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Performance Analysis of Effective Battery Management Controller for Solar-Diesel Hybrid Power System

[1]P. Raju, [2]S. Vijayan

[1]*HOD, Dept. of EEE, AMKTP College, DOTE, Anna University, Chennai-600123, Tamilnadu, India.*
[2]*Principal, Professor in Dept. of EEE, Surya Engineering College, Anna University, Erode-638107, Tamilnadu, India.*

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ABSTRACT

Background: Demand in electricity today makes us to move towards the renewable energy. This paper proposes standalone solar power system for a rural area with uninterrupted power. Uninterrupted power is the essential quality of power system. **Objective:** In this proposed system Battery Energy Storage System and Diesel Generator are contributed in power system for uninterrupted power. Since the main motive of renewable energy is to reduce the use of fossil fuel, this paper proposes Effective Battery Management Controller to effectively utilize the generated energy by solar power. This paper proposes PI controller for required percentage of Charging. The added main feature in the proposed system is the supplement Battery Energy Storage System which replaces BESS when there is any failure in BESS, it is monitored and controlled by EBMC. **Results:** EBMC monitors and controls charging and discharging of BESS without any wastage of solar power so that the chance of using DG gets reduced. **Conclusion:** The solar power source is effectively utilized and life time of the battery is increased by EBMC. Reliability of the power system is increased by battery fault management system.

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INTRODUCTION

The concentration on the use of fossil fuels for energy supply is the main threat for the stability of the global climate system and our natural living conditions. To conserve our globe, the scientific community gave evidence that mankind has to decrease the green house gases emissions, mainly CO2 and methane, by 60 - 70% as a minimum until the year 2050 (Burri Ankaiah and Jalakanuru Nageswararao, 2013). In order not to harm our natural living spaces and threaten their resilience, a renewed compatibility would require a suitable form of energy alternatives sources that should be independent, easily accessible, and low in cost and should be environmentally clean.

Vital resources of Green energy are solar and wind. Since both resources are not available during the whole day it is essential to hybrid it with the diesel generator. The technical and operational characteristics of wind-diesel hybrid systems are found various disadvantages like power generation only in remote areas; the variability of wind is one of its great disadvantages as an energy source. Bird and bat deaths caused by wind turbines are valid environmental concerns, but wind energy has far less environmental impact than the fossil fuel powered generation that it replaces and is more economically viable than most currently available sustainable methods of Generating Electricity. The gear is another expensive and heavy component and it causes losses. Another disadvantage of the directly grid-connected generator is that the constant speed of wind only allows the turbine to operate at its maximum efficiency; it may not be possible always. The initial and running cost of diesel power generation Machine is expensive. Diesel generator is more expensive compared to other generator type. So we are going to renewable energy resources like PV, the main advantages of this technology are their low maintenance costs and low pollutant emissions and High power density. Coming to the photovoltaic energy generation it offers many advantages compared to other renewable energy sources, particularly in terms of reliability, less maintenance and eco-friendly.

Renewable energy power generation particularly from solar energy using Photovoltaic (PV) has emerged in last decades since it has the aforesaid advantages and less maintenance, no wear and tear. The main applications of PV systems are in either stand-alone systems such as water pumping, domestic and street lighting, electric vehicles, military and space applications (Sam C.M et al, 2011- ChandrashekharLavania et al, 2013) or grid-

Corresponding Author: P. Raju, HOD, Dept. of EEE, AMKTP College, DOTE, Anna University, Chennai-600123, Tamilnadu, India.
Phone: 91-9840390698, E-mail: raju_suma2005@yahoo.com

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connected configurations like hybrid systems and power plants (Achim Woyte et al, 2006). The main criterion in renewable power plant is storage of electricity. The efficiency of the power system depends on the effective storage of power generated. The reliability of the system is uninterrupted supply of electricity. This paper proposes an embedded based automatic battery replacement in case of any failure in main battery bank. This paper proposes uninterrupted power with very less pollution.

II. Solar-Diesel Hybrid power system:

The basic block diagram of solar diesel hybrid power system is shown in figure 1. The power generated by the PV panels is DC power and variable voltage because of the varying irradiance of sun. The DC- DC converter followed by the source make it as constant voltage supply suitable for applications. The maximum power point tracking controller senses continuously the voltage and power produced by panel and controls the DC- DC converter with proper positioning of PV panel. The DC powers from Solar panels and battery are converted into AC with the help of inverter. The transformer placed after inverter helps in leveling the voltage as well as for sine wave. The battery energy storage system is monitored and controlled by EBMC. The source selector is embedded based controller and it selects sources to grid based on available power and load. It minimizes the usage of diesel generator.

