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Micro & Mini Hydro Based Mini-Grid for Rural Energy Access in Taplejung, Nepal

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Abstract

Mini-grid is an isolated, low-voltage distribution grid, providing electricity to a community – typically a village or very small town and derives electricity from a diverse range of small local generators using either diesel or renewable energy technologies with or without its own storage. There are different mini-grid exists in the world. Renewable mini grid is the mostly in the practice and in the operation. The renewable energy sources line solar, wing, hydro, diesel, thermal or combination of these. In this paper, mainly dealing with the hydro sources off-grid mini-grid for the access of energy in rural area eastern part of Nepal. The mini-grid having interconnection of different micro & mini hydro projects (MMHPs) for sharing the excess power to the place where deficit power area. The main objective of interconnection is to improve the system load factor, plant capacity factor, maximize the generation from MMHPs, good quality of power, improve the system reliability, business opportunities to sell excess energy and to serve the local or a regional load demand mainly the Taplejung district headquarter load. Mini grids incorporating renewable energy can be a cost-effective means of supplying affordable and reliable power to rural communities. The benefit and opportunities of Mini grid seems to be more promising in the sector of rural electrification in the coming days.

Keywords

Micro Hydro – Mini Hydro – Mini-Grid – Standalone – Off-grid – Distribution grid – Rural Energy – Interconnected – Power Quality – Reliability – Rural Electrification

Introduction

Nepal is a country blessed with tremendous hydropower potential. It is estimated that Nepal has 43,000 MW of hydropower potential which is techno-economically feasible. However, the present situation is that Nepal has only developed approximately 750 MW of hydropower though the history of development of hydropower dates back to a century. Around 43.9% of total population is yet to be electrified in spite of having abundant hydropower potential. Rural electrification reads to be only 51.5% where 83% of the total population resides. The lack of proper planning and management of energy sector by the government and a decade long civil war has resulted in limited production of electricity. In the present scenario, the clusters electrified by national grid are facing huge electricity shortage of around 12 hours a day during dry season. In this current scenario of electricity deficiency, it is almost difficult for the government to extend the national grid to the non-electrified rural areas.

1. Background

There is different source of electricity in rural area of Nepal in rural Area in off-grid. Micro hydropower plants, solar home systems, wind energy systems, biomass and biogas plants which are among the various forms of decentralized energy system are presently providing electricity to the rural areas. These renewable energy technologies have proven to be the most suitable for powering the rural communities of Nepal. Micro hydropower plants operating in isolation mode are serving many remote settlements of Nepal. They have been electrifying the rural communities for more than two decades which was only limited to lighting purpose.

Table 1: An overview of the current micro hydropower scenario in Nepal till mid July 2012

SN	Hydropower	Total Non-Subsidy Installation		Total Subsidy Installation		Grand Total		
		No.	Capacity (kW)	No.	Capacity (kW)	No.	Capacity (kW)	Capacity (MW)
1	Mini Hydro	41	15940	1	400	42	16340	16.340
2	Micro Hydro	167	2614.5	1120	21990	1287	24604.5	24.6045
3	Pico Hydro	87	264.5	1547	3438	1634	3702.5	3.7025
	Total	295	18819	2668	25828	2963	44647	44.647

The connectivity of the access road between rural and urban clusters has drawn the attention of rural communities to all form of modern electrical appliances like TV, Laptop and other electrical appliances, which they were unable to use due to limited power. Energy demands of the rural communities are also growing day by day. In the present scenario of power shortage in the national grid, it is almost impossible to supply electricity from National grid. The dissatisfaction of rural people in using electricity for only lighting purpose has forced the government to look for other alternatives. An effective use of decentralized energy technologies can be an option for already electrified settlements to get relatively fast relief form the present energy crisis on local level. Interconnection of micro hydropower plants forming mini grids, wherever techno socio economically viable, is one of the options for the rural electrified settlement to get access of electricity at rural place.

Development of renewable energy technologies (RETs), both on-grid and off-grid, has become crucial to increase energy access (including electricity) for better overall development, poverty reduction and shared prosperity. Isolated RETs such as micro hydropower, mini hydropower, solar photovoltaic (SPV) and biogas can substantially improve the rural economy. Specifically, micro hydropower plants (MHPs) have been serving off-grid rural households in the hilly regions since they were introduced in Nepal in the 1960s.

1.1 The focal agency in Nepal for off-grid Rural Electrification

The Alternative Energy Promotion Centre (AEPC) was established in 1996 as a central body of the GoN to promote alternative energy, especially in rural areas. Due to efforts by the Government of Nepal (GoN) and development partners since the 5th development plan (1975–1980), rural electricity access through MHPs and the number of stakeholders in this sector have been steadily increasing. With support from the AEPC, more than 25 MW of pico/micro/mini hydropower schemes have been providing off-grid electricity to more than 400,000 rural households.

Significant achievements in the micro hydropower sector have also brought about various challenges that require new approaches. One such major challenge is to address the MHP–national grid interface. As the state-owned electricity utility, Nepal Electricity Authority (NEA), extends its grid to rural areas, many MHPs become redundant if they cannot be grid-connected. According to a preliminary estimate by the AEPC, 90 MHPs with net capacity of 2.7 MW have been affected by the grid extension and this number is steadily increasing. The GoN continues to support isolated MHPs in areas where the grid is unlikely to be extended within a five-year time-period. However, since the NEA does grid extension planning on a yearly basis while the MHPs are built to have an economic life of minimum 15 years, it is hard to predict how grid extension will affect MHPs in the long term.

This issue is further compounded because the GoN does not formulate a separate rural electrification master plan. If the right policies for connecting MHPs to the grid are not in place, these plants will be forced to shut down and then abandoned. From a national perspective, shutting down such plants before their economic life is over is a waste of resources, especially as implementation of such MHPs has been subsidized and because significant investments have been made by the communities. On the other hand, if these MHPs are allowed to be grid-connected, the resources that have already been invested in building and operating these plants will continue to be utilized. Thus, scaling up and bolstering partnerships on grid-based approaches requires new perspectives by the GoN.

