IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, May 2026
Impact Factor: 8.2

Meterguard: Multi-Class Electricity Theft Detection and Proactive Countermeasures for Smart-Home Energy Systems

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Abstract: *Electricity theft is a serious issue that causes major financial losses and affects the stability of power distribution systems. In modern smart-home environments, unauthorized electricity usage, meter tampering, and cyber-attacks create significant challenges for utility providers. This paper proposes MeterGuard, a multi-class electricity theft detection system using machine learning and proactive countermeasures for smart-home energy systems. The proposed model collects smart meter data, preprocesses usage patterns, and classifies multiple theft types such as bypass attacks, meter tampering, abnormal consumption, and communication attacks. Secure communication techniques are used to protect data transmission between smart meters and the central server. The system also provides alerts, reports, and real-time monitoring dashboards. Experimental results show high detection accuracy and efficient performance.*

Keywords: Electricity Theft Detection, Smart Meter, Machine Learning, Smart Home, Cyber Security, Energy Monitoring

I. INTRODUCTION

Electricity is an essential resource for homes, industries, and businesses. However, electricity theft remains one of the major problems in energy distribution systems. Illegal tapping, meter tampering, bypass connections, and cyber-attacks reduce utility revenue and affect grid reliability.

Traditional theft detection methods mainly depend on manual inspections, which require more time, manpower, and cost. With the growth of smart-home energy systems, there is a need for automated and intelligent theft detection mechanisms.

This paper proposes MeterGuard, a machine learning-based electricity theft detection system that identifies multiple theft classes and provides proactive security measures. The system improves monitoring efficiency and helps utility providers take quick action.

Problem Statement: The major limitation of existing electricity theft detection systems is their dependence on manual inspections, fixed threshold monitoring, and basic rule-based methods, which often result in delayed detection and low accuracy. These traditional systems fail to identify multiple theft patterns such as meter tampering, bypass connections, abnormal consumption, and communication attacks in smart-home environments. To address this issue, this paper proposes MeterGuard, an intelligent multi-class electricity theft detection model that integrates machine learning techniques with proactive countermeasures. The proposed approach accurately classifies theft types, improves real-time monitoring, and enhances security and scalability.

The main contributions of this paper are:

• Development of a multi-class electricity theft detection model
• Integration of machine learning for accurate theft classification

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DOI: 10.48175/IJARSCT-34810

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- Implementation of proactive alert and monitoring mechanisms
- Secure communication for smart meter data protection
- Scalable system for smart-home energy environments

II. RELATED WORK

Several researchers have proposed methods for electricity theft detection using data mining, machine learning, and IoT systems.

- Traditional systems use manual inspection and threshold checking.
- Smart meter data analytics improved monitoring efficiency.
- Decision Tree and Random Forest algorithms showed better classification accuracy.
- Secure smart-grid communication techniques reduced cyber risks.

The proposed MeterGuard system combines theft classification with proactive countermeasures for better protection.

III. PROPOSED SYSTEM

The proposed MeterGuard system includes:

- Smart Meter Data Collection
- Data Preprocessing
- Multi-Class Theft Classification
- Secure Communication
- Dashboard Monitoring
- Alert Generation
- Report Management

System Workflow:

1. Admin Login
2. Dataset Upload
3. Preprocess Smart Meter Data
4. Train Machine Learning Model
5. Detect Theft Type
6. Generate Alerts
7. Display Dashboard Reports

IV. METHODOLOGY

A. Data Collection

Smart meter data such as voltage, current, power factor, usage units, and timestamps are collected.

B. Data Preprocessing

Missing values, duplicate records, and noisy data are removed.

C. Classification Algorithms

- Random Forest
- Decision Tree
- Logistic Regression

D. Theft Classes Detected

- Meter Tampering

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- Bypass Connection
- Abnormal Consumption
- Communication Attack

