ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

Optimal Scheduling of ICT for Demand Side Management in Smart Grid

N.Naslin Sithara[1] , V.Saminathan[2]

PG scholar[AE], Department of ECE Maharaja Engineering College, Avinashi, Tamilnadu, India [1]

Assistant Professor, Department of ECE, Maharaja Engineering College, Avinashi, Tamilnadu, India [2]

ABSTRACT: The electric grid is considered an engineering marvel; still a new kind of electric grid is being developed which comprises of additional features provided by the Information and Communication Technology (ICT). Smart Grid is characterized by a two-way flow of electricity and information which is enumerated in this paper with the incorporation of a smart energy meter. It supports the real time online electricity billing concept. Optimal scheduling of the appliances is proposed for efficient energy management of residential customers that promises a well balanced load curve. Along with all these this paper proposes an approach to reduce the carbon footprint of the electric power system by integrating renewable energy resource. The proposed scheduling algorithm along with the additional options of demand side management ensures a combination of load balancing, advanced metering and environmental improvements.

KEYWORDS: Smart Grid, Demand Side Management, Optimal Scheduling, Real Time Pricing, Smart Meter.

I.INTRODUCTION

The electric power grid was the most significant engineering achievement of the 20th Century. The modification of power grid into smart grid has been necessitated by the following potential drawbacks: 1) The load curve is highly unbalanced as everyone relies on the same power grid. This results in inefficient load management, leading to overloads during the peak time which demands power cut. 2) Conventional electrical meters only measure total consumption and so provide no information of how much energy was consumed. They have poor configurability and they are read manually on a monthly basis concealing the time-to-time usage of the customer. This billing process is quite cumbersome and outdated. 3) Approximately 40% of global CO_2 emissions are emitted from electricity generation through the combustion of fossil fuels to generate heat needed to power steam turbines. Burning these fuels results in the production of carbon dioxide which is responsible for global warming. 4) Difficulties related to the maintenance of the overburdened distribution infrastructure.

The use of renewable energy sources to generate electricity instead of traditional thermal power plants will lead to fossil fuel conservation and environmental improvements as a result of reducing green house gases (especially CO_2) emitted as a result of thermal generation. Thus smart grid provides a methodology to reduce effect of global warming. Optimal scheduling of the appliances helps in managing peak load through demand response during peak hours resulting in a well balanced load curve. This approach incorporates features of Information and communication Technology (ICT).Smart Meters are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems. The combination of the electronic meters with the scheduling unit facilitates data acquisition, monitoring and control. It is commonly referred to as Advanced Metering infrastructure (AMI). These features in the proposed system help to shift the work load from the peak working hours of the grid. The major advantages of this project include peak levelling, democratization of energy, self-healing and other commercial benefits.

The additional components to the power grid that builds a smart grid include renewable energy generating infrastructure, energy storage options and facilities for demand side management. The proposed system relies on solar energy as an option from the green energy sources. Photovoltaic modules can be used by the residential customers for energy harvesting. Need for a storage device emerge from the scenario of shifting the load curve from the peak time as well as based on the real time pricing information. The preferable option is to use a battery which serves as a means of

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

temporary energy storage. The energy demands of smart home system can be managed effectively by shifting energy consuming workload from peak hours to off peak hours for the sake of balancing the load and minimizing the monetary expense of the consumer. There are two types of energy demands namely elastic and inelastic. If the energy demands of customer satisfied within a certain time limit then they fall under the category elastic energy demand. On the other hand when appliances are to be powered as per the necessity then they can be stated as inelastic. Apart from the conventional method of manual data acquisition, smart grid includes option for automatic and systematic data acquisition with the help of smart meters.

II.RELATED WORK

High quality demand side management has become indispensable in the smart grid infrastructure for enhanced energy reduction and system control. In this paper, a new demand side management technique, namely, a new energy efficient scheduling algorithm is proposed to arrange the household appliances for operation such that the monetary expense of a customer is minimized based on the time-varying pricing model. The proposed algorithm takes into account the uncertainties in household appliance operation time and intermittent renewable generation. Moreover, it considers the variable frequency drive and capacity-limited energy storage. Our technique first uses the linear programming to efficiently compute a deterministic scheduling solution without considering uncertainties. To handle the uncertainties in household appliance operation time and energy consumption, a stochastic scheduling technique, which involves an energy consumption adaptation variable, is used to model the stochastic energy consumption patterns for various household appliances. [1]

III. PROPOSED METHODOLOGY AND DISCUSSION

Optimal scheduling algorithms bring significant gains to customers to find a series of price thresholds. The proposed framework attempts to achieve a desired trade-off between minimizing the monetary expense and minimizing the waiting time for the operation of each appliance in a household. There is a limit on the total load demand for each household during a certain time interval. When the total load demand of household appliances exceeds the given load limit of the household, then the home power network trips out. Figure 1 shows the architecture of the household appliance monitoring system.

