CHAPTER ONE

1.0 INTRODUCTION TO SOLAR SYSTEM

Solar energy is a clean and in expensive renewable power source that we can harness nearly everywhere in the world. Any point where sunlight hits the surface of the earth is a potential location to generate solar power. Renewable energy technologies generate electricity from infinite resources and since solar energy comes from the sun. Solar energy systems are among the most promising renewable energy technologies, converting sunlight into electricity or heat through various materials and mechanisms. Their global adoption has surged in recent years due to the urgent need to transition away from fossil fuels and mitigate climate change. This review explores the key components of solar systems, materials used in their construction, technological advancements, and associated challenges it represents a limitless source of power (Doe, 2024).

1.1 SOLAR POWER

It refers to converting sunlight into electricity using photovoltaic (PV) cells or through the concentration of solar energy to generate electricity. Solar power is a renewable and sustainable energy source that harnesses the vast energy emitted by the sun. The sun's energy is abundantly available worldwide, making solar power an accessible and inexhaustible resource.

Electricity is the principal force that powers modern society. It lights buildings and streets. Runs computers and telephones, drives trains and subways and operates all variety of motors and machines (Zubairu et.al,2015).

It is important to recognize that electricity is not mined or harvested, it must be manufactured. Since it is not easily stored in quantity, it must be manufactured at the time of demand. Electricity is a form of energy, but not an energy source. Different generating plants harness different energy sources to make electrical power. Some of these sources are thermal plants. Kinetic plants, geothermal power and solar photovoltaic.

Since, the demand for electricity in this area of the world is alarming, there is the need for the production or generation of constant electricity, due to the epileptic condition of electricity in the country. This gives rise to the design and construction of a 5KVA hybrid inverter. A hybrid inverter, otherwise known as a hybrid grid-tied inverter or a battery-based inverter, combines two separate components-a solar inverter and a battery inverter-into a single piece of equipment

An inverter is a critical component of any solar energy system: you need it to convert the direct current (DC) electricity generated by your solar panels into alternating current (AC) electricity for your home's appliances. (Smith, 2024).

However, when you pair your solar panel system with a hybrid inverter. a separate battery inverter isn't necessary: it can function as both an inverter for electricity from solar panels and a solar battery.

A solar hybrid inverter's main job is to convert DC power generated from the array into usable AC power. Hybrid inverters go a step further and work with batteries to store excess power as well. This type of system solves issues renewable energy variability and unreliable grid structures. Hybrid inverters are commonly used in the developing world, but they are starting to make their way into daily use in certain areas of the U.S and some part of Africa due to their ability to stabilize energy availability. Hybrid inverters work with batteries to store power which is the aim of this project. Figure 1.1 is a depiction of the basics of solar power generation (Phansopkar, 2020).

1.1.2 BACKGROUND OF PROJECT

Solar technologies are characterized as either passive or active depending on the way the energy captured converts & distributed. Active solar techniques use photovoltaic panel which was used. Electrical power supply from renewable sources is advantageous as the increasing electrical demand is a scientific contribution to the peak demand on the grid. As individuals and companies generate their power through renewable energy, the stress on the grid is reduced. The solar resource is so massive that it dwarfs every other resource on the planet. The DC electricity from the panels passes through DC distribution network to an inverter, which converts the DC electricity into AC for Single phase operation by using state of the art technology with MOSFET methodology and fed through A/C distribution system linked to the consumer load.

Most of the electrical appliances operate with an AC power supply of 220V and at 50Hz frequency. But in case of power failure, AC power cannot be stored due to repetitive change in polarity of electric current. The batteries can be charged through a solar panel using a charge controller and AC power supply from the utility which makes it hybrid powered.

An inverter is designed and obtainable in order to provide an AC output from a DC source. The AC could be at any required voltage and frequency with the use of appropriate transformers, switching and control circuits. It maintains a continuous supply of electric power to connected equipment or load by supplying power from a separate source, like battery, when utility power is not available. It is inserted between the source of power and the load is protecting. (Seger, B.2016)

1.1.3 PROJECT AND THE SITUATION OF ENERGY IN NIGERIA

Nigeria, the most populous country in Africa, is facing a serious energy crisis despite its vast natural resources. The national electricity grid is outdated and unreliable, supplying less than 5,000 megawatts of power to over 220 million people. This is far below the estimated demand, which exceeds 30,000 megawatts. As a result, millions of Nigerians either lack access to electricity entirely or experience frequent power outages, especially in rural areas.

