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Smart Energy Distribution Management with Solar - Grid connected Multilevel Inverter

R. SUNDARARAJAN[1], S.VINOTH KUMAR[2], V.LAVANYA[3]
Department of ECE[1, 2, 3], P.G scholar[1], project coordinator[2], guide[3], Aksheyaa College of engineering[1, 2, 3]
Email: sundar9445252693@gmail.com.[1] aceece12@gmail.com.[2] lavanya1520@yahoo.co.in [3]

Abstract—Energy supply has become one of the most challenging issues facing the world in the 21st Century. Growing populations, more homes and businesses and a numberless of new appliances have caused energy demand to skyrocket in every part of the country. The fundamental method of operating the nation's power network has not changed much in the past 100 years. It has remained essentially the same, although the number of customers and their needs have grown exponentially. Utilities across the nation and indeed, around the world are trying to figure out how to bring their networks into the 21st century and the digital age. In this paper, we propose a Smart Energy Distribution Management (SEDM) which functions as a control using a battery status and setting time of power usage to reduce power consumption. The SEMS not only supplies power as the way the common power strips do but also controls sockets of the SEDM using ZigBee wireless communication. That is, such solutions need to include the electrical energy distribution management due to the passive operation according to the variation per hour or battery status.

Key words: Photovoltaic System, Microcontroller unit, ZigBee, Multi level Inverter, Battery

1. INTRODUCTION

Energy is one of the issues that are causing the most disagreement as fossil fuels are the greatest pollutants and the greatest contributors to the greenhouse effect .The increasing importance of green concern, fuel savings and unavailability of power has led to the renewal of interest in renewable energies. It therefore stands to reason that developing countries whose energy utilization rate is increasing at a very fast rate should be investigating new energy systems based on renewable energies that do not pollute and which are unlimited such as the Solar system. Fig.1 shows the structure of general renewable energy system.

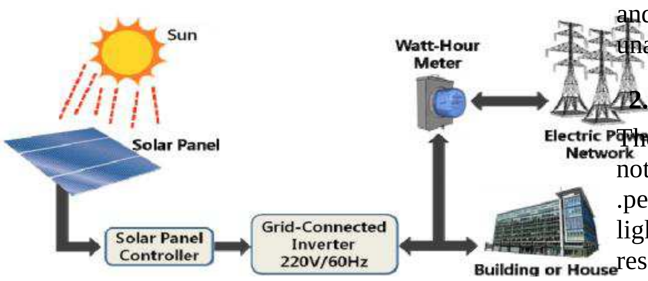

Fig.1 Structure of general renewable energy system

Renewable sources are also called Echo friendly technologies are very important due to their pollution free energy generation and having sustainable growth. There are many sources of energy that are renewable and considered to be environmentally friendly and not dangerous natural processes. These sources of energy provide an alternate "cleaner" source of energy, helping to negate the effects of certain forms of pollution. All of these power generation techniques can be described as renewable since they are not depleting any resource to create the energy. While there are many large-scale renewable energy projects and manufacture, renewable technologies are also suited to small off-grid applications, every now and then in rural and remote area, where energy is often crucial in human development. In this paper a simple, reliable and successful solar panel charging system has been introduced consisting of a solar panel of desired size and shape. This solar panel is integrated with an embedded system. This embedded system regulates the electricity produced between the storage battery and charging output with the help of microcontroller which is programmed to combat the situations in presence and in absence of input supply and able to supply stored energy at night or in unavailability of solar source.

2. RELATEDWORK

The world today's facing the most critical difficulty of not getting the expected power. In many countries .peoples had not getting at least the major needs of lights, fans, TV etc. In nearly every country, researchers expect existing energy production capabilities will fail to meet future demand without new sources of energy, including new power plant production. However, these supply side solutions ignore another attractive alternative which is to slow down or decrease energy consumption through the use of technology to significantly increase energy efficiency. To manage the available power more often the power is cut for particular area, and that area goes in dark i.e. not even a single bulb can work. Instead, we can use available power in such a way that only low power devices like Tubes, Fans, and Desktops TV. Which are primary needs should be allowed and high power devices like heater, pump-set, A.C. etc should not be allowed for that particular period. To reach this, system can be created which will distinguish between high power and low power devices at every node and allow only low power devices to be ON. In present days the administration of the domestic laboratories in the research institute and universities has issues of poor real time, high cost and low accuracy .It is difficult to determine the quality of the environment of the laboratory. By using this project should be developed to employ early warning, remote control, real-time monitoring and other functions. Also we design solution of an embedded web-based remote monitoring system for the environment in the laboratories, which realizes the local management and remote publishing applications for large-scale dynamic data of sensor networks.

