International Journal of Emerging Technology and Advanced Engineering
Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 514-520
An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

COMPREHENSIVE STUDY OF COMMUNITY MANAGED MINI GRID

Sanjeev Pokhrel[1], S.K.Singal[2], S.N Singh[3]
[1,2,3]Alternate Hydro Energy Centre (AHEC), Indian Institute of Technology Roorkee, India.
E-mail: [1]**er.sanjeevpokhrel@gmail.com**

ABSTRACT

Mini-Grid is an innovative and cost effective solution to deliver reliable electricity supplies to households and commercial use. Implementing such projects involves complex technical, financial, policy and organizational issues which must address the end-users and their needs. Other challenges include capacity building and training, tariff and subsidy mechanism and institutional strength. The current paper deals with the comprehensive study of community managed mini-grid having few micro-hydropower plants in Nepal. The lesson learned from these projects will create a new approach towards mini-grid in technology and model transfer. The paper intends to explore the technology adopted for mini-grid, the governance practice for implementing the project, policy barriers and related issues regarding the sustainability of the project.

Keywords: Mini-Grid, On-grid, Off-grid, Micro-hydropower, Micro Hydro Functional Group, Independent Power Producer.

1. INTRODUCTION

Out of the total world population about 1.3 billion people live without access to electricity [1]. The total electrified population will not increase without a concerted effort. In context of Nepal, 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 [2]. Over past four decades, around 2500 micro-hydro plants (ranging from 5kW to 100kW including IWM and Peltric Sets) have been constructed in Nepal providing electricity to over 200,000 people in remote areas [3]. 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 lighting 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 considerations, 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.

The paper presents a case study of Mini-Grid development in Energy Valley, Baglung District of Nepal, where seven micro-hydropower plants running in isolation mode sizing 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 132 kW in an islanding mode [4]. The operation of the project started since 2011. Mini-Grid connection tremendously increased the utilization of energy for 24 hours/day and enhancing the plant load factor about 67% (as of authors' field visit findings) of these micro-hydropower plants, which previously operated with very poor plant load factor. This cost effective and sustainable power system encouraged local entrepreneurship and several other socio-economic dimensions to be discussed. In addition, the community co-operative based business model has worked at its best with the active involvement of the community people. This is the first pilot project initiated in Nepal by Renewable Energy for Rural Livelihood Program (RERL)/AEPC (previously Rural Energy Development Program(REDP)), Nepal with financial support, around US $ 0.172 million (NRS 15 million) from United Nation Development Program(UNDP) and local contribution of around US $ 0.011 million (NRS 1 million) [4]. The main objectives of such initiatives was to increase capacity utilization of the individual plant, micro hydropower plant to supply surplus electricity to the locations outside the jurisdiction, create an opportunity for large end use enterprisers, and ease interconnection of micro hydropower plant with national grid so that they can take full advantage of generating additional revenue by selling electricity (when excess) to NEA or purchasing electricity from it to meet the extra electricity demanded by the community members.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 514-520*

Unfortunately, study reveals that grid connection of micro hydropower and mini-grid initiatives are not internalized and owned by policy and institutional mechanism. Policy and institutional mechanism need to be revised and restructured so as to adopt mentioned initiatives and to introduce synergy effects which are not often realized because of parallel policy and institutional mechanism of NEA and AEPC [4]. The technology adopted for mini-grid, the business operational modality and the socio-economic dimension will remain at the centre of further discussion.

2. METHODOLOGY

Different articles, policy documents and analysis report related to rural electrification and mini grid in Nepal were reviewed. Discussion and field visit were held with key stakeholders who were directly involved in piloting of Energy Valley (Urja Upatyaka) Mini Grid (situated in Baglung District, Nepal). Furthermore, government and concerned officials who were closely associated with such initiatives were consulted.

