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IOT BASED ELECTRICITY THEFT DETECTION USING ARTIFICIAL INTELLIGENCE TECHNIQUES FOR SUSTAINABLE ELECTRICITY USAGE

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Abstract : This work presents a new system that leverages the Internet of Things (IoT) and state-of-the-art Artificial Intelligence (AI) techniques to combat electricity theft, a major issue, and to advance sustainability in the energy sector. By tracking and analyzing electricity consumption trends in real time, the Internet of Things (IoT)-based approach seeks to identify anomalies and potential theft incidents. Detecting theft in a proactive manner is made possible by our system's integration of these cutting-edge technologies, which also improve the power grid's wider sustainability. Data collection can be done effectively with the integration of IoT devices. Then, using AI algorithms, these data are analyzed to find any consumption anomalies that would enable energy providers to promptly implement corrective measures. The results of the study indicate that this approach has a lot of potential for enhancing the reliability and security of electrical distribution networks. It can also promote sustainable energy use and discourage theft.

1.INTRODUCTION

The global electrical supply chain faces numerous challenges, including the pervasive issue of electricity theft, which causes financial losses, power outages, and detrimental environmental effects. Addressing these problems and advancing sustainability in the energy sector involves actively researching creative solutions that incorporate state-of-the-art technologies. This research offers a novel system that integrates artificial intelligence (AI) and Internet of Things (IoT) methods to deter energy theft and promote responsible electricity use. This research aims to present a comprehensive analysis of the current state of affairs, along with the suggested IoT-based solution and its potential effects, with regard to the sustainability of power distribution networks.

2.NEED OF THE STUDY.

Power theft remains a persistent issue in numerous regions across the globe. Unauthorized connections, meter tampering, and other fraudulent methods can be the cause of this. Utility companies experience increased operating costs and financial losses as a result of this issue, which also poses a serious risk to the electrical system's stability. Furthermore, the fact that poor energy usage habits and electricity theft often coexist exacerbates the financial and environmental challenges associated with the distribution of electricity. This study provides a novel solution to these issues by addressing the more urgent challenge of detecting theft and the more general issue of encouraging sustainability in the energy industry through the use of artificial intelligence and the Internet of Things. The incorporation of IoT devices into the electrical distribution infrastructure is a crucial component of the proposed methodology. We can collect real-time data from multiple network nodes using IoT technology, which makes it possible to monitor patterns in electricity consumption in great detail. Synchronous analysis of this data is done by sophisticated artificial intelligence (AI) algorithms, which identify unusual patterns of consumption that might point to electricity theft. In order to detect theft more accurately and efficiently and to enable energy providers to react faster, real-time data and AI-driven analysis may be combined. By decreasing energy waste and associated environmental effects through theft and inefficient use, the recommended technology not only increases power distribution security and reliability but also contribute to the achievement of larger sustainability goals.

3.LITERATURE SURVEY

S.no	Title	Authors	Technology	Advantage	Limitations
1	Electricity-theft detection for smart grid security using smart meter data: A deep-CNN based approach	Ejaz Ul Haq, Can Pei, Ruihong Zhang, Huang Jianjun, Fiaz Ahmad	Deep Convolutional Neural Network (Deep CNN) used to analyze smart meter data for electricity theft detection.	High accuracy in electricity theft detection. Deep CNN excels in image and pattern recognition tasks, making it suitable for detecting anomalies in smart meter data.	Limited to monitoring, no prevention method mentioned. Deep learning models can be computation ally expensive and require large datasets.
2	An Efficient Power Theft Detection Using Modified Deep Artificial Neural Network (MDANN)	G. P. Dimf, P. Kumar, V. N. Manju	Deep Learning, Smart Grid technologies utilized for power theft detection. Deep Learning models analyze power consumption data. Smart Grid technologies enable better monitoring and control.	Improved accuracy, recall, precision, AUC, F1 Score. Deep Learning involves neural networks with multiple layers that can capture complex patterns. Smart Grid technologies enhance monitoring capabilities.	Limited to monitoring, no prevention method mentioned. Deep learning models may require significant computational resources and expertise.
3	Methods and applications for Artificial	Joey Li, Munur Sacit Herdem, Jatin Nathwani, John Z. Wen	AI, Big Data, IoT, Blockchain applied for energy management. AI is used for predictive	Enhanced energy management, forecast energy use,	Consumption of resources for AI mentioned as a concern.

