ISSN 2229-5518

The Smart Home: Renewable Energy Management System for Smart Grid Based On ISM Band Communications

Ms. S. Mathavi, Mrs. D. Vanitha, Mrs. S. Jeyanthi, Mr. P.Senthil kumaran

Abstract—Increasing complexity of power grids, growing demand, and requirement for greater reliability, security and efficiency as well as environmental and energy sustainability concern continue to high light then need for a quantum leap in harnessing communication and information technologies. This leap toward a "smarter" grid is widely referred to as "smart grid". A smart grid can help us reach the goal of clean air and energy independence by utilizing renewable power such as wind and solar energy. In earlier a real time, massive, online, multi-time frame simulation is proposed as a means for building a common vision of smart grid functions. A massive simulation will include hundreds of participants that play roles of reliability coordinators, transmission operators, distribution operators, power plant operators, and substation operators. In this paper critically reviews the reliability impacts of major smart grid resources such as renewable, demand response and storage. A Smart Meter is designed via ISM band communication to develop a smart grid. These highly visible drills can demonstrate how the new smart grid systems, people, and processes can all work together economically and reliably. We can get low cost, safe, and easily configurable simulations instead of waiting for expensive and hard wired deployments.

Index Terms—Embedded System, HEMS, ISM Band, Solar Panel, Substation, Smart meter, Microcontroller

---

1 INTRODUCTION

1.1. What is Smart Grid?

The Smart Grid is a combination of hardware, management and reporting software, built atop an intelligent communications infrastructure. In the world of the Smart Grid, consumers and utility companies alike have tools to manage, monitor and respond to energy issues [1]. The flow of electricity from utility to consumer becomes a two-way conversation, saving consumers money, energy, delivering more transparency in terms of end-user use, and reducing carbon emissions. Modernization of the electricity delivery system so that it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices. The Smart Grid in large, sits at the intersection of Energy, IT and Telecommunication Technologies.

- *S.Mathavi is currently pursuing master degree program in Applied Electronics Anna University Trichy. E-mail: mathavi.2007@gmail.com*
- *D.Vanitha Asst.Prof master degree program in Applied Electronics Jayaram College of Engg & Tech, Anna university Trichy.. E-mail: vanitha_nevi@yahoo.com*
- *S.Jeyanthi Asst.prof master degree program in Computer Science Anna university Chennai E-mail: sk.jeyai@yahoo.com*
- *P.Senthil kumaran Asst.Prof is currently pursuing master degree program in VLSI Design RVS College of Engg & Tech, Anna university of technology Madurai E-mail: senthiladh@yahoo.co.in.com*

1.2 Pillars of Smart Grid

- Transmission Optimization
- Demand Side Management
- Distribution Optimization
- Asset Optimization

1.3 Demand Optimization

- Demand Response – Utility
- Demand Response – Consumer
- Demand Response Management System
- In Home Technology enabling

1.4 Why Smart Grid?

- Integrate isolated technologies: Smart Grid enables better energy management.
- Proactive management of electrical network during emergency situations.
- Better demand supply / demand response management.
- Better power quality
- Reduce carbon emissions.
- Increasing demand for energy : requires more complex and critical solution with better energy management