3. LITERATURE REVIEW

B. Adhikari *et al* (2010) studied the design of low cost automatic synchronizer consisting of few digital gates, relay and contractor as main component, which is useful to form mini-grid with power plant using Induction Motors as Generators (IMAGs)[6]. S.N. Singh *et al* (2010) conducted the design of mini grids of nine SHP plants of Bageshwor District, Uttrakhanda, India. Based on system layouts, transmission routing, line length and selection of conductor, 5 different alternates of mini-grids were developed to connect these SHPs together as well as with the nearby 33 kV grid substations. The optimization of these alternates was done on the basis of the Break Even Point (BEP) with shortest line length, low line losses and minimum capital investment for the mini-grid implementation [7]. V. Bhandari *et al* (2010) reviewed the development of Mini-grid laboratory in Kathmandu University, Nepal. The paper focuses on the step by step procedure for developing the laboratory and challenges faced during the building process. It also highlights the importance and scope of this laboratory in context of the development of mini-grid power systems in Nepal [8]. V. Bhandari *et al* (2010) reviewed the performance study of the laboratory fabricated test kit developed as a part of R&D at Kathmandu University, Nepal. The test kit contains lab-fabricated Induction Generator controller (IGC) unit and an Automatic Synchronizer (AS). These two units can be individually switched on or off (as per the necessity) by a simple switch. The test kit is connected in various test environments to simulate both isolated and grid connected scenario. The performance of the kit is evaluated on the basis of its synchronizing ability and power sharing ability keeping in mind other factors voltage regulation and protection issues [9]. V. Bhandari *et al* (2010) reviewed the effect of Mini-Grid from a socioeconomic dimension including not only quantitative but also qualitative factors.

Thereafter, in a long run, these identified factors can be used during implementation of Mini-Grid concept in developing countries like Nepal, Bangladesh, Bhutan, Namibia, Tunisia etc [10]. R.K Maskey *et al* (2010) reviewed that in absence of national grid, in rural areas, the concept of mini-grid becomes more important to realize. It deals with prospect of SHP plants based Mini-Grid Power System (MGPS) through three-tire strategy that makes possible Village to be electrified first and later that could be interconnected with District level grid and regional level transmission lines [11]. V. Bhandari *et al* (2010) reviewed that In Nepal there are many isolated Micro Hydro Plants (MHPs) which operate around a radius of 5 to 6 km; presently they feed the generated electricity to their respective loads center. If these load centers and generators are inter-connected via mini-grid there are lots of possibilities of power sharing and saving. This will enhance the system stability and supply reliability which will dramatically increase the life span and economic viability of the plant [12]. Deshmukh *et al* (2006) studied the feasibility of grid extension and distributed generation considering biomass and diesel based generation options and BEP (break even point) based optimization suggested it as a cheaper option than grid extension. [13]

The literature reveals that very less or even no work has been done on the implementation of mini-grid in the real field level powered by micro-hydropower, and research has been limited to academic interest and few lab setups. The research work needs to be extended to field level. Therefore, the comprehensive study of community managed mini-grid has been undertaken as area of research.

4. AREA OF STUDY

“Energy Valley Mini Grid” at Baglung District, Nepal is taken as the area of study. It is the first successfully piloted project in Nepal connecting seven micro hydropower plants in an isolation mode and fully managed by community.

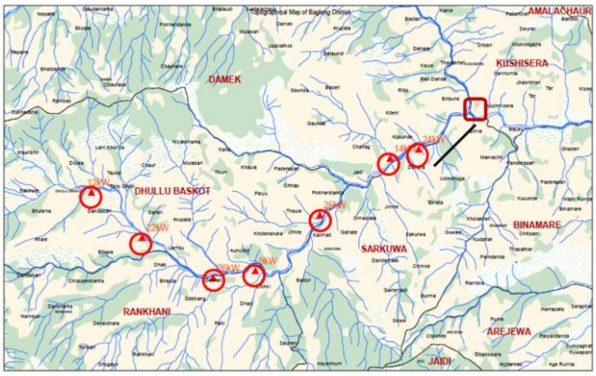

Figure 1: Bird’s-eye view of the Mini-Grid [14]