	Intelligenc e, Big Data, Internet of Things, and Blockchai n in smart energy manageme nt		analytics, Big Data handles vast datasets, IoT collects data, and Blockchain ensures secure transactions.	reliable performance. AI, Big Data, IoT, and Blockchain technologies provide a comprehensiv e framework for intelligent energy management.	Implementati on of Blockchain can be complex and energy-intensive.
4	Prevention and Detection of Electricity Theft of Distributio n Network	Sajad Ali, Min Yongzhi, Wajid Ali	Smart Meter data collected, Neural Networks employed for anomaly detection, and IoT facilitates data exchange.	Improved theft detection, early warning, insights into energy consumpti on. Smart Meters enable real-time data collection. Neural Networks are used for pattern recognition , and IoT ensures data exchange.	Limited to monitoring, no prevention method mentioned. Integration of IoT may raise privacy and security concerns.
5	Data- driven intelligent method for detection of electricity theft	Junde Chen, Y.A. Nanehkaran, Weirong Chen, Yajun Liu, Defu Zhang	Data analysis techniques and Convolutional Networks applied for electricity theft detection.	High precision and recall for theft detection. Data analysis techniques are used for pattern recognitio n, and Convoluti onal Networks	Deep learning models require significant computation al resources, and large amounts of data for training may not be available.
				excel in image and data analysis tasks.	

6	Prevention and Detection of Electricity Theft of Distribution Network	Sajad Ali, Min Yongzhi, Wajid Ali	Smart Meter data collected, Neural Networks employed for anomaly detection, and IoT facilitates data exchange.	Improved theft detection, early warning, insights into energy consumption. Smart Meters enable real-time data collection. Neural Networks are used for pattern recognition, and IoT ensures data exchange.	Limited to monitoring, no prevention method mentioned. Integration of IoT may raise privacy and security concerns.
7	IoT based energy monitoring and energy theft detection	Vishakha Yadav, Anita Keshav Patil, P. Janardhan Saikumar, Santaji Krishna Shinde, B. Karunamoorthy, S. Hemavathi	IoT devices collect real-time energy data, and Arduino is used for data processing and transmissio n.	Real-time energy theft detection, user accessibility. IoT devices collect data for real-time monitoring, and Arduino is used for data processing and transmission.	Limited to monitoring, no prevention method mentioned. Data security and privacy in IoT can be a challenge.
8	Clustering and Ensemble Based Approach for Securing Electricity Theft Detectors Against Evasion Attacks	Islam Elgarhy, Mahmoud M. Badr, Mohamed M. E. A. Mahmoud, Mostafa M. Fouda, Maazen Alsabaan, Hisham A. Kholidy	Machine Learning models and Ensemble methods applied for securing electricity theft detectors.	Robust against evasion attacks, high detection accuracy. Machine Learning models and Ensemble methods are used to create robust	Limited to monitoring, no prevention method mentioned. Training robust models can require significant data and
				models for theft detection and prevention.	computati onal resources.