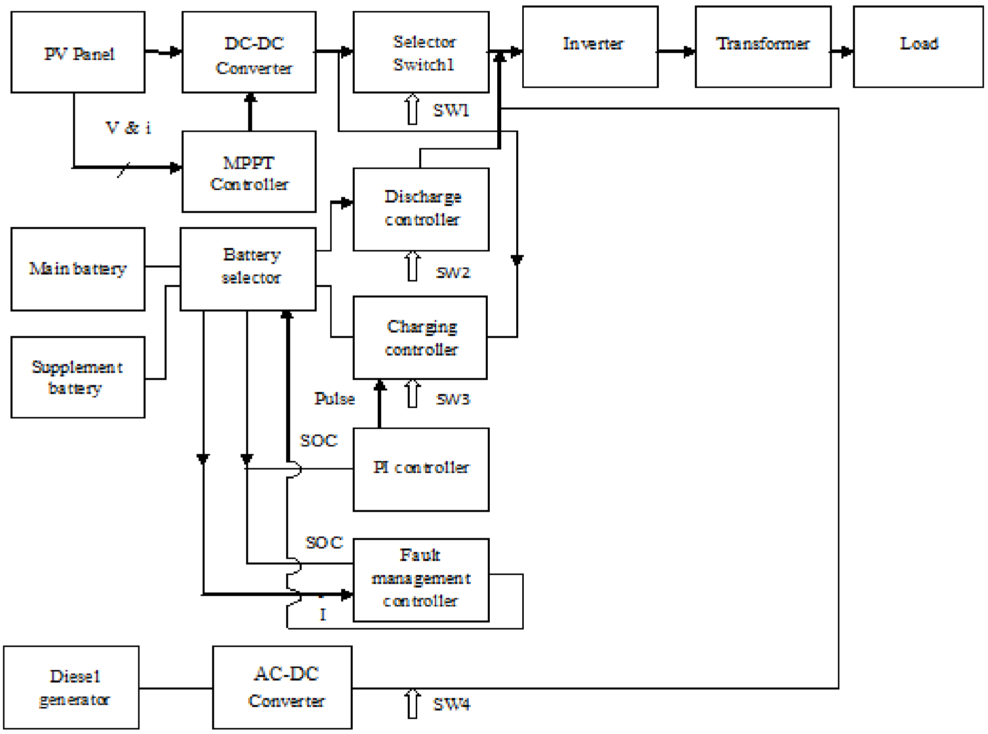

Fig. 1: Block Diagram of HPS

III. PV panel:

The PV cells generate DC electricity whenever sunlight falls in it. Solar radiation sustains all form of life on earth. According to estimates, sun radiates 1.74 x 10^{17} W of power per hour to earth the daily solar energy radiation varies from 4-7 kwh per m2 and there are 270-300 sunny days in a year. Single PV cell produces a rather small voltage that has less practical use. The real PV panel always uses many cells to generate a large voltage (Roman Kedi Roman Keding, ng et al, 2013).

The following parameters were used in the calculation of the net current of a PV cell.

Saturation current of the diode, Io, Net current from the PV panel I, Light-generated current inside the cell I_L, Series resistance Rs, which is internal resistance of the PV panel, Shunt resistance Rsh, in parallel with the diode, Rsh ,is very large unless many PV modules are connected in a large system, Diode quality factor, n.

In an ideal cell Rs is 0 and Rsh is infinite. The net current of the PV cells is the difference between the output current from the PV cells and the diode current is given by (Surya Kumari.J and Ch. SaiBabu, 2012) (Dorin Petreus et al, 2008).

$$I=I_L-Io[e^{(q(V+IRs)/nkT)}-1] \quad (1)$$

Where V is the voltage across the PV cell, k is the Boltzmann's constant (1.381 x 10 $^{-23}$J/K), T is the junction temperature in Kelvin, q is the electron charge (1.602 x 10^{-19} C), n is the diode quality factor (1.62).

III. A.Incremental Conductance Mppt:

In this paper Incremental Conductance algorithm is proposed for MPPT. It decides duty ratio based on the power deviation. In incremental conductance method the array terminal voltage (Snyman D and Enslin J, 1993) (M. Lokanadham and K.Vijaya Bhaskar, 2012) is always adjusted according to the MPP voltage it is based on the incremental and instantaneous conductance of the PV module.

The basic equations of this method are as follows.

$$\frac{di}{du} = -\frac{i}{u} \tag{2}$$

$$\frac{di}{du} > -\frac{i}{u} \tag{3}$$

$$\frac{di}{du} < -\frac{i}{u} \tag{4}$$

The I and V are P-V array output current and voltage respectively. The left hand side of equations represents incremental conductance of P-V module and the right hand side represents the instantaneous conductance. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at the maximum power point (M. Lokanadham and K. Vijaya Bhaskar, 2012). The Flow chart of incremental conductance MPPT is shown in fig 2.

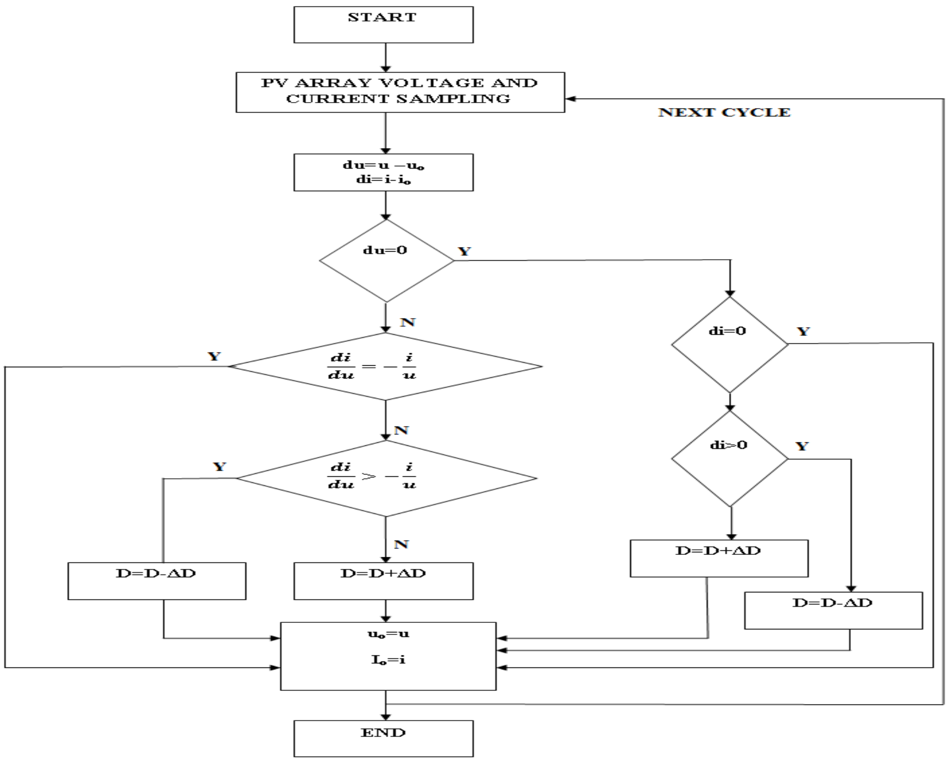

Fig. 2: Incremental conductance MPPT Flow chart

In this method the peak power of the module lies at above 98% of its incremental conductance. This method is easy to implement.

