ICRANET2018-180903

INFRASTRUCTURE AND IMPORTANT FUNCTIONS OF SMART HOME ENERGY MANAGEMENT SYSTEM

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Abstract

Energy demand and its cost are increasing exponentially. Its mass generation has environmental as well as economical issues. Energy Management is used to overcome these issues without replacement of major components of the existing system. Renewable energy integration, automated & remote control of appliances and applications of ubiquitous computing are making their way into our life due to the importance of their smart nature. With recent development in information and communication technology the realization of Smart Home technology is possible. SHEMS overview, control and display the energy flow of Smart Home. Infrastructure and the important functions of SHEMS are given in this article. Issues relating complexity, security and control strategies are also discussed.

Keywords: energy management; smart home; infrastructure, demand management.

1. INTRODUCTION

A smart home consist of sensors and transducers to collect data and perform tasks according to resident's expectations [1]. Three things are important to make a smart home which are network, intelligent control and automation. Smart Home is a concept of home which can provide comfort, control, reliability, security and health care [2]. Smart Home is customizable to our needs and it can depend on consumers that what type of customization they want in their home environment. Smart home can provide us real time monitoring as well as it can save our time by automating our different daily life tasks like turning on air-conditioning or heating system just before the personnel arrive at home and turning on or off lights after entering or leaving a room. Amazon Echo & Alexa and Google smart home are already in the market of United States. Toshiba and Panasonic are actively working on smart solutions in Asia to find cost effective automated control of smart devices [3].

Electrical Energy is an essential part of our lives and is a remarkable energy resource. Electrical Energy is used for bringing comfort, reliability and to save time. Its demand is consistently increasing due to which generation is being increased. But this increasing consumption and production of electrical energy has serious environmental and economical issues [14]. Thus generation and energy consumption needed sustainability, proper control and management due to depleting natural resources and increasing environmental concerns. So the concept of management of energy was realized. First digital solution was presented in 1976 [4]. EMS can manage the energy flow and its consumption by proper monitoring & control of the facility, resulting in energy and cost savings from 5 to 15% depending on the investment level in Energy Management. Reviewing the Digital media report of 2018, penetration rate of Smart Home Energy Management in over 50 countries and regions was 0.6% in 2016, is 1.1% in 2018 and will become 3.4% at the end of 2022. Average revenue will increase by 100% in 2020. Smart Home household penetration is over 31% in China, United States and Norway [15].

Development in information and communication technology gave us smart and IOT devices. These devices are becoming popular day by day due to their

easy connectivity with other devices. They play vital role in SHEMS. IOT is an abbreviation of internet of things. It means the devices are connected via internet and can share information. It has brought smart solutions of management [5], [13]. We just need application in our smart phone. When our devices are connected we can easily access their data and use it for the management purpose. That's why it is getting appreciation by the display of prototypes [3]. End goal here is same to get comfort, reliability, safety, healthcare, energy saving and time saving by automated management of home as well as our workplaces.

SHEMS is a topic of interest and is consistently being explored in different approaches [8], [7]. Every aspect of it needs more research and development. Complex operation and control of smart environment still consumes more energy than expected [6]. It's not secure as we expect it to be. So overall goals must be identified and defined well. Advance Metering Infrastructure, communication systems, smart sensors, actuators, smart devices, energy storage system and data analytics approaches are being explored in research articles. Table 1. gives the list of important studies of Smart Home base systems.

Table 1. List of Smart Home base studies.

No.	Title	Year
1	A Review of Smart Homes—Past, Present, and Future [2]	2012
2	Energy savings by energy management systems [4]	2015
3	Smart Home Energy Management [6]	2017
4	Smart Home energy management systems: Concept, configurations, and Scheduling strategy [8]	2016
5	Smart Home Energy Management System Using IoT and Big Data [9]	2016
6	Communication Network Architectures for Smart-House with Renew-Energy [10]	2015
7	Experimental Study of 6LoPLC for Home Energy Management Systems [11]	2016

2. INFRASTRUTURE OF SHEMS

Building Energy Management System is a combination of energy sources and monitoring devices, helping to overlook the building's system by computer aided management. BEMS is necessary to increase generation and decrease operational cost. Management of buildings with feedback devices as well as buildings with feedback & feed forward approach. Smart buildings consist of smart devices in it. Smart Home Energy Management System ideally include both of these systems. Smart Home Energy Management System includes 5 main components. Fig.1 shows the building blocks of SHEMS.

