

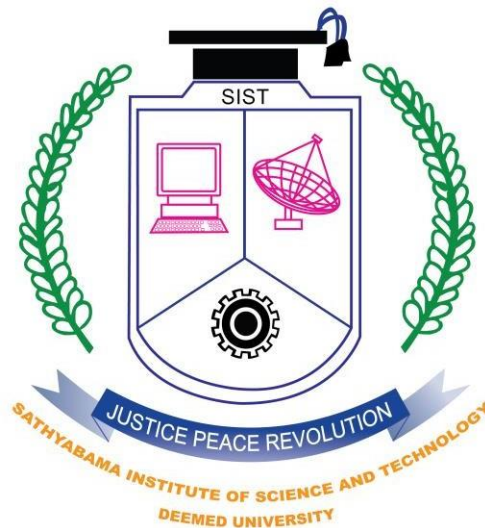
DUAL AXIS SOLAR TRACKING SYSTEM

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

By

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **S.SUPRIYA** (Reg. No. 37140080) and **B.VINOBA** (Reg. No. 37140094) who carried out the project entitled “**DUAL AXIS SOLAR TRACKING SYSTEM**” under our supervision from December 2020 to April 2021.

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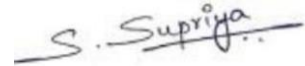
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DECLARATION

We **S. SUPRIYA** (Reg. No. 37140080) and **B. VINOBA** (Reg. No. 37140094) hereby declare that the Project Report entitled “**DUAL AXIS SOLAR TRACKING SYSTEM**” done by us under the guidance of **Mrs. M. KAVITHA** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

1.



2.



DATE:

PLACE:

SIGNATURE OF THE CANDIDATES

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ABSTRACT

This project deals with dual-axis solar tracking to collect maximum rays using LDRs. It resolves the problem by providing an arrangement for a solar panel to track the movement of the sun on both axes. With the increase of scarcity of nonrenewable resources, people are trying to identify alternate sources of energy. From all available renewable resources, solar energy is relatively easy to convert to electrical energy. The use of solar panels to convert the sun's energy to electrical energy is very popular. But due to the movement of the Sun from east to west the fixed solar panels may not be able to generate ideal energy. Hence single-axis solar tracking systems were introduced aiming to generate ideal energy. But even single-axis solar tracking has been analyzed and results show that it can track sun rays on only one axis (either north-south or east-west). Hence a prototype is constructed more efficiently to track maximum sun rays in both the axes (both north-south and east-west). It is a low-cost system that provides better efficiency. Here the analog signals are analyzed and controlled by Arduino Uno. This automatic system is completely programmed. The energy obtained from the sun is collected using a solar panel by arranging four LDRs. The amount of energy obtained and positions at two LDRs on the same axis are compared and analyzed to decide the movement of the servo motors which moves the panel to the direction where more energy is available. It has an LCD to display the output visual information of the type of rotation needed and angle of rotation and inclination.

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LIST OF SYMBOLS AND ABBREVIATIONS

LCD	-	Liquid Crystal Display
LDR	-	Light Dependent Resistor
DC	-	Direct Current
AC	-	Alternating Current
PV	-	Photo Voltaic
IC	-	Integrated Circuit
2D	-	2Dimensional
WLTP	-	Worldwide Harmonized Light Vehicle Test Procedure
SOC	-	State of Charge
EV	-	Electric Vehicle
LED	-	Light Emitting Diode

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Nowadays the depletion of conventional energy resources forced many researchers to search for various renewable energy sources. Among the non-conventional resources available, solar energy has the greatest potential to be converted into electrical energy. Converting solar energy into electrical energy signifies one of the favorable technologies, providing dirt-free, dependable with negligible environmental impact. Solar energy is well known as an unrestricted, endless source, and involves no pollution filtrates or greenhouse gases emission.



Fig 1.1 Solar panels

Figure 1.1 represents solar panels arranged in a specific area. The solar photovoltaic industry has been improving very well recently. Most of the currently installed PV systems are of the fixed-tilt mounting design, of which the PV

modules are tilted at an optimal angle. For this type, these PV modules are reduced to severe cosine losses during harnessing of solar energy, especially early in the morning, and in the late evening. This project employs a sun-tracking solar panel to track the maximum rays using LDR's. This is more acceptable when compared to the light-sensing method that may not be accurate. The main aim of this work is to design a system that could track the sun with solar panel in a more efficient way compared to the existing system. This is obtained by coupling the LDR sensors with a DC servo motor to the solar panel such that the panel maintains its face always perpendicular to the sun to generate maximum energy. This is achieved by employing a programmed ARDUINO IC.

1.2 LITERATURE SURVEY

Prof. (Dr.) Mukesh Pandey et al., (2020) described exploring the usage of solar trackers and their cost-effectiveness in a paper with the title “A Review Paper on Solar tracking System for Photovoltaic Power Plant”. This paper talks about a Solar tracking system that is defined by its degrees of rotation. According to the degrees of rotation, tracking systems can be categorized namely Single Axis Solar Tracking and Dual Axis Solar Tracking. Single-axis solar tracking is able to track the sun either horizontally or vertically. Dual-axis solar tracker could track the sun in both horizontal and vertical ways and guarantees maximum efficiency. There are several methods of solar tracking namely Active tracking, Passive tracking, and Chronological tracking.

G. Pavan Kalyan et al., (2019) discussed sun tracking system in “Sun tracking system using microcontroller”. This paper explains the movement of the motor by an indication from a sensor circuit when the intensity of solar rays is heightened. This project discusses the construction of a prototype that features a single axis of freedom. The different ways of accelerating the efficiency of solar panels are discussed here. Very efficient trackers will show high efficiency because they're ready to track the sun with accuracy.

D. T. Cotfas et al., (2019) listed very important methods to enhance the efficiency and the lifetime of photovoltaic panels in a paper “Multi concept methods to enhance photovoltaic system efficiency”. Several cooling methods and the maximum power point tracker methods are presented in this paper. The methods to increase the solar radiation which pounce on the PV panels are Sun tracking system, Reflective system, active reflectance, Passive reflectance, refractive system. The clear and detailed classification of various types of solar trackers is discussed in this paper. The Important cooling methods of the photovoltaic panels that are mentioned in this paper are Air cooling, Water cooling, Phase change material, and Thermoelectric. Karami et al. gave some criteria in choosing the best MPPT technique for various applications like Implementation, sensors, efficiency, and cost.

M. Prem Kumar et al., (2019) discussed various MPPT methods for the PV systems in their research paper “An effective maximum power point tracker for partially shaded solar photovoltaic systems”. This paper talks about a maximum power point tracking technology to obtain the peak power from the PV array during partially shaded conditions. The results from the simulation show that the Whale Optimization technique presents high efficiency of tracking and less merging time with lesser power oscillations. The PV solar characteristics under different operating conditions with graphs are mentioned.

Shin'ya Obara et al., (2018) proposed the development of a solar tracking system of a nonelectric power source by using a metal hydride actuator. This study deals with the sun tracking system of a non-electric power source by employing a metal hydride actuator with a sun radiation drive. The proposed tracking system includes two MH reactors that are placed perpendicular to the photovoltaic cell array. This study showed the result of the proposed system after four months of testing. In order to attain highly reliable solar tracking with the proposed system, excessive cooling by wind should be prevented by installing a windshield. The Hydrogen element is discharged from MH by heating, and it is reserved by cooling. The pressure of the proposed reactor depends on its MH temperature. Therefore, it's

possible to modify the actuator by creating a temperature difference between the MH reactors, which then creates a pressure difference.

Jose A. Carballo et al., (2018) introduced a new low-cost solar tracking system based on open-source hardware for educational purposes. In his paper, a small prototype based on low-cost open-source hardware is developed in Simulink. This prototype has been developed to be a powerful tool that can be used for a wide range of applications. The accuracy is conditioned by constant aberrations. In the literature, there are reviews about solar tracking systems one and two axes tracking systems with open-loop, closed-loop, control based on continuous movements, maximum beam, electro-optical sensors, solar equations, or a hybrid. In this work, a new solar tracker is proposed, with the main objective of developing a unique educational tool to understand solar tracking problems regardless of solar technology. The proposed system can detect the position of the Sun and the receiver; also it is time and location independent.

Fabio Moacir Hoffmann et al., (2017) discussed monthly profile analysis based on a two-axis solar tracker proposal for photovoltaic panels. The objective of this study is to develop a dual-axis solar tracker and evaluate the performance of a solar panel, compared to a fixed system. Each system is composed of a mechanical structure, a solar panel, and a resistive load. This work talks about the development and performance of a dual-axis solar tracker and evaluates the movement cost of the PV system. To study the alternatives, this paper depicts the development of a dual-axis solar tracker.

Masoumeh Abdollahpour et al., (2018) proposed a dual-axial tracker that works based on processing images of a bar shadow through a research paper "Development of a machine vision dual-axis solar tracking system". The system is composed of a shadow casting particle, a webcam, few electronic circuits, and stepper motors. The study results presented that the tracking system followed the sun with an accuracy of about $\pm 2^\circ$ and generates an increased power output. Arul Kumar

and Arjun, 2016 developed an automatic solar tracking system that was a single axis, five positions in the LDR sensor, and was designed for low power. Kadmiri et al. showed a novel solar tracker system based on Omni-directional vision technology. Performance of the morphological and regression analyses was compared in terms of root-mean-square error and mean absolute percentage error. In this study, a moderated dual-axis tracker independent of initial settings and local location based on image processing of a bar shadow was developed, which uses the shadow length to determine the zenith angle and height.

Boon-Han Lim et al., (2020) explained the design of a dual-axis sun tracker with a vertical axis and multiple row elevation. The algorithm of the software determines the number of counts is required to set the amount of pin-gear rotation to a specific amount. For every excitation of the motor initiated by a control signal, the number of rotations will be constant due to feedback control in the form of a counter; therefore, a good tracking precision is achieved. The range of motion and slew rate for various months is studied for both tracking axes.

L.M. Fern_andez-Ahumada et al., (2019) proposed a unique backtracking approach for two-axis solar PV tracking plants. One of the foremost important aspects in tracking is shading between the modules and also appearance of hot spots within the modules. The tactic presented here is useful for the optimization of the planning of the latest photovoltaic two-axis tracker plants. Therefore, this novel backtracking approach explains that the tracker must point towards the irradiance direction within the non-shaded region. Consequently, this novel method is expected on algorithms that are significantly more simple and fast. Thus, this method is simpler to be wont to simulate energy production with different radiative models.

Muhammad E. H. Chowdhary et al., (2019) proposed a new algorithm in a research paper “A Low-Cost Closed-Loop Solar Tracking System Based on the Sun Position Algorithm”. The Astronomical Almanac’s algorithm was executed for its

reliability, simplicity, and fast computation capability of the solar position. Results revealed that incorporation of the sun position algorithm in a solar tracking system supports in performing the stable system and optical tracking system. As a fact, there are few ways to increase the efficiency of PV systems like to increase the efficiency of power generation of the PV cells, the efficiency of the control algorithms for the energy translation, and to endorse a tracking system to achieve extreme solar energy. The core area of this paper is to accelerate efficiency by blending the second and third approaches. The angle between the direction of the sun and the zenith is called the zenith angle. A real-time solar position tracking system is successfully executed using the AA algorithm.

Rafid Khan et al., (2018) described Enhanced energy extraction in an open-loop single-axis solar tracking system with tracker rotation about a tilted axis. Fathabadi came up with a dual-axis solar tracker with minimum tracking error. Based on the tracking algorithm, solar tracking systems can be broadly classified as open-loop and closed-loop systems. Al Naima and Yaghobian proposed the dual-axis solar tracking system based on astronomical coordinates of the sun and demonstrated that the system performed better than conventional sensor-controlled systems.

A.Z. Hafez et al., (2018) discussed technologies and tracker drive types in their paper “Solar tracking systems: Technologies and trackers drive types – A review”. A single-axis sun tracking system helps to track the sun from one side to another using a single pivot point to rotate. This system has three types: horizontal, vertical, and tilted single-axis tracking system. Nomenclature, Greek symbols, and acronyms are listed in this paper. The historic overview of the solar tracking systems is described and new techniques of the solar tracking systems are discussed. The solar tracking system types are described, as well as introduced the solar trackers drive types. Finally, the conclusion is summarized.

Jose A. Carballo et al., (2018) proposed a new approach for sun tracking systems based on computer vision and deep learning. Nowadays, STSs are classified as agreeing with the definition method of the sun's relative position within the sky. There are two important methods namely, solar position algorithms or optical methods/algorithms. It is often concluded that the new approach proposed is valid, fully functional, and shows a good margin for improvement. The new approach is unrestrained of solar technology, system size, location, and time.

Najibhamisu Umar et al., (2018) listed PV power simulation softwares in this research paper “Comparison of different PV power simulation software: a case study analysis of 1 MW grid-connected PV solar power plant”. In this, ten simulation softwares SAM, PVSyst, PV F-Chart, HOMER, RETScreen, PV*SOL, Solarius PV, HelioScope, SOLARIS, and Solar Pro are explained. A study on performance analysis of 1 MW grid-connected PV solar energy plant has been explained using these simulation tools. Simulation results are compared with actual data of the power plant to identify the suitable and most effective software for research and development. This study is very helpful for further study on degradation and performance analysis of PV power plant and a comparison of various PV simulation tools to identify the most suitable software.

V. Baby Shalini et al., (2019) presented a pre-feasibility estimation of a grid-connected roof-mounted solar PV system on the roof of the buildings in the campus of JNTUH College of Engineering Jagtial, Telangana, India. To compute the solar yields precisely, a true exposition of the shading of the various locally present arbitrary objects at the chosen location is essential, this is exactly what PV-SOL premium does i.e., all roof-mounted systems are often visualized-even on the ground-with modules and 3D object shading are often calculated. System Advisor Model (SAM) software is defined by the NREL (USA). It analyses the technical also as economic performances of varied solar plants depending upon the actual inputs.

Linta Khalil et al., (2020) described the Optimization and designing of hybrid power systems using HOMER pro. HOMER stands for Hybrid Optimization Model for Electric Renewals. In HOMER Pro this data is fed to the HOMER Pro. The basic objective is to optimize the minimization of pollution gas emission and consumption.

Huseyin Gunhan Ozcan et al., (2019) suggested a comprehensive evaluation of PV electricity production methods. This paper presented the study about electricity generation from solar photovoltaic technology-supported four different methodologies with some performance indicators. Installation of cleaner production systems has recently increased rapidly due to environmental concerns, in terms of global warming, the Paris Agreement, and low carbon, etc. The performance of the observed system indicated the difference from STC due to the meteorological part of the system, energy conversion phenomena. While FF and CUF were annually determined to be almost similar based on the theoretical approach and the PVSOL program

Rakhi Sharma (2019) introduced urban flash flood observation, mapping, and prediction via a tailored device network system. Optimization of a PV system is completed by simulation software system tool PVsyst five.52. Choice of PV array, controller, pumping unit, water system network is needed to fulfill style needs. The theoretical study has supported the factors that are specialized in simulation software systems. The theoretical analysis of the solar PV water pumping system includes hydraulic power calculation, filler of electrical phenomenon array, motor filler, and efficiency calculation of the system. This study represents a simplified style optimization approach for a solar photovoltaic Water Pumping System with the help of theoretical computations and PVsyst simulation software system.

1.3 SCOPE OF THE PROJECT

In this work, an improved solar tracking system with a dual-axis tracking mechanism has been proposed. Due to the transition of the sun from east to west, the fixed solar panel may not be able to generate optimum energy. Single-axis solar

tracking couldn't produce ideal energy. The proposed system solves this problem by an arrangement for the solar panel to obtain maximum sun rays throughout the day.

1.4 OBJECTIVE

The objectives of the proposed work are as follows

- To design a dual solar tracking system that can collect maximum amount of sunlight on the solar panel.
- To optimize and increase the efficiency of output than existing system.
- To analyze the performance of various solar tracking and find out the best efficient way to maximize the output.

1.5 ADVANTAGES OF TECHNIQUE

- More efficient.
- Less maintenance.
- Less complexity.
- More economical.
- Increased output.
- More accurate.

1.6 APPLICATION

- Used for solar power towers
- Used to improve solar pumping system
- Used for street lightning system
- Used to provide electricity in remote areas.

CHAPTER 2

PROJECT DESCRIPTION

2.1 INTRODUCTION

In this chapter block diagram of the existing system and its disadvantages are discussed along with the block diagram of proposed system and its advantages.

2.2 EXISTING SYSTEM BLOCK DIAGRAM

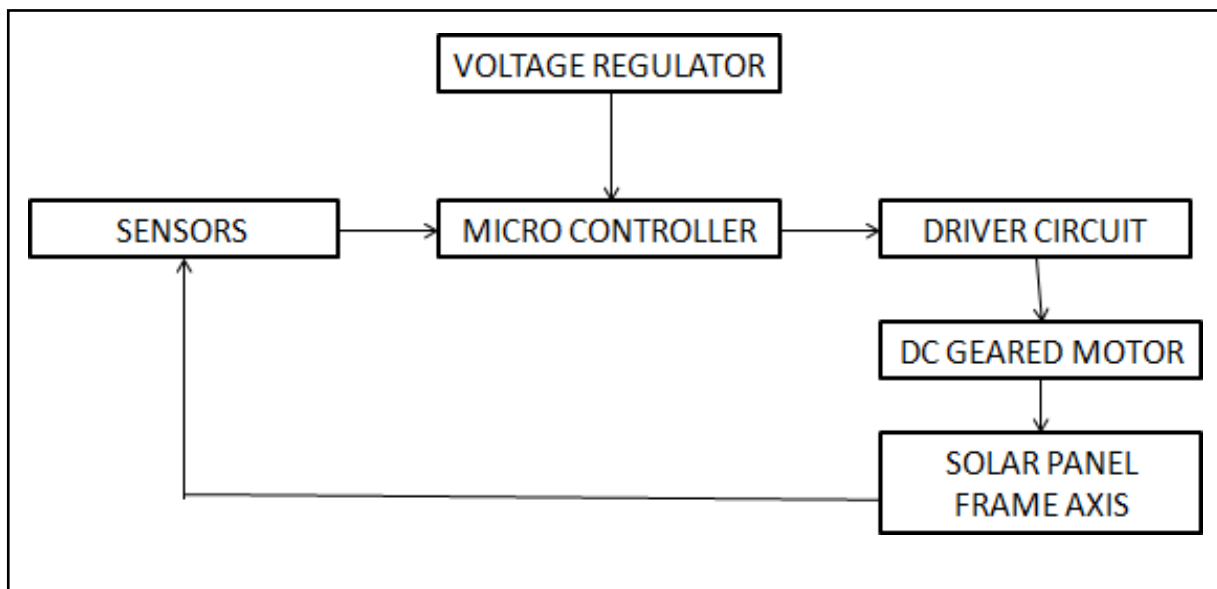


Fig 2.1 Existing system block diagram

Fig 2.1 shows the block diagram of the single-axis solar tracking system which is considered an existing system. It consists of a microcontroller, sensors, voltage regulator, driver circuit, dc geared motor, and solar panel frame axis. Here the sensors are arranged in such a way that the solar panel rotates in only one degree of freedom. When the sun travels from east to west, the sun's highest position also changes. Hence this system is only helpful in tracking either of the axes. Due to this ideal energy is not provided to the solar panel. As a result, the output energy is also not ideal.

2.3 EXISTING SYSTEM DISADVANTAGES

- Lower energy output during sunny conditions, when compared to dual-axis trackers and during cloudy days the efficiency of the single-axis tracker, is almost close to the fixed panel.
- It involves less technological advancement.
- It also requires an additional focus on company stability and bankability in large-scale implementation. When it involves getting projects financed, these systems are more complex and thus are seen as a better risk from a financier's viewpoint.
- Even with the evolution in reliability, there is more maintenance required than a traditional fixed rack, though the quality of the solar tracker can play a role in how much how frequently often this maintenance is required.
- It has access to only one degree of freedom i.e. either horizontal or vertical axis. So the output performance gets reduced on annual basis.

2.4 PROPOSED SYSTEM BLOCK DIAGRAM

Here Fig 2.2 shows the block diagram of the Dual-axis solar tracking system that tracks the maximum sun rays using LDR sensors. This block diagram is designed according to track solar rays in both axes all day. The system includes a power supply, Arduino, two servo motors, four LDR sensors, battery, charge controller, and solar panel. This total system is designed in a form so that it tracks the sun efficiently and obtains maximum solar energy from the sun and increases the output efficiency and provides better performance even in cloudy conditions. The power supply is given to Arduino. The LCD is also powered by the Arduino. The analog information is transferred from LDRs to Arduino. According to the Arduino program, instructions are given to the servo motors and these motors eventually provide movement to the solar panel. The overall blocks connection is represented in order.

