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Dual Axis Solar Tracking of Solar Radiation for Agriculture usage

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Abstract: Energy is one of the important parts of our life. As there is decline in fossil fuels and increasing demand for energy an alternate energy source is required which is renewable energy source like solar, wind etc. So, we use solar panels which trap the energy from the sun and produce electricity, and this energy is used for agriculture purpose like to run water pumps and to meet other energy requirements in agriculture. Due to rotation of earth the stationery solar panel will receive energy only for smaller duration so to overcome this we use dual axis tracking system which rotates solar panel according to direction of sun and helps in producing more solar energy. Agriculture is one of the major contributing sectors to the economy of a country and it requires automation and advanced technology so that it helps farmers in producing more yield and better crops. So, in agriculture continuous monitoring of soil and water level is required so we can automate this which helps the farmers where the device continuously monitors and depending upon the moisture level of the soil the water pumps get on automatically and we can use this for different crops and set threshold depending upon the crop type. And we can also integrate this idea with IOT technology for improvements. By this we create sustainable energy indirectly producing sustainable environment.

Keywords: Dual-Axis Sun tracker, LDR, Photovoltaic cells, Solar energy, Solar panels

1. Introduction

Efficient utilization of soil moisture and water resources is paramount in agriculture. The constant depletion of soil water underscores the need for a well-designed irrigation system. To address this challenge, a solar-powered autonomous watering system is proposed. This system integrates sensors to detect soil moisture levels and adjusts irrigation accordingly. The primary objective is to harness solar energy effectively by employing dual-axis solar trackers that automatically orient the solar panels to the sun's position, maximizing energy absorption. Key hardware components include Light Detecting Resistors (LDRs), servo motors, solar panels, batteries for energy storage, and moisture sensors. These components work in tandem with a microcontroller, serving as the software and processing unit. The LDRs detect sunlight intensity, allowing the system to track the sun's movement and adjust panel orientation accordingly. Additionally, a moisture sensor-based autonomous irrigation system ensures precise water delivery based on soil moisture levels, mitigating water wastage common in manual irrigation methods. By combining these components, the project aims to optimize agricultural productivity while conserving water resources.

2. Related Work

Solar tracking systems are extensively discussed in "Alternative Energy Systems in Building Design" by Peter Gevorkian, published in 2009. These systems are designed to align solar photovoltaic (PV) modules with the sun's movement throughout the day, thereby enhancing solar energy generation efficiency. Dual-axis trackers, specifically, can boost solar energy production by 30-40%. These trackers ensure optimal sunlight exposure by continuously adjusting the orientation of solar panels to follow the sun's path across the sky. Dual-axis solar trackers feature both horizontal and vertical axes, allowing them to accurately track the sun's apparent motion regardless of location. Various software tools exist to predict and monitor the sun's trajectory automatically, enhancing the efficiency of solar panels. In heliostat systems, dual axis tracking mechanisms direct solar reflectors toward concentrators, further optimizing energy collection. Extensive research has been conducted on autonomous irrigation systems, equipped with temperature and humidity sensors to assess soil conditions, and initiate appropriate watering actions. Microcontrollers process sensor data to operate irrigation systems efficiently, reducing reliance on manual labor.

However, automated irrigation systems necessitate electricity to power motors or pumps, leading to increased energy consumption. Limited access to electricity in rural areas poses a challenge to deploying such systems in these regions. Nevertheless, technological advancements aim to mitigate resource wastage and reduce operational costs. Efforts are being made to leverage available resources, such as solar energy, to power irrigation systems. Solar trackers play a crucial role in this endeavor, ensuring optimal solar panel alignment to maximize energy generation.

Table 1 illustrates various solar tracking and smart irrigation techniques developed by different authors.

