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# Household Energy Monitoring System

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**ABSTRACT:** The Power Theft Detection and Power Billing System is a state-of-the-art method of controlling electricity that is introduced in this article. Using microcontrollers, this system takes advantage of the Internet of Things (IoT) to provide continuous energy use monitoring and ease billing. The Atmega 328p automates the generation of bills, reducing errors and improving accuracy. In addition, the NodeMCU gives customers the ability to monitor their usage in real time, giving them the information they need to make wise decisions about how best to manage their energy. In addition, the system protects infrastructure and electrical devices by including safeguards against overload and voltage fluctuations. Most significantly, it incorporates anti-theft measures that support a fair and moral electricity distribution system by recognizing and reporting anomalous usage trends. The Power Theft Detection and Power Billing System, in short, marks the beginning of a new era in intelligent energy management and is poised to completely transform the way that electricity is used, billed, and secured

**KEYWORDS:** Power Theft Detection, Automated Billing, Power Variation Detection, Fire Detection, IoT Technology.

## I. INTRODUCTION

In the realm of energy management, the persistent challenges of power theft, inaccurate billing, and inefficient consumption have underscored the necessity for innovative solutions. This introduction presents a pioneering endeavor aimed at addressing these challenges: the development of a Power Theft Detection and Power Billing System. Grounded in the convergence of advanced microcontroller technology and Internet of Things (IoT) capabilities, this system represents a paradigm shift in the way electricity is monitored, billed, and safeguarded.

The landscape of energy management is marked by the ubiquity of power theft, a phenomenon that poses significant economic and operational burdens on utility companies and honest consumers alike. Traditional methods of detecting and preventing power theft have often fallen short, necessitating a more sophisticated approach. In response, our project endeavors to combat power theft through meticulous analysis of power consumption patterns, leveraging the computational power of Atmega 328p and NodeMCU microcontrollers.

Furthermore, the inefficiencies inherent in manual billing processes have long plagued consumers and utility providers, leading to billing inaccuracies and disputes. To address this challenge, our system introduces automated billing capabilities facilitated by the Atmega 328p microcontroller. By automating the billing process, the system not only enhances accuracy but also streamlines the billing workflow, alleviating the burden on consumers and utility companies alike.

Moreover, the advent of IoT technology has ushered in a new era of connectivity and real-time data analytics. Harnessing the power of NodeMCU microcontroller, our system enables users to monitor their electricity consumption in real-time, empowering them to make informed decisions to optimize energy usage and reduce costs. This real-time monitoring capability not only enhances consumer awareness but also facilitates proactive energy management strategies.

## II. RELATED WORKS

Power theft is a significant hurdle to achieving universal access to electricity, particularly in developing nations. Here, exposed overhead lines act as easy targets for those seeking to steal electricity. This problem stands in stark contrast to the challenges faced by developed countries, where smart meters and sophisticated grids are more

prevalent.

### The Disconnect Between Existing Research and Developing World Needs

The current landscape of research on power theft detection often focuses on cyberattacks targeting smart grids. While this is a crucial area of study, it doesn't directly address the primary concern in developing nations: physical theft from bare conductor lines. This disconnect highlights the need for research that tackles the specific challenges faced by these regions.

Many existing studies rely heavily on data analysis from smart meters to identify anomalies indicative of power theft. This approach proves ineffective in developing nations where smart meter penetration is low or non-existent. Some research delves into methods utilizing predictive models for technical loss (losses due to inefficiencies) in electrical grids. However, differentiating technical loss from power theft becomes a challenge when smart meter data isn't readily available.

There have been attempts to address power theft detection in smart grids, but these solutions often overlook the bi-directional power flow present in microgrids, a growing concept gaining traction in developing areas. Microgrids are smaller, localized grids that can operate independently of the main grid, making them a promising solution for areas with limited access to traditional electricity infrastructure.

### A New Approach: Power Theft Detection in Microgrids

This research gap paves the way for a new approach to power theft detection, specifically tailored for microgrids in developing nations. Here, the focus shifts from cyberattacks to physical tampering with distribution lines, the most common method of theft in these regions.

