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Cloud Powered AI Based Solar Tracker

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Abstract- Solar energy is the most cost-effective form of energy generation among other renewable energy sources. However, structurally the traditional solar panels have a common problem i.e. they are fixed at a particular angle & the sun rotates throughout the day making maximum solar radiations getting reflected from the surface making the traditional solar panel system less effective. In this paper, we have proposed a Cloud-powered AI-based solar tracking system that for a given location forecasts the position of the sun & guides the solar panel controller to move the panels to their respective angel.

Index Terms- Solar, Solar Tracker, AI, Cloud, Azimuth

I. Introduction

Renewable, Green & clean energy is the need of an hour & it is the prime focus of all the governments across the globe. Every country's vision is to become a self-sustained clean energy producer in two to three decades. There are various renewable energy sources like wind energy, geothermal energy, and solar energy but the most cost-effective of them is solar energy. Hence, solar energy is going to be an integral part of achieving the clean energy revolution vision for each nation. Traditional Photovoltaic (PV) solar system exists for more than 7 decades but they have a fundamental problem which is they are fixed on the supporting vertical frame at a particular angle usually at the longitude of the location.

Since the sun changes its position throughout the day & solar panels are installed at a fixed angle, the maximum amount of solar radiation gets reflected & goes unutilized, making the traditional fixed angle PV solar system inefficient. This results in lesser energy being generated than its potential.

The solution to overcome this issue is to rotate the solar panels as per the direction & movement of the sun. So, we need the solar tracking mechanism which tracks the movement of the sun & the physical hardware that rotates the solar panels at the required angle. There exist various forms of solar tracking systems in the market such as Active tracking, Passive tracking, and Chronological tracking which we have discussed in the subsequent sections in detail. However, these tracking systems have their limitations such as limited scalability, increased cost, and accuracy which makes it hard for them to adapt at mass.

In this paper, we are proposing a novel approach for solar tracking which is based on AI & can be hosted on the cloud to make it scalable. The proposed AI-based solar tracker is an attempt to resolve the limitations of the other solar tracking system and make them more adaptable at scale. Let's understand some of the key concepts.

Photovoltaic (PV) Cell/ Panel

PV materials and devices convert sunlight into electrical energy [1]. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected in chains to form larger units known as modules or panels.

Sun Path

As shown in Figure 1, Sun path [2] sometimes also called day arc, refers to the daily and seasonal arc-like path that the Sun appears to follow across the sky as the Earth rotates and orbits the Sun. The Sun's path affects the length of daytime experienced and the amount of daylight received along a certain latitude during a given season. A Sun Path Diagram shows the azimuth angle, elevation angle, sun paths throughout the years, sunrise and sunset time, etc.

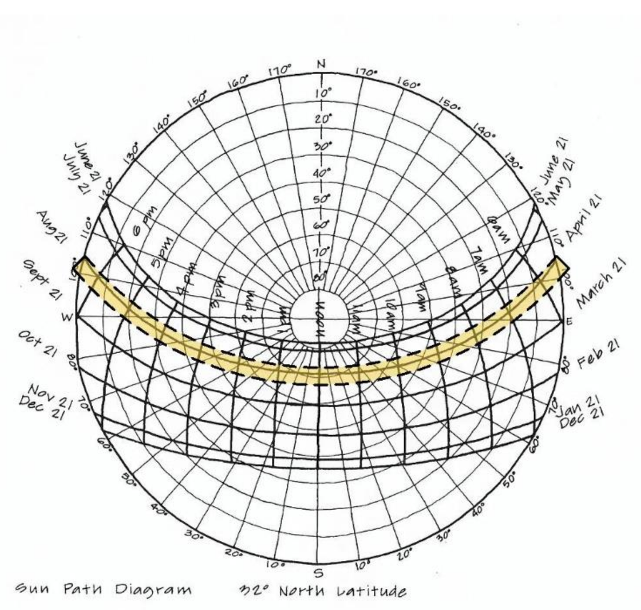

Fig1. Sun Path Diagram

Azimuth Angle

As shown in Fig 2, Azimuth Angle [3] is the direction of the sun from the observer, expressed because of the hour angle from the north point of the line to the point at which a vertical circle passing through the sun intersects the horizon.

