Scope and Challenges of Electrical Power Conservation in Smart Grids

Al-Saheer S.S.[#1], Shimi S. L.[#2] and Dr. S. Chatterji[#3]
[#1] PG Student, [#2] Assistant Professor, [#3] Professor and Head,
Dept. of Electrical Engineering,
National Institute of Technical Teachers Training and Research,
Chandigarh, India

***Abstract*—In India, the gap between the electrical energy supply and the demand is -3.9% (MW) as per the report of CEA, India in March, 2014. Since there are constrains in increasing the supply, the better means is to conserve the available energy. This paper studies different strategies suitable for power management in Indian Energy Scenario and also identifies the scope and challenges of implementing Smart Grids and Smart Meters in India.**

Keywords*— Energy Management; Energy Conservation; Demand Side Management; Smart Grids; Smart Meters

I. INTRODUCTION

Energy is a fundamental resource in the economy. There is a very strong link between energy use and economic growth. Economic growth is directly related to energy consumption and is influenced by energy availability. India is a country with more than 1.2 billion people accounting for more than 17% of world's population and suffers from energy poverty and pervasive electricity deficits [1]. In 2008, India's energy use was the fifth highest in the world [1]. 3.9% (MW) was the deficit estimated in March, 2014 [2]. 84 million households in the India do not have access to electricity [1]. Even those who have access to power suffer from both shortage and quality of power [1]. Equipments are frequently damaged due to the erratic electricity supply [1]. Low voltage during peak hours has been reported to be a general power management issue, in India. It has been a unanimously spoken fact that power drastically drops during this peak hours. The supply cannot increase with the demand rate because of the limited resources and economic constraints. In India about 60% of the total power generated is from Coal [2], increasing the use of Coal will cause the emission of carbon dioxide more and thereby increasing the global warming. The best solution to these issues is the conservation of electrical energy by means of proper management of the available energy. This paper investigates need for Smart Grids as well as Smart meters, optimum pricing system and its influence on Demand Side Management and finally, the energy conservation with Smart Meters, Smart Grids, Demand Side Management and Pricing System in Indian Energy Scenario. The rest of the paper is organized as follows. In section two a brief discussion on different methods for energy conservation has been presented. Section three explains Demand Side Management. A brief on Smart Grids and Smart Meters has been given in section four. The section five discusses the merits and challenges for smart grid implementation and the last section outlines the conclusion.

II. METHODS FOR ENERGY CONSERVATION

Conservation of energy can be done at both supply side and demand side. In supply side, energy can be conserved by means of improving the efficiency of the power generation and transmission systems as well as proper management of Grids. Demand Side Management (DSM) can be done for Industrial, Commercial, Domestic and Agricultural sectors [3]. Industrial energy management can be done with regular energy auditing programs. In India, energy conservation at the agricultural side cannot be done easily because in many states of the country, for agricultural purpose energy is sold with subsidized tariff. Substantial amount of energy is wasted due to mismanagement and extra consumption in the agricultural side. Giving awareness to the farmers is the only remedy for the issue. Commercial consumers in India is already charging high tariff, and the management in this side is having least preference. Residential load management programs are having so much importance because it has been reported that 40% of the global power consumption is residential [4]. These residential management programs usually aim at one or both of the following objectives-reducing consumption and shifting consumption from peak time to off peak time [5].

'Load shedding' is a common demand side control practice usually followed by public utility providers in India. It is a kind of direct controlling, but not an acceptable one. In contradiction to this an alternative way of power management can be thought of.

DSM program is an indirect way of energy conservation. Through controlled usage of electrical energy, during peak hours from the consumer side, i.e., DSM allowing the consumer to use a minimum load during these hours, which is well sufficient for primary power necessities such as lighting and ventilations. Hence energy deficit can be efficiently managed.