The location of the micro-hydropower plants are shown in Figure 1. The circular block represents the individual micro hydro power stations whereas the rectangular block is the nearby 33/11 kV central grid (NEA) substation.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 514-520*

The substation is located at Kushmishera which is just around 0.6 km from the mini-grid, near the Theule Khola MHS (24kW) at Sarkuwa VDC. Almost all the plants utilize the same source, Kalung River to generate electricity and few plants are operated in cascade mode. The study area lies in 4 VDC (Village Development Committee), namely Sarkuwa, Paiyun, Rangkhani and Damek of Baglung District, Nepal. The study area is 25 km south-east from Baglung Bazar, the district headquarter of Baglung District. Baglung Bazar lies approximately 230 km west of Kathmandu. [5]

5. TECHNICAL DETAILS

Almost all the micro-hydropower in the study area utilizes the same source, Kalung River to generate electricity. There are seven micro-hydropower plants ranging from 9 kW to 26 kW with total output power of 132 kW connected to mini-grid power system of length approximately 8 km operating at 11 kV with ACSR Rabbit conductor for power transmission [3]. The details of the plants with their locations, installed capacity and beneficiary households are presented in Table 1.

Table 1: Details of the Micro-hydropower plants.

S. N	**Name of Plants**	**Location** (V.D.C)	**P_{kW}**	**HHs**
1	Theule Khola MHP	Sarkuwa	24	290
2	Kalung Khola MHP	Paiyun	22	230
3	Urja Khola I MHP	Rangkhani	26	250
4	Urja Khola II MHP	Rangkhani	9	120
5	Upper Kalung Khola MHP	Paiyun	12	120
6	Urja Khola III MHP	Paiyun	25	210
7	Urja Khola IV MHP	Damek	14	140

Source: RERL/AEPC Nepal.

The layout of the Mini-Grid with axial network is given in the Figure 2 showing the arrangements of bus bar, transformer, breakers, 11 kV transmission line and the installed capacity of the individual Micro Hydropower Plants.

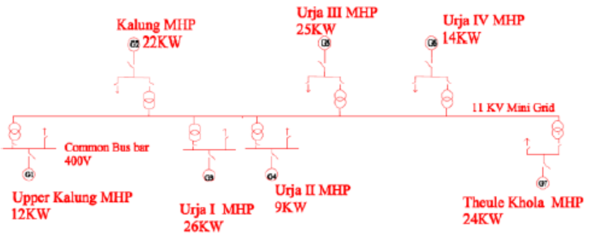

Figure 2: Layout of the Mini-Grid.
Source: RERL/AEPC Nepal.

The parallel operation of two or more than two generators is a complex process and needs advance control system which was not available in existing micro-hydro plants in the isolation mode. Microprocessor based control panel is the main technology that made possible to synchronize various number of micro-hydro plants and to connect the mini-grid with the national grid in future.

The synchronization process needs measurement, control with load sharing options, synchronization and protection system. For implementing mini-grid technology on the existing isolated micro-hydro plants lot of modification was done on the control system, Electronic Load Controller, Protection System, and a new 11 kV transmission line was added to the existing system. The specifications and details of the modified equipments are presented in Table 2.

Table 2: Details of the new & old control panel

S. N	**New Control Panel**	**Old Control Panel**
1	Microcontroller based digital ELC.	Power electronics based analog ELC.
2	Digital metering system showing voltage, frequency & phase sequence of generator & grid while synchronization.	Lacks such facility.
3	Bus Bar arrangement provides facility to transport generator power to grid or grid power to load centre.	Lacks such facility.
4	Micro controller based static relays are used for the protection of generator during abnormal conditions.	Lacks such facility.
5	O/U Voltage, O/U frequency, Reverse power, Phase unbalance, Earth fault, Over Current and Voltage resistance relay are used.	Lacks such facility.
6	Synchronization can be done is manual & auto (automatic) mode.	Lacks such facility.
7	Advance protection schemes with backup protection for contractor & village MCCB.	Protection is achieved through MCCB only.
8	Facility for emergency disconnection of generator & village load.	Lacks such facility.
9	Advance digital type ELC with display of percent (%) ballast load.	Lacks such facility.
10	Controllers, monitoring systems and annunciations are powered by battery backup.	Few display system are powered by mains.
11	APFR for the synchronization with the central grid.	Lacks such facility.
12	Advanced metering system showing kW/ kWh generated and consumed.	Simpler metering system.
13	Can easily be upgraded to suite with the modern technology.	Difficult in upgrading to cope with modern system.