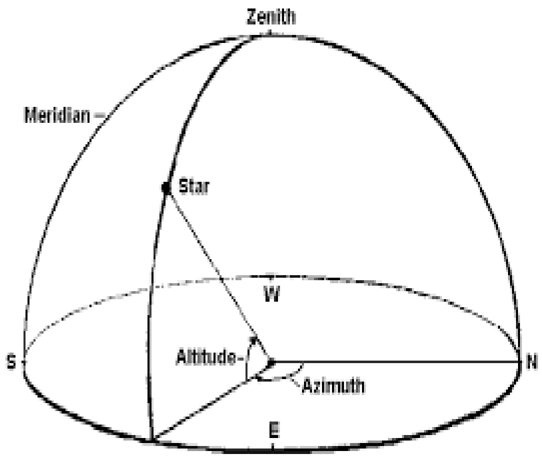

Fig2. Azimuth Angle

Methods For Solar Tracking

There are three basic methods of solar tracking [4].

Active Tracking.

Passive Tracking

Chronological Tracking

Active Tracking

Active trackers use microprocessors and/or sensors to detect the position of the sun. The sensor triggers the motion of the motor or actuator in such a way that the solar panel will always face the sun throughout the day. This type of tracker faces issues false trigger issues during cloudy days as well as this type of sensor is costly compared to its counterparts.

Passive Tracking

The passive tracking method does not use sensors like activity tracking. The most common Passive trackers use a low boiling point compressed gas fluid that is driven to one side or the other (by solar heat creating gas pressure) to cause the tracker to move in response to an imbalance. This method does not have to rely on electrical sensors and requires a negligible amount of power to operate however accuracy is not reliable in this type of tracker.

Chronological Tracking

A chronological tracker is a timer-based tracking system. The structure is moved at a fixed rate throughout the day since the sun moves across the sky at a fixed rate of about 15 degree per hour. This method is better suitable for single axis tracking without sensors. For dual axis tracking a modified version can be implemented. The position of sun throughout the day can be calculated and set by the program implemented on the controller module. The solar tracker rotates according to data sent from control unit's memory of pre-stored data or calculated from given formula. This method of sun-tracking is accurate and reliable.

However, data storage, calculation continuous data transmission is power consuming and unnecessary rotation when sun light is too low can never be avoided. All the three methods are applicable with single axis and dual axis tracking system. Which method is best suitable, is determined by the location of installation, purpose of generation and demand of solar power. Modern trackers combines both the sensor controlled method and sensor less control method at the same time to increase efficiency. Which method is best suitable, is determined by the location of installation, the purpose of generation, and the demand for solar power.

Components of Solar Tracking System

A solar tracking system has several components. But the most basic & important ones are mentioned below.

Sun Tracking Mechanism

As mentioned in the previous section, overall there are three methods of sun-tracking i.e. Active, Passive, and Chronological.

Tracker control unit

The control unit executes the sun-tracking mechanism and necessary calculations. It can also coordinate the movement of the positioning system. A microprocessor or a computer can be used as the center of the control unit.

Panel Positioning System & Drive Mechanism

The positioning system handles the task of rotating the solar panels according to the preference of the control unit. It can be either electronic or hydraulic. The drive mechanism includes mechanical devices- rotary motors, linear actuators, linear drives, hydraulic cylinders, swivel drives, worm gears, planetary gears, and threaded spindles. The fixed PV solar system does not have this drive mechanism as the panels are fixed at a certain angle.

Why Optimization through solar Tracker is required

The fixed PV solar system has limited energy production capacity than its potential because the maximum solar radiation gets lost due to reflection. The solar tracker increases the efficiency & throughput in terms of energy generation as now the panels rotate as per the sun's movement which results in lesser energy loss & increased energy production without a significant increase in the cost.

The increased energy production can meet the ever-increasing energy demand & the electricity can be provided to light more households and industries.

Proposed Methodology

In this paper, we are proposing AI-based trackers that will forecast the position of the sun (azimuth angle) at every 15 minutes time interval for a given location. As shown in Figure 3, the LSTM based time series forecasting model is the core engine of the AI based tracker & the forecasted angle will be fed to the local microcontroller installed at each solar plant which will accept the target angle of the solar panel from the solar tracker engine & will instruct the microcontroller to trigger the panel rotation through the panel positioning system and drive mechanism. This is the novel AI-based solution for solar tracking & optimizing the solar panel angles based on the AI model.

The microcontroller [5] acts as the intermediatory communicator between solar tracking engine and the actual hardware that rotates the solar panel. The role of the microcontroller is like translator which helps communicate between two people speaking in different languages.

This solution eliminates the need of having separate solar tracker sensors installed on the individual solar panels which results in saving the cost of the hardware. Also, the angle optimization is done centrally on a cloud for all the panels in the solar farm, only a single Drive Mechanism needed can control panel movement as opposed to multiple in the case of a sensor-based approach. This results in significant cost reduction.

For the solution, LSTM based time series algorithm is used to build the AI model. The proposed solution can forecast the azimuth angle for any location which can be different from the location on which the model is trained.

