

Solar Tracker Implementation Using MATLAB/SIMULINK

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Abstract: In this paper we present a mathematical modeling of photovoltaic module and a complete simulation of Solar Power Tracker and by using them on MATLAB Simulink we obtain V-I and P-V characteristics of PV module. The V-I and P-V characteristics are obtained for constant temperature at various solar irradiations. In this paper we also present a concept of Sensor array based solar maximum rays point tracking and motion of the solar panel accordingly. Microcontroller based control system design is developed to track the sun position.

IndexTerms – Solar Tracker, MPPT, Stepper Motor, Solar Panel.

I. INTRODUCTION

As we know that a non-renewable resource (also known as a finite resource) is a resource that does not renew itself at a sufficient rate. The energy which is taken from these resources are available on the earth in limited quantity and will vanish fifty-sixty years from now. Non-renewable resources are not environmental friendly and can have serious affect on our health. Non-renewable sources exist in the form of fossil fuels (natural gas, oil and coal). Fossil fuels are continually produced by the decay of plant and animal matter, but the rate of their production is extremely slow, very much slower than the rate at which we use them. Any non-renewable energy resources that we use are not replaced in a reasonable amount of time and are thus considered “used up”, not available to us again. The problems that are occurring due to the use of non-renewable sources of energy can be overcome by using renewable sources of energy. A renewable resource is a natural resource (sun, wind, rain, tides) which can be replenish with the passage of time. They are available in plenty and by far most the cleanest sources of energy available on this planet. Renewable sources have low carbon emissions, therefore they are considered as green and environment friendly. Nowadays, the most widely used renewable form of energy is solar energy. Solar Energy is the energy received from the sun. For many decades solar energy has been considered as a huge source of energy and also an economical source of energy because it is freely available and be used for heating, lighting and cooling homes and other buildings, generating electricity, water heating, and a variety of industrial processes. Most forms of renewable energy come either directly or indirectly from the sun. For example, heat from the sun causes the wind to blow, contributes to the growth of trees and other plants that are used for biomass energy, and plays an essential role in the cycle of evaporation and precipitation that makes hydropower possible. However, it is only now after years of research that technology has made it possible to harness solar energy. Sunlight can be converted directly into electricity using photo-voltaic (PV), or indirectly with concentrated solar power (CSP), which normally focuses the sun’s energy to boil water which is then used to provide power. Photovoltaic module, also known as solar module works on the principle of photovoltaic effect. The output of PV module depends on some factors such as cell temperature and solar irradiation. Thus for maximum power output solar tracking PV module is used, which operates the solar module near the point of maximum power. Various maximum power point tracking algorithm has been introduced for operating the PV module near the point of maximum power.

II. NEED OF RENEWABLE ENERGY

The various sources of renewable energy are tides, sunlight, rain, geothermal energy and wind. These resources can be naturally replenished and never go out of stock. Generally, the prime source of energy these days come directly or indirectly from fossil fuels which are slowly getting exhausted from the earth storage unlike these renewable resources which are inexhaustible in nature. With time and development people around the world have been searching for nonconventional sources for long term fulfilment of their basic energy demand. With rapidly increasing population and growing consumption of fossil fuel the pollution caused to the environment also increases, hence there is a urgent need of Clean and Green Mechanisms which are now popularly adopted by nations throughout the world. The clean and no pollution consumption of these renewable energy is what attracted the current globe and hence a huge capital is investment is being done for harvesting these resources.

III. SOLAR POWER

The rising power demand of day to day life cannot only be maintained by using conventional energy recourses due to its unavailability. Along with conventional systems the demand for renewable sources has increased to meet the energy demand. Renewable sources like solar energy and wind energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has drastically affected the environment depleting the biosphere and causing global warming. Harvesting Solar energy is possible because of its abundantly availability. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Since the availability of grid is very low at rural areas the use of renewable sources is maximum over there. Another importance of using solar energy is the portable operation, can

be used everywhere as per the necessity. The present energy crisis can be tackled by developing power efficiently and can be extracted from the incoming solar radiation. The power conversion techniques have been greatly reduced in the past few years. To withstand the high power demands, the development in power electronics and material science has helped technicians to come up very brief but powerful systems. The increased power density is the major disadvantage of these systems. Trend has set in for the use of multi-input converter units that can effectively handle the voltage fluctuations. But due to high production cost and the low efficiency of these systems they can hardly compete in the competitive markets as a prime power generation source.

The constant increase in the development of the solar cells manufacturing technology would definitely make the use of these technologies possible on a wider basis than what the scenario is presently. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy.

The conversion of solar energy was originated by the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy has two major applications. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar PV cells or with concentrating solar power plants.

IV. RESEARCH METHODOLOGY

The smart tracker panel was installed with two LDR sensors. Assuming both sensors are placed in parallel with the PV panel, the effective irradiance is similar. As the results, the smart tracker is unable to perform the proposed sun tracking algorithm. To circumvent this, the top and bottom sensors were positioned at 45° and 135° respectively as seen in Fig.3.1. When the sunlight falls onto the PV panel, the LDR sensors generate different voltages (that is V_{LDR_B} and V_{LDR_T} according to the changes in the sun irradiance) to move the PV panel