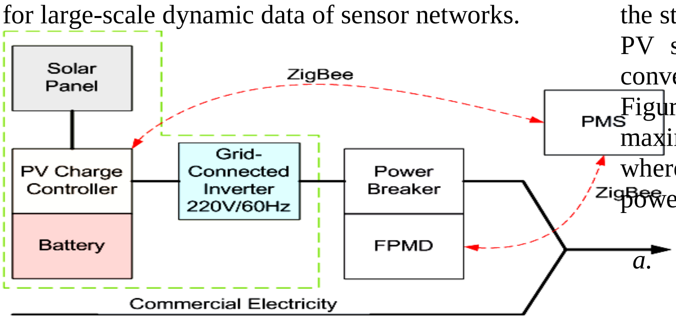

Fig.2 - Structure of Photovoltaic Generation System with the SEDM

Fig. 2 show how to generate the photovoltaic system used in this paper. We install a solar panel system on the side of a window, and it consists of an inverter, battery, and PV charge controller which can manage the battery charge efficiently. Then, this generation system is connected to a power breaker in the PMS to be associated to the commercial electricity grid. The FPMD with the power breaker and battery measuring device in the solar panel controller sends power data to the PMS regularly through the ZigBee network. Therefore, based on ZigBee technology, laboratory intelligent monitoring system has a very important importance. ZigBee is a wireless communications technology, with a short distance, safe and reliable; you can use ZigBee technology to collect the data from sensor controlling board to web server. These sensors automatically monitoring the local environmental data in laboratory. Therefore, based on ZigBee technology, laboratory smart monitoring system has a very important significance.

3. SYSTEM ARCHITECTURE

The PV power generation have low efficiency due to the various constrains. This project gives a new proposed method to improve the performance of the PV system. The PV cell is connected to boost chopper and Multi-Level Inverter (MLI). In order to improve the efficiency and for making the power generation available to the grid MLI is employed. MLI have emerged as attractive high power medium voltage converter to reduce harmonic component in the output current due to filter. In the proposed MLI there are 2-H bridge inverters to achieve the 5-level output voltage. A PWM technique is used to generate the PWM signal for boost chopper inverter switches. Boost chopper is connected between the PV array and MLI. The purpose of boost chopper is to step-up the voltage and to produce continuous current to MLI. The simulation results are validated for the improvement in the PV cell system. The hardware is implemented with boost chopper and multilevel inverter. The microcontroller is used to generate the PWM signal for boost chopper and inverter switches. Boost chopper output is fed to multilevel inverter and the stepped wave is obtained. The grid connected solar PV system is composed of solar PV array, boost converter, power inverter and utility grid as shown in Figure. Solar PV array generates DC power at its maximum using boost converter with MPPT algorithm whereas power inverter converts this DC power to AC power and feeds to utility grid.

a. PV Array & Modeling

Solar energy is generally present in the form of solar irradiance. The PV cell works in the principle of Photoelectric effect; light striking on solar cell is converted to electric energy. These cells are made by silicon or other semiconductor materials. A typical silicon solar cell generates about 0.5 volts in normal operation. Large numbers of solar cells are connected in series, forming a module to meet the voltage requirement of the system. Large numbers of solar modules are connected to make arrays. The rating of a solar module is given by the maximum output or maximum power it can deliver. The output of a solar module depends on the number of cells in the module, type of cell and the total surface area. The output of a module changes depending on the amount of solar irradiance, the angle of the module with respect to the sun, the temperature of the module and the voltage at which the load is drawing power from the module. The solar cells are combined in series and parallel operation which convert solar energy to electric energy. The electric energy produce by the solar cell depends upon internal parameters of cell, solar irradiance and cell temperature.

b. Grid Connected Five-Level Inverter

Boost converter is DC-DC converter which converts lower voltage to higher voltage and then boosted voltage is applied to five level inverter.

