SMART DISTRIBUTION BOARD FOR ACTIVE LOAD SHIFTING FOR DEMAND SIDE MANAGEMENT APPLICATIONS

C C Majani and MTE Kahn

Cape Peninsula University of Technology, Cape Town, South Africa

ABSTRACT

Initiatives that are directed towards improving power management by a utility provider have to consider technical feasibility, socio-economic and the environment. Power consumption patterns world over indicate continuous rise in demand for electric power leading utility provider resorting to controlling the usage through actions of load shedding. Load shedding imposes inconveniences to the consumers since they are completely disconnected from the grid. This study considers a technique of implementing Demand Side Management (DSM) program to benefit the utility provider, the customer, the nation and the world by installation of a smart distribution board (Smart DB) at the consumer's point to enable utility company to selectively turn on or off, the appliances connected. The Smart DB will consist of electronic actuators connected to the switches of the various circuits to the appliances and controlled by signals transmitted from the utility provider with limited option to the consumer. Implementation challenges include the integration of the Smart DB into the existing system as well as initial replacement cost.

Keywords: **load shedding, selective, active shifting, DSM, smart DB**

1. INTRODUCTION

Improvements of power management by a utility provider have to consider technical feasibility, socio-economic and the environment. There has been an exponential rise in power consumption world over indicate due to increase in activities which demand usage of electricity. These activities include construction and property development, development of industries and infrastructure. The activities have resulted in strained the electric power production, whose development does not match the increase in demand. A case to consider is Eskom, a government authority mandated to generate, transmit and in some cases, distribute power in the Republic of South Africa [1]. The demand for power has far surpassed the generation capacity, leading to the utility provider resorting to controlling the usage of energy through actions of load shedding. The country is one of the most industrialised in Africa and is extremely energy-intensive due to lack of awareness of energy efficiency and demand side management. Also the low cost of electricity previously contributed to poor financial viability of energy reduction projects [2]. Load shedding imposes inconveniences to the affected consumers by completely denying them access to electrical energy, at times for unpredictable periods of darkness.

Introduction of electrical energy management in industrial sector is the effective method of minimising the energy consumed by industries as well as for improvement of reliability of power supply system of the Power Supply Industry. However, in this study, electrical energy management is to concentrate on selective (discriminative) shedding of the load in homes by the energy provider as a way of stabilising the demand. This will involve the energy provider sending signals to disengage certain appliances from the supply especially during peak energy demand times. It will be necessary for the consumers to install a Smart distribution board (Smart DB). The Smart DB will have electronic actuators connected to the switches of the various points to the appliances. These actuators are controlled through signals transmitted from the utility provider. The point of departure of the Smart DB compared with traditional ones is that the utility provider can activate the selective switching of the appliances connected from a remote centre.

2. BACKGROUND

Demand-side management (DSM) is related to investments that are directed towards energy efficiency and load management [3] so as to improve performance of energy supply facilities, thereby reducing the requirements for new facilities, and to more efficiently assign available energy resources for greater benefits for the national economy. The current increasing costs of fossil fuel have made electricity production to be expensive. This has set the platform for Power Utilities to seek alternate strategies such as investment into renewable energy technologies and work towards optimising demand side consumption. [4] The goal of DSM is to cut on the consumption of energy, an act that is bound to reduce the profits for utility. At the same time, it is a considered duty for the energy providers to make profit [5]. This calls for a balancing act by the utility company so as not to compromise the 'business oriented profit making goal' and implementation of energy reduction strategies. DSM programme acts as a "tool-box" for utilities and governments in their work to make energy systems more suited to their purpose [6]. Furthermore, there have been many changes in the organisation of the energy markets in the world and the DSM programme has accordingly been adjusted in order to cater for the actual and changing circumstances.

Globally electric utilities are always seen in terms of power plants including generators and transformers with the aim of providing electrical energy for use by the consumers. Nevertheless, utility providers have diversified their operations by formulating policies and strategies that are geared towards reducing consumption of energy by their consumers. One of the major problems encountered by an electric utility is determination of the actual manner of energy consumption over a period of time. Accurate load forecasting is paramount since it results to more effective demand side management [7]. The utility planning and strategic corporate objectives (of realising maximum earnings and cash flow, reduction of risks are affected by the behaviour of the load [8]. Some of the ways in which these objectives are realised include peak clipping, load shifting and energy conservation. This calls for investigation of energy consumption to be undertaken in conjunction with the general shape of its load and the variation of this shape during the year [4].

