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Smart Home Energy Management Systems: A Literature survey

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***Abstract*—** India being a developing country produces a large amount of CO_2, Major portion of which includes Electricity production. This paper aims to bring light to the technologies related to Smart Grid Systems and Smart homes which can be incorporated to reduce energy usage. Smart Grid is a technology to decentralize energy supply and communicate with users to dynamically set prices to reduce load on the power grid. Smart Home Technology automates and controls all electrical devices connected in the network. The combination of these two technologies can help reduce load on Power Grid and thus save energy consumption.

***Keywords*—** Smart homes, smart grid, smart home energy managment system, real-time pricing, Internet of Things

I. INTRODUCTION

With recent advancement in population and increased standards of living, the need and demand for electricity has risen drastically over the years. The advancements in technology has also help industry to keep up with the increasing demand. These demands also have a heavy cost on earth, mainly causing pollution. There are not many incentives in place to keep it in check. With time electricity demand will only increase, thus increasing pollution. To keep pollution under check, we need to use technologies at hand and invent new ones to decrease the need and load of electricity. The technologies like Internet of Things (IoT) and smart homes which have increased standards of living are also helping managing energy demands. IoT, a system of interrelated computing devices, mechanical and digital machines, objects, animals or people and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction has developed Smart home technologies like security, automation, convenience and energy.

With the beginning of the 21st century, more and more decentralized energy systems are coming into the network again, so future architectures will have to support both centralized and decentralized concepts. Consequently requirements for distributed and centralized concepts and applications need to be considered. This decentralized system is called a Smart Grid. To stabilize the power usage the companies have started varying power costs on an hourly basis and generally fluctuate by an order between low-load peak night hours to high-load peak afternoons. In general, almost all retail users are currently charged some average price that doesn't reflect the actual usage price [1]. To counter this issue, various models for differentiated pricing have been proposed: Real-Time Pricing (RTP), Critical-Peak Pricing (CPP), and Time-of-Use Pricing (ToUP), etc.

This change is effectively achieved by shifting from a centralized management system to decentralized system in which consumers participate to interact cooperatively.

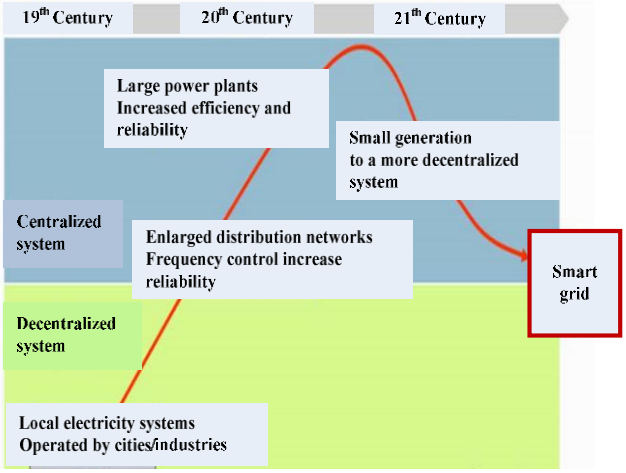

Figure 1. Levels of Decentralization [2]

With implementation of Smart Grid it is now possible to perform demand response actions at user side. Demand response (DR) is defined as "changes in electricity use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" [3]. These programs use the energy more proficiently by triggering demand side actions when

consumer side demand peeks to stabilize the usage. These programs aim at reducing and shifting consumption. Energy consumption can be reduced using smart meters that communicate with service provider to monitor energy pricing to control consumption when pricing peeks at peak hours.

Rest of the paper, authorized by BVUCOE (Pune), is organized as follows, Section I contains the introduction of Smart Systems, Section II contain the related work of Smart Homes, Section III explains the need of Smart homes and Smart Grids in India, Section IV contain the details of Smart Systems, Section V describes results and discussion, Section VI concludes research work with future directions.

II. RELATED WORK

In recent years, many efforts have been made to develop Smart Home Energy Management Systems like for instance Qinran Hu and Fangxing Li [4], presented a detailed Paper on how to implement available technologies to create a SHEM system integrated with machine learning algorithm to optimize the system based on user activities an preferences. In a Similar Paper by K. M. Tsui and S. C. Chan [5], they propose Demand Response Optimisation of Smart Homes by Scheduling Appliances in such a way that they provide users proper functionality and decrease load on grid when overall load peaks by communicating with the Smart Grid system. In a paper by Matteo Cabra et al.[6] proposed two algorithms for different scenarios for SHEM, and the system is not for a single household, but controls groups of smart homes in a single neighborhood. In the sections ahead we will see how these ideas can be utilized for making an Optimal System.

