New Age Energy Monitoring System

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Abstract - *With the increasing impact of digitalisation, energy needs of human civilization are at an all time high. Along with increased needs comes the increased wastage and mis-handling of electricity. These have the potential to lead the world into an energy crisis sooner than ever. In such a case, the traditional metering systems seem inadequate. This paper showcases the design of a New Age Energy monitoring system whose primary purpose is to provide constant monitoring of energy consumption with added functionality of 'Miniature circuit breaker'. The system makes use of ESP32 Board with in-built Wi-Fi capabilities and ADE7753-Energy meter IC for measurement of energy related parameters. A website provides a user-interface for users to check their energy consumption and to input values for circuit breakers.*

***Key Words*: Energy meter, Smart meter, ADE7753, Circuit breaker, ESP 32, Energy monitoring, Embedded system design**

1. INTRODUCTION

The current electricity meter system poses few limitations and drawbacks. Illegal power usage and theft, improper management, inability to keep track of the changing maximum demand of consumers are some of them.

The current meter reading system requires humans to physically go to each and every energy meter to take readings & generate bills. This system is very time consuming and can be inaccurate in case of theft and human errors. A Smart energy meter which applies principles of Internet of things(IOT) can address the growing issue of power management. This will help the consumers and the distribution companies in the near future.

We designed the New age Energy Meter with following functions and benefits:

1) The proposed model is not only capable of reducing the implementation and maintenance cost, but also hardware costs and supports the concept of Internet of Things (IoTs) by the use of a low cost Wi-Fi module, ESP32.

2) The energy meter in such a system is connected to a web server through WiFi protocol. The web server receives instantaneous data of power consumed continuously

3) For added security, this system provides users with an option to set usage limits for a particular room or set of appliances, post reaching which, the supply will be cut off and can be restored manually by a switch.

4) Flexible GUI in the form of a website to ensure users have a smooth experience, especially those without a technical background.

5) Data collection over short and long periods of time to learn about the energy consumption behavior of the users.

6)Precise monthly billing cycle ensures users are not charged for any extra days which may happen in case of delayed meter reading by traditional method.

Thus, by the use of functions provided by the New age energy monitoring system, consumers can monitor their power usage as well as get access to precise billing cycle. This makes the process hassle free and efficient.

2. LITERATURE SURVEY

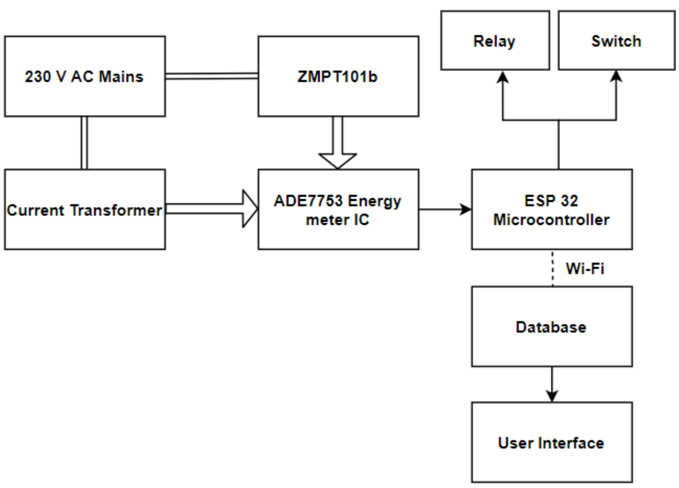
In recent years, a large number of papers have proposed the design and implementation of smart energy meters for energy consumption monitoring or bill generation. The common goal was to overcome human errors, manual labor, and cost reduction in energy consumption with a more efficient power management system. One of the papers focused mainly on IoT`s energy monitoring in which the proposed system implemented a very low cost wireless sensor network and a protocol for smart energy and along with a web application which is capable of automatically reading the unit and sending the data automatically to users to view their current energy meter reading. The system consisted of a digital energy meter, ESP8266 WiFi module and web applications for management systems. The ESP8266 WiFi module was embedded into the energy meter and implemented TCP/IP protocol for the communications between the meter and web application [1].

