

Methods to Regulate Energy Consumption in Smart Homes

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ABSTRACT

A significant amount of research has been conducted in order to make home appliances more efficient in terms of energy usage. Various techniques have been designed and implemented in order to control the power demand and supply. This paper reviews different research works on a wide range of energy management techniques for smart homes aimed at reducing energy consumption and minimizing energy wastage. The idea of smart home is elaborated followed by a review of existing energy management methods which are usually based on fuzzy logic, heuristic methods, neural networks and evolutionary algorithms.

KEYWORDS: Smart grid, Smart home, Energy management, ZigBee

INTRODUCTION

A home constituting of such appliances or devices that consume energy in an efficient manner and operate digitally is known as a smart home [1]. This usually involves an in-home communication network. A network oriented home makes communication between devices in an efficient manner, using suitable communication technologies. It enables the devices to be connected to the internet server and usually communicates wirelessly. The internet or service providers are the ones responsible for providing new services to the customers and making them easily accessible for the individuals. In some cases, the smart devices are supposed to be smart enough to observe the inhabitants residing in these homes. Latest technologies are used to build such devices that operate and communicate automatically. The sole purpose of these smart devices is to provide its residents with a secure, active and quality environment leading to a positive impact on their lives. The issues such as environmental disruptions, insecurity, communication difficulties, health dilemmas and entertainment discrepancies are reduced to a minimum by the use of smart devices. Smart home devices are capable of monitoring internal activities of the home and use technology that enables the devices, for example, to turn on and turn off automatically.

The first use of smart home technology was in order to control the internal environmental issues like lighting and heating problems. Later on, this technology was designed and integrated further to operate smart devices on an automated basis. Almost all the appliances inside a smart home are connected to the internet from which it is easy to view their state and also trigger any action by sending a user command. The evolution and access of high speed internet has enabled mankind to bring comfort and security in their lives. As a result, many corporations have designed and implemented the concept of smart homes in the real world aiming at a stress free life. These devices observe the occupants' activities and act accordingly so as to maximize their level of comfort and satisfaction. The role of these devices includes energy management and reducing the wastage of energy as much as possible.

Service providers provide means that enable the devices to communicate wirelessly and automatically in a controlled manner. An issue associated with a smart home technology is difficulty in modifying old devices according to new specifications. Concept of home energy management is described in Fig. 1. It shows the smart appliances used for energy management in smart homes.