III. NEED FOR SMART SYSTEMS IN INDIA

In the FY 2015-2016, Indian consumed 1,001,191 GWh, out of which 42.30% was used for industrial purposes and 23.86% was used for domestic purposes [7]. And this figure has been growing through the years and will continue to grow to support the development of India. The worrisome part is that India lacks much of Renewable energy source and mainly depends on Coal and other thermal power plants for Electricity generation.

Table 1. Weighted average emission factor (adjusted for electricity transfer) for the Indian Grid over the period 2011-12 to 2015-16 [7]

Fiscal Year	tCO_2/MWh
2011-12	0.78
2012-13	0.83
2013-14	0.82
2014-15	0.83
2015-16	0.82

India is more than capable of generating Electricity to meet demands but the problem lies with transmission, which results in loss of upto 30% of transmission power figure 2]. All these reasons add upto a huge amount of Co2 production Alone from the electric depart alone. The latest emission figures of the 'CO2 baseline database' reveal that power plants in India emitted 846.3 million tons of CO2 in the year 2015-2016 [7]. And as India continues to grow, so will the production of Co2 if not appropriate measures are taken.

Table 2. All India yearly coal consumption for Power Generation [8]

Year	Coal Consumption Million Tonnes
2004-05	278.00
2005-06	281.00
2006-07	302.00
2007-08	330.00
2008-09	355.00
2009-10	367.00
2010-11	387.00
2011-12	417.56
2012-13	454.60
2013-14	489.40
2014-15	530.40
2015-16	545.9

IV. SMART SYSTEMS

IoT which refers to uniquely identifiable objects and their virtual depictions in an Internet. Radio frequency identification (RFID) is also essential for IoT. If all objects and people in daily life were equipped with RFID tags, they could be identified and tagged by computers. IoT with its features to communicate between machines have made it possible to develop Smart home Automation system.

Smart home has been a hot area of research for several years and has attracted attention from academy and industry in recent years. Researches have been focused on design of architecture, infrastructure, intercommunication and realization of smart home system.

A. Smart Grids

A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication [9]. This system allows for observation, analysis, control and communication within the supply chain to help improve efficiency, reduce energy usage and cost, and maximize the transparency and reliability of the energy supply chain. This system was introduced to overcome the weakness of conventional centralised system.

Many governments all around globe have started furthering the use of smart grids to control and deal with global warming, emergency resilience and energy independence scenarios. The popularity of Internet in homes has made the smart grid more practically consistent to implement. Smart grid devices transmit data in such a way that allows for users, suppliers and automated devices to swiftly respond to changes in smart grid conditions.

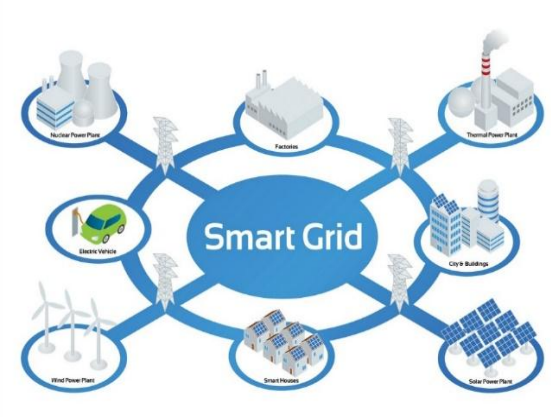

Figure 2. Smart Grid Infrastructure

The entire smart grid system is automated for tracing the electricity usage at every location. Smart Grid architecture can also be combined with energy management software for calculating the energy usage and it's Demand-Price for a particular institutions. Generally, electricity prices surge along with demand. By providing users with information about current usage and energy demand prices, smart grid energy management services help to lessen the usage during high-cost, peak-demand times.

A smart grid's key features include:

- Load Handling: The electricity usage of a power grid is not stable and it fluctuates over time. In case of high demand, a smart grid system can instruct users to briefly minimize energy usage.
- Demand Response Support: It provides users with an automated way to reduce their electricity bills by guiding them to disengage low-priority electronic devices when rates are higher and balancing high consumption devices such that they can be shut off when prices peak.
- Decentralization of Power Generation: A decentralized grid system lets the users to generate local power by using any appropriate method of their choice

Advanced Metering Infrastructure (AMI) is a method to incorporate users based upon the development of open standards. It provides users with the ability to use electricity more proficiently and provides utilities with the capability to detect problems on their systems and operate them more efficiently. AMI enables user-friendly effectiveness concepts like "Prices to Devices" to work like: Assuming that energy is priced on what it costs in near real-time – a Smart Grid imperative – price signals are relayed to "smart" home controllers or end-user devices like – the home's main energy-users. The devices, in turn, process the information based on users' learned requirements and power accordingly. The house responds to the users, rather than vice-versa. Because these interactions occur mostly "in the background," with minimal human intermediation, there's a huge savings on energy that would otherwise be used.

