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DESIGN, SIMULATION AND INSTALLATION OF COST-EFFICIENT AND RELIABLE OFF-GRID SOLAR SYSTEM

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Abstract: - One of the abundant sources of renewable energy available is solar energy, it can be harvested to generate electric power using Solar Panel. It has proven and have provided solutions to many sector that face the outage of electricity, and in this Off-Grid Solar System stands out to resolve the problem of outage of electricity. It is now feasible up-to certain extent to design the Off-Grid solar system providing electric supply to the appliances during the outage of electricity. The purpose of this paper is to make use of available solar energy to generate power and provide illumination and ventilation to the kitchen and dining hall at the canteen facility. The illumination and ventilation scheme will be fully operated on DC (direct current) supply, which will increase the efficiency of the solar system and decrease the pay-back period. The circuit for the installation of solar system is simulated using Proteus Circuit Simulator Software-8.

Keywords: - *Abundant, solar energy, Off-Grid, DC supply, Increase in efficiency, decrease in payback period*

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I INTRODUCTION

The sun provides the solar energy which helps to manage the continuity of life in our solar system. The energy received by the earth for one hour is enough energy which will help to meet the energy demand for whole year. Photo Voltaic cell is used to directly transform the solar energy into electric power that is used to power electrical machines and electrical appliances. Photo Voltaic systems can be used to harness the solar energy that is generated form sun, knowing the fact about depleting fossil fuel made PV system extremely important that more than 1.4 billion individuals access the power throughout the world. So, in order to enhance this power utilization to next level an off-grid installation is considered for rural areas. As the PV system generates DC itself, it can be made used to power the DC loads, while battery bank is used to store the energy and utilized when there is demand.

Solar energy are the radiation of the sun that reaches the earth which is later converted to electrical power through various strategies. There is a DC-DC converter used to convert the variable DC power that is produced from the photo voltaic system to fixed DC power for making it suitable to the DC appliances that are used in the canteen facility. Using DC electric power directly is challenging but much more cost-efficient than the AC system. For regions in rural places in India off-grid roof-top solar will be an ideal fit. Typically a rooftop will need approximately few kW of PV to be augmented to a stable grid, but in rural canteen facilities it would need few hundred power of watts only, for lighting and ventilating scheme. Furthermore there is also instability of the grid that increases the complexity of the system making them inefficient and also expensive. Hence a different solution is needed to address this problem, this paper presents one of the most cost-efficient and reliable solution towards this problem.

Our project is sponsored by Gram Pratishtan Yojana, who works for the welfare of people residing in the area. In our proposed system, we will be designing, simulating and installing an off-grid solar system in the canteen facility. The canteen facility was facing the problem of power outage and was in need of a cost-efficient and reliable solution for the problem of power outage. Our project work focuses on these thing which will help in resolving the issue and maintaining the continuous supply to the canteen during power outage. In our system we would be making use of power that is generated from the solar panel directly without converting it to alternating current power, making use of this direct current power source which will ensure us the continuous supply to the load. We will also be installing a battery backup in the system which will store the charge and provide the backup during power outage. Use of Maximum Power Point Tracking charge controller will ensure that the maximum power will be fetched from the solar panel with having an inbuilt algorithm in it. At the load side we will be using all the direct current load which comprises of bulb and fans, which will provide the best lighting and ventilating

II LITERATURE REVIEW

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"Solar-DC Microgrid for Indian Homes: Transforming Power Scenario,"

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Technology and Policy Analysis" IEEE First International conference on DC Microgrids, June, 2015 "Solar- DC Deployment Experience in Off-Grid and near Off- Grid Homes: Economics,

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From the literature reviewed it is evident that most researchers have, to date, focused primarily on the off-grid DC operation. Most of the work has been done on implementation of the dc power scheme in rural area and finding effective measures for the same. Various components and practices have been adopted from the above literature in the system we have proposed, simulated and developed. There is a wide scope for study on the implementation of different strategies for powering the small DC operated lightning and ventilating scheme in the various facilities of rural areas.