Source: RERL/AEPC Nepal.

The single line diagram of one of the micro-hydro connected to mini grid, load centre and the bus-bar arrangement is shown in Fig 3.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 514-520*

5.1 Working Principle

Among the seven micro-hydropower plants, Urja I is the biggest with installed capacity of 26kW. The biggest unit is considered as the master unit. Since the whole mini-grid is in isolation mode, Urja I is operated at no load condition. The power generated is dumped as ballistic load; the percent of the ballistic load will be displayed in the ELC monitor or load meter. Now the 0.4 kV bus bar is energized by operating the contractor 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 3. The power generated is used to charge 11 kV, 3 phase, Single Circuit, 8 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 ballistic load in the ballistic heater.

Now, the grid voltage & the grid frequency is determined by the first plant Urja I. When the second plant is operated say Urja II MHS, it will firstly be operating at no load condition, i,e most of its load is being dump in the ballistic heater. When the grid side circuit breaker is closed the grid parameters are available at 0.4 kV bus bar of Urja II MHS. In this case the power flow is in the direction D-B-A as shown in Figure 3.

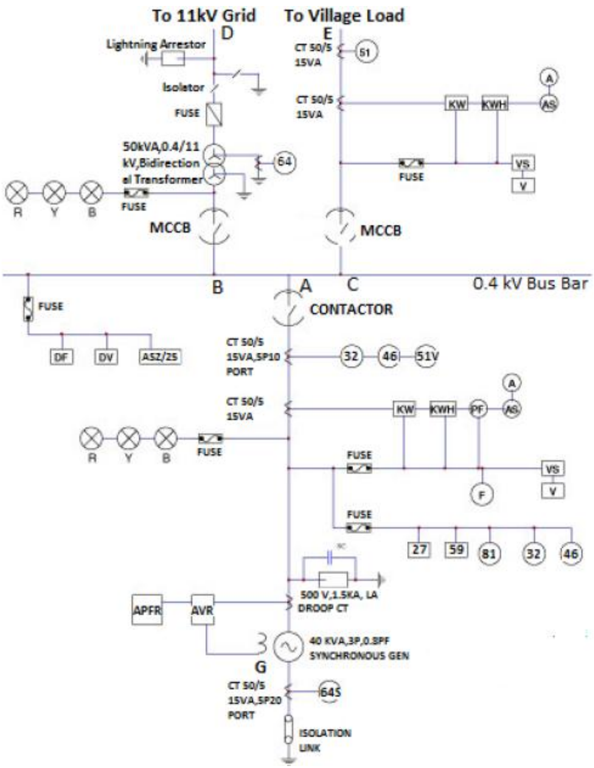

Figure 3: Single line diagram of the control panel and bus bar arrangement of Urja I MHS (22kW)
Source: RERL/AEPC Nepal.

The grid voltage & frequency are shown in the digital meters in the control panel. Now the Urja II 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 contractor is closed automatically when it's in auto synchronization mode and the synchronization is done. Single line diagram of control panel and bus bar arrangement of Urja I is shown in Figure 3. After the synchronization is done one of the load center breaker of Urja I cluster is closed with load of 20 kW. 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 relay 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 conditions these relays gets energized and gives signal to the master trip relay which gives signal to the contractor 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 centre, it can be powered by the grid power via 0.4 kV bus bars as shown in Figure 3 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 Urja-I are shown in Figure 3. 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.