III. DEMAND SIDE MANAGEMENT (DSM)

India is having a pricing system with average electricity tariffs being generally below the costs of power generation and distribution [6]. This has tended to encourage inefficient use of electricity in the subsidized domestic sectors. A revision of electricity tariff rates is thus urgently needed in India [6]. Advantages of DSM include increased savings for consumers as well as utilities, reduced peak to average ratio (PAR) and peak demand [7]. Currently in India, consumers are charged with uniform tariff both for the energy consumed during peak and normal hours. Consumers will not change their consumption behavior in response to supply shortage, without tariff change, because they don't have any kinds of incentives while doing so. Only with the participation of consumers DSM can be achieved. A solution for these problems may be to transform domestic customers from static consumers into active participants in the production process. Tariff could play a potentially important role as a demand side management tool in India [6]. If the energy consumed during peak hours could be monitored and charged separately, the consumption can be reduced during these hours. Since peak prices tend to be higher than the fixed retail rates and off-peak prices are lower, this will create awareness among the public about the significance of energy conservation rather than the fear about the financial loss. Consumers would change in the load pattern by flattening peaks and shifting those loads to off-peak hours which may increase flexibility and allow greater use of renewable energy source. Thus extra expense of peak hour power production can also be reduced. This is more acceptable both from the utility provider side and from the consumer side than the 'load shedding'. The load demand curve in traditional grid, where flat pricing rates are active, shows that load demand is comparatively high during peak periods when compared to off-peak [7]. So the utilities are not able to provide such high power from their base plants and they have to compulsively switch on their 'peaker-plants' (thermal power plants) for which the power generation costs and emission of Green House Gases (GHG), are very high as compared to base plants [7]. The originally inelastic load demand curve needs to be altered to reduce peak load demand, energy cost and emission of GHG [7]. A DSM programs in smart grid enables managing and altering electricity consumption on electricity supply basis. The DSM schemes are combined with different pricing schemes in order to make the scheme more efficient. The pricing schemes proposed so far for smart grid are Real-Time Pricing, Day Ahead Pricing, Time of use or Time of Day pricing, Critical Peak Pricing, etc. [8]. The pricing system can shift load from peak periods to off-peak periods to avoid the services of peaker plants and hence reduce the generation cost and emission of GHGs. Efficient consumption of electrical energy results fruitfully in lowering peak load, reducing electricity bills and minimizing the emission of GHG [7]. Hence smart grid, the set of smart meters, low cost sensors, smart loads, and the integration of Information and Communication Technologies has opened a window for residential energy management programs [9].

Most of the utilities are not capable of tracking and measuring the power usage by end-use sectors in real-time because of legacy constraints as well as lack of tools and equipment [10]. By the use of an Automatic Meter Reading (AMR) system or Smart Meters, these problems can be deliberately addressed. A proper billing system will induce the consumers in energy management programs.

Aggregate Technical & Commercial (AT&C) losses which include theft, non-billing, incorrect billing, inefficiency in collection and transmission and distribution losses exceeded 40% for the country (India) as a whole in 2005 [1]. Energy conservation by means of DSM can be achieved by implementing Smart Grids. Smart Meters are the back bone of the Smart Grids, which measures the real time energy consumption in Smart Grids.

IV. SMART GRID AND SMART METERS

Electrical power grid is a system with some or all of the following four capabilities, power generation, transmission, distribution and control [7]. Integration of advanced Information and Communication Technologies (ICT) increases the efficiency of the traditional grid which makes it capable to make decisions fast and accurate [7]. The integration of ICT in traditional grid results in more automation, reliable provision of electrical services and safe operation of electrical appliances and hence an increased level of consumer comforts [11]. Population across all over the world and the dependency level of human on electricity are continuously and exponentially increasing phenomena [7]. As not much change has been made to the traditional grid to cope with the increased demand, the ultimate result is that the traditional grid has worn out and the idea of smart grid has evolved [12]. Distributed applications for smart grid may be found in consumption, distribution, transmission, and generation of electrical energy [7]. Smart grid enhances the electricity usage efficiency. Efficient consumption of electricity proves beneficial to us both socially and economically [7]. The employment of DSM systems in a residential area reduces energy bills for consumers and peak demand. Distributed power generation option is always there in smart grid technology, where in-home electricity can be generated (photovoltaic, wind power), use the required energy locally and sale spare power back to utility [7].

