



RESEARCH ARTICLE

LOW COST PORTABLE CLOUD BASED HYBRID DUAL AXIS SOLAR POWER MONITORING SYSTEM

Atulya Alok and Gagandeep Singh Kukreja

School of Electrical and Electronics Engineering, VIT University, Vellore(T.N).

Manuscript Info

Manuscript History

Received: 20 June 2020

Final Accepted: 24 July 2020

Published: August 2020

Key words:-

Clean Energy, Portable, Dual Axis Solar Trackers, IoT, Cloud Management System, Gps And Ldr Feedback, Real Time Data, Water Based Cooling System

Abstract

With the rapid increase in global demand of electricity, it becomes very important to have an influence of clean energy with zero emissions in the surrounding. Solar Energy being one of the most prominent sustainable energy resource stands as a backbone especially for the developing countries today ensuring good returns with one-time investment. This study presents the efficiencies of energy conversion of LDR with a solar tracking system. The proposed sun tracking system uses 4 LDRs, which are mounted on the sides of the solar panel. By these Light depending resistors, the solar tracking system becomes more sensitive and it allows us to determine a more accurate location of the sun. This paper presents a low-cost portable solution to provide remote access using IoT based Cloud Management System to real time power generation data along with the track of physical parameters involved in determining the efficiency of the system. The dual axis solar power generation has been improvised with the GPS and LDR feedback altogether to improve the characteristics of the actuator movement along with an efficient water-based distributed cooling system to boost cell life and to have an efficient power generation.

Copy Right, IJAR, 2020,. All rights reserved.

Introduction:-

Increasing population, urbanization and limited stocks of fossils have drastically increased the research and development of sustainable energy solutions in the market. Being the most efficient scalar technology, solar energy has been leading the market of eco-friendly power solution for past two decades. Various researchers have been working on improving the efficiency of photovoltaic power generation with the help of latest technology advancements [1]. However, the efficiency of solar power generation highly depends upon geographical locations, climatic conditions as well as the material quality of solar cells [2]. New advancements in Electrical Engineering as well as in the field of Material Science are helping in achieving high energy conversion ratio to enhance the efficiency and build a good capital return of an individual's investment. Recent trend and research show reduction in the market prices of PV and solar thermal generation equipment's have helped in achieving low cost power generation unit. The total amount of solar power generation has drastically increased from 6TWh in 2006 to 720TWh in 2019 and is expected to grow as much as 3268TWh by 2030 as shown below in the Figure 01 [3].

Corresponding Author:- Gagandeep Singh Kukreja

Address:- School of Electrical and Electronics Engineering, VIT University, Vellore(T.N).

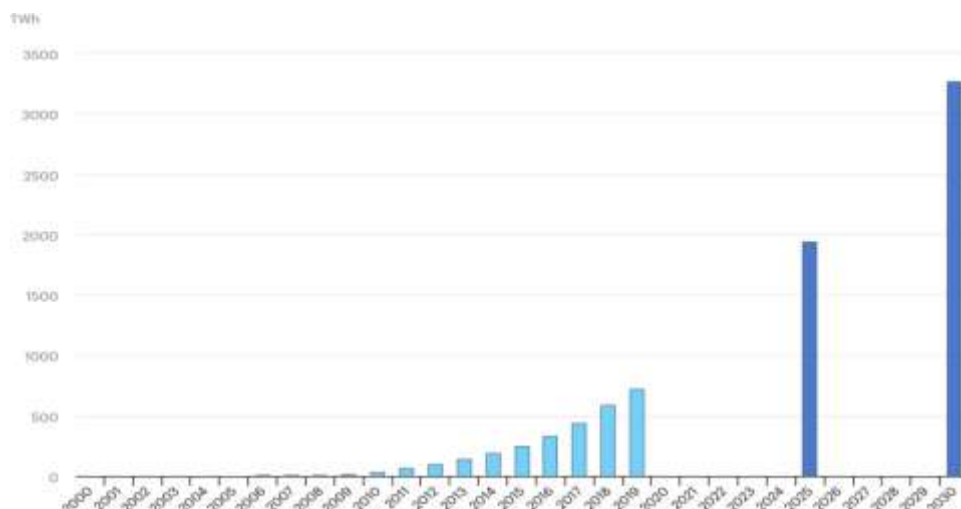


Figure 1:- Solar PV Development generation in the sustainable Development Scenario, 2000-2030 [3].

Solar power generation involves large number of energy utilization opportunities from low power water heating systems to domestic power lighting. However, the power loss minimization depends upon various critical factors such as efficient panel cooling, positioning of the panels, inter spacing and climatic conditions. General weather is considered as an uncontrollable factor, thus the controllable factors taken into consideration are tilt angle, azimuth angle, solar panel cleanliness and wind intensity [4]. Earlier during the initial stages of solar power generation, the panel setup was manually changed every three months in order to ensure good output. With the advancement in technology, automatic single axis motor-controlled PV Cell arrangement came into practice. The single axes tracker improved the efficiency of panels by overcoming the issue of solar path tracking. Later the dual axis solar panels came with two degree of freedoms ensuring good coverage of solar energy under the solar window [5].

