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SOLAR TRACK AI: A LOW-COST IOT-BASED SINGLE-AXIS SOLAR TRACKING AND INTELLIGENT - DUST MITIGATION SYSTEM

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Abstract:

Solar photovoltaic systems are an essential component of renewable energy, yet their efficiency is often limited by improper alignment with the sun and the accumulation of dust and pollutants. Fixed solar panels cannot continuously face the sun as it moves from east to west, leading to energy losses of up to 45% in some cases. Additionally, dirt and environmental pollution can block and reflect sunlight, reducing panel efficiency by 20–40% in certain regions. Although traditional sun-tracking systems help improve alignment, they often lack effective integration with cleaning mechanisms. Existing cleaning systems may also be inefficient, as they operate only after significant dirt accumulation. This paper presents Solar Track AI, a cost-effective system that utilizes internet connectivity and advanced sensors to optimize solar panel performance. The system employs light sensors to ensure panels continuously face the sun, maximizing energy capture. It also monitors voltage output to detect dust accumulation and uses a predictive algorithm to determine optimal cleaning times with 95% accuracy. The system avoids unnecessary operation, such as activating cleaning at night, thereby enhancing reliability. Experimental results indicate a 20–22% increase in energy output, with simulations predicting an additional 4–5 kWh annually. Overall, Solar Track AI significantly improves solar energy efficiency.

Keywords: *Solar PV, Single-Axis Tracking, IoT, Machine Learning, Dust Detection, Smart Cleaning.*

1. Introduction

The demand for energy is getting bigger and bigger because of industrialization population growth and concerns about the environment. Solar energy is one of the options because it is available everywhere can be used on a large scale and does not harm the environment. Many people are using energy systems in their homes, offices and schools especially in countries like India where the sun shines brightly throughout the year. Even with all these advantages solar energy systems are not working as well as they could. There are reasons for this, including solar panels that are not facing the right direction dust building up on the panels changes in temperature and not being

able to monitor them properly. Solar panels that are fixed in one place cannot follow the sun as it moves across the sky, which means they are not capturing much energy as they could. In fact studies have shown that fixed solar panels can lose up to 45% of the energy they could be producing depending on where they're what time of year it is. Another big problem with energy systems is dust building up on the panels. Dust, dirt and other things can cover the panels blocking sunlight and reducing the amount of energy they produce. In areas with a lot of dust and not much rain, like cities and deserts this can reduce energy production by up to 40% or more. Usually people clean the panels by hand, which's time-consuming, wasteful and does not happen often enough. To fix these problems we are proposing a system that uses artificial intelligence and the internet to track the sun detect dust clean the panels automatically and monitor everything from the cloud. This system brings together different technologies to make a single unified system. By using intelligence and the internet the system can make decisions in real-time be monitored from afar and take care of itself.

2. Literature review

People have already looked into tracking, IoT monitoring and automated cleaning but they did this one thing at a time. Solar tracking and IoT monitoring and automated cleaning were each done separately. Robotic cleaning systems are really good at what they do. They cost a lot of money and are hard to understand. If you want to use a camera to see how much dust is on something you need to have a lot of computer power to make it work. IoT systems are good at keeping an eye on things. They are not very good, at doing something about what they see. Some systems will clean when they reach a level of dust but this is not a very good way to do it because it does not always work. Not many people have tried to put all these things like solar tracking and smart dust detection and automated cleaning and cloud monitoring into one system that is affordable. This is why we made Solar Track AI to fill this gap and make something Solar Track AI is a system that does all these things. It is not too expensive.