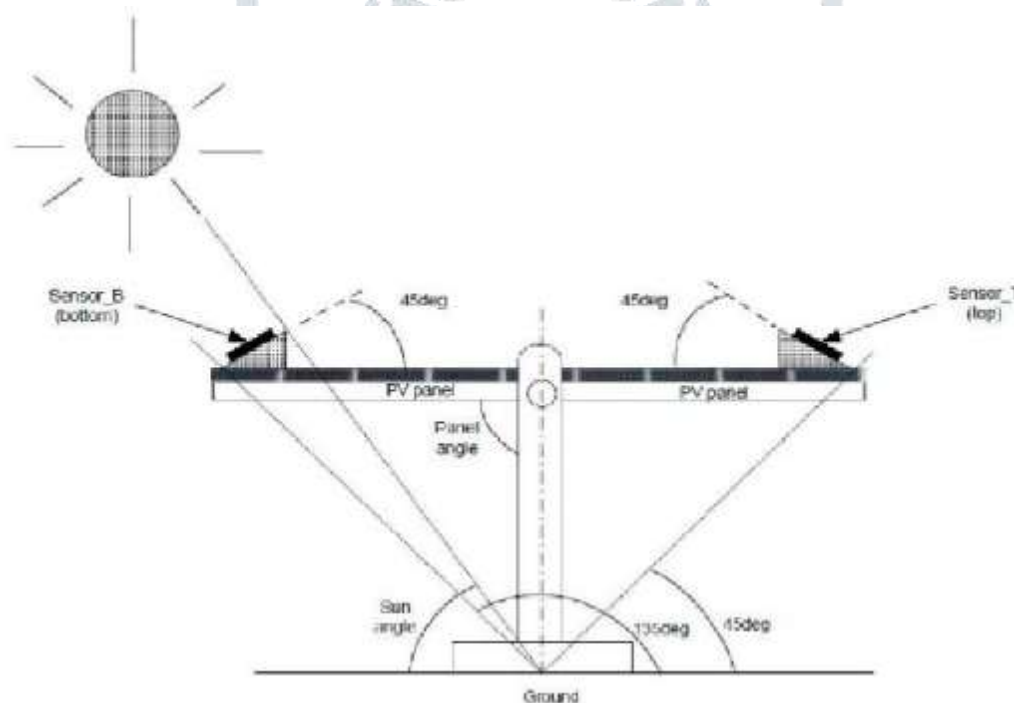


Fig. 1 PV panel and LDR sensor Position

4.1 Solar Tracking Cell Module

A solar tracking cell generates current when incident light falls on its surface. The amount of current generated is proportional to the light and is determined by the flux density. In Simulink, the model of solar cell can be found in the library of Sources in SimElectronics. This block models a solar cell as a parallel combination of a current source, two exponential diodes and a parallel resistor, that are connected with a series resistance R_1 . Figure 2 shows the implementation of solar cell module in Simulink.

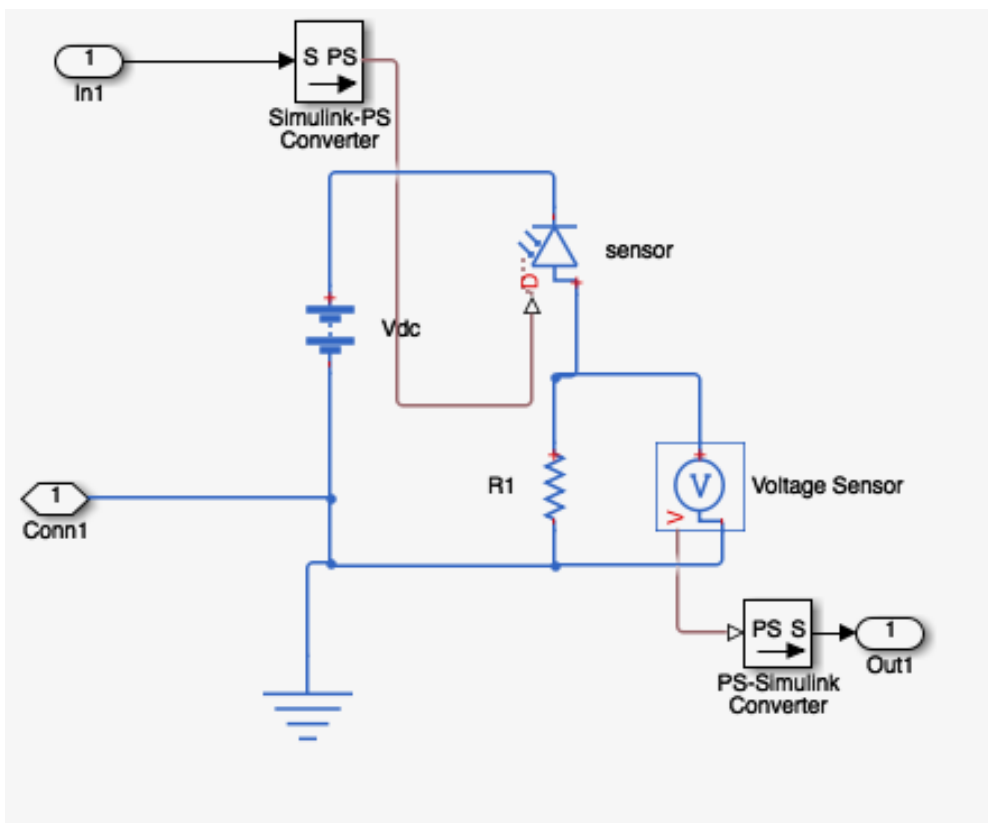


Fig. 2: Sensor Module circuitry

4.2 PV cell Modeling

The MATLAB simscape toolbox have a predefined solar cell which follows the equation as given in equ 1

$$I = I_{ph} - I_{s1} * (e^{(V+I * R_s) / (N * V_t)} - 1) - I_{s2} * (e^{(V+I * R_s) / (N2 * V_t)} - 1) - (V+I * R_s) / R_p \tag{e.q 1}$$

Where, I_{s1} and I_{s2} are the diode saturation currents,

V_t is the thermal voltage,

N and $N2$ are the quality factors (diode emission coefficients) and

I_{ph} is the solar-generated current.

