International Journal of Enhanced Research in Educational Development, ISSN: 2320-8708
Vol. 1 Issue 4, May-June, 2013, pp: (59-64), Available online at: www.erpublications.com

A Review of Smart Home for Smart Grid

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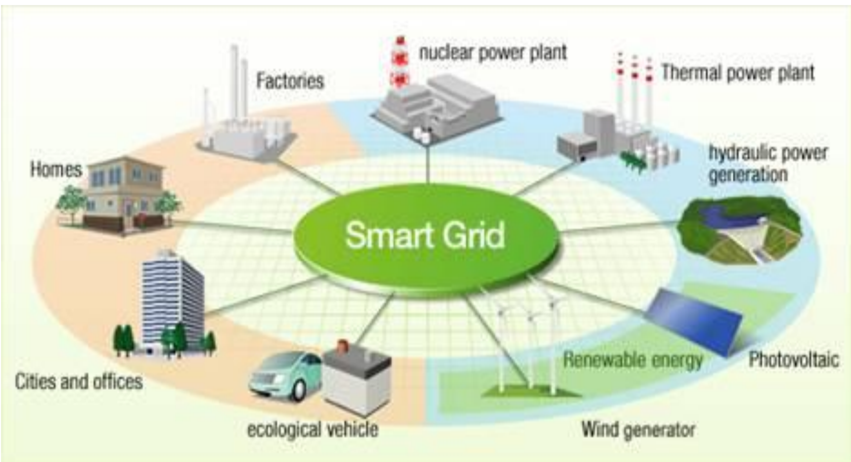
Abstract: This paper presents a smart home computing platform architecture that extends smart home network to be compatible for smart grid integration. The proposed hardware architecture along with a tailored software algorithm empowers utility companies and homeowners to communicate bidirectionally with home appliances via a public mobile network to monitor and manage power consumption of home appliances. The platform also enables homeowners to operate, monitor and control their home appliances locally via a control panel and remotely via their mobile phones. A smart home is an application of ubiquitous computing in which the home environment is monitored by ambient intelligence to provide context-aware services and facilitate remote home control. This paper presents an overview of previous smart home research as well as the associated technologies. A brief discussion on the building blocks of smart homes and their interrelationships is presented. It describes collective information about sensors, multimedia devices, communication protocols, and systems, which are widely used in smart home implementation. Special algorithms from different fields and their significance are explained according to their scope of use in smart homes. This paper also presents a concrete guideline for future researchers to follow in developing a practical and sustainable smart home.

Index Terms: Healthcare, home automation, pervasive computing, smart homes, telemedicine, ubiquitous computing.

Introduction:

Smart homes constitute a branch of ubiquitous computing that involves incorporating smartness into dwellings for comfort, healthcare, safety, security, and energy conservation. Remote monitoring systems are common components of smart homes, which use telecommunication and web technologies to provide remote home control and support patients remotely from specialized assistance centers. Smart homes offer a better quality of life by introducing automated appliance control and assistive services. They optimize user comfort by using context awareness and predefined constraints based on the conditions of the home environment. A user can control home appliances and devices remotely, which enables him or her to execute tasks before arriving home. Ambient intelligence systems, which monitor smart homes, sometimes optimize the household's electricity usage. Smart homes enhance traditional security and safety mechanisms by using intelligent monitoring and access control. By 2050, approximately 20% of the world's population will be at least 60 years old . This age group will face problems with living independently and is more likely to suffer from long-term chronic diseases. According to the World Health Organization, 650 million people live with disabilities around the world.Smart homes require energy management system (EMS) for utilizing renewable and stored energy sources. Energy efficiency can be improved by automating the connection between energy sources and loads.



The Smart Home:

How will the Smart Grid affect your home? It won't look very different, but behind the scenes a lot will be happening. Even right now, in many cities across the nation, new equipment, appliances, and software are available that use emerging Smart Grid technologies to save energy, seek out the lowest rates, and contribute to the smooth and efficient functioning of our electric grid. A key element that allows all of the emerging Smart Grid technologies to function together is the interactive relationship between the grid operators, utilities, and you. Computerized controls in your home and appliances can be set up to respond to signals from your energy provider to minimize their energy use at times when the power grid is under stress from high demand, or even to shift some of their power use to times when power is available at a lower cost.