III METHODOLOGY

1. PLANNING AND SITE SURVEY

a. To optimize energy generation, solar modules must face the Sun at all times of the year.
b. In the northern hemisphere, this is accomplished by facing the modules south, while in the southern hemisphere, this is accomplished by facing the modules north.
c. This is commonly referred to as the solar system's 'tilt.'
d. In this project we have decided to install the solar panel on the roof of the canteen.
e. It was found that the roof of the canteen was an optimum place for the installation of solar panel, having a slope towards north direction making it more efficient to harvest the solar energy.

2. LOAD ASSESSMENT

a. Off-grid systems are sized to meet the power and energy demands of the connected appliances: systems are sized to satisfy the user's power and energy needs.
b. As a result, the system designer must perform a load assessment to determine the user's requirements.
c. Load assessment is making a list of the appliances that will be connected and recording the quantity of each type of appliance, its wattage, and the number of hours it will be used each day on a load assessment worksheet.
d. Total DC watts and watts per hour is calculated.
e. Equipment's watt rating can be obtained on its name plate directly or by multiplying the volt and ampere ratings, which are provided when the watts are not provided.
f. Watt-hours are calculated by multiplying watt by the amount of time used.
g. You should have identified DC loads by the end of the load assessment; you should also have estimated the contribution of DC appliances to the load demand, which is the total watt for each type of appliance; and finally, you should have estimated the energy demand for each type of appliance.

3. SIMULATION

a. For the simulation of the proposed system we have used Proteus Circuit Software which is developed by Lab Centre Electronics.
b. It is a software tool that is mostly used for schema creation. Simulating Electronics and Embedded Circuits, as well as creating PCB Layouts Proteus is quite lenient in circuit designing and it works on ideal conditions.
c. Proteus is also used for designing and testing codes for different Microcontrollers like Arduino, PIC Microcontroller 8051 and Microcontroller 8085.

4. BATTERY SIZE CALCULATION AND CHARGE CONTROLLER CALCULATION

a. Deep cycle batteries are the type of battery that are recommended for use in solar PV systems.
b. A deep cycle battery is designed to be discharged to a low energy level and quickly recharged, or to be cycle charged and discharged for years on end.
c. The battery should have adequate capacity to power the appliances at night and on overcast days.
d. To find out the size of battery, calculate as follows:
   i. Calculate the total Watt-hours consumed by appliances each day.
   ii. For battery loss, multiply the total Watt-hours per day consumed by 0.85.
   iii. For the depth of discharge, multiply the answer obtained in item by 0.5.
   iv. Subtract the answer in item from the nominal battery voltage.
   v. Multiply the result obtained in item by the number of days of autonomy (the number of days the system must operate when no power is produced)

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e. For calculating the charge controller rating
  i. Obtain the total watts output from solar PV Panel.
  ii. Calculate the battery Nominal Voltage.
  iii. Calculate the Current by dividing the Total watts output of PV cells by the nominal voltage of battery for calculating the current rating of Charge Controller.

5. DESIGN AND INSTALLATION

a. This is the last step of the project.
b. Designing of single line diagram is done using Etap software.
c. On-site Installation of Lamp, Fan and Solar System will be done in this phase.

IV EXPERIMENTAL RESULT

1. LOAD ASSESSMENT AND CALCULATION

The load consists of 6 DC operated LED bulbs for lighting scheme and 2 DC operated Fan for ventilating scheme. Which leads to 94 Watts of total connected load. Operated on 12 V supply. Total current of 7.38 A is required to power the load. Capacitors are connected across the solar panel to maintain the constant voltage on to the terminals.

TABLE 1:- LOAD CALCULATION

Name of Component	**Number of Component**	**Total**
9 W DC LED Light	6	54W
20 W DC Fan	2	40W
Total		94W

2. SIMULATION USING PROTEUS SOFTWARE

We have to build a lot of electronics or embedded circuits, and it's always a good idea to simulate these circuits first using simulation software such as Proteus or PSPice before putting them together on real hardware.

