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Improving the Efficiency of Solar Energy Output with two-Axis Solar Tracking System and MPPT-SEPIC Converter

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Abstract:-This paper is proposed to optimize the efficiency of photo voltaic conversion by orienting the panel in accordance with the real position of sun by tracking in dual axis and also increases the output voltage with the help of SEPIC converter. The Dual axis tracking is facilitated by using LDRs(Light Dependent Resistors) on each axis. The MPPT algorithm is used to obtain maximum power point at any climatic condition and thus the output power can be kept constant at any instance of time. A modified P&O technique controls the amount of perturbation depending on operating point of PV solar cell is proposed. The proposed method improves voltage and power output by both solar tracking and by effective power tracking algorithm with SEPIC (Single Ended Primary Inductor Converter) controlled by PIC microcontroller. The System is tested and simulated with the help of MATLAB/Simulink

Keywords:-PIC microcontroller, Dual axis tracking, Maximum Power Point Tracking, Photovoltaic Systems, P&O technique, SEPIC Converter.

I. INTRODUCTION

The global demand for energy is reaching new milestones on every year and the conventional sources of energy are getting depleted consecutively. This imbalance made way for the non-conventional forms of energy. Though this discovery has happened so long ago, the efficiency to which it serves the consumers are still low.

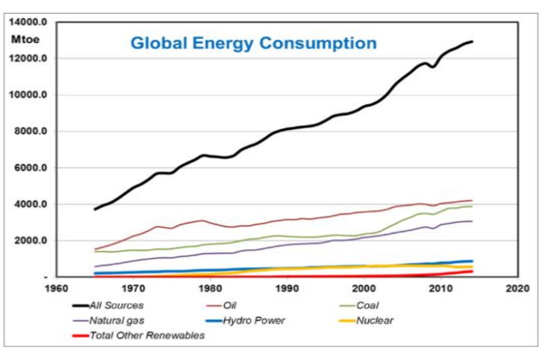

Fig 1:- Global Energy Consumption

of renewable energy sources. One of the emerging form of renewable energy is solar energy which can have great impact on energy production as far as statistics.

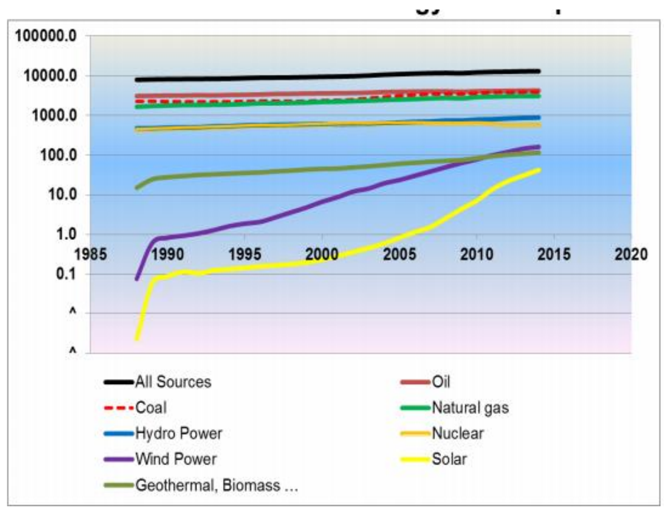

Fig 2:- Global Energy Consumption

Additionally, PV(Photo Voltaic) systems has advantages over other forms like cleanliness, no noise and very less maintenance. Hence, herewe come up with an idea of using solar energySo the increasing demand for energy can be achieved only with the advancement in the fieldto utilize them to the fullest and to meet the energy demands to a greater extent. The PV systems are now extensively used for low power electrical generation and have applications such as electrification for domestic applications, water pumping and air condition in rural and isolated areas. It is very difficult to establish a new utility system in rural areas because of cost and maintenance consideration. So DC micro grid can be directly used for rural requirements and solar energy can be utilized to generate power. The installed power can be increased by adding panels, which is one of the most attractive features of PV systems. The low conversion efficiency of PV mong dule and the variation of the output power due to changes in atmospheric conditions such as solar irradiation and temperature variation, requires specific control technique to ensure maximum power point operation in order to harvest maximum power from each module. A DC-DC boost converter with high voltage gain is