Smart Meters and Home Energy Management Systems:

Smart meters provide the Smart Grid interface between you and your energy provider. Installed in place of your old, mechanical meter, these meters operate digitally, and allow for automated and complex transfers of information between your home and your energy provider. For instance, smart meters will deliver signals from your energy provider that can help you cut your energy costs. Smart meters also provide utilities with greater information about how much electricity is being used throughout their service areas. This energy information coming to and from your home through your smart meter can be run through a home energy management System (EMS), which will allow you to view it in an easy-to-understand format on your computer or hand-held device. A home EMS allows you to track your energy use in detail to better save energy.

For instance, you can see the energy impact of various appliances and electronic products simply by monitoring your EMS while switching the devices on and off. An EMS also allows you to monitor real-time information and price signals from your utility and create settings to automatically use power when prices are lowest. You can also choose settings that allow specific appliances and equipment to turn off automatically when a large demand threatens to cause an outage—avoiding peak demand rates, helping to balance the energy load in your area, and preventing blackouts. Your utility may provide financial incentives for doing so.

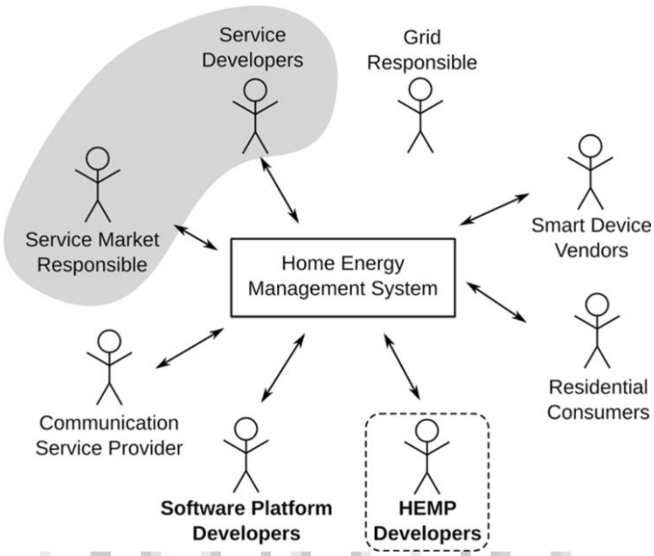
Smart Appliances:

In your smart home, many of your appliances will be networked together, allowing you to access and operate them through your EMS. An EMS provides the ability to turn on your heater or air conditioner from work when you're about to go home or keep track of the energy use of specific appliances or equipment—like tracking the energy use of your pool pump, or seeing how much energy you saved with your new Energy Star dishwasher. Smart appliances will also be able to respond to signals from your energy provider to avoid using energy during times of peak demand. This is more complicated than a simple on and off switch. For instance, a smart air conditioner might extend its cycle time slightly to reduce its load on the grid; while not noticeable to you, millions of air conditioners acting the same way could significantly reduce the load on the power grid. Likewise, a smart refrigerator could defer its defrost cycle until off-peak hours, or a smart dishwasher might defer running until off-peak hours.

Of course, these smart appliances will include consumer controls to override the automated controls when needed. If you need to run your dishwasher right away, regardless of the cost of power, you'll be able to do so. One unique type of smart "appliance" is the plug-in electric vehicle, or PEV. See the PEV Section for information on how PEVs will interact with the Smart Grid.

Home Power Generation:

As consumers move toward home energy generation systems, the interactive capacity of the Smart Grid will become more and more important. Rooftop solar electric systems and small wind turbines are now widely available, and people in rural areas may even consider installing a small hydropower System on a nearby stream. Companies are also starting to roll out home fuel cell systems, which produce heat and power from natural gas.The Smart Grid, with its System of controls and smart meters, will help to effectively connect all these mini-power generating systems to the grid, to provide data about their operation to utilities and owners, and to know what surplus energy is feeding back into the grid versus being used on site. A potential feature of the Smart Grid will be to allow your community to use your solar array—and your neighbor's—to keep the lights on even when there is no power coming from a utility. Called "islanding," it will allow a home to grab power from "distributed resources," such as local rooftop solar, small hydropower, and wind projects, until utility workers can bring the grid back online.



