DESIGN, DEVELOPMET & SIMULATION OF SOLAR LIGHTING SYSTEM

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ABSTRACT

Global interest in harnessing renewable energy resources has dramatically increased due to the confluence of several factors. The world cannot continue to relay for long on fossil fuels for its energy requirements. Fossil fuels reserves are limited. In addition, when burnt, these add to global warming, air pollution and acid rain. These systems are non- polluting, don't deplete the natural resources in the long run. The advantages of using solar energy are the cost reduction of installation in the case of non availability of electric grid, reduction of electricity bill and contribution to the protection of the environments (Clean and renewable energy source).After a brief, but broad overview of renewable Energy utilization scenarios, this paper focuses on the employment of a solar lighting system which can make a 3w lamp glow continuously for about one hour if the battery is fully Charged has been constructed. The device can be used for small-scale lighting applications in remote areas that are far away from the power grid. The system has a panel to collect the sun's energy, a battery to store that energy and a light source to use the energy. The system operates like a bank account. Withdrawals from the battery to power the light source must be compensated for by commensurate deposits of energy form the solar panels.

Keywords - Solar lighting system, solar panel, integrated circuit, light source, photovoltaic, battery, relay,solar panel.

I. INTRODUCTION

With increasing concerns about fossil fuel deficit, skyrocketing oil prices, global warming, and damage to environment and ecosystem, the promising incentives to develop alternative energy resources with high efficiency and low emission are of great importance. Among the renewable energy resources, the energy through the photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resource because of the ubiquity, abundance, and sustainability of solar radiant energy. Regardless of the intermittency of sunlight, solar energy is widely available and completely free of cost. Recently, photovoltaic array system is likely recognized and widely utilized to the forefront in electric power applications. It can generate direct current electricity without environmental impact and contamination when is exposed to solar radiation. Being a semiconductor device, the PV system is static, quite, and free of moving parts, and these make it have little operation and maintenance costs. Even though the PV system is posed to its high capital fabrication cost and low conversion efficiency, the skyrocketing oil prices make solar energy naturally viable energy supply with potentially long-term benefits. Solar lighting system is the use of natural light to provide illumination. Solar lighting system is the technology of obtaining usable energy from the light of the sun using semi conductor materials and this is energy efficient lighting technology. They are used in residential, commercial, institutional and light industrial applications. The construction of a solar lighting system serves as a means of reducing energy imports and dependence upon oil and gas, which mitigate the risk of fuel-price volatility and supplies energy for small-scale lighting applications when and where electricity is most limited and most expensive.

the introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

Fig:1 solar energy

Solar power is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaic's and heat engines. A partial list of other solar applications includes space heating and cooling through solar architecture, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

A. SUN AS A SOURCE

The energy from the sun is supplied in the form of radiation. The energy is generated in the sun's core through the fusion of hydrogen atoms into helium. Now due to the larger distance of sun from the earth only a small portion of sun's radiation reaches earth's surface. The intensity of solar radiation reaching earth's surface is around 1369 watts per square metre. This is known as the solar constant. The total solar radiation intercepted by earth's surface can be calculated by multiplying solar constant with the cross section area of the earth. In order to calculate the solar radiation received, on average per square metre of earth's surface we divide the above multiplied result by the surface area of the earth.

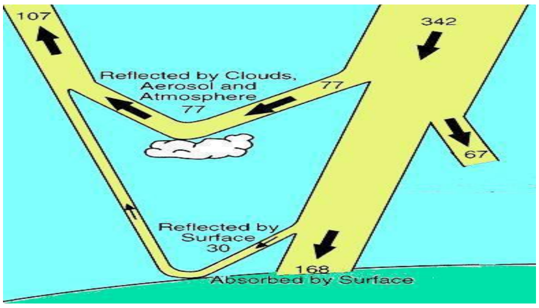


Fig: 2 Distribution of solar radiation

From the fig: 2 we can see that every square metre of the upper regions of the atmosphere receives 342 W/m^2, 67 W/m^2 of energy is absorbed by the atmosphere and 77 W/m^2 is reflected. About 198 W/m^2energy reaches the earth's surface of which 30 W/m^2 is reflected back to space.

The energy that reaches the earth surface is around 3.2 EJ/y. If we are able to harvest even a small fraction of the available energy at the earth surface we could solve our energy problems. The energy reaching the earth surface is around 7000times the global energy consumptions. But the global solar energy consumptions were only 0.014% of the total solar energy reaching the earth surface.

