels	1	
	Cooling Fan		1	
	Panel Heater		1	Not in Function
	Panel Lighting only for switchgear section)		1	

Table 11: Equipment Specification of (Upper Kalung Khola, Urja Khola II & IV)

Particulars	Description	Make	Qty.	Remarks
Q/V Control unit	AVR with droop facility suitable for parallel operation (95SP6 Model)	Sanelec	1	
	Automatic power factor regulator	Y-tek	1	Not in Function
	Digital Potentiometer (10 K Ohm)	Y-tek	1	Not in Function
	Excitation adjusting Pot(2 K Ohm)		1	
	Voltmeter for excitation Voltage	AE	1	
	Ammeter for excitation Current	AE	1	
	Droop CT (50/5 Amp, 5 VA, 5P10 class)	HAI	1	
P/F Control Unit	Digital ELC, With droop compensation, 6 Channel	Y-tek	1	
	Driver Card	Y-tek	1	
	Electronic Load Monitor (ELM)	Y-tek	1	
	HRC fuse for Ballast Load (63 Amp)		6	
	Thyristors (97 Amp, 1600 V)	Smicrone	6	
DC Supply Unit	Battery Charge Controller	Y-tek	1	
	Supply Transformer (12-0-12,18-0-18)		one/one	
	Charging Transformer(0-36 V, 2 Amp)		1	
	Diodes (15 Amp)		2	
	Thyristors (15 Amp)		2	
	HRC Fuse (32 Amp)		3	
	Battery (12 V, 17 AH , Series connected)		2	
	DC contactor		1	
	Voltmeter for Battery Voltage (0-50 V)	AE	1	
	DC on Key		1	
Synchronizing Unit	Automatic Synchronizer (AS-200)	Y-tek	1	

	Dual Frequency Meter(25- 100 Hz, Digital)	Y-tek	1	
	Dual Voltmeter (0-500 V)	AE	1	
	Dark Lamp		2	
	Auxiliary relay for switching (9 Contact)		6	
	Selector switch for Synchronization (Auto-Off-Manual)		1	
	Synchronization Process enable Push On Button		1	
Protection Unit	O/U Voltage Relay with adjustable setting	Y-tek	1	
	O/U Frequency Relay with adjustable setting	Y-tek	1	
	Over Current Relay	Y-tek	1	
	Voltage Restrain Over Current relay	Y-tek	1	
	Reverse power Relay	Y-tek	1	Not in Function
	Reverse power Relay	Y-tek	1	
	Phase Unbalance Relay	Y-tek	1	
	Master Trip Relay	Y-tek	1	
	Current Transformer (50/5, 5 VA, 5P10 Class)	HAI	6	
Generation Measurement Unit (After Ballast)	kWHr Meter (3 ph ,4 Wire, Digital)	AE	1	Unsatisfactory performance
	kW Meter (3 ph, 4 Wire, Analog, 0-20 kW)	AE	1	
	Voltmeter with selector switch (0-500 V)	AE	1	
	Ammeter with Selector switch (0-25 Amp)	AE	1	
	Current Transformer (25/5, 5 VA, 5P10 Class)	HAI	3	
	Power factor meter (Leading/ Lagging)	AE	1	Unsatisfactory performance
Dedicate Load Measurement Unit	kWHr Meter (3 ph ,4 Wire, Digital)	AE	1	Unsatisfactory performance
	kW Meter (3 ph, 4 Wire, Analog, 0-80 kW)	AE	1	
	Voltmeter with selector switch (0-500 V)	AE	1	
	Ammeter with Selector switch (0-100 Amp)	AE	1	
	Current Transformer (100/5, 5 VA, 5P10 Class)	HAI	3	
Indicators	Alarm Annunciater (16 Channel) With power on, Test & Reset point)	Y-tek	1	
	Electronic Hooter		1	
	Generation Indicators (R,Y,B) Lamp		3	
	Dedicated Load Indicators (R,Y,B) Lamp		3	
Push on Buttons	Common Bus Indicator (R,Y,B) Lamp		1	
	DC On/OFF indicator Lamp		1	
	Semaphore (Contactor On/Off) Indicator		1	
	Mushroom Type Emergency Button		1	
	Contactor Turn On Button		1	
	Reset Button (Relay)		1	
	Voltage Up Button		1	

	Voltage Down Button		1	
	BFV Close Button		1	
	BFV Open Button		1	
Miscellaneous	AC Contactor (70 Amp, AC3 Duty)	L &T	1	
	MCCB with Shunt trip Coil (50 Amp,415 V)	L &T	2	
	MCB (6 Amp)	Havels	6	
	MCB (10 Amp)	Havels	1	
	MCB(2 AMP)	Havels	1	
	Cooling Fan		1	
	Panel Heater		1	Not in Function
	Panel Lighting only for switchgear section)		1	

2.8 Single Line Diagram

Figure below shows the single line diagram adapted in the control system of Urja Khola I station. Detail specifications of equipments are summarized in above section. Each of all station has similar arrangement except their capacity. Panel consists of two sections, one Bus Bar section and another switchgear and control section. Switchgear & Control section provides housing for ELC, Thyristors, Relays, Switching and Battery charging system etc. Whereas Bus Bar section provide space for AVR, APFR and Bus Bar arrangement etc. Synchronization is done in between Generator and common bus bar with Contactor at distribution voltage. Front wall of panel provides space for Metering, Indication equipments etc. Load bus bar along with load MCCB evacuates power to the dedicated feeder. Grid bus bar along with grid MCCB provides way for power exchanging with Grid. Common bus bar is common to both Grid & Generator power for evacuation. Generator feeds to common bus bar through Generator bus bar and AC contactor.

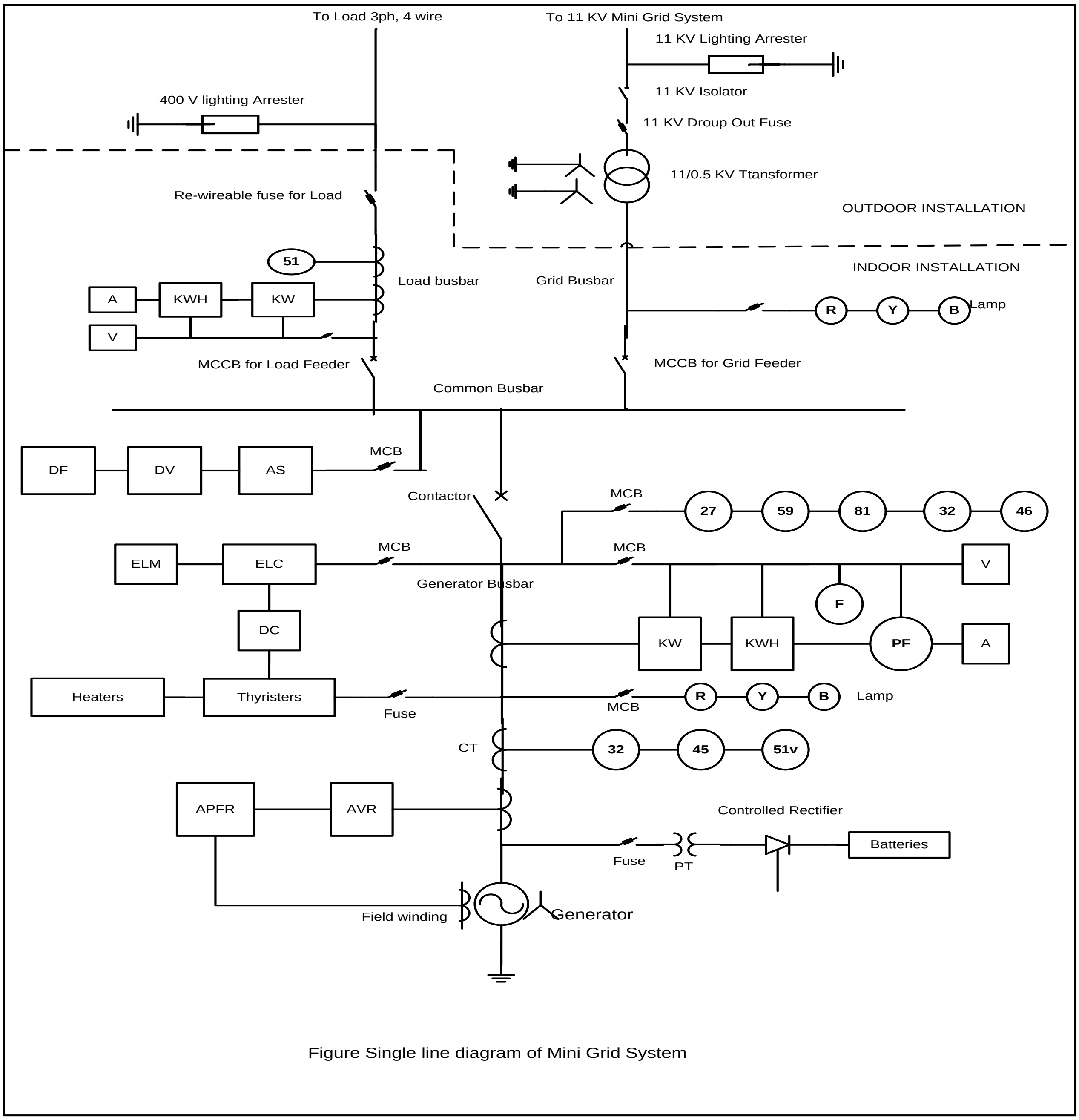


Figure 4: Single Line Diagram of Control Panel

2.9 Modes of Operations

Depending upon the condition of Transmission system, Distribution system, Generating station, Natural disaster and type and Nature of fault etc. to optimize the use of plant, bus bar arrangement provides various mode of Plant operation. Grid operator assigns or plant operators decide the mode of operation in which the respective plant could be operated.

- ISOLATED MODE OF OPERATION: In this mode of operation dedicate/ local load demand is met by operating the respective plant. If there are some fault / abnormal operating condition in the HT line, Transformer etc. then plant is operate in this mode of operation.

- ONLY MINI GRID CONNECTED MODE OF OPERATION: When there is fault in the local load feeder of plant or for carrying out regular maintenance activity of that feeder, then respective plant is used to balance the deficit power of another plant by operating it in only grid connected mode. In this condition local feeder is cut out and whole of the generating power is feed to the Mini Grid System.

- MIX MODE OF OPERATION: It is normal mode of operation. In this mode Plant is synchronized with Mini Grid line and operated. Load is shared in according to the control mechanism adopted within ELC and AVR balancing the active and reactive power requirement.

- SHUT DOWN MODE OF OPERATION: In this mode of operation plant is shut down and power is imported from Mini Grid to fulfill the electricity demand of local load of respective plant. To carry out our forced, regular maintenance activities of Intake, Cannel, For-bay, Penstock Pipe, Turbine, Valves, Generator and various equipments of control panel and during regular shut down period plant is operated in this mode. Protective and control system remains inoperative in this mode. Only Voltmeter, Ammeter, kW and kWHr meter for local load remains in operation.

CHAPTER 3: TECHNICAL STUDY

3.1 P-F Control system

Electronic load controller is the central part of this system. It is an electronic device that maintains constant load to the generator despite of the variation of the load in the village. This is done by diverting or cutting suitable amount of power to the secondary ballast load from generator bus bar depending upon the frequency of generation. Since the generator is loaded constantly & the water is constantly available, the frequency of generated voltage must be constant. The general principle of ELC can be stated as:

GENERATING POWER = MAIN LOAD POWER + BALLAST LOAD POWER

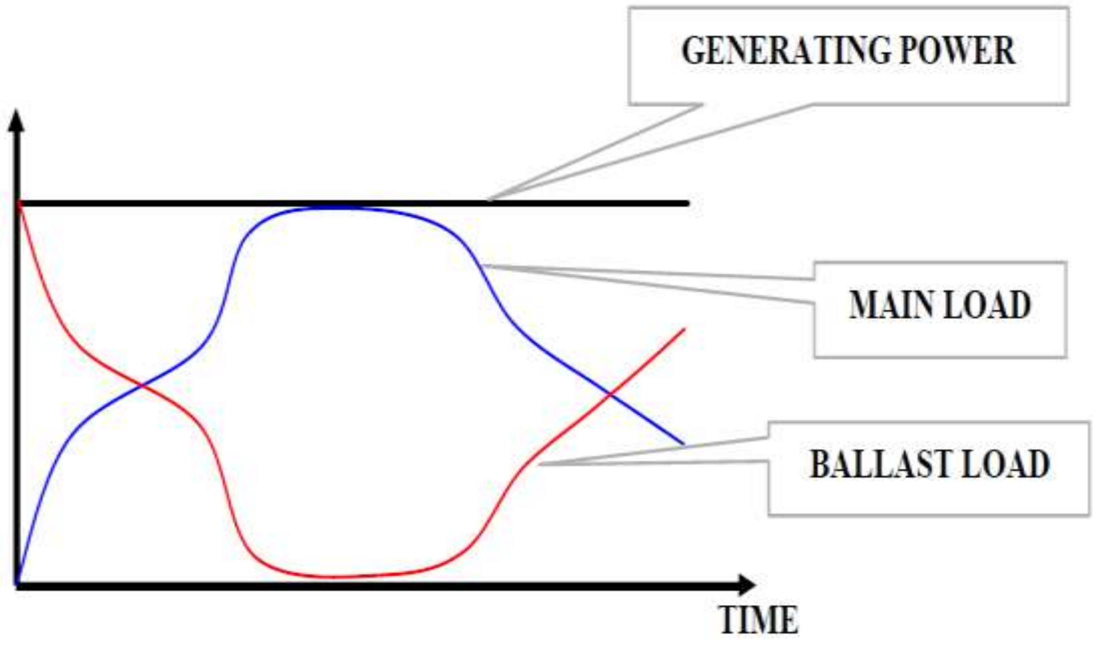


Figure 5: Principle of Electronic Load Controller

Microcontroller based programmable digital electronic load controller is used in this system which functions differently in isolated and grid connected modes. In isolated mode, ELC operates so as to make the system frequency at the constant value, while at the interconnected mode, power sharing takes place through droop mechanism, thereby frequency is allowed to vary with in certain limit (2% in this case). That means the frequency drops from the rated value (no-load state) to 98% at its full load state. Another importance of frequency droop is that there is proportional sharing of added load to the system. Suppose two generator having capacity 100 & 40 kVA having droop setting of 2%, both of them operating at no load. If a load of 25 kW is switch on then, first generator will share 17.85kW and second generator will share 7.15 kW of load. The details of the ELC system are presented in Annex. The ELC unit consists of ELC block, gate driving unit and ELM. The input signals are associated with the voltage values at the generator terminals, voltage values of grid and other signals from the switching units. The input signals are processed by the ELC unit and the control signals are generated to feed circuit driving unit (Drive Card) and ELM unit. The main function of the drive card is to provide the gate signals to Thyristors, so that the frequency of the output voltage would be maintained at the desired value. It also helps to suppress the spikes while chopping the ac cycles. Apart from the ELC block and drive card, there are other components used with ELC system, such as voltage transformers and IC units. When proper signals are produced from the ELC system, the Thyristors would feed ballast load, thereby balancing the load and regulating the frequency. Electronic Load Monitor is an electronic device. It has LCD display & shows how much percentage of the rated capacity of ballast is diverted to the secondary ballast load by the ELC. There are six water cooled ballast heater, two for each phase. Six channel Digital ELC first load three heater (One for each Phase) at their full capacity and then load the remaining second sets of ballast heater. Experimental data to verify the isolated operation of ELC is shown table below.

S.N	Generation Current (Amp)			Voltage (V)	Ballast Current (Amp)			Frequency	%
	R	Y	B	L-L	R	Y	B	(Hz)	ELM
1.	5.3	4.0	4.6	370	5.0	4.0	4.6	49.5	8
2.	18.4	15.3	17.8	367	18	15.3	17.8	50	41
3.	26.2	25.7	29	366	26.3	25.7	29.4	50.5	75

Table 12: Testing of Electronic Load Controller in no load condition (Isolated mode)

S.N.	Generation Current(Amp)			Load Current (Amp)			Voltage (V)	Ballast Current (Amp)			Frequency	%
	R	Y	B	R	Y	B	L-L	R	Y	B	(Hz)	ELM
1.	12.5	15.2	17	6.3	11	11.8	381	5.3	3.7	5.2	49.5	8
2.	30.2	33.3	37.5	6.8	10.7	11.4	380	24.5	23	25.2	50.2	57

Table 13: Testing of Electronic Load Controller in loading condition (Isolated mode)

In parallel mode of operation ELC divides the added load to the plant in according to the rated capacity of ballast size. To examine the operation of ELC during parallel mode, we have taken two plants namely Kalung Khola Station and Urjakhola I station. All other load and Generator are disconnected. Conditions are varied and data are taken which are presented in following table:

S.N	Urja Khola I st Station									Kalung Khola Station								
	Generator Current (Amp)			Local Load Current(Amp)			Vol.	Freq.	ELM	Generator Current (Amp]			Load Current (Amp)			Vol.	Freq.	ELM
	R	Y	B	R	Y	B	L-L	Hz	%	R	Y	B	R	Y	B	V	Hz	%

1.	30.4	28	33.4	0	0	0	369	50.36	65	21.5	22.3	30.3	0	0	0	380	-	65
2.	25	27.6	32.1	9	12	13	374	49.9	36	12.2	17	12.4	7	8	6	380	-	37
3.	24.5	26	33.4	6	11	17	373	50	41	21.5	20	18.6	0	0	0	380	-	41

Table 14: Load sharing test of Electronic Load Controller

3.2 Q-V Control system

Automatic Voltage Regulator (AVR) along with Automatic Power Factor Regulator (APFR) play very important role to control Reactive power and Voltage of the system. Voltage variation is related to reactive power sharing and vice versa. Since consumers have varying unpredictable reactive power demand which is very difficult to predict so there is always mismatch between reactive power generation with consumption which is the main cause of voltage variation and flow of circulating current. AVR is a device that provides the necessary dc current to the field windings of the generator to provide the constant magnetic flux in the air gap so that the generator produce required voltage. In spite of using the AVR we can configurate generators in shelf excited mode in which external excitation system is not required. Generator first builds up some voltage from the residual magnetization which is picked by AVR & builds rated voltage at rated speed. The main function of the AVR is to sense the generator voltage & control the excitation so as to obtain desired output voltage. It operates in two different modes, in isolated and the Mini Grid modes. In isolated mode it regulates the terminal voltage at the constant value, while in the MG connected mode, voltage regulation is performed by droop regulation techniques. Setting of the automatic voltage regulator is very important as it plays important role for the reactive load sharing. AVR with droop voltage characteristics helps for the parallel operation that means when load increases AVR must decrease its excitation voltage, so that generation voltage is decrease. In this system 4% to 0% V-Q droop is adjusted, i.e 4% voltage deviation causes 100% change in reactive power output. For example, if no load voltage is set at 400V, the full loaded terminal voltage will be 384V, while proportionally sharing the applied reactive load. Suppose two generator having capacity 60 &30 kVA having droop setting of 4%, both of them operating at no load. If a load of 30kVAR is switched on then, first generator will share 20 kVAR and second generator will share 10 kVAR loads. Experimental data to verify the AVR Droop setting is shown in following table.

S.N	Name of the Scheme	No load Voltage (V)	Full load Voltage (V)	Remarks
1.	Upper Kalung Khola	400	387	
2.	Kalung Khola	400	400	
3.	Urja Khola I	400	395	
4.	Urja Khola II	400	400	
5.	Urja Khola IV			Cannot be checked due to problem on those Plant (ELC problem)
6.	Theula Khola			

Table 15: Droop Checking of Electronic Load Controller

In parallel mode of operation Synchronous Generator can operate in three mode of operation. First Normal mode: In this mode the excitation of all Generators are so adjusted that there is no flow of circulating current. Other two are over and under excited mode. In Both condition, there is flow of some circulating reactive current due to which the current sharing are more than that of normal condition. Panel mounting adjustable potentiometer is used to adjust the open circuit terminal voltage of the Generator in both isolated and parallel mode of operation. Excitation Voltmeter and excitation Ammeter provide information regarding excitation condition of Generator. In present situation APFR and DPM are placed in inoperative mode. APFR regulates the power factor of the generator at constant set value by varying the resistance of Digital Potentiometer, which provides feedback signal to the AVR to control excitation. Voltage droop (static voltage variation) with respect to the reactive current delivered by the generator is created by adding vectorially the image of voltage picked between two generator phases and the image of current in the third phase picked through a droop CT.

3.3 Switchgear and Protection system

Protection system is the primary requirement of the power system. For the protection of power system equipment and personal, various protection equipments are provided in our control panel. They are fuses, MCBs, MCCBs, contactors, relaying system and emergency switches.

3.3.1 FUSE, MCB, MCCB AND Contactor

Fuses are much conventional type of protection elements. They are placed in series with the element that has to be protected. Small Cartridge fuses are provided in all equipment, such as AVR, ELC, and diver card. High Rupturing (HRC) Fuses of various capacities are provided for the protection of ballast heater and Battery charging units. For the protection against overload and short circuit inside the equipment of control panel a numbers of MCBs are provided. MCBs are superior protection element than fuse. They can be operated manually or automatically during over current. The control panel uses 8 MCBs to provide protection from over current to the different circuit branches. Two MCCBs have been used in control panel, one MCCB for village load feeder and the other is for grid feeder inside panel. They can be operated manually or automatically by providing 24 V supplies to its shunt trip coil. Both village & grid MCCBs are operated by the action of master trip relay depending upon the nature of fault. Both MCCBs can also be operated manually. In case of contactors, DC and AC contactors are used in the control panel. The DC contactor requires 24V DC supply to operate and it acts as switch for dc system, whereas AC contactor requires 220V AC supply to energize. It provides protection to the generator and blocks the generator power supply to Grid and Village load.

3.3.2 Relay System

It is used to sense abnormal condition in the circuit and gives the tripping signal for the MCCB and Contactor. Relaying system consists of a number of sensors to sense abnormal condition in the circuit and giving the tripping signal for the MCCB and Contactor. These relays operate in three modes; Scan mode (gets activated for searching of faults), set mode (setting the value of tripping parameters) and value mode (shows the instantaneous values of the parameters). The main relaying functions include:

a) Over-under frequency relay
b) Over under voltage relay
c) Over current rely
d) Phase unbalance relay
e) Voltage restrained over current relay
f) Reverse power relay
g) Earth fault relay
h) Master trip relay

The objective of these relays is to protect the generator and consumer load from abnormal condition of faults and any other disturbances. Relays give the signal to Master trip relay which will trip the ac contactor and MCCBs. All above relays are used to protect Generator except Earth fault relay which is used to sense the Transformer earth fault, and is remains in operative in present situation. We can set the relays in anyone of three modes as described earlier. The block diagram of the protection scheme applied in our system is presented in Figure 5.4.There are six auxiliary relays used in the control panel which provides both ac and dc supply for various equipment at suitable instant and are energized by 24 v dc supply. All relays have 11 terminals. Any relay can be used for Normally Open (NO) and Normally Closed (NC) position.

3.3.3 Emergency case Handling

The emergency tripping unit is the most important unit in the control panel. It allows the operator to disconnect the generator and village load from grid if he\she so desired. If the operator feels any abnormal condition inside power house or village distribution system or grid transmission system, he can operate mushroom type emergency key which prevent the generator to supply to village & grid. It also trips the both MCCBs so grid connection to village can also be stopped.

3.4 Measurement & Instrumentation System

Measurement of various electrical parameters & variables of the system play important role to provide the idea of what is going on inside the system and what sort of actions need to be applied for corrective action, if any. The measurement system includes, acquiring data of generation, consumption and other at the different places. Separate units are provided for Generation (After ballast) measurement, local load measurement, Excitation measurement and other miscellaneous measurement and Indication system.

3.4.1 Generation Measurement System

It includes monitoring values of voltage at generator output terminal and output current injected by generator after the ballast load. For current measurement, three current transformers are installed in between generator and contactor in vertical bus bar; while for voltage, it is directly tapped through the bus bar. It shows the instantaneous values of Generating line voltages, Line current, Generator Power factor, Generator kW load and total unit of Generation. Frequency of generating voltage is shown by the Digital frequency meter.

3.4.2 Local load Measurement System

It includes monitoring values of voltage at load terminal and output current taken by the local load for current measurement, three current transformers are installed in between generator and contactor in vertical bus bar; while for voltage it is directly tapped through the bus bar. It shows timely instantaneous RMS values of line voltages at local load terminal, Line current, kW load consumed and total unit of local load consumption.

3.4.3 Miscellaneous

Ammeter and Voltmeter are provided in the control panel for acquiring the current and voltage data of excitation system. Ammeter shows the magnitude of excitation current whereas voltmeter shows the magnitude of excitation voltage. These values should not exceed the present values provided on the generator name plate otherwise generator may be overheated and may cause undesired damages. Likewise, Battery voltage is measured with a dc voltmeter (provided in the control panel), showing the Voltage, and the ballast measurement system observes how much load is diverted to ballast in percentage fashion through the electronic load monitor. It gives the idea of net power supplied by the generators; high value of power to ballast load means low power injected to system and vice versa.

Beside these, there are other measuring units; such as dual voltmeter and dual frequency meter used for synchronization, Semaphore to identify weather the ac contactor is on or not, and 16 channel Alarm Annunciater to provide information about the nature of fault. Electronic hooter gives warning sound of the abnormal condition to the operator so that operator can take necessary corrective action.