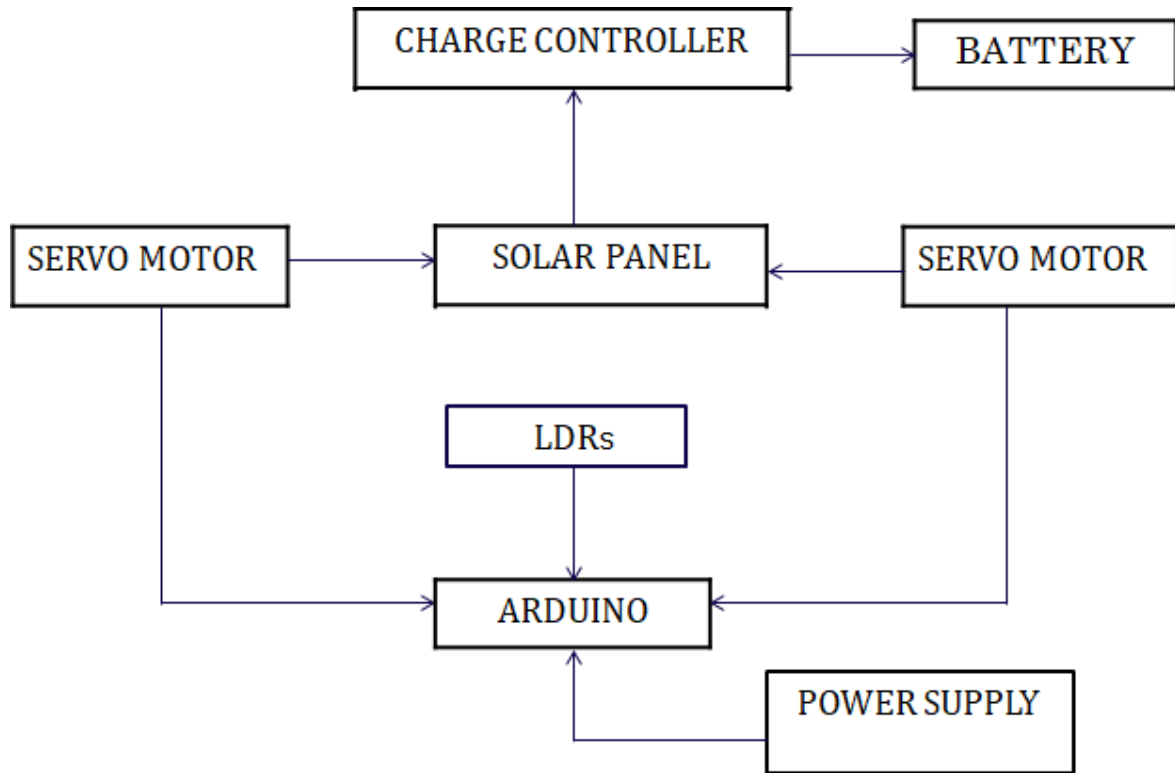


Fig 2.2 Block diagram of proposed system

2.4.1 SOLAR PANEL

The array of the solar panels is named non-literally for a photovoltaic module. A PV module can be coined as an assembly of photovoltaic cells mounted during a framework for installation. PV cells use sunlight as an energy source and produce DC electricity. Arrays of a PV system supply solar electricity to electrical equipment. PV modules use light energy from the Sun to get electricity through the photovoltaic effect. Most of the modules use crystalline silicon cells or thin-film cells. The structural members of a module are often either the upper layer or the rear layer. These must be protected against mechanical damage and moisture. Most modules are rigid, but semi-flexible ones supported thin-film cells also are available. The specifications from the manufacture on solar panels are seen under the standard conditions which is not the real operating condition the solar panels are exposed to on the installation site.

Each one of the modules is rated by its DC output power under standard test conditions and thus the on-field output power might vary with various circumstances. Power values typically ranges from 100 to 365 Watts.

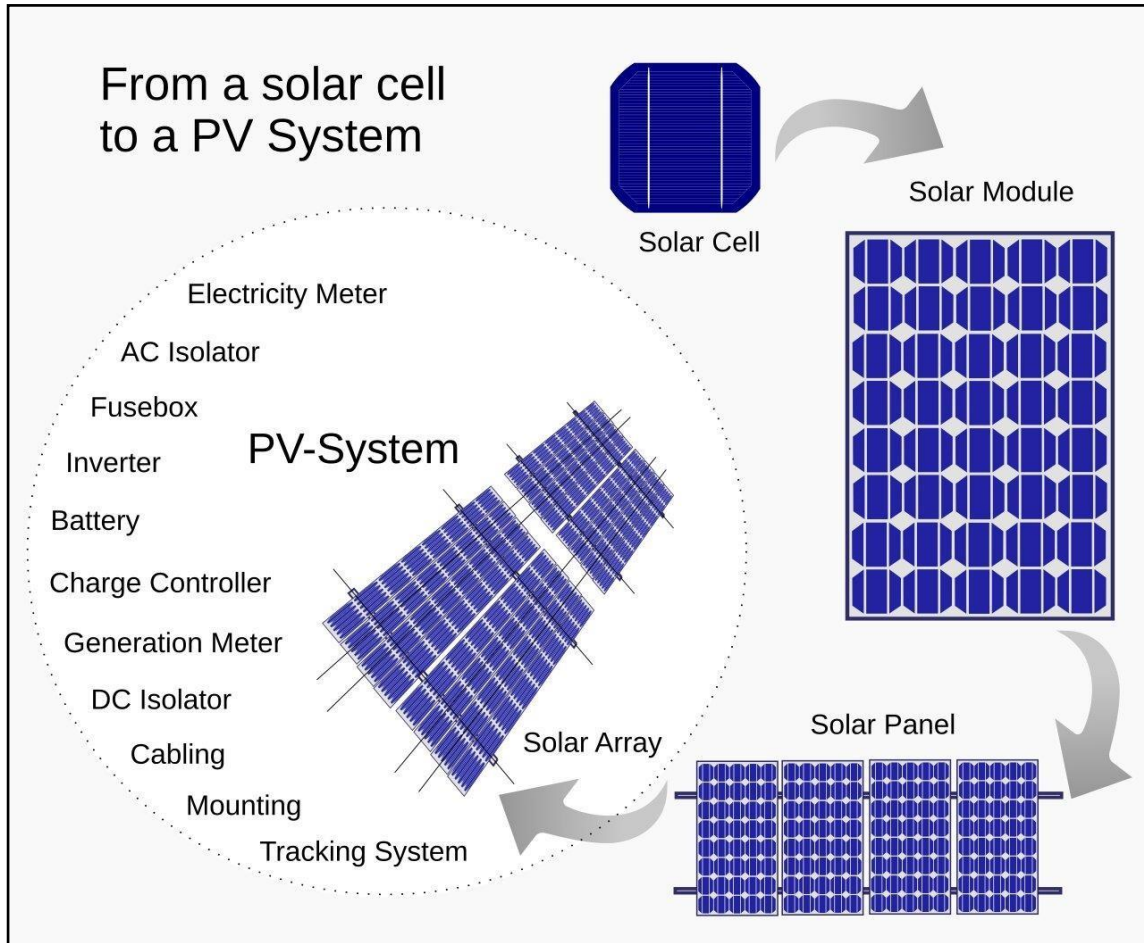


Fig 2.3 PV Solar module

Figure 2.3 represents the conversion of the solar cells into a PV system. The efficiency of a module determines the area of a module given a similar rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. Some commercially available solar modules exceed 24% efficiency. Hence, most of the incident sunlight energy is wasted by PV modules and another design concept is to separate sunlight into six to eight different wavelength ranges that may produce unique color sunlight and direct the beams onto different cells tuned to those range. To produce electricity, solar cells are made from a semiconducting material that converts light into electricity. The most common material used as a

semiconductor during the photovoltaic cell manufacturing process is silicon. Both monocrystalline and polycrystalline solar panels have cells made from silicon wafers.

2.4.2 LDR SENSORS

An LDR is defined as a component that features a resistance that varies with the sunlight intensity that falls upon it. This allows them to include in light sensing circuits. Figure 2.4 represents the LDR circuit symbol.

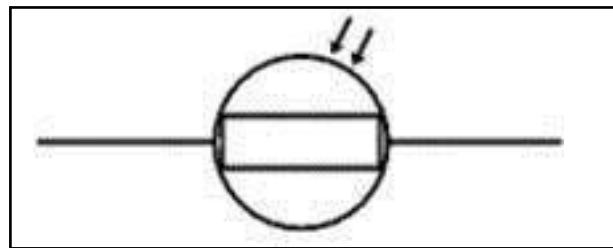


Fig 2.4 LDR circuit symbol

When the light is projected on its surface, the material conductivity decreases, and also the electrons in the valence band of the device are jumped or excited to the conduction band. These photons in the incident light should have energy greater than the band gap of the semiconductor material considered.

2.4.2.1 TYPES OF LDRs

LDRs are categorized based on the materials used in them. Intrinsic Photo-resistors are made of pure semiconductor devices like silicon or germanium. When the light falls on the LDR, then the electrons get excited and the number of charge carriers increases. Extrinsic Photo Resistors are injected with impurities and these impurities produce a new energy band over the valence band. These are filled with electrons. Therefore, this decreases the band gap and a small amount of energy is needed for moving them. These are mainly implemented for applications with long wavelengths.

2.4.2.2 CHARACTERISTICS OF LDR

LDR sensor is very sensitive to light. The resistance is inversely proportional to strength of light. With the increase of illumination intensity, the resistance value of the LDR's photo resistor decreases rapidly. When a light-dependent resistor is kept in dark, its resistance is extremely high. This resistance is known as dark resistance. It is very high and if the device is allowed to absorb light its resistance will be decreased drastically. The characteristics are shown in figure 2.5 below.

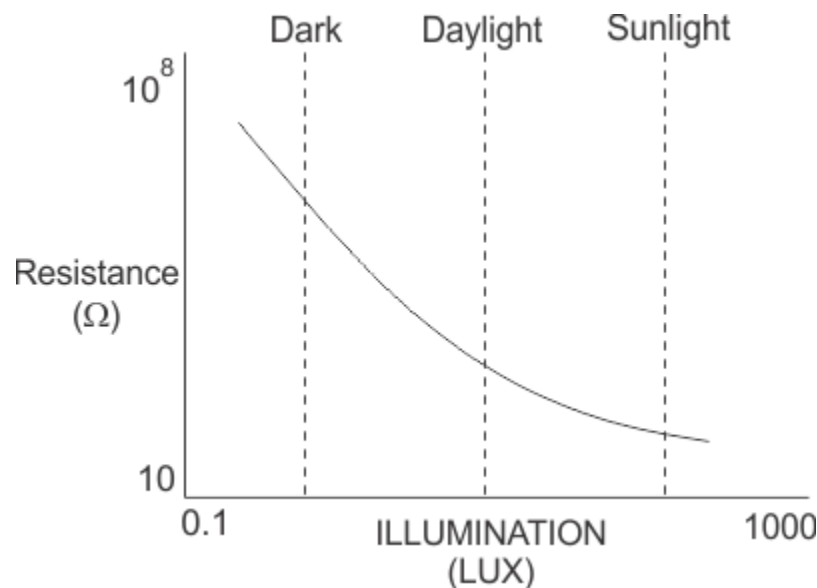


Fig 2.5 Characteristics of LDR

Photocells are nonlinear devices. The sensitivity of these photocells differs with the wavelength of light falling on them. Based on the material used, different cells have a different spectral response.

2.4.3 SERVO MOTOR

A servo motor is a motor that rotates with great precision. Normally this kind of motor comprises a control circuit that comes up with feedback on the present position of the motor shaft; this allows the motors to run with great precision. It comes with a gear arrangement that helps us to get a very high torque servo motor in lightweight

packages. It is a closed-loop system where it makes use of a positive feedback system to control motion and the final position of the shaft.

2.4.4 BATTERY

A battery is interpreted as an electrochemical device made up of numerous electrochemical cells, connected to external inputs and outputs. They are widely employed to power small electric devices such as mobile phones, remotes, and flashlights. They are broadly divided into two categories, namely primary batteries and secondary batteries.

2.4.4.1 TYPES OF BATTERIES

Table 2.1 Types of batteries

SNO	BATTERY TYPE	CHARACTERISTICS	APPLICATIONS
1.	Zinc – Carbon	Common, low cost, variety of sizes	Radios, toys, instruments
2.	Magnesium (Mg/MnO ₂)	High capacity, long shelf life	Military and aircraft Radios
3.	Mercury (Zn/HgO)	Very high capacity, long shelf life	Medical (hearing aids, pacemakers), photography
4.	Alkaline (Zn/Alkaline/MnO ₂)	Very popular, moderate cost, high performance	Most popular primary batteries
5.	Silver/Zinc (Zn/Ag ₂ O)	Highest capacity, costly, flat discharge	Hearing aids, photography, pagers
6.	Lithium/Soluble Cathode	High energy density, good performance, wide temp range	Wide range of applications with capacity between 1 – 10,000 Ah
7.	Lithium/Solid Cathode	High energy density, low temp performance, long shelf life	Replacement for button and cylindrical cells
8.	Lithium/Solid Electrolyte	Low power, extremely long shelf life	Memory circuits, medical electronics

Table 2.1 shows different types of batteries. There are various types of batteries available for various purposes. The nine-volt battery, or a 9-volt battery, maybe a common size of battery that was introduced for the first transistor radios. The nine-volt battery format is usually available in primary carbon-zinc and alkaline chemistry, in primary lithium sulfide. Carbon-zinc is made up of six flat cells with a stack, enclosed during a moisture-resistant wrapper to stop drying. Primary lithium types are made with three cells serial.

2.4.5 CHARGE CONTROLLER

A charge controller is a regulator to avoid batteries from overcharging. If there's no regulation the batteries are damaged from overcharging. Nearly all PV panels rated over 140 watts aren't standard 12-volt panels, and can't be used with standard charge controllers.



Fig 2.6 Battery charge controlling

2.4.6 BRIDGE RECTIFIER

Rectifiers are electrical components used to convert AC to DC power. It can be described as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to convert alternating current to a direct current efficiently. Figure 2.7 represents a bridge rectifier circuit. The input of the bridge rectifier is ac input. The input signal is provided across terminals A and B and the output DC signal is gained across the load resistor R_L between terminals C and D. In figure 2.8 the output waveforms of the bridge rectifier are shown.

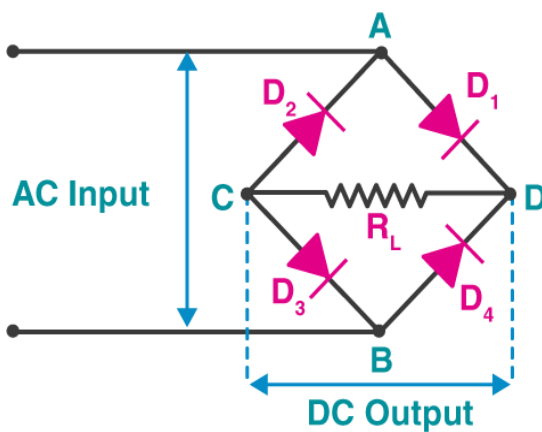


Fig 2.7 Bridge rectifier

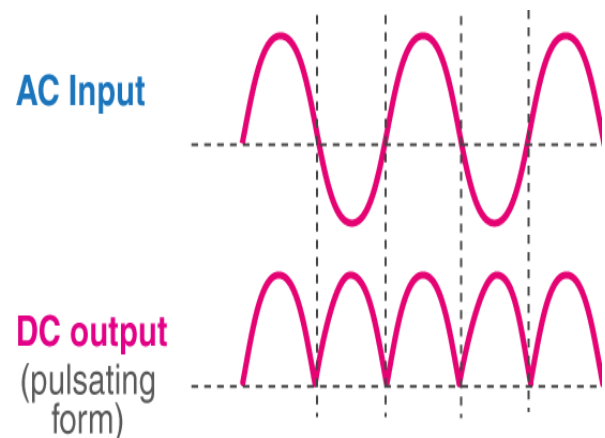


Fig 2.8 Output waveforms

2.4.7 MOTOR DRIVER IC

The motor driver IC is used as a motor controlling unit in robots and embedded circuits. It is a small current Amplifier that takes a low-current control signal and then turns it into a higher-current signal that can drive a motor. Motor Driver ICs are used in uncontrolled robotics only. Most microprocessors operate at low voltages. They require a small amount of current to operate while the motors require a relatively higher voltage and current.

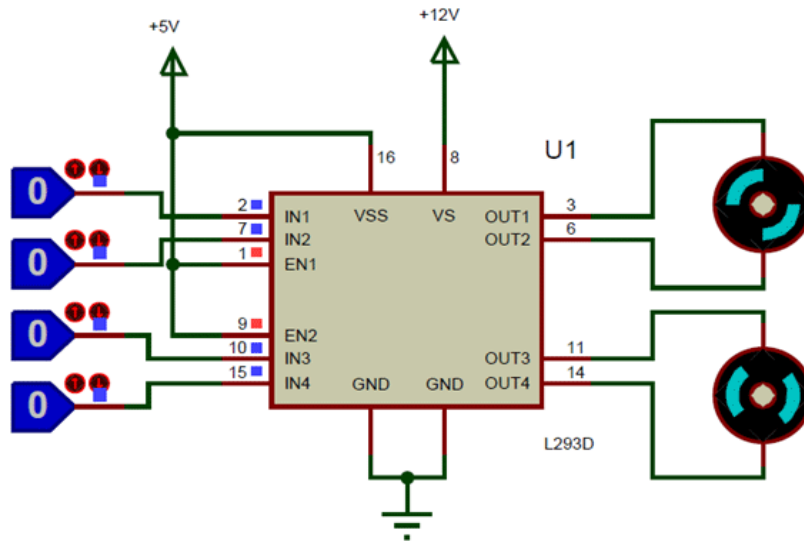


Fig 2.9 Motor Driver IC Pin Diagram

The L293D is a type of Motor driver which can drive 2 DC motors simultaneously. L293D and ULN2003 are the most common motor Driver ICs. Figure 2.9 represents L293D motor driver IC. L293D is a dual H-bridge motor driver integrated circuit. L293D IC transfers signals from the microprocessor to the motors. It's two voltage pins, one among which is employed to draw current for the working of the L293D, and therefore the other is employed to use voltage to the motors. The L293D is a 16 pin IC that is dedicated to the controlling of a motor. L293D consists of two H-bridge. H-bridge is that the simplest circuit for controlling a low current rated motor.

In the given figure 2.10, the arrow represents flow on the left points to the higher potential side of the input voltage of the circuit. L293D has 2 sets of arrangements where one set has input 1, input 2, output 1, and output 2 and another set has input 3, input 4, output 3, and output 4.

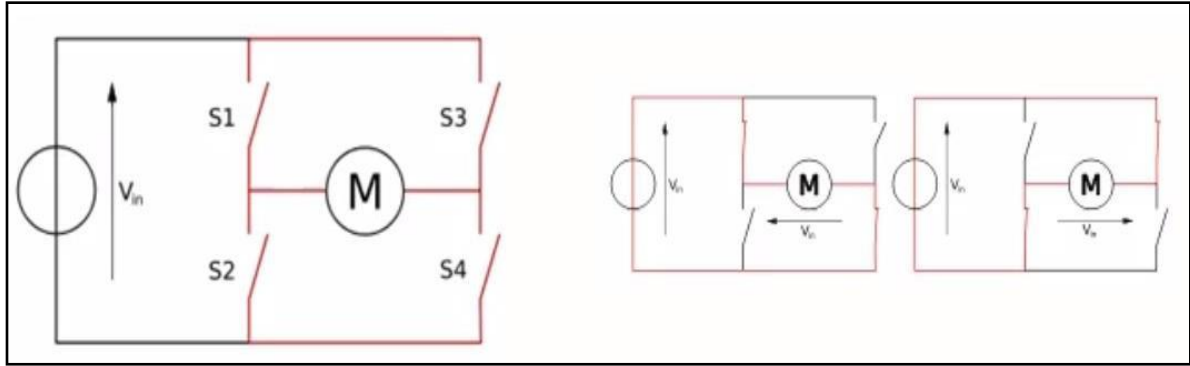


Fig 2.10 H Bridge

2.5 PROPOSED SYSTEM ADVANTAGES

The various advantages of proposed system are listed below.

- Dual axis solar tracking panel can increase the power output by 40% when compared to fixed and additional 5% when compared to single axis system.
- Receiving continuous energy from the sun throughout the day more efficiently and maximize the absorption of sun rays can be achieved by this proposed system.
- The system will tend maximize the amount of power per unit area.

CHAPTER 3

SIMULATION OF GRID CONNECTED PV SYSTEM USING PV*SOL

3.1 GENERAL INTRODUCTION ABOUT SOLAR ENERGY

Solar energy is an inexhaustible, unbounded, and immense source of the energy. The power from the sun interrupted by the earth is many thousands of times larger than the current consumption rate on the earth of all other energy sources. Contrary to fossil fuels and nuclear power, it is an environmentally pure and non-polluting source of energy. The real challenge in using solar energy is economic apprehension.

3.2 SIMULATION SOFTWARES

Simulation is the perception of the important word processing system. Simulation is used for modeling and investigating the system or process performance. There is much expansion of online simulation softwares, which are categorized within the simulation tool, economic evaluation tools, photovoltaic industry-related tools, analysis and planning tools, monitoring and control tools, radiation maps. Solar design software makes it easier to automate system design.

3.2.1 TYPES OF SIMULATION SOFTWARES

In this section, table 3.1 is mentioned which gives the information about various simulation software that can be used for PV system simulation. There are many types of software available which are tabulated below according to its usage. Here in this table various simulation softwares are categorized according to their type of usage. The various types described in the table are Simulation type tools, Economic

evaluation tools, Photovoltaic industry-related tools, Analysis and planning tools, Monitoring and control tools, and solar radiation maps.

TABLE 3.1 TYPES OF PV BASED SOFTWARES

S.NO	TYPES OF SOFTWARES	NAMES OF SOFTWARES
1	Simulation type tools	INSEL and TRNSYS
2	Economic evaluation tools	HOMER, Solar Advisor Model (SAM), RET Screen, SOL invest and Energy Periscope
3	Photovoltaic industry related tools	APOS photovoltaic Stat Lab and PV cost simulation tool
4	Analysis and planning tools	String Design Tool, PV*SOL, Blue Sol, PV F-CHART, Sol metric PV Designer, DDSCAD PV, Polysun, REA System Sizing Tool, PVSYST and Solar Pro
5	Monitoring and Control Tools	Meteocontrols, SPYCE, pvspot, Autodesk ECOTECH Analysis, METEONORM
6	Solar radiation maps	Focus Solar, SolarGIS, 3TIER and PVGIS

3.2.2 PV*SOL SOFTWARE

PV*SOL is a 2-dimensional design tool for simulating the performance of a photovoltaic system. It designs PV systems with no limit on the number of arrays in 2D and includes graphic 2D and Photographic roof and ground layout. It visualizes detailed energy balance with all stage losses. It is capable of Power clipping to reduce grid export when limited. Simulation of electric vehicles in combination with PV systems can also be done in this software.

