Grid Connected Hybrid Wind-Solar-Diesel Power System

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Abstract— This paper intends to net cost minimization in design and considering the environmental beneficial factors, GCHPG is designed using Green Energy Resources (GES). The Solar and Wind energy are green sources and potential sources of RES. The Grid Connected Hybrid System sources, wind and solar are integrated and complement each other in order to meet the load demand of an area. Hybrid power system usually takes advantage of both the Photovoltaic (PV) System and Wind Energy Conversion System. During peak load periods, the diesel unit used to compensate the power demand. Modeling and sizing of a Grid connected hybrid energy system is based on the cost reduction and reliability. The MPPT (Maximum Power Point Tracking) technology is used to extract the maximum available power from the wind and PV array.

Key words: hybrid energy system, MPPT

I. INTRODUCTION

Energy is playing an important role in human and economic development. One of the driving forces for social and economic development and a basic demand of nation is energy. In present scenario only 55% households in India have access to electricity; remaining 45% of households' area was isolated from the grid system. In order to provide Uninterrupted and Reliable supply of electricity for 24 hours a day to the isolated households by Stan-Alone Hybrid Power Generation System (SAHPG) and it is the most viable to the areas without grid facility. Most of the energy production methods are one-way, which requires change of form for the energy. In parallel to developing technology, demand for more energy makes us seek new energy sources.[1] In parallel to developing technology, demand for more energy makes us seek new energy sources. Researches for Renewable energies have been initiated first for wind power and then for solar power. A hybrid renewable energy system utilizes two or more energy production methods, usually solar and wind power. The major advantage of solar / wind hybrid system is that when solar and wind power production is used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced slightly as there is less reliance on one method of power production. Often, when there is no sun, there is plenty of wind. Solar-PV and wind energy are being recognized as cost effective generation sources in small isolated power systems. Wind energy and solar energy are reliable energy sources but their output greatly depends on climatic conditions, including solar irradiance, wind speed, temperature, and so forth [2]-[5].

A maximum power point tracking (MPPT) is discussed on wind and photovoltaic energies [6]. The components and subsystems of a stand-alone power supply system based on renewable sources are inter connected to optimize the whole system. Off-grid hybrid power systems can also incorporate energy storage. If some of the loads connected to a hybrid PV-wind system require permanent electric power supply, a backup diesel generator can be connected to the system to provide electric energy for peak loads which cannot be covered by the hybrid wind-solar combination.

All the energy sources are modeled using MATLAB software tool to analyze their behavior. A simple control method tracks the maximum power from the wind/solar energy source to achieve much higher generating capacity factors. The simulation results prove the feasibility and reliability of this proposed system.

II. PROPOSED GRID CONNECTED HYBRID SYSTEM MODEL

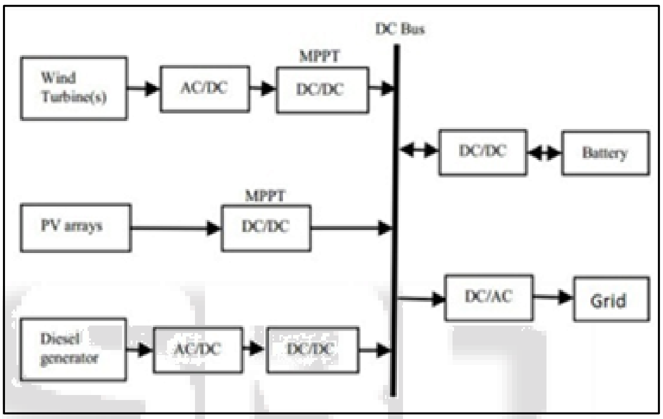

Fig. 1: Block Diagram of Hybrid Energy System

A. *Wind Energy System:*

The kinetic energy of the wind due to its speed is captured by the turbine and is covered to mechanical energy. Along with the turbine, there is a generator present at the tower top which is coupled to the wind turbine by shaft and often with a gear box. The generator converts mechanical energy of turbine to electrical energy and it feeds to the load.

$$P_m = 0.5\rho A C_p v^3 \quad (1)$$

Where

- ρ = Air density (Kg/m^3)
- A = Swept area (m^2)
- C_p= Power coefficient of the wind turbine
- v = Wind speed (m/s)

Power coefficient is the ratio of maximum output to total available in the wind. The theoretical maximum value of C_p is 0.593, which is also known as the Betz limit.

$$Cp = \frac{Pmax}{Ptotal} \quad (2)$$

It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The pitch angle refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis. TSR is defined as the linear speed of the rotor to the wind speed.

$$TSR = \lambda = \frac{\omega r}{v} \quad (3)$$

B. PV System:

A solar cell is the most fundamental component of a photovoltaic (PV) system. The PV array is constructed by many series or parallel connected solar cells to obtain required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce currents by the photovoltaic effect. The global formula to estimate the electricity generated in output of a photovoltaic system is given by

$$E = A*r*H*PR \qquad (4)$$

Where

- E= Emitted energy (kWh)
- A= Total solar panel area (m^2)
- r= Solar panel yield (%)
- H=annual average solar radiation
- PR= Performance Ratio

C. Battery System:

Battery energy storage system (BESS) are includes batteries, control system and power electronic devices for conversion between alternating and direct current. The batteries convert electrical energy into chemical energy for storage. Batteries are charged and discharged using DC power, regulates the flow of power between batteries and the energy systems is done by a bi-directional power electronic devices.

