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# AI Based Smart Energy Meter

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## Abstract

The world is evolving towards sustainability and the demand for the management of sustainable energy is increasing globally. This also requires development of electricity monitoring and optimization solutions. The present Energy meters help to monitor the energy consumption and generate electricity bill. These are mostly manually operated meters and no automation or artificial intelligence used. Present research papers concentrated on IoT based energy monitoring and few provide with AI analysis of energy consumption. The proposed idea is AI Based Smart Energy Meter. It is an innovative energy monitoring device which provides real-time information on voltage, current, and power usage. This advanced system is capable of displaying current, voltage, energy consumption and instantaneous electricity bills on an display and users mobile. There are three separate time periods for this project: morning, noon, and night. The meter compares the power usage over various slots at the end of each day, displaying on the user's phone the period with the highest consumption. The project offers customers a smooth and dynamic platform to track their energy usage. The system's capacity to produce instantaneous electricity bills based on real-time consumption and adjustable tariff rates is what makes it special. The combination of Hardware and Software in the AI-based Smart Energy Meter exemplifies how modern technology can enhance real-time energy data display, calculation, promoting energy conservation and cost savings.

## Keywords

Energy Monitoring, Artificial Intelligence, Real-Time monitoring, Electricity Bill generation, Tariff rates.

## 1. Introduction

The demand for the management of sustainable energy is increasing globally, the development of electricity monitoring and optimization solutions is also gaining pace. This makes the AI-based Smart Energy Meter a visionary approach towards energy management in residential as well as commercial environments by making use of AI combined with sensors to track electrical information in typical electrical circuits. It makes it easy to monitor in real time. Literature survey helped us to know about the present advancements and limitations in the existing energy monitoring systems. This project focusses to overcome those loose ends and provide with optimized outcomes with user friendliness.

In this present market of energy meters, we have only manually operated meters that help to monitor energy consumption and generate electricity bill. There is a huge demand and need to develop a Smart Energy Meter that not only monitors but also gives an analysis of energy usage by observing the energy utilization patterns. There is a need of a smart monitoring system that gives a complete analysis of energy usage. These give a lot of advantages when compared to the conventional energy meters that are used now in the market.

One major highlight of this AI meter is that it further subdivides the energy used over a day into different parts and gives an analysis of when to conserve energy. This way, consumers can easily identify at which time slot the maximum use of energy occurs so they may make proper decisions accordingly. These smart meters also deliver billing that takes in GST and other levied rates so that users clearly and accurately view their expenses on energy. This Smart Energy Meter simplifies energy tracking and provides valuable insights into more sustainable and budget-friendly energy habits, making it a useful device for monitoring your energy consumption.

### 1.1 Objectives

The aim is to create a smart energy meter that utilizes AI for the purpose of measuring and tracking the voltage and current in a standard electrical system so that there can be real-time analysis of the use of energy. The device will be using sophisticated AI to assist users to easily monitor and control electricity consumption, give alerts in case of too much usage of power, and issue detailed monthly bills. The meter will break down usage into time slots and provide clear reports that will help customers better understand their usage habits to make decisions that can help them sustain and improve efficiency.

## 2. Literature Review

V. Preethi and G. Harish developed the Design and implementation of smart energy meter. This Smart Energy Meter (SEM) is developed for preventing power theft and improving the metering and billing process. The meter continuously monitors energy usage and displays real-time consumption and costs. They have used GSM module for notifying user, which is not the most efficient way to communicate with user. They have only focused on the energy monitoring but it does not give any analysis of energy consumption.

Tariq Masood and Umer Farooq developed AI-Based Smart Energy Metering System for tracking and analyzing the patterns of energy usage. The machine learning algorithms applied to their system were used not only to predict future energy usage but also to detect anomalies that may be indicative of potential faults or inefficiencies. Their AI model was trained using previous energy consumption data, which significantly improved the accuracy of its predictions. The system furnished actionable insights to the users about optimization of energy usage in the pursuit of minimizing cost and improving efficiency.

N. Chandra Das and M. Ziaul Haque Zim developed Electric Energy Meter Integrated with Machine Learning and Conducted by Artificial Intelligence of Things (AIoT). They brought in Smart Energy Meter with an intention of tackling the inefficiencies prevalent in traditional power distribution systems. It has minimized human interactivity while automating processes, minimizing errors since it relies on IoT and AI to do its functions. The consumers can check their live status of usage, voltage, current, and power factor through an online portal. Unlike the typical systems, this SEM maintains data in power outage. Therefore, its availability enhances reliability and accuracy in billing. This system fails to provide with accurate AI analysis of the energy consumed.