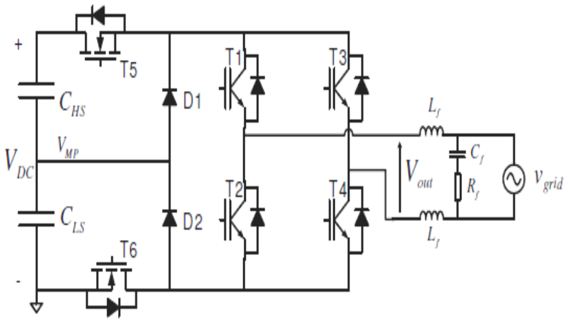

Fig.3. Architecture of the proposed five-level solution.

Fig 3. Shows the proposed converter topology. This converter architecture, known as the H6 Bridge, was originally developed in, in combination with a suitable PWM strategy, in order to keep constant the output common mode voltage in case of a transformer less inverter for photovoltaic applications. With the same purpose, another PWM strategy for the H6 Bridge was developed in. In this paper, this converter structure is used to obtain a five-level grid connected converter for single-phase applications. In steady state conditions, due to the low voltage drop across the inductances Lf of the output filter, the output voltage of the converter has a fundamental component very close to the grid voltage. The frequencies of these two voltages are identical while the amplitudes and their phase displacement are only slightly different. As a consequence, the shape of the modulation index, m, of the power converter is very similar to the grid voltage waveform. The output voltage of the converter can be written as $V_{out} = mV_{DC}$. Depending on the modulation index value, the power converter will be driven by different PWM strategies. As a matter of fact it is possible to identify four operating zones & for each zone the output voltage levels of the power converter will be different according with TABLE1

Zone	**M**	***Output Voltages***
Zone 1	**0 < M < 0.5**	**V_{MP} AND 0**
Zone 2	**0.5 < M < 1**	**V_{DC} AND V_{MP}**
Zone 3	**−0.5 < M < 0**	**$-V_{MP}$ AND 0**
Zone 4	**−1 < M < −0.5**	**$-V_{DC}$ AND $-V_{MP}$**

Table 1 - Output Voltages In The Different Working Zones

With reference to the schematic of Fig 4, the behavior of the proposed solution is shown for a whole period of the grid voltage i.e., of the modulation index. During the positive semi-period the transistors T1 and T4 are ON and T2 and T3 are OFF. In Zone 1, T5 is OFF and T6 commutates at the switching frequency, while in Zone 2 T5 commutates at the switching frequency and T6 is ON. During the negative semi period the full-bridge changes configuration, with T1 and T4 OFF and T2 and T3 ON.

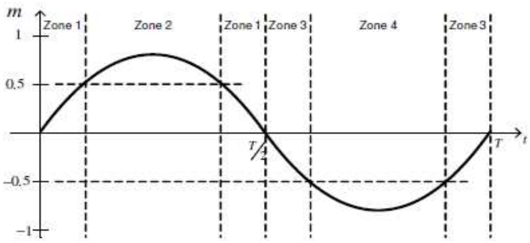

Fig.4. Modulation index waveform in steady state conditions and definition of the four different PWM zones.

With similarity to Zone 1 and 2, in Zone 3 T5 commutates while T6 is OFF, and in Zone 4 T5 in ON and T6 commutates. Fig. 5 and Fig. 6 show the current path during the positive semi-period, respectively in Zone 1 (Fig. 5) & Zone 2 (Fig. 6). In the figures the controlled power switches that are ON during the whole PWM period are substituted by a solid line, while devices that are OFF during the whole PWM period are not displayed. In Zone 1 the switching of the transistor T6 changes the output value between $+V_{MP}$ (that is provided by the low side capacitor, Fig. 5a) and 0 V. During the free-wheeling phase both diodes D1 and D2 are ON, imposing an almost null voltage at the full-bridge output, see Fig.5b.

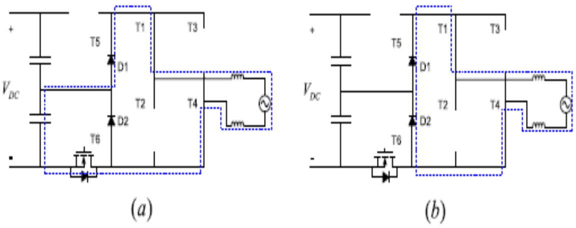

Fig. 5. Proposed five-level PWM strategy for the Zone 1, Active phase (a) and free-wheeling phase (b).