Another paper shows the design of a smart meter that offers multiple communication possibilities, like USB, Ethernet, ZigBee or Bluetooth. This smart meter can be used as an energy meter (few minutes average) or as a power quality meter (10 seconds average). The design describes a cheap smart meter that enables and supports operation and control functions in the distribution networks. It is based on open source hardware (Arduino and Arduino Ethernet Board). The smart meter uses the ADE7753 as a converter and stores only the most important data on the SD card, so that all other calculations can be performed by an external central system [2]. Another approach designed a wireless sensor network and protocol for smart energy meters in which a ZigBee module from Atmel was adopted as a communication unit and the system is capable of automatically reading the energy units consumed and then sending a terminal and cover alarm to the management system. The system was able to support upto 100 energy meters, 10-hop network depth and can automatically detect any new energy meter [3].

Some researchers implemented a smart energy meter which was GSM enabled along with a smart switch board which reduced the need of upgrading appliances which made the system more economic. The GSM module included was used to communicate with customer, utility and remote switching of appliances[4]. An energy meter using LORA is represented in [5] in which again Arduino is used as it is energy efficient.

A new concept of energy meter using embedded systems was devised wherein the maximum demand of energy of the user was indicated in the meter. If the maximum demand was exceeded, the meter and connection would get automatically disconnected by the embedded system which was inserted into the energy meter itself [6]. Another smart energy meter coupled with an iOS application to report power consumption, power generation and power quality parameters is presented in [7]. These were several past investigations in making and designing smart energy meters. Most of the work is limited to the design of low cost models of smart energy meters. Also no work has been reported for a smart energy meter with an inbuilt and on-board MCB(miniature circuit breaker) functionality to check status of the devices.

3. BLOCK DIAGRAM



3. IMPLEMENTATION

3.1 Hardware

Hardware design of the new age energy meter is based on the serial interface between low-cost ESP 32 Microcontroller and Energy meter IC ADE7753. The measurements are done via ADE7753 and this information is made available on the external GUI through ESP32.

A hardware consisting of Relays & current transformers connected to ESP32 serves the purpose of the Add-on functionality of a Miniature-Circuit breaker.

3.1.1 Selection of microcontroller:

For our design of the New Age energy meter, we needed a Microcontroller with built-in Wifi Capabilities, SPI Interface and an accurate ADC.

ESP 32 comes with 3 SPI interfaces, 18 12-bit ADC channels and ultra-low power consumption. Apart from the above features ESP-32 has 23 usable GPIO port pins which makes it a comfortable choice considering the future scope of this system and the prospective add-on features. ESP-32 is also compatible with the open-source Arduino IDE which is easy to use and comes with its own SPI library.

Fig - 1: Microcontroller ESP-32 DO-IT DevKit

3.1.2 ADE5573 Energy Meter IC:

ADE7753 is a low-cost metering IC which sends data using the SPI serial interface. It provides highly accurate meter readings and comes with a programmable gain amplifier that allows direct interface with current transformers & shunts for current and voltage measurement respectively.

In our system we read the values of RMS Current & Voltage and Active Energy through the chip. ADE7753 is capable of measuring various parameters like active, reactive, and apparent energy, sampled waveform, RMS current and voltage.

It comes with built-in digital calibration for power, phase, and input offset making it as close to real reading as possible. The chip displays less than 0.1% error in active energy measurement over a dynamic range of 1000 to 1 at 25°C making it an ideal choice for our system.

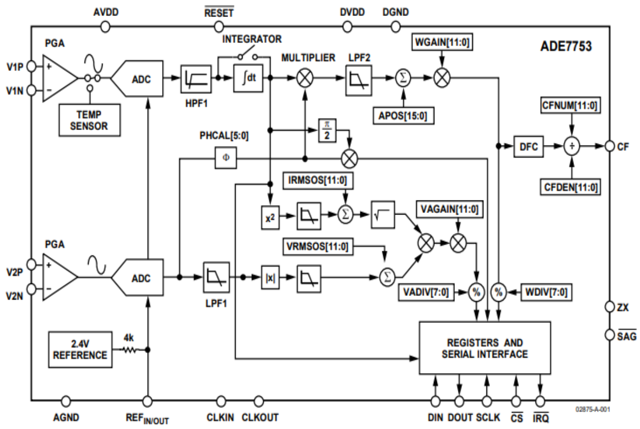


Fig - 2: Functional block diagram of the ADE 5573

3.1.3 Current and Voltage Inputs

A current transformer with a turns ratio of 1:2500 is used to step-down the current and make it available to the current channel in the energy meter IC. The differential voltage achieved at the PGA of the current channel is 0.5 V.

