A SIMULATION MODEL OF SOLAR PHOTOVOLTAIC AND DIESEL HYBRID ENERGY SYSTEM

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Abstract: The integration of renewable energy sources such as PV system and diesel energy system is an excellent option for distributed energy production. The integration of different configuration is reliable and also efficient. Conventional PV system bears unstable output characteristics and thus its integration with other conventional sources increases the utilisation and energetic efficiencies of energy conversion system. Optimal Battery Energy storage for grid connected PV System is used in hybrid system to store the energy absorbed and to be used later. The procedure adopted here is the power can be brought from the grid as well as can be fed back to the grid when surplus power is stored in battery. The proposed energy management technique is tested in simulation under different scenarios and the obtained results demonstrate the effectiveness of the proposed approach.

Index Terms: **Solar Photovoltaic, Diesel Energy System, Hybrid Energy System, Maximum Power Point Tracking**

I. INTRODUCTION

Hybrid renewable energy systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system, or hybrid power, usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. Rapid depletion of fossil fuels has necessitated an urgent need for alternative sources of energy to cater the continuously increasing energy demand. Another key reason to reduce our consumption of fossil fuels is the growing global warming phenomena. Environmentally friendly power generation technologies will play an important role in future power supply.

The renewable energy technologies include power generation from renewable energy sources, such as wind, PV(photovoltaic), MH(micro hydro), biomass, ocean wave, geothermal and tides. In general, the key reason for the deployment of the above energy systems are their benefits, such as supply security, reduced carbon emission, and improved power quality, reliability and employment opportunity to the local people.

1.1 Solar-Diesel Hybrid System

A Solar PV diesel hybrid system usually consists of a PV system, diesel generator sets and intelligent management to ensure that the amount of solar energy fed in the system matches the demand at that time. PV systems require large storage arrangements which make them a costly option. Consequently, solar PV system integrating diesel generator with battery storage is an efficient solution in which the disadvantage of one can be overcome by the advantage of another. Diesel engine is integrated with solar photovoltaic such that there will be uninterruptible power supply throughout to avoid the energy crisis. Hybrid power systems are formed when there is a combination of at least two different power sources. This could be a renewable energy sources plus a low-carbon resource.

A solar PV system becomes feasible at an average irradiation of 3-6 kWh/m^2 per day which is about 1825 kWh/m^2 per annum.

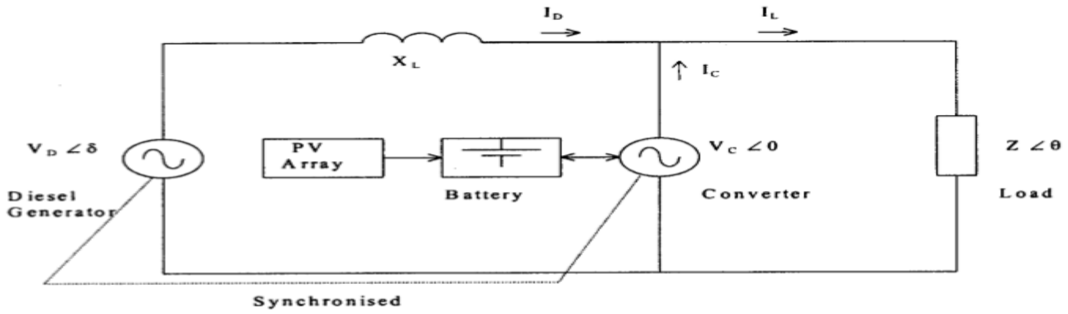


Fig 1.1: Equivalent Circuit of PV-Diesel HPS

1.2 Physical description of the PV Field

The PV field is the renewable energy power source of the plant. It is mainly composed of the PV modules and the electrical inverters. The PV modules convert the solar energy to electrical energy in the shape of DC current. The output power of the PV modules is a function of the solar irradiation on the field and the nominal peak power. The inverters of the PV field convert the DC current into AC current at the frequency of the grid. The inverters can also control the output power by changing the operation point of the PV field. However, it is not possible to increase the output power to more than the maximum power point at a certain irradiation.