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employed to step up the output DC voltage from the PV module to a high voltage level without losing the overall efficiency of the system. Energy conversion is most efficient when the rays fall perpendicularly onto the solar panels. This can be possible only with suitable alignment of panel in accordance with sunlight is made for every inclining angle (solar angle). For this a proper tracking system has to be developed in order to rotate the solar panel for every solar angle. Thus, the work is divided into three main parts namely the mounting system, the tracking controller system and the electrical power system. The mounting system consists of mechanical parts which are responsible for the proper positioning of solar panel. The Tracking system is purely based on the output of LDR sensors suspended on each side of the solar panel followed by performance of MPPT algorithm. Though there are three methods of tracking like active, passive and chronological tracking, maximum power tracking gives the maximum output power from the panel there by giving the maximum efficiency from the panel. Then comes the electrical power system which consists of DC geared motor and relaysto incline the panel in alignment with the solar angle.

A. Solar Energy

The Solar Energy from the Sun is harnessed in the form of electrical energy in solar cell. This conversion is made possible only due to the high energy particles emitted from sunlight called Photons. The Energy of these photons are absorbed and is transmitted to electrons present in semiconducting material. As these semiconducting materials possess an appreciable forbidden energy gap, the valence electrons are subjected to the action of photons.

B. Solar Panel

The Solar panel is the main component of the system which converts solar energy into electrical energy which is a collection of many photovoltaic cells. They work on the principle of Photovoltaic effect. This principle states that when two dissimilar metals are exposed to sunlight, the photons are absorbed by the semiconducting material and thus the energy of photon is transferred to the electron that makes it to escape from its bond with atom and generates electric current. This process continues to produce excess electrons and holes which is responsible for the continuous supply of electric energy as long as the photon emission takes place. This same effect takes place in every solar cell of solar panel.

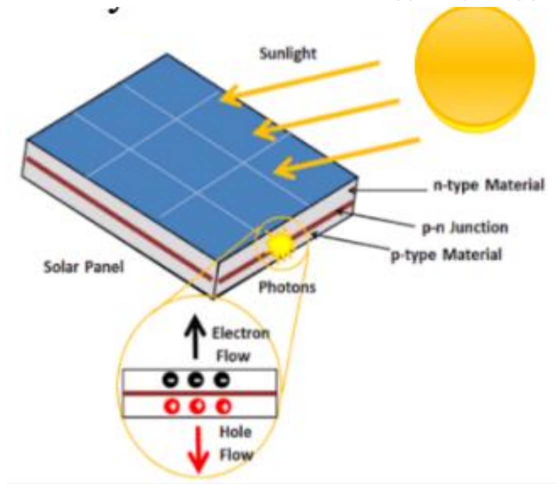

Fig 3:- Working of solar panel

C. Solar Tracking System

The global warming has increased the demand and request for green energy produced by renewable sources such as solar power. Consequently, solar tracking is increasingly applied as a sustainable power generating solution. Solar tracking system is a device for orienting a solar panel orconcentrating solar reflector or lens towards the sun. Concentrators, especially in solar cell applications, required high degree of accuracy to ensure that the concentrated sunlight is directed precisely to the powered device. Precise tracking of sun is achieved through systems with single or dual axis. But with the existing single or dual axis the power is tracked up to some extent only. Thus we are proposing the Quadruple axis solar tracking system to track the sunlight throughout the 360 degrees.