5.2 Load Details

The mini grid powers around 1350 households and small scale rural industries. The small scale industries include 17 rice cum oil expeller mills, 3 saw mills, 8 poultry farm, 2 photo studios, communication cum computer center, stone crusher, Milk dairy and mobile BTS station. The capacity of small scale industries varies from 0.4 kW to 12 kW in size. The average hourly load curve has been plotted combining all the energy meter reading obtained from seven power house as shown in Figure 4.

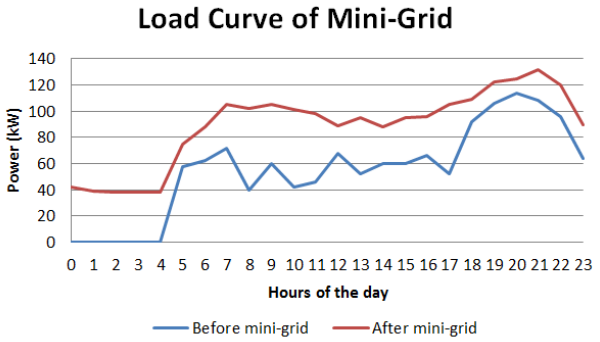

Figure 4: Average hourly load curve of mini-grid.

After mini-grid the utilization factor has rise abruptly from 42% to 67%. The rural industries especially the milling, oil expelling and Milk dairy are generally operated from 05:00 hours, and others during (08:00-16:00) hours. The increment in the demand is observed during (18:00-22:00) hours. The peak load of the system is 132 kW compared to 106 kW in isolation mode whereas, the base load of mini-grid is observed 40kW. [5]

6. BUSINESS & OPERATIONAL MODEL

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 four models. They are Community-based model, Private sector-based model, Utility-based model and hybrid model. 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 cooperative model suits the best at such scenario. Thus, Energy Valley Mini-Grid Cooperative was formed and subsequently, rules, regulation and other legal documentation 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 and all other related issues.

7. TARIFF STRUCTURES

With the introduction of trading arrangement, the demand based tariff (Rs/W) that was practiced by individual MHFG before the formation of mini-grid was changed to energy based tariff (Rs/kWh). Resulting energy based tariff is less than the national tariff but higher than the equivalent demand based tariff. The PPA rate between mini-grid cooperative and MHFG is 5.18 US cent (NRs 4.5)/kWh, whereas the minimum tariff at the consumer level is US $ 0.862 (NRs 75) up to 12 units (kWh) and 8.05 US cent (NRs 7)/unit after each addition of the unit. The change in tariff system required installation of energy meter at consumer level and at individual power plants for power trading.

8. SOCIO-ECONOMIC ASPECTS

Several technological advancements have certain socio-economic dimensions attached to them. The socio-economic analysis encompasses indices such as employment, local entrepreneurship, health, education and environmental issues. Operation of mini-grid has opened several prospects of local business among the rural people. The project area is facilitated with equipped health post having pathology lab, computer and communication center, standard kitchen accessories and smoke free cooking mechanism as a result of mini-grid operation. Moreover, small scale industries such as milling and grinding, poultry farm, furniture, briquettes industries, bakery, dairy cold center have come into the pictures with influential upgrade in the standard of living of the people. Mini-grid, moreover, empowers the community people with better co-ordination and sense of togetherness.

9. CHALLENGES

Formulation of Mini-Grid will unite different communities of MHS users but it's equally challenging to bond them without any dispute. This technology is more complex than the isolated MHS management, operation & maintenance as the rural communities have limited resources in term of finance, human resources and technical knowhow. With two separate institutions (NEA & AEPC) involved in parallel with less or no coordination planning effort, isolated micro hydropower plants installed in remote areas are in risk that carries serious question of sustainability and overall development planning process. Hence, it is essential to connect micro hydropower plants to national grid where micro hydro are encroached by grid or develop mini grid by interconnecting them where grid is not expected for many years.