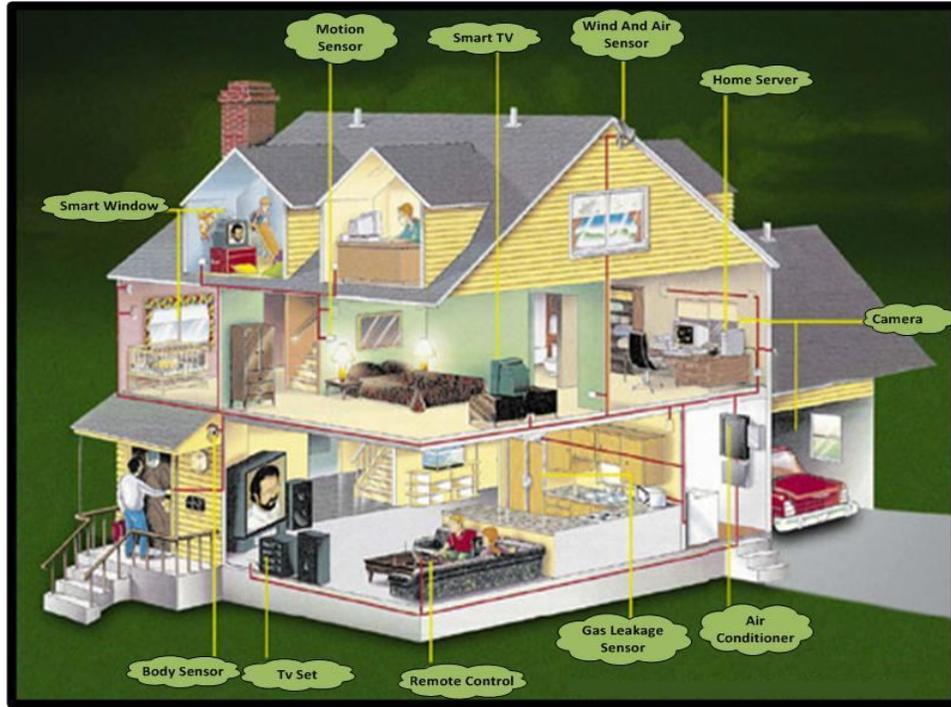


Figure 1: Smart Appliances for Energy Management

A part of this work has been accepted as conference paper in [25]. Rest of the paper is organized as follows. Section 2 is dedicated to energy regulation methods used in smart homes where as section 3 describes the quest for efficient energy resources and energy management using ZigBee. Conclusions are drawn in section 4.

MANAGING ENERGY IN SMART HOMES

The use of neural fuzzy network has been in use to control devices in the house. A controller based upon a neural fuzzy logic has been designed in MATLAB interface and converted into a tool with the help of hardware and the use of internet technology [2]. This technique is used in automating home appliances in terms of timing and energy usage. It basically works with a human like behavior by observing and sensing the activities of the occupants inside the home and facilitating them with the services they require. Home appliances are able to monitor the routine of the residents at different times throughout the day. By coordinating all these activities they operate in such a way that provides sense of security to the inhabitants.

A method to conserve energy based upon home appliances information has been used in [3]. In order to manage and control appliances that work on the principle of user's operational information, a network including IP, XML and JAVA is present at most of the companies dealing in home appliances. IP is used as a mean of communicating code, XML as a form in which the data is transmitted and JAVA is the language used to build the software used in the appliances. An experiment has been carried out by simulating an environment consisting of one hundred homes involving 16 different home appliances. The simulation results showed that the appliances helped in reducing the energy consumption by 15.6% in contrast to those devices which were operating manually. This concluded that the energy could be significantly reduced by using appliances that operated automatically and that the concept of the smart homes can successfully help in lowering energy wastage [3]. Moreover, the electricity saved can be used in other ways.

Another system to manage energy using a simple desktop PC and some sensors in a building has been presented in [4] aiming at conservation of energy; The sensors are used in order to see how many individuals entered and exited the building while the role of the PC is to turn the devices ON when an individual enters the building and turn it OFF when the occupant exited the building by using the number of counts captured by the sensors deployed at different places inside the building. Only appliances that were required at a certain time were to be switched ON and all other idle appliances to be OFF. Thus the decreased loss of energy contributed towards more energy to be used in other sectors wherever it is required. The simple setup comprising of a PC and some software and a simple hardware resulted in reducing energy wastage. An energy management system has been developed in [5] that works by

observing the activities of individuals using thermal and visual aid. In this system, the sensors have been used to monitor the activities by sensing the heat level of the people. By using this system, the energy wastage has been reported to be reduced significantly. During the day, there is enough daylight and so, there is no need to switch ON the lights. The natural light can be used as an alternate during the day. Likewise, the heat from natural source like sun can also be used as in the case of solar panels. The energy stored can be used during the night providing an economical approach towards saving energy and minimizing energy wastage. The methodology when applied on a large scale for corporations where the electricity requirements are enormous, the use of such an efficient system can lead to reduction in electricity bills.

In [6], a smart home system aimed at minimizing the energy wastage in household has been presented in the context of demand side management (DSM). The idea here is to anticipate the load or demand of energy requirement inside the home. The system predicts the demand from past events and allocates the required energy to be used by the home appliances. The prediction is then used to maximize conformability to the user and minimize the cost of energy. The appliances when being operated in such an efficient manner can contribute towards securing the goal of conserving energy. The consumption is significantly reduces by the automation of home appliances and the system meets the energy demand of the appliances. This in turn helps the providers to satisfy customers and minimize peak hours' energy usage at the same time.