2.1 Communication System A medium to connect and share information between objects is called communication system. In SHEMS the key component is communication system on which system heavily relies upon. Selecting reliable and low power communication system is critical and faces challenges when we want it be breach proof as well as open source.

2.1.1 Wireless Networks: Wireless networks are getting popular day by day and are part of our lives at present [6]. It includes mobile network technology (GSM, GPRS), Bluetooth low Energy, IEEE 802.11(Wifi) and IEEE 802.15(ZigBee). Wifi and ZigBee are popular choices in case of their ranged and multiple user handling capacity. But ZigBee lacks support in order to connect with our daily life devices. So it needs additional devices and software to connect which makes it more complex. While Wifi and Bluetooth low energy are more promising, have no connectivity issues and low power options.

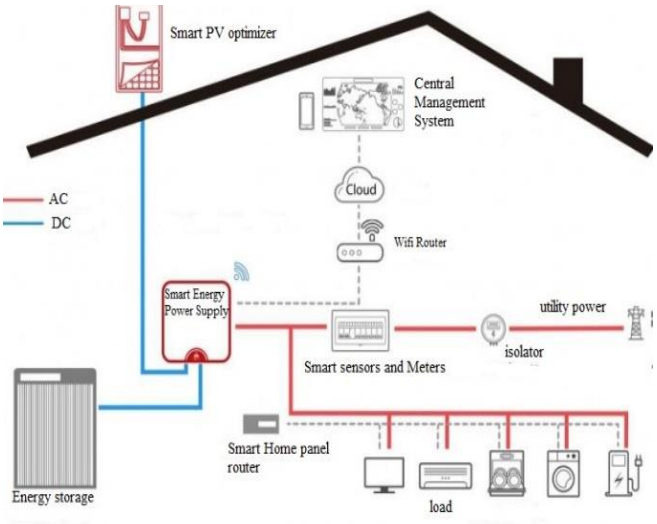

Fig.1. Components of Smart Home [18]

2.1.2 Power Line Communication: PLC is the usage of existing wiring system for the communication purpose. Applications of PLC in SHEMS is still in its early stages. It is used where wireless networks are not available [11]. PLC related issues and future challenges are discussed in [6].

2.2 Central Management System It consists of a central controller which controls the management of energy and data acquisition from sensors and smart meters. It analyzes gathered data through the code containing load balancing and optimization strategies installed in it. Then results are shown on HMI and a recommended solution is suggested on the GUI. Critical situations can be handled by the CMS itself. It also lets consumers to overlook energy generation and consumption in form of monthly and daily reports.

Table 2. List of monitoring devices.

No	Sensors	Objective
1	Temperature	To get temperature of the environment
2	Light	To get light control information
3	Motion	Identifying the presence of some one
4	Camera	To get live or past event access
5	Power	To measure the power flow
6	Pressure	Pressure reading for different purpose
7	Location	Locating different devices and vehicle

2.3 Sensors and Smart meters Sensors are the main interacting devices with the environment which can collect useful physical data. Smart sensors are devices which sense and send the signal for feedback and are connected to the communication system. Most of the smart sensors include multiple functions as well. Smart Home contains the combination of simple and smart sensors network to work properly. Different type of sensors and their objectives are given in Table 2. Smart meters are the programmable electronic devices which can measure, control and display system inputs. It includes measurement, control, communication, power management and display functions.

