Web Based Energy Load Profile Monitoring And Data Analytics For Residential Consumers

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Abstract— In the Energy Management system, the main constraints are accurate metering, energy monitoring and implementation of visual data for consumer load profile. This Project is intended in designing a system at home which monitors the energy consumption of each device, along with the smart energy meter, which is designed to calculate the total energy consumption of the home. All the data calculations will be handled by the Arduino energy meter for the accurate readings. A server will be created with appropriate channels to monitor the energy consumption from each of the devices respectively. These data will be uploaded to the server at the monitoring station. Considering all these data individual energy load profile for each of the devices is displayed on the web-page.
Accordingly the analysis can be made for the precise usage or energy consumption of each device in order to further reduce the usage of the device which is drawing the maximum amount of energy. These monitoring reports would help consumers to take the required action in order to improvise the energy usage.

Index Terms—Arduino, data analytics, load profile, raspberry pi, web-server

I. INTRODUCTION

Nowadays, the concept of the IOT is gaining acceptance and a diverse range of applications will be developed over next years. Within this segment, we can highlight the development of smart meters. However, the employment of smart meters has only been made possible due to the evolution of digital electronics that allows the implementation of software in embedded hardware. All the energy consumption information collected from smart meters through the sensors.

The very first step in managing electric load demand is to know the general patterns of electricity consumption. Electrical power consumptions of end users generally vary due to behavior of customers, ambient conditions, etc. This knowledge about the behavior of the load is learned from experience with the use of consumer data and statistical analysis of consumption. In past few years, energy analytic is emerging and lots of research on electricity consumption analysis like consumer segmentation, characterization, predictions and knowledge extraction from smart meter had been done. The data mining techniques mostly used classification, clustering of electricity demand patterns and cluster analysis of smart metering data[10]. In this paper we target the consumers (household) as an active part.

II. RELATED WORK

A number of studies have focused on identifying load profiles in electrical systems. A system presents a method for the identification of consumer load profiles in a totally automatic way. The main objective was to develop an interface between utilities and consumers in order to obtain data from smart meters and identify the load profile. A database was created to store data related to consumers from which the utility software was able to furnish each consumer's load profiles and to use this information to make decisions [1]. Smart meters can be interconnected in a large network offering a potential value to implement energy savings and other energy-related services, as long as an efficient interface with the final user is implemented. The electronic meters for electricity (smart meters) are undergoing an increasing deployment in private homes all over the world, as a consequence of growing physical communication network with the energy distributors. Hence are enabled at simplified, more efficient, and less costly transactions with the customers, e.g. for meter reading, billing, and energy supply administration [2]. Implementation of smart meters increases the availability of detail level of consumer electricity load profile data. Based on consumers of electricity, the usage of electricity is different for each and every consumer resulting different load shapes due to different consumer behavior, weather situations, different weekdays and time also matters. The primary objective of our load profiling task over a set of users having different recorded attributes and their half hourly demand over a period of month is to build models which approximate their load shapes for certain subsets of customers and self-reliance estimates for those load shapes, for

different consumer weather conditions, times of year, and days of the week. [3].

Load profile analysis in different regions is very useful to power utilities for managing the load requirements in economic and efficient manner. For the demand side management and grid operation, the variation in demand is to be known. For different zones, typical load profiles based on similar consumption are obtained. Primarily, the load factor represents feeder demand variation, and loss factor helps average energy loss estimation in distribution power systems.

Different types of customers have different peak requirements at different period of time. Residential customers have maximum demand in evening hours while commercial customers may need maximum power in early afternoon. In distribution system, level of current (i.e. load) is primary cause of power losses[4]. In addition, we also highlight the methods proposed for demand side management [5]-[8], which can be related either to load control at certain times of the day [5] or to the scheme (divided into different ranges) of pricing electricity during the day [6], [7]. Thus, it is important to mention that techniques for load profile identification aid demand-side management methods, which can be observed when the loads are controlled based on a list of priorities. Thus, the actual loads (list) connected to the residential electrical system could be provided by the method of load profile identification.

