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TIME OPTIMISATION AND THEFTDETECTION OF ENERGY N AN INDUSTRIAL PLANT

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Abstract - Electricity theft is a pervasive issue in many regions, posing significant financial losses and safety hazards. This project focuses on monitoring and analyzing electricity board side energy consumption while alsoimplementing theft detection mechanisms. Through a comprehensive hardware setup involving current transformers (CTs), energy meters, optocouplers, Arduino microcontrollers, LED displays, and switches, the system can effectively monitor energy usage across different junctions. By comparing energy consumption between main and subsidiary junctions, potential theft instances can be identified, triggering alerts through LEDs and buzzers. The methodology involves programming threshold values for energyconsumption, facilitating real-time monitoring and theft detection. Results indicate the successful implementation of the system, with implications for enhancing energy security andreducing financial losses due to theft.

Keywords—Energy theft detection, Smart meter data, Electricity consumption, Monitoring system, Theft prevention, Energy meter, Real time monitoring, Smart grid security Junction monitoring,Theft instances, Alert systems, Theft mitigation.

I. Introduction

In today's modern society, electricity has become an indispensable aspect of daily life, powering everything from household appliances to industrial machinery. With the increasing reliance on electrical energy, there arises a critical need for efficient management and monitoring systems to ensure the equitable distribution of power resources. Additionally, the prevalence of electricity theft poses a significant challenge to utility providers, necessitating the development ofinnovative solutions to detect and prevent unauthorized consumption. In

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this context, the project on the monitoring and analysis of electricity board-side energy, coupled with theft detection, emerges as a timely and crucial endeavor [1].

The requirement for robust monitoring and analysis of electricity board-side energy, along with theft detection mechanisms, stems from various socio-economic and environmental factors. Firstly, ensuring fair and equitable distribution of electricity is essential for promoting social welfare and economic development. By accurately monitoring energy consumption patterns, utility providers can allocate resources more efficiently, thereby minimizing wastage andoptimizing energy utilization. Moreover, detectinginstances of theft or unauthorized usage is vital forsafeguarding the financial interests of utility companies and preventing revenue losses. Additionally, with the global focus on sustainability and energy conservation, implementing effective monitoring systems can help identify areas for improvement and promote responsible consumption practices among consumers [2].

Historically, electricity monitoring and theft detection systems have relied on manual inspections and periodic audits conducted by utility personnel. However, these traditional approaches are often time-consuming, labor- intensive, and susceptible to human error. Moreover, the reactive nature of such systems makes it challenging to detect theft in real-time, leading to significant revenue losses for utility providers. While some automated solutions exist, they often lack the sophistication and accuracy required to effectively detect instances of theft or unauthorized consumption. As a result, there is a growing demand for advanced monitoring systemscapable of providing real-time insights into energyusage patterns while proactively identifying potential instances of theft [3].

II. Related Works

Ejaz Ul Haq et and all observed that electricity theft has a considerable negative effect on energy suppliers and power infrastructure, leading to non-technical losses and business losses. Power qualitydeteriorates and overall profitability falls as a result of energy theft. By fusing information and energy flow, smart grids may assist solve the issueof power theft. The examination of smart grid dataaids in the detection of power theft. However, theearlier techniques were not very good in detectingenergy theft. theft. In this work, they hadsuggested an electricity theft detection approach using smart meter consumption data in order to handle the aforementioned issues and assist and assess energy supply businesses to lower the obstacles of limited energy, unexpected power usage, and bad power management. In

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specifically, the Deep CNN model effectively completes two tasks: it differentiates between energy that is not periodic and that is, while keeping the general features of data on power consumption [4].

Paria Jokar et all presented a novel consumption pattern-based energy theft detector, which leverages the predictability property of customers' normal and malicious consumption patterns. Using distribution transformer meters, areas witha high probability of energy theft are short listed, and by monitoring abnormalities in consumption patterns, suspicious customers are identified.Application of appropriate classification and clustering techniques, as well as concurrent use oftransformer meters and anomaly detectors, make the algorithm robust against nonmalicious changes in usage pattern, and provide a high and adjustable performance with a low sampling rate. Therefore, the proposed method does not invade customers' privacy. Extensive experiments on a real dataset of5000 customers show a high performance for the proposed method [5].