Energy conservation has become a major concern in many countries of the world and the policy makers are faced with the challenge of identifying the best way to promote efficient use of energy by consumers. Some of the countries with high energy prices and taxes aver that the market forces are sufficient economic incentives for energy conservation, and therefore the intervention by governments or states needs to be in areas of doing away with impediments of market mechanisms and/or providing consumers with information regarding benefits of conservation [10]. Studies have been carried out to examine the reasons of running programmes that assist consumers in keeping in check their electricity bills. Utilities began to seriously run DSM programmes in the early eighties as a result of the oil embargo imposed by the Arab nations [11]. With the increase in the world population, energy demand in both developed and developing worlds has continued to rise. This demand has put strains on the energy utility providers and at the same time, it has presented technological challenges that can lead to reduction of specific consumption [12], [13]. DSM option is more attractive where the demand for electricity grows faster than the generation capacity and in an environment in which the utility provider is faced with limited financing options [14].

The major categories of Demand Side Management are shown in Figure 1. The topology or the DSM technique applied has an impact on the energy use, which effectively contributes to safeguarding the environment, reducing greenhouse gas emissions, promoting sustainable use of energy resources and reducing energy costs. The other benefits derived from DSM include reduced demand during peak periods, rescheduling requirement for infrastructure capital investment, reduced costs in electricity, consumer choice from a range of electricity efficient options to implement and hence benefit financially.

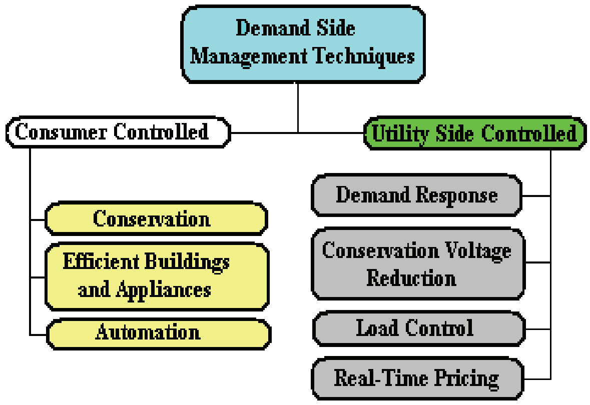

Figure 1: Categories of demand side management techniques

2.1 CONSERVATION

In this method of DSM the consumer is provided with information on ways that will lead to either less energy utilisation or usage of energy in a less expensive manner. Conservation programs that include media advertising or inserts. The programs are essential in building a positive image with consumers. More importantly, they serve as effective relationship builders and marketing tools, providing a way for utility representatives to meet with and see the facilities of consumers who might be candidates for other services or products [15]. In fact, Lombard C. *et al* [16] correctly identify promotion and education as one of the four actions that need to be emphasised on and incorporated into the development plan of a utility. However, the success of this programme largely depends on the willingness of the consumer to participate. The evaluation problem arises due to the difficulty in the decision taken by the consumer after such education has been provided. The option of implementing the strategy lies squarely with the consumer.

2.2 CONSERVATION VOLTAGE REDUCTION

This option of DSM allows utility company to lower the voltage on the distribution circuits feeding homes and businesses to the lowest value that will not harm equipment or make it perform poorly. This would seem to be a better option since the connected consumers will still continue to receive a measure of electrical power. However, the efficiency of the machines using lower voltages will be compromised, and at the same time, equipment(s) that is/are sensitive to voltage fluctuations may malfunction during the times that the power has been reduced.

2.3 AUTOMATED DEMAND RESPONSE

This is DSM programme is motivated by a need to reduce peak demand cost saving. The utility company sends out economic or emergency request. The economic request indicates that the cost of electricity at that time is above the agreed amount between utility and consumer while the emergency request is when the utility's reserve capacity is critically low. The response for the later request is mandatory.[17] According to Sioshansi F *et al* [18], the success of Demand Response lies in the ability to encourage some consumers to forego their electricity usage in capacity-constrained systems in order that others may continue to be served by the utility provider. This implies that the targeted consumers have elastic or discretionary demand and have to be enticed to forego usage of energy during those periods that the capacity on the utility is constrained by the demand. The DR programs are best suited for networks that are "over-subscribed" during a significant number of hours.

2.4 LOAD CONTROL

There are two ways in which the control of load at the consumer's side can be achieved. One method involves the control of many appliances from a central location (the electric utility in consultation with the consumer) to manage their usage, dropping the demand at peak and allowing the electric system to serve more homes with less peak energy output. The other method is to send information to the consumer regarding the prevailing situation; the consumer is then expected to take action within a stipulated time [19]. Just like other techniques discussed, the utility provider has to liaise with the consumer, and only when the capacity can not support the demand is when the utility provider can decide to completely remove some of the consumers from the grid. To this consumer it is no longer 'load control' but 'energy denied'. The technique suggested will allow this consumer to still have supply of energy to certain appliances as the utility provider selectively off loads others.