3.3 SIMULATION PROJECT OVERVIEW

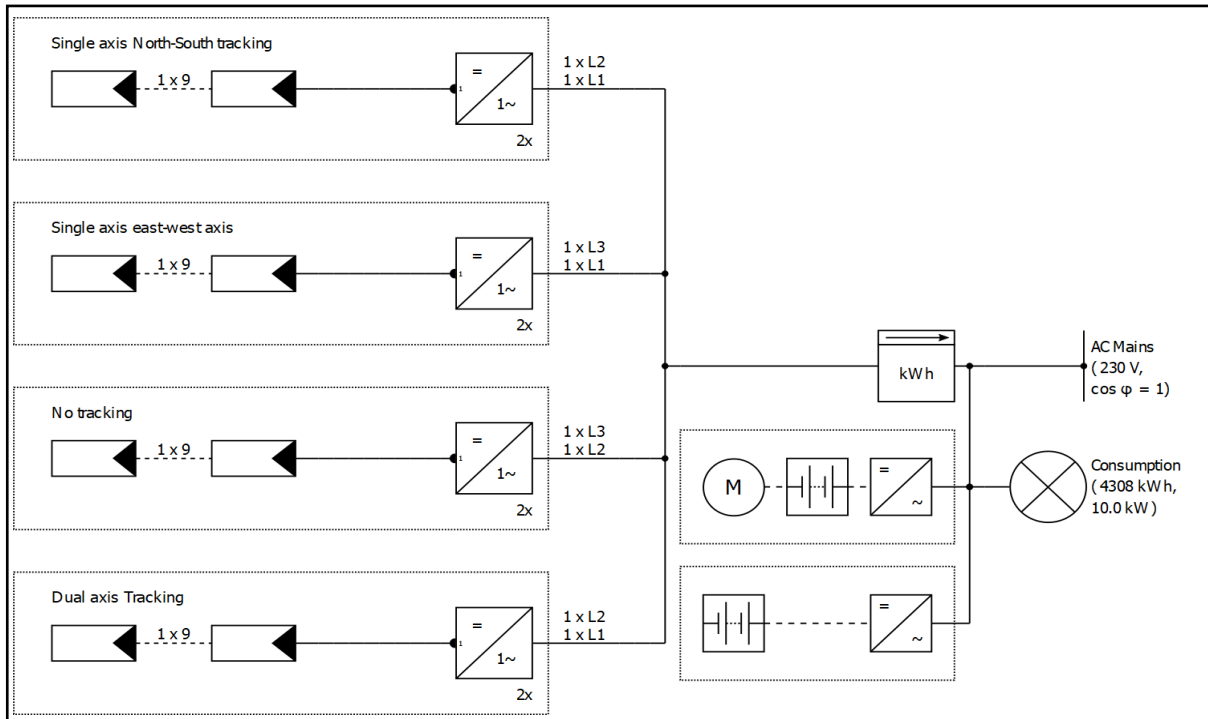


Fig 3.1 Circuit Diagram of Grid Connected PV system with Electric vehicle, Electric Battery and Electric appliances

Four various tracking systems are compared in this simulation of the project. All the four types of tracking systems are connected in the fig 3.1 circuit diagram. Overall, 72 PV modules of 200Wp-si polycrystalline, 8 inverters of 1MPP-1700W, one battery system of 2kW-AC Coupling-14.45kWh, and an Electric vehicle of 22kWh are included in this simulation project..

This is simulation of a Grid connected PV system with Electric appliances, Electric vehicle and Battery system in the location MADRAS, India. The latitude and longitude details are:

- ❖ Latitude: 13° 0' 0" and Longitude: 80° 10' 58"
- ❖ Time zone: UTC+5.5
- ❖ Annual sum of global irradiation: 1926 kWh/m²

- ❖ Annual Average Temperature: 28.2 °c
- ❖ Time steps for simulation: 1 Minute (for precise simulation)
- ❖ Power losses resulting from drop in voltage at bypass diodes: 0.5%
- ❖ Power losses resulting from mismatched yield: 2.0%
- ❖ AC Mains: Mains voltage between phase and neutral = 230 v
- ❖ No. of phases = 3 and Displacement power factor $\cos \theta = 1$

3.3.1 PV MODULES SELECTION

In many applications, strings are bound to form a module. The PV panel is the basic building block of a PV system and multiple panels can be connected together to give the desired output. For all four types of systems, the type of PV module used is 200W-si polycrystalline. The number of PV modules per tracking system is 18(3.60kW) and the installation type of PV module is also the same for all the four tracking systems i.e. Mounted roof type installation. The inclination details of the No tracking system are Inclination angle is 110, the Orientation angle is 1800, and the Azimuth angle is 00. The inclination details of a Single north-south axis tracking system are Rotation axis Inclination: 100 and Rotation angle of opening: 1600. The inclination details of the Single east-west axis tracking system are Inclination: 00 and Rotation angle of opening 1800. The inclination details of the Dual-axis tracking system are the Rotation axis Inclination 900 and Rotation angle of opening 2000.

3.3.2 INVERTERS SELECTION

The inverter or the Power conditioning unit converts DC power into AC power. The conversion from DC to AC voltage includes losses. PV*SOL determines the output power as a function of the input power. Selection of Inverters is represented in figure 3.2

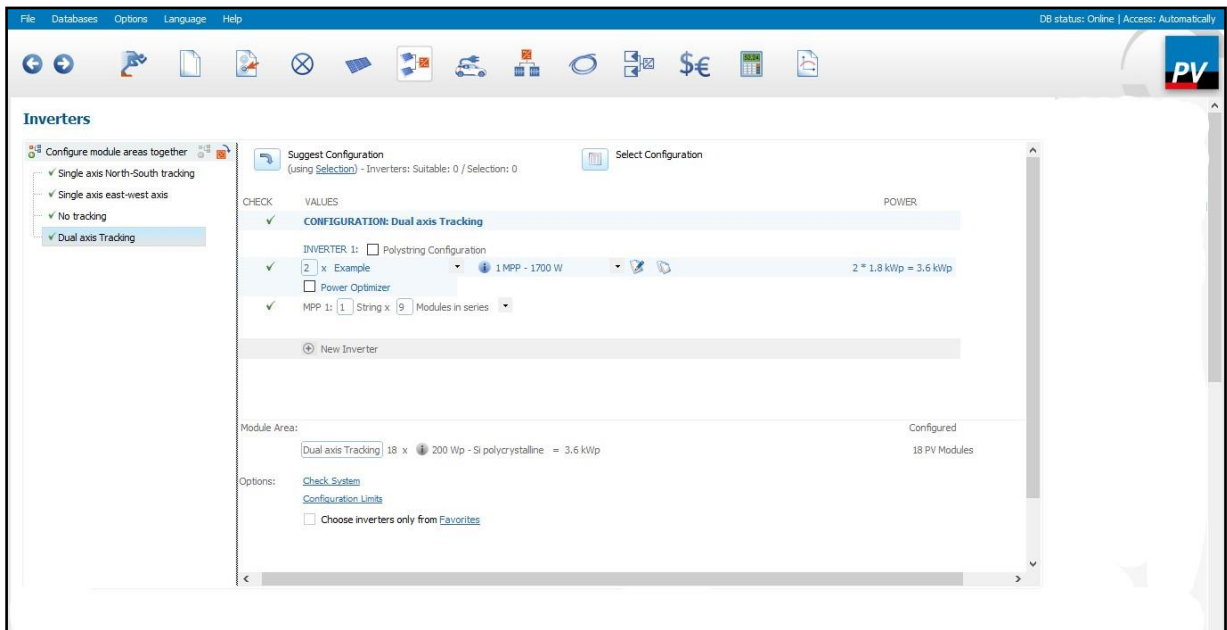


Figure 3.2 Selection of Inverter for various tracking systems

On the Inverter page, the selection of inverters are defined. A connection can be defined in three different ways:

- ❖ Manual connection
- ❖ Propose connection
- ❖ Select connection

One module surface is connected by default. To interconnect different module surfaces together, select the specified module surfaces within the tree view and click on the button.

3.3.3 CABLES SELECTION

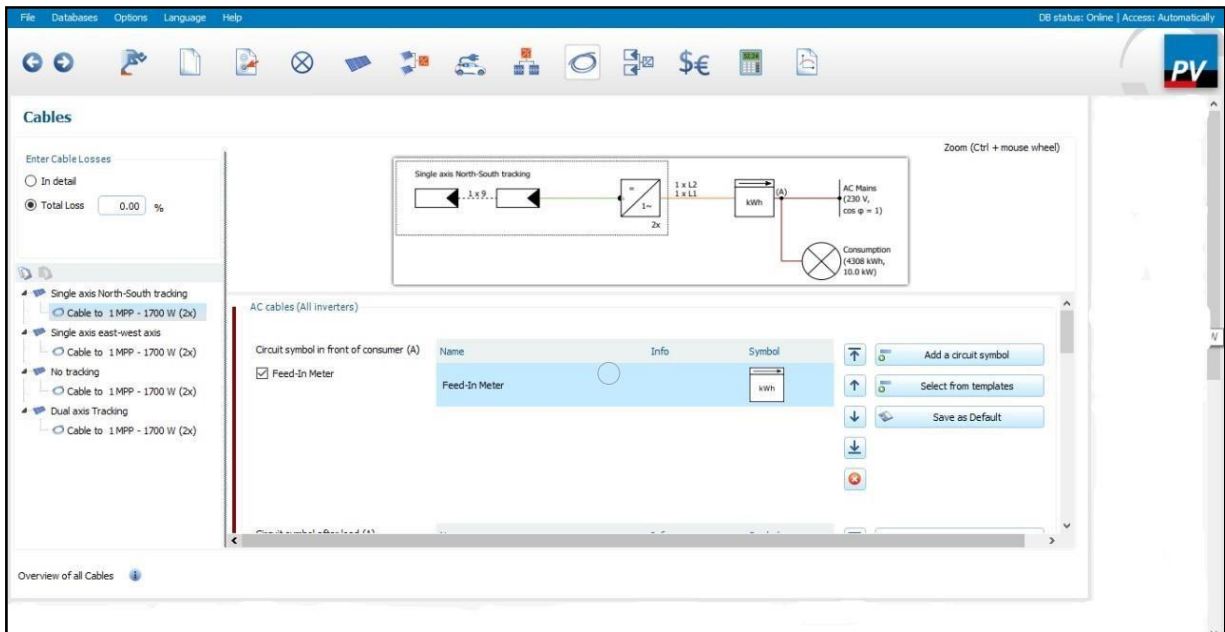


Fig 3.3 Selection of cables

The selection of cable profiles is shown in the figure 3.3 selection of cables. The cable losses of PV system are defined on the cables page. The safety devices are defined without depending on the cable losses. If total loss is selected for the input of the cable losses, the losses are used in the simulation as a lump sum. Fig 3.4 shows the selection of cable losses.

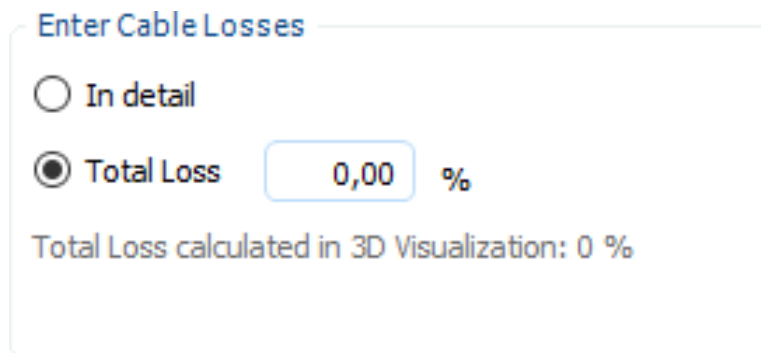


Fig 3.4 Cable losses

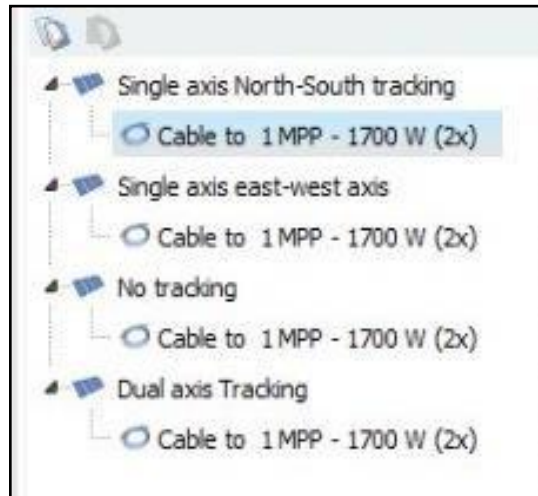


Fig 3.5 cables overview

In figure 3.5 the selection of cables for each type of tracking systems is represented. Cable losses are assumed to be zero as ideal case.

3.3.4 ELECTRIC VEHICLE SELECTION

A solar electric vehicle is an electric vehicle that runs remarkably on direct solar power. PV cells contained in the panels convert the sun's energy directly into electric energy. The battery inverter is the charging station of the vehicle. The battery system takes precedence over the mains. A typical electrical vehicle is shown in figure 3.6. All the parts are mentioned in the figure. Here the solar panel is attached at the top of the electric vehicle. The solar panel is connected to the peak power tracker next to a battery pack which is connected with motor control. This motor control is connected with the motor that has to be controlled.

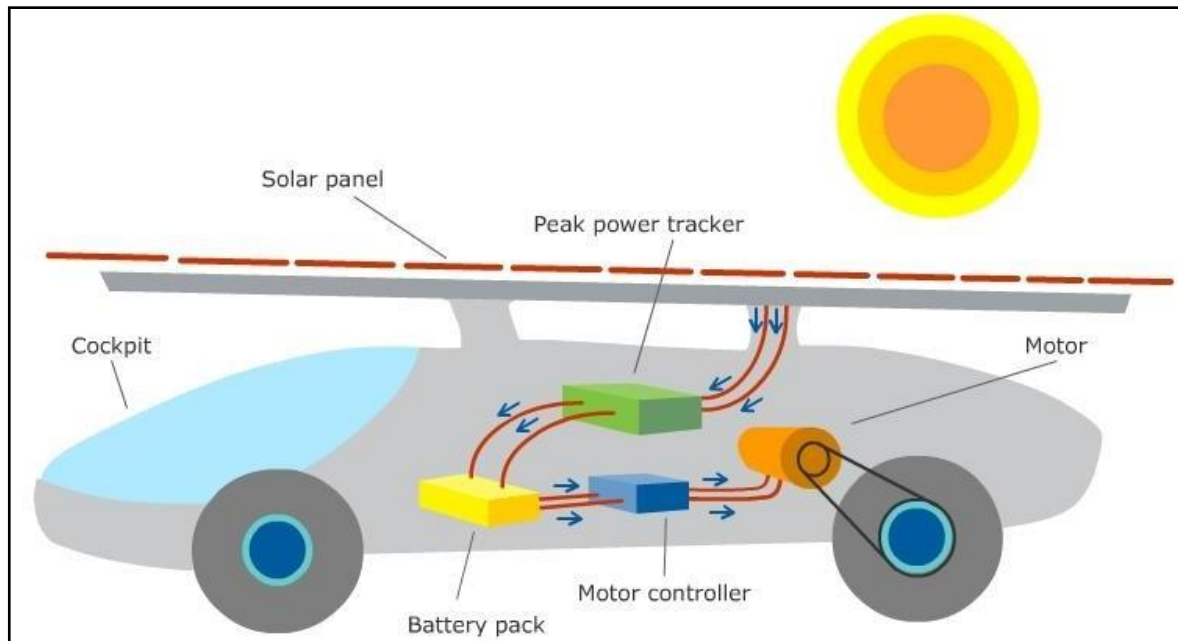


Fig 3.6 Typical electric vehicle

The screenshot shows the 'Electric Vehicles' page in a software application. The interface includes a menu bar (File, Databases, Options, Language, Help) and a toolbar with various icons. The main content area is titled 'Electric Vehicles' and contains a section for 'Electric vehicle and Charging station'. This section includes fields for 'Manufacturer' (set to 'Example'), 'Electric vehicle' (set to '22 kWh AC Typ 2 @ 3.7 kW'), and 'No. of vehicles' (set to 1). Below these fields, there are two columns of specifications: 'Electric vehicle' and 'Charging station'. The 'Electric vehicle' specifications include Range in accordance with WLTP (190 km), Battery Capacity (21.6 kWh), Consumption (input/calculated) (12.9 / 11.4 kWh/100 km), Number of seats (4), and Engine power (125 kW / 170 PS). The 'Charging station' specifications include Charging Power (3.7 kW), Charging technology (AC Typ 2), Charging mode (Standard), and Discharge for covering consumption (No). At the bottom, there is a 'Use' section with fields for 'Desired range per week' (350 km), 'No. of trips per week and per vehicle' (12 (29.2 km per journey)), and 'Mileage per year' (18250 km (2354 kWh/a)).

Figure 3.7 Selection of Electric Vehicle

Electric vehicles can be connected on the Electric Vehicles page. Various electric vehicles with different user behavior can be grouped with the number of vehicles in each group, set in addition to the opting of manufacturer and model of the vehicle. Figure 3.7 describes all the specifications of the electric vehicle selected for the simulation. The charging power of the electric vehicle is 3.7kW.

Electric vehicle	
Range in accordance with WLTP	190 km
Battery Capacity	21.6 kWh
Consumption (input/calculated)	12.9 / 11.4 kWh/100 km
Number of seats	4
Engine power	125 kW / 170 PS

Fig 3.8 Electrical details of Electric vehicle

Figure 3.8 shows the details of electric vehicle that has been selected for simulation. The range of that vehicle in accordance with Worldwide Harmonized Light Vehicle Test Procedure (WLTP) is 190km. The battery capacity of the electrical vehicle is 21.6kWh. The consumption assumed calculated is often 12.9/11.4kWh/100 km. The engine power is 125Kw/170PS.

3.3.5 ELECTRIC BATTERY SYSTEM SELECTION

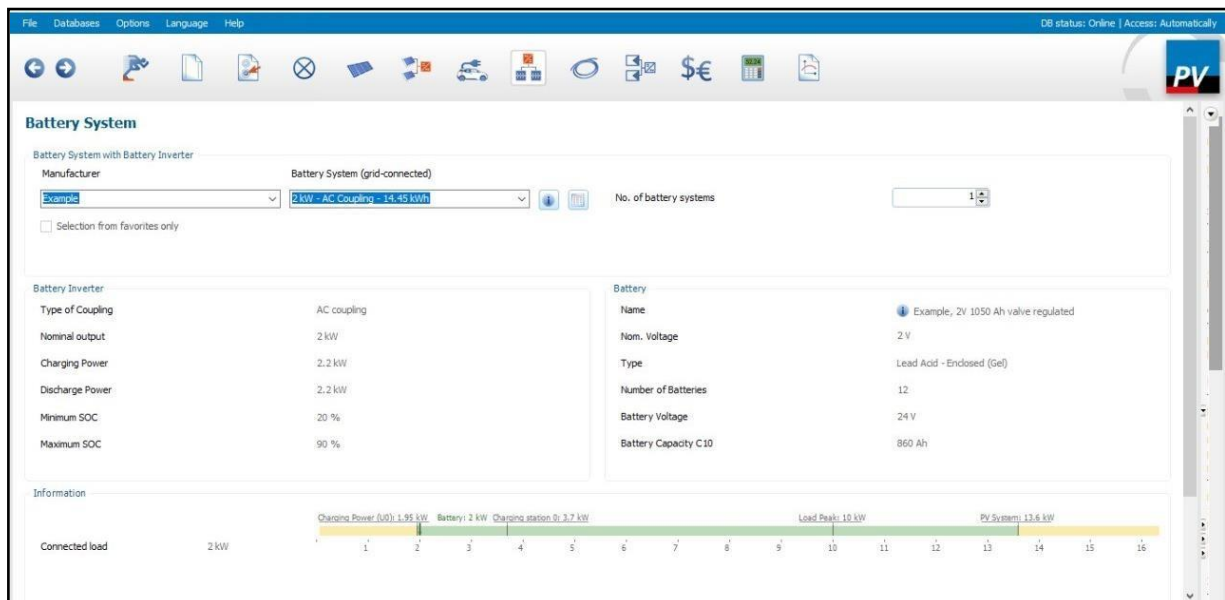


Fig 3.9 selection of electric battery system

Figure 3.9 represents all the specification details about the electric battery system. The Battery system for the simulation is chosen on the Battery system page. The navigation can be chosen for respective grid-connected PV systems. Based on the system, a PV inverter with an MPP tracker could be integrated, but these are independent devices. The battery is classified into AC- and DC-coupled types. In AC-coupled, the PV module and battery components are bound behind the DC/AC inverter. These are the most adjustable types to design, easy to modify into existing systems, and can take energy from the grid. Battery systems store the energy that comes from the PV system and release it to consumers. For certain types of battery charging, they can absorb energy from the grid. The specifications of the battery used here are 2v, 1050Ah valve-regulated battery.

