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STANDALONE SOLAR POWER SYSTEM

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Abstract: A standalone solar power system is a self-sufficient renewable energy solution that harnesses solar energy to generate electricity, operating independently of the grid. This system integrates solar panels, a charge controller, a battery bank, and an inverter, synergistically working together to provide a reliable and sustainable source of energy. During the day, solar panels convert sunlight into DC power, which is then regulated by the charge controller and stored in the battery bank. The stored energy is subsequently converted into AC power by the inverter, supplying electricity to homes, businesses, or remote areas, thereby mitigating reliance on fossil fuels and promoting energy autonomy.

1. INTRODUCTION

Over the years there has been an increase in the earth's population which is directly proportional to the energy used as well. All the possible gadgets and equipment need some or the other kind of energy to function. With depleting fossil fuel reserves it becomes necessary to identify viable renewable energy resources that can decrease the dependency on fossil fuels.

Solar energy is the most abundant form of energy available to us. It is approximated that 10000 TW worth of solar energy is incident on earth's surface in a day (Bosshard, 2006). According to a report, the world energy consumption in 2015 was 17.4 TW altogether (Seger. 2016). There has been a minimal increase in the energy consumption every year, approximately 1-1.5% annual growth. The world's total energy consumption is expected to grow by 56% by the year 2040 (U.S Energy Information Administration, 2013). Comparing current consumption, projected growth in two decades, and the amount of solar radiation received in an hour the potential solar energy usage is good. Despite this energy potential available to us the current utilization of solar energy is less than 5% globally. There are countries that are taking initiatives to switch from using fossil fuels to solar applications. These countries form a pool called the G-20 countries which have taken the global leadership to adopt renewable resources of energy. Germany is one of the G20 countries that has switched its energy needs to approximately 38% to solar and aims to go completely stop its dependency on nuclear and replace it with solar by the year 2050 (Richardson, 2017).

Apart from harvesting the resource and decreasing the dependency on fossil fuel because they are limited, burning of fossil fuels for energy has an adverse effect on the environment. It releases CO_2 into the atmosphere which is responsible for the greenhouse effect. Further, it also causes the ozone layer to be depleted. These mentioned phenomena can result in acid rain, air pollution.

2. LITERATURE SURVEY

Being off grid means the system works independently and the consumer is not connected to any utility's power system. An off-grid PV system refers to an installation that is not connected to the electricity grid. This means that all the energy produced is stored and used on site.

Census 2011 throws light on the darkness across India. Of the 246 million households.67 per cent get electricity from the grid, while 31 per cent have no option but to use kerosene lamps. In 2001, government initiated a nationwide programme to provide off-grid, clean alternatives, mostly solar, in remote areas. Solar has now lit up more than a million homes-a 100 per cent increase since 2001-though the programme has its share of loopholes. This situation presents both challenges and opportunities. The answer to the country's energy poverty could lie in decentralized solar. **Joel Kumar, Ankur Paliwal** and **Sayantan Bera** from Down to earth organisation who assessed the programme's performance, says the case for off-grid solar is clear and urgent and carries out a reality check in Uttarakhand, Bihar and Uttar Pradesh, and in Assam where there is a need of electricity to the households.

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According to **IFC's lighting India program**, nearly 400 million people in India do not use grid electricity as their primary source of lighting. 43 percent of rural households still use kerosene as a primary source of fuel for lighting. A variety of modern off-grid electric lighting technologies have emerged globally over the last decade. These technologies are popular because they are cost-effective, robust, and use small amounts of energy. The emergence of a large market for these technologies has led to efforts to develop the market for them.

As per the research conducted by **Times of India**, barely one in every ten households in rural Bihar and two-thirds of houses in the state's urban areas use electricity to light their houses. Just over half of rural India uses electricity as its main source of lighting, an increase of 12% over 2001. If that seems heartening, the data also shows that 43% of rural households still use kerosene to light their houses, implying that the kerosene subsidy may not be as pointless as some would suggest. In urban India, the spread of electricity is more complete, with 93% ofhouseholds using electricity as their primary source of light.