9	Improving cloud/edg e sustainabi lity through artificial intelligenc e: A systematic review	Belen Bermejo, Carlos Juiz	AI, IoT, Cloud, Fog, Edge technolog ies used for sustainab ility improve ment.	Potential for sustainability improvement in ecosystems. AI, IoT, and Cloud/Fog/Ed ge technologies optimize resource usage and sustainability.	Consumption of resources for AI mentioned as a concern. Implementatio n of cloud and edge AI may require infrastructure upgrades.
10	Which Industrial Sectors Are Affected by Artificial Intelligenc e? A Bibliometr ic Analysis of Trends and Perspectiv es	Lorena Espina-Romero, José Gregorio Noroño Sánchez, Humberto Gutiérrez Hurtado, Helga Dworaczek Conde, Yessenia Solier Castro, Luz Emérita Cervera Cajo, Jose Rio Corredoira	AI and Machine Learning technologies applied in various industrial sectors.	AI's growing impact in technology, finance, healthcare, environment , and construction sectors.	Consumption of resources for AI mentioned as a concern. Adoption of AI may require workforce upskilling.

Table 1 represents literature survey

Examining different approaches to tackle the pervasive issue of electricity theft and promote energy sustainability is the focus of this literature review. According to Haq et al. [1], the first step toward the accurate detection of electricity theft is the deployment of Deep Convolutional Neural Networks (Deep CNN), with a focus on greater precision in identifying energy theft. Subsequently, the Modified Deep Artificial Neural Network (MDANN) is introduced employing deep learning and smart grid technologies, showcasing improvements in theft detection and monitoring (Dimf et al. [2]). The integration of Big Data, Blockchain, Internet of Things (IoT), and Artificial Intelligence (AI) for all-encompassing smart energy management is being included in the review, expanding its purview (Li et al. [3]). Furthermore, the application of IoT, smart meters, and neural networks shows promise as a potent tool for improving theft detection and early warning systems (Sajad Ali et al. [4]). Utilized are convolutional networks in an intelligent data-driven approach that enhances recall and accuracy in the identification of energy theft (Chen et al. [5]). Yadav et al.'s [7] additional study builds on Internet of Things (IoT)-based energy monitoring and theft detection, emphasizing user accessibility and real-time detection. A cluster-based ensemble method to counter evasion attempts is presented by Elgarhy et al. [8], significantly increasing detector robustness. Additionally, studies are being conducted on how AI can improve sustainability in Internet of Things, cloud, fog, and edge ecosystems (Bermejo and Juiz [9]). The bibliometric study concludes by highlighting the revolutionary impact of AI on various industrial domains, which could potentially result in a more sustainable economy (Espina-Romero et al. [10]). Together, the aforementioned works describe a quickly evolving field in the identification of electricity theft and intelligent energy management, emphasizing the critical role that resilience and cutting-edge technologies play in addressing this urgent problem.