3. Methodology

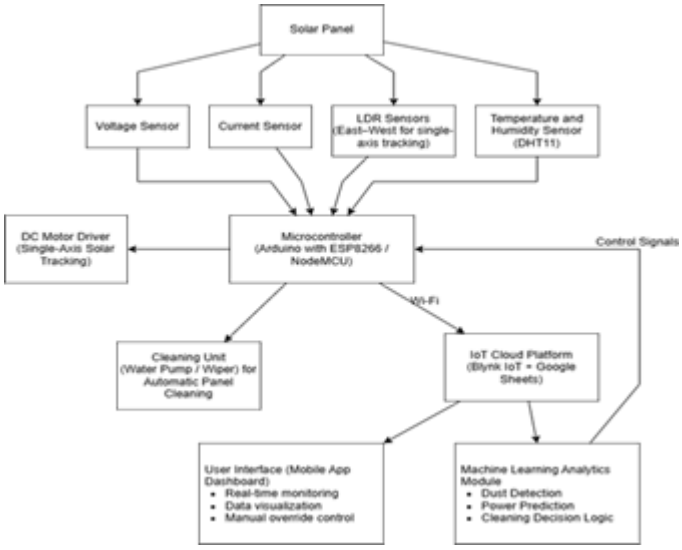


Figure 3: Proposed Methodology

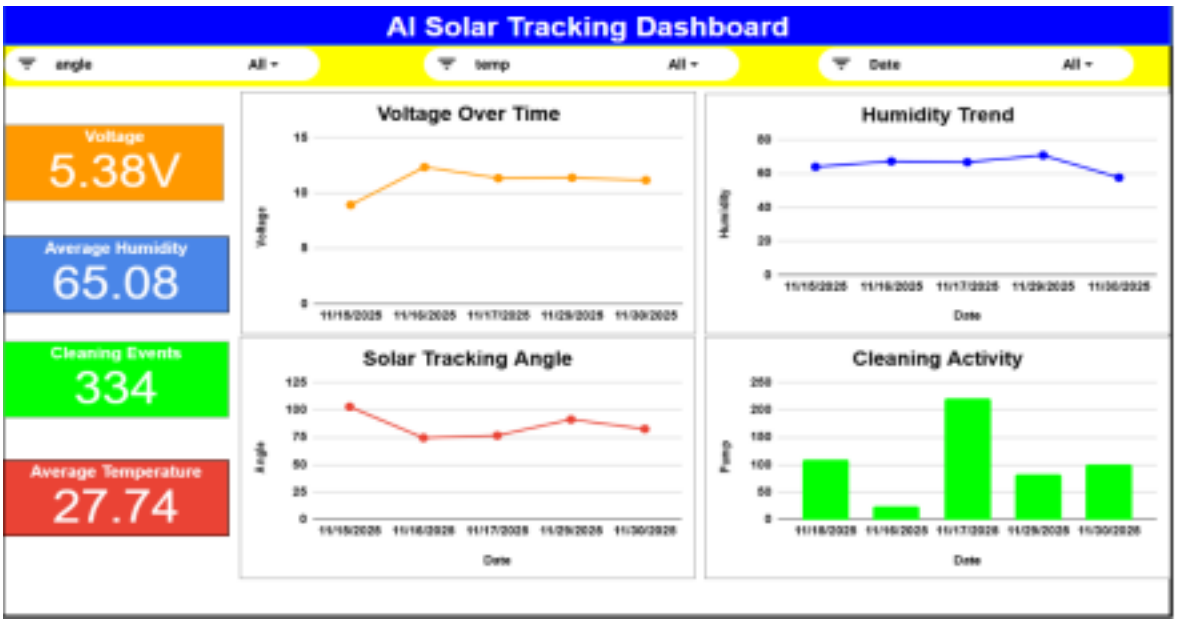
The proposed system has a main parts: a single-axis tracking module, an IoT communication layer and a machine learning-based dust detection system. The single-axis tracking module uses two LDR sensors to check if sunlight's not balanced. These sensors help a servo motor move the panel to face east or west. The Arduino Uno collects data

about the environment and electricity. This data includes temperature, humidity and voltage. The ESP8266 module sends this data to Google Sheets and the Blynk cloud. This is for monitoring and storing the data. A Random Forest model is trained using data from the sensors. It predicts dust conditions. There's also a rule that checks the voltage and temperature. The rule is: the voltage must be between 1.5V and 4.0V and the temperature must be, between 28°C and 50°C. This rule helps make sure the machine learning predictions are correct. It prevents the system from getting activations at night. The system uses the Arduino Uno and ESP8266 module to work. The Arduino Uno and ESP8266 module are parts. The single-axis tracking module and machine learning-based dust detection are also parts.