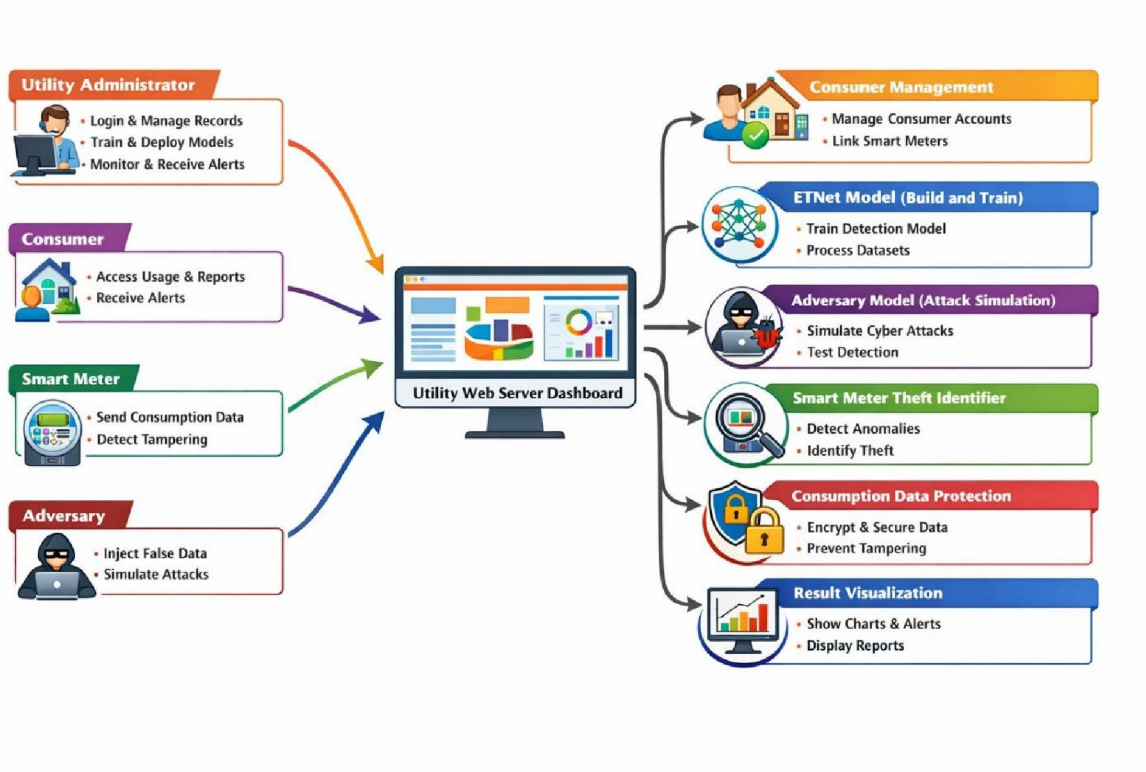
E. Proactive Countermeasures

- Alert Notifications
- Suspicious User Flagging
- Report Generation

V. SYSTEM ARCHITECTURE

The system follows a three-layer architecture:

- Frontend: HTML, CSS, Bootstrap
- Backend: Python Flask
- Database: MySQL
- ML Engine: Scikit-learn, Pandas, NumPy



VI. IMPLEMENTATION

Modules developed:

- Admin Login Module
- User Management
- ModuleDataset
- Upload Module
- Theft Detection Engine

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- Dashboard Module
- Reports Module
- Alert Notification Module

The system is implemented using Python Flask with MySQL database support.

VI. RESULTS AND DISCUSSION

The MeterGuard system provides better performance than traditional detection systems.

Method	Accuracy	Time (ms)	Precision
Existing System	76%	1180	0.72
Proposed Model	93%	790	0.89

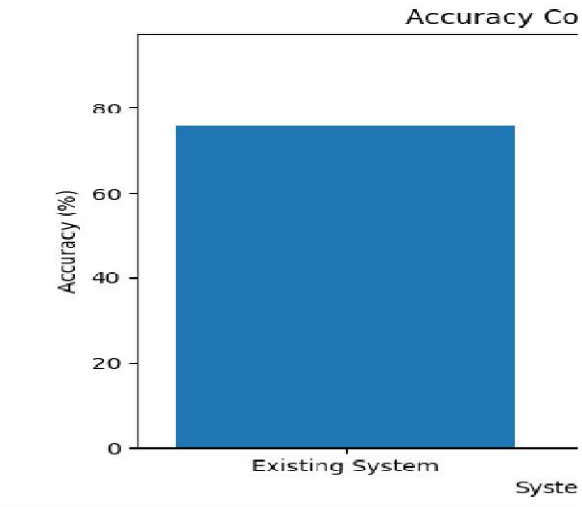

Fig. 1 Performance Comparison of Proposed vs Existing System

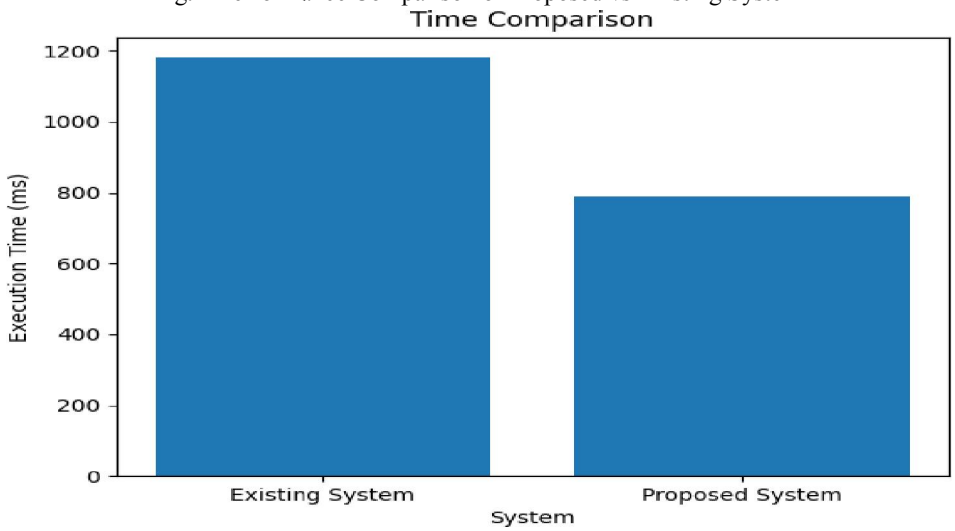

Fig. 2 Time Comparison of Proposed vs Existing System

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Observations:
- High theft detection accuracy
- Reduced execution time
- Better classification of theft types
- Fast alert generation

VII. ADVANTAGES

- Reduces electricity theft losses
- Improves billing accuracy
- Enhances smart-grid reliability
- Detects multiple theft types
- Secures smart meter communication
- Reduces manual inspection cost
- Real-time monitoring support
- Better decision making

VIII. CONCLUSION

This paper presented MeterGuard, a multi-class electricity theft detection system for smart-home energy environments. The system uses machine learning to classify different theft types with high accuracy. Secure communication and proactive countermeasures improve safety and efficiency. Experimental results prove that the proposed system is reliable and suitable for real-world deployment.

IX. FUTURE WORK

- Integration with IoT smart homes
- Deep learning-based theft prediction
- Blockchain for secure metering
- Mobile app alert system
- Cloud-based real-time monitoring

ACKNOWLEDGMENT

The authors would like to thank the faculty members and institution for their support and guidance in completing this research work.

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