# Investigation on Execution of Hybrid Micro Grid for Remote Villages

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***Abstract*—In this work a micro grid concept for a village in the Himalayas is presented. The unique feature of these micro grids is that they use locally available resources, such as solar, wind, water stream and biomass for electricity generation. In order of estimate the current electricity consumption and future demand, door to door survey was done. Based on this survey the power consumption pattern for 24 hours was estimated. Using this power consumption and the available local energy resources the energy alloy for the village was estimated. The chosen village has different resources for power generation and we can opt for different configurations of the micro grid as well. The ideas presented in this paper will be useful for designing micro grids for remote locations in the developing world.**

***Keywords: Micro grid, Electric Hybrid System, Power Plant, Converters, Generators*.**

## I. INTRODUCTION

According to International Energy Agency (IEA), “Access to Electric Energy is an Indispensable element of sustainable human development”. As per the recent data till 2011 about 1.6 billion i.e. more than 20% of the world is having no access to electricity and further if any country is not having access to modern, commercial energy, poor countries and even regions of developing country can come under the trap of poverty, social instability and underdevelopment [1]-[3]. A direct relation with the Human Development Index has been found with electricity and been proved over time considering various countries of South Asia and sub-Saharan Africa. A similar case had been found in remote areas of Himalayas as well, where people are out of electricity and if they have access, it’s for the least period of time and worst regulated voltage level and issues including voltage fluctuations and under voltage. Due to isolated and decentralized nature of renewable energy resources, it is apt to develop the unit’s off grid and decentralized to feed local needs. This decentralized system is called Distributed Generation System. Power generated from locally available renewable energy resources can be utilized to meet the requirements of a cluster of loads. Micro-grid can include generation from more than one type of distributed energy resources depending on the availability of different renewable resources to provide stable and reliable power to the local loads. Micro-grid can operate either in is landed mode or in parallel with the grid. Installation of renewable energy based micro-grids in rural areas or in small scale industries, will help relieve the dependence on the utility grid for electric power and also avoids the losses associated with transmission and distribution of power [4-10]. Our work aims to design hybrid micro grid with locally available renewable energy sources which can be set-up in these areas with ease and assure reliable supply of electricity .This would help to develop the standard of living of these people and moreover as stated the HDI would vary rapidly. Being located away from regular areas of urban and industry, these people lack basic infrastructure such as roads, water, sanitation and communication. A necessity to educate these rural communities about the economic impact of electricity was felt. Electricity plays a very important role in making changes in HDI. Both are related directly to each other. Thus if we aim at developing the power sector of any society, state or country; development is likely to follow. Many similar works have been done so far considering various regions of world. The option of being off grid is always preferred and standalone systems have become popular in days. A case study was done in Vishakhapatnam (Vizag) District of Andhra Pradesh state with a goal of producing renewable energy at a high level of inclusion into the energy infrastructure. They developed a micro grid that constitutes of multiple generation sources, at least one of which is renewable and storage as well. Their vision of using solar forecasts a growing market for micro grid in developing countries especially PV micro grid.