IOT Based Energy Monitoring And Management System For Smart Homes

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Abstract— Today’s advanced technologies have brought the era of automation. Automations have been adapted in industries, in transportation, in communications. Electrical energy is the most usable form of energy in this era, hence its conservation is today’s need. Control over the use of electrical energy is necessary. Automation to control and monitor the electrical energy consumption can be very useful as it can provide the framework for real-time decision. This review focuses on different intelligent home automation systems and technologies from a various features standpoint. The work focuses on concept of home automation where the monitoring and control are provided using smart devices installed in residential buildings. Heterogeneous home-automation systems and technologies considered in review with central controller based (Arduino or Raspberry pi), web based, email based, Bluetooth-based, mobile-based, SMS based, ZigBee based, Dual Tone Multi Frequency based, cloud-based and the Internet with performance.

Keywords— Home-Automation; Intelligence; Microcontroller; Sensor System; User-friendly Interface

I. INTRODUCTION

Automation is a technique, method, or system of operating or controlling a process by electronic devices which reduces human involvement to a minimum level. Automation systems for office or home are becoming more complex and advanced with numerous benefits. Industrialist and researchers have been working on design and development of efficient and affordable automatic systems to monitor and control different machines like lights, fans, AC based on the requirement. Automation can improve efficiency, conserve electricity and water and reduce much of the wastage [1]. Internet of things (IoT) facilitates the connectivity between people and things to be connected without any constraints on time, place, person, network and service [2]. Automation is an important application of IOT technologies. It is the monitoring of the energy consumption and the Controlling the environment in buildings, schools, offices and museums by using different types of sensors and actuators that control lights, temperature, and humidity.

Electric loads in commercial and residential buildings

As per the Energy Statistics carried by India National Statistical Organisation(NSO)’s. The electricity consumption in India is 26% in domestic, 24% in agriculture, 11% in commercial sector and 46% in industrial sector. This is expected to increase to 76 per cent by 2040. A large quantity of incremental electricity demand will come from the residential sector in India[3]. Sector wise energy consumption is shown in graph below.

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Fig. 1. Sector wise electricity consumption in India

i. The estimated electricity consumption increased from 43,724 GWh during 1970-71 to 7,72,603 GWh during 2011-12, showing a CAGR (Compound Annual Growth Rate) of 7.08% [4]

ii. The increase in electricity consumption is 11.26% from 2010-11 (6,94,392 GWh) to 2011-12 (7,72,603 GWh) [4].

iii. Of the total electricity sales in 2011-12, industry sector accounted for the largest share (44.84%), followed by domestic (22.01%), agriculture (17.30%) and commercial sector (8.97%)

iv. The electricity consumption in domestic sector and agriculture sector has increased at a much faster pace compared to other sectors during 1970-71 to 2011-12, with CAGRs of 9.44% and 8.43

v. Loss of electricity due to transmission has increased from 17.55% during 1970-71 to 32.86% during 2000-01 and it has decreased since then to around 24% during 2011-12 [4].

Electricity consumption in residential sector

The residential building sector is one of the largest consumers of electricity in India. Continuous urbanization and the growth of population result in increasing power consumption in buildings [5]. The energy is used in residential sectors for electronic appliances and also controlling climate of the building. In other sectors, some parts consume energy for purposes similar to that in the buildings. These small parts include the administration buildings in the industrial, agriculture sector. Energy is used in residential buildings for various purposes: Lighting, Air conditioning, Fans, Refrigerator, Television and other installed equipments. The other installed equipments includes oven, toaster, laptops, set-top box, home audio, computer monitors etc. [6]

Table 1. Loads in Residential Building (Electrical Energy Usage)

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<tbody>
<tr>
<td>Lighting</td>
<td>28%</td>
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<tr>
<td>Air conditioning</td>
<td>7%</td>
</tr>
<tr>
<td>Fans</td>
<td>34%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>13%</td>
</tr>
<tr>
<td>Television</td>
<td>4%</td>
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</tbody>
</table>

