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Design of Mini Hydro/PV Hybrid Power Plant and Storage in Rwanda

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Abstract

Nowadays the use of generating systems, which uses a renewable energy sources, has experienced a fast development. Moreover, their intrinsic intermittent nature can be overcome using hybrid systems which combine more energy sources. This project proposes the design of a hybrid generation system and energy storage purpose which will be able to cover the energy needs. The system is going to be developed around MPENGE River at Musanze district in North province of Rwanda to obtain optimal result by combining the advantages of both energy conversion systems. The hydro power works as a dominant part in this hybrid system to generate 300KW. However, PV-system works to compensate the inconvenience found in the hydro power to generate 100W and also after generating this energy it is used to store it in batteries after rectifying that one from mini-hydro power before being stored. Indeed, this mini hydro/PV power plant will be able to generate a 400 Kilowatts per day. At the end this system will be connected to national Grid and when there is a reduction of power due to any problem occurs in national power system, this MH-PV should be connected so that it compensates that power. Thus, the hybrid of Mini-hydro/PV and their storages projects have a number of benefits over other sources of power generation where they save a large amount of money on the cost of buying diesels compared to diesel generators with a continuous supply of electricity and easy and cheap maintenance. Therefore, an emphasize should be made by providing facilities to investors in this energy field to improve and to increase the accessibility of Mini hydro/PV power plants and storages to all different areas where they can be applicable.

Keywords: *Hydropower, 300KW, PV system, 100KW.*

1 BACKGROUND

Now, life without energy is unimaginable. The access to electricity has proven to be a key factor necessary for socioeconomic development, both for the peoples and infrastructure of a country. It is a basis for urbanization and industrialization in the current modern times (Tesfaye, 2014).
This research is going to be done on the design of a hybrid by combining water and solar energy with the purpose of storing the generated power but sometimes we shall connect to national grid when we are asked to interconnect with them and after our battery get full charged.

In most countries of south equatorial in Africa, it is difficult to satisfy power demand all year long by hydro sources alone. Hence it is necessary to interconnect other renewable/alternative energy sources for reliability and consistence power supply. Renewable energy sources offer a viable alternative to the provision of power in rural areas. One of the widely available energy sources is the solar energy. Seasonal variations of water and solar resources are complementary to each other. A consistent exploitation of the complementarities of these two sources of energy with battery storage seems necessary to maintain a consistent level of electricity production in favorable sites. Therefore, much research is conducted on minimization of usage of diesel fuel.

Although, hydropower projects can have negative impacts on the environment such as resettlement and disruption of communities, destructions and/or modifications to forests, wildlife habitats and hydrological regime, the use of small or mini hydropower schemes are likely to become an alternative and attractive means of expanding energy supply to rural areas and is eco-friendly. Technological advancement, high expected lifetime and low maintenance costs makes hydro an ideal source for locations with access to flow-of-river. Even a small contribution of hydro may already be valuable.

The alternative/renewable energy sources such as solar energy and mini hydro-power plant have the greater potential to generate power for system utilities. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable and clean way to supply the necessary power to elevate the living standards of people without access to the electricity grid. If stability is concerned with available voltage and power variation, these problems can be solved by integrating the possible alternative/renewable energy sources. The concept of hybridizing renewable energy sources is that the base load is to be covered by largest and firmly available renewable source(s) and other intermittent source(s) should augment the base load to cover the peak load of an isolated mini electric grid system (Lal, 2011)

Rwanda is an under developing country which has a well growing rhythm, but not only does it needs electricity as fuel driving to attain on 2020 vision and other millennium goals where it is primordial that the electrical systems are the most economic and reliable. Moreover, there are the EDPRS targets for energy sector and the electrification program coordinated by the Electricity access roll-out program (EARP) which need to be attained.

The energy has long since been recognized as the basis of all human activities. It is appreciated that the development of a country is determined by how much is efficient and effective to the country to exploit its energy resources. The higher the per capital energy consumption, the higher the gross domestic product (hence the higher the productivity), and consequently, the higher the standards of living of the country.

The Mini hydro/ PV Power Plan and energy storage project involved building a 400 Kw. Mini hydro/PV power plant and energy storage project is not yet done practical here in Rwanda. We researched to locate it around Mpenge River in Musanze district. The grid connected Electricity from REG is located 5km from a business park on an urban fringe, which provides a local load centre. The plant is designed to provide consistency power during daytime peak hours and to be operated in conjunction with power from REG. By combining the two (plants hydro and PV) the project is able to achieve full consistency.