3.3.6 SIMULATION ANALYSIS

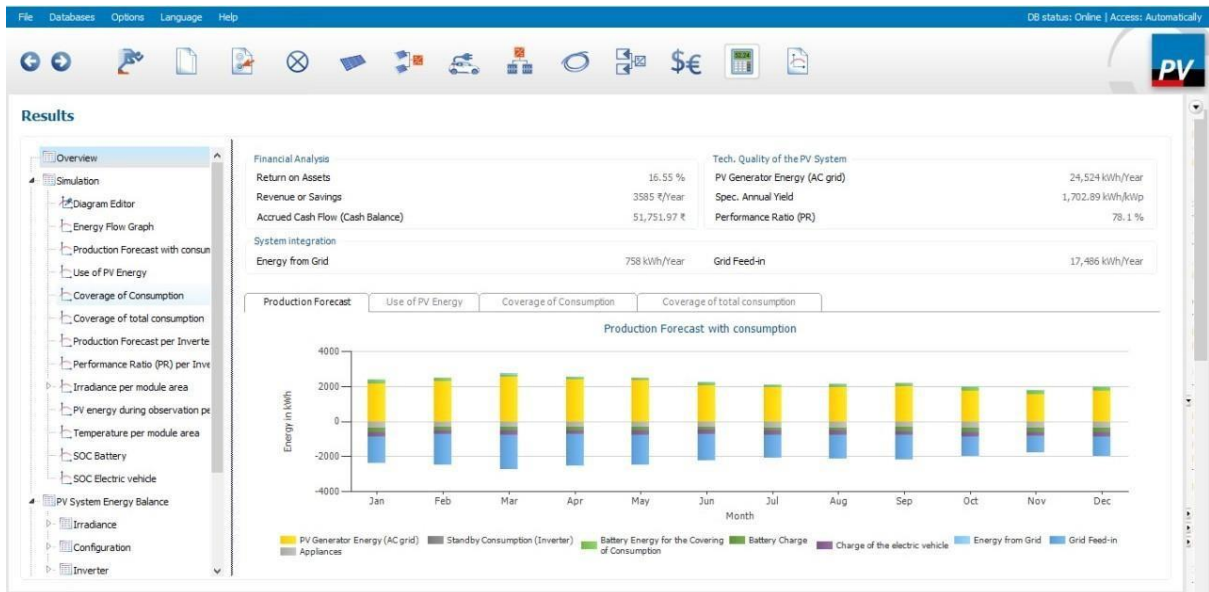


Fig 3.10 Overview of simulation results

Figure 3.10 represents overall simulation results profile at the end of simulation process. The return on the assests is expected to be 16.55%. The PV generated energy (AC Grid) is 24,524kWh/year. The Specific annual yield is 1702.89 kWh/ kWp. The Grid feed-in value is 17,486kWh/year. The energy from the Grid is 758kWh/year.

3.4 PV SOLAR SYSTEM

A photovoltaic system, also a PV system, is considered as a power grid designed to contribute consumable solar energy by using photovoltaics. It includes appointing several components, which includes solar panels to soak up and converting sunlight into electricity, a solar inverter and other electrical supplementary for a system. It uses solar tracking system to enhance the overall performance of system and includes an integrated battery. A solar battery can only enclosure the association of solar panels, the visible part of the PV system.

3.4.1 PV MODULES ANALYSIS

Table 3.2 Specifications of PV Modules

S No	Type Of Tracking	Module Type	No Of PV Modules	Installation Type	Inclination & Orientation
1.	No Tracking	200Wp – si polycrystalline module	No of PV modules: 18 (3.60 kW)	Mounted Roof	Inclination: 11 ⁰ Orientation: 180 ⁰
2.	Single North-South Axis Tracking				Inclination: 10 ⁰ Rotation angle of opening: 160 ⁰
3	Single East - West Axis Tracking				Inclination: 0 ⁰ Rotation angle: 180 ⁰
4.	Dual axis Tracking				Rotation axis Inclination: 90 ⁰ Rotation angle: 200 ⁰

Designing the PV generator is the second step within the simulation for photovoltaic systems. The electrical behavior of the photovoltaic modules is simulated from the output data of the radiation modeling. The result of the current-voltage characteristics takes place at each step within the simulation for every module. The characteristic curves of the modules are overlaid in series or parallel.

In table 3.2, all the specifications of the PV module are tabulated. For all the four types of tracking the type of PV module used is 200W-si polycrystalline. The number of PV modules per tracking system is 18(3.60kW) and the installation type of PV module is also the same for all the four tracking systems i.e. Mounted roof type installation. The inclination details of the No tracking system are Inclination angle is 11° , the Orientation angle is 180° , and the Azimuth angle is 0° . The inclination details of a Single north-south axis tracking system are Rotation axis Inclination: 10° and Rotation angle of opening: 160° . The inclination details of the Single east-west axis tracking system are Inclination: 0° and Rotation angle of opening 180° . The inclination details of the Dual-axis tracking system are the Rotation axis Inclination 90° and the Rotation angle of opening 200° .

The PV system generator output is 14.4 kW. The average performance ratio of the PV system is 78.1%. The PV generator AC GRID energy is 24,524kWh/year. The own power consumption is 28.7%. The grid feed-in value is 17,486kWh/year. The specific annual yield as per the assumed case is approximately 1,702.89kWh/kWp. The battery charge includes an amount of 2317kWh/year.

3.4.2 IRRADIANCE PER MODULE AREA

Solar irradiance is defined as the power per unit area obtained from the Sun in electromagnetic radiation and is measured in the wavelength range. It is measured in watt per square meter in SI units and is often separated during that time period. This integrated solar irradiance is also called solar exposure or solar insolation.

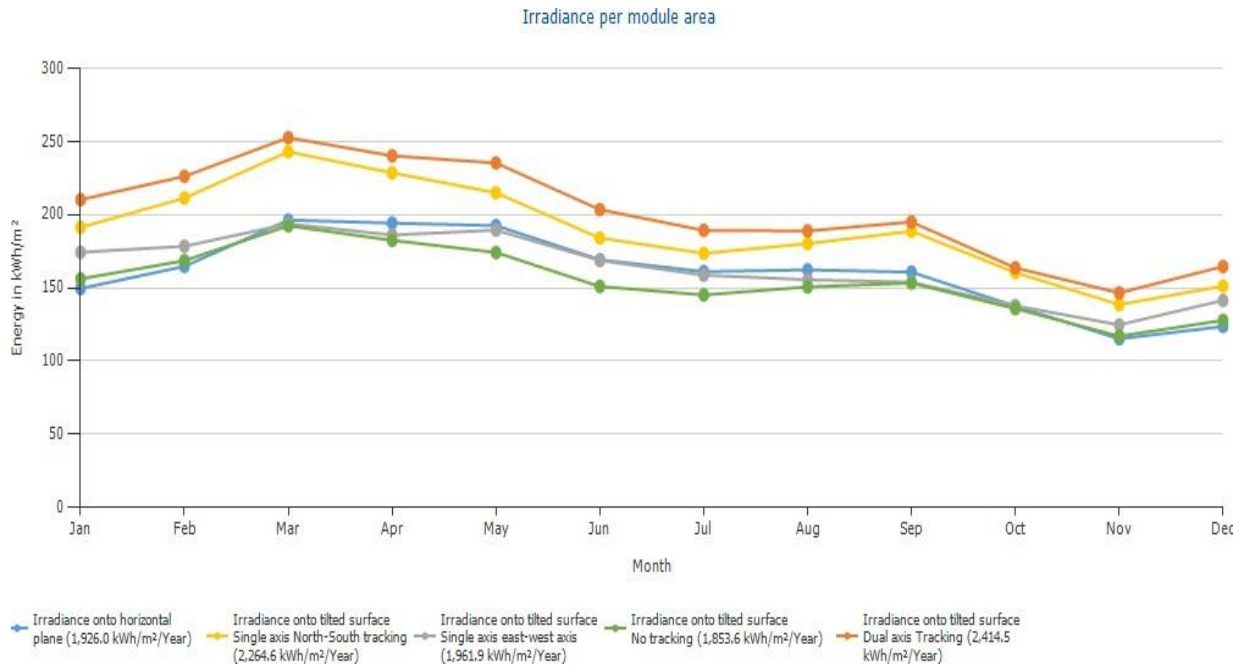


Fig 3.11 Irradiance per module area

In this figure 3.11 the graph is plotted between each month of the year and energy in kWh/m². The top slope in the graph with red color represents irradiance onto tilted surface in Dual axis tracking. The yellow color slope indicates the irradiance of single north-south axis tracking system. The grey color slope indicates the irradiance of single east-west axis tracking system. The blue color slope indicates horizontal plane irradiance. The annual average irradiance per module of different tracking systems are 1853.57kWh/m² for No tracking system, 2264.9kWh/m² for Single north - south axis tracking system, 1961.91kWh/m² for Single east - west axis tracking system and 2414.1kWh/m² for Dual axis tracking system. Various irradiance per module values per each month for various tracking systems included in the simulation. For all the months values are tabulated in the table 3.3.

Table 3.3 Global Irradiance per module

S.No	Months	No Tracking	Single East-West Tracking	Single North-South Tracking	Dual Axis Tracking
1.	January	156.1	174.2	191.2	210.1
2.	February	168.5	178.3	211.2	226
3.	March	192.3	192.2	242.8	252.4
4.	April	182.3	186	228.4	240
5.	May	174.1	189.3	214.8	235.1
6.	June	150.9	168.7	183.9	203.3
7.	July	145.1	158.6	173.5	189.2
8.	August	150.6	155.5	180.1	188.8
9.	September	153.2	153.2	188.6	194.9
10.	October	135.8	137.7	160.4	163.6
11.	November	117	124.7	138.5	146.5
12.	December	127.8	141.4	151.2	164.5

The highest irradiance value in the dual-axis tracking system was recorded as 252.4kWh/m² in the month of March. However, the irradiance values of dual-axis tracking system are more when compared to other available tracking systems.

Table 3.4 Results per module area

SNO	Type of tracking	PV generator output	PV generator energy (AC grid)	Spec. Annual Yield	Performance ratio
1.	No tracking	3.6 kWp	5391.5 kWh/year	1497.6 kWh/kWp	77.5%
2.	Single north – south axis tracking	3.6 kWp	6516.9 kWh/year	1810.2 kWh/kWp	78.3%
3.	Single east – west axis tracking	3.6 kWp	5691.3 kWh/year	1580.9 kWh/kWp	77.8%
4.	Dual axis tracking	3.6 kWp	6924.1 kWh/year	1923.4 kWh/kWp	78.7%

In the table 3.4 the various factors like PV generated output, PV generated energy (AC Grid) values, and Specific annual yield and performance ratio were tabulated. The performance ratio of No tracking system is 77.5%, for Single north-south axis tracking is 78.3%, for Single east-west axis tracking is 77.8% and for dual axis solar tracking system is 78.7% which is highest of all the other compared tracking systems.

3.4.3 Analysis of PV Energy

The energy related with PV system is analyzed in this section. The following table 3.4 represents PV energy values in the simulation output. The DC PV energy in No

tracking system is 5752.56kWh, in Single north – south axis Tracking is 6956.29 kWh, in Single east – west axis Tracking is 6069.69 kWh and in Dual axis Tracking is 7390.15 kWh. This table shows that the PV energy of dual axis tracking system is highest among all the other values.

Table 3.5 PV Energy analysis

SNO	Type of tracking	Rated PV Energy	PV Energy (DC)
1.	No Tracking	6677.68 kWh	5752.56 kWh
2.	Single north – south axis Tracking	8158.41 kWh	6956.29 kWh
3.	Single east – west axis Tracking	7068.98 kWh	6069.69 kWh
4.	Dual axis Tracking	8698.49 kWh	7390.15 kWh

The rated PV energy values are also tabulated in the table 3.5. The rated PV energy of No tracking system is 6677.68kWh, Single north – south axis tracking system is 8158.41kWh, Single east – west axis tracking system is 7068.98kWh and dual axis tracking system is 8698.49 kWh. Here also the rated PV energy value of dual axis solar tracking system is highest when compared to all other tracking systems.

3.5 ENERGY FLOW OF SYSTEM

Energy Flow Diagrams are used to represent energy transformation visually and quantitatively. Figure 3.12 represents the energy flow of the system designed in simulation. The yellow color represents energy flow from PV generator to grid,

consumer, battery, and electrical vehicle. The purple color indicates energy flow from a car battery to the consumer. The blue color indicates energy flow from the grid to an electric vehicle, electric battery, and consumer end. The green color indicates energy flow from electric battery to electric vehicle and consumer. The energy generated at the PV system is 24,524Kw. The energy flow from the PV system to the Electric battery is 2,317 kW, to Electric vehicle is 2,895 kW, to the consumer is 1830 kW and to Grid is 17,486 kW. The energy at the Electric battery system is 1,799 kW. The energy flow from the battery to the electric vehicle is 2kW and to the consumer are 1,797 kW.

Energy Flow Graph

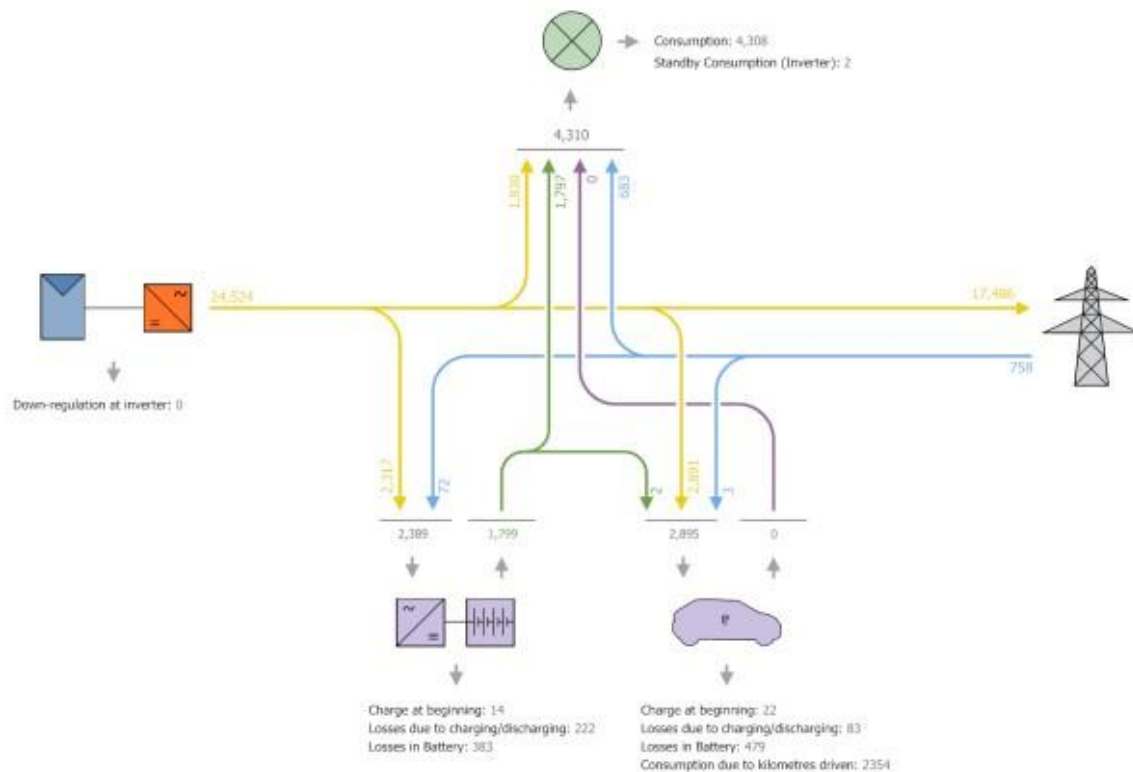


Fig 3.12 Energy Flow Diagram

The energy flow from the Grid to electric vehicle is 3 kW and to Electric battery system is 72 kW. The energy cannot flow from electric vehicle to other factors so it is zero practically. The total energy sent to consumer end is 4,310 kW. The standby

consumption of inverter is 2kW. All the energy flow values are mentioned in the energy flow diagram in detail.

3.6 INVERTER ANALYSIS

In this section outputs related to the inverter like performance ratio are discussed.

3.6.1 PERFORMANCE RATIO

The performance ratio is described as the ratio of measured output to expected output for a given period depending upon the system name-plate rating index. Ratio analysis collates the data from financial statements to reveal insights of profitability, liquidity, operational efficiency, and solvency. The main purposes of performance monitoring of PV are:

- Identifying performance trends in an individual system
- localizing potential faults in system
- comparing PV system performance to design expectations
- comparing PV systems of various configurations
- comparing PV systems at various locations

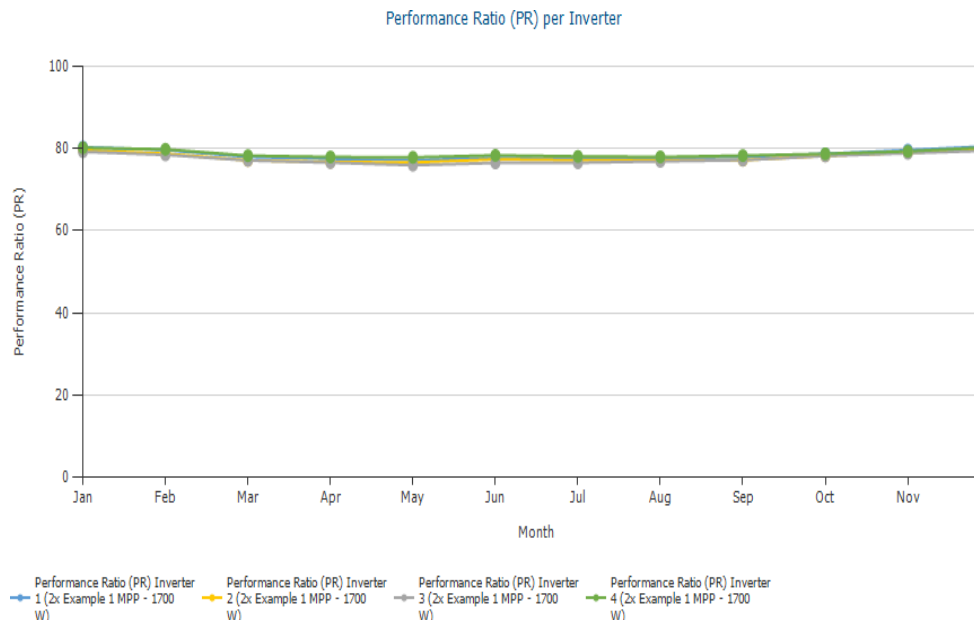


Fig 3.13 Graph representing Performance Ratio of Inverter

Table 3.6 Performance ratio values of Dual axis tracking system

Month	Dual-axis tracking performance ratio
January	80.2
February	79.8
March	78.2
April	77.9
May	77.8
June	78.3
July	78.1
August	77.9
September	78.2
October	78.7
November	79.3
December	80.1

In the fig 3.13 graph, the grey color represents the performance ratio of the inverter of no tracking system and the green color represents the performance ratio slope of the inverter of the dual-axis tracking system. The blue color represents the performance ratio slope of the inverter in single north-south axis tracking which has similar values with the performance ratio of inverter in single east-south axis tracking represented by the yellow color in the graph. Hence both lie on the same line and can't be seen clearly in the graph. Here the x-axis of the graph is each month of the year and the y-axis of the graph is the performance ratio in values. From the graph, we can clearly say that the slope of performance ratio of the dual-axis is high when compared to slopes of the other tracking systems. The performance ratio values of the dual-axis tracking system for all months of a year are tabulated in the table 3.6.

3.7 ELECTRIC BATTERY SYSTEM ANALYSIS

In this section the State of Charge of the battery system is discussed.

3.7.1 SOC OF BATTERY

State of Charge (SOC) is defined as the level of charge of a battery with respect to its capacity. Its units are percentages. The other form of the measure is the depth of discharge. SOC is used while describing the current state of a battery.

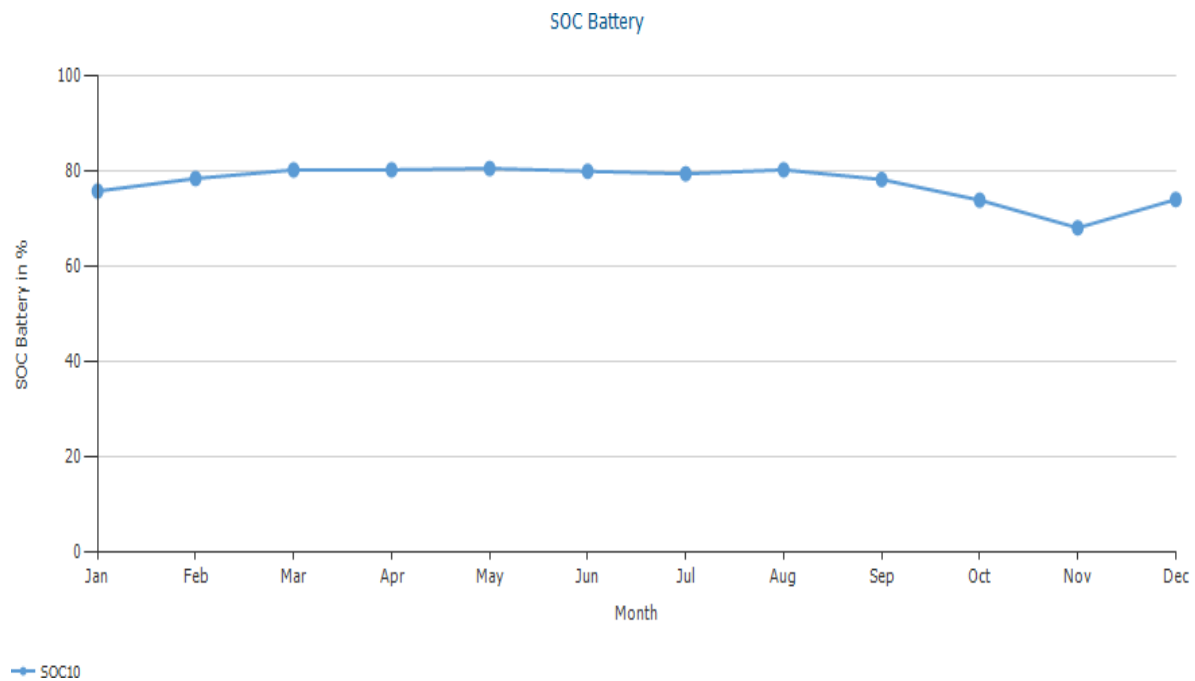


Fig 3.14 SOC of battery

As we can see, SOC is not measured directly. In a few techniques, the battery tries to get charge and discharge at the same rate such as Coulomb-counting. This gives the exact estimation of battery SOC. SOC of electric battery is termed as the ratio of its current capacity to the nominal capacity. In figure 3.14 the graph represents the state of charge of the battery in each month in a year or the SOC slope of the battery system throughout the year. The x-axis is each month of the year and the y-axis is SOC of battery in %. The highest percent recorded was 80.6% in May. The lowest percent recorded was 68.2% in November. From the graph, we can understand that

the energy obtained from the PV module can keep the battery charges 80% on average throughout the year.

