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IoT Based Smart Energy Meter Monitoring with Theft Detection

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Abstract: *IoT-based applications are becoming more popular and provide effective solutions for many real-time problems. In this project, real-time monitoring and a prepaid system for energy monitoring system are proposed. A solution is a cheap and easy-to-implement and manages energy monitoring system for our daily usage of electric power. In order to overcome human errors, manual labor and cost reducing in energy consumption with more efficiency for the power management system, in this project, we focus mainly on IoT prepaid energy monitoring. The proposed design is to implement a very low-cost wireless sensor network and protocol for smart energy and a web application capable of automatically reading the unit and sending the data automatically for the power users to view their current energy meter reading. By using this system, the users will be aware of the electricity usage in his/her home to reduce the power wastage and cost of consumption. And also we can set the monthly unit limit from web application to restrict the over usage. The system consists of a digital energy meter, ESP8266 Wi-Fi module and web applications for management system. load entered into the energy meter and shown on the IOT. Energy meter supplies a current, and a current sensor measures the load. The ESP8266 Wi-Fi module will be embedded into the meter and implement the TCP/IP protocol for the communications between the meter and the web application.*

Keywords: *Arduino Uno,ESP8266 Module, TCP/IP, IoT ,Wi-fi Module, LCD display*

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I. INTRODUCTION

Electricity is one of the vital requirements for sustainment of contents of life. It should be used very judiciously for its proper utilization. But in our country, we have lot of locality where we have surplus supply for the electricity while many areas do not even have access to it. Our policies of its distribution are also partially responsible for this because we are still not able to correctly estimate our exact requirement and still power theft is prevailing. On the other hand, consumers are also not satisfied with the services of power companies. Most of the time they have complaints regarding statistical errors in the monthly bills. With this we can monitor meter and track if any fault is there or not. In previous meter a circular metal strip rotates and according to that rotation we calculate the consumption. But our meter works on pulse which is obtained with the help of LDR sensor according to consumption and we previously connected Arduino board which monitors the pulse and according to pulse the bill is generated. With the help of this project we are aiming to receive the monthly energy consumption from a remote location directly to centralized office. In this way we can reduce human efforts needed to record the meter readings which are till now recorded by visiting every home individually. Smart energy meter is an electronic device that measures the most accurate amount of electricity consumed by a residence, business or any electrically-powered device. A smart meter is reliable source for most accurate information of consumed energy that reduces the chance of error in the existing billing system to minimal. The work system adopts a totally new concept of "Prepaid Energy Meter" 2

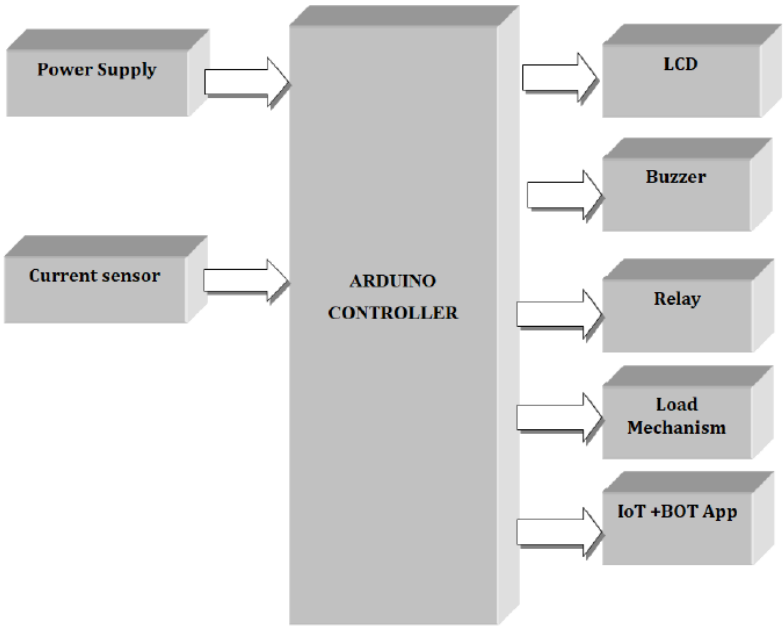

Figure 1. Block diagram of Smart Energy Meter

This model has the Arduino UNO as CPU. The entire system is interfaced with Arduino UNO. The micro controller is serially connected with the controller which is used as communication module between User and provider. The module uses its own network for the transfer of data. Special coding in Arduino is used for programming AT89S51 microcontroller. The relay is used as switching device to cut off and restore power supply. The LCD is interfaced to microcontroller using parallel connection. In this project the Microcontroller based system continuously measures the readings and the current meter reading can be sent to the Electricity department on request.

