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Implementation of IoT based Dual Axis Photo-Voltaic Solar-Tracker with MPPT using ARDUINO UNO and OCTABRIX

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Abstract
In this study IoT (Internet of Things) based Dual Axis Photo-Voltaic (PV) solar tracker with maximum power point tracking (MPPT) is proposed. In order to extract more amount of energy from PV module, MPPT technique along with calculation of azimuth angle and sun elevation angle are done. So that we can obtain the position of the sun with respect to the PV panel geographical location. Unlike sensor-based PV tracker which uses auxiliary devices such as LDR, small PV cells, photo diodes, etc ,to obtain the position of the sun, here we have used sun SPA algorithm to obtain the sun's position taking input parameters as latitude, longitude, time and day number. MQTT (Message Queuing Telemetry Transport) protocol is used to transmit and receive data form PV module (OCTABRIX) and server (ARDUINO). The shared information will be voltage, current, azimuth angle, altitude angle and duty cycle for boost converter. Here Algorithm for solving sun equations and MPPT logic is placed in ARDUINO, it calculates the duty cycle required to extract the maximum power from the PV system. CAYENNE platform is installed on the ARDUINO , and for changing the position of PV module 2 servo motors were used and one OCTABRIX which acts as a client for the server and also it acts as a controller for the PV module and boost converter. A photovoltaic system has been constructed and experimentally verified that the proposed sun tracker finds the sun's position with a tracking error of 0.18^o and 0.61^o for altitude and azimuth angle respectively, and there is an increase in energy of 38.579%, using proposed sun tracker.

Keywords – IoT, CAYENNE, OCTABRIX, ARDUINO, MPPT, Photovoltaic system.

I. INTRODUCTION

The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction". The IoT is influencing our lifestyle from the way we react to the way we behave form air conditioners that you can control with your smart phone to smart cars providing the shortest route or your smart watch is tracking your daily activities IoT is a giant network with connected devices[1]. These devices gather information and share data about how they are used in the environment and how they are operated it's all done using sensors, sensors are embedded in every physical device which can be traffic lights, smart watches, etc that we come across in day to day life [3].

These sensors continuously emit data about the working state of the devices, but the important question is how they share this huge amount of data, and how do we put this data to our benefit. Internet of Things provides a common platform for all these devices to dispose their data and a common language for all these devices to communicate with each other.

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IoT platform security. IoT platform integrates the collected data from various sources further analytics is performed on the data and valuable information is extracted as per requirement [4]. Finally, the result is shared with other devices for better user experience automation and improving efficiencies. The future of IoT industry is huge. Business insider intelligence estimates that around 24 billion internet connected devices will be installed by 2020[2].

Cayenne is an online IoT dashboard that takes most of the complication out of creating hardware-oriented programing. Originally it worked with just the Raspberry Pi. Now it is available for the Arduino as well.

Cayenne is a drag-and-drop programming system for the IoT that really does make it much easier. It not only makes it possible to build programs using drag-and-drop, it standardizes the connection of devices such as sensors and motors and makes sure that drivers are in place. In this sense it makes the programming and the hardware much easier[6].

All you have to do is install the Cayenne agent using the web site. The Arduino needs to have an Internet connection - after all this is the Internet of Things - and this means either an Ethernet or WiFi shield. You also need the Arduino IDE setup on a PC or Mac connected to the Arduino by USB, but this is fairly standard. Using Arduino, we can use cayenne and access the required data from the cayenne my devices.

MQTT (Message Queuing Telemetry Transport) is a messaging protocol that works on the principle of publish and subscribe mechanism, for simply communicating between the machines. For running it is required to install a server which is named as broker. We can install the broker on almost all platforms (windows, mac os, linux…) and on raspberry-pi. Here mosquito broker [7] is installed on arduino. MQTT consumes 11 times less energy compared to HTTP for transferring messages [9]. Cayanne dashboard is a best tool for controlling monitoring our IoT application. It is a user interface for all our flow.