C.H. Lo and N. Ansari in [10] have discussed the purpose of the Smart Grid as to be smarter, to be Smarter, to boost the deployment of Renewable Energy Sources, to augment the efficiency of generation, transmission, and usage for energy, to shift and customize consumer's energy demands, to slacken the pace of rising energy demands, to build a safe and secure system between supplier and consumer and to reduce unnecessary expenditures and recurring costs.

Smart grid will become the next-generation electrical power system to provide reliable, efficient, secure, and cost-effective energy generation, distribution, and consumption [13]. Smart Grids consist of Smart Meters to measure the real time power consumption data, communication system to communicate between end-user and smart control centers and smart control centers to monitor and control the entire system. The concept of smart grid has been introduced with the decentralized infrastructure that provides better demand side management and intelligent power supply [13]. Smart grid will use two-way data communications technologies to integrate the electrical power control system with consumers so that the intelligent power generation, distribution, and consumption can be achieved [13].

Recent efforts in building a smart grid system have focused on addressing the problems of global warming effects, rising energy-hungry demands, and risks of peak loads [10]. One of the major goals of the new system is to effectively regulate energy usage by utilizing the backbone of the prospectively deployed Smart Meters and Demand Response (DR) programs via the advanced distribution automation and dynamic pricing models.

The function of the power grid is no longer a system that only supplies energy to end users, but also allows consumers to contribute their clean energy back to the grid in the future [10]. A.H. Mohsenian-Rad, V.W.S. Wong, J. Jatskevich, R. Schober and A. Leon-Garcia in [5] have proposed an idea, where users can store energy at certain hours, during off-peak times and can then sell the energy back to the grid at peak hours. This is possible in Smart Grids. The distributed energy resources coordination (Local Generation) along with different pricing schemes leads towards efficient energy consumption [7]. Emerging new technologies like distributed generation, distributed storage, and demand-side load management will change the way we consume and produce energy [14]. These techniques enable the possibility to reduce the greenhouse effect and improve grid stability by optimizing energy streams [14].

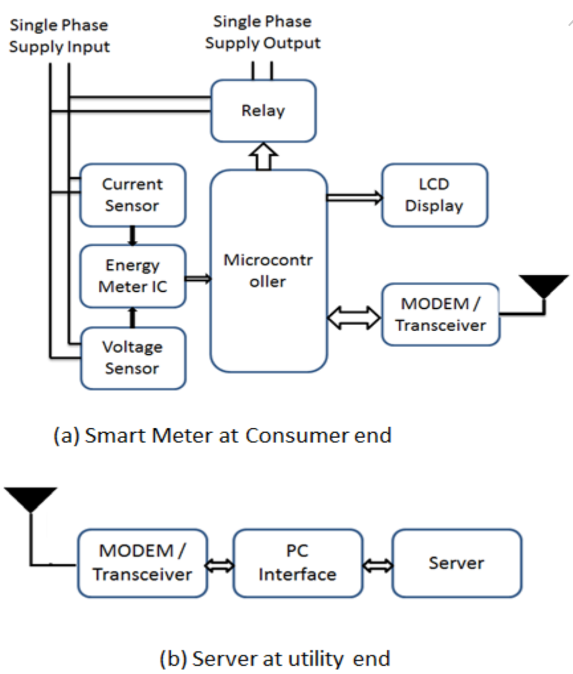

Fig. 1. Simplified Architecture of Smart Meteing system for single phase supply.