II. Literature Survey:

An IoT-based smart energy meter designed to enable real-time monitoring of electricity consumption. Their system integrates current and voltage sensors with a microcontroller for accurate measurement of power usage. The collected data is transmitted to a cloud platform using Wi-Fi or GSM modules. This eliminates the need for manual meter reading and reduces human errors in billing. The system provides live updates to both consumers and electricity provider.

1. It supports remote monitoring through cloud integration. The authors highlighted the importance of reducing non-technical losses in power systems. Their design includes tamper detection mechanisms. Real-time alerts are sent via SMS or mobile applications. The system reduces revenue losses caused by illegal power usage. It ensures faster response to unauthorized connections. The study emphasizes automation in energy monitoring. It also reduces dependency on manual inspection. The architecture is simple and cost-efficient. Experimental results showed reliable theft detection performance. The research contributes to secure smart grid development.

1. It supports real-time data visualization. The system minimizes billing inaccuracies. It enhances transparency between consumers and providers. The authors focused on scalable IoT architecture. The design reduces operational costs. It allows efficient energy management. Alerts are generated for abnormal consumption. The system ensures continuous data logging. It supports remote troubleshooting. Their work demonstrates reliable communication between hardware and cloud. The study highlights the importance of IoT in modern energy systems.

1. An IoT-based prepaid smart meter with theft detection. Their system allows users to recharge electricity credits remotely. Energy usage is deducted automatically from prepaid balance. Alerts are generated when balance is low. The model detects meter tampering effectively. It provides automated billing without manual intervention. Theft detection is integrated with load monitoring. The system sends instant notifications during suspicious activity. It improves revenue collection efficiency. The authors

3

emphasized smart grid compatibility. Their design enhances user convenience. It supports cloud data storage. The system reduces electricity misuse. It ensures transparency and accuracy. The research contributes to next-generation prepaid metering systems.

III. METHODOLOGY

The IoT-Based Smart Energy Meter Monitoring with Theft Detection system is designed to modernize traditional electricity metering by enabling real-time monitoring, remote data access, and automatic detection of power theft. Conventional energy meters require manual readings and are vulnerable to tampering, billing errors, and electricity theft. This project addresses these issues by integrating smart sensors, microcontrollers, and Internet of Things (IoT) technology to create an intelligent and secure energy management system. The system uses a microcontroller (such as ESP8266/ESP32 or Arduino) connected to current and voltage sensors to measure real-time power consumption. The collected data is processed and transmitted to a cloud server or web platform via Wi-Fi. Users and utility providers can monitor electricity usage remotely through a mobile application or web dashboard. This enables transparent billing, accurate consumption tracking, and improved energy management. A key feature of the system is theft detection. The system continuously compares the measured current and voltage parameters to identify abnormalities such as meter bypassing, line tapping, or sudden load variations. If any suspicious activity is detected, the system automatically generates alerts via SMS, mobile notifications, or email. In advanced implementations, the system can even disconnect the power supply using a relay to prevent further unauthorized usage. This project improves efficiency, reduces human intervention, enhances billing accuracy, and minimizes revenue losses caused by electricity theft. It is highly scalable and can be deployed in residential, commercial, and industrial environments. Overall, the IoT-based smart energy meter provides a cost-effective, secure, and intelligent solution for modern energy management systems

IV. Hardware Requirements

1.Arduino Controller: The Arduino UNO is a widely used open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits The board features 14 Digital pins and 6 Analog pins. It is programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable.[4] It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts.

2.ESP8266 Module: ESP8266 was designed by the Chinese company Espress if Systems for uses in Internet of Things (IoT) systems. ESP8266 is a complete WiFi system on chip that incorporates a 32-bit processor, some RAM and depending on the vendor between 512KB and 4MB of flash memory. This allows the chip to either function as a wireless adapter that can extend other systems with WiFi functionality, or as a standalone unit that can by itself execute simple applications. Depending on the specific module variant (ESP-1 to ESP-12 at the time of this thesis) between 0 and 7 General Purpose Input/output (GPIO) pins are available, in addition to Rx and Tx pins of the UART, making the module very suitable for IoT applications.