II. ANALYSIS OF PROPOSED TRACKER

A. This section is going to represent the importance of solar phenomena, atmospheric and location effect, calculation of sun positions and components of solar radiation on different tilted surfaces. It will include also some definitions, figures and equations that thought to be essential for solar tracking. Since accuracy and stability are two of the primary design parameters for a CSP solar tracking system, various control strategy options have been proposed, tested and reported on in the general literature.

These include open-loop control systems, closed-loop control systems and in some cases an integrated or hybrid-loop control system where open-loop and closed-loop control configurations are combined.

There are four main categories of control elements that will need to be considered in open-loop and closed-loop controllers in order to meet the design criteria for this study.

These include:

1. Position of the sun: To determine the sun vector SQ(γs, θs) from the location of the CSP system;
2. Effective drive system: To be able to move the structure efficiently so that it points directly towards the sun;
3. Control inputs: Type of control inputs to use, e.g. sun vector algorithm, photo-diodes or camera;
4. Control system: Control sequence and intelligence (state diagrams) to manage the electric motors and drives that move the payload or Stirling power system.

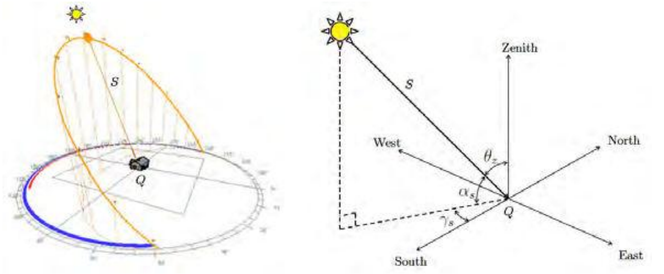

Figure 1 – Observer at location Q illuminated by sun ray observed along sun vector SQ, showing solar tracking azimuth and elevation/zenith angles.

A solar position algorithm (SPA) implementation determines the position of the sun at any given time for a specific location. The calculations presented herein are based on the SPA of National Renewable Energy Laboratory (NREL) and is classified as an astronomical algorithm because of the high degree of accuracy. The earth angles described below are the angles required to determine the position of the sun with respect to a plane of any particular orientation

- Latitude(φ): The angle north or south of the equator of the solar collector (measured in degrees);
- Longitude(ζ): The east-west position of the solar collector relative to the Greenwich (measured in degrees);
- Declination(δs): The angular position of the sun at solar noon with respect to the equator (measured in degrees);
- Surface azimuth angle(γ): Deviation of the direction of the slope to the local meridian (degrees);
- Solar azimuth angle(γs): Angle of the sun to local meridian or surface azimuth, clockwise from the south (degrees);
- Elevation angle(αs): Solar-vector elevation from observer (degrees);
- Zenith angle(θz): Angle of incidence on a horizontal surface, solar-vector zenith (90◦ − αs) (degrees);
- Angle of incidence and reflection(θ): Angle between incident solar radiation and surface, solar-vector elevation (degrees);
- Hour angle based on the solar time(ω): Conversion of solar time to an angle where 24 hours = 360◦ and solar noon is zero.

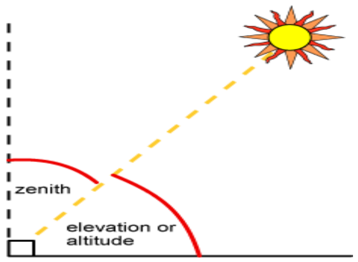

Figure 2 - angle of elevation and zenith angle

The position of the sun relative to the coordinates on the surface of the earth is described by two angles which are solar altitude and the solar zenith angle is shown in figure 2. The all angles are described with respect to the central ray from the sun.

Solartime = Standardtime + 4 × (ζst − ζloc) + E (1)

E = 229.2(0.000075 + 0.001868 × cosB − 0.04089 × sin2B) (2)

B = (360/365)× (n − 1) (3)

δ = 23.45 × sin(360/365× (284 + n)) (4)

cos θz = (cosφ × cosδs × cosω) + (sinφ × sinδs) (5)

γs = sign(ω) ×(cos−1 (cosθz × sinφ – sinδs) (sinθz × cosφ)) (6)

The solar vector SQ(γs, θs) computed through Equation 1 to Equation 6 describes the azimuth angle (γs) for the horizontal alignment and zenith/elevation (θs, αs) for the vertical alignment of the solar concentrator at location Q to pin-point at the sun at any given time of the day.