Solar energy can be used by man in a planned direct or indirect way. In the case of indirect utilization of solar energy we consider the use of renewable energies which are secondary effects of solar energy [1, 2], i.e., wind energy, hydro energy, ocean energy, and secondary energy from photosynthetic process that is mostly connected with the use of biomass and bio fuels. Using solar energy in the direct way we can apply two fundamental methods of energy conversion:

- Photo thermal conversion of energy of solar radiation;
- Photoelectric conversion of energy of solar radiation.

B. PHOTOVOLTAIC SYSTEMS

1) Photovoltaic cell

The p-n junction diode conducts when it is forward biased similarly the photo voltaic cell is like p-n junction diode by the incidence of photons it will conducts and produce voltage. PV cell are basically semiconductor diode. This semiconductor diode has got a p-n junction which is exposed to light. When illuminated by sunlight it generates electric power. PV cell are made up of various semiconductor materials. But mono-crystalline silicon and poly-crystalline silicon are mainly used for commercial use.

2) Photovoltaic module

The power produced by a single PV cell is not enough for general use. So by connecting many single PV cell in series (for high voltage requirement) and in parallel (for high current requirement) can get us the desired power. Generally a series connection is chosen this set of arrangement is known as a module. Generally commercial modules consist of 36 or 72 cells.

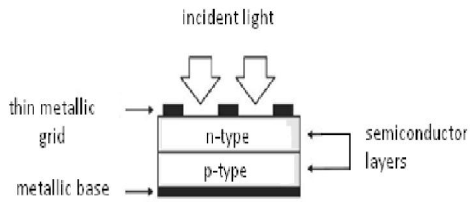


Fig: 3 Basic PV cell structure

3) Photovoltaic Array

A photovoltaic array (PV system) is an interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by a single module is seldom enough for commercial use, so modules are connected to form array to supply the load. The connection of the modules in an array is same as that of cells in a module. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current. In urban uses, generally the arrays are mounted on a rooftop. In agricultural use, the output of an array can directly feed a DC motor.

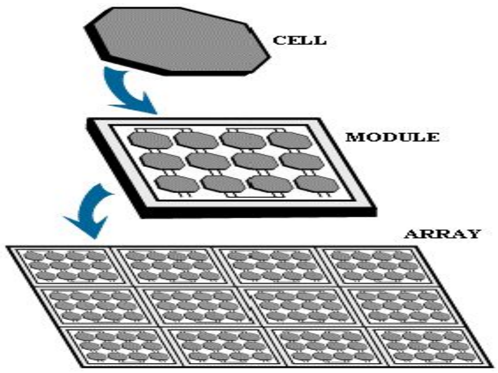


Fig: 4 Photovoltaic Hierarchies

4) Working of PV cell:

Working of a PV cell is based on the basic principle of photoelectric effect. Photoelectric effect can be defined as a phenomenon in which an electron gets ejected from the conduction band as a consequence of the absorption of sunlight of a certain wavelength by the matter (metallic or non-metallic solids, liquids or gases).So, in a photovoltaic cell, when sunlight strikes its surface, some portion of the solar energy is absorbed in the semiconductor material. If absorbed energy is greater than the band gap energy of the semiconductor, the electron from valence band jumps to the conduction band. By this, pairs of hole-electrons are created in the illuminated region of the semiconductor. The electrons thus created in the conduction band are now free to move. These free electrons are forced to move in a particular direction by the action of electric field present in the PV cells. These flowing electrons constitutes current and can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and the voltage (created because of its built-in electric fields) produces required power.

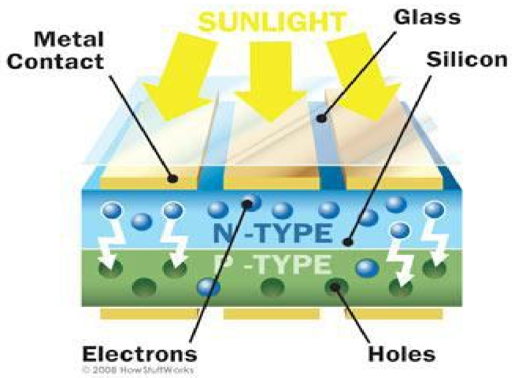


Fig: 5 Working of PV cell

C. MODELING OF PV ARRAY

The PV devices are basically represented in Single diode model.