To cope with the energy shortfall, many households and businesses rely on petrol or diesel generators. While these provide temporary relief, they are expensive to operate and contribute significantly to environmental pollution and carbon emissions. In this context, renewable energy—especially solar power—has become an essential alternative for providing clean, reliable, and affordable electricity.

Nigeria receives high levels of solar radiation, between 4.0 and 7.0 kilowatt-hours per square meter per day, and enjoys over 2,000 hours of sunshine each year. This gives the country enormous potential for solar energy development. Unlike large power plants that require connection to the national grid, solar energy systems can be installed directly in homes, schools, hospitals, and businesses—even in the most remote villages.

Promoting solar energy is also critical for achieving national and international development goals. It aligns with Nigeria's commitments to reducing greenhouse gas emissions under the Paris Agreement and supports the United Nations Sustainable Development Goal 7: access to affordable, reliable, sustainable, and modern energy for all.

In summary, solar energy offers Nigeria a sustainable way to expand electricity access, reduce dependence on fossil fuels, create jobs, and improve living standards. It is not just an option, but a necessity for the country's future development. (Franklin, E.2017)

1.2. HISTORY OF SOLAR ENERGY

Solar energy has long supported humanity, with at least two forms, passive solar energy and biomass fuel use. Thus solar energy has been our partner throughout the progress of mankind. The growth of agriculture in the sunny "cradle of civilization" played a critical role in the development of civilization. People have used the sun for drying crops, bricks, etc. since prehistoric times. The first known crop drying installation has been found in France and dates from around 8000 BC. There is evidence from around the world of dryer development in many civilizations and this relatively simple solar technology continues to change lives and economies for the better, even today, in remote locations all over the planet.

The US Department of Energy timeline provides a series of important historical milestones for solar energy. Butti and Perlin describe that his- tory, beginning with ancient classical Greek and Roman over-consumption of biomass and including the passive solar dwelling and city design. In the case of the Roman Empire, the architect Vitruvius recommended different passive solar building designs for different latitudes, outlining principles that are still applied today. Solar access rights for buildings were included in the Justinian Code of law in the sixth century AD. Both ancient Greek and Chinese cultures developed concentrating solar reflectors to generate high temperature ignition for religious, civil and military purposes. "Burning mirrors" have since then been designed and used by many cultures through the centuries. Glazed heat traps in buildings were developed by the Romans and the idea was revived much later in Europe as the conservatory or greenhouse for horticulture of plants outside their natural ranges or out of season.

The commercial availability of the Climax Solar Water Heater at the end of the 19th century in the USA initiated the mass availability of afford- able solar domestic heating of water that has continued to drive the development of flat plate and evacuated tube heaters ever since. The harnessing of the sun for mechanical power began at least as early as the 1st century AD with solar water siphons built in Alexandria. The invention of the first solar steam engine has been attributed to Augustin Mooched in France in 1866. He went on to develop solar cooking ovens and solar thermoelectric generators. The early 20th century saw an explosion of applications for solar engines for water pumping and other remote energy applications in the American west and elsewhere.

Three main forms of concentrator have been developed to generate either high temperatures in solar thermal collectors or high conversion efficiencies in photovoltaic collectors: parabolic troughs that focus light onto a line, parabolic dishes that focus light onto a point and arrays of heliostats focusing onto a central receiver mounted on a tower. Concentrating solar power has been developed significantly since the oil shocks of the 1970s, principally in the US, Spain, Australia, and Israel. "Solar One", a 10 MW central-receiver demonstration project which opened in the US in 1982, was the first of several large solar concentrators constructed in the modern phase of growth to establish feasibility. It generated steam to drive a turbine for electricity generation. Solar One was expanded and upgraded to Solar Two in 1995, including molten salt thermal energy storage. (Richardson, L. 2019)

