Modeling & simulation of Utility interfaced PV/ Hydra Hybrid Electric Power System

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Abstract

Renewable energy is derived from natural processes that are replenished constantly. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and bio-fuels and hydrogen derived from renewable resources. Each of these sources has unique characteristics which influence how and where they are used. This project presents the modeling the simulation of solar and hydro hybrid energy sources in MATLAB/SIMULINK environment. It simulates all quantities of Hybrid Electrical Power system (HEPS) such as AC output current of the inverter that injected to the load/grid, load current, grid current. It also simulates power output from PV and Hydraulic Turbine Generator (HTG), power delivered to or from grid and finally power factor of the inverter for PV, HTG and grid. The proposed circuit uses instantaneous p-q (real-imaginary) power theory.

Keywords : MATLAB, HEPS, HTG, SIMULINK, AC, DC

I INTRODUCTION

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. With electricity, lines being confined to large cities and towns, developing countries lag far behind in many sectors when compared to industrialized countries. Ethiopia, despite being the one of Eastern African country, has a very poor electricity penetration rate. Electricity is available for 41% of the population and only 17% of the households are connected to the central grid; even the above coverage is confined to major towns and cities [02].

Since the Ethiopian Government advocates Green Economy Renewable energy sources (solar, wind, hydropower etc) are attracting and got more attention as an alternative energy sources than conventional biomass based energy system it accounts 88 % of the total primary energy consumption in the country [09].

This is not only due to the diminishing fuel sources, but also due to environmental pollution and global warming problems. Among these sources is the solar and hydropower energy, which is the most promising, as the fabrication of less costly photovoltaic (PV) devices becomes a reality and Attractive exploitable capacity of Hydropower. However, using only one type of energy source may result shortage of reliable and sustainable energy supply for the country. Such kinds of problems arise due to large variances of PV output power under different insolation levels and reduction of stream flow during drought seasons. Hence an alternative option to overcome is by integrating Hydropower with Photovoltaic panel which alleviates this problem.

Hybrid energy systems are combinations of two or more energy conversion devices (e.g. Diesel/Wind with storage devices), or two or more Renewable energy resources (e.g. PV/Hydro), Hybrid systems provide a high level of energy security, and reliability through the integrated mix of complementary generation methods, and often will incorporate a storage system (battery, fuel cell) and backup system (Generator) to ensure consistent supply [Clean Energy Action Project, case studies].

II Off Grid-PV -Micro Hydro Power System

Off grid, electricity can be generated by single-source system using solar photovoltaic panel, wind turbine generators, micro-hydro power plant or fuel-powered combustion engine generator sets, or by integrating, one or more types of these electricity-generating sources in a so-called hybrid system (see figure 1.2), hybrid system can supply power to AC or DC load or both. It may require AC, DC or both types of buses power conversion devices are used to transform power.

An off grid power system will need somewhere to store the generated electricity and this is usually stored in batteries. The battery bank provides electricity at night, and during periods of cloud cover (9).