1.2 Hydropower category as per AEPC

As per the guideline from AEPC published under Government of Nepal have the following category for the category of different type of hydropower as per the delivery mechanism 2006.

Table 2: Hydropower Category as per AEPC

SN	Hydropower	Capacity Range
1	Mini Hydro	>100kW to 1000 kW
2	Micro Hydro	>5kW to 100kW
3	Pico Hydro	<5kW

1.3 Objectives

The overall objective of this research in the sector of mini grid/micro grid is how to interconnect standalone MHPs into a network to form a local mini-grid. The specific objectives are:

- How to change the technical parameters like load factor, reliability etc. of the overall system.
- How the load has been shared to each other by the MHPs in the networks.
- How the mini-grid for the rural energy access in system have been changed in the real scenario of development of Taplejung mini-grid for the transfer of energy from one MHPs to the another MHPs for the demand and supply management through interconnected Micro-Mini Hydro Plants Mini-Grid.

2. Micro-mini hydro scenario in Nepal

Before the 1960s, diesel-operated mills were used in the hills of Nepal for agro-processing. In the 1960s, small water mills known as “turbine mills” were introduced in Nepal using locally developed turbines as an alternative to diesel-operated mills. By the late 1980s, small generators were added to the turbine mills for lighting the mills at night and supplying surplus power to light a few houses in the vicinity. These turbine mills that were modified to supply electric power were known as micro hydropower plants (MHPs). Since the early 2000s more than 25 MW of micro/ mini hydropower schemes have been constructed with support from the Alternative Energy Promotion Centre (AEPC) and its various development partners. The Government of Nepal (GoN) in collaboration with development partners that support Nepal’s rural and renewable energy sector, designed the National Rural and Renewable Energy Programme (NRREP). The NRREP, being implemented by the AEPC for five years (from 2012 to 2017) as a single program modality, aims to install an additional 25 MW of micro/mini hydropower to provide electricity to an additional 150,000 rural households by 2017.

With the Nepal Electricity Authority (NEA; the centrally managed utility responsible for supply of grid electricity in the country) extending its grid to rural areas served by MHPs, the absence of a grid connection policy for MHPs will render such plants redundant. According to a preliminary estimate by the AEPC, the grid is currently approaching 90 MHPs9 with a total capacity of 2.7 MW and this number is steadily increasing. These plants will have to be shut down and abandoned as their customers switch to the national grid, which supplies power of better quality and does not impose power caps. Due to this trend, invested resources and the hard work of the local community are going to be wasted. Figure 1 shows the map of Nepal with the existing transmission and distribution lines down to 11 kV in MHP areas (i.e. hills and mountains) along with the installed MHPs as of 2013.

In Baglung the grid has reached the northeast part of the district where the interface with the existing MHPs has occurred. The other 17 districts where such interfaces have occurred are: Baitadi, Doti, Dailekh, Pyuthan, Myagdi, Kaski, Lamjung, Gorkha, Dhading, Sindhupalchowk, Kavrepalanchowk, Dolakha, Okhaldhunga, Khotang, Sankhuwasabha, Terathum, and Panchthar.

The MHP–national grid interface has created an urgent need for policy level discussion and coordination to avoid duplication of resources, maximize the benefits of investment, and provide sustainable electricity access to the rural population. Technical, financial, managerial/ownership, and community aspects need to be analyzed to propose how isolated MHPs can be sustainably connected to the grid. The adequacy of AEPC and NEA’s technical, environmental and policy frameworks, as well as regulatory guidelines have to be reviewed for sustainable promotion of the micro/mini hydropower sector.

2.1 Stand Alone MHPs

As mentioned earlier, standalone MHPs serve communities well in the absence of the national grid. With the subsidy and technical support provided by the GoN (through AEPC), the numbers of isolated MHPs are steadily growing. This alone indicates that there is: (a) a demand in non-electrified rural communities for MHPs, and (b) with subsidy support, communities are able to afford such MHPs. The majority of MHPs are functioning well beyond their economic life (15 years as per AEPC guidelines), which indicates that the technology has become sustainable. While communities have not been able to recover capital costs, they are able to meet the operation and maintenance costs.

2.1.1 Technical Reliability

Isolated standalone MHPs were found to be doing well except for a few minor technical problems. The most frequent technical problems discovered during the site survey were turbine runner damage due to silt abrasion, bearing rupture, ELC breakdown, and belt damage. Silt problems arise from bad design and construction of the settling (desilting) basin. A settling basin must be designed to lower the velocity of water by providing a large basin surface area such that abrasive silt particles can settle. Using a high-quality belt and bearings can help prevent these issues. The ELC diverts unused electrical power to ballasts (heaters) so that the frequency of the generator can be kept constant. ELC is a home-grown electronic technology manufactured in Nepal according to international design. ELCs are found to be highly susceptible to fault currents caused by lightening or short circuits. ELC breakdown can be avoided by using high quality lightening/surge arrestors to protect from fault currents. These minor problems can be avoided to a large measure by taking precautions, building a robust design and its faithful implementation. If these measures are taken, technical reliability of MHPs will be very high.

2.1.2 Ability to Meet Power Needs

Most of the MHPs met the lighting power needs of households adequately in their service area. However, most also were found to have a power deficit during the peak hours. The subsidy for MHPs is provided on the basis of 100–200 W/household. Due to increase in household demand (500–800 W rice cookers) and commercial use (7.5 kW agro-processing motors) of electricity, this 100–200 W/household ceiling for subsidy is becoming inadequate. This is resulting in load-shedding during peak hours and eventually, most MHPs will suffer from this problem as the demand for electrical energy increases and the installed capacity of MHPs remain constant.