II. EXISTING SYSTEM

Earlier, the fixed mount solar panels existed which does not use any type of tracking methodology. It directly converts the emitted sunlight that falls perpendicularly to the panel into electrical energy. It is inclined in a single fixed angle where only at certain times the solar angle can align with the panel. Thus this type produces only an appreciable value of output. Then after the proposal of tracking phenomena, the solar energy generation systems with PV panels have changed with new techniques as follows-

A. Single Axis Solar Tracker

The Single Axis Solar tracking System can move the panel in two directions (either to left or to right), depending upon the output of LDR (Light Dependent Resistor). The LDR on either side of solar panel sense the intensity of light and pass the resulting signals to the controller. Depending upon the output of each LDR, the controller will pass the control signal to the motor, which turns the solar panel proportionately to suitable to the angle of inclination.

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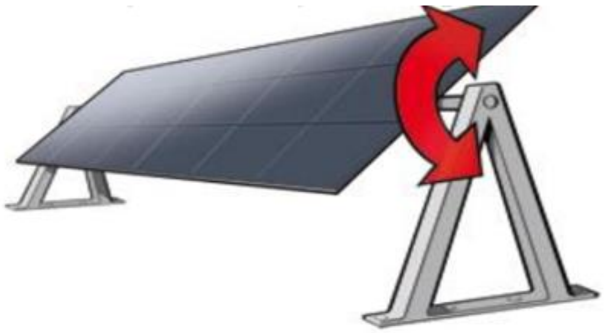

Fig 4:- Single Axis Tracker

According to the use of single-axis tracking can increase the electricity yield by as much as 27 to 32 percent. This kind of tracker is most effective at equatorial latitudes where the sun is more or less overhead at noon. Due to the annual motion of the earth the sun also moves in the right and left direction depending on the season and due to this the efficiency of single-axis is reduced since the single-axis tracker only tracks the movement of sun from top to bottom. During cloudy days the efficiency of the single axis tracker is almost close to the fixed panel.

B. Dual Axis Solar Tracker

The Dual Axis Solar tracking system is enhanced version of Single axis tracking, wherein this can rotate the panel in all four directions, facilitating its movement in around 360 degrees. This monitors the movement of the sun in every axis as it has four LDRs connected in all the four sides of the panel.

Fig. 5:- Dual axis tracker

It has several advantages over other tracking processes as the fixed systems are only positioned at the optimal angle for energy production for a limited number of hours each day. With a dual-axis solar tracker, panels will always be oriented towards the sun, no matter the season or time of day, maximizing the solar-system energy production and resulting in up to 45% moreenergy.

III. PROPOSED SYSTEM

The proposed system works on the solution to increase the output of dual axis solar tracking system by using P&O method of MPPT algorithm and also increasing its efficiency with SEPIC converter. The SEPIC converter is mainly used in the proposed system instead of normal boost and buckboost converters because of its output gain flexibility. The SEPIC converter has noninverted output and it uses a series capacitor to isolate input from output unlike the other conventional buck-boost converters. The boost converter has continuous input current, but the output voltage is always larger than the input which may not achieve the maximum power voltage is less than input. Thus the maximum efficiency is derived from the solar panel by using two combined

techniques –

A. Dual axis solar tracking which gathers the light energy and produces electricity which uses MPPT algorithm to sense the maximum power point at any time

B. Convert the output voltage from the solar panel to suitable amplitude to charge the battery using SEPIC converter Thus by using both these phenomena together, we can receive high voltage output with less ripples and thus making the system more efficient.