4. Implementation

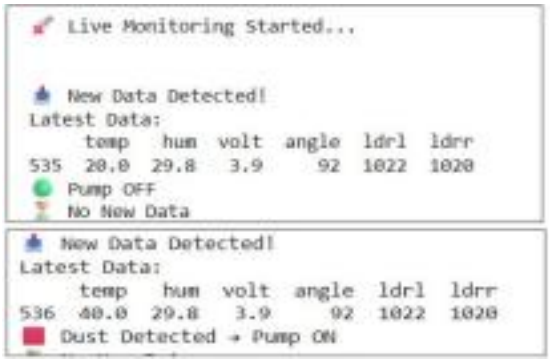
The system is made up of a few parts. It has a 6V panel, an Arduino UNO, an ESP8266 Wi-Fi module a DHT11 sensor, a voltage sensor, a servo motor, a relay and a water pump. The Arduino UNO and other parts work together to make the system work. The firmware is like the brain of the system. It looks at the data, from the sensor and uses it to control the tracking. It also keeps an eye on the environment all the time. The sensor data is sent to the cloud at times. The system uses Python and special libraries to analyse the data and make predictions. The machine learning model is. Then saved so it can be used to make predictions in real time without having to be trained again. The cleaning process only starts when the machine learning prediction and the hybrid validation conditions are both met. The system uses machine learning and the solar panel and other hardware to make it all work together.

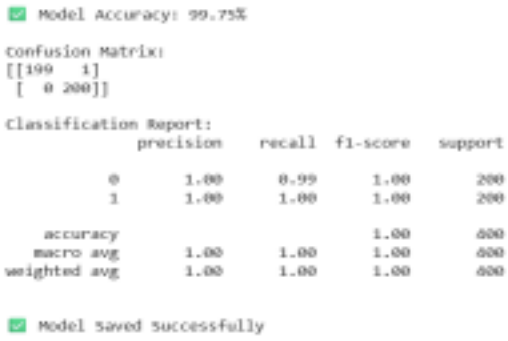
5. Results and analysis



When we did some testing we found out that using single-axis tracking can make a difference in how much energy we can generate. It is 20 to 22 percent more than what we get from fixed panels. We also checked the voltage of panels and it was usually between 5.8 and 6.2 volts.. When the panels got dusty the voltage went down a lot below 4 volts. We used a thing called the Random Forest model to make predictions. It was really good, at it getting it right about 95 to 99 percent of the time. We had to make sure the data was balanced and add some noise to it to get those results. We also made sure that the pumps did not turn on at night when they were not supposed to

which was a problem before. We set up a way to monitor the system from afar. It worked really well. We could see what was going on in time and take control of it if we needed to. The single-axis tracking and monitoring system really helped us make the energy generation better. Single-axis tracking was a part of this and it helped a lot.





6. Applications

The solar track AI system is great for homes with rooftops farms that need to water their crops and small businesses. It is also good for schools that want to study things. Solar track AI does a job to robots but it costs a lot less. One problem is that the sensors are not perfect and the weather can affect how well it works. The good thing is that the solar track AI system can be improved later with new features like being able to move in two directions being able to predict what will happen and being able to work on its own with edge AI. The solar track AI system is a choice because it can be used in many different places and it is not too expensive. The people who made the solar track AI system thought about how to make it better in the future. The solar track AI system is very useful, for people who want to use solar track AI.

7. Discussion

The Solar track system is really good at helping solar panels work better. It does this by moving the panels to follow the sun all day. This means the panels can catch energy than if they were stuck in one place. The Solar track system also keeps an eye on the panels. Can tell when they get dirty. It uses tools to make sure it is right about the dirt. This means the system does not turn on the cleaning pumps when it is not needed, like at night. The Solar track system is a way to make solar panels work better in a simple and affordable way. It is perfect for medium-size solar projects. The Solar track system is practical and reliable. It helps solar panels work better. That is what the Solar track system is all, about.

Conclusion

The Solar track system is really good at helping solar panels work better. It does this by moving the panels to follow the sun all day. This means the panels can catch energy than if they were stuck in one place. The Solar track system also keeps an eye on the panels. Can tell when they get dirty. It uses tools to make sure it is right about the dirt. This means the system does not turn on the cleaning pumps when it is not needed, like at night. The Solar track system is a way to make solar panels work better in a simple and affordable way. It is perfect for medium-size solar projects. The Solar track system is practical and reliable. It helps solar panels work better. That is what the Solar track system is all, about.

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