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Design Automatic Control and Remote Monitoring System of Center Pivot Irrigation System Using Wireless Sensor Network (WSN) and GPRS Technology

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Abstract
The implementation of an automatic irrigation system based on the microcontroller and a wireless system network is presented in this paper. This implementation aims to demonstrate that automatic irrigation can be used to minimize and optimize water use. The automated irrigation system consists of the master control unit (MCU) and a distributed wireless sensor network (WSN). The communication between the WSN and the MCU is via a radio frequency (NRF25L01). The MCU has a radio transceiver that receives the sensor data from the wireless sensor network also has a communication link based cellular-internet interface using general packet radio service and a global system for mobile (GSM/GPRS). The activation of the automated system is done when the threshold value of the sensors in the WSN is reached. Each WSN consists of a soil moisture sensor probe, soil temperature probe, radio transceiver, and a microcontroller. The sensor measurements are transmitted to the MCU to analyze and activate/deactivate the automatic irrigation system. The internet connection using GPRS allows the data inspection in real-time on a server, where the temperature and soil moisture data are graphically displayed on the server using a graphical application and stored these data in a database server.

Keywords: GPRS, GSM, Center pivot faults, Irrigation System, Wireless Sensor Network (WSN).

1. Introduction
Center pivot is a mechanized irrigation system type. It consists of a pumping station, which captures water from a source such as a river, reservoir, or well. The pumps transport the water from the source at the pivot or through the underground pipelines from a remote water source to the central tower or pivot point. Water is driven through the span structure and distributed to the sprinklers which apply water drops of the right size to maximize absorption into the soil. The center pivot moves by an electric motor which is distributed on the pivot sections. Each motor moves on wheels rotating around the center. There are many methods of the pivot and pump layout. Some illustration is one pump is supplying the water to the single pivot, multiple pumps are fed the same pivot or one pump feeding more than a single pivot. Soil temperature and soil moisture are the properties that detecting the requirement of water to the soil. For the last decade, few existing systems are working to optimize and reduce water consumption. So we require technology to resolve this problem and support better irrigation management to save water. The remote and automatic irrigation system can increase efficiencies, reduce environmental impact, and improved yields. The implementation of the WSN systems offers the potential to increase productivity while saving water in a center pivot irrigation system. A watering schedule for center pivot irrigation based on a microcomputer system is developed. The irrigator can start and stop the pivot manually or by programming the microcomputer to start and stop at given times. There is also an alarm system that alerted the

grower if the pivot malfunctioned or if power is interrupted, [1].

A microprocessor-based irrigation controller for a small center pivot at the University of Georgia. The irrigation decision was based on four tensiometer stations located in two quadrants of the field is developed and tested, [2,3]. A microcomputer-based program is used to implement the water balance method on a center pivot is developed at North Dakota State University [4]. Control up to 15 center pivots used two-way radio technology along with a host microcomputer is developed, [5]. A remote soil moisture sensing system distributed by the Irrometer Company is implemented. The system required burying long lengths of the cable into the field to connect sensors to a centralized data collection unit, [6]. Sensed and transmitted soil moisture data through cables to a centralized microcomputer data acquisition system for irrigation scheduling of a center pivot is implemented, [7]. The network of multiple devices using a wireless sensor network which able to make communication, computation, and sensing is developed. It provides a bridge between the real physical world and virtual worlds and having a wide range of potential applications of Agriculture, [8]. An infrared telemetry based system to perform automatic irrigation scheduling depending on soil moisture sensors is proposed. This system offered a lower cost and much less labor-intensive means of installation for monitoring weather and soil moisture data compared to its predecessors. It did, however, require line-of-site and was susceptible to malfunction during certain atmospheric conditions, i.e. fog, sunrise, and sunset, [9]. The ability to save 30% in irrigation water and energy while increasing yield by 5% using scientific scheduling than grower practices is addressed in the literature, [10]. Irrigation management to optimize water use efficiency, produce high quality, and also ensure that runoff and leaching are minimized addressed in the literature, [11]. An automated irrigation scheduling and control system that responds to stress indicators from the crop itself has the potential to lower crop management and labor requirements, and to increase yields per unit of irrigation water is addressed in the literature, [12].

The advantage of a high-frequency protocol (in the GHz range) where sensor nodes are spaced relatively close to one another includes the usability of small size antennas, frequency reuse, and low powerConsumption. Although these protocols operate within the same bandwidth, it is important to note that the typical data rate for the Zigbee protocol is approximately 250 Kbps, which is much less than the data rates accommodated by Wi-Fi and Bluetooth, which start in the Mbps (Frenzel, 2007). A low enumeration rate and the ability to "sleep" a sensor node are critical features for reducing power consumption in the Zigbee protocol is addressed in the literature [13]. Closed-loop automatic scheduling based on a distributed wireless sensor network using temperature and soil moisture sensors are implemented. In this system, the data transferred wirelessly to a central location which afford the remote monitoring of microclimates and potential widespread access by several users, [14]. Wireless sensor networks offer the advantages of simplification in wiring and harnessing and provide a variety of functional benefits to almost every industry such as mobile communications, remote control, automation, and monitoring is addressed in the literature, [15]. Irrigation control is mainly a question of the management of water resources. So, to define the best strategy, the irrigation program must be elaborated by taking into account the agronomic parameters of each crop, the soil and climate characteristics, and, particularly, climate variability. However, the accuracy of these strategies is often limited by the availability of climatic data and adequate soil and crop information for regional applications. An alternative to these issues could be the use of the field WSN based monitoring system along with a Decision Support System (DSS), which is addressed in the literature [16].