Of this 170 TWh is due to electric lighting and use of major appliances like ceiling fans, televisions, refrigerators and air-conditioners. Therefore bulk of the energy demand is currently from cooking but the above mentioned electric devices account for about 80% of the residential consumption with the rest of the residential electricity demand coming from smaller and less used appliances like washing
machine, geysers, computers etc. Though much smaller in volume compared to fans and TVs, the air conditioning market is galloping at a much faster rate about 25 per cent a year. Electric appliance ownership is significantly increasing both in rural and urban households due to rise in income levels and gradual increase in reliable access. Consequently electricity demand from the residential segment grew at a CAGR of about 9% in last 5 years compared to 8% growth in total electricity consumption in India [7] [8]. B. Electricity Consumption in Commercial Sector The areas where electricity consumption occurs in commercial sectors are non-residential and non-industrial areas such as offices, hospitals, hotels, retail outlets, education institution, etc. These account for approximately nine percent of electricity consumption through utilities, growing at 11% percent in the last decade [9]. The electricity consumption by the commercial sectors seems to be small compared to other sectors, over the past few years the commercial sector is growing rapidly. Energy is used in commercial buildings for various purposes: lighting, HVAC load (Heating, Ventilation and Air conditioning) and plug load. The plug load devices range is diverse and their usage and consumption is very difficult to understand. Plug load accounts for more than 20% of energy consumption in building [10]. Between 2006 and 2012, electricity consumption from the commercial sector has almost doubled from 36 TWh to 70 TWh, growing at an average CAGR of 11.8 percent. Energy consuming equipment in the commercial sector include lighting, heating, ventilation and air conditioning (HVAC), and other office related equipment [11].

![Energy consuming equipments in commercial sectors in India](image)

**Fig. 2. Energy consuming equipments in commercial sectors in India**

HVAC is responsible for the greatest share in electricity consumption, and its demand is primarily from Air-Conditioning. Lighting loads represent the second highest consumption category at 25 percent. ‘Others’ category is constituted by internal loads such as servers, service-specific machines and equipment, etc. Commercial sector also relies on central HVAC and lighting solutions (luminaires) that are considerably more expensive than stand-alone devices, but offer greater scope for efficiency improvement [12].

**Different home automation systems**

Home Automation System with their technology with features, benefit and limitations they have are mentioned below;

1. **Wireless Sensor Network:** Mohammed Abo-Zahhad *et al* have presented a Design and Implementation of Building Energy Monitoring and Management System based on Wireless Sensor Networks Comprising of XBee-PRO ZigBee module and ACS712 current sensor. Thing Speak Cloud-based for storing and displaying sensor measurements have been carried out. In which they have connected each sensor node to four loads with different priorities. The proposed system monitors and controls all energy consumption in buildings in real-time and forecast the future energy consumption [17]. As per the survey carried out by Gang Zhao on Wireless Sensor Networks for Industrial Process Monitoring and Control, WSN technology is not capable for wide use in process control applications due to increasing constraints for process monitoring and control applications which put many challenges to the industrial implementation of WSNs. Various issues relating to implementing the WSN technology to process monitoring and control have to be considered. EMS based on wireless sensor networks for efficient load management has been prepared by [17]. The system monitors and controls all energy consumption in buildings in real-time and forecast the future...
energy consumption. NI LAB-VIEW software for monitoring and control and the sensor node is implemented using Arduino Uno microcontroller, XBee-PRO ZigBee module and ACS712 current sensor. Finally, we use ThingSpeak Cloud-based for storing and displaying sensor measurements. Wireless sensor networks (WSNs) play a key role in extending the smart grid implementation towards residential premises and energy management applications. Efficient supply and demand balance, and consequently reducing the electricity expenses and carbon emissions, is an immediate benefit of implementing smart grids.

