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Home Energy Management System for Residential Customer: Present Status and Limitation

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Abstract

As environmental pollution has become worse green technologies to replace or reduce consumption of fossil fuel get spotlight from government, industry and academia globally. It is reported that 40% of carbon dioxide emission is caused by electricity power generation. And 37% of end user electricity power is used by residential costumer in US. Smart Grid is considered as one of promising technology to alleviate severe environmental problem. In residential environment, Home Energy Management System (HEMS) can play a key role for green smart home. The HEMS can give several benefits like as lowering electric utility bill, improvement of efficiency of electric power consumption and integration of generator using renewable energy resources. However just limited functions of HEMS can be used for residential customer in real life because of lack of smart function in home appliances and optimal managing software for HEMS. This study provides comprehensive analysis for Home Energy Management System for residential customer. Simple HEMS system with real products on the market are explained and limitation of current HEMS are also discussed.

Keywords: *Smart Grid, Energy Management System, Smart Home, Home Area Network, Greenhouse Gas, Renewable Energy*

1. Introduction

Recently, the problems of energy crisis, global warming and air pollution have been getting worse. Therefore these issues have received spotlight globally by industry, government and academia. These problems have become significantly worse by increasing consumption of fossil fuel in industry and residence sector. The power plant, steel manufacture and transportation sector are one of major consumers of fossil fuel. The greenhouse gases (GHG) is usually emitted by burning of fossil fuel to get energy. It causes global warming and air pollution. To reduce dependency on conventional energy resources especially for fossil fuel, many researches have been conducted. Also international organizations and governments have been trying to reduce the use of fossil fuels to minimize the generation of carbon dioxide (CO_2). It is known that 40% of carbon dioxide emission is produced by generation of electricity power [1]. Also the transport sector has responsibility of around 14% of greenhouse gas emission [2]. The promising technologies for reducing consumption of conventional energy resource and greenhouse gases are generation using renewable energy resources like as solar and wind power.

Renewable energy resources such as solar photovoltaic and wind are considered as promising candidates for replacing conventional power resources. However renewable power resources are hard to generate electric power continuously and meet demand of power loads securely. Therefore these renewable power resources are normally used for auxiliary power generating resources with main power plant using conventional

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resources or increasing efficiency of power system with Energy Management System (EMS), power storage and intelligent application by managing peak load. This can reduce electric power generation with conventional resources which is expensive and cause environmental problem. The renewable power resources such as solar photovoltaic are normally operated by intelligent electric grid system called smart grid.

The smart gird [3,4] is next generation power grid infrastructure to improve reliability and efficiency of power system with help of Information and Communication Technology (ICT), automated control, sensing and energy management technology. The smart grid is considered as a promising candidate technology to combine usage of renewable energy resources to generate electric power with legacy power system. The figure 1. shows simple example of smart grid architecture.

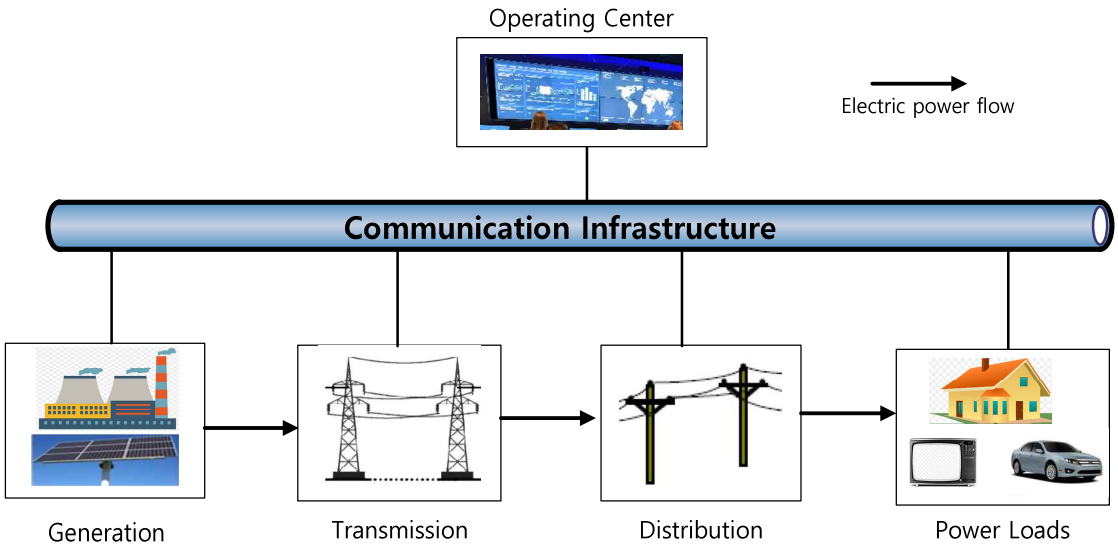

Figure 1. Smart Grid Architecture

As shown figure 1. all components in smart grid are connected with other components using communication infrastructure. The energy management system located in operating center may get information from all components and control power generation to meet demand of power load. However this kind of smart grid infrastructure is not yet available on the market for residential customer. Smart grid infrastructure requires a large amount of power, communication and control facilities. It may take long time and a large amount of manpower for constructing smart grid infrastructure. Also very large budget is essential for constructing facilities and infrastructure to operate power system with smart grid concept. Therefore, until now only a few verification complexes by government or a consortium of major power related companies have been constructed and operated for test and demonstration purpose. The intelligent power system available on the market today is a smart home energy management system.

