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A REVIEW ON IOT BASED ENERGY MONITORING AND CONTROLLING SYSTEM

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***Abstract*- Nowadays, electricity consumption has become one of the basic needs in every sector. Thus to improve the efficiency of all electrical appliances and to reduce wastage of electricity is one of the challenges faced by the world. The objective is to develop load monitoring and controlling system for electric appliances to reduce energy consumption and carbon emission in buildings through fine management of energy usage in an efficient way. This paper presents a review of monitoring and controlling methods for electric loads in commercial and residential buildings, by comparing different methods of implementation of this technology.**

Keywords – Energy efficiency, load monitoring and controlling, energy management.

I. INTRODUCTION

The world's second most populous country is India and it has economic growth of more than 7% per year since 1997. Because of these two reasons there is continuously increasing national consumption of energy. India became the fifth largest energy consumer in the world in 2006, emitting 4.4% of global carbon emissions. Energy production has not been able to satisfy demands, resulting in approximately 400 million Indians with no access to electricity in 2010. According to International Energy Agency, the buildings sector accounts for the largest share (47%) of India's energy use in 2005, with residential buildings accounting for a major 93% of the total building energy use. In residential buildings, urban India constitutes a major share of Indian energy consumption (about 39% of energy use), and a majority of urban households (91%) have access to electricity. In 2012, urban population was 32% of the total population. Thus, an understanding of consumption and conservation practices in urban Indian households is crucial for designing appropriate technologies for this population [1].

Now a days, consumption of energy has also increased by the industrial, commercial and domestic sectors. A poor quality of power transmission system and improper use of energy leads to wastage of energy. As the resources are getting scarce, so it becomes prime important to improve the management of energy consumption. So the challenging task is to identify and control the waste of energy by determining which device uses how much of energy.

One of the most important technique for promoting more accurate management of the resources and for growing new awareness about the cost of the energy is smart metering. Smart meter is specially designed for monitoring energy consumption and controlling individual electronic devices. The energy of electronic devices is measured using smart meter and it reports the measured data over the internet for analysis and controlling the devices. Huge number of organization across the world are carrying out research on smart meters for improving efficiency of the energy usage and into reducing energy consumption in residential and commercial buildings.

II. ELECTRIC LOADS IN COMMERCIAL AND RESIDENONIC BUILDINGS

The Energy Statistics 2013 of India's National Statistical Organisation (NSO) shows electricity accounted for more than 57 per cent of the total energy consumption during 2011-12 in India, and building sector is already consuming close to 40 per cent of the electricity. 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 [6]. Sector wise energy consumption is shown in graph below.

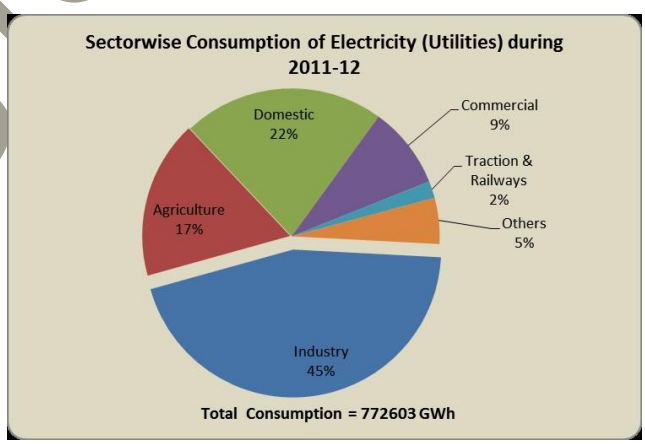

Fig. 1. Sectorwise electricity consumption in India [3]

- 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% [3].
- The increase in electricity consumption is 11.26% from 2010-11 (6,94,392 GWh) to 2011- 12 (7,72,603 GWh) [3].

- 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%)[3].
- 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% respectively [3].
- 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 [3].

A. 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 [9]. 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.

Table I ENERGY CONSUMPTION IN RESIDENTIAL BUILDING [8]

Loads in Residential Building	Electrical Energy Usage
Lighting	28%
Air conditioning	7%
Fans	34%
Refrigerator	13%
Television	4%

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 [4][6].

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 [5].

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 [2]. 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 [5].

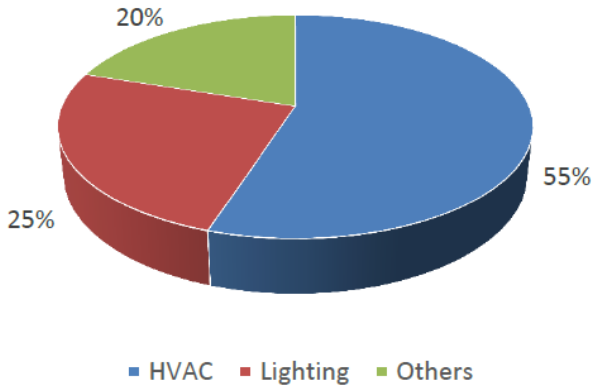

Fig. 2. Energy consumption in commercial sector [5]

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 (luminares) that are considerably more expensive than stand-alone devices, but offer greater scope for efficiency improvement [5].