Rong Jiang et all observed that with the proliferation of smart grid research, the Advanced Metering Infrastructure (AMI) has become thefirst ubiquitous and fixed computing platform. However, due to the unique characteristics of AMI, such as complex network structure, resource-constrained smart meter, and privacy-sensitive data, it is an especially challenging issueto make AMI secure. Energy theft is one of the most important concerns related to the smart grid implementation. It is estimated that utility companies lose more than $25 billion every year due to energy theft around the world. To address this challenge, in this paper, we discuss the background of AMI and identify major security requirements that AMI should meet. Specifically, an attack tree-based threat model is first presentedto illustrate the energy-theft behaviors in AMI. Then, we summarize the current AMI energy-theftdetection schemes into three categories, i.e., classification-based, state estimation-based, andgame theory-based ones, and make extensive comparisons and discussions on them. In orde provide a deep understanding of security vulnerabilities and solutions in AMI and shed lighton future research directions, we also explore some open challenges and potential solutions for energy-theft detection [6]

Xiangyu Kong et all observed that the theft of electricity affects power supply quality and safetyof grid operation, and non-technical losses (NTL) have become the major reason of unfair power supply and economic losses for power companies.For more effective electricity

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theft inspection, an electricity theft detection method based on similarity measure and decision tree combined K-Nearest Neighbor and support vector machine (DT-KSVM) is proposed in the paper. Firstly, the condensed feature set is devised based on feature selection strategy, typical power consumption characteristic curves of users are obtained based on kernel fuzzy C-means algorithm (KFCM). Next, to solve the problem of lack of stealing dataand realize the reasonable use of advanced metering infrastructure (AMI). One dimensional Wasserstein generative adversarial networks (1D-WGAN) is used to generate more simulated stealing data. Then the numerical and morphological features in the similarity measurement process are comprehensively considered to conduct preliminary detection ofNTL. And DT-KSVM is used to perform secondary detection and identify suspicious customers. At last, simulation experiments verify the effectiveness of the proposed method [7].

Md. Nazmul Hasan et all observed that among an electricity provider's non-technical losses, electricity theft has the most severe and dangerouseffects. Fraudulent electricity consumption decreases the supply quality, increases generationload, causes legitimate consumers to pay excessive electricity bills, and affects the overall economy. The adaptation of smart grids can significantly reduce this loss through data analysistechniques. The smart grid infrastructure generatesa massive amount of data, including the power consumption of individual users. Utilizing thisdata, machine learning and deep learning techniques can accurately identify electricity theftusers. In this paper, an electricity theft detection system is proposed based on a combination of a convolutional neural network (CNN) and a long short-term memory (LSTM) architecture. CNN is a widely used technique that automates feature extraction and the classification process. Since thepower consumption signature is time-series data, we were led to build a CNN-based LSTM (CNN- LSTM) model for smart grid data classification. In this work, a novel data pre-processing algorithm was also implemented to compute the missing instances in the dataset, based on the local values relative to the missing data point. They also observed that in this dataset, the count ofelectricity theft users was relatively low, which could have made the model inefficient at identifying theft users. This class imbalance scenario was addressed through synthetic data generation. Finally, the results obtained indicate the proposed scheme can classify both the majority class (normal users) and the minority class (electricity theft users) with good accuracy.

Andreas Kamilaris et.al presented that the currentstate of the art regarding work performed related to the electric energy consumption for Informationand Communication Technologies

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(ICT) and Miscellaneous Electric Loads (MELs), in office and commercial buildings. Techniques used for measuring the energy consumption of office plug loads, and efforts for saving energy by using this equipment more rationally and efficiently are identified and categorized. Popular methods and techniques for energy metering are discussed, together with efforts to classify and benchmark office equipment. Our study reveals that many issues are still open in this domain, including moreaccurate, diverse and meaningful energy audits for longer time periods, taking into account device profiles, occupant behavior and environmental context. Finally, there is a need for a global consensus on benchmarking and performance metrics, as well as a need for a coordinated worldwide activity for gathering, sharing, analyzing, visualizing and exposing all the silos ofinformation relating to plug loads in offices and commercial buildings.