In this paper we provide comprehensive analysis for Home Energy Management System for residential customer. The remainder of the paper is organized as follows. In the following section background of the Home Energy Management System is described. In section 3 simple HEMS system design with real products on the market is shown and limitation of HEMS is discussed. Section 4 concludes this paper.

2. Technologies for Energy Management System at Smart Home

In Smart Home [5], all appliances or electric devices in the home may be connected with main controller through communication infrastructure. The smart home technology has been researched from 1990s [6].The primary purpose of smart home is to control and manage electric appliance by central or remote unit to improve comport for customer in residential environment. Currently " Green Smart Home Technology" which is aim

to reduce emission of greenhouse gas by managing power consumption in residential house is highlighted. This green smart home technologies have been studied with association with smart grid.

2.1 Smart Home Energy Management System

The Energy Management System in residential environment is a key player of Green Smart Home. This system can integrate all appliances and electric device into one network to communicate with each other through Home Area Network (HAN) [7]. The Home Energy Management System (HEMS) can provide optimization of electric power consumption by sensing, controlling and managing the operation of all home applications. The primary goal of HEMS for home owner is to reduce electric utility bill. From perspective of utility company, the main purpose of HEMS is to minimize power consumption at peak load hour to reduce peak load demand. Also HEMS can support clean green energy resource to generate electric power like as solar photovoltaic and wind turbine [5].

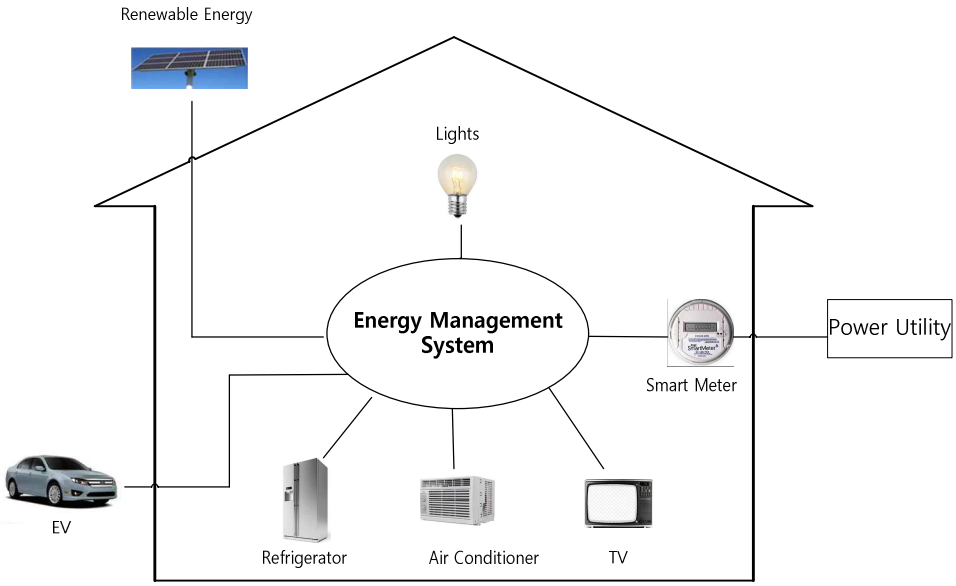

Figure 2. Example of HEMS

In United State, It was reported that the total electricity bill consisted of 20 percent of water heating bills , 41 percent of space heating, 5% for cooling and 31% for other appliance in 2005[5]. Also it is estimated 37% of end user electricity is consumed by residence in US [8]. The HEMS [9,10,11] receives information including Real Time Pricing (RTP) from utility market and status signal including power consumption from all component in home to control Heating, Ventilation and Air Conditioning system (HVAC), home appliances and local generating facilities like as solar photovoltaic unit. The HEMS may supply infrastructure for automatic control, measurement through smart meter and collection of information from all components. The Real Time Pricing is most important factor for residence to alleviate electric utility bill. They can change time for using power load at home from peak time to off peak time for reducing utility cost. EMS can support scheduling of electric consumption to avoid peak time. EMS can manage and schedule electric load by predetermined priorities to meet planned electric consumption by residence for specific time period. Many scheduling EMS algorithms have been proposed and researched [10].

