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An Arduino-based system for the intelligent monitoring and prevention of theft associated with electricity

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Abstract - Theft of energy is a significant issue in countries such as India, where the population is growing at the same time as energy consumption is increasing. The utilities that operate inside the electrical grid suffer enormous financial losses as a result of this illicit behaviour. Despite the installation of Advanced Metre Reading (AMR) equipment, which are designed to increase the accuracy of energy measurement, administrative losses resulting from power theft continue to occur. This is mostly due to the fact that irregular inspections are carried out at the locations of customers. Because of the magnitude of the problem, conventional methods of combating theft, such as conducting physical door-to-door inspections, are effectively ineffective. The purpose of this study is to provide a unique approach to identifying and regulating compromised energy metres that have been affected by power theft by using the Atmega328P embedded microcontroller. The proposed method enables prompt action to be taken in order to shut off and restore service as soon as unlawful activity is discovered. This is made possible by the remote detection and administration of metres that have been tampered with. In the event that any irregularities are discovered, the GSM module will promptly transmit a text message notification to the utility's central server. After that, a message that is a match is sent to the microcontroller, which results in the power supply that is not authorised being turned off. This integrated solution provides a new way to address billing discrepancies, decrease voltage fluctuations in the electrical grid, and combat non-technical losses. It does this by using solid-state relay technology and the GSM capabilities that are present in smart metres. This system offers a proactive method to safeguard utility revenues and ensure efficient energy distribution. It does this by integrating communication technologies and hardware in a seamless manner.

Keywords- **Ardunio, Intelligent, Electricity, GSM, Remote, Microcontroller, Energy theft.**

I. INTRODUCTION

There are many aspects of modern life that are powered by electricity, which is a beautiful gift from science to humanity. When this energy is used without authorization, however, not only does it result in losses to the utility company, but it also causes the environment to deteriorate. There are two primary categories of losses that may be found in the electrical energy business. These categories include technical losses and non-technical losses. There are technical losses that occur as a consequence of the inherent inefficiency of the equipment that is used across the whole network of power generation and delivery. Non-technical losses, on the other hand, are caused by abnormalities and intervention in utility operations that has not been authorised [1]. This kind of interference is particularly prevalent in developingnations such include India.

In order to address these concerns, a comprehensive system that consists of a digital energy metre, an Arduino microcontroller, a GSM modem, and a Solid-State Relay (SSR) is described [2]. When the SSR is activated, it establishes a connection between the energy metre and the load by using the Arduino and the GSM modem [3]. The next step in the process involves the system reading data from the EEPROM and displaying it for monitoring purposes. Most importantly, the Arduino makes use of two sensors to monitor voltage and current. These sensors are referred to as the CT (Current Transformer) and the PT (Potential Transformer). By measuring the current difference between the CT sensors and recognising fluctuations in supply voltages, the system ensures that the customer's equipment is protected. This is accomplished by assessing those differences [4,5]. When it comes to energy management, the microprocessor is also responsible for controlling and efficiently managing the solid-state relay. The microprocessor gives the relay instructions to cut and reconnect the power supply as necessary. A proactive approach to reducing losses and guaranteeing the sensible use of energy sources is provided by the system that has been described. This is accomplished via the integration of these aspects.

II. EXISTING SYSTEM: ENERGY METERING

Through continuous monitoring of the instantaneous voltage and current, conventional energy metres are able to calculate the amount of energy that is being used in joules. Electronic and electromechanical induction metres are the two distinct kinds of electricity metres that are most often used [6]. There is a one hundred percent rotational connection between the power that is applied and the aluminium disc that is employed by electromechanical

induction metres. But electronic metres give more extensive data; they display power consumption, power factor, reactive power utilisation, and other characteristics digitally on LCD or LED panels. Electronic metres also provide additional information [7, 8]. The fact that this connection is often unidirectional, electronic metres have the capability of transmitting measurements of energy consumption to remote locations over various communication networks.

