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Integrated Utilization of Solar Energy in a Zero Energy Building (ZEB): An Approach towards Sustainable Development

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ABSTRACT

The load demand of any country is directly proportional to the living standards of the people, as the standards of living are increasing the load demand is also getting increased, hence ways are to be looked upon so as to reduce the load on the utility grid. The use of the photovoltaic arrays on the roof tops of the residential as well as commercial buildings can help in reducing the burden from the utility grids, the new trend in these systems is one in which photovoltaic systems interact or communicate with the utility grid, these photovoltaic systems serves the load of the particular building during day hours and supply from the utility grid is taken during the night hours, this kind of hybrid integrated systems tends to improve the efficiency as well as the reliability of a particular photovoltaic system. The net metering phenomenon is also dealt in this paper in this, during the off load hours the power from the photovoltaic panel is supplied back to the grid so total number of units consumed by a particular consumer is counted by subtracting total units fed back to the supply from the total units consumed hence adding up the benefit to the building owner. The simulation model of the grid connected photovoltaic system is developed in Simulink in MATLAB 2014 and the model is simulated under the sample data of Patiala, India region. The effective working of the integrated model is then analyzed using simulation results. The solar windows aimed at eliminating normal lightning system in commercial buildings is also explained in the paper.

Index Terms: Photovoltaic (PV) Generator/array, Voltage source inverter (VSI), Pulse width modulation (PWM)

1. INTRODUCTION

The photovoltaic systems are catching the attention in the energy production era due to its symbol design, easy construction and ease of being installed even in very narrow places. The solar thermal systems and solar photovoltaic systems entered the market at the same time but the solar thermal systems are not being adapted in the market reason being their complex design, large installation costs and requirements of huge areas. The other reason for the outdating of the solar thermal systems is the follow up of the trend, the trend is towards the solar photovoltaic systems because of their simple conversions capabilities from solar energy to direct electrical energy. These systems can be manufactured even in small industries and can be supplied to the consumers very easily.

The PV systems now ever days are being installed in the residential areas, mostly on the rooftops of homes. The installation and purchase price of these systems may be costly but the operation afterwards is almost maintainace free. Once installed these systems can run for 15 years without maintainace. The new configuration of solar photovoltaic systems is the one in which these systems interact with the grid while serving the load requirements of a particular home at the same time, these configurations are called as grid connected or grid interacting systems. During peak load hours the solar panels installed on the rooftops serves the load requirement of a residential complex and while during the off peak hours, the excess of the power is supplied back to the grid. The other technology which can also be installed in our homes or

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commercial buildings is the solar windows in which the light from the roof of the building is transported to a particular room or area of the building using various mirrors and following the reflection phenomenon.

Various schemes and control strategies are available which are used to operate the photovoltaic systems in the grid connected mode of operation [1-5]. In this paper a Simulation model is created in which the PV generator works in parallel with the utility grid and the electrical load of a particular home is supplied using this integrated system. The PV generator is simulated under the sample eight hour data of Patiala, India region. The simulation results confirmed the effective working of the integrated system. All the simulation work is carried out in Simulink in MATLAB 2014.

2. SYSTEM DESCRIPTION

The systems consists of the PV array installed on the rooftop of a particular home, the dc supply is converted into the ac using one VSI PWM inverter, the total load of the home is considered to be 6 KW with the operating power factor of 0.8. The PV array is shown to be operating in parallel with the utility grid. DC isolators are connected just after the PV array so as to isolate the DC supply whenever required.