10. CONCLUSIONS

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.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 514-520*

The detail analysis of the pilot project will take time; preliminary studies have indicated that there is a need for essential policy and institutional changes for replication of the project in other parts of country. This paper has tried to explore a new approach towards mini-grid technology, governance practice and policy restructuring. In a long-run, these factors can be used as a baseline in implementing such projects in other similar developing countries.

Exchange rate: $1 USD=NRs 86.95 [15]
(Source: NRB,Nepal)

ABBREVATIONS

AEPC	Alternative Energy Promotion Centre
AS	Automatic Synchronizer
ASCR	Aluminum Conductor Steel Reinforcement
AVR	Automatic Voltage Regulator
BEP	Break Even Point
BTS	Base Transceiver Station
ELC	Electronic Load Controller
HH's	House Holds
IMAG	Induction Motor as G enerator
IGC	Induction Generator Controller
IPP	Independent Power Producers
IWM	Improved Water Mill
kV	Kilo Volt
kW	Kilo Watt
kWh	Kilo Watt Hour
MHP	Micro Hydropower Plant
MHFG	Micro Hydro Functional Group
MGSP	Mini Grid Power System
MW	Mega Watt
NEA	Nepal Electricity Authority
NPM	National Program Manager
NRs	Nepalese Rupees
NRB	Nepal Rastra Bank
O/U	Over/Under
P_{kW}	Power output in Kilowatts
PLC	Programmable Logic Control
PPA	Power Purchase Agreement
REA	Rural Energy Advisor
REE	Renewable Energy Expert
REDP	Rural Energy Development Program
RET's	Renewable Energy Technologies
RERL	Renewable Energy for Rural Livelihood
SHP	Small Hydropower
UNDP	United Nation Development Program
USD	United States Dollar
W	Watt

LEGENDS

As	Ammeter Selector Switch
A	Ampere Meter
Vs	Voltage Selector Switch
V	Voltmeter
KW	Kilowatt Meter
KWH	Kilowatt Hour Meter
PF	Power Factor Meter
MCCB	Moulded Case Circuit Breaker
F	Frequency Meter
DF	Dual Frequency Meter
DV	Dual Voltmeter
ASZ25	Auto Synchronizer cum Check Sync Relay
27	Under Voltage Relay
32	Reverse Power Relay
46	Power Unbalance Relay
59	Over Voltage Relay
81	Over/Under Frequency Relay
64	Earth Fault Relay
51V	Voltage Resistance over Current Relay
51	Over Current Relay

ACKNOWLEDGEMENT

The authors are very grateful to Mr. Satish Gautam (NPM, RERL) & Mr. Bhupendra Shakya (REE, RERL) for providing opportunity to conduct this study and providing RERL view point on mini-grid regarding different issues. We are also grateful to Er. Basanta Raut, Ms. Manjari Shrestha (REA, RERL) for sharing field level experience and providing valuable information on different issues of mini-grid. Similarly, we would like to express our thanks to Mr. Suraj Baral, Faculty at Department of Mechanical Engineering, Kathmandu University for his valuable suggestions and feedbacks.

REFERENCES

1. International Energy Agency, the International Energy Agency, Energy for all – *Financing access for the poor*, URL:http://www.iea.org/papers/2011/weo2011_energy_for_all.pdf. 15 September 2012.
2. Government of Nepal, National Planning Commission, Central Bureau of Statistics, National Population and Housing Census-2011, URL: http://census.gov.np/images/pdf/chapter10.pdf, 6 October 2012.
3. www.thethirdpole.net/micro-hydro-electrifies-remote-villages-in-nepal. 06 October 2012.
4. Suraj Baral, Suman Budhathoki, Hari Prasad Neopane, "*Grid connection of Micro Hydropower, Mini Grid initiatives and rural electrification policy in Nepal",* IEEE 3rd International Conference on Sustainable Energy Technologies September 24-27,2012, Kathmandu, Nepal.
5. Ranju Pandey, 2010, "Technical & Socio-Economic assessment of a community based mini-grid in Baglung District of Nepal", M.Sc. thesis, SESAM, University of Flesburg, Germany.
6. B. Adhikary, V. Bhandari and R. Dahal, "Design of Automatic Synchronizer for Connection of Induction motors as generators in Mini-Grid Systems" in *IEEE International Conference on Sustainable Energy Technologies (ICSET)*, pp. 1-4, Dec. 2010, Srilanka.
7. S.N.Singh, M.P.Sharma and Ajit Singh, "Design of Mini-Grid for SHP Plants", Hydro Nepal, Issue on 7,2010.
8. V. Bhandari, R. Dahal, B. Adhikary, R.K. Maskey and N. Shrestha "Establishment of Mini-Grid Laboratory in Kathmandu University", in *National Seminar for Power and Communication Sector Development (PCSD)*, pp. 31-34, Dec. 2010, Nepal.