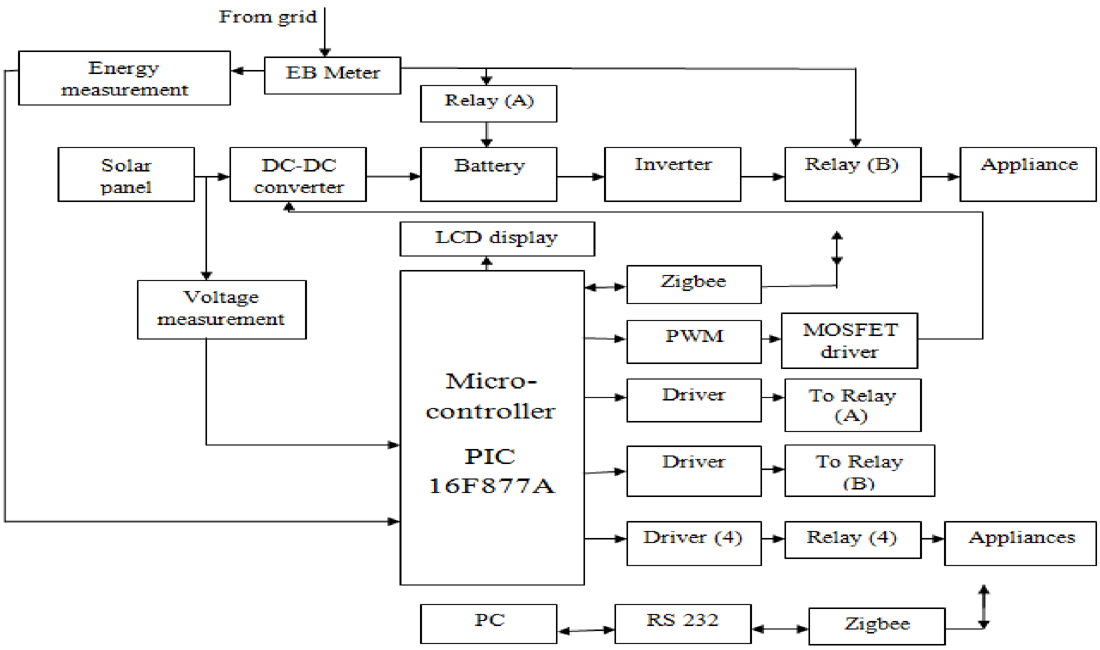

Fig. 1 Architecture of household appliance monitoring system.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

A practical system model consisting of essential components in the smart grid for residential customers is shown in Figure1. Residential customers can use rooftop photovoltaic (PV) system because of its least environmental impact, scalable capacity, as well as decreasing cost. A basic PV cell converts sunlight of certain wavelengths into DC using the photoelectric effect. Unfortunately, a basic PV cell typically generates only a small amount of power, which may not be enough to power a whole household. However, due to their modularity and portability, PV cells can be easily interconnected to form a PV panel to meet any electrical requirement, no matter how large or small it is. Therefore, in this paper, PV systems are selected as the renewable energy source. However, it is quite flexible and can be easily adapted to other forms of renewable energy sources.

Energy storage can alleviate the need to generate power at the time when needed and can smooth out the variations of energy utility due to random power demand and uncertain energy supply. Ensuring bi-directional communication between consumer and utility companies to enable tamper detection, supply cut-off in case of leakage detection or non-payment, remote configuration etc. Since solar energy cannot be dispatched and the fluctuations in solar irradiance may occur in a minute-to-minute time scale, the energy generating profile of a PV system does not coincide with residential energy demand profile for most of the time. There may be electricity spillage at daytime when the PV electricity generation is high and electricity shortage at night time when the PV electricity generation is low. To cope with this mismatch, energy storage may have to be used. By storing some excessive generated electricity at daytime, it can be released at night time to supplement the power usage for a household. Intuitively, through this method, the total amount of electricity drawn from the electric utility grid can be reduced.