Figure 3 shows the equivalent circuit diagram of the single solar cell

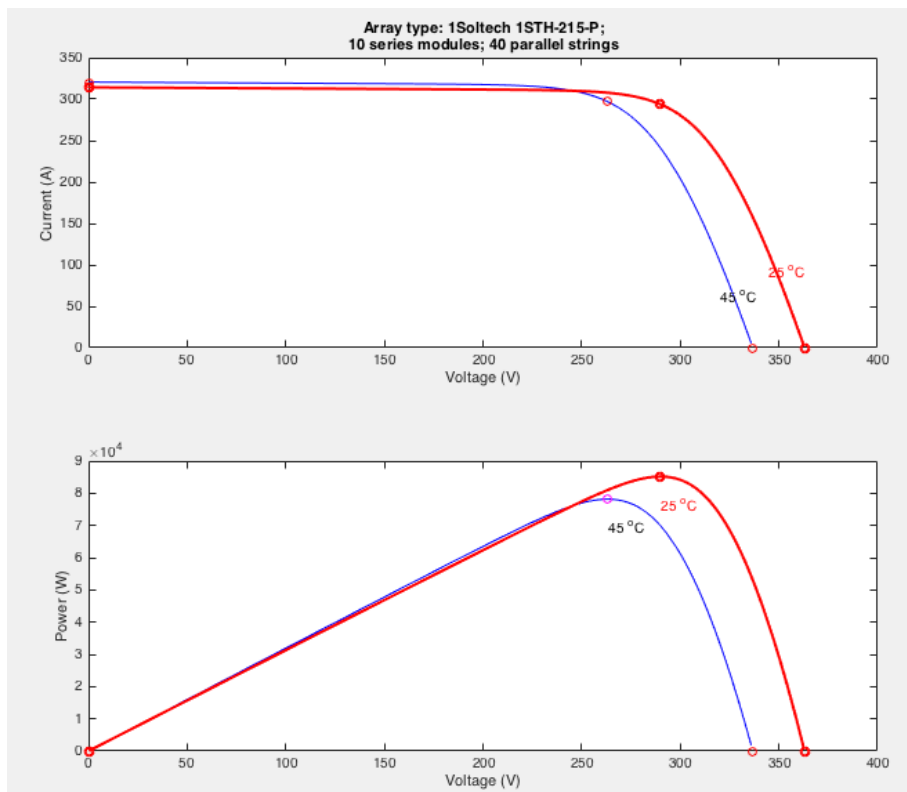


Fig. 3. Displays the Temperature variation of P-V and V-I curve of PV cell

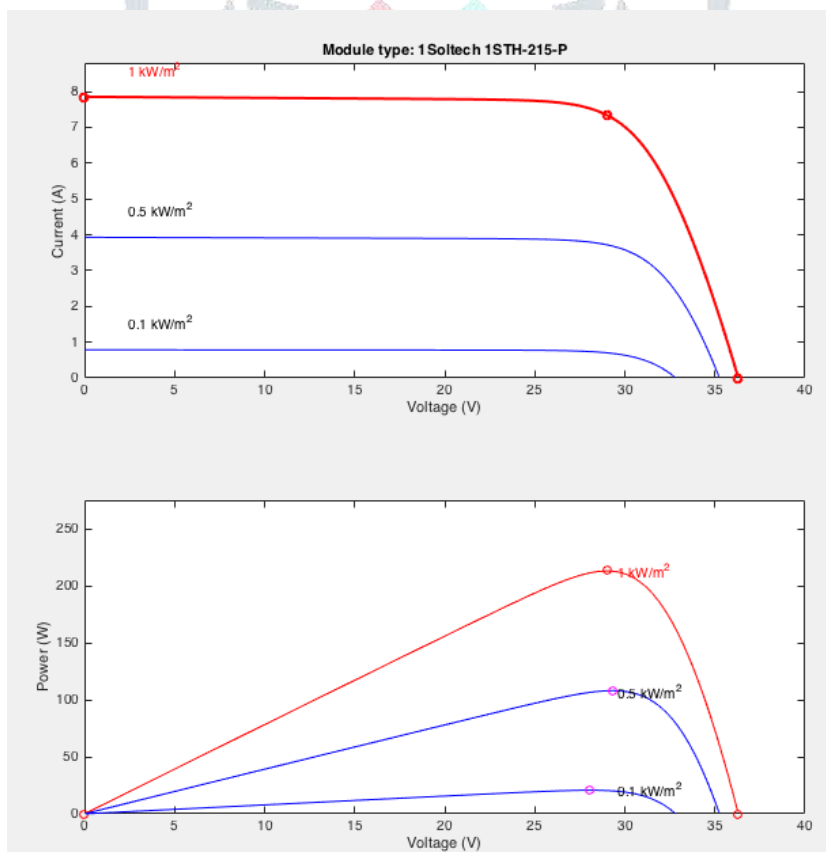


Fig. 4. different irradiation variation of a PV cell

4.3 Controller

Figure 5 shows the control algorithm. The controller is implemented as an embedded Matlab function in the simulation. The first block is initialization that turns on power for all components. Next, the output voltage of the east and the west tracking cells are added to determine if it is daytime or night. If it is night, the program will repeat the loop. After sunrise, the program will jump out of the loop and proceed to daytime tracking loop. There are three situations based on the output voltage from east and west tracking cells. If the maximum rotation steps are reached, the controller will go to the night mode state. It will first rotate clockwise until the steps number is equal to 0 and then it starts to go into the sleeping state for certain delay period of time until sunrise. The embedded Matlab function allows convenient evaluation and modification of the control algorithm. In the prototype solar tracker system, the controller will be implemented using a microcontroller