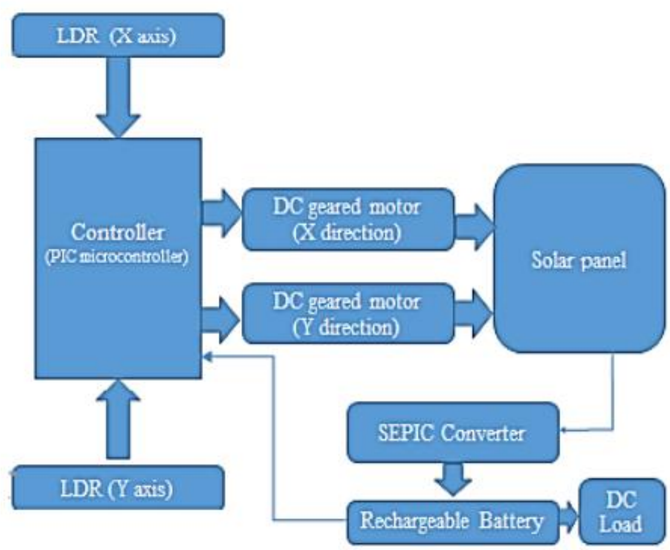

Fig. 6:- Block Diagram

The main objective of this system is to increase the efficiency of the output from solar panel using dual axis solar tracking system. As mentioned in the existing system, the dual axis tracking system is mainly dependent upon the output of four LDRs fixed in all four directions of the solar panel. The sensed output from the LDR will be passed

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onto the controller through the Signal Conditioning Unit (SCU). The controller programmed with MPPT algorithm will detect the maximum power point and will pass the proper control signal to relays of the motor, in order to facilitate the panel rotation to proper position. On the other hand, the solar energy falling on the panel will be converted into electrical energy and this voltage will pass onto the SEPIC converter, which converts them into suitable amplitude to recharge the battery. Hence, the battery can drive any DC load.

IV. HARDWARE IMPLEMENTATION

Our project is mainly focused on increasing the efficiency of power output from the solar panel, it includes the following components which acts as the main parts of the proposed system-

- PIC microcontroller
- Light Dependent Resistor
- DC motor
- Solar panel
- Rechargeable battery
- DC load
- Worm gear arrangement

A. PIC microcontroller

A microcontroller is a computer control system on a single chip. It has many electronic circuits built into it, which can decode written instructions and convert them to electrical signals. The microcontroller will then step through these instructions and execute them one by one. As an example of this a microcontroller could be used to sense the light intensity output from LDR and can control the motor speed through relay. Microcontrollers are now changing electronic designs. Instead of hard wiring a number of logic gates together to perform some function we now use instructions to wire the gates electronically. The list of these instructions given to the microcontroller is called a program. There are different types of microcontroller, this research focus only on the PIC16F877A Microcontroller. PIC microcontroller offer different kinds of memories. PIC 16F877A has different types
of memories such as EEPROM, EPROM, FLASH, etc. FLASH is the most recently developed technology. So, that data is retained even when the power is switched off.
Easy Programming and Erasing are other features of PIC 16F877A. Some of the core features of PIC 16F877 are,

- High-Performance RISC CPU
- All single cycle instructions except for program branches which are two cycle Operating speed: DC – 20MHz clock input DC – 200 ns instruction cycle
- Up to 368 x 8 bytes of Data Memory(RAM)
- Up to 256 x 8 bytes of EEPROM data memory
- Interrupt capability