A DC-to-DC boost converter is used when electricity generation from a solar panel is low, that will produce an output voltage greater than its input voltage. Unfortunately, battery charges and discharges will impact the operational life of a battery. In order to protect the battery from overcharge and over discharge, a controller is needed to regulate the charging and discharging process. Because of the finite capacity of energy storage, some PV generated electricity may still be spilled.

As the power generated by PV panels is DC, an inverter is needed to convert DC into AC before it can be used by household appliances. Moreover, a synchronization device is required to adjust the voltage phase and magnitude of the output power from the inverter, so that the output power can be combined smoothly with the power drawn from the electric utility grid to supply electricity to household appliances together. This combination is usually completed at the main fusion box. In the smart grid, customers would be enrolled in a real-time electricity pricing environment, where the electricity price is time varying. The electricity drawn from the power grid can also be stored in the battery through the battery charger so that it can be reused later. Intuitively, the total electricity cost can be reduced by recharging the battery from the electric power grid when the electricity price is low while discharging it during the high electricity price period.

Each residential customer is equipped with a smart meter that is connected to the power distribution system. Each smart meter includes a scheduling unit which implements the workload shifting mentioned above. It periodically receives the updated pricing information from the utility companies, and its scheduling unit arranges different household appliances for operation during different time periods. It is effective in reducing the monetary expense charged to end users since different electricity rates can be applied at different time periods in the popular real-time pricing model.

The monetary expense of a single customer is minimized through optimally scheduling the operation and energy consumption for each appliance under the real-time pricing environment. Oftentimes, there is a limit on the total load demand for each household during a certain time interval. When the total load demand of household appliances exceeds the given load limit, the home power network trips out. This will lead to degradation of customer comfortableness. The probability that the home power network trips out during a time interval is defined to be the trip rate. Since there are uncertainties in the energy consumption of household appliances as well as renewable generation, the trip rate can only be minimised to a very small value in practice.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

IV. STOCHASTIC OPTIMIZATION ALGORITHM

The proposed operation scheduling algorithm takes the parameters time-varying pricing information released by power utility companies ahead of time, distributed renewable generations and energy storage, and the customer-defined target trip rate as inputs. With all these inputs it generates an operation schedule over a pre-defined time domain. All this minimizes the monetary expense and meets the customer-defined trip rate. The household appliances can tap energy both from electric power grid and from the renewable energy sources. These energy sources may be intermittent by nature and the electric power grid may pose some uncertainties in operating its household appliances.

Let r(t) denote the amount of renewable energy generated in slot t and we assume that this energy is first stored in battery before it can be used in the next time slot. A controller is to regulate the portion $\gamma(t)$ of the generated energy stored into battery for each slot t in order to prevent battery overflow. The other portion is spilled.
Hence

$$0 \leq \gamma(t) \leq 1$$

Moreover, there is a maximum value r_{max} for r(t), that is,

$$0 \leq r(t) \leq r_{max}$$

V.REAL TIME PRICING MODEL

Electricity prices tend to be different for varying time intervals while they maintain a flat nature within each time interval, this is the nature regarding Real Time Pricing (RTP) model. As the energy consumption of the residential unit reaches a predetermined threshold, the inclining block rate (IBR) pricing model shows a steep increase in its price and shows a considerable rating in electricity price over rest of the time. This paper combines both the RTP and IBR pricing models which leads to the much ensuring model of current flat rate tariffs. This model provides the recharging of the battery from the electric power grid during times of low electricity price and during peak electricity pricing the appliances draw power from the battery.

A smart meter is a modified or upgraded version of the conventional energy meter. It records utilization of electric energy in short intervals of time and sends the relevant details to the utility unit for scrutinizing and billing purpose. A bidirectional communication between meter and the central system is provided by smart meter. The Advanced Metering Infrastructure (AMI) is a technique incorporated by smart meter. This helps to reduce the monetary expense charged to customers in the real time pricing scenario. The following complementary features are assured in smart meter environment: it eliminates the risks and difficulties in the manual payment of bill at the EB office, it fetches details regarding updated pricing power utilization, it verifies accuracy and authenticity of bill.

VI. EXPERIMENTAL RESULTS

In this system four 100W bulbs are used as load. During the OFF peak time the consumer has the ability to turn ON all the four appliances without scheduling. Where as, during the peak time the scheduling unit will automatically turn OFF any one of the appliance to reduce the energy usage.

