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IoT based smart energy meter

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ABSTRACT

In the recent digital era, technology starts to find new ways of improving and enhancing human lives, all the devices are getting smarter than we could expect it would be. In the same way, we have an idea of making the energy meters of Electricity Board highly smarter using the technology "Internet of Things (IoT)". The smart energy meter is connected with Electricity Board, household appliances and the user through IoT and mobile application. We are focusing on making the smart energy meter too smartly connect with the household appliances through IoT and also to connect with the authorized persons through a mobile application to have control over it.

Keywords— *Internet of Things, Smart systems, Energy meter, Electricity board*

1. INTRODUCTION

A smart meter system has several control devices, sensors to identify parameters and devices used to transfer data and command signals. Smart meters applied to distribution grids plays an important role in monitoring the load energy usage characteristics and performance on the grid. Works that have been carried out to advance the Internet of Things (IoT) technology in business domains because of the value gained by connecting an endpoint device for system reliability, automation, and centralized management. Although projects are developed for business applications, many of these advanced IoT technologies are also applicable to all types of smart systems which include EB meters, mobile phones, healthcare equipment, security devices, cloud and deep-learning systems.

2. RELATED WORKS

There is an incorporation of mobile technology into TNEB (Tamil Nadu Electricity Board) automation system due to the rapidly advancing mobile communication technology and the decrease in cost and manpower. The power grid is an aggregation of several networks. The transition from traditional power grid towards a smart grid is a movement from static to flexible infrastructure with improved observance, controllability and efficiency. Smart grid implies to smart generation, smart transmission, smart storage and smart sensors. [1-4]

The proposed system collects the energy consumption from residential as well as corporate zones and sends it directly to the central server maintained by the administrator where processing is done on that data for preparation of bills as well as monitoring the power consumption. AMR (Automatic Meter Reading) system can be divided into wire AMR system and wireless AMR system according to the communication medium used. In the current scenario for collecting power consumption data, the representatives from TNEB come and visit every residential at each month and take a record of power consumption data from the meter manually.[3-7]

This collected data is submitted to the local TNEB office. Thereafter the officials read the snapshot and meter readings and then gives it to the local software for the generation of the bill. The consumer then makes payment for the received bill. This process is so much hectic process. Man-made mistakes can be countless. In traditional energy metering, human resources wasted and many other problems do occur. Implementation of wireless ad hoc networks in the field of electricity billing makes the process simple. This project is making use of this technology to such an extent so that even complex problems can be handled in an easier way through the mobile application. [7-8] Mobile Application is the eminent futuristic replacement of humans and reduces their stress of work. This application can also be used for creating emergency responses when there is a peak use of power and the absence of human at home. [8]

The microcontroller is attached to our traditional energy meters that will scan the meter reading periodically. Smart meters are digital electricity meters that accurately measures both

electricity consumption and production. These meters have the ability to communicate the measured data automatically, which provides them with the "smart" aspect. [8-13] Then the meter reading will be transmitted to the centralized server along with the unique meter identity number. This data will be processed by the server and the bill amount will be communicated to the consumer via the GSM module. [14]

It also provides security for power transmission. Smart meters are predominantly used by energy suppliers as a contribution for more precise and secure transmission. Smart meters related to their connected infrastructures alter end-users to be enclosed within the sensible grid management context, as they provide information about electricity flow measurements and energy prices to end-consumers. [15]

The energy consumption knowledge collected on a daily basis permits utility firms to expeditiously manage electricity demand and to advise customers to expeditiously use their appliances. This is communicated via the Mobile application.

The energy consumption data collected on a regular basis allows utility companies to efficiently manage electricity demand and to advise consumers to efficiently use their appliances. [16-17].The proposed system collects energy from residential as well as corporate zones and sends it directly to the server maintained by admin and billing is finalized.

