Advanced Solar Tracking System with MPPT For PV Application

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Abstract* – With growing demand for energy worldwide, a drastic shortage of the non-renewable sources of energy will be observed in future. Hence, there is a need to replace these resources with those that are renewable. For collecting the solar energy, solar panels are used. These technologies provide only 22% efficiency as it faces the sun only for a limited amount of time period per day. In our work, an advanced dual axis tracker design which also logs the data such as battery voltage, current and total output power by means of Bluetooth technology has been designed and implemented. This tracker is used to tilt the solar panel according to the sun's position. In addition to that this circuit has equipped with the MPPT technology, which can boost the efficiency up to 42%. The P&O algorithm is used for the MPPT technique in this project. Both the Dual axis tracker and the MPPT circuit are controlled and operated by Arduino UNO.

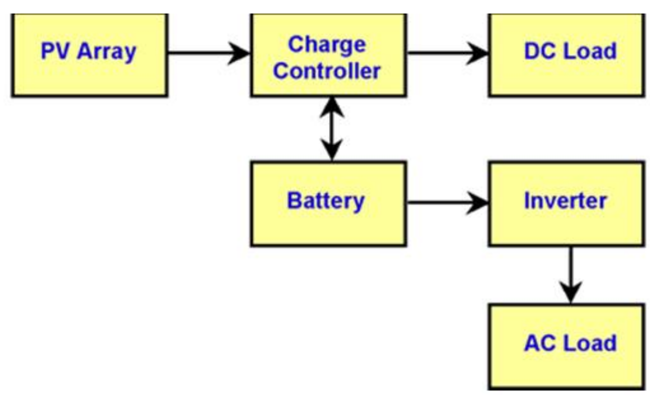
Keywords* – solar tracker; dual axis; MPPT; advanced tracking; data logger.

I. INTRODUCTION

As the demand for energy is continuously increasing it is imposing an excessive amount of pressure on the existing sources of power generation such as fossil fuels which is leading to high concerns of environmental pollutions and thus pushing society to explore new technologies for producing electrical energy from renewable sources such as wind energy, hydro energy, geothermal energy and solar energy. The most widely used renewable sources are hydro and wind energy, with solar energy being moderately used worldwide. Still, solar energy affords the adequate potential for conversion into electrical energy and hence solar power is an important source of energy. Also with solar power being a highly researched field it has now become a cheap and feasible option. With a peak efficiency of 32% and an average efficiency of only 15-20%, maximum efforts should be made to recover energy from the solar power system and hence light gathering losses, inverter losses and storage losses should be minimized [2]. Therefore, an attempt has been by designing, implementation, and evaluation of a compact two-axis solar tracking system along with a maximum power point tracking algorithm. With the discovery of photoelectric mechanism and subsequent development of the photovoltaic cell (a semiconductive material which is used for conversion of light energy to electric energy).

Deriving useable energy from the sun was made possible and hence a DC voltage is being generated which is used across a load [3]. While comparing the two-axis solar tracker to a fixed panel one, a mobile photovoltaic panel which is driven by the solar tracker is better as it gives more precision to the light falling to the geometric normal incident angle. The conversion efficiency of a photovoltaic panel is consistently boosted by the automatic solar tracking system using the light intensity sensing and hence utmost energy is extracted from the sun. Along with solar tracking, MPPT technology squeezes maximum power form the panel and also the parameters such as battery voltage, current solar panel output power is also recorded with the help of an onboard Bluetooth data logging technique where all the parameters are being registered after an interval of one second. Hence the tracker changes its photovoltaic panel orientation according to sun's direction. These registered values are later used for analyzing the efficiency of the tracking mechanism.

A] EXISTING SYSTEM



A free standing or **Stand Alone PV System** is made up of a number of individual photovoltaic modules (or panels) usually of 12 volts with power outputs of between 50 and 100+ watts each. These PV modules are then combined into a single array to give the desired power output. A simple *stand alone PV system* is an automatic solar system that produces electrical power to charge banks of batteries during the day for use at night when the suns energy is unavailable. A stand alone small scale PV system employs rechargeable batteries to store the electrical energy supplied by a PV panels or array.