A. Arif, M. Al-Hussain, N. Al-Mutairi, E. Al-Ammar, Y. Khan and N. Malik developed an Experimental study and design of smart energy meter for the smart grid. This project develops a Smart Energy Meter to improve energy efficiency in response to rising demand in the world. Unlike traditional meters, this digital meter provides real-time monitoring of energy consumption and facilitates two-way communication between consumers and utility providers. It sends data to the provider, who can notify consumers via SMS or the internet, promoting better awareness and management of energy usage. This focusses on monitoring the energy consumption but does not provide solution for AI analysis.

A. K. Salama and M. M. Abdellatif developed AIoT-based Smart Home Energy Management System. This explores the integration of Artificial Intelligence of Things (AIoT) in a smart home energy management system (SHEMS). By utilizing machine learning and neural networks, the system predicts future power consumption and automatically turns off devices to reduce energy usage. The findings highlight significant cost savings for users by keeping energy consumption below a specified threshold, showcasing AIoT's potential for optimizing energy efficiency in smart homes. This gave an idea of shaping out our final methodology to be followed to develop our project.

A. Othman and N. H. Zakaria developed an Energy Meter based Wireless Monitoring System using Blynk Application via smartphone. This paper presents a wireless energy meter monitoring system using the Blynk application on smartphones. Designed with backup battery support, this smart meter concept promotes efficient energy management

in smart cities by enhancing user awareness and providing real-time monitoring through IoT integration. It gives output via internet and does not provide any AI classification or prediction.

From all these articles we have got many insights and also understood the loopholes and limitations. They helped to give a clear idea of an optimal methodology that is also user-friendly. These helped us to understand and develop a better method of building project. These researches showed the importance of smart energy meters and needs of energy conservation in the recent times. These helped us to build a conclusion on the methodology to be followed during process.

## 3. Methods

The primary process involves sensors gathering voltage and current information from the electrical system. Precise measurement of energy usage is ascertained through the location of the voltage sensor- ZMPT101B and the current sensor- ACS712 at strategic points in the system. The two, along with real-time information regarding voltage and current data collected by these sensors, provide a constant check of power consumption. This system features detection of sudden spikes or fluctuations of electricity that exceed set thresholds, which may indicate probable malfunctions.

The generated dataset is fed into an AI model for training, enabling the system to better predict energy consumption and increase the accuracy of its predictions. The past data of energy usage are used in the training process, using PyTorch, a machine learning library. Then, the model is exported to ONNX (Open Neural Network Exchange) for better compatibility and deployment. It means that real-time data is processed using the model. The implementation can be put in place, where information is read through sensors from the STM32-F401RE Nucleo Board and then transferred to the processing unit through the HC-05 Bluetooth module in which the AI of the model runs. Using PyTorch and ONNX techniques, these data then undergo an elaborative examination to result in actual measurements of real time for power usage through measurements in volts and current. The configuration ensures that the monitoring and predictive capabilities of the system are very reliable and accurate.

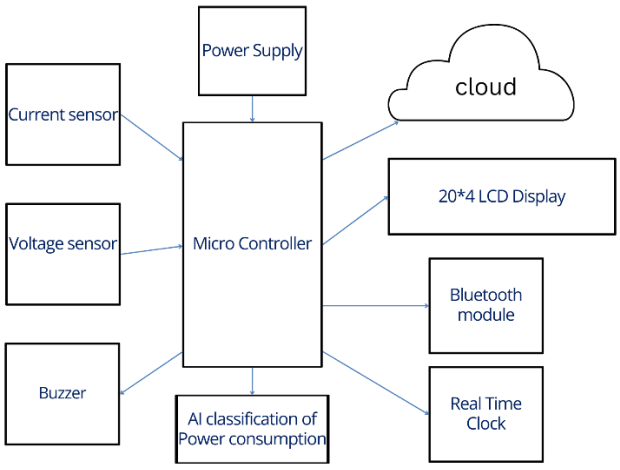


Figure 1. Block Diagram of proposed system.

With the AI model (Figure 1), users can have better control over their energy consumption by knowing the patterns at a clear and distinct level. They then can optimize energy consumption, which may bring cost savings through more efficient habits.