The communication technologies used in good meters got to be valued economical and should offer at the same time a decent transmission vary, increased signal-security characteristics and improved information measure and power quality. The mobile application portal we developed consists of the post as well as pre-billing, consumption of power and automatic on and off of unused application through remote provided in the mobile application.

3. ARCHITECTURE OF SMART ENERGY METER

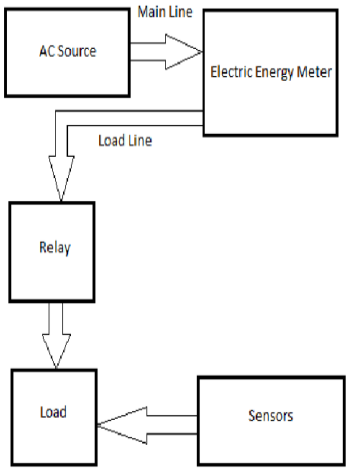


Fig. 1: State diagram of energy reading meter

3.1. Energy Reading Module

Figure 1 sensors detect the supply voltage from the electrical or electronic appliances. The minimum Operating voltage is 3.3v and maximum is 5v. The voltage sensor will detect the voltage automatically without any human influence. Whenever the voltage goes up or down it will read the voltage dynamically.

Current measurement is of vital importance in many power and instrumentation systems. Traditionally, current sensing was primarily for circuit protection and control. However, with the advancement in technology, current sensing has emerged as a method to monitor and enhance performance. The current sensor will measure the current range from -5A ~ 5A. The supply voltage is 4.5v ~ 5.5v DC. The Current sensor has sensitivity from 180mV/A to 190mV/A.

Special features: These are special types of transformers used for the measurement of currents. As the name suggests, these transformers are used in conjunction with some relevant instruments such as ammeters and control relays. Current transformers are usually used when the AC currents exceed the safe worth for the activity instruments. The power loss in CT instrument transformers is incredibly little as compared to power loss thanks to the resistance of aiding devices like shunts or multipliers. By using current transformers with tong testers, the currents in the heavy current circuits can easily be measured.

The ESP8266 local area network Module may be a self-contained SOC with integrated TCP/IP protocol stack that may provide any microcontroller access to your local area network. The ESP8266 is capable of either hosting associate application or offloading all Wi-Fi networking functions from another application processor. This module comes with AT commands code that permits you to induce practicality like Arduino local area network to protect, however, you can load different firmware to make your own application on the modules' memory and processor. It is an awfully economic module and encompasses an immense and growing community support. This module has aboard 80Mhz low power thirty-two bit processor which may be used for custom firmware. This additionally implies that you'll be able to host little webpages with none external controller. For more details see NODEMCU. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF permitting it to figure beneath all in operating conditions and needs no external RF elements. ESP8266 is reworking the globe with its low price and high options that make it a perfect module for net Of Things (IoT). It may be employed in any application wherever you wish to attach a tool to your native network or net. This module ESP01 has two GPIOs accessible on pin headers. Note: The ESP8266 Module is compatible only with 3.3V logic level and will not work directly with 5V devices (for both serial and GPIO access). You need a three.3V compatible device otherwise you can get to convert the degree before you employ it.