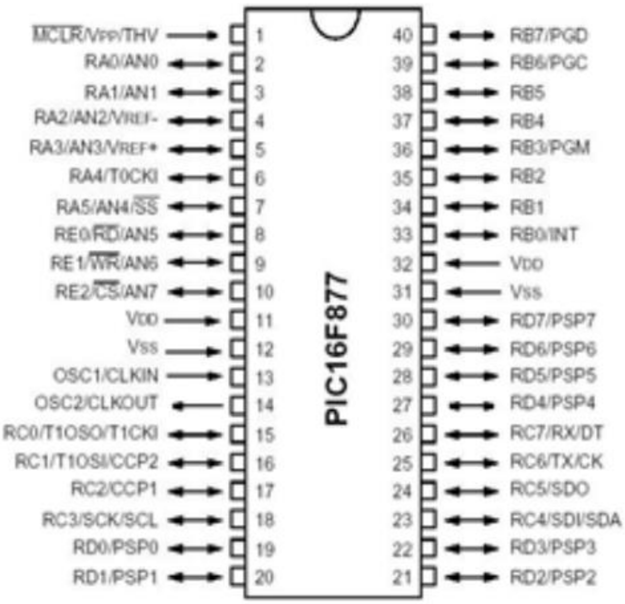

Fig. 7:- PIC microcontroller

B. LDR sensor

A Light Dependent Resistor (LDR) is also called a photo resistor or a cadmium sulfide (CdS) cell. It is also called a photoconductor. It is basically a photocell that works on the principle of photoconductivity. The passive component is basically a resistor whose resistance value decreases when the intensity of light decreases. The main aim of LDR is to sense the higher density range of sunlight give command to relay circuit which will direct the direction of our solar panel.

Fig .8:- LDR Sensor

C. DC motor

It gives gradual yet accurate motion to the panel thus we can obtain precise motion of the tracking system. DC motor consists mainly of a gear reduction unit, a position sensing device and a control unit. It receives output position of the servo shaft and apply power to its DC motor until its shaft turns to that position.

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Fig 9:- DC motor

The speed of a DC motor can be controlled by changing the voltage applied to the armature. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems which adjust the voltage by "chopping" the DC current into on and off cycles which have an effective lower voltage

D. Solar Panel

Solar chargers convert light energy into DC current. They are generally portable, but can also be fixed mount. Fixed mount solar chargers are also known as solar panels. Solar panels are often connected to the electrical grid, whereas portable solar chargers as used off-the-grid (i.e. cars, boats, or RVs). Although portable solar chargers obtain energy from the sun only, they still can (depending on the technology) be used in low light (i.e. cloudy) applications. Portable solar charger are typically used for trickle charging, although some solar charger (depending on the wattage), can completely recharge batteries. Solar panels (arrays of photovoltaic cells) make use of renewable energy from the sun, and are clean.

Fig. 10:- Solar panel

There are two types of Solar panel

- . Crystalline Solar panels
- . Amorphous Solar panels

The Crystalline solar panels are produced in two ways – polycrystalline and monocrystalline. Crystals are grown in special chambers and then sliced to create wafers, whichin turn are then cut and soldered together to create the necessary voltage and current required. Both types are natural materials and are easy to identify by the actual shiny crystals that are visible as well as the solder and weld lines. Because of this flexibility, crystalline panels are used across a variety of applications that have limited space and/or require placement of multiple panels to achieve the desired circuit where it would be impossible to have one larger amorphous panel. Amorphous solar panels are manufactured using a thin film deposition process laid onto glass, wherein the prescribed voltage and current are created as part of the actual manufacturing process. Some suppliers produce a second layer of silicon to boost the electrical output, at extra cost, which is referred to as “dual junction”. The process can be highly automated depending on the factory and their production equipment. Historically, dual junction amorphous has mainly been manufactured in Germany whereas single junction amorphous is mainly produced in China, although dual junction factories are now appearing in China too. They are easily identified because they have a purplish-blackish appearance without any solder or weld lines and look like darkened glass. But amorphous is less efficient than crystalline because amorphous is inherently less efficient than crystalline, only being around 7-10% efficient at light conversion compared to a crystalline panel of the same size which has typically between 12-15% efficiency.

E. Rechargeable Battery

An electrical battery is one or more electrochemical cells that convert stored chemical energy into electrical energy. The invention of the first battery (or "voltaic pile") was in 1800 by Alessandro Volta. Nowadays, batteries have become a common power source for many household and industrial applications. According to a 2005 estimate, the worldwide battery industry generates US$48 billion in sales each year, with 6% annual growth. There are two types of batteries: primary batteries (disposable batteries), which are designed to be used once and discarded and secondary batteries (rechargeable batteries), which are designed to be recharged and used multiple times. Here in this system, a 12V rechargeable battery is used.