2. **WiFi**: Wireless fidelity has been adopted in the home automation systems by several researchers. The system consists of Server which controls hardware one interface module, and can be easily configured to handle more hardware interface module and the hardware interface module in turn controls its alarms and actuators. Server is a normal PC, with built in WiFi card, acts as web server. The webserver software is developed using asp.net technology, to support asp application and .net framework 4.0, like IIS7.0 for Windows OS. System can be accessed from the web browser of any local PC in the same LAN using server IP, or remotely from any PC or mobile handheld device connected to the internet with appropriate web browser supports asp.net technology through server real IP (internet IP). WiFi is chosen to improve system security (by using secure WiFi connection), and to increase system mobility and scalability.
   i. User friendly interface,
   ii. Security and authentication,
   iii. Low cost per node / High node count,
   iv. Large area coverage,
   v. System Scalability

3. **ZigBee**: Zigbee can be a good tool in the energy monitoring systems. ZigBee has following advantages
   i. targets low data rate, low duty cycle
   ii. 250 kbps over the air, 60-115 kbps typical data transfer
   iii. Long battery life (in years)
   iv. More sophisticated networking best for mesh networking
   v. Network latency (typical) New slave enumeration Sleeping slave changing to active
   vi. Mesh networking allows very reliable data transfer
   vii. Uses direct spread spectrum technique
   viii. 2 to 65535 devices per network
   ix. Simple protocol.
   ZigBee’s wireless open standard technology is being selected around the world as the energy management and efficiency technology of choice. Implementing smart meters with an open standard such as ZigBee helps to keep costs down, ensure interoperability, and future-proof investments made by both utilities and consumers. Consumers and businesses will see changes they never dreamed possible. The information collected through smart energy meters provides unprecedented insight into energy demand and usage, allowing utilities and consumers alike to do their part to ensure continued and affordable supply of essential services into the future. The “tipping point” is indeed here and much bigger than ever imagined.

4. **Android**: Rakesh dwivedi has elaborated the design and development of energy measurement system based on 4.1.2 jelly bean android o.s. for e billing app. The system consisted of ATmega16 microcontroller, power supply, GSM module and transformer.
5. Internet Of Things: As the name suggests, internet of things (IOT) is the technology consisting of several things connected to one another via internet. IOT has been used in several applications viz. healthcare, water quality monitoring, power management, power monitoring, street light controlling, pest management, industrial automation and home energy management. IOT provides following advantages over other systems. It provides fastest communication between end user and the things being controlled:
   i. The speed of control is very high
   ii. Effective control over the things and processes
   iii. Reduction in human efforts
   iv. Security and low cost

II. WORK DONE

*Fig 3. Block Diagram of IOT Based Energy Monitoring and Management System For Smart Homes*

**Arduino ATmega2560:**
Arduino board can be powered by using the USB cable from computer. All you need to do is connect the USB cable to the USB connection. The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements. The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz. The Arduino UNO board has five analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
Ethernet Shield (W5100):
The Arduino Ethernet Shield allows an Arduino board to connect to the internet. It is based on the W5100 ethernet. The W5100 provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. The W5100 is IEEE 802.3 10BASE-T and 802.3u 100BASE-TX compliant. The W5100 includes fully hardwired, market-proven TCP/IP stack and integrated Ethernet MAC & PHY. Hardwired TCP/IP stack supports TCP, UDP, IPv4, ICMP, ARP, IGMP and PPPoE which has been proven in various applications for several years. 16Kbytes internal buffer is included for data transmission. Support Hardwired TCP/IP Protocols : TCP, UDP, ICMP, IPv4 ARP, IGMP, PPPoE, Ethernet.10BaseT/100BaseTX Ethernet PHY embedded. Support Auto Negotiation (Full-duplex and half duplex). Support Auto MDI/MDI.