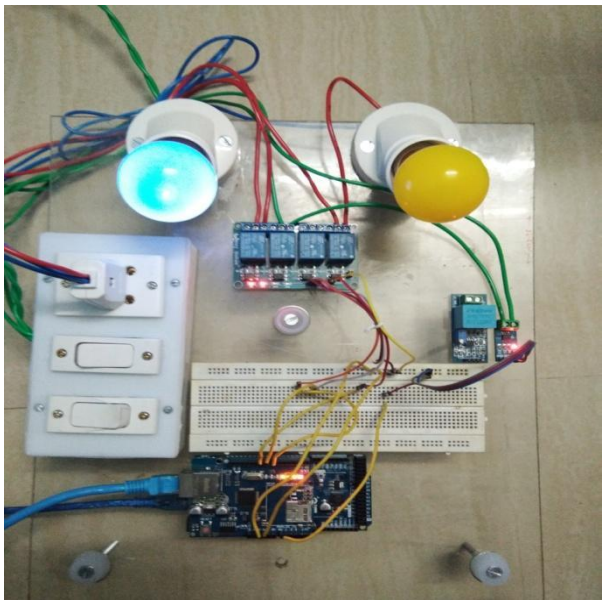


Fig. 2: State of controlling one appliance

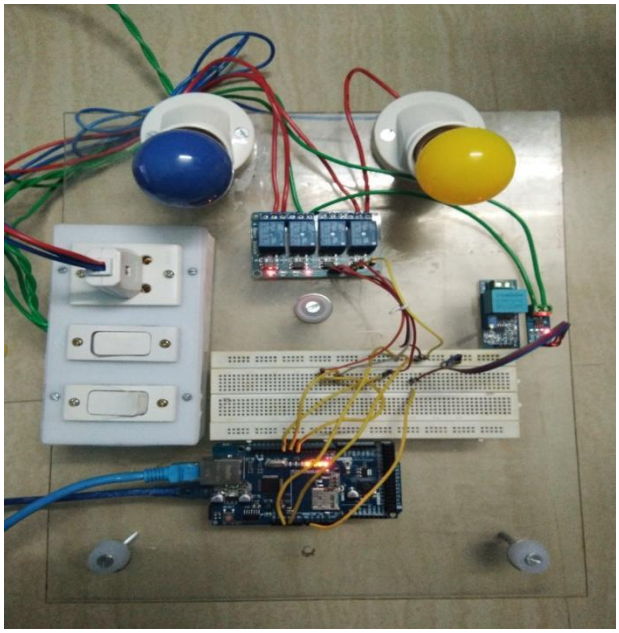


Fig. 3: State of controlling null appliances

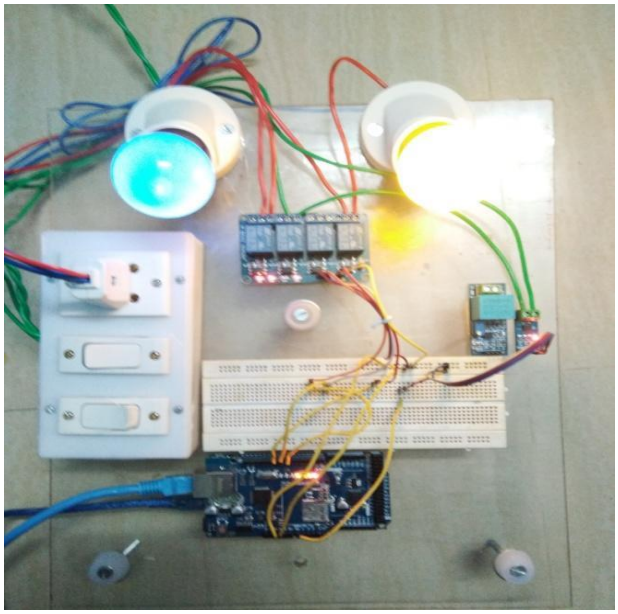


Fig. 4: State of controlling all appliances

3.2 Meter Controller Module

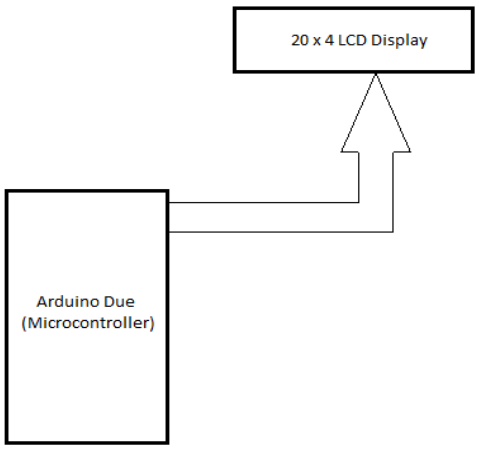


Fig. 5: a Meter control module

It is an ARM Cortex M3 microcontroller it is based on the ARM architecture.it is a 32-bit core microcontroller. Its CPU clock at 84Mhz. Operating voltage is 3.3v. The recommended input voltage in 7-12v.It contains 54 Digital I/O pins and 12 Analog pins. It has a DMA controller that can relieve the CPU from doing memory intensive tasks. The Due is additionally the primary Arduino to feature a built-in digital-to-analog converter, in fact, two of them. It is also to have an audio library to take advantages of its ability to playback wav files. The Arduino capability has perpetually been extended by shields, add-on boards and circuitry such as motion sensors and LED light arrays, many of them for third-party manufacturers. The Due will work with all Arduino shields that adapt to the official Arduino Revision three layout. However, the Due operates at 3.3V whereas earlier Arduino operates at 5V, so some third-party shields that don't follow the R3 specs to the letter may not be compatible, depending on their voltages. This additionally suggests that anyone victimisation the Due in existing applications ought to pay specific attention to voltage.

The Smart meter is made as follows, the voltage sensor is connected with the wire from the meter to the household appliances, and the current sensor is also connected with the wire from the meter to the household appliances. These sensors read data consecutively and find the number of units used per day and send it to a service running in the cloud.

The Arduino board is connected to a power supply, then the voltage sensor the current sensor which is attached with the Mainline of the house is connected to the input pins of the Arduino board. The Arduino board is also connected with a GSM module which helps in providing the board with Internet Availability so that the data collected could be sent to the cloud.

The data collection snippet is as below:

```
#include <Emonlib.h>
#define VOLT 148.7
