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Conference Paper · August 2010

DOI: 10.1109/PES.2010.5589589 · Source: IEEE Xplore

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Demand Side Management and Load Control – An Indian Experience

Subrata Mukhopadhyay, *Senior Member, IEEE*, and Ashok K. Rajput

***Abstract*—In the Indian power scenario Demand Side Management or DSM as popularly known has assumed a significant role in the recent five-year plans. Over the years power development has seen generation addition manifold along with expansion in transmission and distribution system. Optimum utilization of resources in overall sense, however, calls for managing the demand also for proper capacity utilization. This is valid even when both energy and peak shortage exists. More of course will be the pressure when the former is significantly reduced, but the latter is present, thus calling for efficiently managing the system instead of addition in facilities. Besides this, reduction in losses both in terms of power and energy or in other words enhancement in efficiency in load vis-à-vis associated delivery system is further an important step in DSM. Indian power sector has realized these aspects, estimated benefits accruable, and taken steps to achieve success.**

***Index Terms*—Demand Side Management, EHV, Energy Conservation, Energy Shortage, HVDC, Peak Shortage, and Time-Of-Use Tariff.**

I. Introduction

INDIAN power sector starting from a meager 1,360 MW of scattered generation in and around urban agglomeration at the time of independence in 1947 [1] today has reached a level of about 154GW (October 2009) and associated transmission and distribution system with highest voltage level of transmission of 765kV in ac and ±500kV in dc, with distribution ultimately at 3-phase, 400V. During the journey progressively it has incorporated thermal sets from few MW to 660MW and hydro units up to 250MW. State grids came up during fifties and sixties. It was followed by the formation and consolidation of regional grids with the setting up of regional power stations in seventies and eighties. Gradually these regional grids too were connected starting from Eastern with North-Eastern, then with Western, and Northern, thus making it a reality and quantum jump towards formation of National Grid. Only Southern one of the five grids remains asynchronously connected with a long distance HVDC bulk power transmission line to the rest.

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Importance to add generation to cope up with the rising demand for an economically developing country like India was inevitable initially. In order to avoid bottleneck in evacuation and delivery of power, rapid expansion in transmission and distribution drew attention subsequently. However, the journey has not been smooth always. Rehabilitation and resettlement consequent to harnessing of hydropower, environmental pollution to populous places like cities on account of setting up thermal projects, stringing up of EHV transmission lines through forest, etc. have become the constraints that slow down the progress in the overall development of power. All these aspects for the sake of economy, therefore, call for optimum utilization of resources for generation, delivery mechanism as well as efficient use of electricity. This is required otherwise too on account of the fact that most of the sources of energy are not going to last forever. So efficient usage not only allows for going over longer period of time, but also for exploiting other sources of energy which are perennial or renewable in nature.

In this context the importance of management of both, supply side and demand side, has been realized. Unlike other commodities, with the electricity there is a serious problem. Till now it cannot be directly stored in bulk until and unless one is ready to spend exorbitant price for that. In one word it is not affordable. Hence is the requirement of supply side management as well as demand side management at every instant of time. Equipment and associated hardware may be on stress if not always but on various periods to cope up with the demand which is varying every moment, until and unless load is managed well. At the same time additional generation, transmission and distribution capability, if available, may remain unutilized during certain points of time which is not desirable from economic considerations.

In India in the light of the above mentioned issue, due importance has been given in the recent five-year plans to Demand Side Management (DSM) for the optimum utilization of resources basically considering two aspects. Firstly, it is by shifting various types of loads in the periodical cycle to reduce the peak, and then secondly by the efficient usage of electricity so supplied through measures that lead to energy conservation.

II. Definition And Objective

As per the objective stated by the Ministry of Power, Government of India [2], Demand Side Management is used to describe the actions of a utility, beyond the customer's meter, with the objective of altering the end-use of electricity - whether it be to increase demand, decrease it, shift it between

978-1-4244-8357-0/10/$26.00 ©2010 IEEE

high and low peak periods, or manage it when there are intermittent load demands - in the overall interests of reducing utility costs. In other words DSM is the implementation of those measures that help the customers to use electricity more efficiency and it doing so reduce the customers to use the utility costs. DSM can be achieved through.