The authors propose a set of algorithms designed to address two key challenges:

1. **Detection:** Identifying instances of power theft occurring through tampering with distribution lines.
2. **Data Routing:** Efficiently routing the collected data for analysis. This is particularly important in resource-constrained environments where bandwidth and processing power may be limited.

The proposed algorithms offer a vital tool for microgrid operators to identify and combat power theft. This, in turn, leads to several benefits:

- **Reduced Revenue Loss:** By curbing power theft, electricity providers can recoup lost revenue, allowing them to invest in grid infrastructure improvements and expand access to electricity.
- **Improved Grid Stability:** Power theft disrupts the delicate balance of supply and demand within a grid. Effective detection can help maintain grid stability, ensuring reliable electricity supply for legitimate consumers.
- **Fairer Electricity Pricing:** When a significant portion of electricity is stolen, it translates to higher costs for legitimate users. Addressing power theft can pave the way for fairer electricity pricing for all.
- **Beyond the Algorithm: A Multi-pronged Approach**
- While the proposed algorithms represent a significant step forward, a truly comprehensive approach to power theft requires a multi-pronged strategy. Here are some additional considerations:
- **Field Testing:** Validating the proposed algorithms in real-world microgrid settings is crucial for ensuring their effectiveness and adaptability to diverse situations.
- **Low-Cost Implementation:** Developing cost-effective solutions for algorithm implementation and data collection is essential for widespread adoption in resource-limited environments.
- **Consumer Engagement:** Encouraging responsible electricity consumption through education and community outreach programs can reduce the incentive for theft and promote a culture of sustainable energy use.

By combining innovative detection methods with practical implementation strategies and consumer engagement initiatives, we can move closer to a future where power theft is no longer a significant barrier to achieving universal access to electricity in developing nations. This not only improves the quality of life for individuals but also paves the way for economic growth and development in these regions.

This research not only addresses a critical gap in existing knowledge but also sets the stage for further exploration and collaboration. As we move forward, a focus on developing cost-effective and adaptable solutions, coupled with community engagement efforts, will be key to overcoming the challenge of power theft and ensuring equitable access to electricity for all.

### III. BLOCK DIAGRAM

When someone touches a grid wire to steal electricity, the appropriate components shown in the block diagram are used to detect the theft, and the Blynk mobile app notifies the authorities of the theft.

Additionally, the detection of automation billing for our current system relies on manual labor to bill household electricity usage, which is labor-intensive and time-consuming because workers must visit each home to check the meter and produce a bill.

power changes, such as undervoltage, overvoltage, and overload, are detected using a buzzer in conjunction with block diagram fire detection.

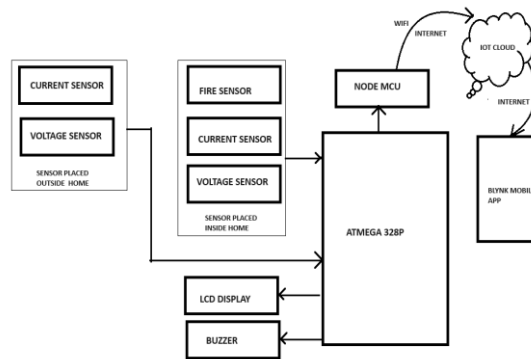


Fig. 1: Block Diagram

Fig. 1. Shows the block diagram of the proposed system. The hardware and software requirements are elaborated in detail in next chapter.

### IV. HARDWARE REQUIREMENTS

#### 1. Arduino UNO Microcontroller

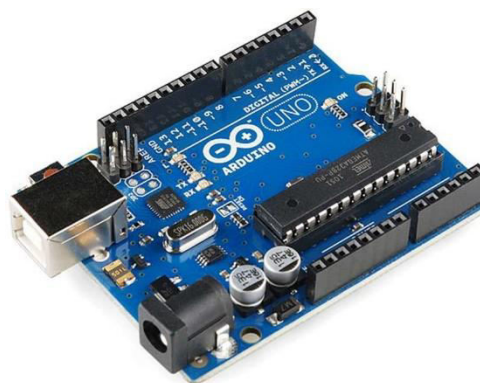
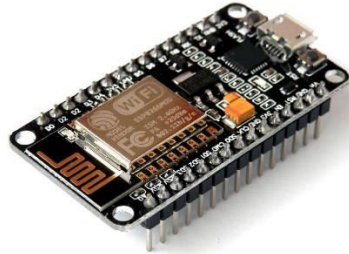