[11] Environmental protection and increasing demand for high power quality have attracted wider attention with growing demand of energy and its reliability. The concept of developing hybrid micro grid especially standalone is becoming promising. Deng, Tang and Qi proposed a small signal model of the hybrid wind/PV system based on the concepts of micro grid and comprising of an asynchronous wind turbine and inverter type DG. In this work, they designed the system controller, checked the performance of system to optimize the controller parameters and enhance the performance of system transient stability. They concluded and showed that fast control of the inverters type DG to be exploited to meet the change in the power demand and maintaining stability. [12] A feasibility study on hybrid micro grid for Wawa hang complex in Nicaragua is presented in [13]. Complex’s complete off-grid hybrid system is studied with focus on the feasibility of standalone photovoltaic/micro hydropower system. They also presented a new PV system. The simulation showed the climatic impact i.e. low solar irradiation and suggested changes in the present grid construction. Green energy storage, an option to store energy in the form of gas (Hydrogen and oxygen) with multiple energy sources and storage for hybrid micro-grid based residential utility interfaced smart energy system was proposed in [14]. The work suggested development of independent AC and DC grid to feed AC and DC loads respectively. Ghasemi et.al in [15] designed a simple DG plant with a hybrid fuel cell and micro turbine connected to power grid with assumption of fuel cell and micro-turbine to be equipped with power and voltage control loops. They tested with various values to determine the accuracy of model. With technologies focussing on the use of distributed renewable energy, development in DC micro grid was tracked. In [16] authors suggested a voltage selection guide and proposed an efficient wind-PV hybrid generation system. Further an energy storage element was also connected to provide ability to ride through larger voltage dips and outages. A model of the isolated wind-solar-diesel-battery hybrid micro grid was developed to improve the existing technique. [17] They used advanced application functions of the energy storing emergency frequency and voltage regulation control to maintain long term safe and stable operation. Load sharing to improve the reliability and feasibility of hybrid micro grid is another important aspect to be taken care. Alsharif and Lopara presented control strategies for each sub-grid of main grid and droop control strategies for interfacing the converters [18]. They gave challenge to manage the power flow through the entire grid i.e. dynamically variable supply and demand including energy storage in simulation and hardware. A hybrid AC/DC micro grid was proposed and studied in [19]. It consists of AC grid and DC grid with operation in both grid tied and autonomous mode. They classified the grid tied and autonomous mode. They classified the grid on the basis of AC and DC output as well as input AC grid comprises of PV system with boost, fuel cell generators and DC loads. Stability was studied under various load and supply conditions resulting in inference that a hybrid grid has much better efficiency than individual DC and AC micro grid due to avoidance of AC-DC or DC-AC conversions. An extension to this work was presented in [20]. In this architecture, operation and control was studied. Various operating modes are discussed with different control algorithms for PV, wind turbine generator, network and energy storage are presented. A new normalization technique is proposed for merging information from both the DC and AC sub-grids to control power transfer between DC and AC links. Reliability for consumer satisfaction is another considerable point in the set-up of system. Basu et.al to study the reliability conditions of micro grid in power system checked parameters including bus-voltages, maximum line flow, stack bus injection and system line loss. He used fast decoupled load flow analysis scheme considering 6-bus system. He concluded to focus on voltage stability in reliability evaluation and added to share soft-computing optimization technique for calculating optimal size and location of DER for reliability. Practical scenarios of shown that connecting to grid have reduced the reliability of supply and cost of electricity per kWh have also been reduced. Considering an example from USA, especially on Northeast and California, the cost of electricity always remains high. [21] Grid reliability is most often perceived as unsatisfactorily in regions with bad weather and lower costumer density. Further if we consider the changing scenarios of technology, we can see that the cost of equipment's of distributed generation have reduced abruptly and reducing till date. Depending on where in live, work or shop, there is always a need of development to comply with the standards and maintain economics with other developed region of our country. The paper is organized in as follows. Section-II presents the description of the site and the method used for data collection. Section-III describes the various features of the proposed system. Finally, Section-IV gives conclusion.