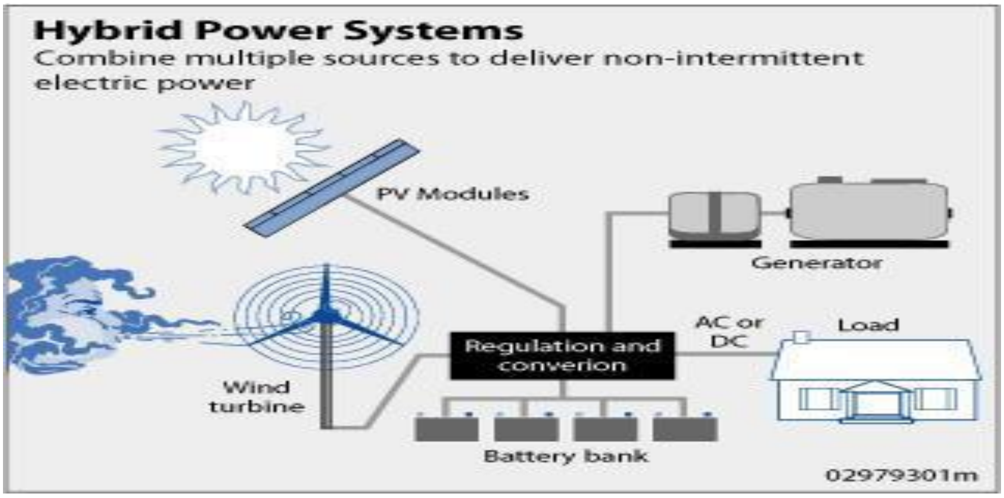

Fig 1.1 system component of typical hybrid energy system

According to Ministry of Water and Energy recent studies, Ethiopia has potential capacity of more than 1.3 million MW for wind resources and annual reserves of 2 million TWh of solar energy and 45MW exploitable hydropower potential according to the Master Plan.

1.2 Background and Problem statement

According to EEPCO, current data with only 17% of households connected and 41% of the he population is estimated to have access to electricity and the per capital energy consumption is 100kWh, which is the lowest in the sub-Sahara average, that is 510kWh. [www.mowe.gov.et]. Most of the non-electrified regions are found in rural part of the countries. These regions can be electrified either by extending the grids of the existing power systems or by constructing isolated (standalone) power systems. In general, it is preferred to go for the extension of the existing grids but they are not always affordable the fact that most of the non-electrified parts are located in remote and difficult areas, like hilly regions, forests, and they are scattered, which demand enormous investment for grid.

1.3 Project Description

The proposed Hybrid system is comprised of a renewable energy generator (PV), and inverter (DC/AC converter), 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.

1.4 Objective of the study

The main objective of this PROJECT is to study the feasibility of micro-hydro-photovoltaic system and energy storage for hybrid electrification of remote villages for sustainably and efficiently satisfy the energy demand of remote village, where central grid electricity has not reached yet due to many geographical and economic constraints.

1.5 Scope of the study

The scope of this study is to assess the technical and economical feasibility of a standalone PV-Micro hydro hybrid energy system to supply the rural community detached village from national grid in Ethiopia. The study will investigate different renewable energy option to satisfy the energy demand of the village. This study shall collect and analyze relevant data and information to examine and select the most suitable systems configuration, recommend necessary action, necessary measures that configure a system to accommodate the current and near future electrical energy demand for the village. The study only focuses on solar energy and micro-hydro resource assessment of among different renewable energy resource in the village, like biogas and biomass. In so doing, we shall recommend for further production of a model by other researchers and the limitations of this research shall then clearly be told as to give a way to next coming researchers and those who are interested in the area

III PRINCIPAL COMPONENTS OF MICRO-HYDROPOWER PLANT

3.1 Hydraulic Turbines

The device, which converts hydraulic energy into mechanical energy or vice versa, is known as Hydraulic Machines. The hydraulic machines, which convert hydraulic energy into mechanical energy, are known as hydraulic turbines

3.1.1Types of Hydraulic Turbines

Turbines can be categorized mainly in two types: Impulse turbine and Reaction turbine. Turbine is the heart of hydro system, as they transform the hydraulic energy in the mechanical one, which is a more easily usable form of energy.

3.1.2 Impulse Turbines

The impulse turbine generally uses the velocity of the water to move the runner and discharges to atmospheric pressure. The water stream hits each bucket on the runner. There is no suction on the down side of the turbine, and the water flows out the bottom of the turbine housing after hitting the runner. An impulse turbine is generally suitable for high head, low flow applications.

There are three basic types of impulse turbines, which distinguished and which have different physical principles and characteristics. These are the Pelton turbines, the Turgo-turbine and the Cross flow-turbine (also known as Banki-Mitchell or Ossberger-turbine).

3.1.3 Pelton Turbine

Pelton turbines are impulse turbines where one or more jets impinge on a wheel carrying on its periphery a large number of buckets. Each jet issues water through a nozzle with a needle valve to control the flow (figure 6.4). they are only used for high heads from 60m to more than 1000m. The axes of the nozzles are in the plan of the runner. In case of an emergency stop of the turbine (e.g. in case of load rejection), the jet may be diverted by a deflector so that it does not impinge on the buckets and the runner cannot reach runaway speed. In this way the needle valve can be closed very slowly, so that overpressure surge in the pipeline is kept to an acceptable level (max 1.15 static pressure)