2.5 REAL-TIME PRICING

In this program, the utility installs a 'smart' meter on the home or business that communicates with the utility's control centre to obtain the current 'price' for power. The consumer's computer checks when the price is higher, it shuts down the appliances until the price level drops to the set value. Real-time pricing programs have the potential to overcome some of the limitations of behavior modification incentives present in other DSM techniques [20]. As suggested by Corner W.G. [21], when a consumer's 'pocket' is affected, he is capable of changing his energy usage pattern, leading to implementation of new on-site controls. Additionally the consumer will be motivated to replace the less efficient equipment and facilities in order to realise some savings. Although this alternative DSM technique is pro-active, it has the drawback of initial capital cost of installation of the equipment to monitor the pricing. Demanding constant monitoring of the system imposes an inconvenience to the consumer, who may see the system as restrictive rather than a solution.

2.6 EFFICIENT BUILDINGS

This category of DSM calls for design measures that keep buildings naturally warm during winter season and cool during summer season. The design and implementation cost of this category may seem to be high in short term. However, the long term benefits will be derived by both the utility provider (less energy use) and the consumer (less electricity bill to pay).

2.7 EFFICIENT APPLIANCES

This programme requires that appliances such as motors, air conditioners, lights etc, be designed with characteristics of reducing the energy consumption and minimising energy wastage. As Philipson, L et al note [22] the cost of efficient appliances is moderately high, though the benefits obtained in using these appliances far outweighs the effect of the initial cost. An innovative design of a ceiling fan by Schmidt, K et al [23] is an addition to other designs of energy efficient appliances that can be used in DSM programmes.

While discussing the future of DSM in the US, Hirst, E et al [11] observed that measuring the performance of DSM programmes presents a challenge of making comparison of energy behaviour shown by the programme participants with the non-existent behaviour that the participants would have exhibited if they did not participate in the programme. They identified three factors that would make future DSM programmes succeed as technical cost-effective energy efficiency improvements, changes in the regulatory practices under which utilities operate and incentives offered by the utility providers.

Energy management programmes are usually initiated by the utility provider for the purpose of minimising the demand during peak hours. Most of them are implemented by the consumers on a voluntary basis. In case these strategies fail in reducing the demand at peak times, the utility provider is forced to completely disconnect some of the clients from the network. A proposed strategy is to initiate a mechanism that gracefully (selectively) disconnects appliances so as to control the power consumption when the demand surpasses the capacity of the utility.

3. PROPOSED TECHNIQUE

Introduction of electrical energy management in industrial sector is the effective method of minimising the energy consumed by industries as well as for improvement of reliability of power supply system of the Power Supply Industry. A typical load profile for a utility provider in South Africa is shown in Figure 2.

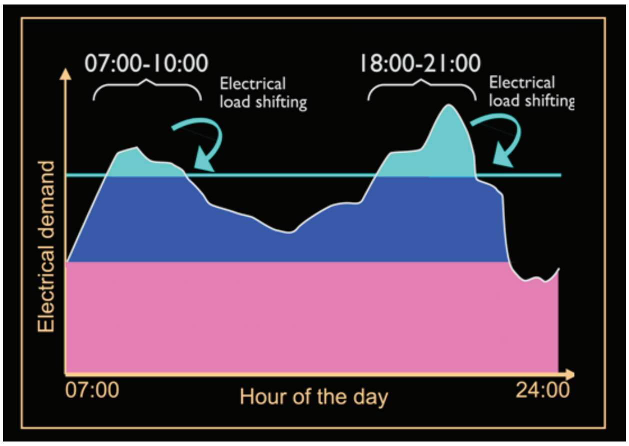

Figure 2: Typical load profile for utility provider

The load profile indicates two time periods 07h00-10h00 and 18h00-21h00 when there is peak demand for energy from the utility. These time periods are candidates for selective load shedding so as to shift the load to the times within the valley (off-peak). This will involve the energy provider sending signals to disengage certain appliances from the supply during peak energy demand times. A smart DB will be installed at the consumer's side. The Smart DB will have electronic actuators connected to the switches of the various circuits on the distribution board to control the on off conditions of the appliances. These actuators are controlled through signals transmitted from the utility provider. The actuators can be activated remotely from the utility provider's side or by the consumer to disengage their respective switches. However, activation from the utility provider's side overrides any attempt or effort by the consumer to change this state. This precaution is necessary to avoid the consumer switching on the appliances, and thereby defeating the main objective of DSM programme. Figure 3 illustrates the way signals are sent from a central point (utility company).