1.5 Smart Grid Function

The term "smart grid" can cover a wide variety of technologies and functions ranging from home automation systems to interconnection-wide pharos monitoring systems [1][2]. The emphasis of this paper is on development of smart grid functions that require integrated control of generation, transmission, distribution, and customer premises. The future smart grid must accommodate larger penetrations of intermittent wind and solar energy sources both centralized and distributed. It must also accommodate rapid demand growth due to plug-in electric vehicles and learn how to make optimal use of their inherent storage capacity. Self-healing grids can adapt to any level of multiple contingencies due to acts of nature, acts of terror, equipment failures or operator error. They can gracefully degrade by shedding the lowest priority loads first and leaving on all critical loads without interruption. Smart islanding will be implemented at both transmission and distribution levels. At the transmission level, islands will be formed to limit the propagation of generation load imbalances. At the distribution level local generation will continue to provide power even when power from the utility is absent. Combining distributed resources of every description—rooftop PV solar, fuel cells, electric vehicles—the community can generate sufficient electricity to keep the most critical loads up and running. Maximal flow grids are designed to efficiently move remote generation to local loads. In a maximal flow grid the transmission path flows will be maximized. The transmission transfer limits will be determined primarily by the real-time thermal and voltage stability limits. Contingency-based thermal, voltage, and transient stability limits will be mitigated using direct load and storage controls. Tapping the potential to directly manage appliances on millions of customer premises will be the silver bullet that makes many smart grid applications feasible. A large proportion of customer loads including air conditioners, water heaters, freezers, and refrigerators have thermal inertia. They can all be interrupted for 15 min to 1 h without any inconvenience for customers. The smart grid will require improved interfaces and analytical methods, to support operator decision-making. System operators will play an even more vital role as they supervise more sophisticated control systems that actively manage systems with tighter transmission and generation reserve margins.

1.6 The Smart Grid as an Economic Development Tool

The smart grid is a transformative set of technologies and business models. With mutually supportive private and public investment and with governmental policies that accommodate entrepreneurial smart grid innovations, we can grow our economy, create new high-paying jobs, and help protect our environment. The convergence of these diverse benefits represents an unparalleled opportunity for policy makers to advance an agenda based on research and development, on innovation, and on economic development. Through continued advancement of the Illinois Smart Grid Regional Innovation Cluster, the state is positioned to be a leader in the development and deployment of smart grid enabling strategies, services and technologies.

2 ENERGY MANAGEMENT SYSTEMS

Existing energy management systems have been designed around the concept that the power system can operate in one of four states [4]. In the normal secure state all equipment is operating within limits and no single or probable double contingencies will cause real-time operating limit violations. In the normal insecure state, all equipment is operating within real-time limits but one or more single or probable double contingencies will cause operating limit violations. In the emergency state some equipment is operating outside of its real-time operating limits. The restorative state occurs when there has been a major outage of generation, transmission, and customer load. The restorative state may be entered as a result of contingencies that cause loss of customer load or as a result of deliberate control actions to shed load and/or generation in a portion of the system. Control actions in the restorative state should be designed to transition the system back to the normal state but could inadvertently transition the system to an emergency state. EMS applications focus on providing operator decision making tools for the normal secure and normal insecure states.

There are few real-time tools that have been designed to support operator decision making in the emergency and restorative states. There are also few tools that can prepare the system or operator to handle extreme contingencies. Energy management systems have evolved slowly over the last twenty five years. The core specifications for functions such as SCADA, alarming, state estimator, and contingency analysis have not changed significantly. These functions now run on much lower cost computers and use higher resolution displays for showing system maps and station diagrams. Many application codes written in the early 1980s are still running today[3].The rate of evolution of energy management systems has to accelerate if smart transmission grids are to be deployed by 2020.

2.1 The Role of Simulators

Massive, real-time, multi–time frame, open architecture simulators can accelerate the development and implementation of smart grids. Building a smart self healing grid requires continuing education and creation of a common vision and goals for players at all levels including politicians, regulators, executives, managers, engineers, operators, linemen, and technicians. Highly visible massive real-time simulations of the major U.S. interconnections with hundreds of participants can demonstrate how new smart grid systems, people, and processes can all work together to benefit system reliability and economy. The industry and especially smart grid system developers can get feedback from all parties through low cost, safe, and easily configurable simulations instead of waiting for expensive and hardwired deployments. As an example, these massive real-time simulations will more clearly demonstrate how fast wide area control of loads on customer premises can be used to prevent cascading outages by enhancing rotor angle, voltage, frequency, and thermal stability. Smart grid home automation suppliers would then be incented to build in faster load controls.