## II. SITE DESCRIPTIONS AND DATA COLLECTION

The chosen site, Leporiang is Tehsil in Papum Pare District of Arunachal Pradesh State, India situated at the foothills of Himalayas. Leporiang is located at 27.12°N 93.2°E. It has an average elevation of 1089 M. It is 50 KM towards west from District head-quarters Yupia and 52 KM from State capital Itanagar towards East. It has a rich flora and fauna. The village appears isolated from all the main regions and towns of Arunachal Pradesh. One can find a miserable life of people without electricity and mobile communication. Wireless Local Loop (WLL) was tracked in few locations but they don't work as the power supply was not available. There were no network operators found over the village or nearby. For every single amenity, they have to be dependent on various action plans of Government. There were schools, shops and offices but due to lack of electricity every data was recorded analogously using any primitive way like in written. A door to door survey was conducted with an objective to get the electrical consumption and future demand. A set of questioner was framed keeping in mind the type of electrical equipment used by the people, their ratings, hourly usages and any future prospects of purchasing new electrical equipment.

*Figure 1: Proposed Site Location*

Separate questioners were formulated to distinguish the various load types and to obtain a clear profile of power consumption. This survey gave us another advantage of understanding the consumer behavior which is of utmost importance and plays a crucial role while planning to undertake any project in any society. While the interaction with the village people we discovered the frequent power outages and unreliability of grid. Further, they addressed us with their basic needs and the opportunities we have in that village. They gave us an overview of their income structure that gave us an idea of investment that we will make and its outcome as well. The present scenario of all the available resources was pictured in-front of us. The hilly terrain and its impact on the daily livelihood were told. We finally came to a conclusion of developing a mixed generation station that would include Micro-Hydro, Wind, Solar, Biogas, battery backup and a diesel generator system. Being an interior location of state and lack of basic electricity requirement there was no weather station that would provide everything in detail. We managed to cater the data's of wind speed and solar from NASA's website using the latitude and longitude of that place. Meteorological data's gave us further supplement and encouragement for this project. Following factors were considered based on the survey conducted for proposing a solution:-

*A) Grid availability*

The supply from the grid was found unreliable and power outage was frequent. Sometimes electrical outages persist for even a month due to negligence of grid. Even the grid supply was very low with lot of fluctuations leading to the failure of any electrical devices that are being used.

*B) Population and electrical usages*

It consists of 250 houses, 4 Offices including one health centre and 1 secondary school. It has a population of around 1500. Figure 2-7 shows the typical load duration curve and load types used.

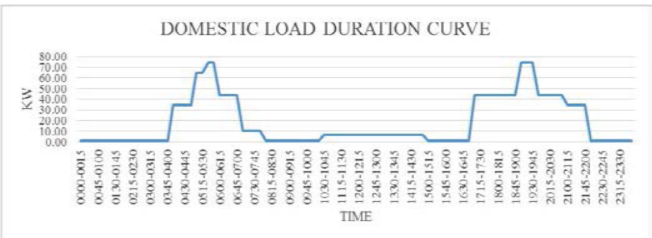


*Figure 2: Domestic Load duration curve*

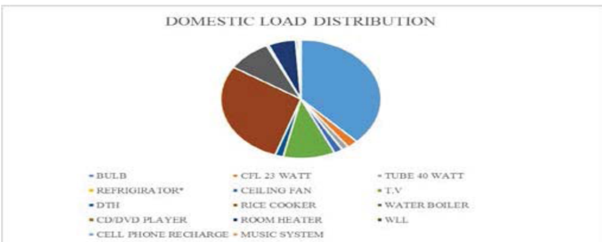


*Figure 3: Domestic Load Types demand.*

As shown in the above figures, the domestic load mainly constitutes of lightning load i.e. bulb, rice cooker and television respectively. From the load duration curve, the electricity demand is at peak for around 2 Hours in morning and 4 hours during night respectively. Office load duration curve shows a constant load demand for 8 hours which is about 12 kW, around 15 % of domestic load

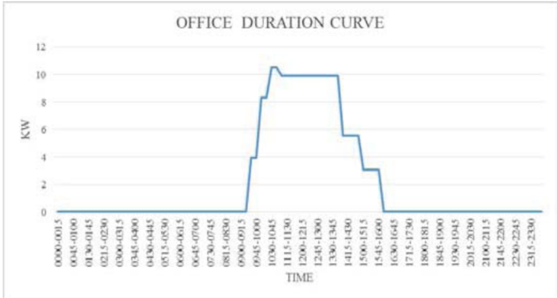


*Figure 4: Office Load duration curve*

*C) Communication to village*

The communication to the village was in worst condition. The roadway was only route to village which was temporarily running. With changes in the weather the road gets blocked. This include heavy rain leading to wash away of land and so creation of big manholes in road, sudden landslide which may take a week to be cleared, forest fires, and fog in winter season that makes difficult to travel in that location.

