Anisotropic Active Single Axis Solar Tracker using Machine Learning

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Abstract:
Background: Solar is always promising one for largely used renewable energy source over worldwide. After the era of fuels, the solar energy paved its way due to the decrease of resources and the world in need of a clean and harmless energy. Global warming and climate change are the outcome of increasing carbon dioxide from the power plants and are widely seen to be one of the most serious problem as it contributes to the danger of environmental issues and so today the world is making its step for the SDG goals which help the world to be reborn and problem free within 2030.By keeping this in mind, in this project we are developing the prototype that supports the SDG goal 7 that provides CLEAN AND AFFORDABLE ENERGY and the energy we chose is the Solar energy. **Findings**: Nowadays many people use solar energy for then and there activities. Offices, homes, industries use solar energy for regular activities and works and thereby saving lot of costs. Several automations rose to extract maximum power from the radiations of the sun and thus came the technique of rotation of solar panel thereby increasing the extraction like the sunflower that follows the sun. Though Solar tracker extract maximum power it also has some limitations like cloud factor and dust and climate change makes the solar energy extraction a bit low. Dual Axis tracker (i.e. E to W and also N to S) is the best model for extracting maximum power yet it costs about $26000 and that it high cost and makes not affordable for everyone. **Methods**: Thus in this project, we have developed a prototype based on single axis solar tracker (direction wise) by introducing advanced technologies like machine learning to identify the degree of radiation falls on panel to extract maximum power. This new method will be efficient and makes us explore new opportunities to identify the horizons of solving the problems in solar energy tracking.
Keywords Solar Tracker, Orientation, Tilt angle, Machine learning

1.INTRODUCTION

Solar energy is being extracted through sun. Utilizing photovoltaic panels, light energy from the sun's array is transformed, which is made up of energy particles known as "photons," into electricity to run the equipment[1]. The panels can be used to provide building's necessary electricity to power up the remote locations. The main factors that determine a PV panel's efficiency such as light intensity, voltage and temperature. As to conclude, a real-time solar monitoring and tilting system is necessary to increase the performance of the solar panel. Solar energy has received a lot of eyes in the past few years. Machine learning approaches are also used to forecast outcomes in order to obtain high performance[23]. The development of solar power dates back more than 300 years[3,4]. In the era of past, solar energy was used primarily for the time zone calculation and also for the production of steam for the machinery works. But later the discovery of the "photovoltaic effect" allows the conversion of light of the sun to solar electric energy. Many different applications are powered by solar panels today. Calculators and numerous other small, hand-picked gadgets still employ solar panels as an alternative to solar cells[5,6]. They are used to provide solar power to entire homes and commercial buildings also with the solar power that are extracted.

Sunlight from solar panels is captured as clean, renewable energy and transformed into electricity, which is then used to power electrical loads [7]. The individual solar cells that make up solar panels are made of layers of silicon, phosphorous (which gives the negative charge), and boron (which provides the positive charge).Photons are absorbed by solar panels, which then start an electric current[9]. Electrons can be thrown out of their atomic orbits and released into the electric field produced by the solar cells, which subsequently pulls these liberated electrons into a directed current. This process is made possible by the energy produced when photons strike the surface of the solar panel.

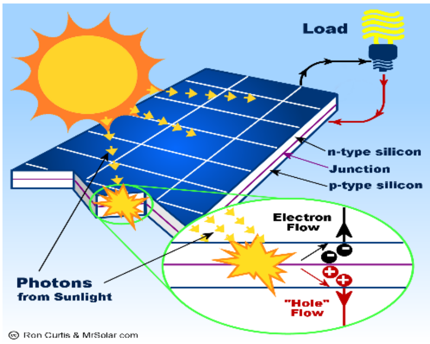

Figure 1 . Solar Panel Power Flow

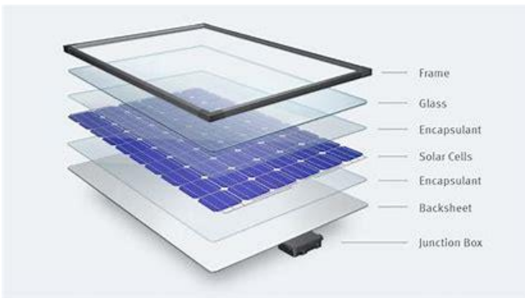

Figure 2 . Solar Panel Layer

Many of us are highly in need to reduce the cost spent on electricity bills. As of today's market every item is so costly so people need the technology that reduces the cost and increases the income. To achieve this we need the technology to reduce the cost and increase the extraction of solar energy. In this project we are going to manages the solar tilt angle[5].

