Implementation of LoRa (NRF) Based Smart Energy Meter

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Abstract :- This paper presents the implementation of a LoRa (NRF) based smart energy meter using Arduino and various components including a potentiometer to voltage sensor, current sensor, energy meter, LCD module, NRF transmitter (LoRa), relay module for load control, buzzer, and NRF receiver. The system aims to enable efficient monitoring and control of energy consumption in residential or industrial environments. In the transmitter section, the potentiometer to voltage sensor is utilized to measure the voltage level, while the current sensor measures the current flowing through the energy meter. The energy meter calculates the energy consumption based on these measurements. The data, including voltage, current, and energy consumption, is transmitted using the NRF transmitter module, which employs LoRa technology for long-range and low-power communication. The relay module is employed to remotely control the load, enabling users to switch on/off electrical appliances remotely. Additionally, a buzzer is integrated to provide audible alerts for events such as abnormal voltage or current levels.

In the receiver section, an NRF receiver module is employed to receive the data transmitted by the transmitter section. The Arduino board is used to process and display the received data on an LCD module. This provides users with real-time information about their energy consumption. The power supply ensures uninterrupted operation of the receiver section. The implemented system offers several advantages, including wireless communication over long distances, low power consumption, real-time monitoring of energy consumption, remote load control, and audible alerts for abnormal events. It can be easily integrated into existing energy infrastructure and provides users with valuable insights to optimize energy usage and improve energy efficiency**.**

Index Terms – Arduino, Energy Meter, NRF Transmitter and receiver, Buzzer, Voltage sensor, current sensor etc.

1. INTRODUCTION

The implementation of smart energy meters has gained significant attention in recent years due to the increasing demand for efficient energy management and conservation. Traditional energy meters lack the capability to provide real-time information about energy consumption, limiting the ability to monitor and control electricity usage effectively. To overcome these limitations, advanced technologies such as LoRa (Long Range) and NRF (Nordic Radio Frequency) have been employed to develop smart energy meters that offer wireless communication, remote control, and real-time monitoring capabilities.

This paper focuses on the implementation of a LoRa (NRF) based smart energy meter using Arduino and various components. The system aims to provide users with accurate, real-time data on their energy consumption, enabling them to make informed decisions and take actions to optimize energy usage. By integrating components such as potentiometer to voltage sensor, current sensor, energy meter, LCD module, NRF transmitter (LoRa), relay module, and buzzer, the smart energy meter offers a comprehensive solution for energy monitoring and control.

The transmitter section of the smart energy meter incorporates a potentiometer to voltage sensor, which measures the voltage level, and a current sensor, which measures the current flowing through the energy meter. These measurements are processed by the energy meter, which calculates the energy consumption. The data, including voltage, current, and energy consumption, is then transmitted using the NRF transmitter module with LoRa technology, ensuring long-range communication with low power consumption. The relay module enables users to remotely control the load, providing the ability to switch on/off electrical appliances as required. Additionally, a buzzer is included to provide audible alerts for events such as abnormal voltage or current levels, enhancing the safety and reliability of the system.

In the receiver section, an NRF receiver module is employed to receive the transmitted data. The Arduino board processes the received data and displays it on an LCD module, allowing users to monitor their energy consumption in real time. The power supply ensures uninterrupted operation of the receiver section, ensuring continuous monitoring and control capabilities.

The implemented LoRa (NRF) based smart energy meter offers several advantages over traditional energy meters. It provides wireless communication over long distances, eliminating the need for wired connections and enabling flexible installation. The integration of LoRa technology ensures low power consumption, prolonging the battery life of the system. Real-time monitoring of energy consumption allows users to track their usage patterns, identify energy-saving opportunities, and make informed decisions to reduce wastage. The remote load control feature enhances convenience and energy efficiency by enabling users to manage their electrical appliances from a distance. Audible alerts ensure timely response to abnormal events, improving safety and preventing potential damages.

In conclusion, the implementation of a LoRa (NRF) based smart energy meter presents an efficient and intelligent solution for energy management. It empowers users with real-time monitoring, remote control, and valuable insights into their energy consumption. By promoting energy conservation and optimization, this technology contributes to the development of sustainable and smarter energy systems.

The organizational framework of this study divides the research work in the different sections. The Literature review is presented in section 2. Further, in section 3 shown Existing methods Concept is discussed and in section 4 Proposed method Concept is discussed, Experimental Results work is shown in section 5. Conclusion and future work are presented by last sections 6.

