

IOT BASED SMART ENERGY TRACKING SYSTEM

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Abstract-The motivation to manage energy usage at residential home is influenced by the continuous evolution of smart grid technology and economics environmental condition. The evolution of smart grid technology will allow consumers to make more informed decisions about their energy consumption, adjusting both the timing and quantity of their electricity use. This demand side management offers the promise of cutting costs for commercial customers, saving money for households and helping utilities operate more efficiently in turn reducing emissions of green house gases. This paper proposes a IOT based energy monitoring and controlling system that can monitor energy usage by measuring voltage and current of different appliances continuously or during the peak periods in a residential house and have control over the overall loads consumption on priority of the devices when the consumption of the residential house exceeds the preset threshold limit thereby reducing their energy consumption overall. Furthermore this can also determine whether an appliance is drawing unusually high amounts of power than its rated power consumption. In this way electricity consumption and cost can also be reduced. These consumptions are displayed through GSM module and webpage display.

Keywords: Internet of Things, GSM Module, Microcontroller (Raspberry pi), Android Apps.

1. Introduction

Electricity plays vital role in growth of our country. Even though power production corporations focussing highly on generation, transmission and distribution, energy shortage continued to exist. This is mainly because of increasing demand, limited resources, rapid depletion and increasing cost of harnessing the resources. Hence it becomes imperative to attribute a special status to energy conservation in the world. Thus energy conservation is crucial for the economical way of power generation. Energy conservation does not mean curtailment in energy use, rather it means effective utilisation of energy resources.

Domestically, in light of the increasing cost of electricity and the Global Warming campaigns to reduce general electricity usage, there is a growing interest in analyzing power consumption in households. By analyzing the electricity usage of each individual appliance separately, more accurate conclusions can be drawn on their efficiency and need for replacement. Furthermore this can also determine whether an appliance is drawing unusually high amounts of power when turned off and whether it should rather be unplugged. In this way electricity consumption and cost can be reduced.

During the past few years, in the area of wireless communications and networking, a novel paradigm named the Internet of Things (IoT) which was first introduced by Kevin Ashton in the year 1998, has gained increasingly more attention in the academia and industry. By embedding short range mobile transceivers into a wide array of additional gadgets and every items, enabling new forms of communication between people and things and between things themselves, IoT would add a new dimension to the world of information and communication. This whole report is centred on the field of embedded systems, Internet of Things and use of Raspbian OS and python programming to run the applications on them.

The objective of the paper is to develop a IoT based smart energy tracking system that can monitor energy usage by measuring voltage and current of different appliances continuously or during the peak periods in a residential house and have automatic control over the overall loads consumption on priority of the devices when the consumption of the residential house exceeds the preset threshold limit thereby reducing their energy consumption overall. Furthermore this can also determine whether an appliance is drawing unusually high amounts of power than its rated power consumption. In this way electricity consumption and cost can also be reduced. The analog measurements of the voltage and current of the electrical appliances read through the current transformer and potential transformer are converted into digital data through Analog Digital Converter (MCP3008). The digital data output of the ADC is processed in the Raspberry pi 3 microcontroller to obtain the power consumption of the individual appliances. The total power consumptions recorded is compared with the preset threshold limit and if the total power consumptions of the house building exceeds the preset threshold limit then the low priority device is turned off through IoT and a sms notification is sent to the mobile number through the GSM Module (SIM 800A). The same can be viewed through the webpage and specific loads can be controlled that is turned off and tuned on by commanding from the webpage through Raspberry pi microcontroller.

2. Literature Survey

1. Photovoltaic Energy Sharing System in a multifamily Residential House to Reduce Total Energy Cost:

This paper describes a photovoltaic (PV) energy sharing system in a multifamily house. The community-shared PV system is connected to each home, monitors each home's energy use, and assigns more energy to a large energy-consuming home. Under increasing block tariffs, this architecture contributes to reducing total energy costs.

