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PERFORMANCE ANALYSIS OF ENERGY MANAGEMENT CONTROLLER FOR STAND ALONE SOLAR POWER GENERATION SYSTEM USING SOFT COMPUTING TECHNIQUES

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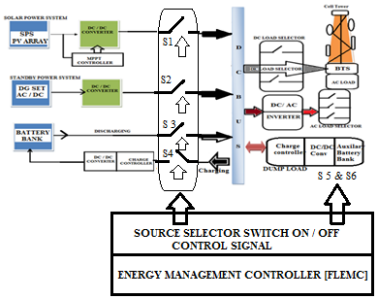
Graphical abstract



Abstract

This paper presents a viability study of solar renewable power generation system for telecommunication tower applications. Rapid depletion of fossil fuel resources necessitated research on alternative energy sources. A solar power generation using photovoltaic system is one of the reliable alternative energy sources for conventional power generation system. Main objective of this paper is to supply uninterruptible power for telecommunication tower equipments from standalone solar power system with necessitate energy storage unit and a backup power system. The Energy Management Controller is developed using soft computing techniques which monitor the power generation from renewable source, SOC of battery bank continuously. The working rules of the monitoring system have been developed for all seasonal climatic weather conditions in India. It provides uninterrupted power during day time, improves life time of battery and minimized usage of diesel run generator. The whole system is analyzed using MATLAB / Simulink.

Keywords: Solar Renewable Power Generation System (SRPGS), Maximum Power Point Tracking (MPPT) and Fuzzy Logic Energy Management Controller (FLEMC)

1.0 INTRODUCTION

Climatic change is one of the most compelling global challenges. There has been a considerable increase in the average temperature of the earth during the past century. This rise in temperature is attributed to the effects of global warming brought about by the accumulation of Green House Gases (GHG) in the atmosphere. The reason for increased GHG mainly Carbon Dioxide (CO_2), is the increased energy consumption which results in emissions of pollutants. The Information and Communications Technology (ICT) industry alone accounts for about 2% of the world's GHG. Self reliance in energy production is vital for the economic development in India and any part of the world. The Indian telecommunication industry is one of the fastest growing in the world and India is projected to become the second largest in the telecom market. Growing telecommunication infrastructures (2G, 3G and 4G) requires an increasing amount of electricity to power it. In this paper, Renewable Power Generation Systems (RPGS) are installed to supply the telecommunication tower equipment's generally called as Base Transceiver Station (BTS), [11] or Base Station Transceiver Subsystem.

The power generation from various sources in India touches around 2, 50,000 MW. The major power contribution is from thermal power source and renewable power contribution increases every year. The CO_2 emission from the conventional power plant (particularly thermal power plant) is very high in the order of 0.869 kg per kWh. Fossil fuels are too expensive and a depleting resource. Burning fossil fuels such as coal, oil and natural gas produces carbon dioxide (CO_2) and other greenhouse gases, which cause global warming. The CO_2 emission from various sectors is shown in Figure 1.

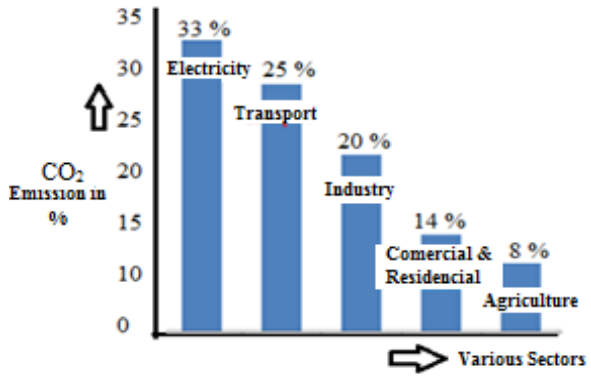


Figure 1 CO_2 Emission contributions by a various sector in %

The CO_2 emission to the environment from various sectors mentioned in the Figure 1 is a serious issue. The renewable based power generation is the reliable and alternate power sector in future generation. The future energy sustainability depends heavily on how the renewable energy problem is addressed in the next few decades. The reduction of CO_2 emission from all above said sectors simply suggest that all the sector can promote and utilize the renewable powered power generation for their own. This will minimize the usage of diesel generator and dependency of grid supply and the pollution free environment can be given for the future generation.