III. RELATED WORK

A lot of research is going on plug load monitoring and analysis. In the past few years there have been number of studies on plug load monitoring and analysis. This section consists of the study of available techniques for measuring and reporting the energy use over a network.

A. Different technique for measuring and reporting energy use

The voltage, current and power are the unique characteristics of the electrical signal present in electrical loads. We can identify the type of load (e.g. Lamp, PC, etc.) and its operational status (e.g. active, ready, standby, etc.) by using these characteristics. Based on this data the analysis and controlling of electronics devices is done. This method is called as non-intrusive load monitoring system (NILM).

A general block diagram of NILM system is shown in Fig. 1. In this method, the voltage and current waveforms of loads are sampled continuously. The current measurement is done by two ways. The first method is to measure the current of each electronic load separately, the cost of this installation of sensors is relatively high. The second method is to measure the current where the multiple loads are connected or at a central point.

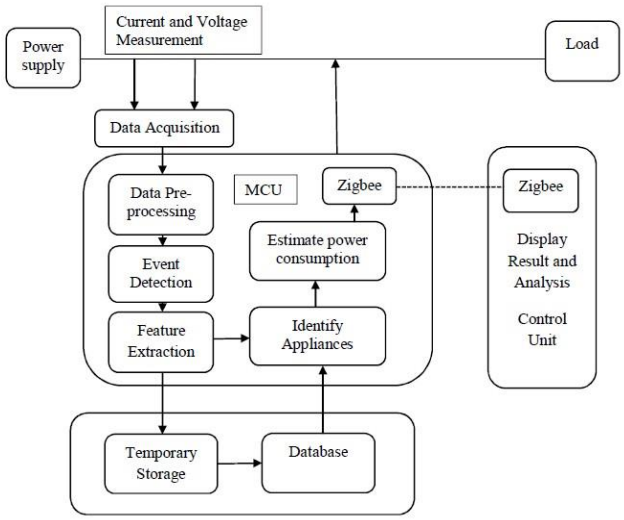

Fig. 3. Non-intrusive load monitoring system

In data acquisition system uses sensors and measure the current and voltage of signal. These data are transferred to data pre-processing module. In this module, that measured value of signal converted into traditional power matrices (active and reactive power, power factor, etc.). An appliances state transition e. g. turn-on event will cause changes in active power which can be detected using event detection module. After that various features are extracted. These features are stored in database together called as power signature. Based on stored data from database identify appliances and calculate power consumption of device using microcontroller. Microcontroller calculates the voltage and current waveforms, their RMS values, the power factor, the apparent, real and reactive powers then send to display unit through ZigBee. Control the individual appliances by ZigBee protocol.

This technique works well for large (over 150 W) loads that operate in discrete levels (e.g., ON/OFF and high/medium/low), but does not work as well for low-powered loads or loads with large number of variable states, such as the dishwasher or electric stove. NILM still does not achieve the same level of accuracy as direct metering at the end use [7].

Branch-circuit metering method measures energy use at branch circuit level. Branch circuit metering in individual building can be used to identify large individual loads, for example refrigerator or aggregates for a large number of smaller loads. Circuit level metering is expensive to install, and this limits studies to relatively small number of circuits [2].

Device-level metering method measures energy use of each device. The data is collected through these studies have significantly improved the knowledge of plug loads energy use in U. S. building [2]. These are software and hardware infrastructure that facilitate communication between the end-use monitor and the central entity. The embedded systems are programmed to gather data from the energy monitor and communicate this information over the network layer to the data server. A user dashboard would be located on a mobile device or PC, which allows control and monitoring via the data server [7].

Steven Lanzisera [7], "Communicating Power Supplies: Bringing the Internet to the Ubiquitous Energy Gateways of Electronic Devices", introduced the concept of the communicating power supply (CPS) that adds electricity metering, computation, and communication to electronic devices. It presented an Internet-connected system of CPSs that enables improved energy awareness of devices and users. CPS technology is the future of energy monitoring for plug loads, and that all energy-using devices will one day be aware of their identity and share energy information over IP networks.

S. Lanzisera, H. Y. I. Cheung [8], introduced "Methods for detailed energy data collection of miscellaneous and electronic loads in a commercial office building. This paper, explain how to quantify different aspects of the metering, such as number of devices to inventory and meter, how long to collect meter data, sampling rate and so on. The study was designed to look at the methodology for collecting accurate energy information on annual energy use, usage patterns, and energy savings opportunities of representative plug loads in a typical office building.