#define CUR 62.6
EnergyMonitor emon; //instance of the class from lib.
emon.voltage(1,VOLT,1.7)//input pin,calibration,phase shift
emon.current(0,CUR) //input pin,calibration
emon.Irms; // Current read
emon.Vrms; //Voltage read
```

These data will be read at a delay of 30seconds, all these data will be approximated and the number of units consumed is calculated using the formula below, Let us take a reading from the Voltage sensor and the Current sensor consecutively at an interval of 30 seconds. At the end of One Hour, we have 120 values from Current Sensor and 120 values from the Voltage Sensor. For the household appliances we could consider the Power Factor as 0.8, thus

$$P_i = V_i \times I_i \times Cos\varphi$$

Where,
P: Power
V: Voltage
I: Current
cosφ: Power Factor

Here the power factor could be considered as 0.8 since the approximate power factor for household appliances in India is 0.8. Thus,

$$P_i = V_i \times I_i \times 0.8$$

We would have 120 power data at the end of every One Hour. The average of these is taken and Single power data at the end of One hour is calculated as follows,

$$Power\ (P) = \frac{P_1 + P_2 + P_3 + \cdots + P_{120}}{120}\ wh\ (Units)$$

$$P1 + P2 + P3 + ...+P120$$

Thus for unit consumption calculation,

$$Power\ (P)a = \frac{Power\ (P) in\ wh}{1000}\ Kwh\ (Units)$$

At the end of the day we have 24 Power (P) data consumed in each hour. Thus adding all those will result in us with the Unit Consumed for the whole day.

$$Power\ (P) = \frac{P_a + P_b + P_c + \cdots + P_x}{24}\ wKh\ (Units)/Day$$

This power data is sent the service and stored in the backend for further calculations. The data we collect is not only used for calculation we use it for prediction also, but these data are also send to an SVM Model which is trained using different sample data. This SVM when gets these data will result in the fare prediction at the end of the month according to the present electricity consumption.

In this module, there is a 20×4 serial LCD display which contains 20 columns and 4 rows of character. This 20x4 Character LCD Display is built-in with RW1063 controller IC which are 6800, 4 line SPI or I2C interface options. The WH2004G 20x4 LCD Display has the same AA size and pin assignment as existing WH2004A and WH2004B character LCD modules but with a smaller outline and VA size.