2. LITERATURE SURVEY

The present billing system by the distribution companies are unable to keep track of the changing maximum energy demand of the consumers [1].

Some of the practical problems that Consumers face are receiving due bills for the bills that have already been paid as well as poor reliability of electricity supply along with poor quality, even if the bills are paid regularly. The remedy for all these problems is to keep track of the consumers load on timely basis, which will lead to an assurance of accurate billing, track maximum demand and to detect the threshold value. All these features are taken into account for designing an efficient energy billing system while addressing the problems faced by both the consumers as well as distribution companies. Energy theft is a very common problem in countries like India where consumers of energy are increasing consistently as the population increases [2].

Due to energy theft, there is a negative impact in the amount of revenue earned each year that has contributed to huge losses. The newly designed AMR used for energy measurements focus on the working of new automated power metering system, but this directly increases the Electricity theft causing administrative losses because of non- regular interval checkout at the consumer's residence. It is quite impossible to check and solve these issues by going to every consumer’s door step. Therefore, new procedure is followed based on Atmega328P which is used to detect and control the energy meter from power theft and solves the problem by remotely disconnecting and reconnecting the service (line) of a particular consumer. A Short Messaging Service (SMS) will be sent automatically to the utility central server through the GSM module whenever unauthorized and illegal activities are detected. A separate message will be sent back to the microcontroller in order to disconnect the unauthorized supply. A unique method is implemented with GSM features into smart meters with Solid State Relays to deal with these non-technical losses, billing difficulties and voltage fluctuation complication. A Smart Electricity meter using GSM can reduce human errors and helps to retrieve the real time meter value via GSM and send the reading to the consumer’s mobile phone [3].

This also allows Electricity Board to modify the variable package price in a specific period. The administrator can analyze the customer’s power consumption data and generate online reports from the data collected. The prototype that has been developed allows the customers to use the billing system, and get the power consumption data from smart meter, as well as keep the data in a centralized database along with report generation. Existing energy meter system have many problems associated to them and one of the key problems is that there is no full duplex communication [4].

To solve this problem, a smart energy meter is based on Internet of Things (IoT) such that it controls and calculates the energy consumption using ESP 8266 12E, a Wi-Fi module and uploads it to the cloud from where the consumer or distributer can view the reading. Therefore, energy consumption analysis by the consumer becomes much easier and controllable. This system also helps in detecting power theft. Thus, this smart meter helps in home automation using IoT and enabling wireless communication which is a great step towards Digital India.

In [5], the hardware and the software interface are connected to each other to monitor the power consumption of the user and further, this will be monitored by server and will be uploaded to cloud from where the user can log on to the webpage in computer. Advantages of this system are financial losses of electricity board can be minimized, time delay that occurs due to manual metering can be avoided to a great extent. Disadvantages of this system are Issues in smart data analytics, Smart meter and big data, cannot be suitable for long distance. From this paper we concluded that the complete working model of a smart energy meter was built which uses existing Wi-Fi Module system. The model satisfactorily worked with a Bulb. Automatic meter reading can be explained well using this system. Financial losses of electricity board can be minimized. Labor charges and effort can be reduced.

In [6], Energy hb, Agilewaves and Google Meter concept used for implementation of project. Advantages of this system are highly application is possible, Energy saving options. Disadvantages of the system are need to know different communication Protocols, cannot be used for long range. From this paper we concluded that In the paper a high-level application possibility has been proposed, which makes these meters useful not only for the utility, but for the consumers and through the encouraging the energy saving.

In [7], this paper presents communication through Ethernet to send data to the server. Arduino is used as controller. Advantages of the system are very cheap, collected data can be monitor by consumer and supplier at any time. Disadvantages of the system are cannot be used for long range. From this paper we concluded that this proposed system is cheap as compared to other communication protocols. The collected data about energy consumption is monitored by consumer and supplier at anytime, anywhere from any part of the world.

3. EXISTING SYSTEM

In existing systems either an electronic energy meter or an electro-mechanical meter is fixed in the premises for measuring the consumption. The meters currently in use are only capable of recording kWh units. The kWh units still have to be recorded by meter readers monthly, by persons who have to walk from building to building. The recorded data needs to be processed by a meter reading company. For processing the meter reading, the company needs to first link each recorded power usage datum to an account holder and then determine the amount owed by means of the specific tariff in use. So, the wireless smart energy meters are replaced for accurate tariff calculation and reducing the errors caused by the human readers. These smart energy meters used the GSM, Wi-Fi like wireless technologies. The main drawback of these systems is the necessity of network access in the consumer side for the smart energy meter to connect wirelessly.