Stand alone PV systems are ideal for remote rural areas and applications where other power sources are either impractical or are unavailable to provide power for lighting, appliances and other uses. In these cases, it is more cost effective to install a single stand alone PV system than pay the costs of having the local electricity company extend their power lines and cables directly to the home.A stand alone photovoltaic (PV) system is an electrical system consisting of and array of one or more PV modules, conductors, electrical components, and one or more loads. But a small-scale PV system does not have to be attached to a roof top or building structures for domestic applications, they can be used for camper vans, RV's, boats, tents, camping and any other remote location. Many companies now offer portable solar kits that allow you to provide your own reliable and free solar electricity anywhere you go even in hard to reach locations.

B] LIMITATION OF FIXED CONFIGURATION

Through the I-V and P-V characteristics of a solar panel in Fig 2, it can be observed that the maximum output power of a solar panel is obtained when the solar panel is operated close to the knee point. This is done through the method of Maximum Power Point Tracking (MPPT) algorithms. However, MPPT cannot only provide maximum power for fixed position solar panels, it also can be used when the panel oriented towards the sun. Therefore, a tracking configuration is developed in order to fully maximize the power output from the solar panel by always aligning it towards the sun.

II. PROPOSED SYSTEM DESCRIPTION

A] BLOCK DIAGRAM

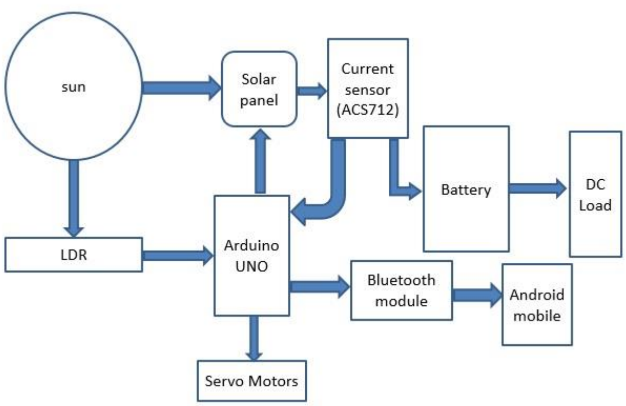


Fig 1. Block diagram of the solar tracker with data-logging.

The block diagram consists of various blocks like input block, control block, and output block. The input block deals with the primary source(sun), Solar panel, Current sensor and the LDR. The light energy from the sun is the main input to this system. The spectral lines of sunlight consist of various spectrum such as IR, UV, visible light And others. With respect to these spectral line's intensity, photovoltaic effect takes place and respective electrical energy is produced. The LDR senses the sunlight intensity and feeds it to the control unit. The LDR has a property of varying resistance with respect to the light intensity. The PV panel produces the electrical energy with respect to the sunlight's input. The PV panel works

with respect to the sunlight's input. The PV panel works basis on the photovoltaic effect and produces electrical energyWhen the photon of the sunlight hits on the PV panel, the valence electrons were released and that electrons is used to produce electrical energy. Polycrystalline panel is used in this prototype due to less cost. The current sensor used in this project is ACS712. A hall effect based sensor which is used to measure the short circuit current and the panel voltage. This current sensor gives the value to Arduino board for the P&O method of MPPT calculation.
The control block consists of Arduino board and Servo motors. The Arduino board has the control algorithm to drive the servo motor and to determine Maximum Power Point Tracking. The Arduino programming is similar to the advanced version of the C++ programming language. The program which gives the respective control pulses to the servos by the input gives by the LDR. The Arduino gives the gate pulse of PWM signal to the servos connected in its 9^{th} and 10^{th} port. The triggering of the gate pulses is based on the sun's position with respect to the panel. There are two servos placed for accurate tracking. One is horizontal servo(x-axis), and another is vertical servo(y-axis). Both the servo operated on the gate control of the Arduino board. Towerpro MG995 type servo motor were used in the project. Last block is called output block. This block consists of a Battery, Bluetooth module, relay circuit, DC load, and LCD display. The battery is used to store the DC voltage from the PV panel. Bluetooth module is used to transfer the data from the Arduino board to an external device within the Bluetooth range. This is used to get the exact power, exact position of sun, and the current values. LCD display is used to display the parameters in the kit. This LCD display is the display unit in the kit which displays the necessary parameters of the MPPT technology. DC load is connected parallel with the battery unit. The relay circuit is provided for undervoltage condition. The battery volt falls below the threshold value, the relay switches an alternative source to drive the load. The 12v relay used as switching circuit in the kit.