3.8 LOADS

An electrical load is an electrical component or portion of a circuit that consumes electrical power, like electrical appliances and lights inside the house. The term may additionally confer with the power consumed by a circuit. this can be in opposition to a power source, like an electric battery or generator, which produces power. If an electrical circuit has an output port, a pair of terminals that produces an electrical signal, the circuit connected to the present terminal is that the load. Mains power outlets provide a simple example: they provide power at constant voltage, with electrical appliances connected to the facility circuit collectively making up the load.

3.8.1 HOUSEHOLD LOAD FEED IN DATA SPECIFICATIONS

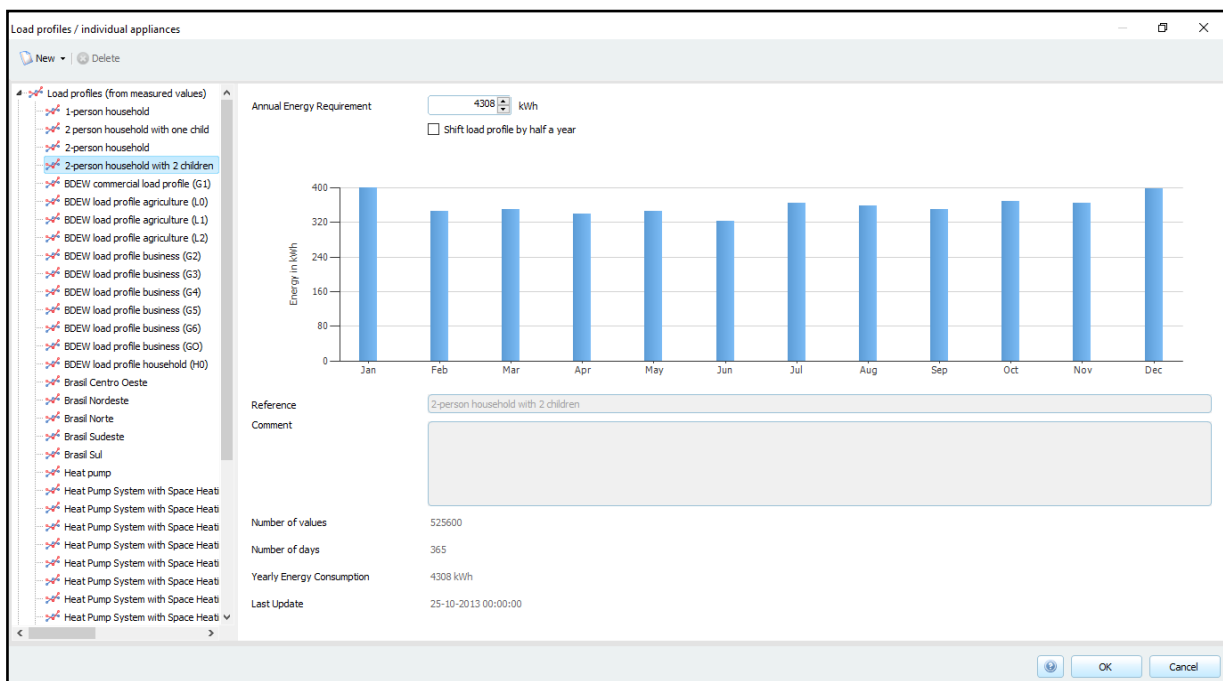


Fig 3.15 Load profiles

Consumption details to be assumed are 2 person household with 2 children. The assumed consumption is 4308 kWh (approximate) per year. Various appliances are available like Load profiles / Individual appliances, Monthly/annual consumption for net metering, and Surplus consumption. The selecting details and options are shown in detail in figure 3.15.

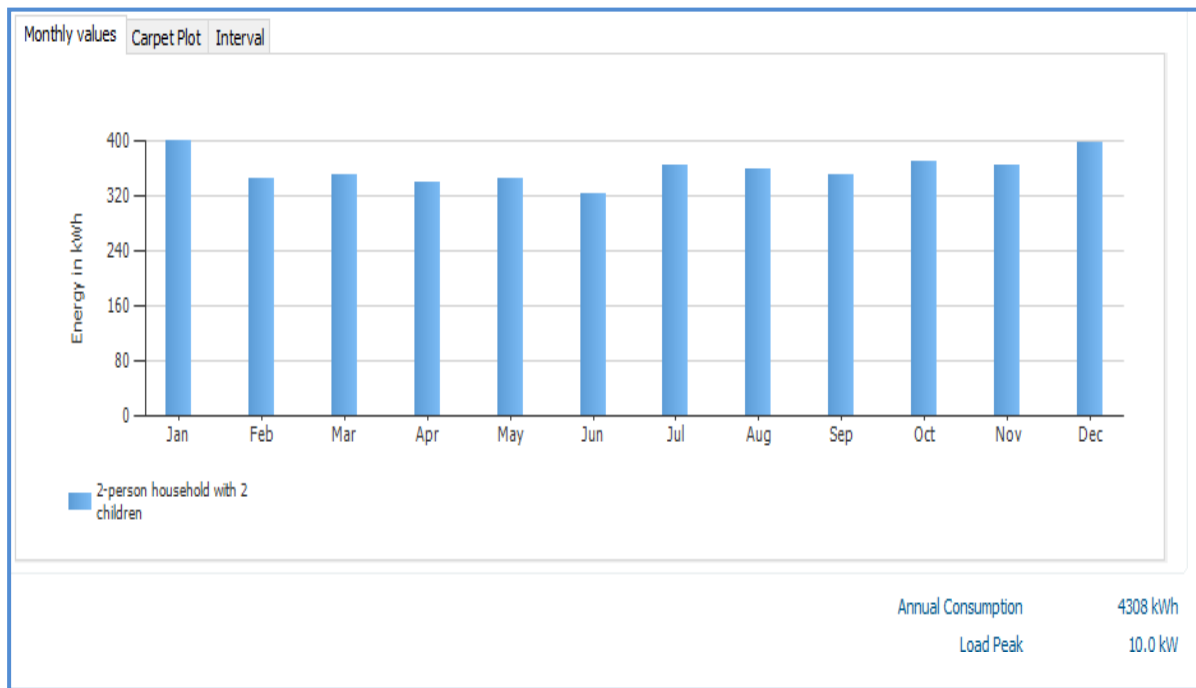


Fig 3.16 Graph of Monthly consumption

The figure 3.16 gives monthly information of energy consumed by various appliances for assumed consumption case of 2 person household with 2 children. The analysis of monthly values of consumption is plotted in the graph and mentioned in the below table. The x-axis represents each month and y-axis represents energy consumed per each month in kWh. The load peak in this case is 10 kW. The resolution of the data is 1 Minute. The values are imported in table represented in the figure 3.17, which are used for the simulation.

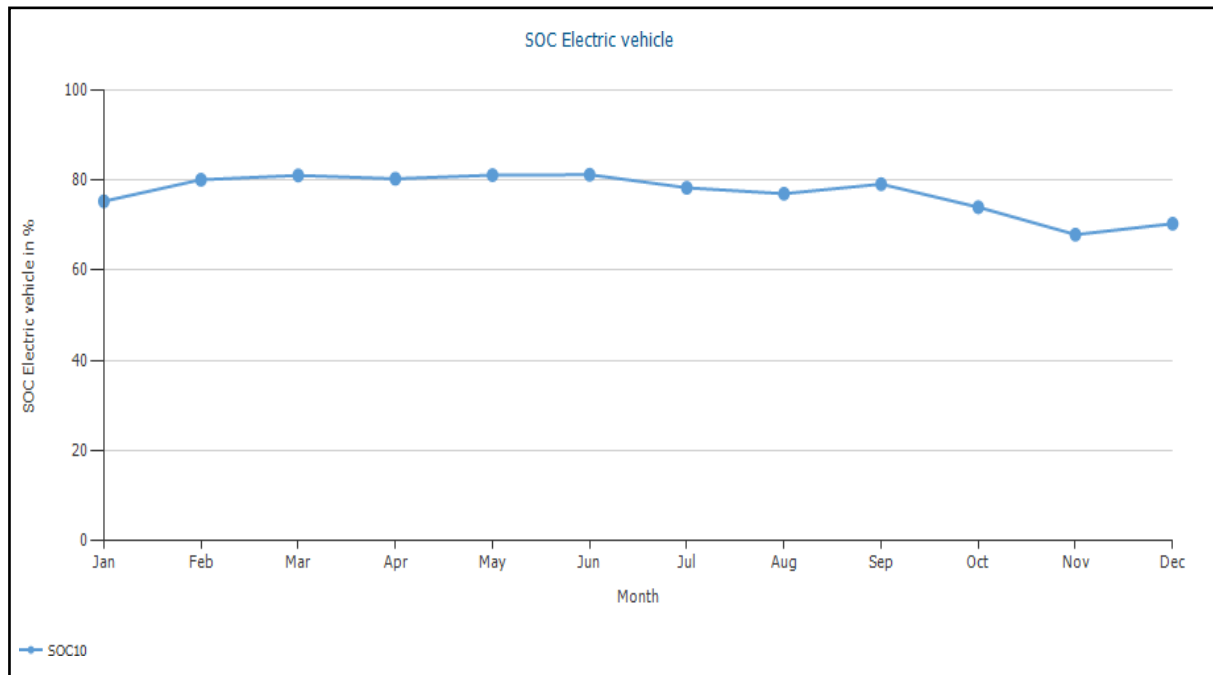
S.NO	Month	Energy Consumed In kWh
1.	January	400
2.	February	345.9
3.	March	350.1
4.	April	340.1
5.	May	344.6
6.	June	323.4
7.	July	365.1
8.	August	358.3
9.	September	349.5
10.	October	369.2
11.	November	364
12.	December	398.1

Fig 3.17 Monthly consumption data

3.8.2 ELECTRIC VEHICLE - PART OF LOAD - SOC OF ELECTRIC VEHICLE

Electric Vehicle chargers are getting more efficient, smarter, and faster with every generation. The latest DC fast chargers can know the EV battery's state of charge because it is plugged in and charging. In a battery electric vehicle, hybrid vehicle or plug-in hybrid electric vehicle, SOC for the battery pack is that the equivalent of a fuel indicator. It is important to mention that state of charge, presented as a gauge, or

perceptual value at any vehicle dashboard, especially in plug-in hybrid vehicles, may not be representative of a real level of charge.



3.18 SOC of Electric vehicle

In the above graph in figure 3.18 the SOC values of electrical vehicle are plotted and slope is drawn. The x-axis parameter is each month of the year and y-axis is SOC in %. The highest percentage recorded was 81.2% in the month of June. This graph shows the charge of electric vehicle in each month maintained by the energy from PV module.

3.9 ENERGY FORECASTING

Energy forecasting is forecasting the demand for electricity and other renewable energy sources. Forecasting is often expected price value and probabilistic forecasting.

3.9.1 PRODUCTION FORECAST WITH CONSUMPTION

Forecasting is to maintain how to separate their budgets or plan for various expenses for an upcoming period of time. This is based on the represented projects for the goods and services they offer.

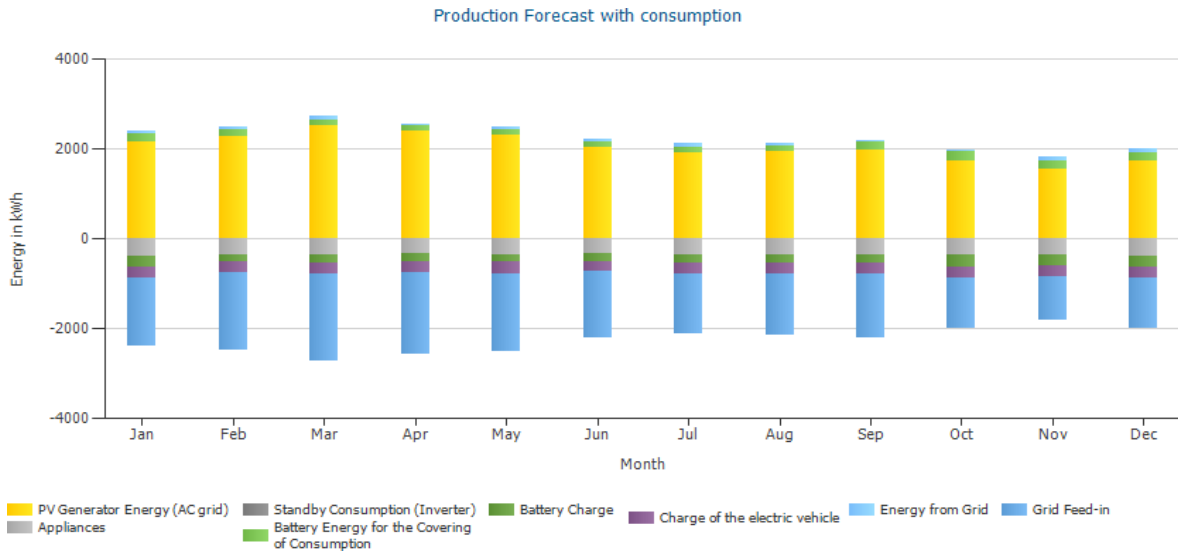


Fig 3.19 Production Forecast with consumption

The graph in figure 3.19 shows an analysis of the production forecast with consumption all over the year. The x-axis of the plotted graph is each month and the y-axis is energy in kWh. The yellow color indicates PV Generator Energy (AC Grid). The pale blue indicates Energy from the grid. The dark blue indicates Grid feed-in energy. The dark grey color indicates standby consumption (Inverter). The light grey color indicates energy consumed by the appliances. The purple color indicates the charge of the electric vehicle. The dark green indicates the battery charge. The light green indicates battery energy for the covering of consumption. In table 3.7, the energy generation and consumption for January month are shown. PV Generator Energy (AC Grid) is 2152.5 kWh, Battery Energy For The Covering Of Consumption is 177.9kWh and Energy From Grid is 64.6kWh. The consumption of Appliances is 399.7 kWh, Battery Charge is 225.9 kWh, Charge Of Electric vehicles is 241.4 kWh,

and Grid Feed-In is 1527.8 kWh. Similarly, all the values of energy consumed and energy generated can be recorded and tabulated for all the months.

Table 3.7 Production Forecast With Consumption

SNO	ENERGY	VALUES
1.	PV Generator Energy (AC Grid)	2152.5 kWh
2.	Battery Energy For The Covering Of Consumption	177.9kWh
3.	Energy From Grid	64.6kWh
4.	Appliances	-399.7 kWh
5.	Battery Charge	-225.9 kWh
6.	Charge Of Electric Vehicle	-241.4 kWh
7.	Grid Feed In	-1527.8 kWh

3.9.2 USE OF PV ENERGY

The graph in Fig 3.20 depicts how the energy generated is used by various consumption factors. The yellow color represents PV energy (ac grid). The purple color represents the charge of the electric vehicle. The green color represents the battery charge. The blue color represents grid feed-in and the grey color represents direct own use. The x-axis of the graph is each month and the y-axis of the graph is energy in kWh.

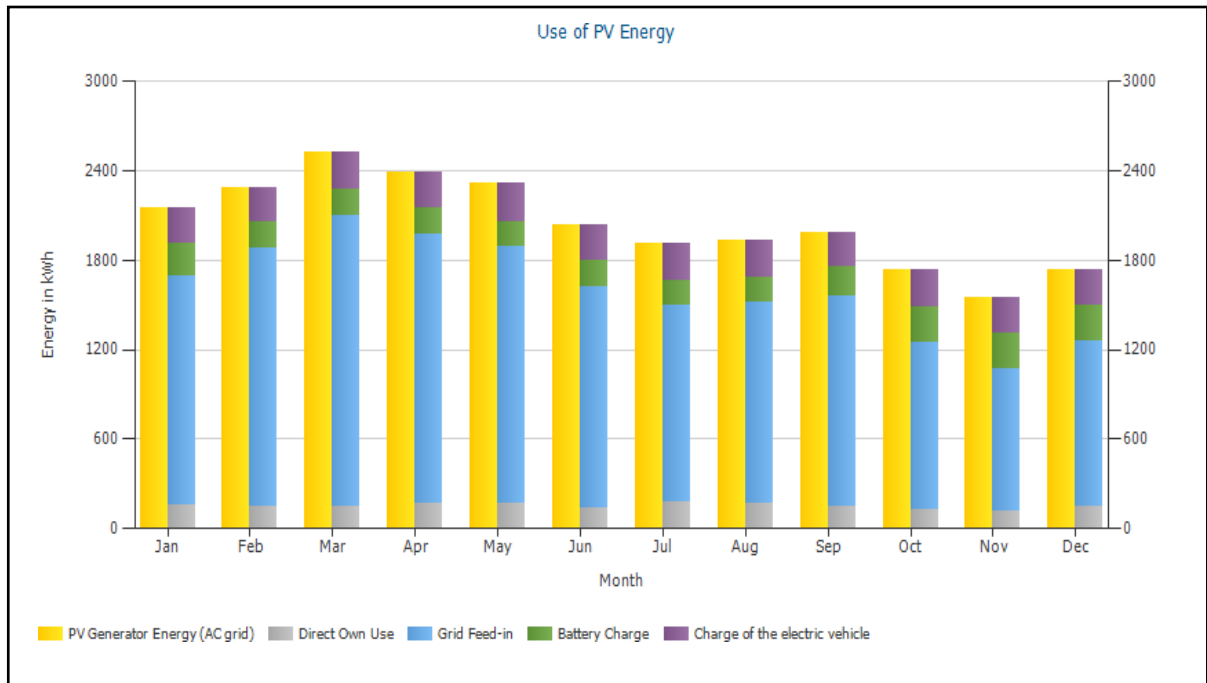


Fig 3.20 Use of PV energy

For the month of January, the values of energy are tabulated below in the table 3.8.

Table 3.8 Usage of PV Energy

January	PV generator energy	2152.5 kWh
	Charge of electric vehicle	-241.4 kWh
	Battery charge	--220.5 kWh
	Grid feed-in	-1527.8 kWh
	Direct own use	-162.8 kWh

The table shows values of generated energy and consumed energy. The generated energy values are given in positive whereas the consumed energy values are given in negative. Similar tabulation can be done for all the other months. The highest value of

PV generation is recorded in the month of March with a value 2519.1kWh which is shown in the graph.

3.9.3 COVERAGE OF CONSUMPTION

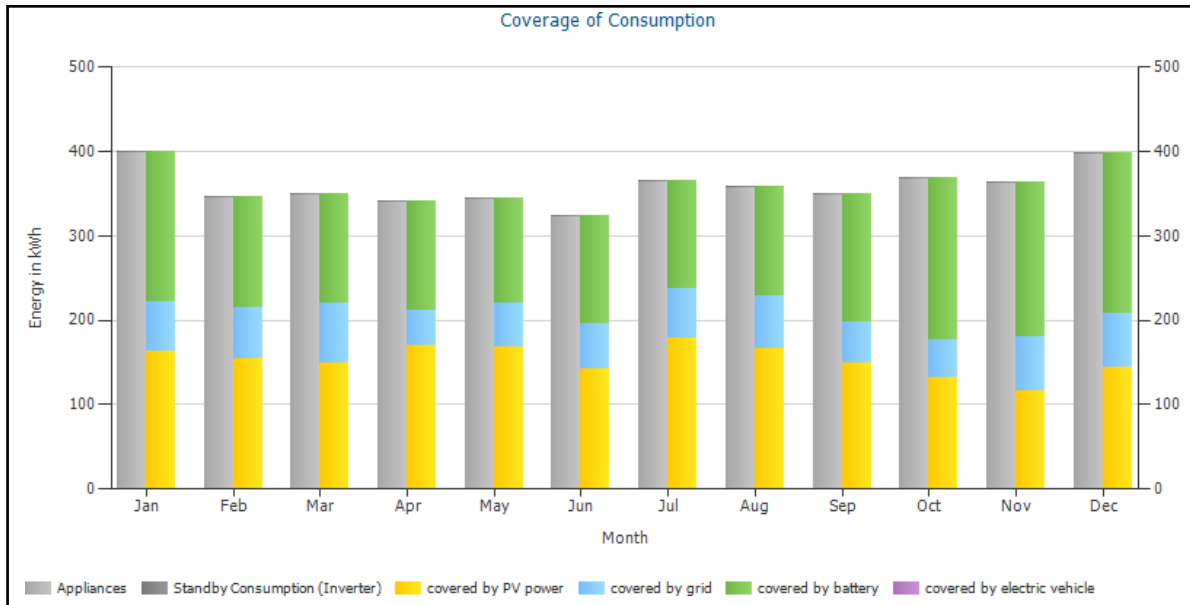


Fig 3.21 Consumption coverage

S.NO	Month	Coverage of consumption	Energy in kWh
1.	January	Appliances	399.7 kWh
2.		Covered by battery	177.9 kWh
3.		Covered by grid	59.3 kWh
4.		Covered by PV power	162.8 kWh

Table 3.9 Coverage consumption

In figure 3.21, the graph represents how consumption is covered among all the included factors. The x-axis of the graph is each month in a year and the y-axis of the graph is the energy consumed in kWh. The light grey color indicates appliances and the dark grey color indicates standby consumption values. Since standby consumption values are negligible they are not visualized in the graph. The yellow color indicates consumption covered by PV power. The blue color indicates energy consumed by the grid. The green color indicates energy consumed by the battery. The purple color indicates the energy consumed by the electric vehicle. Below table 3.9 shows the values of energy consumed in January in detail. The energy covered by Appliances is 399.7kWh, the battery is 177.9 kWh, the grid is 59.3 kWh and by PV power is 162.8 kWh. The energy values of other months also can be tabulated.