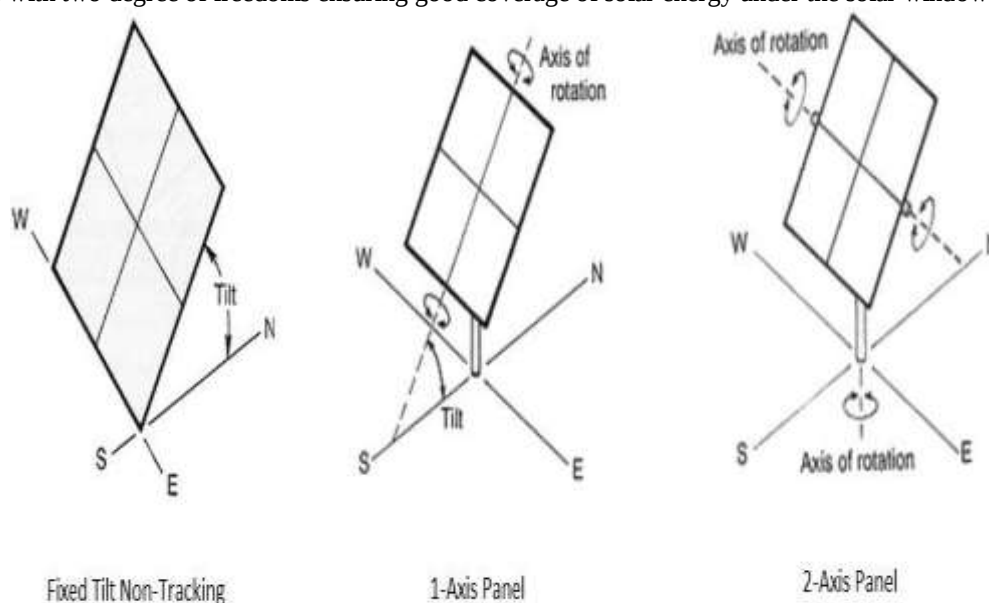


Figure 2:- Three types of Solar Panel arrangements based on axes.

The dual axes improve the net efficiency of power generation but still the direct incidence of sun rays lead to increased panel temperature which can again reduce the life of solar cells and cause inconsistent instantaneous voltage while operating. Photovoltaic cells can absorb up to 80% of solar energy however very small amount of energy is convertible to electric power generation. This is mainly because of the wide range of radiations absorbed which ultimately leads to ample amount of panel overheating degrading the net power generation as shown in the Figure 3 below.

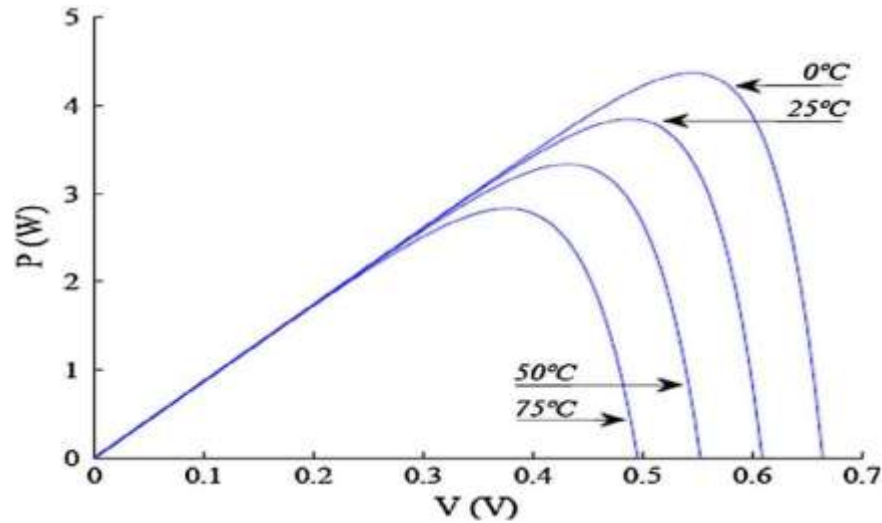


Figure 3:- Power generation v/s Voltage Degradation Plot on different temperatures [6].

Hybrid Solar Panel arrangements with cooling system have come into existence in past few years for improving panel life and to boost power generation. With the improved cloud service technologies and IoT, it has become possible for an individual to have remote access to the real time set-up to ensure proper working of their system and perform recommended servicing in order to ensure longer durability and life of the photovoltaic panels.

Operational Principle And Calculation Involved:

The task of the dual axes system is to identify and track the position of sun between sunrise and sunset throughout the day so as to ensure perpendicular visible horizon onto the solar panel. The main advantage of having two degree of freedom over the panel is higher resolution, low radiation loss and less manual adjustments. Anemometers are being installed with the system to track the pressure due to wind on the panel surface along with LDR and GPS sensor to deliver the feedback to NodeMCU for the actuators. Here actuators are two servo motors, each responsible for one axis.