Alexander Martin Tureczek et.al presented the smart meters for measuring electricity consumption are fast becoming prevalent in households. The meters measure consumption on a very fine scale, usually on a 15 min basis, and thedata give unprecedented granularity of consumption patterns at household level. A multitude of papers have emerged utilizing smart meter data for deepening our knowledge of consumption patterns. This paper applies a modification of Okoli's method for conducting structured literature reviews to generate an overview of research in electricity customer classification using smart meter data. The process assessed 2099 papers before identifying 34 significant papers, and highlights three key points: prominent methods, datasets and application. Three important findings are outlined. First,only afew papers contemplate future applications of the classification, rendering papers relevant only in a classification setting. Second; the encountered classification methods do not consider correlation or time series analysis when classifying. The identified papers fail to thoroughly analyze the statistical properties of the data, investigations that could potentially improve classification performance. Third, the description of the data utilized is of varying quality, with only 50% acknowledging missing values impact on the finalsample size. A data description score for assessingthe quality in data description has been developedand applied to all papers reviewed.

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III. Methodology

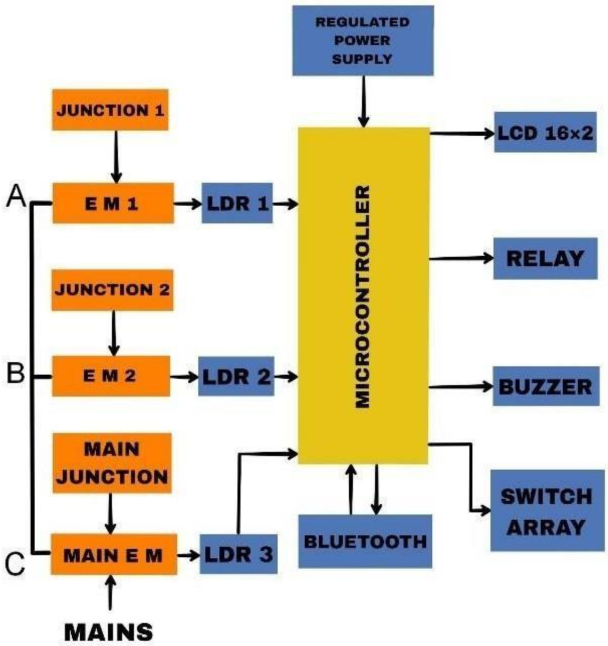

Fig. 1: Block diagram represents a system designed for monitoring electricity consumption and detecting potential theft

This block diagram represents a system designed for monitoring electricity consumption and detecting potential theft. Here's an explanation of the different components and how they work together:

Power Supply:

The system is powered by a regulated power supply.

Energy Meters (EM1, EM2, Main EM):

These are energy meters that measure the electricity consumption at different points. EM1 and EM2 measure consumption at two separate junctions or branches, while Main EM measures the overall consumption from the mains.

LDRs (LDR 1, LDR 2, LDR 3):

LDRs, or Light-Dependent Resistors, are used to sense and transmit the energy meter readings to themicrocontroller.

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IV. Microcontroller:

The microcontroller is the central processing unit that receives data from the LDRs and processes it.It also communicates with other components like the LCD, relay, buzzer, and Bluetooth module.

LCD 16x2:

A 16x2 character LCD display is used to show theenergy consumption readings and potentially otherrelevant information.

Relay:

A relay is included, which can be used to control or switch electrical circuits based on the microcontroller's commands.

Buzzer:

A buzzer is connected to provide audible alerts ornotifications, such as in case of potential theft detection.

Bluetooth Module:

The system includes a Bluetooth module, which can be used for wireless communication and data transfer, possibly to a monitoring device or mobileapplication.

Switch Array:

A switch array is present, which may be used to control or configure various settings or functions of the system.traffic density, which can significantly improve traffic flow and reduce waiting times. The system is also equipped with amanual override feature to ensure the smooth passage of emergency vehicles.

V. Results and Discussion

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Fig. 2: Monitoring and analyzing electricity board-side energy

The project focused on monitoring and analyzing electricity board-side energy while detecting theftusing a system comprising three junctions (J1, J2,and main), current transformers (CTs) for sensing current, energy meters for consumption readings, and optocouplers for pulse rate measurements.