Fig. 2: Arduino board having ATmega 328PU Microcontroller

An Arduino microcontroller, a user-programmable device ideal for designing electronic equipment thanks to its open-source nature, can perform specific tasks as instructed. The Arduino board itself features pins for both digital and analog input/output (I/O) to receive and transmit information. These pins connect to breadboards for easy prototyping, and the board's functionality can be expanded with additional modules or custom circuits. One such board is the Arduino UNO, built around the ATmega328PU microcontroller. It offers around 20 pins, with six dedicated to analog inputs, and includes a reset button, a USB port for programming and power, a resonator for clock speed, and a built-in power supply unit.

## 2. Node MCU



**Fig. 3:** ESP8266 NodeMCU CP2102 Board

Prominent for its affordability and ease of use, the ESP8266 NodeMCU CP2102 Board is an interactive, programmable development platform that is open-source. With its Wi-Fi connectivity, users may easily develop intelligent Internet of Things devices and projects. Streamlining the development process, this Arduino-inspired hardware IO board includes necessary parts such as a TR switch, balun, LNA, power amplifier, matching network, PLL, regulators, DCXO, and power management units. It has an inbuilt USB to serial chip that makes programming and uploading code through the Arduino IDE simple. It is the preferred option for Wi-Fi enabled projects since embedded logic level converter circuits and a 3.3V regulator provide dependable and stable performance. The ESP8266 NodeMCU CP2102 Board provides unparalleled ease of use for IoT application prototyping and experimentation, thanks to its handy breadboard-friendly compact factor and convenient access to GPIO pins.

## 3. Voltage Sensor



**Fig. 4:** Voltage Sensor

The Voltage Detection Sensor Module 25V offers precise voltage monitoring capabilities across a wide DC 0-25V range. This module provides comprehensive coverage for a range of applications, with accurate voltage detection as low as DC 0.02445V to a maximum voltage of 25V. With a voltage analog resolution of 0.00489V, this voltage sensor offers precise and comprehensive voltage measurements. Additionally, a 3P connector facilitates a seamless integration into Arduino-based applications by making it simple for users to interface this module with an Arduino expansion board. Furthermore, users can increase accessibility and utility by using the IICLCD1602 LCD to graphically depict voltage measurements. In general, the Voltage Detection Sensor Module 25V provides a stable and efficient solution for voltage monitoring needs in electronic projects and applications.

#### 4.Current Sensor:

An apparatus that senses electric current and transforms it into a voltage or signal proportionate to the current is called a current sensor. They are employed in many different applications, including motor control, overload protection, and power management systems.



Fig. 5: Current Sensor

This sensor boasts a low-noise analog signal path, ensuring accurate current readings. For optimal performance, the device bandwidth can be customized through a dedicated "FILTER" pin. Despite its compact size in a low-profile SOIC8 package, it delivers a fast response with a 5-microsecond output rise time in reaction to changes in current. The sensor offers a high level of isolation with a minimum voltage of 2.1 kVRMS between input and output sides. It operates on a DC supply voltage ranging from 4.5 to 5.5 volts and is designed to measure currents up to 30 amps. Additionally, it features a sensitivity of 100 millivolts per amp, making it ideal for various current measurement applications.

#### 5.LCD Display

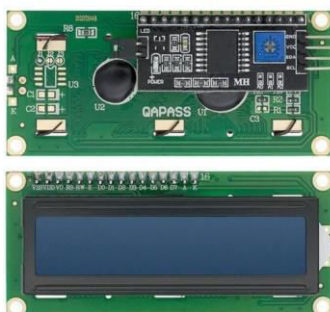


Fig. 6: LCD Display

With this little LCD1602 display module, you may effectively and clearly convey information visually in your projects. It has a traditional 16-character by 2-line layout that lets you see text, numbers, and even simple symbols in a clear white background. The display has a cool blue lighting for excellent viewing, making it simple to read even in dimly lit environments.