Table I. Summary of various existing works

Sl.No.	Author/Reference Number	Title	Features	Observations/Limitations
1	Abhishek Shukla and Dr. Surya Prakash [1]	Dual Axis Solar Tracker System Using LDR	Simple and cost-effective technique and it has ability to adjust the tracking efficiency	The observation here is we get more solar energy than the single axis and fixed part.
2	Prathamesh kadam and Prop. Engle [2]	PV Solar Tracker with Drip Irrigation System	This technique is suitable for any type of land, and it targets the root of a crop, so crop yield will be more.	We can use dual axis solar tracker and IoT based irrigating system can be extended by adding. automatic spraying chemicals based on growth of a crop
3	V Mohanapriya [3]	Implementation of Dual Axis Solar Tracker System	It has good efficiency, as they have used a dual axis solar tracker using microcontroller	Lower reliability
4	Rashid Ahammed Ferdaus and Mahir Asif Mohammed [4]	Energy Efficient Hybrid Dual Axis Solar Tracking System	In hybrid dual axis solar tracking system one motor runs continuously to track continuous	It is not cost effective as the small model only takes more amount to build for high end applications this would not be suitable.

			movement of sun	
5	Amit Chakraborty Chhoton [5]	Dual Axis Solar Tracking System	They used mono crystalline PV panel for better efficiency of tracking.	poly crystalline material-based PV panel can be used for more efficiency and that energy can be used for irrigation system.
6	Dr.Nookala Venu and Sandhya rani B [6]	IOT Based Smart Irrigation System Using Node MCU	In this they have used Node MCU as a main processing unit. They have included many sensors such as moisture sensor.	This project can be enhanced by using image processing to identify the crop disease.
7	M. Saranya Nair And Karan Bhatia [7]	A Solar Tracker Assisted Automatic Irrigati on System for Irrigati on Fields	They have used single-axis solar tracker for storing energy and they have implemented irrigation system	We can include Dual-axis Solar Tracker for more energy storage and that can be used in agriculture purposes by integrating both.
8	Senthil Murugan and Vibha patro [8]	Dual Axis Solar Tracker	They implemented tracker using dual- axis to get higher efficiency.	They are effectively reducing power but they are not utilizing for any application in this
9	Satya Prasanth and Krupali V Rajesh Kumar [9]	Energy management in an automated	They have used automated solar generation for	This can be enhanced by using NodeMCU which is having inbuilt

		solar powered irrigation system	irrigation system which includes GSM module	Wi-Fi and we can get readings based on sensors
10	Jagdish M Rathod And Tanmay Pawar [10]	Dual Axis Solar Tracking System with Low Power Consumption and Increased Efficiency	In this project they have used ARM microcontroller as a main processing unit to achieve low power consumption.	Observation here is they used arm processor which handles complex instructions, so it is faster and smoother in handling the data.
11	Dr. Joseph Merlin Florrence [11]	Smart Irrigation System Using IOT	In this paper IIOT technology is used for e monitoring temperature, humidity by using various sensors.	We can integrate this idea with solar tracking mechanism so that it could reduce the agriculture power needs.
12	Ashwini B V [12]	A Study on Smart Irrigation System Using IoT for Surveillance of Crop-Field	In this project they implemented an automated irrigation system by using android application. Based on this they are monitoring the crop.	Here everything is automated so we can add some extra features like controlling from android itself so the farmer could decide the on and off status.
13	Jitesh Kumar [13]	A Research Paper on Solar Powered Irrigation System	They developed a system which is useful to the farmers. Based on the sensor input values it	Automation is a better idea in this project, but we could include the IOT features so that the farmer could get the real time updates about

			will compare with the threshold values for various crops it will sprinkle the water to the crops.	the crop and can act according to that.
14	Mr. Dhanaji Baravade, Miss. Mayuri Mali & Miss. Simran Mulla [14]	Study Paper on Smart Irrigation System	Arduino as the main processing unit is proposed as a system which reduces water and electricity wastage.	The proposed drip irrigation is the major observation of this project where it hands different crop with different water levels.
15	S P Vimal [15]	Smart Irrigation System in Agriculture	It is based on microcontroller and effectively monitors on drip irrigation.	IoT can be included in this so that we could get real time data and can easily monitor the crop.