2.1.3 Financial Viability

To determine financial performance of standalone MHPs, there are different parameters affect the financial viability of the projects. The factors are listed here as: Plant size, Plant life, Capital cost and financing mix of the MHP, Component-wise Capital Cost, Loads: Domestic and Commercial, Plant load factor, Tariff, Operations and maintenance costs, Salary cost, Financial analysis, Observations on Financial Analysis of Standalone MHPs

2.2 Interconnection of MHPs for form Mini-Grid

Interconnection of standalone MHPs into a local grid is termed a mini-grid. Often, as a community's power needs grow, isolated MHPs are unable to meet the growing demand. In such cases, a mini-grid could become the next available option. To form a mini-grid, some standalone MHPs must have power in surplus and others a power deficit. By connecting these MHPs to form a mini-grid, the power can be balanced between communities served by isolated MHPs, especially during off-peak and peak hours. Furthermore, with mini-grids, in case one or two MHPs are shut down, the others can continue to supply power although in limited loads (or to a small distribution area) thereby increasing system reliability compared with isolated MHPs.

However, in Nepal, mini-grids have been planned as one of the strategies to connect to the grid when it arrives in the vicinity of an MHP. The AEPC has been trying to form mini-grids that are at least 100 kW or more in size in response to NEA's reluctance to let MHP of less than

100 kW size to connect to the grid.

In Nepal, mini-grids have only been attempted as pilot projects. One such mini-grid is already operational since 2012 at Rangkhani, near Kushmishera in Baglung district. Another mini-grid is built in Gulmi by connection two MHPs to form mini-grid in Nepal and it is in operation in 2015. Therefore, technical reliability, financial viability and economic benefits of mini-grids are not fully confirmed.

2.2.1 Technical Reliability

The successfully implemented pilot mini-grid project in Baglung indicates that a mini-grid is technically reliable. The main challenges related to interconnecting MHPs are synchronization and load sharing between them. To achieve synchronization, the three-phase synchronous generators (alternators) of the interconnected MHPs must have the same voltage and frequency. Additionally, they must be connected to each other at the moment the three phases of one alternator line-up with the three phases of the other alternator.

2.2.2 Ability to Meet Power Needs

Mini-grids become pertinent where some of the nearby standalone MHPs have a power surplus while the others have a power deficit. The MHPs with power deficit can be upgraded to deliver more power; however, upgrading entails large quantities of civil and electrical works. At the same time, the MHPs with power surplus are wasting power when nearby MHPs with power deficit have an immediate need for more electrical power. By connecting these individual MHPs, loads can be shared between them to balance the surplus in some MHPs with the deficit in some others. The problem of load sharing is handled by conducting a load flow study. This study simulates the power delivered to probable loads and the losses in interconnection links (transmission lines) of a mini-grid. If one of the MHP's is shut down, the load flow study also indicates the loads that have to be disconnected from the mini-grid for proper operation.

2.2.3 Financial Viability

Usually, MHPs in standalone mode suffer not only from low Plant Load Factors (PLF) but also peak deficit during evening hours (17:00–22:00 hours) when most households are drawing power from it. During the rest of the period, they have very low loads and many hours when there is no load at all and the power generated is either dumped into the ballast or the MHP is simply shut down. When a few MHPs with surplus power during peak times, a few MHPs with peak deficit, a few MHPs with high loads during non-peak hours and a few MHPs with no loads/low loads during non-peak hours are interconnected and operated as a single distribution system, the overall PLF of the interconnected system is expected to be higher than the weighted average PLF of the individual MHPs taken together. The reason for the higher system PLF is for better utilization of surplus capacities and is the primary basis for forming a mini-grid of MHPs. It is pertinent to note that if there is no surplus during peak time in a few of the MHPs in the mini-grid, then there would be no improvement in quality and quantity of electricity delivered to households. Similarly, if there are no significant productive end-uses coming up during non-peak hours, then the PLF of the mini-grid does not improve significantly. More importantly, since productive end-use tariffs are usually higher than household tariffs, not having sufficient productive end-use loads will lead to little increase in revenue for the mini-grid.

Major costs incurred in forming a mini-grid of MHPs are in drawing of 11 kV high tension lines to evacuate power from each MHP and inject it into the distribution grid, installing appropriate ELCs with synchronoscopes which will automatically sense the mini-grid parameters (voltage, current, phase and frequency), and in matching the MHPs own parameters to synchronize the generating MHP with the mini-grid. In addition, microprocessor- based controllers sense the size of the load from the load centers and dispatch power from different MHPs in proportion to their installed capacity. Finally, appropriate and adequate protection systems are needed to ensure there is no backflow of current when an MHP is shut down for repairs and maintenance. Usually, the largest MHP is treated as the master and it sets the mini-grid parameters for other MHPs to match. In addition, it is used to provide the necessary reactive power and active power to charge the HT lines and transformers. Thus, the capital cost incurred in setting up a mini-grid depends on the number of MHPs being interconnected, the length of the high-tension line and the extent of load development expected which would determine the need for distribution transformers. However, the first two factors greatly determine the capex of a mini-grid.

3. Methodology

The following methodology is adopted for the study:

- Review different articles and papers.
- Studied reports and analysis report related to rural electrification and mini-grid in Nepal.
- Detail study report has been reviewed of the Taplejung Mini-Grid Development Functional Group (TMGDFG).
- Data has been analysed for the different configuration of the network and conclude final network configuration.