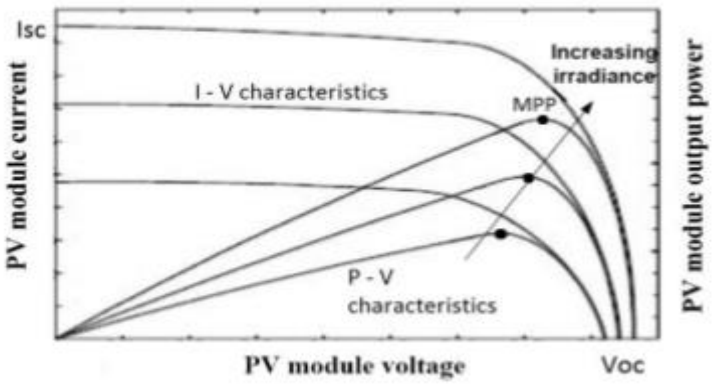


Fig 1.2: The I-V and P-V Characteristics of the PV Field

1.3 Maximum Power Point Tracking

The Maximum Power Point Tracker (MPPT) is needed to optimize the amount of power obtained from the solar PV system to the power supply. The output of a diesel generating system is characterized by a performance curve of voltage versus current. This value can be determined by finding the maximum area under the current versus voltage curve. The inputs of the MPPT consists voltage and current outputs. The adjusted voltage and current output of the MPPT charges the power supply. Hardware and software integration was necessary for the completion of this component. The Perturb & Observe Algorithm is used in this Maximum Power point tracking method. The P&O algorithm calculates the present available power and subtracts it from the previous power value to find the difference (ΔP). As long as ΔP remains positive, power is increasing. However, when $\Delta P < 0$, the controller moves in the opposite direction, and thus continually moves in the direction that ensures the greatest power. This perturbation causes the power of the diesel generating unit changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the method oscillates around the peak point. A PI controller then acts moving the operating point of the system to that particular voltage level. The P&O algorithm periodically measures the PV voltage (V_{PV}) and PV current (I_{PV}), computes PV power (P_{PV}), compares it with the PV power calculated in previous perturbation cycle and applies perturbations to PV reference voltage (V_{REF}) by incrementing or decrementing it.

1.4 Model of Diesel Generator

The model contains three main blocks. The electric control box is an analogue controller type PT1, which gives the control signal. The actuator converts the control signal into a signal of fuel flow rate (throttle). The engine block represents the delay of the combustion to convert the fuel signal into torque signal.

The analysed governor has droop characteristics, which are determined by the parameters of the model. The parameters should be configured in order to approximately simulate the actual performance of the diesel engine.