3.1. BLOCK DIAGRAM OF IoT BASED ELECTICITY THEFT DETECTION

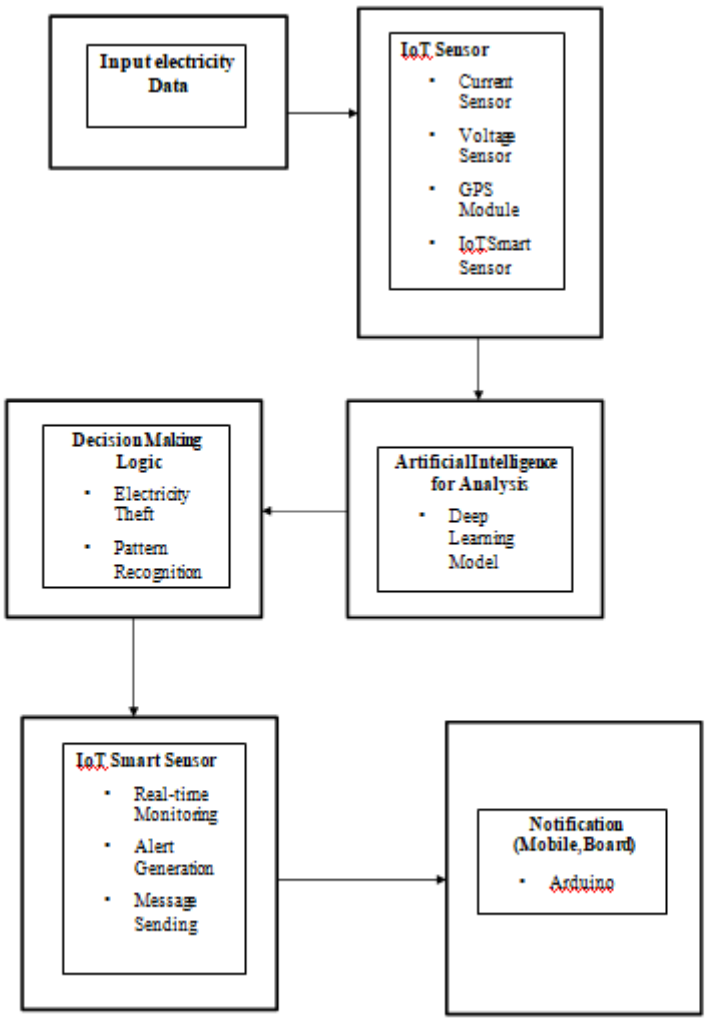

Figure 1 represents block diagram of IoT based electricity theft detection

The Internet of Things-Based Energy Theft Detection system's foundation is its input data, which includes detailed information on electricity consumption. This data serves as the system's foundation and enables the analysis and tracking of power utilization patterns. Electrical data typically includes historical usage patterns, time-stamped consumption statistics, and the total amount of electricity used.

3.1.1.IoT Sensor Layer

This layer consists of multiple sensors and modules that collect data necessary to detect instances of electricity theft. In this layer, each component serves a specific purpose:

3.1.2.Current Sensor

By continuously monitoring the amount of electricity used, this sensor serves as the system's eyes on the power flow in real time.

3.1.3.Voltage Sensor

This sensor continuously measures the voltage within the electrical grid. It gives vital information about voltage variations, which could be a sign of theft or other irregularities. GPS Module: This sensor is necessary to pinpoint the exact location of the smart meter.

3.1.4.GPS Module

This component is crucial for accurately determining the smart meter's location. These geographic data must be used to trace the origin of incidents involving theft of electrical power. By supplying the exact location of the theft, the system can assist in identifying undesired connections and usage.

3.1.5.IoT Smart Sensor

The main real-time energy consumption monitor is the IoT Smart Sensor. It continuously monitors consumption patterns and actively looks for any irregularities that might indicate theft. This smart sensor serves as the system's first line of defense against improper use of electricity.

3.1.6.Artificial Intelligence for Analysis

Deep Learning Models are used to interpret and analyze the collected data. Deep learning models provide an advanced and data-driven approach.The following are the specific components of this layer:

3.1.7.Convolutional Neural Networks (CNN)

CNN is used to find complex patterns and anomalies in energy-related data. It is very adept at identifying odd usage patterns that might indicate theft. For example, sudden spikes or unusual consumption patterns may set off CNN's anomaly detection.

3.1.8.Long Short-Term Memory (LSTM)

LSTM was developed specifically for time-series analysis of consumption data. It can analyze historical consumption patterns and spot variations over time to assist in identifying abnormal behavior. For instance, it can spot gradual changes in consumption trends that might point to theft.

3.1.9.Decision Making Logic

This component serves as the brains of the system, making decisions based on the data that the AI models have assessed. It compares the analyzed data to predefined standards to determine whether electricity theft is suspected. The standard could entail setting thresholds for unusual consumption patterns or differences that might point to theft. When these conditions are met, the decision-making logic raises red flags for additional research.

3.1.10.IoT Smart Sensor

There are several ways in which the IoT Smart Sensor aids in the detection process.Real-time monitoring ensures that any unusual usage is promptly detected by continuously monitoring the amount of electricity used. It collects information from the voltage and current sensors to understand the state of the electrical grid at the moment.