2.0 SOLAR RENEWABLE POWER GENERATION SYSTEM (SRPGS)

In this paper, telecommunication (BTS) tower equipment is taken as a load, because they are the second largest diesel consumer in India next to Indian railway. Power generation from renewable sources have been deemed clean, inexhaustible, unlimited, and environmental friendly. Such characteristics have attracted the energy sector to use renewable energy sources on a larger scale. With the use of renewable energy based system the emission of carbon and other harmful gases is reduced to approximately 80% to 90% in environments. Frequent unavailability of power from the grid is a critical problem faced by Indian industries, and with the Indian industry growing at a hectic pace, this deficit is even more harmful.

According to the Telecom Regulatory Authority of India (TRAI) statement, the number of telecom subscribers in India increased day by day and it showing a monthly growth rate of 0.15%. Now it crosses more than 1billion. TRAI said the overall teledensity in the country increased to 79.50 at the end of 2014. The world wide mobile phone subscribers are increasing day by day. It will cross over the global population within short period and some countries have more than 100% teledensity which means the number of mobile subscribers is more that the country population. The communication equipments (mobile phones) models and technologies are developed enormously. Worldwide, the leading companies are introducing new technology, compact size of instrument with more advanced technologies and low tariff will initiate the consumer to buy a new instrument as well as the usage. In India all the existing telecom networks are converted from 2G into 3G and 4G network are introduced in all locations.

The off Grid cell site is not connected to the common grid. Most of the sites use Internal Combustion (IC) engine driven generator sets, generally called as Diesel Generator (DG) set. Each of these installations has enough battery power on site to run the system for at least several hours. They can be backed up by a diesel fuel generator system which allows the cell site to work continuously when the renewable sources are not enough. The standby and storage systems are essential for renewable based load centre in order to completely get a self- sufficient power structure. The storage systems are activated (discharge mode) only when renewable sources are

not enough to supply energy the load demand needs. The DG system is activated only when main source of hybrid system and SOC of storage systems are not enough to supply energy the load demand needs.

3.0 SOLAR POWER GENERATION SYSTEM (SPGS) FOR BTS

The solar energy received by the earth is more than 15,000 times the world's commercial energy consumption and over 100 times the world's known coal, gas and oil reserves. As this renewable energies are abundantly available during the day for any one to free of cost and without any constraint. India lies between latitude 7° and 37° N, and receives an annual average intensity of solar radiation between 16700-29260 kJ/m^2/day. (400-700 cal /cm^2/day).

In India solar radiations in peak values are generally present in April, May with receiving over 25100 kJ/m^2/day (600 cal/cm^2/day). During the monsoon and winter months the daily solar radiation decreases to 16700 kJ/m^2/day, (400 cal /cm^2/day).During July, August, and September month the minimum values of diffuse radiation (> 300 cal /cm^2/day) measured over many parts of the country and the maximum values measured during February to May (>600 cal /cm^2/day).

PV system will provide DC output directly without any conversion unit, suppose if AC supply is obtained using DC to AC converter unit. The solar modules (photovoltaic cell) generate DC electricity whenever sunlight falls in solar cells. 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 [9].

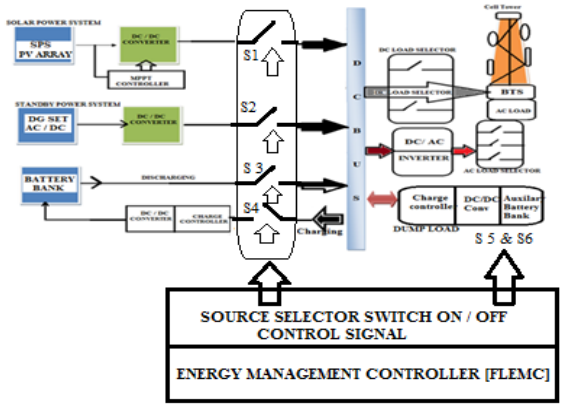


Figure 2 Block diagram of SPS for BTS

Electricity generated by solar PV cell is still more than twice as expensive as electricity from fossil fuels. A stand-alone solar photovoltaic system is suitable for most of the applications, taking care of seasonal changes. Many DC-DC converters are introduced for a renewable power generation system, which is used to give a constant DC voltage. The rating of DC-DC converter [4] is selected according to the load demand and applications. The SPGS is developed with necessary rating of DC-DC converter battery (energy) storage system, dump load (for higher PV power system) and diesel generator is shown in Figure 2.