2.2. Cost saving theme

At the moment KPX does not provide exact billing information to its customers, so HEMS type of system is not supported. However, the situation should be changing with the Smart Grid technology. Smart Grid is a system that can integrate environmental friendly energy sources into conventional power grid. Other important feature is the city level load balancing, using different power plants based on the current power consumption.

To be able to balance loads, Smart Grid requires online power consumption information from the houses. In return, the smart grid provides house-level functions in form of the smart meter. Smart meter should provide up-to-date information to the user, so monitoring energy consumption in the house is possible online. Therefore it is very likely that the customer can track the energy costs in the future as well.

2.3. Energy saving theme

Statistical data presented in the following tables show that currently the users do not care about how much an appliance is consuming. In Table 1, the appliances' energy consumption (kWh) is presented on the left side. It can be seen that in many cases, especially in case of an air conditioner, the energy consumption is not regarded as a problem. This means that the user understands the inefficiency of the appliance but is still using it.

In Table 2, the amount of days an appliance is used in a year is presented. As it can be seen, the consumption of the device is not a factor when deciding if the device is used or not.

Table 1

Yearly Consumption of Different Appliances with Different Power Consumptions (3500 Hours)

kWh	Electronic Fan	Air conditioner	Humidifier	Electric blanker	Electric heater
100 below	34.751	349.532	43.731	97.722	199.139
101-150	35.760	396.792	47.465	98.283	208.568
151-200	35.264	433.944	50.146	105.094	216.240
201-250	35.670	457.032	53.874	103.230	212.440
250-350	36.462	467.830	52.767	104.152	216.177
351 upper	38.003	492.279	55.628	109.045	218.640

Table 2

Time Average Number of Usage Days per Appliance in a Year (500house)

kWh	Electronic Fan	Air conditioner	Humidifier	Electric blanker	Electric heater
100 below	99	53	98	98	85
101-150	98	53	94	94	88
151-200	95	56	93	96	101
201-250	98	67	98	111	98
250-350	98	64	98	114	94
351 upper	102	65	99	124	104

3 HOME ENERGY MANAGEMENT SYSTEMS

A home energy management system (HEMS) providing the alternative energy sources, smart houses would be equipped with a solar power generator and a windmill power generator. Also intelligent appliances are controlled by power line communication, and a smart meter. Every 15 minutes the smart meter would provide reports on power consumption through an energy service portal (ESP)via a broadband Internet connection and that information would be available online through a Web interface[3]. The HEMS relies on the power consumption history to control appliances.

Our home network model is based on three basic network entities: (1) Devices, (2) Networks and (3) Services. Each of them contains some information or working concepts, which restrict interaction between other entities or enable functionality between them. These three basic entities can be further defined is as follows:

1. Device: Device is an entity that can contain services or functions. These services and functions can be accessed device, the device can also activate other device's services/functions. Each device should have at least one network. The basic operation of a device is to be controlled or monitored.

2. Network: Network has own specific properties such as Address, QoS and some configuration information. Network represents a path from device to device.

3. Service: Service is a process that contains the service logic. The service logic executes different device functions and services, and monitors their states. Service logic handles the

relationship with the device and the network, as well as the relationship between the devices it interacts with.

