ECO-POWER MONITOR

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College : New Horizon College of Engineering, Bengaluru
Branch : Department of Information Science Engineering & Electrical and Electronics Engineering
Guide(s) : Mrs. Shruthi G R
Mrs. A S Anitha Nair
Student(s): Ms. Nikitha R
Mr. Neelam Tusshar
Ms. Shravani S
Ms. Spoorthi R

Keywords:

Python Flask, Machine Learning, SQLite Database, Real-time Data Acquisition, Demand Prediction, Energy Monitoring, Power Switching (Solar/Battery/Grid), Web Dashboard, Data Storage and Retrieval, Renewable Energy Integration, Industrial Energy Planning, Sustainable Power Solutions, Reduced Grid Dependence, Scalability, Cost Efficiency, Sustainability.

Introduction:

The Eco Power Monitor is an advanced solar energy monitoring and management system that integrates IoT and machine learning to optimize energy use. Built around ESP32 microcontrollers, it connects with sensors to track solar energy generation, household consumption, and environmental factors like temperature and humidity.

Real-time data on voltage, current, and energy usage is stored in an SQLite database, ensuring efficient management of both historical and real-time information. The hardware includes relay modules for seamless switching between solar power, batteries, and grid energy, optimizing energy distribution based on demand.

The system's software component consists of a Python Flask application and a machine learning model that uses regression algorithms to forecast daily energy demand. This enables efficient energy distribution, prioritizing solar power while conserving battery reserves and minimizing grid dependence.

A user-friendly web interface, built with HTML, CSS, and JavaScript, displays real-time energy data, consumption trends, and insights through interactive visualizations. Machine learning-driven predictive analytics automate energy sourcing, reducing waste and lowering costs.

The SQLite database ensures reliable data storage and fast retrieval, supporting scalability for larger deployments. By combining IoT-driven data acquisition, machine learning analytics, and real-time resource management, the system promotes sustainability and efficiency.

Beyond residential use, it applies to industrial energy planning, smart city projects, and large-scale renewable energy integration. By predicting electricity demand and dynamically managing energy flow, the Eco Power Monitor enhances efficiency and supports sustainable energy solutions.

Objectives:

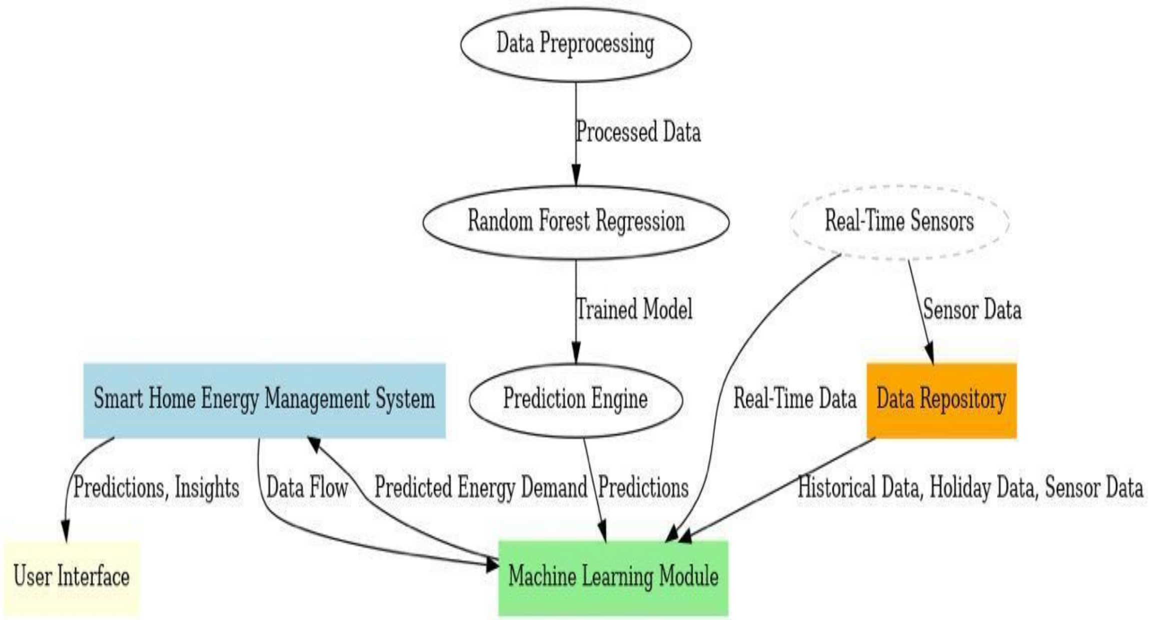
- **Real-Time Monitoring:** Enable real-time energy usage tracking through user interfaces or mobile apps to give users greater control and visibility over their energy consumption.
- **Develop Predictive Model:** Build a machine learning model using Random Forest Regression to accurately predict daily energy requirements.
- **Analyse Energy Usage Patterns:** Examine four weeks of energy consumption data to identify trends, including the influence of holidays and special events.
- **Reduce Environmental Impact**: Promote sustainability by leveraging renewable energy sources and optimizing energy consumption patterns to lower carbon emissions.

