Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 7 April-June (2015) pp. 60-64

http://www.krishisanskriti.org/areee.html

Optimal Management Strategy for PV/Diesel-Battery Hybrid Power System

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Abstract—*Integration of photovoltaic system with the diesel generator as a backup system is being escalated worldwide to minimize the consumption of fossil fuel resources. The hybrid power generation bring into productive action only by employing a suitable strategic control in operation of connected system. This paper deals with a control strategy that was developed to control the operation of diesel generator and charging/discharging of the battery storage system. The controlling action was detailed in such a way that it coordinates when the power is generated by the solar panel and when to operate the diesel generator and the battery so that the demands of the local utilities in the remote areas should be met with the installed generating system. The main focus in the management strategy of PV/diesel-battery hybrid system is to make the maximum usage of the renewable resource with battery storage system while making the operation of diesel generator in adverse conditions. The management strategy is described in detail through the data flow chart that narrates the different modes of operation considering the variant solar radiations.*

Keywords*: photovoltaic PV system, battery, diesel generator, hybrid system, management strategy.*

1. INTRODUCTION

Many villages in world are isolated from public grid. It becomes inconvenient to meet their requirements by the conventional resources because of high cost of transportation and the distribution of energy to the remote areas. At present, the electric provisioning of these sectors is done by the hybrid system for the power supply to the consumers.The main problem with the renewable energy resources such as solar, wind, biomass, geothermal etc. is that they are highly unpredictable and inconsistent.

The hybrid system is the unification of different energy sources like wind, photovoltaic, mini hydro,

Biomass, fuel cell and many more. Every year the demand of electrical energy is growing rapidly. Green technologies play an important role in future power supply.Since the hybrid topologies are employed because of the intermittent nature of the renewable energy resources. Hybrid power system has a great future due to its more flexibility in operation research. A combination of different but complementary energy generation systems based on renewable resources or mixed is known as hybrid power systems.

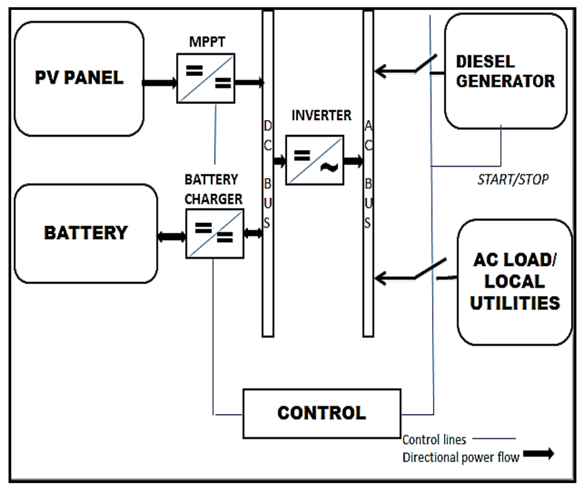

Fig. 1: PV/diesel/battery hybrid system conFig. uration

A photovoltaic panel output depends upon the solar radiations fall on the panel and which in turn depends on the direction of the Sun. but this dependency of the solar energy should be reduced by implementing some storage system such as batteries and back up supply like diesel generator to make the continuity of the supply and for a reliable operation of the hybrid unit an optimal management strategy is necessary [2].

Integration of photovoltaic system with the diesel generator is the better option for the remote areas which is not coupled to the grid, whereas add-on of the national grid is not a cost-effective option. In case of insufficient solar irradiation and after day time, a large amount of budget will be needed for the setup of large storage system. Hybrid systems capture the best features of each energy resource and can provide grid quality electricity with power range of 1 Kilowatt (KW) to several hundred. Also they can be developed as new integrated designs within min grids and can also be combined with diesel based power generating system.