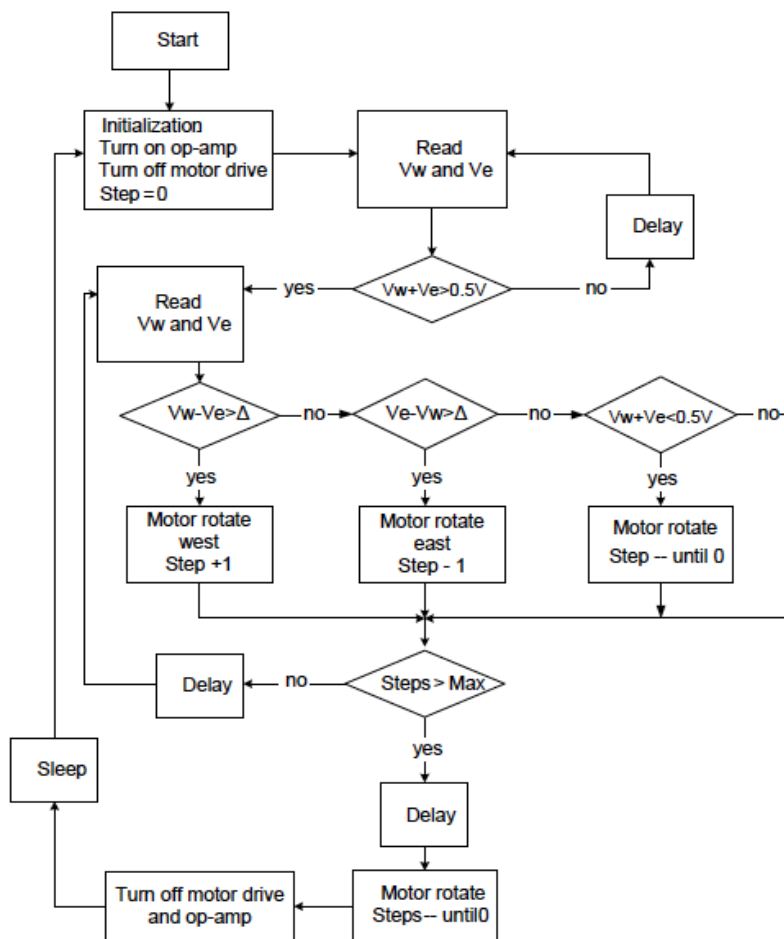


Fig. 5. Control Algorithm

4.4 Motor and Drive

Figure 3.4 shows the Simulink simulation of the stepper motor and drive. The motor driver has three input pins to control the motor move. One is step clock signal which is PWM signal used to control the motor rotate. The second input is direction pin used to control the direction of rotation by switch the logic between 1 and 0 (0/5V). The third input is enabled.

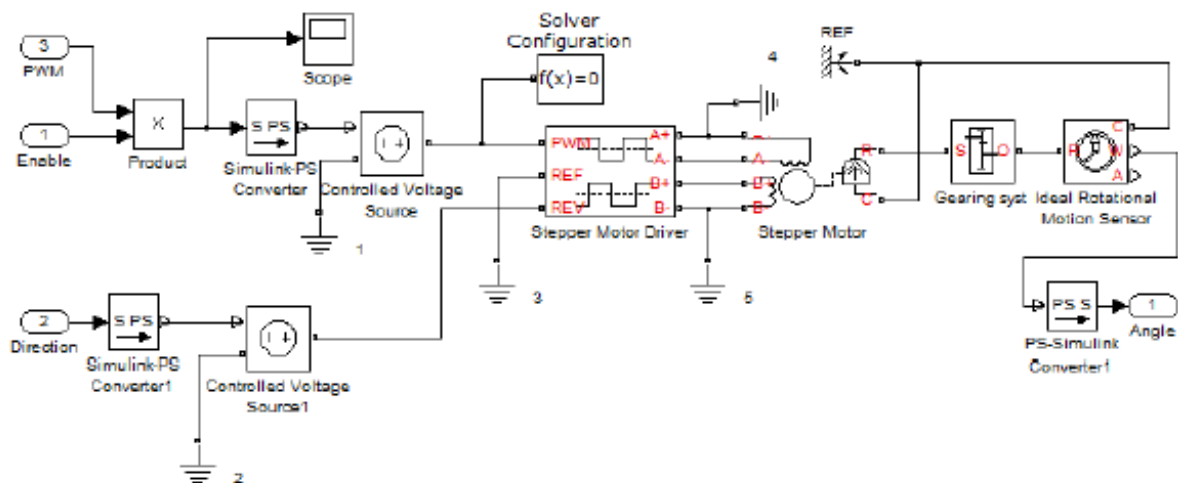


Fig. 6. Simulation of Stepper Motor and Drive

3.5 Stepper Motor

Stepper motors are very important in robotics, process control and instrumentation. They enable precise control of motor angular position, speed and direction of motor rotation. They are capable of discrete precise movements i.e. movements in precise steps so they are named as 'stepper motors'. Stepper motors are transforming electrical energy (excitation) into mechanical movement. They are constructed as rotating or translating motors. Although stepper motor is known for a long time, they have achieved their wide popularity in the last thirty years due to development of electronics which enables construction of cheap and reliable control circuits capable to satisfy complex requirements regarding motor torque, speed and angular displacement. In order their transient performance characteristic to be analyzed Matlab/Simulink is chosen as simulation tool and motor characteristics are analyzed under different operating regimes: no-load, rated load and over load. Advantages of stepper motors are: low costs, small dimensions, possibility to transform the pulses from digital inputs into angular movement-step, number of steps is equal to the number of control pulses. The above mentioned advantages have led to their wide application in control systems and robotics and have made them irreplaceable moving force of industrial processes.

3.6 MPPT algorithm

Maximum Power Point Tracking (MPPT) is a technique that grid-tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices. The output power of a PV system can be maximized by continuously tracking the maximum power point of a system and the maximum power point is dependent on the solar temperature, solar irradiation and on the load connected. Thus maximum power point can be tracked continuously by using a theoretical means known as the algorithm. Several MPPT algorithm has been developed and in this paper we present a Perturb and Observe algorithm.