Methodology:

- **Hardware Setup**: Using energy meters, sensors, and relays to monitor and switch between mains, solar, wind, and battery sources.
- **IoT Integration:** Enable real-time data transmission using IoT devices for continuous monitoring of energy usage and generation. The ESP32

microcontroller processes data from sensors measuring energy usage, AC voltage, and environmental factors. Solar panels and batteries provide power, with automatic switching between energy sources based on demand.

- **Machine Learning:** Train a Random Forest Regression model on historical data to predict daily energy demand. rain the model with pre-processed historical energy data, incorporating holiday-specific trends to predict future energy demands.
- **Energy Management:** Users can monitor the system and set preferences through a Flask-based web interface, enabling greater control over energy consumption. Continuously update and adjust the system's predictions and appliance settings through the web interface. Utilize SQLite for storing real-time and historical data for further analysis.
- **Data Optimization:** Store real-time and historical data in SQLite databases for further analysis and to refine the machine learning model. This continuous feedback loop helps improve prediction accuracy and overall system efficiency over time.



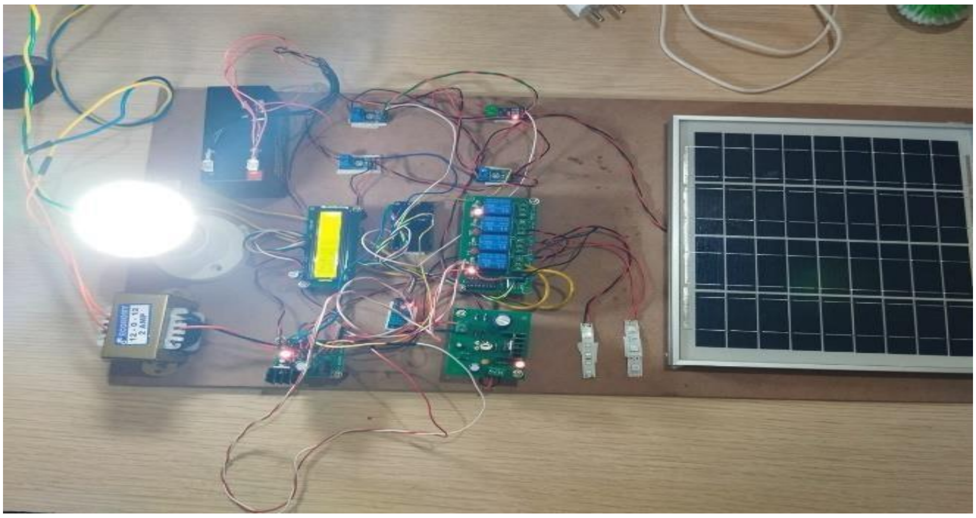
1. **User:** Initiates requests for energy usage analysis and predictions.
2. **Smart Home Energy Management System (SHM):** Manages the interaction between the user, machine learning model, and data repository.
3. **Machine Learning Model (ML):** Trains on energy usage and holiday data, and predicts energy requirements using random forest regression.
4. **Data Repository:** Stores energy usage and holiday data, providing them to the SHM as needed.

Result and Conclusion:

Conclusions:

The Eco-Power Monitor successfully integrates IoT, machine learning, and web technologies for real-time electricity monitoring and forecasting. Using an ESP32 IoT device with sensors, it efficiently collects voltage, current, temperature, and humidity data. The Random Forest model, trained on historical data, provides accurate demand predictions, validated by MAE and RMSE metrics. A Flask-based web interface offers an intuitive experience, allowing users to track electricity usage trends. The seamless hardware-software integration ensures efficient data processing, making the system a reliable tool for energy management.