II. SIMULATION OF SOLAR PV- DIESEL HYBRID SYSTEM

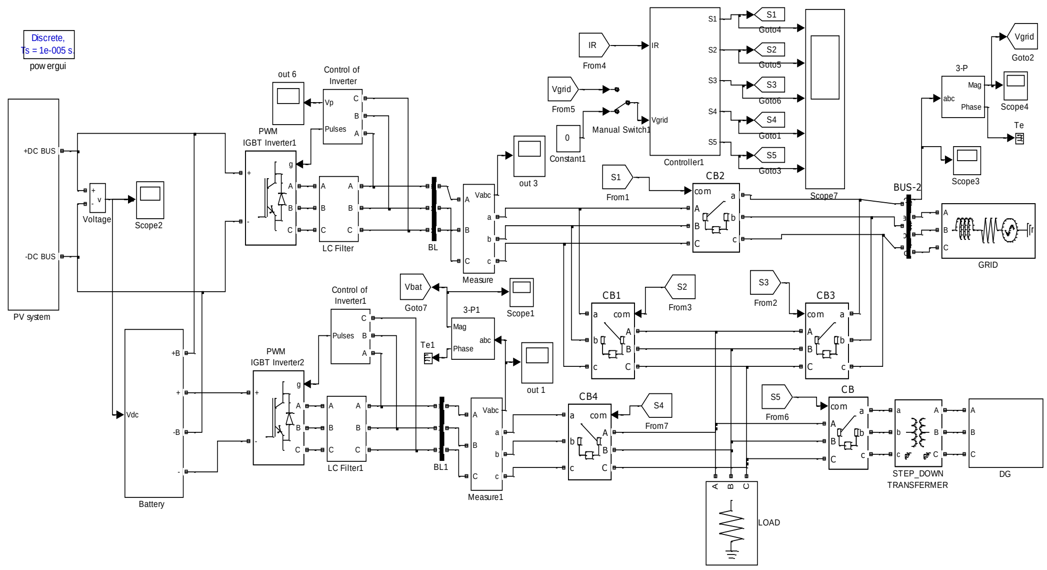


Fig 2.1: Simulation Model of Solar PV- DG Hybrid System

A model is constructed in MATLAB Simulink to create a PV generated system. The samples of the various waveforms are taken for further analysis. A detailed model of PV system is shown for both constant as well as variable solar irradiation. There are 66 cells connected in series. The output of a single cell is 5.87 V. The total output of the PV cell is 20 KW.

The equations for the calculation of photon current and reverse saturation current is given below:

$$I_{ph} = \left[\left[\left(T_{ref} - T\right)\mu\right] + I_{SC}\right] \qquad \text{------------------- (1)}$$

$$I_o = e^{\wedge}\left[\frac{E_g q^2}{A_k}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]\left[\frac{T}{T_{ref}}\right]^3 \qquad \text{------------------- (2)}$$

$$I_{ref} = \frac{I_{se}}{e^{\frac{V_{OC}\,q}{KTN_S A}} - 1} \qquad \text{--------------------- (3)}$$

T_{ref} = Reference temperature= 25+298=323 k

T = Actual temperature

I_{SC} = short circuit current

E_g = Band gap=1.2

N_s= Number of cells connected in series

G= Solar insolation=1000 W/m^2

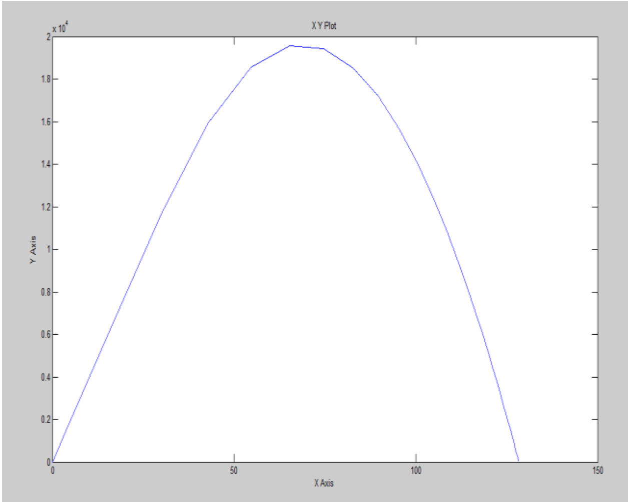
I_D = Diode current

The parameters of solar PV cell on which the output of the cell is dependent are temperature of the solar cell, irradiance. The temperature reference is taken to be 25^0 C and the irradiance is taken to be 1000 W/m^2.

2.1 Hysteresis Control and MPPT Control

The voltage output obtained from the PV cell is tracked with the use of MPPT controller based on Perturb & Observe algorithm. The maximum power point is traced by varying the duty cycle to match the maximum power point whether increasing or decreasing fron the MPP.

The output from the inverter is controlled by the hysteresis control action. It takes the input as the reference current and actual current and when both remains same, there is no need for the controller action. By changing from 0 to 1 in case of negative error to 1-0 in case of positive error, the control action is carried out. The hysteresis band is taken to be ±10% of the current.