3. OBJECTIVE OF THE PROJECT

- A small attempt is made to electrify EEE classrooms using solar energy and contribute a minute way (micro level) to the energy crisis solution.
- Normally, the classrooms of EEE dept. are powered with grid supply. In order to reduce the dependency on fossil fuels, the electric load of the classrooms is powered by using off grid PV solar system.
- An off-grid PV system will generate enough power all year-round, with enough battery capacity to meet the power requirement of classrooms, even in the heart of winter, when the days are short and there is a lot less sunlight.
- Off-grid solar systems will produce extra electricity during the day. This extra electricity is stored in the batteries. The energy stored in the batteries can then be accessed at night or during cloudy days when the system is not producing energy.

4. METHODOLOGY

4.1. Proposal to use Standalone PV System for EEE Classroom's lighting/fans:

Department of Electrical and Electronics Engineering of RYMEC has always been a leader in embracing new technologies that promotes betterment of the environment and its students. The classrooms of EEE dept. teaches hundreds of the students on a day-to-day basis. Currently, all the classrooms in the department are connected with the existing electrical grid. Hence, taking an initiative to contribute to the department (socio-responsibility) and create awareness among the students regarding the need for alternate energy source the following PV system has been designed.

4.2. BLOCK DIAGRAM

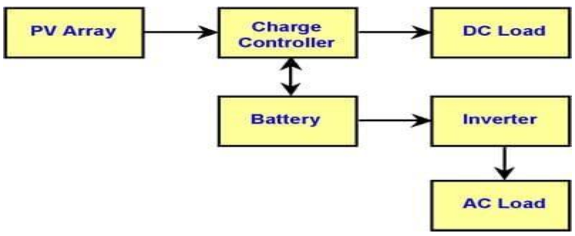

Figure: Block diagram of battery solar PV system

4.3. Load calculations:

In LH1 Classroom:

Total number of tube lights = 4 Total number of fans = 5
Power consumption of each tube light = 20 W Power consumption of each fan = 70 W
For four tube lights = 20*4=80 W For five fans= 70*5=350 W
Total load in LH1 Classroom = 80+350=430 W

In LH2 Classroom:

Total number of tube lights = 4 Total number of fans = 5
Power consumption of each tube light=20w Power consumption of each fan=70w
For four tube lights=20*4=80w For five =70* 5 = 350W
Total load in LH2 Classroom = 80 + 350 = 430W
According to the above load calculations, the components are considered as below:
In this direction an "**OFF GRID PV SOLAR SYSTEM**" of 900 W is installed using the following **COMPONENTS**
The components used are listed below:

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[1] Solar panel
[2] Battery
[3] Inverter
[4] Charge controller

The ratings of the above components are given below:

4.4. Solar Panels Sizing

As per the load calculations for LH3 and LH4 classrooms, Wattage details of solar panels used is described below:
Total Number of solar panels used = 2 solar panels with rating of 36V ,450W = 2
Total Wattage of solar panels used 450+450=900 W

4.5. Battery Sizing

Total number of batteries used = 2 Specifications of a battery:
Nominal Voltage: 12V Max. charge Current: 25A Capacity: 100Ah
Type: C20, tall tubular, Lead-Acid Battery

4.6. Invertor Sizing

As per the solar panels used, the Invertor with following specifications is used:
Input voltage: 100V-300V
Output Voltage (Main mode): 100V~300V Output Voltage (UPS mode): 210V±10%

Current: 50A
Output Waveform: Pure Sinewave

4.7. CONNECTION DIAGRAM

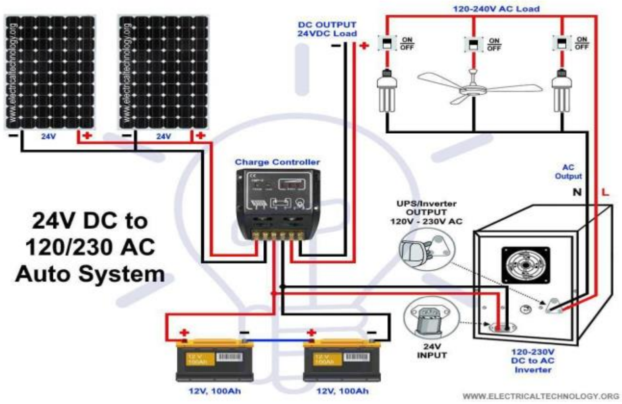

Figure: Connection diagram of battery based on sloar PV system

The above **Connection diagram** shows **how to wire a four 36V Solar Panels in series-parallel connection to a pair of 12V, 100Ah battery** with an automatic inverter system. Note that the number of solar panels and batteries depends on the system's design and load requirements i.e., multiple batteries and solar panels can be connected in series, parallel or series parallel connection to increase the Ah rating and storage capacity.