III. DESIGN OF THE PROTOTYPE

A dual axis design is chosen for the solar tracker to enable efficient tracking of sun's position throughout the day. The movement of the solar tracker in both the horizontal and vertical directions allows the solar panel to be continuously exposed to direct rays of the sun which ensure that output of the solar panel is maximum at all times in a day. The data logging part is included to keep track, the output of the solar panel. The MPPT technique captures maximum power from the solar energy.

A] construction of the design

The components used in the project are as follows:

i] Servo motor:
Modulation: digital;Torque: 48V: 1305 Oz-in (940 Kg-cm) 60V: 1528 Oz-in (1100 Kg-cm),Speed: 48V: 020 Sec/60 degree 60V: 016 Sec/60 degree,Weight: 194 Oz (550 G),Dimensions: length: 160 In (407 Mm) width: 078 In (197 Mm) height: 169 In (429 Mm)

ii] Current sensor:

Hall current sensor module acs712 5a model the device consists of a precise, low-offset, linear hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the hall IC converts into a proportional voltage.

iii] Arduino UNO:

Microcontroller: ATmega328;Operating Voltage: 5V;Input Voltage (recommended): 7-12V;Input Voltage (limits):6-20V;Digital I/O Pins: 14 (of which 6 provide PWM output);Analog Input Pins: 6;DC Current per I/O Pin: 40 mA;DC Current for 3.3V Pin: 50 mA.

iv] Solar panel:

Polycrystalline solar panel is used in the circuit. 60v panel of blue hue is used. The panel size of 25x25 were taken.

v] Bluetooth module:

Frequency : 2.4GHz ISM Band; Bluetooth Protocol : Bluetooth Specification v2.0 + EDR; Emission Power : ≤4dBm, Class 2; Modulation : GFSK (Gaussian Frequency Shift Keying); Operating Voltage : 3.3V; Input Power Supply : 3.6V ~ 6V; Security : Authentication & Encryption; Working Temperature : -20°C ~ +75°C; Dimensions : 35.7mm x 15.2mm x 5.6mm; Auto Connect to Last Device on power as default; Supports Master and Slave Modes; On-board Re-search Button HC-05 6-Pin Serial Bluetooth Module.

vi] Battery:

12V battery is used. Li-Ion battery is used due to the rechargeable purpose.

B] Working of the design

The solar panel is exposed to the sunlight with the help of cast steel stand design implemented on the servos. The horizontal servo is placed in the bottom and the vertical servo is placed in top. The triggering pulse, +ve, -ve terminals are connected with the Arduino board. Next to the tracking setup the current sensor is used to sense the value of the output values from the panel. Based on the position of the sun, LDR gives the signal to Arduino board. After that, the respective position of the panel should be decided by the Arduino's control sequence. The Arduino gives PWM signal to the servos to tilt the panel in suitable angle. The microcontroller used in the Arduino is, ATmega328. There are 6 analog pins in the board which takes the input from the LDR. The A0 pin is configured to current sensor and the other 5 pins are configured for 5 LED's the digital pin D4-D7 are configured for the LCD display which acts as the display unit in the kit. The transmitter and receiver pins of Arduino were connected to the receiver and transmitter pins of the Bluetooth module respectively. Bluetooth terminal is the application used to connect the Bluetooth module to the external world. The battery is used to store the DC output from the solar panel. A DC load is connected to the relay circuit, which is connected with the battery unit. The relay is used as a switching circuit. The Bluetooth module is used for external connectivity to the world.