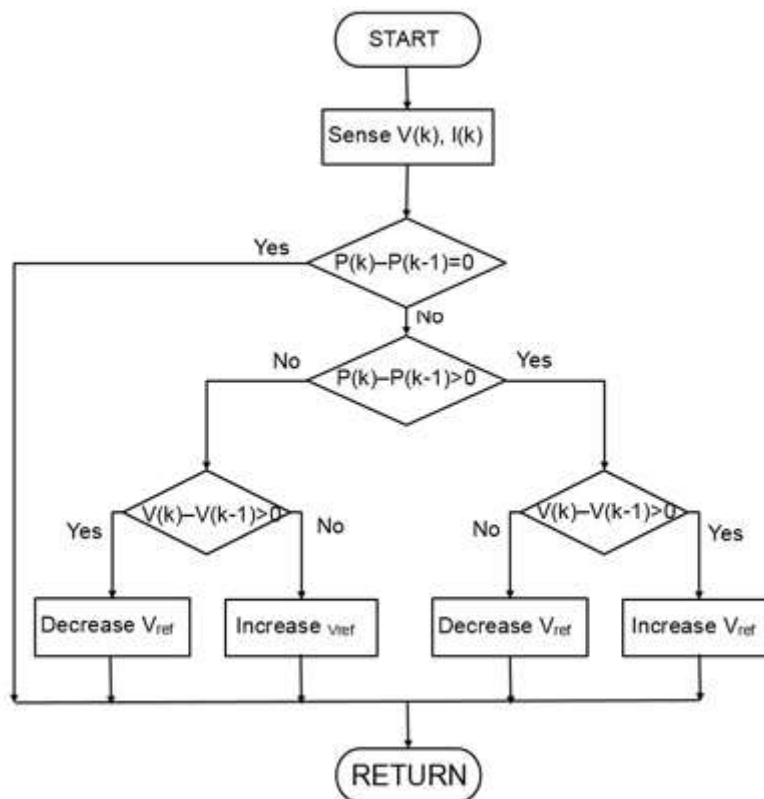


Fig. 7 P & O Algorithm

The working of P&O algorithm is as shown in figure 7. Firstly, the current and voltage of PV array are sensed at a point and then power is calculated corresponding to that point. If the power is greater than its previous values, then the power is increasing in that direction and operating point is moving toward its maximum power point and the voltage is perturbed in that direction. But if the power drawn from the PV array decreases then the operating point is moving away from maximum power point and the voltage is then perturbed in reverse direction.

IV. RESULTS AND DISCUSSION

4.1 Solar Tracker Simulink Model

The complete solar tracker system is implemented in MATLAB 2015b SIMULINK environment. Figure 8 showing the complete simulation model with four major subsystems. The solar panel with boost converter is having the solar panel of 100KW capacity. The sensor array subsystem is having the sensor modules with four LDR sensors two on each side. East side and the west side. The work of the sensors is to take the current position information of the SUN as per the irradiation captures by the sensors.

The controller design subsystem is having the control logic written in script form which decides the stepper motor movement i.e. speed and angle. The stepper motor drive subsystem contains the complete stepper motor Simulink model which takes the controller input and runs the stepper on desired steps.