2 METHODS

As it is indicated in the title, this chapter includes the research methodology of the dissertation. In more details, in this part the author outlines the research design, the methods of data collection, observation, the type of data analysis, and the research limitations of the project.

a) Study design

This is a qualitative study which made use of a phenomenological approach to gather relevant data. The aim of such method is not to generalize but to understand and interpret the meanings and intentions that underlie everyday human actions (Bogdan, R., & Taylor, S. J., 1975).
Qualitative design deals with data that is primarily verbal and derives meaning from the participant's perspective and also aims to understand meaning that people attach to everyday life (Bless, C. & Higson-Smith, C, 1995).
The qualitative approach is appropriate for this study because the data collected and used focuses on the participants' subjective experiences on the process of disclosure and the way they interpret them.
Marshall & Rossman (1995) further outline that the qualitative approach to research is uniquely suited to uncovering the unexpected and to exploring new avenues.

b) Observation and interview method

This study was done well because the researcher went live to site. He saw the situation himself so that it gave him how hybrid system can be implemented at Musanze.
Also, this study was done through interview with REG staffs, electrical engineers and other related sources on the following points:

- Is really applicable to construct a hybrid and storage system in this selected area?
- What are the materials to be used and how are related to this project?
- What are the economic considerations of the design of the project?
- How do people agglomerate in this area?
- What is the gross profit to the country according to MDG'S plan?

3 RESULTS

This party analyzed and interpreted the data according to the objectives of the study.

a. **Climate of Musanze District** (NAPA-RWANDA, December 2006)

The climate in Musanze is warm and temperate. There is significant rainfall throughout the year in Musanze district. Even the driest month still has a lot of rainfall. This climate is considered to be Cfb according to the Köppen-Geiger climate classification. In Musanze district, the average annual temperature is 17.8 °C. The rainfall here averages 1302 mm.

The driest month is July, with 21 mm of rain. Most precipitation falls in April, with an average of 182 mm.

b. Analysis

i- Hybrid system continues to grow around the world, it is important to show the public how feasible hybrid systems actually are in a suitable site. The only requirements for mini hydro/PV power are water sources, sun source, turbines, generators, proper design and installation, which not only helps each individual person but also helps the world and environment as a whole.

ii- Run-of-river micro-hydro turbine schemes generate electricity when the water is available and provided by the river. When the river dries-up and the flow falls below predetermined amount or the minimum technical flow for the turbine, generation will cease.

iii- Medium and high head schemes use Weirs to divert water to the intake, it is then conveyed to the turbines via a pressure pipe or penstock. Penstocks are expensive and the design is usually uneconomic due to the high penstock friction head loss. An alternative is to convey the water by a low-slope canal, running a long side the river to the pressure intake or forebay and then in a short penstock to the turbine.

iv- The choice of turbine will depend mainly on the pressure head available and the water flow rate. The Francis turbine is a reaction turbine where water changes pressure as it moves through the turbine, transferring its energy. A watertight casement is needed to contain the water flow. Generally, such turbines are suitable for sites such as dams where they are located between the high-pressure water source and the low-pressure water exit.

Francis turbines can be designed for a wide range of heads and flows and along with their high efficiency makes them one of the most widely used turbines in the world.

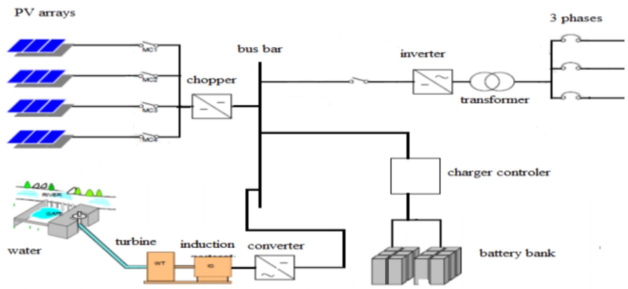
Large Francis turbines are usually designed specifically for each site so as to gain highest levels of efficiencies (these are typically in the range of over 90%). Francis turbines cover a wide range of head- from 20 meters to 700 meters and can be designed for outputs power ranging from just a few kilowatts to one Gig watt.

v- The proposed Hybrid system is comprised of a renewable energy generator (PV), and AC/DC converter (rectifier), a back-up unit generator set (Generator) and a storage system (batteries), and uses renewable energy resources of solar radiation and water resource as a main energy source for storing energy.