III.B. DC–DC buck-boost converter:

In buck–boost, step-down/up or bi-directional converters, the output voltage magnitude may be lower or higher than the input voltage magnitude (Jain S and Agarwal V, 2007), so this topology can be used in connecting nearly-matched battery or load and module voltages. A negative output also results from the common terminal of the input current.

It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least two energy storage element, a capacitor and an inductor. The basic schematic of a boost converter is shown in figure 3. The switch is typically of a MOSFET, IGBT or BJT.

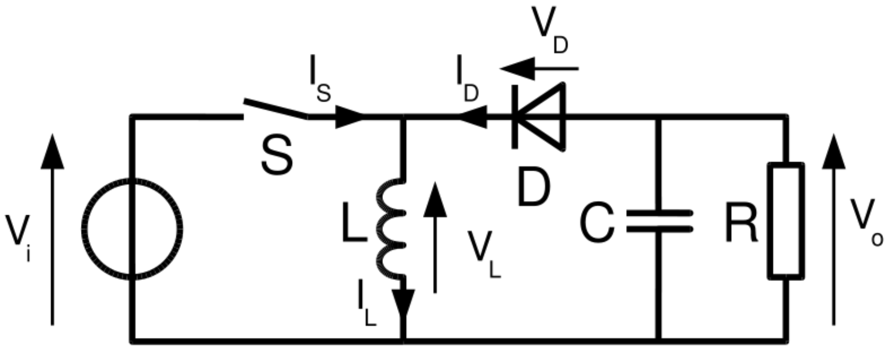

Fig. 3: Schematic of buck-boost converter

Buck–boost topology can be achieved through cascade connection of the two basic converters (buck converter and boost converter). The output–input voltage conversion ratio is the conversion ratio of the two converters in cascade when the switches in both the converters have the same duty cycle. Buck–boost conversion ratio obtained through buck converter in the first stage results in a buck-boost-cascaded converter.

The resistance conversion ratio of buck–boost converter while increasing D decreases the input impedance Ri thus the PV operating voltage moves to the left region of the I–V curve, and that decreasing D increases Ri thus the operating voltage moves to the right of the I–V curve. Buck-boost converter thus does not have an on-operational zone, so changing the duty cycle enables operation from short-circuit current to open-circuit voltage. The topology is also the only one able to trace the load resistance, which ranges from zero to infinite.

IV. Battery Energy Storage System:

Energy storage system is very essential for renewable energy based power system to provide a constant power to the load. The lead-acid battery is proposed in this paper for energy storage. It has two modes of operation charging and discharging modes. When the current to the battery is positive, the battery is in the charging mode. When the current to the battery is negative, the battery is in the discharging mode. The following parameters were used for modeling the battery (M. Kalantar, S.M. Mousavi G, 2010). SOC varies linearly with Vocb (open-circuit battery voltage).

_ SOC1 is the initial state of charge,
_ SOC (%) is the available charge.
_ SOC m is the maximum state of charge.
Ns is the number of 2 V cells in series.
_ D (h_1) is the self discharge rate of battery.
_ Kb (no unit) is the charging and discharging battery efficiency.

As the terminal voltage of the battery is given by

$$V_{bat} = V_1 + I_{bat} R_1 \tag{5}$$

Here R1 is the equivalent resistance of the battery. V1 and R1 both depend on the mode of battery operation and have different equations. Battery current; Ibat is positive when battery is in charge (ch) mode and negative when it is in discharge (dch) mode.

In charging mode, R_1 and V_1 are written as (J.-M. Kwon et al, 2006),

$$R_1 = R_{ch} = \left(0.758 + \frac{0.139}{[1.06 - SOC(t)]n_s}\right)\frac{1}{SOC_m} \tag{6}$$

$$V_1 = V_{ch} = [2 + 0.148SOC(t)]n_s \tag{7}$$

$$P = P_s + P_w - P_b \tag{8}$$

Equation (8) shows the total power of the HPS when the battery is charging.

In discharging mode R1 and V1 are written as

$$R_1 = R_{dch} = \left(0.19 + \frac{0.1037}{[SOC(t) - 0.14]n_s}\right)\frac{1}{SOC_m} \quad (9)$$

$$V_1 = V_{dch} = [1.926 + 0.124SOC(t)]n_s \quad (10)$$

$$P = P_s + P_w + P_b \quad (11)$$

Equation (11) shows the total power of the HPS when the battery is discharging.

V. Effective Battery Management controller:

This paper proposes embedded system based EBMC for fault management. EBMC continuously monitors the SOC of battery whenever the SOC of battery is not raised as per defined conditions it is noted as fault. Then EBMC replaces supplement battery instead of main battery to the system. Also the main advantage of EBMC is to control the charging with the help of Proportional Integral controller for effective charging.

V.A. PI controller:

PI controller is the simple method of control and widely used in industries. Proportional plus Integral Controller increases the speed of response (Govind Anil et al, 2013) (Hebertt Sirra Ramirez, 1991). It produces very low steady state error. In this paper error of SOC is given as input to PI controller and output is taken to the charging controller. PI controller produces duty ratio for MOSFET in charging controller. General equation of the PI controller is

$$U(s) = K_p E(s) + \frac{K_i}{s} E(s) \quad (12)$$

E(S) is difference between 100% of SOC and available SOC.

Where K_p is proportional gain, K_i is the integral gain, E(s) is the controller input and U(s) is the controller output. Fig 4 shows the block diagram of PI controller.