There are several good histories documenting the beginnings of photo- voltaic, among them that by Crossly et al. The French scientist Edmond Becquerel discovered the photovoltaic effect in an experimental photoelectric- trochemical setup in 1839 At that time it was not possible to distinguish between chemical and photoelectric effects and the explanation of these experiments was originally in terms of chemistry. It was not until 1914 that Goldmann and Brodsky made a photoelectric interpretation. In the 1870s, William Gryllis Adams and R.E. Day investigated "whether it would be possible to start a current in the selenium merely by the action of light ". The result was positive, "clearly proving that by the action of light alone we could start and maintain an electrical current in the selenium". They did not, however, understand the processes at work in their devices, explaining the voltage as being due to extra light-induced crystallization in the material. Charles Fritts foresaw great potential for solar power from selenium photovoltaics. There were at least four American manufacturers of selenium photovoltaic cells by 1949. Copper–cuprous oxide cells were also under investigation since 1917 and there was intense rivalry between groups in Germany and USA through the 1920s, when copper- based cells were commercialized. The photovoltaic effect was found in germanium in 1944 in USA but all of these materials were eclipsed by the success of silicon as a photovoltaic material. Russel Ohl of Bell Laboratories filed patents in 1941 that were granted in 1946 and 1948 for the p–n junction photovoltaic effect in silicon and markets gradually grew for terrestrial and space applications. Silicon underpinned the development of serious and significant application of photovoltaic but cells based on alternative materials, cadmium–telluride, copper–indium–gallium–dieseline and III-V semiconductors (i.e. compounds of elements from Groups III and V of the Periodic Table), have also been developed and commercialized in the late 20th century (Weis, C. 2013)

1.2.1 AREA OF APPLICATIONS OF SOLAR ENERGY

Methods to collect solar energy and convert it to useful forms range from the simple and traditional to modern and highly sophisticated. Outputs include low grade heat, high temperature industrial process heat, hydrogen, synthesis gas, synthetic hydrocarbons and other chemical energy carriers such as ammonia and metals, and intermittent or dispatch able electricity. These technologies are all at different developmental stages and associated cost of energy. We introduce a range of them in this section before they are treated in detail in the following chapters. (Franklin, E. 2013)

1.2.2. ADVANTAGES OF HYBRID SOLAR SYSTEM

Hybrid inverters have many advantages -here are some of the top ones to consider as you're comparing inverter solutions:

Resiliency

A common misconception about solar is that if you install a system. You'll always have power during outages. In most cases, this is not true: traditional grid-tied solar inverters automatically shut off during power outages for safety purposes, cutting off power generation from your solar panel system.

Monitoring

With a hybrid inverter, all of your solar electricity-whether being sent to the grid. Self-consumed on your property or being stored in your battery-is converted through one component. This allows for "centralized monitoring." which means you can monitor both your solar panel system and battery performance through one platform.

Retrofit battery storage installations

One of the biggest benefits of a hybrid inverter is that it combines the functionality of two separate pieces of equipment into one. This can mean a cashier installation process for your solar installer. Depending on the prices of the individual components and the cost of labor, you may save money by installing a hybrid inverter from the get-go as opposed to paying for both a solar inverter and a battery-specific in crier separately. (Hongtao Xu, 2017)

1.3 TYPES SOLAR POWER SYSTEMS

There are basically three kinds of solar power systems through which electricity can be generated. These include:

1.3.1 ON-GRID SOLAR:

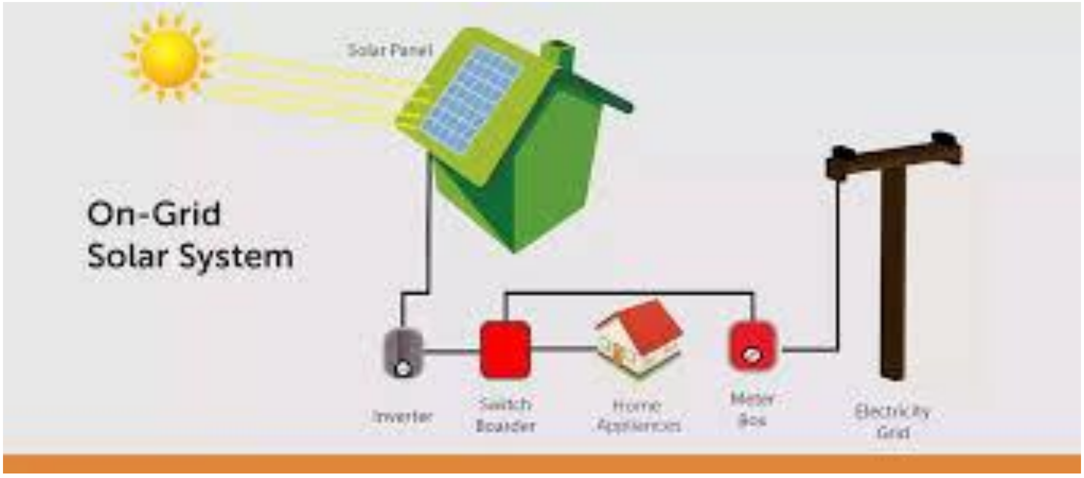
The on-grid solar also known as grid-tie or grid feed solar system consists of the solar panels, the inverter, meter and the power/utility grid. The electrical energy which is obtained through solar cell is direct current. An alternating current is used for powering most of the appliances. The alternating current is obtained through an inverter which flows through the electric meter that feeds electricity into devices.

If the solar system produces more than required energy which is needed, the excess electricity is sent back to the electricity, and can get paid feed in traffic (Fit).

During night or when the solar power system is not a proper condition the electricity can be used from the power grid.

DISADVANTAGE OF ON-GRID SOLAR:

The disadvantage of on-grid solar is that during certain climatic conditions or when there is a problem with the electricity grid, we cannot store the electricity for immediate use which becomes a drawback for this system.



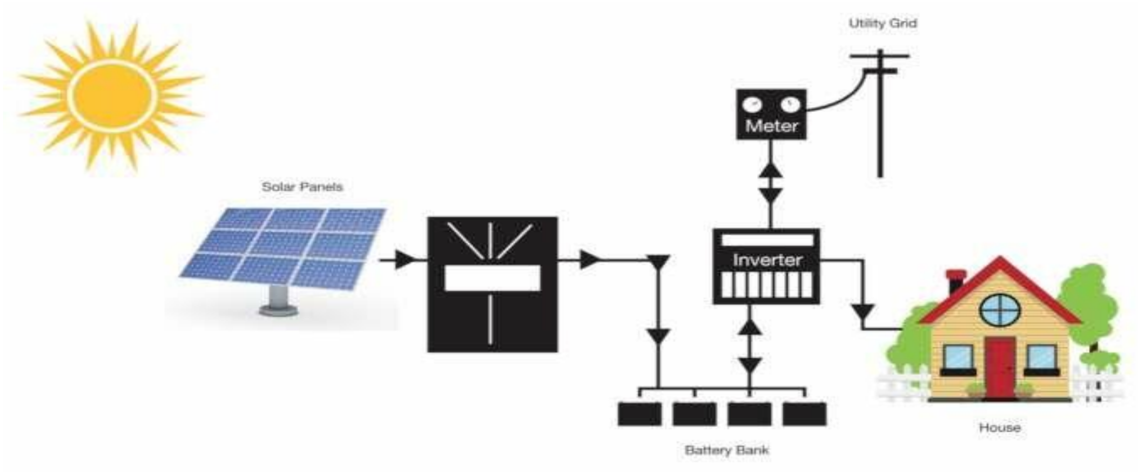
1.3.2 HYBRID SOLAR

Hybrid solar is the amalgamation of on grid and off grid solar power systems. The storage of power through batteries for use at any time, without consuming it from the electricity grid makes this system convenient to use and reduces the electricity cost.

Working of Hybrid solar power system:

During day, the sunlight is converted into electricity. Any excess amount will be stored in the batteries which is similar to off grid system. Incase if there is excess power stored it is fed back into the electricity grid similar to the on grid solar.

When there is neither support of solar energy nor the electricity grid, power can be used from the batteries. Similarly, when there is no sufficient battery backup left and no solar power an uninterrupted flow of electricity can be obtained from the electricity grid and the battery can also be charged.