3.1.4 Reaction Turbine

A reaction turbine develops power from the combined action of pressure and moving water. The runner is placed directly in the water stream flowing over the blades rather than striking each individually. Reaction turbines tare generally used for sites with lower head and higher flows than compared with the impulse turbines

3.2 Photovoltaic Technology and Solar Energy Resources

3.2.1 Introduction

The energy source of all-live on the earth is the sun. In addition, the sun is the ultimate source of most of renewable energy sources. Solar energy can be used to generate electricity in a direct way with the use of photovoltaic modules. PV technology is now spreading into terrestrial applications ranging from powering remotes sites to feeding utility grids around the worlds. Photovoltaic is the field of technology related to the devices, which directly convert sunlight into electricity where the term photovoltaic is a compound word and comes from the Greek word for light, photo, with, volt, which is the unit of electromotive power. The technology of photovoltaic cells was developed rapidly over the past few decades.

3.2.2 Photovoltaic Cells

There are two main types of photovoltaic system. Grid connected systems (on-grid system) are connected to the grid and inject the electricity into the grid. For this reason, the direct current produced by the solar modules is converted into a grid-compatible alternating current. However, solar power plants can also be operated without the grid and are then called autonomous system (off-grid systems)

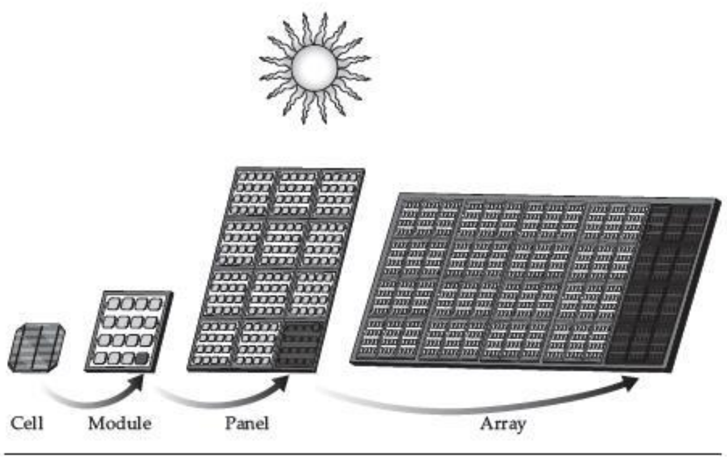

Fig 2. PV system component

3.4 Common Terminologies of Photovoltaic Cells

Solar irradiance is an instantaneous quantity describing the rate, or flux of solar radiation (power) incident on a surface, commonly expressed in units of kilowatts per square meter (kW/m2). Outside the earth's atmosphere, the solar irradiance on a surface oriented normal (perpendicular) to the sun's rays is essentially constant at 1.36kw/m2. Due to atmospheric effects, the peak solar irradiance incident on a terrestrial surface oriented normal to the sun, at noon on a clear day is about 1 kW/m2. A solar irradiance level of 1kW/m2 is often called peak sun and is the reference condition commonly used to rate the peak electrical output of photovoltaic modules and arrays.

3.4.1 Solar insolation: is an amount of solar energy received on a surface commonly expressed in units of kilowatt-hours per square meter (kWh/m2). Solar insulation (energy) is essentially the average solar irradiance (power,) integrated with respect to time. When solar insulation data is represented on an average daily basis, the value is often called peak sun hours (PSH), and can be thought of as the number of equivalent hours per day that solar irradiance is at its peak level of 1 kW/m2. The worldwide average daily value of solar insolation on optimally oriented surface approximately 5 kWh/m2. Figure 2.15 shows the relationship between solar irradiance and in solution

3.5 Main Components of Photovoltaic System

3.5.1 PV modules

A PV module is composed of interconnected photovoltaic cells encapsulated between a weatherproof covering (usually glass) and back plate (usually a plastic laminate). It will also have one or more protective by-pass diodes. The output terminals, either in a junction box or in a form of output cables, will be on the back. Most have frames. Those without frames are called laminates. In some, the back plate is also glass, which gives a higher fire rating, but almost doubles the weight.