3.Current Sensor: A current sensor is a device that measures the flow of electric current in a circuit. Current sensors are widely used in power systems, industrial automation, and energy monitoring applications to ensure safe and efficient operation of electrical equipment. They help in monitoring load conditions, detecting faults, and controlling electrical devices. One common type of current sensor works based on the electromagnetic field principle. When electric current flows through a conductor, it generates a magnetic field around it. The sensor detects this magnetic field and converts it into a proportional electrical signal.

4.Channel Relay Driver: The 1 Channel Relay Module is a convenient board which can be used to control high voltage, high current load such as motor, solenoid valves, lamps and AC load. It is designed to interface with microcontroller such as Arduino, PIC and etc.

5.Fault Theft Mechanism: The fault and theft detection mechanism works by continuously monitoring electrical parameters such as voltage and current using sensors connected to an Arduino microcontroller. During normal operation, the measured current remains within a predefined safe limit and matches the expected consumption. If the current exceeds the threshold due to overload or short circuit, the system identifies it as a fault and automatically disconnects the supply using a relay to prevent damage. For theft detection, the system compares the current measured at the main distribution line with the consumer-side current; any significant mismatch indicates illegal tapping or meter bypassing. In such cases, the system generates an alert notification and can automatically cut off the power supply to prevent further energy loss.