9. V. Bhandari, R. Dahal, B. Adhikary, R.K. Maskey and N. Shrestha "Performance Evaluation of laboratory fabricated test-kit for mini-grid systems" in *International Conference in Quality, Reliability and Information Technology (ICQRIT)*, p.22, Dec. 2011,Nepal.
10. V. Bhandari, B. Adhikary, R. Dahal, R.K. Maskey, N. Shrestha, "SOCIO- ECONOMIC ASPECT OF NEPALESE MINI-GRID", 2nd *International Conference on the Development in Renewable Energy Technology(ICDRET)*-5th-7th Jan,2012.
11. Ramesh Kumar Maskey, Vivek Bhandari, Brijesh Adhikary, R.Dahal, N. Shrestha, " PROSPECTS FOR SMALL HYDRO POWER PLANTS BASED MINI-GRID POWER SYSTEMS IN NEPAL", 2nd *International Conference on the Development in Renewable Energy Technology(ICDRET)*-5th-7th Jan,2012.
12. V. Bhandari, R. Dahal, B. Adhikary, R.K. Maskey and N. Shrestha "Mini-Grid: A Concept for Empowering Rural Nepal" in *Addressing Climate Change for Sustainable Development through Up-Scaling Renewable Energy Technologies (RETRUD)*, pp.125-128, Oct. 2011,Nepal
13. Ravi G. Deshmukh and Rajkiran V. Bilolikar, "Optimization of Rural Electrification Methods:A Comparative Analysis of Grid Extension vs. Distributed Generation"
14. Department of Survey, Government of Nepal, Topographic map of Rangkhani, Paiyun, Sarkuwa VDC, Baglung District Nepal.(Courtesy: RERL Nepal)
15. Nepal Rastra Bank, as on date 8th December, 2012 http://www.nrb.org.np/fxmexchangerate1.php?YY=2012&MM=12&DD=08&B1=Go

BIOGRAPHS

[1]**Sanjeev Pokhrel** is a final year M.Tech Student in Alternate Hydro Energy System, Indian Institute of Technology Roorkee, India. He completed Bachelor of Engineering in Electrical and Electronics in 2006 from Kathmandu University, Nepal. He has five years' experience in the field of renewable energy. His area of interest is mini-grid and small hydropower development.

[2]**S.K.Singal** graduated in Civil Engineering from University of Roorkee (India) (now Indian Institute of Technology Roorkee) in 1983. Then he obtained his ME degree in earthquake engineering and a PhD from IIT Roorkee. In 1984 he joined the Alternate Hydro Energy Center (AHEC) at the University of Roorkee as Scientist. Currently he is working as Senior Scientific Officer in AHEC, IIT Roorkee. Dr. Singal has research, teaching and consultancy experience of more than 26 years in the field of small hydropower. Email: sunilksingal@gmail.com

[3]**S.N.Singh** is working as senior Scientific Officer at Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, India, as Electrical Engineer since 1983.He has research teaching and consultancy experience of more than 29 years. His area of research is modeling of induction generators, development of electronic load controller and design of T&D lines. Email: nishafah@iitr.ernet.in