B. Smart Homes

Smart home automation technology, provides users security, relief, ease and energy efficiency by allowing them to control smart devices. A part of the internet of things (IoT), smart home systems and devices operate together, sharing user usage data among themselves and automating activities based on the users' preferences. A smart home's devices are all connected with each other and manageable through one central point. Door locks, televisions, thermostats, home monitors, cameras, lights and even appliances such as the refrigerator can be controlled through one home automation system. The system is installed on a mobile phones or other networked device, and the user can generate time schedules for certain actions to take effect and can also monitor the devices from any internet-connected device in the world.

Smart home devices come with self-learning algorithms whereby they can learn the user's timetables and adjust as needed. Smart homes enabled with lighting control allow users to reduce electricity usage and thus profit from energy-related cost savings. Some home automation systems alert the users if any motion is detected in the home while away, while others can call the fire department in case of any impending conditions. Once these smart devices have been connected, we have a system of what is called as Internet of Things (IoT) technology. Smart homes can have systems that are wireless or hardwired. Wireless systems are cost-effective and easier to fit while hardwired systems are more reliable and are harder to break into. While hardwired systems are also more exclusive than wireless system, installing a hardwired system can increase the resale price of a home. Installing wireless home automation with features such as smart lighting, climate control and security can charge a household a couple thousand dollars. Meanwhile, luxury and hardwired options can cost homeowners tens of thousands of dollars.

V. RESULTS AND DISCUSSION

In the paper presented by Qinran Hu and Fangxing Li [4] they combine already present technologies to make a model for smart home and test them to provide definite conclusions on how the model can help save energy consumption.

- They use wireless power adapters [9], Intelligent meters [10] and the software architecture is based on MavHome [11].
- They simulated different devices in differently: Electric water heater, heating ventilation and air-conditioning, and lastly electric vehicle, Washing Machine and Dryer
- The one point to note about their design is that we can use their hardware even without smart devices as they have incorporated sensors into their hardware design.

In the paper by K. M. Tsui and S. C. Chan [5], they propose a Demand Response optimization framework using versatile

convex programming. They have dived the devices based on their load usage as:

- Schedule-based appliances with interruptible load: They can run anytime and can be shut down during operation.
- Schedule-based appliances with uninterruptible load: They follow a predefined steps of operation and cannot be shut down while in operation
- Battery-assisted appliances: These devices are equipped with internal battery and can provide addition energy source during peak hours
- They have derived different Equations based on different types of devices as mentioned above for two pricing models Linear Price model and Quadratic price Model.
- They ran 200 simulations to intensively study the effects of their program on Smart home energy management.
- Their Simulations Show that at max 14% energy is being saved in case of any device.

In the paper by Matteo Cabra et al. [6], they propose two algorithms Cost Saving Task Scheduling algorithm (CTCS) and Renewable Source Power Allocation algorithm (RSPA).

- CTCS: it schedules high load task in off-peak hours and postpone staring time of such devices until Renewable Energy Source is available.
- RSPA: It uses a max-consensus negotiation among appliances to dynamically choose which device to start immediately when Renewable Energy Sources are available to maximize efficiency and reduce main power usage.
- They also demonstrate how complexity of CTCS shrinks with increment of time slot, making it easier for processor to handle additional devices.
- The Programmes can save upto 30% costs and energy and with presences of Renewable Energy Sources it goes as high as 48%.

VI. CONCLUSION

In this paper we have seen the need for SHEM system in Indian and why it is crucial for development of such systems as soon as possible. It explains what the main technologies that need to be adopted for the same. Also I have compared 3 papers related to the topic to present how those technologies can be integrated for use. Qinran H. and Li F.'s Hardware when coupled with Tsui K. and Chan S.'s Algorithm would be most effective way to save energy in this scenario and reduce load on peak hour. Also these systems are flexible and can be expanded to incorporate more devices and the combined system would give best results when Renewable Energy Sources are present in neighbourhoods.

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