International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 2, February- 2013

Utilization of Hybrid Energy Sources for Uninterrupted Constant (Fixed) Power Applications

S.V.Sreeraj[1], T.Annamalai[2]
[1] *PG Research Scholar Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India*
[2] *Assistant Professor Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India*

Abstract

This paper presents power-control strategies of a standalone hybrid generation system with versatile power transfer. The new concept of mixing two sources has been introduced in this paper by connecting EB source parallel to PV thus improves the quality of power fed to the load by eliminating voltage dips at the load due to the fluctuating nature of supply voltage sources. This configuration is more useful for those applications which require constant (fixed) power to the loads such as industrial, hospitals and even corporate office (lighting, computer and HVAC) systems.

1. Introduction

We have been acknowledged to uncontrolled and unscheduled power outages these days because of insufficiency of power met between supply versus demand requirements. There are several applications which require constant (fixed) uninterrupted power to the loads. These applications are getting affected because of the unscheduled power outages. The above situation forces us to go for renewable energy sources.

There are various renewable energy sources are available and their different configuration are explained in previous works. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. As we know that wind energy and solar energy are fluctuating in nature, their presence is highly unpredictable. Solar energy is present during sun hours but their irradiation level varies time to time. So we need to look for a combo of either PV-EB or PV-DG with a battery backup.

The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain or improve the power-supply stability and quality. Combining multiple renewable resources via a common dc bus of a power converter has been prevalent because of convenience in

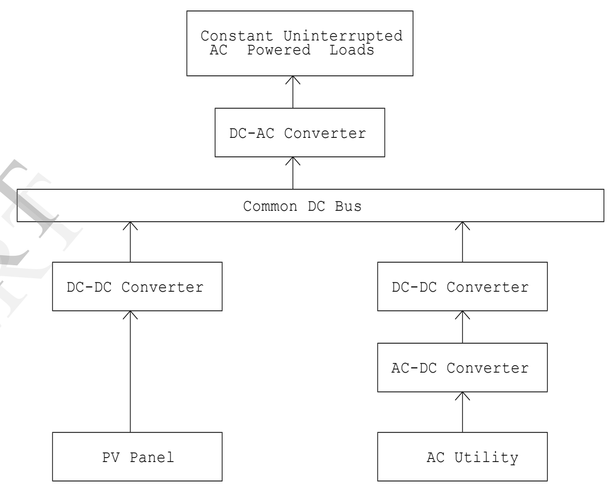

Figure 1.Configuration of hybrid power and control system

integrated monitoring and control and consistency in the structure of controllers as compared with a common ac type. There are some previous works on similar hybrid systems. In this proposed work, all the sources are connected parallel to each other as shown in Fig 1 to meet the load requirement. This kind of configuration has a greater advantage of eliminating voltage dip at the load side due to PV as well as EB. Also in this kind of configuration where the Battery energy storage system (BESS) is connected at the common DC bus so that life time of battery is more, as the DC bus is maintained a constant voltage all the way.

This Paper addresses the dynamic modeling of PV-EB-BESS which are connected parallel to each other to meet uninterrupted constant power to the load. A 2.3-kW commercial load and its control system were developed. Descriptions of the system and control, simulation works were focused on the dynamic performance. A study of unit sizing or long-term-based reliability is beyond the scope of this paper. The simulation result is discussed to evaluate the dynamic performance of the proposed control strategies for versatile power transfer.

The Existing works are modeled in such a way that different renewable energy sources are connected via a central control switch, so when a particular source is available that source is switched to the load.But this kind of configuration will not be reliable for loads which require constant uninterrupted power

2. Proposed topology

This paper addresses dynamic modeling of PV-EB-Battery sources which are connected in parallel to the common DC bus to meet uninterrupted constant power to the load as shown in Fig 2.