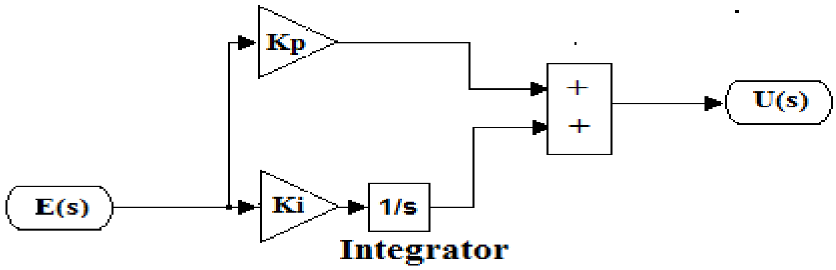

Fig. 4: PI controller

In this paper Ziegler Nichols' method of tuning is implemented to find the optimum value of K_p& K_i values. Output of the PI controller is compared with the saw tooth and produces pulses for charging controller as shown in fig 5. It produces pulsed DC as shown in fig 6 to the battery charging.

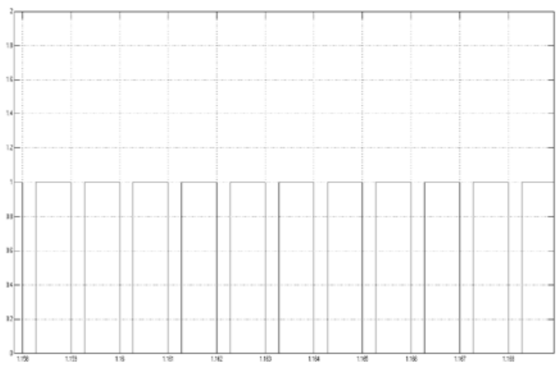

Fig. 5: Triggering pulses from PI controller

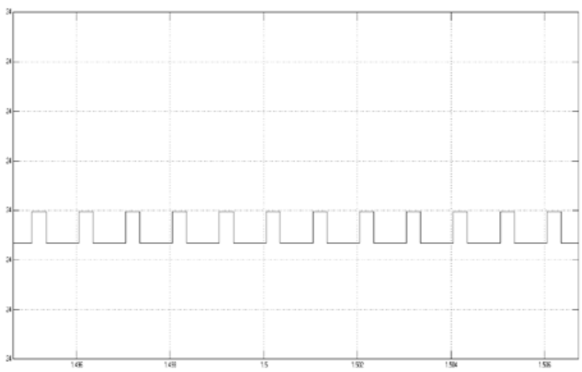

Fig. 6: Pulsed DC from charging controller

VI. Diesel Generator:

In this paper diesel run generator is used as a standby power system. It is switched ON only when all the sources are individually or in combined conditions are not able to meet the load demand. In this condition controller activate the selector switch automatically. Now the load demand is met by DG and also battery charging continuously up to SOC of >95 %. This process is withdrawn if the main source is ready to supply to the load. Output of DG is AC, it is converted to DC through diode rectifier (Joanne Hui et al, 2010). Fig.7 shows the block diagram of DG system.

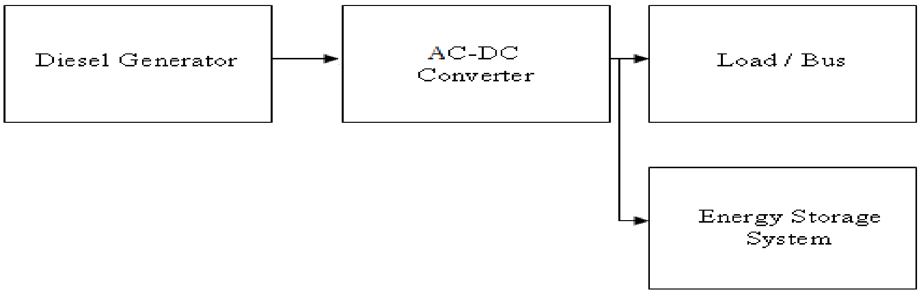

Fig.7: Block Diagram of Diesel Power Source

VII. Source Selection Controller:

Source selection controller continuously monitors the power of solar panel, SOC of BESS and load power. Based on the available power and load it selects sources to grid. The sources may select individually as solar power or BESS or combination of Solar and battery or Diesel generator. This controller minimizes the usage of Diesel Generator. It activates the power system in 5 modes based on sources and load availability. The different modes are Solar alone Supplies load when solar power is greater than load power, Solar Supplies load and battery when solar power is very greater than load power, Solar and Battery Supplies load when solar power is lesser than load power, Battery alone Supplies load when solar power is very lesser than load power and DG alone Supplies load when solar power and battery power is very lesser than load power.

VIII. Simulation Results and Discussion:

Simulation model of HPS with energy management controller is developed using MATLAB/ Simulink R2011b. Rating of the HPS is given below

Solar power plant : 3 KW
Battery : 3 KW
Diesel Generator : 6 KW
Load (AC) : 3KW, 230 V, 50Hz, 1 Phase

Simulation model of the HPS is shown in figure 8.