Real-Time otherwise called present time data is crucial in every project as it manages the day-to-day data and time in real world. This real-time data helps in tilting the solar panel based on time-variance and introducing the advanced technologies like machine-learning helps the mechanism to learn on its own and implement the tilt angle based on the time and radiation [22, 24]. The existing system used LDR which is known Light dependent resistor which is based on light intensity and though it's efficient we observed that it's not long-lasting and needs to change the LDR on often times and also we don't know whether the LDR is broken or not and in case if it's broken we will be wasting lots of radiation and we don't know how and it needs regular maintenance. In this project we are going to try with Linear Regression model and SVM model and also ANN models for better efficiency model[10,11].

Thus, we propose a simple time-based solar tracker that runs and learns on its own about the angle and radiation received each day and makes the decision based on the real time data and previous data's. It is efficient than the previous model as it uses real time data and it's long lasting and needs minimum maintenance than the previous project and use of modern technologies reduces the cost and introduces the new horizons of improving the solar tracking models.

2. LITERATURE SURVEY

To justify the above said steps, we hereby present and discuss here the following steps and papers we referred and came to this solution. In 1960, the solar panel models were build using the theory values[1] and they proposed in an isotropic section so that it can access the above location and get them the angle they wanted, though it is a success model in that time with the kind of technology they have in the 1960's in today's world it paves a way for creating the models with much higher efficiency. We can take a hand from this paper and improve it for the anisotropic regions so that it will really easy for the users all around the world in a single touch. In 1977,[2] a 3D model was developed that uses one direction in East to West. It paved a way to extract maximum power from the solar radiation in spite of the other effects. In 1990, [3]a methodology was introduced using the Runge-Kutta ,ensure the solution at subsequent steps. It is the major consideration in this project that theories can be changed to the practical's result of that methodology introduced a new way that makes working continual for about three- and one-half years on the trips from the equator related to PV super capacitor system. Though this model were immense improved and the mmodel is based on Spain and also, it's equation and methodology paves way for the technology we use today yet extraction of max power is not achieved. In short the computers that time did not support the innovation that has been made and manual mathematics is much more tedious and error problem.

In 2002, models were built in anisotropic regions but they were in 3D and not in physical hardware and that makes the innovation bit less but much more as it paves way for the path we made it today. As the days go by several models were innovated and in this modern age that is across the 2000's In 2012,[5] a study was conducted to Analyse the Radiation across different zone in a region and summing up the optimum angles. In this Saudi Arabian study, the optimal tilt angles for Abu Dhabi were computed on a yearly, bi-annual, and monthly basis, and the impact of orientation on solar radiation absorption was examined. As the data increases the handling needs more space and now in the age of big data. As for this project this helps in analyzing the optimum tilt angles for each of the month. In that same year 2012,[6]. The model developed by Reindl et al. for calculating the radiation on a tilted surface computes a monthly optimal tilt angle.To determine the diffuse radiation on a horizontal surface, use the Erbs et al. model. This computation using this mathematical model paved a immense role and reducing the epochs and losses in the optimum angles and helps us in extracting the maximum power from the solar radiations. The part where it fails is they failed to implement in the computer as the computer were in the edge of breakthrough.

In 2019,[7] the most immensely and widely used innovation of using LDR and stepper motor to actually rotate the solar panel and acts like a sunflower which follows the sun to extract power which is higher than all those previous methodologies. It is widely used in more than all parts of the world for non-renewable energy and it made the way for the MPPT innovation to take over the world. These were all the primary studies which was taken into consideration for developing this project.

3. METHODOLOGY AND IMPLEMENTATION

To validate this conceptual model, we divide the approach into two parts as Component Design and Computer Design and the domain name is System Design. This is just to give the idea of how this project has been developed and in this way the computer model design for machine learning and the hardware part is carried out side by side. The component system consists of software-controlled modules (such as a microcontroller, wifi module, stepper motor, solar panel, and solar panel stand) and a smartphone [8]. The computer system consists of the Arduino IDE for microcontroller embedded systems and an Android webpage for showing the tilt angle level and solar radiation obtained through the respective time and climatic humidity present and an alarm for cleaning the solar panel based on triggering an alarm system thus giving a user-friendly view to get accurate data.

3.1 Component Design

This design uses a solar panel of 50w 12V capacity that tilts based on real-time with the help of servomotor that runs based on the signal given from the model deployed. The angle will be based on the theoretical values from the elevation angle and that helps in finding the accurate angle of the solar panel rotation [12]. The rotation angle is deployed from the cloud to the microcontroller. The WIFI-Module is linked to the Arduino Uno serially to allow data to be transferred from Uno to NodeMCU and NodeMCU to Uno.So for the first time the data is being sent to the cloud server in our project that is google cloud services which process the machine learning model to react with the data that is time in real world and location the solar panel fixed, it generates the solar angle which is developed by the theoretical values used in this project like elevation angle.