Azimuthal and Elevation Angles: The tilt angle for the net actuation for the two degrees of freedom are based on calculated trajectory of tilt angle based on the angle of elevation (α), azimuthal angle (Ψ). The angle of elevation is further formulated using the below formula:

$$\alpha = a \sin (\sin \delta \sin \varphi + \cos \delta \cos \varphi \cos \omega), \quad (1)$$

Where α denotes angle of elevation, φ is the latitude, ω is the hour angle, and δ is defined as the solar declination. It can be defined using Cooper's equation [7]

$$\delta = 23.45 \sin (360/365 (284 + N)), \quad (2)$$

$$\beta = 90 - \alpha. \quad (3)$$

$$\Psi = a \sin (\cos \delta \sin \omega / \cos \alpha) \quad (4)$$

Where, α = Angle of Elevation,

N = day of the year,

β = Tilt angle of PV

Panel

Ψ = Azimuth Angle

The heading angle is being calculated using the true north bearing system which is given by the azimuthal angle and GPS module acts as a digital compass for the same. Declination Angle varies from place to place and can be obtained from NGDC (National Geographical Data Centre). The true North direction is thus obtained by adding magnetic North and Declination angle together.

In order to retain good efficiency, panel is being cooled using flow of water inside the tubes to ensure efficient cooling and avoid rise in temperature of solar panels. Panels have been provided with flatbed water cooling boxes underneath with temperature regulation and sprinkling over solar bed based on the tuned temperature.

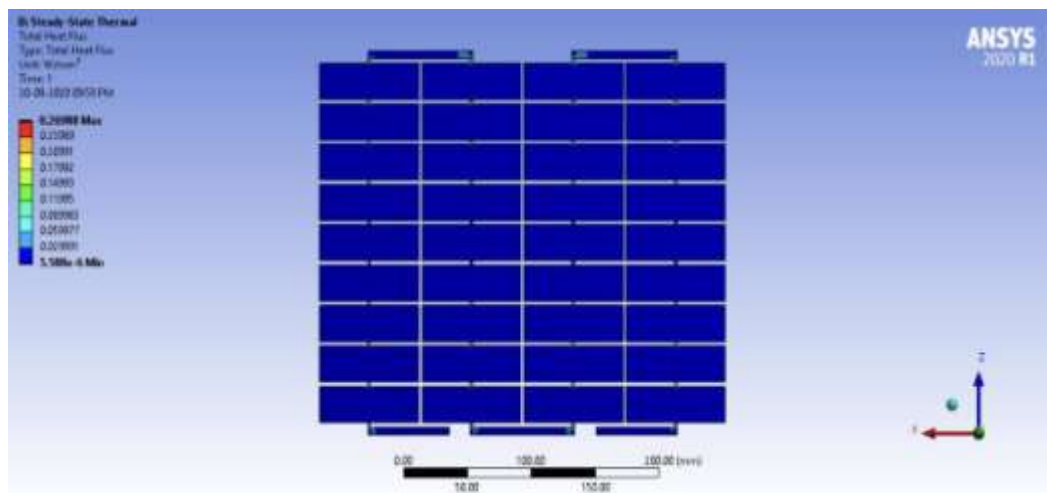
Thermal analysis and clear sky radiation estimation:

In order to estimate the heat distribution over the surface of Photovoltaic thermal Collector we considered following parameters to perform thermal analysis of a photovoltaic cell using Ansys:

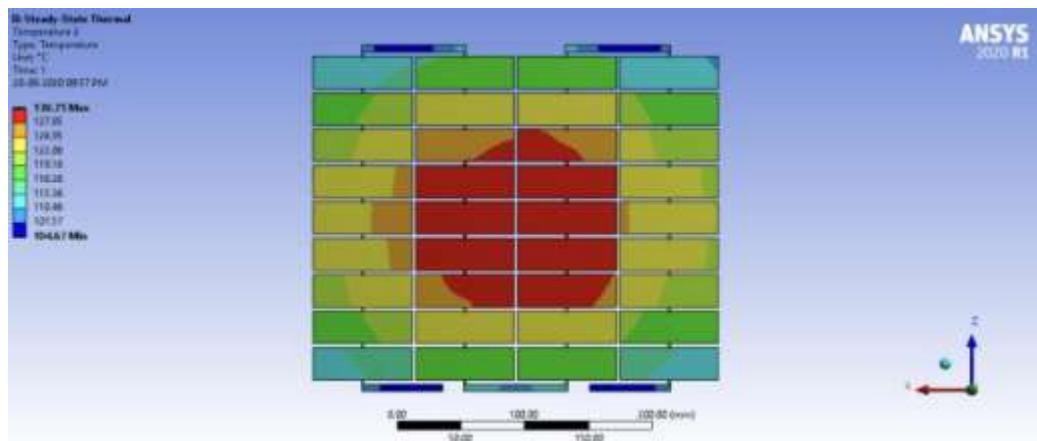
Table 1:-

Material:	K(W/m.k)	ρ (kg/ m ³)	CP (J/kg.k)
Tempered Glass	1.8	3000	500
EVA	0.35	960	2090
PV	148	2330	677
PVF	0.2	1200	1250

The declination angle was being calculated using the Cooper's equation (2) for a generalized day-wise temperature from 6AM-6PM to estimate the clear sky radiation. Correction factor, photovoltaic cell and array arrangement were taken into consideration for the analysis [8] for more precise results with the arrangement shown below.