In this study dual axis tracker is used which tracks both altitude and azimuth angles.

B. *MPPT:* A MPPT controller plays an important role in PV system. **MPPT** charge controllers used for extracting maximum available power from PV module under certain conditions. The duty of the MPPT is to increase the efficiency of the PV module by adjusting the output power of PV to the PV module by adjusting the output power of PV to its MPP under all conditions. There are so many and different topologies are available in the literature. MPPT technique is mainly applied to the system whose output power varies with time and is not constant for a time period.

The main problem faced by MPPT[13] is that the power transfer efficiency of the solar panel depends on two factors, one is the amount of sunlight falling and other is the electrical characteristics of load. As we know that sunlight varies with time, so the corresponding load characteristics which gives highest power transfer efficiency changes. So, inorder to have high efficiency the load characteristics should also change w.r.t change in the sunlight, at this particular load characteristics we

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can say that MPP is achieved and the task of the MPPT to find MPP is also accomplished.

In this study P&O[14] algorithm is used. Which perturbs the PV module current and voltage and power is calculated, and it was compared with previous value to determine perturbation in next step.

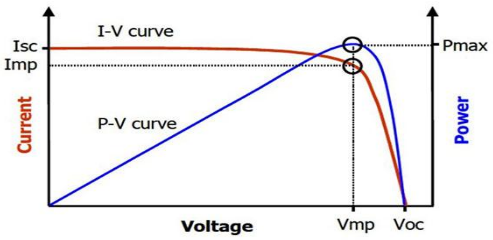

Figure 3- I vs V and P vs V curves (MPP)

C. All you have to do is install the Cayenne agent using the web site. The Arduino needs to have an Internet connection - after all this is the Internet of Things - and this means either an Ethernet or WiFi shield. You also need the Arduino IDE setup on a PC or Mac connected to the Arduino by USB, but this is fairly standard.

Once the Cayenne agent is installed you can interact with it via the mobile app or the website. Using the dashboard you can monitor and configure the device, but more importantly you can install sensors[6].

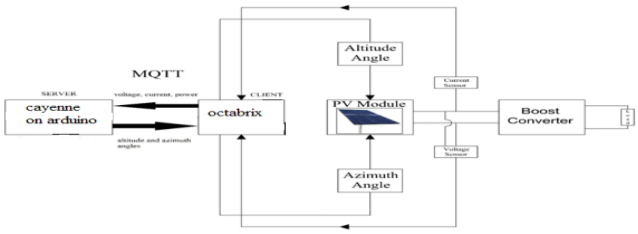

Figure -4 Block diagram of the proposed tracker

D. Electrical components:

1. **MG996R**[15] **servo:** Two identical servo motors are used for adjusting the both altitude and azimuth angles. This servo motor is having maximum stall torque of 11kg/cm, the angle of the servo motor can be easily controlled by connecting them to arduino digital pins, It is less power consumption compared to stepper motor and cost is also less.

2. **Octabrix** is a Wi-Fi development board based on the famous and low-cost **Wi-Fi SoC ESP8266**. ESP8266 is a wireless SoC that provides ability to embed Wi-Fi capabilities within other systems, or to function as a standalone application, with the perfect combination of lowest cost and minimal space requirement. Octabrix houses the ESP-12F version of ESP8266.Octabrix has **10 digital input/output pins** (all of which can be used as PWM outputs), **a single analog input**, a micro USB connection, a reset button, an on-board light sensor, programmable push button and LEDs. One of the interesting features of Octabrix is the user programmable **RGB Pixel Ring**. Octabrix can be powered via the micro USB port or with an external power supply.