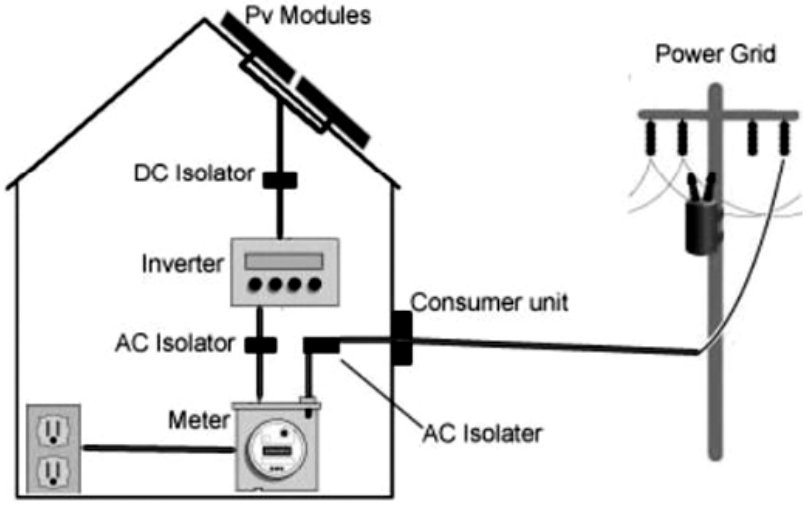

Figure 1: System Configuration

Similarly the AC isolators can be used to isolate the PV systems from the, this is usually done when the load requirements are very low. The above DC isolators can hence be used to operate the home load only from the grid. One meter is also given in the system which can measure the net units i.e. the total energy units consumed – total energy units supplied by the PV modules to the grid. The graphical representation of the above phenomenon is as shown in Fig. 2

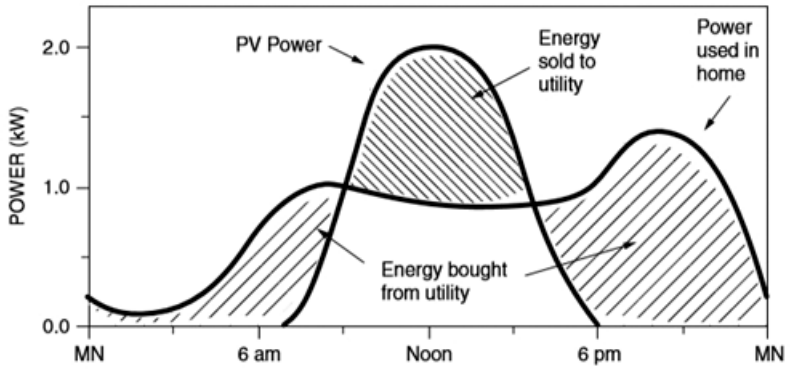

Figure 2: Net metering process [6]

3. SOLAR WINDOW SYSTEMS

The solar windows are the newest explored areas of the solar light technology, this technology is most explored in the high rise commercial buildings where a large number of tube lights are installed. This technique of solar windows tries to eliminate the normal lightning system in the commercial or normal building by transporting the solar rays from the rooftops of to each and every level of the building. The schematic diagram of such a technique is shown in Fig. 3

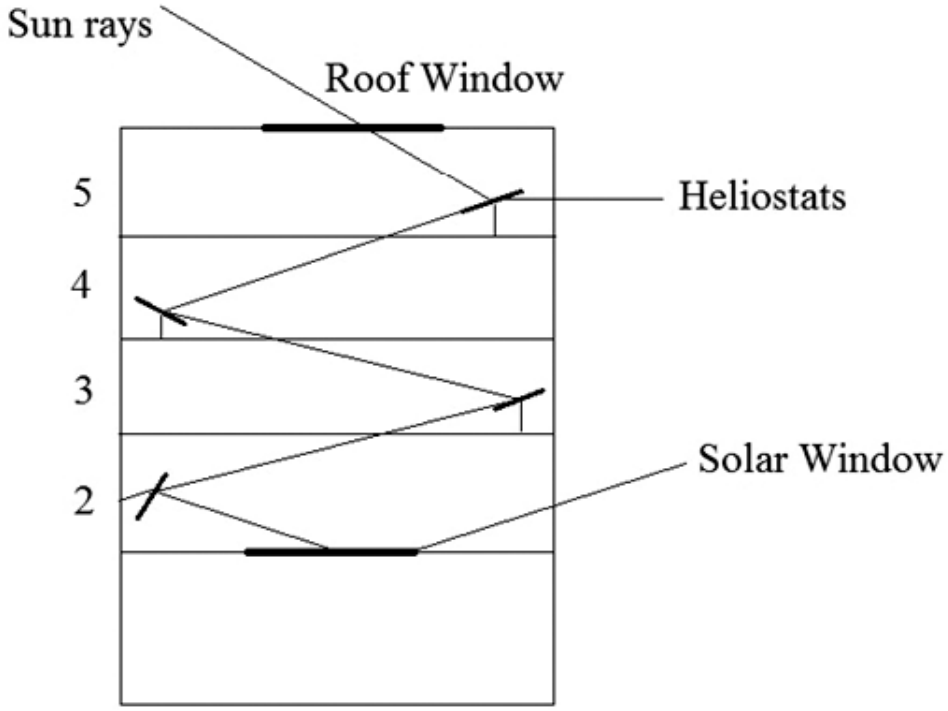

Figure :3 Solar window systems

The working phenomenon of this entire scheme is 'Reflection' , the solar radiations are easily available on the rooftops of the high rise towers, the heliostats which are basically the reflectors are then being used at each and every floor so as to transfer the sun's rays to the various floor levels of the particular building. At each level the windows are provided which can scatter the light available from the sun, one typical pictorial representation of such a window is as shown in Fig. 4