3.5 DC System

For the operation of protective switchgear, Switching application, Indicating equipment and operation of other equipment DC system is used. It consists of two 12 V DC battery having capacity 17 Ah (In General) connected in series to provide 24 V DC system. 0-36 V, 2 Amp step down transformer is use to charge the Batteries. Two 12-0-12 V transformer are use to supply the battery card. Automated battery charge controller along with adjustable charging current and voltage. Combination of diode and Thyristors forms semicontrolled bridge rectifier in which gating signal for Thyristors are provided by Controller card. DC supply is used in the following equipment.

- ✓ 12 V for Driver card.
- ✓ 24 V for main relays.
- ✓ 24 V for auxiliary relays.
- ✓ 24 V for ELC during synchronization.
- ✓ 24 V for Electronic hooter.
- ✓ 24 V for Automatic synchronizer during synchronization.
- ✓ 24 V for semaphore indicator etc.

3.6 Synchronization

3.6.1 Condition of Synchronization

The process of connecting an alternator in parallel with another generator or with infinite bus bars to which a numbers of alternators are connected is called synchronizing. Before synchronizing, the incoming generator should necessarily meet certain conditions, which are:

- The terminal voltage of the incoming generator must be exactly equal to that of the grid Bus bar voltage connecting the other generators.
- The speed of the incoming generator must be such that its frequency (being equal to the P*Ns/120) equals grid Bus bar frequency.
- The phase of the incoming generator voltage must be same as that of the Bus-Bar voltage relative to the load.
- Phase sequence of the incoming generator must be same as that of the Bus-Bars.

Synchronization is the major characteristics of the Mini Grid system. Bus bar arrangement provides the facility for Synchronization. It is done at the generation voltage at the common bus bar by turning ON the AC contactor. It can be done in two mode i.e. automatic and manual mode. During synchronization process, when synchronization enable switch is turn on, auxiliary relay 4 & 5 gets energizes which closes path for generator and grid signal to dual meters & AS-200. Automatic synchronizer displays whether phase, frequency & voltage are matched or not. Dark lamp also shows the phase matched condition of both voltages. Dual frequency meter and Dual voltmeter displays voltage and frequency of Generator and Grid Signal. These instruments help for synchronization. These parameters can be matched for synchronization by following ways:

- Adjusting water entering to the turbine by means of gate valve to match the frequency.
- Adjust the potentiometer knob to change the excitation until both grid and generator voltage becomes equal.

When phase angle gets matched, auto synchronizer provide signal to auxiliary relay 3 which energizes the auxiliary relay 1 and hence AC contactor gets closed at that time synchronization of generator with grid will occur. After the synchronization frequency & voltage of generator and grid becomes same.

3.6.2 Synchronization Procedure in Auto Mode

In automatic mode, when three parameters get matched, Automatic synchronizer automatically closes the AC contactor through auxiliary relay 3 and 1.

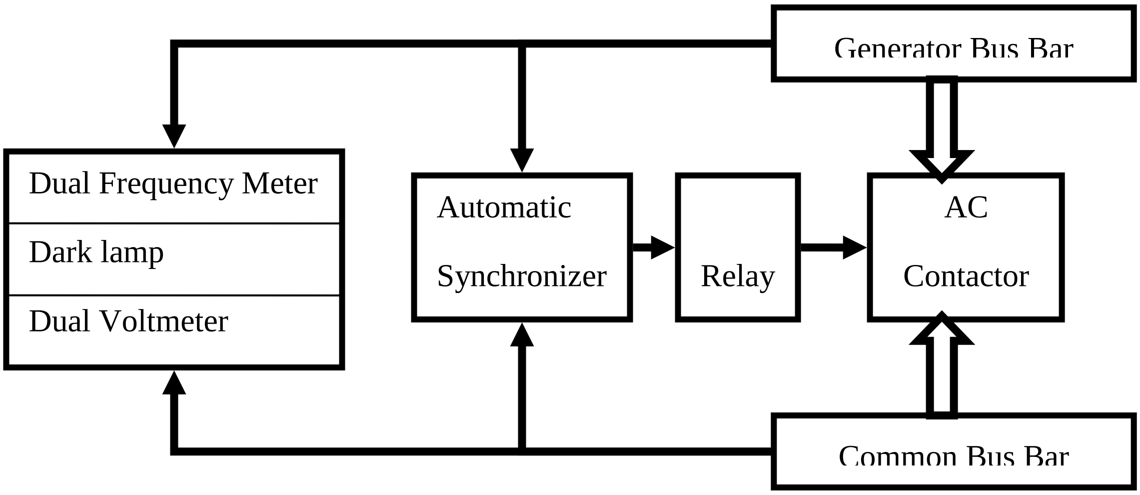


Figure 6: Block diagram of synchronization in automatic mode *[Source: RERL]*

When plant is running in isolated mode.

1) Turn off the ac contactor with the help of emergency key and cut off the local load i.e turn OFF the MCCB of village.
2) Turn ON the grid MCCB.
3) Place the selector switch in auto mode.
4) Operate the Sync Enable key.
5) Match the grid and generator frequency by controlling the water entering to the turbine with the help of the gate valve. If both of them get matched then green LED on the frequency line of the auto synchronizer will glow.
6) Match the generator and grid voltage by adjusting the potentiometer that changes the excitation. If both of them get matched then green LED on the voltage line of auto synchronizer will glow.
7) When the phase angle gets matched then ac contactor will automatically becomes ON making the synchronization.
8) Adjust the excitation voltage and water input if necessary.
9) Give supply to the local load, continuously monitor the running system and take necessary action if necessary.

When the plant is in shut down condition.

1) Start the power house as in usual operating manner but do not turn ON the ac contactor.
2) Set relays in scan mode.
3) Turn OFF the village MCCB.

4) Turn ON the grid MCCB.

5) Follow the same operating procedure as described above from step no 3.

3.6.3 Synchronization Procedure in Manual Mode

In manual mode only the difference is that we should turn ON the ac contactor manually at the time when all three parameters are match as indicated by auto synchronizer or Dark lamp, Dual voltmeter and Dual frequency meter. Following procedure was adapted.

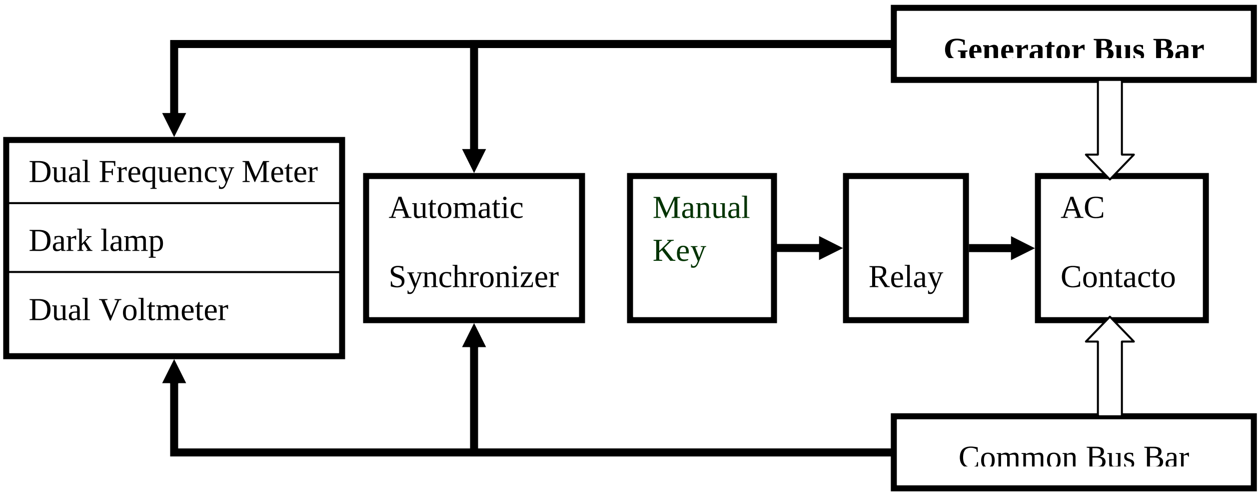


Figure 7: Block diagram of Synchronization in manual mode *[Source: RERL]*

1) Follow the same procedure up to the point 6.

2) Place the selector switch in manual mode.

3) Since voltage and frequency get already matched, when the phase gets matched (at that instant, green LED on all three row of automatic synchronizer will glow and white lamps will be dark), turn ON the ac contactor by enabling the connection key.

4) Adjust voltage and water input as mentioned above and give the power to the village. If synchronization process fails, operate the emergency switch to protect our generator from operating in motering mode.

3.7 Technical Benefit of Mini Grid

After the formation of the Mini Grid, there are a lot of technical up gradation in the control system, protection, safety, measurement, Instrumentation and in other field. There are technical up-gradations in all MHPs after the introduction of MG Technology, because the older control technologies were designed for the isolated mode and could not be compatiable with MG operation. These technology and equipment has resulted stable voltage & frequency, reliable service due to effective relaying. Further, Fault detection process is made easier and faster by using indicators, Alarming facility & relays based protection system in the control system. After the commissioning of the MG, the localities have observed numbers of benefits in different aspects. The consumers and the IPPs both have gained technical, social and financial benefits by its operation. Following subsection summarized the technical benefits of Mini Grid.

- Quality of the Electricity: The quality of the supply is mainly governed by its voltage and frequency. Because of system interconnection and paralleling of generators, voltage deviation and frequency variation range is drastically reduced then isolated mode. Also adjustable voltage control facility in the new control panel helps to boost up the terminal voltage at the feeder end point. According to local people, same bulb used for lighting glows more brightly after the formation of Mini Grid, proving that quality of electricity has been drastically increased.

- Reliability of Electricity supply: One of the major objectives of the Local grid formation is to increase the reliability of electricity supply. In case of isolated plant the supply to the local consumer would be interrupted if any problem (caused by forced condition) occurs in any structures from intake to tailrace i.e. penstock, Turbine system, Drive system, Generator and control system. Also the same case would happen during the period of regular maintenance. In all above condition local consumer receive electricity from Mini Grid. Moreover during regular shut down period of each day, consumers do not feel the sense of load shedding. So we can say that Mini Grid increases the reliability of electricity.

- Introduction to energy based tariff structure from power based tariff system: Before the formation of Mini Grid consumers paid the charge of electricity according to the amount of power they used. Such system has various disadvantages. Now each consumer has installed energy meter to measure amount of energy they used. Consumer using less energy pays less charge and one who uses more pays more which helps to balance deficit power of one house by surplus electricity of other house. Also deficit amount of electricity of one plant is balanced by surplus electricity of other plant. This is due to the load sharing between Generators. For example Theule Khola station has its own local load greater than its capacity, which is fulfilling by importing power from grid. Kalung Khola and Urja Khola IV station have excess of electricity. Energy based tariff structure and load haring help to reduce the overloading of Generators.

- Better operating condition of Generator: The temperature and sound of Generator becomes better when operating in parallel which also extends its operating life. According to operators it is very easy to start Induction motors used for domestic and Industrial Purpose.

- Starting and processing speed of agro-processing and saw mill: According to the entrepreneurs of these enterprises, it is very difficult to start their Induction motor when plant is running in isolated mode. It is very easy to start those motors also the processing speed of these motors largely increases, they can easily increase load without any drought. Especially in case of small plant of capacity less than 15 kW such problem troubles them frequently.

- The provision of large scale end use application is expanded due to surplus of large amount of powers. For example, power for N-Cell tower is supplied by MG, stone crusher of about 40 kW capacity has been planned for future installation that can be run during the off load period. Other current examples are, they can run 4 mills of cumulative capacity of 34 HP simultaneously at the dedicated feeder of plant having capacity 24 kW which was not possible without Mini Grid. This is only the case of Theule Khola station, similar case is happening in other feeder of plant.

- Mini Grid is becoming a research place; different organizations in energy field are interested to replicate the technology and management model in other parts as well. Such visit was made by team from Ministry of Rural and Reconstruction from Afghanistan. Several students from various Universities are currently engaged for their thesis work in Graduate and post Graduate Programs related to technical, social and environmental issues of Mini Grid.

- Better safety for personnel and equipment: Due to the adaptation of relaying based protection system, it is very easy to find the condition of abnormal operating condition and can easily be cleared which provides safety for both personal & equipments. The fault indicating alarm Annunciater, electronic hooter and Emergency switch helps to rapid clearance of fault preventing the further damage and destruction due to fault.

- Advanced metering system: Microcontroller based digital frequency counter, Digital Electronic Load monitor and other appropriate metering systems provide sufficient technical information about the system which play important role to provide the idea of what is going on inside the system and what sort of actions need to be applied for corrective action, if any.

- Easiness of plant operation: Due to the automatic control and protection it is very easy for operators to operate the plant. According to them they do not take care of over / under voltage, Current, over / under frequency etc. In any abnormal condition of fault, protection system automatically isolates the generator from fault and hooter calls them to take necessary action. Also sudden increase or decrease of load is easily balanced by the system especially while starting and stopping large motors.

- Infrastructure Development of Connection of Mini Grid with National Grid. It offers sizeable capacity (Both load and Generation) to NEA for encouraging to connect the Min-Grid with the national grid.