Figure 1: Location of Mini-grids that have been reviewed (Map Source: mapworld.com)

4. Study Area

The study area for this paper is chosen as Taplejung District of Nepal. Taplejung lies approximately 850 km North East of Kathmandu. Taplejung district lies in the Mechi zone of Eastern Development Region (EDR) of the country. The economy of the district is dependent on the agricultural production in which water, one of the known natural resources of the district, plays a great role. Taplejung district is one of the district which is not yet powered by central grid electricity. In the year 2041 BS Nepal Electricity Authority initiated a micro hydropower project namely Sobuwa Khola Micro Hydropower (125kW). The aim of the project was to power the house hold of the district headquarter Taplejung Bazar (Phungling Bazzar) and its nearby vicinity.

As the micro hydropower plant establishment was more than 15 years during that time, it was only able to generate 90 kW of power. During the span of last 15 years the load demand was more than 400 kW in the year 2058 BS. Due to huge gap in the energy supply and energy deficit there was power shortage throughout the day. As there was no possibility of nation grid extension to the district, the local people came up with the idea of Diesel Generator (DG) Plant Installation and supply the load by DG and micro hydropower plant in scheduling basis. There was installation of 250 kVA diesel plant in the year 2066 BS forming total install capacity of around 250kW (160kW from DG + 90 kW from MHP). By that time the system peak load was above 580kW. When the system load curve and generation details with and without DG plant is shown is far away. After the introduction of DG in the power system the people of Taplejung Bazar got relief from acute power shortage for at least 7-8 hours a day. In the present scenario, there is load shedding for more than 8-10 hours a day. In the vicinity of the Taplejung Bazzar, there are many Micro hydropower Projects in 13 VDC (Tiringe, Phawa Khola, Sikaicha, Phurumbu, Hangdewa, Lingkhim, Ekhabu, Tapethok, Khejinim, Sanwa, Thukima, Nalbu, Lingtep) of Taplejung District, Nepal. There are 12 Micro Hydro Project in that area currently operating in islanding mode. The pin in the figure represents the isolated MHP.

Now the concept is coming out for the formation of these micro hydropower projects are for interconnection forming 11kV transmission line in an islanding mode to fulfil the demand of the Taplejung Bazzar by sharing the surplus power to the grid and supply to the Taplejung Bazzar. This local grid can be either operated in islanding mode or connected to central grid in future.

5. Technical details

To fulfill the purpose, the first detail feasibility study was made in year 2013.

5.1 Technical details with 12 MHPs interconnected Mini-Grid

Today, conservative calculations of life-cycle costs show that hybrid mini grids, powered chiefly by renewable energy with a genset – normally working on diesel fuel, are usually the most competitive technical solution. However, translating this great technical potential into real success stories on the ground has turned out to be extremely challenging. Deployment of hybrid mini grids involves complex financial and organizational questions. The bottlenecks for the sustainable success of mini grids are not the technologies, but financing, management, business models, maintenance, sustainable operations, and socioeconomic conditions.

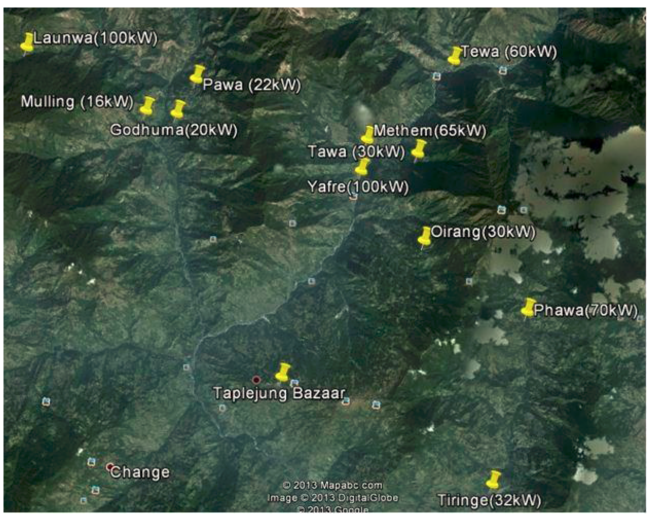

Figure 2: Bird Eye View for the different MHPs in the Vicinity

Each community presents a cluster of characteristics and interests which will define the best technical solution according to local financial, social, and environmental terms. The isolated micro hydro powered village electrification is presented in Figure 3.

This study addresses those rural communities for whom mini grids are the most suitable solution and underlines the benefits of using a mix of technologies based on renewable energies especially powered by small hydropower. It focuses on rural communities isolated from public grids and without any prospect of connection in the next 15-20 years; having a certain load demand and serving a concentrated group of 15 or more households.

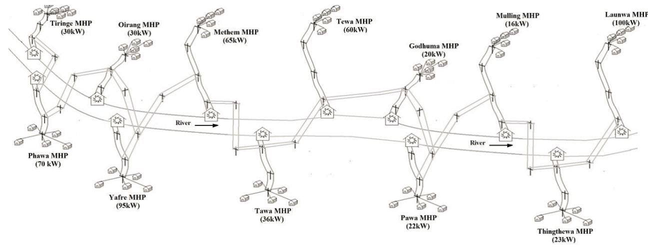

Figure 3: Isolated Micro-Hydro Powered Village Electrification

The lessons learned from these projects will create a new approach towards mini grids. Whereas the traditional approach was centered on the technological aspects, the new one focuses on end-users, their needs and involvement, capacity building, markets, policies, financing, and allocation of responsibilities. The major area of the finding will be on the technology adopted for mini–gird, the governance practice for implementing the project, socio-economic analysis, the working modality used to run the project smoothly, the technical difficulties and related issue regarding the operation and maintenance of the project. This new approach does not lead to any master plan, but helps formulate solutions adapted to local conditions and national frameworks.