1.3.3 OFF-GRID SOLAR

In off-grid solar power system also known as stand-alone power system has battery storage instead of the connectivity to the electricity gnd. The off grid solar power minimally uses the electricity that comes from the grid. It consists of solar cell, inverter and a battery bank if required a generator can also be used for backup of power.

Working of off grid solar power system:

The conversion of sun light into electricity is done through the solar cells and this direct current is converted into alternating current using an inverter.

After supplying the electricity to the devices if there is any excess amount of electricity that is left out, it is stored in the batteries which act as a backup when there is no support of solar energy.

But at times when the requirement of electricity is more and there is no sufficient solar power nor there is no adequate power to supply from the battery, it becomes difficult to perform the necessary requirements. This system is more advantageous for people living in remote areas where there is no accessibility to the utility grid.

So, to overcome the disadvantages of the on grid and off grid solar power systems one can inculcate a hybrid solar power system instead of these two power generating techniques. (Phansopkar, 2020).

1.3.4 ADVANTAGES OF SOLAR POWER SYSTEM AND LIMITATION

The more we can capture the benefits of solar energy, the less we will rely on fossil fuels. Adding a solar energy system to your home allows you to tap into these solar energy advantages:

1.3.2.1 LIMITATION OF THE PROJECT

The disadvantages of solar energy are becoming fewer as the industry advances and grows. Creating economies of scale. Technological advances are helping solar go mainstream. Here are how the disadvantages of solar energy and the pros and cons stack up.

The high initial costs of installing panels the most commonly cited solar energy disadvantage, cost, is declining as the industry expands. The initial cost to buy and install the equipment is not cheap. Still, if cost is an issue. Leasing options may reduce the amount of your initial outlay. If you do choose to buy. You will need to live in your home for several years before the system pays for itself. It's a long-term investment better suited to property owners than renters.

Solar energy storage is expensive of the disadvantages of solar energy, the temporary decline in energy production during bad weather has been a major issue. Days with low solar energy, however, are having less of an effect due to advances in battery technology. Old technology for storing solar energy. Like lead acid batteries is being replaced by alternatives. Lithium-ion batteries offer greater power at a lower cost. Nickel-based batteries have an extremely long life. New technologies, like flow batteries, promise scale and durable power storage

Solar doesn't work for every roof type

Not every room will work well with solar panels. Orientation matters. If your roof doesn't face the san, you won't be able to capture enough solar energy. Roofs that angle into the sun tend to work better than flat roof. (Goldmann, 2000)

1.3.3. COMPONENTS OF SOLAR POWER SYSTEM

The main solar components that come with every solar power system or solar panel kit are:

a. Solar panels

b. Inverters

c. Rack (mounting system)

d. Batteries and battery cage.

1.4 COMPONENTS OF HYBRID SOLAR POWER SYSTEM

a. Solar Panels
b. Charge Controller
c. Battery Bank
d. Inverter
e. Backup Power Source (Generator or Grid)
f. System Controller / Energy Management Unit
g. Mounting Structure
h. Wiring and Electrical Protection Devices (Cables, Breakers, Fuses, etc.)

a. **Solar Panels**: These are installed on the roof or open ground to capture sunlight and convert it into DC electricity.
b. **Charge Controller**: The DC power from the panels flows into the charge controller, which regulates the voltage and current going into the battery bank to prevent overcharging or damage.
c. **Battery Bank**: Stores the excess electricity produced during the day. This stored power can be used at night or during power outages.
d. **Inverter**: Converts the DC electricity from the solar panels or batteries into AC electricity, which is what household appliances use.
e. **Energy Management System (EMS)**: This controls how power flows between the solar system, batteries, grid, and backup generator. It decides when to charge batteries, when to use solar, and when to switch to backup power.
f. **Backup Power Source**: When solar power and stored battery power are not enough, the system can switch to a backup source—either the national grid or a generator.
g. **Mounting Structure**: Supports the solar panels, ensuring they are positioned at the right angle for maximum sunlight exposure.
h. **Wiring and Protection Devices**: Cables connect all the components. Safety devices like circuit breakers and fuses protect the system from overloads or faults. (Richardson, L. 2019)

1.5. WORKING PRINCIPLE OF HYBRID SOLAR POWER SYSTEM:

During day, the sunlight is converted into electricity. Any excess amount will be stored in the batteries which is similar to off grid system. Incase if there is excess power stored it is fed back into the electricity grid similar to the on grid solar.