To do this wiring, the two sets (pairs) of PV panels are made and connected them in series. This way, we will have two pairs of solar panels connected in series. Now, the two sets of series connected solar panels are connected in parallel as shown in the above fig. Now, we are having four 36V, 10A solar panels connected in series-parallel configuration.

As a next step, you can connect these solar panels to a charge controller. A basic DC load (12 or 24V) can be directly powered up by connecting it to the charge controller.

The AC load can be powered up in two ways. Firstly, it can be directly powered up by solar power during the normal sunshine (day). Secondly, the AC load (120V/230V AC) can be powered up by the stored power in the batteries using an inverter during shading (or night). The
number of solar panels and batteries depends on the load requirements where solar panels keep charging the batteries as well as power up the AC load

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Solar panel Photovoltaic Cells

In the 18th century, Swiss physicists assembled a warm trap, which was a small-scale greenhouse. He developed a hot box, by a glass box in another larger glass box, a total of up to five boxes. When they are proposed to coordinate the sun illumination, the temperature in the deepest box can be raised to 108 degrees Celsius; warm enough to soak water and cook food. These crates can be considered the world's first solar collection. In the late 1950, some organizations and research facilities began to create a silicon based solar cell that considers the goal of controlling Earth-orbiting satellites. These include RCA, Hoffman Electronics, and in addition, the U.S. Army Alert Corps (Desideri, Zapparelli, & Garroni, 2013).

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of photons that are incident on it to electrical energy, which is a natural and synthetic marvel. A separate cell unit can be connected to a frame module, also known as a solar panel. Different solar cells in a unified set, all arranged in the plane represents a solar photovoltaic board or module. PV modules usually have a glass in front of the panel, allowing light to pass through, while ensuring that the semiconductor plate is protected inside the case.

Solar cells are usually associated, and arranged in series or parallel module, depending upon the requirement of the customer. The parallel interface unit gets higher current; however. the problem, for example, that shadow effects can turn off weaker (less bright) parallel strings (different permutations of cells) can cause great unpleasant effects and may cause damage because of their enlightened complicity and the reversal of dark cell tendencies. A series of stacked units are usually autonomous and not parallel, but starting from 2014, each module provides a singular power box on a regular basis and connects in parallel.

Working Principle of Solar Panels

There is abundance of solar energy available to be harvested. A brief discussion of what PV cells is done. It is necessary to understand how these cells generate electricity to design systems that can be in tandem with these basic concepts. The following discussion will explain how the cells generate electricity.

Principle: Sun is a powerhouse of energy, and this energy moves around in the form of electromagnetic radiations. These radiations are of several types such as light, radio waves, etc. depending upon the wavelength of the radiations emitted. A very less percentage of sun's radiations reach the earth's atmosphere in the form of visible light. Solar cells use this visible light to make electrons. Different wavelength of light is used by different solar cells.

Solar cells are made up of semiconductor materials, such as silicon, which is used to produce electricity. The electricity is conducted as a stream of tiny particles called electrons and the stream is called electric current. Two main types of electric currents are DC (direct current) in which the flow of current is in the same direction while in AC (Alternating current) it may reverse the direction of current. A typical solar cell has two layers of silicon, which is n-type at the top and p-type at the bottom.

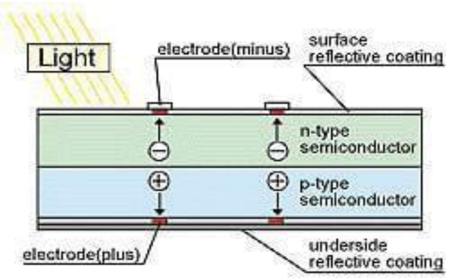

Figure working of solar cell

When sunlight strikes the solar cell, the electrons are absorbed by silicon, they flow between n and p-layers to produce electric current and the current leaves the cell through the metal contact. The electricity generated is of AC type.

