Real-time monitoring and data acquisition using LoRa for a remote solar powered oil well

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ABSTRACT

Real-time monitoring is essential for solar-powered systems as they can be affected by sudden environmental changes, which may occur unpredictably, especially in isolated regions. This study proposes a wireless communication-based approach that allows for data acquisition and system monitoring of the entire solar system of a remote oil well. The proposed instrumentation method offers an affordable solution for monitoring the battery voltage, photovoltaic (PV) current, the converter's alternating current (AC), and oil well management. A wireless communication tool for a long-range called LoRa is used, with the TTGO LoRa32 SX1276 organic light-emitting diode (OLED) as the sender node and Heltec long range (LoRa) ESP 32 as the transmitter node. These I.C.s are ESP32 development boards with an integrated LoRa chip and an SSD1306 flash memory. System design and some test results are included in the paper.

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1. INTRODUCTION

This paper introduces a real-time monitoring approach to address the exploitation of orphaned wells, which are abandoned oil and gas wells left uncapped, leading to the release of harmful greenhouse gas, into the atmosphere. To mitigate this problem, the study proposes the utilization of solar-powered pumps to remove the remanent from the wells with a monitoring system should be cost-effective and independent of any internet network frame, considering the remote location of the oil well. In a previous paper in reference to this study [1], a power monitoring and data logging system using parallax data acquisition tool (PLX DAQ) was introduced, enabling the real-time recording of system design characteristics such as PV voltage and current, inverter alternating current (AC) output, oil level, temperature, and relative humidity however, a long-range wireless communication is needed for system control. This low-cost data logging solution using PLX-DAQ, facilitates easy maintenance and provides valuable data for further analysis but isn't feasible for long range transmission. Given the site location and specific requirements, long range (LoRa) technology is implemented for real-time monitoring and long-range wireless data transmission. The paper emphasizes the need of monitoring the environmental impact and system performance of orphaned wells solar pumping system that serves as an effective solution to mitigate greenhouse gas emissions from abandoned wells with LoRa technology for oil level control and cost- effective power metering system. In areas lacking connectivity or internet access, transmitting sensor data from one location to another can pose challenges. In such situations, wireless sensor monitoring systems are often employed to transfer data from low network coverage areas to sites with internet access [2]. This process involves utilizing a LoRa module transmitter to receive sensor data in the low network coverage area. Subsequently, the data is transmitted from the LoRa sender node to a receiver node to establish a gateway connection to the cloud. As a result, the data becomes accessible from any location, facilitating real-time updates of cloud data. The system typically comprises a sender node, receiver node, and display unit for data acquisition [3].

Guragain *et al*. [4] tackle the challenge of energy consumption and storage in wireless sensor networks (WSNs) for system monitoring by proposing an innovative solution centered on energy harvesting. In [4], the primary innovation involves the creation of an almost perpetual self-sustaining sensor node. This groundbreaking sensor node comprises two primary components: wireless sensor nodes (WSN) and a gateway connected through a LoRa transceiver. The LoRa network employs a star-shaped topology, where sensor nodes send messages to a central gateway, which is a cost-effective Raspberry Pi device communicating with the network server. The gathered data is then forwarded to a web server via Wi-Fi, enabling remote monitoring through internet access. To enhance power efficiency, the sensor node operates on a periodic working and shutdown schedule. A programmable timer known as TPL5111 is employed for timekeeping, boasting an impressively low power consumption rate. The software, developed using the open-source Arduino IDE, is responsible for gathering sensor data and transmitting it to the gateway via the LoRa module. Following data transmission, the sensor is powered off, while the LoRa transceiver remains active, and the entire sensor node enters a powered-off state. It is only reactivated after the predefined threshold time has passed. While the proposed methodology successfully overcomes the limitations of energy consumption and battery depletion in conventional sensor nodes, one major limitation is the absence of real-time power monitoring. Additionally, the use of Lora Technology as the receiver node is dependent on the webserver, which may introduce potential constraints. While The researcher's contribution involves introducing an innovative energy harvesting sensor node as a solution to the energy limitations of WSNs. The proposed system optimizes power usage through a periodic working and shutdown mechanism and employs a programmable timer for timekeeping. However, the absence of real-time power monitoring due to the periodic operating time of the sender node and dependency on the webserver for Lora Technology are noted limitations in this approach for remote oil well system monitoring.

