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Design and Development of Sun Tracking Solar Panel with Implementation in Irrigation System using IOT

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***Abstract*—In the context of the current state of agricultural development, the suggested system incorporates Solar Tracking and Internet of Things-based technologies to construct an autonomous irrigation system. This represents a paradigm change from the traditional farming approaches that have already been utilized. This innovative system takes on challenges such as erratic power supply and rising fuel costs by increasing the efficiency of solar panels through the use of a motorized tracker. Additionally, it makes use of the internet of things (IoT) for seamless real-time monitoring and control, which guarantees a dependable and sustainable irrigation process that is independent of the conventional power grid. This integration not only brings the agricultural industry into the modern era, but it also resonates with the global tendency towards environmentally benign practices that are pushed by technical advancements. Not only is the deployment of this system a step toward modernizing agriculture, but it is also a cornerstone for future investigation in precision farming and alternative energy solutions, thereby establishing a big stride in the evolution of agriculture and the management of resources.**

Keywords—Solar Tracking, IoT-Based Irrigation, Precision Agriculture, Sustainable Farming Practices, Renewable Energy, Motorized Solar Trackers, Wireless Sensor Networks, Real-Time Monitoring, Remote Control, Energy Efficiency.

I. Introduction

The agricultural sector has traditionally served as the foundation of many economies throughout the world. However, in light of the rapidly changing technological landscape, it is absolutely necessary to incorporate more effective technology into farming operations in order to promote improved management. Agriculture is one of the many industries that is being revolutionized by the Internet of Things (IoT), which is a notion that makes life easier with less interaction from humans. Through the utilization of the Internet of Things (IoT), a network of interconnected devices and sensors can share and analyze data, thereby providing vital insights into the circumstances of the farm in real time. A crucial part of this digital revolution of agriculture is played by Wireless Sensor Networks (WSNs), which are networks that consist of a network of sensor nodes that are connected to one another to gather and send data about the environment [1].

The harmful effects that fossil fuels have on the environment have been a driving force behind the shifting of the global energy system toward more sustainable sources of energy. Solar power, which is a source of energy that is both abundant and renewable, offers a feasible option. These solar panels, which are able to transform sunshine into electricity, are at the vanguard of this change in energy utilization. However, in order to achieve the highest possible efficiency, solar panels must be positioned so that they face the sun throughout the whole day [2]. In order to considerably increase the amount of energy that can be generated by these panels, it is necessary to have a solar tracking system that is capable of dynamically adjusting the location of the panels in order to capture the maximum amount of sunlight [3].

The solar tracking and Internet of Things-based autonomous irrigation system that has been devised is intended to bring about a modernization of agriculture by using these technologies. A motorized solar tracker is incorporated into it in order to maximize the efficiency of the solar panels, and the Internet of Things is utilized in order to perform rigorous real-time monitoring and management of the irrigation process. Not only does this approach show promise in lowering reliance on traditional power grids, but it also guarantees the implementation of environmentally responsible watering methods [4]. The method is in line with worldwide trends that favor technology-driven sustainable practices and represents a significant advancement in the industry. It also paves the way for additional study in the field of precision agriculture and applications of renewable energy [5].

II. Related Work

In recent years, the concept of precision agriculture has been gaining popularity as a means of enhancing the efficiency and long-term viability of agricultural operations. This is because precision agriculture is a way that can improve both of these aspects. Solar energy and the Internet of Things (IoT) are two examples of cutting-edge technologies that are necessary for the implementation of this paradigm. Research conducted in the past has demonstrated that the Internet of Things (IoT) can be beneficial to the agricultural industry. It has made it feasible to remotely monitor and manage agricultural irrigation, which has resulted in significant savings in the amount of water that is used and the amount of work that is necessary (1). Additionally, the Internet of Things has brought data-driven insights on soil and weather conditions, which have been vital in the process of making educated judgments that are in line with sustainable agriculture practices [2]. These insights have been essential in the process of making more informed decisions.

In addition, a considerable amount of study has been conducted on the topic of the utilization of solar energy in agricultural settings. The use of solar panels to power a variety of agricultural operations, most notably irrigation systems, has been the subject of a number of research [3]. The purpose of these studies is to reduce the amount of reliance on energy sources that do not replenish themselves. It has been established that the employment of solar trackers can significantly increase the efficiency of solar panels by aligning them with the position of the sun throughout the day, hence optimizing the quantity of energy that is captured [4]. This can be accomplished by aligning the solar panels with the sun's position.