- Improving the efficiency of various end-uses through better housekeeping correcting energy leakages, system conversion losses, etc,
- Developing and promoting energy efficient technologies, and
- Demand management through adopting soft options like higher prices during peak hours, concessional rates during off-peak hours seasonal tariffs, interruptible tariffs, etc.

DSM, in a wider definition, also includes options such as renewable energy systems, combined heat and power systems, independent power purchase, etc, that utility to meet the customer's demand at the lowest possible cost.

Hence DSM can be achieved through energy efficiency by reducing energy consumption on the one hand and on the other hand by managing the load demand itself. The first may be achieved through awareness on use of energy efficient equipment on the part of consumer. Thus it leads to conservation of energy. However, the latter calls for reduction in power demand or shifting it to off-peak hours. This can be achieved with utility providing incentive like time-of-use tariff giving rebate during off-peak. Of course utility has a leading role always through its actions that effect quantity or pattern of energy consumption by the consumer through reduction of drawl during peak period. This will in turn help the utility to reduce investment for generation vis-à-vis transmission and distribution, as the case may be.

In fact power shortages have resulted in voltage fluctuations, frequent load shedding, and installation of captive generation. DSM which aims at reducing peak demand, shifting of demand from peak to off-peak period and strategic conservation of energy through end-use energy efficiency, can mitigate power shortage and drastically reduce capital needs for capacity expansion. Some time back World Bank assessed a saving potential of over 25,000 MW through Demand Side Management. The major activities in this regard include energy conservation in industry and commercial sectors, replacement of agriculture pump sets, municipal water pumping efficiency, power factor correction, domestic lighting, introduction of time-of-use-tariff and fixing of standards and labelling on major electricity consuming appliances.

III. Various Issues On DSM [3]

The Indian economy is primarily agriculture based. Government has accorded high priority to rural electrification plans and a massive investment has been made in electrifying half a million villages spread over the country. Millions of agriculture pumps have been installed. Most of these pumps are working inefficiently. Govt. of India (Ministry of Power) has given subsidies up to 80% for various schemes on retrofitting of agricultural pump sets in different states. Due to subsidized electricity available to this sector, all efforts to improve the performance of these pump sets have not succeeded. Various strategies for promotion of energy conservation in agriculture, therefore, require both legislative and promotional support. These include massive awareness campaigns, training of management and operating personnel, appropriate pricing of electricity supply including metering and priority to new consumers willing to put up new meters while seeking connection for pump sets. Meanwhile, large number of pump sets connected to the grid in all states needs adequate level of supervision on design, testing, rectification/ replacement for their efficient operation.

Integrated rural management schemes, which combine investments in rural distribution system along with pump sets programs, would increase the benefits. In fact for the last 5 years, Govt. of India has encouraged various schemes giving effect to improvement of efficiency in the power system. Subsidies varying from 50% to 80% have been given to different utility/ implementing agency for pilot projects on power system audits, load management schemes, development of single-phase high voltage distribution system, installation of amorphous core distribution transformers and different R&D schemes giving effect to energy conservation. Government of National Capital Territory of Delhi has issued a Gazette Notification, dated September 28, 2006, regarding Mandatory use of Compact Fluorescent Lamps (CFL), Electronic Chokes in Government Buildings and Solar Water heating systems, ISI marked Motor Pump sets Power Capacitors & reflex valves etc. for various types of energy consumers for efficient use of energy & conservation. All states are advised to take similar measures to encourage demand side management.

A. DSM Measures and Approach

Demand Side Management (DSM) is the process of managing the consumption of energy, in order to optimize available and planned generation resources. DSM programs consist of the planning, implementing, and monitoring activities of electric utilities that are designed to encourage consumers to modify their level and pattern of electricity usage.

Demand Side Management can be explained as “actions taken on the customer's side of the meter to change the amount or timing of energy consumption. Utility DSM programs offer a variety of measures that can reduce energy consumption and consumer energy expenses. Electricity DSM strategies have the goal of maximizing end-use efficiency to avoid or postpone the construction of new generating plants."