Smart Meters forms the heart of the Smart Grid. A smart meter is a digital, advanced device with high accuracy, control, and configuration functionality with better theft-detection ability, which enable remote connect/disconnect, real-time pricing, power-quality measurement, load management, and outage notification [15]. A smart energy meter records consumption of electric energy and communicates that information to the utility provider for monitoring and billing purposes. Smart meters enable two-way communication between the meter and the central system. Real time energy consumption data can be collected from Smart Meters. Fig.1. shows the simplified architecture of a smart metering system for single phase supply. In this system a metering device kept at consumer end communicates with a server in the utility provider side in both directions. With the help of Smart meters, utility provider can remotely control the energy consumption of the user-end. It can remotely turn on/off the supply. Separate monitoring of the energy consumption during peak and off peak, Real Time Pricing, Tamper detection, two way communications between utility and consumer end, etc. can be made possible by the implementation of the Smart Meters. Features like real time pricing, time of use pricing, day ahead pricing, critical peak pricing, etc. can be achieved by using Smart Meters. Traditional meters only measure the energy consumed through human reading, following numerous drawbacks and the impossibility of implementing any automatic action useful for improving efficiency [16]. In the 1990s, utilities began addressing these problems by introducing Automatic Meter Reading (AMR), with the ability of unidirectional communications of the energy consumption to a central unit by means of power-lines or wireless communications, yielding significant reductions in billing costs and improvements in accuracy [16]. AMR reduces the expense of periodic trips to each physical location to read a meter. Another advantage is that billing can be based on near real-time consumption rather than on estimates based on past or predicted consumption. This timely information coupled with analysis can help both utility providers and consumers to control the consumption and production of electric energy. Smart grids can achieve DSM only with the aid of AMR with two way communication, i.e., Smart Meters. Hence it is the heart of the Smart Grid.

V. MERITS AND CHALLENGES FOR SMART GRID IMPLEMENTATION

The need for Smart Grids can be due to environmental, rising energy demands, climbing fuel costs, for customer needs, energy wastage, efficient billing, monitor meter status, theft and remote control over the consumer end. The challenges in implementing smart grid include infrastructure challenges and lack of innovative technologies.

More than 80% of resources used to produce energy throughout the world today are fossil fuels, i.e., non-renewables [10]. These cause global warming and greenhouse effect by the emission of CO_2. Also due to the rapid increase in the fuel consumption, the fossil fuel shortage is increased. Increasing the supply production is not a good remedy for the issue. Due to the population growth, higher per capita consumption, and rapid development of industrial & commercial sectors, higher GDP growth and structural changes in the economy the demand of electricity is increased. Due to the rapid increase in the fuel consumption, the fossil fuel shortage is increased causing the rapid increase of fuel cost. Power cut and low voltage during peak hours are the main power quality issue. Equipment is frequently damaged due to the erratic electricity supply [1]. Consumers are paying for such an electric supply having low power quality and they are eligible for interrupted power supply with high power quality. Consumers are asked to pay for their utilities without knowing how much money they have been charged until the end of the billing cycle [10]. Consumers so far have no way of knowing how much energy they have accidentally wasted through leakage until the electricity bill is received [10]. Most of the utilities are not capable of tracking and measuring the power usage by end-use sectors in real-time because of legacy constraints as well as lack of tools and equipment [10]. Traditional billing system is having lot of draw backs like time consuming, tiresome and requires more human resource, etc. If the manual meter reading and bill data entry process can be automated, the laborious task of meter reading and money spent over for human resources by the utility provider can be fully excluded. In traditional Grid system and Metering system there is no way to identify whether the energy meter is in function or energy theft is happening, without visiting the site. If the utility provider wants to penalize the consumers with outstanding dues or accused of power theft, usually the operator should visit the site for disconnecting the power.

Though Smart grids are having lot of advantages, transformation from the existing grid to a Smart Grid needs huge financial investment. Insufficient investment for improvement is a big challenge. The innovative technologies, including new materials, advanced power electronics, and communication technologies, are not yet mature or commercially available for the revolution of transmission grids; on the other hand, the existing grids lack enough compatibility to accommodate the implementation of spear-point technologies in the practical networks [17].

VI. CONCLUSION

Energy management is the best solution for the energy crisis. Energy conservation can be achieved by supply side management and demand side management. Demand side management can play an important role in conservation of electrical energy in India. The DSM program can only be achieved by the use of Smart Meters and Smart Grids. Implementation of Smart Meters, Smart Grids and DSM programs address the problems of energy deficit there by reduces the peak load and demand patterns. In India, Smart grids will play a vital role in energy conservation, but due to the lack of investments the implementation of the system is difficult.

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