IV. DISCUSSION

The solar panel in tracking configuration was observed to be more effective in collecting solar energy over a period of eleven hours as compared to the solar panel in fixed configuration. The average voltage maintained by the solar panel in fixed configuration was found to be 3.53V, whereas the average voltage maintained by the solar panel in the tracking configuration and MPPT algorithm was found to be 4.815V. This is seen in Table 1.

Table 1. Comparison of the Solar Panel Output for Fixed and Tracking Configuration.

Time (Hour)	Fixed Configuration (V)	Tracking Configuration (V)
8:00 AM	3.6	4.2
9:00 AM	4.13	4.6
10:00 AM	4.86	5.03
11:00 AM	5.1	5.2
12:00 PM	5.35	5.35
1:00 PM	5.35	5.35
2:00 PM	4.9	5.35
3:00 PM	3.2	5.35
4:00 PM	2.6	5.35
5:00 PM	1.7	5.08
6:00 PM	0.8	3.72
7:00 PM	0.8	3.2

Therefore the average voltage maintained by the solar panel in tracking configuration was 36.3% higher than the fixed configuration. Since the automated tracking configuration was able to keep the solar panel aligned to the sun longer, there was an increased average voltage and consequently increased power output. This shows that the solar panel in tracking configuration was able to output its peak voltage for a longer period of time as compared to the solar panel in fixed configuration. The onboard automatic data logging system made the recording of measurements of battery voltage, solar panel output voltage, and light dependent resistor reading easier as compared to recording measurements manually

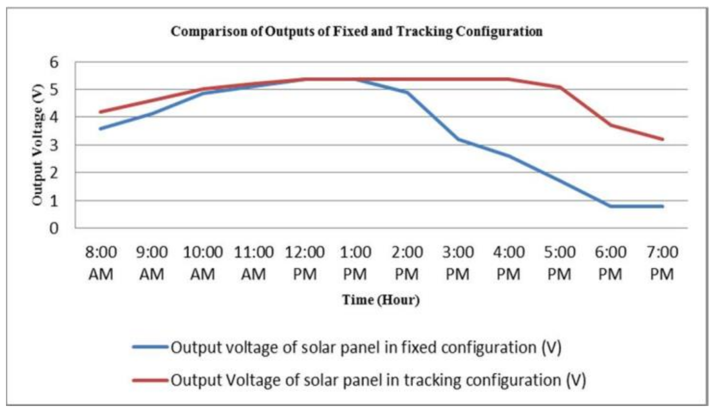


Fig 6: comparison of the output voltages between the fixed and tracking configurations

The comparison of the output voltages between the fixed and tracking configurations is plotted in Fig 6.

V. CONCLUSION

Thus the Avanced solar tracking system with MPPT for PV applications were successfully implemented and executed. The automated dual-axis solar tracking system was implemented using an ATMega328 microcontroller programmed using the Arduino IDE. This syste can be used as an alternate source for household power generation when fitted with a high power rated solar panel.

When compared with a fixed configuration set at an inclination of 20^{o}, the tracking configuration showed an average output voltage that was 37% higher. The power consumption of the system also reduced by using low power modes in between takingreadings. The tracking configuration has the ability to replace and improve the efficiency most of the fixed configuration panels. The panel used in tracking configuration was able to maintain its peak voltage for longer time as compared to the fixed panel thus yielding more solar energy. And the communication system used in this project gives the exact value of the PV system. The MPPT algorithm provides a maximum constant output voltage by P&O method.

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