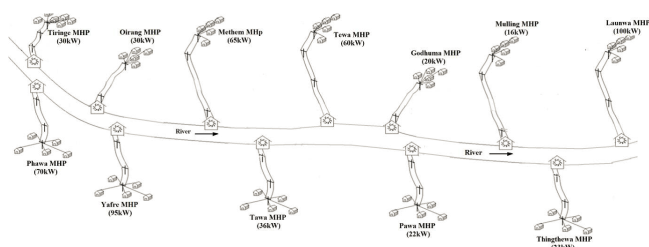

Figure 4: Arrangement of Mini grid network

There are twelve micro-hydropower plants ranging from 16 kW to 100 kW with total output power of 567 kW connected to mini grid power system of length approximately 65 km operating at 11 kV with ACSR Rabbit conductor for power transmission. The summary of the plants with their locations, installed capacity and beneficiary households are presented in table 3.

In this concept, the total power generated through the 12 MHPs are accumulated and supplied to the Taplejung Bazzar to sell the energy. But due to the conflict in some of the MHPs to form the mini-grid. Then a modified detail study is made in the different options for

Table 3: Technical Details of Individual Micro Hydro Plants

SN	Name of MHP Plant	Gross Head (m)	Design Discharge (lps)	Installed Capacity (kW)	House-hold (No.)	Year of Establish-ment (BS)	Generator Capacity (kVA)	Turbine Type	Governor Type
1	Tiringe Khola MHS	50	120	30	281	2063	40	Crossflow	ELC
2	Phawa Khola MHS	42	305	70	585	2068	140	Crossflow	ELC
3	Oirang Khola	70	85	30	300	2063	60	Pelton	ELC
4	Yafre (Mauwa) Khola MHS	147	113	95	800	2070	180	Pelton	ELC
5	Methem Khola MHS	178	65	65	400	2069	140	Pelton	ELC
6	Tawa Khola MHS	119	63	36	289	2067	70	Pelton	ELC
7	Tewa-Mekwa MHS	70	160	60	407	2069	125	Pelton	ELC
8	Godhuma Khola MHS	59	70	20	195	2066	40	Pelton	ELC
9	Pawa Khola MHS	96	47	22	200	2063	45	Pelton	ELC
10	Mulling Khola MHS	115	28	16	135	2066	35	Pelton	ELC
11	Thingthewa Khola MHS	305	31	23	185	2063	45	Pelton	ELC
12	Launwa Khola MHS	130	135	100	535	2070	180	Pelton	ELC

the operation of mini-grid.

5.2 Technical details with 8 MHPs interconnected Mini-Grid

The detail study carried in December 2015 out again in 10 VDC of Taplejung District namely Phawa Khola, Sikaicha, Hangdewa, Linkhim, Phurumbu, Khejenim, Ekhabu, Hangpang and Phungling VDC to study the possibility of interconnection of MHP forming a local grid. The main objective of interconnection is to improve the system load factor, plant capacity factor, maximize the generation from the MHPs, good quality of power, improve the system reliability, business opportunities to sell excess energy and to serve the local or a regional load demand mainly the Taplejung district headquarter load. The district headquarter is in acute energy crisis throughout the day with expensive tariff of Rs 24/kwh as it is powered by diesel power plant for more than 8 hours a day. The district headquarter is not yet connected to national grid.

These eight number of micro hydropower are proposed to be connected via 11 kV local grid with rabbit ACSR conductor with a total length of 41 km in islanding mode. Out of total 42 km there exist 11 km network so only 31 km of network is proposed. The total installed capacity of the plants is 541 kW benefitting 3574 no of household in the mini grid cluster and 1704 household in the cluster of Taplejung Bazar, Phungling. The largest size of the plant is 95 kW while the smallest size is of 36kW. One mini hydropower plant of 360kW is under construction which is expected to be completed by Jan of 2017.

After the commissioning of mini hydro, it will be connected in the proposed mini grid resulting the total installed capacity of the system to be 901 kW. Combining the mini grid cluster and Taplejung Bazar as a single load, the base load of the system is 187 kW whereas the peak load of the system is 733 kW while the supply of power is limited to 503kW. There is a peak deficit of 230 kW power during hours 18:00-22:00. After interconnection the load factor, plant factor and utilization factor are to be improved to compared present.

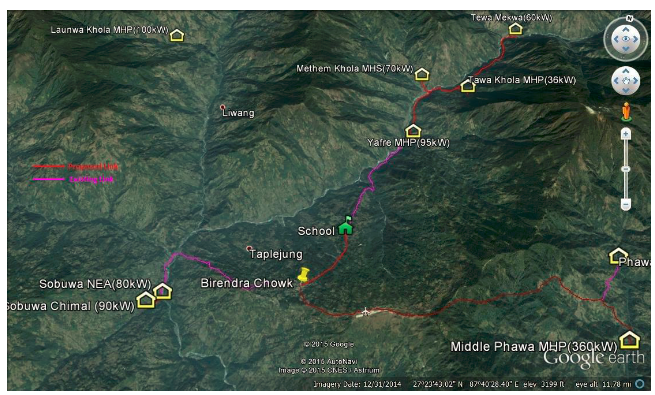

Figure 5: Bird eye view of Interconnection of MHP in Taplejung District

5.3 Working Principle Of The Mini Grid Power System

Among the 8 micro-hydropower plants, Yafre Khola MHS with installed capacity 95 kW near the big load center is considered as the master unit. Since the whole mini grid is in isolation mode, Yafre MHS is operated at no load condition. The power generated is dumped as ballast load; the percentage of the ballast load will be

Table 4: Technical Details of the TMGDFG with 8 MMHPs

SN	Name of MHP Plant	Gross Head (m)	Design Discharge (lps)	Installed Capacity (kW)	House-hold (No.)	Year of Establish-ment (BS)	Generator Capacity (kVA)	Turbine Type	Governor Type
1	Phawa Khola MHS	42	305	70	585	2068	140	Crossflow	ELC
2	Middle Phawa HEP**	48.5	950	360	1700	2073	2x250	Francis	Electro Hydraulic
3	Yafre (Mauwa) Khola MHS	147	113	95	800	2070	180	Pelton	ELC
4	Methem Khola MHS	178	65	65	400	2069	140	Pelton	ELC
5	Tawa Khola MHS	119	63	36	289	2067	70	Pelton	ELC
6	Tewa-Mekwa MHS	70	160	60	407	2069	125	Pelton	ELC
7	Sobuwa Khola (Chimal) MHP	68	211	90	750	2012 AD	180	Crossflow	ELC
8	Sobuwa MHP*	68	220	125	1705	1986 AD	200	Turgo	Flow Control