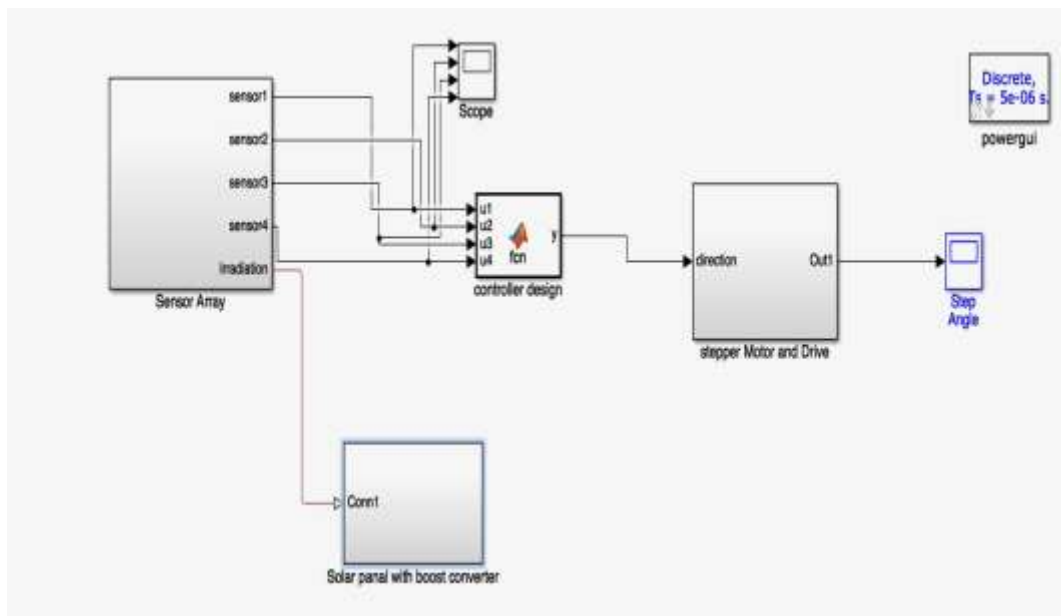


Fig. 8 Solar Tracker Simulink Model

4.2 Solar panel Subsystem

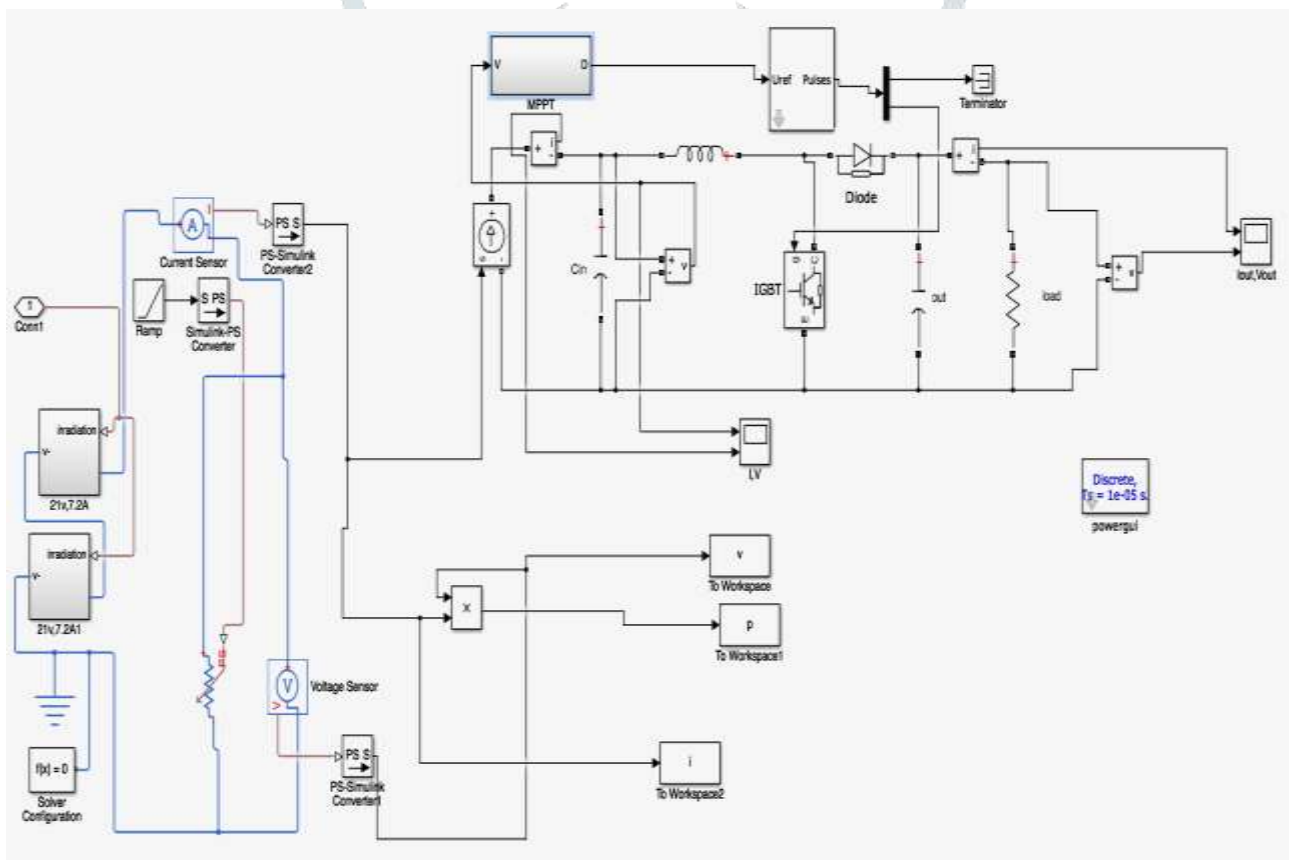


Fig 9 Solar panel Subsystem

In Figure 9, the solar panel subsystem inside is the combination of the various solar cells of the MATLAB Simulink connected in series and parallel combination to generate the desired power level form the complete panel. The PV panel is then attached to the boost converter which is used to stabilized the V_{dc} of the P.

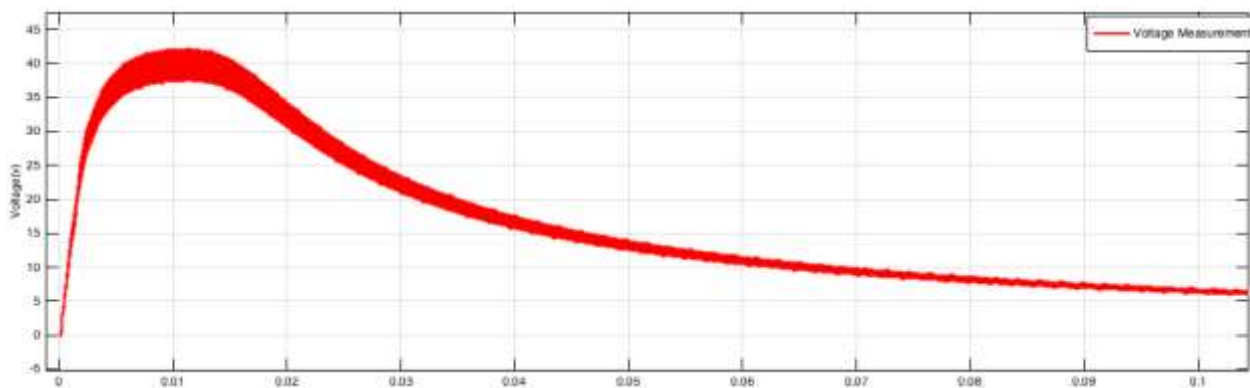


Fig. 10 Voltage of PV panel

Figure 10 and Figure 11 shows the current and the voltage levels of the PV panel respectively. The D.C. voltage (Vdc) is tuned at around 0.1 sec time. The ripple level of the waveform is on the lower side.

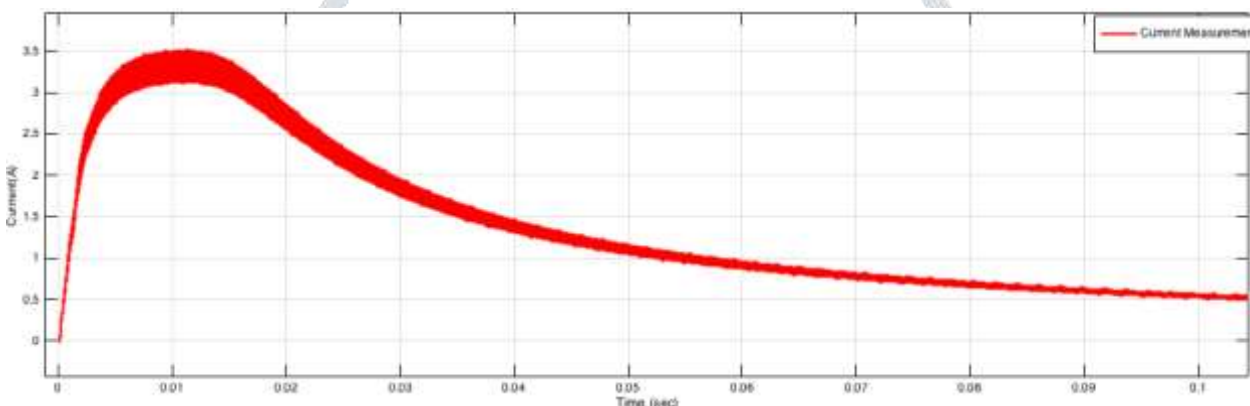


Fig. 11 Current of PV panel

4.3 Stepper Motor drive subsystem

The stepper motor subsystem consists of the stepper motor with its driver and load sensor to know its current step position. The direction of movement is decided by the controller which is fed as the input to the stepper motor subsystem and then the motor driver generates the suitable pulses to move the motor to the desired direction with desired speed