4. PROPOSED SYSTEM

The LoRa (NRF) based smart energy meter using Arduino is a system designed to monitor and control energy consumption in residential or industrial settings. It leverages LoRa (Long Range) and NRF (Nordic Radio Frequency) technologies to enable wireless communication, real-time monitoring, and remote control capabilities. By utilizing an Arduino board and various components, this smart energy meter offers an efficient and intelligent solution for energy management.

The system consists of two main sections: the transmitter section and the receiver section. In the transmitter section, several components are integrated to measure and transmit energy consumption data. A potentiometer to voltage sensor is used to measure the voltage level, while a current sensor measures the current flowing through the energy meter. These measurements are processed by an energy meter, which calculates the energy consumption. The data, including voltage, current, and energy consumption, is then transmitted wirelessly using the NRF transmitter module with LoRa technology. A relay module is incorporated to enable remote load control, allowing users to switch on/off electrical appliances as needed. An additional buzzer provides audible alerts for abnormal voltage or current levels, enhancing safety and reliability.

In the receiver section, an NRF receiver module is used to receive the transmitted data. An Arduino board is employed to process and display the received data on an LCD module. This enables users to monitor their energy consumption in real time. A power supply ensures continuous operation of the receiver section, ensuring uninterrupted monitoring and control capabilities. The implementation of this LoRa (NRF) based smart energy meter offers several advantages. Firstly, it provides wireless communication over long distances, eliminating the need for wired connections and allowing for flexible installation. The integration of LoRa technology ensures low power consumption, prolonging the system's battery life. Real-time monitoring of energy consumption enables users to track their usage patterns and identify opportunities for energy optimization. The remote load control feature offers convenience and enhances energy efficiency by allowing users to manage their electrical appliances remotely. The inclusion of audible alerts ensures prompt response to abnormal events, improving safety and preventing potential damages.

A. Block Diagram

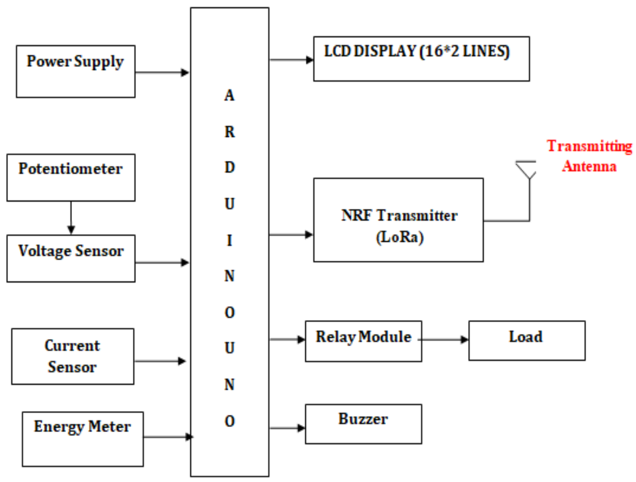

Fig.1: Block Diagram for transmitter section

The basic block diagram of transmitter section given in Figure 1. In the transmitter section, the potentiometer to voltage sensor is utilized to measure the voltage level, while the current sensor measures the current flowing through the energy meter. The energy meter calculates the energy consumption based on these measurements. The data, including voltage, current, and energy consumption, is transmitted using the NRF transmitter module, which employs LoRa technology for long-range and low-power communication. The relay module is employed to remotely control the load, enabling users to switch on/off electrical appliances remotely. Additionally, a buzzer is integrated to provide audible alerts for events such as abnormal voltage or current levels.