The solar power is mainly dependent on the solar radiations and the radiation changes from hour to hour. For extracting maximum power, we are calculating the solar elevation angle which provides the sun's elevation angle from the respective latitude we are placing the solar panel [13]. The solar elevation angle depends on the three factors and that is Declination angle and Hour angle and latitude. Declination angle can be obtained from the formulae, here d is the number of days from the January 1.

$$\delta = -23.44^\circ \times \cos\left(\frac{360}{365} \times (d + 10)\right)$$

The hour angle is found by using the formulae here LST is local solar time in 24-hour format and the solar elevation angle is expressed in the formulae

$$h = 15^\circ \times (\mathrm{LST} - 12)$$

$$\sin(\alpha) = \sin(\phi)\sin(\delta) + \cos(\phi)\cos(\delta)\cos(h)$$

here the α denotes the elevation angle and Φ denotes the latitude and δ denotes the declination angle and h for the hour angle. The latitude and longitude of the Chennai is given as latitude is 13.0827 degrees [14, 15]. These are some of the pictures which are predicted using the formulas listed above and converted into the excel for the full-time data in 24-hour format.

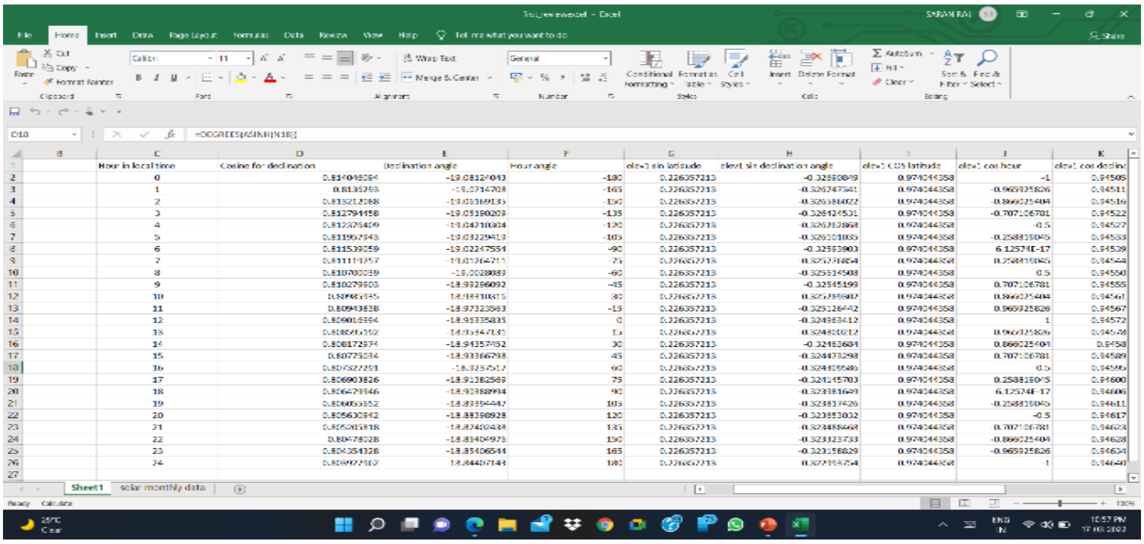

Figure 3. Elevation angle calculations are being calculated in the excel for the model training and classification and further for the training purposes of the machine learning model.