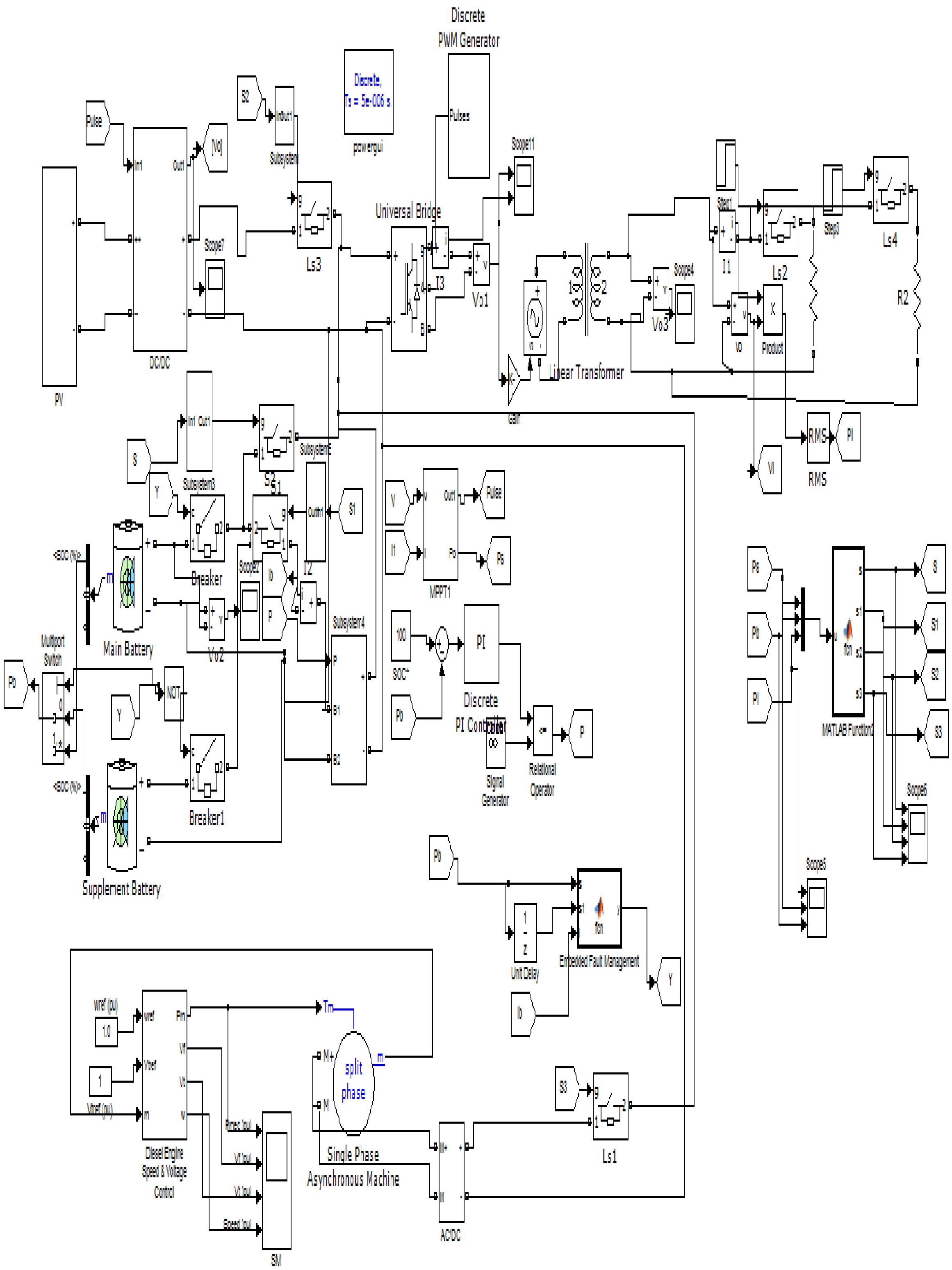

Fig. 8: Simulation model of the HPS

Figure 9 shows the operation of EBMC in case of failure of main battery.

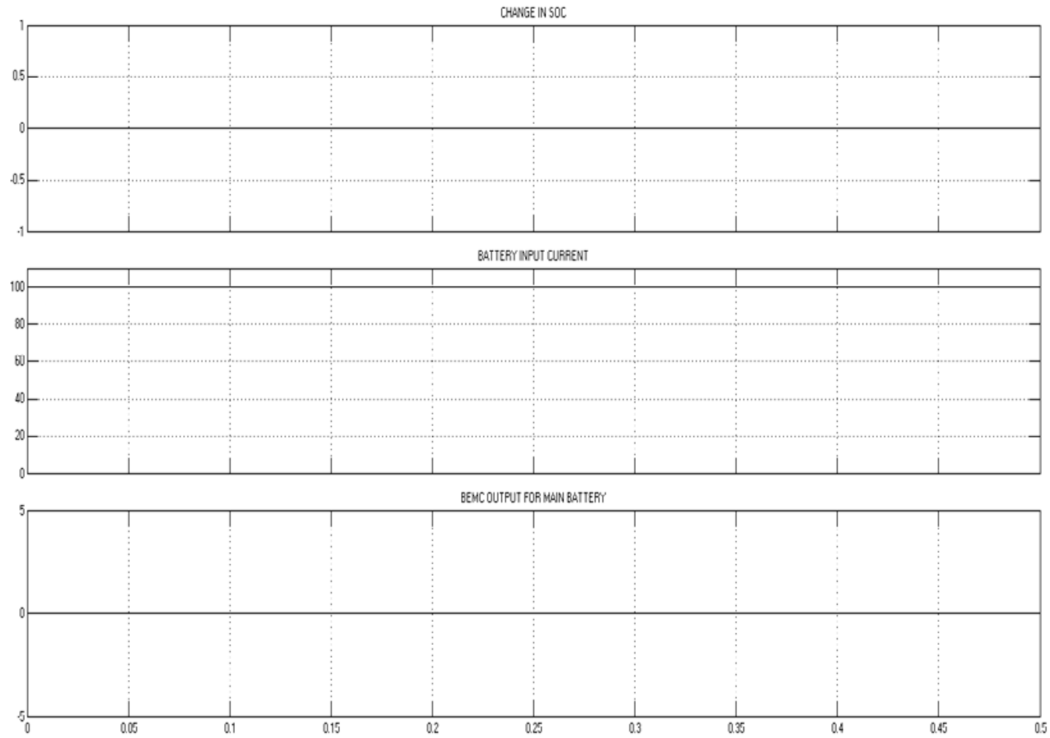

Fig. 9: Operation of EBMC in case of failure of main battery

Mode 1:

Solar alone Supplies load when solar power is greater than load power.