Those academics who have linked these two fields have carried out an inquiry into the synergistic effects that solar-powered Internet of Things devices can have on irrigation systems. These kinds of systems have not only demonstrated the advantages of energy efficiency, but they have also made it possible to achieve precision in watering. This has made it possible for them to meet the specific needs of crops based on the actual levels of soil moisture that are detected in real time [5]. In addition, fail-safe approaches have been incorporated into these systems in order to lessen the likelihood of system failures and to guarantee that they will continue to work without interruption [6]. Furthermore, the introduction of Wireless Sensor Networks (WSNs) has resulted in an expansion of the scope of real-time data collecting, which has led to a more comprehensive awareness of the surroundings of the farm area [7]. A strong foundation has been formed for the creation of more complex and linked systems that can drive the agricultural industry towards a future that is both more efficient and more sustainable. This foundation has been established by taking into consideration all these initiatives.

III. PROPOSED WORK

A solar tracking system that is intricately linked to an Internet of Things-based irrigation management setup is going to be designed and assembled as part of the implementation of the task that has been proposed. By adjusting the position of the solar panels with the use of servo motors that are controlled by a microprocessor, the solar tracking system is able to ensure that the solar panels receive the maximum amount of sunshine throughout the day. The efficiency of this system is dependent on the precise operation of light-dependent resistors. These resistors provide real-time input on the location of the sun, which enables the panels to absorb the maximum amount of energy possible into their components. Fig. 1 shows block diagram.

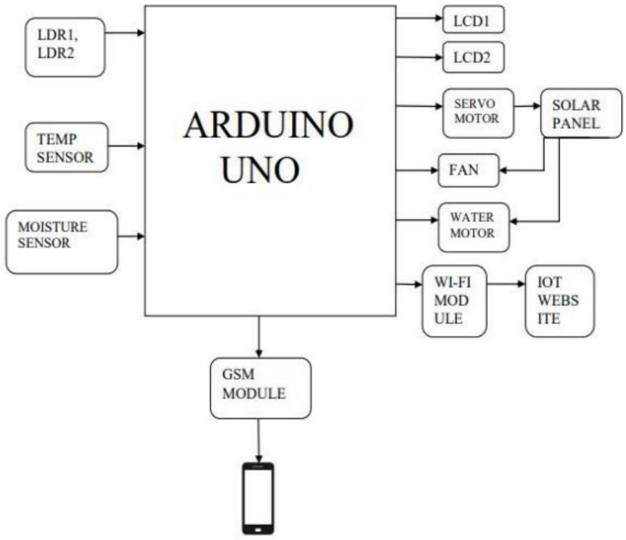

Fig. 1 Block Diagram

The adoption of the infrastructure for the Internet of Things comprises the construction of a network of sensors that are strategically situated to monitor a variety of environmental data. This is done in conjunction with the tracking of solar energy. This includes the moisture content of the soil, the temperature of the surrounding environment, and the humidity levels. For the purpose of making informed decisions regarding the timing and duration of irrigation, these sensors provide data back to the microcontroller, which subsequently uses this information to evaluate the situation. This automated process is designed to maximize agricultural yields while simultaneously minimizing water use. It accomplishes this by supplying water to plants at precisely the right point in time.

The capability of the Internet of Things system to communicate data to the end-user in real time is a key component of the system. To accomplish this, a Wi-Fi module is utilized. This module creates a connection between the microcontroller and the internet, which in turn optimizes the process of uploading data to a cloud service. Users can acquire access to this information by using a web portal or a mobile application, which provides real-time monitoring and control from any place. This information can be accessed by users. Additionally, a GSM module has been added with the gadget in order to guarantee that essential information is communicated even in the event that internet access is interrupted. The usage of short messaging service (SMS) is made possible by this module, which enables the transmission of pertinent alerts or notifications directly to the phone of the user.

The system that is being described includes failure-safe methods, which are an essential component of the system. These mechanisms are incorporated into the system. The goal of these is to uncover any faults that may exist inside the system or any deviations from the operational parameters that were anticipated, such as excessive levels of moisture or probable hardware failures. In these kinds of circumstances, the system is designed to turn off the water pump in order to prevent any water from being wasted or any damage to the equipment. This is done in order to prevent any potential potential problems. One more thing that happens is that an alert is triggered in order to inform the user about the issue.