Relay Module:
A relay is an electrically operated switch. On-board 5V, 10A / 250VAC, 10A / 30VDC relays. Relay long life can absorb 100000 times in a row. Relay Module can be directly and MCU I/O link, with the output signal indicator. Module with diode current protection, short response time. PCB Size of the relay module is 45.8mm x 32.4mm (small in size).

SD3004 Current Measurement SOC:
It is a High precision energy measurement. Which Provide RMS voltage and RMS current. It Calculates active power and power factor also Calculates AC frequency. it is High frequency CF pulse for calibration. Which Calculates total energy usage over time. IC having 24 seg x 4 com LCD drivers, can be switched to become I/O ports. Which Supports LED driving with Real time clock, can output second signal. It also having UART and I2C interfaces.

Working:
As shown in Fig 3 Arduino ATmega 2560 work as a controller which perform controlling of a load via relay module. Relay module works as a ON/OFF the appliances which can be operated electrically. similarly Ethernet module W5100 is used for giving connectivity of the devices from arduino to our laptop/computer for controlling and monitoring purpose through internet.

Similarly we are going to use SD3004 current measurement SOC for solution of the power supply like to measure exact value of current, voltage, phase difference and power consumption. it will gives rms voltage, rms current, active power, reactive power. Here we are going to use TCP/IP protocol and MQTT which can be used on top of the TCP/IP protocol. It is designed for connections with remote locations where a small code footprint is required or the network bandwidth is limited.

The working flow is like the signal from laptop or desktop is given to Arduino via Ethernet through TCP/IP protocol that controlling signal arduino will gives to the Relay board and relay will perform that task and gives signal return back to the controller and the performed task will be shown to laptop/desktop.

III. SOFTWARE DEVELOPMENT
Arduino IDE: In order to write the Internet connectivity code, you need following software:
Arduino IDE 1.6.4 or later version Circuit In this section, we are going to build the circuit required for Internet connectivity using Ethernet.
1. Make sure your Arduino is not connected to a power source, such as a computer via USB or a battery
2. Attach the Ethernet shield to the top of Arduino. All the pins should align.
3. Connect an Ethernet cable from Arduino to the LAN (Local Area Network) port of your router.
The router should already be connected to the Internet.

**MQTT Protocol**: MQTT protocol is a Machine to Machine (M2M) protocol widely used in Internet of things. It is a message based protocol. It is extremely light-weight and for this reason, it is adopted in IoT ecosystem. Almost all IoT cloud platforms support MQTT protocol to send and receive data from smart objects. There are several implementations for different IoT boards like Arduino, Raspberry and so on. There are other IoT protocols used to implement IoT projects but MQTT is one of the most efficient from bandwidth point of view. Moreover, it is power saving.

**Cayenne**: Cayenne is the world’s first drag and drop Internet of Things (IoT) project builder that empowers developers, designers and engineers to quickly prototype and share their connected device projects. Cayenne helps users to create IoT prototypes and then bring them to production.

There are several major components in the platform:
- Cayenne Mobile Apps
  Remotely monitor and control your IoT projects from the Android or iOS Apps.
- Cayenne Online Dashboard
  Use customizable widgets to visualize data, set up rules, schedule events and more. The cayenne interfacing needs
- Hardware
  A Raspberry Pi or Arduino device connected to the Internet, or a LoRa device connected to a public or private gateway. The list of hardware that works with Cayenne will keep growing.
- Smartphone or Browser
  Cayenne was designed to work from iOS and Android smartphones and popular browsers.

### IV. IMPLEMENTATION AND RESULTS

![fig4](Image)

*Fig 4. Assembly alongwith the controlling widgets*
Fig 5. Assembly along with the controlling widgets

Fig 6. Different parameters recorded by software programme specially designed for the Home Automation

V. CONCLUSION

The prepared system is fast and efficient with high speed performance of Arduino uno microcontroller. The system provides not only accurate monitoring but also the control over the
power consumption by the domestic appliances. The provision of Ethernet connectivity widened the scope and development of the user friendly interface is the great achievement of this work.

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