4 DISSICUTION

This chapter is to review findings in the context of the literature and the existing knowledge about the subject. It includes structure of hydro/PV hybrid system and designing calculations.

Structure of a hydro/PV power plant and storage



Hydropower system design

$P_h=\rho * g * Q * H$

$P_m=p_h * \eta_T$

$P_{el}=p_m * efficiency * \eta_{Alt.}$

$G=9.81 m/s^2$

$Q=2.3 m^3/S$

$H=18.9 m$

$\rho=1000\ kg/m^3$

$\eta_T=0.8$(efficiency of Turbine)

$\eta_{Alt}=0.9$(efficiency of Alternator)

Resultant efficiency= efficiency of Turbine x efficiency of Alternator

Efficiency= 0.8*0.9=0.72

P_h=1000*9.81*2.3*18.9=426 440.7W

P_m =426 440.7W *0.8=341 152.56W

P_{el}=341 152.56W *0.9=307 037.304W =**307.0373KW**

PV system design

- **100 KW PV system Design**

PV system capacity = 100KWp

- Avg. Sun hrs per Day whole year = 5Hrs (INFRASTRUCTURE, January 2016)

Total Power per day =100 kWp

Total Watt-hrs per Day =500000W-h/day

- Maxi. Solar Insolation at the site = 6.18 KW-h/m²/day (Gasore, 2012)

Panel generation factor

Panel generation factor (PGF) is a key element in the size determination of solar photo voltaic cells on the basis of total watt peak rating and then for estimating the number of panels required for a particular SPV plant, which varies with the solar intensity and sun shine period of the site

Solar irradiance = 1800 kw/m^2 (Richard, 2016)

Standard test condition irradiance = 1000

Panel generation factor:

$$\frac{\text{Solar irradiance} * \text{sunshine hours}}{\text{Standard test conditions irradiance}} \frac{1800*5}{1000}$$

= 9

Energy required from PV modules

Energy required from PV modules can be calculated by multiplying peak energy requirement in kW h/day times 1.3 (the energy lost in the system) to get the total kW h/day which must be provided by the panels Peak energy requirement.

Energy lost in the SPV system=30%

Energy required from PV modules = 1.3*500000watt hour = 650 000watt hour = 650 Kwh/day

Total watt peak rating for PV modules

Total Watt peak rating is calculated using the energy required to be produced from the solar PV modules and the panel generation factor

Total Watt peak rating for PV modules = $\frac{\text{Energy required from PV modules}}{\text{Panel generation factor}}$ = $\frac{650000(watthour/day)}{9}$ =72 222.22watt = 72.222 KW

- **Number of PV modules required**

Total numbers of PV modules required in the power plant are estimated by using the total watt peak rating required and the PV module peak rated output. (Mevin Chandel, 2014)

Number of PV modules required= $\frac{\text{Total watt peak rating}}{\text{PV module peak rated output}} = \frac{722222}{300}$ = 240.74=241Panels.

5 CONCLUSIONS

Dissertation topic is to design a MINI HYDRO/PV HYBRID POWER PLANT AND STORAGE IN RWANDA; this was designed with the aim of showing how to produce and store electrical energy from combining both solar radiation and falling water. Rwanda country having two main seasons such as season of rain and season of sun and it has many rivers with feasibility studies where they can generate several amount of power. This should help the country to achieve on millennium development goals (MDG'S) about the electricity access roll-out program. Thus, the hybrid of Mini-hydro/PV and their storages projects have a number of benefits over other sources of power generation where they save a large amount of money on the cost of buying diesels compared to diesel generators with a continuous supply of electricity and easy and cheap maintenance.
Therefore, an emphasize should be made by providing facilities to investors in this energy field to improve and to increase the accessibility of Mini hydro/PV power plants and storages to all different areas where they can be applicable.

6 LIST OF ABBREVIATION

REG: Rwanda Energy Group Ltd
MDG'S: Millennium Development Goals
EDPRS: Economic Development and Poverty Reduction Strategy.
EARP: Electricity access roll-out program
PV: photovoltaic
MH: mini hydro
Kw: kilowatts
AC: alternative current
DC: direct current
Ph: power due to the head
S: reactive power
Pel: electrical power
Pm: mechanical power
H: head
Q: flow rate of water

G: gravity

ρ: density of water

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Authors Contribution

RAS conceptualized the idea and carried out all necessary project requirements.

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