Sutikno *et al*. [5] focuses on the use of the internet of things (IoT) in solar photovoltaic (PV) systems for remote monitoring, supervision, and performance evaluation. The main objective is to enhance the long-term viability, consistency, efficiency, and maintenance of energy production. However, due to the complexity and potential risk of data loss due to poor internet connection in PV monitoring systems, to address these issues, the author presents a simple and cost-effective IoT-based PV parameter monitoring system. The system utilizes a NodeMCU ESP8266 development board as the main controller, which is a system-on-chip (SOC) microcontroller with integrated Wi-Fi and low-power support, thereby reducing the system's overall cost. Additionally, the proposed solution incorporates backup data storage on a microSD card to mitigate the risk of data loss. Although the system offers a viable solution for remote monitoring, it has some limitations. One limitation is its applicability to abandoned wells solar powered pumping monitoring system, where long-range communication and wireless connectivity independent of network coverage are required. Furthermore, despite the provision of a storage unit for data backup, there is a possibility of exhausting the SD storage space, which can result in data loss. Nevertheless, the study presents a valuable contribution to the field by offering a simpler, more cost-effective, and reliable IoT-based PV monitoring system with data backup capabilities. Utilizing a LoRa module within a wireless sensor network enables remote system monitoring in remote locations, such as rural areas, forests, farms, and national roads, where network connectivity is limited. By connecting LoRa modules with sensors, this network facilitates remote data access from diverse regions. Furthermore, the network's low power consumption makes it well-suited for security monitoring and surveillance applications. A wireless network using LoRa technology for long-range data transmission for monitoring system comprises nodes and a gateway. LoRa operates on low power, making it suitable for battery-operated applications that require end-to-end communication. LoRa can detect specific sensor data type and transmit and receive it over far distances, even without internet access, while requiring very little power [6]. In a literature survey conducted in [6], the authors primarily focus on long range wide area network (LoRaWAN) and its application in water grid. The LoRaWAN technology is made up of relay node discovery, LoRa modulation, layer formation, LoRaWAN protocol clustering, spreading factor assignment, network joining, data transmission, flow table setup and protocol requirements and validation. The developed algorithm demonstrates precision in calculating the rate of error of the packet and single-hop networks energy consumption. However, a limitation or research gap identified in this study is the lack of evaluation for the number of nodes in each relay node [7]. The system uses Ra-02 LoRa modules to send data from the sender node to the receiver node. The sender node receives and sends the sensor data to the receiver node using LoRa and ESP8266 microcontroller. In addition, solar panels driven by low power consumption can be used for power supply. The received data is then updated in a database using the Wi-Fi network.

LoRa technology, specifically LoRaWAN, is a technology utilized in low power wide area networks (LPWAN), as mentioned in [8], this LoRa technology is a proprietary development of Semtech Technology [9].

LoRa offers an optimized combination of long-range communication, secure data transmission and low power consumption by incorporating the spread spectrum modulation technique derived from Chirp Spread Spectrum and integrated forward error correction. The LoRa alliance developed LoRaWAN [10] as an open standard with the network, MAC, and application layers. These combined technologies enable wide-area communication, low-power consumption, and gateways in wireless sensor networks, catering to low-latency, low-bandwidth internet of things (IoT) applications. The LoRa wide area network protocol, also known as LoRa, offers interoperability among LPWAN networks and delivers additional advantages, including easy installation, cost-effectiveness, flexibility, scalability, bi-directionality, security, and encryption. LPWAN technologies have the potential to support a massive number of devices in the future internet of things. Specifically, LoRaWAN technology is optimized for sensor based IoT applications where only small amounts of data must be transmitted over long distances, resulting in efficient battery life. Designed within the LPWAN space, LoRaWAN prioritizes range, battery life, and cost to cater to the requirements of such IoT applications [11], [12]. This paper introduces a remote system monitoring approach for an efficient solar-powered pump designed as a solution for abandoned oil and gas well. The proposed method utilizes LoRa technology and aims to offer real-time system monitoring that operates independently of a network connection. Additionally, it presents a cost-effective solution for long-range wireless data transmission.

The flowchart shown in Figure 1 illustrates the step-by-step process utilized to initialize the setup, collect sensor information, and transmit the data as packets to the receiver node. The depicted sequence of events in the flowchart starts with initializing the LoRa receiver module and the hardware system, followed by sensor data acquisition. Subsequently, the data is transmitted to the receiver node, and the packets' status is displayed.

The receiver node executes a similar sequence of events as the sender node, except for the absence of transmission of sensor data, which is exclusive to the sender, as shown in Figure 2. The transmitter LoRa node sends the data in the form of packets and is received by the receiver LoRa module. The organic light-emitting diode (OLED) display shows the status of the packet received. The following flowchart presents the system of methods employed in the receiver node.