III. PROPOSED DESIGN

In the Energy Management system, the main constraints are accurate metering, energy monitoring and implementation of visual data for consumer load profile. This can be achieved by using Smart Meters. This Project is intended in designing a system at home which monitors the energy consumption of each device, and displaying the usage in a graphical way. The aspects of the proposed design will cover three categories where utility which represents a computational system installed where the data acquisition from consumers smart meters can be processed and analyzed. Network which is a bidirectional link to transmit and receive data of consumers through the internet enabled devices. Consumer active where they can online monitor the load profile created and take required actions based on data analytics done. The main improvement in this system as compared is to complete the loop and making the consumer as an active part of the system to take decision depending on the notifications/messages provided after data analytics.

Live energy consumption reading from the Smart energy meter is sent back to the web server periodically and details are updated in a central database. The web server is created and an interface is created for the users to track the consumption of each appliance in the home continuously from anywhere and anytime.
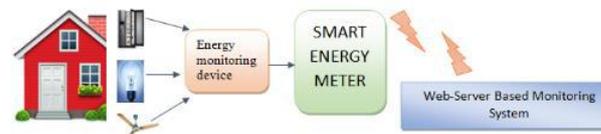

Fig 1: Top level block diagram

IV. ARCHITECTURE DETAILED

This system is implemented to measure the power, thus the energy in terms of Kilowatt-hour so we need to measure the current and voltage from the mains supply. The voltage is

measured from the lines passing through the step down transformer and a voltage regulator so that its give the regulated dc output that is in the acceptable range of the microcontroller i.e. Arduino Uno. Arduino is an open-source electronics platform based on easy-to-use hardware and software. It senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators. Arduino Uno, is a microcontroller board based on the ATmega328P. It is an AVR based microcontroller with 5v supply, 8 bit and 16Mhz clock frequency. The software coding is done in Arduino programming language and using the provided Arduino Integrated development environment.

The current sensors are used to give the accurate current consumption values of each load connected. The current sensor used is ACS712. The Allegro ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, etc. The power calculation is done using the current and voltage values obtained from the supply and also the energy consumption for each of the devices is done in Kilowatt-hour. These data will be sent wirelessly through the Wi-Fi module interfaced with the microcontroller. The ESP8266 is a low-cost Wi-Fi chip with full TCP/IP stack and MCU (microcontroller unit) capability supporting IEEE 802.11 b/g/n Wi-Fi standards.
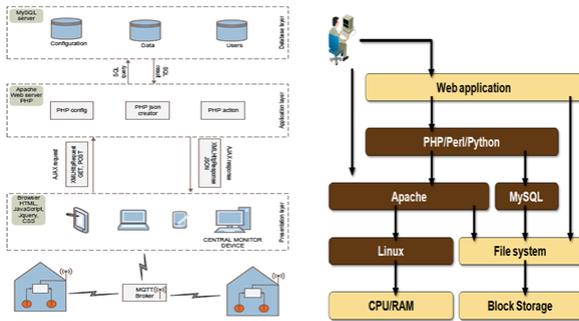
Fig 2: (a) MQTT Stack (b) LAMP software stack

Fig 2 (a) shows the layers and flow of data in the different layers built using the MQTT (Message queue telemetry transport) protocol upon of TCP/IP stack. MQTT is a machine-to-machine (M2M) or Internet of Things connectivity protocol. It was designed as an extremely lightweight publish/subscribe messaging transport. In such architecture, a sensor device whose main task is to continuously produce and send data to server is defined as publisher. Central server, an MQTT broker, collects messages from publishers and examines to whom the message needs to be sent. On the other side, every device who had previously registered its interests with a server will keep receiving messages until subscription is cancelled. Using this architecture, publishers and subscribers do not need to know for each other which is one of the major advantages of this protocol.