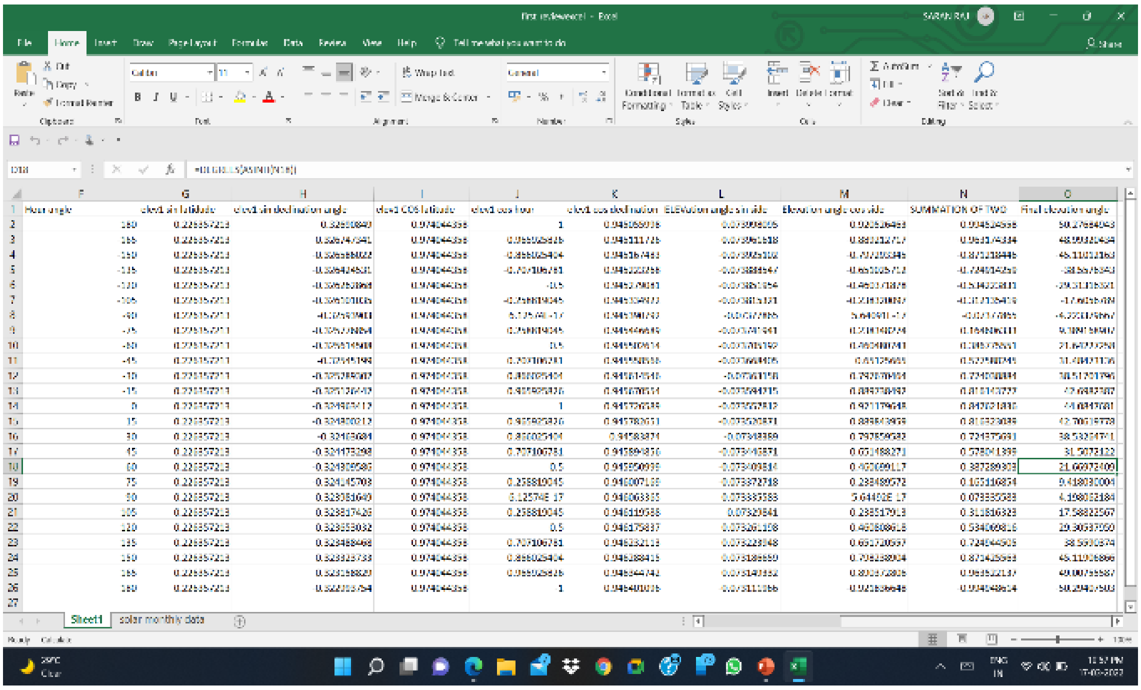

Figure 4. Elevation angle calculations of the figure 3 where it shows the extended calculations for the model building.

Then the data the predicted value of the angle will be sent to the NodeMCU and then to the Arduino Uno to enable the servomotor to rotate the respective degree. Since this is a real time basis so every 2 minutes this data sent and receiving is done [16]. The servomotor changes the solar panel tilt angle. A web page is developed for checking the proper maintenance of solar power and also for any enquires related the project details.

3.2 Computer Design

The Arduino IDE, which stands for Integrated Development Environment, was used to interface the programme with the microcontroller and Android Studio to create the computer design [17]. These computer programmes can easily be changed and are written to meet the needs of the user. Free embedded system software called the Arduino IDE is available. Writing code and uploading it to a microcontroller is quite upbeat.

All operating systems are compatible with the Arduino IDE, which also supports all user-developed devices [18, 19]. As the first step starts with the building of a machine learning model, we first imported the csv format of the data and then data processed the values and neglected the null and improper variables that was going to bring down the efficiency of the model. After finishing the data pre-processing, we trained and fitted the model into a algorithm called Linear Regression. The purpose we choose this algorithm is that it has higher efficiency than other Supervised machine learning models. We can't use the Logistic Regression as it is a two binary class regressor and gives the values like yes or no. We also trained with the DescionTreeClassifier and Random Forest Classifier and Ada Boost models yet since it is a linear data we choose this Linear Regression. The Linear Regression works like Gradient Descent technique that learns with the values and implements the regular data testing. After training the model, we converted the ipynb(Python Notebook) to the Pickle format (Serializer and Deserializer) model that will compress the model into AVRO format and then used in the User Interface models and deployments of machine learning models. We have attached the implementation of the cloud model deployment and the flask to request screenshots for reference.