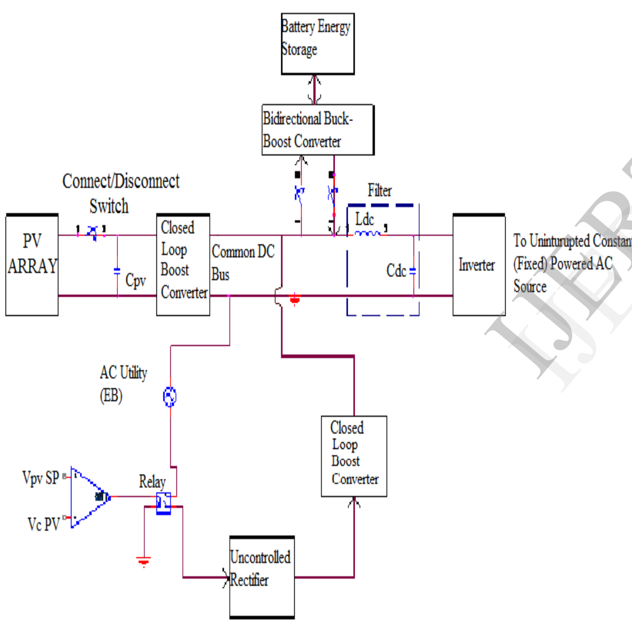

Figure 2. Proposed Topology for uninterrupted constant (fixed) power application using hybrid power conditioning unit

Here there are four modes of operation are considered, they are as follows;

1. PV mode
2. PV + AC Utility (EB) -mixing mode
3. AC Utility (EB) mode
4. Battery Energy Storage mode

The kind of mode is selected based on the availability of power from a particular source. The top most preference is given to PV source as usual, then to AC Utility EB and finally with the Battery backup.

2.1. Mode 1 PV mode

This mode is selected by default if PV is able to provide the required power to the load. (Say if the load requires 2.3kw and PV alone is able to fulfill the requirement) as shown in Fig 3.During this mode the PV array output is given to a closed loop boost converter in order to maintain the required voltage and current at the DC bus line.

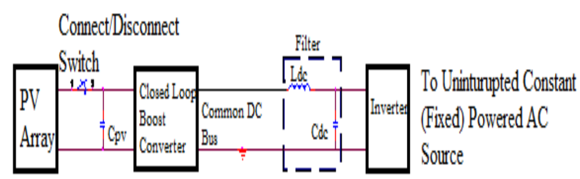

Figure.3. PV alone mode

In this mode, output of PV array is given to a boost converter in order to maintain constant voltage at the DC bus and is then fed to the inverter to fulfill the load requirement. Here the load should be provided with 230Vrms and 10Arms at fundamental frequency (50Hz).

2.2. Mode 2 PV + AC utility (EB) - mixing mode

The second preference is given to this mode called as mixing mode shown in Fig 4. This mode is changed automatically through a relay switch when PV itself is not able to meet the complete load requirement. (Eg: say if the load requires 2.3kw and PV is able to give only 1.5kw.)

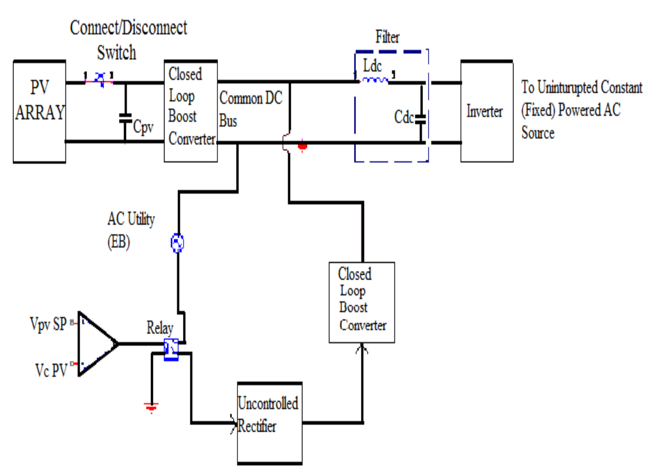

Figure 4. Mixing mode

During this mode both PV and AC Utility are switched on. PV will provide the load with its available power and the rest is compensated through AC Utility to ensure that the load is met with uninterrupted constant (fixed) power. This mixing mode is achieved by connecting the two sources parallel to each other to a common DC bus. Here in this mode, the available PV array output is given to a boost converter to maintain constant DC voltage.

2.3. Mode 3 AC utility (EB) mode

As we know that PV cannot produce power during cloudy days and also during non-sun hours or in other way that, this particular mode is selected when the output of PV is not able to contribute significantly to the load requirement as shown in Fig 5.