3. Methodologies

3.1 Solar Tracking

Energy produced by the solar panel which is fixed to a particular direction is limited, that is it depends upon the number of active peak sun hours. So, the total amount of energy produced by a solar panel in a day can be calculated by the formula below.

Total power produced in a day = (Power rating of solar panel*Duration of active sun hour)

If we consider an example solar panel of 100 Watts, and an active sun duration is 5 hours, then the solar energy produced is 500 watts per day. This is not sufficient for daily needs, so we require a solar tracking which tracks the movement of the sun and rotates accordingly in the direction of the sun. So, a single axis comes here where the solar panel rotates according to the direction of the sun in single axis that is either north-south or east-west direction with the help of LDR sensors. LDR sensors give the light intensity which are connected on either side of the solar panel, so from that data we rotate the solar panel in direction of sun. So, by this we can increase the active peak sun hour which in turn increases the solar panel efficiency of storing energy. The tracking can also be dual axis where the solar panel rotates both north-south and east-west which increases the active peak sun hour by some time so helping in getting more solar energy.

3.2 Solar Efficiency

The efficiency of solar panels is an important factor here because in agriculture need, we require more amount of power which is in HP (horse power) so we require a greater number of solar panels and efficient solar panels which have higher efficiency. The single axis solar panel alone cannot produce the amount of solar energy required for the agriculture need so we use the concept of series connection where we connect many solar panels in series and take final output of power from that series connection and we get higher power. According to the power requirement and power rating of solar panels we decide the number of solar panels that must be connected in series to achieve the desired power level. Table 2 shows the example of number of solar panels required in series. The reference solar panel power rating is 325 watts.

Table 2. Solar energy produced by connecting N number of panels in series

No. of Solar panels in series	**Reference solar panel rating=325 watts**	**Total power generated (In watts)**	**Approximate horsepower (1hp=735.499 watts)**
4	325*4	1300	1 HP
7	325*7	2275	2 HP
10	325*10	3250	3 HP
25	325*25	8125	7.5 HP
31	325*31	10075	10 HP

3.3 Irrigation System

Agriculture is one of the most important industries of a developing nation. It is a main source of income for two thirds of people and since it contributes the most to national GDP this must be taken care of and should be integrated with advanced technology so that this gets higher efficiency and there is better yield of crops. Still many farmers follow the traditional agriculture practice so we should help this famers by introducing them to new technology and helps them in getting better ideas and better crops techniques and coming to power requirement we should make sure that they use sustainable energy so that we can save large amount of power and water is also one of the important factor, so proper water management is required so that there is no wastage of water and there is an proper utilization of resources and not wasted unnecessarily [16-26].

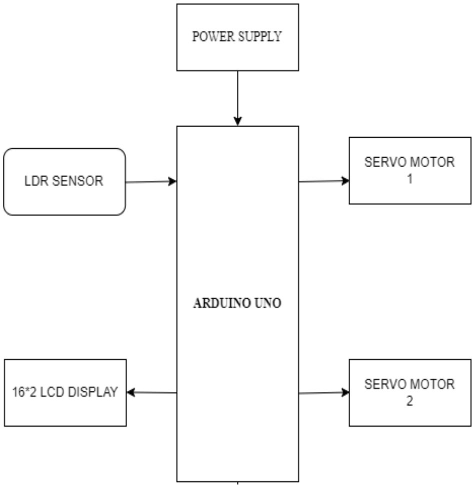

Figure 1. Block diagram for dual axis solar

4. Proposed System

The existing solar panel has limited peak amount of active sun time, so the power is limited, so in proposed system we use the dual axis solar tracking where we track the movement of sun and rotate the solar panel according to the direction of sun. We use LDR sensors and connect them in the four direction of solar panel and using these sensors we measure the intensity of amount of sunlight falling on the solar panel, depending upon the intensity in each LDR sensor we decide in which direction the solar panel to move. The dual axis solar tracker rotates north-south or east-west depending upon the intensity on the solar panel. And we store the energy using lithium-ion batteries and use this power for agriculture needs Figure 1.