It is more capable to display sufficient information when comparing with 16×2 character LCD and Dot matrix display. The integrated circuit will help to interface the LCD with microcontroller easily.

3.3 Data storage module

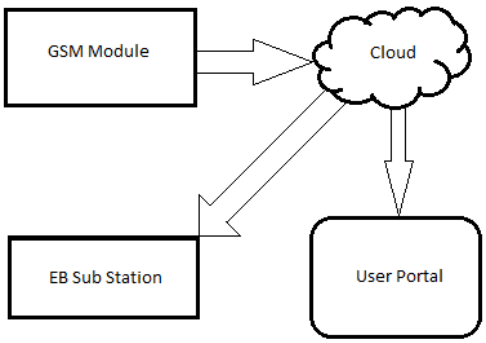


Fig. 6: a Data storage module

GSM module will enable the remote access through the internet, SMS and call facility. It will provide the GPRS facility for internet access. It supports communication through RS232 with DB9 connector, TTL pins and I2C pins. Mic input, LINE input and Speaker output are also available.

- Quad-Band 850/ 900/ 1800/ 1900 MHz
- Dual-Band 900/ 1900 MHz
- GPRS multi-slot class 10/8GPRS mobile station class B
- Compliant to GSM phase 2/2+Class 4 (2 W @850/ 900 MHz)
- Class 1 (1 W @ 1800/1900MHz)
- Control via AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands)
- Low power consumption: 1.5mA (sleep mode)
- Operation temperature: -40°C to +85 °C

GSM technology has been matured since long and hence GSM mobile phones and modems are widely available across the world. It provides very cost effective products and solutions. The GSM-based networks (i.e. base stations) square measure deployed across the planet and thus same mobile works across the world. This leverages value edges similarly as provides seamless wireless property. This will facilitate users avail knowledge and voice services with none disruption. Hence international roaming is not a concern. Advanced versions of GSM with a higher range of antennas can offer high-speed transfer and transfer of information. SAIC and DAIC techniques offer a terribly high transmission quality. SAIC stands for Single Antenna Interference Cancellation technique whereas DAIC stands for twin antenna interference cancellation. It is straightforward to take care of GSM networks thanks to the convenience of a huge range of network engineers at a reasonable value. This will facilitate in revenue increase by the telecommunication operators. The phone works supported SIM card and thus it's straightforward to alter the various forms of phones by users. The GSM signal doesn't have any deterioration within the workplace and residential premises. It is easy to integrate GSM with other wireless technology based devices such as CDMA, LTE etc.

Through this GSM module, the data is sent to the Service running in a server which would store the data in the database for further use. The user has remote access control of the household appliances from anywhere he is present. We have a set of relays to connect the board with the household appliances. In the Users portal will be given where the user could control his household appliances over the Internet using IoT Platform.

3.4 User access module

The user portal is a Progressive Web Application (PWA) which is in recent trends hitting in the IT industry. Here the application once builds could be directly used in any platform independent of its specifications. That is if an Application is built in PWA we have access in any devices like Android, iOS, Linux, Windows and much more Operating Systems.

The Users portal initially has the Sign-Up page where the new user gets his account registered with the portal using his/her meter Consumer Number. There would be verification of the account by sending the verification link to the user's email ID. If the account is verified the user will be allowed to log in. If he tries to verify with a false code the account will be deactivated and the registration will be deleted.

Once the user logs in to the portal using his Consumer Number and Password, he has a graphical view of the Power consumption over the past two weeks, the highest consumption, Lowest consumption with value and date, the bill to be paid and much more. He/She has the feature to change the password of their account or even change the data from their personal information. He/She has the page from where they could control the household appliances over the Internet using the IoT Platform.

The user is given with the privilege of choosing the type of graph He/She would like to see in the graphs over the portal. Like the Bar, Line, Pie, Doughnut and much more. Similarly, He/She could choose the Theme of their portal from the available various themes.