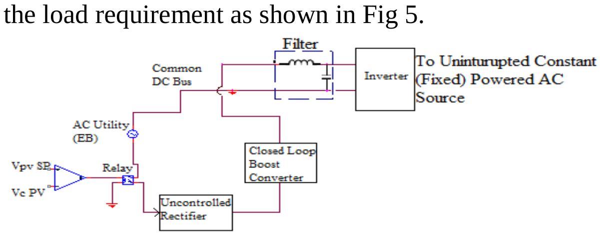

Figure 5. AC utility (EB) mode

This situation is handled alone by AC utility. The particular source is connected to the common DC bus via a rectifier and a closed loop boost converter.

2.4. Mode 4 battery energy storage mode

As usual during the absence of PV and EB, the battery backup provides the required output to the load. The battery is connected to the common DC bus via a bidirectional buck boost converter as shown in fig 6 topology which already exists. The battery is charged and discharged from/to the common DC bus by buck and boost operation respectively.

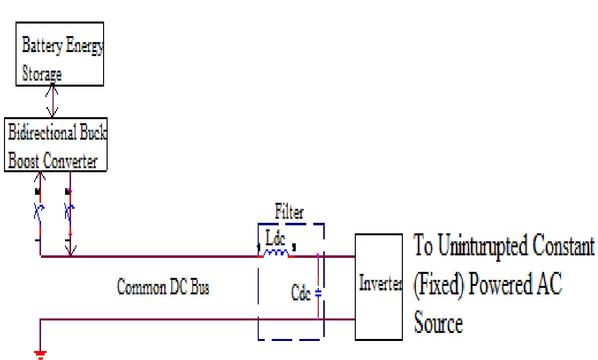

Figure 6. Battery energy storage mode

2.4.1 Bidirectional buck-boost converter

Here the battery is charged via a buck converter shown in fig 7, because the DC bus line will have greater potential (say 405V, 6A) than the battery sized (say 120V, 100Ah).

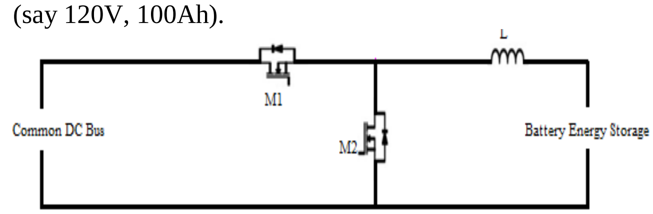

Figure.7. Bidirectional buck boost converter

During this process switch M1 and diode D1 will operate and during battery discharge boost mode is enabled where switch M2 and diode D2 operates.

3. Analysis and calculation

The analysis is done for a 2.3Kw load (small corporate office load). Assuming 90-95% efficiency at all converter stages, the calculation has been done.

3.1. Common DC bus power calculation

As the load require 2.3Kw at 230V and 10A (at fundamental frequency), the DC bus calculation as follows;

$$Vdc = \frac{230}{0.8} * 1.414 = 405V \qquad (1)$$

Vdc, voltage at the common DC bus,
ma, is the modulation index for fundamental frequency.
Assuming Po=0.95Pin; Idcbus=6A

3.2. Solar panel selection

To provide 2.3Kw during PV alone mode, the panel should be sized as follows,

$$\text{Psolar} = \frac{\text{Pdc}}{\text{\% of conv efficiency}} = \frac{405 * 6}{0.9} = 2.8kw \qquad (2)$$

Here, Psolar is solar panel power; Pdc is Common DC bus power
Solar panels produce around 150w (watts) per m2- domestic systems range from around 1.5Kw to 4Kw (1Kw = 1000w) so a medium size domestic system of 2.5Kw would require around 17m2 of roof space. The solar panels are kept away from the edges of the roof by around 300mm as a minimum.
As a 60w Module gives 3.5A and 17.1V Imp and Vmp respectively, to obtain our requirement we need to go

for 12 Modules in series and 4 in parallel (so totally 12*4 modules)

4. Closed loop control

Open loop transfer function of the Boost Converter is,

$$G(s) = \left(\frac{Vs}{D'^2}\right)\frac{1}{1 + sL/RD'^2 + s^2LC/D'^2} \quad (3)$$

$$D' = (1 - D) \quad (4)$$

$$G(s) = \frac{1234.57}{1 + (3.85 * 10^{-3}s) + (7.72 * 10^{-6}s^2)} \quad (5)$$

Where R=10 Ω, L=5mH, C=200µF, Vs=160V, D=0.64, D'=0.36. The closed loo control is shown in the fig 8.