3.9.4 TOTAL COVERAGE CONSUMPTION

In this section, the total consumption and how the energy generated is divided into various consumptions were analyzed. The graph in figure 3.22 shows the coverage of total consumption. The light grey implies appliances. The dark green implies battery charge by Grid. The purple color indicates the charge of the electric vehicle. The yellow color indicates energy produced by the PV system. The blue color indicates energy produced by the grid. Light green indicates energy drawn from the battery. Light purple color indicates energy taken from the electric vehicle. Since it is very negligible it is not visible in the graph. We can observe that all the light colors indicate energy generated by each part and dark colors indicate energy consumed by them. The x-axis of the graph is each month of year and the y-axis is the energy in kWh. The standby consumption is also neglected because of its minor values. The below table shows the values recorded for the month of January. Similarly, tables can be drawn from the values of other months. In the table 3.10, the values of coverage of total consumption are tabulated. The energy consumed by appliances is 399.7 kWh, by battery is 177.9 kWh, by the Grid is 59.3 kWh, and by PV power is 162.8 kWh. The

energy covered by Battery charge (Grid) is 5.3 kWh and by Battery charge (System) is 5.3 kWh. All the values for other months can also be tabulated.

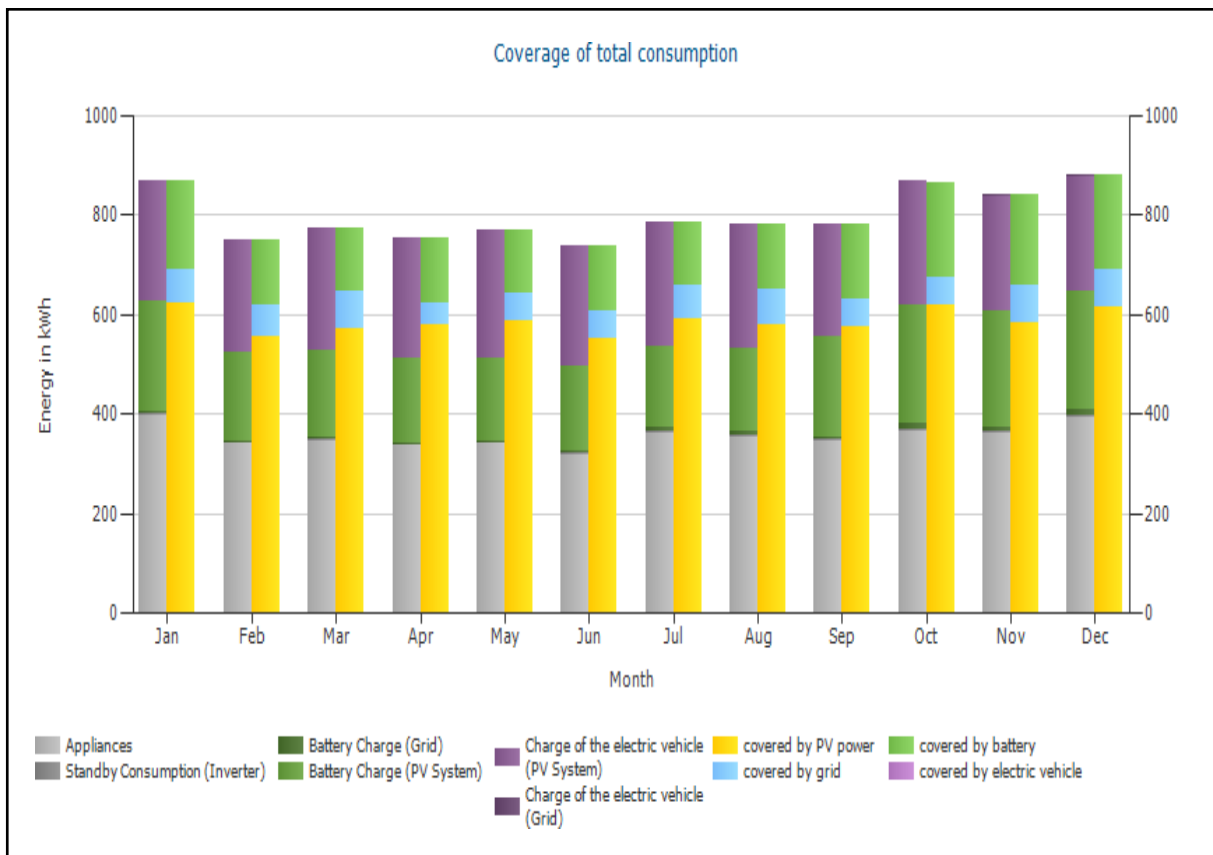


Fig 3.22 Coverage of total consumption

Table 3.10 Coverage of total consumption

S.NO	Month	Coverage of consumption	Energy in kWh
1.	January	Appliances	399.7 kWh
2.		Covered by battery	177.9 kWh
3.		Covered by grid	59.3 kWh
4.		Covered by PV power	162.8 kWh
5.		Battery charge (Grid)	5.3 kWh
6.		Battery charge (System)	220.5 kWh
7.		Charge of electric vehicle	241.4 kWh

3.10 CONCLUSION FROM THE SIMULATION

From the above simulation output and all the graphs obtained, the following points are concluded:

- Simulation of GRID connected PV system with electrical appliances, battery and electric vehicle is analyzed and outputs are noted.
- The performance ratio of Dual axis solar tracking system is 1.1 times more when compared to all other types of tracking systems.
- The Global Irradiance of Dual axis solar tracking system is 1.3 times more when compared to all other types of tracking systems.

CHAPTER 4

HARDWARE DESCRIPTION

4.1 CIRCUIT DIAGRAM OF THE PROPOSED SYSTEM

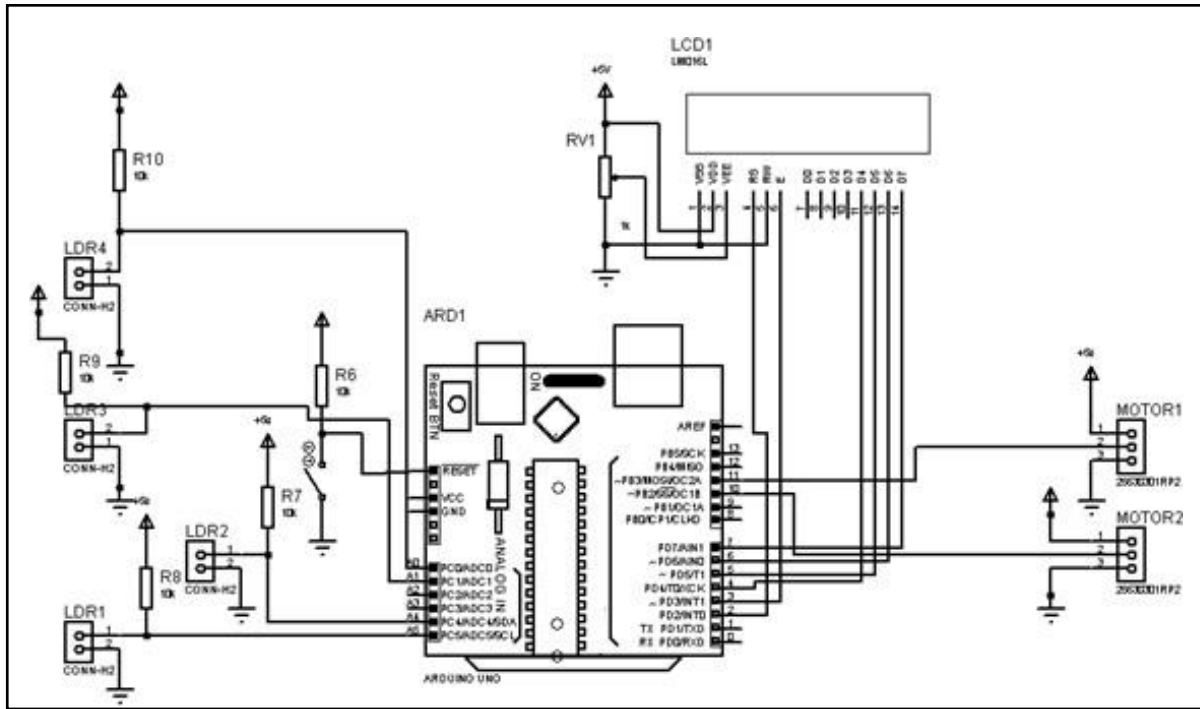


Fig 4.1 Circuit Diagram of proposed system

Figure 4.1 explains the circuit diagram of the proposed system. Here four LDRs namely LDR1, LDR2, LDR3, and LDR4 are connected to the pins A5, A4, A1, and A0 of the Analog section in the Arduino respectively. The resistors R8, R7, R9, and R10 are connected to LDR1, LDR2, LDR3, and LDR4 respectively. These four resistors are connected with the power supply. A switch with one side connected to the ground and the other side connected to resistor R6 with power supply is connected to the RESET pin connection in the Arduino. Besides the reset pin, the RESET button is arranged. The VSS and RVV pins in the LCD are connected to the ground along with the resistor RV1, VDD pin is connected to the power supply along with the RV1. VEE pin is directly connected to the resistor RV1. The RS pin, E pin of LCD are connected to the PD2/INT0 pin and PD2/INT1 pin of the Arduino respectively. The other pins D4,

D5, D6 and D7 are connected to P4, PD5, PD5 and PD6 pins of Arduino respectively. The pins PB2 and PB3 (10 & 11) of Arduino are connected to second pin of the servo motors M2 and M1 respectively. The pin3 in both the motors are grounded. The pin 1 in both motors is connected with power supply.

4.2 POWER SUPPLY

In this section block diagram and circuit diagram of Power supply are discussed in detail.

4.2.1 BLOCK DIAGRAM OF POWER SUPPLY

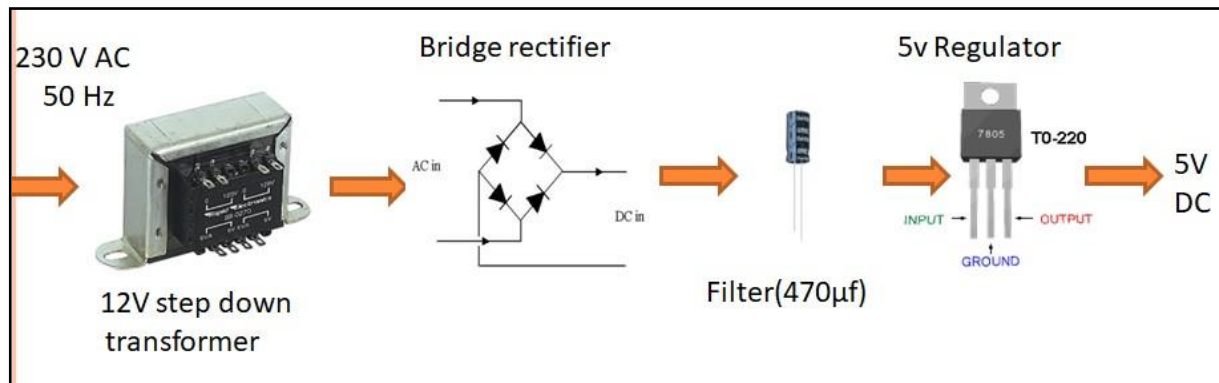


Fig 4.2 Block diagram of Power Supply

Figure 4.2 represents the block diagram and figure 4.3 represents the circuit diagram of power supply connections involved in the system. They both represent 230V AC 50 HZ supply, 12V step down transformer, Bridge rectifier, Filter, and Regulator. Below figure 4.3 represents its circuit diagram. The 230V AC supply is given to a 12V step-down transformer. The transformer steps down the voltage into 12V and supplies it to the bridge rectifier. The bridge rectifier consists of 4 diodes forming a Bridge Rectifier that delivers pulsating dc. This bridge rectifier converts ac voltage to dc voltage. This converted DC 12V is connected to filter dc which is then filtered by an electrolytic capacitor of about 470microf to 100microF and sends the resultant voltage to the voltage regulator. The voltage regulator regulates the 12V voltage. The regulated 5V is filtered using an electrolytic capacitor to avoid noise caused by the circuit. An LED

is associated with this 5V point in series with a resistor of 330ohms which is connected to the ground i.e. negative voltage to specify 5V power supply availability.

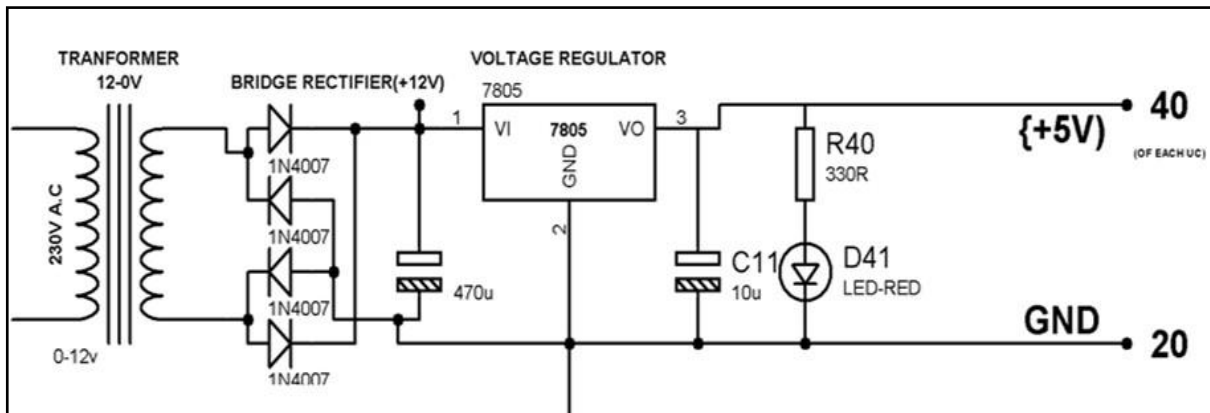


Fig 4.3 Circuit of Power Supply

4.3 HARDWARE COMPONENTS

The hardware components involved in the project are as follows,

- Arduino Uno R3
- Transformer
- Voltage regulator 5V
- LCD display (16*2)
- Servo motors
- Solar panel
- LDR sensors
- Capacitors
- Resistors
- Diode IN4007

4.3.1 ARDUINO

The Arduino Uno R3 is described as a microcontroller board that depends upon a removable, dual-inline-package (DIP) ATmega328 AVR microcontroller. It contains 20 digital input/output pins (of which 6 are often used as PWM outputs and 6 are often used as analog inputs). Programs are loaded onto it from the easy-to-use Arduino program. The Arduino has a spacious support community, which makes it much easier to be started working with embedded electronics. This is often the 3rd revision of the Uno (R3), which has several changes: The USB controller chip changed from ATmega8U2 to ATmega16U2. This doesn't increase the flash or RAM available to sketches. Three new pins are added which are duplicates of previous pins. The I2C pins (A4, A5) are also brought out on the side of the board near AREF. There's an IOREF pin next to the reset pin, which is the duplicate of the 5V pin. The reset option is now next to the USB connector, making it more accessible when a shield is employed. Fig. 4.4 shows the Arduino Controller.

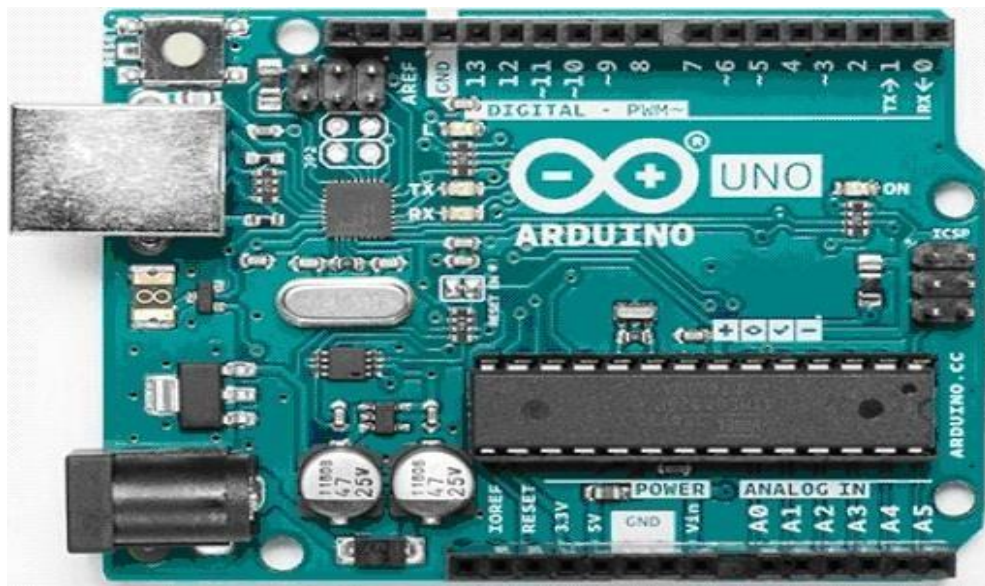


Fig 4.4 Arduino Controller

4.3.1.1 ARDUINO SPECIFICATIONS

The Arduino Uno R3 board includes the following specifications.

- The Operating Voltage of the Arduino is 5V
- The recommended input voltage ranges from 7V to 12V
- The i/p voltage limit is 6V to 20V
- Analog i/p pins are 6
- DC Current for each I/O Pin is 20 mA
- DC Current used for 3.3V Pin is 50 mA
- EEPROM is 1 KB
- The speed of the CLK is 16 MHz
- Length and width of the Arduino are 68.6 mm X 53.4 mm
- The weight of the Arduino board is 25 g

4.3.2 TRANSFORMER

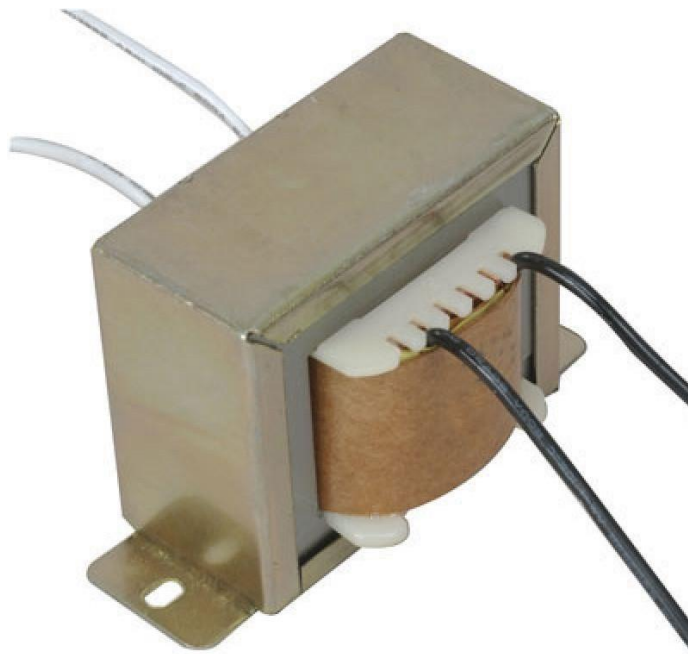


Fig 4.5 Step down transformer

Figure 4.5 represents a step-down transformer. For this step-down transformer, the secondary coil has lesser windings than the primary. The primary

winding is the first set of coils that connects to an alternating source. The secondary coil is connected to the load, allocating the electrical power from the transformer.

The alternating current flowing in the primary voltage produces an alternating magnetic flux which induces a similar current in the secondary coil that creates a secondary voltage. Here, the reduced winding numbers in the secondary coil reduces the output voltage, hence stepping down the voltage to a lesser value while maintaining a constant frequency.

4.3.2.1 *TRANSFORMER SPECIFICATIONS*

- Input Voltage: 230V AC
- Output Voltage: 12V or 0V
- Output Current: 5A
- Mounting: Vertical mount type
- Winding: Copper

4.3.3 *VOLTAGE REGULATOR*

A voltage regulator helps in creating and maintaining a fixed output voltage, and independent of changes in input voltage. Voltage regulators are used for DC/DC power conversion, AC/AC, or AC/DC power conversion. Figure 4.6 shows a 5V voltage regulator. Voltage regulators are created to maintain and stabilize voltage levels. Voltage regulators can be used to step down from a single higher output source.

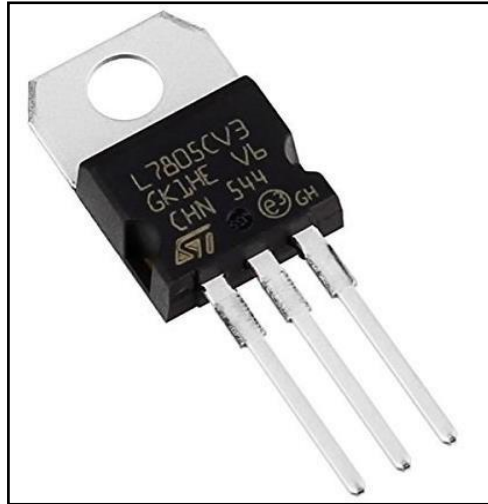


Fig 4.6 Voltage Regulator

4.3.4 LCD DISPLAY

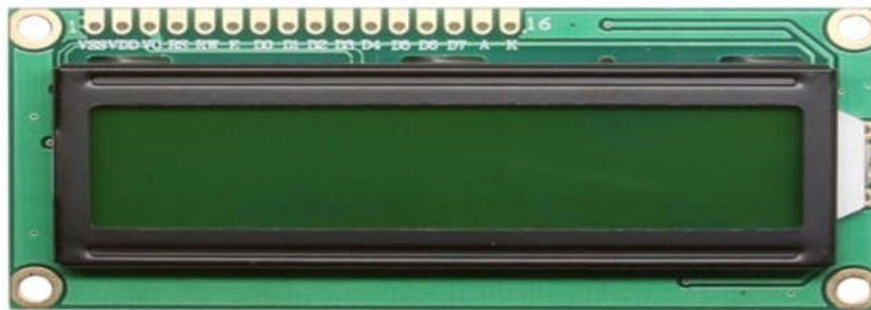


Fig 4.7 16x2 line Hitachi HD44780 display

An LCD is a display module that uses liquid crystal to provide a visible image. It is a basic module that is used commonly. It displays 16 characters for a line in 2 such lines. It has 16 connection pins, from left to right. The LCD modules form an important part of many Arduino-based embedded systems to improve the user interface of the system. When Arduino is interfaced with LCD, it gives the programmer more freedom to modify the code easily. The nominal operating voltage of LED is 5V at full brightness, with dimming at lower voltages. Figure 4.7 represents an LCD 16*2 display. The pin out is as follows:

1. Ground
2. VCC +3.3 to +5V (typical)
3. Contrast adjustment is an analog input connected to a potentiometer. Register Select (RS). RS=0: Command, RS=1: Data
4. Read/Write (R/W). R/W=0: Write, R/W=1: Read Clock. Falling edge triggered
5. Bit 0 (Not used in 4-bit operation)
6. Bit 1 (Not used in 4-bit operation)
7. Bit 2 (Not used in 4-bit operation)
8. Bit 3 (Not used in 4-bit operation)
9. Bit 4
10. Bit 5
11. Bit 6
12. Bit 7
13. Backlight Anode (+) (If applicable)
14. Backlight Cathode (-) (If applicable)

4.3.5 *SERVO MOTOR*

There are different servo motors available and every one has its unique specialty and applications. Most of the servo motors operate from 4.8V to 6.5V, but most ordinarily they're utilized at +5V. Most servo motors can rotate only from 0° to 180° because of their gear arrangement. The gears within the motors are involved to wear and tear. The commonly available one is that the 2.5kg/cm torque which comes with the Towerpro SG90 Motor. This 2.5kg/cm torque means the motor can pull a weight of two .5kg when it's suspended at a distance of 1cm. Figure 4.8 represents the servo motor used for the hardware designing of the system.