2.4 Demand Management Information about load of a Smart Home is important in establishing an EMS. Loading of a SHEMS varies over time and according to requirement of the consumer. Improper loading can cause overloading, wastage and loss of energy. There are two ways to manage the demand of a SHEMS which are energy conservation and energy efficiency. Energy conservation include behavior management of the personnel living in the Smart Home. It involve careful use of electricity. This type of management function can also be solved by the smart nature of CMS and this management reappears in another form of overlooking the recommended savings provided by the CMS as Demand Side Management. DSM gives awareness to the consumer to use different loads, at a recommended time suggested by Central Management System by reviewing its power consumption and electricity rate. There are two main strategies of DSM which are Demand response and load shifting [12]. Second way of the management is use of energy efficiency products or appliances. Smart lighting system and daylight harvesting are becoming popular. It is recommended that one should replace 100 watt bulbs by 25 watt energy savers. This comes with the advantage of energy saving as well as cost savings. These energy savers are also available in low power DC energy savers too which are more reliable options. AC and DC low voltage intelligent lighting system with dimming solutions are available and are 87% more energy efficient [l6]. Energy labeled fans are also available in market which consume less power. Integration of renewable energy and energy storage devices are viable and most important energy management option in Pakistan because of

electricity shortage and constant interruptions in the utility power supply. It reduces the load on the utility side and saves the cost as well as energy.

2.5 Power Supply Management Renewable energy generation at Smart Home needs monitoring and proper control for increasing generation and lowering energy cost. Integration of different energy sources adds complexity in EM system. Renewable Energy is intermittent in nature and need proper energy balancing techniques between demand and generation. It helps in making the Smart Home power system stable and sustainable. [8].Smart energy power supply lets the consumer combine renewable energy, Utility supply and generator backup. SEPS is then connected to CMS.

3. IMPORTANT FUNCTIONS

A system having multiple functions to control and monitor human needs is strongly desired. These functions, if combined, result into effective solutions. Combination of monitoring, behavior management and energy efficiency gives maximum energy savings [17]. SHEMS has 4 main functions defined below:

3.1 Monitoring Function Monitoring functions are the functions overlooking the scenery, security and control of Smart Home. These controls include real time and online monitoring of Smart Home.

3.2 Control Function Control functions are main functions controlling the actions of Smart Home. These controls include following techniques:

- load Scheduling/shifting
- Cost control/DSM
- Comfort control

3.3 Analysis Function Analysis function of SHEMS consist of algorithms and different strategies to predict, forecast and optimize the system performance. Good predictive algorithm provide good information and give predictive & preventive measures of failures in advance. It includes:

- Forecasting or prediction
- Optimization techniques
- System Analysis/fault detection

3.4 Advance Function Advance functions are the functions making SHEMS smarter by introducing Artificial Neural Networks. Artificial intelligence is one of the advance function of Smart Home. AI monitoring of health and security measures are future challenges for SHEMS.

4. ARRISING ISSUES

We can control and monitor security of the Smart Home but security of the system is of major concern in case of our connection to the internet. As the system is connected online it can be breached and hacked. So proper steps are need to be taken to isolate the communication from cyber-attacks. The overall system cost is still higher due to less application and not addressing to the customers need. It highly relies on a communication network and cannot work without it. Sometimes wrong information of sensors and recorders are also a problem. Recently Amazon Echo misunderstood the noise to a command and send a personal video to someone else without permission. A variety of security and networking issues are also discussed in [2].

5. CONCLUSION

Demand for electrical energy is continuously being increased by innovating new technologies for our comfort. Our daily life usage of electricity and increased green-house gas emissions need proper management due to environmental concerns and depletion of natural energy resources. Energy Management is necessary to increase generation and decrease operational cost in addition of monitoring quality, sustainability and reliability of the system. SHEMS is a growing research area which is in constant development and better control strategies are being developed. Combination of managing operation, human usage and production efficiency gives maximum energy savings. Infrastructure, complexities and its arising issues need to be addressed soon.

NOMENCLATURE

Abbreviations

SHEMS	Smart Home Energy Management System
EMS	Energy Management System
BEMS	Building energy management system
CMS	Central Management System
ICT	Information and communication technology
PLC	Power Line Communication
SEPS	Smart Energy Power supply
DSM	Demand Side Management
IOT	Internet of things
ANN	Artificial Neural Networks
AC	Alternating Current
DC	Direct Current

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