The ZMPT101B high-precision voltage transformer is used to provide the necessary isolation between high voltage and low voltage. A shunt resistor is used to provide 0.5 V differential voltage to the PGA at voltage channel in the energy meter IC.

Fig - 4 : ZMPT101B Transformer

Fig - 5: Current

3.1.4 Miniature Circuit Breaker

To provide the functionality of a circuit breaker for the purpose of safety, Current Transformers were interfaced with the ADC of ESP 32 to measure the current reading.

The system depends on its Relay interface for a switching mechanism which is the core of the circuit breaker.

A switch-interface (push button) is provided as a means for the manual switching ON of a device.

3.2 Software

The software Implementation of this system consists of mainly three parts. These include

1. Serial Interface between ESP32 and ADE7753

2. Visualization of the Guided User-Interface (GUI)

3. Interfacing the MCB

3.2.1 Serial Interface between ESP32 and ADE7753

The SPI Library of arduino IDE is used to interface the ADE7753 with ESP32. Appropriate gain setting for PGA is applied and the desired proportionality factors are chosen for conversion of register values to real readings. Functions for reading internal Voltage, Current and Energy registers are called every 5 seconds to check the respective readings. These values are averaged over 20 cycles so as to ensure accurate readings.

Through the HTTP protocol these values are sent to a database at the backend of a hosted website.

3.2.2 Visualization of the Guided User-Interface (GUI)

One of the key aspects of the project was to have electricity monitoring at the fingertips and so the website is created. The frontend technology stack consists of HTML, CSS and the backend consists of MySQL & PHP.

HTML is a markup language used to define and describe the structure of a webpage and CSS adds style, and design to it.

MySQL is an open-source relational database management system that is used to store and organize data like power factor, current rating, voltage rating and to process the data. PHP is a server-side open-source scripting language used for web development to make web pages dynamic and interactive, and it also makes it easy to add functionality to the webpage. Functions like receiving data from the database and displaying it on the website are carried out using PHP.

User interface viz., the website helps the user to track or monitor their consumption at any point of time using data tables and charts wherein the user can select to view total consumption till date or between any two timestamps. Users can generate an approximate bill for the consumption and can set thresholds for the MCB functionality to have a status check of their devices/appliances.

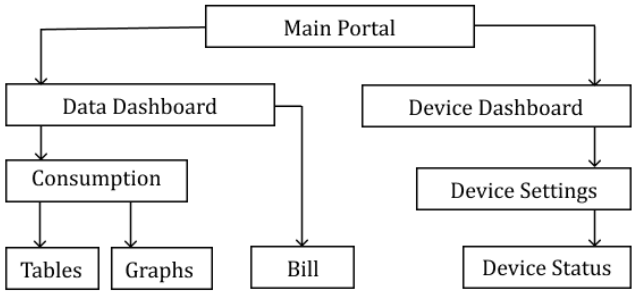
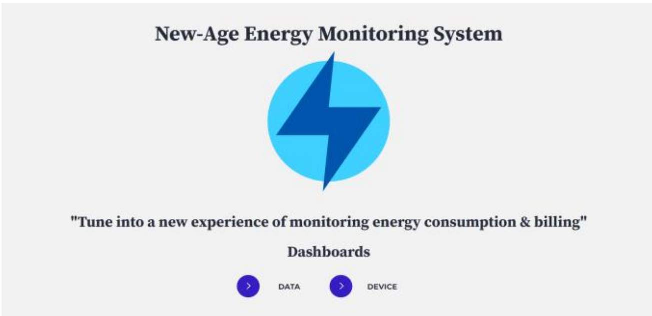
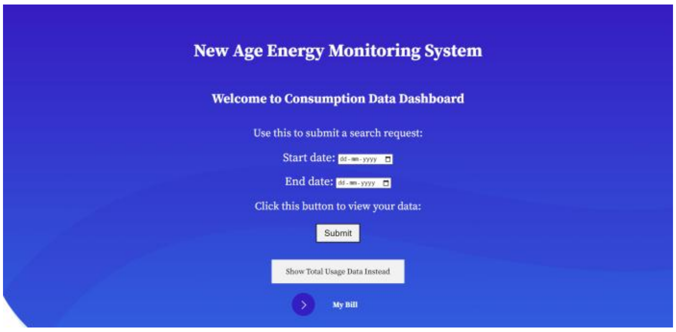
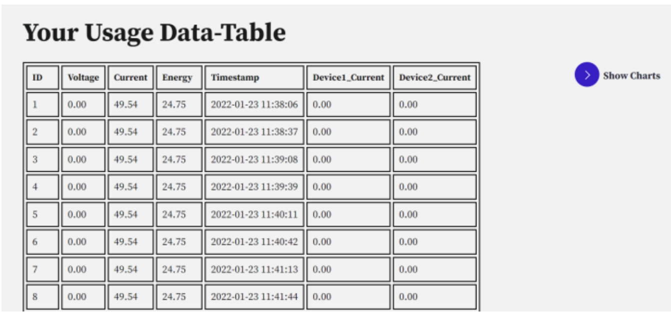