D. Diesel Unit:

Diesel Generators are useful appliances that supply electrical power during a power outage and prevent discontinuity of daily activities or disruption of business operations. Generators are available in different electrical and physical configurations for use in different applications.

III. MPPT

The maximum amount of energy obtained from the wind is at a specific rotation speed to maintain the optimum tip-speed ratio (TSR). The purpose of the MPPT is to maintain the TSR of the wind turbine as close as possible to the optimal TSR. The MPPT technology can be classified into two main groups. The first group has no information about C_P curve of the wind turbine; this method is known as P&Q (Perturbation and Observation). The second group uses the C_P curve to estimate the optimum operating point.

The operating point can be on the positive slope or negative slope. If the operating point is in the positive slope, the operating point must be moved to the right to obtain the maximum point. This can be attained by reducing the load current. By lowering the load current the electromagnetic torque will be reduced, and the difference between the turbine torque and electric torque will accelerate the wind turbine. If the operating point is on the negative slope the load current must be increased to increase Te. If the torque developed by the turbine is smaller than T_e and the losses caused by friction, the turbine will decelerate. When the wind speed steps over the cut-in speed the controller will produce a perturbation. This perturbation will lead to power increase or decrease so the controller finds out on which side of the slope is the operation point at the given moment. After that the load is increased or decreased until the slope is zero. When the slope becomes zero the system has reached the maximum power point.

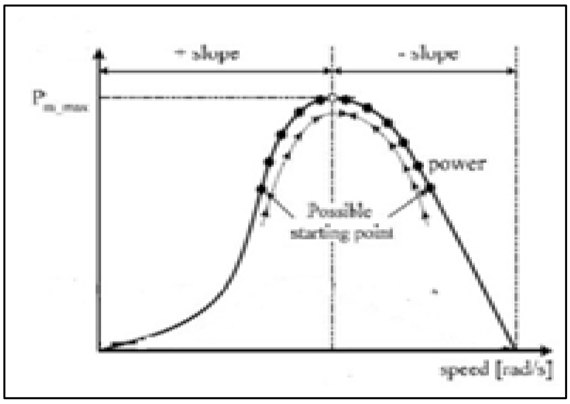

Fig. 2: MPPT Mountain Slope

IV. SIMULATION RESULTS

Study of simulation was carried out to analyze the active performance of the proposed standalone hybrid energy system design with the complete system is simulated using SIMULINK software. A 10-kW wind/PV/BESS/DU hybrid system was considered. The system parameters used in the simulation study are presented below. All the energy sources are accurately modeled in SIMULINK so as to predict their actual characteristics. Tables give the specification of the wind turbine, photovoltaic and fuel cell which used for the modeling and simulation.

Rated Power Output	8.5 kW
Stator Connection winding	Star
Number of Rotor pole pairs	4
Frequency	50
Stator Phase Resistance	0.425Ω
Stator phase Inductance	8.5mH
Inertia Constant	0.01197kg.m^2
Friction factor	0.001189N.m.s

Table 1: Specifications of PMSG

Maximum Power (Pmax)	250w
Voltage at Pmax (Vmp)	37.1v
Current at Pmax (Imp)	8.28A
Open circuit voltage(Voc)	37v
Short circuit current(Isc)	17A
Total PV array ratings	9.9kv

Table 2: Specifications of PV Array

Battery type	**Nickel-Metal Hydrate**
Rated Capacity	6.5Ah
Initial State -Of-Charge	60%
Nominal Voltage	300