4.0 MAXIMUM POWER POINT TRACKING (MPPT) FOR PV CELL

In general, PV generation systems have two major problems; the conversion efficiency of electric power generation is low (in general less than 17%, especially under low irradiation conditions). The amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell (current–voltage) characteristic is nonlinear and varies with irradiation and temperature. There is a unique point on the I-V or (power voltage) curve of the solar array called MPP [1], at which the entire PV system operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms [3]. Therefore MPPT techniques are needed to maintain the PV array's operating point at its MPP. The maximum power point tracking is an essential and challenging controller in PV system because the energy produced in PV panel is based on irradiation which is not constant during the whole day. Since the irradiation is not constant, the Voltage produced in PV is non linear with its current. It necessitates the MPPT to work effectively with non linearity and imprecise data.

In order to ensure the operation of PV modules for maximum power transfer, a special method called maximum power point tracking is employed in PV systems, electronic circuitry is used to ensure that maximum amount of generated power is transferred to the load. Now a day's the maximum power is extracted using power converter and use of an algorithm. The mechanism i s based on the principle of impedance matching between load and PV module, which is necessary for maximum power transfer. The impedance matching is done by using DC –DC converter [7]. Using a DC-DC converter, the impedance is matched by changing the duty cycle of the switch.

The PV model combined with MPPT controller and DC-DC SEPIC converter [2], [5] is shown in Figure 3. The generated power is directly given to DC-DC converter and constant output voltage is obtained irrespective of radiation, using MPPT unit. The constant voltage is maintained in a bus continuously.

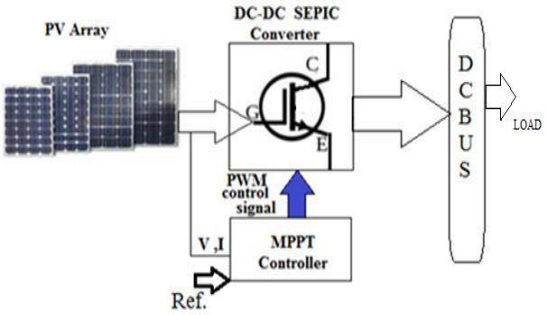


Figure 3 Solar PV power system with power converter and MPPT

5.0 FUZZY LOGIC MPPT TECHNIQUE FOR SOLAR PV SYSTEM

As the solar radiation varies throughout the day, the power output also varies Thus, a power conditioner or DC-DC converter is introduced between the solar PV module and the load. This converter adapts the load to the array so that load characteristics are transformed along locus of maximum points and maximum power is transformed from the array. The duty cycle, D, of this converter is changed till the peak power point is obtained. The Pulse Width Modulation (PWM) signal adjustment can be done by Maximum Power Point Technique (MPPT) controller which is developed using algorithms. The most popular soft computing techniques such as Fuzzy MPPT algorithms [10] have been developed and implemented with solar power system. The fine tuned fuzzy rules will help and produce smooth and quick output than conventional MPPT technique like P&O, Incremental Conductance MPPT system [6].

The fuzzy logic controller is proposed for effective MPPT. In this method of MPPT change in voltage and change in power is taken as input like incremental conductance method. Fuzzy logic controller of MPPT produces duty ratio as output. A pulse based on this duty ratio controls the switch (MOSFET) used in Single Ended Primary Inductor Converter (SEPIC) [8].

The Mamdani type of fuzzy is proposed. The inputs of fuzzy are represented as Δp and Δv. A degree of truth for inputs are 7 and for output is 9. Membership functions of inputs are {NB, NM, NS, Z, PS, PM, PB} named as Negative Big, Negative, Medium, Negative Small, Zero, Positive Small, Positive Medium and Positive Big. Membership functions of output are {NVB, NB, NM, NS, Z, PS, PM, PB, PVB} it is similar to the inputs except Negative Very Big and Positive Very Big.

The solar power systems are developed according to the load demand with the suitable rating of PV array, power converter units, battery bank, dump load (if necessary) diesel generator and other necessary accessories. By providing a suitable technology supports to the solar PV power system, it can be promote to all seasonal conditions and all kind of applications.

6.0 SIMULATION RESULTS OF SOLAR PV MODEL WITH FUZZY MPPT CONTROLLER

The simulation model with Fuzzy MPPT Controller [12] gives constant output voltage (48V) to the bus for all radiation level. Based on the above said fuzzy MPPT rules, fine tuned output is obtained for the radiation between ≥ 100 W/m^2 to ≤ 1000 W/m^2. The simulation results for solar radiation 650 W /m^2 are shown in Figure 4.