2. A Smart Switch to Connect and Disconnect Electrical Devices at Home by Using Internet

This paper presents the development of a firmware for a Smart Switch, which can control the on-off of any electrical device at home by using internet. The Smart Switch is connected to internet via Wi-Fi, through a computer, smartphone, tablet or any device with internet access. In order to perform this connection, it is necessary to write the IP pre-programmed into the Smart Switch in a web browser (Internet Explorer, Chrome, Firefox, etc.) with the purpose to load the Smart Switch server, which will open a configuration page to write the data of the user's network. Then, the user will select in automatic mode the network, the security type, and the user must have written a passphrase. Once these information is uploaded and saved, it is necessary to restart the Smart Switch in order to get access to internet, from which the user can control the Smart Switch simply sending a number one or a number zero to switch the electrical device, this process is done in principle via the internet, but it can be done without the use of internet, i.e. by using a local network.

3. Electronic Energy Meter With Remote Monitoring and Billing System:

In this paper measurement of energy, remote monitoring, preparing of bill and billing system is presented. Low cost ATMEGA8L microcontroller is used here to control the whole system. Sampling of voltage and current is done by it. Then it processes data to achieve power in that instant. Then it stores the value of total energy consumed by the consumer and can calculate energy charge according to the tariff. LCD display is attached with this system to show total energy consumed, power factor and amount of charge etc. Communication between central energy distribution office and energy meter is done through power line. Complex tariff rate set up and cash card based billing is possible in this system. Electronic meter gives high accuracy for nonlinear loads than conventional rotating disc type electro-mechanical meter. Greater accuracy and stability can be maintained in this system.

4. Electronic Energy Meter With Instant Billing:

This paper presents automated billing of energy meter. It is just like postpaid mobile connection. In the proposed work, the front end is user friendly and one can work on this software with minimum knowledge of computers and can read the meter by sitting in the office. This is useful for billing purpose in electricity board authority. A GSM modem is connected to the energy meter. Each modem will be having its own sim (ususalmobile phone sim). A PC is connected to other modem, which contains the data base. The module is designed such that user can have the complete usage details about the energy meter. Just like postpaid mobile connections, one can know our due bill instantly and can even pay for it. The SIM card used is implemented in energy meter and it sends a message to the user about the due bill. A LCD is used in the hardware module for the user interface. The LCD displays the current usage and units consumed. After the usage of each unit the amount and total units will be incremented whenever

user wants to know his/her bill he/she can message a given code to sim card attached to the meter and can know his/her present bill. The user can pay the amount just by knowing the given code which is fed in the meter.

5. Design and Implementation of Low Cost Electronic Prepaid Energy Meter:

This paper proposes a smart energy tracking system that can monitor the energy usage at different time slots, compare the energy usage with past data and provide details about the daily energy usage and helpful instructions to manage the energy consumption. Hence, the proposed system assists the consumers to reduce their electricity bill and the utilities to implement demand side management in the domestic sector.

6. Coordinated Scheduling of Residential Distributed Energy Resources to Optimize Smart Home Energy Services:

In this paper they describe algorithmic enhancements to a decision support tool that residential consumers can utilize to optimize their acquisition of electrical energy services. The decision-support tool optimizes energy services provision by enabling end users to first assign values to desired energy services, and then scheduling their available distributed energy resources (DER) to maximize net benefits. They chose particle swarm optimization (PSO) to solve the corresponding optimization problem because of its straightforward implementation and demonstrated ability to generate near-optimal schedules within manageable computation times.

7. Optimal Residential Load Control With Price Prediction in Real-Time Electricity Pricing Environments:

In this paper, they proposed an optimal and automatic residential energy consumption scheduling framework which aims to achieve a trade-off between minimizing the payment and minimizing the waiting time for the operation of each household appliance based on the needs declared by users. We focused on a scenario when real time pricing is combined with inclining block rates in order to have more balanced residential load with a low peak-to-average ratio. They argued that any load control in real-time electricity pricing environments essentially requires some price prediction capabilities to enable planning ahead for the household energy consumption.