3.8 Current Technical Issues of Mini Grid

Although there are many technical advantages of Mini Grid, there are some technical difficulties or issues which obstruct the smooth operation of Mini Grid. Since Mini Grid is the piloting project which is implemented for the first time in Nepal there is no such prior experience for us, so there is possibility of occurring new and new technical issues and problems in the Mini Grid technology. Some of the current technical issues that were felt in this system are:

- Lack of central control and monitoring unit: For maintaining power quality, active and reactive power balance must be maintained within the system. Mini Grid operator should be able to choose the mode of operation. Similarly, generation, supply and storage of energy must be suitably planned with respect to load demand on the system. So Grid operator should know continuously about Generation and loading condition of the system. But in the existing system, the Grid operator is unknown to what is happening in the system e.g. whether the plant is operating or not, whether it is synchronized or not, whether the village load is ON or OFF, how much power is generating, what is the total load demand, what is the condition of frequency and voltage etc. all are unknown to the Grid operator, for which he/she should go to any plant. On the other, to keep the balance between load and generation, Grid operator should have some control mechanism over the load and generation but in the existing system both of them are within the control of plant operator which are under the separate business group. Hence there is very difficult on the load management.

- Lack of convenient communication mechanism: Mobile communication is only the means of communication between Grid operators and Plant operator and operator to operator. It is very difficult to take continuous information and giving instruction to the operator from phone call. Also it is more expensive. There are lots of cases in which due to the problem on the communication network, many sensitive loads have to be stopped for longer time period. On the other hand there is a confusion who will communicate if there are some general problems.
- Issues on the active power sharing: In the Mini Grid system the active power sharing is proportional to the capacity of the ballast load. So the power sharing is affected by the ballast size. When, any plant is operating at lower capacity than its rated capacity or size of ballast is high than its usual size, in such condition there may be possibility of back feeding by grid to the ballast of that plant, making reverse rotation of generator Energy meter. In this case ballast of one plant acts as load of other plant which is undesirable. Other practical problem on load sharing are:
  - ✓ If the load shared by some plant is low then, plant operator intentionally isolates his plant from grid and operates in isolated mode which is unknown to Mini Grid operator and may bring instability to Mini Grid.
  - ✓ If there is excess load on the grid which overloads the generator then, Plant operator may isolate his plant from grid and operates in isolated mode which is unknown to the grid operator resulting the successive tripping of other plant and finally causing the system black out. Both of the above cases are undesirable and increase the possibility of Grid instability.
  - ✓ Since the income of the plant wholly depends upon the amount of energy sold per day, in some plant it is found, to increase the amount of power sharing, operator make cheating i.e. he blocks the power to the ballast by opening the ballast fuse which affects the power sharing and it is highly undesirable. This is unknown to the grid operator.
- Issue on reactive power sharing: Reactive power must be share in proportion to the kVA rating of the generator. Although reactive voltage droop is created for this due to the difficulties in proper droop setting it is observed that reactive power is not shared in accordance to this rule. Also the reactive power sharing is affected by the open circuit voltage which can be affected by the voltage adjustment with panel mounting

potentiometer. It is impossible to find the correct excitation point by manual tuning so there is always mismatch in reactive power, causing the flow of circulating current which increases the system loss. In extreme condition if the excitation is too low the system voltage becomes low causing voltage instability and if the excitation is high then rotor may overheated resulting into insulation failure of rotor winding.

- Lack of operating and maintenance guideline: The technology provider does not provide any operating and maintenance guidelines, so, it is very difficult for proper operation and maintenance of equipment inside control panel.

- Difficult due to natural disaster: Natural disasters like lightning, flood, and landslide greatly affect the operation of Mini Grid. Lightning causes serious destruction to the control equipments. During rainy season flood and landslide affects intake, canal structure, transmission and distribution system which takes long time for maintenance. Due to the rocky geology of that area the earthing resistance may be high. Moreover due to the lack of maintenance of earthing system small lightning causes serious damage. The latest example is at Theule Khola MHS, last week ELC getting damaged by lightning. There was no lightning arrester at the starting point of that feeder supplying the local load, in which lighting struck. The damaged ELC was carried by the team to Kathmandu to request RERL for their support in maintenance.

- Lack of synchronization check: In the current system operator of the plant is unknown about the synchronization status other plant. Weather other plants are in synchronism or not, how many plants are operating in synchronism is also unknown this will create misunderstanding between operators. To check he/she has to disconnect from the Grid connection which affect the stability of the system also.

- Lack of spare parts, Expensive technology and maintenance problems: Mini Grid technology was imported from India and is more expensive than older system. Since there is no local supplier of panel equipment's it is very difficult to buy the new equipment. Also maintenance of defected equipment cannot be done by local technician, high cost and longer shut down period, lack of timely maintenance even for minor problems. For example Urja IV plant was found operating without ELC for more than one month. Lack of appropriate spare parts is also the major cause of plant shut down.

- Difficulties in dry season load management: All the plants within Mini Grid, uses same source of water and operate in cascade mode, especially in the driest months Falgun, Chaitra, Baishak and Jestha, when water is diverted for irrigation operation of Mini Grid is totally affected causing frequency instability. Lack of load control authority and mechanism with Co-Operative, lack of synchronism check and large local load of each plant are other causes of frequency instability.

- Lack of data recording devices: There is not any data recording devices in all plants. In order to study the technical status we need some past values of the electrical parameters. It is impossible to take data at same instant so it is very difficult to study what is actually happening in the system. Also during field visit it was seen that the accuracy and reliability of indicating devices is below the acceptable level so it is very difficult to take some timely instantaneous RMS data that required.

- Older structures of the plants: Almost all plants were established 10 years ago, so the condition and efficiency of generators, turbines, earthing systems become very poor which needs higher maintenance costs. In case of Theulakhola plant, although efficient AVR system is used voltage regulation is very poor. This plant cannot start induction motors in isolated mode. Contactor gets frequently tripped while starting induction motors.

GHAPTER 4: MANAGEMENT STUDY

4.1 General

The Mini Grid is not a single entity but an arrangement of multiple networks and multiple power generation units with multiple operators employing varying levels of communication and coordination, most of which is manually controlled. Management system of mini-grid will be more complicated than the existing standalone operation. Management and technical aspect is the significant and vital aspect for enhanced operation of the Mini Grid which is entirely new practice in the segment. For a mini-grid power system to sustain and run smoothly, it is significant to determine who invests, develops, owns and operates the system. More importantly, the issue of ownership becomes decisive. The working modality for mini-grid under rural circumstances is specifically dealt with three options. These are*: [reference RERL: report]*

- ✓ Option A: The whole system, including generation and distribution, is managed by one entity.
- ✓ Option B: The "business as usual" situation, where the Mini Grid operator will be receiving surplus power only but it coordinates among the seven MHPs.
- ✓ Option C: The Independent Power

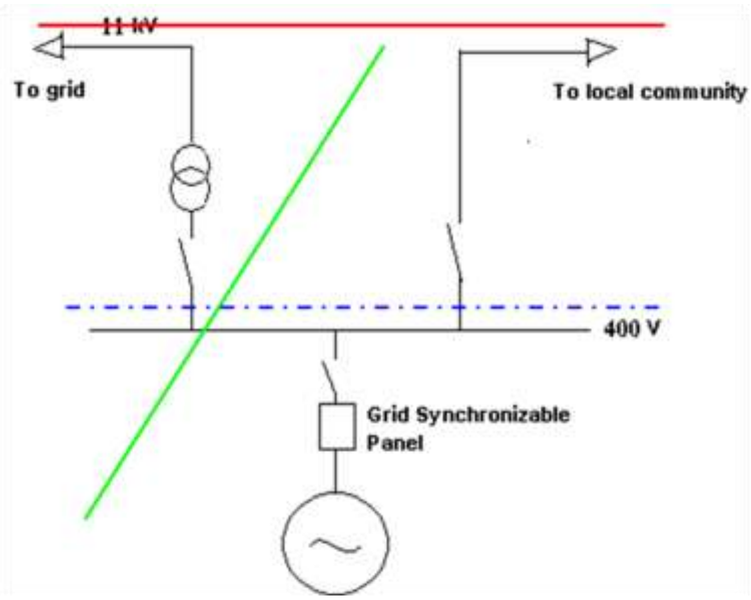


Figure 8: Various options of IPP model

Producer (IPP) model where each MHP will be responsible for the generation only and load management and dispatching will be controlled by the Mini-grid operator.

This mini grid at Baglung District, Nepal is funded by RERL/AEPC contributing 90 % of the total investment cost. The remaining is contributed by the community as kind participation, so Community-based IPP cooperative model suits the best at such scenario. Thus, Urja Upatyaka Mini-Grid Cooperative was formed from the representatives of each Micro Hydro that are connected to the Mini Grid. Each of MHP has number of representatives proportional to their power capacity. Rule, regulations and other legal documentation such as Arthik Niyamawali, Bidhut Bitaran Niyamawali, Biniyamawali, Karmachari sewa Niyamawali & Power purchase agreement were developed. This model enhances the communal responsibility among the members or the beneficiary households for the project sustainability. Cooperative will be responsible for operating and maintaining the Mini Grid, distribution and consumer services, and individual Micro Hydro Functional Group (MHFG) were restricted to independent power producers (IPP). The trading arrangement were made in such a way that Cooperative will buy electricity from respective IPP and sell it to consumers that were previously supplied by individual MHFG and new consumer were added by expanding distribution system as well. This executive body of the co-operative has the decisive power for operation, maintenance, expansion of transmission and distribution lines, fixing power purchase agreement (PPA) rate, tariff structure, office management, hiring the staffs and all other related issues. The main objectives of Urja Upatyaka Mini Grid Co-operative are:

- ✓ To purchase electrical energy generated by the 6 MHPs situated within the Kalung Khola valley and distribute (sell) the same to consumers.
- ✓ To raise financial resources from shareholders to carry out activities for long run sustainability of the organization.
- ✓ To promote and assist cooperatives movement in the project area.

4.2 Duties, Responsibilities and Authorities of Mini Grid Co-Operative.

The following activities are duties, authority and responsibility Mini Grid Co-Operative

- ✓ To make an agreement (PPA) with all 6 micro hydropower plants for the purchase of electricity.
- ✓ To involve plants in the distribution system of the mini-grid.
- ✓ To assist plants in their operations and maintenance.
- ✓ To assist in load dispatch and management.
- ✓ To supervise, monitor and repair all distribution lines
- ✓ To conduct training programs on electrical systems and its uses.
- ✓ To know and make demand forecast of electricity requirement for all consumers residing in the Urja Upatyaka valley.
- ✓ To supply electricity as per the requirement and demand of consumers, and help in electrification of the required areas.
- ✓ To repair and maintain the distribution systems set up by the mini-grid.
- ✓ To properly manage electrification and distributions systems and make it effective.
- ✓ To supply electricity at an optimum price as decided by the general assembly to end-users and household consumers.

- ✓ To assist and make arrangements for consumers to have access to electricity so as to promote income generating activities for better livelihood opportunities.
- ✓ To construct, operate and manage micro hydropower plants as and when required.
- ✓ To provide services in the form of operations, repairs and maintenance to the existing 6 MHPs and others by charging fees.
- ✓ Authority to disconnect the electricity line if consumer does not follow the rules and regulation set by Mini Grid.
- ✓ Authority to decide on any investment on any other sector.
- ✓ To promote, develop and carry-out income generating activities so as to increase the consumption of electricity during off-peak period to aid social, financial and environment upliftment of the community.
- ✓ To conduct and manage training programs on electricity consumption and its security.
- ✓ To abide by and promote cooperatives principles; assist in proper cooperative management.
- ✓ To conduct activities that promotes community involvements and is beneficial to them.
- ✓ To conduct training programs on cooperatives principles for shareholders and organization staffs.
- ✓ To provide financial resources (loans) to shareholders and consumers as and when required provided the financial condition of the organization is favorable.
- ✓ To cooperate and coordinate with other organizations.
- ✓ To make every effort to interlink and connect Mini Grid to NEA's national grid.

4.3 Duties and Responsibility of Micro Hydro Functional Group

Each of the Micro Hydro functional Groups is responsible for the following activities:

- ✓ Generation of electrical power and provide it for Mini Grid according to its requirement.
- ✓ Operating the plant according to the operational schedule prepare by Mini Grid.
- ✓ Follow the instruction as directed by Mini Grid.
- ✓ Maintenance of all civil structure from intake to tailrace, maintenance of electrical and mechanical equipment inside the plant.
- ✓ Collect the revenue from the sale of electricity to the Mini Grid in accordance to the fixed PPA rate.
- ✓ Mobilizing the deposit fund of plant for the various activities to the consumer.