It is possible for electronic metres to record other characteristics in addition to energy consumption. These characteristics may include voltages, power factor, reactive power usage, as well as immediate and maximum rate of utilisation requirements [9]. On the other hand, standard energy metres have a number of drawbacks that should be considered. First of all, the data collection and billing processes are slowed down since they are dependent on the metre readings that are obtained by metre readers during visits to the premises of customers that occur once every month or once every two weeks [10]. It is challenging to locate and resolve issues in a timely manner due to the fact that these metres sometimes lack the capability to do real-time monitoring. It is also possible that traditional metres are unable to accurately account for abnormalities in the patterns of energy usage, which might result in wasteful management of resources and inaccurate billing [11].

Because manual metre reading relies heavily on metre readers, it is impossible to avoid making mistakes due to human error. When human readers are present, they often fail to cross-check or verify the amount of energy that is being consumed, which increases the likelihood of theft and bribery, particularly during events. Additionally, the possibility of altering values via the use of software tools when taking images of energy metres is another factor that makes the quality of data collection more difficult to achieve [12]. When there is a larger workforce of metre readers, the company will incur greater costs for hiring new employees and for travel expenses. Furthermore, when energy metres are installed inside of homes, it is likely that readings would be disregarded due to the fact that the premises are closed. This would lead to inconsistent updates of the overall energy consumption of users, as well as probable delays in the delivery of energy bills in accordance with the typical billing cycle [13].

III. PROPOSED SYSTEM

When a smart energy metre works directly via wireless data protocols, it is not essential for the metre to be manually read at the customer's location [14]. The capability of these metres to communicate via GSM modules in addition to other channels not only ensures precise readings but also reduces the need for labor-intensive processes that are often associated with reading metres [15]. There are several benefits associated with smart energy metres, including the reduction of human costs associated with manual readings and the facilitation of accurate billing via the transmission of accurate use data to the utility provider on a consistent basis. Utilities have the ability to remotely cut off and restore connections for customers who do not pay their energy bills on time, which means that on-site excursions may be avoided. The service provider is alerted to any attempts at tampering by lever switches that are installed on smart metres[16]. In addition, these metres protect consumer devices by re-connecting to the supply in the case that there are issues with the power quality coming from the distribution network [17,18].

It is then that the Solid-State Relay (SSR) is engaged, the Arduino and the GSM modem are switched on, and the energy metre is linked to the load via the SSR. The metre that comes next displays the current reading after receiving data from the EEPROM storage device [19]. For the purpose of identifying discrepancies, the Arduino continuously monitors the values of the voltage and current sensors (PT and CT). When the values of the CTs linked in the phase and neutral lines are different, the Arduino closes the relay and sends a text message to the service provider to notify them of the situation [20]. The Arduino makes it simpler for the utility company to turn off the power supply in the event that payments are late. When seen from the perspective of the customer, smart energy metres have the advantage of enabling them to monitor their daily or monthly use, recognise fluctuations in voltage, and get warnings when the supply is withdrawn. This, in turn, encourages efficient energy management and conservation.

IV. SYSTEM ARCHITECTURE

The Arduino and GSM-based smart energy meter's system architecture combines a large number of components in order to provide an accurate estimation of energy use, as shown in Figure 1. The Arduino microcontroller is the central component of the system. It is responsible for monitoring and processing data as well as carrying out activities that prevent power theft. The Electronic Control Unit (IC) of the Energy metre, the LCD display, the Arduino board, the GSM modem, the relay, the optocoupler, the lever switch, the display unit, and the power supply unit are the several components that comprise this intelligent energy metre system.