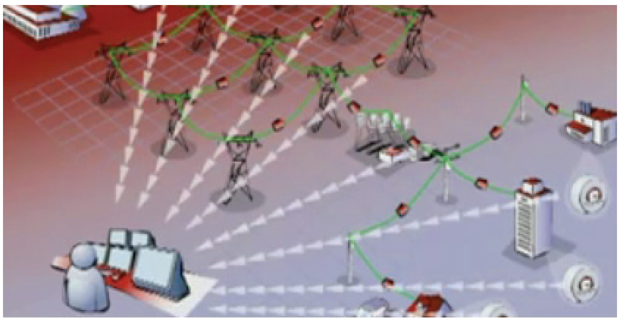

Figure 3: Signals transmitted from a central point to the smart SB

3.1 BENEFITS OF THE NEW TECHNIQUE

The utility provider will benefit by having control and efficient management of the energy produced through active shifting of the load. In order to take care of the peak periods without effecting load shedding actions, the utility provider has to construct new standby plants. These standby plants lie idle for long periods of the day, only being put into action during peak demand. The utility provider can defer the need for construction of standby plants and instead, use signals to selectively apply load shedding that takes care of the peak periods. The consumer will benefit through graceful load shifting in case the demand requires load shedding action. This will be achieved through selective load shifting technique. The nation and the world will benefit through conservation of environment. Figure 4 shows the emissions that come from electric power stations. These emissions have far reaching effects on the environment. Deferment of construction of new plants avoids emission of gasses that can lead to global warming effect.

Figure 4: Carbon emissions by electricity generating plants

3.2 CHALLENGES OF IMPLEMENTING SELECTIVE SHEDDING TECHNIQUE

The challenges that need to be faced when implementing the technique of selective load shedding include the integration of the Smart DB into the existing system and initial cost that will be required to be met as the traditional power distribution boards are replaced by the Smart DBs. In addition, there will be a need for a new legislation to be put in place, requiring use of the Smart DB in any new construction. Need for high frequency bandwidth for signal transmission to individual consumer. With a large data base of consumers appropriate frequency allocation technique is required. To reduce cost of wireless transmission will be an option of using existing utility transmission lines as communication channels.

4. CONCLUSION

The ever increasing demand for electrical energy and the need to conserve the environment imposes challenges to both developing and the developed countries of the world. It is imperative that new and improved energy technologies have to be developed and applied in order to achieve cleaner and more efficient forms of energy production and consumption. The new and improved technologies have to consider changes in the trajectory of the energy sector in several ways; enabling it to deliver better services, become more efficient, and be responsive to environmental matters such as air pollution and global climate change. The proposed Smart DB is not a stand alone topology, but it has to be incorporated within the wider family of other DSM programmes. The programme has appealing advantage of graceful denial of electric power to the customer in the event that such action is necessary. This is possible through installation of a Smart DB at the consumer's side, to replace the current distribution board. The utility provider benefits by having control and efficient management of the energy produced through active shifting of the load. The consumer will benefit through graceful load shifting in case the demand requires load shedding action. In addition, with some modification, the Smart DB can form the base for Home automation. In this case the consumer can control the power consumption via the internet. There is a possibility of the Smart DB facilitating automatic meter reading for purposes of billing the consumer. The nation and the world will benefit through conservation of environment. Deferment of construction of new plants avoids the emission of gasses that would affect the effect of global warming. Despite the benefits of implementing this strategy, it may be seen as a punitive measure. There are foreseen challenges that have to be addressed if the technique of selective load shifting is to be implemented. Among the challenges is the integration of the Smart DB into the existing system. Also there is an initial cost that will be required to be met as the old distribution boards are replaced by the Smart DBs. In addition, there will be a need for a new legislation requiring use of the Smart DB in any new construction. Nevertheless, it is better to be pro-active rather than reactive in implementing efficient and effective DSM programmes in order to safeguard collapse of the generation system. It is on record that by 1996, South Africa had over-capacity of energy and yet the current scenario demands aggressive promotion and implementation of DSM programmes to curb the spiraling energy demand. The Smart DB can be implemented so as to benefit the consumer, utility, the country and the world at large.