The opening of these windows shown in Fig. 4 can be controlled using a manual or an automated system, hence the orifice of these windows can be opened as according to the light required. However these

Figure 4: Solar window

solar windows can only provide light during the day time hence the hybrid of normal electrical lights and solar light is preferred for these commercial building. During night hours the normal lights serves the purpose while during day time these solar window system can serve the purpose. This kind of hybrid system helps in reducing the energy consumption of a particular commercial building.

4. SIMULATION OF MODEL OF GRID CONNECTED SYSTEM

The Simulation of model of the grid connected system of Fig. 1 is shown in Fig. 4. The model consists of one PV array of PV generator operating under the sample solar irradiance data of Patiala, India region. The sample data is collected for eight hours. The simulation is hence also carried for eight seconds with each hour mapping one second. The sample solar radiation data is as given in Table 1.

Table 1
Solar Insolatio Data [7]

Time Division	*Hours*	*Solar Insolation (W/m²)*
0-1	9-10	474.1953
1-2	10-11	647.55
2-3	11-12	777.09
3-4	12-1	819.93
4-5	1-2	804.40
5-6	2-3	719.65
6-7	3-4	536.36
7-8	4-5	321.88

The PV array used in the simulation is Sun Power SPR-305-WHT with 96 cells connected in one module, 8 such modules are connected in series while 60 such strings are connected in parallel to make the array configuration.

The inverter used in Fig. 5 is a simple VSI inverter using PWM technique, the output of the PV array is provided to the single phase inverter so as to get AC. The output of the inverter should match with the grid voltage and frequency hence this matching is achieved by dictating the magnitude and frequency of the