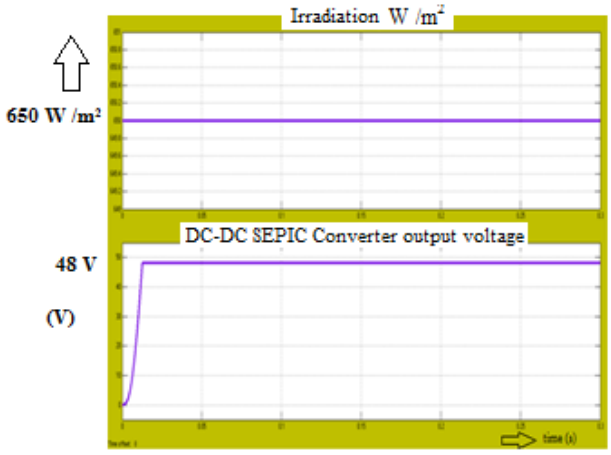


Figure 4 Simulation results with Fuzzy MPPT

7.0 SOLAR PV POWER SYSTEM WITH EMC

The Energy Management Controller (EMC) function is introduced between DC-DC converter bus and load. This will regularise the working function of PV system effectively. The supervisory control is an essential key factor for a stand-alone renewable power generation system. Energy Management Controller simply called as EMC is a system which monitors and regularizes the performance of the renewable power system. It may perform in remote or on site operation. In an onsite operation, EMC is installed at the power converter unit location itself, but in remote operation more than one renewable power systems are combined and connected with a common EMC in a separate control room. The simple block diagram of solar PV array with DC-DC SEPIC converter, MPPT unit and EMC is shown in Figure 5.

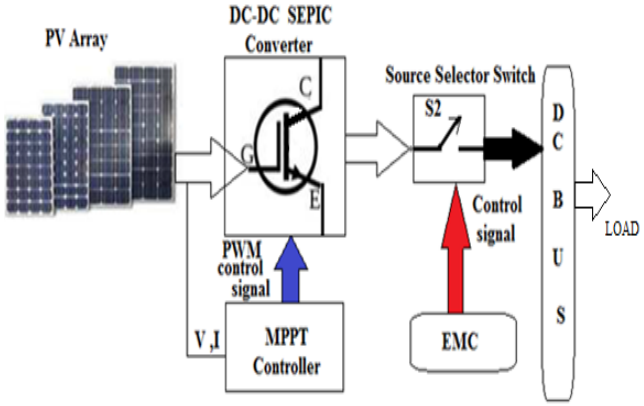


Figure 5 Solar PV power system with power Converter MPPT and EMC

During the lean months that are when power generation is low, a diesel generator is operated for very short duration to load as well as recharge the storage system very quickly by a Fuzzy Logic based Energy Management Controller (FLEMC), which automatically starts and stops the diesel generator for feeding exact amount of energy needed. In case of low power generation during off seasons, low solar radiation period, the battery delivers and shares the power and its energy level falls, at a pre-defined low battery state of charge level (say <20%) the FLEMC tracks and will change over to diesel generator and start the diesel generator. Once the required energy is obtained from renewable sources, the FLEMC will commend the DG to be disconnected or to stop.

8.0 SIMULATION RESULTS DISCUSSION

The Fuzzy logic controller analyses the individual source power and load demand and then controls the selector switch individually. Mamdani type of fuzzy is proposed with Min-Max method of fuzzification and centroid method of defuzzification. It has 4 inputs named as PI, Ps, Pb and Pdb and six outputs namely, S1 (solar source), S2 (diesel generator), S3 (Battery discharging), S4(battery charging), S5 (dump load battery charging) and S6(dump load battery discharging) as shown in Figure 6. The generated power from all the renewable sources is connected to the DC bus through the necessary power converter unit, MPPT controller and source selector switch. The source selector switches are activated by EMC.