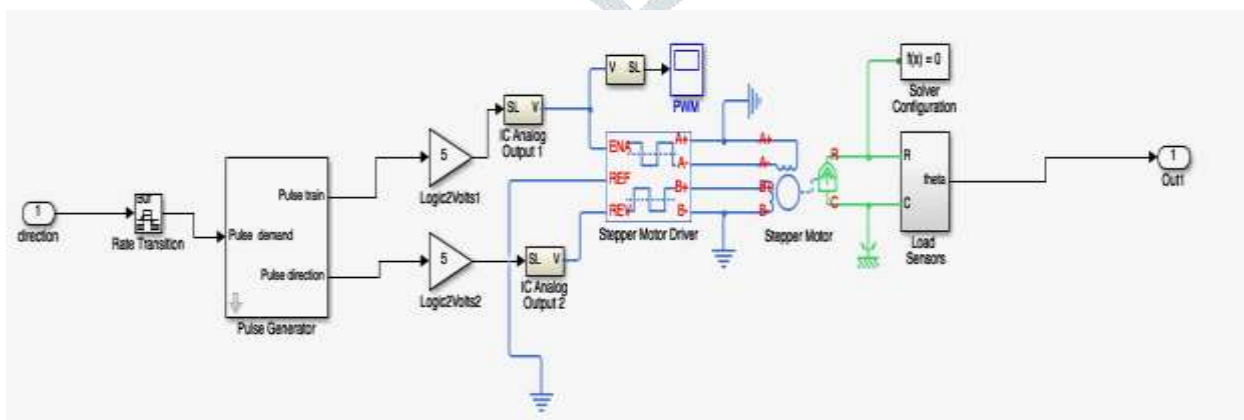


Fig. 12 Stepper Motor Subsystem

Figure 12 illustrates the stepper motor subsystem components which comprises of the Pulse generator which generates the desired pulses for the stepper motor for its step movement. Stepper motor driver which runs the stepper motor with sufficient current. Then the load sensor which gives the information about the motion of the stepper step wise.

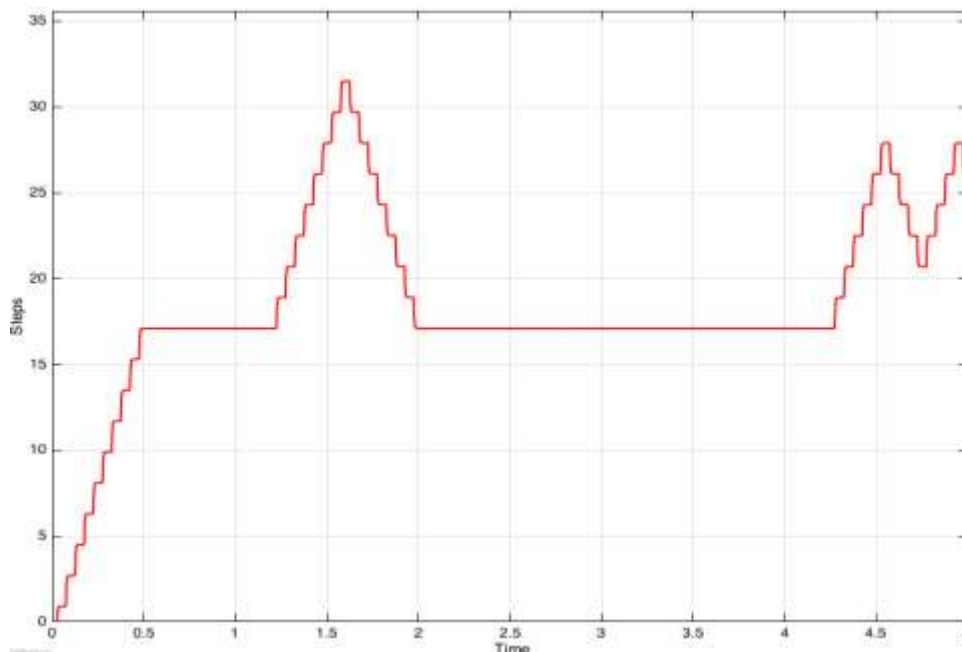


Fig. 13 Steps motion of stepper motor

Figure 13 displays the step movement of the stepper motor from 0 to 5 seconds.