Agriculture requires daily monitoring of water and moisture so that the required amount of water is given to plants for proper irrigation but as we have advanced technology, we can integrate this technology with agriculture so we can get better yields. We use moisture level sensors and humidity sensors so depending upon the input from these sensors we turn on/off the pump automatically. We set a threshold value for different types of crops and depending upon that threshold if it is more than the threshold then the water pump gets on. We also use the stored energy from solar panels and use them to run the water pumps, so we save a lot of power and using this smart irrigation we save water wastage depending upon the crop moisture level we on the pump.

We also integrate the idea of Wi-Fi module in this smart irrigation system to make it smart enough so this Wi-Fi module sends the real time information about the power stored, moisture level, humidity levels and on/off status to the farmer so he can get the real time updates about the crop and soil moisture content.

So, we integrate both the ideas of solar tracking and smart irrigation system, where coming to solar tracking we store more power using this technique and use this stored power for the agriculture needs to run the motor pumps or use it in home appliances so there is a lot of power saving which helps us in creating a sustainable environment.

The dual axis solar tracking main control is done by Arduino uno where we enter the code according to our requirements and design a system such that we take input from IDR sensors and send signals to the servo motor which rotates the solar panel in the requited direction, so we use the IDR sensor as input and servo motor as output to rotate the solar panel. And depending upon the moisture levels the water pumps get on and we can set the threshold for different types of crops using the potentiometer and we can decide the threshold.

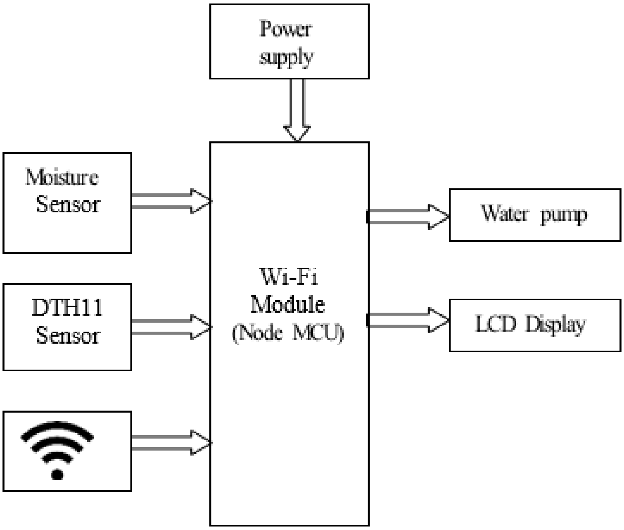

Figure 2. Block diagram for smart irrigation

The smart irrigation system includes the Wi-Fi module which takes the input from the different humidity and water sensors and depending upon the sensor values the Wi-Fi modules send the report to the farmer. We use Wi-Fi technology for transmitting messages to the farmers. So, by this the farmers get the updated information. We can add many extra features depending upon our requirements and add furthermore features Figure 2.

5. Results and Discussion

The dual axis solar tracking solar panel is used, and the values are measured and amount of power that is stored is used to analyze the output and we also compare the power that is obtained from both single axis and dual axis and use it for comparison and from the results we can see that dual axis yields more power and has better efficiency than single axis and fixed solar panel. The output data is presented, and a graph has been used for visual comparison. The below Table *3* shows the data of power stored for single axis vs dual axis.