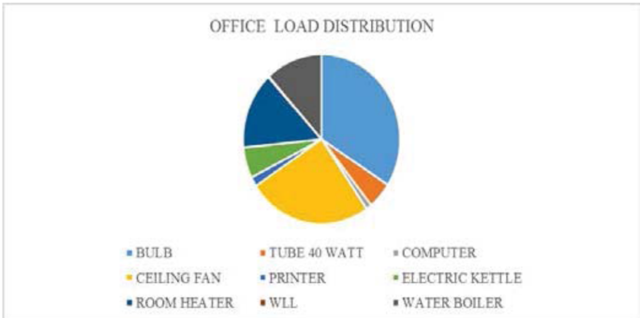


*Figure 5: Office Load duration curve*

*D) People behavior*

A very important factor is the frame of mind of people living in that society as they define the output of any work done in their location. Peoples' response confirmed that they favor the use of resources available locally and the outcome to be distributed locally instead of connecting the generating stations to grid. Grid connectivity can be a future scope after fulfilling the need of vicinity.

*E) Solar and wind resources assessments*

The village is located at an average elevation of 1089 m. Being located at such a height the solar intensity is not always excellent. The wind velocity varies seasonally. Hydro source seems to be constant all the year and the biogas that we would extract from biomass is also available round the year. The average solar isolation data as per

NASA lies between 3.36 to 4.57 kW/m2 and an annual average of 3.94 kW/m2. Maximum amount of radiation as seen in Figure 6 is available from April to July only. As seen from Figure 7, the monthly average wind speed is not more than 5 m/s and is maximum during the months of January to March and November to December respectively. During mid-year, the wind speed is even less than 4 m/s. As the location of the village is in the foothills of Himalayas, the availability of water streams is throughout the year, but the location of stream is not near the village but far from it. Even the availability of Wind for tangible production of power was only available only on the mountain heights.

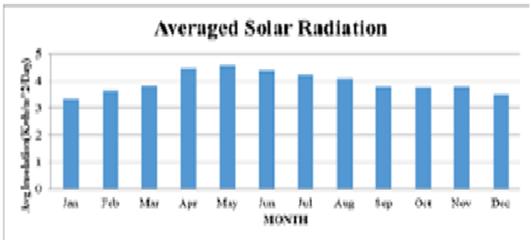


*Figure 6: Monthly average solar radiation from NASA*

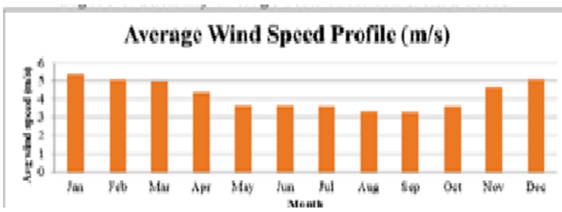


*Figure 7: Monthly average Wind radiation from NASA*

*F) Economics of region*

The village is in developing phase and the economy doesn't seem to be better. Most of the people are having an average income of INR 1, 00,000. It would be preferable to design a low cost, robust, reliable and controlled structure whose investment can be earned by the revenue and running charges can be managed from revenue collected.

## III. PROPOSED SYSTEM

Based on the above stated factors, following off-grid stand- alone system is proposed. As the nature of the load constitutes mainly of AC type, AC Grid system is proposed with suitable conversion wherever required.

*A) Solar-Diesel Generator Hybrid System*

Figure 8 shows a schematic diagram of Solar-DG based Hybrid systems. The capacity of solar power plant and Diesel Generator is 200 kW and 120 kW respectively. Solar power plant is designed using PV array delivering a maximum of 200 kW at maximum solar irradiance of 1000 W/m2.