- ✓ To assist the Mini Grid for fixing tariff rate, addition of new consumer, distribution and consumer service, fault finding in distribution line and other social works.
- ✓ Making Power Purchase Agreements with Mini Grid.
- ✓ To assist the Mini Grid for the maintenance of transmission and distribution lines.
- ✓ To actively participate for fixing the objective and making other important decision in Mini Grid.
- ✓ To provide advice & suggestion for the better sustainability of Mini Grid.
- ✓ To give information to public from Mini Grid if any e.g. result of discussion, future work plan etc.

4.4 Distribution and Consumer Service

In order to fulfill the enlisted objective and to provide better service to the consumer, Co-Operative management committee established an office at the center part of the Mini Grid (at Rumta) from where all the activities of the Mini Grids are being conducted. There are three regular staffs at the office. One is technical Manager having intermediate degree in Electrical Engineering from CTEVT. Technical manager is responsible for all the technical works of Mini Grid. Preparation of operation schedule for plants, help plant operators for maintenance of control panel, controlling and monitoring of all plant, to assist the management committee for deciding the future work plan, keeping the technical record of the system e.g. log book, load curve, energy consumption and generation record etc, to identify, mobilize, create close relationship with support organization, supervise and support to the other staffs, calling for the meetings as required are the major responsibilities of the technical manager. Accountant of the Co-Operative is responsible for keeping overall financial record of the Co-Operative, collection of tariff from the consumer, keeping the record of fee, dues and other charges from consumer, keeping the data record of energy meter reading, paying to the plant for the price of electricity that Mini Grid purchases, suggest for management committee and manager about financial status of Mini Grid and support for office management are major duties of Accountant. Another regular staff is the technician, whose main responsibility is to perform the meter reading, line maintenance, providing service for the consumer e. g. replacement of energy meters, maintenance of wiring, other consumer service, helping to operators for maintenance activities and support for the office management etc.

Regular customers service have been providing through the Co-Operative office, for this office opens from 10 AM to 4 PM from Sunday to Saturday except those days of meter reading, during which all the staffs are in the process of metering and collecting tariff from consumer so office remains closed during these days. Metering process is running for each month from 1st to10th of every month. Billing is done by the meter reader. Tariff is collected at one, two or three places for each feeders of plant at pre specified time and places by the accountant of the co-operative. For the consumers who are missing to pay for tariff at specified places are given a chance to pay from 11th to 15th of that month without any extra charges at office time in Co-Operative office. Those consumers who miss such opportunity are charged Rs 1 per day plus 15 rupees (for first 15 day of the month) from 15th of that month.

After the completion of the metering for the consumer of particular feeder, metering of that plant is done which gives total amount of electricity sold by that plant to the Mini Grid during that month. Mini Grid provides the charge for that energy to plant operator or manager or chair person of that plant at the time of regular meeting which held approximately at mid time of each month.

4.5 Price of Electricity

For Mini Grid, domestic households act as consumer and for each plant, Mini Grid acts as consumer. Separate tariff structures were formed for both consumers. Mini Grid sells the electricity to the domestic consumer at specified tariff structure and purchases the electricity from plants in fixed Power Purchase Agreement rate. Regular expenses and maintenance cost of Mini Grid is achieved from the margin between these two rates.

- **Tariff:** Each of the domestic consumers was installed single phase energy meter to measure the amount of electricity consumed. The load specified to these single phase consumer is 6 Amp. Due to the various difficulties for purchasing NEA recommended energy meter some of the consumers do not have meters till now. Following table summarizes such consumers.

A	Name of feeder	Total no of active HHs	No of HHs (having Meter)	No of HHs (not meter)	Remarks
1.	Upper Kalung Khola	114	111	3	Un available
2.	Kalung Khola	232	232	0	
3.	Urja Khola I	267	265	1	Un available
4.	Urja Khola II	165	165	0	
5.	Urja Khola IV	124	124	0	
6.	Theule Khola	282	275	7	Un available

Table 16: Meter connected HHs of Mini Grid

Tariff for the domestic consumers is fixed from the discussion with the consumers & Micro hydro functional groups. There are major two difficulties for fixing the tariff rate. If we go for higher tariff structure it is very difficult to convince for local people. Also high rate compels the consumer to decrease the use of electricity which ultimately reduces the energy consumption of households thus reducing the net revenue. On the other hand if we go for low tariff rate to increase the consumption of electricity, then it becomes necessary to go for load shedding which creates negative impact towards Mini Grid. So compromise is made to fix the tariff structure. The current tariff rate is Rs75 for minimum of 12 units and Rs 7 for each additional unit.

There are no large bad debts on tariff collection. All the consumers follow the rules of Co-Operative. Consumer who do not pay the tariff at specified time, are fined at certain rate. Since there is some socio-political problems in the Theulekhola plants, three consumers (all three are local political leaders) do not pay for tariff till now. Although Co-Operative has authority to disconnect line of consumer who does not follow the rules and regulation, such consumer are not punished by the Co-Operative. Till now energy based tariff system is not adopted for the three phase consumers. Depending upon the amount of energy consumption and hours of operation per day, three phase consumers are charges at separate rates as:

2	Name of feeder	No of 3 phase consumer	Tariff structure Per month (Rs)	Remarks
1.	Upper Kalung Khola (Mill)	3	1150	
2.	Kalung Khola (Mill)	5	1300	
3.	Urja Khola I (Mill)	3	800	
	Urja Khola I (N-Cell)	1	10000	
	Urja Khola II (Mill)	2	1000	
4.	Urja Khola IV(Mill)	1	500 as minimum + 7 per unit	Meter Installed
	Urja Khola IV(Mill)	1	800	
5.	Theula Khola(Mill)	4	1000	

Table 17: Tariff structure of Mini Grid for Three Phase consumer

- **Power Purchase Agreement (PPA)**

  Each of the generating stations sells the energy to the Mini Grid at specified PPA rate. Since there is no such prior experience, it was fixed by the negotiation with the Micro Hydro Functional Group. Along with some preliminary calculation, PPA rate is fixed as Rs 4 Per unit and is implemented from Ashadh of 2069 for the first time. When this agreement was applied, it was observed that the income statement of larger plant (having capacity greater than 15 kW) increased but that of plants of capacity less than15 kW was reduced such that, income from the energy sell in not sufficient to meet the salary of two operator. Especially such problem was occurring for Urja II MHP (9 kW Capacity). In order to solve such problem PPA Rate was modified to Rs 4.5 per Unit from 2069 Mangsir and was implemented from the same time along with modified operational schedule for plants.

4.6 Grid Operation

Despite of long unanticipated delays and uncertainty, the project was finally completed at the mid of 2068. Immediately the project was entered into the testing phase and after preparation for office management and Energy meter installation, Mini Grid was operated in IPP model from beginning of 2069. According to the Mini Grid manager, from the beginning of grid operation a lot of methods were practiced to optimize the generation, minimize the outage rate and making economic load dispatching. These could be summarized as:

- Operational schedule: To cope with the load variation, during light load period (night and day time) some of the plants are shut down and as the load grows additional plants are brought into operation. The operational schedule of plants is prepared by Co-Operative in close co-ordination with operator, accounting the Generation and loading condition at that season. Operating time of plants vary according to the requirement. Separate schedule for three phase agro-processing mills is applied to restrict them from unnecessary load burden at the same time to Mini Grid.
- Black Start Mechanism: When the system collapses due to some reason, firstly larger plants ie either Kalung Khola or Uja Khola I or Theula Khola station charges the gird and the other plants successively come into synchronism. According to the operator the normal black start time is about 2 minutes and it takes long time in certain instances.
- Complete and partial Grid shutdown: Mini Grid system is not operated in complete shutdown mode. If there are problems in the Grid transmission line each of plants are operated in isolated mode providing supply to the local load feeder. The partial system break down will occur in the following conditions;
    - ✓ If there is fault in the Grid transmission line. If the fault clearance time is expected to be long then Grid section is broken into two sections which permits to operate the Grid in partial break down mode in respective sections.
    - ✓ While fault or carrying out maintenance activities in any feeder of distribution lines.
    - ✓ Due to the negligence of the operator ie violence of time schedule.
    - ✓ If there are some problems in the generating stations.

The major problems in the HT grid transmission line after implementation of IPP Model can be summarized as:

S.N.	Faults Description	Shut down period	Date
1.	Broken of transmission line at Zadi while constructing road.	15 day	2069/3/16
2.	Puncture of Disc insulator near Tosha	2 day	2069/5/13
3.	Line short due to Bamboo falling in between Urja IV and Theulakhola MHP	1 day	2069/10/12
4.	Melting of conductor at LV side of Theulekhola Transformer in Red phase and neutral connection	1 day	2069/11/15

5.	Melting of conductor at LV side of Theulekhola Transformer in Red Phase connection	1 day	2069/12/20
6.	Broken of transmission line at Zadi while constructing road	70 day	2069/12/25
7.	Melting of conductor at LV side of Theulakhola Transformer in Neutral connection	1 day	2070/1/18
8.	Melting of conductor at LV side of Urja I Transformer in R phase connection	1 day	
9.	Melting of conductor at LV side of Theulekhola Transformer in R phase connection	1 day	2070/2/19

Table 18: Number of system collapse of Mini Grid

- Communication Mechanism: Mobile phones call and messaging are the major means of communication mechanism in the Mini Grid system. Meeting, Visiting and message through someone are also the means of communication.
- Component failure rate of control panel**:** After the testing and commissioning various equipment of the control panel have failed due to abnormal operating condition and failure of semiconductor chips. Mostly equipment of the control panels are semiconductor based digital ICs the failure rate of which seems to be high. During the field visit it is experienced that, repair and maintenance rate is almost negligible. The operation of the plants in such condition seems to be very danger. According to the operators, we can say that Battery Charger controller cards, Relays, Electronic Load monitors, Automatic synchronizers are among frequently falling components. Dual frequency meter, AVR and ELC are comparatively less damaged.

4.8 Issues of Current Management System

Followings are the noticeable issues of the current management model (IPP Model)

- Gap creation between Micro Hydro functional Group and Co-Operative: In straight forward way both of these are two separate business groups so both of them tries to generate more revenue from the common source of income i.e. electricity. This creates dispute between them. Micro Hydro functional group tries to make higher PPA rate and lower tariff structure for consumer which is not in favor of Mini Grid. The hidden fact is that, staffs within both groups are internally jealous to each other regarding to scope of work, facilities etc. which affects the management of Mini Grid.
- Delay in problem solving: Micro Hydro functional groups do not have authority over the distribution system up to consumer energy meter. If there are some problems in Distribution

line and consumer connection, due to large coverage area, limited staffs and long procedures it will be very much delayed to solve even for the simple problems.

- High financial burden over the Mini Grid: Especially according to this IPP Model distribution line is under the Mini Grid which is old and it needs high cost for repair & maintenance. More over to operate whole distribution system Co-Operative either has to hair additional staff or use plant operators by paying extra charge. Due to this difficulty all the distribution lines are looked after by the Micro Hydro functional group till now in Mini Grid system.
- If any generating plant is shut down for long time due to some reason then the income of that plant is very low which may create financial problems for MHFG.

CHAPTER 5: SOCIO-ECONOMIC STUDY

5.1 Demand Side Aspect

This scope of study mainly focuses on the energy consumption pattern of these localities, energy demand of this area, generation and consumption scenario etc. Along with this, various indexes will be calculated based upon the data availability so that we can describe the Mini Grid using engineering parameters. This is studied under the following topics.

1) Daily load curve:

To know the hour to hour variation of the load requirement of the Mini Grid it is very important to study about the load curve. Load curve shows peak and base load requirement. It helps to prepare operational schedule, economic load dispatching between plants. Daily load curve is prepared by measuring local loads of each Plants and the sum up them to obtain the daily load curve of Mini Grid:

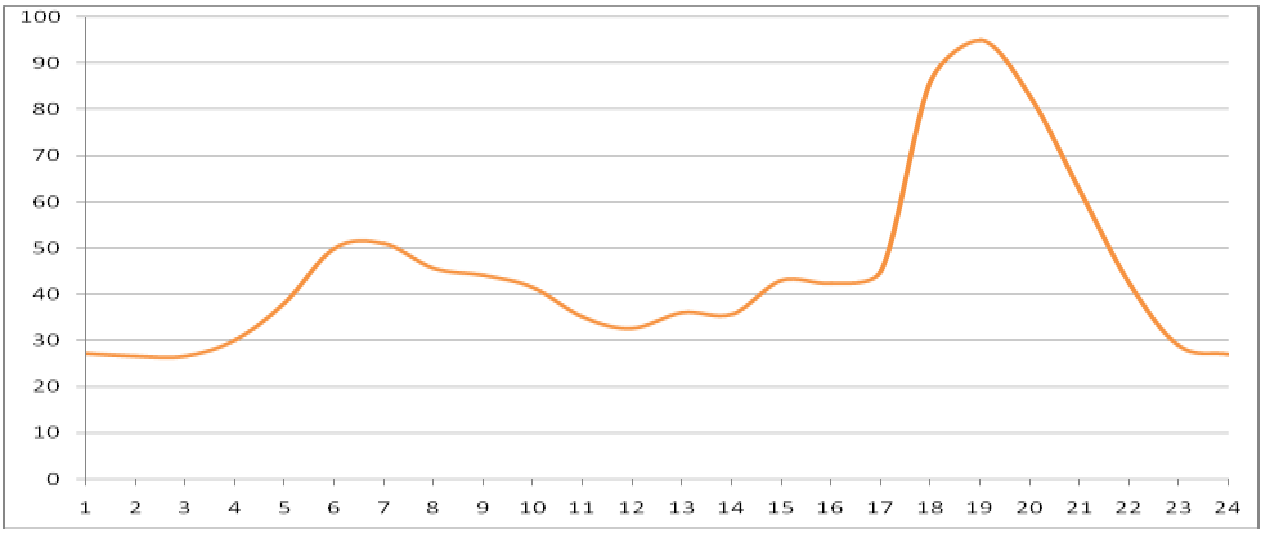


Figure 9: Daily load curve of Mini Grid

Above figure shows the daily average load curve of Mini Grid system. The peak / maximum load is of 95 kW, minimum/base load is about 26.6 kW and average load of 44.7 kW. The calculated load factor is of 47 % which seems to be quite acceptable.