3.1.11.Alert Generation

When it notices unusual usage patterns or signs of theft, the IoT Smart Sensor notifies users. These notifications are the first line of defense against potential theft. For example, it might sound an alert if it detects an abrupt increase in electricity consumption during off-peak hours.

3.1.12.Sending Messages

In the event that theft is confirmed, the IoT Smart Sensor takes the initiative to alert and caution the relevant parties. These notifications provide the location of the purported theft. Furthermore, the sensor may provide data to support further research, such as timestamps and consumption trends.

3.1.13.Notification (Mobile, Board)

This component is in charge of sharing information and alerting the right people.Mobile Users: Both individuals and businesses receive real-time alerts on their mobile devices regarding potential theft situations. Clients receive the resources they require to keep an eye on and learn about their electricity consumption. They might receive alerts saying something like, "Unusual electricity usage detected at your location."

3.1.14.Power Board

The power board is immediately notified when theft is detected. This notice is meant to serve as a call to action for the police, motivating them to investigate the theft issue more fully and promptly. Comprehensive reports are sent to the board, detailing the location of the theft and the kinds of anomalies discovered.

4.EVALUATION METRICS

The system that is being presented uses artificial intelligence (AI) and the Internet of Things (IoT) to fight electricity theft and improve sustainability in the energy industry. A variety of criteria are included in the evaluation metrics. The system's ability to accurately identify theft incidents is measured by Detection Accuracy (DA), and the frequency with which normal consumption is mistakenly identified as theft is measured by False Positive Rate (FPR). Precision and Recall provide information about how accurately theft incidents are identified and how well the system can identify real theft incidents, respectively. Precision and recall are combined to provide a balanced metric that is the F1 Score. Response Time measures how quickly the system finds and reports theft incidents. Resource Utilization evaluates the effectiveness of system resources, while Data Collection Efficiency evaluates how well IoT devices collect data in real time. While user acceptance measures how satisfied end users and energy providers are with the system, environmental impact reduction measures how much the system contributes to lessening environmental effects. Furthermore, in order to provide a comprehensive evaluation of the system's performance and impact, Cost-Benefit Analysis compares the total costs and benefits related to its implementation and upkeep.

4.1.CONCLUSION

In conclusion, a powerful and creative approach to raising the sustainability of electricity use is the IoT-Based Electricity Theft Detection System, which is driven by artificial intelligence. Using a multi-layered architecture, this system makes use of Internet of Things sensors, alerting mechanisms, real-time monitoring, and deep learning models. Data on the use of electricity is first collected. Subsequently, advanced artificial intelligence (AI) models, such as Long Short-Term Memory (LSTM) and Convolutional Neural Networks (CNN), scan the data to identify unusual patterns of consumption. The decision-making logic processes the AI-generated insights and, upon reaching specific thresholds that signify theft, sounds an alarm. The IoT Smart Sensor allows for real-time monitoring, alarm generation, and notification to both the power board and mobile users. This comprehensive approach ensures the timely detection of any theft, safeguarding against unauthorized power usage and promoting sustainability. The proposed process expeditiously addresses electricity theft, thereby promoting equitable distribution of electrical resources, minimizing non-technical losses, and building a more robust and efficient power system. The approach described in this work offers a cutting-edge solution to the urgent issue of electricity theft, in keeping with the growing demand for efficient energy management in the Internet of Things era.

4.1.2.FUTURE WORK

- Automating the response to theft detection is a crucial aspect to consider, along with real-time response. In order to reduce damage and expedite response times, future research can concentrate on creating automated protocols that turn off the electricity in areas that are suspected of being stolen.
- Integration and Scalability: It's imperative to ensure that these systems can expand in size and seamlessly integrate with the existing infrastructure as IoT networks get bigger. Further research endeavors could explore methods of integrating theft detection Internet of Things systems with smart grid capabilities and other grid management alternatives.
- Data Security and Privacy: Given the increasing use of sensitive consumption data, it is imperative to address data security and privacy issues. Research can focus on developing robust encryption and privacy-preserving techniques that protect data integrity and facilitate efficient theft detection.
- Behavioral analytics: A thorough examination of consumer behavior and consumption trends can provide valuable insights into identifying theft. Future studies could look into how social science and behavioral analytics can be combined approaches to understand the underlying motivations of energy theft and create more effective preventative measures.

