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Solar – Wind Hybrid a Solution for Electrifying Isolated Rural Areas in Sub-Saharan Countries

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Abstract **-Sub-Saharan Africa Rural electrification besides lighting has been the major stimulus of social and economic development of people. However, electrifying rural areas remains to be service provision to people other than business which is the major challenge to any investor. Unless subsidized electrification to most of rural areas cannot be possibly done. On the other hand, most of sub-Saharan rural areas are far from the national grid that extending the grid to reach the areas is economically infeasible. In some cases, grid extension to some areas is difficult for some reasons. Therefore electrification using decentralized renewable energy resources is the best option for such areas.**
Sub-Saharan Africa is abundantly blessed with solar and wind energy resources potential for electric power generation. The use of solar PV system has been the simplest and reliable rural electrification option. However, the high initial cost makes them to be undersized and consequently seizes operation after a short time. Sometimes load control by layman people to match the available charge is difficult leading to battery life reduction. Since sub-Saharan countries have strong winds potential for electricity generation, the best option is hybrid system that mixes solar and wind energy so that wind charges the battery at night.
This paper discusses the suitability of solar-wind hybrid for Africa sub-Saharan rural community. Using Tanzania as a case study, some solar-wind hybrid system performance will be discussed.

Keywords: Solar, Wind, Hybrid, Isolated, Generation

INTRODUCTION

Isolated rural areas in sub-Saharan countries are characterized by low access to clean and safe water, poor health services, poor educational services, poor social welfare and social economy. The root cause to most of these is low access to modern energies including electricity. It is estimated that about three quarters of sub-Saharan Africa population has no access to electricity (http://joinmosaic.com/blog/sub-saharan-africa-set-solar-revolution). Nearly 66 percent of the population in sub-Saharan Africa lives in areas where connection to the grid is too expensive or too difficult for some reasons. (http://joinmosaic.com/blog/sub-saharan-africa-set-solar-revolution).

Isolated and local renewable energy resources harnessing is the best option for these areas. Most of sub-Saharan areas receive sunlight for a many hours of the day throughout the year. So solar can be specifically advantageous in these situations to electrify many of sub-Saharan Africa's rural communities. However, its being unavailable at night at which electricity is mostly used brings a challenge to the size of the solar energy harnessing system, hence the initial cost of the system installation. For rural community of which funds is always meager, the system is normally undersized leading to short life of the system. To avoid this problem for such society the best solution would be mixing solar and any other energy source which is available at night.

Most of Africa sub-Saharan countries have strong winds with adequate speeds potential of generating electricity. Since at night there is no sunlight but there is wind of even higher speed than daytime, an efficient electrification system is the one that combines solar and wind (Dunlop, 2010). To justify this, the performance of solar-wind hybrid systems in Tanzania will be discussed. Solar-wind hybrid systems have been installed at 6 dispensaries in Manyara region in Tanzania and are working properly for 2 years now. Having turbines with low cut-in speed, this could be applied even in low wind speed wind regimes.

METHODOLOGY

Relevant literature was thoroughly reviewed to find out the appropriate energy resources for sub-Saharan Africa rural areas and the suitable harnessing technologies. The personal experiences in renewable energy development and consultancy emphasized on the use of particular energy resources for the areas. Through observation of the performance of renewable energy projects in Tanzania, the comparison of the suitability of various renewable energy resources available in the rural areas was made in order to get more efficient and cost-effective ones.

FINDINGS

According to the National Solar Power Research Institute (NSPRI) of America, most African countries receive 325 days of sunlight a year and daily solar radiation between 4 kWh and 6 kWh per square meter. This high amount of insolation correlates to a high generating capacity potential. The decentralized nature of solar power makes them particularly suitable for small grids or off-grid communities (http://joinmosaic.com/blog/sub-saharan-africa-set-solar-revolution). The major hindrance for electrification of sub-Saharan rural despite the above fact is the high initial cost of solar PV system for indigenous people. Normally the system is undersized to lower the cost though at the expense of the system operating life. The observation from many schools and dispensaries where solar PV systems

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have been installed, the battery seizes to operate properly after 1 to 2 years of operation. The reason behind has been excess discharge whereby in most cases the system is used until it shuts down. On the other hand, when completely discharged sometimes solar panels become unable to fully charge the batteries or exceed 50 % during daytimes.

The shallower the average depth-of-discharge (DoD) is, the higher the life of the battery becomes. In order to increase the life of batteries avoid DoD that is less than 10% or greater than 80%. When this is observed, the gelled deep cycle battery can stay up to 8 years before starting to deteriorate (http://marine-electronics.net/techarticle/battery_faq/b_faq.htm#7). This kind of operation is possible when solar-wind hybrid system is used. The batteries will be charged by both solar and wind during daytime and by wind only during nighttime.