The module connects using the I2C communication protocol. This reduces clutter and complexity in wiring by just needing a few wires to link the display to your microcontroller. This module's unique I2C address is 0x27, which your microcontroller code will use to talk to the display.

## 5. Buzzer



With a sound pressure level of 85 decibels, this buzzer provides a loud and clear alarm that is perfect for drawing attention in settings with moderate noise levels. The buzzer runs on a 12VDC power supply, which is often supplied by power adapters and a variety of electronic equipment. Its elegant black style guarantees that it works well with a variety of projects. The buzzer is pre-wired with a 110 millimeter cable, making installation simple and preventing the need for extensive wiring adjustments.

## 6. Flame Sensor



Impressive capabilities for dependable fire detection are offered by this flame sensor module. The LM393 comparator chip, which powers it, is at the center and guarantees reliable readings. Because the module runs on a broad voltage range of 3.3V to 5V, it can be powered by a variety of sources. Its quick reaction time, which enables prompt flame detection, is one of its main advantages. In addition, the sensitivity can be changed to fine-tune the detection level for the best results in your particular application. The 760nm–1100nm wavelength band, which is very sensitive to the flame spectrum, is where the sensor finds light sources. The sensor has an approximately 60-degree detection angle, and its detection range is configurable up to 100 cm. It is a useful tool for fire safety applications because of its flexibility and attention to the flame spectrum.

# V. SOFTWARE REQUIREMENTS

## 1. Arduino IDE



Fig. 7: Arduino IDE

Here's an even more detailed explanation of Arduino, incorporating the strengths of the previous versions and addressing potential areas for improvement:

Arduino isn't just a platform; it's a revolution in democratizing electronics creation. Imagine a world where anyone, from students to artists to engineers, can bridge the gap between imagination and reality by building interactive objects and intelligent devices. That's the magic of Arduino!

This open-source philosophy means the underlying designs and software are freely available for anyone to use and modify. This fosters a vibrant and collaborative community where users share ideas, troubleshoot problems, and constantly push the boundaries of what's possible. Whether you're a seasoned programmer or a complete beginner, Arduino welcomes you with open arms.

The user-friendly programming environment, based on Processing and similar to C/C++, provides a gentle learning curve. No need for expensive specialized tools! Arduino boards come pre-programmed with a bootloader, a tiny program that acts like a bridge between your computer and the microcontroller on the board. This bootloader allows you to easily upload your code from a standard computer using a USB cable. It's like dragging and dropping your ideas directly onto the hardware!

This seamless integration of open-source hardware, beginner-friendly software, and a streamlined upload process empowers anyone to explore their creativity and delve into the world of electronics. Imagine a child building a robot that reacts to light, an artist creating an interactive light installation, or a scientist developing a sensor to monitor environmental conditions. With Arduino, these possibilities become realities. It's a platform that fosters innovation, education, and a sense of accomplishment, making it a valuable tool for makers, hobbyists, and professionals alike

## 2. Blynk Mobile Application



Fig. 8: Blynk Mobile Application

An Internet of Things platform called Blynk is used to operate Arduino, Raspberry Pi, and Node MCU from a mobile device running iOS or Android. This program is used to create a graphical user interface (HMI) or connection point by adding and designating the appropriate place on the devices that are available. IOT was meant to be Blynk's domain. It can imagine things, store information, display sensor data, and perform a host of other amazing tasks. It can even remotely control equipment.

The Blynk app allows you to create fantastic points of contact for your projects by leveraging the various devices provided

ii) Blynk Server: It is responsible for all exchanges between the equipment and the phone. Either use your private Blynk server locally or make use of the Blynk Cloud. It is free and open-source, capable of running on a Raspberry Pi, and could easily handle a large number of devices.

iii) Blynk Libraries: These enable interactivity with all incoming and outgoing orders as well as communication with the server for all well-known equipment phases. Upon pressing the Button within the Blynk program, data is transferred to the Blynk Cloud and thereafter becomes enchantedly transferred to the newly introduced



equipment. Everything happens in an instant and operates in the opposite manner. Making it incredibly easy to support the mobile application is the primary goal of the Blynk stage.