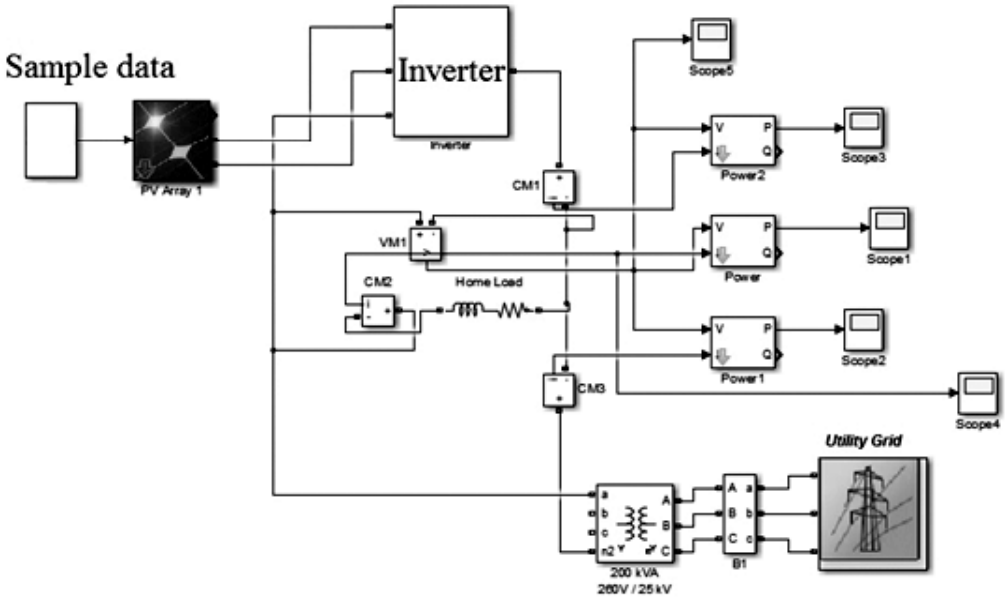

Figure 5: Simulation model of grid connected system

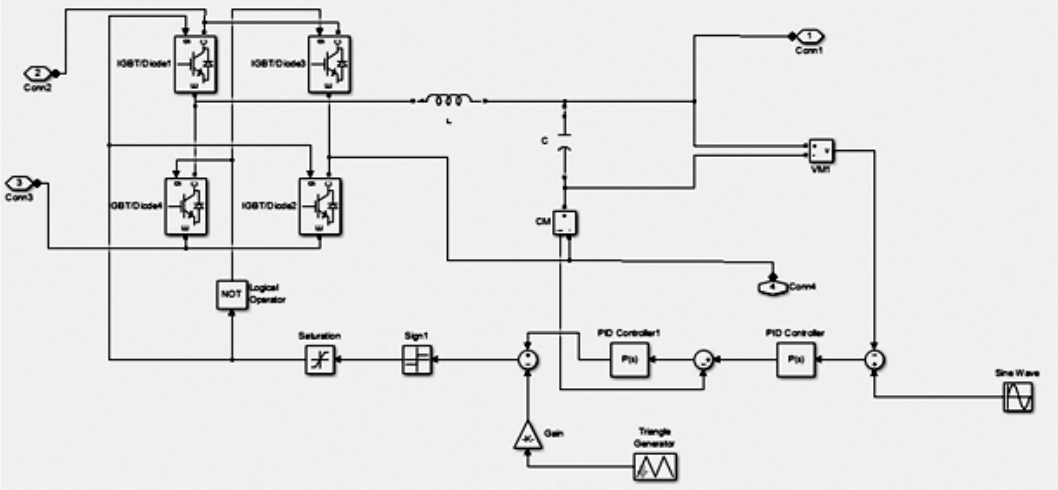

Figure 6: Simulation model of VSI Inverter [8].

reference Waveform in VSI inverter. The reference is set as 230 Volts and 50 Hz, the output of the inverter hence follows the reference [ ]. The detailed MATLAB model of inverter is given in Fig. 6

In the utility grid model, the 2500 MVA three phase generator is used generating at 120 KV, further two transformers are used on converting from 120KV/25KV and then 25KV/230V after the nominal voltages are achieved the supply is then given to the load of the home in parallel to the supply coming from the inverter connected with the PV array. The load of home is shown as one RL load with active power demand as 6000 W and reactive power demand as 4500 W (0.8 Power Factor)

5. SIMULATION RESULTS

The Simulation results of the simulation model of grid connected PV systems shown in the Fig. 5 is presented in this section. The results illustrated the normal operation of a integrated systems. Fig. 7 illustrates the voltage waveform of the system operating under the given sample data, the voltages are somewhat below than 230 volts because of the imbalance in the output of the PV array due to change in the operating conditions i.e. the deviations from the standard test conditions.

Fig. 8 illustrates the current waveform across the current measurement connected in series with the home load in the simulation model. The value of current remains within the acceptable limits, the load current is fluctuating from -50 A to 50 A.