In Zone 2 T6 is ON and the switching of T5 changes the output voltage from +VDC (Fig. 6a) to +VMP (Fig. 6b).

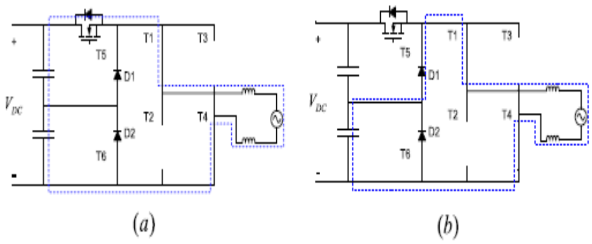

Fig.6. Proposed five-level PWM strategy for the Zone 2,

Active phase (a) and free-wheeling phase (b).

A similar analysis can be repeated for the negative semi-period, Zones 3 and Zone 4. It must be noted that only a transistor is switching for every zone. Furthermore the anti-parallel diode of every power switch is not used allowing the use of MOSFETs for all the transistors. Fig. 7 shows the gate signals for the proposed five level modulation strategies. In the above described operations, the output voltage level $+V_{MP}$ is provided by the discharging of C_{LS}, while the output voltage level $-V_{MP}$ is provided by the discharging of C_{HS}.

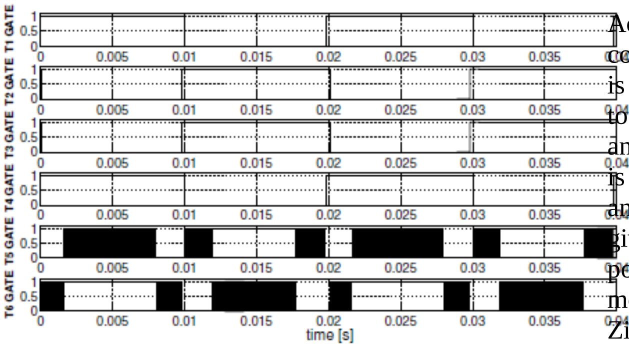

Fig.7. PWM gate signals for the proposed five-level modulation strategy during two grid voltage periods.

In fully symmetric conditions, the midpoint voltage will be equal to $V_{MP} = V_{DC2}$, however, an asymmetry could unbalance the system. This choice allows obtaining the minimum number of commutations but causes a voltage ripple in V_{MP} at the same frequency of the grid voltage. In fact, it would be possible to reduce the ripple of the midpoint voltage [V_{MP}], but it would imply a greater number of commutations of T5 and T6. This choice is avoided in order to pursue the maximum efficiency.

c. Smart Energy Distribution Management

Smart Energy Distribution Management system is the most important in order to determine how effectively the power generated from renewable sources are distributed. The system decides when to use the energy stored in the battery, that is whenever the power generated from the commercial electricity grid is very low then the switching action takes place, switches to the solar grid. If the energy generated from the solar panel is sufficient then power supplied as usual as the commercial grid otherwise controlling action takes place. The energy stored in the battery is always compared with the preset levels and if it is low then it communicates with control room to take necessary steps.