This is one of the unique features of this designed system, it can put daily power usage into different time slots, such as morning, noon, or night. At the close of every day, the system analyses the power utilized during the periods and send an alert to the mobile of the user showing during which time slot the highest energy utilization was done in that particular day. In addition, this information is displayed on an LCD screen the next day from 6 AM to 9 PM. At the end of every month, it calculates the total cost, inclusive of the applicable GST rate and tariff structure for usage during that particular month.

With this methodology, the integration of advanced sensor data collections, AI model training via PyTorch and ONNX, and real-time processing of data will lead towards the delivery of accurate and perceptive energy monitoring and management. This holistic approach fosters the empowerment of user control over their energy usages, thus developing habit-forming efficiency with probably saved costs (Figure 2).

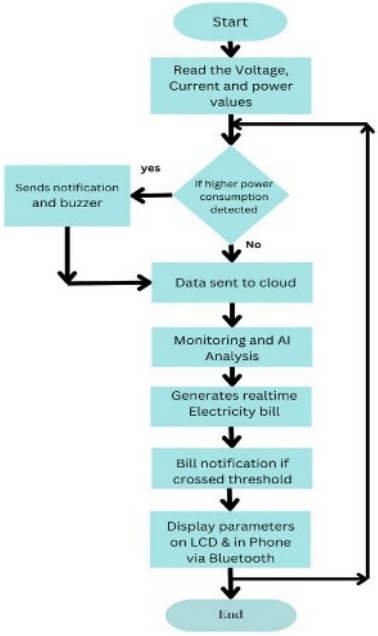


Figure 2. Flowchart of proposed system.

## 4. Data Collection

Dataset for this project is gathered by collection of current consumption data from our college laboratory, measuring it every single second throughout the month. We categorized the data chronologically by date and by time, as well as through power, current, and consumption levels, specifically highlighting them as low, medium, or high-power consumptions. This dataset formed the basis of training of our AI model, hence aiding in its ability to classify power utilization into any of these three categories.

## 5. Results and Discussion

In this project we have trained AI model interface with a Bluetooth module and have connected it to show real-time electricity usage monitored by the Mobilephones from which users can monitor every day's energyconsumption for them to understand their details of billing. In case of higher use of voltage or current, a buzzer alerts the user regarding such issues so that there can be prompt response actions taken. The system breaks down the power usage into three subcategories: Morning, Noon, and Night. This indicates which time in the day is used with the most amount of utilization on both the mobile app and LCD screen. From this, users can observe the times they are spending the most amount of energy and take precautionary steps to decrease it accordingly. At the end of the month, the system calculates the total electricity bill and includes taxes and tariff, this helps the users manage their finances well and also conserve energy (Figure 3). With the use of AI for the analysis of past and present data, the system comes up with predictions and recommendations for improving efficient use of energy. This helps the users achieve better habits that help save them money and enables the effective handling of energy consumption.


Figure 3. Energy consumption readings in Bluetooth terminal.

## 5.1 Graphical Results

The below shown results show the graphical outputs of the Current, Voltage, Power, Electricity bill generated, Number of units of energy used other parameters. There are various graphs that show the graphical pattern of energy utilized by the user in the below Figure 4.

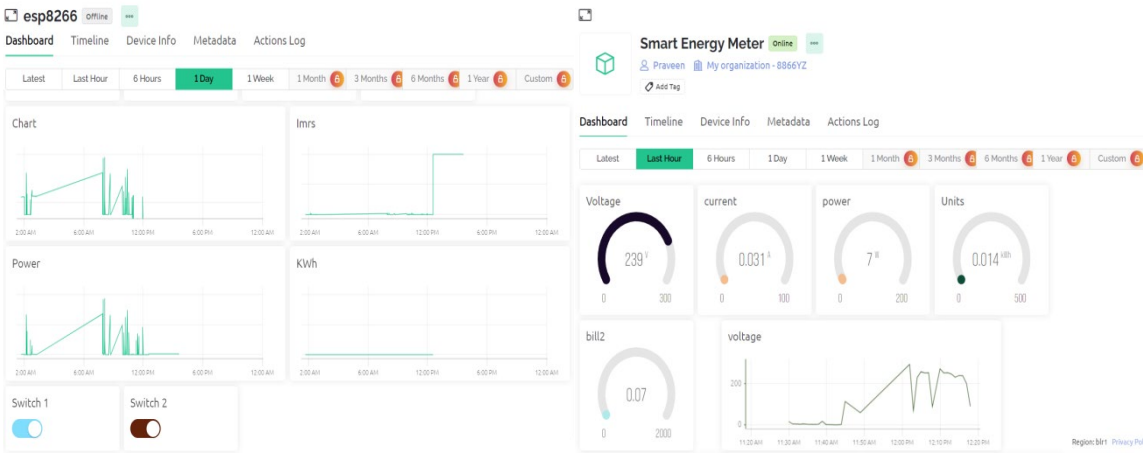


Figure 4. Output graphs showing the Voltage Current and other parameters.