These future directions aim to improve the efficiency, security, and adaptability of IoT-based electricity theft detection to evolving issues in the energy sector.

REFERENCES

[1] Dimf, G. P. ., Kumar , P. ., & Manju, V. N. . (2023). An Efficient Power Theft Detection Using Modified Deep Artificial Neural Network (MDANN). International Journal of Intelligent Systems and Applications in Engineering, 11(1), 01–11. Retrieved from https://www.ijisae.org/index.php/IJISAE/article/view/2437

[2] Ejaz Ul Haq, Can Pei, Ruihong Zhang, Huang Jianjun, Fiaz Ahmad,
Electricity-theft detection for smart grid security using smart meter data: A deep-CNN based approach,
Energy Reports,
Volume 9, Supplement 1,
2023,
Pages 634-643,
ISSN 2352-4847,
https://doi.org/10.1016/j.egyr.2022.11.072.

[3] Joey Li, Munur Sacit Herdem, Jatin Nathwani, John Z. Wen,
Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management,
Energy and AI, Volume 11,
2023,
100208,
ISSN 2666-5468,
https://doi.org/10.1016/j.egyai.2022.100208.

[4] Ali, S.; Yongzhi, M.; Ali, W. Prevention and Detection of Electricity Theft of Distribution Network. Sustainability 2023, 15, 4868. https://doi.org/10.3390/su15064868

[5] Junde Chen, Y.A. Nanehkaran, Weirong Chen, Yajun Liu, Defu Zhang, Data-driven intelligent method for detection of electricity theft, International Journal of Electrical Power & Energy Systems,
Volume 148,
2023,
108948,
ISSN 0142-0615,
https://doi.org/10.1016/j.ijepes.2023.108948.

[6] Vishakha Yadav, Anita Keshav Patil, P. Janardhan Saikumar, Santaji Krishna Shinde, B. Karunamoorthy, S. Hemavathi; IoT based energy monitoring and energy theft detection. *AIP Conf. Proc.* 24 March 2023; 2690 (1): 020045. https://doi.org/10.1063/5.0119807

[7] I. Elgarhy, M. M. Badr, M. M. E. A. Mahmoud, M. M. Fouda, M. Alsabaan and H.
A. Kholidy, "Clustering and Ensemble Based Approach for Securing Electricity Theft Detectors Against Evasion Attacks," in IEEE Access, vol. 11, pp. 112147-112164, 2023, doi: 10.1109/ACCESS.2023.3318111.

[8] Belen Bermejo, Carlos Juiz,
Improving cloud/edge sustainability through artificial intelligence: A systematic review, Journal of Parallel and Distributed Computing,
Volume 176,

2023,
Pages 41-54,
ISSN 0743-7315,
https://doi.org/10.1016/j.jpdc.2023.02.006.

[9] Espina-Romero, L.; Noroño Sánchez, J.G.; Gutiérrez Hurtado, H.; Dworaczek Conde, H.; Solier Castro, Y.; Cervera Cajo, L.E.; Rio Corredoira, J. Which Industrial Sectors Are Affected by Artificial Intelligence? A Bibliometric Analysis of Trends and Perspectives. Sustainability 2023, 15, 12176. https://doi.org/10.3390/su151612176

[10] Alzahrani, A.; Aldhyani, T.H.H. Design of Efficient Based Artificial Intelligence Approaches for Sustainable of Cyber Security in Smart Industrial Control System. Sustainability 2023, 15, 8076. https://doi.org/10.3390/su15108076