When there is neither support of solar energy nor the electricity grid, power can be used from the batteries. Similarly, when there is no sufficient battery backup left and no solar power an uninterrupted flow of electricity can be obtained from the electricity grid and the battery can also be charged.

1.6 WORKING PRINCIPLE OF SOLAR PANELS

In the previous discussion it has been established that there is abundance of solar energy available to be harvested. A brief discussion of what PV cells is also being covered. It is necessary that we understand how these cells generate electricity so that we can 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) 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. 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. (Johnson, F. 2024).

1.7 SOLAR PV POWER GENERATOR

Solar electricity, also known as Photovoltaic technology, is the process through which sunlight is directly converted to electricity. Solar as a source of electric power has been put to use for decades in rarely mentioned areas like space programs. In the last decade, the advances in solar PV technology has meant the emergence of a stronger electricity power market which has provided viable alternatives in powering both grid and off grid homes. Despite the existence today of various types of Solar electric systems, three components that make up each of these individual systems are at the core of their operating systems; these are namely - the module, inverter and battery (depending on the type). The solar modules convert sunlight into electricity, the inverters convert the same electricity (DC) from the modules into Alternating Current (AC) making it safe for domestic and household use. The batteries store up excess electricity produced by the solar PV system. Other components which are equally important include equipment such as circuit breakers and wirings. With the advance of Solar PV technology, sunlight converting modules are now built into glass roofs, walls, car roof tops.

A process called Net Metering ensures additional electric power produced by the PV system (which is in excess of that being used by the building and stored in the battery), can be fed back into the grid, allowing the customer to pay only for the net electricity consumed - which is the power consumed by the consumer from the grid minus (-) the power generated by their solar PV system. With the metering system, consumers are able to realize good value for the electricity produced by their PV systems. Solar PV systems, as will be further expatiated, differ slightly with specific regards to the presence or not of battery storages within the system. Grid connected (On grid) PV systems do not require batteries, save for some in which they are used for backup power in emergency situations. The Off grid and the Hybrid PV systems both have the use of batteries considering their peculiar nature and the alternative power option they are conceptualized and built to provide. The Solar Energy Systems, come in various configurations and is basically a choice between staying completely Off grid or On grid.

The figures below are illustrative of the three common Solar Photovoltaic (PV) power systems.

On-Grid Solar System

Also known as the Grid Tied system, is always connected to the grid as the name (grid tied) suggests. The excess energy that the solar panels produces is fed to the grid. During periods in the day when there is no sunlight, and the domestic load consumption goes up, it draws from the grid's electricity. For the Grid tied system, the use of a battery to store electrical energy is unnecessary as the grid serves as its means of storage - this has its benefits and disadvantages. The On Grid Solar system is relatively cheaper than the Off-grid or Hybrid systems. Its disadvantage lies in the fact that electricity cannot be stored within the system, hence, if the grid is down at anytime, there will be no alternate source of electricity.

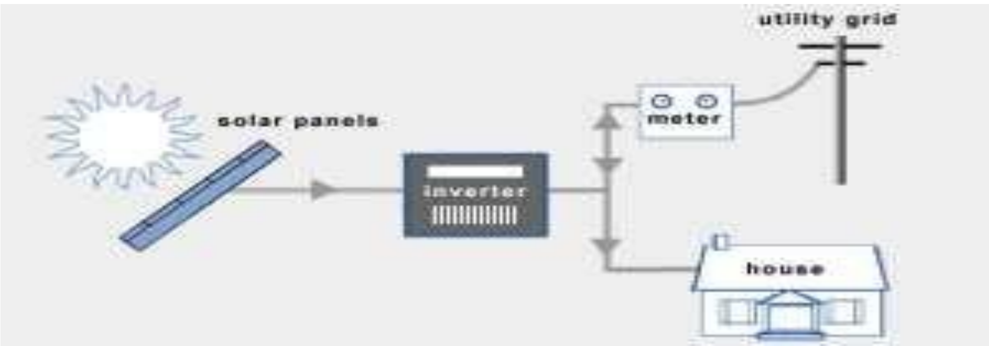


Figure 1.7.1: On-Grid Solar System,

Figure 1.7 further illustrates the lack of battery within the On Grid Solar System, the arrow heads also indicate the working pattern as the sun rays from the solar panel are immediately fed to the inverter as DC, converted to AC and supplied to the house, the excess load of which is sent to the grid, having been measured through the meter.