Remote control and sense of an irrigation system using a wireless sensor network are proposed in the literature, [17]. A weather station for sensing parameters of field addressed in the literature, [18]. The parameters send using Bluetooth, TCP/IP technology. The system gives a low-cost solution for WSN. The operation range is limited to a few meters. So one can remotely monitor and

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control devices using this technology, but it is a prerequisite for each controlling device design to have a dedicated Bluetooth module. As the single Bluetooth module is shared by several devices so it results in an access delay. Interference is another very big problem of Bluetooth technology. A GSM is used for remote monitoring and control. GSM network responsible for transmitting the remote signal and communication takes place between the monitoring center and remote monitoring station is proposed in the literature, [19]. Receiving and sending of the data in the central monitoring station is achieved by using the GSM wireless communications module TC35,[20]. Another approach using GSM technology to communicate with the remote devices via SMS is a remote monitoring system, [21]. Reading electricity meter remotely using SMS is addressed in the literature, [22].

Wireless communication based on Bluetooth and GSM for remotely electricity meter reading is analyzed in the literature. There is a meter reading system that consists of measures sensor intelligent terminals, meter, management center, and wireless communication network. The meter reading system is described and the system's hardware and software are detailed. Bluetooth technology defined information that can be gotten from meters and sensor control. this system has excellent features such as a good quantity of data transmission, low expenses, and low workload, [23]. Design a Remote Control System for Submersible Pumps Based on GSM-SMS. The system can remotely ON/OFF and monitoring pump status by sending and receiving messages on mobile phones to help the farmer to supply water to the crops and get information about the type of faults. This system, saving time, less Physical effort and inconvenience Loss/ Frequent damage of irrigation equipment Wastage of water and electricity Objective. The design consists of the Arduino UNO board that uses an ATMEGA328P-PU connected with a GSM modem, [24]. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments, [25]. The use of Wireless Sensor Networks (WSNs) in precision agriculture increases the efficiency, productivity, and profitability of many agricultural production systems, [26].

Real-time environmental information can be remotely gathered from the agricultural fields and transferred to where it can be processed to discover problems, store data, and/or take needed actions. This contrasts with the traditional agricultural approaches in which decisions are taken based on some hypothetical average condition, which may not reflect reality. WSNs are key components of the Internet of Things (IoT) in which different pieces of information gathered from almost anywhere and anything in the world is accessible through the Internet. The integration of WSNs with IoT resulted in a plethora of applications such as smart cities, remote healthcare, energy and water control, precision agriculture, wildlife monitoring, structural and ancient building monitoring, etc. In this paper, we propose a cloud-based IoT architecture that is applicable in different precision agriculture applications. The proposed architecture is composed of three layers: a front-end layer that collects the environmental information and applies the needed agriculture actions; a gateway layer that connects the front-end layer to the Internet, and a back-end layer in which the data storage and processing take place.

2. Material And Method

The proposed system consisted of three components, a master control unit (MCU), a wireless sensor network (WSN), and a fault monitoring board (FMB). MCU and WSN are linked by radio transceivers that allowed the transfer of soil moisture and temperature data, MCU and FMB are linked by GSM to sending and receiving commands from pivot and pumps. The data transmitted to a web server using a mobile network using GPRS which in the MCU. The sensor data is remotely monitored online using the graphical application by Internet access devices. This system was developed to optimize water use and ensure crop health.

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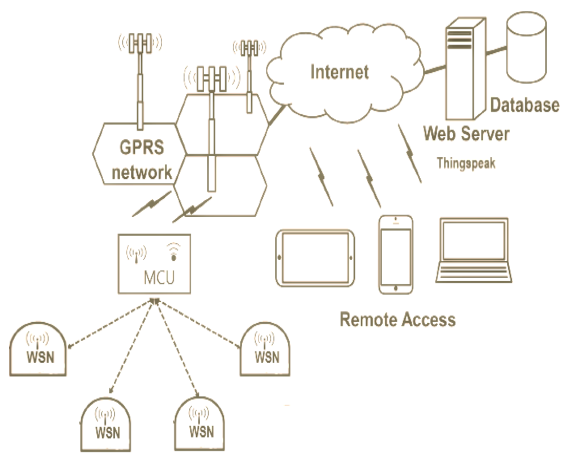

Fig 2. Proposed system components.

The master controller unit is the brain of the entire system. It requests data from and monitors all nodes in the system as well as communicates all pertinent information to the end user. The MCU consists of an arduino mega microcontroller, an NRF24 radio modem to receive data from WSN, a GPRS module SIM900 GSM/GPRS, Four electronic relays, compass sensor to detect pivot location and RTC. All the MCU electronic components were encapsulated in a waterproof PVC box. The MCU located at the center pivot device. The arduino mega 2560 is a microcontroller board based on the ATmega1280. It has 54 digital input/output. Arduino programming language is a simplified form of C/C++ programming language. The NRF2401L transceiver module uses the 2.4 GHz band and it can operate with baud rates from 250 kbps up to 2 Mbp. The NRF2401L is an appropriate original equipment manufacturer module to establish communication between a WSN and the MCU because of its long-range operation and reliability of the sensor networking architecture. So once we connect the NRF24L01 modules to the Arduino boards, we are ready to make the codes for both the transmitter and the receiver. GSM-GPRS module is an ultra-compact and reliable wireless module. It is based on the SIM900 4 Frequency GPRS module. Features are Fully suitable with Arduino Uno and Mega.

A distributed WSN of temperature and soil moisture sensors placed in the pivot area is implemented to optimize the use of water for an agricultural crop. The MCU which is placed at the center of the pivot handles sensor information using an algorithm was developed with threshold values of temperature and soil moisture that programmed into Arduino programmer based MCU to control the operation of the pivot and transmits data to a web server using GPRS in MCU. The automated system was tested in KOBE BUSSANS's center pivot systems. The WSN is linked by radio transceivers that allowed transferring of temperature and soil moisture data to MCU to analyze and sending them to a web server. The WSN is comprised of an RF transceiver (NRFL01) which is mentioned in MCU, soil moisture and temperature sensors, microcontroller, and power sources. The WSN in this study is based on the Arduino microcontroller (Arduino UNO) that controls the radio modem (NRF24L01) and processes information from the soil moisture sensor and temperature sensor (DS18B20) these components is powered by rechargeable batteries. The charge is maintained by a photovoltaic panel. These components were selected to minimize the power consumption for the proposed application.