F. Worm Gear Arrangement

A worm drive is a gear arrangement in which a worm (which is a gear in the form of a screw) meshes with a worm gear (which is similar in appearance to a spur gear). The two

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elements are also called the worm screw and worm wheel. The terminology is often confused by imprecise use of the term worm gear to refer to the worm, the worm gear, or the worm drive as a unit. Like other gear arrangements, a worm drive can reduce rotational speed or transmit higher torque. A worm is an example of a screw, one of the six simple machines. One of the major advantages of worm gear drive units are that they can transfer motion in 90 degrees

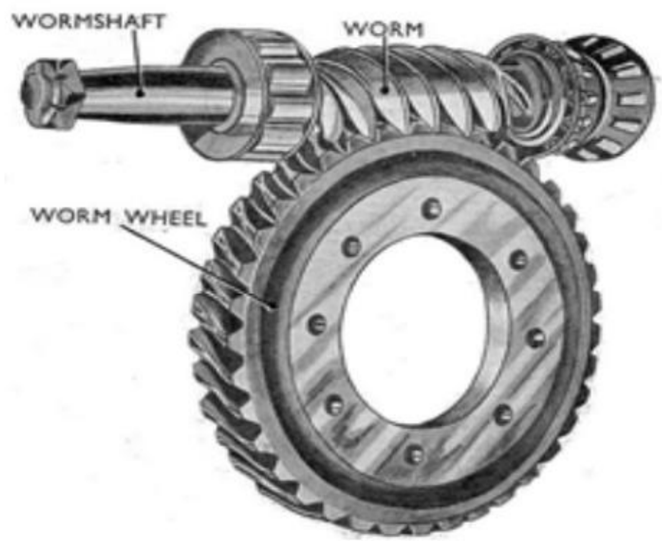

Fig. 11:- Worm gear arrangement

G. DC Load

The DC load connected to the battery is used for practical application purpose only. It can be in any form like LED lamp, DC fan etc., depending upon the requirement.

V. SIMULATION AND RESULTS

The Results of the dual axis tracking system are already analyzed and its output does not go beyond 10V practically. But the system that we propose can produce up to 15V with input of less than 5V with the help of SEPIC converter. And it can also buck the input voltage from the solar panel if the resultant voltage from the panel can go beyond 20V, in any extreme case.