Table 3. Power comparison of single axis vs dual axis

Time	Single Axis (Power measured in Watts)	Dual Axis (Power measured in Watts)
05:00	0	0
06:00	0.0162	3.2368
07:00	2.323	4.392
08:00	3.762	4.773
09:00	4.464	4.921
10:00	4.94	5.382
11:00	5.148	5.56
12:00	5.265	5.343
13:00	5.226	5.343
14:00	5.054	5.304
15:00	4.386	4.454
16:00	4.148	5.48
17:00	3.944	4.978
18:00	0.0134	4.625
19:00	0	0.909

From the above data we can analyze that we achieved more solar energy in case of dual axis than the single axis Figure 3. The fixed solar panel has lesser peak active time, and we get less amount of solar energy whereas in case of dual axis we increase the duration of peak sunlight time, so the active sun duration increases and hence the energy efficiency increases. We use standard LDR so that these accurately tell us about the intensity of sunlight falling on it so we can accurately decide the direction of the sun and move the solar panel in that direction and achieve higher efficiency.

The automatic water irrigation system works in such a way that the motor pump gets on automatically when the threshold value is reached Figure 4. We set a threshold value for different types of crops so when the threshold value is reached the water pumps get on automatically. We can set the threshold for different types of crops by rotating the potentiometer so that we can alter the threshold.

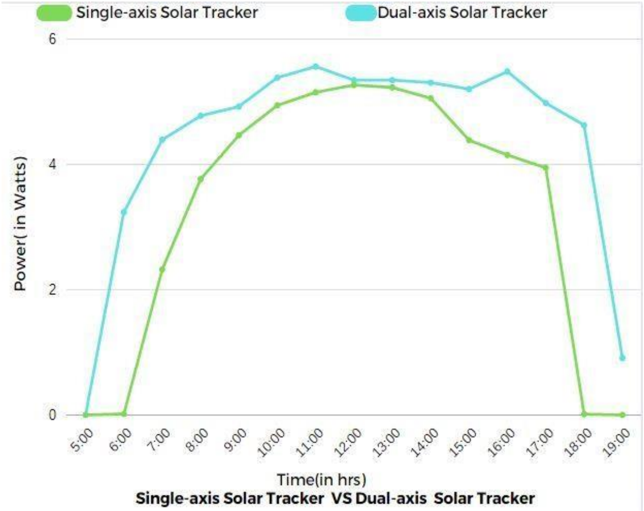

Figure 3. Power Comparison graph of single axis vs dual axis

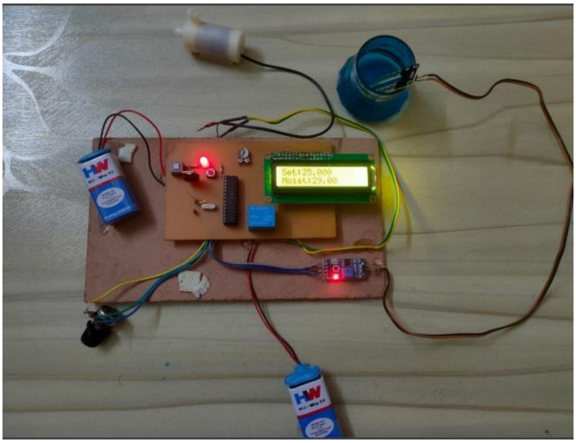

Figure 4. Smart irrigation with automatic watering System

For large scale we can use the power supply directly from the solar panel and use it to run the water pump so that we can reduce the power need and create a sustainable environment with sustainable energy.

6. Conclusion

The IoT technology is also used as we use this to send the message about the motor on and off status. We set the threshold limit for each different crop as the moisture level reaches that limit the motor pump gets on so the motor pump status will also be sent to the user so that he can have an idea about the motor on or off status. And we also included temperature sensor where we get real time information about the humidity and other factors etc. So, this IoT technology makes it smarter and more efficient where we can monitor the data real time and get it in daily basis so we stay updated about the crop and in future scope we can also include features like the pump can be off if user wishes to from his location itself so we can add these extra features and build an efficient atmosphere where we can create a sustainable environment and grow quality crops with help of this technology.

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Conflict of interest

The Authors have no conflicts of interest to declare that they are relevant to the content of this article.

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