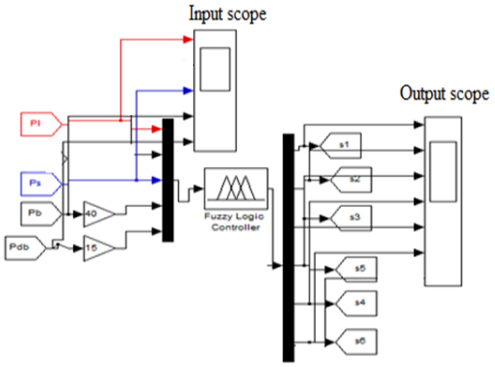


Figure 6 Solar PV power system with Fuzzy EMC

The following six switching function can be done by the EMC towards the power generation, distribution to the load and safety aspects, such as:

- Switch OFF the solar renewable source (S1) switch, whenever the radiation goes below 50 W/m^2
- Switch OFF the Diesel generator (S3) switch, whenever the support from DG is not required and power generation capability from renewable sources are improved, is given in equation (1):

$$PGen = PS = PLOA D \quad (1)$$

- Switch OFF the battery discharging (S4) condition, whenever the power sharing and support from battery bank is not required and SOC goes less than 20%, is given in equation (2):

$$PGen = PS \neq PLOA D, \text{ then } PLOAD = PB \text{ disc} \quad (2)$$

- Switch OFF the battery charging (S5) switch, whenever the SOC reaches 100%, further power fluctuation and fails to generate power from renewable sources, is given in equation (3):

$$PGen = PS \neq PLOA D \ \& \ SOC\ 100\% \quad (3)$$

- Switch OFF the dump load battery discharging (S6) switch, whenever the power sharing and supports are not required and SOC goes less than 20% and also power generations from renewable sources are improved.

- Switch OFF the dump load battery charging (S7) switch, whenever the SOC reaches 100%, further power fluctuation and fails to generate power from renewable sources, is given in equations (4) and (5):

$$PGen = PS = PLOA D + PDBchar \quad (4)$$

$$PGen = PS = PLOA D\ SOC\ 100\% \quad (5)$$

The simulation results have been obtained for different solar radiation and load condition. A few of the sample simulation results are shown in Figures 7, 8 and 9. The simulation results of solar PV power system for radiation 50 W/m^2 are shown in Figure 7. The generated power from solar power system alone is not enough to meet the load demand.

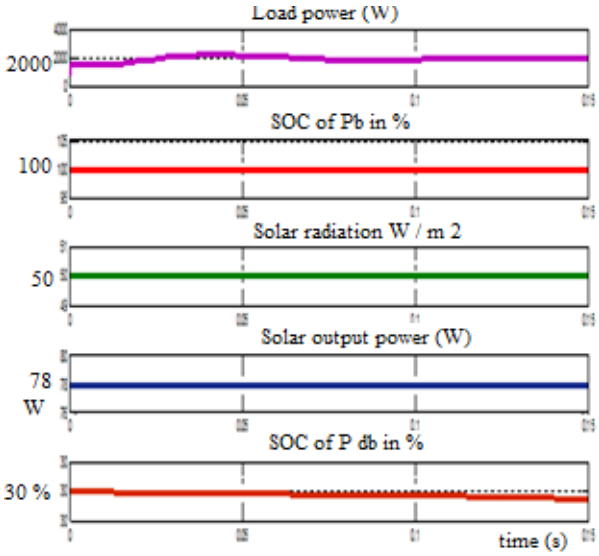


Figure 7 Solar PV hybrid simulation results at radiation 50 W/m^2

The load demand can be met out by solar power system and discharging of battery bank. If there is any further fluctuation or improvements in the solar radiation, the power management can be changed. If necessary, the load demand can be shared by other source combination also. The simulation results of solar PV power system for radiation 500 W/m^2 are shown in Figure 8.The source selection and its corresponding switching function is shown in Figure 9.