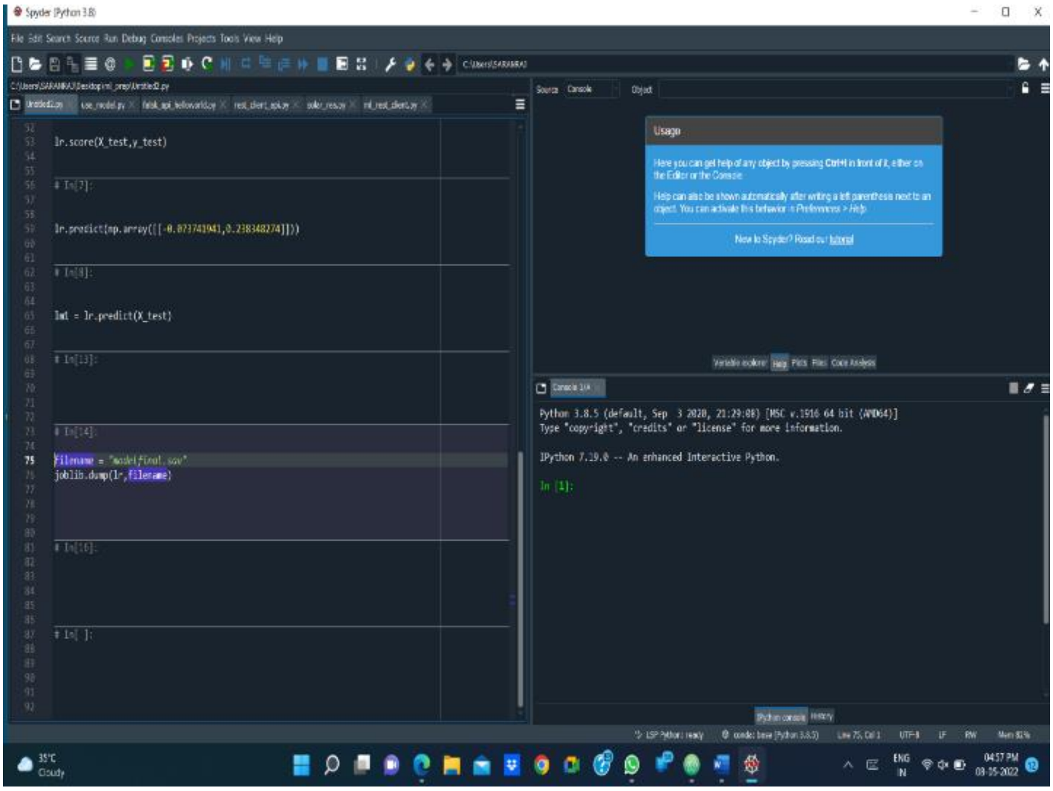

Figure 5.Machine Learning Model is being trained in the IDE software known as the SPYDER for integrating and developing the machine learning projects in the language of python.

Now as the model is ready to be deployed, we choose the Google Cloud Services as it is easy to deploy and pay as you services. We built a Virtual-machine for deployment of our project. A virtual machine is a computer-based Node that is Virtually runs the work and models for us and gives the answer so that everyone in the world can use this project. Since it is a pay as you go service it is very cheap and depends on the regional model for the pricing method. As the virtual machine is ready now, we need a method to access the cloud and get the prediction of our model and display it in the web browser for the user interface. Now this process is done with the help of two python-based framework which is very popular in today's market and free to use. We used Flask (python framework) for interacting with the Google cloud with the help of local host and request method to interact with the google cloud service and virtual machine and pass in the values of the user to the model and get the angle from the prediction and display it in the user interface webpage.

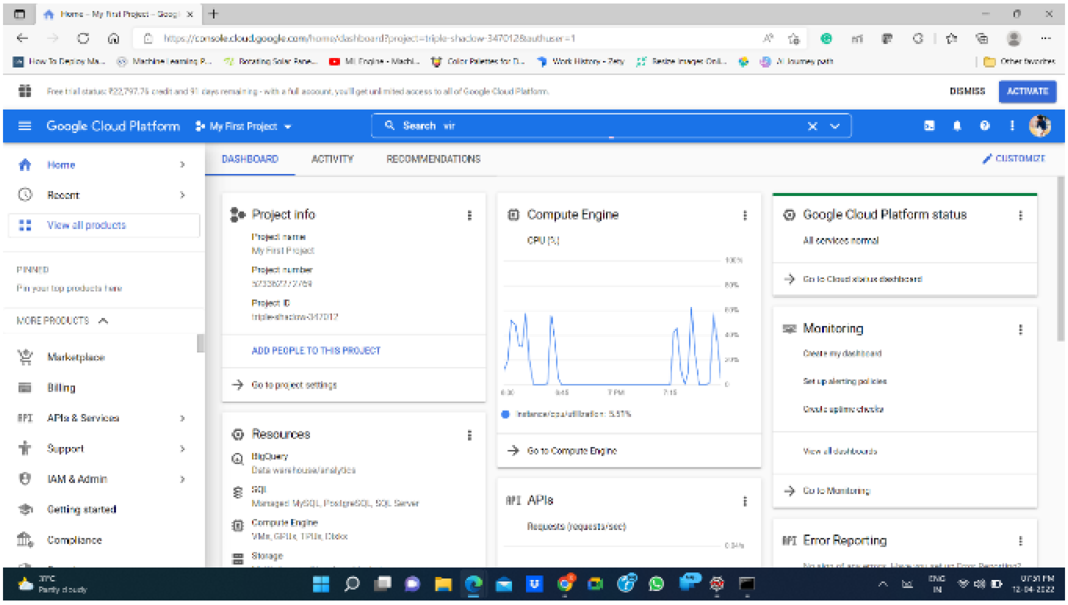

Figure 6. Google Cloud Model is an online cloud service portal where the model is getting ready to be deployed so that every consumer can use it and being ready to be deployed in a market for the use.