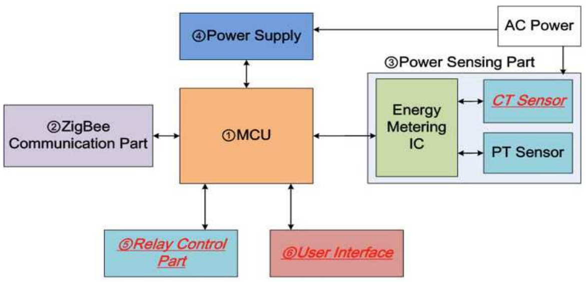

Fig. 8. Hardware architecture of Smart Energy distribution Management

According to the energy levels in the stored battery the controlling of devices takes place. If the energy level is below the first preset level then the power that goes to the least priority devices are automatically shut off and the high priority devices are run and if the energy is below that then the next priority devices are shut off and allows to run only the highest priority devices giving a signal to take the necessary actions. The power monitoring device has three power sockets to measure the power consumption of devices and Zigbee network module, that can transmit the status of the battery and receives the control signals to control the power through the devices. Fig.8 shows the basic block diagram for Smart Energy distribution Management system consisting of microcontroller unit, relay control unit; Zigbee communication; user interface, power sensing unit (energy meter) and power supply exist in the system. The energy meter measure the power consumption, consisting of a CT sensor converted to a current value which can handled in the MCU. The renewable energy management system manages the generated power and battery charging conditions in the solar power generator. The power management methods are of two types, efficiency oriented and user oriented. In the efficient method the generated power and the battery charging conditions are transmitted to the smart power management system and it is compared with the power consumption data stored in the MCU. But the problem with this technique is that it finds only the optimal time to use the charging battery for decreasing power consumption and electric charges.

In this paper we proposed a user oriented method to run the devices by setting the priorities and run the device having highest priority for a long time compared to the devices having least priority, which increases the efficiency in the point of user.

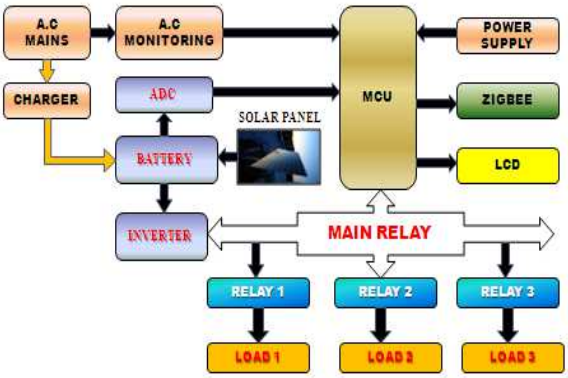

Fig. 9. Smart Energy distribution Management with Priority Load

The block diagram in fig. 9. having three sockets is nothing but three loads. The intelligent system efficiently distributes the power generated from the solar panel to these prioritized loads depending upon the status of the battery.

4. IMPLEMENTATION

In the previous section we describe the efficient Smart Energy Distribution Management system. Now we can see how to implement this system, when the electricity generated from the thermal plants is enough then it is connected to the connected to the energy meter through the power grid network, otherwise when the this electricity is not available then the energy generated from the solar panel is connected to the energy meter trough the grid inverter and distributed to the devices according to the prioritization which increases the efficiency of the solar power. Always the power requires is compared with the stored value in the battery and generates the control signals according to conditions specified. As the consumption of power increases, the energy stored in the battery decreases causes that no longer the devices operate with the solar energy. In order to increase the efficiency of the solar system it is required to distribute the energy intelligently, sends a control signal from the control room to turn off the least priority devices and keep on monitoring the battery status. If the battery value reaches the threshold value which is set for safe operation runs only the highest priority device making all remaining devices turn off. To make the switching action between commercial electricity and solar power a relay is placed. To monitor the electricity from power grid network, 5v input is given to the MCU whenever the monitor pin reads 0V then relay connects the solar system to the energy meter and it displayed on the LCD display and on the PC in control room. Zigbee provides the communication between the control station and distribution system. The control commands are given remotely to control power going to the devices depending on the battery status.

The algorithm is as follows:

Step1: Initialization of devices.
Step2: Initially both AC and Inverter sections are in ON condition.
Step3: Devices are run with AC power
Step4: In microcontroller one pin is programmed to monitor the AC power, when it is goes off, the relay is connected to the inverter.
Step5: Now the solar energy is connected to the meter
Step6: In micro controller the stored energy is always compared with presetting levels
Step7: If the stored energy is greater than the power Consumption then the least priority device is automatically turn off.
Step8: Otherwise highest priority load will run by turning off other loads.
Step9: Whenever the AC power is available then the relay connects it to the energy meter.
Step10: Stop the process.

5. EXPERIMENT RESULTS

a. Simulink Model for Grid connected Inverter Using Mat lab

The five-level solution was simulated using the toolbox, which allows fast simulation of power electronic circuits under Simulink / Mat lab environment.