There are many definitions for Smart Grid. However, most agreed that a smart grid consists of three layers namely Automatic Meter Reading (AMR) layer, an Advanced Metering Infrastructure (AMI) layer and AMI compatibility (AMI+) layer. The AMR layer is responsible for real-time power consumption measurement. The AMI layer is responsible for consumer outage detection, remote turn ON/OFF, hourly remote meter readings and rate programming. The AMI+ refers to the system that collects, monitors, controls, analyzes and optimizes the energy usage through various communication media either on-demand or on pre-defined schedules as well as integrating alternative energy resources. At the AMR layer, smart home controllers and power consumption automatic meters are not new concepts. Many smart home controllers' architectures have been reported in the literature. Design and implementation of a simple object access protocol based residential management for smart home system was described in paper. Others used Zigbee or Bluetooth for local controllers and the World Wide Web for remote access . Moreover, several energy AMR systems have been reported. Liu et al. proposed AMR as a mean to estimate daily workflow, workforce management, asset management, call center philosophy, and others reported automating billing systems . For example, an automatic billing system that can read power consumption, generate automatic bills and detect outages was designed and tested.

Future homes will be able to offer almost all required services, e.g., communication, medical, energy, utility, entertainment, and security. People spend a significant amount of time in their houses, which attracts potential investors to promote the integration of all possible services into traditional homes. Current trends in smart home research imply that healthcare services will receive more emphasis in the future. One of the main objectives will be providing assistive services for the elderly and disabled. Remote patient monitoring will become more popular because providing healthcare services to certain groups of patients requires less manpower. Other services related to comfort and security will be improved gradually with the improvement of associated components. Recently, a new research area regarding the intelligent control of electricity usage has emerged. This new branch of study is called smart grid research [78]. A smart grid is an intelligent electricity network that provides bidirectional communication between electricity suppliers and consumers. Similar to the smart grid concept, there is the possibility of more new service networks emerging that will connect homes to share information. These networks will act as a platform for local authorities and utility providers to gain easy access to every home for service delivery and payment transactions. From the home owner's perspective, a networked home provides emergency telemedicine service, natural disaster assistance, time sensitive information delivery from law enforcement department, and social support from local government.

Energy Management:

Energy management is a broader term, which applies differently in different scenarios, but we are concerned about the one which is related with energy saving in homes, public sector/ government organizations or business. In this scenario the process of monitoring, controlling and conserving energy in an organization/ building may be termed as energy management. In smart grid where the consumers can generate local energy from several distributive generation units and where there is a plenty of space for different pricing schemes, the need for energy management programs has been pointed out by many researchers.

Demand side management can contribute in reduced emissions, reliable supply of power and lowering the energy cost. Current grid has demand side management programs for consumers like commercial buildings and industrial plants; however it does not have any such scheme for domestic consumers due to the reasons of lack of effective communication, efficient automation tools and sensors. Secondly implementation costs of various demand response programs are higher when compared with its impact. However in smart grid, smart loads, low cost sensors, smart meters and the information and communication technology open a window for domestic energy management programs .

Optimization Based Residential Energy Management (OREM):

Optimization based residential energy management (OREM) has been proposed by authors in . The objective function given in manages the energy consumption by scheduling home appliances in suitable timeslots. Scheduling an appliance in an appropriate timeslot may bring a non acceptable amount of delay to the appliance cycle and an exploded load in the low price timeslots.

iHEM:

iHEM application manages the home energy by shifting the load form peak to off-peak periods i.e. reduces peak load demand. When a consumer turns on an appliance a data packet is sent to the EMU. EMU then communicates with smart meter and local generation units to know about the price information from utility and the available local energy respectively. Based on these information, EMU schedules the starting time of the appliance. Waiting time of the appliance is calculated as the difference between the suggested time by EMU and request start time. The consumer requests have been modeled as a Poisson process.

Decision Support Tool (DsT):

Decision Support Tool (DsT) has the primary aim to help users in making intelligent decisions during their appliance operation. Advantages of energy management program may be increased if besides appliance coordination there is distributed energy resources (DER) coordination too in parallel. The concept of DER coordination has been evaluated. The work has used an enhanced PSO solver i.e. CPSO-R, to quantify value added by the DER coordination. Coordination value has been calculated first for the case when each DER is scheduled independently and then for the case when the DER cooperates with each other.

Optimal and Automatic Residential Energy Consumption Scheduler:

The optimization based residential load control scheme discussed is based on simple linear programming computations. The scheme is proposed for real time pricing which needs a price predictor. The combination of price predictor and energy consumption scheduling (ECS) design significantly lowers the peak to average ratio (PAR) in load demand for different load scenarios.