This can be used to open your carport entrance with a phone, screen the dirt dampness of your vegetable nursery, and turn on the water. Also, you may use it to install computer-based intelligence and Internet of Things (IoT) into common modern goods like evaporators, operate on the security and reliability of oilfields, and operate smart furniture that learns from your routines. Personal use and prototyping are permitted with Blynk.

## VI. WORKING METHODOLOGY

### Building an Automated Electricity Billing and Monitoring System with Theft Detection

This document outlines the construction process for an innovative system designed for automated electricity billing, monitoring, and theft detection. Leveraging the combined capabilities of the Atmega328p and NodeMCU microcontrollers, this system offers a comprehensive solution for both electricity consumers and authorities.

#### Hardware Arsenal: Building the Core

The hardware foundation of this system comprises several key components, each playing a crucial role in data acquisition, processing, and communication:

##### Microcontroller Minds:

**Atmega328p:** This versatile microcontroller serves as the workhorse for real-time data acquisition. Connected to current and voltage sensors, it continuously measures electricity flowing through the line. Furthermore, it performs calculations for power consumption, generates bills based on pre-defined tariff structures, and monitors power quality for potential issues like undervoltage, overvoltage, and overloads. It also triggers alerts for these disturbances and manages communication with the NodeMCU for data transmission.

**NodeMCU:** Acting as the communication bridge, the NodeMCU utilizes its built-in Wi-Fi capabilities to transmit data wirelessly from the Atmega328p to the Blynk server. This enables remote monitoring and user interaction.

##### Sensor Network: The Eyes and Ears of the System

**Current Sensor:** This sensor, like the ACS712, plays a vital role by measuring the current flowing through the electricity line. This data, along with voltage readings, forms the basis for calculating power consumption.

**Voltage Sensor:** Paired with the current sensor, a voltage sensor (e.g., ACS712 with voltage adapter) measures the voltage across the line. Combined with current readings, it provides a complete picture of electricity usage.

**Fire Sensor:** Safety is paramount. A fire sensor, such as the MQ-2 Smoke Sensor, is integrated into the system to detect smoke or heat, indicating potential fire hazards. When triggered, it promptly sends alerts through the user interface, enabling swift intervention.

##### Additional Components:

A 16x2 LCD display can be optionally integrated to provide local visualization of key data like current power consumption and voltage levels.

A buzzer serves as an audible alert system, notifying users of power disturbances, fire hazards, and theft detection.

Connecting wires, resistors, capacitors, and a breadboard complete the hardware assembly, with component values determined by chosen sensors and circuit design.

##### Software Symphony: Programming the Brains

The software development process involves programming both the Atmega328p and NodeMCU microcontrollers, as well as creating a user-friendly interface on the Blynk app.

##### Atmega328p Programming:

Utilizing the Arduino IDE or similar platforms, code is developed to leverage sensor communication libraries specific to the chosen sensors (e.g., ACS712 library).

##### Algorithms are implemented to:

Convert real-time current and voltage measurements into power consumption.

Monitor power quality for potential issues like undervoltage, overvoltage, and overload, triggering alerts when

necessary.

Generate bills based on calculated power consumption and pre-defined tariff structures.

Process fire sensor data and trigger alerts for potential fire hazards.

Establish a serial communication protocol for data transmission to the NodeMCU.

NodeMCU Programming:

Similar to the Atmega328p, code is developed using the Arduino IDE with ESP8266 libraries specific to the NodeMCU.

Wi-Fi credentials are configured for connection to the Blynk server, enabling data transmission.

A secure connection with the Blynk server is established using Blynk libraries and user authentication to safeguard data privacy.

The code facilitates receiving data from the Atmega328p via the defined serial communication protocol and transmits it to the Blynk server at set intervals.

Blynk App Development:

The Blynk platform allows for the creation of a user interface (UI) that facilitates data visualization and user interaction. The UI incorporates various widgets:

Gauges display real-time data on current, voltage, and power consumption, providing a clear picture of electricity usage.

Value displays can showcase current bill amounts and historical usage data, offering insights into consumption patterns.

Notification alerts (both visual and audible) keep users informed of power disturbances, fire hazards, and theft detection, ensuring timely action.