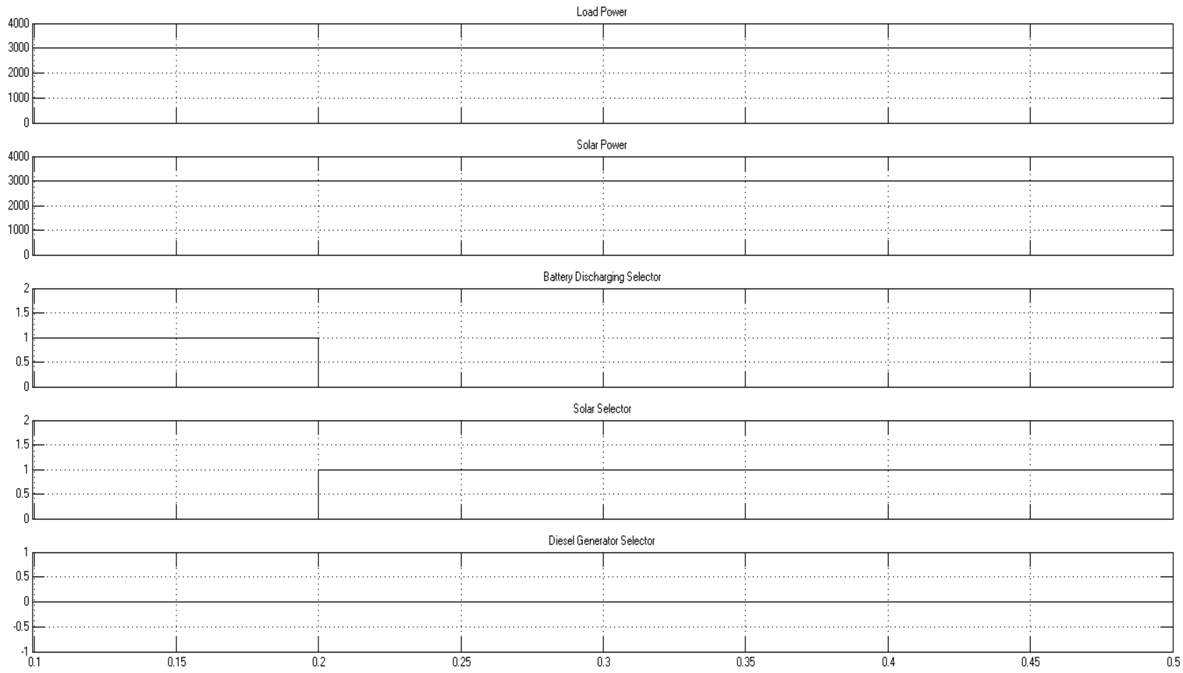

Fig. 10: Solar alone Supplies load when solar power is greater than load power.

Mode 2:

Solar Supplies load and battery when solar power is very greater than load power.

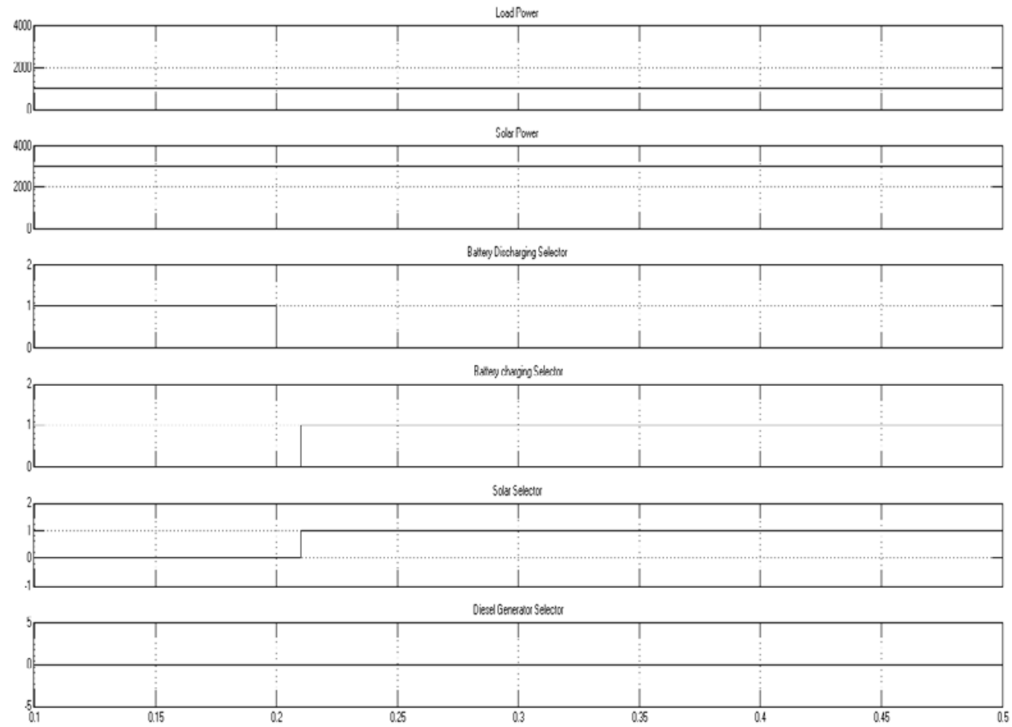

Fig. 11: Solar Supplies load and battery when solar power is very greater than load power.

Mode 3:

Solar and Battery Supplies load when solar power is lesser than load power.