Proteus Design Suite (created by Lab Centre Electronics Ltd.) is a software tool set that is mostly used for schema creation. Simulating Electronics and Embedded Circuits, as well as creating PCB Layouts Proteus is quite lenient in circuit designing and it works on ideal conditions i.e. If you don't include pull-up resistors in your Proteus simulation, the result will not be garbage. Proteus is also used for PCB designing, we use Proteus ARES for that. Proteus is also used for designing and testing codes for different Microcontrollers like Arduino, PIC Microcontroller 8051 and Microcontroller 8085.

The below image shown, is the simulation done using Proteus Circuit Simulator Software.

Nominal Voltage =12V

Current to the load= 3.25 A

Total Wattage = 94W

The below simulation sets the proof that to power the Load of 94 W, four Solar panels are enough to provide the lighting and ventilating scheme at the canteen facility.

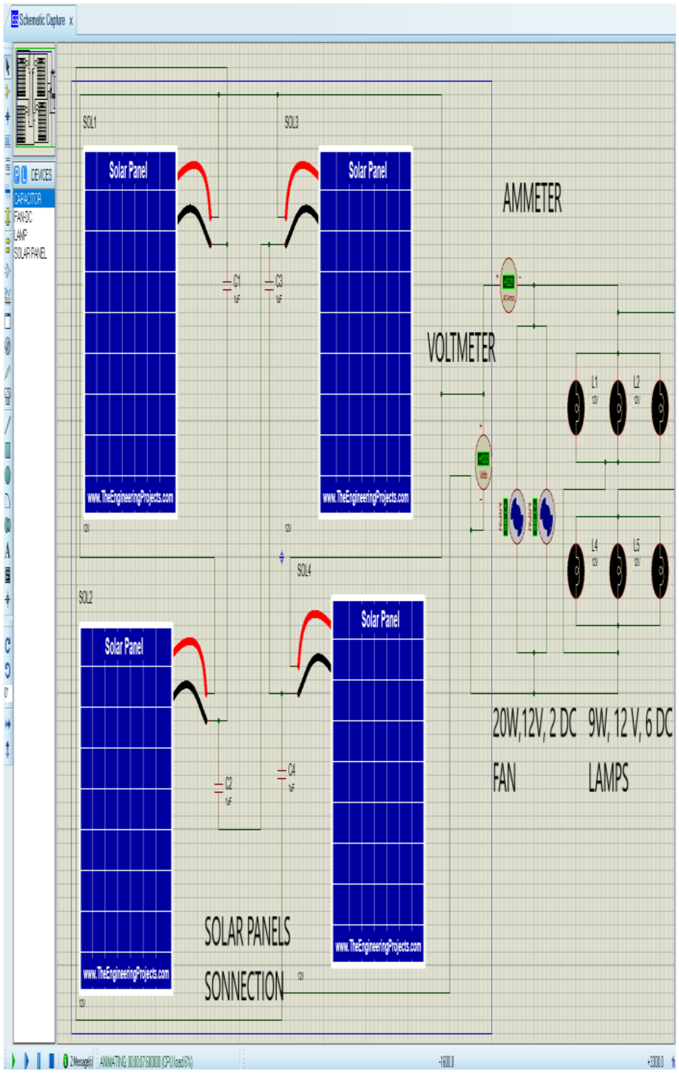

FIGURE 1:- SIMULATION ON PROTEUS SOFTWARE

In the simulation we have used 4 panels rated 12V, 50W to deliver the total load of 200 W, Ammeter and voltmeter are used for measurement of current and voltage respectively.

3. BATTERY SIZE CALCULATION AND CHARGE CONTROLLER CALCULATION

The first decision that one needs to make for battery sizing is how much hours the total power is required and how much backup is needed so that there is no discontinuity in the power supply. It is based on the number of hours that one expects his/her system to provide electric power without receiving any input charge from the off-grid solar PV array. Moreover, load usage pattern should be also considered. The battery capacity in (Ah) may be simply calculated using the equation below.

Total (Ah) = (Watt-hour of load*DOA)/ (efficiency of panel*DOD%*Battery Nominal Voltage)

Total (Ah) needed= (94*8*1)/ (0.85*0.5*12) =147.45Ah

TABLE 2:- BATTERY SIZE CALCULATION

Total Daily Watt-Hour Requirements (Wh)	94*8=752
DOA (Hours)	1
Maximum Depth of Discharge (DOD %)	50%
Nominal Battery Voltage (V)	12
Daily Amperes-Hours needed (Ah)	147.45

From the above calculation it is evident that, we will be requiring 2 batteries of 80 Ah each.