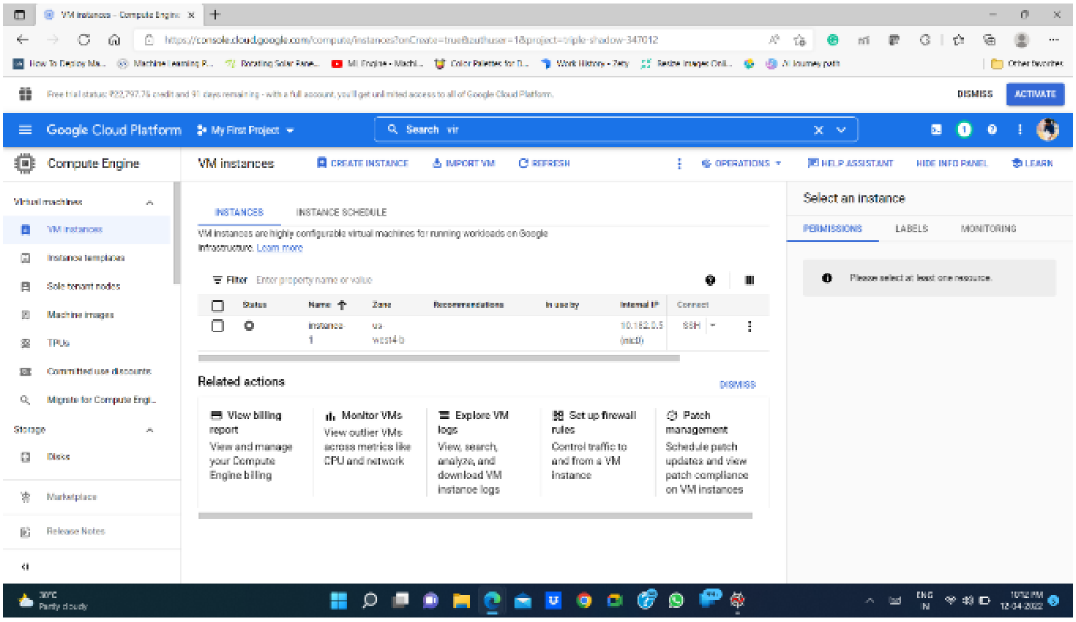

Figure 7. Google Cloud Model VM Instance where the machine learning model is deployed for the virtual machine cause the amount of ram taken by the local machine might not be enough to support the deployment and hence a virtual machine.

The web-page is built using the HTML which is also called the Hyper Text Markup Language and it is one of the primary and a long used one for building the Webpage blue print kind of model and the life to the webpage and beauty is given by the CSS which is known as Cascaded Style Sheet which adds the colours and design to the web page and the web-page interacts using the backend language called JavaScript. These 3 were the main components for building the web-page. We created and linked 3 pages and the first one is the main page where the user can get started with their solar tracker and monitor the health of it.We attached the following screenshots of the main page.

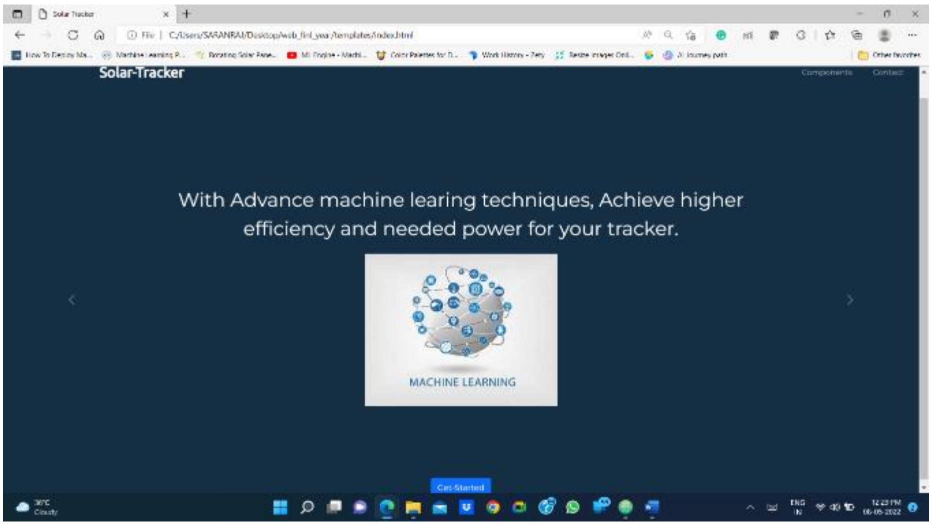

Figure 8. Web-page is a user portal for the consumers to use the easy access and also to locate the solar tracker of the particular consumer and to track the power produced by each tracker for an individual house.

As the user selects the get started button it takes the user to the landing page where user can interact with his own solar tracker. This is done using the authentication methods which will be developed when production. There the user can select the location of the tracker and the weather API will display the user's selected location weather and also displays the power now extracted by the solar panel and the angle tilt now and the time will display the predicted power at the user's selected time. Attached is the web-page of the get-started.