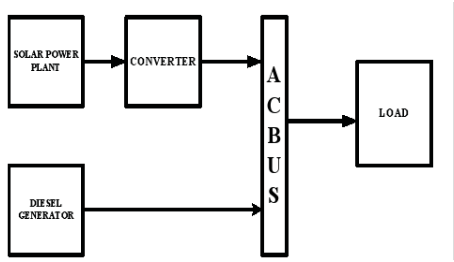


*Figure 8: Schematic Diagram of Solar-Diesel Generator Hybrid system*

The 200-kW PV array of the detailed model uses TATA POWER TP305 modules. The array consists of 66 strings of 10 series-connected modules connected in parallel (66*10*305W= 201.30 kW). Manufacturer specifications for one module are: xNumber of series-connected cells : 76 x Open-circuit voltage: Voc= 44.8 V xShort-circuit current: Isc = 8.81 A xVoltage and current at maximum power :Vmp =36.8 V, Imp= 8.31 A The characteristics of the TATA POWER TP305 are reproduced below.

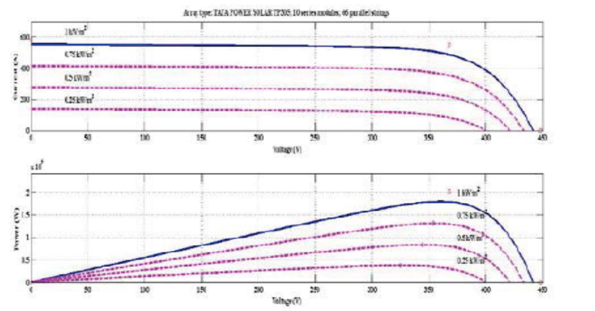

*Figure 9: I-V and P-V Characteristics of PV array*

A detailed model of a 200-kW array connected to a 120 kW DG via a DC-DC boost converter and a three-phase three- level Voltage Source Converter (VSC) is designed using MATLAB/Simulink Power System Block set. Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of a Simulink model using the "Incremental Conductance + Integral Regulator" technique [22-23]. Simulated results with a load of 120 kW are illustrated in figure 10.

Figure 10 shows the waveform of Solar-DG system with load. The mean power output of the solar PV array in kW with corresponding value of solar irradiance, array voltage, duty cycle and the power in kW at AC bus is shown. Depending upon the different value of solar irradiance the corresponding change in power output from array can be seen A 200kw PMSG based wind energy as shown in figure 11 is connected to 120 kW DEG system is fed to AC bus and then to load.

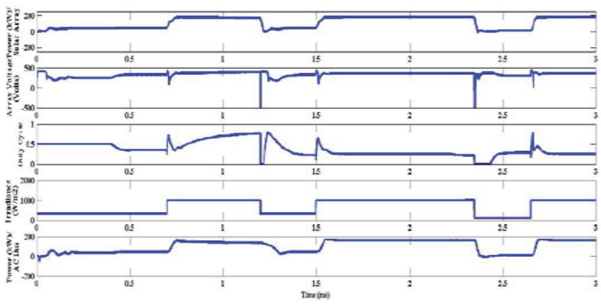

*Figure 10: Simulated Result of Solar –DG Hybrid system with Load*

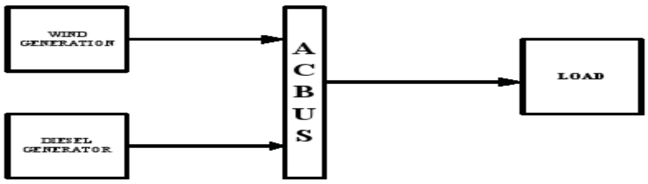


*Figure 11: Schematic Diagram of Wind-DEG Hybrid system*

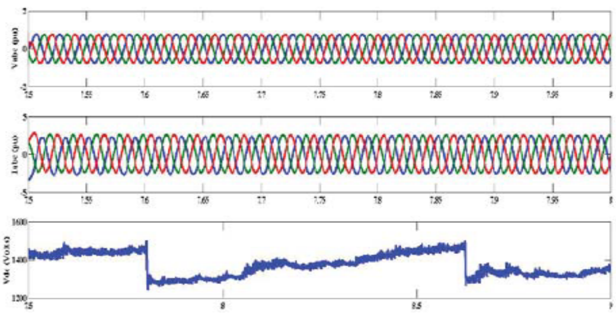

*Figure 12: Simulated Result of Wind –DEG Hybrid system with Load*

The complete model is simulated using Simulink PSB block- set of MATLAB. The simulated results are depicted in figure 12 showing the generated voltage and currents along with dc bus voltage of the converter.