**Figure 04:-** Photovoltaic Array Arrangement considered for analysis.

Furthermore, the panel was analyzed with a day-wise temperature variation on the cells. The total heat flux on the surface of solar array was maximum at the center.

**Figure 05:-** Heat Flux over the array of PV cells.

Assuming the maximum temperature rise during mid-day hours and uniform distribution of cells with equal spacing, the maximum rise in temperature can be seen at the middle of the panel as shown below.

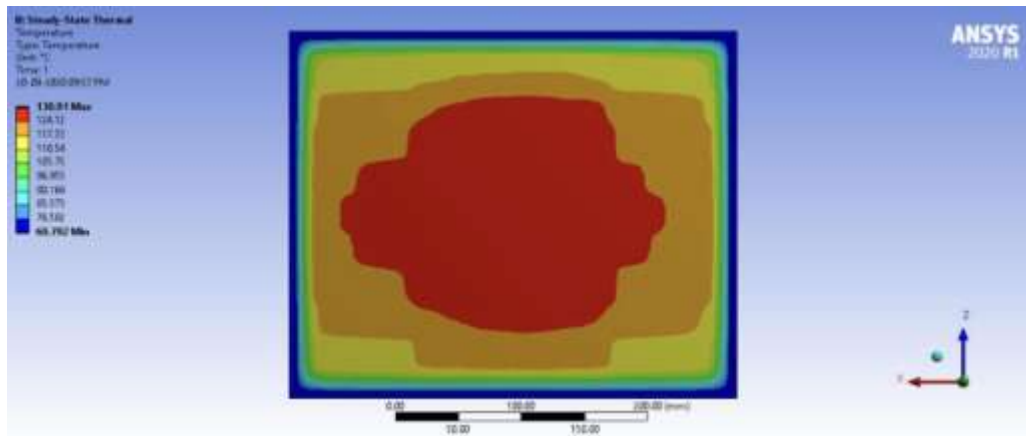


Figure 06:- Heat Flux over the PV array bed.

Proposed Methodology:-

The proposed tracking system can track a lot of daylight in fact by PV panel rotation in different axis. In the dual axis system, we can track the sun in four directions; as a result, we can achieve more energy from the solar panel. During this emerge; we can confine additional sun rays. The dual axes solar system has been modified here with dual feedback comprised of both LDR as well as GPS. Node MCU has been added to the system for providing cloud access to all the physical parameters involved to ensure efficient power generation. Remote access to Panel Temperature, Instantaneous Voltage Generation, plot helps in keep a track to ensure maintenance and efficiency of photovoltaic array in an individual's home.

The system is being initialized with the azimuth and altitude elevation via GPS sensor and the atmospheric temperature from DHT11. Feedback is calculated with the mixing of LDR feedback and old retrieved data from the GPS sensor as shown below in the Figure 06.