A similar system has been presented in [7], where a management system operating automatically in a residential area has been presented. The idea here is to modify the consumption of power and limit the use of energy to a minimum level based upon past events and records. The control system described in this work aims at satisfying the needs of the residents in the residential area. The people who are affected directly by the change in any system are the end users or customers. Therefore, they should be part of any control system as it is necessary for them to be up to date whenever a change occurs. The use of fuzzy control systems in managing the energy demand and supply is for the sole purpose of reducing the wastage of energy and minimizing the cost. The system in [9] tries to minimize the cost as well as contributes towards an energy efficient economy using fuzzy control mechanism. The devices operate in such a way that is user friendly and comforts the consumers by providing utmost satisfaction. Energy wastage is minimized by the efficient use and operation of the smart devices in homes. The users are no longer bound to turn these appliances ON or OFF manually.

The appliances in a smart home are supposed to be fully automated and work on a technology that is intelligent enough to sense and monitor the needs of the residents and work accordingly. For instance, efficient system analysis technology is used to solve the issues regarding the heating requirements of an individual [10]. The appliances used for thermal comfort like oven, water heaters etc. are managed through energy conserving methods. Automation of such devices allows them to observe the inhabitants and then operate accordingly. These devices have sensors that monitor various activities of the occupants and then turn ON and turn OFF the appliances accordingly. This results in reserving more energy for the other appliances and lesser energy wastage occurs. The technology not only manages the energy crisis problem but also comforts the end user such that the individual senses a feeling of security.

A systematic way of delivering the services is planned by the service providers to facilitate the continuous provision of these services, as discussed in [12]. The system optimizes an efficient way of how to provide these services while utilizing the maximum amount of resources and at a considerable low cost. The system is a perfect example of an automatically operated device. The system only provides the required energy to be used by appliances when the benefits derived from these services are at maximum. Whenever the system senses that the services are providing low-benefits, it does not regulate the required actions so that the energy could be delivered in more fruitful manner.

In [14], an automatic decision making system was developed to be used for managing appliances of the smart home. The purpose was the management of energy and the supply of power in an un-interrupting manner. This system actually operates on the principle of giving the customers the decision power to assign fixed units of the energy required by the devices to operate. Thus the consumers are the ones who select how much quantity of the energy is required by the appliances. The technology regulates the optimum amount by comparing the statistics provided by the user and those which are present independently.

An automated system devised to schedule the electricity supply for the appliances of the smart home is presented in [15]. It focuses on cutting the electricity tariff by providing energy when required. During the peak hours, the appliances are provided with the required energy at specific intervals, which lowers the tariffs by implementing a specific schedule that optimizes the energy supply. During the off peak hours, the energy is also supplied in a specific schedule to minimize energy wastage as well as lower the tariffs. This schedule system not only helps the residential users but also the users of large companies.

A system devised to control and manage the thermal devices minimizing the tariffs has been described in [16]. The thermal devices usually consume large amounts of energy which results in high tariffs. The system

predicts the right amount of energy required by these appliances and schedules a pattern which ensures the supply of uninterrupted energy to these appliances while lowering the energy tariffs at the same time. The comfort level of residents is maximized by optimizing the amount of energy required by the thermal devices.

In [17], a data processing system is applied to schedule the electricity and thus the price of energy consumed. It works by setting the prices based on the power supplied to the appliances. The system makes use of the previous data related to the energy consumption by various devices. The system then sets the prices according to the usage during the peak time and the normal time. The equilibrium is achieved by the exchange of information between the service providers and the appliances. The outcome of the scheduling scheme reveals that the system reduces the burden of the tariffs significantly for the customers by managing the demand and supply of energy during the peak and normal timings.

An information based network using Bluetooth is presented in [11]. Benefits of using Bluetooth technology include wide range, less energy consumption and less operating expense. The Bluetooth forms infrastructure for a broad range of appliances to be connected and communicated with each other. The use of internet and wireless based technology enables the devices to be operated automatically. The devices are embedded with numerous units that are understandable to the recording devices capable of displaying the information regarding energy demand to both customers and service providers. Moreover, the implementation of wireless technology provides a safe, secure and fast way to understand and anticipate any energy related problem in time and thus less wastage of time, resources and energy will occur. Such wireless systems are quite easy and simple to assemble and install. The users do not have to wait any more for certain topologies to start. As soon as the system is installed and integrated in the home's power circuit, the owner shall be able to monitor and observe all the energy inflow and outflow. These systems are generally maintenance free and even if the maintenance is required, it can be managed easily.