This portal also has a module for controlling the household appliances using IoT platform. This also has a smart way to pay the bills. The user could also recharge his/her wallet in the portal and could check the auto pay feature wherein once the

bill is generated for the user the portal itself pays the bill instead of the user having to remember about the bills and stuff. There will also be an Online payment Integration with the portal along with the third party gateways like Paytm, Paypal, PayUmoney etc. As a new initiative of Indian Government, we also have the feature of paying the bills through the Unified Payments Interface (UPI) which was introduced and developed by BHIM.

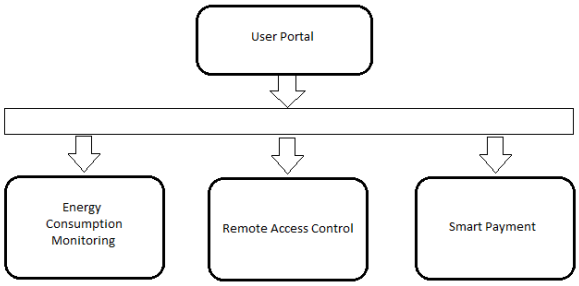
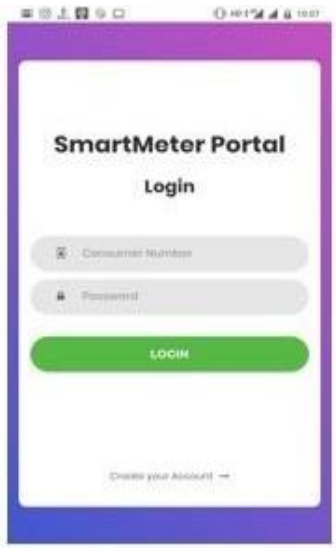


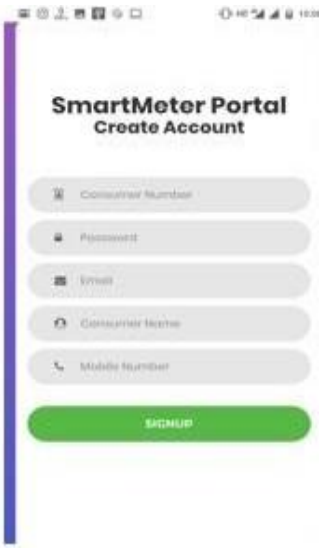
Fig. 6: User portal

4. RESULTS AND DISCUSSION

The Automatic Meter Reading (AMR) system is made using smart sensors and components along with an online platform to let the user have control over the appliances used in his/her home. The portal also has a detailed view of Power consumption of the house and also having the smart way to pay the electricity bills produced by the Electricity Board.



(a)



(b)

(c)

(d)

(e)

Fig. 7: (a) Login page, (b) Signup Page, (c) Mobile portal, (d) Graph, (e) Map

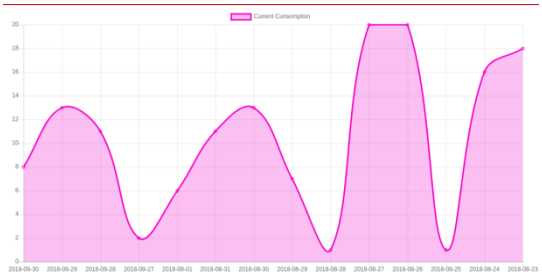


Fig. 8: Current consumption analysis

In figure 7 (a) The login page allows user to log in the authorized user, (b) provide sign up option for new user, (c) the mobile application part where the control of appliances is done, (d) graph is generated on weekly basis(report generation) for bills, power consumption etc. (e) this shows the recent login location details for security purposes.

5. CONCLUSION

Real-time monitoring and decision-making will be possible just in case of usage reports transmission in very short time intervals. By applying such an extremely lightweight scheme, not only we can opt more cost-effective hardware for the Smart Meters, but also we can manage many more using the same hardware through an Interactive Online Portal. Our comparative analysis indicates that our scheme dramatically outperforms the existing works in this field.

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