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AI-Powered Prepaid Smart Energy Meter with LSTM Load Forecasting and Anomaly Detection Government College of Engineering, Amravati

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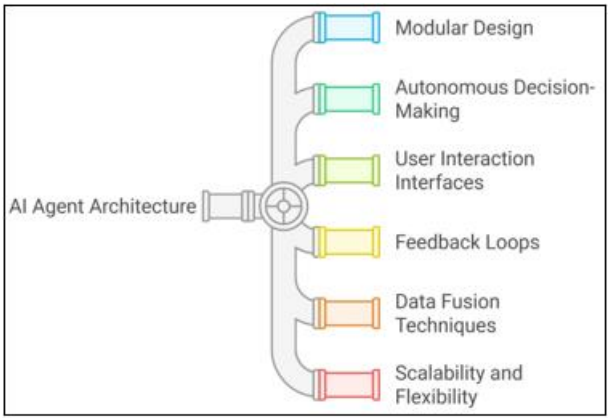
Abstract: ***The increasing demand for efficient energy management has led to the development of smart metering systems integrated with artificial intelligence. This paper presents an AI-powered prepaid smart energy meter that combines Long Short-Term Memory (LSTM) based load forecasting with real-time anomaly detection. The proposed system enables consumers to monitor and control electricity usage through a prepaid mechanism while providing predictive insights into future consumption patterns. LSTM models are employed to capture temporal dependencies in energy usage, improving forecasting accuracy. Additionally, anomaly detection algorithms identify irregular consumption patterns, power theft, and system faults. The integration of forecasting and anomaly detection enhances grid reliability, reduces energy wastage, and promotes efficient demand-side management.***

Keywords: smart energy meter, prepaid electricity system, energy load forecasting, anomaly detection, power theft monitoring

1. Introduction

Smart energy systems are transforming traditional electricity distribution by enabling real-time monitoring, automation, and intelligent decision-making. The integration of AI techniques such as machine learning and deep learning has significantly improved the efficiency of energy systems, especially in **load forecasting and anomaly detection**.



Prepaid smart meters allow users to pay for electricity in advance, promoting responsible energy consumption and reducing billing issues. However, these systems lack predictive capabilities and advanced monitoring. This research proposes an enhanced system that combines prepaid metering with AI-based intelligence.

2. Objectives

- To design an AI-powered prepaid smart energy meter
- To implement LSTM-based load forecasting
- To detect anomalies such as power theft and abnormal usage
- To improve energy efficiency and user awareness
- To enable real-time monitoring and alerts

3. Methodology

3.1 Data Collection

- Smart meters collect time-series energy consumption data
- Data includes voltage, current, power usage, timestamp

3.2 Data Preprocessing

- Missing value handling
- Normalization
- Time-series windowing

Component	Function
ESP32/Arduino	Main controller
Current Sensor (ACS712)	Measures current
Voltage Sensor	Measures voltage
Relay Module	Power control
LCD Display	Displays units and balance
GSM/Wi-Fi Module	Communication
Cloud Server	Data storage
Mobile App	User monitoring
LSTM Model	Load prediction
AI Engine	Anomaly detection

3.3 LSTM-Based Load Forecasting

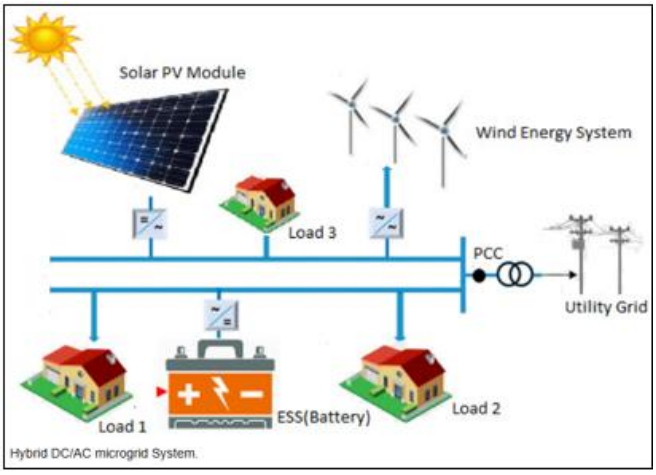
LSTM networks are used because they effectively model **long-term dependencies in time-series data**, making them ideal for energy forecasting.

Steps:
- Input: Historical consumption data
- Hidden layers: LSTM units
- Output: Future load prediction

Advantages:
- Handles nonlinear patterns
- Captures seasonality and trends
- Improves prediction accuracy over traditional models

3.4 Anomaly Detection

Anomaly detection identifies unusual energy consumption patterns.



Techniques used:
- Statistical methods (Z-score)
- Machine learning (Isolation Forest)
- Deep learning (LSTM Autoencoder)

Anomalies may include:
- Power theft
- Faulty appliances
- Sudden load spikes

Smart meter anomaly detection is challenging due to complex and non-linear data behavior, which deep learning models handle effectively

3.5 Prepaid Energy Management

- Users recharge energy credits
- Real-time deduction based on usage
- Automatic disconnection when balance is low
- Notification alerts for recharge

4. Results and Discussion

Expected Results:
- Improved load prediction accuracy
- Early detection of abnormal consumption
- Reduced electricity theft
- Better demand-side energy management

Studies show that combining forecasting and anomaly detection provides better operational efficiency and real-time decision-making in smart grids.

5. Advantages
- Real-time monitoring
- Accurate energy forecasting
- Theft detection
- User-friendly prepaid system
- Reduced energy wastage

6. Limitations

- Requires large dataset for training
- High initial setup cost
- Dependence on internet connectivity

7. Applications

- Smart homes
- Industrial energy monitoring
- Smart grids
- Renewable energy systems

8. Future Scope

- Integration with solar energy systems
- AI-based dynamic pricing
- Blockchain-based energy trading
- Edge AI for faster processing
- Integration with smart city infrastructure

9. Conclusion

This research demonstrates that integrating AI techniques such as LSTM and anomaly detection with prepaid smart energy meters significantly enhances energy management. The system not only provides accurate load forecasting but also ensures security through anomaly detection. It contributes to efficient power utilization, reduced losses, and improved reliability of modern energy systems.

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