Another technique involving wireless communication is presented in [13] that controls the home appliances using the remote control. It is actually designed to minimize power consumption in the standby mode just by the click of a button. One can control all the appliances and monitor them easily. Basically it uses ZigBee controller technology. A fixed amount of threshold power is set as a standard to coordinate all the activities of the devices. A different infra red code is developed for each different threshold of light. Data information is displayed on monitors as threshold unit of energy. When the power being regulated falls below the standard level, the power source cuts off the whole power supply from the main provider. The system declines to operate in such a situation. Moreover, when the power is again normalized, the control directs the system to turn ON and provide the required energy supply by sending an IR code designed for the specific purpose. The increase in the intensity or dimming out of light can be easily controlled by the remote control. The ZigBee provides the pathway for the light threshold data to be continuously transmitted between the sender end and the receiver end of the proposed system in which all the devices of the smart home are being operated. It is an easy and efficient way to minimize the loss of power. It provides the residents with the comfort and ease of excess to the appliances.

The multiplexer is an important part of the microwave front end as it is used for the separation of channels which are used in various applications i.e. radar, transceivers etc. The multiplexer give different frequency bands to every channel so that it can operate at high bandwidth [5]. One of the well known multiplexer is a diplexer which multiplexes a combined spectrum of frequencies into two sub-bands.

The dual frequency band operation in the latest communication systems requires a diplexer to be used in the design of a transceiver so that a single antenna can operate at two different frequency bands to both transmit as well as receive. To fulfill the high requirements of the latest transceiver design the diplexer should be planar and compact [6]. Diplexer is a three port device that separates two frequency bands from a combined frequency spectrum and makes them available on the two output ports while keeping the interference between the signals to the minimum and the two ports can be fed to two different receivers for parallel processing [8].

The design of a diplexer involves two different filters with respective frequencies having distinctive non-overlapping pass bands. If the pass bands of the filters are close to each other there will be an adverse effect on each other due to that. This detrimental effect will cause the return loss to decrease and insertion loss to increase where as destroying pass band's symmetry and flatness [8].

Most widely used diplexer for wireless communication consists of two bandpass filters, however, the main hurdle in the design of the diplexer is that it's size is never small enough [9]. On the other hand the modern trend in the design of the diplexer is to achieve high performance while keeping the cost and size to minimum. Bandpass filters are a good choice to achieve this because they can be fabricated on a dielectric substrate with low cost [10]. An increase of sections in diplexer help in increasing the bandwidth of the passband causing increase in losses as a tradeoff [12].

QUEST FOR EFFICIENT ENERGY RESOURCES AND ENERGY MANAGEMENT USING ZIGBEE

Over the years, due to increase in the electricity tariff and installation of excessive home appliances, residential power consumption has increased rapidly. Increased power consumption and exhausted natural energy resources have forced the humans to find alternate energy resources over the years. The problems such as global warming, pollution, matter decay, ozone depletion and the like have increased the use of natural resources which are not in abundance to meet the energy demands of the modern world. Moving towards finding efficient energy source will require changing the way energy is supplied as well as used [18]. The communication protocol used has to be efficient as well as continuous so that the devices being operated provide an un-interrupting service.

In most power related applications the use of wireless technology can bring profit to the end users by integrating wireless technology and output optimization etc. ZigBee is the popular wireless network used in home energy management system. It is a general communication protocol that consumes less power while being economical at the same time.

In Pakistan, a considerable number of the power meters installed are operating mechanically instead of being automated. The data loss and labor cost is enormous which can be reduced significantly by implementing digital power meters combined with ZigBee networks. Not only that labor cost can be reduced by a great amount by digitizing the power meters but also reliable and accurate data about the energy consumption by home appliances can be recorded. The devices operate by monitoring the activities of the residents in the area where these appliances are set. The receiver end of the ZigBee system processes and displays the data in the most simple manner that is easily understandable by the customers as well as the service providers. It also helps the providers to supply the adequate amount of energy to the households by providing detailed information for further analysis. The sole purpose of using a ZigBee communication protocol is the fact that ZigBee has some salient features and advantages of its own, as shown in Fig. 2.