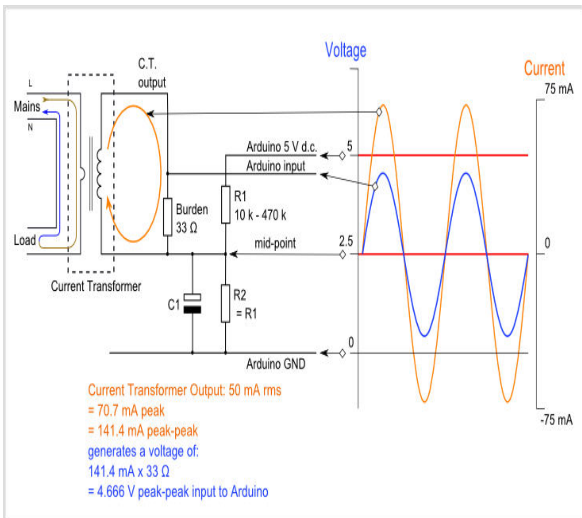

Fig 3 . Circuit diagram of the current sensor.

Here the system work deals with The IoT 'Thingspeak' web service which is a generous open API service that acts as a host for the variety of sensors to monitor the sensed data at cloud level and composite a special feature of porting the sensed data to the MATLAB using a channel ID and read API key that is assigned by services and able to track data value at a picky sample at particular intervals. Thingspeak is a web-based open API IoT source information platform [04, 05, 06] that comprehensive in storing the sensor data of varied 'IoT applications' and conspire the sensed data output in graphical form at the web level. Once channels are created in the 'Thingspeak' the data can be implemented_ and alternately one can process and visualize the information using Matlab.

3. The Operation of the Performed System

3.1 Remote Mode

Over-irrigation and under -irrigation can have negative effects on the environment and farm production. Cools soil reducing root growth, drowns roots, stressing the plants, reduces crop quality, and Increases system operating costs these are the effects of over-irrigation in the farm. If there is a problem with the pivot the problem of over-irrigation is occurring because the pumps are continuously supplied to the pivot by water. The effect of under-irrigation on the farm is to Reduce plant growth, weakens the plant, reduces crop quality (fruit and vegetable size), and Reduces crop yield. When the pump is off through the irrigation process the problem of under irrigation is occurring. So, the implementation of remote monitoring and control system remotely allows the user to manage pivots and pumps using a mobile phone.

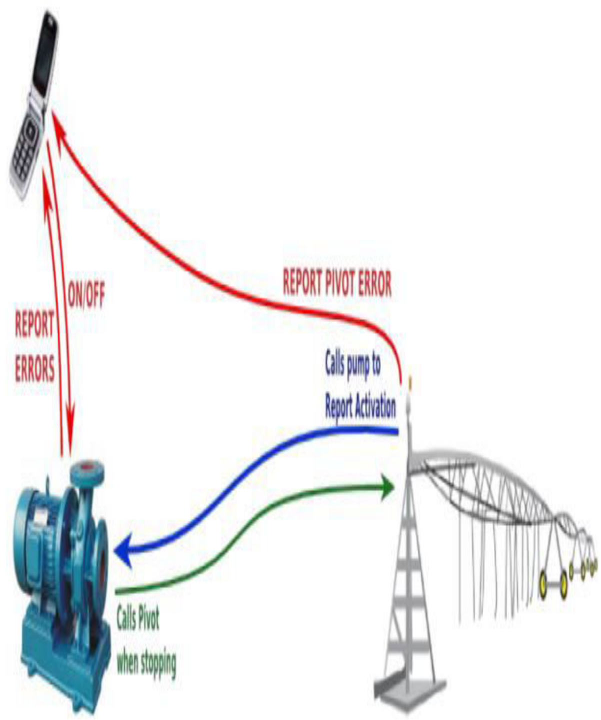

Fig 4. Shows the operation of the remote mode.

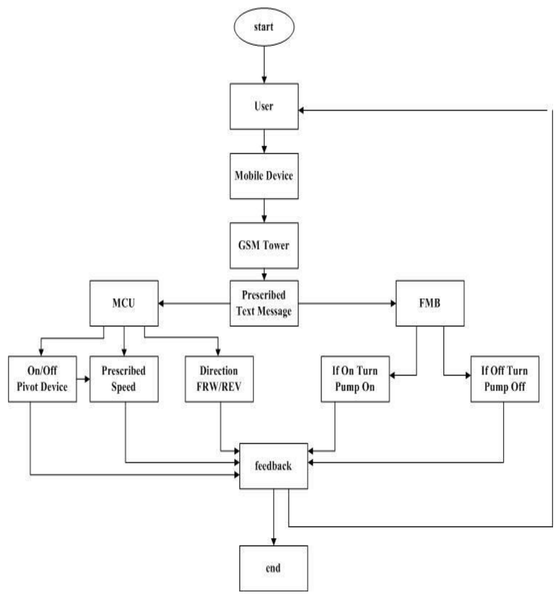

Fig 5. Flowchart for remote mode system.

With GSM located in the MCU, A node mounted at each joint of a center pivot irrigation system can monitor the motor switches. When a pivot section has failed to move properly, a signal is sent to the MCU and by using GSM a text message can be used to notify maintenance personnel that a section of the pivot assembly has stopped working.