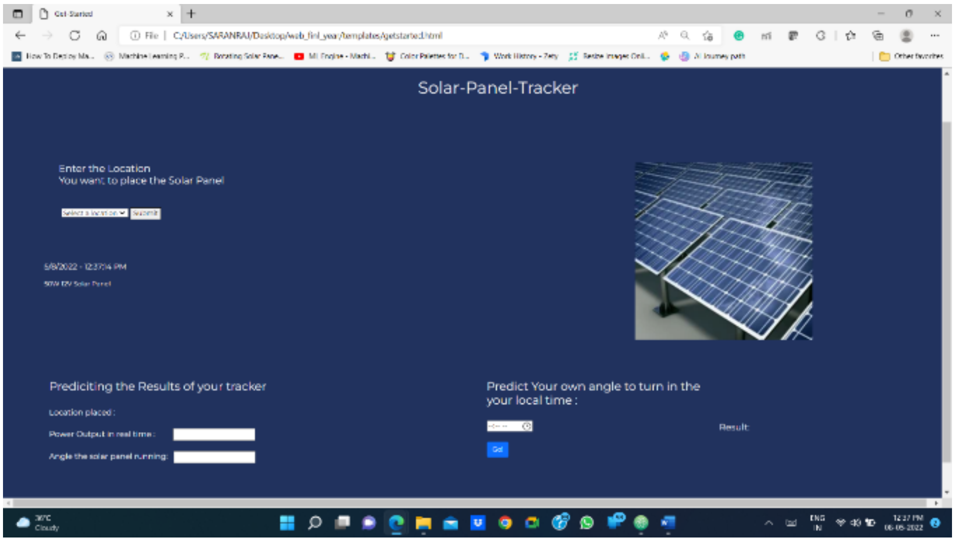

Figure 9. Web-page shows the landing page for tracking an tracker based on the location and also for the power tracking purposes they are displayed in the web-page so that we can access anywhere in the world.

The next page is in the home page where the components page will display the components of the solar tracker used and also displays the link for all the components that has been bought.

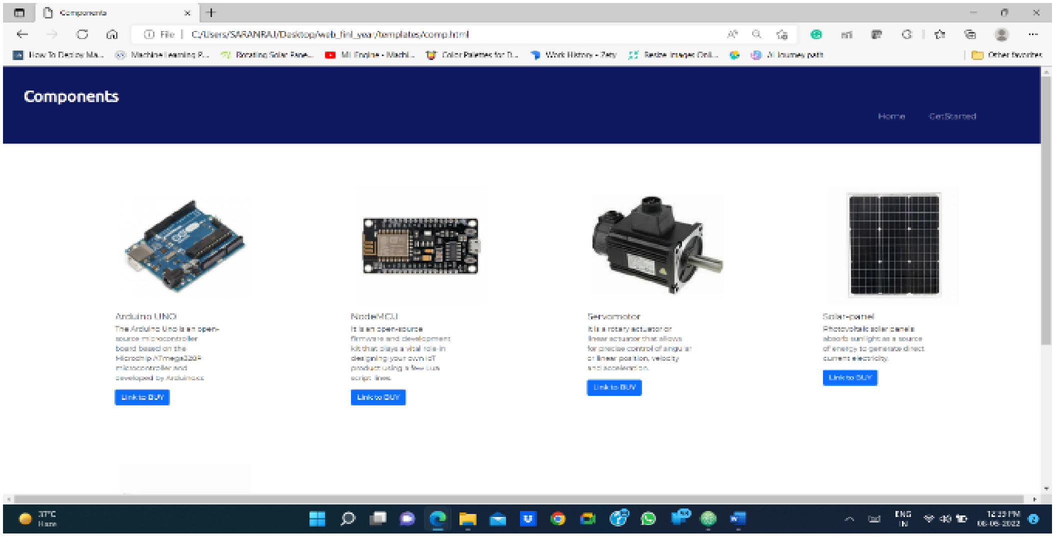

Figure 10. Web-page shows the component used in the particular product/Solar tracker and also provides a link for the later shopping purposes.

Finally we have also added the Contact page where the user can contact the developer in case any problem and also for upgrade to higher power panels and maintenance kind of contacts.To conclude, we used the Google cloud services for monitoring and deploying the Machine learning model in a virtual machine which runs in the cloud server monitors the data and predict the angle from the model developed. The Machine learning model we used is a Supervised Machine Learning model since we are using a labelled data and also we use the model called the Linear Regression since it is a regression-based model and all are numeric data. The model takes in time and location and calculates the angle and returns the data to the NODEMCU and as it said in component design. The web page we use is linked with Google cloud with the help of Flask , a python IDLE framework to interact with the Virtual machine. The languages we used is HTML and CSS for web page and python for the backend services.

4. RESULTS AND CLARIFICATIONS

The project starts with the assembly of solar panel of 50W 12V power supply which is connected to the solar stand for rotation based on time angle. The servomotor is connected to the solar panel on both sides for the rotation of solar panel.

The servomotor angle is supplied to the microcontroller for accurate machine learning-based angle calculation, and then via the WiFi module to the cloud. In this project, the regulating process is crucial. The power output of solar panels is boosted and their efficiency is greatly increased by the precise tilting angles. The conversion is carried out using the elevation angle, which is calculated using the declination angle, solar hour angle, sin and cos angles of the declination angle, as well as the placement of the solar tracker [20]. By using this strategy, we can manage the radiation considerably better than the previous one while also reducing the use of LDR.