The electricity board maintains a database that records unit usage and bill amount of each consumer for a predetermined time interval. This information can be viewed as well as monitored by the customer from his PC. Such a methodology makes customer aware of the power usage in his house. This database is made available to the Real Time Pricing module to facilitate the scheduling.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

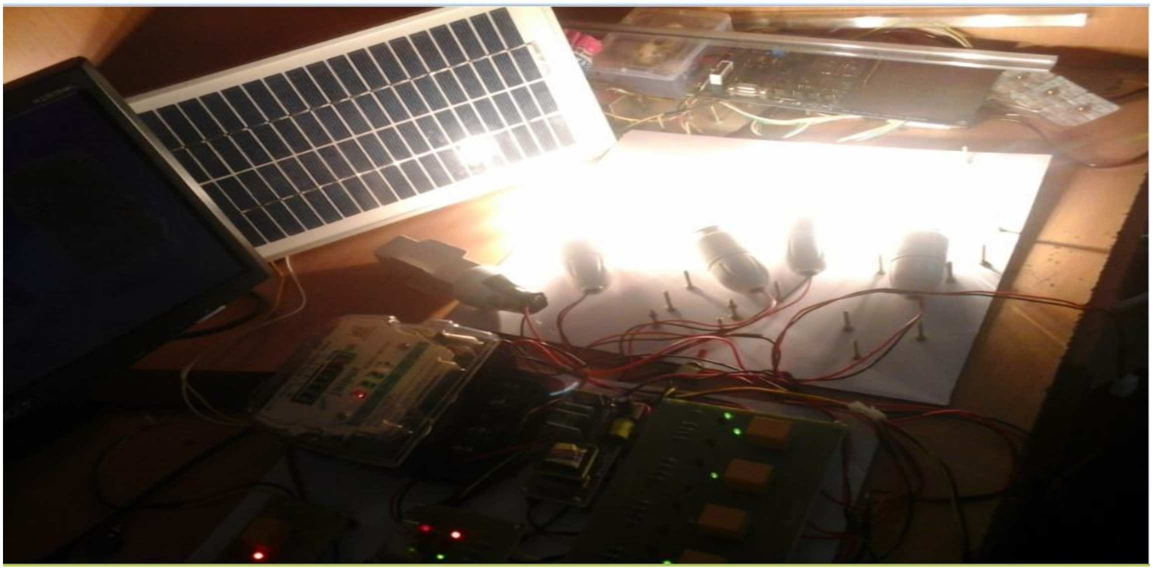

Fig. 2 Sectional View of Kit- OFF PEAK TIME

In the OFF peak time consumer has the ability to turn ON all the four appliances without scheduling, shown in Fig.2. But the switching between the power grid and solar power charged battery is done by verifying the threshold from the solar panel. If the panel outage is more than the threshold all load derives power from theat, otherwise the conventional grid itself is the source of power. But the scheduling unit has to consider many other factors like real time pricing information etc.

Fig. 3 Sectional View of Kit- PEAK TIME

In the peak time the scheduling unit will automatically turn OFF one of the appliance to reduce the energy usage, as shown in Fig.3. It can be any device preferred by the consumer interest. In the real time scenario the load connected will be variety of appliances like television, refrigerator, air conditioner, bulbs, fans, laptops etc. Depending upon the customer requirement the scheduling unit can be programmed, such that during peak hours the appliance that is turned OFF is of less significance regarding the residential customer. For instance a refrigerator can be opted to turn OFF during the peak time because it is of less relevance than bulbs, fans and AC. So before implementing the system there is an option for the customers to opt devices that are to be scheduled.

VII.CONCLUSION

An approach to addressing the optimal management of real-time pricing, inelastic and elastic energy demands, renewable energy generation, and energy storage to reduce the electricity cost for a residential customer in the smart grid is proposed in this paper. The intuition behind this approach is to use energy storage to harvest excessive renewable energy for later use and to charge the battery when the electricity price is low while discharging it when the electricity price is high. In this proposed system energy meter billing is automatic without human intervention and consumer can directly know the amount has to pay. If the units consumed by the user crosses certain utilization of the power automatically switch off the load connected to it. So that wastage of power in the households can be reduced. The methodology proposed in this paper is to store the excessively generated renewable energy for further use and thereby to charge the battery at times of low electricity price and simultaneously discharging them during peak pricing time to minimize the monetary expense.