5) Single diode model

In a single diode model, there is a current source parallel to a diode. The current source represents light-generated current, which varies linearly with solar irradiation. This is the simplest and most widely used model as it offers a good compromise between simplicity and accuracy. Figure below shows the single diode model circuit.

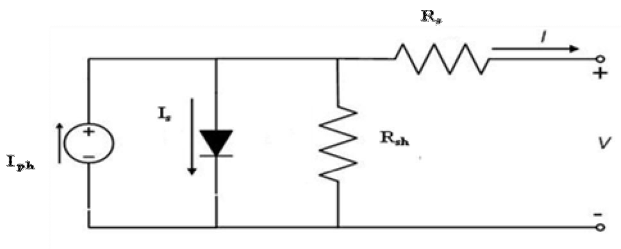


Fig 5.1: Single diode model

The characteristic Equation for the PV cell is given by:

$$I = I_{ph} - I_s \exp\left[q\left(\frac{V+IR_S}{KT_cA}\right)-1\right] - \frac{V+IR_s}{R_{sh}}$$

Where

I_{ph} = light-generated current or photocurrent,

Is = cell saturation of dark current,

q = 1.6 ×10−19 C is an electron charge,

k = 1.38 ×10−23J/K is a Boltzmann's constant,

T_c = cell's working temperature,

A = ideal factor,

R_{sh} = shunt resistance, and

R_s = series resistance.

The photocurrent mainly depends on the solar isolation and cell's working temperature, which is described as

$$I_{ph} = [I_{sc} + KI(T_c - T_{ref}\lambda$$

Where I_{SC} is the cell short-circuit current at a 25°C and 1kW/m^2, K_I is the cell short-circuit current temperature coefficient, T_{ref} is the cell's reference temperature, and λ is the solar isolation in kW/m^2. On the other hand, the cell's saturation current varies with the cell temperature, which is described as

$$I_s = I_{Rs}\left(\frac{T_c}{T_{ref}}\right)^3 \exp\left[\frac{qE_G\left(\frac{1}{T_{ref}} - \frac{1}{\ }\right)}{KA}\right]$$

Where I_{RS} is the cell's reverse saturation current at a reference temperature and a solar radiation E_G is the bang-gap energy of the semiconductor used in the cell. The ideal factor A is dependent on PV technology.

$$I_{RS} = I_{SC}/[\exp\left(\frac{qV_{OC}}{N_S KAT_C}\right) -$$

Where I_{RS} = Reverse saturation current of PV cell.

I_{SC} = Saturation current of PV cell.

V_{OC} = Open circuit voltage of cell.

A = Ideal factor of cell.

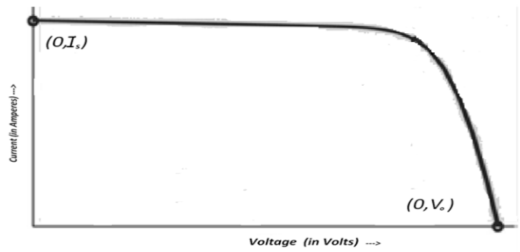
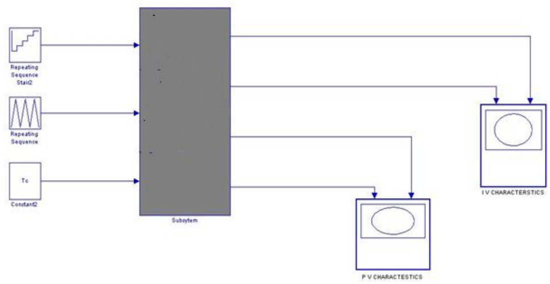