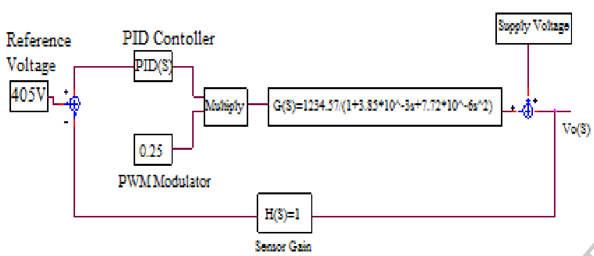

Figure 8. Closed loop control of boost converter

5. Design of a PV module of 60w

5.1. Mathematical model of PV cell

$$I = I_{ph} - I_s(\exp(q(V + IR_s/KT_cA) - 1) - (V + IR_s/R_{sh}) \quad (6)$$

$$I_{ph} = (I_{sc} + Ki(T_c - T_{ref})H \quad (7)$$

5.2. Mathematical model of PV module

The above equation is modified as shown below,

$$I = I_{ph}N_{ph} - N_pI_s(\exp(q\,(V + IR_{sm})/KT_c\,N_sA) - 1) \quad (8)$$

$$R_{sm} = N_sR_s/N_p \quad (9)$$

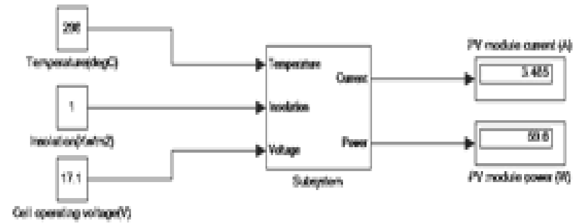

Figure 9. Matlab Model & Simulation of a PV Module of 60w at STC

5.3. PV array sizing

As we have to maintain 405V and close to 6A current at the DC bus, we need to go for 200V and 13.8A. As one Module gives 3.5A and 17.1V Imp and Vmp respectively to obtain our requirement as shown in fig 9 and 10, we need to go for 12 Modules in series and 4 in parallel (so totally 12*4 modules).

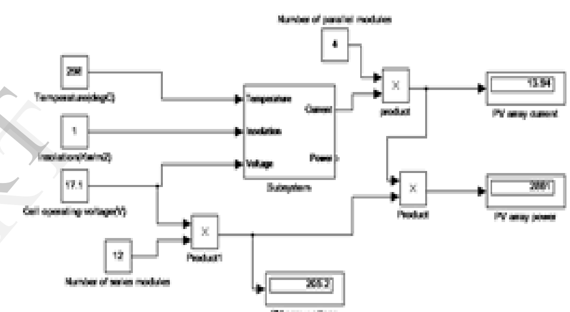

Figure 10. 2.8KW PV Array Sizing

Insolation (W/m2)	Current (A)	Voltage (V)	Mode
1000	13.94	200	PV Alone Mode
900	12.52	179	Mixing Mode
800	11.1	159	
700	9.665	138	
600	8.23	118	
500	6.78	97	
400	5.33	76	
300	3.8	55	

Table 1. Output power at different insolation

6. Simulation results

6.1. PV alone mode

PV alone supplying the load at an Insolation of 1000w/m2.This mode is selected by default if PV is able to provide the required power to the load shown in fig 11 & 12. In this mode PV array produces an output voltage around 200V and current of 13.8A, as the common DC bus is to be maintained at 405V, the PV array output is converted to 405V and the current becomes6.3A(to maintain the power constant) which is sufficient to fulfil the requirement of the load. In this mode output of PV array is given to a boost converter inorder to maintain constant voltage at the DC bus and is then fed to the inverter to fulfill the load requirement.

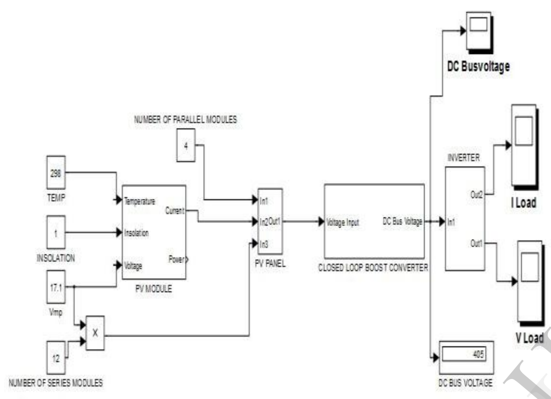

Figure 11. Matlab Simulink model of PV alone mode

Here the load should be provided with 230Vrms and 10Arms at fundamental frequency (50Hz). The DC bus power is given to the SPWM inverter section to produce an output of 230V and 10A rms values at fundamental frequency Here the first half cycle is slightly distorted because the boost converter takes nearly 0.01seconds to reach 90% of final value.