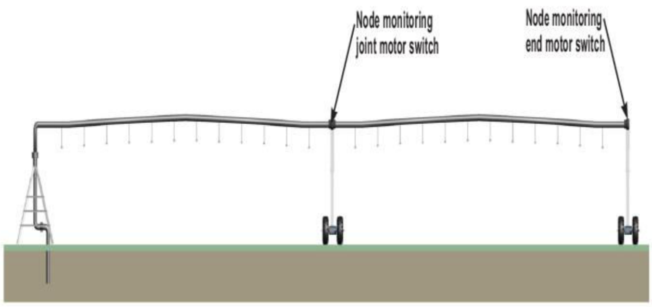

Fig 6. Monitoring motor switch.

Also, the GSM allows the user to send a remote command from mobile phones to operate the irrigation system and make all functions on/off, setting speed and direction. Also, the GSM at the pump house allows the user to send a remote command from a mobile phone to operate the pump and receive any faults in the pump via SMS. With the MCU, there is no need to drive to your site to operate the system or check the irrigation system is still running correctly, we can send commands remotely and the system will contact you if there is a problem. You can also request the system to send you a report at any time that shows it is still operating.___Firstly the user sends a

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command to the unit at the pump house to switch on the pump. When pressure arrives at the pivot the message was sent to the user that the pressure is ok then the user sends a command to set speed, direction, and start the pivot. The pivot and pumps send the feedback SMS to notify the user that the system working correctly.

3.2 Monitoring pivot faults

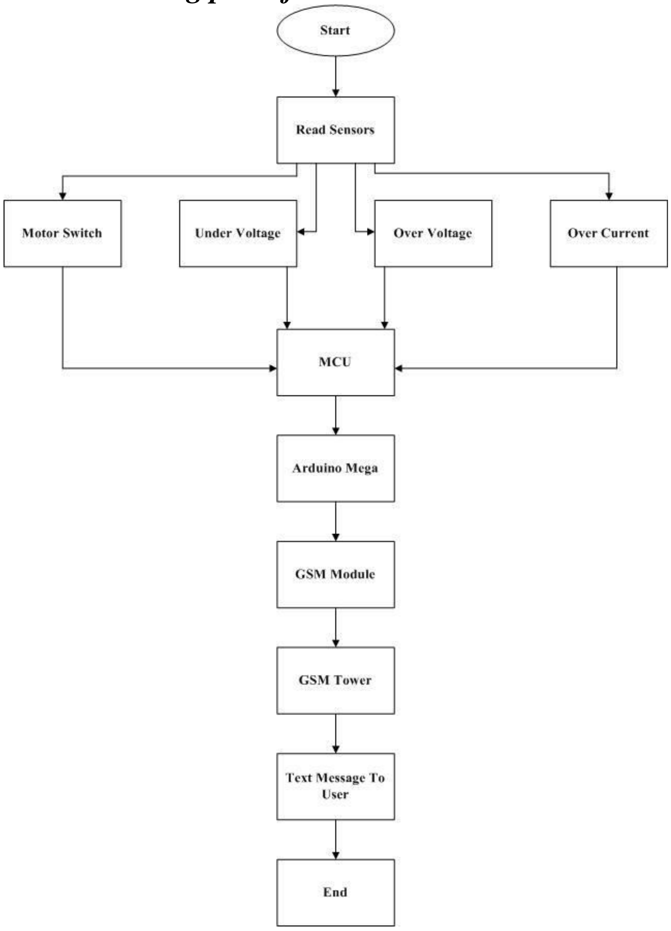

Fig 7. Flowchart for monitoring pivot faults.

The MCU located at the center pivot device is responsible to monitor the pivot operation and notify the user of any faults that happened in the pivot device also MCU sends commands to the user and also to shutdowns the pumps to avoid over-irrigation when the pivot stop working. Each pivot tower has switched to monitor the motor status, so if any problem happened the user knows where that the section problem. Also, if the pivot stops because of any faults the pivot sends a command to shutdowns the pumps and notifies the user.

3.3 Monitoring the pump faults

The FMB located at the pump house is responsible for sending messages to the user notifies the pump status and electrical parameters also receive commands on/off. The FMB also has sim900 GSM/GPRS which send and receive commands and data to a webserver to monitor the electrical parameters and temperature and updated it on the graphical interface using the internet of thing (thingspeak) which allow the user to analyze these data and calculate the electrical consumption for the pumps.