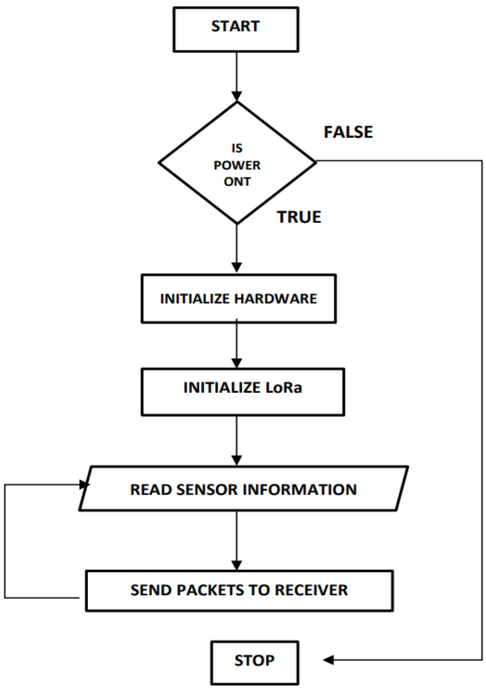

Figure 1. LoRa sender node flowchart LoRa receiver

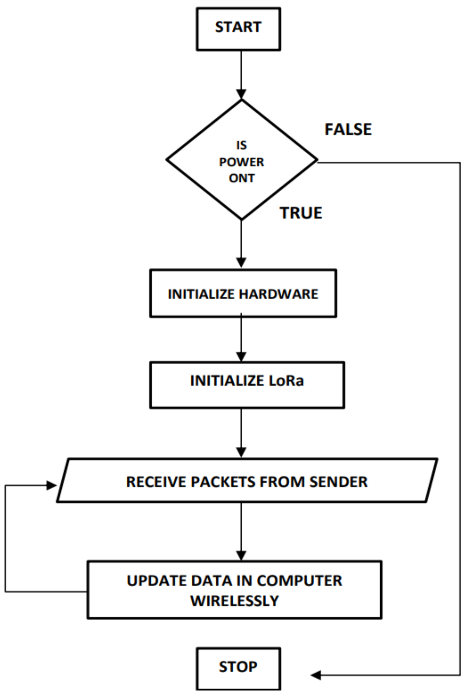

Figure 2. LoRa receiver node flowchart

2. WIRELESS COMMUNICATIONS

Cellular networks are extensively utilized because they provide high-speed data coverage. However, for IoT applications, high-speed data is not always essential. Devices that rely on cellular networks often suffer from short battery life and encounter coverage gaps. In contrast, ZigBee mesh networks are popular in-home automation because of their reliable performance over short to medium distances. However, they are not suitable for long distances of a few kilometers. Bluetooth/BLE data rates are moderate, but the range is severely restricted.

The IEEE802.11 WLAN standard is one of the most prevalent wireless methodologies utilized today, primarily due to its high data rate and bandwidth capabilities. However, it has limitations such as limited range and high battery consumption. Wi-Fi devices often have short battery life and must be close to the Wi-Fi access point for effective communication. Additionally, operating frequencies of 2.4 and 5 GHz of Wi-Fi signals make them less effective at passing through obstacles. When overcoming these limitations, LoRaWAN technology is a promising solution for IoT-driven applications in various fields [13].

2.1. Advancement of LoRa technology

In the study by So *et al*. [14], the paper discussed the implementation of a LoRa network server on the OpenStack platform. They successfully updated the operations of the LoRa network server to achieve service flexibility and scalability by leveraging the system services provided by OpenStack. They created an experimental setup to validate their approach utilizing commercially available LoRa hardware, an open-source terminal, a gateway, and OpenStack software. To address the challenge of transmitting large amounts of data, the authors utilized Wi-Fi service to overcome the limitation of low data rates in LoRa technology. By combining these two technologies, they developed a multi-interface communication module that could meet the requirements of long-range communication and low-power operation with LoRa, while also enabling the transmission of large data volumes using wireless local area network (LAN) (Wi-Fi).

The design principles of LoRa technology encompass various aspects such as modulation, receiver sensitivity, and spreading factor. The spreading factor quantifies the relationship between the chips and bits, a crucial parameter in LoRa modulation [15]. LoRa technology employs chirp spread spectrum (CSS) modulation, allowing flexible long-distance communication while minimizing power consumption by utilizing different spreading factors (SF). The SF value can be adjusted from 7 to 12, resulting in LoRaWAN transmitting rates ranging from 0.3 to 27 kbps. A higher SF value leads to increased communication range and prolongs the duration of data packet transmission in the air [10], [15].

Kim *et al*. [16] examines the increasing importance of indoor localization in the internet of things (IoT), particularly in smart homes. This is driven by advancements in low-power and affordable wireless technologies. The study acknowledges various wireless technologies used for indoor localization, including Wi-Fi, ultra-wideband (UWB), Bluetooth low energy (BLE), radio-frequency identification (RFID), and LoRa. LoRa stands out for its low cost and long-range communication capabilities, making it valuable for both indoor and outdoor IoT applications. The research begins by assessing the feasibility of using LoRa for distance measurement and proceeds with experiments to assess its effectiveness in indoor localization within a typical apartment. The key findings reveal impressive accuracy results: greater than 1.6 meters in line-of-sight scenarios and 3.2 meters in challenging non-line-of-sight situations. Precision levels of greater than 25 centimeters are achieved in all cases, even without data filtering on the location estimates. This study is a significant contribution to the field, exploring indoor localization with LoRa technology in smart homes. The results suggest that LoRa is a reliable and cost-effective solution for indoor positioning, enhancing smart home functionality and valuable for understanding LoRa's potential in indoor localization.

In the context of large-scale implementation, LoRa, a wireless sensor network (WSN), is highly valuable due to its utilization of both network and node characteristics. LoRa sensor networks are employed by utility companies to connect end-user devices to their network, facilitating streamlined administration. Similarly, in urban areas, LoRa networks are used by cities to pioneer "smart" concepts aimed at improving the efficiency of resource and service administration. Additional applications of LoRa networks include an automated reading of water meters for water companies, eliminating the need for on-site human intervention, and city-wide intelligent parking solutions. In traditional rural environments with limited resources, LoRa sensors can also be applied to intelligent agriculture applications [17].