Fig 5.2: characteristics of a PV cell

D. SIMULATION OF PV ARRAY AND ITS RESULTS

6) PV ARRAY



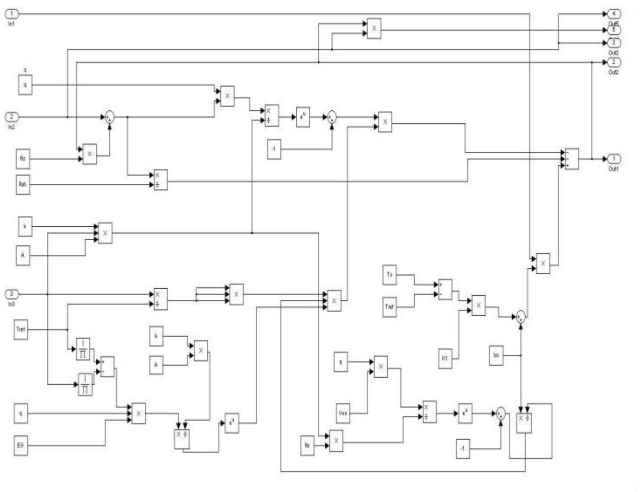


Fig 6.8: PV current Equation implementation in Mat lab

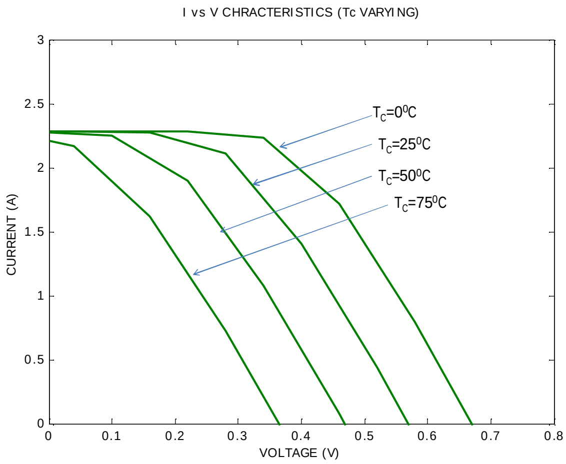


Fig 6: I-V characteristics by varying cell working temperature

From fig 6 it is clearly known that as cell working temperature increasing the voltage is going to reduce. The current versus voltage characteristic shows that cell working temperature is inversely proportional to current, voltage and the output characteristic can be obtained in an exponential dependency function.

E. P-V CHARACTERSTICS, CELL WORKING TEMPERATURE VARYING

Power vs voltage characteristics by varying cell working temperature

From fig 7 it is clearly knows that as cell working temperature increases the voltage is going to reduce. The power versus voltage characteristic shows that cell working temperature is inversely proportional to power; voltage and the output characteristic can be obtained in this manner because of exponential dependency function.

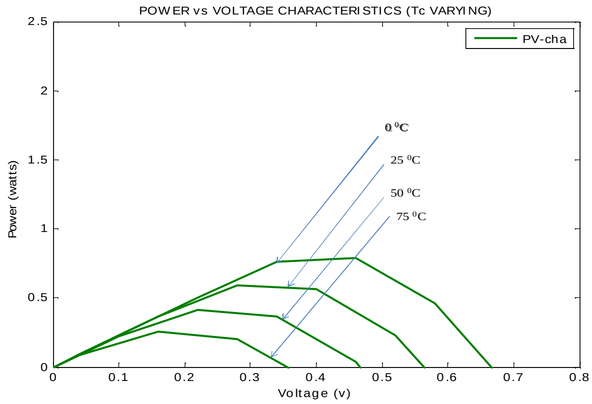


Fig 7: P vs V characteristics by varying cell working temperature

II. HARDWEAR IMPLEMENTATION

The aim of is to demonstrate how we can utilise solar light to electrify the remote areas, i.e., how we can store the solar energy and then use it for small-scale lighting applications. Urban and rural lighting can be done by using solar energy. The advantages of using solar energy are the cost reduction of installation in the case of non availability of electric grid, reduction of electricity bill and contribution to the protection of the environments (Clean and renewable energy source).

F. EQUIPMENT USED

The components used in the construction are 12-16V solar panel, 35 micro farads capacitor,10 v relay, integrated circuit (IC 7808), light emitting diodes, diodes, resistors, switches, lamp (6V,1A,3W) & they are explained as follows,

The relay: A relay in an electrically operated switch that allows one circuit to switch a second circuit which can be completely separate from the first. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and charges the switch contacts. The coil current can be ON or OFF, so the relays have two switch positions and can be double throw (changeover) switches

The regulator: An automatic voltage regulator circuit is designed to be powered by a 12 AC supply. The designed circuit will fail to operate at a voltage below 12V. However, if the entire circuit draws up to 0.5A and voltage passing through it is about 12V, then the power dissipated by the regulator will be I(Vm-Vr)=0.512 8 2*w*,Where 8v is the regulated voltage. The regulator requires a heat sink to avoid it shutting down when operated for a long time.

The power supply: The 6v, 4.5AH battery used here is charged by means of the power supply of 6V using one 2200 micro(35V) capacitor, one IC 7808 regulator, one 12V 2000 ohms relay, twelve diodes, one kilo ohm resistor, two 100 ohms resistors, three light emitting diodes, 12-16v solar panel.