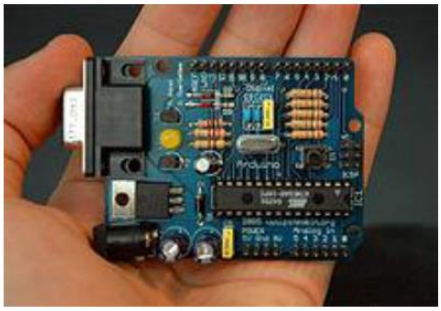

Figure 2: Arduino Controller

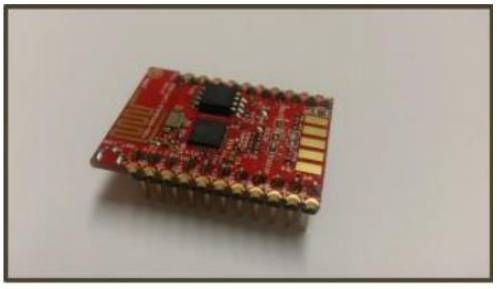

Figure 3: ESP8266 Module

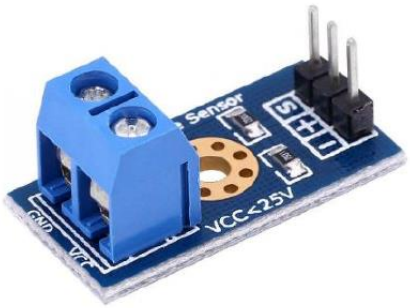

Figure 4: Current Sensor

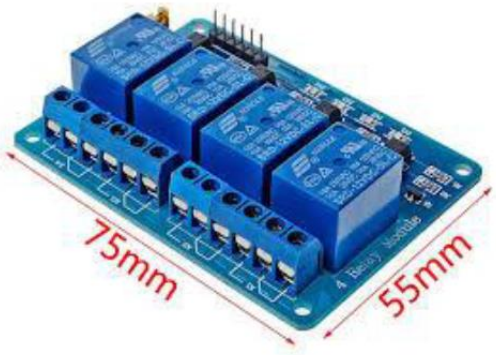

Figure 5:Single Channel Relay Driver

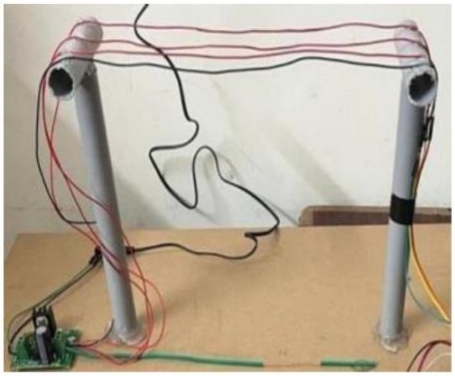

Figure 6: Theft Mechanism

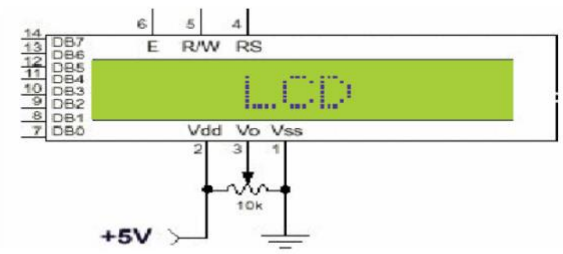

Figure 7: Pin Diagram of 1x16 led

PIN	SYMBOL	FUNCTION
1	Vss	Power Supply(GND)
2	Vdd	Power Supply(+5V)
3	Vo	Contrast Adjust
4	RS	Instruction/Data Register Select
5	R/W	Data Bus Line
6	E	Enable Signal
7-14	DB0-DB7	Data Bus Line
15	A	Power Supply for LED B/L(+)
16	K	Power Supply for LED B/L(-)

5.Software Requirements

The Arduino Software (IDE) is anything but difficult to-use for fledglings, yet sufficiently adaptable for cutting edge clients to exploit too. For instructors, it's helpfully in view of the Processing programming condition, so understudies figuring out how to program in that condition will be acquainted with how the Arduino IDE functions.

Step 1: Download the most recent variant from this page: http://arduino.cc/en/Main/Software. Next, continue with the establishment and please permit the driver establishment process.

Step 2: In this instructional exercise, you're utilizing an Uno R3. You additionally require a standard USB link (A fitting to B plug): the kind you would associate with a USB printer, for instance.

Step 3: The USB association with the PC is important to program The USB association with the PC is important to program the board and not simply to control it up. The Uno and Mega consequently draw control from either the USB or an outside power supply. Associate the board to your PC utilizing the USB link . Open the LED blink example sketch: CD > For Arduino>Demo Code>Lesson1-LED_bink>led blink.

Step 4: You'll need to select the entry in the Tools > Board menu that corresponds to your Arduino board. Select the serial gadget of the board from the Tools | Serial Port menu. This is probably going to be COM3or higher (COM1andCOM2are generally held for equipment serial ports). To discover, you can detach your board and re-open the menu; the passage that vanishes ought to be the Arduino board. Reconnect the board and select that serial port. 6

Step 5: Presently, essentially tap the "Transfer" catch in the earth. Hold up a couple of moments - you should see the RX and TX leds on the board blazing. On the off chance that the transfer is fruitful, the message "Done transferring." will show up in the status bar. A few seconds after the upload finishes, you should see the pin 13 (L) LED on the board start to blink (in orange). If it does, congratulations! You've gotten Arduino up-and-running.

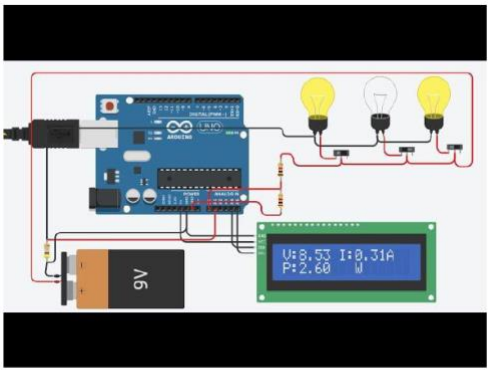

Figure 8: Schematic Diagram

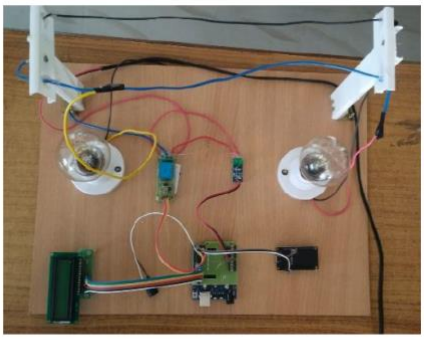

Figure 9: Structure of Smart Energy Meter

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Conclusion

This provides an efficient and reliable solution for monitoring electricity consumption and preventing power theft. In this system, the **Arduino controller** acts as the central unit that collects data from the **current sensor** to measure power usage accurately. The measured data is displayed on the **LCD** and transmitted to the **IoT and BOT application**, allowing users and authorities to monitor energy consumption remotely in real time. If any abnormal usage or theft is detected, the system activates the **buzzer** for alert and controls the **relay** to disconnect

the load if necessary. This approach improves energy management, reduces manual meter reading, enhances security, and ensures transparent monitoring of electricity usage. Overall, the proposed system is cost-effective, reliable, and suitable for modern smart grid and smart home applications. 7

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