After the physical components have been assembled, the focus shifts to the process of creating the software stack that will be in charge of controlling the system. This is the next step in the process. This includes the development of the logic for managing cloud data, the creation of the user interface for the monitoring and control application, and the construction of the firmware for the microcontroller. All of these tasks are covered in this. After the essential hardware and software have been installed, the system is subjected to a battery of extensive tests in order to ensure that it is reliable and has the capability to function effectively. It is necessary to conduct these experiments in order to develop the system before it can be utilized in an agricultural setting that is representative of the real world. This is due to the fact that the system has the potential to have a significant impact on the effectiveness of irrigation techniques as well as the overall sustainability of farming operations.

Solar tracking and irrigation systems that are based on the internet of things can be integrated into the proposed system in such a way that they provide a synergistic effect, which allows the system to function. As a consequence of this, a coherent framework is established, which guarantees the most effective management of water resources and the most effective utilization of solar energy to the maximum extent feasible. The components that are responsible for the operation of the solar tracker itself are a collection of light-dependent resistors, which are also referred to as LDRs in some instances. These light-dependent resistors, also known as LDRs, are responsible for determining the quantity of sunlight that is available. They then transmit this information to a microcontroller, which is typically an Arduino. Microcontrollers are responsible for a variety of tasks, including the processing of information as well as the transmission of commands to servo motors. Following that, these servo motors would make adjustments to the angle of the solar panels in order to bring them into alignment with the path that the sun would take. As a result of the dynamic adjustment, the panels are able to convert the sunlight into electrical energy in a manner that is more effective than the panels that remain immobile. By doing so, they are able to take in the greatest potential quantity of sunlight that is available to them.

Simultaneously, the irrigation system that is based on the Internet of Things makes use of a variety of sensors that collect data from the environment that is all around it. These sensors capture information about the surroundings. In the process of determining the amount of water that the crops require, the utilization of soil moisture sensors is a vital component that must be included. When the levels of moisture in the soil drop below the threshold that has been established, the microcontroller is notified by these sensors and gets a signal from them. It is possible to determine the amount of moisture that is present in the soil by using these sensors. Sensors that do temperature and humidity measurements offer supplementary information regarding the surrounding environment. With the use of this information, it is possible to ensure that the irrigation system is operating in an environment that is conducive to the cultivation of crops.

When it comes to the communication layer, the microcontroller is outfitted with an ESP8266 Wi-Fi module, which enables it to connect to the internet and send sensor data to a cloud platform. This feature will allow the microcontroller to fulfill its communication requirements. The ability to undertake data analytics in real time and the capabilities of remote monitoring are both made feasible as a result of this. The employment of a user interface that can be accessed by a computer or a smartphone is what allows this to be accomplished. The installation of a GSM module ensures that communication will continue without interruption if the Wi-Fi connection is severed for any reason. This is accomplished through the transmission of text message notifications. Consequently, the customer will always be kept up to speed with the most recent information thanks to this guarantee.

As far as the hardware components that comprise the system are concerned, the Arduino UNO microcontroller is the component that functions as the central component of the system. For the purposes of its applications, this particular microcontroller was selected because of its durability, adaptability, and the extensive range of peripherals that are compatible with it. The precise motions that are necessary for the solar tracker are carried out by servo motors, which are responsible for fulfilling this task. On the other hand, light-dependent resistors, also known as LDRs, are the components that are accountable for delivering the feedback that is essential for the positioning of the solar panels. The DHT11 sensor is utilized for the purpose of environmental data collection due to the fact that it provides constant readings of both temperature and humidity. This is in contrast to capacitive soil moisture sensors, which are less likely to be affected by corrosion and therefore provide accurate readings of the amount of moisture that is present in the soil. The DHT11 sensor is utilized in the process of acquiring information about the environment that is surrounding the device.

A water pump is chosen for the irrigation system because it is suitable for the volume of water that must flow through the system and because it is compatible with the voltage output of the solar panels. All of these factors contributed to the selection of the water pump. When it comes to the irrigation system, the water pump is widely regarded as one of the most important components. The pump is activated by microcontrollers, which are controlled by the readings from the sensors and the cloud data analytics. The microcontrollers are responsible for controlling the pump. When it comes to controlling the pump, microcontrollers are the ones in charge. The system features a liquid crystal display, which is often referred to as an LCD depending on the context, in order to provide on-site readings of the system's state. The amount of power that is currently being produced by the solar panels as well as the amount of moisture that is contained inside the soil are both included in these figures. The need for remote access is removed as a result of this, and it is now feasible to carry out evaluations in a relatively short period of time.