In a study conducted by Petäjäjärvi *et al*. [18], commercially available equipment was used to investigate the distance coverage of LoRaWAN technology in two different scenarios. The data was collected by deploying a node on land and another node on water, and both reported data to a base station. Based on the collected data, the authors calculated the communication range of LoRaWAN to be 15 km on land and 30 km on water.

The LoRa wireless networks performance evaluation is presented in [19], the assessment analyzes the impact of bitrate, time on air (ToA), and SF. on performance levels. The findings reveal that increasing the S.F. parameter results in a corresponding increase in ToA, however, a significant reduction in ToA is observed with increased communication channel bandwidth. Sacaleanu *et al*. [20] presents results on data compression in wireless sensor nodes utilizing LoRa technology for data transmission. Additionally, a comparison of energy consumption is conducted with other commonly used data communication protocols in WSN, such as ZigBee, to highlight the advantages of LoRa. While Kim and Song [21] proposed a dual-key scheme to enhance the security of LoRa. Although the proposed plan was deemed adequate, it was found to have increased computing requirements, resulting in higher power consumption and system costs. The were challenges in meeting the demand for low-power, long-range, high-data transmission anticipated with IoT commercialization, the data transmission rate in the proposed scheme was observed to be low. The IoT offers significant potential for enhancing energy management and improving occupant comfort in smart buildings by enabling continuous and accessible data collection of environmental and equipment parameters. LoRa technology stands out as a robust wireless solution for data acquisition and communication within smart buildings, boasting exceptional attributes such as extended transmission range, low power consumption, and robust signal penetration. Liang *et al*. [22] explores an in-depth analysis of LoRa's coverage and transmission capabilities within building environments, beginning with critical performance metrics such as network transmission delay and packet loss rates. To carry out this investigation, three LoRa receiver nodes were strategically positioned on the same floor, while eight LoRa receiver nodes were distributed across multiple floors within a 16-story building. The data acquisition terminal was centrally located within the building. The assessment of LoRa's communication performance involved systematic adjustments to parameters such as transmit power, communication rate, payload length, and the placement of wireless modules. Erwinski *et al*. [23], a self-sustaining distributed light measurement system is introduced, designed for prolonged monitoring of light pollution in urban settings. This system primarily consists of self-sustaining measurement devices equipped with LoRa wireless communication capabilities, enabling extensive coverage in diverse environments. Unlike similar devices discussed in existing literature, the devices and data acquisition system presented in this study offer a distinct advantage: they can operate autonomously for extended periods on battery power while maintaining wireless connectivity to a central network server. The paper provides comprehensive insights into the development of the wireless sensor module and the overall system architecture. It also addresses design challenges related to different environmental seasons that had to be overcome to ensure the system's functionality. The paper includes experimental results illustrating the devices' ability to operate within a LoRa network-based system for extended durations without requiring maintenance, thanks to the low power consumption and well-planned transmission rate of LoRa technology.

Given the challenges posed by the COVID-19 pandemic, which resulted in issues like curfews, social distancing, and transportation difficulties, particularly in the agricultural sector, the idea emerged to harness LoRa, an advanced wireless communication technology capable of enabling IoT connectivity. This approach serves as the foundation for wireless network system designed to monitor and manage greenhouse sensors. The system consists of two essential components: the first involves deploying IoT-enabled sensors for measuring and controlling greenhouse conditions, with data transmitted using LoRa technology. The second component focuses on remote monitoring and control of the collected data. Leveraging LoRa technology, data from the first section is transmitted and connected to the Internet or an IoT network, enabling access, monitoring, and control from anywhere globally. The data can be stored in the cloud and accessed through a website, providing real-time sensor monitoring wherever internet service is available. Additionally, the system allows for feedback signals to be sent to the greenhouse. This project offers comprehensive greenhouse management within a range of 2 to 15 km, providing a vital solution for businesses forced to operate remotely due to the ongoing COVID-19 pandemic [24].

This paper will update the received data in a computer display instead of using a Wi-Fi module. LoRa technology will send and transmit the analyzed PV. system performance data collected locally in PLX DAQ for further analysis in [19]. A low-cost monitoring system for a solar oil pumping system is proposed and will be helpful in small remote stripper oil wells.

3. METHOD

The instrumentation block diagram of a remote solar oil well is depicted in Figure 3, and this real-time monitoring system can measure the energy flow and oil level and monitor the energy by measuring various parameters such as battery voltage, AC. current from the inverter, and power. The data in [1] measurements are recorded in a plug-in called parallax data acquisition (PLX-DAQ); this paper aims to transmit the data wirelessly using LoRa by using Heltec LoRa 32 device and TTGO LoRa32.

3.1. Instrumentation circuit design and calibration

The circuit includes a temperature sensor, a current sensor and a voltage sensor that are connected to a common power source. Additionally, a level indicator is employed for oil level monitoring. The following hardware used for wireless data transmission in [1] were used for this paper, as continuation of the system monitoring for long range communication.