The live data from the sensors and controller through the Wi-Fi module is sent over to the database for storage. The Server is built so as to monitor the data and visualize these load graphs online. The Raspberry Pi 3 is used to build this server using the LAMP Software stack, as shown in Fig 2(b).

LAMP is an archetypal model of web service stacks, named as an acronym of the names of its original four open-source components:

- the **Linux** operating system,
- the Apache **HTTP** Server,
- the **MySQL** relational database management system (**RDBMS**), and
- the **PHP** programming language.
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The LAMP components are largely interchangeable and not limited to the original selection. As a solution stack, LAMP is suitable for building dynamic web sites and web applications. The data will be sent to the mysql database, and computation happens.
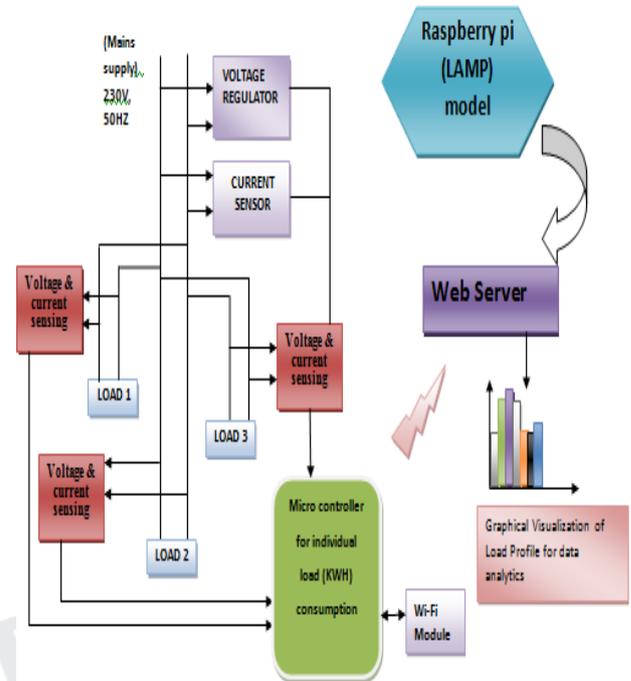

Fig 2: Architectural detailing of complete design

There will be a php file that is responsible for connecting to the database. It contains the configuration settings for the database. The Raspberry Pi sends the data to a simple PHP script which is called add_data.php. This script connects to the MySQL database and stores the data in the database. If we want to see the data from the database all we have to do is to visit the index.php file from a browser. The index.php script will connect to database, using the connect.php script and it will ask the database to return all the stored data. Then it will display all the data in an HTML table. The graphical visualization is done for each home using the API's linking from the Google Charts. The Change in the different values of the database creates the chart with accurate percentage of each appliances used. The data analytics is done so as to compare and notify the users that which home and which appliance is consuming the maximum power.

Accordingly the analysis can be made for the precise usage or energy consumption of each device in order to further reduce the usage of the device which is drawing the maximum amount of energy. These monitoring reports are sent to the consumers on their webpage and can be monitored continuously, so that the required action is taken in order to improvise the energy usage.

Fig 3: Graphical representation of Power consumption by various appliances at different homes.

CONCLUSION

In this paper, a study concerning the acquisition and identification of data provided by different loads and consumers has been presented. The identification of consumer load profiles was the main objective.

The experimental tests furnish real data concerning the loads commonly used by residential consumers, which is made possible by applying the data analytics over the results obtained for the graphical visualization of each appliance usage. Usage of the smart metering technique allows for the accurate readings and un-tampered data for the proper calculation to monitor the energy consumption of each appliance. Drawing the signatures from the charts, data analytics provide the maximum and minimum usage of each appliances under each home. Thus helping the consumers to visualize, monitor and act accordingly for further energy usage improvisation.

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