In the architecture of the system, the voltage transformer, which is also often referred to as a potential transformer (PT), plays a significant contribution. Through the use of precision step-down transformers (PTs) with precise turn ratios, high-voltage signals are converted into lower voltages that are suitable for measurement [21]. Within the framework of the proposed system, the PT is responsible for reducing the voltage in order to provide accurate measurement by the Arduino, GSM modem, Solid-State Relay (SSR), and digital energy metre. Due to the fact that higher voltage and current levels cannot be directly monitored, this adjustment is absolutely necessary. As a result, the system is equipped with two current sensors and one voltage sensor in order to effectively monitor energy use and prevent power theft. The smart energy metre system, which is based on

Arduino and GSM, ensures accurate measurement and efficient management of power consumption by making use of these components and characteristics.

Fig. 1: Solid State Relay

Electrical supply control is comprised of a number of fundamental components, including relay connections and disconnections. On the other hand, a contemporary alternative known as the Solid State Relay (SSR) has emerged in order to mitigate the inherent drawbacks that are associated with traditional electrical relays. Due to the fact that they are fully electrical and contactless, SSRs do not have any moving components, in contrast to conventional relays. Rather of relying on mechanical connections, SSRs make use of power transistors, thyristors, or triacs. This allows them to circumvent the wear and tear normally associated with traditional relay systems. Through the division of the input control voltage and the output load voltage, light sensors of the optocoupler type are able to make SSRs work in a precise and efficient manner [22]. Since SSRs are semiconductors, it is necessary to have efficient heat dissipation systems, which are often heat sinks, in order to prevent the semiconductor devices from overheating while they are operating for a long period of time. By using the advantages of SSR technology while catering to its thermal management requirements, electrical systems have the potential to extend their longevity and reliability while also lowering the amount of maintenance that is required.

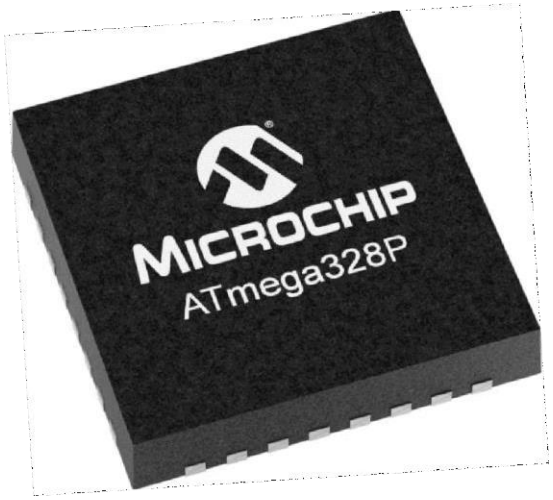

Fig-2: MICROCONTROLLER Atmega328P

The distinctive characteristics of the Atmel Pico Power 8-bit AVR RISC-based microcontroller include an impressive combination of advanced functionality and exceptional performance. Featuring 32 kilobytes of read-while-write In-System Programmable (ISP) flash memory, a generous 1024 byte EEPROM, and 2 kilobytes of SRAM, this microcontroller offers a generous amount of memory and storage space within its design. Additional versatility in interacting with peripherals and other devices is provided by its 32 general-purpose working registers and 23 general-purpose input/output lines. In addition, the microcontroller has three timers and counters that can be adjusted, and it also has compare modes, which enables precise timing activities. In addition to this, it permits interruptions from both the inside and the outside, which makes the management of asynchronous events more efficient. The serial programmable Universal Synchronous/Asynchronous Receiver/Transmitter (USART) features of this microcontroller make it possible to establish a seamless connection with a wide variety of devices and systems. These features are widely used in embedded applications.

Fig-3: GSM Module

"It is the GSM/GPRS module that serves as a vital connector that enables communication between

computers and GSM-GPRS systems. In addition to being widely recognised as the basis for mobile cellular communication systems, the Global System for Mobile Communication (GSM) provides a standardised framework that is supported by a large number of countries all over the world. GSM modems, such as the Sim900A-RS232, are equipped with essential components required for seamless computer integration. These components include a power supply, as well as USB and RS-232 connection interfaces. In addition to being an essential component of these modules, the modem is the fundamental component that enables the transmission and receiving of data and serves as the basis for trustworthy communication networks. Due to its robust construction and adaptable interfaces, the GSM/GPRS module is an essential component in the facilitation of communication and the exchange of data across a wide range of applications and different industries.