2) Monthly Energy Generation, Consumption and Loss pattern of Mini Grid (Only HT line loss is consider)

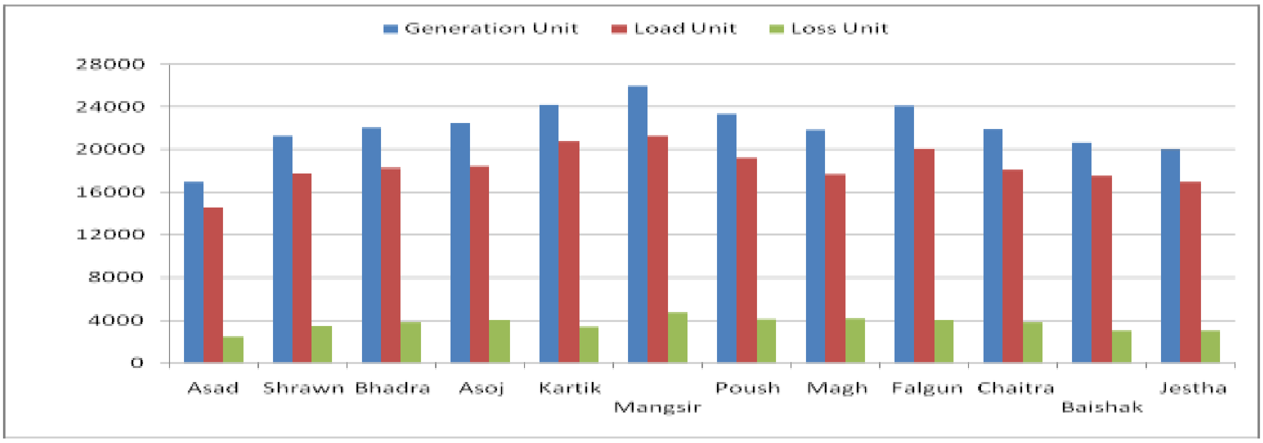


Figure 10: Energy Generation, Consumption and loss pattern per month

Figure above shows the Generation, consumption and loss scenario of the Mini Grid in the fiscal year of 2069/70. From this chart we can say that the maximum demand of electricity was occur in the month of Mangsir where total demand was about 20799 kWHr, total energy supplied was about 26000 kWHr. In that month total HT loss is about 4712 kWHr which is 18.13% and the system was operated at plant factor of 34 %. The demand was minimum in the month of Ashadh. The system loss depends upon the flow of the power and was maximum in the months of Mangsir.

3) Plant factor:

Plant factor indicates the extent of use of generating stations. If the plant is always run at its generating capacity, the percentage plant factor is 100%. Plant factor should be high to generate more revenue. We always try to increase plant factor. Plant factor is calculated by obtaining total no of unit generate from the plant for each months.

Month/ Scheme	Upper Kalung	Kalung Khola	Urja I	Urja II	Urja IV	Theulakhola	Mini Grid
Ashadh	16.4	26.7	21.2	23.8	20.4	22.0	22.1
Shrawn	24.6	33.3	29.2	26.5	23.6	24.8	27.6
Bhadra	30.6	32.2	25.9	34.5	36.3	20.8	28.7
Asbin	32.2	36.9	23.3	42.3	32.7	20.0	29.2
Kartik	32.3	34.8	30.0	39.9	34.7	24.1	31.4
Mangsr	27.9	30.3	31.5	48.3	29.8	39.1	33.7
Poush	20.8	35.0	31.6	48.9	34.7	20.0	30.3
Magh	19.4	30.3	26.6	47.7	27.6	26.2	28.4
Falgun	19.9	33.7	27.1	47.7	25.8	36.3	31.3
Chaitra	23.0	26.5	28.4	40.6	24.6	30.9	28.5
Baishak	13.5	32.0	27.9	31.0	22.1	28.5	26.8
Jestha	15.4	32.3	38.5	30.9	22.0	23.2	26.0

Table 19: Plant factor for each month of each plant

Table above shows the plant factor of individual generating stations and Mini Grid as a whole. From this it is clear that Upper Kalung Khola generating station operated in lower plant factor and Urjakhola II which is the smallest plant in the Mini Grid system operates in highest plant factor. Average plant factor of Upper Kalung is about 24 % and that of Urja Khola II generating station is about 40%. Urja Khola II Khola generating station operates at highest of about 50% plant factor in the months of Poush at which plant factor of overall Mini Grid system was only 30.3 %.

4) Energy consumption scenario of domestic Consumer:

The main characteristic of the rural electrification is low consumption rate, less reliability requirement and lighting is the main requirement. In the Mini Grid system most of the domestic consumers use electricity mainly for lighting purpose. In the analysis performed for 1125 consumer, to know the consumption rate of electricity, result obtained is shown in the figure.

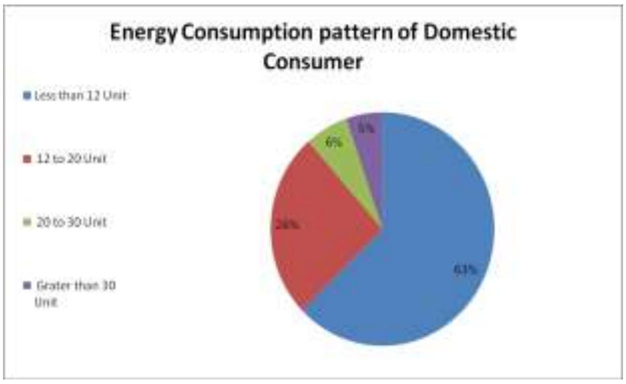


Figure 11: Energy Consumption pattern of domestic consumer

63 % of consumers use electricity less than 12 Unit per month. Only 5% of consumers use electricity more than 30 units per month. 26% use in between 12 to 20 unit per month and 6% use from 20 30 unit per month.

5) Yearly energy generation and contribution of each plant :

There are 6 Generating stations having capacity ranging from 9 to 26 KW within Mini Grid system. Each station sells the energy to Grid. Larger plant sells more electricity and vice versa. In the fiscal year 2069/70 the total energy generated by all plants is about 264886 units. The contribution of each plant is shown in the figure.

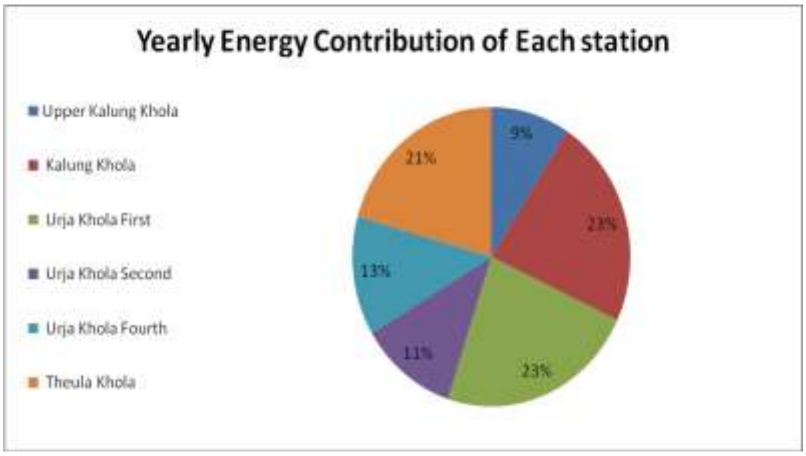


Figure 12: Yearly energy contribution of each plant

From this PIE chart it is clear that Urja Khola I (26 kW) and Kalung Khola (22 kW) contribute same % of energy. Upper Kalung Khola of 12 kW Capacity contributes lowest percentages of total energy generation.

5.2 Financial Statement of Plant and Co-Operative

The scope of this topic includes the financial analysis of Plants and Mini Grid. Here we consider the source of income for individual plants is only the sale of energy to the Grid. Some of the plants have small amount of income from the interest of deposit fund which was mobilized to the local communities, such incomes of plant is neglected in this study. Also for the Co-Operative some negligible amount of income was being generating from consumer service, dues etc, which has negligible effect on total income so such income of Co-Operative is not considered while making such evaluation. The sources of expense for Co-operative are:

- ✓ Salary of staffs.
- ✓ Expenses on book keeping, House rent, Meeting expenses, Communication expenses etc.
- ✓ Expenses on Grid operation and Maintenance.

Source of expenses for Micro Hydro functional Groups are:

- ✓ Salary of Operators and Manager.
- ✓ Regular maintenances of canal, intake, line clearance etc.
- ✓ Maintenance of equipment within the power house.
- ✓ Miscellaneous expenses e.g. communication, Meeting, stationary etc.

It is very difficult to determine the maintenance cost of control equipment provided by Y-tek controls India. For simplicity maintenance cost of each component is considered as the 20 % of the replacement cost of that equipment, which is taken from the quotation provide by that company. Other expenses are taken as per actual and are collected during field visit for this fiscal year. The details of calculation are presented in annex and result can be summarized as:

S.N	Scheme	Income	Expense	Revenue	Remarks
1.	Upper Kalung	101390	128752	-27363	
2.	Kalung Khola	260840	238736	22104	
3.	Urja First	266880	261900	4980	
4.	Urja Second	129305	214064	-84760	
5.	Urja Fourth	144120	198384	-54264	
6.	Theulekhola	238950	216028	22922	

Table 20: Annual financial statement of Plants

Annual Income, Expenses and Revenue of Co-Operative can be summarizes as:

S.N	Income	Expense	Revenue	Remarks
1.	363357	321000	42357	

Table 21: Annual Financial statement of Mini Grid

5.3 Financial Benefits of Mini Grid

Followings are the financial benefits of the Mini Grid.

- Income of power houses has increased. Basically power houses of capacity greater than 15 kW has increased their annual income by NRs 50000 to 70000 while power houses with capacity less than 15kW increased their annual income by NRs 15000 to NRs 30000 per annum. In above financial calculation lower plants Upper Kalung, Urja Khola II and Urja Khola IV seem to be financially unfeasible, the main reason behind this are increased salary of operator and maintenance of Panel equipment.
- It creates more than 55 job opportunity for local people through the establishment of Agro processing mills, Poultry farming, Computer Institute, Photo studio, electronic shop etc. People in this area are very motivated towards the establishment of small and medium sizes enterprises i.e. vision of small industries comes forward after establishment of Mini Grid.
- Individual earns a lot of money through small poultry farm, small saw mills, electronic shop, photo studio etc. Due to freedom from limited electricity use, small carpentry using electric grinder becomes important source of income for disadvantageous people.
- The income of Entrepreneurs has increased as they can use electricity any time of day and night as their requirement. Moreover, entrepreneurs can operate their enterprises continuously even if there are some problem in respective plants, in the case of forced outage and regular maintenance period.
- Many possibilities of financial strengthening of the micro hydro and Mini Grid seem to be possible by the establishment of medium sized industries, supply to communication tower, tone crushing plant, slate processing plants.

5.4 Financial Challenges and Issues

Followings are the major obstacles for the financial sustainability of Mini Grid:

- Low electricity consumption rate of domestic consumer.
- Higher repair, maintenance and replacement cost of control equipments. Older structures of the plants lead to more maintenance costs of civil, electrical and mechanical components.
- Lack of deposit fund with the Mini Grid and plants: It makes difficult for the replacement of equipments requiring huge costs such as to Transformer, Generator, damaging of transmission and distribution system.
- Expensive human resource cost for operation, management staffs, maintenance and resource person causes the additional financial burden over both business groups.

- Difficulties for end use promotion in the Mini Grid area due to adverse geology condition, bad structure of access road, individual biasness of community, lack of human resource etc are the main barriers for the end use promotion.