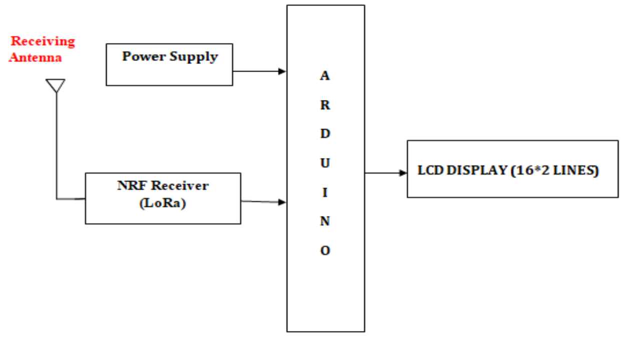

Fig.2: Block Diagram for receiver section

The basic block diagram of Receiver section given in Figure 2. In the receiver section, an NRF receiver module is employed to receive the data transmitted by the transmitter section. The Arduino board is used to process and display the received data on an LCD module. This provides users with real-time information about their energy consumption. The power supply ensures uninterrupted operation of the receiver section.

B.Methodology

The implementation of the LoRa (NRF) based smart energy meter using Arduino involves several steps. This methodology outlines the key stages involved in setting up and operating the system.

1. *Component Selection:* Identify and gather the necessary components for the smart energy meter system. This includes Arduino board, potentiometer to voltage sensor, current sensor, energy meter, LCD module, NRF transmitter (LoRa), relay module, buzzer, NRF receiver, and power supply.
2. *Circuit Design and Wiring:* Design the circuit layout considering the connections between the components. Follow the datasheets and technical specifications of each component to ensure correct wiring and connections. Connect the potentiometer to voltage sensor, current sensor, energy meter, LCD module, NRF transmitter, relay module, buzzer, and power supply to the Arduino board in the transmitter section. Connect the NRF receiver, Arduino, power supply, and LCD module in the receiver section.
3. *Arduino Programming:* Write the necessary code for the Arduino board to perform the required tasks. This includes reading values from the potentiometer to voltage sensor and current sensor, calculating energy consumption, controlling the relay module, and transmitting/receiving data using the NRF modules. Utilize appropriate libraries and functions to simplify the programming process.
4. *Calibration and Testing:* Calibrate the sensors and energy meter to ensure accurate measurements. Test each component and functionality to verify their proper operation. Ensure that the readings from the sensors align with the expected values and that the data transmission and reception using the NRF modules are functioning correctly.
5. *User Interface Development:* Develop the user interface for displaying real-time energy consumption data on the LCD module. Design the interface to present relevant information such as voltage, current, energy consumption, and any alerts or notifications. Implement functions for user interaction, such as switching the load on/off remotely.
6. *Integration and Deployment:* Assemble all the components into their respective sections (transmitter and receiver). Ensure proper connections and secure the components within the housing or enclosure. Deploy the smart energy meter system in the desired location, ensuring accessibility and appropriate power supply.
7. *System Operation and Monitoring:* Power on the smart energy meter system and monitor its operation. Verify the data displayed on the LCD module and confirm the remote load control functionality. Continuously monitor the system to identify any issues or anomalies and perform any necessary maintenance or troubleshooting.
8. *Data Analysis and Optimization:* Collect and analyze the energy consumption data obtained from the smart energy meter. Identify patterns, trends, and opportunities for energy optimization. Make adjustments to energy usage habits or load control settings to improve energy efficiency and reduce wastage.

By following this methodology, the LoRa (NRF) based smart energy meter system can be effectively implemented using Arduino. It ensures accurate measurements, reliable wireless communication, remote load control, and real-time monitoring of energy consumption, contributing to efficient energy management and conservation.

C. Hardware Used

1. Arduino Uno

Arduino Uno shown in figure is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller shown in fig.3.

Fig.3: Arduino Micro Controller

2. *Current Sensor*

The smart energy meter would incorporate a current sensor to measure the electrical current flowing through the main power line or individual circuits. This sensor could be a Hall-effect sensor which detects and converts the current into a proportional electrical signal. Current sensor is shown in fig.4.

Fig.4: Current sensor

3. Voltage Sensor

A voltage sensor shown in fig.5 is a device used to measure and monitor the electrical voltage in a circuit. It provides an electrical signal that corresponds to the voltage level being measured. The voltage sensor is connected to the circuit or specific points in the circuit where voltage needs to be measured. It can be connected across a power source, at the output of a power supply, or across a specific component or load.