Results:



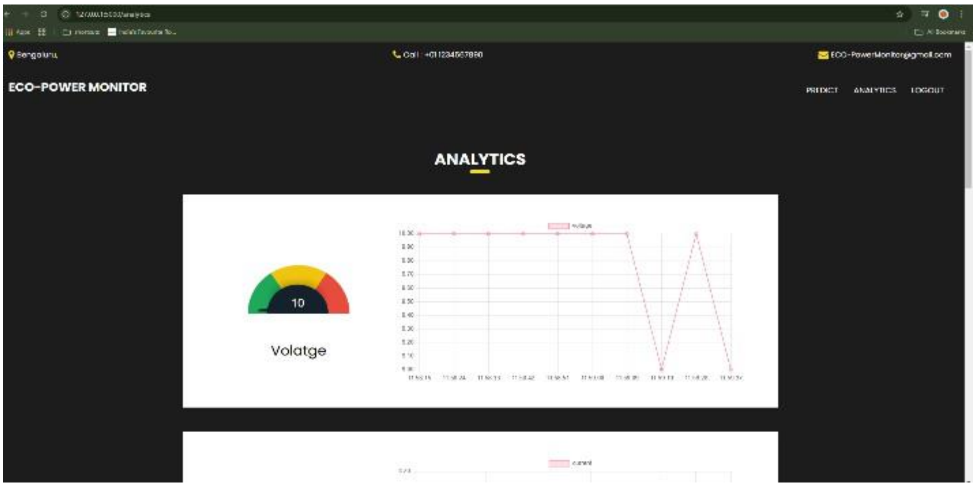


Figure.3.

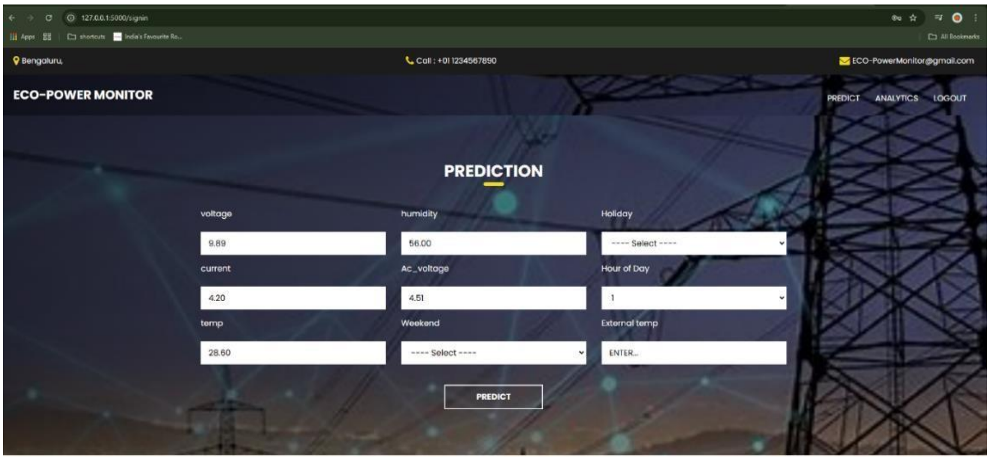


Figure.4

Future Scope:

The current model provides a solid foundation for further research and development in the field of sustainable energy systems. In the future, the project can be enhanced by integrating smart technologies such as IoT-based monitoring, AI-powered energy management, and predictive maintenance systems. These upgrades would enable better efficiency, remote diagnostics, and real-time performance tracking.

Battery technology is another area of interest. Incorporating advanced storage solutions like lithium-ion or flow batteries could improve storage capacity and lifespan. Similarly, hybrid models combining solar with wind or biogas could ensure a more reliable energy supply across varying weather conditions.

On a larger scale, the system could be adapted for microgrid development in rural areas or emergency energy setups in disaster-prone zones. Grid-tied versions with net metering capabilities could also allow users to contribute surplus energy back to the utility grid, promoting decentralized energy production.

Further research could focus on improving inverter efficiency, exploring low-cost materials for affordability, and developing modular plug-and-play kits for easy deployment. With proper support, this project could evolve into a commercially viable solution addressing both environmental and energy access challenges.

The future scope of this project includes:

1. Integrate weather data for better forecasting accuracy.
2. Expand data collection to multiple locations for scalability.
3. Shift to cloud-based storage for improved accessibility.
4. Deploy deep learning models for more precise predictions.
5. Implement real-time anomaly detection to identify unusual patterns.
6. Use time-series forecasting to refine predictions dynamically.
7. Develop a mobile app for easy monitoring and alerts.
8. Add notifications for peak demand periods.
9. Support additional IoT devices like smart meters.
10. Integrate with smart grids for advanced energy management.