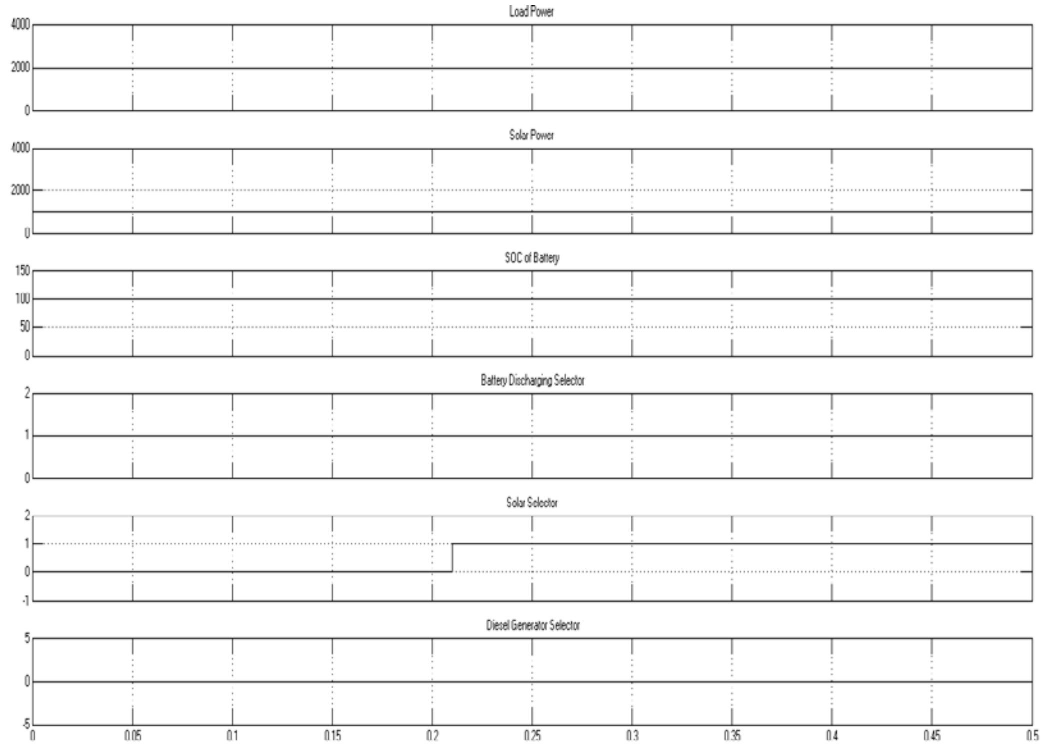

Fig. 12: Solar and Battery Supplies load when solar power is lesser than load power

Mode 4:

Battery alone Supplies load when solar power is very lesser than load power.

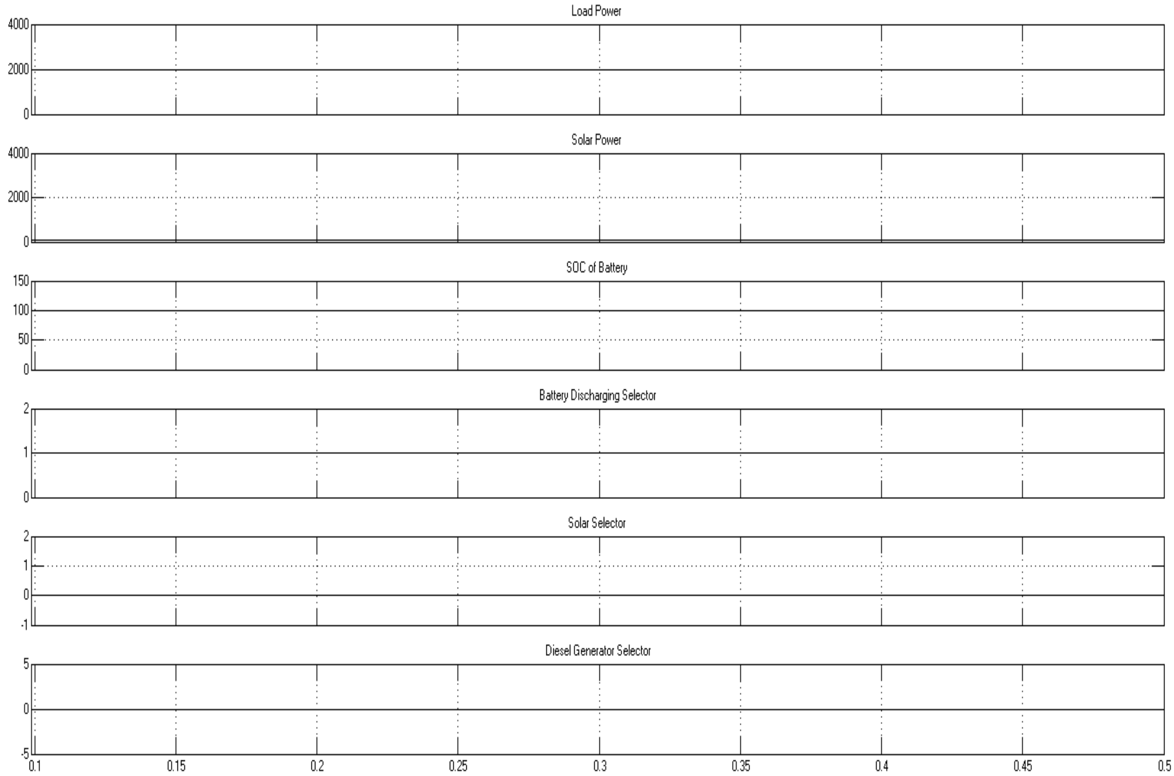

Fig. 13: Battery alone Supplies load when solar power is very lesser than load power.

Mode 5:

DG alone Supplies load when solar power and battery power is very lesser than load power.