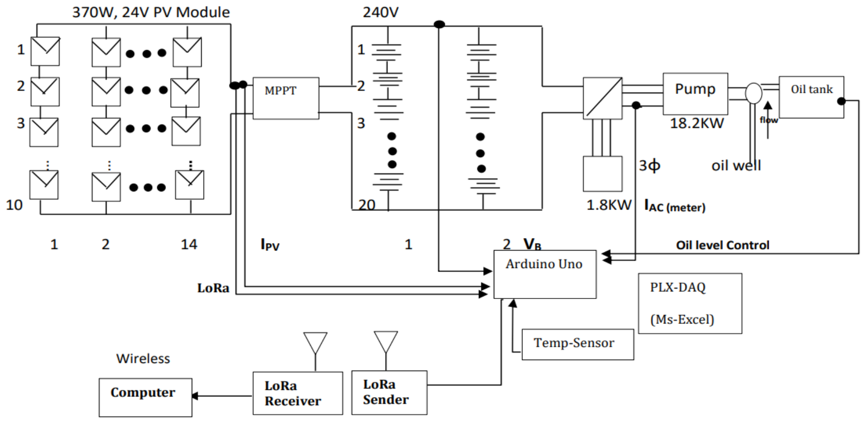

Figure 3. Instrumentation block diagram of the entire monitoring system

3.1.1. Temperature sensor-DHT11

This sensor uses digital signal acquisition techniques and temperature and humidity sensing technologies to provide exceptional reliability and precision. The sensor measures 0 to 50 °C of temperature with an accuracy of 1 °C, 20% to 90% as humidity range, and a precision of 1%. The power supply is denoted as Vcc, the circuit ground as ground, and the serial data output for reading temperature as data. The sensor is designed to operate within a voltage range of 3 to 5.5 V. To connect the sensor's output pin to the microcontroller's Vcc, a 10-k pull-up resistor is used. For this work, the data pin of the sensor will be connected to GPIO 33 of the Heltec LoRa 32 microcontroller, shown in Figure 4.

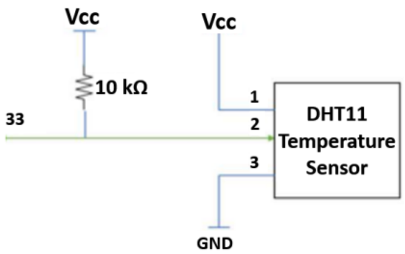

Figure 4. Temperature sensor circuit connection

3.1.2. Voltage sensor

The voltage measurement of this sensor is based on the voltage divider principle, which utilizes a series connection of 7.5 k and 30 k resistors to create a 5-to-1 voltage divider for accurate measurement shown in Figure 5. With the resistor specifications in the circuit diagram in Figure 5. The provided equation can be used to calculate the actual output voltage of a photovoltaic panel.

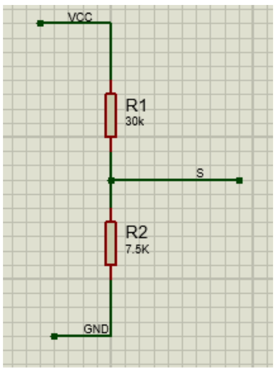

Figure 5. Voltage divider rule embedded in the IC

$V = \frac{(R_1+R_2)}{R_2} \times V_{OUT1} \times \frac{3.3}{4095}$. The equation is the voltage divider principle used for the esp32 connection in Figure 5. The sensor operates within a voltage range of 3.3-5.0 V and can monitor the voltage in the 0-25 V DC range using a 12-bit ADC. It's worth noting that the ESP32 microcontroller requires a 3.3 V input voltage for proper functioning. To connect the voltage sensor to the ESP32 microcontroller, pin S of the sensor is linked to analog pin 32 of the ESP32, while pin - is connected to the GND pin, as shown in Figure 6. The voltage sensor module has a resolution of 3.3 V/4095 analog voltages, allowing it to detect input voltages as low as 0.0008058 V multiplied by 5.