3.5.2 Battery bank

For systems that require energy storage, like any system that needs to operate without the utility grid. A battery bank, multiple batteries wired together to achieve the specific voltage and energy capacity desired. The battery bank is typically housed in a container to keep the batteries safe. The PV array connects to it in order to provide charging a charge controller. The battery bank is also connected to the inverter to provide power for the AC loads. If the system also uses DC loads, the battery bank is wired to a DC load center

3.3 Photovoltaic Rating

Photovoltaic's modules are available in a range of sizes. Those used in grid tied or stand-alone systems range from 80w to 300w. The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under the Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25oC (77 F), an incident solar irradiant level of 1000 w/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always present PV modules and arrays operate in the filed with performance of 85 to 90 percent of the STC rating.

3.5 PV Technology Many crystalline or thin film PV modules power a solar PV system. Individual PV cells are interconnected to form a PV module. This takes the form of a panel for easy installation. PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive and electric current. There are two broad categories of technology used for PV cells, namely, crystalline silicon, as shown in figure 2.17. This accounts for the majority of PV cell production and thin film, which is newer and growing in popularity. The "family tree" in figure 3 gives an overview of these technologies available today and figure 6 illustrates some of these technologies.

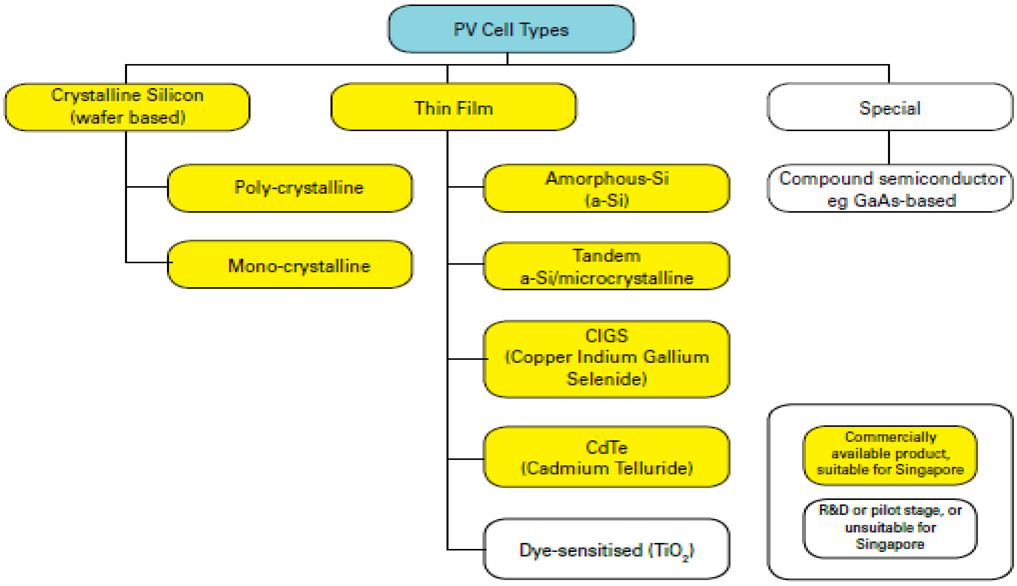

Figure 3 PV technology family trees

IV SYSTEM DESIGN AND PERFORMANCE PREDICTION OF THE HYBRID SYSTEM

4.1 Introduction

A hybrid system is a combination of one or more resources of renewable energy such as solar, wind, micro/mini-hydropower and biomass with other technologies such as batteries and diesel generator. As an off-grid hybrid power generation, the hybrid system offers clean, efficient and sustainable power that will in many cases be more cost-effective than sole energy systems. As a result, renewable energy options have increasingly become the preferred solution for off-grid power generation,