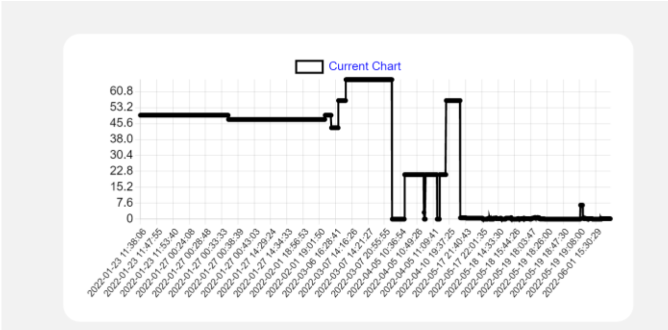
Fig - 6: Functionality of Website



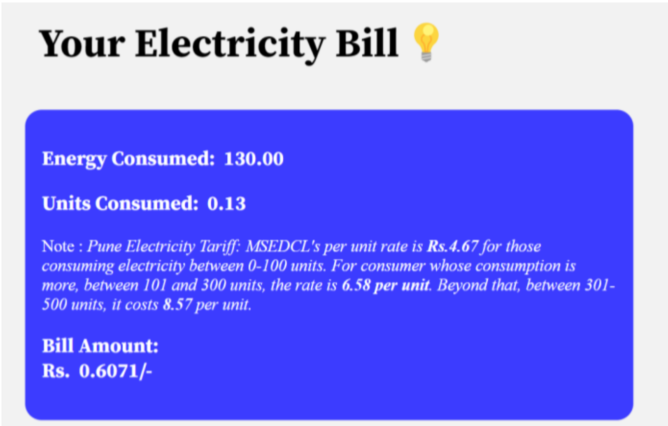


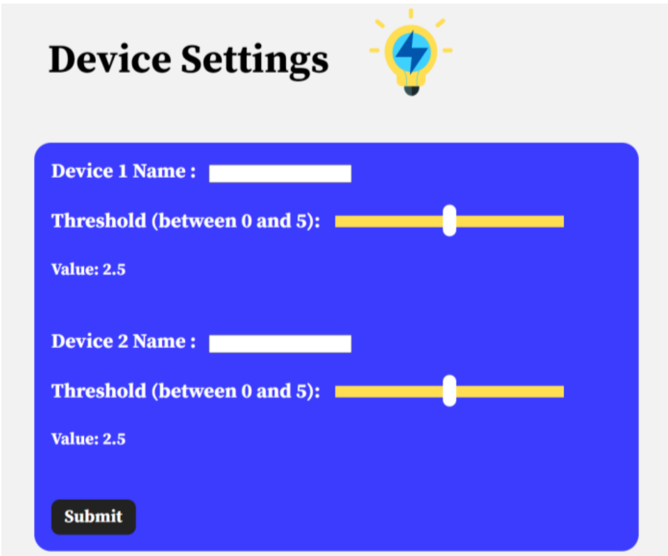


ID	Voltage	Current	Energy	Timestamp	Device1_Current	Device2_Current
1	0.00	49.54	24.75	2022-01-23 11:38:06	0.00	0.00
2	0.00	49.54	24.75	2022-01-23 11:38:37	0.00	0.00
3	0.00	49.54	24.75	2022-01-23 11:39:08	0.00	0.00
4	0.00	49.54	24.75	2022-01-23 11:39:39	0.00	0.00
5	0.00	49.54	24.75	2022-01-23 11:40:11	0.00	0.00
6	0.00	49.54	24.75	2022-01-23 11:40:42	0.00	0.00
7	0.00	49.54	24.75	2022-01-23 11:41:13	0.00	0.00
8	0.00	49.54	24.75	2022-01-23 11:41:44	0.00	0.00



Current Chart





3.2.3 Interfacing the MCB

The ADC channels of ESP32 reads calibrated current values from various devices in a loop.