TABLE 3:-SELECTED BATTERY

Battery Manufacturer	Exide Battery IR 80
Battery Capacity (Ah)	80
Battery Type	Lead Acid
Nominal Battery Voltage (V)	12
Daily Amperes-Hours needed	752
Number of Batteries in Parallel	2
Total needed Batteries	2

The charge controller is to be selected in order to regulate the voltage and current coming from the PV panels going to the battery bank and to the load i.e. electrical appliances which will prevent battery overcharging and also increases the battery life. A charge controller decides the amount of current should be supplied to the battery bank for its overall performance.

The charge controller provides protection to the battery bank from overcharging as it determines the efficiency of the entire solar system as well as the operating life of the batteries that is why it is considered as very important component of the off-grid solar PV system.

To calculate the rating of Charge Controller

Obtain the Wattage output from the PV module and divide it by Battery Nominal Voltage

Total Wattage Output from PV Panel=200W

Battery Nominal Voltage=12V

Current Rating of Charge Controller=16.667A

From the above calculation done, it is evident that the current rating of charge controller should be 20A, 12V.

TABLE 4:- CHARGE CONTROLLER SPECIFICATION

Charge Controller Manufacturer	SCC 1800
Nominal Voltage (V)	12V
Maximum Continuous Power (W)	200
Input Voltage Range (V)	12
Charge Controller Type	MPPT
Battery Capacity	20A
Battery Voltage Range(V)	17-25 V for 12V
Charge Controller Efficiency	93%

4. DESIGN AND INSTALLATION

The above line diagram shows the detail design of installation of Solar Panel. Four terminals from four solar panel i.e. positive and negative terminals from the solar panel is taken out to the shorting links, where all the positive and negative terminals are shorted together.

Further the connection are given to 12 V input to the charge controller, and total three output are further connected to battery and load. The charge controller helps to control the flow of charge to load and to the battery.

If there is demand that needs to be fulfilled presently all the power which is generated will be transferred to load directly, and whenever there in no demand for load, the charge controller charges the battery up to its full capacity.

A single-line diagram (SLD), often known as a one-line diagram in power engineering, is a simplified notation for expressing a three-phase power system.

The one-line diagram is most commonly used in power flow investigations. Standardized schematic symbols are used to depict electrical elements such as circuit breakers, transformers, capacitors, bus bars, and conductors. Only one conductor is displayed, rather than each of the three phases being represented by a distinct line or terminal.

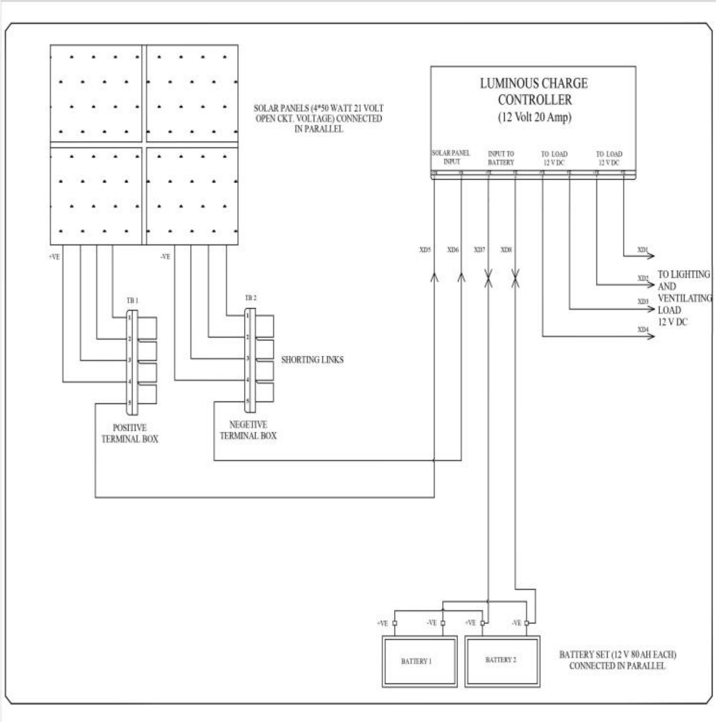

Figure 2:- DESIGN IN PROPOSED SYSTEM

FIGURE 4:- INSTALLATION OF CHARGE CONTROLLER

This is MPPT charge controller, Used to control the charge that is produced from the solar panel to the battery and the Load.