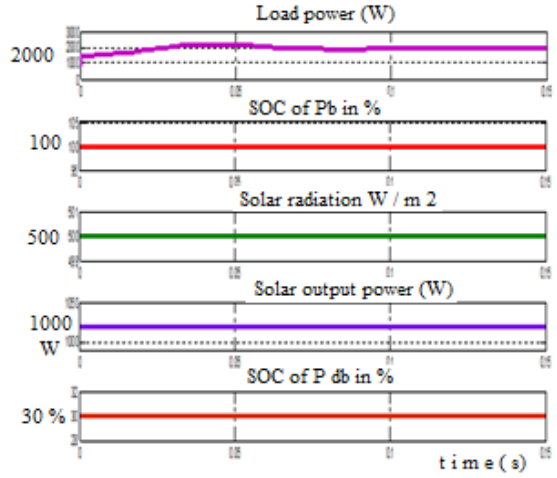


Figure 8 Solar PV simulation results at radiation 500 W/m^2

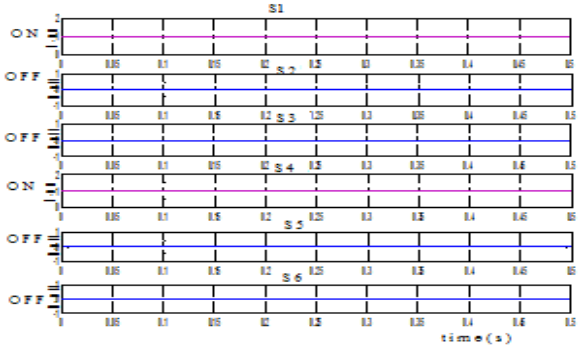


Figure 9 Source switching function

9.0 CONCLUSION

The simulation model of solar PV power system was developed along with battery bank, dump load and diesel generator unit and tested using Matlab/Simulink. The performance analyses were carried out for different seasonal climatic weather conditions, and load. The constant output voltage is obtained from SPS and WPS using SEPIC converter for the radiation ranges from 100 to 1000 W/m^2, and load with the support of well programmed MPPT algorithms. The possible power generation period from solar PV power system throughout the year for different seasonal weather conditions in Tamil Nadu, India with the reference of previous year meteorological data was discussed.

References

[1] Aryuanto Soetedjo, Abraham Lomi, Yusuf Ismail Nakhoda & Awan Uji Krismanto. 2012. Modelling of Maximum Power Point Tracking Controller for Solar Power System. *Telkomnika.* 10(3): 419-430.

[2] Al-Saffar, M. A., Ismail, E. H., Sabzali, A. J. & Fardoun, A. A. 2008. An Improved Topology of SEPIC Converter With Reduced Output Voltage Ripple. *IEEE Transactions on Power Electronics.* 23(5): 2377-2386.

[3] Ali Reza Reisi, A., N., Mohammad Hassan Moradi. B. & Shahriar Jamasbb. 2013. Classification and Comparison of Maximum Power Point Tracking Techniques for Photovoltaic System: A Review. *Renewable and Sustainable Energy Reviews*. 19: 433-443.

[4] Ainah Priye Kenneth. 2012. Design of dc-dc Converter with Maximum Power Point Tracker Using Pulse Generating (555 Timers) Circuit for Photovoltaic Module. *International Journal of Scientific & Engineering Research*. 3(6): 1-10.

[5] Chiang, S. J., Hsin-Jang Shieh & Ming-Chieh Chen. 2009. Modelling and Control of Pv Charger System with Sepic Converter. *IEEE Transactions on Industrial Electronics*. 56(11): 4344-4353.

[6] Dolara, A., Faranda, R. & Leva, S. 2009. Energy Comparison of Seven MPPT Techniques for Pv Systems. *J. Electromagnetic Analysis & Applications*. 3: 152-162.

[7] Eugene, V. Solodovnik, Shengyi Liu & Roger A. Dougal. 2003. Power Controller Design for Maximum Power Point Tracking in Solar Installations. *IEEE Transactions on Power Electronics*. 19(5): 1295-1304.

[8] Henry Shu-Hung Chung, Tse, K. K., Ron Hui, S. Y., Mok, C. M. & Ho, M. T. 2003. A novel-maximum Power Point Tracking Technique for Solar Panels Using a SEPIC or CUK Converter. *IEEE Transactions on Power Electronics*. 18(3): 717-724.

[9] Mellit, A. 2007. Sizing of Photovoltaic Systems: A Review. *Revue des Energies Renouvelables*. 10(4): 463-472.

[10] Md Fahim Ansari, S., Chatterji & Atif Iqbal. 2010. Fuzzy Logic Control Scheme for a Solar Photovoltaic System for a Maximum Power Point Tracker. *International Journal of Sustainable Energy*. 29(4): 245-255.

[11] Panagiotis, D. Diamantoulakis & George, K. Karagiannidis. 2012. On the Design of an Optimal Hybrid Energy System for Base Transceiver Stations. *Journal of Green Engineering*. 3: 127-146.

[12] Weidong Xiao, Nathan Ozog & William, G. Dunford. 2007. Topology Study of Photovoltaic Interface for Maximum Power Point Tracking. *IEEE Transactions on Industrial Electronics*. 54(3): 1696-1704.