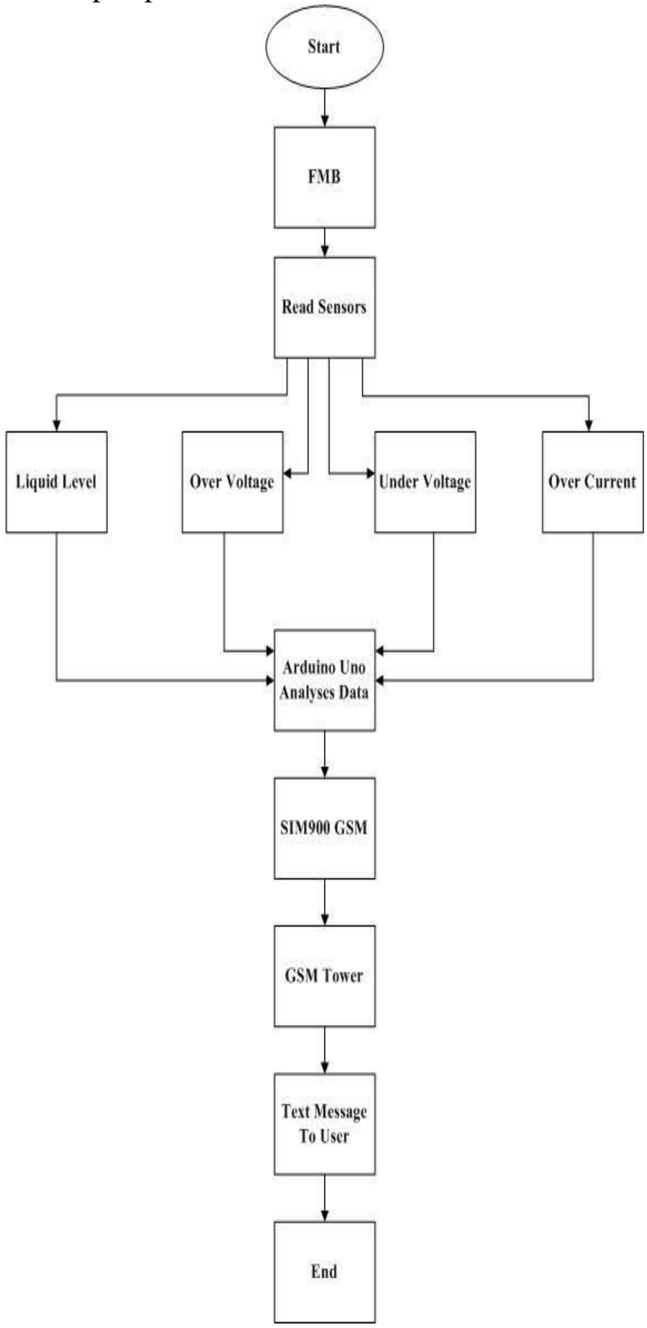

Fig 8. Flowchart for monitoring pump faults.

3.4 Automatic mode

The MCU transmits the sensor information to a web application. The threshold values of soil

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moisture and temperature are programmed into the Arduino controller to control water quantity.

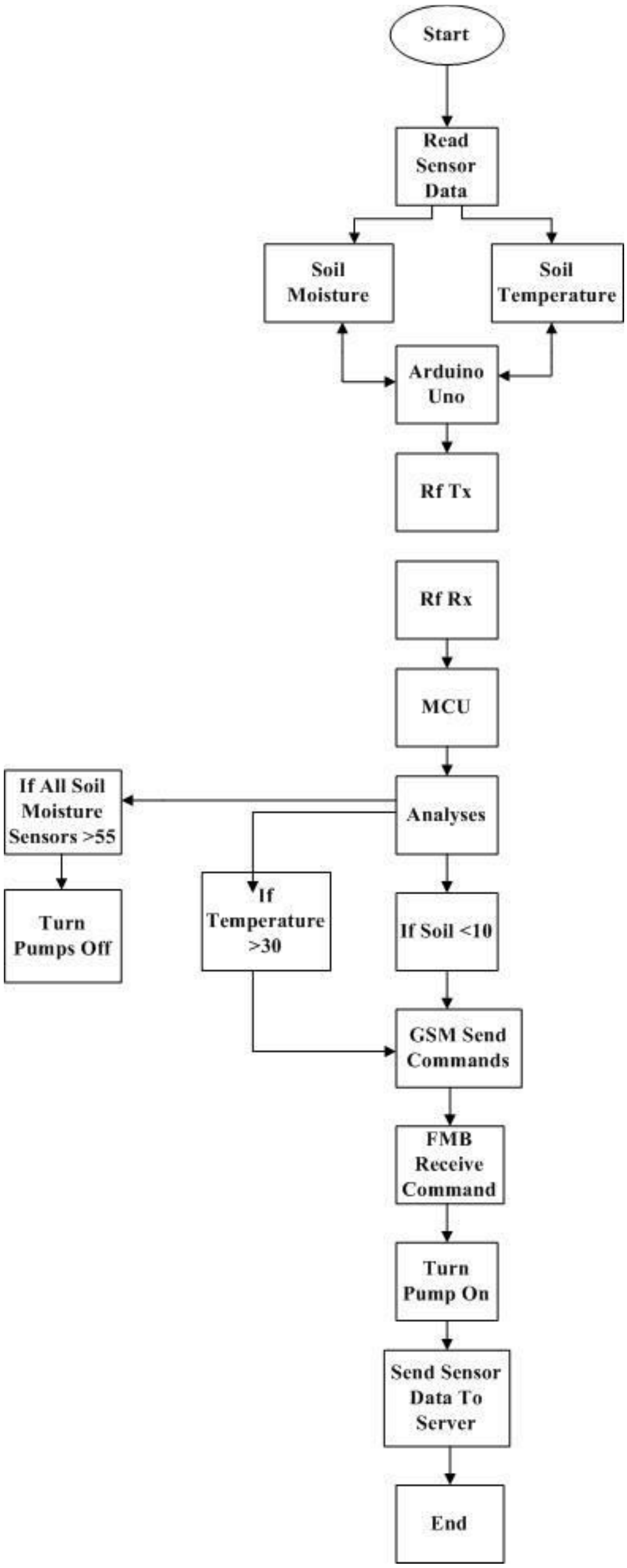

Fig 9. Flowchart for automatic mode.

The radio transceiver is responsible for the link between MCU and WSN that allowed the transfer of soil moisture and temperature data to operate the system automatically. The WSN unit which is mounted and distributed in each quarter of the pivot senses the soil moisture and temperature and sends these data to MCU located at the center of the pivot using a radio transceiver and the transceiver in MCU receive these data to be analyzed by the microcontroller. The temperature and soil moisture data are compared with programmed values of maximum soil temperature and minimum soil moisture to activate the irrigation process pumps and pivot for the desired period. Under the organic producer's experience, a 30% C as the temperature threshold level for the automatic irrigation mode and a minimum value of 5% VWC for the soil was established as the moisture threshold level. All data were uploaded to the webserver and inserted into the corresponding field in the database for remote supervision

4. Result and Discussion

The sensor data are collected, processed, and transmitted to ThingSpeak application and API software using SIM900GSM/GPRS and displayed through the ThingSpeak channel in the form of a graph. The ThingSpeak allows the user to analyze the output data also act as an application programming interface to store and retrieve the data using the HTTP protocol over the internet or via a local area. We can see the graphs of, Soil moisture value, Soil temperature values, Pivot voltage, Pivot current, Electrical power consumption, and the pivot position value. A real-time data visualization can be analyzed in the thingspeak, which is an IoT hub. The following figure shows the real-time data visualization. The value is being analyzed by taking various readings of them.