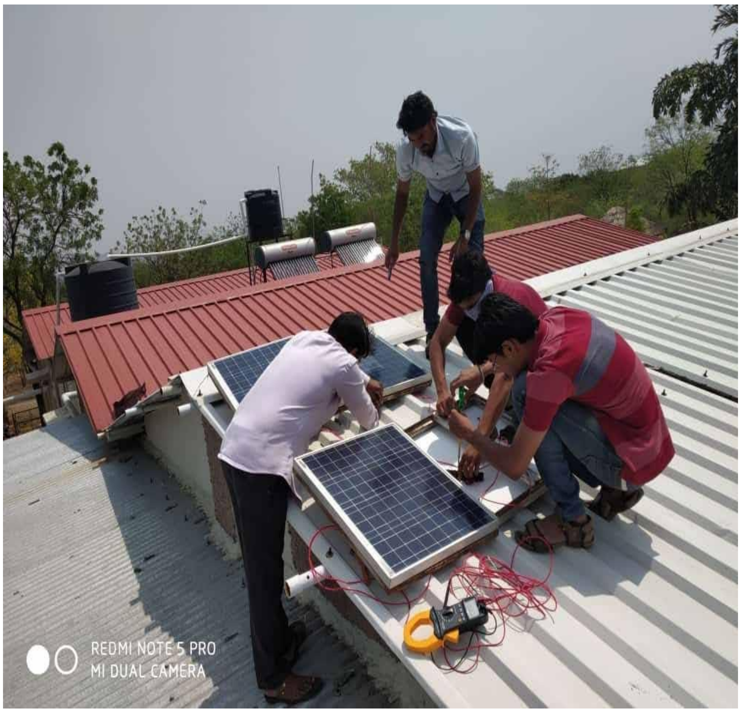

FIGURE 3:- INSTALLATION OF SOLAR PANEL

The above image, installation of solar panel is been done by the group members, at the roof top of canteen facility, Sasvad, Pune. The Solar Panel were fabricated on steel casing so as to fix it firmly on the roof. After the fixing of the Solar Panel on the roof, all the terminals were brought in the terminal box for further connection to charge controller.

FIGURE 5:- INSTALLATION OF BATTERY BACKUP

FIGURE 6:- INSTALLATION OF DC LOAD

The Above images are evident of Successful completion of Designing, Simulating and Installation of Proposed System in the canteen facility.