Not only is each individual piece of hardware picked based on the precise traits it possesses, but it is also selected based on its capacity to collaborate correctly with the other components that are included in the system. For the purpose of developing a method of crop irrigation that is not only more efficient but also less harmful to the environment, the combination of these two elements results in the creation of a strong agricultural instrument that makes use of renewable energy sources.

As part of the process of putting the task that has been proposed into action, a solar tracking system that is intimately linked to an irrigation management setup that is based on the

Internet of Things is going to be built and assembled. It is possible for the solar tracking system to ensure that the solar panels receive the maximum amount of sunlight throughout the day by altering the position of the solar panels using servo motors that are controlled by a microprocessor. This allows the system to maximize the quantity of sunlight that the solar panels receive. The effectiveness of this system is going to be determined by how precisely the light-dependent resistors are going to function. By providing real-time input on the location of the sun, these resistors make it feasible for the panels to take in the greatest amount of energy that is possible into their components. Fig. A block diagram is shown in 1.

Fig. 1 Schematic of Blocks

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IV. Results

Results that were encouraging were obtained through the implementation of the sun tracking solar panel system that was coupled with the Internet of Things-based irrigation system. The efficiency of the solar panels was shown to have significantly increased once the system was put into operation once it was implemented. The solar panels were dynamically changed by the motorized solar tracker, which was responsive to the data from the light-dependent resistors. This allowed the panels to catch the best angle for sunshine throughout the working day. In comparison to standard solar panel configurations, this resulted in a discernible increase in the amount of power that was produced. The increased energy collection had a direct impact on the operational capacity of the irrigation system, which resulted in the provision of a dependable and consistent power supply that was previously unreachable with conventional energy sources. Fig. 2 shows the project picture.

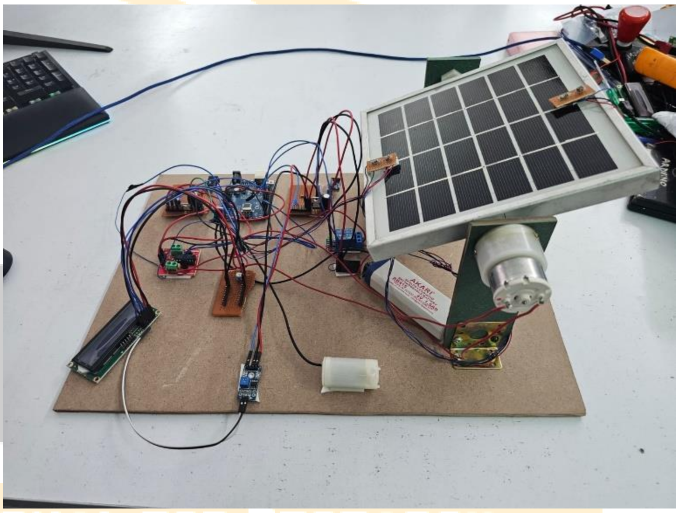

Fig. 2 Project Pic

In terms of irrigation management, the system's capacity to independently regulate watering cycles based on real-time soil moisture data led to a considerable reduction in the amount of water that was used. The accuracy with which the system administered water resulted in a more effective utilization of this essential resource, which brought about a reduction in waste and prevented over-irrigation, which is a problem that frequently arises in farms that are managed manually. A further refinement of the irrigation process was achieved with the installation of temperature and humidity sensors, which ensured that environmental elements were taken into consideration while formulating the maintenance plan.

The capabilities of the Internet of Things framework to transmit data in real time and to perform remote monitoring were put through intensive testing, and the results showed that the system constantly provided the end-user with information that was both accurate and timely. The robustness of the communication system was particularly noteworthy; the Wi-Fi module made it possible to upload data to the cloud platform in a fluid manner, and the GSM module transmitted SMS warnings in a reliable manner, ensuring that the user was kept informed even when there was no internet connectivity.

Farmers were able to readily engage with the system, monitoring a variety of parameters and modifying settings as required, thanks to the user interface, which was both user-friendly and straightforward. The user interface was available through cellphones and PCs. The users placed a high importance on the convenience of controlling the system and the fast availability of information. This allowed them to make decisions based on the data even when they were located at a distance. Fig. 3 shows the prototype image.