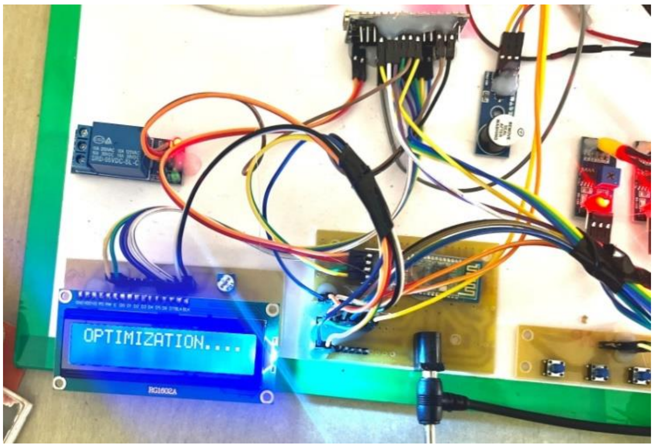

Fig. 3: Components integrated with Arduino for programming energy consumption

These components were integrated with Arduino for programming energy consumption thresholds and a LED display for real-time monitoring, with a buzzer for theft alerts. The system featured two modes: optimization for accessing real-time consumption and theft detection.

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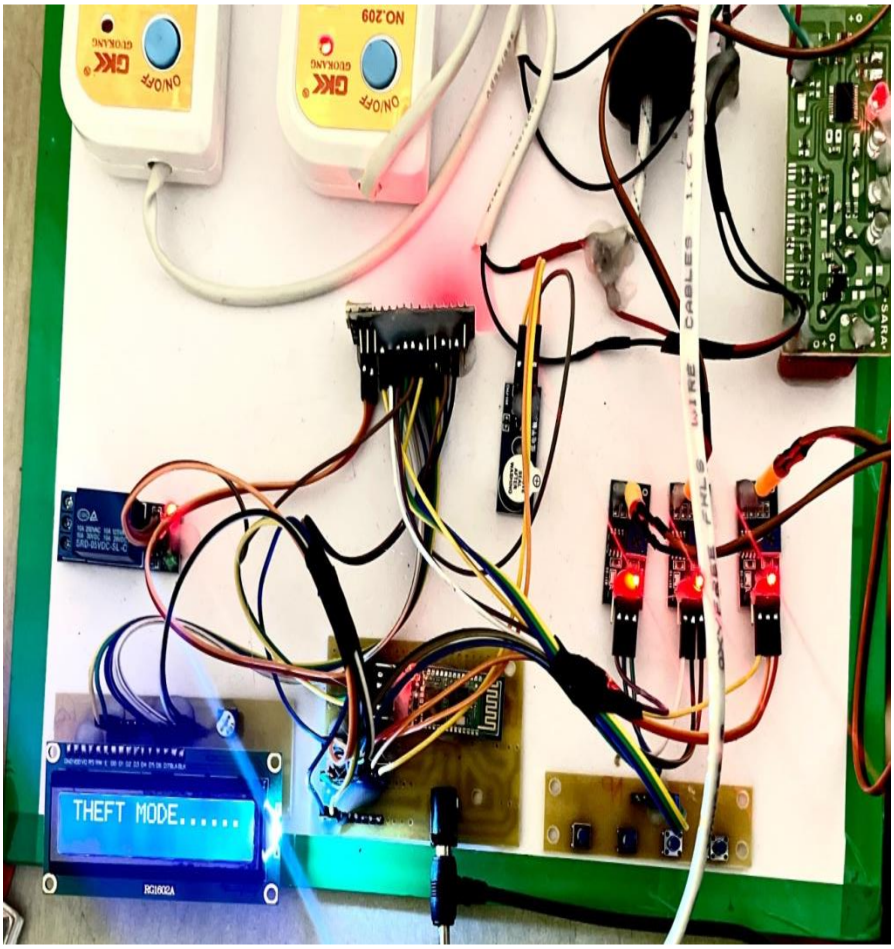

Fig. 4: Real-time monitoring and effective theftdetection by comparing consumption at J1 and J2 with the main junction

Results showed successful real-time monitoring and effective theftdetection by comparing consumption at J1 and J2 with the main junction. If J1+J2 consumption wasless than the main junction, indicating direct load connection, theft was detected. This projectdemonstrates a practical approach to addressing energy theft, offering a robust solution for enhancing electricity board-sidemonitoring and security.

V. Implications

1. Energy Monitoring: The project facilitates real-time monitoring of energy consumption at different junctions, enabling better understanding and management of electricity usage.

2. Theft Detection: By comparing the energy consumption of individual junctions with the mainjunction, the system can detect potential theft scenarios, enhancing security and revenue protection for electricity providers.