Off-Grid Solar System: The Off grid solar system is also referred to as the Stand Alone Solar System. As the name implies, they are not connected to the grid, the solar panels produce electricity which is stored in the battery banks. Night time, the stored power is used to provide electricity. The Off grid solar system is popularly mostly used in remote areas with little to no grid connection or power supply. It's advantages lies in the feeling of energy self-sufficiency it gives, and the fact that grid failures and power down times won't affect system power supply. Its disadvantage lies in the additional cost that come with battery bank or generator installations, and the increased need for delicate care and maintenance services.

Figure 1.7.2: Off-grid Solar System, [20]

The Off grid Solar System as explained and illustrated above in Figure 3, is stand-alone completely separate and independent of the grid. It comprises the solar panel, a charge controller, inverter and then the house receiving the electricity supply. The solar panel receives the sun rays and sends to the battery for storage, there is an optional charge controller which serves the purpose of limiting the rate at which electric current is added or drawn from the battery. The inverter converts to AC current ready for residential supply and use. (Richardson, L. 2015)

1.8 ENERGY DEMAND AND COMPENSATION IN SOLAR POWER SYSTEM

1. Energy Demand

Energy demand refers to the total amount of electrical power required by a household, business, or facility to operate its appliances, equipment, and systems. This includes:

- Lighting
- Refrigeration and cooling (fans, AC)
- Cooking appliances
- Electronics (TVs, computers, phones)
- Industrial or commercial machinery (in businesses or factories)

The **total demand is usually measured in kilowatt-hours (kWh)** per day or per month. Energy demand varies by location, time of day, season, and usage patterns.

2. Energy Compensation in a Solar System

Since solar energy is available only during daylight hours, and not always at peak levels due to weather or shading, a solar power system must **compensate** for demand in various ways:

a. Real-Time Solar Generation

- During sunny periods, the **solar panels produce electricity** to meet immediate demand.
- If generation is more than demand, the excess is sent to **batteries** or **the grid** (if net metering is available).

b. Battery Storage

- At night or during cloudy periods, stored energy from the **battery bank** is used to **compensate for demand** when solar panels aren't generating power.

c. Backup Power (Grid or Generator)

- When both solar and battery power are insufficient (e.g., prolonged rain or high energy usage), the system **automatically switches to the grid** or a **diesel/petrol generator**.
- This ensures **continuous power supply**, maintaining balance between demand and supply. (Smith, 2021)

1.9. THE AIM AND OBJECTIVES OF THE PROJECT

1.9.1. AIM OF SOLAR POWER SYSTEMS

The aim of this project is to provide an uninterrupted power supply to domestic appliances and lighting where there is public mains supply failure and also generates a stable source of power supply in I.O.T. Offices.

1.9.2 OBJECTIVES OF SOLAR POWER SYSTEMS

a. To ensure that there is continuous power supply

b. To reduce reliance on fossil fuels and decrease carbon emission

c. Lowering electricity costs in the long run1

1.10. PROBLEM STATEMENT

If there is one factor that has perpetually maintained the status of Nigeria as a less developed country, it is the electrical sector. To date, many households and industrial businesses even in schools and hospitals cannot be guaranteed 24 hours supply of electricity from the national grid. Rather. Nigeria has continued to rely on electricity generators for their power supply. Fuel marketers are taking a significant portion of households, institutions of learning. And business income to supply and noise pollution has become an integral part of living for many Nigerians with unimaginable consequences to health. So, there is a need to design and construct the solar panel inverter to reduce cost and eliminate noise environmental pollution associated with running the generator.

1.11 SCOPE OF THE PROJECT

The scope of this project is typically based on the specific objectives which are checking the problem of the unstable power supply in the school, purchasing a solar panel and battery, studying the major electronic component to be used in the inverter circuit, coupling the inverter, testing it with the batteries and fully installin