5.6 Social Impact Assessment

5.6.1 General

The service area of Mini Grid is restricted within the limited area of Rangkhani, Paiyauthanthap, and Sarkuwa and Dameak VDC of Baglung district. The approximate population of this area is about 9000 and about 1500 no of households. Among them approximately 200 households do not have excess of electricity till now. Some of them use small Peltric sets only for lighting purposes and others are planning to bring the National Grid which surrounds the whole service area of Mini Grid. Average monthly income of the households is about Rs.11,590.00 Rupees. Agriculture is the main occupation of the people. Besides this Governmental jobs, teachers, employment in private /public organization and especially abroad employments (army for India, British, Singapore, Malaysia and workers in gulf countries) are the main source of income. The literacy level is about same percentage as that of National scenario. There is complex community composition consisting of Bramhan, Chhetri, Magar, ,Damai, Kami, Sarki, and small numbers of Gurung (in Local language) and Hinduism is the main religion.

A numbers of social organizations provide services in this area. There are three Higher secondary schools (From 1 to class 12), one secondary school, one lower secondary school and a numbers of Primary and lower primary schools contributing for education growth of that area. Private boarding schools do not play any significant role in this area and there is only one private Boarding schools provide primary level of education. Children occupy almost 33% of total population. All of these have access of education. Higher secondary schools use computers for their practical course subjects. The trends of using the computers, printers are going to be increasing from Secondary to Primary schools from last years. For Bachelor and above level of education, students are used to move Kushmi Sera, Baglung, Pokhara, Kathmandu and Other cities of Nepal. A number of community owned Co-Operative has been established in the last years. Three health posts and some private medical clinica are providing health service for public. A steep dirty road of 35 Km long provides the access to the Kushmisera and Baglung Bazzar only in dry seasons. The communities are still out of scope of Internet and Banking service for which they must travel up to Kushmi Sera. Almost all HHs uses mobile phones (Nepal Telecom/N-Cell/Smart- Cell/CDMA/Sky phones) for communication and post office as required. All the HHs use at least one mobile phone for communication. Police station at Kushmi Sera and Barang oversees the overall security status of this area. Two cable industries provide Television service in this area.

Women are given priority for the social activities and their contribution in social organization, local politics, Education, Decision making process etc seems to be quite appreciable. A members of women managed Groups like AMA SAMUHA, Community based agriculture groups, active involvement in the dispute settlement of local groups etc. are gaining more and more reputation in this area. A numbers National NGOs and INGOS have been launching various programs for women empowerment and motivating them for income generating activities. To know impact of

Mini Grid we have performed an individual household's survey for 185 households selected randomly from each plant. According to this study

- ✓ 90 % consumers are satisfied from the service provided by Mini Grid and 10 % are not satisfied.
- ✓ 50 % of consumers think that the current management model is good, 34 % think bad and remaining are unknown to the management model.
- ✓ Following result is observe about the current tariff structure applied by Co-Operative

Description	Medium tariff	Cheap tariff	Expensive tariff
No of consumer	114	46	25

- ✓ For the question, does the formation of Mini Grid helps for end use promotion? The result can be summarized as.

Description	Yes	No	Unanswered
No of consumer	131	53	1

- ✓ 84 % of people think the quality of electricity is good for end use promotion, 10% think bad quality of electricity and 4 % of households are unknown to the quality of electricity.
- ✓ The income statement of 18% households was increased from the increased income from the end uses in last year.
- ✓ Almost 82 % of people use electricity only for lighting purpose.

5.6.2 Social Impact and Issues of Mini Grid

The social benefits of MG are summarized as follows.

- ➢ End Use promotion: Mini Grid plays important role for the end use promotion. A large numbers of existing end users are presented in the fact sheet of generating stations. Agro-processing mills, Furniture industries, Computer institute, Poultry firm, Electronic shop, Individual carpentry, Photo studio etc are the existing end uses. Various trainings, seminars, capacity building activities organized by the AEPC/RERL become the key source of motivation for the end use promotion. Local people are quite motivated towards the income generating activities through the establishment of small size enterprises. Communities are ready to maximize the use of rural energy. All the existing end use are presented in the data sheer of individual plants.
- ➢ Concept towards the use of electricity has been changed: Before Mini people thought that electricity is only for the lighting purpose but now they use electricity for various household purposes. According to household survey data.

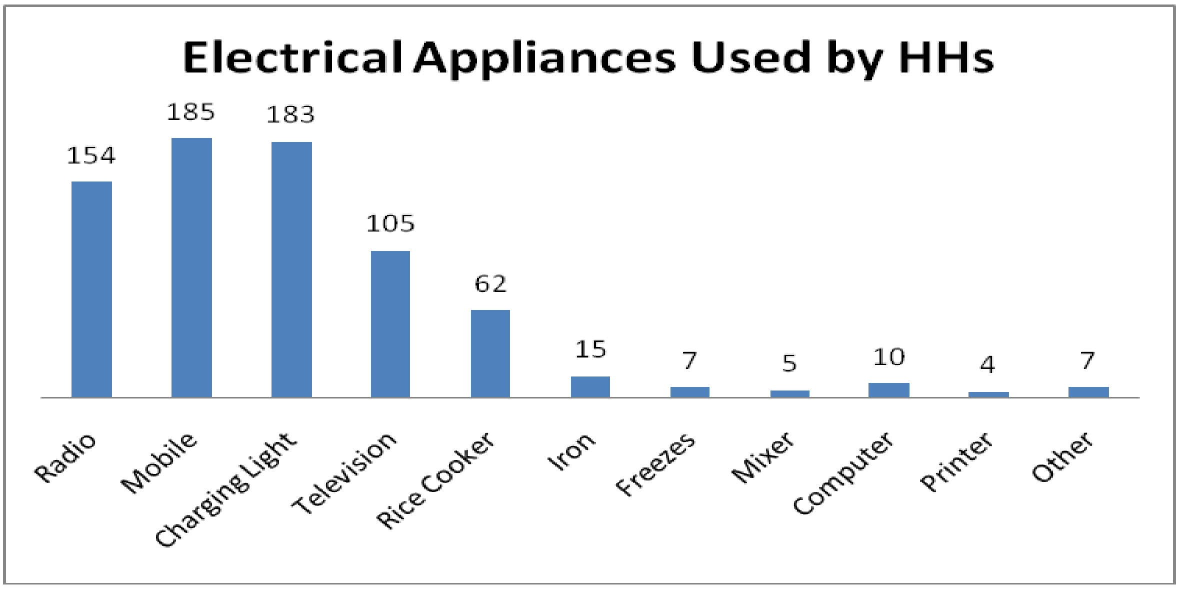


Figure 13: Electrical appliances used by HHs

Chart above shows the, number of consumers that use the various electrical appliances among the surveyed consumer which will reflect the overall scenario of all consumers. This study also shows that before Mini Grid formation each of households expenses monthly 36 hours to collect firewood, which is reduced now due to the application of Rice Cookers, Electric Induction cooker, Roti-maker, tea pot etc. Average cost of firewood per month per HHs was 1100 rupees prior to MG formation which reduces appreciably now.

- People know about saving the electricity: Power based tariff structure was used before Mini Grid concept, so consumers made large misuse of electricity. After using energy based tariff structure, people know the price of electricity and are shelf motivated for saving of electricity.
- Confidence of the community has increased to construct, own & manage bigger projects. Community mentality has changed and they are confident that micro hydro connected to mini grid can be the permanent source of electricity if utilized properly.
- Mini-grid unites the six different communities socially as well. That protects the MHPs from vanishing, even if the grid has already covered the area. Inter community Coordination seen due to the establishment of Cooperative in the Mini Grid society. Seven different community groups merge into one huge community and became members of common institution.
- It is easy for the educational institution for providing computer education and internet facility to the students because of availability of quality, reliable and continuous energy from Mini Grid.

Although there are lots of social benefits of the Mini Grid, equal social challenges have to be solved for the sustainability of this pilot project. Difficulty in Community mobilization, Lack of ownership feelings of Mini Grid, Local Political interference and individual biasness of local people, lack of unity of different community etc. are the major social issues of Baglung Mini Grid.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATION

Formation of the Mini Grid Network through the interconnection of nearby isolated Micro Hydro Plant can be the best method of solving the various issues of standalone MHP. Affordable and reliable supply to the rural communities of Nepal can be given through the construction of such local grids. Implementation of Baglung Mini grid opens the floor for the construction of such community managed projects. In a given context, such projects require suitable choice of technologies and implementation strategies right from the design stage. Mini Grid project has resulted much positive impact regarding technical, economical and social aspects to the localities in the short period of implementation. There are number of technical rationales for system interconnections, many of which have economic components as well. The technical rationales for system interconnection include:

- Improving reliability and pooling reserves: The amount of reserve capacity that must be built by individual networks to ensure reliable operation when supplies are short can be reduced by sharing reserves within an interconnected network.
- Reduced investment in generating capacity: Individual systems can reduce their generating capacity requirement, or postpone the need to add new capacity, if they are able to share the generating resources of an interconnected system.
- Improving load factor and increasing load diversity: Systems operate most economically when the level of power demand is steady over time, as opposed to having high peaks. Poor load factors (the ratio of average to peak power demand) mean that utilities must construct generation capacity to meet peak requirements, but that this capacity sits idle much of the time. Systems can improve poor load factors by interconnecting to other systems with different types of loads, or loads with different daily or seasonal patterns that complement their own.
- Economies of scale in new construction: Unit costs of new generation and transmission capacity generally decline with increasing scale, up to a point. Sharing resources in an interconnected system can allow the construction of larger facilities with lower unit costs.
- Diversity of generation mix and supply security: Interconnections between systems that use different technologies and/or fuels to generate electricity provide greater security in the event that one kind of generation becomes limited (e.g., hydroelectricity in a year with little rainfall). Historically, this complementarily has been a strong incentive for interconnection between hydro-dominated systems and thermal-dominated systems. A larger and more diverse generation mix also implies more diversity in the types of forced outages that occur, improving reliability.
- Environmental dispatch and new plant sitting: Interconnections can allow generating units with lower environmental impacts to be used more, and units with higher impacts to be used less. In areas where environmental and land use constraints limit the sitting of power plants, interconnections can allow new plant construction in less sensitive areas.
- Coordination of maintenance schedules: Interconnections permit planned outages of generating and transmission facilities for maintenance to be coordinated so that overall cost and reliability for the interconnected network is optimized.

There are large numbers of financial and social benefits of Mini Grid to the both users and plants which are discussed in previous chapters. Although, formation of Mini Grid is an effective way for long term sustainability of Micro Hydros, to achieve this goal, and there are many challenges on the way, including technical, managerial, financial and other regulatory issues. The technical, managerial, financial and social breakdown of Baglung Mini Grid, presented in this report may play important role for further enhancement of Grid development in Nepal. These issues must be resolve for the better sustainability of Baglung Mini Grid. The major findings of the reports can be summarizes as:

- Technically, it is a new technology, so the equipment and human resources for installation, testing and commissioning need to be imported at present. Since the cost and the time associated with the installation, operation and maintenance of imported equipment and technology is high, the technology should be developed at domestic level. Our technical team is quite motivated to make research for the development of ***"Third Generation Electronic Load Controller"*** within our country so we kindly request to AEPC/NRREP to make co-ordination with us.

- As it is being the new technology other issues like Power sharing, Metering, Protection, Central control and monitoring with appropriate communication mechanism between plant operators and in between plant operators and grid operator must be adopted, upgraded and enhanced for better effectiveness of Mini Grid. For effective load management and frequency stability it is better to construct an additional plant that feeds to Mini grid only. This also helps to meet the additional future load growth in the system.

- Managerially, the choice of the particular management modality depends upon the various factors like arrangement of Network formation, overall plant factor of the system, system size(Total capacity of integrated system), geological condition of the system , capacity of community to manage etc. From the beginning stage of design National grid like planning may help to solve various issues of Local grid management.

- The financial profile of both Business group (MHFG & Co-Operative or grid operator) is not attractive enough. To improve this, energy sell must be increased through the establishment of more and more end use to operate during day time and night time if possible. Connection with National grid will resolve all financial problems. Especially for small Plant of capacity less than 15 kW, either separate PPA rate shall be agreed or must be operated for more time per day. To improve financial state of Co-Operative additional activities like saving and credit, share distribution etc, should be adopted.

- Since there is large variation in power generation and consumption during monsoon and dry seasons. During monsoon seasons 70 % of energy is wasted but during dry season there is large shortage of electricity. Tariff structure may play important role to balance power in these two seasons. Although the present tariff seems to be practicable it needs to be revised according to result observed. It is better to adopt seasonal tariff structure i.e. different for monsoon and dry seasons which may play important role to keep power & financial balance.

- To eliminate the social issues and to make the feeling of ownership of Mini grid comprehensive workshop must be organized at site, including major stakeholders.
- Suitable guideline and framework need to be developed, which would reflect the entire context and directs the ways forward. Such guidance will provide information and required technical standards, managerial policy and possible financial approaches for a given context.
- Lastly, from the study it is seen that, the case of Baglung Mini Grid does not acquire the function of full National Grid however it is simply an interconnection of nearby plants which increases the quality and reliability of electricity significantly. So there are lots of challenges for its sustainability.