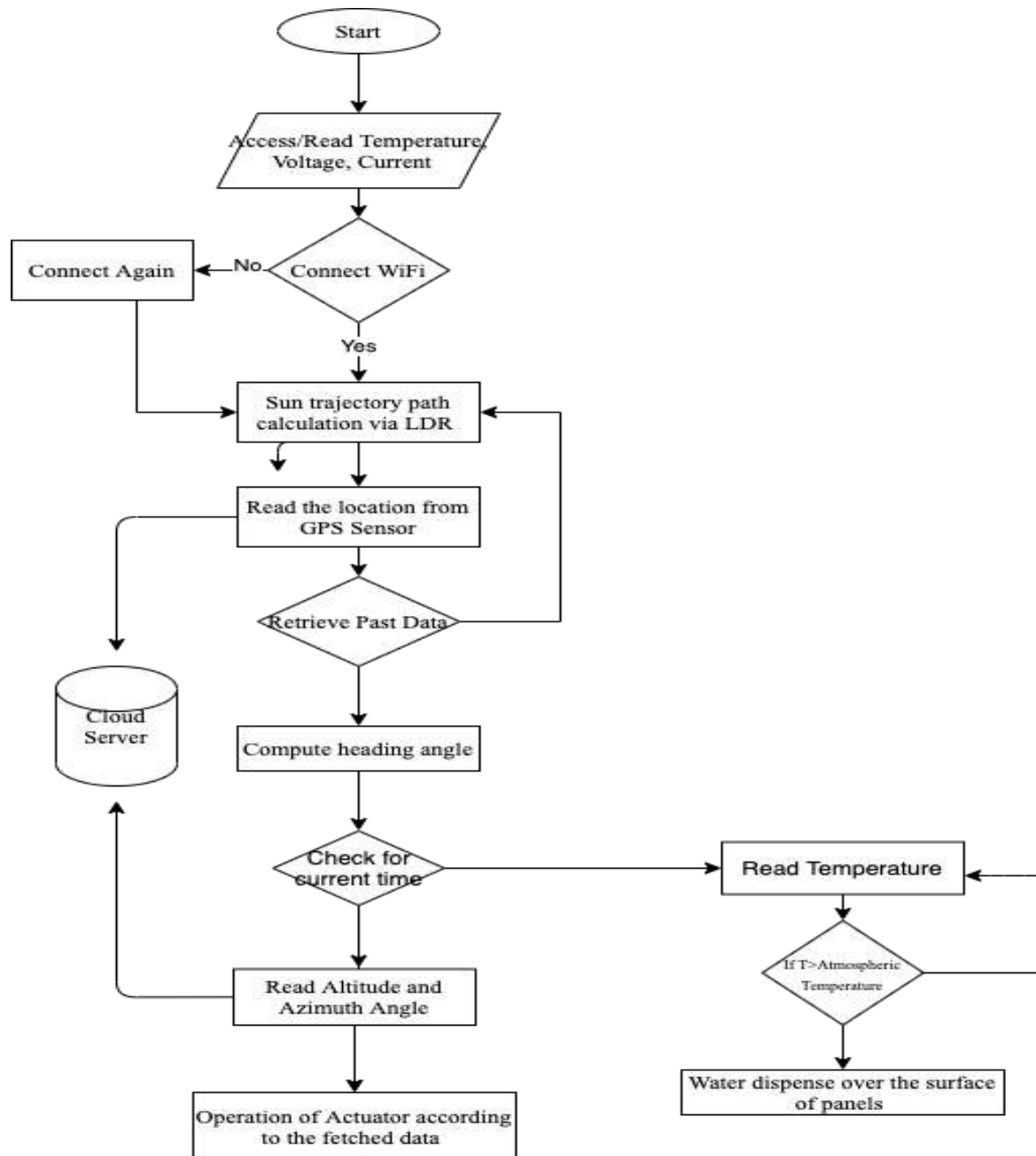


Figure 06:- Flowchart of the proposed PV feedback system.

One set of LDRs and one motor is used to incline the tracker in the sun's east-west route and the other set of LDRs and also the other motor that is mounted at the base of the tracker is used to tilt the tracker within the sun's north-south route. Sunlight sense by LDR sensors and send a signal to the Arduino microcontroller.

The microcontroller received signals from LDR sensors and its deciding rotation direction of servo motors. Dual Axis tracker solar tracking system is explained with the help of this block diagram.

In order to reduce the on-surface heat of panel generated, when the panel temperature rises more than the atmospheric temperature, Node MCU will initiate the water dispense over the surface. Cloud server provides proctoring of all these physical parameters efficiently.

Apparatus Arrangement:

The dual-axis tracker uses feedback from four different LDR's mounted at the 4 different corners of the solar panel. When it collects data from LDR sensors then the main algorithm is started. LDRs productivity is analog that's stimulated to digital signals. This serviceable task is performed using an analog to digital converter (ADC). Digitized signals are forwarded to the Arduino microcontroller. After collecting digital signals, it decides relating to the movement direction and steep angle of servo motors.