2. PV/DIESEL/BATTERY HYBRID CON*FIG.* URATION

The hybrid conFig. uration of the PV/diesel-battery energy system is shown in the Fig. ure1. The hybrid topology allows all the power generating resources to supply the load separately at their minimum and maximum load requirement as well as supplying the load from the integration of the system by coordinating the converter output with the battery and the output of diesel generator [7]. The charging/discharging of battery and the diesel generator start/stop can be obtained from the controlling action that must be basically controlled by the converter output. The converter may provide the switching control of the diesel generator when the load requirement is not met by the photovoltaic panel output as well as the battery storage during the critical weather conditions when there would be no generation from the panel for long time. There are number of positive features of hybrid topology-

- Minimizing the consumption of diesel fuel in hybrid system as compared to standalone diesel generator power generation unit.
- Reliable operation of the battery system by limiting its usage within its operating limits.
- Maximizing the use of the renewable power source [12].

A. Model Of PV Module

Photovoltaic panel converts the direct solar radiations falling on the surface of the panel into the direct current and then with the implementation of charge controller and the boost converters this power can be efficiently used for the various applications. Several models of photovoltaic panel have been proposed by the researchers in the MATLAB/SIMULINK. In some cases irradiance and the cell temperature are considered as the input parameters and some proposed a model of PV array based on the basic electrical circuit of the solar cell considering the effects of various parameters [3]. In this, the design of the model is based on the equivalent circuit of the solar cell and the basic circuit equivalent equation of the parameters including the irradiance effect on the characteristics of the solar cell. In this paper, detailed I-V parameters are developed for a cell, a module and an array in series and parallel. The Simulink model predicts the I-V and P-V characteristics by considering the varying irradiance.

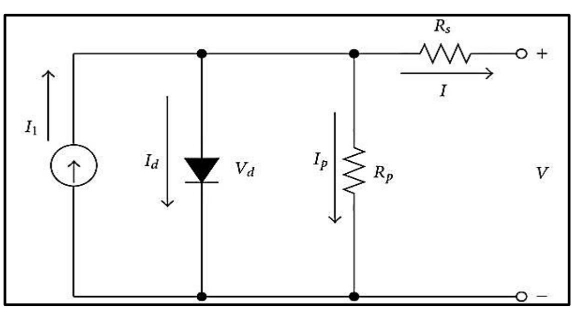

Fig. 2: Equivalent circuit of solar cell [3]

The equivalent circuit of the solar cell comprises of a controlled current source, a diode, a series resistance (R_s) and a shunt resistance (R_p). The antiparallel diode is modified to an external controlled current source which is placed antiparallel with the original source [1] [6].

According to Kirchhoff's current law,

$$I = Irr - Id - Ip$$

I-V relationship for a single solar cell is given by the equation:

$$I = Irr - Io[e^{\frac{q(V+IRs)}{nKT}} - 1] - \frac{V+IRs}{Rp}$$

Where,

$I_{rr,}$ is the photocurrent or irradiance and it varies linearly with the radiations for certain cell temperature

$I_{0,}$ is the saturation current of antiparallel diode.

n, is the ideality factor or the emissivity factor

Boltzmann constant (K=1.3806503 × 10^{-23} J/K)

The output obtained from the panel must be step up with the help of dc-dc boost converter and for the efficient system MPPT charge controller is implemented to make the system operate at its maximum power point[4]. Since the output of the panel is DC so a dc to ac converter or an inverter is then connected after boost converter to meet the ac load requirements.

Battery Model

The generic model for the battery in the Simulink/ Matlab is shown in the Fig. ure3 below.