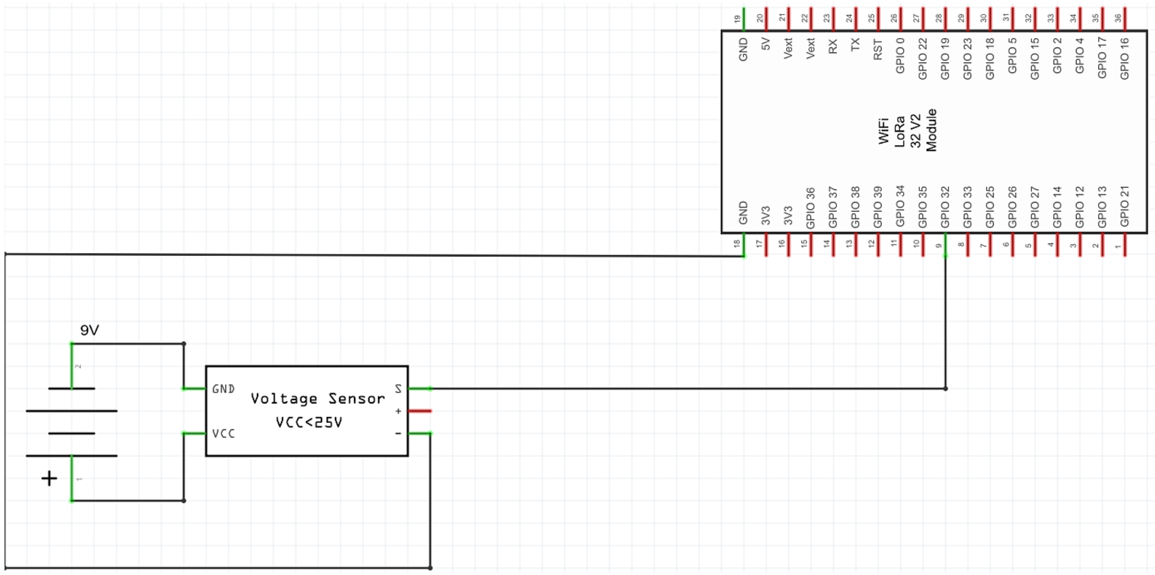

Figure 6. Voltage sensor schematic diagram

3.1.3. Current sensor

The ACS712 chip measures DC/AC by the Hall effect, this sensor highlights the advantages of using Hall-effect magnetic detectors, such as inherent voltage isolation and the integration of the Hall element and interface electronics on a single silicon chip. Advanced BiCMOS technology has further improved the performance of integrated circuits (ICs) used in Hall-effect current sensing. For currents exceeding 200 A, the ICs can be employed in a current divider configuration by splitting the current path. However, this approach reduces current resolution proportionally to the current division. In battery monitoring, accurate current measurement is crucial for capacity monitoring algorithms. Traditional methods using shunts in the ground path or low side face challenges with low-current accuracy due to small shunt values. This can lead to complications in estimating residual capacity, resulting in conservative capacity loss calculations. To reduce power dissipation in the battery pack and address space constraints, hall-effect devices are proposed as shunt solutions. These devices offer low insertion loss and effectively mitigate the limitations posed by traditional current measurement methods. The ACS712 Hall-effect device is well-suited for monitoring input power or battery charge current due to several advantages. Firstly, its small form-factor significantly reduces the required volume compared to an equivalent current transformer (CT) solution. Additionally, using the ACS712 eliminates the need for gain and additional protection components. This is possible because the ACS712 ensures that there is no overshooting of voltage on the isolated side of the device [25].

The current is determined by measuring the voltage generated by a fully integrated, low-cost, high-precision sensor. This sensor utilizes a non-invasive approach to detect current by sensing the magnetic field generated around the wire. It employs a low-resistance current conductor and can measure both D.C. and A.C. currents. The ACS712 Hall-effect sensor is available in three sizes: 5 A, 20 A, and 30 A shown in Table 1. When no current is detected, it outputs a voltage of 2.5 V DC. The sensor's sensitivity varies depending on the module size, ranging from 66 mV/A for the 5 A module, 100 mV/A for the 20 A module, and 185 mV/A for the 30 A module in Table 1. In Figure 7, a voltage divider is used to reduce the voltage from 5 V to 3.3 V since the Esp32 pins are powered by 3.3 V.

Table 1. ACS712 and model sensitivity

S.L.	Part number	TA (°C)	Optimized range, IP (A)	Sensitivity, Sens (Typ) (mV/A)
1	ACS712ELCTR-05B-T	–40 to 85	±5	185
2	ACS712ELCTR-20A-T	–40 to 85	±20	100
3	ACS712ELCTR-30A-T	–40 to 85	±30	66