Technologies adopted for Demand Side Management may include one or more of the following: Leveling of Load curve, Load management, consumer benefit oriented public participation program, tariff measures (Time-of-Use Rates), Power Factor based Charges, Real-Time Pricing etc.

B. Benefits of DSM

The benefits of DSM to consumers, enterprises, utilities, and society can be as:

- Reduction in customer energy bills.

- Reduction in the need for new power plant, transmission, and distribution network
- Stimulating economic development.
- Creating long-term jobs due to new innovations and technologies
- Increasing the competitiveness of local enterprises.
- Reduction in air pollution.
- Reduced dependency on foreign energy sources.
- Reduction in peak power prices for electricity

C. Approaches to DSM Program

Various approaches can be adopted to achieve benefits of Demand Side Management as:

- General information programs for customers about energy efficiency options.
- Information programs about specific DSM techniques appropriate for industry
- Financing programs to assist customers to pay for DSM measures
- Turnkey programs that provide complete services to design, finance, and install a package of efficiency measures at the consumer end.
- Alternative rate programs by the utilities like time-of-use rates and interruptible rates to shift loads to off-peak periods.
- Schemes and incentives to invest in energy conservation and efficiency programs
- Incentives for new innovations and technologies for Load Response/Load Management Programs.
- These DSM programs and policies can be promoted and implemented at different levels of the society as:
    a) Government policies and regulations
    b) Utilities programs
    c) Customer participation.

Each of three components described above has its own significant role to play. For optimum results coordinating the role of all the three is a must. Government agencies can make various policies and regulations, provide subsidies for these programs and Utilities can implement these more effectively through different cost-effective and customized programs in coordination with the end-users i.e. the consumers.

D. DSM Programs Strategies

The following strategy may be adopted to design and implement DSM program:

- Identify the sectors and end-users as the potential targets
- Visualize the needs of the targeted sectors
- Develop the customized program
- Conduct analysis for cost-effectiveness
- Prepare an implementation plan to market/promote the program
- Implement programs

E. Demand Side Management in India

- India currently faces a peak capacity shortage of about 13% and approximately 10% of the total energy demand is left un-served. Chronic power shortages have resulted in voltage reduction, involuntary load shedding and installation of captive generation.
- The increased electricity end-use efficiency and Demand Side Management (DSM) can mitigate power shortages and drastically reduce capital needs for power capacity expansion.

DSM can be achieved through energy efficiency, which is reduction of kilowatt-hours (kWh) of energy consumption or demand load management, which is a reduction of kilowatt (kW) of power demand or displacement of demand to off-peak times. For practical purposes DSM could cover all sorts of activities which will help a utility in:

a) reducing peak demand
b) shift demand from peak to off-peak period
c) End-use energy efficiency to reduce overall demand of electricity.

In other words, utility driven end-use efficiency and load management is considered as DSM.

F. DSM Potential in India

All India Saving Potential from DSM according a study few years back shows peak saving ranges from 837 to 4,904 MW and energy saving from 3,311 to 17,852 GWH under various options, such as, Variable Speed Drives in Industry, Agricultural Pump Rectification, Motor Rewinding, Downsizing, Agricultural Pump Metering, High-Efficiency Agricultural Pump sets, Improved High-Efficiency Refrigerators, Compact Fluorescent Lamps and Electronic Ballasts.

G. Barriers to DSM

- Skewed tariff ranging from almost free electricity to farmers, low tariff to domestic consumer to very high tariff to the industrial customers.
- Cross-subsidy from industry and commercial customers to agriculture and domestic customers.
- Lack of knowledge or awareness both in utility and among the consumers.

H. Issues in Implementation of DSM

- Utilities may not support any activities for strategic energy conservation among industrial and commercial customers loss of revenue from the high paying customers.
- Agriculture water pumping though has potential of over 40% energy saving through end-use efficiency in water pumping, does not attract the market for investment given nil to low tariff, Agriculture DSM, however, could be one of the major gaining areas for the utilities.
- Nil to inadequate penal provision in most of the utilities do not enforce power factor correction, by and large.