8. Intelligent Online Measurement and Management of Energy Meter Data Through Advanced Wireless Network:

In this paper, we point out key problems with the current Internet Architecture and propose directions for the solutions. We propose a general architectural framework for the next generation Internet, which we call Internet 3.0. The next generation Internet should be secure. It should allow business to set their boundaries and enforce their policies inside their boundaries. It should allow governments to set rules that protect their citizens on the Internet the same way they protect them on other means of transports. It should allow receivers to set policies for how and where they receive their information. They should have freedom to select their names, IDs and addresses with as little centralized control as possible. The architecture should be general

enough to allow different governments to have different rules. Information transport architecture should provide at least as much control and freedom as the goods transport networks provide.

9. Towards the Implementation of IoT for Environmental Condition Monitoring in Homes:

In this paper, they have reported an effective implementation for Internet of Things used for monitoring regular domestic conditions by means of low cost ubiquitous sensing system. The longitudinal learning system was able to provide a self-control mechanism for better operation of the devices in monitoring stage. The framework of the monitoring system is based on a combination of pervasive distributed sensing units, information system for data aggregation, and reasoning and context awareness. Results are encouraging as the reliability of sensing information transmission through the proposed integrated network architecture is 97%. The prototype was tested to generate real-time graphical information rather than a test bed scenario.

10. Wireless Communication System for Energy Meter Reading:

This paper proposes a new network communication system for energy meter reading by integrating communication technology and software system along with the existing meters. A wireless or wired communication system will be integrated with electronic energy meter to have remote access over the usage of electricity. Even though they are two different modules, energy meter deliver the reading details as on when it demands by the communication system. The communication system is further connected with electricity regional/sub-regional office, which will rather act as a base station. Instead of creating a separate communication system and backbone, any of the secure existing communication service infrastructures may also be utilized to avoid any initial investments. The communication channel is identified by the consumer's number and it is secured by any cryptographic standards. Base office can verify the energy meters performance by checking the day to day consumption of energy. This will also help to avoid any tampering or break down of energy meter.

3. Existing Method

In the present system of the energy monitoring and control, the microcontroller Arduino acts as the processing and control unit. Arduino doesn't have any built-in capability for connectivity. If you want to connect it to the internet, you'll need to add an extra piece of hardware that includes an ethernet port. If you want wifi connectivity, you'll need a different piece of hardware again. A single port can be used to connect the Arduino to your computer via your computer's USB port, but that's it. The Raspberry Pi, on the other hand, has four USB ports that you can use to connect it to a router, a printer, an external hard drive, or a wide variety of other devices. Arduino doesn't come with any software per se. It has very basic capabilities to interpret the code that it receives and alter the functions of the hardware that it's connected to, but the board doesn't have an operating system or any sort of interface besides the Arduino integrated development environment (IDE).

Table 1. Comparison between Aurdino and Raspberry Pi.

Features	Arduino	Raspberry Pi
Memory	0.002MB	512MB
Processor speed	16MHz	700MHz
On Board Network	None	10/100 wired Ethernet RJ 45
Multitasking	No	Yes
USB	One Ports	Four ports
Operating system	None	Linux distributions

5. Proposed Method

In this paper, it has been proposed to monitor and control the electrical appliances in house building. The added advantage is that monitoring and controlling is also done through webpage display in home laptop and sms notification is received in our personal mobile. Using Raspberry Pi is an added advantage making the entire system more compact with all built in hardwares such as USB ports, DSI display ports, HDMI video output, CSI camera port etc.