2.2 Configuration and Functionalities of HEMS

2.2.1 Configuration of HEMS

HEMS can be composed of central unit, smart meter, communication system and home appliances. The Energy Storage System can be included at HEMS optionally. Also user interface and display facilities for

operation may be included. The example of configuration of HEMS is shown at figure2. The brief explanations of main components of HEMS are as follows

- Central Unit

  The central unit is core part of HEMS. It receives a lot of information from inside and outside of home through communication infrastructure. The real time price and weather information are from outside of home. Base on received information it can manage HVAC and other appliance. The central unit also provides user interface for displaying the status of system and ordering new task. It also controls and manages renewable energy resource, Energy Storage System and EV facility.

- Smart Meter

  The smart meter receives information of power consumption of power loads in home and communicates with power utility company. The smart meter sends information of power consumption in home to power utility company and get necessary information like as current electricity price. Also it may get data from water meter and gas meters.

- Communication System

  Many wired and wireless technologies can be used for HEMS. Power Line Communication, WIFI and ZigBee technologies are widely used in smart home environment.

- Home appliance

  Home appliance can be classified usually as two part: schedulable and non-schedulable appliance. Refrigerator, TV and computer are considered as non-schedulable appliances. Otherwise Air conditioner, washer & dryer and electric vehicle are considered as schedulable appliances. All appliances in HEMS should have function of communication and process for optimal operation.

The generation with renewable energy resources are promising field for smart home environment. It was reported that utilization of renewable energy resources are increased by 2.0% annually and around half of renewable energy resources are used for residential, commercial and public purpose in 2012 [8]. Due to easy installation and low cost comparing with other renewable resources solar PV are widely used at home solely or in cooperation with HEMS. Electric Vehicle has unique characteristic now. It was considered as just power load however battery of EV is considered as another power source. This concept is called vehicle to Grid (V2G). With help of HEMS EV can supply electric power at peak period to reduce utility bill.

2.2.2 Functionalities of HEMS

The primary purpose of HEMS is to improve power efficiency and reduce power consumption by managing all appliance in home. To fulfill this purpose HEMS should get meaningful information and control effectively all appliances. 5 typical functions of HEMS are described as below [12,13].

- Monitoring

  All appliances are periodically checked and HEMS gives information of status and power consumption of home appliances in real time mode to customer.

- Control

  Customer can control all appliances and whole HEMS system by UI or smart phone at outside of home.

- Management

Management is a key function of HEMS to increase efficiency of power consumption by managing all home appliance, renewable resources and energy storage system.

- Logging

  HEMS receives information of power status from all appliance including power consumption, energy storage state, electric generation by renewable resources. It also receives information like as real time price from central utility company

- Alarm

  All appliance in home are monitored. If an appliance is in abnormal status it will be informed to central unit with alarm.

3. Smart Home Energy Management System

Many researchers have proposed numerous management algorithms for HEMS and tried to implement HEMS in real home environment [10,11]. However almost researches assume that all home appliances are smart loads and home already has infrastructure for smart home. With help of IoT technology major home appliance company such as LG and Samsung introduced smart home appliances like as smart refrigerator and TV to the customer. But theses smart appliances are expensive and almost home appliances do not have function for smart home and HEMS. Many companies have researched and introduced reference design for HEMS. But the power consumption pattern of residence is too diverse to find optimal power management for each home. Also power utility company should participate as member of HEMS but it may take much budget for making infrastructure for HEMS. Therefore products which you can find at the market for energy management for home environment are just smart meter and smart monitoring system now. In this paper we design Home Energy Management System with commercial product on the market for real residential environment.

3.1 Design of HEMS with commercial product.

We assumed all home appliances are not smart loads that do not have function for communication and automation. So we use "Smartplug" for all electric appliances. Smartplug can give monitoring, controlling and automation function. The price of Smartplug varies from 20$ to 100$. The products of smartplug are shown at table.1[14].

Table 1. Smartplug Products

Manufacturer	Product	Function	Price
Belkin	Conserve series	monitoring	30$
PlugWise	Plugwise Home Basic	Monitoring, communication, Control & automation	8 Plugs & SW for 299$
ThinkEco	Energy - saving modlet starter kit	Monitoring, communication, Control & automation	10 Plugs & S/W for 355$
Visible Energy	UFO Power Center	Monitoring, communication, Control & automation	4Plugs & iPhone App. For 99 $

Almost Air conditioner and space heater have own thermostat to control operation. Refrigerator may not need to be controlled by HEMS to keep food fresh. All other appliances are assumed to be connected through smart plug to power grid. Home Area Network technology like as WiFi or Power Line Communication is used for communication among components in home. Figure 3. shows configuration of Home Energy Management System with commercial product.