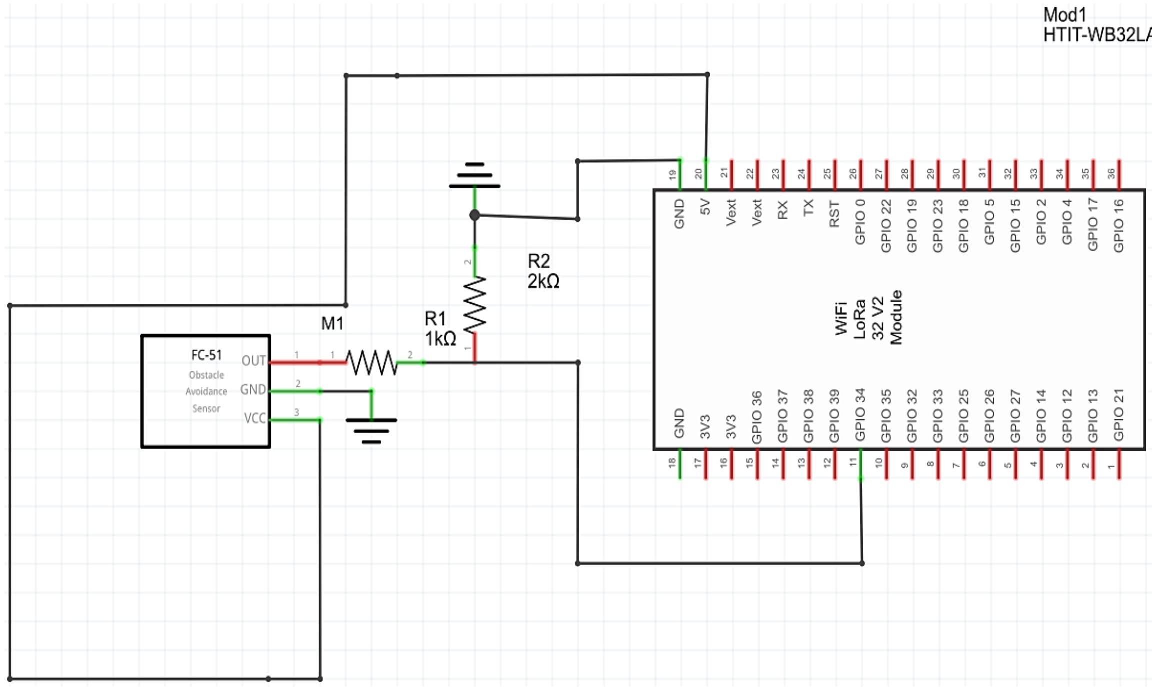

Figure 7. Current sensor schematic diagram

3.1.4. Float switch

A float sensor is integrated to determine the oil level in an oil tank in a solar pumping system. An electromagnetic on/off switch, like a magnetic sensor, detects the tank's oil level by establishing a switching connection. In the circuit connection, one wire is connected to the ground and the other is connected to any digital pin. It is used to measure the level of the oil tank.

3.2. LoRa code and Syntax explanation for the system instrumentation

3.2.1. LoRa sender

When facilitating the configuration of LoRa, including the library that facilitates the communication between the TTGO LoRa 32 and the LoRa transceiver module is necessary. Additionally, it is imperative to specify the specific pins employed by the LoRa Sender module. Within the setup() function, it becomes essential to carry out a manual software reset of the OLED by utilizing the RST pin. This reset entails declaring the RST pin as an output, setting it to a LOW state, and reverting it to a HIGH state. Initializing the user interface (UI) will also initialize the display. To designate the LoRa node, the phrase "LORA SENDER" should be displayed on the screen for identification. In order to identify and establish the necessary connections for the LoRa chip, the LoRa transceiver module utilizes the SPI pins and must be defined. Subsequently, initialize the LoRa transceiver module by invoking the begin() method on the LoRa object and specifying the desired frequency as a parameter. Upon successful initialization of the display, a message indicating success will be exhibited on the OLED display. In the loop() function, the transmission of packets will occur. The beginPacket() method is employed to commence a packet, while the print() method is utilized to incorporate data into the packet. Finally, the endPacket() method is used to finalize the packet.

3.2.2. LoRa receiver

The syntax for the receiver code is similar to the sender In order to streamline the configuration process of LoRa, it is essential to integrate the appropriate library that facilitates seamless communication between the Heltec ESP32 and the LoRa transceiver module. Furthermore, it is crucial to explicitly define the pins employed by the LoRa Receiver module. Within the setup() function, the execution of a manual software reset for the OLED becomes necessary, wherein the RST pin is utilized. This reset procedure involves declaring the RST pin as an output, setting it to a LOW state, and restoring it to a HIGH state. Initialization of the user interface (U.I.) will concurrently initialize the display. To identify the LoRa receiver node, the designation "LORA RECEIVER" should be employed. In the loop() function, the transmission of packets received will be parsed. The int packetSize = LoRa.parsePacket(); is to receive a packet from the sender module, while the while (LoRa.available()) { is to read the packet.

```
void loop() {
 // try to parse packet
 int packetSize = LoRa.parsePacket();
 if (packetSize) {
 // received a packets
 Serial.print("Received packet. ");
 display.clear();
 display.setFont(ArialMT_Plain_16);
 display.drawString(3, 0, "Received packet ");
 display.display();
 // read packet
 while (LoRa.available()) {
 currentTemperature = LoRa.readStringUntil('|');
 Serial.print("Temp:");
 Serial.println(currentTemperature);
 currentVoltage = LoRa.readStringUntil('|');
 Serial.print("Voltage (V):");
 Serial.println(currentVoltage);
 currentCurrent = LoRa.readStringUntil('|');
 Serial.print("current(A):");
 Serial.println(currentCurrent);
 currentPower = LoRa.readStringUntil('|');
 Serial.print("Power(W):");
 Serial.println(currentPower);
 currentButtonState = LoRa.readStringUntil('|');
 Serial.print("OilLevel:");
 Serial.println(currentButtonState);
 currentCounter = LoRa.readStringUntil('|');
 Serial.print("Counter:");
 Serial.println(currentCounter);
 }
 // print RSSI of packet
 Serial.print(" with RSSI ");
 Serial.println(LoRa.packetRssi());
 display.drawString(20, 45, "RSSI: ");
 display.drawString(70, 45, (String)LoRa.packetRssi());
 display.display();
```