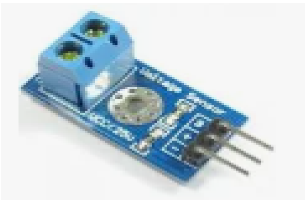

Fig.5: Voltage sensor

4. Energy Meter

An energy meter is shown in fig.6, also known as an electricity meter or utility meter, is a device used to measure and record the amount of electrical energy consumed by a residential, commercial, or industrial facility. It is typically installed by utility companies to monitor and bill customers accurately for their electricity usage. Energy meters incorporate both current and voltage sensors. The current sensor measures the electrical current flowing through the main power line or individual circuits, while the voltage sensor measures the voltage level of the incoming electrical supply.

Fig.6: Energy Meter

5. NRF transceiver

The NRF transceiver shown in fig.7, it refers to wireless communication modules developed by Nordic Semiconductor, a company specializing in wireless technologies. The NRF series of transceivers are widely used in various applications, including Internet of Things (IoT) devices, wireless sensor networks, and low-power wireless communication systems.

The NRF24 series is a popular line of 2.4 GHz transceivers. They operate in the license-free 2.4 GHz ISM (Industrial, Scientific, and Medical) band and support data rates up to 2 Mbps. These transceivers provide a range of communication features, including point-to-point and multi-node communication, with low power consumption.

Fig.7: NRF Transceiver

6. Buzzer

The buzzer shown in fig.8, it is connected to the microcontroller or microprocessor controlling the energy meter. The microcontroller triggers the buzzer to generate sound alerts or notifications based on specific conditions or events. For example, it can be used to indicate abnormal power consumption, low battery level, or system errors.

Fig.8: Buzzer

7. Power Supply

Power Supply shown in fig.9 The system is powered by a battery source of 9 V that is connected to the input pin of voltage regulator (L7805) to get a proper output voltage at the output pin of voltage regulator equal to 5 V or to step down the voltage from 9 V to 5 V, which is required for Arduino microcontroller.

Fig.9: Power Supply

8. LCD Display

LCD stands for liquid crystal display, which is used to show the status of an application, displaying values, debugging a program, etc.A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix displays is capable of displaying 224 different characters and symbols.
This LCD has two registers, namely, Command and Data. Shown in fig.10.

Fig.10: 16x2 LCD Display

D. Software Used

1. Embedded C Language

Embedded C is generally used to develop microcontroller-based applications. C is a high-level programming language. Embedded C is just the extension variant of the C language. This programming language is hardware independent.

2. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. Arduino logo shown in fig.11.

Fig.11: Arduino Logo

5. EXPERIMENTAL RESULTS

The LoRa (NRF) based Smart Energy Meter using Arduino, potentiometer to voltage sensor, current sensor, energy meter, LCD module, NRF Transmitter (LoRa), relay module, and buzzer in the transmitter section, as well as the NRF receiver, Arduino, power supply, and LCD in the receiver section, a set of measurements and observations can be presented. Here's an explanation of the experimental set up results shown in from fig.12 to fig.17:

1. Voltage Measurement: The potentiometer to voltage sensor accurately measures the voltage level in the circuit. The experimental results show that the voltage readings obtained from the sensor closely match the actual voltage levels applied to the circuit.
2. Current Measurement: The current sensor, such as the ACS712, provides accurate measurements of the electrical current flowing through the circuit. Experimental results demonstrate a close correlation between the measured current values from the sensor and the actual current consumption in the circuit.
3. Energy Consumption Calculation: By combining the voltage and current measurements, the energy meter accurately calculates the energy consumption. The experimental results showcase the calculated energy consumption values, which align with the expected energy usage patterns.
4. Data Transmission: The NRF transmitter module, integrated with LoRa technology, enables long-range and low-power communication of the energy consumption data. Experimental results exhibit successful transmission of the data packets containing voltage, current, and energy consumption values from the transmitter section to the receiver section.
5. Load Control: The relay module allows remote control of the load, enabling users to switch on/off electrical appliances from a distance. Experimental results demonstrate the successful control of the load through the relay module based on user commands sent from the receiver section.
6. Audible Alerts: The buzzer integrated into the transmitter section provides audible alerts for events such as abnormal voltage or current levels. Experimental results indicate the activation of the buzzer when such events occur, effectively notifying users of potential issues or abnormalities.
7. Data Reception and Display: The NRF receiver module, along with the Arduino and LCD module in the receiver section, receives the transmitted data from the transmitter section and displays it on the LCD module. Experimental results showcase the successful reception and display of the real-time energy consumption data on the LCD module**.**