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3. Remote Monitoring: Utilizing remote devices for energy monitoring and theft detection allows for efficient management and surveillance of electricity usage, even in remote or inaccessible areas.

4. Optocoupler Integration: The integration of optocouplers ensures safe and efficient transfer ofdata between AC and DC components, enhancingsystem reliability and reducing the risk of electrical hazards. Arduino Programming: The use of Arduino forprogramming threshold values and system mode adds flexibility and adaptability to the project, allowing for customization according to specific requirements and conditions.

VI. Conclusion

The culmination of the project on monitoring and analyzing electricity board-side energy and detecting theft represents a substantial achievement in the realm of energy management and security. The extensive journey from conceptualization to implementation and evaluation has yielded invaluable insights and conclusions that resonate profoundly within the domain of energy infrastructure and management.

At the heart of the project lies a commitment to addressing the multifaceted challenges associated with energy distribution, particularly the pervasive issue of theft. Through a meticulous and systematic approach, the project has endeavored todevelop a comprehensive solution that not only monitors energy consumption but also detects andmitigates instances of theft effectively.

The performance analysis conducted throughout the project lifecycle has provided invaluable insights into the various dimensions of system functionality and effectiveness. Central to this analysis is the evaluation of energy monitoring accuracy, theft detection sensitivity, real-time monitoring capabilities, and mode switching efficiency. These aspects collectively determine the system's ability to fulfill its core objectives anddeliver tangible benefits to stakeholders.

Energy monitoring accuracy stands as a cornerstone of the system's functionality, ensuringthat consumption data is reliably captured and analyzed. The calibration of current transformers (CTs) and the consistency of pulse rate measurements from energy meters are critical factors in achieving this accuracy. By meticulously calibrating and validating thesecomponents, the system can provide stakeholders with a clear and accurate understanding of energy

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consumption patterns. Equally vital is the system's ability to detect instances of theft with precision and sensitivity.

The threshold settings programmed into the Arduino serve as a pivotal mechanism for identifying anomalies in energy consumption indicative of theft. Through rigorous testing and validation, these thresholds are optimized to strikea balance between minimizing false alarms and maximizing detection sensitivity, thereby ensuringtimely intervention in cases of theft. Real-time monitoring capabilities represent another key facet of the system's functionality, enabling stakeholders to access up-to-dateinformation on energy consumption patterns. The efficiency of data transmission and processing, coupled with the responsiveness of the LED display, is paramount in facilitating informed decision-making and prompt intervention in casesof theft or inefficiency. Furthermore, the seamless switching between optimization mode and theft detection mode enhances the system's usability and flexibility. Byproviding operators with the ability to toggle between these modes effortlessly, the system caters to diverse operational requirements and facilitates a more intuitive and user-friendly experience.The comprehensive testing conducted throughout the project lifecycle has played a pivotal role in validating the functionality, reliability, and robustness of the system. Functional testing, threshold validation, load variation testing, and mode switching evaluation have provided critical insights into the system's performance under diverse operating conditions. By subjecting the system to rigorous testing protocols, potential vulnerabilities and shortcomings have been identified and addressed, thereby enhancing its overall effectiveness and reliability. The implementation phase of the project has underscored the importance of meticulous hardware configuration, software development, integration, and user interface design. The seamless integration of hardware components, coupled with robust software algorithms, has laid the foundation for a reliable and efficient energy monitoring and theft detection system. Additionally, effective interfacing between ACand DC components using optocouplers has ensured signal integrity and system safety, further enhancing the system's reliability and performance.

In conclusion, the project represents a significant milestone in the ongoing effort to enhance the integrity and efficiency of energy distribution systems. By leveraging advanced technologies andinnovative approaches, the system offers a robust,reliable, and cost-effective solution for detecting and mitigating instances of theft. Moreover, the project serves as a testament to the transformative potential of technology in addressing complex societal

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challenges and advancing the transition towards a more sustainable and equitable energy future.

Looking ahead, further research and development efforts can focus on enhancing the scalability,interoperability, and resilience of such systems to meet the evolving demands of the energy sector. Additionally, ongoing monitoring and optimization will be essential to ensure the long- term sustainability and effectiveness of energytheft detection initiatives. Ultimately, the project underscores the critical role of innovation, collaboration, and continuous improvement in driving positive change within the energy landscape.

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