Battery: The battery stores electricity for use at night or for meeting loads during the day when the modules are not generating sufficient power to meet load requirements. To provide electricity over long periods, PV systems require deep cycle batteries. These batteries, usually lead-acid, are designed to gradually discharge and recharge 80% of their capacity hundreds of times. Automotive batteries are shallow-cycle batteries and should not be used in PV systems because they are designed to discharge only about 20% of their capacity. If drawn much below 20% capacity more than a few dozen times, the battery will be damaged and will no longer be able to take a charge. Deep-cycle batteries cost from about $65up to $3,000. The cost depends on the type, capacity (ampere-hours), the climatic conditions in which it will operate, how frequently it will receive maintenance, and the types of chemicals it uses to store and release electricity. A PV system may have to be sized to store a sufficient amount of power in the batteries to meet power demand during several days of cloudy weather. This is known as “days of autonomy.”

G. Direct-Current System Equipment Charge Controller

The charge controller regulates the flow of electricity from the PV modules to the battery and the load. The controller keeps the battery fully charged without overcharging it. When the load is drawing power, the controller allows charge to flow from the modules into the battery, the load, or both. When the controller senses that the battery is fully charged, it stops the flow of charge from the modules. Many controllers will also sense when loads have taken too much electricity from batteries and will stop the flow until sufficient charge is restored to the batteries. This last feature can greatly extend the battery’s lifetime. Controllers generally cost between $20 and $400, depending on the ampere capacity at which your PV system will operate and the monitoring features you want. When selecting a controller, make sure it has the features you need; cost should be a secondary consideration.

H. CIRCUIT DIAGRAM AND OPERATION OF A SOLAR LIGHTING SYSTEM

The dc voltage generated from the solar panel was used to charge the battery and control the relay. Capacitor C1 connected in parallel with a 12V relay coil remained charged in daytime until the relay was activated. Capacitor C1 was used to increase the response time of the relay, so switching occurred moments after the voltage across it fell below 12V. Capacitor C1 also filters the rectifier output where the battery is charged though AC power. During daytime, relay RL1 is energized provided on the solar panelside. Due to energization of relay RL1, and the positive terminal of the battery was connected to the out of regulator, IC7808 (a 3-terminal, 1A, 8V regulation) through diode D1 and normally-open (N/o) contacts of relay RL 1.