Optimum Load Management (OLM) Strategy:

In an optimization based residential load management strategy has been proposed. The optimization problem needs several interests forecasting and activity scheduling by users to form an objective function. Various interests are local power production i.e. from solar, wind etc, load, and electricity prices for next day.

Monetary Cost Minimization :

Different pricing schemes may be employed for energy billing purposes by utilities like time of use (ToU) pricing scheme, real time pricing (RTP), day ahead pricing (DAP), critical peak pricing (CPP) etc. In ToU scheme, consumer is charged more during peak periods, less during mid-peak and the least during off-peak.Base plants provide power to base loads. During peak periods as the consumer demand goes higher the utilities switch on their peaker plants to maintain load-supply balance, which generate power at a comparatively high cost and with production of high amount of green house gases (GHG). The ultimate result is increase in price of electricity and global environmental problems. Smart grid gives opportunity to the consumers to generate local power from distributed energy resources(DER) e.g. solar, wind mill, use it locally and sell back the extra power to utility.Monetary cost minimization can be acheived by applying demand side management schemes. The energy management algorithms can shift load from peak periods to off-peak and hence reduce the cost and emission of GHG. Previous work shows that the objective can also be achieved by scheduling the distributed energy resources i.e. scheduling the DER by optimizing an objective function. In subsections below few of energy management schemes are presented.

iHEM Application:

iHEM, an energy management scheme is presented for domestic energy management. The scheme uses smart appliances, a central energy management unit (EMU) and wireless sensor home area networks (WSHAN) for communication purposes among appliances, EMU and smart meters. iHEM uses Zigbee protocol for the implementation of wireless sensor network, organized in cluster-tree topology. The application is based on appliance coordination system (ACS). Unlike the OREM the consumer demands are processed in near real time in iHEM. The consumer may turn on any appliance at any moment on the clock irrespective of the peak hours concern and iHEM suggest a convenient start time to the consumer. On switching the appliance on, a START-REQ packet is sent by the appliance to the EMU. Upon receiving the START-REQ packet, EMU communicates with the storage system to inquire about the available stored energy by sending AVAIL-REQ packet.EMU also communicates with smart meter to know about the updated prices. The storage unit sends an AVAIL-REP packet in reply, containing the information about the amount of stored energy. When EMU receives the AVAIL-REP packet, it schedules a convenient start time for the appliance according to the iHEM algorithm and notifies it to consumer by sending a START-REP packet.

Residential Load Control (RLC):

An optimal and automatic residential energy consumption scheduler has been proposed for a scenario where real time pricing (RTP) is combined with inclining block rates (IBR). Load control programs for real time pricing needs a price predictor hence the scheduler is combined with a price predictor shown in fig.5. The simulation results show that this combination reduces the consumer â€™s payments by 10-25%.

Optimum Load Management (OLM):

Using the communication infrastructure of the future smart, this paper proposed an optimal load management strategy for real time pricing. By adopting this strategy, consumers can bring a balance between their energy bills and economical situations. The primary purpose of this strategy is to reduce the energy consumption cost of the consumers.

Conclusion:

On a conclusion note, this paper has revisited the need for domestic energy management for efficient consumption of electricity in smart grid. Consuming electrical energy efficiently results in reducing peak load, lowering electricity bills and minimizing the emission of green house gases (GHG). In smart grid where there is bidirectional communication and better home automation, effective home energy management system can be designed. This paper has discussed several home energy management schemes where different pricing schemes have been applied to get economical and social advantages. Both communication-based and optimization-based home energy management techniques have been evaluated. We have also discussed some communication and networking technologies for future smart grid that can play a key role in smart energy usage systems in future smart grids. We are of the hope that this work will channelize the efforts towards a more efficient, user friendly home energy management system for future smart grids. 5. Conclusion On a conclusion note, this paper has revisited the need for domestic energy management for efficient consumption of electricity in smart grid. Consuming electrical energy efficiently results in reducing peak load, lowering electricity bills and minimizing the emission of green house gases (GHG). In smart grid where there is bidirectional communication and better home automation, effective home energy management system can be designed. This paper has discussed several home energy management schemes where different pricing schemes have been applied to get economical and social advantages. Both communication-based and optimization-based home energy management techniques have been evaluated. We have also discussed some communication and networking technologies for future smart grid that can play a key role in smart energy usage systems in future smart grids. We are of the hope that this work will channelize the efforts towards a more efficient, user friendly home energy management system for future smart grids.

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