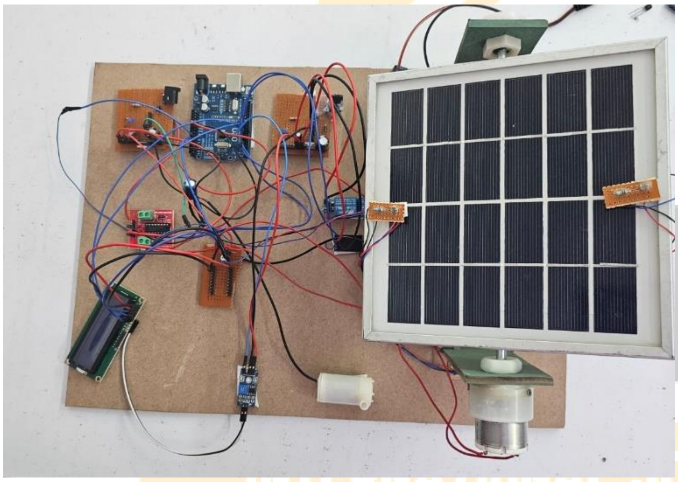

Fig. 3 Project Image

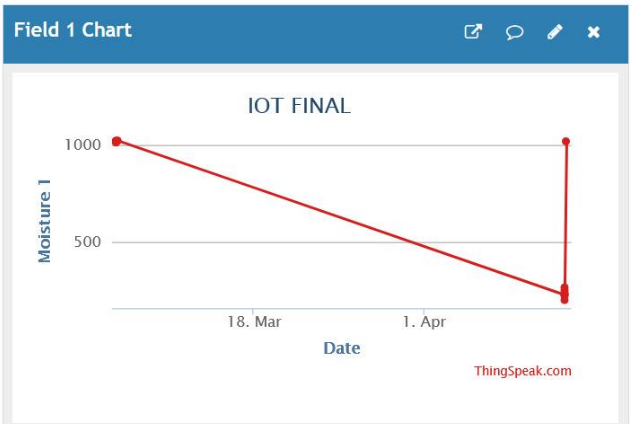

Fig. 4. Moisture Content in Soil

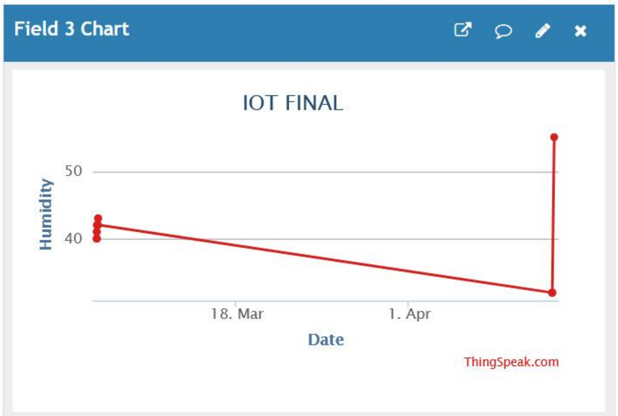

Fig. 5. Humidity in Percent

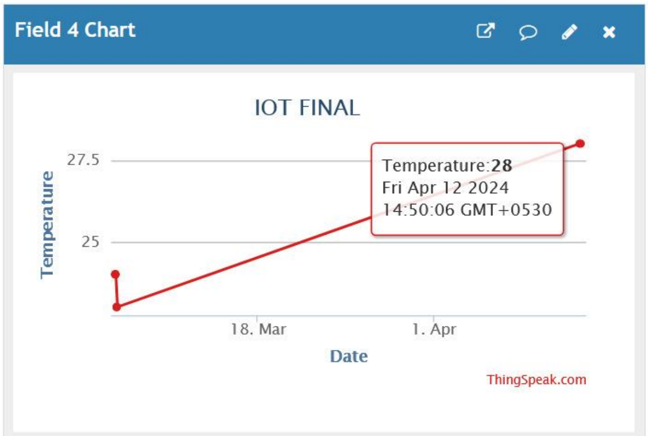

Fig. 6. Temperature in Celsius

When taken as a whole, the findings suggested that the integrated solar tracking and Internet of Things-based irrigation system represents a significant step forward in the field of agricultural technology. This not only improves the efficiency with which solar energy is utilized and water management is carried out, but it also provides a model that can be scaled up to accommodate sustainable and independent farming techniques. As a result of the successful implementation and operation of this system, the potential of integrating renewable energy and the internet of things in agriculture has been strengthened, and a benchmark has been established for future discoveries in this field.