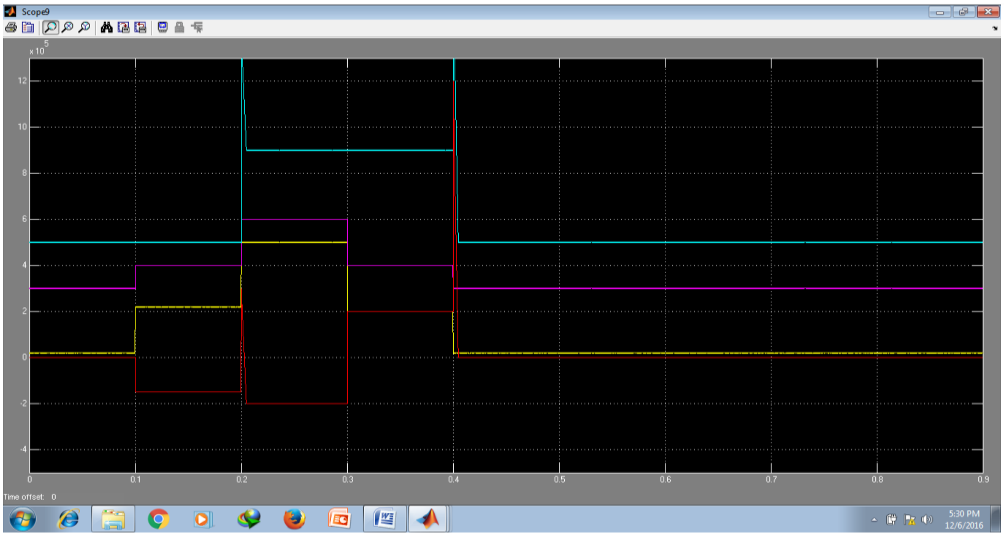

Fig.5.1 Generated power from PV/HTG, load demand grid power

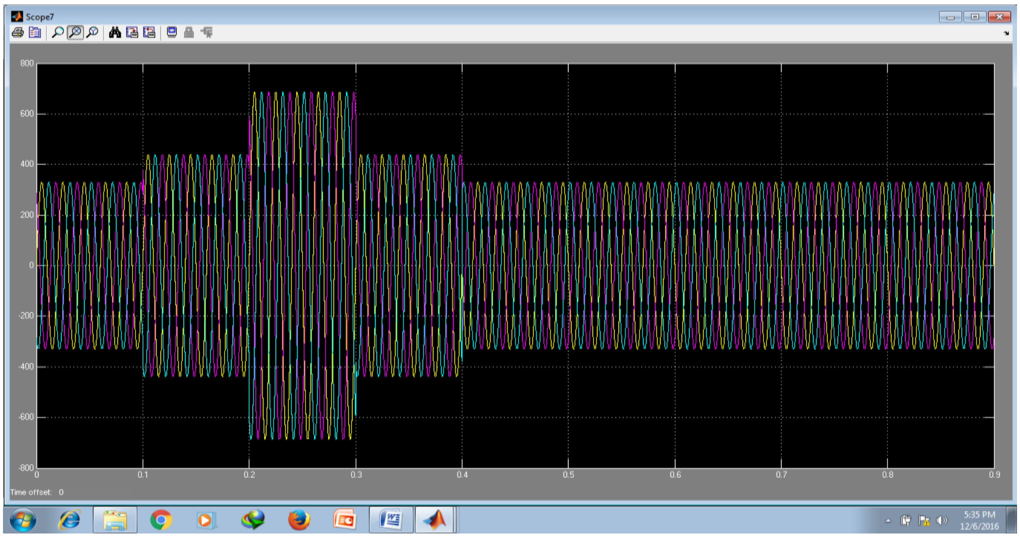

Fig.5.2 Inverter line current from HTG to the load/grid

V CONCLUSION AND FUTURE WORK

The design and manufacture of highly reliable equipment made integration of HEPS easier nowadays. In this project PV/HYDRO HEPS interface with EU for solving power crisis problems are simulated by using Matlab/Simulink environment. The control circuit for the converter for all radiation and hydraulic turbine speed has been successfully simulated. The total harmonic distortion (THD) at the local bus is within acceptable limits and reached to 0.14% for the inverter current from HTG, 0.15% for the inverter current from PV and 0.20% for the grid current.

1.From Technical point of view, a hybrid Micro Hydro/PV / Battery system is proposed in the project

2.From Economic Point of View, it is found that for the village under study ,which is characterized by average stream flow potential of 12,320 liters/second and solar radiation potential of 6.01kWh/m2/day, The hybrid system is cost competitive with 0.044$/kWh, this is less than the current grid price of Ethiopia 0.06$/kWh.

3.From Environmental Stand point, the renewable energy fraction of the project is 99%, which implies the total energy almost obtained from Renewable Energy Resources. Due to this study promoting clean energy and its contribution to the reduction of Pollutant emission released to the environment.

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