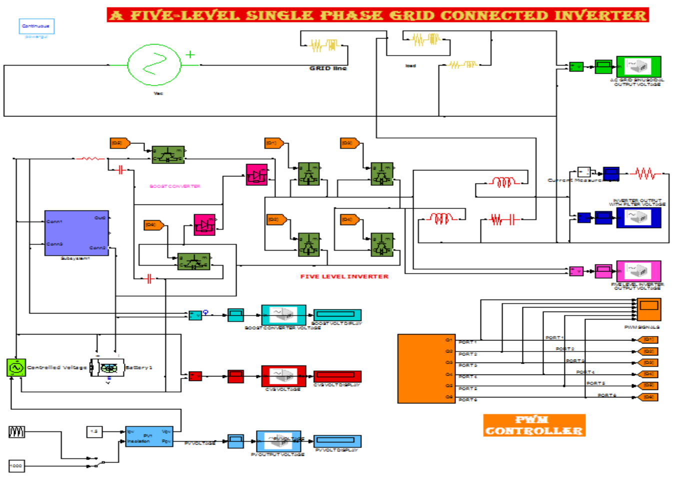

Fig.10. Simulink Model for Grid connected Inverter Using Mat lab

Referring to Fig.11, the simulation parameters were: V_{DC} = 400V, $V_{grid} = 230\sqrt{2}\sin(2\pi 50t)$, $C_{HS} = C_{LS}$ = 2mF, L_f = 1000μH, C_f = 2μF, R_f = 0.5. A grid impedance Z_{grid} = (jω50μH + 0.4) was considered. The switching frequency was 20 kHz. The power converter control, formed by the MVC and the current controller, was the same shown in the block scheme of Fig.10. The simulation results refer to a sinusoidal current injection of A_{RMS} into the grid with unity power factor. Fig. 11.a and 11.b. showed a close up of the converter output voltage and current. Multilevel – Five level Inverter and Grid sinusoidal output Voltage Wave Form with the help of Simulink / Matlab as Shown in Fig.12.a and Fig.12.b.

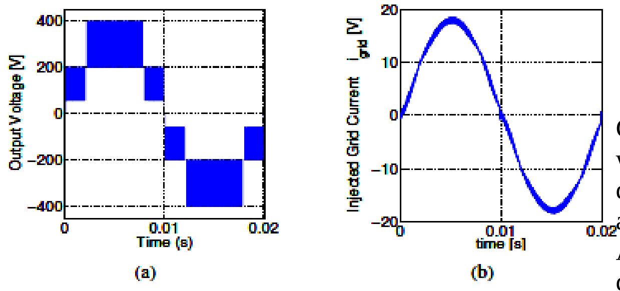

Fig.11. Close up of the converter output voltage V_{out} (a) and of the injected grid current (b).

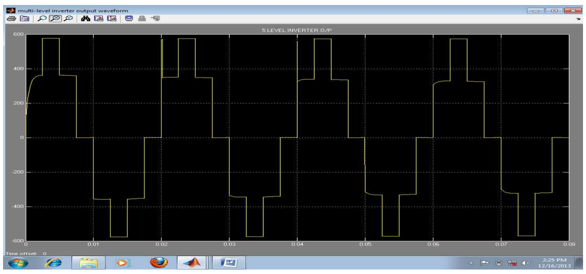

Fig.11.A. Multilevel Inverter output Voltage Wave Form using mat lab

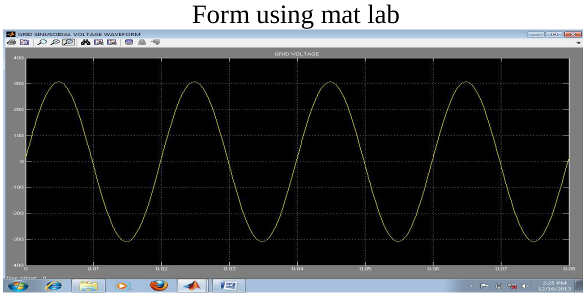

Fig.11.B. Grid Sinusoidal -output Voltage Wave Form using matlab

b. Load Distribution with Battery Charge status.

The results shows that, when the power from both power plant and solar system are present then the efficient distribution system connects the energy meter to power line generated from power plant and runs all the devices. Otherwise the remote control station sends the command signal to connect the solar system to the energy meter and compares the battery status continuously to run the prioritized devices.