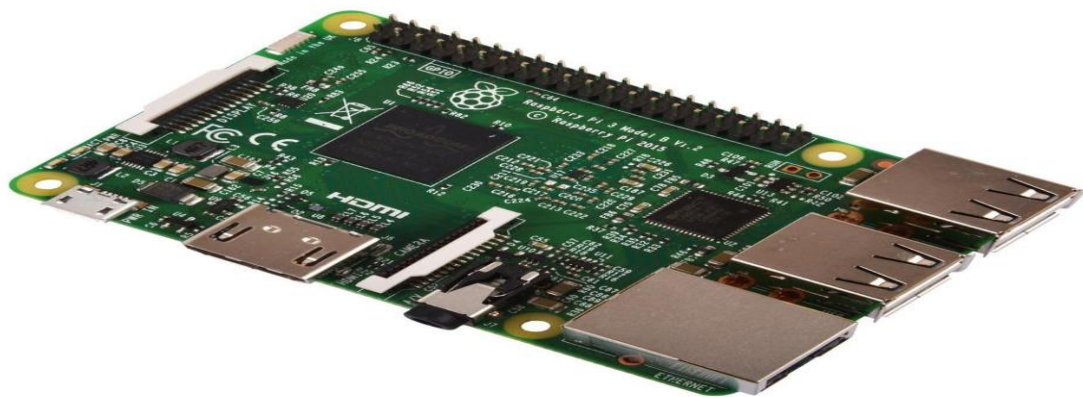


Fig 1: Raspberry Pi 3 Model B

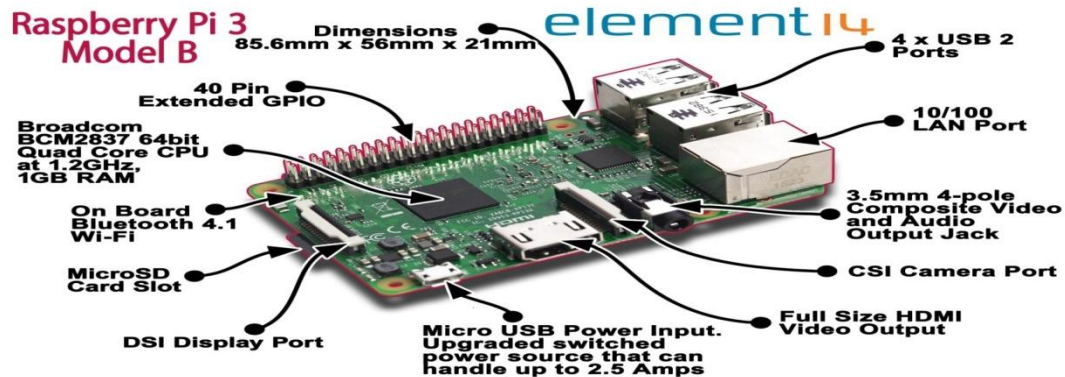


Fig 2: Hardware arrangements in Raspberry Pi 3

Raspberry pi is programmed using python programming as to read the values from the load. But Raspberry pi by itself can't able to read directly from the load. But Raspberry pi by itself can't able to read directly from load, so we are measuring the load with CT and PT sensors.

The CT and PT sensor's output is analog so that we use analog to digital converter (MCP 3008) to obtain the digital input. Using the programmed Raspberry pi microcontroller the current and voltage readings are calculated to obtain power consumptions within micro controller memory.

Then the data can be monitored with the internet through other system can control the devices like switch ON / OFF through a webpage that will be developed through PHP coding. The microcontroller calculates the power output of the individual appliances and also the total power output of all the connected appliances. When the total power output exceeds the preset threshold limit of energy usage, the Raspberry Ri microcontroller through the python programming language sends intimation through UART RS232 to the GSM module which in turn sends sms to the mobile that the power consumption exceeds the preset threshold limit. And also the least priority electrical appliances is turned off through the microcontroller through laptop webpage.

Thus the power consumption of the household electrical appliances are monitored from the webpage display and controlled from the webpage display through the microcontroller Raspberry Pi and with the sms notification to the mobile about the power consumption surpassing.