5. REFERENCES

[1] "S.A: ESKOM's Massive Investment Hits New Snag" *The Electricity Journal*, *Volume 21, Issue 7*, *August-September 2008*, *Pages 24-25.*

[2] Eskom. The SA Demand Side Management Programme-*an Operational Guide for Energy Services Companies*. http://www.eskomdsm.co.za/pdfs/DSMOperGuideESCos150207.pdf

[3] Ashok, S. Banerjee, R. "Load management Applications for the industrial sector" *Applied energy,* Vol. 66, 2000:105-111.

[4] IIEC. Demand Side Management Best Practices Guidebook for pacific island power utilities, July 2006:3.

[5] Lee, D.K. Sang, Y. P. Soo, U.P. Development of assessment model for demand-side management investment programs in Korea. *Energy Policy* 35 (2007) 5585-5590.

[6] Pete, S. An Overview of International Energy Agency Demand Side Management Program Task XIII: Demand Response Resources Prepared For: *Federal Energy Regulatory Commission's Technical Conference on Demand Response and Advanced Metering* 2006:2.

[7] Ali A, Islam, S.M. Demand side management for remote area power supply systems incorporating solar irradiance model. *Renewable Energy* 29 (2004) 2027-2036.

[8] Schaefer, J. Cost-benefit analysis of energy management research, EPRI selected papers on Demand-Side Management, June 1985.

[9] Mitropoulos, S. Assimakopoulos, V. Charalbidis, Y. Two-dimensional colour pattern load analysis: A tool supporting demand-side management. *Decisions Support Systems* 13 (1995) 159-166.

[10] Sioshansi, F.P. Restraining energy demand: The stick, the carrot, or the market? *Energy Policy* 1994 22 (5) 378-392.

[11] Hirst, E. Cavanagh, R. Miller, P. The Future of DSM in a restructured US electricity industry. *Energy Policy* Vol.24 (4) 1996 303-315.

[12] Marechal, F. Favrat, D. Jochem, E. Energy in the perspective of the sustainable development: The 2000 W society challenge. *Resources Conservation & Recycling* 44 (2005) 245-262.

[13] Rankin, R. Rousseau, P.G. Demand side management in South Africa at industrial residence water heating systems using in line water heating methodology. *Energy Conservation and Management 49 2008 62-74*.

[14] Boyle, S. DSM progress and lessons in the global context. *Energy Policy* Vol.24(4) 1996 345-359.

[15] Gerling, K.L. Can Yesterday's Demand-Side Management Lessons Become Tomorrow's Market Solutions? *The Electricity Journal* Vol.15 Issue 5 (2002) 63-69.

[16] Lombard, C. Mathews, E.H. Kleingeld, M. Demand-Side Management through thermal efficiency in South African houses. *Energy and Buildings* 29 (1999) 229 – 239.

[17] Jordan, S. Load Shedding Leads to Major Savings. Buildings October 2007 page 30.

[18] Sioshansi, F.P. What Could Possibly Be Better than Real-Time Pricing? Demand Response. *Electricity Journal* 2001 39-50.

[19] Saini, S. Conservation V. generation: The significance of Demand Side Management (DSM), its tools and techniques. *Refocus*. Vol 5(3) May-June 2004 52-54.

[20] Chapman B, Tramutola T. Real-Time Pricing: DSM at Its Best?. *Electricity Journal* 1990 40-49.

[21] Conner, W.G. The Information Age Meets Demand-Side Management. *Electricity Journal* 1990 50-55.

[22] Philipson, L. Willis, H.L. n.d Understanding Electric Utilities and De-Regulation. 2nd Ed. Found at http://books.google.com/books?id=BLSxrV7BATAC&pg=PA143&dq=Demand+Side+Management+of+electric+energy&sig=L5jrxhfP5HlFDGrDSB4oyUSZUp0#PPP1,M1

[23] Schmidt, K. Patterson, D.J. Performance results for a high efficiency tropical ceiling fan and comparisons with conventional fans: Demand side management via small appliance efficiency. Renewable Energy 22 (2001) 169-176.

6. AUTHORS

Principal Author: Charles C Majani completed his BTech in Electrical Engineering at Cape Peninsula University of Technology in 2007. He is currently pursuing MTech at CPUT.

Co-author: MTE Kahn is a Professor of Electrical Engineering at Cape Peninsula University of Technology. He is a lecturer in Electrical department and he supervises DTech, MTech and BTech projects. He is also the head of Centre for Distributed Electronic Systems.

Address

Cape Peninsula University of Technology
P. O. Box 1906
Bellville
7535 Cape Town

Presenter: The paper is presented by Charles C Majani.