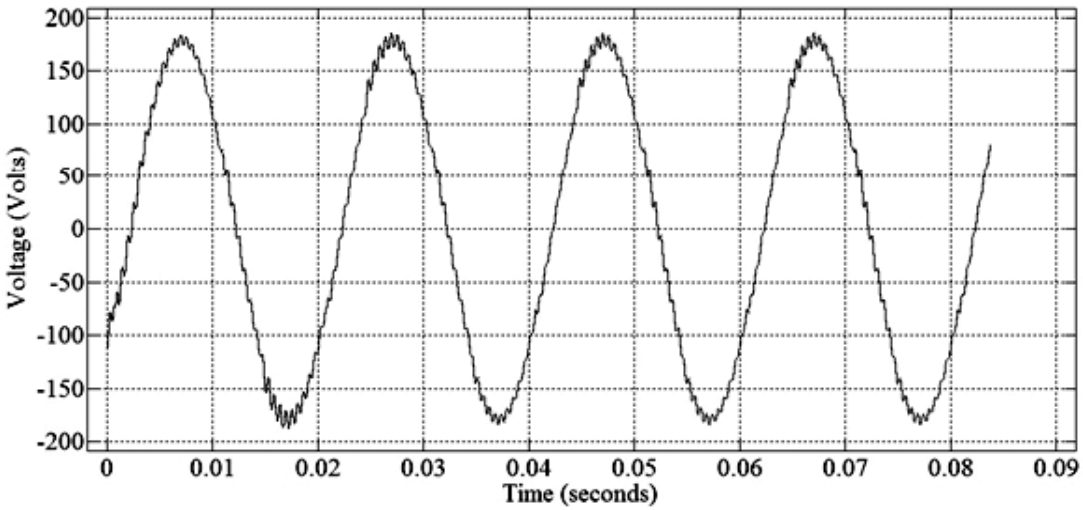

Figure 7: Voltage waveform of grid connected system

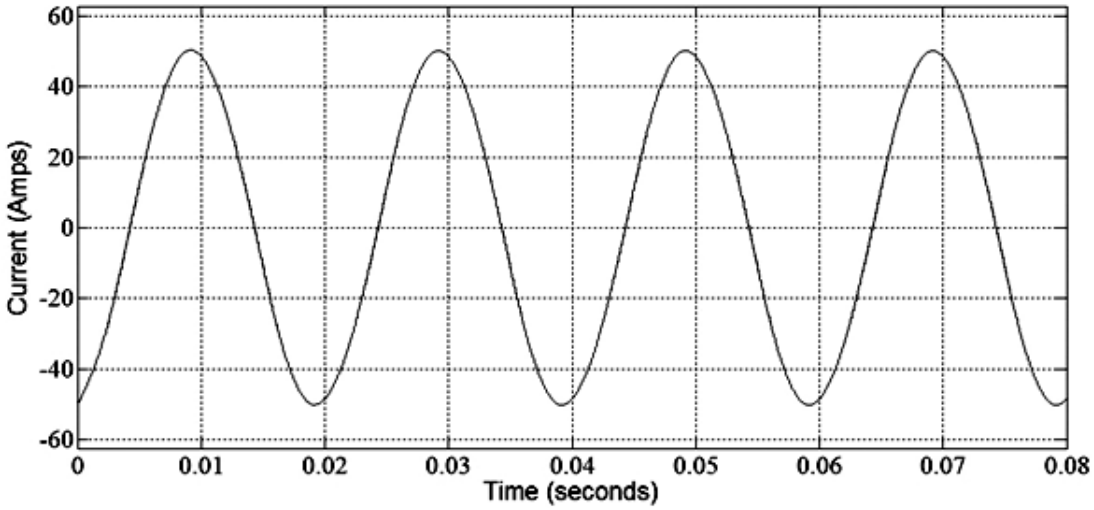

Figure 8: Current waveform across the load in model

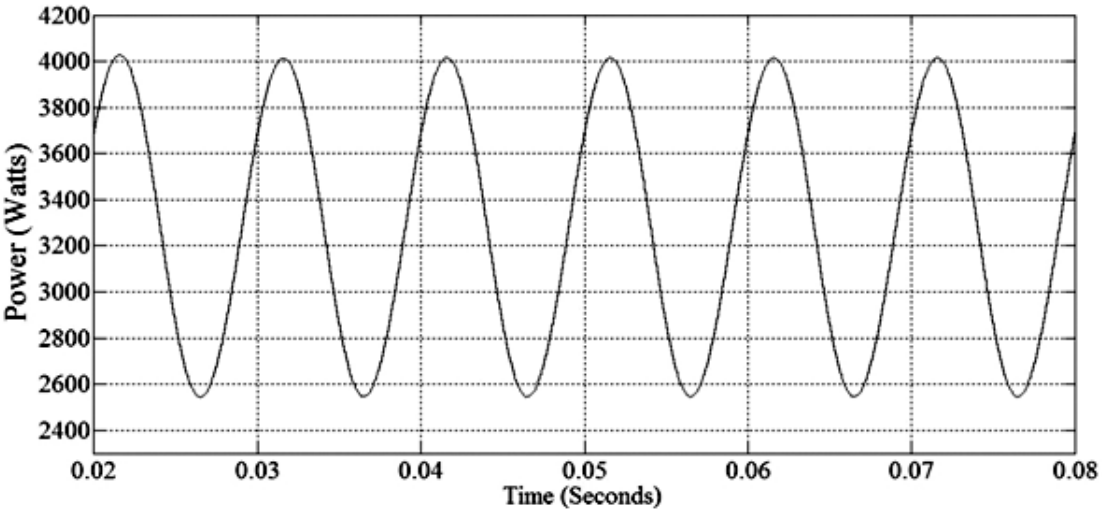

Figure 9: Active Power across the load in simulation model

Fig. 9 shows the active power across the home load, the active power waveform is smooth without any pulsation or peaks illustrating the smooth functioning of the PV system in parallel with the utility grid.

6. CONCLUSIONS

The integrated solar photovoltaic systems consisting of photovoltaic panels installed on the rooftops of the buildings interacting with the utility grid helps in reducing the burden on the normal utility grid by decreasing the total number of energy units abstracted from the main grid. The process of net metering further reduces the net monthly electricity bill of a particular building by supplying the electric power back to the utility grid during off peak hours, resulting in net addition of the total units consumed and supplied. The simulation model of the grid connected system is simulated under the sample data of Patiala, India region and satisfactory results are hence obtained. All the simulation work is carried out in Simulink in MATLAB 2014. The solar windows can also helps in reducing the consumption by normal lightning system in commercial buildings.

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