The Google cloud services is used to deploy the machine learning model and used a virtual instance for the machine learning model and used a flask IDLE for the request and retrieval of accurate linear regressed data for which the servomotor has to turn. This is then displayed in the webpage for the user interaction with the prototype whether it is working or not and also for alerts on cleaning the solar panel and repair of solar panel.

Thus the user will be able to know the power extracted per hour and also for upgrading the solar panel or buying additional plan. Thus this is a prototype that is market ready and to be deployed for working. Attached is the small figure that explains the radiation that is received during the yearly months and explains clearly about the summer and winter conditions and also the average solar radiation that is received during the months.

Month	Solar radiation received per day(KW/HR)	Per month(KW/hr)
January	5.55	166.5
February	6.4	179.2
March	6.68	207.08
April	6.71	201.3
May	6.12	189.72
June	5.36	160.8
July	4.71	146.01
August	4.91	147.3
September	5.46	169.26
October	5.08	152.4
November	4.54	140.74
December	4.65	139.5

Figure 11. Seasonal Power shows the monthly power tracked and observed by the solar panel in the location of Chennai.

The data we produced from the machine learning model improved the solar panel tilting and also used for forecasting with the data's being stored into the google cloud services and also used for the analyses and improve the services we once used for the model [21]. Attached is the proof of the data which concludes that it works from the 6 am to 6 pm.

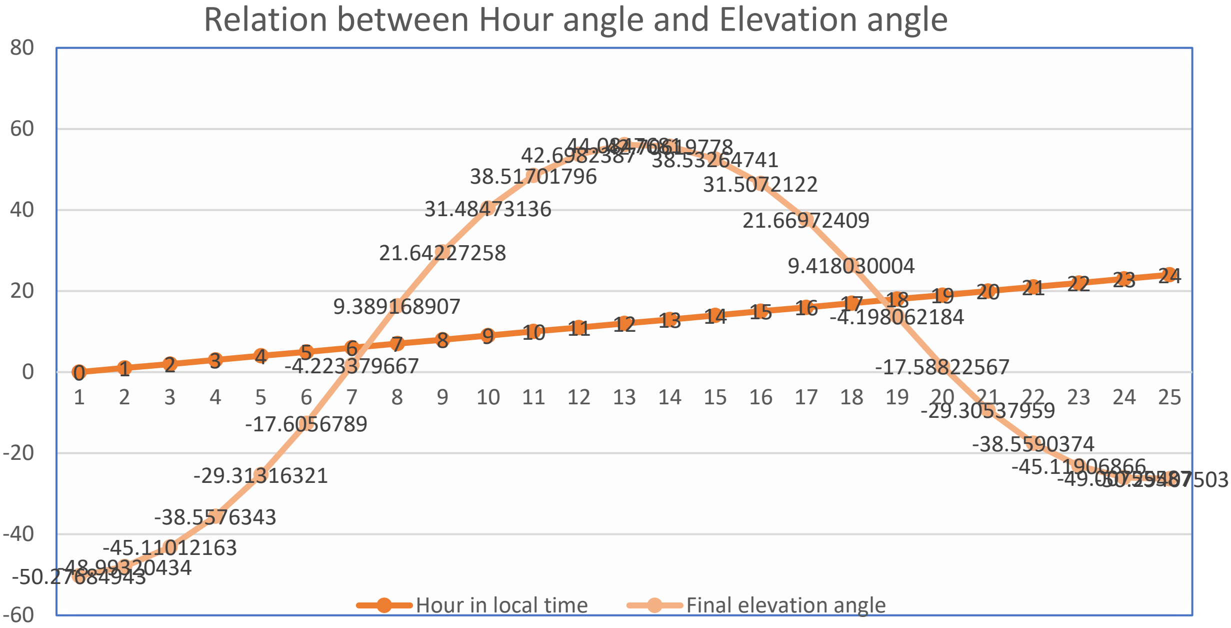

Figure 12. Time Varied Power on Solar Panel shows the time variation where these values are extracted from the Figure 3 and Figure 4 where we developed the elevation angle using the formulae mentioned.

5. CONCLUSION:

Using web development and the communication support of a NodeMCU module, a low-cost wireless solar tracker monitoring system based on a microcontroller was successfully conceived and constructed for tracking solar tilt angle on a closed channel system.It is constructed with a hardware and software system that includes an Arduino Uno, NodeMCU, and Servomotor. The suggested system will offer real-time data collecting, do away with manual measurement errors, and provide incredibly accurate automatic operation measurement as well as long-term effectiveness. It benefits from the system's simple, user-friendly, precise measurement, real-time data collecting, and internet capabilities.

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