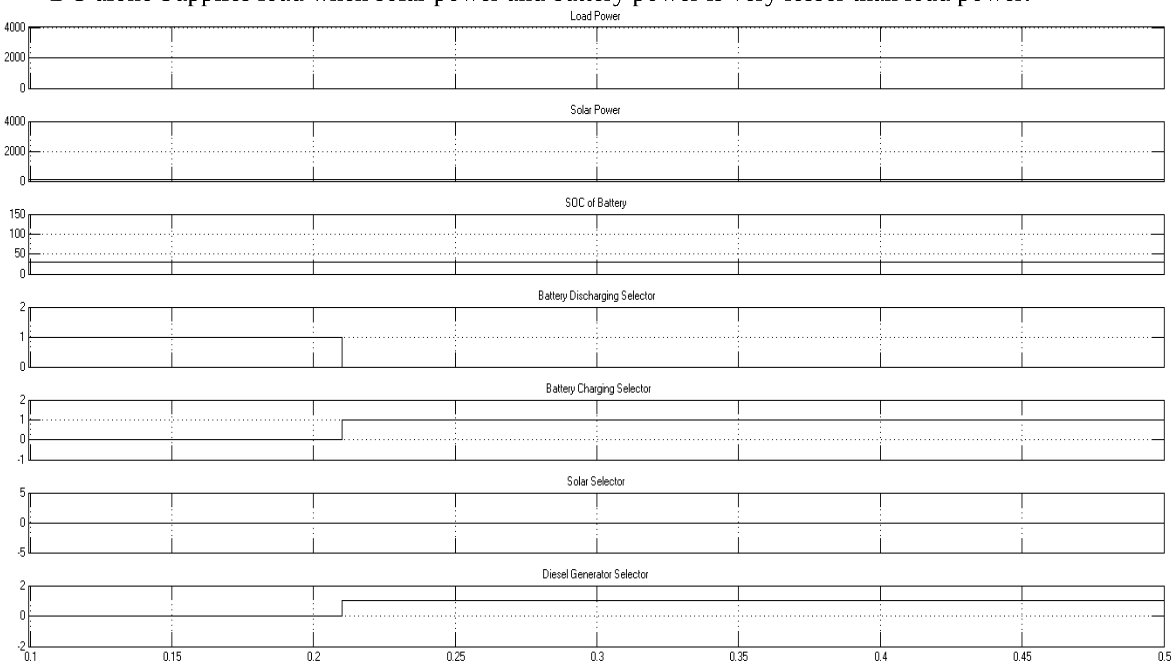

Fig. 14: DG alone Supplies load when solar power and battery power is very lesser than load power.

Simulation results show that source selector effectively selects the sources based on load demand and available power.

IX. Conclusions:

Green energy is the essential power today for its pollution free nature. Demand of electricity and fossil fuel also necessitates it. PV power resource is advantageous than any other resources as it is suitable for any individual application or for grid. The effective utilization of energy is proposed in this paper with the help of Embedded based source selector. Life time and efficiency of battery is increased with help of PI controller based charging. Reliability of the power system is increased by using automatic replacement of battery in case of fault by EBMC. Uninterrupted power is delivered by solar-diesel hybrid power system. The proposed system reduces utilization of diesel generator which results into reduction of cost for fossil fuel and reduced pollution.

REFERENCES

AchimWoyte, Vu Van Thong, Ronnie Belmansand Johan Nijs, 2006. “Voltage Fluctuations on Distribution Level Introduced by Photovoltaic Systems”, 21(1): 202-209.

BurriAnkaiah, Jalakanuru Nageswararao, 2013. “Enhancement of Solar Photovoltaic Cell by Using Short-Circuit Current Mppt Method”, International Journal of Engineering Science Invention, 2(2): 45-50.

Chandrashekhar Lavania, Shrisha Rao and Eswaran Subrahmanian, 2013.“Reducing Variation in Solar Energy Supply Through Frequency Domain Analysis”, IEEE Systems Journal.

Dorin Petreus, Cristian Farcas, Ionut Ciocan, 2008. “Modelling and simulation of photovoltaic cells ACTA”, Technicanapocensis Electronics an, 48(1): 42-47.

Govind Anil, Nirmal Murugan, Mufeed Ubaid, 2013. “PI Controller based MPPT for a PV System”, IOSR Journal of Electrical and Electronics Engineering, 6(5): 10-15.

Hebertt Sirra Ramirez, 1991. “Nonlinear PI Controller Design for Switch mode DC-DC power converters, IEEE Transactions on Circuit and systems, 38(1): 410-417.

Jain, S., V. Agarwal, 2007. A Single-stage grid connected inverter topology for solar PV Systems with maximum power point tracking, IEEE Transactions on Power Electronics, 22: 1928–40.

Joanne Hui, Alireza Bakhshai and Praveen K. Jain, 2010. “A Integrated Wind-Solar Energy System: A New Rectifier Stage Topology”, IEEE, pp: 155-161.

Kalantar, M., S.M. Mousavi, 2010. “Dynamic behavior of a stand-alone integrated power generation system of wind turbine, microturbine, solar array and battery storage”, Applied Energy, 87: 3051-3064.

Kwon, J.-M., W.-Y. Choi, J.-J. Lee, E.-H. Kim and B.-H. Kwon, 2006. “Continuous-conduction-mode SEPIC converter with low reverse-recovery loss for power factor correction”, IEE Proc.-Electr. Power Appl., 153: 673-681.

Lokanadham, M., K. Vijaya Bhaskar, 2012. “Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic System”, International Journal of Engineering Research and Applications, 2: 1420-1424.

Roman Keding, David Stuwe, Mathias Kamp, Christian Reichel, Andreas Wolf, Robert Woehl, Dietmar Borchert, Holger Reinecke, and Daniel Biro, 2013. “Co-Diffused Back-Contact Back-Junction Silicon Solar Cells without Gap Regions”, IEEE Journal of Photovoltaics, 3(1): 236-1242.

Sam, C., M. Huiand Miss, S.C. Chan, 2011. **“**Integration of green roof and solar photovoltaic systems”, Integrated Building Design in the New Era of Sustainability.

Surya Kumari., J and Ch. Sai Babu, 2012. “Mathematical Modeling and Simulation of Photovoltaic Cell using Matlab-Simulink Environment”, International Journal of Electrical and Computer Engineering”, 2(1): 26-34.

Snyman, D., J. Enslin, 1993. An experimental evaluation of MPPT converter topologies for PV installations. Renewable Energy, 3: 841-8.