Battery Charge status	Relay ON Condition	Loads condition
100 % (12 V)	R1,R2,R3	Three loads are run(no priority device)
90 % (10.8V)	R1,R2	Load -3 turn off(least priority device)
80 % (9.6V)	R1	Load-1 only ON(highest priority),turns off reaming devices
70 % (8.4V)	R1	Along with running the highest priority device gives an alert signal

Table 1: Load Distribution with Battery Charge status

Control station that is remotely located, communicates with the efficient system through the Zigbee and it displays the results like on PC like, when AC power and Solar power present AC power ON, Otherwise AC power off and solar power present and also display the voltage in the inverter. According to the battery status it operates the loads given in the following table in this for demo purpose three loads are considered.

c. Load Distribution with load duration status.

An additional function is setting time of power usage. This function demands setting port using the program as a first step. User then set time whenever the user wants the sockets to be turned on. The sockets are turned on only during the time user set and are turned off for the rest of the time. Furthermore, users are capable of setting maximum power consumption for preventing excessive power usage and setting maximum power to avoid fuse blow.

Time Period	Relay ON Condition	Loads condition
6 P.M to 10 P.M	R1,R2,R3	Three loads are run(no priority device)
6 A.M to 6 P.M	R1,R2	Load -3 turn off(least priority device)
10 P.M to 6 A.M	R1	Load-1 only ON(highest priority),turns off reaming devices

Table 2: Load Distribution with load duration status

When the power consumption and power exceed the limitation, the sockets are turned off from low priority to high priority. Secondly, in case of a function which sets time of power usage, we set the function on control using time setting program. In accordance with the usage patterns of the SEDM, we set time range from 6 pm to 10 pm in all socket, time range from 6 am to 6 pm in a first and second socket and time range from 10 pm to 6 am in the first socket and measured the power consumption in control station for all days. The time we set was simply for experimental measurement and thus the time can be set whenever a user want to use the appliances using the function of setting time of power usage. Table 2 is the experimental result of the function of setting time of power usage.

6. CONCLUSION

In this paper we proposed a system to distribute the power generated from renewable sources efficiently using a battery status and setting time of power usage to reduce power consumption. By increasing the capacity of solar panel and efficiency of the battery, it is possible to construct a solar energy supply parallel to the commercial energy supply from power plant which solves the problems of electricity in future and it can be distributed effectively to the rural and urban areas which solve the problems of electricity. But the problem with this system is that to require huge inverter to store the largely variable solar energy and its maintenance. This can be overcome by constructing solar grids parallel to the existed grids by the government. The future scope of idea is proposed system can be installed and maintained in residential environments with ease. A ZigBee based Intelligent Energy Management System for residential building system can provide significant cost savings in a building environment, great level of flexibility and control for the building administrators and great comfort for the occupants.

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Mr**.VINOTH KUMAR.S** has completed his Masters Degree in Communication systems, undergoing Research scholar in Sathyabama University. He is currently working as Associate Professor & Head of the Department in Aksheyaa College of Engineering, Puludivakkam, Kancheepuram, Affiliated to Anna University. His areas of interest are Network protocols, IPV4, IPV6, image processing, VOIP, network security, Mr. wireless communication. He got certified in MCP, MCSA, Novell, A+, N+, RHCE, ITIL, remote management tools. He is also certified in MISSION 10X from WIPRO and ANNA UNIVERSITY. He published many research journals in both national and international publications.

Ms**.LAVANYA.V** has completed her Bachalor Degree in Electronics & Communication Engineering in Shri Angalamman College of Engineering, Trichy and Masters Degree in Applied Electronics in Jerusalem Engineering College, Chennai, Affiliated to Anna University. She is currently working as Assistant Professor in Aksheyaa College of Engineering, Puludivakkam, Kancheepuram, Affiliated to Anna University.

Mr**.SUNDARARAJAN.R** received his B.E degree in Electrical & Electronics Engineering from Sri Chandrasekharendra Saraswathi Viswa Maha Vidhyalaya (SCSVMV) University, Kancheepuram, Tamil Nadu and currently pursuing M. E in Applied Electronics from Aksheyaa College of Engineering, Puludivakkam, Kancheepuram, Affiliated to Anna University.