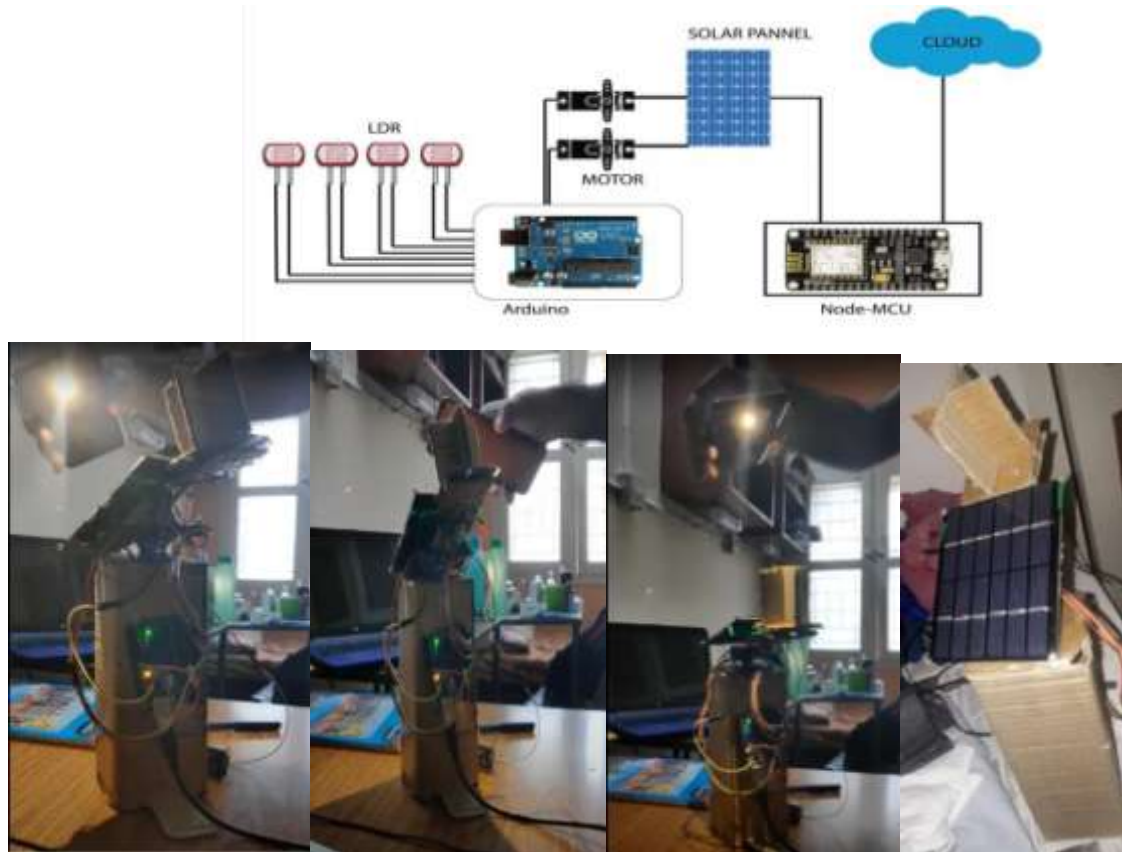


Fig 07:- Circuit Diagram and Model Arrangement to demonstrate multi feedback system in dual axes PV arrangement.

For better tracking of rays, we have used the comparable algorithm in our Arduino code. The four LDR's are termed as Top Right, Top Left, Bottom Left, and Bottom Right. Arduino reads the analog resistance value of all the 4 LDR's then these values are compared in the following cases:

- i) Greater of the two is taken - Top Left and Top Bottom
- ii) Greater of the two in Bottom left and Bottom Right is taken

Then these two values from (i) and (ii) are compared for further inclination of the solar panel. These values are used as a feedback control to the servo motors. One servo motor takes the input of top and bottom LDRs' and the other one right and left. Both the Servo motor keeps on shifting the axes till the maximum intensity of the sun is received in that particular direction the same thing is done by the other motor. Then that value of Voltage generated by the solar panel is recorded and is sent to the cloud where we can see the increase from the previous values.

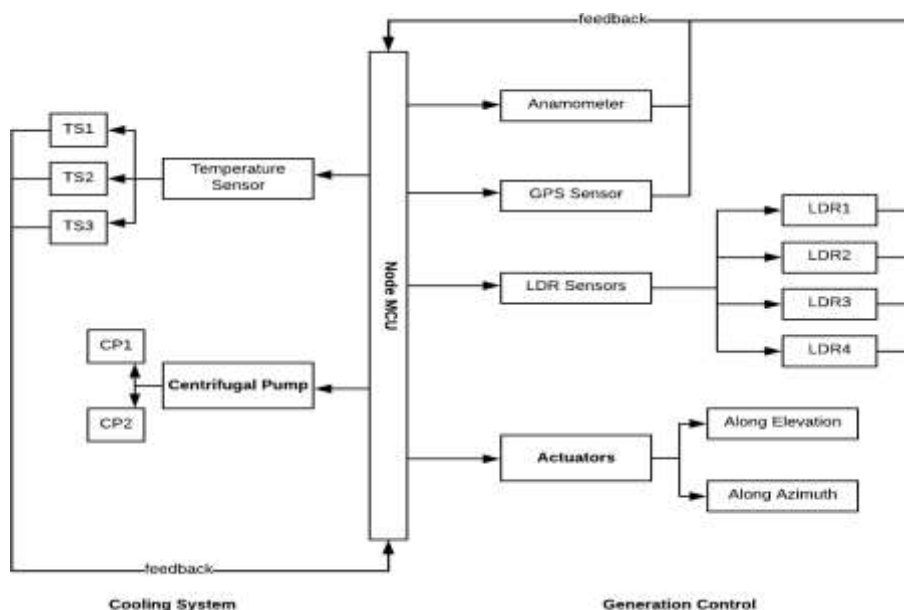


Fig 08:- System Classification on the basis of driving systems.

Feedback from LDR is constituted with all of the four LDR sensors placed at the edges of the PV array and the GPS feedback is taken into consideration while calculating the final azimuth and elevation angle.