I. DSM Measures Likely to Receive Support

In the background of skewed tariff and unwillingness on the part of the utilities to promote energy efficiency among the high paying consumers, viz. industries and commercial,

following DSM activities are likely to receive support from Utilities.

J. Agricultural Sector DSM

Inefficient use of energy in the agriculture sector can be the corner stone of utility driven DSM strategy. This will require not only replacement of pump sets and the entire pumping system with an encouraging Energy Service Companies (ESCOs) to take up the same in an agreement which will involve Utility as well as farmers for a sustainable result. Reasonable tariff on agriculture will further give boost to agriculture DSM.

K. Municipal Water Pumping

Municipal water pumping is highly inefficient in India. The potential for saving is estimated to be over 30 to 40%. The investment in replacement of pumping system and plugging leakages could save energy over 40% with low pay back period. Thus this could be implemented in all the major municipalities through performance guarantee contract mechanism by ESCOs.

L. Power Factor Correction

Notification for penalty for low power factor or incentives for near-unity power factor for all the HT consumers and LT commercial/individual consumers will give significant gains in terms of energy savings to the utilities. Such notification will help in developing market to make investment on performance contracting mechanisms.

M. Time-of-Use Tariff (TOU)

Introduction of Time-of-Use Tariff will incentive energy intensive HT customers to shift activities/part activities to off-peak period to take advantage of low tariff. This can give a very major gain to utilities to reduce peak demand. However, to introduce TOU tariff requires tri-vector meters and a complete computer software and hardware to manage the same.

N. Water Pumping in High Rise Buildings

Water pumping in major buildings is very energy in-efficient. The utilities could promote energy efficient pumping system through notification and promote implementation through market mechanisms.

O. Domestic Lighting

Lighting loads generally coincide with the peak demand of the utility. Hence targeting lighting efficiency improvements would be in the interest of the utility to reduce peak demand and strategic conservation reducing overall average consumption of the utility. The latest lighting technologies utilizing compact fluorescent lamps, fluorescent tube lights with electronic chokes would need to be encouraged for domestic sectors.

P. Action plan

Energy efficiency in industry and commercial clients will be promoted by Bureau of Energy Efficiency (BEE) as required under the Energy Conservation Act and this activity will obviously not receive adequate support from utilities, similarly for the residential customers, energy efficiency in lighting, heating, cooling and ventilation will be promoted through the process of Standards & Labelling action for utility driven DSM activities in the country. The action plan could be:

- To make each and every utility set up DSM Cell and take up load research, and prepare an action plan for agriculture DSM, energy efficiency in municipal water pumping and domestic lighting, introduce Time-Of-Use (TOU) tariff, introduce notification for power factor correction etc.
- BEE will help the utility in setting up DSM Cell.
- BEE will help in conducting feasibility studies and designing agriculture DSM project for few areas for implementation through market based mechanisms.
- BEE will help the utilities in project designing for energy efficient municipal water pumping system and for domestic lighting to be implemented through market based mechanism.
- BEE will do capacity building among the utility staff.
- BEE will also develop capacity among the regulators who could mandate utilities to mainstream DSM in their activities.

IV. Various Issues On Energy Conservation [3]

Similarly on the other hand possibility of energy conservation may be looked sector-wise, namely, in industrial, agricultural, commercial and residential sectors as detailed below.

A. Industrial Sector

Industry that consumes over half of the commercial energy intensity of Indian Manufacturing sector is comparatively high. Relatively small number of sub-sector constitutes 75% to 80% of energy consumption in industry. Accordingly potential for saving energy in the industrial sector varies from 10 to 25%. There is wide variation in energy consumption as noticed in the industrial sector. Energy efficient units have been improving their efficiency year after year. For sustainability of efficient use of energy and its conservation it would need corporate commitment possibly through ISO 1400X or other similar international certifications, which focus on energy reduction. Also lack of faith by industry with energy auditors need to be addressed. It could be by developing a professional accreditation of energy auditors. Promotion of performance based energy efficiency projects and development of energy service-company would bring in accountability and credibility to efficient use of energy and its conservation among end users. Since there is a wide variation in specific energy conservation within the similar industrial groups, it would be necessary that sector-wide associations take a lead in evolving voluntary energy consumption norms through exchange of information and effect improvement through dissemination of best practices followed by leaders.