Figure 2: Features of Zigbee

ZigBee has a strong ability to form mesh networks which not only allows the ZigBee nodes to communicate with each other but also route the data easily and in a smooth manner [19]. Another benefit of ZigBee is that it is extremely tolerant to interference of other radio waves which does not disturb the transmission of data from the sender to the receiver end. One of the many advantages of ZigBee is that it consumes low power and has long battery life which increases its efficiency. The Comparison of ZigBee, Bluetooth and Wi-Fi technology is shown in

TABLE 1. Comparison of Bluetooth, Wi-Fi and Zigbee

Category	Bluetooth	Wi-Fi	ZigBee
Ease of Use	Normal	Hard	Easy
Prime Cost	Low	Normal	Low
Reliability	High	Normal	High
Security	62 bit, 128 bit	SSID	128 bit AES
Cost of Use	None	None	None
Cost of terminal unit	Low	High	Low
Linking time	Up to 10 s	Up to 3 s	30 ms
Network Nodes	8	50	65535
Frequency range	2.4 GHz	2.4 GHz	868 Mhz,916 MHz, 2.4 MHz
Transmission Speed	1 Mbps	1-54 Mbps	25. Kbps
Complexity	Complicated	Very Complicated	Simple
Power Supply	Days	Hours	Years
Extension	None	Depend on Network	Automatic
Distance	10m	50m	50-1600m

A smart home energy management system based on ZigBee sensors and PC based interfaces has been presented in [20]. The proposed system consists of a home that has been distributed into different zones as shown in Fig. 3 [20]. Each zone contains different appliances which operate separately from one another. Each appliance is connected with the Human-Machine Interface (HMI) via wireless technology and is consistently monitored. Appliance scheduling is done based upon single knap-sack method. Comprehensive reviews of the home energy management systems have also been carried out in [21-26]. These reviews cover the different optimization and simulation techniques used for energy efficiency in smart grid. Moreover, a regional energy potential is provided in [27].

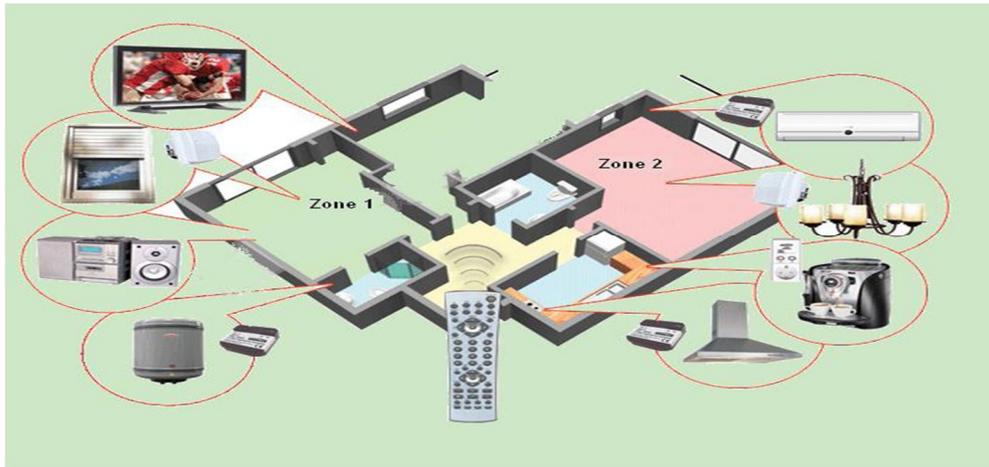


Figure 3: Concept of zoning for Home Energy Management

CONCLUSION

This paper is a compilation of numerous energy management related research works that focus on analysis and implementation of various technologies in order to obtain efficient solutions to the energy management issues. The devices present in the smart homes are automated and work in a manner that provides the customer/occupants with higher comfort level. Moreover, the intelligent home energy management system provides an easy solution to the complex energy problems. The methods to reduce the energy wastage can be further improved and simplified by applying efficient optimization techniques. A modern approach in resolving the energy management issues involves a smart home based on ZigBee communication which gives benefits in comparison to other wireless technologies.

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