Actuators are being activated for the alignment of the panel based on both the feedbacks. Anemometer is being used to add the correction factor due to the wind to optimize the response. Three temperature sensors DHT 11 are being used to monitor temperature over the panel, atmospheric temperature and the dispensed water temperature. Centrifugal Pump is being operated with the collector drum to discharge water over the panel based on the atmospheric temperature and the surface panel difference as shown in the above figure. Water discharge pressure is being set from 30psi to 70psi according to the temperature difference as shown in the figure 08.

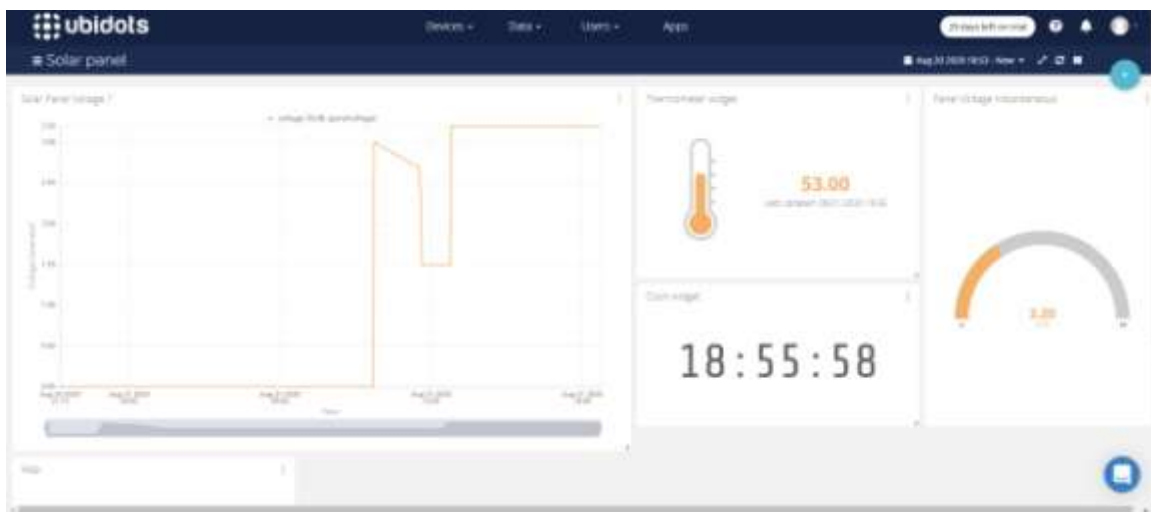


Figure 09:- Dashboard of Cloud Monitoring System with Panel Temperature, Instantaneous Voltage, Time and Plot of Voltage v/s Time.

Plot in the above figure explains the successful maintenance of the Voltage generated by the solar panel. There was a drop in the voltage generated when the dual tracking was off but once it is on again the value rises to the previous peak, this ensures the maximum voltage generated at all moments whether there is change in azimuthal angle or the change in position of Sun.

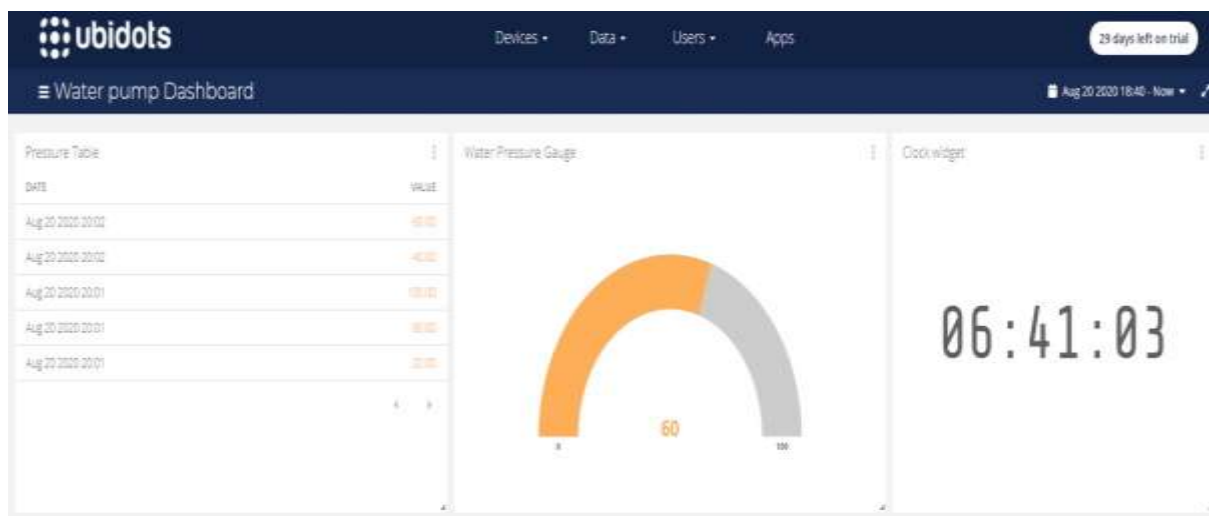


Fig 10:- Water pressure discharge gauge and Voltage generation plot with respect to time.