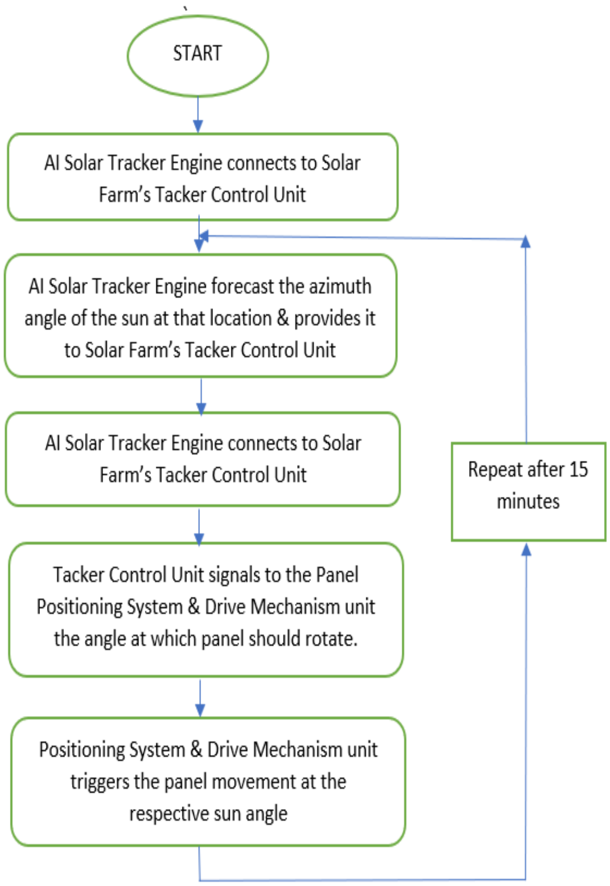

Fig3. Flowchart of proposed approach of AI based solar tracker engine

Dataset

The dataset for this use case is not taken from any open source but it is derived from an open-source website called www.suncalc.org which provides the sun movement information (azimuth angle) for any location, for a given date & time. The dataset has the date & time information along with the azimuth angle of the sun at the given time in a day. The collected data is spaced at 15 minutes timestamp so each data instance represents the sun position in terms of azimuth angle at the 15th minute.

For this research, the model is trained on 45 days of data from Jan 1st, 2022 to Feb 15th, 2022 & model has been validated on the 15 days of data from 16th Feb 2022 to 28th Feb 2022. The model can predict the azimuth angle of the sun for any date & time from March 2022.

The data is preprocessed first before feeding it to the model. The data is arranged in a timestamp window of 100 which means to predict the azimuth angle at timestamp t, t-100 to t-1 are used as input variables.

Model

As shown in Figure 4, The AI solution has been built on the LSTM-based time series model with 3 dense layers of 50 LSTM units each followed by a dense neural network layer on the training dataset. The given model has been trained on 50 epochs with a batch size of 64.

Model: "sequential"

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 100, 50)	10400
lstm_1 (LSTM)	(None, 100, 50)	20200
lstm_2 (LSTM)	(None, 50)	20200
dense (Dense)	(None, 1)	51

Total params: 50,851
Trainable params: 50,851
Non-trainable params: 0

Fig4. Solar Tracker Time Series model configuration

Model Performance

The model has been trained on a fairly simple configuration, yet the model performance is high. To evaluate the performance, RMSE is used as the evaluation metric. The model has an RMSE of 186.83 on train data & RMSE of 188.19 on test data. The model performed well to generalize on test data as well.

We have built the UI to showcase the performance of the proposed solution with hardware based solar trackers results to compare the results of the proposed methodology with more prominent solutions in the market.

As shown in figure 5, the result of the LSTM based solar tracker on a specific latitude, longitude shows the forecasted azimuth angle of the sun & comparison of that with the angle derived from the physical solar sensors.

As can be observed in the figure 5, the AI based solar tracker model's forecasted angle movement is smoother as compared to the physical solar sensors-based tracker's result & AI model result is more accurate, precise as compared to sensor data.

Since the sun moves in specific trajectory throughout the day which is getting captured well with AI model-based forecasting method whereas the sensor-based solution's result is jittery & moves up and down which shows the error in the sensor-based method.