3.1 General Block Diagram of Smart Meter

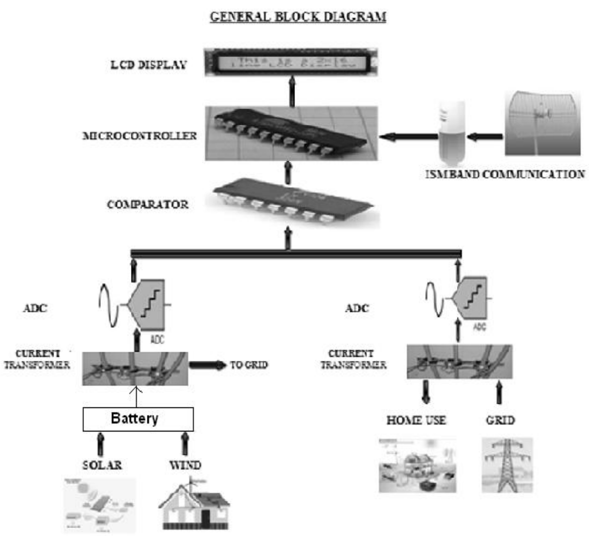


Fig.1 Block Diagram of Smart Meter

3.2 Smart Meter

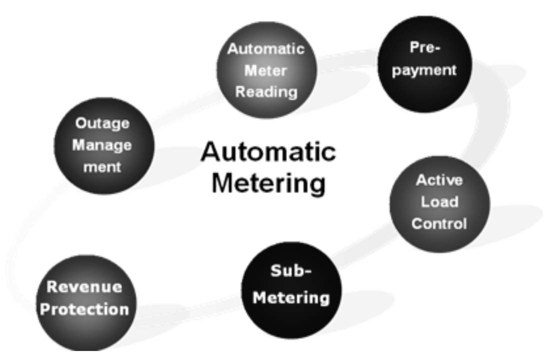


Fig.2 Automatic Metering

3.3 Smart Meter Benefits

Fig.3 Automatic Metering benefits

3.3 HEMS

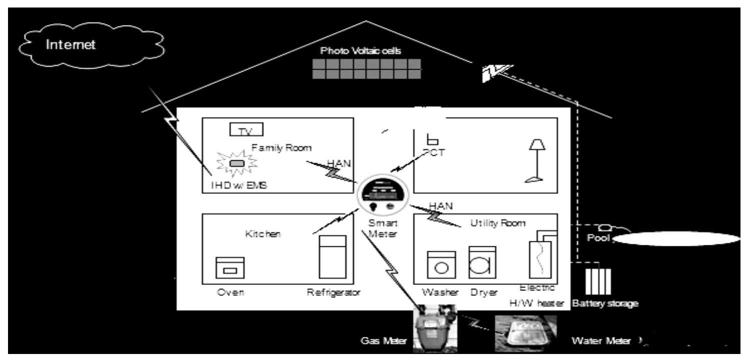


Fig.4 Energy Distribution in HEMS

4 KEY FUNCTIONALITIES OF ENERGY MANAGEMENT

Energy management consists of a group of functions that facilitate remote monitoring, controlling, planning and repairing of operations and provide information on the status of installed devices and the network. The HEMS has the following four functions:

- Auto-configuration: auto-configuration is the most important function for customers of home network services because many homes have a wrong configuration.
- Easy monitoring: comfort and easy access to real-time information on energy consumption help the user pay attention to energy saving.
- Remote controlling: online access to a customer's usage pattern and device status enables appliances to be controlled remotely.
- Smart planning: automatic peak load management provides smart planning for reducing energy consumption.

5 DEMAND RESPONSE

5.1 Load Management / Demand response

Load management involves reduction of load in response to emergency and/or high-price conditions. Such conditions are more prevalent during peak load or congested operation. Reduction initiated by the consumer is usually referred to as demand response. Nonemergency demand response in the range of 5% to 15% of peak load can provide substantial benefits in reducing the need for additional resources and lowering real-time prices[3]. Demand response does not substantially change the total energy consumption since a large fraction of the energy saved during load curtailment is consumed at a more opportune time—thus a flatter load profile. Load rejection as an emergency resource to protect the grid is well understood and is implemented to operate either by system operator command or through under frequency and/or under voltage relays. In a smart grid, this can be enhanced to allow more intelligence and wider customer participation. Price-based demand response as a system resource to balance demand and supply has not been widely adopted yet. Contract-based participation has been typically below 5% (with MISO below 8%) of peak load. In a smart grid, real-time prices enable wider voluntary participation by consumers through either automatic or manual response to price signals, or through a bidding process based on direct communication between the consumer and the market/system operator or through aggregators and/or local utilities. In addition to capability to flatten the load profile, demand response can serve as an ancillary resource to help reliability.