All home appliances except refrigerator get electric power through smartplug from power grid. This smart plug plays an important role of this HEMS. The smartplugs measure power consumption of home appliance

and send this information to the central unit through home network. Power Line Communication and IEEE wireless communication are considered as promising technologies for smart home environment. Smart Thermostat measures temperature of home and sends this information to the central unit periodically. Smart Motion sensor detects movement in home and send this information to central unit. This is normally used for security purpose or turn on/off the light.

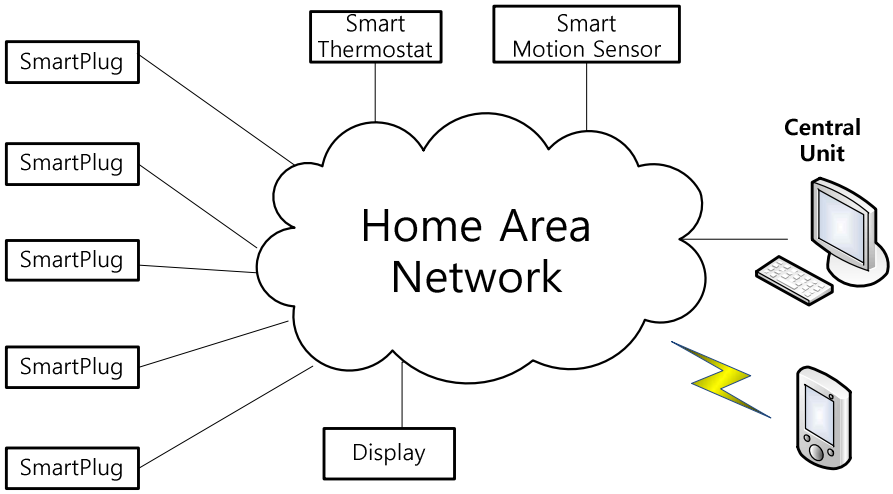

Figure 3. Home Energy Management System

The central unit collects these information periodically and can manage the all appliances in accordance with real time electric price, environmental condition and other factors to reduce electric utility bill. However in the market we can get only home energy monitoring systems that display power consumption of whole house or individual appliances, real time utility cost, status of application and electric generation with solar panel. Several home monitoring systems are described at table 2.[15].

Table 2. Home Energy Monitoring Products

Manufacturer	Product	Function	Price
Sense	Home Energy	Appliance recognition Real time monitoring, Solar available, Mobile APP.	299$
Smappee	Smappee	Appliance recognition Real time monitoring Mobile App.	249$
Neurio	W1	Real time monitoring Energy saving tip Mobile App.	219$
CURB	Home Energy Monitoring System	Real time monitoring and control Solar available, Mobile App.	399.99$

The function of showing real time power consumption in HEMS is considered as most attractive and beneficial part of home energy management system [16]. Though HEMS does not provide sophisticated management for home appliances it was reported that 7.8% of electric consumption in home was reduced with help of just function of monitoring power consumption [16]. The HEMS can show power consumption of all

appliances so it may reduce power consumption by unnecessary electric appliances and standby power in residential environment. Utility rate plan for residential customer is also limited. The Georgia Power [17] which is one of largest electric generator of US provides 6 rate plans: Smart Usage, Flat Bill , Plug in EV, Nights & Weekends, PrePay and Standard service. Normally residential customer uses standard service. With this plan price for electricity is 5.7cents per a kWh for first 650 kWh , 9.4 cents for 650 ~ 1,00 kWh and 9.7 cents for over 1,000 kWh at summer time. Residential customers who choose "Smart Usage" plan can reduce utility bill to minimize power consumption at peak time. The price for electricity is 9.6052 cent per a kWh at peak time and 4.9409 cents per a kWh for other time. The HEMS can be helpful for manage home appliances to lower electricity bill with several rate plan. However it is almost unavailable to buy electric power at real time price for residential customer currently.

4. Conclusion

It is known that 37% of end user electricity is consumed by residential costumer in US and electric consumption by residential customer is increased continuously. Currently, most electric power generation uses fossil fuels and the combustion of fossil fuels causes serious air pollution. Therefore renewable energy resources are highlighted as clean green energy resources for reducing usage of fossil fuel. To alleviate environmental problem smart home energy management system is considered as promising technology now. The purpose of HEMS for residential customer is to minimize utility bill with reduction of electric consumption and efficient consumption of electricity. To achieve this goal many researches have been conducted. However these researches are assumed that all home appliances are smart load. Also it is hard to developed optimal algorithm to satisfy all customer because the pattern of power consumption is really diverse. This paper provides comprehensive review of Home Energy Management System and discusses current status of it. We designed simple HEMS using only commercial products which are available on the market. The HEMS products on the market are introduced and utility rate plans for residential customer are also discussed.

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