4.3.5.1 SERVO MOTOR SPECIFICATIONS

- 3 pole ferrite, all nylon gear
- Top ball bearing
- Operating Voltage: 4.8V~6.0V
- Operating speed: 0.12sec/60 degree
- Output torque: 1.6kg/cm 4.8V
- Dimension: 21.5 x 11.8 x 22.7mm
- Weight: 9



Fig 4.8 Servo motor

4.3.6 SOLAR PANEL

Most of the solar array options currently available slot in one among three types: Monocrystalline, polycrystalline, and thin-film. These solar panels vary in how they're made, appearance, performance, costs, and therefore the installations each are best fitted to. Counting on the sort of installation you're considering, one option could also

be more suitable than the others. In the figure, 4.9 types of solar panels with their advantages and disadvantages are tabulated.

Solar panel type	Advantages	Disadvantages
Monocrystalline	• High efficiency/performance • Aesthetics	• Higher costs
Polycrystalline	• Low cost	• Lower efficiency/performance
Thin-film	• Portable and flexible • Lightweight • Aesthetics	• Lowest efficiency/performance

Fig 4.9 Types of solar panels

The Monocrystalline type has high efficiency and provides better performance but higher cost. The polycrystalline are low cost but lower efficiency. The thin-film type of solar panel is portable, flexible, and very lightweight. The disadvantage is that they have the lowest efficiency of all the types of solar panels.

4.3.6.1 SOLAR PANEL SPECIFICATIONS

- DC Output Voltage (V): 12
- Max. Output Current (Amp): 1.03 -1.4
- Max Power Output (W): 20
- Weight (gm): 2880
- Material: Polycrystalline Silicon
- Application: Outdoor Power Bank
- Shipment Dimensions: 75 × 37 × 1 cm

4.3.7 LDR SENSORS

Light-dependent resistors are used in electronic circuits where it is needed to detect the presence of light. These components can be described by a variety of names from the light-dependent resistor, LDR, photo-resistor, or even photocell, photocell, or photoconductor. In view of their low cost, easy manufacture, and simple use, LDRs are utilized in a range of various applications. At one time LDRs were employed in photographic light meters, and even now they're still utilized in a range of applications where it's necessary to detect light levels. Light-dependent resistors are widely available:- they're normally stocked by electronic component distributors, and seeable of the way the industry supply chain operates recently, this is often the conventional method to obtain them. Electronic component distributors large and tiny will typically have a decent selection.

4.3.7.1 LDR SENSORS SPECIFICATIONS

- Diameter: 5mm
- No. of Pins: 2
- Type of Mounting: PCB Through Hole
- Maximum Operating Temperature: +800°C (Approx.)
- Dark resistance:1-20 Mohm

4.4 HARD WARE PROTOTYPE

This section explains the workflow of modelling and simulation of the prototype hardware.

4.4.1 PROTOTYPE FABRICATION

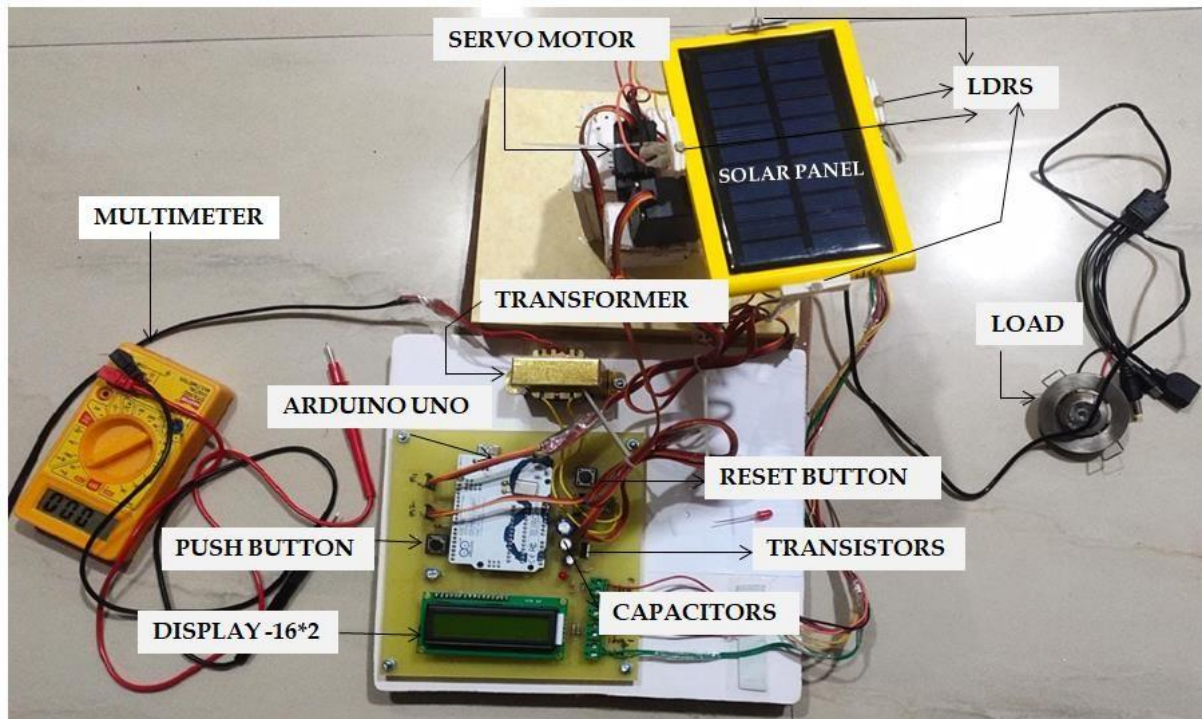


Fig 4.10 Hardware prototype

Figure 4.10 shows the full hardware combined with the circuit. This section explains the process of the fabrication of the prototype dual-axis solar tracker. The initial part is the base of the dual-axis solar tracker. A square box is used for the bottom of the base so that it can hold the top part and support the servo motors. Then square cardboard is used to support the motor in the middle so that the motor can turn the azimuth axis position. Square cardboard is used to support the bottom part of the pcb board so that it can hold stronger. A 12V stepdown transformer is installed near to PCB board. While connecting motors small box pieces of cardboard are attached to the motor to arrange grip in connecting and holding the solar panel and also the LDRs. To support the square board at the top, a rectangular box is attached which goes through the center of the beam with another DC motor so that the top part can turn the elevation axis. The Arduino Uno R3 in each circuit is a microcontroller board based on the Atmega328 which is programmed in C language. Once the Arduino board gets powered from the power supply, it starts controlling the features of

the devices interfaced to it. The Arduino Uno R3 and devices interfaced with it are shown in figure 4.11.

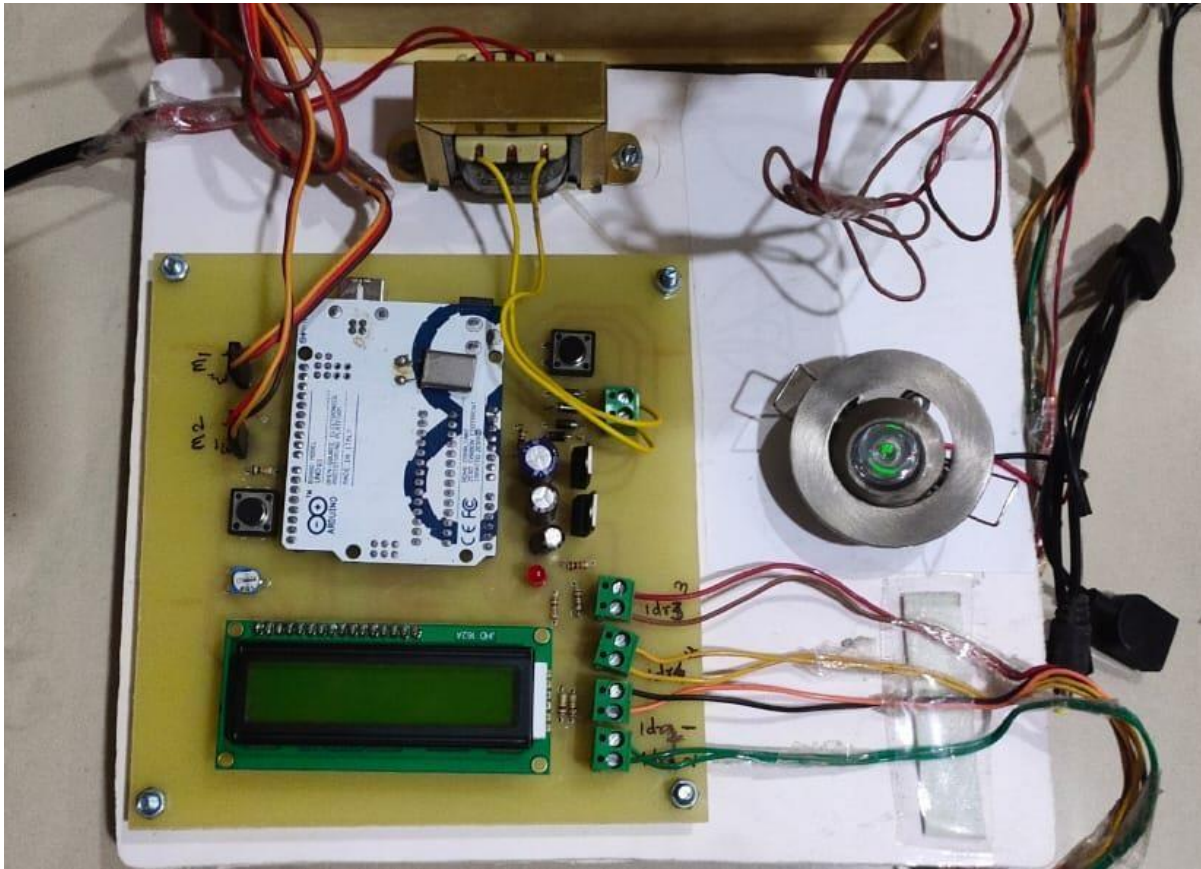


Fig 4.11 circuit connections

4.4.2 TRACKING PROCESS

DC servo motor movement will follow the condition of the LDR. In dual-axis solar tracking system, there are 2 DC servo motors. One motor is used to control the elevation axis and another motor is used to control the azimuth axis.

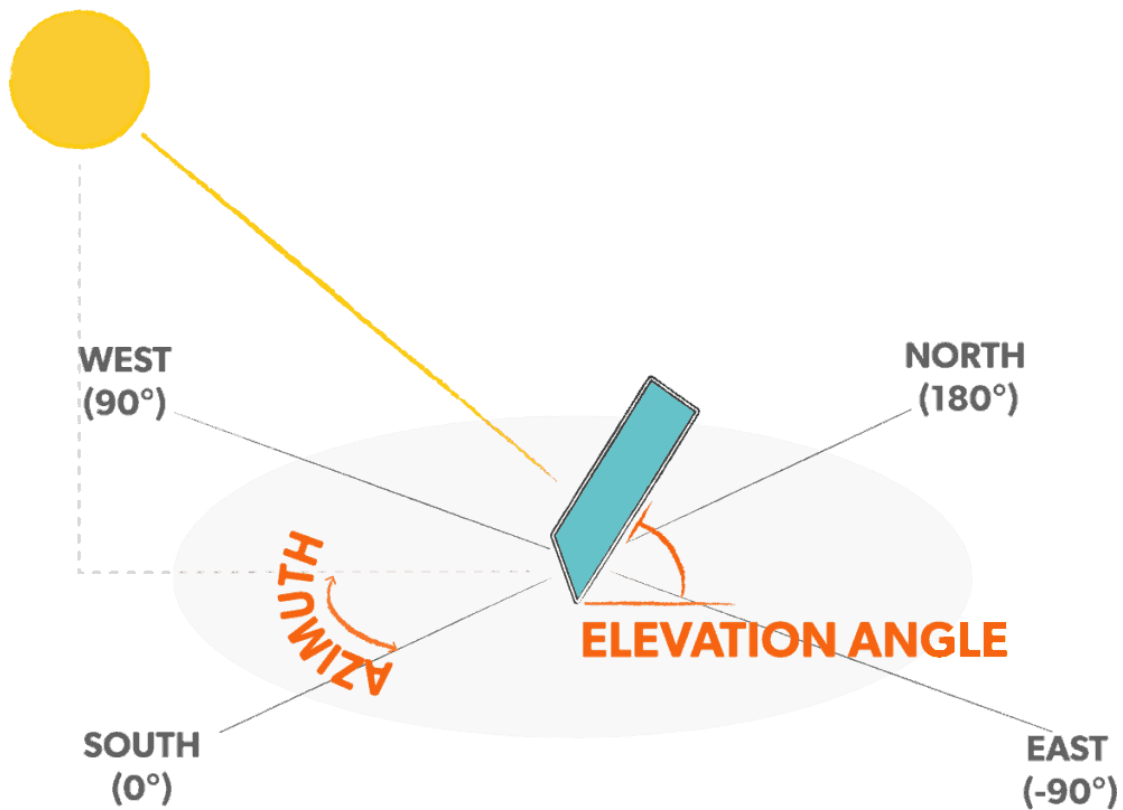


Fig 4.12 Azimuth and Elevation angles

Figure 4.14 represents the Azimuth angle and Elevation angle for a solar panel. The vertical tilt of the solar panel is called the Elevation angle. The horizontal orientation of the solar panel is called the Azimuth angle. To lean toward more production in the summer panel is tilted at location latitude minus 10-15°. To lean toward more production in the winter, the panel is tilted at location latitude plus 10-15°.

4.4.2.1 CASES OF SOLAR PANEL MOVEMENT

There are various cases to study to decide the position of solar panel using LDRs.

Case 1: LDR1 light intensity > LDR2, LDR3 and LDR4

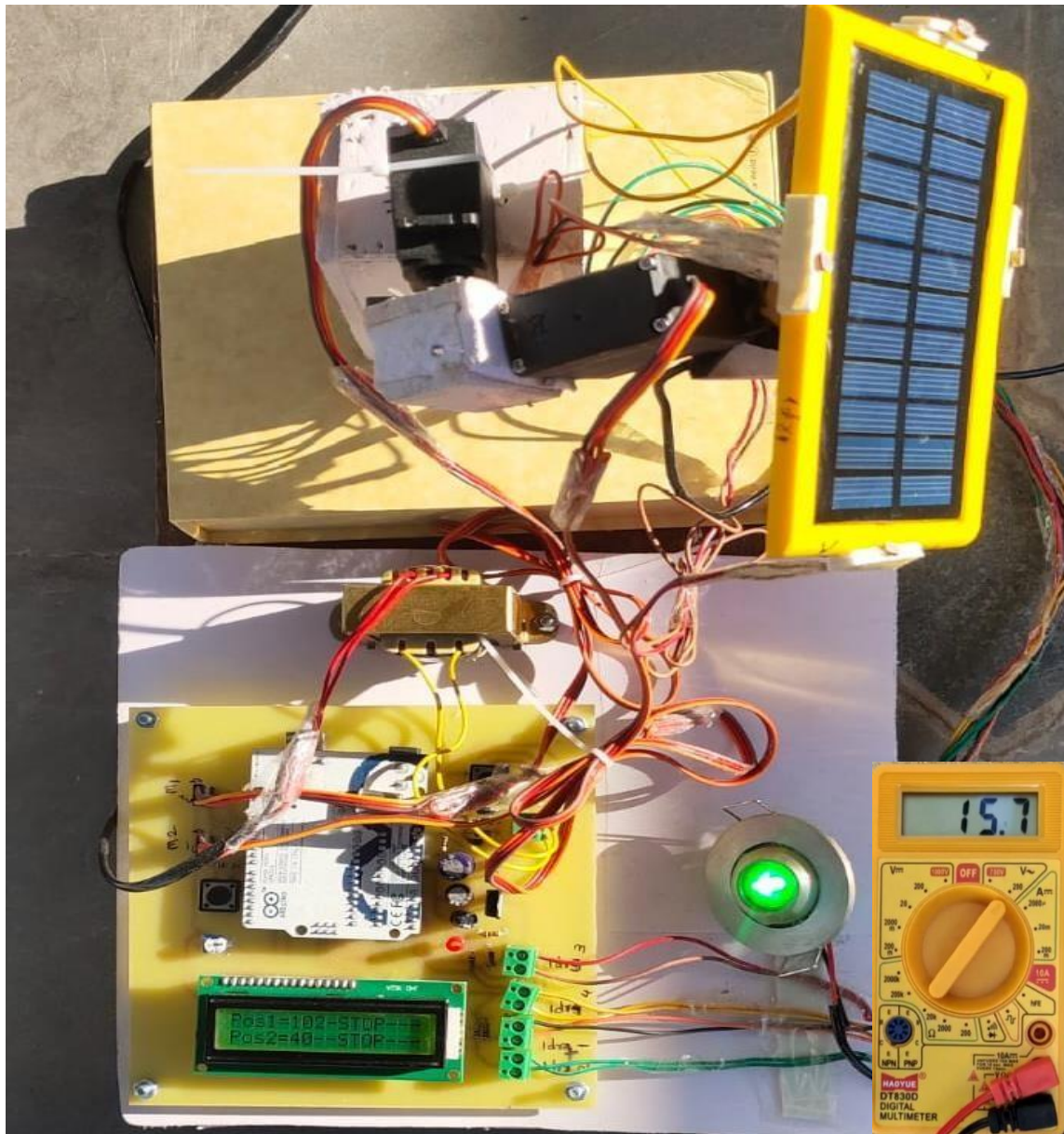


Fig 4.13 when LDR1 has more light intensity

Figure 4.13 shows that LDR sensor 1 has the highest intensity of light hit on it thus producing a higher voltage output than the other sensors. In this simulation, the solar energy is taken by solar panel and analog signals of LDR values are compared with each other. For case 1, Servo motor 1 rotates in clockwise direction and servo motor 2 rotates counter-clockwise direction. Servo motor 1 will control the movement of

elevation axis of the solar tracker and servo motor 2 will control the azimuth axis of solar tracker. The voltage recorded while measuring with multimeter is 15.7V.

Case 2: LDR2 light intensity > LDR1, LDR3 and LDR4

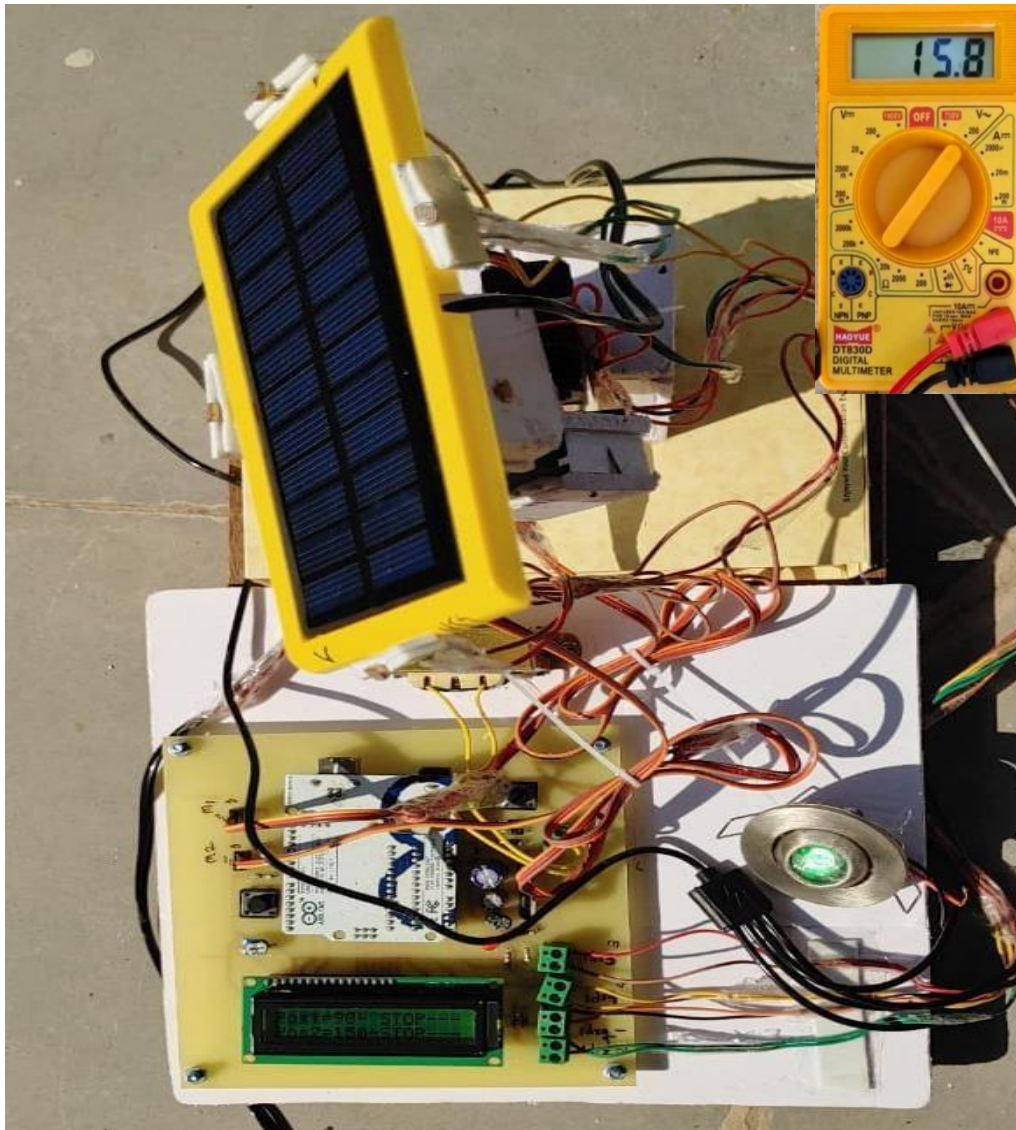


Fig 4.14 when LDR2 has more light intensity

Figure 4.14 shows the condition when LDR sensor 2 gains the highest intensity of light. The position of light in this case is at position 2. Therefore, in order to make all the sensor gain the same intensity of light the elevation axis has to move counter-

clockwise and the azimuth axis move clockwise as shown by the servo motor 1 and 2 in Figure 4.16. The voltage recorded while measuring in multimeter is 15.8V.