6 PARTS OF SMART METER

- Current Transformer
- Digital Converter
- Comparator
- 8051 Micro Controller
- ISM
- LCD Display

6.1 Current Transformer

In electrical engineering, a current transformer (CT) is used for measurement of electric currents. Current transformers, together with voltage transformers (VT) (potential transformers (PT)), are known as instrument transformers. When current in a circuit is too high to directly apply to measuring instruments, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can be conveniently connected to measuring and recording instruments. A current transformer also isolates the measuring instruments from what may be very high voltage in the monitored circuit. Current transformers are commonly used in metering and protective relays in the electrical power industry.

Usage

Current transformers are used extensively for measuring current and monitoring the operation of the power grid. Along with voltage leads, revenue-grade CTs drive the electrical utility's watt-hour meter on virtually every building with three-phase service and single-phase services greater than 200 amp.

The CT is typically described by its current ratio from primary to secondary. Often, multiple CTs are installed as a "stack" for various uses. For example, protection devices and revenue metering may use separate CTs to provide isolation between metering and protection circuits, and allows current transformers with different characteristics (accuracy, overload performance) to be used for the devices.

6.2 A-D Converter

Normally analogue-to-digital converter (ADC) needs interfacing through a microprocessor to convert analogue data into digital format. This requires hardware and necessary software, resulting in increased complexity and hence the total cost.

An analog-to-digital converter (abbreviated ADC, A/D or A to D) is a device that converts a continuous quantity to a discrete time digital representation. An ADC may also provide an isolated measurement. The reverse operation is performed by a digital-to-analog converter (DAC).

Table 3

Sample Ratings

Voltage levels [V]	Binary representation
0-0.62	000
0.621-1.25	001
1.251-1.87	010
1.871-2.5	011
2.51-3.12	100
3.121-3.75	101
3.751-4.37	110
4.371-5.00	111

6.3 Comparator

LM324

The LM324 contains four independent high gain operational amplifiers with internal frequency compensation. The four op-amps operate over a wide voltage range from a single power supply. Also use a split power supply. The device has low power supply current drain, regardless of the power supply voltage. The low power drain also makes the LM324 a good choice for battery operation.

ATmel 89C51 PIN DIAGRAM

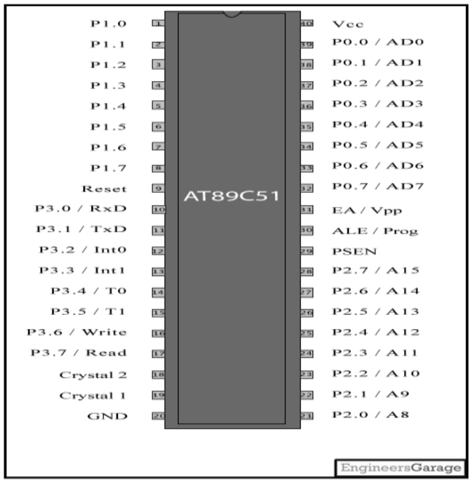


Fig.5 Pin Diagram

6.4 Microcontroller

AT89C51 is an 8-bit microcontroller and belongs to Atmel's 8051 family. AT89C51 as 4KB of Flash programmable and erasable read only memory (PEROM) and 128 bytes of RAM. It can be erased and program to a maximum of 1000 times. In 40 pin AT89C51, there are four ports designated as P1, P2, P3 and P0.All these ports are 8-bit bi-directional ports, i.e., they can be used as both input and output ports. Except P0 which needs external pull-ups, rest of the ports have internal pull-ups.When 1s are written to these port pins, they are pulled high by the internal pull-ups and can be used as inputs.These ports are also bit addressable and so their bits can also be accessed individually. Port P0 and P2 are also used to provide low byte and high byte addresses, respectively, when connected to an external memory. Port 3 has multiplexed pins for special functions like serial communications, hardware interrupts, timer inputs and read/write operation from external memory.AT89C51 has an inbuilt UART for serial communication. It can be programmed to operate at different baud rates. Including two timers & hardware interrupts, it has a total of six interrupts