REFERENCES

[1] Xiaodao Chen, Tongquan Wei, Shiyan Hu, “Uncertainty-Aware Household Appliance Scheduling Considering Dynamic Electricity Pricing in Smart Home,” IEEE Transactions On Smart Grid, vol. 4, no. 2, June 2013.
[2] Yuanxiong Guo, Miao Pan, Yuguang Fang, “Optimal Power Management Of Residential Customers in the Smart Grid,” IEEE Trans. Parallel And Distributed Systems,vol.23, Sep 2012.
[3] Megalingam, R.K.; Krishnan, A.; Ranjan, B.K.; Nair A.K.; , "Advanced digital smart meter for dynamic billing, tamper detection and consumer awareness," Electronics Computer Technology (ICECT), 2011 3rd International Conference on , vol.4, no., pp.389-393, 8-10 April 2011
[4] Palensky P. and Dietrich D., “Demand side management: Demand response, intelligent energy systems, and smart loads,” IEEE Trans. Ind. Informat., vol. 7, no. 3, pp. 381–388, 2011.
[5] Kim T. and Poor H., “Scheduling power consumption with price uncertainty,” IEEE Trans. Smart Grid, vol. 2, no. 3, pp. 519–527, 2011.
[6] Xiong G., Chen C., Kishore S., and Yener A., “Smart (in-home) power scheduling for demand response on the smart grid,” Proc. IEEE PES Innov. Smart Grid Technol. (ISGT), 2011.
[7] Mohsenian-Rad and Leon-Garcia A., “Optimal residential load control with price prediction in real-time electricity pricing environments,” IEEE Trans. Smart Grid, vol. 1, no. 2, pp. 120–134, 2010.
[8] Venayagamoorthy G., “Potentials and promises of computational intelligence for smart grids,” in Proc. IEEE Power Energy Soc. Gen. Meet.,2009.
[9] Pedrasa M., Spooner T., and MacGill I., “Coordinated scheduling of residential distributed energy resources to optimize smart home energy services, ” IEEE Trans. Smart Grid, vol. 1, no. 2, pp. 134–144, 2010.
[10] Oleg Gulich, “Technological And Business Challenges Of Smart Grids - Aggregator's Role in Current Electricity Market”, Lappeenranta University Of Technology, 2010.
[11] Kamat, Vithal N.; , "Enabling an electrical revolution using smart apparent energy meters & tariffs," India Conference (INDICON), 2011 Annual IEEE , vol., no., pp.1-4, 16-18 Dec. 2011.
[12] Palak P. Parikh, Mitalkumar. G. Kanabar and Tarlochan S. Sidhu, “Opportunities and Challenges of Wireless Communication Technologies for Smart Grid Applications”, IEEE International Conference, July 2010.
[13] Megalingam, R.K.; Krishnan, A.; Ranjan, B.K.; Nair A.K.; , "Advanced digital smart meter for dynamic billing, tamper detection and consumer awareness," Electronics Computer Technology (ICECT), 2011 3rd International Conference on , vol.4, no., pp.389-393, 8-10 April 2011.
[14] Kalogridis, G.; Zhong Fan; Basutkar, S.; , "Affordable Privacy for Home Smart Meters," Parallel and Distributed Processing with Applications Workshops (ISPAW), 2011 Ninth IEEE International Symposium on , vol., no., pp.77-84, 26-28, May, 2011.
[15] A. Kalirasu, and Shubhransu Sekhar Dash, “Implementation of an Embedded Controlled High Efficiency Improved Boost Converter for Solar Installation System” International Journal of Smart Grid and Clean Energy, vol. 2, no. 2, May 2013 pp. 177-183.
[16] Todd D, M Caufield, B Helms, M Starke, B Kirby, and J Kueck., “Providing Reliability Services through Demand Response: A Preliminary Evaluation of the Demand Response Capabilities of Alcoa Inc.” ORNL/TM-2008/233, Oak Ridge National Laboratory, Oak Ridge, Tennessee., 2009.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

BIOGRAPHY

N.NASLIN SITHARA is a PG scholar doing her M.E Applied in MaharajaEngineering College and she received B.Tech Degree with Honors in Electronics & Communication Engineering in Govt. Engineering College, Wayanad under Kannur University, Kerala in the year 2010.

V.SAMINATHAN completed his BE Degree in the year 2003 at Government College of Technology Coimbatore and ME in the year 2008 at Maharaja Engineering College and currently pursuing PhD at Anna University in the area of Low Power VLSI Techniques.