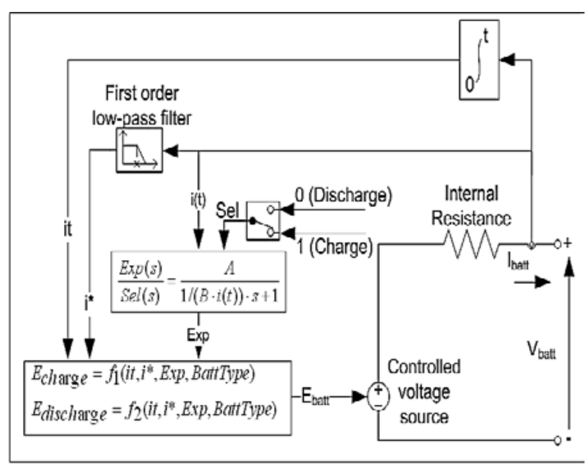

Fig. 3: equivalent circuit of the battery in Simulink/Matlab[2]

The battery stores the energy produced by the photovoltaic panel and the charging and discharging of the battery must be controlled by the battery controller so that it must operates within the limits. The state of charge (SOC) of battery must be calculated by using expression:

$$SOC = 100[1 - \frac{1}{Q}\int_0^t i(t)dt]$$

The power of the battery can be used for the period where there will be not enough light to meet the load requirement from the panel.

B. Diesel Model

The model of the diesel generator unit is mainly comprised of a diesel engine governor for the fuel power control and speed of the generator, excitation system and the synchronous machine. The mechanical energy must be converted into the electrical energy by the diesel engine. The SIMULINK model of the diesel generating unit is shown in the Fig. ure4 [10].

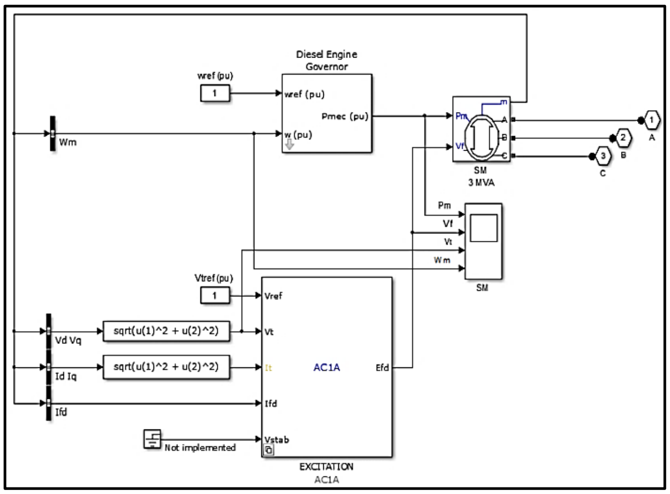

Fig. 4: simulation model of diesel generator

3. OPERATIONAL MANAGEMENT CONTROL STRATEGY FOR PV/DIESEL –BATTERY HYBRID SYSTEM

A. Hybrid Controller

The hybrid system conFig. uration consist of the dc power generating resource photovoltaic panel, battery for storing the dc power connected to dc bus and the diesel generator connected to the ac bus. A three phase inverter or a dc to ac converter is needed to convert the direct current obtained from panel to the ac current for the local utilities. The controlling unit of battery is implemented in between the boost converter and the inverter to control the charging and the discharging of the battery system.A hybrid controller conFig. uration is shown in Fig. ure5.The controller shows the monitoring and the controlling parameters of the hybrid unit [5].The main varying parameters considered for the operation is the radiations availability and the state of charge of the battery. As per the availability of the renewable energy and the battery SOC, the controller coordinates when to switch on the diesel generator and when to control the charging and discharging of the battery.

B. Optimal Management Strategy

The optimal control management strategy is depicted with the help of flow chart as shown in Fig. ure6. There can be operation of controller in four modes depending on the power required by the load and the power able to be supplied by each source of energy [9] [11]. The optimal operational management strategy modes of operation are interpreted as below:

Mode1: Whenever there will be maximum solar radiations then the system must operate under this mode. In this case, the excess amount of power is produced by the panel and supplied to the load directly through the inverter as well as charges the battery only up to its maximum SOC limits. Also the diesel generator must be connected to the system but will remain shutting off as the load requirement is fulfilled by the panel output. The battery charge controlling unit controls the overcharging and undercharging of the battery system. The battery SOC limit must be adjusted to 0.4<SOC<0.8 in the management strategy and the controller tends to maintain this limit to avoid the degradation of battery.