* Sobuwa MHP (Sobuwa NEA 90kW) is the project is actually 125kW but it is generating 80kW. So this plant is not considering as master plant.
** Middle Phawa HEP 360kW is not commissioned yet. So it is not considered as master plant in this design.

displayed in the ELC monitor or load meter. Now the 0.4 kV bus bar is energized by operating the contactor and the circuit breaker towards the grid side is closed. The direction of the power flow will be from G-A-B-D as shown in Figure 6. The power generated is used to charge 11 kV, 3 phase, Single Circuit, 65 km long transmission line and the distribution transformers. The transformers are operated in bi-directional mode. When the mini grid is charged some portion of power is consumed by the grid, rest is dumped as ballast load in the ballast heater. Now, the grid voltage & the grid frequency is determined by the first plant Yafre MHS. When the second plant is operated say Phawa Khola MHS, it will firstly be operating at no load condition, i.e. most of its load is being dump in the ballast heater. When the grid side circuit breaker is closed, the grid parameters are available at 0.4 kV bus bar of Phawa Khola MHS. In this case the power flow is in the direction D-B-A as shown in Figure 6.

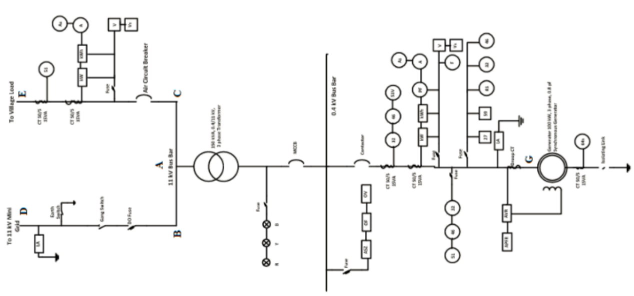

Figure 6: Single line diagram of the control panel & bus bar arrangement of Yafre MHS
Source: Ytek Control/Deharadun, India

The grid voltage & frequency are shown in the digital meters in the control panel. Now the Phawa Khola MHS generating voltage & frequency is matched with the incoming grid parameters.

Synchronization Check button is pressed which starts comparing the voltage and the frequency parameters between the grid and the generator. Dark Lamp method is applied for synchronization. It can be done in automatic (auto) mode or manual mode. The voltage is adjusted by the external AVR on the control panel and the frequency is maintained by adjusting the discharge. The generating parameters are thus matched with the incoming grid parameters.

The contactor is closed automatically when it's in auto synchronization mode and the synchronization is done. Now the same procedure is repeated and the village load is also connected after each the plant synchronization to maintain the stability of the system.

Single line diagram of control panel and bus bar arrangement of Yafre MHS is shown in Figure 6. After the synchronization is done one of the load center breaker of Yafre MHS cluster is closed with its respective load. The load is shared by both the generators according to their capacity proportions. Similarly, other generators are also connected to the mini grid.

Micro controller based static relays are used in the control panel for protection under different fault and abnormal conditions. They have over and under voltage relay (59), over and under frequency relay (81), reverse power relay, phase unbalance relay (32), earth fault relay (64), over current relay (51), Voltage restraint over current relay (51V), phase sequence relay and synchronization check relay(ASZ25). Whenever there is a fault or abnormal condition, these relays get energized and gives signal to the master trip relay which closes normally open contact in series with the contactor and the faulty part gets disconnected and the generator remains out of synchronism. If any of the plant is on maintenance mode the village load can be powered without operating the generating units of the respective load center, it can be powered by the grid power via 11 kV bus bars as shown in Figure 6 along the path D-B-A-C-E. The reverse power relay is used to protect the generator from the flow of reverse power. The details of the control panels, metering and the breakers of Yafre MHS are shown in Figure 6. The metering includes the village load and mini grid parameters including Voltage (V), power (kW), Energy meter (kWh) and Current (I). It also includes dual voltage, dual frequency, Excitation Voltage & Current, Power factor, ELC monitor or load meter and Annunciator.

Finding and implementation of revised concept in this mini-grid are described below and this in the one focus area of this paper.

- The protection system is considered and implemented in the design in the control panel are robust than the previous mini-grid systems.
- The contactor is in generation side in such a manner that it will supply continuously without interruption and it will disconnect to the generator if there is fault in the power house or in generation side.
- The MCCB is used in grid side and it will operate if there is fault in the grid side of the mini-grid system.
- In local load, here it is proposed the ACB (air Circuit Breaker) and it is more accurate than MCCB and if there is any fault in the local load it will operate and there is no any disturbance in the generation side and there is continuous supply to the mini-grid.
- There is some change in the supply model to the local loads. In this mini-grid proposal, the local load is supplied from the mini-grid and due to that all the power is first deliver to the grid by the individual power producer and mini-grid community will sell the electricity as per the demand to the local loads. It means it will help the mini-grid community to control all the generation power as per the requirements and the mini-grid community will sell the power as per their requirements.
- It also helps the mini-grid to sell the power and generate the revenue and accordingly they will control the revenue as per the grid demand.

5.4 Load Details

The mini grid powers around 5279 households (3574 Households in mini grid cluster and 1704 Households in Taplejung Bazzar cluster) and small scale rural industries. The small-scale industries in mini grid cluster include 10 rice cum oil expeller mills, 4 saw mills and furniture industry, 6 poultry farms, 5 communications cum computer center, 1 thukpaa processing plant and 2 bee hive manufacturing cottage industries. The capacity of small scale industries varies from 0.4 kW to 10kW in size.