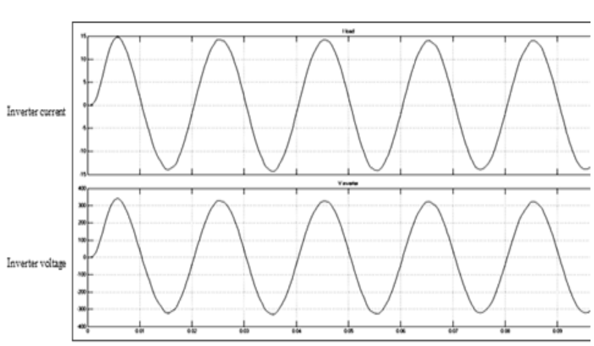

Figure 12. Inverter output current and voltage waveforms

6.2. Mixed mode

Fig 14, 15 & 16 shows the simulation model and waveform for mixed mode. During this mode both PV and AC Utility are switched on. PV will provide the load with its available power and the rest is compensated through AC (fixed) power. This mixing mode is achieved by connecting the two sources parallel to each other to a common DC bus. Here in this mode, the available PV array output and EB is given to a boost converter to maintain constant DC voltage, the current is shared from the two sources by the load.

During this mode both PV and AC Utility are switched on. PV will provide the load with its available power and the rest is compensated through AC Utility to ensure that the load is met with uninterrupted constant (fixed) power. This mixing mode is achieved by connecting the two sources parallel to each other to a common DC bus. Here in this mode, the available PV array output is given to a boost converter to maintain constant DC voltage

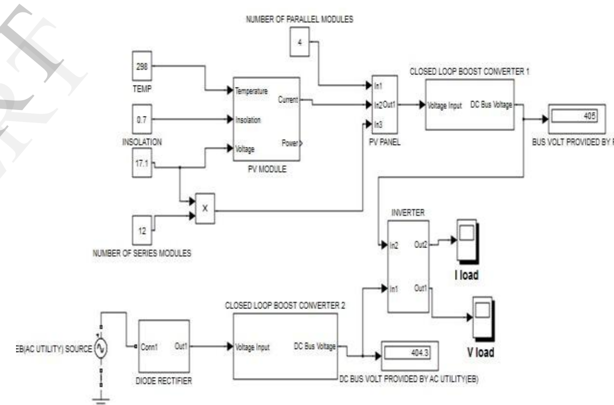

Figure 13. Matlab Simulink model for mixed mode

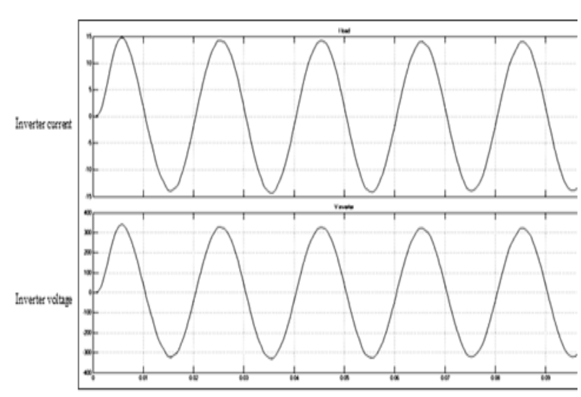

Figure 13. Inverter output current and voltage waveforms

During this mode both PV and AC Utility are switched on. PV will provide the load with its available power and the rest is compensated through AC Utility to ensure that the load is met with uninterrupted constant (fixed) power. This mixing mode is achieved by connecting the two sources parallel to each other to a common DC bus. Here in this mode, the available PV array output is given to a boost converter to maintain constant DC voltage

7. Application and analysis of the configured model

7.1. Study of PC behavior using the designed configuration

The inverter output of mixing mode is given as the input to a personal computer through a step down transformer. The sinusoidal output current and voltage is applied to the SMPS unit which consists of rectifier and a storage capacitor which is then given to a choke (R&L). It is interesting to see that although the supply voltage is sinusoidal in nature, the output current is not sinusoidal. The THD at the output current is around 62%.