4. RESULTS

While LoRa technology has found extensive use in wireless data transmission, it is predominantly employed in conjunction with a network gateway. However, the existing solutions proposed in previous studies is not suitable for remote locations. This paper addresses the issue by proposing a wireless communication approach that utilizes LoRa technology specifically for areas with inadequate network coverage, enabling data transmission over distances of approximately 28 km. The real-time data storage is achieved through PLX-DAQ Excel in [1], or an open-source terminal emulator. In the simulation, the ACS712 sensor is limited to 5A maximum current, the F031-06 sensor is limited to a range of 25 V maximum voltage, and the DHT 11 sensor is limited to a temperature range of -40°C to 125°C. The results presented below were obtained using a 9 V non-rechargeable alkaline battery and changing the oil level for practical demonstration, the circuit diagram and the sender node is seen in Figure 8.

In Figure 9, the receiver node shows just the temperature data and the RSSI, the receiver node used is a Heltec esp32 LoRa. In Figure 10, the results were displayed on PuTTY and Figure 12 shows that the oil level was high from counter 71, RSSI 32. For further data analysis, PLX-DAQ was used in the previous study [8] to evaluate the data further. Serial.println(currentButtonState); currentCounter=LoRa.readStringUntil('|'); will only return 1 when the oil level is high and 0 when the oil level is low, as shown in Figure 11. The above results are from a lab test and do not represent data from an oil well pumping.

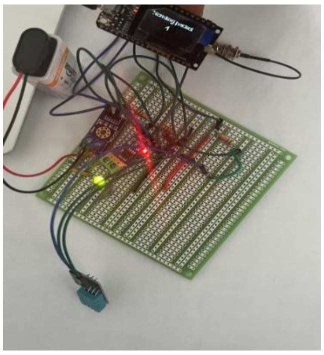

Figure 8. Implemented circuit with sender node

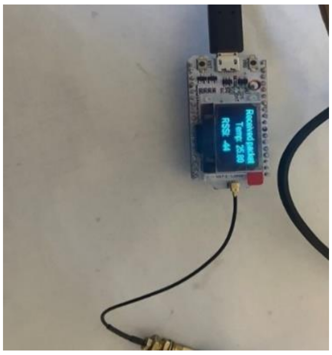

Figure 9. Receiver node

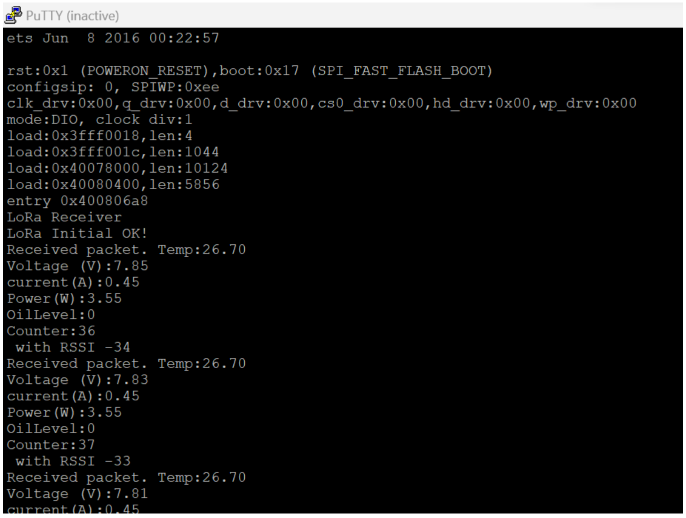

Figure 10. Data transmitted wirelessly to PuTTY

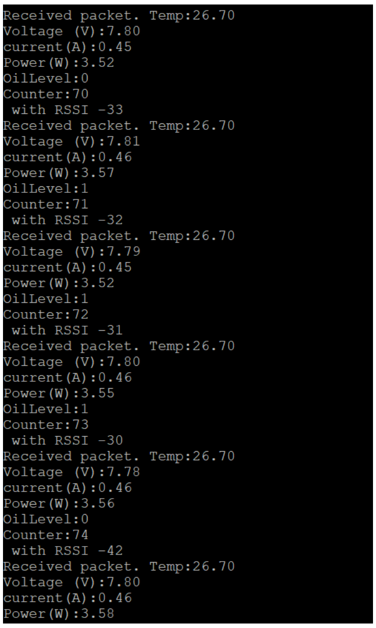

Figure 11. Data indicating that the oil level is high

5. CONCLUSION

To tackle the problem of oil spillage from an abandoned oil well, a solar-powered pump was initially installed at the remote location of the well. Using renewable energy sources reduced production costs, and the system design was documented in a prior publication. LoRa wireless communication introduced affordable data logging instruments that accurately captured real-time information about the system design characteristics, such as PV voltage and current, AC from the inverter, oil level monitoring, temperature, and relative humidity. This research presents a cost-effective wireless monitoring system for remote oil wells that is also easy to maintain, and the collected data can be utilized for further analysis. This system is particularly suitable for areas without internet connectivity.

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