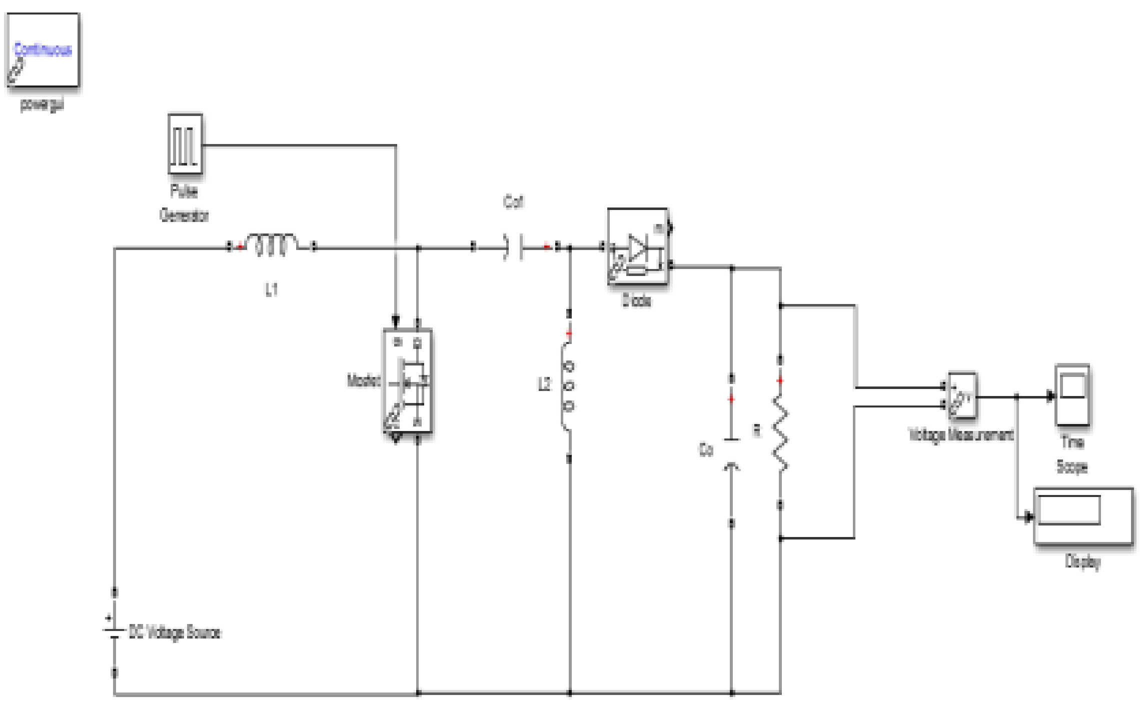

Fig.12:- Simulation of SEPIC

The simulation results are as follows-

- If the input voltage is 5V, the proposed system achieves 12Vwithin 60ms
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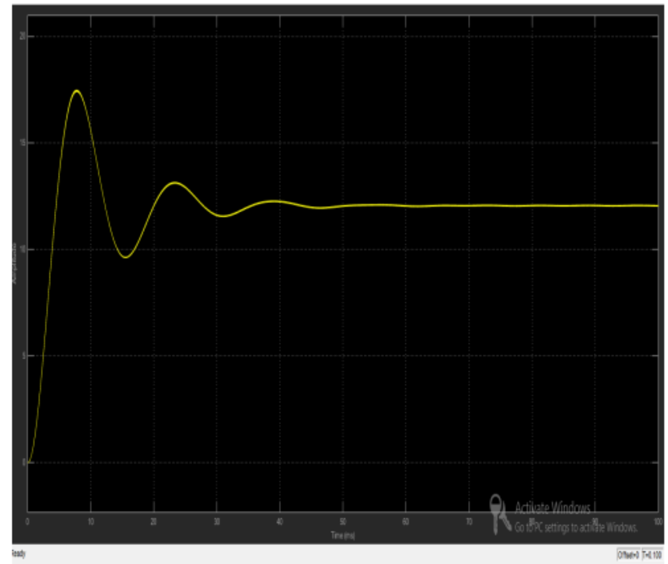

Fig 13:-Output 1.

- Even if the input voltage is 25V, the proposed system can buck and achieve 12V within 60ms

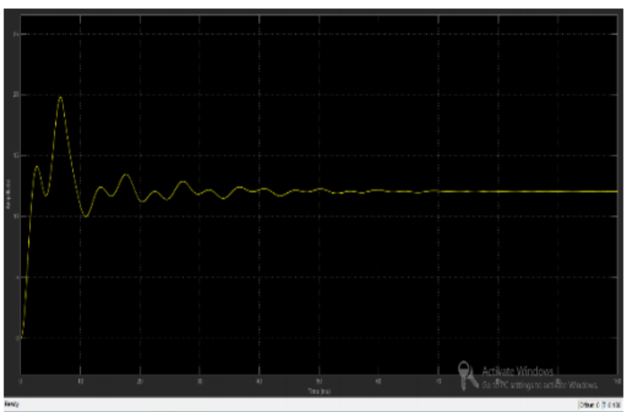

Fig 14:-Output 2.

VI. CONCLUSION

In this project, the system consists of a high efficiency, Buck-Boost type dc/dc converter, and a microcontroller based unit which controls the dc/dc converter directly from the PV. In case of failure of supply main supply can be connected to overcome the power interruption. Thus, we experimentally verified the combined working of dual axis solar tracking system with SEPIC converter and the efficiency of output is maximized as constant voltage is achieved.

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