ATmel 89C51 Technical Description

- 4K Bytes of In-System Reprogrammable Flash Memory
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM 32
- Programmable I/O LinesSS
- Two 16-bit Timer/Counters
- Six Interrupt Sources Programmable Serial Channel
- Low-power Idle and Power-down Modes 40-pin DIP

6.5 ISM Band Communication

History

Radio frequencies in the ISM bands have been used for communication purposes, although such devices may experience interference from non-communication sources. In the United States, as early as 1958 Class D Citizen's Band was allocated adjacent to an ISM frequency. In the US, the FCC first made unlicensed spread spectrum available in the ISM bands in rules adopted on May 9, 1985. Many other countries later adapted these FCC regulations, enabling use of this technology in all major countries.[citation needed] The FCC action was proposed by Michael Marcus of the FCC staff in 1980 and the subsequent regulatory action took 5 more years. It was part of a broader proposal to allow civil use of spread spectrum technology and was opposed at the time by mainstream equipment manufacturers and many radio system operators.

Uses

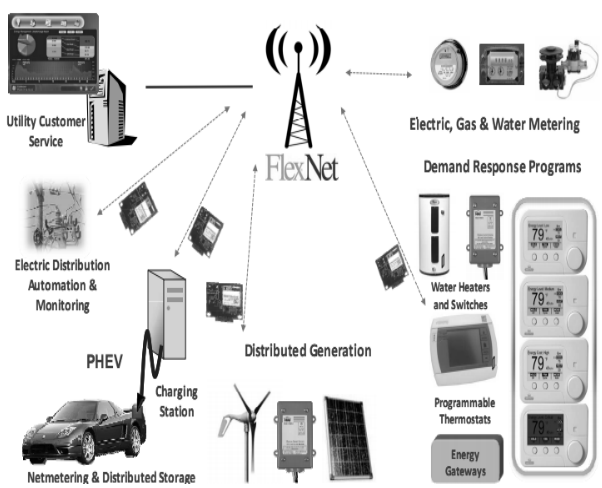
For many people, the most commonly encountered ISM device is the home microwave oven operating at 2.45 GHz. However, in recent years these bands have also been shared with license-free error-tolerant communications applications such as Wireless Sensor Networks in the 868 MHz, 915 MHz and 2.450 GHz bands, as well as wireless LANs and cordless phones in the 915 MHz, 2.450 GHz, and 5.800 GHz bands. Because unlicensed devices already are required to be tolerant of ISM emissions in these bands, unlicensed low power uses are generally able to operate in these bands without causing problems for ISM users; ISM equipment does not usually include a radio receiver in the ISM band. In the United States, according to 47 CFR Part 15.5, low power communication devices must accept interference from licensed users of that frequency band, and the Part 15 device must not cause interference to licensed users. Note that the 915 MHz band should not be used in countries outside Region 2, except those that specifically allow it, such as Australia and Israel, especially those that use the GSM-900 band for cell phones. The ISM bands are also widely used for Radio-frequency identification (RFID) applications with the most commonly used band being the 13.56 MHz band used by systems compliant with ISO/IEC 14443 including those used by biometric passports and contactless smart cards.

The industrial, scientific and medical (ISM) radio bands are radio bands (portions of the radio spectrum) reserved internationally for the use of radio frequency (RF) energy for industrial, scientific and medical purposes other than communications. Examples of applications in these bands include radio-frequency process heating, microwave ovens, and medical diathermy machines. The powerful emissions of these devices can create electromagnetic interference and disrupt radio communication using the same frequency, so these devices were limited to certain bands of frequencies. In general, communications equipment operating in these bands must tolerate any interference generated by ISM equipment, and users have no regulatory protection from ISM device operation.

6.6 LCD Display

A 16 Character x 2 Line LCD Module to the Parallel Port. These LCD Modules are very common these days, and are quite simple to work with, as all the logic required to run them is on board.