ANNEXES

Case Study for Urja Khola III Plant

Urja Khola Third Micro Hydro Plant is located in Paiyauthanthap Village Development committee, of Baglung District. The construction of Plant was started in 2060 and was completed in 2063 and is supported by REDP/AEPC, DDC, VDC and community. The canal length is about 900 meter long, with gross head 47 m, design discharge 110 lps and power output capacity of 25 kW. Total no of beneficiary households are 250.

Figure 14: Urja Khola III Plant

The actual site of this plant is situated in between Urja Khola II and Urja Khola IV stations of Mini Grid. Although Mini Grid network was successfully and commercially operated from the beginning of 2069, communities and MHP are benefited from Mini Grid, still this plant is running in isolated mode and people of this community do not make any response towards Mini grid connection. Sudden death of first Chair person of K2U2MGWC, who was also the Chair person of Urja III plant was the main cause of isolation of this plant from Mini Grid. Although installation of control panel was completed in that plant, this plant remains isolated from the Mini Grid Network. Mainly the social and financial (at the time of construction) problem within community, dominancy of single person over whole community, political biasness, lack of awareness of that particular community, uncertainty of successful implementation of imported technology at that time etc. are the main cause behind the isolation of this plant. Although various efforts were made to include this plant through a number of ways, successful result was not achieved towards grid connection. Good operation and management of Co-Operative, maintenance of imported technology of Mini Grid, concrete steps towards the National grid connection, solving the social and financial problems of Urja III and motivation of Community may bring the positive result towards the Mini Grid connection of Urja III Micro Hydro Plant.

RERL support for Mini Grid

Financial support:

- Support for office establishment.
- Support for establishment of communication center.
- Support for establishment of Chilling Vat.
- Planning to support for the establishment of Cold store & Crusher Industry.
- Planning to support for providing spare parts.

Capacity building & skills enhancement trainings:

- Field visit of mini grid for working committee to India.
- Seminar for fixing the operating modality of Mini Grid.
- Basic Technical training for operators through technology provider.
- Technical training (Operational and maintenance) for the technical manager, selected operators and local electronic maintenance entrepreneurs through technology provider.
- Line man training to the technical person of Mini Grid.
- Orientation for consumers about IPP Modality.
- Accounting system training for Accountant.
- Co-operative management & accounting system training for management committee and staffs.
- Rural electrification training for MHP functional group and Co-operative.
- Management training for plant manager.
- Seminar for designing the 1 year business plan and 5 year strategic plan.

Income generating activities:

- Business promoting training for local entrepreneurs.
- Poultry farming training.
- Computer training.
- Dairy product and chilling vat operation training.
- Kaulo to Agarbati manufacturing training.
- Lapsi to Achar, Morubba and Candi processing training.
- Bamboo and its product manufacturing training.

Possible Mini Grid cluster In Nepal

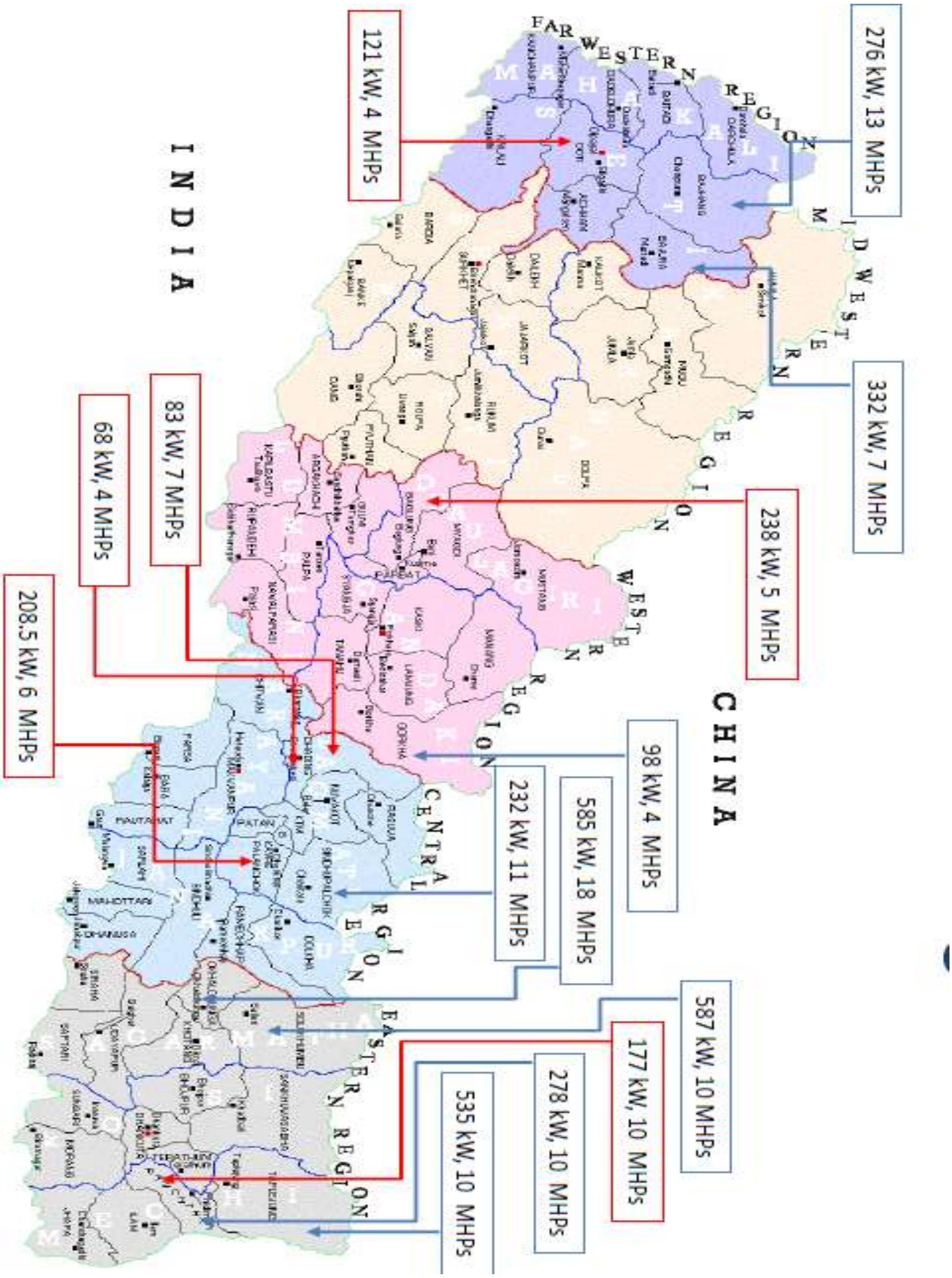
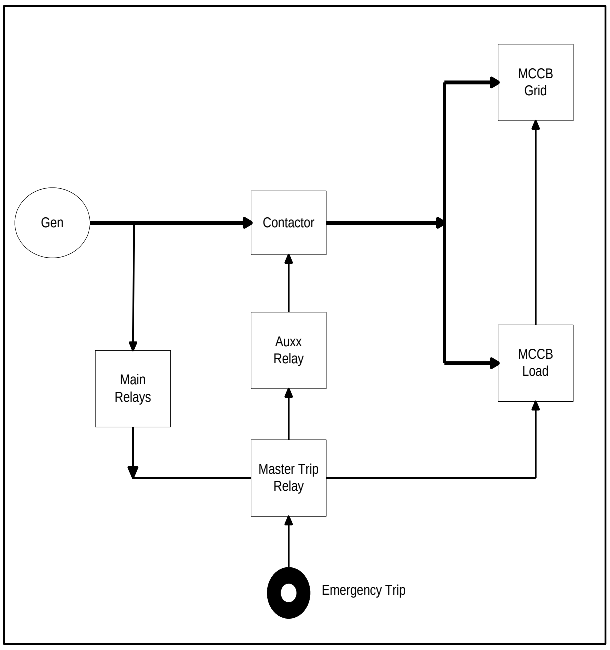
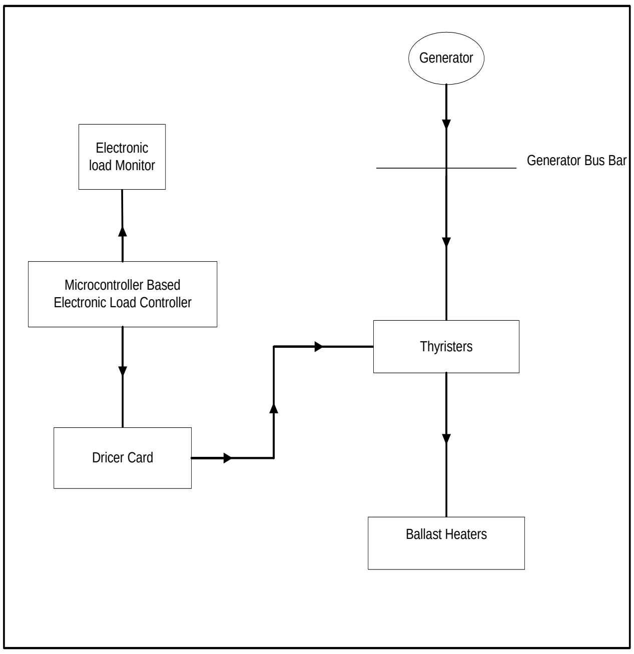


Figure 15 Possible Mini Grid Clusters in Nepal [Source: RERL presentation]

Block diagrams of Protection System & ELC





Block Diagram of Measurement system

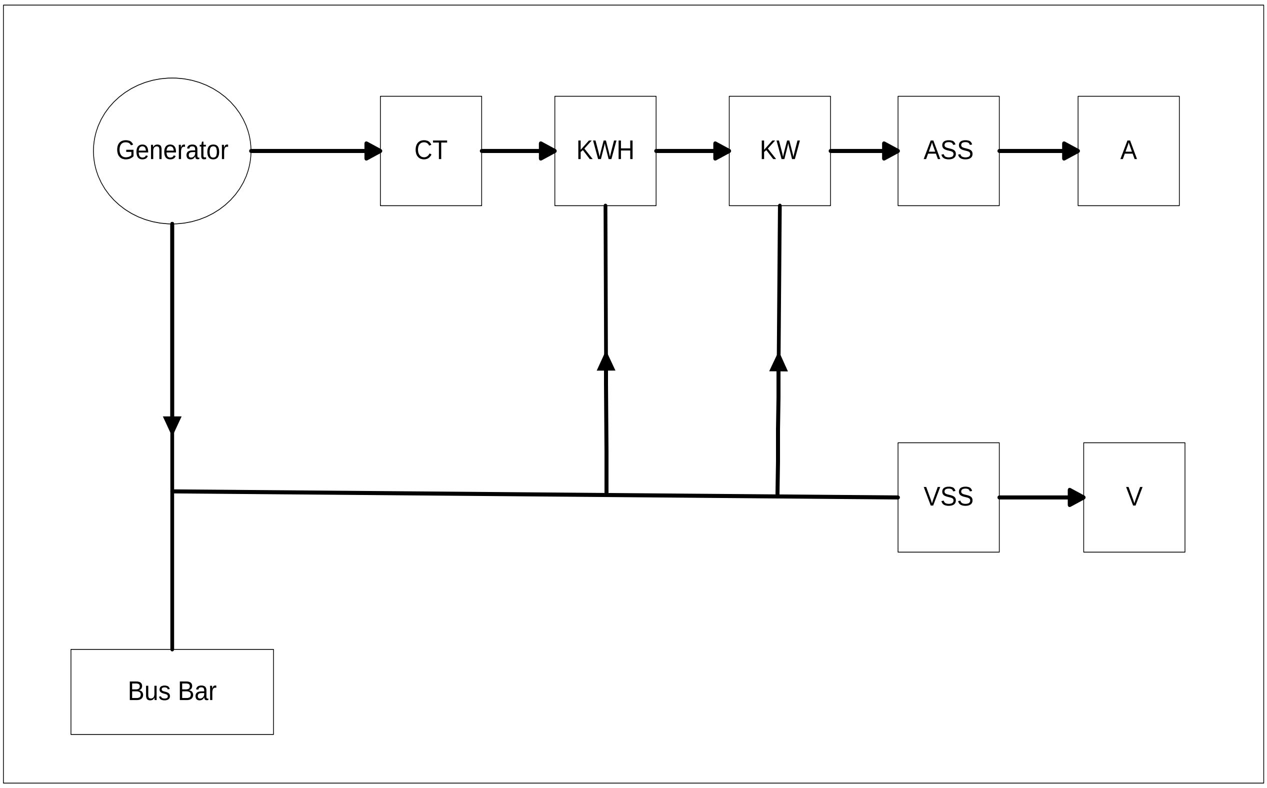


Photo Gallery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2013/05/29


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2013/06/03


2013/06/02


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