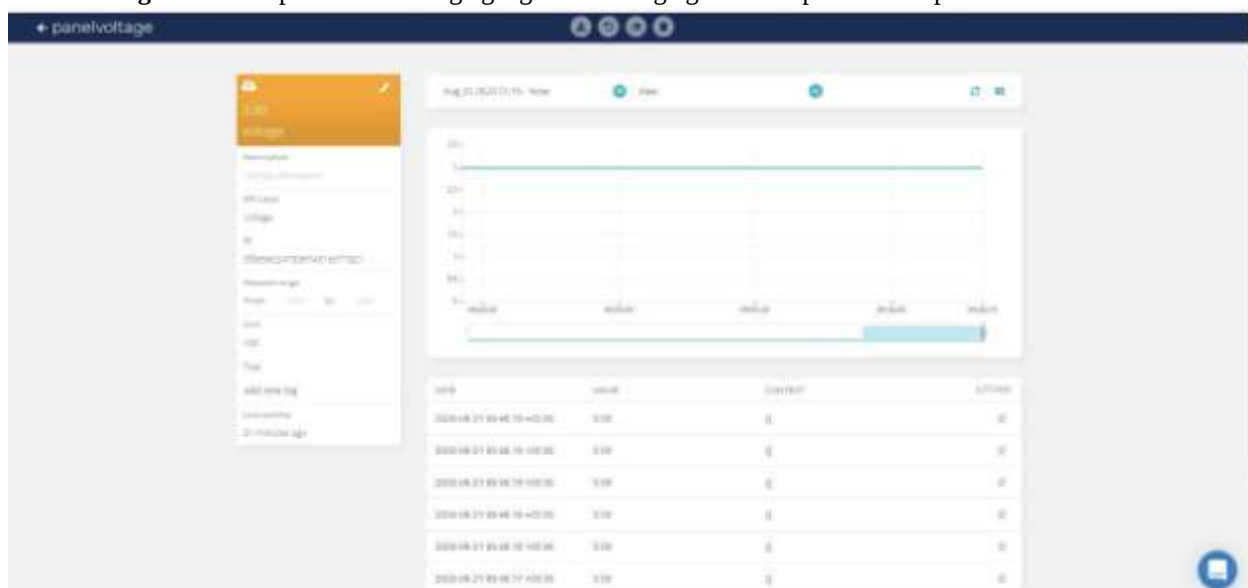


Fig 11:- Values of data set of voltages for the entire day with respect to time.

The above two figures are providing user interface to access previous instantaneous voltage recordings along with the temperature and dispensed pressure which can be stored as a real time data for thirty days to track the net power generation.

Conclusion:-

The paper presents a real time cloud monitoring system with the panel and pressure measurement of water to avoid chances of decrease in efficiency due to heating. This system will help in maintaining an efficient solar tracking panel irrespective of any day night or seasonal changes weather conditions. SOS warning system and real time tracking can help in providing condition of solar panel it's setup and hardware. In the future the system can be further advanced by addition of extra features.

Dual axis tracker utterly aligns with the sun route and tracks the sun movement in a very a lot of cost- effective loom and includes a marvelous performance upgrading. The proposed system is value effective conjointly as a stroke adjustment in single axis tracker provided notable power increase within the system.

Through our experiments, we've got found that dual axis tracking will increase energy by about 40% of the fixed arrays. With a lot of works and higher systems, we tend to believe that this figure can raise more.

References:-

1. Nadia, A.R., Isa, N.A.M. and Desa, M.K.M., 2018. Advances in solar photovoltaic tracking systems: A review. *Renewable and sustainable energy reviews*, 82, pp.2548-2569.
2. Furkan, D. and Mehmet Emin, M., 2010. Critical factors that affecting efficiency of solar cells. *smart grid and renewable energy*, 2010.
3. IEA, Solar PV power generation in the Sustainable Development Scenario, 2000-2030, IEA, Paris <https://www.iea.org/data-and-statistics/charts/solar-pv-power-generation-in-the-sustainable-development-scenario-2000-2030>
4. Almusaied, Z., Asiabanpour, B. and Aslan, S., 2018. Optimization of solar energy harvesting: An empirical approach.
5. Mereddy, D. and Sadula, T., 2015. Smart Dual Axes Solar tracking. In 2015 International Conference on Energy Systems and Applications (pp. 370-374). IEEE.
6. Bijjargi, Y.S., Kale, S.S. and Shaikh, K.A., 2016. Cooling techniques for photovoltaic module for improving its conversion efficiency: A review. *International Journal of Mechanical Engineering and Technology (IJMET)*.
7. Shivalingaswamy, T. and Kagali, B.A., 2017. Determination of the Declination of the Sun on a Given Day. *European Journal of Physics Education*, 3(1), pp.17-22.
8. Teo, H.G., Lee, P.S. and Hawlader, M.N.A., 2012. An active cooling system for photovoltaic modules. *applied energy*, 90(1), pp.309-315.