3.**Boost converter:** boost converter[16] used in this system is shown in Figure – 5, it consists of one MOSFET(IRNZ44N) is used as switch , with a duty cycle of D=Ton/T, and constant switching time period of T=1/f, where f is the switching frequency and Ton is on time period. Here current through the load (I_L) is constant during steady state (PV voltage is constant) and is given as $I_L = V_{PV}/(R_{ds} + R_L)$, R_{ds} is drain source resistance. Current through the capacitor is ignored and the average load current is approximately equal to the PV output current.

$$I_{PV} = D*I_L \qquad (10)$$

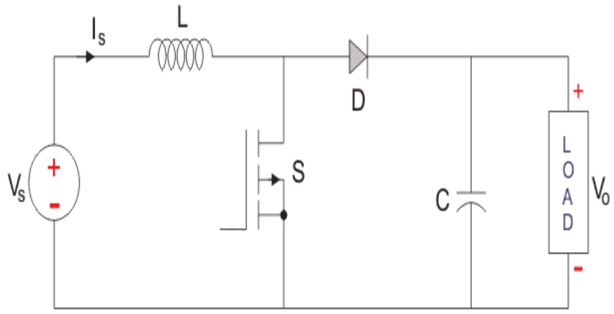

Figure 5– Boost converter

4. *PV Module:*A commercially available PVmodule (12V 150mA) is used with following specifications. Peak Voltage: 13.97V, Peak Current: 0.152A.

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III. EXPERIMENTAL RESULTS

A PV tracking system has been built and experimentally validate the theoritical results and performance of the proposed system. The MPPT logic is implemented in arduino code in arduino.cc.

Octabrix is used as the controller for the PV tracker and the information for the octabrix is being sent from cayenne server which is installed on arduino uno through mosquitto broker using MQTT publish and subscribe protocol., here arduino is a server and octabrix is a client. The MPPT logic is running on arduino and duty cycle information is sent to the arduino and PWM pulses is given from the pwm pin of the arduino to the MOSFET in the Boost converter.

The overall block diagram of the proposed tracking system is shown in the Fig. 4. The PV output current is measured using ACS712 sensor and the voltage is measured using voltage sensor which is resistive based. Here load for the PV panel is resistive load. octabrix will send information of voltage, current, power of the PV panel to the cayenne using MQTT protocol, and arduino. Duty cycle, altitude and azimuth angle information will be send to arduino.

Two MG996R servo motors each for altitude and azimuth angle adjustments, when the arduino receives the information of altitude and azimuth it will adjust he servos to the respective angles. These servos has an stall torque of 9.8kg/cm (4.8V).The cayenne is designed to monitor the PV tracker remotely. To access the dashboard we have to type “cayenne my devices” in the browser and enter the user and password to monitor power, voltage, current of the pv panel.

Figure 6- PV tracker

In the experiment, the constructed sun tracker was activated. The actual data of altitude and azimuth angles of the sun position in the sky was obtained from the SUNCALC.ORG website at a geographical position of (17.6868° N, 83.2185° E) were measured from hour to hour in daylight (6:00-18:00) on Aug.11, 2019. Fig 8, Fig. 9 compare the actual altitude and azimuth angles of the sun position with the altitude and azimuth angles tracked by the tracker. The comparision shows that the average tracking error of altitude and azimuth angles are 0.18^{o} and 0.61^{o}respectively. The overall experimental setup is shown in Fig.7 .