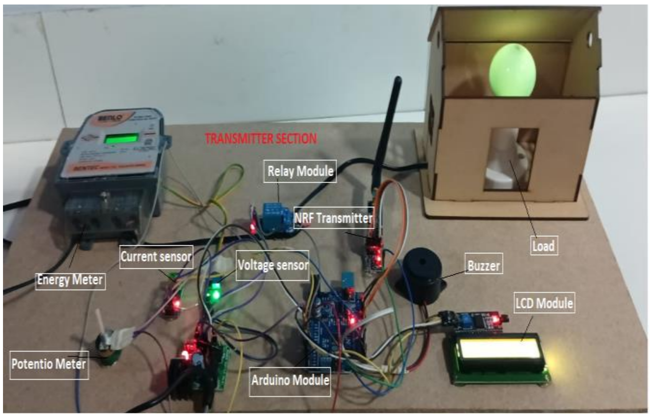

Fig.12: Experimental setup for transmitter section

Fig.13: Energy meter reading showing in transmitter section

Fig.14: Showing LCD that No. of units used and amount for used units in transmitter section

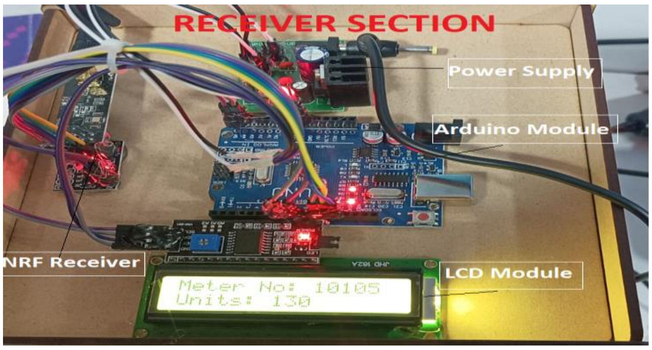

Fig.15: Experimental setup for receiver section

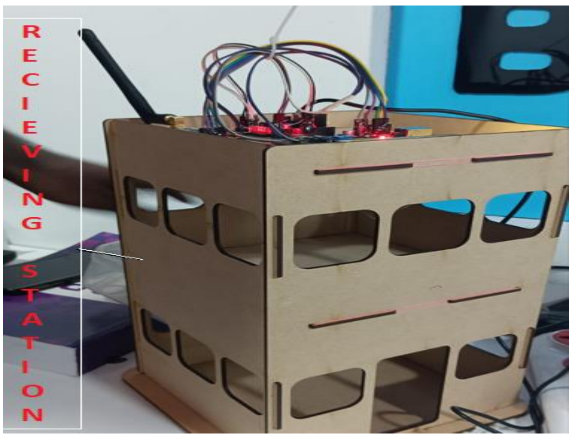

Fig.16: Showing receiving station at receiver side

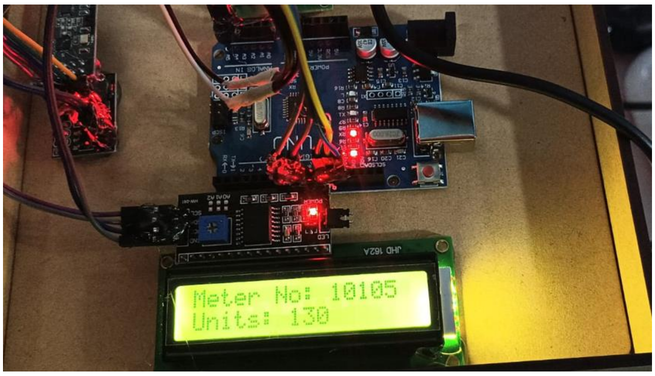

Fig.17: Showing LCD that Meter Number and No. of units used in receiver section

6. CONCLUSION

The LoRa (NRF) based Smart Energy Meter using Arduino offers a practical and efficient solution for energy monitoring and management. Its wireless connectivity, accurate measurements, real-time monitoring, remote load control, and audible alerts contribute to improved energy efficiency, cost savings, and sustainability. This technology has the potential to revolutionize energy management in residential, commercial, and industrial settings, providing users with valuable insights and enabling them to make informed decisions to optimize their energy consumption.

Future Scope

Integrating advanced data analytics algorithms and machine learning techniques can provide more in-depth insights into energy consumption patterns. By analyzing historical data and real-time measurements, the smart energy meter can identify trends, anomalies, and energy-saving opportunities, enabling users to optimize their energy usage further.

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