Case 3: LDR3 light intensity > LDR1, LDR2 and LDR4

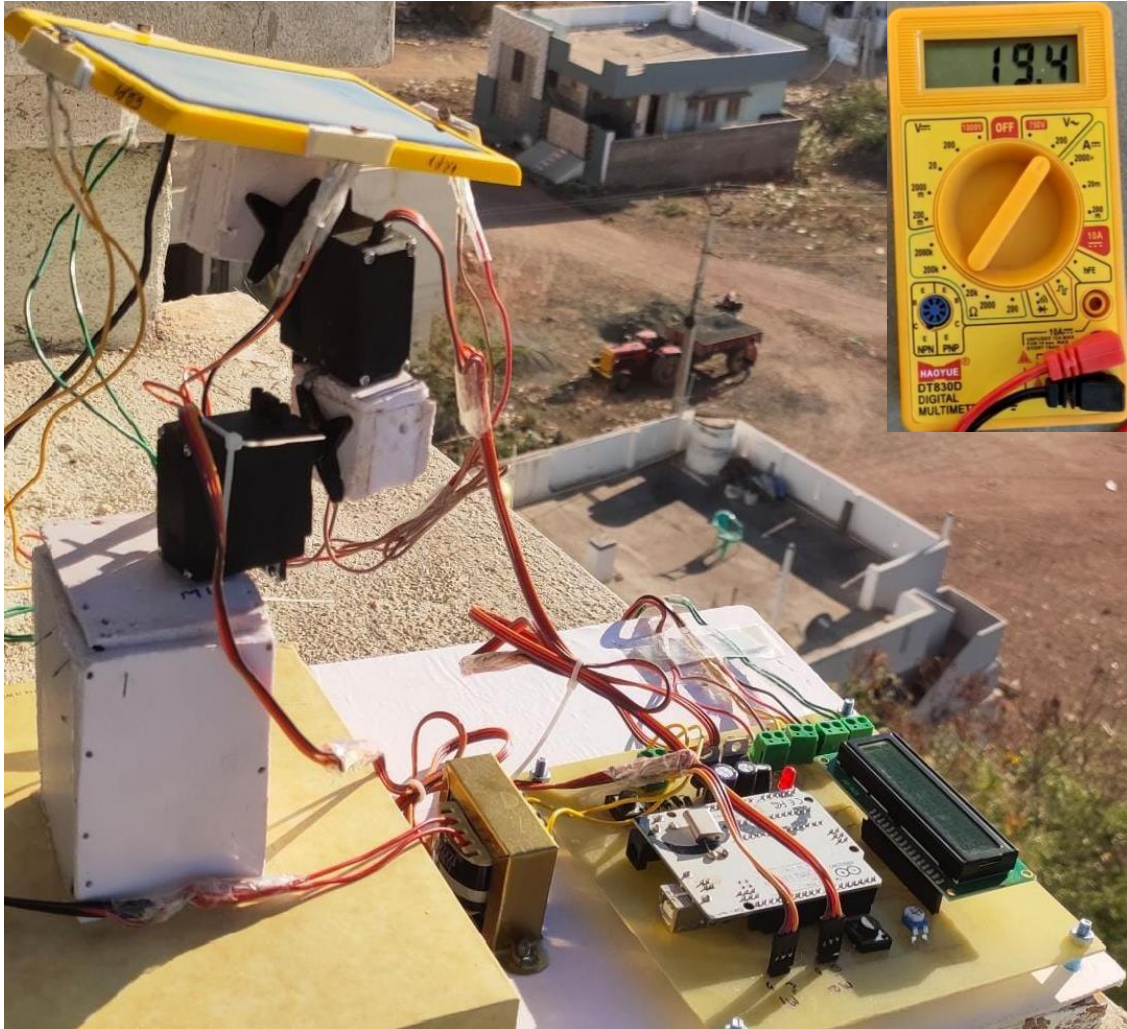


Fig 4.15 when LDR3 has more light intensity

Figure 4.15 is the condition when light is placed on position 3, thus LDR sensor 3 gains the highest intensity of light compared to other sensors. In order for the entire LDR sensor to achieve the same light intensity the elevation axis which is servo motor 2 rotates clockwise. On the other hand, azimuth axis which is controlled by servo motor 1 will rotate counter-clockwise. The voltage recorded while measuring the multimeter is 19.4V.

Case 4: LDR4 light intensity > LDR1, LDR2 and LDR3

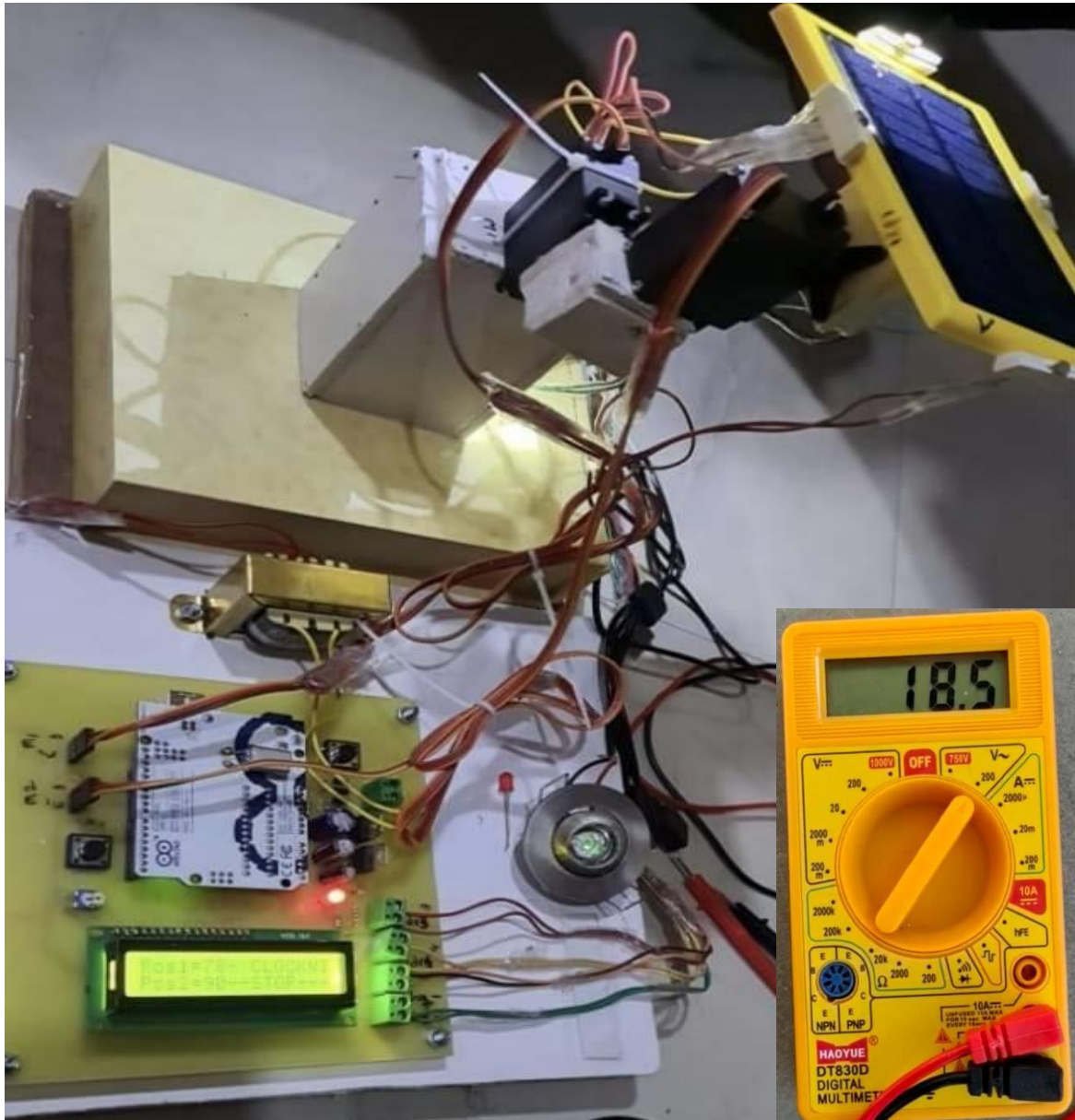


Fig 4.16 when LDR3 has more light intensity

Figure 4.16 shows the condition when LDR sensor 4 received the highest intensity of light and the position of light is at position 4. At this case, the solar tracker needs to rotate its elevation axis clockwise and the azimuth axis must rotate counter-clockwise. In this case, servo motor 1 moves counter-clockwise and servo motor 2 will rotate clockwise. The voltage recorded while measuring with multimeter is 18.5V.

Case 5: $\text{LDR1 light intensity} = \text{LDR2} = \text{LDR3} = \text{LDR4}$

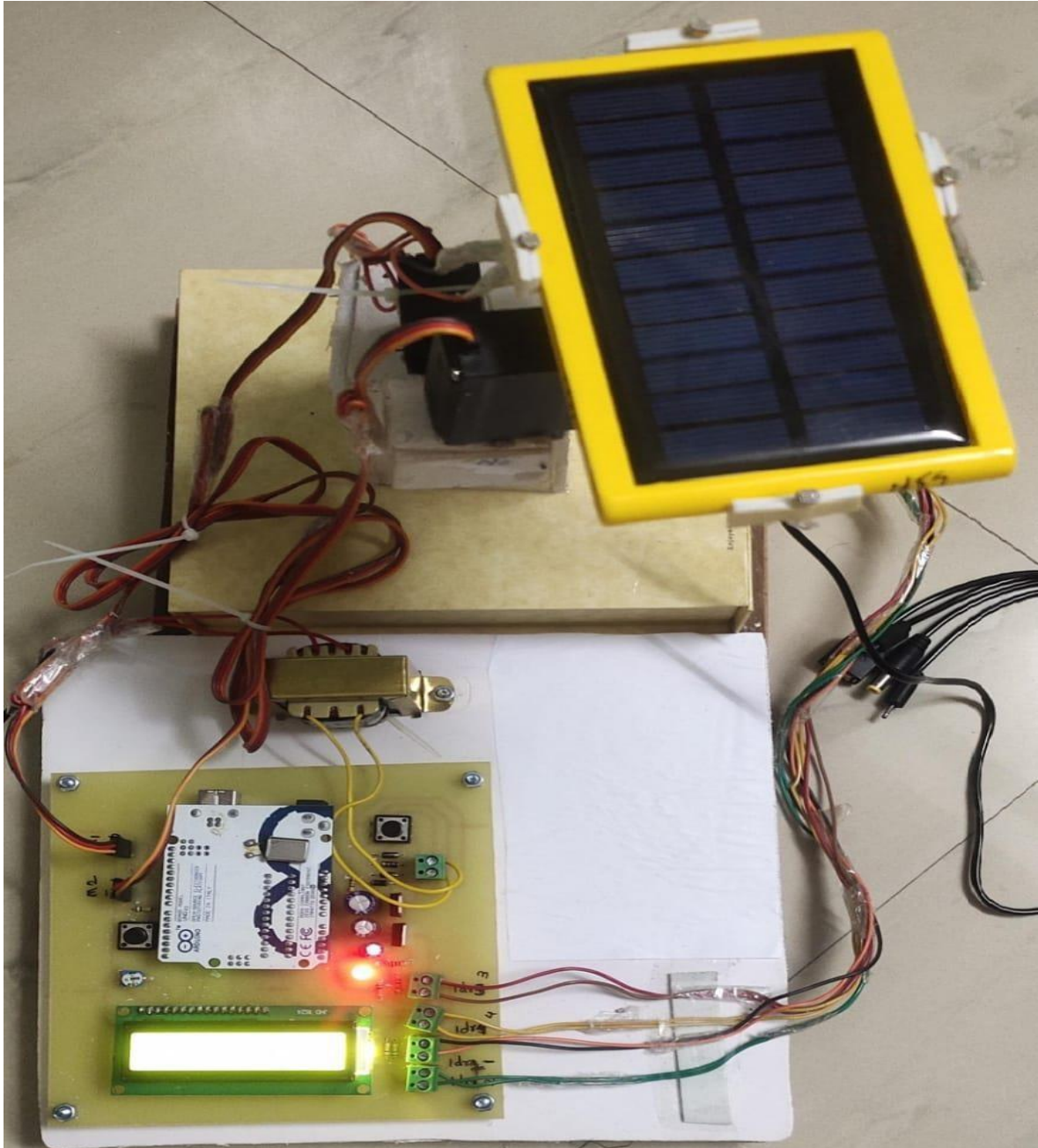


Fig 4.17 when $\text{LDR1}=\text{LDR2}=\text{LDR3}=\text{LDR4}$

Figure 4.17 is the final case of programming part. This compares the entire sensor on one fixed values which means all the sensors are receiving the same light intensity. The position of light is placed at position 5 where light distributed are equally. Therefore, the servo motor 1 and 2 stay at the same position instead of rotating.

4.4.3 TABLE OF VOLTAGE RECORDED IN DIFFERENT CASES

Table 4.1 Output voltage in different cases

SNO	LDR CONDITION	VOLTAGE IN V
1.	LDR1>LDR2, LDR3, LDR4	15.7
2.	LDR2>LDR1, LDR3, LDR4	15.8
3.	LDR3>LDR1, LDR4, LDR2	19.4
4.	LDR4>LDR1, LDR2, LDR3	18.5

Table 4.1 shows the real-time voltage output measurements of the 4 LDR sensors when the light intensity varies its position concerning the sensor positions. It is noted that the output voltage of the LDR sensor is not that stable. Some uncertainty occurs in each of the sensor values. This is because the connection of the LDR sensor towards the Arduino controller is by using a voltage divider apart from the LDR sensors directly.

CHAPTER 5

CONCLUSION AND SCOPE OF THE PROJECT

5.1 CONCLUSION

In this project, a dual-axis solar tracking system has been proposed. This project deals with dual-axis solar tracking to collect maximum rays using LDRs. It resolves the problem by providing an arrangement for a solar panel to track the movement of the sun on both axes. Here two DC Servo motors are used to give two types of movement i.e. horizontal axis and vertical axis directions. Motor Driver IC is arranged such that it can control both the servo motors simultaneously. Here the LDR sensors are used to sense the photovoltaic cells and analog signals are sent to the comparator where the voltage is compared and using Arduino the direction of movement is decided and it is displayed on the LCD display. The simulation conducted on a Grid-connected PV system with an electric vehicle, electric battery, and load resulted in concluding that Dual axis tracking is the best efficient method of tracking when compared to other existing sun-tracking methods thereby, increasing the output obtained. It is a low-cost system that provides better efficiency. Here the analog signals are analyzed and controlled by Arduino Uno. This automatic system is completely programmed. The positions and amount of energy obtained at two LDRs on the same axis are compared and analyzed to decide the movement of the servo motors which moves the panel to the direction where more energy is available. It has an LCD display to output visual information of the type of rotation needed an angle of rotation and inclination.

5.2 SCOPE OF THE PROJECT

- This project can be implemented as a completely automated system in future. The input signals which are given through the comparator are directly obtained from the LDRs.
- The fluctuations in the output can be overcome using proper DC-DC converter. They can improve the steady-state accuracy by reducing the steady state error.
- There are various types of controllers like linear and non linear types. To make the output voltage high and constant proper controllers like SEPIC, Zeta, Interleaved and many other which are suitable to system are analyzed and connected with the system for improving its output features.
- Sometimes non linear type of controllers like fuzzy logic, fuzzy with PID controller and other types can also be studied and suitable one is included with the system.
- This system is also used to provide ac supply by using proper dc-ac inverter.

REFERENCES

1. Bhagwan Deen Verma, Prof. (Dr.) Mukesh Pandey, Asst. Prof. Anurag Gour. "A Review Paper on Solar Tracking System for Photovoltaic Power Plant". *International Journal of Engineering Research & Technology* Vol. 9 Issue 02, February(2020): 2278-0181
2. Pavan kalyan .G, Dharma .B, Anil kumar .B, Sagar nayak. "Sun Tracking Solar System Using Microcontrollers." *International Journal of Innovative Research In Technology* 147981: 2349-6002.
3. Cotfas, D. T., and Cotfas P. A. "Multiconcept methods to enhance photovoltaic system efficiency." *International Journal of Photoenergy* 2019 (2019).
4. Premkumar, M., and R. Sowmya. "An effective maximum power point tracker for partially shaded solar photovoltaic systems." *Energy Reports* 5 (2019): 1445-1462.
5. Obara, Shin'ya, Kazuhiro Matsumura, Shun Aizawa, Hiroyuki Kobayashi, Yasuhiro Hamada, and Takanori Suda. "Development of a solar tracking system of a nonelectric power source by using a metal hydride actuator." *Solar Energy* 158 (2017): 1016-1025.
6. Carballo, Jose A., Javier Bonilla, Lidia Roca, and Manuel Berenguel. "New low-cost solar tracking system based on open source hardware for educational purposes." *Solar Energy* 174 (2018): 826-836.
7. Hoffmann, Fábio Moacir, Rolf Fredi Molz, João Victor Kothe, Elpidio Oscar Benitez Nara, and Leonel Pablo Carvalho Tedesco. "Monthly profile analysis based on a two-axis solar tracker proposal for photovoltaic panels." *Renewable energy* 115 (2018): 750-759.
8. Abdollahpour, Masoumeh, Mahmood Reza Golzarian, Abbas Rohani, and Hossein Abootorabi Zarchi. "Development of a machine vision dual-axis solar tracking system." *solar energy* 169 (2018): 136-143.

9. Lim, Boon-Han, Chern-Sing Lim, Hu Li, Xing-Lan Hu, Kok-Keong Chong, Jin-Long Zong, Ke Kang, and Woei-Chong Tan. "Industrial design and implementation of a large-scale dual-axis sun tracker with a vertical-axis-rotating-platform and multiple-row-elevation structures." *Solar Energy* 199 (2020): 596-616.
10. Fernández-Ahumada, L. M, Ramírez-Faz. J, López-Luque. R, M. Varo-Martínez, Moreno-García. I. M., and Casares de la Torre. F. "A novel backtracking approach for two-axis solar PV tracking plants." *Renewable Energy* 145 (2020): 1214-1221.
11. Chowdhury, Muhammad EH, Amith Khandakar, Belayat Hossain, and Rayaana Abouhasera. "A low-cost closed-loop solar tracking system based on the sun position algorithm." *Journal of Sensors* 2019 (2019).
12. Khan, Rafid Adnan, Rezwanul Mahmood. M, and Anisul Haque. "Enhanced energy extraction in an open loop single-axis solar tracking PV system with optimized tracker rotation about tilted axis." *Journal of Renewable and Sustainable Energy* 10, no. 4 (2018): 045301.
13. Hafez. A.Z, Yousef. A.M, and Harag. N.M. "Solar tracking systems: Technologies and trackers drive types—A review." *Renewable and Sustainable Energy Reviews* 91 (2018): 754-782.
14. Carballo, Jose A., Javier Bonilla, Manuel Berenguel, Jesús Fernández-Reche, and Ginés García. "New approach for solar tracking systems based on computer vision, low cost hardware and deep learning." *Renewable energy* 133 (2019): 1158-1166.
15. Umar, Najibhamisu, Birinchi Bora, Chandan Banerjee, and Panwar. B. S. "Comparison of different PV power simulation softwares: case study on performance analysis of 1 MW grid-connected PV solar power plant." *International Journal of Engineering Science Invention (IJESI)* 7, no. 7 (2018): 11-24.

16. Baby Shalini. V, Gattu Vinay Goud, Chandragiri Radha Charan. " Grid Connected Rooftop Solar Pv System: A Pre-Feasibility Estimation Using Pvsol Premium And System Advisor Model(Sam) " *International Journal Of Scientific & Technology* (2019)
17. Khalil, Linta, Kamran Liaquat Bhatti, Arslan Iqbal Awan. M, Mughees Riaz, Kiran Khalil, and Nashitah Alwaz. "Optimization and designing of hybrid power system using HOMER pro." *Materials Today: Proceedings* (2020).
18. Ozcan, Huseyin Gunhan, Huseyin Gunerhan, Nurdan Yildirim, and Arif Hepbasli. "A comprehensive evaluation of PV electricity production methods and life cycle energy-cost assessment of a particular system." *Journal of Cleaner Production* 238 (2019): 117883.
19. Sharma, Rakhi, Shivanshu Sharma, and Sumit Tiwari. "Design optimization of solar PV water pumping system." *Materials Today: Proceedings* 21 (2020): 1673-1679.
20. Mochi, Pratik K. "Simulation and Performance Analysis of 100kWp Grid Connected Solar Photovoltaic Plant Using PVSyst Software." *In National Workshop on Research challenges in Power Electronics & Power System*. NIT Calicut, 2016.