The threshold values of current entered by the user on the GUI are received by the ESP 32 via HTTP protocol every 5 seconds. This value is constantly compared with the real-time rms current of the device.

If the latter exceeds the former, the microcontroller switches the corresponding device's relay off. Once the device is turned off, only by long pressing its corresponding push-button interfaced with the microcontroller can turn it on.

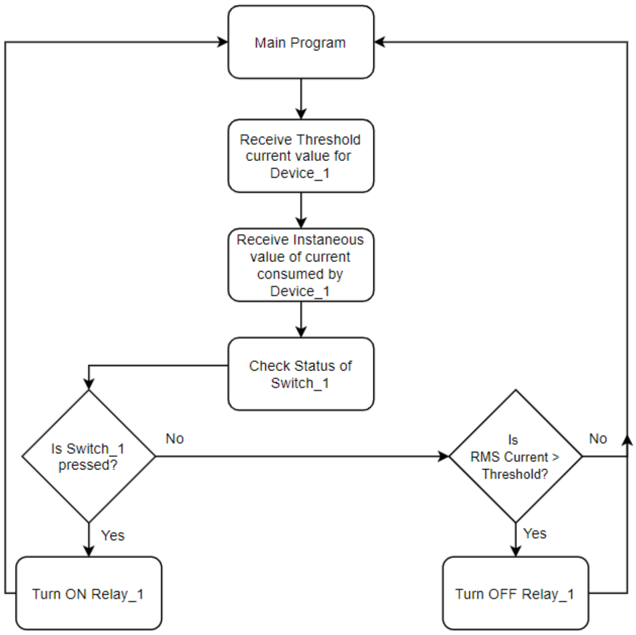


Fig - 7: Flowchart of MCB functionality for one Device

4. RESULTS AND OUTCOMES

A working Energy meter with minimal functionality and a display screen was connected in series with our prototype.

The testing was done on three conditions:

1. Measuring the Energy parameters when all components work fine:

In which, after every 0.5 seconds, the Energy, Current & Voltage readings were registered in the database of our hosted website. These readings matched with the readings displayed on the screen of the Test meter.

2. Measuring the Energy parameters when a device is faulty:

In which, the faulty device was turned off as expected and the energy parameters of all other working devices were registered to the database successfully. Various threshold readings were given to the system through the GUI and it worked as expected for all input parameters. The desired device status was also visible on the GUI.

3. Testing functionality of switch for a device that is turned off:

In which, after long-pressing the corresponding switch for the faulty device, it was successfully turned on. Long pressing the switch for devices that were already turned on did not affect them.

Thus, the above outcomes have provided us with a proof of concept for an energy meter that could be beneficial as well as commercially viable.

5. CONCLUSION

Energy monitoring systems are a major requirement given the fast paced forward movement of the world towards global warming. This system will also form a crucial part of industries where energy consumption standards have to be complied with. Constant monitoring leads to proactive problem management and saves industries from incurring huge losses. This will also help in early detection in case of electricity theft, for which otherwise the user has to wait till the end of the billing cycle.

The Energy monitoring system checks all the boxes of requirements posed by today's world and thus can be considered suitable for use and production.

6. FUTURE SCOPE

The current prototype deals with power management at a residential/organizational level. With a few modifications, this system can benefit the country on a larger scale. Setting it up across the nation would result in time saving, reduction in manual labor, theft detection and transparent bill generation.

To implement this system on a larger scale the following change would be necessary:

Usage of LORA protocol instead of Wi-Fi protocol LORA is a long range protocol which can range anywhere between 15 to 20 Kms. This attribute can be utilized by energy distribution companies to replace the traditional meter reading practice. A single person can be assigned to an area of upto 15 Kms.

By simply standing at the focal point and carrying a LORA receiver, All the meter readings in the area will be registered in the respective authority's mobile phone app.

A system like this ensures minimal manual effort hence saving a lot of time, In addition to the benefits already provided by our prototype.

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