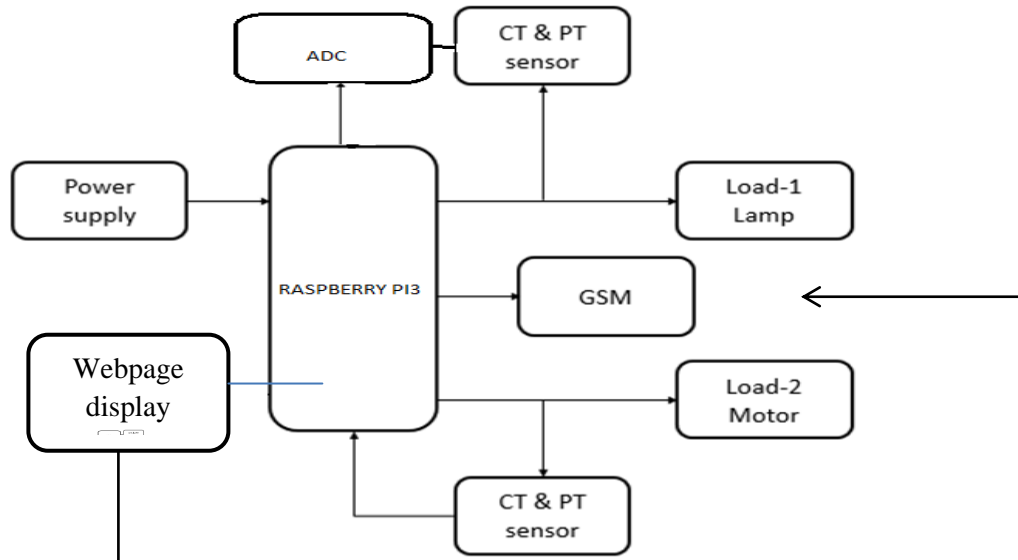


Fig 3: Block diagram of proposed system

Internet of Things - The term Internet of Things commonly abbreviated as IoT today is used to denote the connectivity of devices, systems and services that goes beyond the traditional machine to machine communications and covers a variety of protocols, domains and applications intended to collect and distribute information to people as well as systems and allow these systems to be managed by machines and people in an efficient secure and personalized manner. So it goes beyond the traditional Internet into transports like mesh networks, point to point connections, near field, sonar and more. These devices can be interacted with or interact with us in ways that will help us manage the ever growing volume of information that we are collecting by having all of these devices running. One example of IoT that few people think about is our own cell phones. These devices are connected to radio networks and have GPS or cell tower triangulation built in that allows them to be used to determine traffic patterns and congestion.

Raspberry Pi 3- The Raspberry Pi board contains a processor and graphics chip, program memory (RAM) and various interfaces and connectors for external devices. Some of these devices are essential, others are optional.

RPI 3 operates in the same way as a standard PC, requiring a keyboard for command entry, a display unit and a power supply. It also requires 'mass-storage', but a hard disk drive of the type found in a typical PC is not really in keeping with the miniature size of RPI 3.

Instead we will use an SD Flash memory card normally used in digital cameras, configured in such a way to 'look like' a hard drive to RPI 3's processor. RPI 3 will 'boot' (load the Operating System into RAM) from this card in the same way as a PC 'boots up' into Windows from its hard disk.

Raspberry pi is much more advanced as compared to microcontroller. It has the features of microcontroller plus additional features of computer like ethernet, USB, hdmi interface and many more. Raspberry is better suited for applications like image processing.

Only controller board that has inbuilt internet connection facility, through Ethernet cable or with through inbuilt wifi module. So it is very useful for IOT applications. And another its processor is based on ARM Architecture.

GSM Module - GSM/GPRS Modem-RS232 is built with Dual Band GSM/GPRS engine-SIM900A, works on frequencies 900/ 1800 MHz. The Modem is coming with RS232 interface, which allows you connect PC as well as microcontroller with RS232 Chip(MAX232). The baud rate is configurable from 9600-115200 through AT command.

The GSM/GPRS Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as DATA transfer application in M2M interface. The onboard Regulated Power supply allows you to connect wide range unregulated power supply.

Using this modem, you can make audio calls, SMS, Read SMS, attend the incoming calls and internet ect through simple AT commands.

Analog to Digital Unit (MCP3008): Raspberry pi does not have inbuilt Analog to Digital Unit, so we are using MCP3008 IC to convert analog values to digital. Our energy reading will be in analog, from CT PT sensors, so we need to convert, analog to digital.This chip will add 8 channels of 10-bit analog input to your microcontroller or microcomputer project. It's super easy to use, and uses SPI so only 4 pins are required. We chose this chip as a great accompaniment to the Raspberry Pi computer, because its fun to have analog inputs but the Pi does not have an ADC.