5.2. Battery

An electrochemical power source or battery is a device which enables the energy liberated in a chemical reaction to be converted directly into electricity. Batteries fulfil two main functions; they are portable sources of electric power and they are used to store the electrical energy. The primary cell or battery is a system whose useful life is ended once its reactants have been consumed by the discharge process. But the secondary battery is capable of being charged or recharged when its reactants have been used up. The spontaneous electrochemical reaction can be reversed by passing current through the cell in the opposite direction to that of cell discharge. It means the secondary battery might be considered as an electrochemical energy storage unit. For our application we select the lithium-ion battery because it came with less maintenance cost and more power efficient. Here we are using 12V 100Ah battery. We used two 12V 100Ah battery in series connection.

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LEAD-ACID

Li-ion batteries, as one of the most advanced rechargeable batteries, are attracting much attention in the past few decades. They are currently the dominant mobile power sources for portable electronic devices, exclusively used in cell phones and laptop computers. Li-ion batteries are considered the powerhouse for the personal digital electronic revolution starting from about two decades ago, roughly at the same time when Li-ion batteries were commercialized. As one may has already noticed from his her daily life, the increasing functionality of mobile electronics always demand for better Li-ion batteries. For example, to charge the cell phone with increasing functionalities less frequently as the current phone will improve quality of one's life. Another important expanding market for Li-ion batteries is electric and hybrid vehicles, which require next-generation Li-ion batteries with not only high power, high capacity, high charging rate, long life, but also dramatically improved safety performance and low cost.

The demand for Li-ion batteries increases rapidly, especially with the demand from electric powered vehicles (Fig. 1). It is expected that nearly 100 GW hours of Li-ion batteries are required to meet the needs from consumer use and electric-powered vehicles with the later takes about 50% of Lead acid battery sale by 2018. Furthermore, Li-ion batteries will also be employed to buffer the intermittent and fluctuating green energy supply from renewable resources, such as Charge controller and wind, to smooth the difference between energy supply and demand. For example, extra Charge controller energy generated during the day time can be stored in Li-ion batteries that will supply energy at night when sun light is not available.

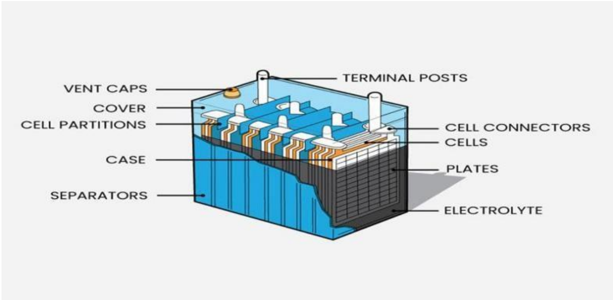

Figure: cross sectional diagram of Lead Acid battery

Lead Acid Batteries

A Lead acid battery is constructed by connected basic Li-ion cells in parallel (to increase current) in series (to increase voltage) or combined configurations. Multiple battery cells can be integrated into a module. Multiple modules can be intergrade into a battery pack. For example, the 85-kWh battery pack in a typical Tesla car contains 7104 cells. Typically, a basic Li-ion cell consists of a cathode (positive electrode) and an anode (negative electrode) which are contacted by an electrolyte containing lithium ions. The electrodes are isolated from each other by a separator, typically microporous polymer membrane, which allows the exchange of lithium ions between the two electrodes but not electrons. In addition to liquid electrolyte. polymer, gel, and ceramic electrolyte have also been explored for applications in Li-ion batteries. Figure 2 illustrates the basic operating principle of a typical Lead acid battery cell. The basic design of Li-ion cells today is still the same as those cells Sony commercialized two decades age, although various kinds of electrode materials, electrolyte, and separators have been explored.

The commercial cells are typically assembled in discharged state. The discharged cathode materials (e.g., LiCoO2, LiFePO4) and anode materials (e.g., carbon) are stable in atmosphere and can be easily handled in industrial practices. Li-ion batteries by using discharged electrode materials in full cells for the first time.

During charging process, the two electrodes are connected externally to an external electrical supply. The electrons are forced to be released at the cathode and move externally to the anode. Simultaneously the lithium ions move in the same direction, but internally, from cathode to anode via the electrolyte. In this way the External energy is electrochemically stored in the battery in the form of chemical energy in the anode and cathode materials with different chemical potentials. The opposite occurs during discharging process: electrons move from anode to the cathode through the external load to do the work and Li ions move from anode to the cathode in the electrolyte. This is also known as "shuttle chair" mechanism, where the Li ions shuttle between the anode and cathodes during charge and discharge cycles.