Electric energy from both solar and wind are made to charge the battery bank either simultaneously when both are available or separately when only one is available. The alternating voltage produced by the wind turbine is rectified and join the direct one coming from the solar PV panel (Fig. 1). A dump load is installed in order to dissipate excess energy to safeguard the battery bank.

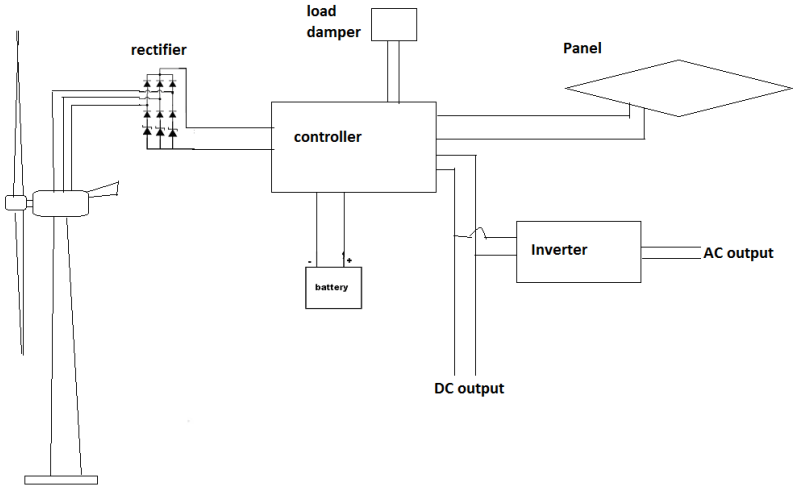

Figure 1: wind turbine and solar PV panel

Hybrid systems were installed at 6 dispensaries/ health centers in Manyara region, Babati and Hanang districts (Table 1). All the systems are working properly for about 2 years now. The systems are used for lighting, refrigeration of vaccine, microscope, phone charging and sterilization. For all systems, it has never happened for a system to discharge below 50 % because at any time the system is charging. Figure 2 shows the hybrid system installed at Gidas health center.

Table 1: Hybrid systems installed at 6 dispensaries/ health centres

S/N	Health Center	District	Components of Hybrid System Installed
1	Gidas HC	Babati	1.5 kW wind turbine, 1 kW PV Array, 1,600 Ah battery bank, 1.5 kW controller-inverter
2	Quameyu	Babati	1 kW wind turbine, 1 kW PV Array, 1,200 Ah battery bank, 1 kW controller-inverter
3	Secheda	Babati	1 kW wind turbine, 1 kW PV Array, 1,200 Ah battery bank, 1 kW controller-inverter
4	Bassodesh	Babati	1 kW wind turbine, 1 kW PV Array, 1,200 Ah battery bank, 1 kW controller-inverter
5	Getanuwas	Hanang	1 kW wind turbine, 1 kW PV Array, 1,200 Ah battery bank, 1 kW controller-inverter
6	Dumbeta	Hanang	1 kW wind turbine, 1 kW PV Array, 1,200 Ah battery bank, 1 kW controller-inverter

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Figure 2: 1.5 kW Wind-Solar Hybrid System installed at Gidas Health Centre in Babati District Manyara Region

DISCUSSION AND CONCLUSION

The system installed at Gidas included the energy meter of which a person was given a task to record the reading every after an hour in order to monitor the power usage. It was also installed with a voltmeter to measure the battery bank voltage and reading was taken after every an hour. The essence was to make sure that the usage is always below capacity and that the battery do not discharge below the minimum allowable level. The energy meter readings showed that the connected load is below the installed capacity. Whereas the voltmeter readings showed every reading to be greater than 24 V the battery bank voltage indicating a very low discharge depth.

The battery is the major component which affects the life of the isolated electric power generation system. In order to have high battery life the batteries should not be allowed to discharge too much to avoid lead sulfation in case of lead acid battery that kills the battery in short time. Also a battery operating at low charge has reduced number of cycles hence reduced life. Wind energy in solar-wind hybrid system complements solar energy so that the battery does not discharge much to prolong the battery life. Solar-wind hybrid system is the recommendable system for sub-Saharan rural receiving sunlight for many hours of the day throughout the year and strong winds throughout the year. These energies are free of charge making the solar-wind hybrid system cost effective as the running cost is very low.

The battery charging system avoids the need to worry about the stochastic nature of wind since battery absorbs any power provided below the instantaneous demand. This eliminates the sophisticated control that would need to match power generation with demand. The combination also reduces the intermittent in generated power (Jocobson *et al*, 2007). The combination is an optimal way of using intermittent renewable energy ((Oğuz *et al.*, 2012),).

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