V. Conclusion

The project's investigation into the possibility of merging solar tracking technology with an irrigation system that is based on the internet of things has resulted in a comprehensive solution that addresses important challenges pertaining to the management of resources and increasing energy efficiency in agriculture. This demonstrates the huge impact that good solar panel orientation may have, as demonstrated by the successful implementation of a motorized solar tracker, which resulted in a considerable increase in the amount of energy received from the sun. At the same time, the incorporation of the Internet of Things made it possible to exercise meticulous control over irrigation. This ensured that water was distributed sparingly and sustainably, according to the specific requirements of the crops. Not only did this dual strategy aid in the conservation of vital resources, but it also provided farmers with the ability to monitor their crops remotely and access data in real time. This project highlights the tremendous potential of smart agricultural solutions, which combine the technology of renewable energy sources with powerful data analytics in order to create a future of farming that is both ecologically responsible and technologically advanced. The findings argue for the widespread adoption of precision agriculture practices and the continuation of innovation in these practices. They also provide a look into a future in which technology and sustainability will work hand in hand in the cultivation of the farms of the future.

References

[1] P. Rani, O. Singh and S. Pandey, "An Analysis on Arduino based Single Axis Solar Tracker," 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), Gorakhpur, India, 2018, pp. 1-5, doi: 10.1109/UPCON.2018.8596874.

[2] T. Kaur, S. Mahajan, S. Verma, Priyanka and J. Gambhir, "Arduino based low cost active dual axis solar tracker," 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Delhi, India, 2016, pp. 1-5, doi: 10.1109/ICPEICES.2016.7853398.

[3] M. Karthik, R. Vishnu, M. Vigneshwar and M. Logaeshwar, "Arduino based Dual Axis Smart Solar Tracking System," 2023 Third International Conference on Artificial Intelligence and Smart Energy (ICAIS), Coimbatore, India, 2023, pp. 169-174, doi: 10.1109/ICAIS56108.2023.10073860.

[4] A. Singh, S. Adhav, A. Dalvi, A. Chippa and M. Rane, "Arduino based Dual Axis Solar Tracker," 2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), Coimbatore, India, 2022, pp. 1789-1793, doi: 10.1109/ICAIS53314.2022.9742876.

[5] K. R, K. PR, M. K. C, N. K. A and K. R, "Dual Axis Smart Solar Tracker Using Arduino," 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2021, pp. 45-50, doi: 10.1109/ICESC51422.2021.9533014.

[6] C. Karmokar, J. Hasan, S. Arefin Khan and M. I. Ibne Alam, "Arduino UNO based Smart Irrigation System using GSM Module, Soil Moisture Sensor, Sun Tracking System and Inverter," 2018 International Conference on Innovations in Science, Engineering and Technology (ICISET), Chittagong, Bangladesh, 2018, pp. 98-101, doi: 10.1109/ICISET.2018.8745597.

[7] A. Shufian, M. M. Rahman, R. Islam and S. K. Dey, "Smart Irrigation System with Solar Power and GSM Technology," 2019 5th International Conference on Advances in Electrical Engineering (ICAEE), Dhaka, Bangladesh, 2019, pp. 301-305, doi: 10.1109/ICAEE48663.2019.8975634.

[8] A. Kumar, S. Deb, S. Datta and K. R. Singh, "GSM Based Smart Irrigation System with Arduino UNO Powered by Solar Panel," 2023 5th International Conference on Energy, Power and Environment: Towards Flexible Green Energy Technologies (ICEPE), Shillong, India, 2023, pp. 1-6, doi: 10.1109/ICEPE57949.2023.10201533.

[9] S. N, N. L, G. N, S. Jahagirdar, S. A. R and S. N, "Efficient Usage of water for smart irrigation system using Arduino and Proteus design tool," 2021 2nd International Conference on Smart Electronics and Communication (ICOSEC), Trichy, India, 2021, pp. 54-61, doi: 10.1109/ICOSEC51865.2021.9591709.

[10] A. Kumar, S. Deb, S. Datta and K. R. Singh, "GSM Based Smart Irrigation System with Arduino UNO Powered by Solar Panel," 2023 5th International Conference on Energy, Power and Environment: Towards Flexible Green Energy Technologies (ICEPE), Shillong, India, 2023, pp. 1-6, doi: 10.1109/ICEPE57949.2023.10201533.

[11] I. H. Rosma, I. M. Putra, D. Y. Sukma, E. Safrianti, A. A. Zakri and A. Abdulkarim, "Analysis of Single Axis Sun Tracker System to Increase Solar Photovoltaic Energy Production in the Tropics," 2018 2nd International Conference on Electrical Engineering and Informatics (ICon EEI), Batam, Indonesia, 2018, pp. 183-186, doi: 10.1109/ICon-EEI.2018.8784311.