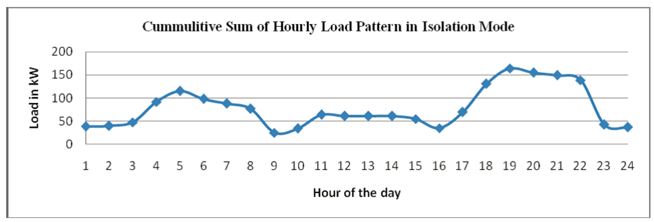

Figure 7: Hourly Load consumption & generation of Taplejung Bazar without DG

The average hourly load curve has been plotted combining all the energy meter readings obtained from 12 power house as shown in Figure 7. While the load details of Taplejung Bazaar clusters are 1704 Households, 20 no of small scale industries including grill, furniture, printing press, thukpaa processing, mills, bakery and other. There exist more than 44 government offices, 7 Private Banks, 2 FM stations etc. After interconnection of MHPs and including the load of Taplejung cluster the system load factor has risen abruptly from 49.79% to 71.91%. The base load of the overall system is observed to be 187 kW while the peak load as 733 kW.

The increment in the demand is observed during 18:00-22:00 hours, there is deficit of 230 kW of the power during the peak hour. There has been remarkable increment of load factor, plant factor and utilization factor from 49.79%, 20.44% and 50.315 to 71.91%, 61.13% and 100% respectively.

5.4.1 Hourly Load Consumption Pattern in Isolation Mode

In the stand-alone mode, the micro hydropower is used to feed the load only near its vicinity. The five power plants of size 36 kW to 95 kW are used to supply power to 3574 households in 10 VDC of Taplejung district and more than 15 different types of end uses. In standalone mode, the hourly load consumption pattern has been plotted combining all the reading of 8 energy meters in the respective power houses. It has been observed that the base load of the system is 25 kW while the peak load of the system is 164 kW. The load factor, plant factor and utilization factor in the isolation mode are 49.79%, 20.44% and 50.31%. The assumption is only for five micro hydropower plant which is not associated with the supply to the Taplejung Bazaar. The cumulative sum of hourly load consumption pattern in standalone mode is shown in figure 8.

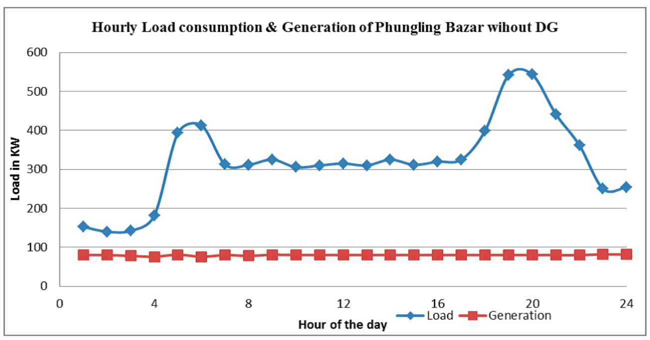

Figure 8: Cumulative Sum of hourly load consumption pattern in isolation mode

5.4.2 Hourly Load Consumption Pattern in Interconnected Mode

After interconnection of micro hydropower projects and feeding the mini grid cluster load and Taplejung bazaar load, the system performance parameter has been drastically improved. The load factor, plant factor/capacity factor, utilization factor has been improved to 71.91%, 61.13% ,100% as compared to 49.79%, 20.44% and 50.31% in isolation mode. In this scenario, the base load of the system is observed to be 245 kW while the peak load of the system is 498 kW. The peak load of the system is observed during 18:00-22:00 hours of the day. The assumption is made on the interconnection mode connecting 7 Micro hydro Projects and Taplejung Bazar load. The hourly load curve of the system in interconnection mode is presented in Figure 9.

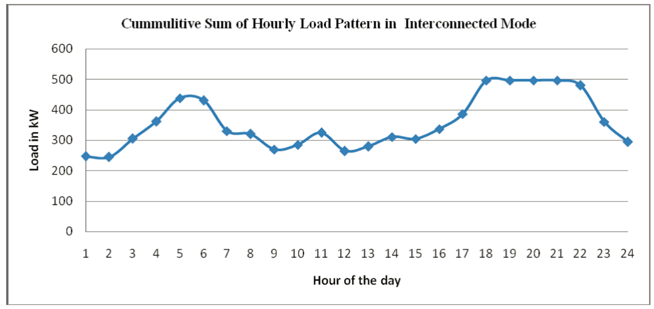

Figure 9: Hourly Load curve of the system in interconnection mode

The hourly load curve of the system before and after interconnection of MHP with mini grid load cluster and Taplejung Bazar Load is presented in the figure 10. From the data analysis, it is seen that the base load of the interconnected system is 187 kW and the peak load of the system is 733 kW while there is deficit in the supply of energy during peak hour from 18:00-22:00 hours of the day. The deficit power during the peak is 230kW. During hour 05:00-07:00 there is also deficit of power 32kW. There is a mini hydro power plant of 360 kW which is under construction phase at Sikaicha VDC namely Middle Phawa Khola Mini Hydropower Project (360 kW). It is expected to be commissioned by the starting of the year 2017 thus the deficit energy during the peak hour of the overall network is compensated by the additional power injection. The demand and supply trend of energy after interconnection is presented in the figure 10.