C. Beckel [10], introduced "Improving device level electricity consumption breakdowns in private households using ON/OFF events," In this paper, investigate the use ON/OFF events, which can control individual electronic appliances. To improve the accuracy of disaggregation algorithm that uses such events along with smart meter data to estimate the consumption of single appliances.

D. Balsamo [11], introduced "Non-intrusive Zigbee Power Meter for load monitoring in Smart Buildings" In this paper, an innovative Energy-Neutral and Nonintrusive Wireless Energy Meter (NIWEM) is presented, with self-power capability for smart metering applications. It embeds a clamp-on current transformer, which is used for the current consumption measurement, there is no direct contact with main supply. So it is safer method. The NIWEMs feature a low-power, 32-bit NXP microcontroller for data processing and a wireless transceiver for sending data to an Energy compliant Gateway, via ZigBee PRO standard.

In [17], the Internet of Things (IoT) concept proposes that everyday objects are globally accessible from the Internet and integrate into new services having a remarkable impact on our society. This paper proposes the use of the IoT gateway as a fundamental component in IoT architectures to provide seamless connectivity and interoperability among things and connect two different worlds to build the IoT: the Things world and the Internet world.

B. Communication protocol

In wired communication i.e. power line communication during data transmission signal interference occur in network. This causes signal attenuation and distortion which implies very low security. The complexity and re-wiring cost of wired communication is more than wireless technology. So there are various short-distance wireless technology are available. It has flexible networking pattern. So it is very convenient to use in resident. The various wireless technologies are Bluetooth, ZigBee and Z–Wave. These technology operates in the Industrial Scientific and Medical Bands (ISM Bands), and the frequency range is 2.4GHz. Low cost, low power consumption, low speed these are various features of wireless technologies.

By leveraging the flexible SoC features and the communication protocols available to the designers, manufacturers have a wide design space to effectively address the range of metering options: from low-cost solutions to top meters which offer wider memory, higher configurability, reliable network protocol and higher accuracy of the measure [13].

The ability to code and track objects has allowed companies to become more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible organizational systems through Internet of Things (IoT). The IoT is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology. They are going tag the each object for identifying, automating, monitoring and controlling [15].

IV. PROPOSED METHODOLOGY

The proposed block diagram as shown in fig 4. Communicating Power Supply (CPS) concept measures the energy use of the device it is powering, reports the energy use and device's identity over a network to a central entity, and receives control information from users or other devices via the same central entity. At the same time, the user is still able to control power state directly using interfaces on the product, so that the existing, native controls are retained [7]. Measure energy consumption of each device and store this data to cloud based web service. The web service collect this information and if user want to control power state then receive network based control information from user and pass this control request to the CPS device. According to that control the power state of that device. The device should be connected to power line to control it. Energy data uploaded to internet immediately after measurement. This data is monitored in real time and control the individual device at the same time.

In analog measurement circuity current is measured by current sensing circuit. By knowing current and voltage value we can calculate power. This analog value is converted to digital by using A-to-D converter and this value is sent to raspberry pi. Ethernet is interfaced with raspberry pi to store a data on cloud, where data is uploaded and archived by using a cloud-based data storage and web hosting. The user can monitor this stored data in real time and control the device.

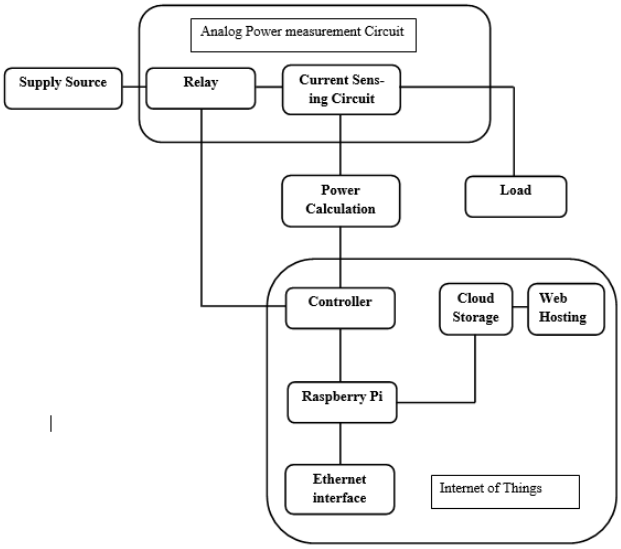

Fig. 4. Proposed block diagram

V.CONCLUSION

In this paper, literature review of various methods of energy monitoring and controlling systems is presented. Out of the presented techniques device-level monitoring over internet was selected. This method combines advantages of connection to internet and load monitoring and controlling individual electronic appliances. The future of internet of things will be that the devices connected over network will be

able to communicate and share data through individual IP network. Thus providing users with the control of things and information about status of things.

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