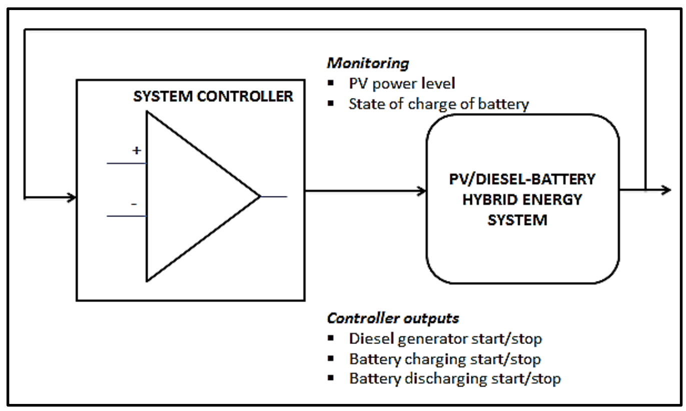

Fig. 5: Hybrid System Controller [5]

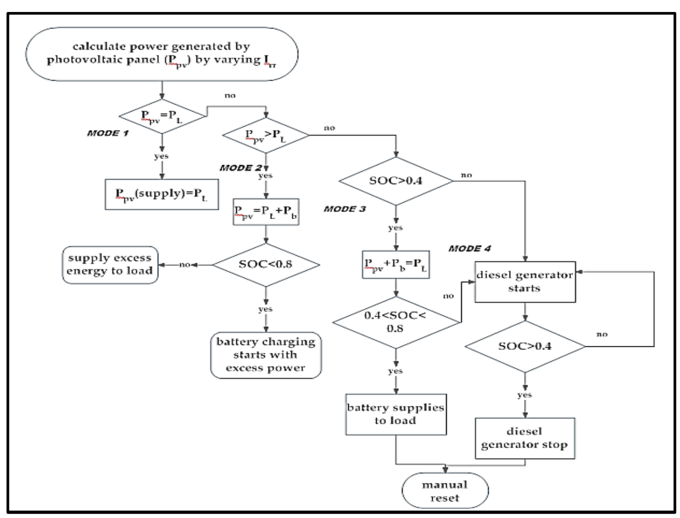

Fig. 6: Flow Chart of Management Control

StrategyMode2: In this operating mode, the prerequisite is met by both panel and the battery as due to the variation in the radiations falling on the panel ,the panel alone not able to meet up with the load demands. The medium power thus also used for charging the battery as in the previous mode.

Mode3: When the system is in mode 3, there should be negligible power generated by the panel and hence the battery SOC is maximum then the load demand is accomplished by the battery until it reaches to the minimum SOC limit of 0.4. After some period of time, it is not possible to generate the power required by the load and there comes the mode 4 operation.

Mode4: When the system operates in the mode4, it implies that the PV and battery is not sufficient to supply the load.

4. SIMULATION RESULTS

Simulation results of the different components of the PV/diesel-battery hybrid conFig. uration are shown as below:

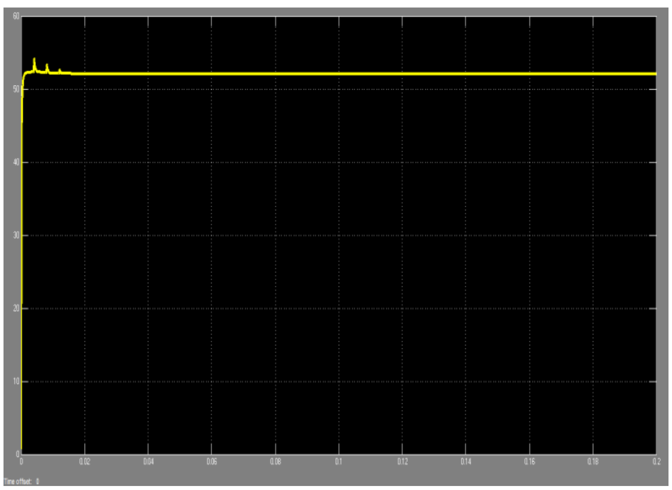

Fig. 7: DC output voltage of dc-dc converter

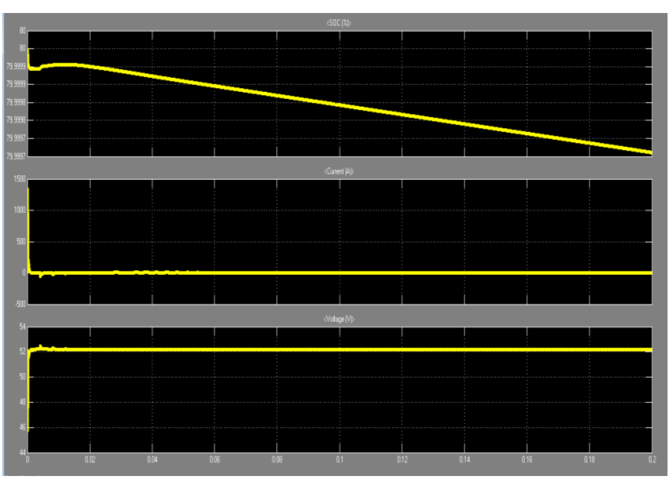

Fig. 8: Battery SOC, current and voltage

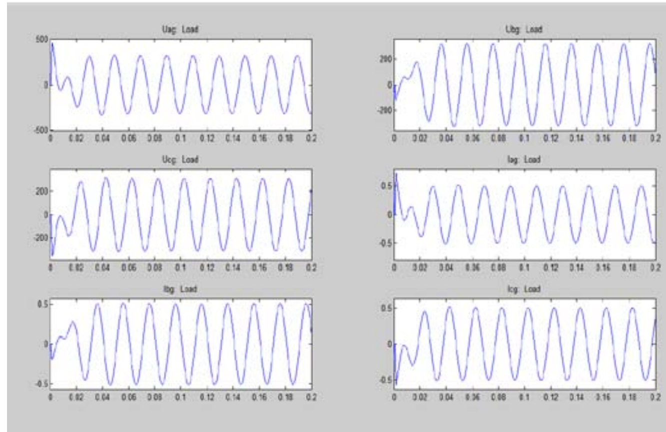

Fig. 9: simulation results of phase to phase load voltages and currents through Multimeter

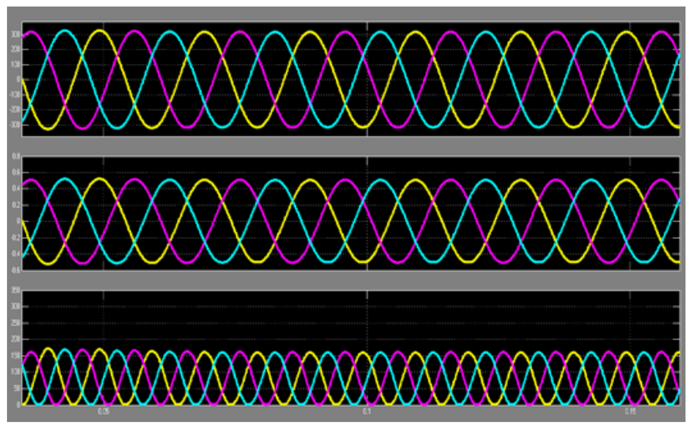

Fig. 10: output load power requirement

5. CONCLUSION

The variable radiating conditions are taken on the basis of which the system decides in which mode of operation it has to work for that period. The controller systematizes the different power generating resources in the hybrid conFig. uration. This paper grants the management strategy that is intended to maximize the use of the non-conventional energy resource by proper switching control given to the battery and the diesel generator so that the power must be supplied to local utilities for certain period under any circumstances.

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