7 TECHNOLOGY IMPROVEMENTS



8 ADVANTAGES

- Low cost
- Safe and easily configurable simulations
- Reduce Power Shortage
- Simple Construction
- Security
- Efficiency
- Greater Reliability

9 OBSTACLES OF FUTURE DEVELOPMENTS

In 2010, the global value of smart meters was in excess of $4.3 billion, and is forecasted to reach as much as $15.2 billion by 2016. China has purchased 48 million smart meters in the past two years and in 2010 Chinese Taipei announced its AMI deployment plan.

The Council of the European Union formally adopted the third Energy Package in April 2009. The new smart meter provision will require Member States to carry out a cost-benefit assessment within 18 months of entry into force of the new legislation, and then roll out the meters to at least 80% of domestic customers by 2020 - but the 80% will only apply to those customers who have been identified as cost efficient to supply with meters. The intention is ultimately a 100% roll out by 2022.

Security:
Many of the technologies discussed above to support Smart Grid, such as smart meters, sensors, and advanced communications networks, can themselves increase the vulnerability of the grid to cyber attacks. Accordingly, it is essential that Smart Grid deployment leverage the benefits of increased threat awareness while mitigating against heightened security concerns. It will be a difficult task, but one that can be addressed by being aware of the risks and leveraging security best practices from other industries.

Upfront Consumer Expenses:
In the responses of 200 utility managers to a 2009 survey, 42 percent cited "upfront consumer expenses" as a major obstacle to the smart grid. These concerns were confirmed by consumer responses in which 95 percent of respondents indicated they are interested in receiving detailed information on their energy use; however, only 1 in 5 were willing to pay an upfront fee to receive that information. Regulatory approval for rate increases needed to pay for smart grid investments is always difficult, and the receptiveness of regulators varies from state to state.

Lack of Standardization:
Lack of technology standards has been considered as a major obstacle to smart grid deployment. A Smart Grid is a new integrated operational and conceptual model for utility operations. This requires it to both implement a system-wide installation of monitoring device and to maximally communicate with components. However, developing this kind of system will usually cost multi-years.

Because smart grid is still a new concept and the technologies that there is misunderstanding amongst consumers, regulators, policymakers, what its costs and benefits are. Stakeholders that are generally aligned conclusions based on a different understanding of the smart grid.

10 CONCLUSION

This paper describes the smart grid System and its implementations using ISM Band. For supporting energy management services, HEMS monitors smart meter and make a plan to control the appliances related to energy remotely from smart meter providing auto-configuration, remote monitoring, energy management, feasible controlling. Especially, planning makes to shift device controlling on peak price time and to smooth power demand work load. Finally, HEMS can deliver clear benefits about resource utilization, energy conservation and cost reduction to users.

REFERENCES

[1] Robin Podmore, Fellow-IEEE, and Marck Ramon Robinson., "The Role of Simulators for Smart Grid Development"., IEEE Transactions On Smart Grid,VOL.1,NO.2, September2010.

[2] Khosrow Moslehi, Member-IEEE and Ranjit Kumar, Senior Member, IEEE., "A reliability Perspective of the Smart Grid", IEEE Transactions On Smart Grid,vol.1,no.1,june 2010.

[3] Young-Sung Son, Topi Pulkkinen Kyeong-Deok Moon and Chaekyu Kim, "Home Energy Management System based on Power Line Communication", IEEE Transactions on Consumer Electronics, Vol. 56, No. 3, August 2010.

[4] Hamid Gharavi, Fellow IEEE and BinHu, Member IEEE., Multigate Communication Network for Smart Grid, Proceedings of the IEEE Vol.99, No.6, June2011.

[5] M. A. S. Masoum, Senior Member, IEEE, P. S. Moses, Student Member, IEEE, and S. Deilami, Student Member, IEEE "Load Management in Smart Grids Considering Harmonic Distortion and Transformer Derating" 2010.