4.1 Soil Moisture And Temperature

The soil moisture and temperature detection system is an IoT system for the detection of moisture in the soil. The data retrieved by the

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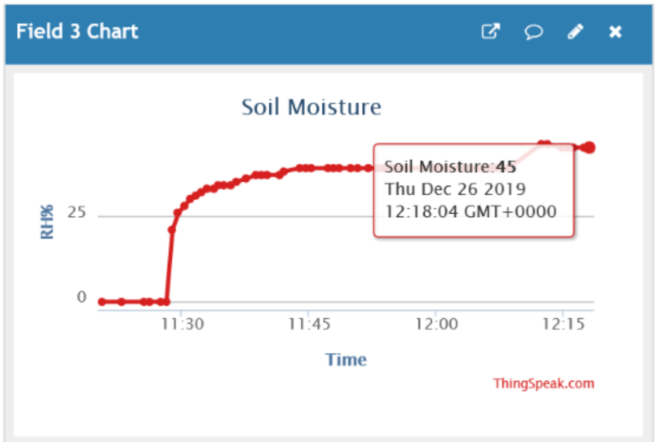
sensors are shown as "Soil Moisture and temperature " then this data is sent to ThingSpeak where the graphical representation of the data is depicted. Figure 10 suggests that the soil moisture value is analyzed in the thingspeak IoT hub. The graph is plotted with RH% value v/s time. In the below fig it is well shown that when the soil moisture drops below the low limit that is set as per the requirement the water pump starts and hence the water flows out of the water pump and thus increasing the moisture of the soil. By the organic producer's experience, a minimum value of 10 for the soil was established as the moisture threshold level and 30 °C as the temperature threshold level for the automated irrigation. Several automated irrigation periods activated by the system during the cultivation because of the temperature or soil-moisture levels As shown in Figure 10, when the moisture content goes below 10 that is the manually set level for the low moisture content indicator the pivot device sends a command to operates the pumps to maintain the moisture of the soil to higher than the lowest value that is 10 in this case. Where the moisture content goes above 55 that is the manually set level for the high moisture content indicator the system stops hence maintaining the moisture of the soil to lower than the highest value that is 55 in this case. The soil temperature using Celsius in Fig 11. The data shows that the soil temperature is around 16°C and 17°C at a particular instant of time. The soil temperature remained below the threshold level which is 30°C. The automated irrigation was triggered by temperature when the soil temperature was above the threshold value (30 °C). The obtained results prove that the sensors are functioning well and all the data from temperature and soil moisture sensors has been uploaded successfully on Thingspeak. The real-time monitoring system on the center pivot system is provided in the proposed system.



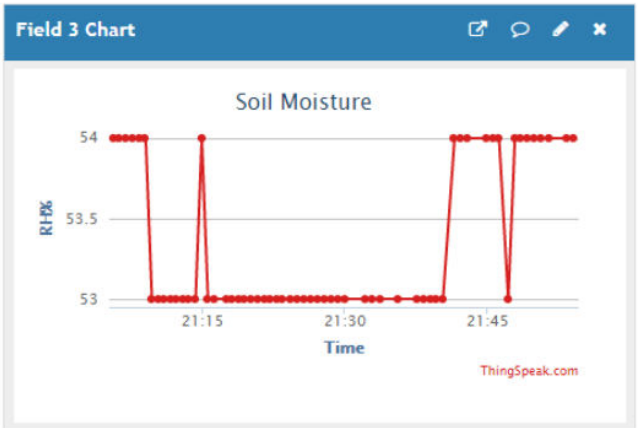


Fig 10. Soil moisture values

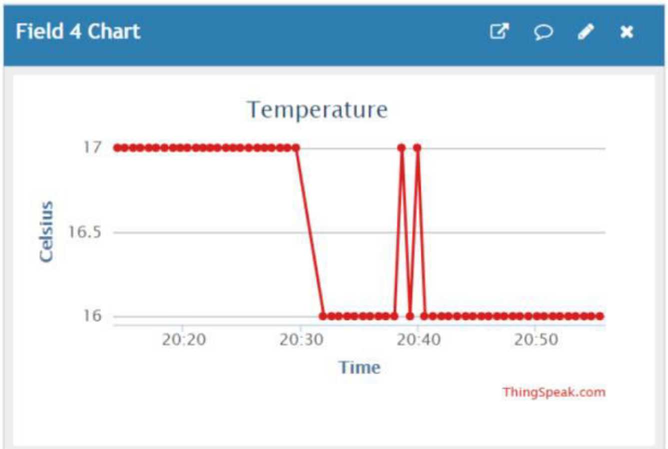


Fig 11. The soil temperature.

Voltage, current, and power consumption for pivot device

The instantaneously monitoring of the voltage and current value using developed voltage and the current sensor was done in MCU and uploaded to the server using SIM900 GPRS to be monitored and calculate the power consumption of a pivot device as shown in Figures 12 - 14.

