

EDGE–Cloud Integrated IOT-Based Smart Metering System For Time-Series Energy Consumption Forecasting In Smart Grids

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Abstract—The purpose of this study is creating a meter framework that merges Internet of Things (IoT) with cloud technology, creating a comprehensive solution for increasing smart grid efficiency. One aspect of the framework includes time series analysis of energy usage trends and patterns. A device that has an Arduino Mega 2560 and NodeMCU is designed to communicate with sensors used to monitor electric consumption, as well as ambient temperature and humidity. A cloud based server receives continuous streaming of this information, allowing users to monitor and control their electric consumption while maximizing safety.

Index Terms— Energy Consumption, Remote Load Control, Smart Meter, Cloud-Based Energy Management, Wireless Data Transmission

I. INTRODUCTION

The exponential growth in electricity consumption due to new technologies and increased industrial performance has led to greater emphasis on efficient management of the energy consumed. Existing post-paid electricity billing systems frequently create delayed payments and energy wastage due to a lack of awareness by consumers of their own consumption patterns; therefore, there is a clear need for an effective solution. The solution proposed will be an Integrated Smart Energy Pre-Paid Metering System using IoT/Cloud technologies within a Smart Grid system for controlling and monitoring electrical usage. This solution allows a user to pre-purchase (recharge) energy credits, just as a mobile phone can be recharged, with continuous tracking of electricity used via a smart-phone application. Each time energy is used, it is subtracted from the available balance (credit) and the consumer will be notified when their balance reaches a threshold requiring immediate action. If a consumer exhausts their credit, the system can disconnect power supply to the consumer until recharge of credits occurs, therefore ensuring the system promotes efficiency in energy consumption. The proposed solution also offers the benefit of real-time energy usage monitoring, and the ability to control and manage energy usage remotely with improved accountability.

Overview

The energy distribution systems are moving towards Smart Grid technologies. Smart grids require the prediction of changes in electricity demand using intelligence and predictive analytics.

Problem Statement

Most conventional systems do not provide time or environmental data. This project will create a Consolidated Edge-Cloud Framework for predicting electrical loads.

II. LITERATURE SURVEY

The Proposed Work section provides an overview of the proposed system for power regulation & safety, as well as metering and data acquisition.

Section II reviews the literature related to IoT advancements that have facilitated gaining finer granularity of data from the electric network. Previous research has investigated several different architectures that can accommodate smart metering; however, most of the studies do not consider both the automation associated with the collection of data as well as the means in which it will be gathered.

Power Regulation & Safety

The input to the proposed system is standard AC voltage (230 VAC).

The step-down transformer will reduce voltage for electronics to work with, at which point the power will be converted to direct current (DC) by bridge rectifying the output.

The capacitor will smooth the output of the bridge rectifier to reduce the amount of “rippling” in the Output DC voltage, and the LM7805 voltage regulator will regulate the output voltage (5 VDC) to support the NodeMCU and other highly sensitive modules as required.

Metering & Data Acquisition

A sub-meter will measure the electrical parameters such as voltage, amperage and kilowatt hours used. Pulse Conversion: Sub-meters interface with counter relays to create digital pulses when converting energy units.

Processing: Within NodeMCU ESP8266, the pulses (ie. Each 3200 Pulses equal 1 Unit) are processed for usage.

Load Control and Communication

Using a sub-meter relay will switch off power to your sub-meter and then pass the load using another relay to the lights, fans, etc., as previously mentioned.

To allow remote monitoring and control of the loads, the mobile app (Blynk) will connect to your mobile device with Wi-Fi.

Audible alarms will alert you when you use more than your allowed amount of power, when you have an overuse or an appliance failure, or when you have no more available credit..