Optional buttons can be implemented to allow users to acknowledge alerts or perform specific actions (e.g., reset bill after payment).

## VII. RESULTS AND DISCUSSION

Future Developments and Issues to Be Considered

Smart Grid Integration: Examine how this system might be seamlessly integrated with smart meters as smart grid technologies proliferate. This might lead to improved data collecting, real-time grid monitoring, and even two-way communication capabilities.

Prepaid Electricity Management: By adding prepaid electricity management to the system, users would be able to remotely top off their accounts and get warnings when their credit is running low.

Data analytics and machine learning: By utilizing machine learning algorithms and historical data, predictive maintenance may be able to detect possible equipment breakdowns and improve grid management tactics.

Social and Regulatory Considerations: A thorough assessment of social and regulatory factors is necessary before putting such a system into place. Campaigns to raise user awareness and transparent communications about data privacy are essential to user approval. Regulatory approval may be required, based on the particular region and the relevant authorities.

We can build an automated electricity billing and monitoring system with theft detection that is reliable, safe, and easy to use by taking these factors into account and never stopping developing. By encouraging responsible usage, lowering income losses, and guaranteeing a more dependable and secure electricity supply for everybody, this system has the potential to completely transform the electrical industry.

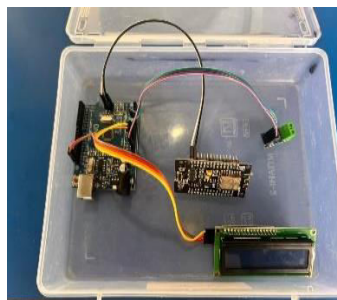


Fig.11: Circuit Connection

## VIII. CONCLUSION

The current method of power management is confronted with issues such as disruptive theft and time-consuming manual meter reading. An appealing alternative is the automated electricity billing and monitoring system that is being suggested, complete with theft detection features. All parties involved—consumers, authorities, and utilities—win thanks to the utilization of microcontrollers and user-friendly interfaces.

With automated billing and real-time access to consumption statistics via an easy-to-use mobile app, customers experience a world of ease. This gives individuals the ability to decide with knowledge in order to maximize consumption and possibly cut expenses. Furthermore, a safe and dependable supply of electricity is guaranteed by real-time monitoring of power quality changes and outage notifications. Integrated fire sensors provide an additional degree of safety by instantly alerting users through the app, enabling prompt action in the event of a possible fire hazard.

A more effective method is advantageous to the authorities. Collecting data automatically frees up people resources for other important duties. Proactive grid management is made possible by real-time data, which enables authorities to recognize and resolve possible problems before they get out of hand. Through the identification of possible theft activity, the prevention of further attempts, and the recovery of lost income, the integrated theft detection system, with its sensor pairs and discrepancy analysis, greatly lowers revenue loss. When authorities are able to handle customer issues about billing inconsistencies, power outages, and grid enhancements, there is an increase in customer satisfaction.

There are substantial cost savings for utilities. Operating costs are decreased when manual meter reading is eliminated. Overall cost benefits also include lower revenue losses from decreased theft and increased grid efficiency. By anticipating possible equipment failures and reducing downtime and related repair costs, the technology also helps with preventative maintenance, which enhances grid reliability overall. Utilities are able to make educated judgments on grid upgrades, infrastructure expenditures, and future energy policies because of the abundance of important data on consumption patterns, grid performance, and possible theft attempts.

In terms of the future, the suggested method is a first step toward an electrical management that is more sustainable and effective. By identifying customer usage patterns and providing tailored energy-saving advice, utilities will be able to drastically reduce total energy consumption thanks to advancements in data analytics. Two-way communication, dynamic pricing schemes based on real-time demand, responsible use during peak hours, and off-peak usage incentives are made possible by seamless connection with smart grids. Additionally, the system can be modified to include renewable energy sources, such as solar panels, giving users the ability to track their grid contribution and even take advantage of net metering schemes.

In summary, all parties involved benefit from this automated power billing and monitoring system with theft detection. By adopting data-driven decision-making and technology innovations, we are laying the foundation for an electricity system that is safer and more sustainable in the future.

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### BIOGRAPHY



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