B. Agricultural Sector

While looking at energy conservation in agricultural sector, it may be noted that out of the total irrigated land in India, about 50% is covered by lift irrigation irrigated through about 18 million pump-sets. Out of this, about 60% of the pump-sets are driven by the electric motors and rest by the diesel engines. Over 30% of total power generation is consumed in agricultural sector. About 0.6 Million electric pump-sets are added every year and annual average electricity consumption is around 90 million kWh. Use of low resistance foot valve and low friction suction pipe of proper diameter, pump of higher efficiency, motor of lower rating are some of the remedial measures. This requires rectification on a sustainable manner to improve existing pump-sets through performance contract mechanism on one hand, and on the other evolving energy consumption standards for various components and the system and enforce them in respect of new stock of irrigation pump-set.

C. Commercial Sector

Electricity is the major energy used in commercial sector, end-uses being lighting and air conditioning. Energy audit studies conducted in hotels, hospitals and office buildings reveal that improving HVAC systems and lighting system can achieve an average 15-20% energy savings. Besides these factors, location, building envelope and other factors affect the energy consumption in the commercial buildings. Hence there is an urgent need to evolve standards for energy consumption for these individual equipment and services under the overall code for buildings or specifically through Energy Conservation Building Codes, development performance-based contracts for reducing energy consumption in institutional and Government buildings, introduction of minimum energy consumption and performance standards for equipment such as HVAC, lighting system.

D. Residential Sector

Residential Sector consumes about 17% of total electricity, major end-uses being lighting and fans, refrigerators, air-conditioners, electrical heaters. Barriers to adoption of energy efficiency in residential sector are lack of information on energy efficiencies of the products, non-availability of potential benefits of efficient appliances including information on operating costs for purchase decision, structure and characteristics of market for domestic appliances, a higher first cost in most cases, electric lighting a major contributor to system peak and being a necessity can neither be shifted in time nor be done away with. Therefore, it necessitates introduction of minimum energy performance standards for appliances such as air-conditioners, refrigerators and domestic water heaters, a labeling program for these appliances, minimum energy consumption and performance standards that would pave way for market push and labeling program that would provide the desired market pull for the appliances.

V. Conclusions

Demand Side Management is essentially a tool for optimum operation of power system aimed at reducing peak by rational allocation of load in cycle, energy conservation, and consequent reduction in investment. In India realizing the importance of it, through proper planning attempt has already been made to derive benefit by implementation.

VI. Acknowledgment

The authors wish to convey their gratitude to the Central Electricity Authority and Ministry of Power, Government of India for making available the concerned documents on Demand Side Management. They are also indebted to their colleagues who helped in the preparation of the paper.

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VIII. Biographies

Subrata Mukhopadhyay (S'70, M'70, SM'80) was born in Asansol, India in 1947. He graduated in Electrical Engineering from Jadavpur University, Calcutta in 1968 and had his Master's and Doctorate Degrees from Indian Institute of Technology (IIT), Kharagpur and Roorkee in 1970 and 1979 respectively. His employment experience of about 39 years includes teaching and research in IIT Roorkee, IILM Academy, Greater Noida, Delhi NCR, India, and power system planning, design and operation with the Central Electricity Authority of Government of India. Since July 2009 he is Pro and Acting Vice Chancellor of Lingaya’s University, Faridabad, Delhi NCR, India. He has authored two books and thirty-four papers, won IEEE Third Millennium Medal in 2000, PES Delhi Chapter Outstanding Engineer Award and PES Asia-Pacific Regional Outstanding Engineer Award for 2001, RAB Leadership and Achievement Awards in 2002 and 2004 respectively. He is also a Fellow of the Institution of Engineers (India) and the Institution of Electronics and Telecommunication Engineers, India.

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