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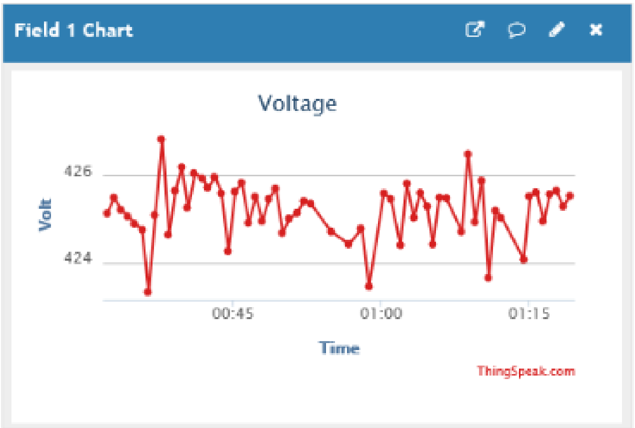

Fig 12. The voltage of the pivot device

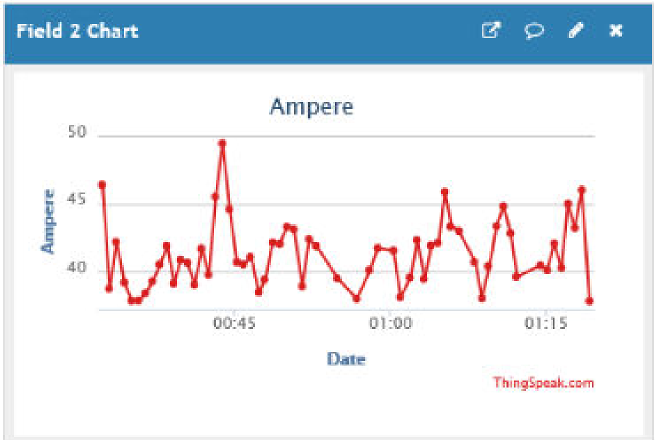

Fig13. a current (Ampere) of the pivot device

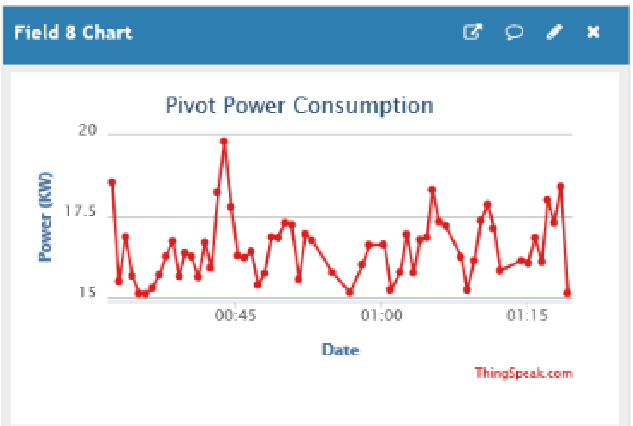

Fig14. Power consumption of the pivot device

4.3 GPS Location

The results obtained are used to track the location of the system used. The GPS location obtained was 26.013325N and 32.468104E, which are the coordinate of the center pivot irrigation system in Kobe Bussan Company, Qena, Egypt. The value obtained in Thingspeak is shown in Fig. 20. All the data from sensors has been uploaded to the Thingspeak IoT.

Fig 15. The GPS location

4.4 Pivot position and ON/OFF status

Thus after the signal conditioning process, the value of the compass sensor as shown in Fig 21 is transmitted through the GPRS module of the proposed irrigation system and then it is received to the user device through the open-source IoT (thingspeak) server.

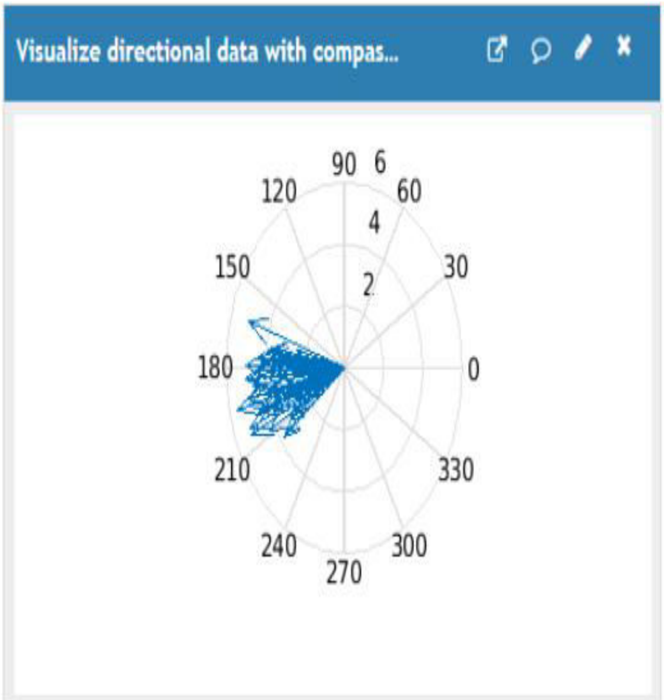

Fig 16. Monitoring Pivot Position.

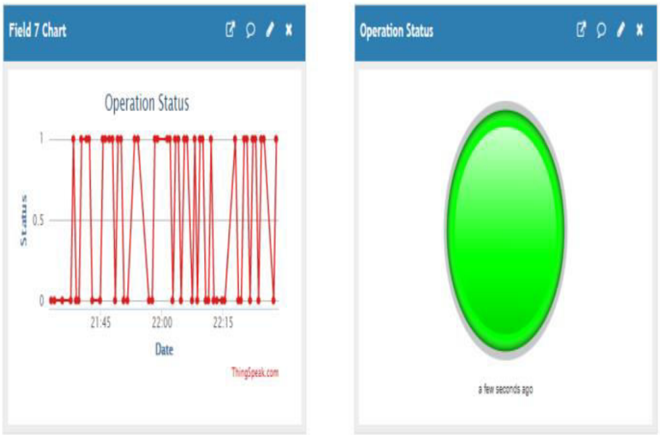

Fig 17. Monitoring Pivot Status ON/OFF.