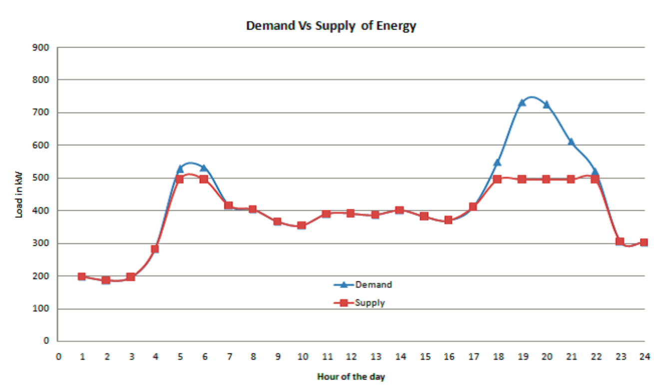

Figure 10: Demand and Supply trend of energy after interconnection

6. Summary cost for interconnection of MHPs

The total cost of project is NRs 4,14,63,500.00 without interest during construction. It consists the cost of 11 kV Local grid transmission system with transformer, steel pole, insulators etc., cost of protection control panel, transportation cost, cost of spare parts, equipment's and cost of testing, commissioning and installation of overall system. All the costs are inclusive of 13% VAT and 5% contingencies. The summary of costs of the interconnection of MMHP in Taplejung District is presented in Table 5

Table 5: Summary of Interconnected mini-grid cost

SN	Descriptions	Amount (NRs)	Sharing (%)
1	11 kV Local Grid Network Cost	27,225,196.00	65.66
2	Power House Control Panel & Protections	8,590,400.00	20.72
3	Installation, testing & Commissioning cost	3,540,000.00	8.54
4	Spare parts and Tool Cost	1,281,904.00	3.09
5	Transportation Cost	826,000.00	1.99
6	Total Project Cost for Local Grid (NRs)	41,463,500.00	100.00
7	Total Project Cost for Local Grid (USD)[a]	383,353.37	

[a]Exchange rate: 1 USD = NRs 108.16

7. Conclusions

The study of the project area shown that interconnect of MHPs in a mini-grid power system network in a sustainable way, lot of parameters including technical, financial, business model and other have to be modified. In technical parameters, it requires a 11kV radial network to interconnect all the eight MHPs for power transfer and exchange between the power plants. The possibility of connection of MHP to mini-grid was done after modification of control panel, protection system, metering and AVR based on data available from field. The calculation from the energy meter reading of daily load profile of each plant was plotted and observed that the system load factor was improved from 49.79% to 71.91% after interconnection.

In the overall system network of mini-grid, the base load of the system is 187 kW and the peak load of 733 kW with peak shortage of 230 kW power in the 18:00-22:00 hours. Thus, it seems soon to construct the 360kW power and inject into mini-grid to get rid of power crisis in the peak hours. However, technical analysis of mini-grid in the research shows that interconnection of these decentralized MMHP improves the system efficiency and reliability. After interconnection, the electrical power will not only be limited to lighting use, it can power a good number of end uses, small scale industries and various incoming generating activities.

The study has revealed that interconnection of micro hydropower plant improved the load factor of the whole generation system, the quality of power, reliability, increased in income generation of the IPPs, and improvement in the socio-economic dimensions. Mini-grids incorporating renewable energy can be a cost-effective means of supplying affordable and reliable power to rural communities. The benefit and opportunities of Mini-grid seems to be more promising in the sector of rural electrification in the coming days.

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References

[1] AEPC/NRREP: *Baseline preparation for rural and renewable energy technologies*. AEPC, Kathmandu, 2014

[2] AEPC-RERL: *Proceeding of Workshop on Experience sharing of Mini Grid and Biomass Gasification*. Workshop on Experience sharing of Mini Grid and Biomass Gasification, AEPC/Renewable Energy for Rural Livelihood Programme, July 12, 2012

[3] Alternate Hydro Energy Centre Indian institute of Technology Roorkee: *Standards/Manuals/Guidelines for small hydro development, Electro-mechanical Works -Power Evacuation and Inter Connection With Grid*. AHEC, 2011

[4] Bhattacharyya, S. C. and Palit D.: *Mini-Grid for Rural Electrification of Developing Countries- Analysis and case studies from South Asia*. Springer, 2014

[5] CED: *Interconnection of Micro hydropower projects in Taplejung district*. Alternative Energy Promotion Centre, 2014

[6] SMART Consult: *Detailed study report of transmission survey/ mapping/design and cost estimation of seven micro hydropower project for mini grid formation in Taplejung District*. AEPC/RERL, 2015

[7] EcoCoDE: *Techno-Socio-Economic study of Baglung Mini Grid*. AEPC, 2013

[8] Pokhrel S.: *Compressive Study of Community Managed Mini Grid*. International Journal of Emerging Technology and Advanced Engineering, 3:514-520, 2013

[9] ME Solutions: *Final Report Analysis and Design of Taplejung Mini-grid*. AEPC/Renewable Energy for Rural Livelihood Programme, Kathmandu, 2014

[10] MEC Consultancy: *Detail feasibility study for Mini-grid development in Urja Upatyaka, Baglung*. AEPC/Rural Energy Development Programme, Kathmandu, 2007

[11] Pandey R.: *Technical and Socio- Economic assessment of a community based mini- grid in Baglung District of Nepal*. Masters of Industrial Engineering for developing countries, University of Flensburg, Germany, 2010

[12] Maps of World: *Nepal District Map*. http://www.mapsofworld.com/nepal/nepal-district-map.html, 2014

[13] Shakya B.: Mini Grid Development in Nepal: An Experience from RERL', Workshop on Experience Sharing of Mini Grid and Biomass Gasification. AEPC/ Renewable Energy for Rural Livelihood Programme, July 12, 2012

[14] World Bank: *Nepal: Scaling Up Electricity Access through Mini and Micro Hydropower Applications A strategic stock-taking and developing a future roadmap*. The World Bank Group, Nepal Office, Kathmandu, 2015

[15] Nepal Rastra Bank: *Webpage information for foreign exchange*. http://www.nrb.org.np/fxmexchangerate1.php?YY=2016&MM=02&DD=02&B1=Go, 2nd February 2016.