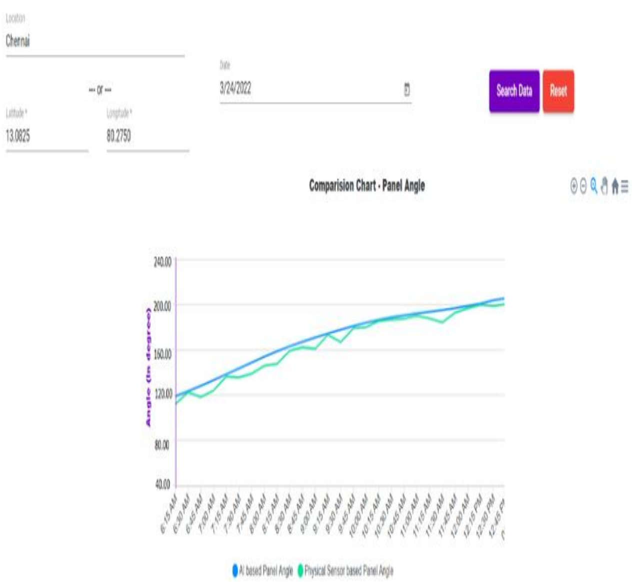

Fig5. Solar Tracker Simulation v/s Sensor based tracker

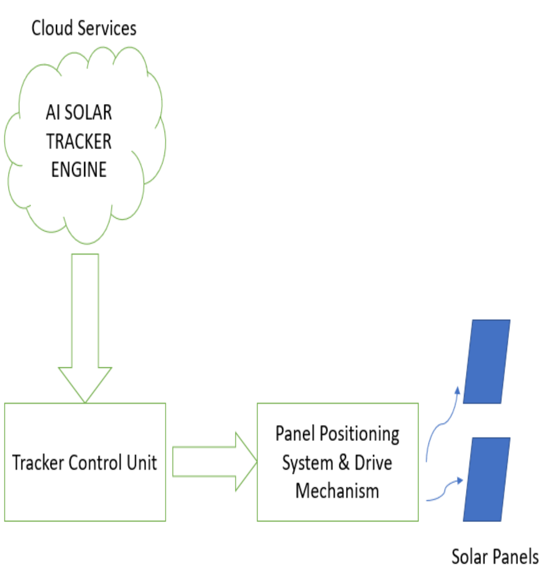

Fig6. Solar Tracker proposed methodology

Proposed Solution Design

The AI-based solar tracker is a unique solution that can be trained on a one Latitude, Longitude data & can be used to forecast the sun position of any other location given solar panel's Latitude, Longitude data. This feature of the solution makes it a global one stop solution for solar position optimization.

As shown in Fig 6, we are proposing to deploy the AI based solar tracker solution on a cloud i.e., AWS or GCP or Azure to make the solution accessible, scalable & adaptable to the any solar farm looking to incorporate the services.

The AI engine will forecast the sun azimuth angle for the client location & the cloud will signal the local solar farm about the position of the sun (azimuth angle) in that location.

The signal gets processed by the Tracker control unit which instructs the Panel Positioning System which commands Drive Mechanism to rotate the panels at their respective azimuth angle. This way multiple solar farms can get connected to the cloud & can avail of the services of solar tracking.

Key characteristics of the model

The finalized model is trained once & used anywhere which means it is trained on one location data & it can be used to forecast the azimuth angle for any other location. This eliminates the need for a separate model for separate locations.

This solution is a novel solution to remove the dependency on the hardware-based solar trackers giving better accuracy at a cheaper cost.

This AI-based solution removes the cons of hardware-based solar trackers such as no service/maintenance being needed or no hassle of faulty/failed physical solar tracker.

In comparison with a fixed PV solar system, the AI-based solar track may provide 40%-45% increased energy production which can be used to meet the increasing energy demands.

II. Conclusion

There exist multiple solar tracker solution ranging from the hardware-based sensor to passive temperature-controlled system. These solutions are decent in delivering the result but comes with various limitations & problems which restricts the adaptation of the same at a scale. The Cloud Powered AI based solar tracker system is an attempt to rectify these limitations and to make the solar tracking system more scalable.

The result from the AI based trackers not only is an improvement in terms of accuracy, precision but also the energy efficiency is higher as compared to the hardware-based models.

This solution eliminates the need of maintaining the physical sensors and it is cost effective as it reduces hardware dependency & it makes the solution scalable to all the solar farms across the globe.

References

[1] https://en.wikipedia.org/wiki/Solar_cell
[2] https://hyperfinearchitecture.com/how-to-read-sun-path-diagrams/
[3] https://en.wikipedia.org/wiki/Solar_azimuth_angle
[4] A.Z. Hafez, A.M. Yousef, N.M. Harag, Solar tracking systems: Technologies and trackers drive types – A review, Renewable and Sustainable Energy Reviews, Volume 91, 2018, Pages 754-782,
[5] P. Sharma and N. Malhotra, "Solar tracking system using microcontroller," 2014 1st International Conference on Non Conventional Energy (ICONCE 2014), 2014, pp. 77-79, doi: 10.1109/ICONCE.2014.6808687.

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