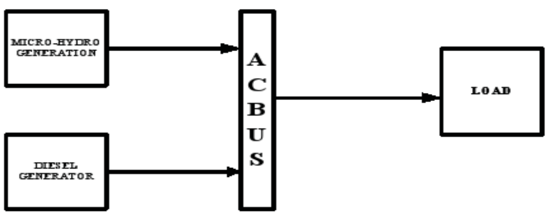


*Figure 13: Schematic Diagram of Hydro-DEG Hybrid system*

The third configuration is based on a 200 kW Micro Hydro connected with a 120kW DEG system being fed to lad through AC bus. The complete system is designed and modelled on Simulink and the voltage and current waveforms are presented in Figure 16. The sources considered can be used for generation with various algorithm and combination. Few algorithms that have been developed for setup are shown below. More algorithms can be developed accordingly.

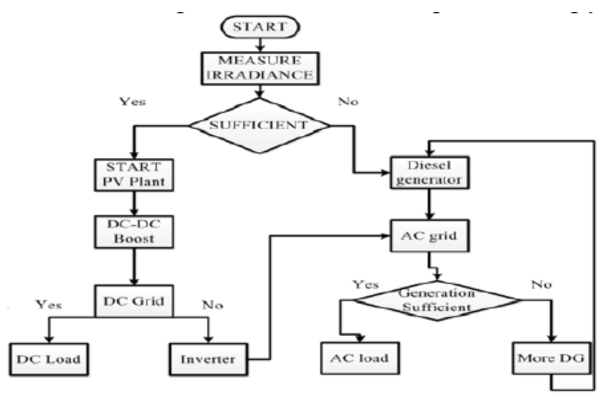


*Figure 14: Algorithm for Running power plant (AC-DC Grid)*

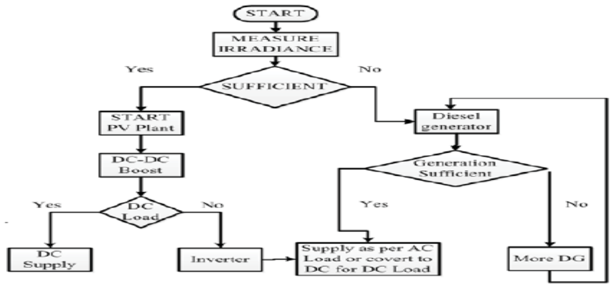


*Figure 15: Modified Algorithm for Running power plant (AC-DC Grid)*

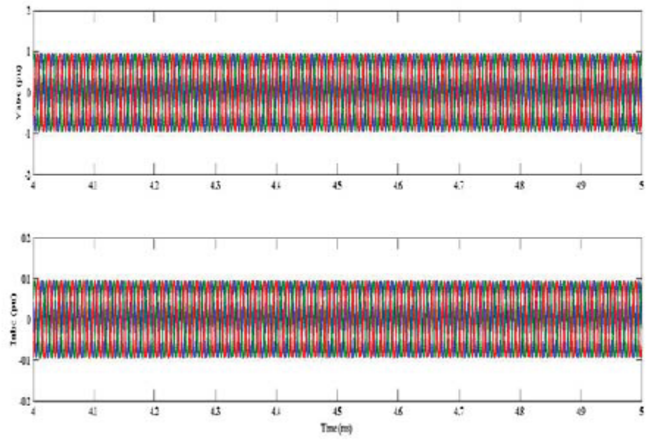

*Figure 16: Voltage and Current Waveforms*

## IV. CONCLUSION

Depending upon the load profile of a typical village located in the foothill of Himalayas, Stand-alone system based on locally renewable energy sources is modelled using Simulink. Three different configurations are taken in account and results are presented. Based on the geographical location and the availability of different sources a solution is being presented in context of rural electrification where grid is not present or feasible.

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