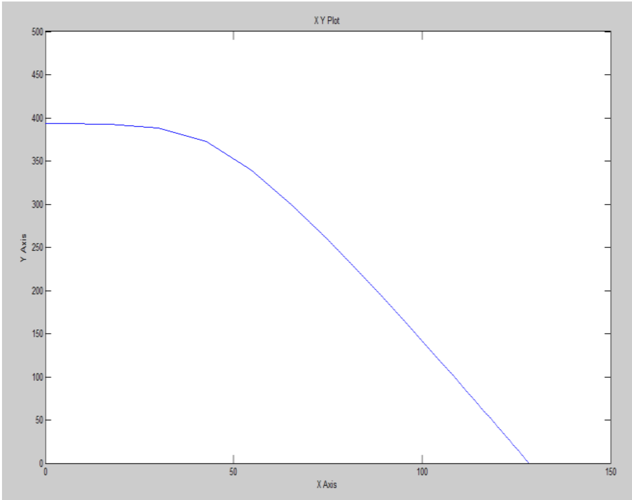


Fig 2.2: P-V & I-V Graph of PV Cell respectively

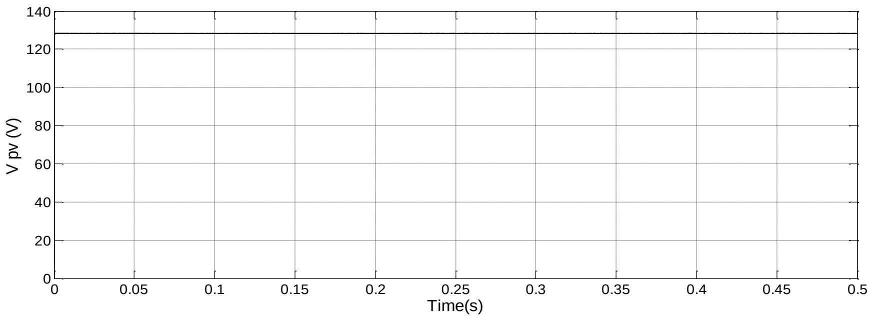


Fig 2.3: Voltage output of PV Cell

The output voltage of the PV cell is measured to be 130 V. The maximum power to be obtained from the PV cell is tracked with the help of the MPPT based on Perturb & Observe algorithm. The output from the MPPT controller is regulated with the help of the CUK converter.

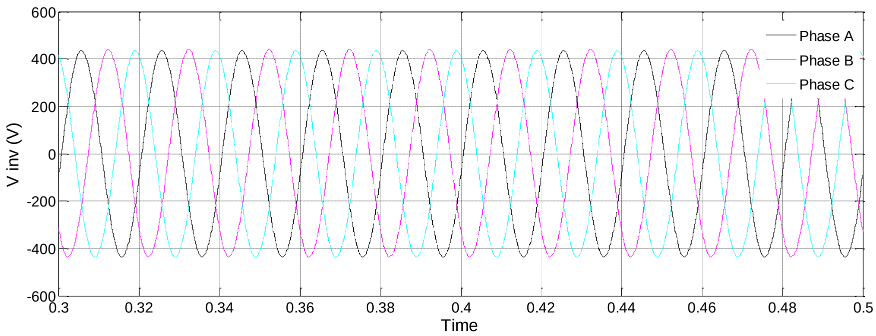


Fig 2.4: Inverter Output

The output obtained from the PV cell is in DC whereas the output obtained from Grid is in AC. Therefore to convert the DC power to AC an inverter is used. The output from the inverter is controlled by the hysteresis control action. It takes the input as the reference current and actual current and when both remains same, there is no need for the controller action. Alternatively, the error is obtained as positive or negative according to which the control action is carried out.

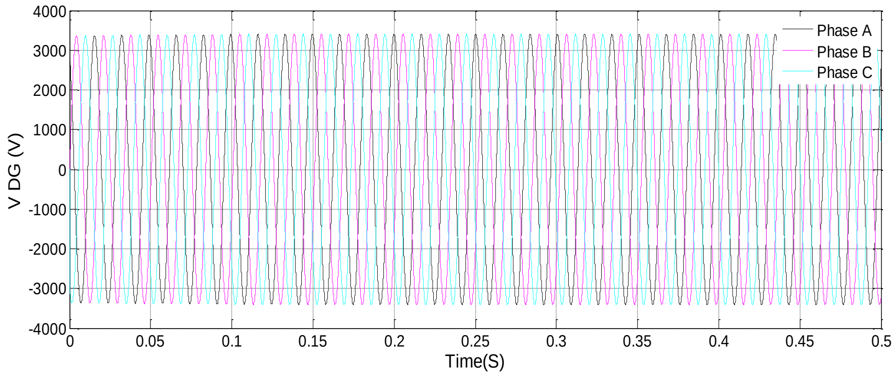


Fig 2.5: Output of Diesel Generator

The Diesel Generator is connected to be operated in the emergency condition to satisfy the load demand. The power output from the Diesel generator is 3KW.