## 5.2 Validation

The dataset taken is given for the validation dataset and then we took readings from the Energy meter as original dataset. When these are given for validation, we have achieved a balanced accuracy of 91% in predicting energy consumption trends and a score of 88.54% when evaluated in Nano Edge AI tool of ST, surpassing the industry average of 85-90%. This high accuracy was achieved by refining the AI training process with a varied dataset and applying a mix of machine learning techniques, such as decision trees and neural networks.

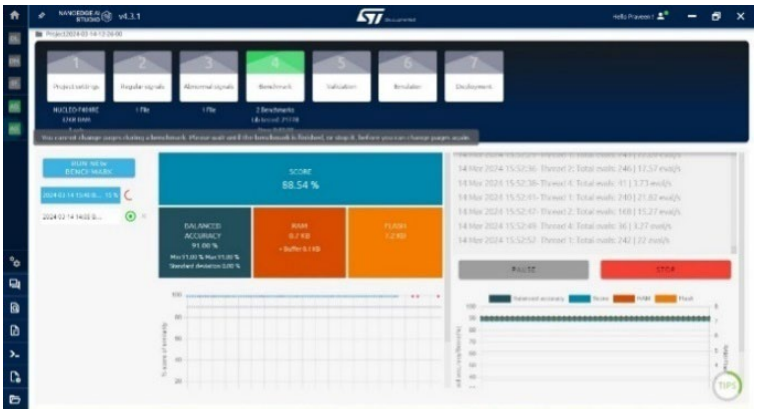


Figure 5. Validation result of AI model on STM Nano Edge AI platform

The above Figure 5 shows our validation result of AI model on STM Nano Edge AI platform and Figure 6 shows Project prototype images

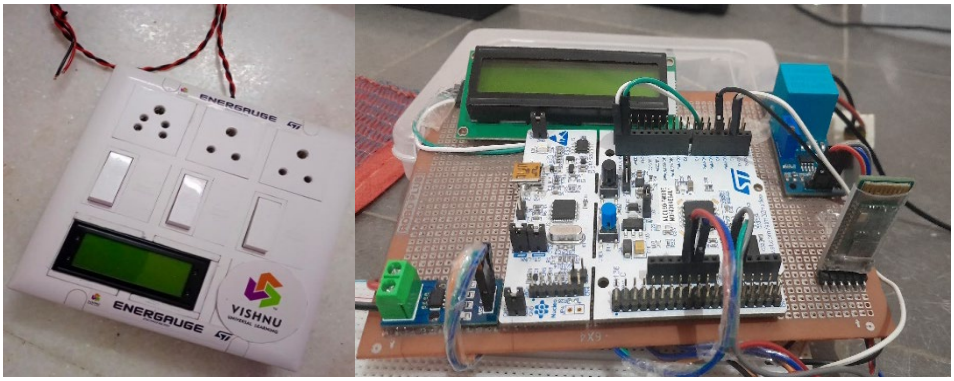


Figure 6. Project prototype images

## 6. Conclusion

Energy management in our project is innovative in the sense that it integrates real-time monitoring with predictive analytics and user-friendliness. It also generates accurate consumption measurements and provides a more realistic view of daily and monthly consumption patterns through AI algorithms, thereby promoting energy sustainability. Besides these monitoring features, this system also has very advanced billing capabilities that compute the cost of electricity with GST as well as with tariffs. The system breaks down the power usage into three subcategories: Morning, Noon, and Night. This helps to identify which time in the day is consuming more amount of energy and notifies to the user.

Some of its salient features include time-slot analysis for categorized energy usage, real-time alerts through Bluetooth, and remote monitoring. These features allow the users to efficiently manage energy both at home and commercially. Moreover, its advanced billing system calculates the costs by applying tariffs and GST, while predictive analytics forecast trends with 91% accuracy. This system supports precise energy monitoring and also promotes responsible consumption.

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