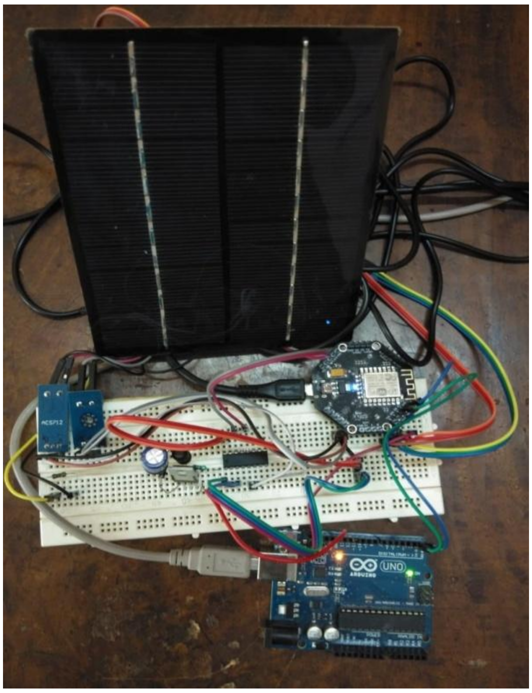

Figure 7 - The overall experimental setup

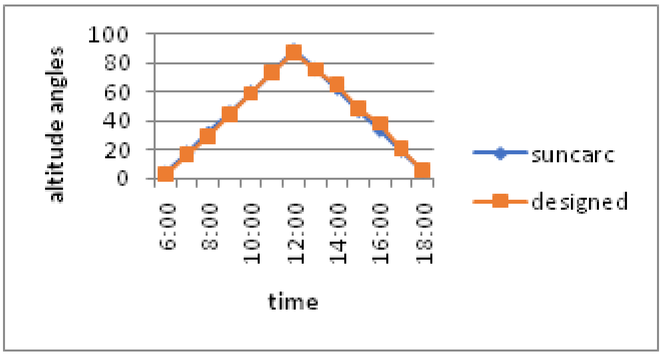

Figure – 8 comparision of actual and calculated altitude angles

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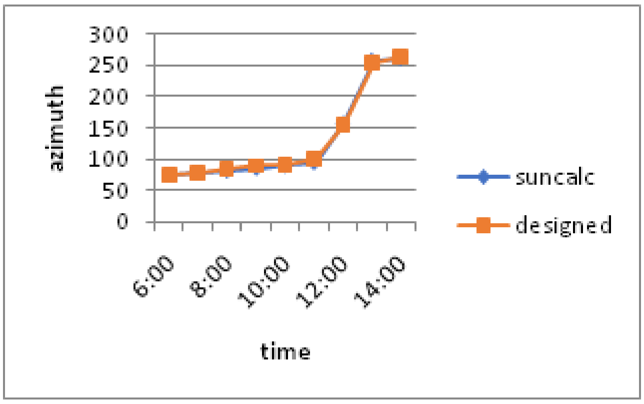

Figure – 9 comparision of actual and calculated azimuth angles

The experiment was conducted in fixed mode and tracking mode, for fixed mode the angle of the pv is set to the value of the latitude angle. The fig.10 shows the comparision of the Power ouput with both fixed and tracking mode. In fixed mode the total energy obtained during a day was 10.745 Wh and in tracking mode the total energy obtained was 14.899 Wh , so there is an increase in the energy efficiency of 38.579% using the proposed tracker.

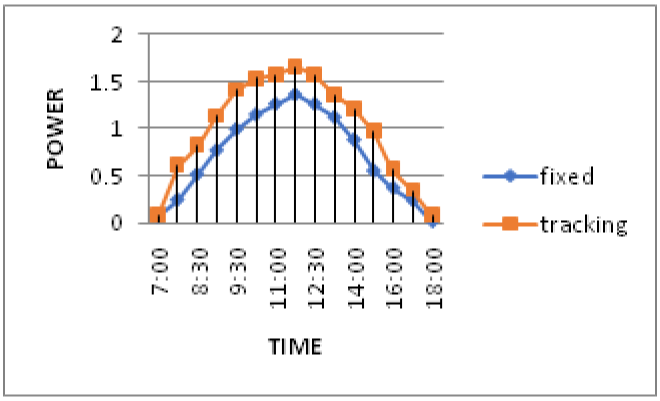

Figure 10 - comparision of the Power ouput with both fixed and tracking mode

IV. CONCLUSION

An IoT based sensor less dual axis sun tracker regulated by MPPT unit was proposed. This proposed system is very well used to test various tracking algorithms and to control and monitor the PV cell remotely which is very useful for research purpose. The advantage of the IoT enabled tracker is that it reduces the effort of collecting the data and analysing it, and to change the position of the PV module can be done remotely. The algorithm used in this study has successfully calculated the position of the sun with an average tracking error of both azimuth and altitude angles of only. The arduino does not need an external operator so the process is smooth.

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