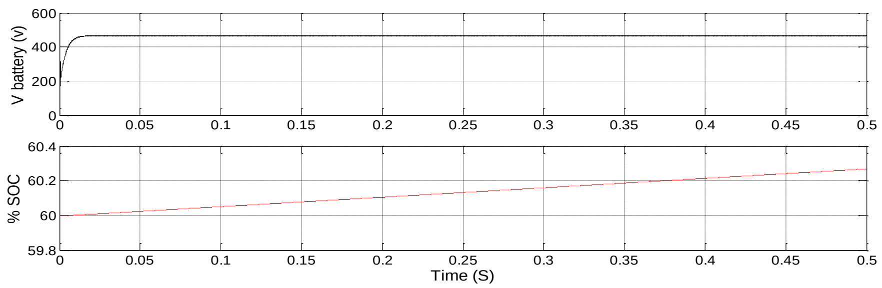


Fig2.6: Charging and Discharging Condition of the battery

The output of the switching characteristics are shown below:

Case 1:

In this case the PV remains unhealthy and only the Grid remains active and supplies power.

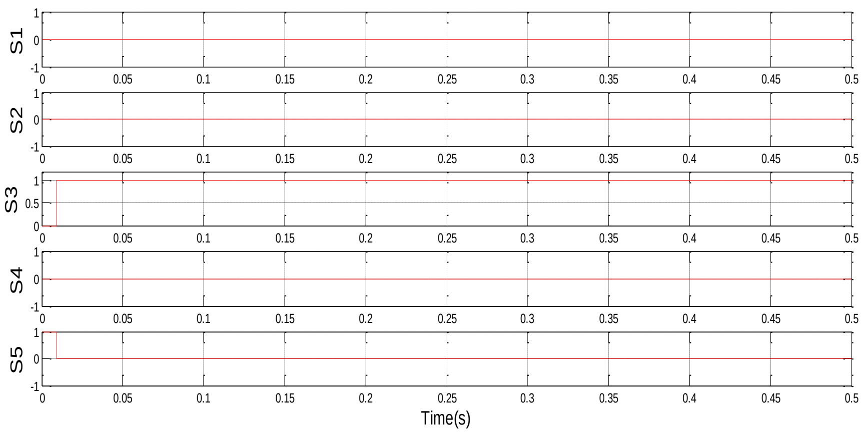


Fig 2.7: Only Grid healthy

Case 2:

In this case both PV and Grid are in operation. Power flow is from PV to grid and Grid to load. The battery remains on but battery does not supply power to the load.

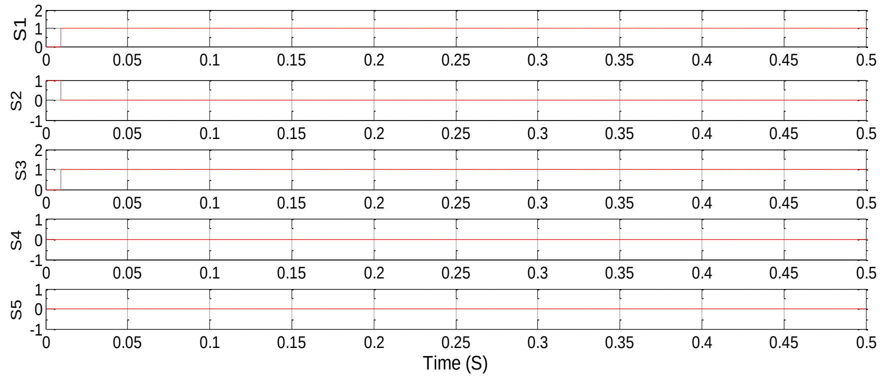


Fig 2.8: Both PV and Grid healthy

Case 3:

The PV panel only supplies power to the load and the grid remains unhealthy. The battery remains on but does not supply power to the load.