V. HARDWARE IMPLEMENTATION

The consumption of kilowatt-hours is calculated by multiplying the data of one current sensor and one voltage sensor in a typical single-phase energy metre. However, if any of these sensors register zero values, there is a possibility that the energy metre may record zero kilowatt-hours. This might happen in the case that there is an unlawful tapping into the power lines. When an additional current sensor is connected to a solid-state relay, there is little interference with the working of the energy metre [23]. This is done in order to fix the issue and prevent power theft on the market. In the event that it is required, this arrangement makes it simpler to attach and remove the power source, and it also makes it possible to identify instances of power theft. A steady 5V DC supply is provided to both the LCD unit and the microcontroller in order to ensure that they continue to work without interruption. Through the use of a GSM modem, which is responsible for establishing contact between the microcontroller and the utility centre, real-time data transmission and monitoring are made feasible. The smart metre is equipped with a lever switch that may detect any potential disturbances or manipulation that may occur physically [24]. Therefore, it is important to emphasise that the job of finding unlawful loads that have been tapped before the metre is not well covered by this model that has been provided [25]. The employment of this all-encompassing strategy makes single-phase energy metres more effective and beneficial in detecting and preventing power theft, as well as ensuring precise monitoring and measurement of energy use.

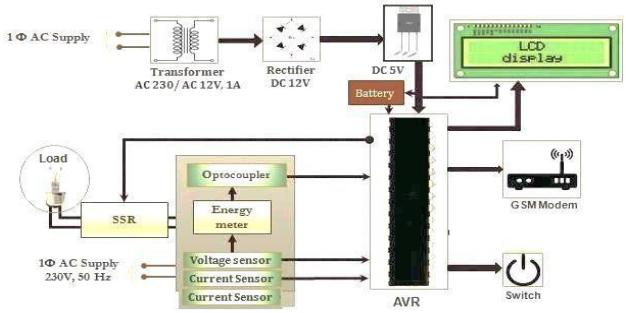

Fig-4: AVR system Implementation Circuit Diagram

VI. SOFTWARE REQUIREMENT

Compilers are used by the languages that are used to develop Arduino programming in order to generate binary machine code that is executable. A more advanced development environment is provided by Atmel for their microcontrollers. This environment includes the more modern Atmel Studio as well as the well-known AVR Studio environment. The Arduino development platform is simple to use and accessible even for inexperienced programmers. This is due to the fact that it utilises an Integrated Development Environment (IDE) that is based on Java cross-platform application principles. programmes, also known as sketches, are developed inside the Arduino ecosystem by using a combination of C and C++ syntax. These programmes are backed by Arduino libraries, which provide a wide variety of pre-defined inputs for a variety of activities. In any Arduino sketch, the setup() and loop() functions are two of the most essential actions. The setup() function is used to initialise settings that are only executed once at the beginning of the programme, in contrast to the loop() technique, which allows for the repetition of certain activities until the board is switched off, hence permitting a cyclical execution of programme instructions. Through the use of Arduino microcontrollers, this architecture facilitates the development of applications that are both versatile and efficient.

VII. CONCLUSIONS

Compilers are used by the languages that are used to develop Arduino programming in order to generate binary machine code that is executable. A more advanced development environment is provided by Atmel for their microcontrollers. This environment includes the more modern Atmel Studio as well as the well-known AVR Studio environment. The Arduino development platform is simple to use and accessible even for inexperienced programmers. This is due to the fact that it utilises an Integrated Development Environment (IDE) that is based on Java cross-platform application principles. programmes, also known as sketches, are developed inside

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