V BLOCK DIAGRAM

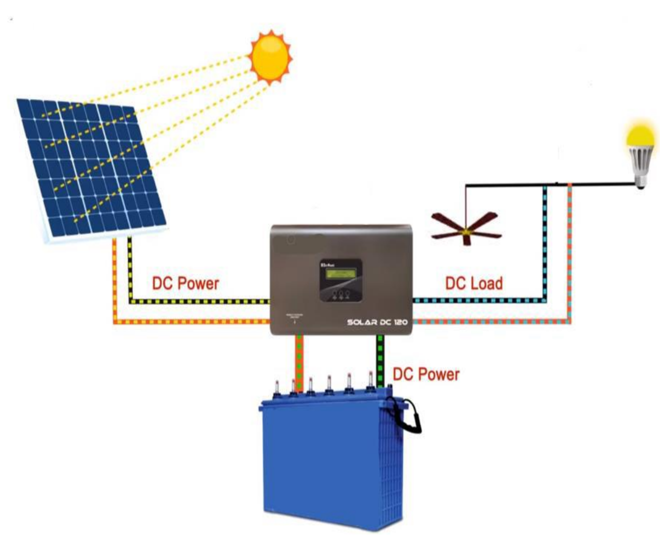

FIGURE 7:- PICTORIAL REPRESENTATION OF PROPOSED SYSTEM

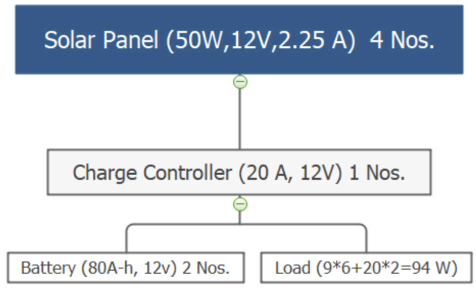

FIGURE 8:- DETAILED BLOCK DIAGRAM

VI ADVANTAGES OF DC SYSTEM OVER AC SYSTEM

1. The energy efficiency of DC power is much higher than that of AC power.
   a. DC motors and appliances are more efficient and have better power-to-size ratios.
   b. LED lighting (DC-based) is up to 75% more efficient than incandescent lighting.
   c. Recent advancements in DC converter technology have resulted in increased efficiency, allowing for better electricity distribution over extended distances.
2. Renewable energy sources such as sun and wind are intrinsically compatible with DC. These renewable sources create electricity on demand (when the sun shines or the wind blows), necessitating the need of storage (batteries) in some applications to provide a consistent supply, as well as a power conversion interface to the grid. Because solar PV and batteries are both DC energy sources, DC has a more naturally suitable interface.
3. Integration of energy storage is improved. To maximise the capacity utilisation of renewable energy sources, energy storage is required. The majority of energy storage solutions are DC-based (mostly in the form of batteries), allowing for increased integration efficiency and lower running costs.
4. DC power is used to power electronic equipment. When AC electricity is converted to DC power, it loses between 5% and 20% of its power. The growing use of electronic devices necessitates the use of DC electricity. Eliminating these AC to DC conversion losses will become even more critical, driving a shift to DC power and necessitating advancements in new power conversion technologies.
5. Micro-grids that are both DC and hybrid AC/DC are being developed. Micro-grid applications can successfully combine local power generation with the

main power grid to supply end-use loads while also increasing dependability.

6. DC energy is already in use since the national (AC) power infrastructure does not reach the "bottom of the pyramid," such as rural India and China. Four Indian states are experimenting with providing DC electricity to houses, as part of a 2014 programme conceived and led by a Business of Humanity® project partner and funded by the Indian government.
7. New technologies enable DC power generation that is clean, localised, and distributed. For green, local power generation, solar, wind, second-generation clean biomass, and new, low-cost natural gas fuel cell designs are perfect. DC infrastructure will aid in better integrating such resources into the grid, as well as improving their overall economic and environmental value proposition.
8. Consider conventional solar system which consist of inverter which is used to convert the DC power to AC power. Let us consider the efficiency of solar panel 70% and that of inverter 80% and the units generated daily be 100. Therefore, 56 units are available for the consumption by the calculation below: 100*(efficiency of panel)*(efficiency of inverter) = 100*0.7*0.8=56 units. Now in our proposed system due to absence of Inverter the output available for the use is increased. Hence increasing the number of units generated daily. 100*(efficiency of panel) =100*0.7=70. So, it is theoretically proven that there is 14 units are generated more, increasing the reliability of the system and decreasing the pay-back period as more units are generated
9. Direct Current (DC) electric power is a new innovation field with the potential to boost economic growth, inspire innovation, expand research and development opportunities, create jobs, and enhance environmental sustainability all at the same time. So much so that, in many applications, DC power is beginning to supplant AC as the global standard for electricity delivery infrastructure.

VI CONCLUSION

Literature review of off-grid solar installation and its effectiveness is conducted. Designed and simulation of the proposed system can fulfil the requirement of:

- Continuous energy supply
- Usage of clean energy
- Reliable and cost-efficient energy
- Meeting the required energy needs.

The technology and applications offer the promise of enhanced energy efficiency, improved power quality and reliability, and inherent alignment with renewable and clean energy development. Hence the provided system solution is capable of fulfilling all the demand.

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