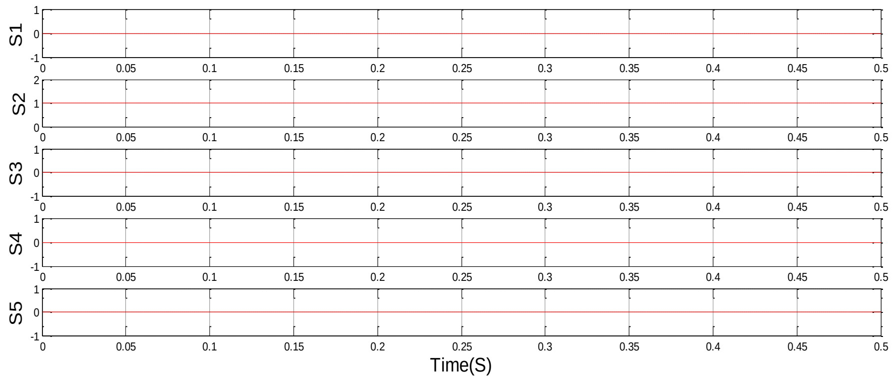


Fig 2.9: Only PV healthy

Case 4:

When the battery is fully charged during the above cases with the power from PV and Grid, it supplies power to the load as a backup when both grid and PV are not in action.

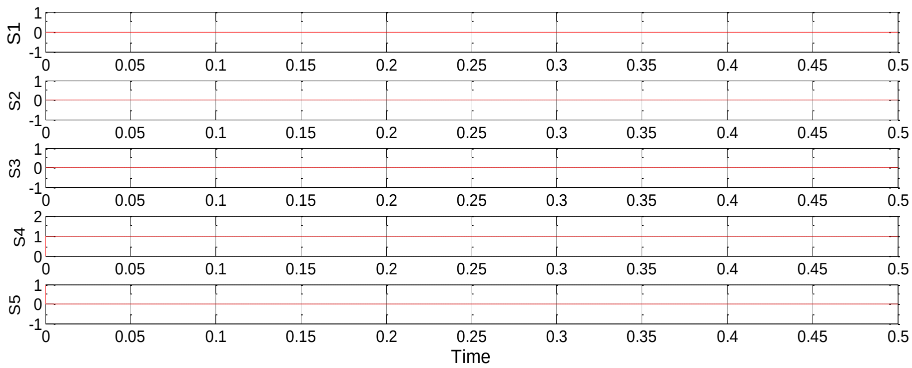


Fig 2.10: Both PV and Grid failure

Case 5:

In this case the Diesel Generator is used as backup in emergency condition when battery is completely discharged and PV panel and Grid are out of action.

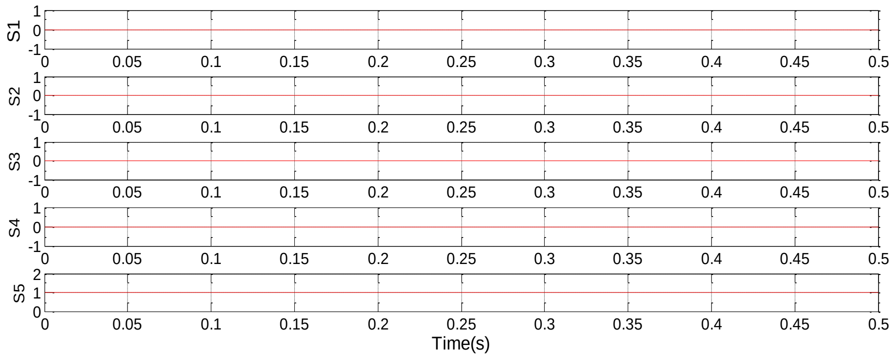


Fig 2.11: All PV, Grid and battery unhealthy. Only DG active

III. CONCLUSION

In this paper, solar photovoltaic is integrated with Diesel generator as a hybrid energy system for the fulfilment of increasing energy demand with the rate of increase of urbanisation and industrialisation and thus avoid the energy crisis. Diesel generator is used for the uninterruptible power supply during the emergency conditions. Perturb & Observe MPPT algorithm is used for tracking of maximum power point such that the system is operated with maximum ratings. Optimal Battery Energy storage for grid connected PV System working is also described in the paper.

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