4.4 Solar tracker Sensor Circuit subsystem

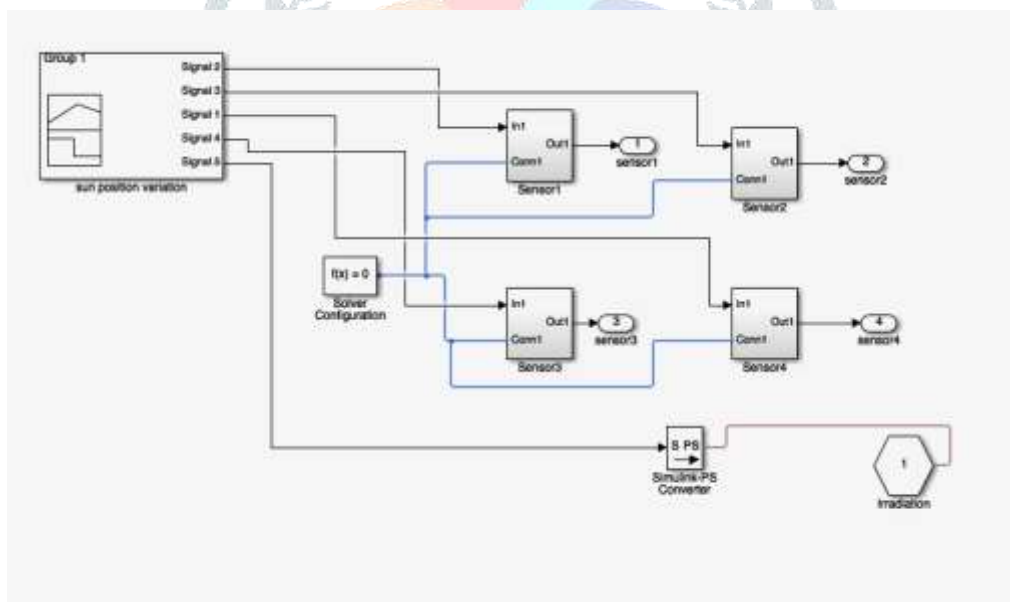


Fig. 14 Sensor module of Solar tracker

The sensor module subsystem consists of four sensors with East and west direction monitoring system. Sensor1 and Sensor 2 are for the east direction. Sensor 3 and Sensor 4 are for the West direction. The simulation of the sun current position the signal build is used which on the basis of the simulation time changes the reading of the sensors in order to simulate the sensor data as per the sun position change. Figure 14 shows the complete sensor outputs as per the SUN irradiation values.

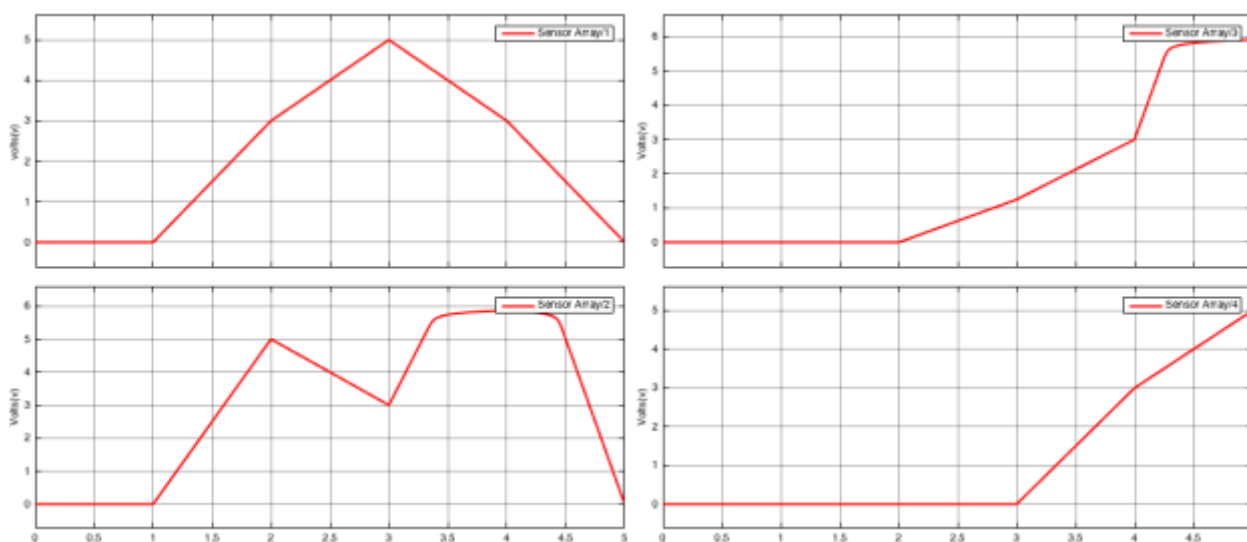


Fig. 15 Sensor array variation as per irradiation

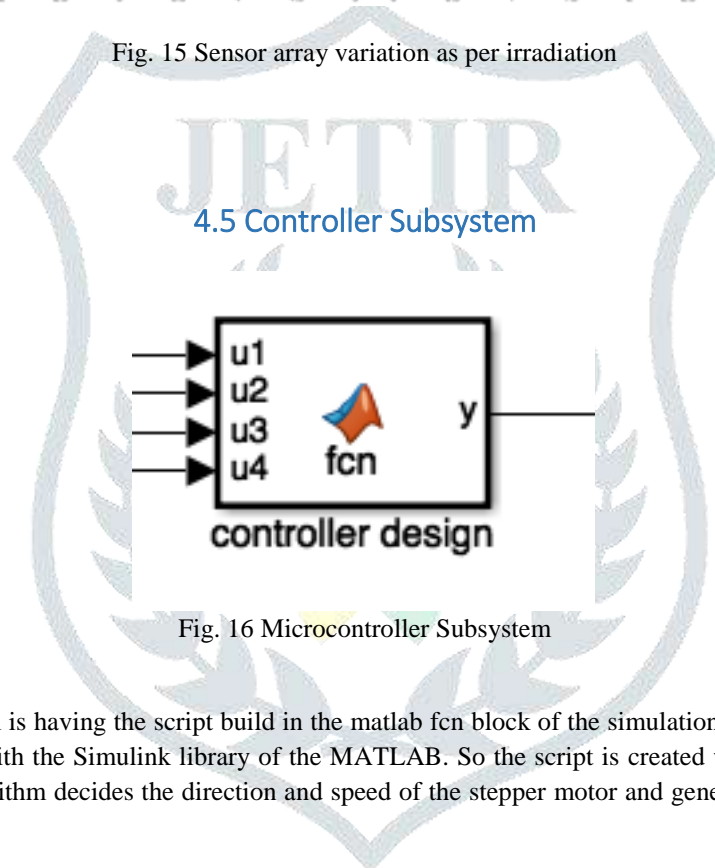


Fig. 16 Microcontroller Subsystem

The microcontroller subsystem is having the script build in the matlab fcn block of the simulation. This block is used to write the script which are compatible with the Simulink library of the MATLAB. So the script is created which takes all sensor output as input and then as per the algorithm decides the direction and speed of the stepper motor and generates the output to be fed to the stepper motor block.

V. CONCLUSION

The single axis solar tracker is successfully created using stepper motor, LDR photo sensor and a PV panel with 72 solar cells of Sim-electronics in MATLAB Simulink. The complete simulation is performed with different ranges of the solar radiation on the LDR sensor array and monitoring the step angle motion of the stepper motor. The control system design for the complete system is working in a robust manner to provide the motion to the solar panel to move the solar panel in a direction of maximum exposure to solar radiations

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