Table 3: Specifications of Battery

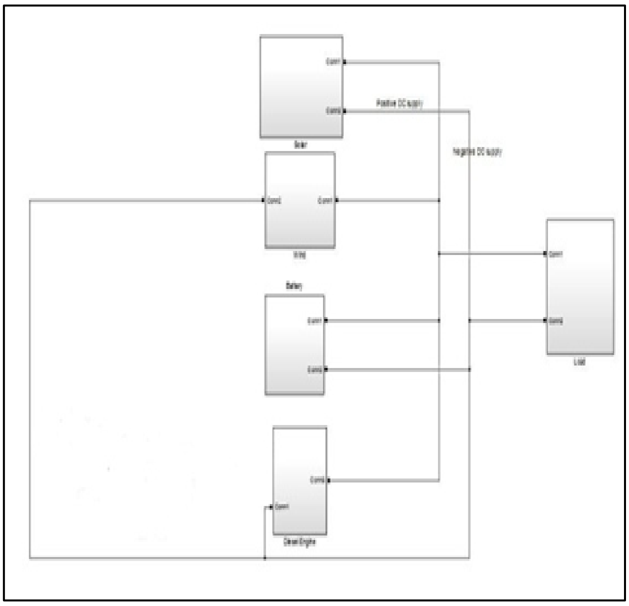

Fig. 3: Simulink Model of Hybrid Energy System

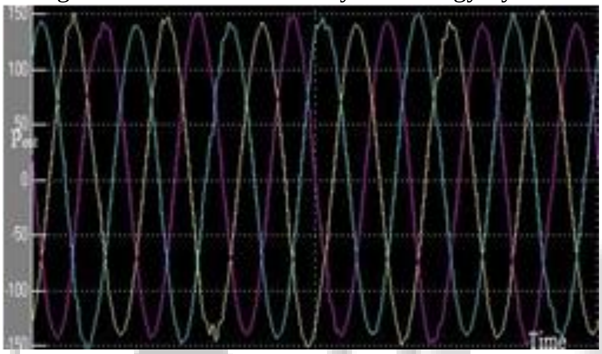

Fig. 4: Graph 1: WECS output

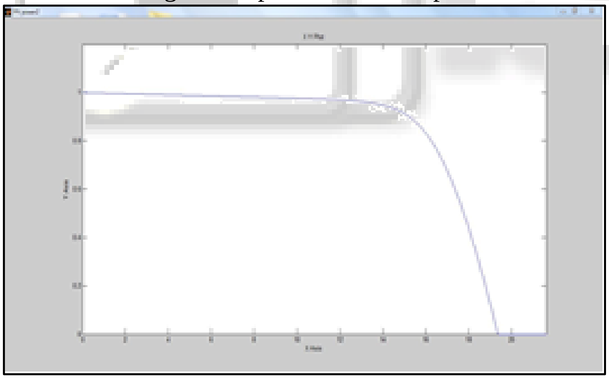

Fig. 5: Graph 2: PV output characteristic curve

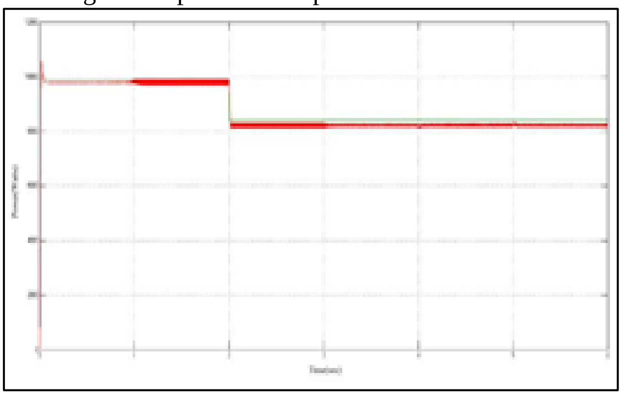

Fig. 6: Graph 3: Battery output

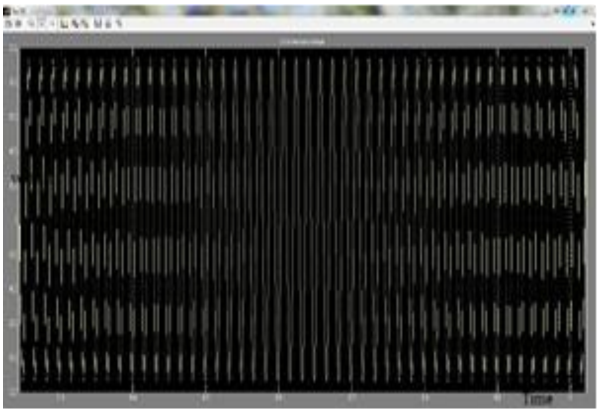

Fig. 7: Graph 4: Diesel unit output

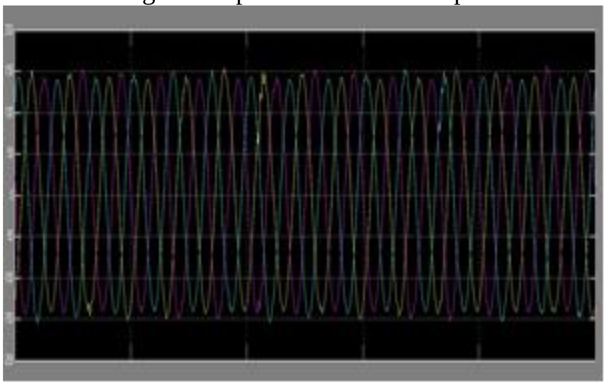

Fig. 8: Graph 5: Overall output of Grid Connected hybrid energy system

V. CONCLUSION

The optimal design of a hybrid renewable generation unit is modeled. Using practical simple simulation model the hybrid system was developed and expected power output is obtained. An inverter is used to convert output from solar & wind systems into regulated AC power output. MPPT was developed to obtain/extract maximum power from both the wind and solar power generating unit. The stimulated output results show higher output efficiency.

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