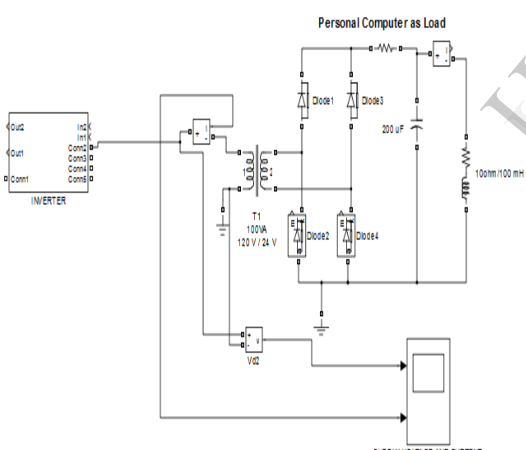

Figure 14. Personal Computer connected to Inverter ouput

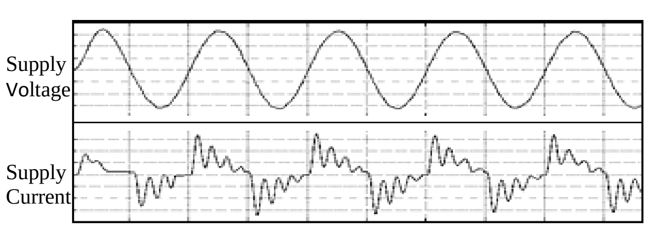

Figure 15. Supply Voltage and current waveforms for a nonlinear load

8. Conclusion

This configuration has several advantages when compared to switched mode control. When we switch different sources to the common DC bus and if the sources are fluctuating, we cannot maintain a constant DC bus voltage which in turn causes voltage dip at the load side. This configuration eliminates voltage dip at the load side in spite of fluctuations in supply voltage sources (PV and EB).Besides this, it also helps in complete utilization of PV array power. We are mainly concerned about the life time of the battery in these kinds of applications. As we connect the battery at the common DC bus which is always maintained constant, the battery terminal voltage will not face fluctuation and it is charged at constant rate which increases the longevity of the battery. Simulation results provided various dynamic characteristics of the proposed control scheme, which enabled comprehensive quantitative and qualitative analysis before a real hardware implementation. Simulation results confirmed the feasibility of the proposed control and showed the effect of versatile power transfer.

9. References

[1] Toshiro Hirose and Hirofumi Matsuo, Fellow, IEEE Standalone Hybrid Wind-Solar Power Generation System Applying Dump Power Control Without Dump Load IEEE Trans on industrial electronics, vol.59, no 2 February 2012.

[2] Joanne Hui, IEEE Student Member, AlirezaBakhshai, IEEE Senior Member, and Praveen K. Jain, A Hybrid Wind-Solar Energy System: A New Rectifier Stage Topology, IEEE Fellow Center for Energy and Power Electronics Research year 2010.

[3]Yutao Zhou and Nadarajahnarendran PV Powered LED Lighting research centerOptical Engineering Publications paper 050071 January 2005.

[4]Seul-Ki Kim, Jin-Hong Jeon, Chang-Hee Cho, Jong-Bo Ahn, and Sae-Hyuk Kwon, Member, IEEE Dynamic Modeling and Control of a Grid-Connected Hybrid Generation System With Versatile Power Transfer IEEE transaction of industrial electronics, vol. 55, no. 4, April 2008.

[5]Sachin Jain and VivekAgarwal, *Senior Member,IEEE*, An Integrated Hybrid Power Supply for Distributed Generation Applications Fed by Nonconventional Energy Sources IEEE transaction of industrial electronics, vol. 23, no. 2, june2008.

[6]SonalPanwara, Dr. R.P. Saini P.G. Scholar, IIT Roorkee, bHead, AHEC, IIT Roorkee Development and Simulation of Solar Photovoltaic model using Matlab/simulink and its parameter extraction International Conference on Computing and Control Engineering (ICCCE 2012), 12 & 13 April, 2012.

[7] N. Mohan, T. Undeland, and W Robbins, "Power Electronics: Converters, Applications, and Design," John Wiley & Sons, Inc., 2003.

[8]Fundamentals of Power Electronics R. W. Erickson.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 2, February- 2013