[6] An Introduction and User's Guide to the IEEE Smart Grid Web Portal, "Claudio Lima, Marty Burns, Henry Louie, Member IEEE. 2010

[7] IEEE Transactions on Applied Superconductivity, VOL. 21, NO. 3, JUNE 2011,Proof-of-Concept of a Smart Fault Current Controller With a Superconducting Coil for the Smart Grid Min Cheol Ahn and Tae Kuk Ko, Member, IEEE.

[8] For the Grid and Through the Grid:The Role of Power Line Communications in the Smart Grid By Stefano Galli, Senior Anna Scaglione, and Zhifang Wang, Member IEEE.

[9] Multigate Communication Network for Smart Grid, By Hamid Gharavi, Fellow IEEE and Bin Hu, Member IEEE.

[10] Transmission Characteristics of Low-Voltage Distribution Networks Under the Smart Grids Environment Ming-Yue Zhai, Member, IEEE.

[11] D. Tao, P. Wei, H. Jiang and L. Xiyu, "Adaptive Energy Saving Monitoring Technology for Air Condition in Telecommunication Equipment Room", pp.155-160, IEEE INTELEC 2007.

[12] K. Moon, Y. Lee, Y. Son and C. Kim, "Universal home network middleware guaranteeing seamless interoperability among the heterogeneous home network middleware", IEEE Transaction on Consumer Electronics, Vol.49, pp.546-553, 2003

[13] C. Lien, Y. Bai, H. Chen and C. Hung, "Home Appliance Energy Monitoring and Controlling Based on Power Line Communication", IEEE ICCE 2009.

[14] KPX (Korea Power Exchange), "Survey on Electricity Consumption Characteristics of Home Appliances", Dec. 2004.

[15] Han, i. Han and K. Park, "Service-Oriented Power Management for an Integrated Multi-Function Home Server", IEEE Transaction on Consumer Electronics, Vol.54, pp.204-208, 2007.

[16] H. Ahn, M. Cho, M. Jung, Y. Kim, J. Kim, and C. Lee, "UbiFOS: A Small Real-Time Operating System for Embedded Systems", ETRI Journal, vol.29, no.3, pp.259-269, June 2007.

[17] Electric Utility Deregulation and Restructuring and Power Technologies (DRPT), 2011 , "6-9 July 2011, Weihai, China Real-Time Operating Systems for Small Microcontrollers Micro, IEEE, Sept.-Oct. 2009.

[18] On memory protection in real-time OS for small embedded systems, Proceedings - Fourth International Workshop on Real-Time Computing Systems and Applications, 27-29 Oct 1997.

[19] New embedded digital front-end for high resolution PET scanner, Nuclear Science, IEEE Transactions on , June 2006.

Wavelet-Based Reactive Power and Energy Measurement in the Presence of Power Quality Disturbances, Power Systems, IEEE Transactions on, Aug. 2011.

[20] Ultra Low Frequency Power-Line Communications Using a Resonator Circuit David W. Rieken, Senior Member, IEEE, and Michael R.Walker II, Member, IEEE, IEEE transactionson smart grid, VOL.2, NO.1, MARCH 2011.

[21] Application of Power Line Communication for Data Transmission over PWM Network Nicolas Ginot, Marc Anthony Mannah, Christophe Batard, and Mohamed Machmoum, IEEE transactionson smart grid, VOL.1, NO.2, SEPTEMBER2010.

[22] Concurrent Simulation Platform for Energy-Aware Smart Metering Systems Seunghyun Park, Hanjoo Kim, Hichan Moon, Member, IEEE, Jun Heo, Member, IEEE, Sungroh Yoon, Member, IEEE, Aug. 2010.

[23] "ARTICLE 1 - Terms and Definitions" (HTML). *Life.itu.ch*. International Telecommunication Union. 19 October, 2009. 1.15. "Industrial, scientific and medical (ISM) applications (of radio frequency energy)".

[24] www.adica.com.

[25] www.istcoalition.org.

[26] Electronics For You, July 2011. Tech Innovation –A Smart Plug That Monitors Power Consumption And Generates Alerts, Wirelessly.