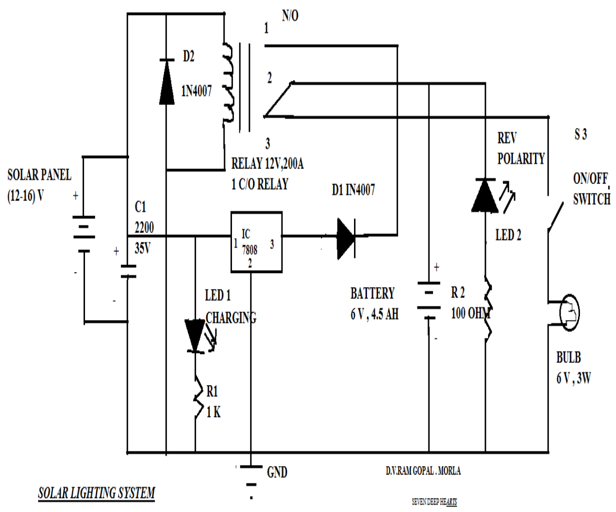


Fig : 7 solar lighting system

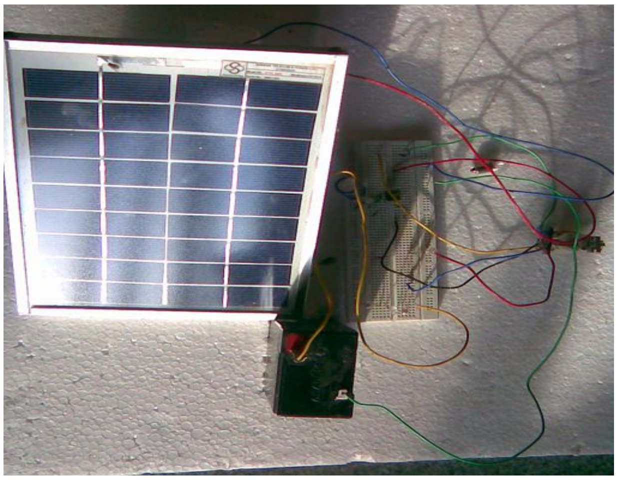


FIG: 8 HARDWEAR IMPLEMENTATION

Here, a 6V, 4.5AH maintenance-free, lead-acid rechargeable battery was used. It requires a constant voltage of approximately 7.3volts for its proper charging. Even though the output of the solar panel kept varying with the light intensity, IC 7808 (IC1) was used to give a constant output of 8V. Diode D1 caused a drop of O. 7V, so giving approximately 7.3V which was used to charge the battery. LED 1 indicates that the circuit was working and the battery was in the charging mode. At night, there will be no generation of electricity. The relay will not be energized and charging will not take place. The solar energy stored in the battery can then be used to light up the lamp. A 3w lamp glows continuous for about one hour if the battery was fully charged.

If the battery is connected in reverse polarity while charging, IC 7808 will get damaged. The circuit will indicate this damage by lighting up LED 2, which was connected in reverse with resistor R2. There is also a provision for estimating the approximate voltage in the battery. This has been done by connecting the IN4007 diodes (D2 through D11) in forward bias with the battery.

So, a transformer and full wave rectifier have been added to charge the battery.

TEST AND RESULT

When the constructed system was completed, it was necessary that some tests be conducted to confirm that the circuit is working. The solar panel was switched to solar panel side, supplied the required 12V dc needed to drive the charging circuit. The output of the regulator IC 7808 (a 3 terminal, 1A, 8V regulator) connected through diode, D1 was the required 7.3V dc (due to 0.7V drop across the diodes, D1) needed to charge the battery. LED 1 was 'ON' when the battery was connected in reverse polarity while charging and finally, the lamp glows when ON/OFF switch, S2, is switched 'ON' to confirm that the battery was delivering the required voltage to the output. Thus, the result obtained from the test shows that there was no short circuit in the system and that the designed circuit worked as it was meant to.

III. CONCLUSION

The process of constructing the solar lighting system just like that of any other electronic device is interesting but not quite easy. The difficulty is due to variations existing between theoretically calculated values and the actual component values used in the construction of the circuit. These variations posed problems in a situation where the researcher is a novice in the field of electronics. For instance, the practical output voltage of the solar lighting system was measured to be 5.78V on the multimeter while its theoretically calculated value from components was 6.0V. this error is mainly due to the tolerances of the components and the intensity of sunlight reaching the solar panel. The result obtained revealed that a 3W lamp glows continuously for about one hour when the battery is fully charged. Nowadays, utilisation of solar energy has a very wide spectrum and is a complex problem. The type of applied solar technology depends not only on the climate. Social and environmental considerations also determine the method of solar energy conversion and its use. The tradition of working with and using the environment in a benign way has become modern again. Modern technologies and innovative materials allow application of old proven energy ideas in a new very efficient way. Modern solar energy utilisation does not only mean applying solar devices and installations. It also entails treating energy and environment in a more global and sustainable way.

IV. FUTURE SCOPE

The future scope of this paper gives the various advantageous developments in electricity generation in the rural areas, where there is no chance of transmission of electrical energy i.e. The electrification of villages by converting DC voltage produced by photovoltaic in to AC voltage which is used for general utilization, and also we can connect the entire system to power grid with power electronic devices nowadays, utilisation of solar energy has a very wide spectrum and is a complex problem. The type of applied solar technology depends not only on the climate. Social and environmental considerations also determine the method of solar energy conversion and its use. The tradition of working with and using the environment in a benign way has become modern again. Modern technologies and innovative materials allow application of old proven energy ideas in a new very efficient way. Modern solar energy utilisation does not only mean applying solar devices and installations. It also entails treating energy and environment in a more global and sustainable way. Utilisation of solar energy treats the problem of energy supply and energy use in the same way, that is to say that energy conservation starts with extraction of energy (fuel) and finishes with its recuperation. Modern solar energy utilisation is nowadays strictly concerned with the building as a whole. Every building is affected by the solar radiation. Therefore buildings should be designed and constructed in a way that assures proper use of the energy existing in environment what means the planned efficient use of solar energy and secondary effects of solar radiation. Solar architecture is beneficial to the energy balance of buildings and indoor living conditions, it links energy conservation with the environment and it also allows the building to be "human friendly" as well as environment friendly.

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