Electrochemical reactions at the two electrodes released the stored chemical energy. The total Gibbs free energy change due to the electrochemical reactions on the two electrodes is determined by the electrode materials selected. Given the overall electrochemical reaction and charges transferred, one can estimate the theoretical cell voltage (E-G/nF). The performance of Li-ion batteries can be evaluated by a number of parameters, such as specific energy, volumetric energy, specific capacity, cyclability, safety, abuse tolerance, and the

dis/charging rate. Specific energy (Wh/kg) measures the amount of energy that can be stored and released per unit

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mass of the battery. It can be obtained by multiplying the specific capacity(Ah/kg) with operating battery voltage (V). Specific capacity measures the amount of charge that can be reversibly stored per unit mass. It is closely related to number of electrons released from electrochemical reactions and the atomic weight of the host.

5.3. Inverter

Inverter deals with following main tasks of energy: (ALTE store, n.d.)

- Convert DC from PV module to AC
- Ensure that the cycle of alternating current cycles is 60 cycles
- Reduce voltage variations
- Ensure that the condition of the AC waveform is suitable for the application

Most system-connected inverters can be introduced externally, and most of the off-grid inverters are not weather-resistant. There are basically two types of grid intelligent Inverters: Those designed for batteries and those designed for systems without battery-connected inverter systems and give excellent void-quality strength. For matrix associations, the inverter should have a "useful-interactive" typeface, which is printed specifically for the publication name.

Grid-connected systems measure the power of extracting PV clusters rather than a bunch of prerequisite buildings. It asserts that what each power supply needs are what the matrix-related PV system can give naturally is drawn from the net.

Invertors used for solar PV systems are usually based upon the total wattage of the solar panels, as the invertor will be continuously converting the power generated. The second consideration one must investigate, is the voltage level of the system. The Invertor used in this project is of 24V 1850 VA.

Square wave

This is one of the simplest waveforms an inverter design can produce and is best suited to low-sensitivity applications such as lighting and heating. Square wave output can produce "humming" when connected to audio equipment and is generally unsuitable for sensitive electronics.

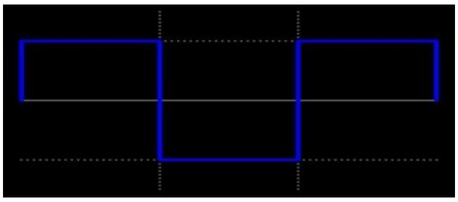

Figure. Square wave

inverter is often regulated to be the same as the grid line voltage, typically 120 or 240 VAC at the distribution level, even when there are changes in the load that the inverter is driving. This allows the inverter to power numerous devices designed for standard line power. Some inverters also allow selectable or continuously variable output voltages.

RESULTS

Sine wave

➤ Aiming to the exact methodology, project

A power inverter device that produces a multiple step sinusoidal AC waveform is referred to as a sine wave inverter. To distinguish the inverters more clearly with outputs of much less distortion than the modified sine wave (three-step) inverter designs, the manufacturers often use the phrase pure sine wave inverter. Almost all consumer grade inverters that are sold as a "pure sine wave inverter" do not produce a smooth sine wave output at all, just a less choppy output than the square wave (two-step) and modified sine wave (three-step) inverters. However, this is not critical for most electronics as they deal with the output quite well.

Figure. Sine wave

pure sine wave

Pure sine wave inverters are up to 2 times more expensive than a modified sine wave Werter. A pure sine wave inverter

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will transform direct current (DC) into alternating current (AC) which can then be used to deliver high-quality electrical current (similar to utility standards, voltage: 230V, frequency: 50/60hz) to all sorts of home appliances. In addition, pure sine wave inverters are also transformers. They raise the input DC voltage, for example, 12V, to a much higher AC voltage, for example, 230V.

Output voltage

The AC output voltage of a power will depict almost like in the block diagram

➤ Off grid PV solar system will be fully functional along with its facilities as desired.

➤ Major aim of the project will be electrifying the classrooms of EEE dept, using solar energy by deploying off grid PV solar system.

➤ Automatically the project will result in promoting the usage of renewable energy

➤ sources effectively.The project can be implemented to help thousands of remote households in providing the stand-alone power where there is no nearby connection to the grid.

➤It can be implemented in promoting to take over from polluting way of power generation to a better and convenient conventional

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