Current Transformer CT sensors - CT is a sensor that measure alternating current. They are particularly useful for measuring whole building electricity consumption (or generation, for that matter). The split core type is particularly suitable for DIY use, as it can be clipped onto either the live *or* neutral wire coming into the building, without the need to do any high voltage electrical work.

Potential Transformer PT sensors - Potential transformers are also known as voltage transformers and they are basically step down transformers with extremely accurate turns ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns.

Python - Python programming language was developed by Guido van Rossum in the late eighties and early nineties at the National Research Institute for Mathematics and Computer Science in the Netherlands .Python is derived from many other languages, including ABC, Modula-3, C, C++, Algol-68, Small Talk, and Unix shell and other scripting languages. Python is a high-level, interpreted, interactive and object-oriented scripting language. Python is designed to be highly readable. It uses English keywords frequently where as other languages use punctuation, and it has fewer syntactical constructions than other languages.

6. Results and Discussion

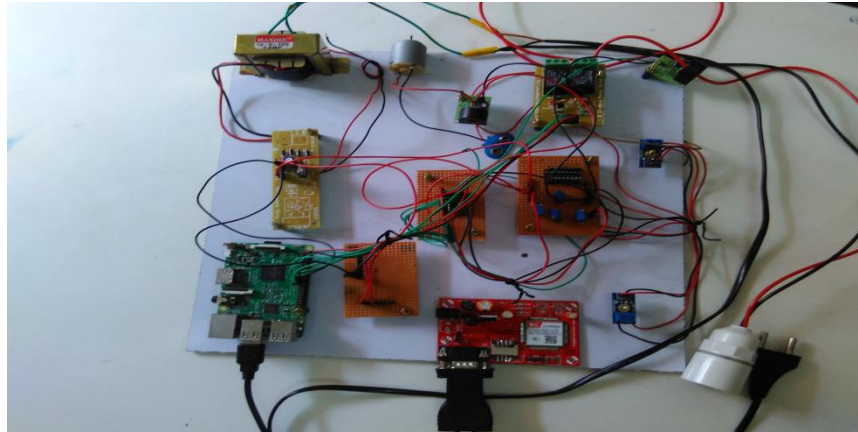


Fig 4: Hardware arrangements of the proposed system

Fig 4 shows the hardware arrangements of the proposed system of smart energy tracking. Only two loads are connected to the tracking system just for demonstration purpose. One a 12W CFL (Power 1) and 5V small toy motor (Power 2) is connected. The loads are switched on (Light ON/Motor ON) through the webpage display and the power output is monitored. If the power output exceeds the preset limit, then sms notification is sent to the mobile and the unwanted load (Light OFF/Motor OFF) is switched off through the webpage display. Since a static IP address is presently used both the tracking device and the monitoring and controlling device i.e., laptop webpage is placed nearby. In this proposed system the mobile acts as internet server and the laptop is connected to the mobile through hotspot feature in the mobile. And the laptop and the raspberry pi microcontroller is connected through the static IP address of the laptop fed to the python program to read the power consumptions. The raspberry pi and the mobile is connected to the GSM module through the UART RS232. The same working is possible if a dynamic IP address is adopted in which the tracking system is placed in the house building where monitoring and controlling is to be done and the monitoring and controlling can be done from the webpage display anywhere from our work place.



Fig 5: Webpage display

7. Conclusion

With the technological development in the society, the consumption is surely escalating. Development of this type of energy monitoring and controlling system would help reduce unnecessary energy consumption and implement demand side management among domestic consumers. Hence the IoT based smart energy tracking system using Raspberry Pi microcontroller and GSM module have been successfully designed and implemented which is capable of monitoring and controlling the loads through a static IP address webpage display. At the same time SMS notifications are send to the user. Further extensions and feature enhancements are always inevitable in the present generation trending technologies. As a future scope this system can be developed such that the consumers can conveniently interact with this energy tracking system through the developed website with dynamic IP address, the developed android application and also through SMS. This prototype system proposed has an added advantage that can be implemented in smart cities applications, education applications, health applications, productivity applications where we have to control the electrical in electronics.

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