4.5 Mobile application to send commands to pivot device

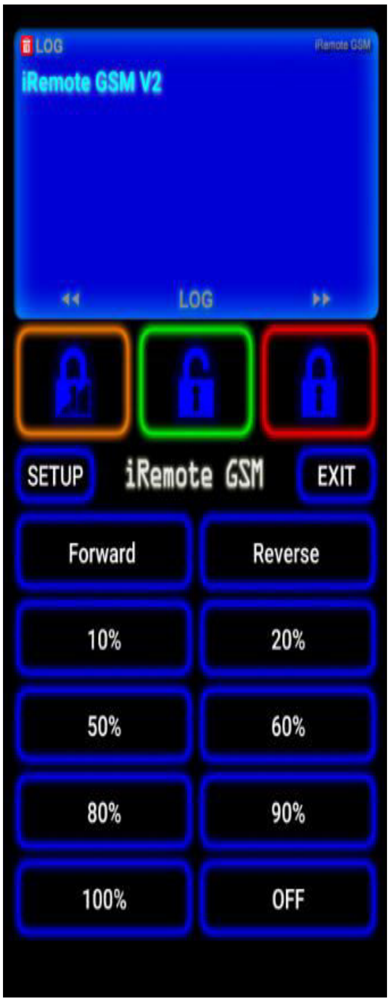

Fig 18. Sending command using a mobile phone.

4.6 Mobile application to monitoring system using internet of thing viewer

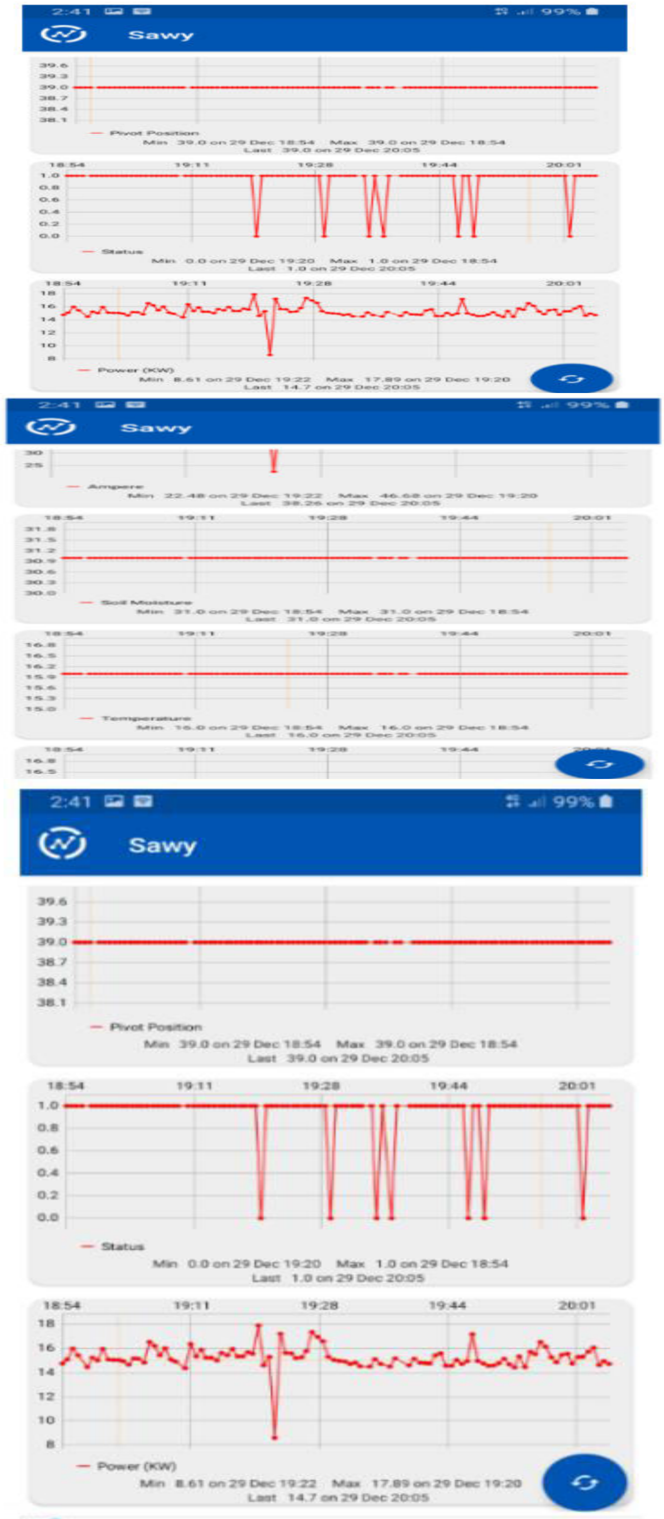

Fig 19. Thingviewr application to the monitoring system.

Conclusion

The Automatic Control and Remote Monitoring System of Center Pivot Irrigation System implemented was found to be feasible and cost-effective for optimizing water resources for agricultural production. The irrigation system requires minimum maintenance and can adjust to a variety of specific crop needs and use for open fields like pivot area

The WSN was an integrated plant feedback system that demonstrated successful automation in the control of irrigation scheduling temperature and soil moisture monitoring can be easily implemented. The Internet provides a powerful decision-making device concept for adaptation to several cultivation scenarios. Furthermore, the Internet link allows the supervision through computer and mobile telecommunication devices, such as a smartphone. The Internet of Things facilitates numerous benefits to society and from our system, we can provide and prove the strength of IoT using the Thingspeak API that is capable to contribute the services for irrigation and help to implement them on the public platform. This design Provide an Moderate and less expensive way of conyrol and Monitoring system in the field and as well industrial standards to implement the IoT.

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