III. PROPOSED METHOD

4.1 Shift from Existing to Future-Backwards: The existing smart meter approach is reactive (measured or basic automated) with no detailed awareness of environmental conditions surrounding usage [cite: 11]. The currently proposed solution is to use an active (real-time) approach utilizing live environmental conditions such as occupancy and temperature in conjunction with projected energy usage [cite: 11]. 4.2 Cloud-based Forecasting and Integration: Using the Blynk IoT platform to wirelessly transmit data through the NodeMCU ESP8266 [cite: 11], will enable: * Predictive analytics: Based on time series data used to determine when peak will occur [cite: 11]. * Remote management: Being able to control loads (i.e., turn on/off individual bulbs or fans) from remote access using your mobile devices [cite: 11].

IV. SYSTEM ARCHITECTURE

The system is designed with a layered approach to ensure seamless data flow and reliable control, bridging the gap between hardware sensing and cloud-based analytics.

Hardware Framework

In order to allow smooth data exchange as well as provide dependable control, the system has been designed in a layered fashion, such that the hardware has been designed to connect with the cloud for the analytics. The Layered Architecture will allow the system to allow smooth data transfer as well as dependable control between the hardware sensing and analytics on the cloud. 5.1. The Hardware Architectural Framework This physical hardware architectural framework includes both computational capability and multi-parameter sensors that will create a complete informative view of the eEnergy Playground. sensors, which together create an entire view of aEnergy Play.

Software Implementation

The intelligence in our system is achieved through Embedded Programming language and/or Cloud Services:

- The Arduino Integrated Development Environment (IDE) is used to write/upload control logic to both Arduino and NodeMCU.
- Embedded C (Preferred Low-Level Language) is used for the efficient low-level hardware interface/control/timing.
- Blynk IoT Framework is used to provide a real time dashboard and remotely control/monitor energy from anywhere by allowing users to see and control all devices via smartphone, tablet, or computer through internet access.

V. STRATEGIC ADVANTAGES AND CHALLENGES

Advantages

1. Intelligent Automation – Less manual management
2. More Convenience
3. Integrated Fire Monitoring System = More Secure Infrastructure
4. Y-Time Visibility = Constant Feed of Energy Trend Data

Factors to Consider During Implementation

Security: Cybersecurity/Data Privacy
Cost: Set-Up Costs/Maintenance Costs

VI. PRACTICAL APPLICATIONS

This system is highly adaptable for various sectors:

Smart Residential Grids: For automated home energy optimization [cite: 11].

Industrial Management: Monitoring large-scale load profile

VII. RESULT AND DISCUSSION

Varied load test was conducted to test out the system's performance. The mobile interface provided appropriate real-time usage of energy as well provided independent control over all connected loads. The ability of the system to update its status; multiple ON & OFF scenarios of the connected loads were demonstrated dynamically. The hardware setup, consisting of relays, bulbs, and energy meters, validated the practical implementation of remote load control.

The results confirm that the system effectively integrates cloud-based monitoring with physical control mechanisms, enabling efficient energy management

Continuous Monitoring

Users can see how much energy is being consumed at any one time along with the environmental conditions occurring at that moment through a cloud based monitoring Dashboard.

Safety Actions

If a fire is detected by the system it immediately disconnects the relay contact and sends out a GSM notification alerting those that are impacted by the “Edge” capabilities of the design.



VIII. CONCLUSION

By establishing a cloud based architecture on NodeMCU; it has gained access to "real-time" data acquisition and predictive analysis of time series data; which enable it to automate and reduce energy consumption. For further information; refer to [11]; NodeMCU has also explored the possibility of introducing other features such as dynamic Tariff notifications and Smart Billing; for reference see [11].

ACKNOWLEDGMENT

This project could not have been completed without the contributions from everyone who has made it possible, but I wish to especially thank my sister for providing support as a peer in refining and editing this manuscript to make it possible to publish. The many suggestions she made and her technical feedback have made me able to move from the initial draft of this essay to its final form. I would also like to extend my gratitude to my colleagues and to those who created an environment here at this institution that has allowed me to successfully complete this research.

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