POTENTIAL ENERGY SAVING BY DEMAND SIDE MANAGEMENT: A CASE STUDY FOR KARACHI, PAKISTAN

[1]AHMAD RASHEED, [2]MURAT FAHRIOGLU

[1]Sustainable Environment & Energy Systems, Middle East Technical University, Northern Cyprus Campus, Guzelyurt, Mersin 10, Turkey
[2]Department of Electrical & Electronics Engineering Middle East Technical University, Northern Cyprus Campus, Guzelyurt, Mersin 10, Turkey

Abstract - Electricity demand is increasing at a rapid pace all around the world due to technological advancements. Usually new power plants are commissioned to overcome the short fall of supply. New technologies are sought to incorporate renewable energy resources that are seemingly cleaner generating power. Currently, most of our electrical power generation systems are using fossil fuels. The demand is expected to rise and building new plants to meet this increase is an expensive solution. An alternative solution is to lessen the demand by simple demand side management (DSM) techniques, and the existing power generation system can be used to fulfil the demand. This paper presents an analytical evaluation of different approaches that may be used to meet the increasing demand of Karachi, Pakistan. The key outcome from this research is the knowledge that an estimated number of 2 million houses in the city are capable of reducing 1900 MW from the total power supply by applying simple DSM techniques.

Keywords - Demand Side Management, Energy Efficiency, Pakistan, Power Generation, Renewable Energy.

I. INTRODUCTION

Karachi – the biggest metropolitan city and industrial hub of Pakistan, is the backbone of the country from an economic perspective. The city has been confronting severe power crisis for a long time because of its immobile power generation capacity. Demand continues to intensify every year due to population growth and several other reasons, while supply remains low and unchanged. Any increase in generation capacity by the installation of new power plants will not only impose adverse effects to Karachi's atmosphere, which is already highly polluted due to industrial activities and transportation, but also upsurge the investment on operation and maintenance of the new power plants.

Meeting the demand of a large city, such as Karachi, can be done either by introducing new generation plants; either by conventional means or by renewable and sustainable means. In both cases, however, there will be some sort of environmental harm and capital costs involved. Indeed, the environmental impacts of a conventional power plant far outweigh the impacts of a renewable power plant but there are alternate approaches to address this issue. An effective method is to lessen the demand of the location. This may be achieved by analyzing the system for better efficiency and overcoming surges in peak demand by using simple and smart DSM techniques. The issue is critical because optimal utilization of the available resources seems the best option for a developing country like Pakistan to deal with its economic catastrophes.

Karachi has a very high demand for electricity as the city's population has reached 21.2 million by 2012 update [1]. In order to contract the supply and demand gap, load-shedding is common practice, which is now a routine to the residents of Karachi. Load-shedding is sometimes planned and scheduled, but unplanned power outages also exist. One of the most important factors that contributes to load-shedding is transmission and distribution losses which, according to a report of the Karachi Electric (KE), formerly known as the Karachi Electric Supply Corporation (KESC), are 35%. One-third (11.67%) of these losses are technical losses that occur due to very old and deteriorated infrastructure, while two thirds (23.33%) are due to unauthorized use by individuals and industries. Usually, the transmission and distribution losses for any system are less than 20%, but for Karachi, this value is exceptionally high [2].

Transmission and distribution systems are usually old structures, especially in developing countries like Pakistan. Even though they play a critical role in linking supply to demand side, these structures seldom go through substantial upgrades due to economic constraints and technical difficulties. However, as pointed out, the losses due to deteriorated systems add even more strain on a problematic supply line that is struggling to meet the demand. Demand side management can help delay the construction of new generation and at the same time help channel some funding into renewing deteriorated transmission and distribution systems.

The government of Pakistan has taken certain measures to lessen the losses and increase the efficiency of transmission and distribution assets by renewing the existing infrastructure. The Shanghai Electric Company is also in the process of acquiring K-Electric Company and the acquisition was expected to be completed by the end of December 2016 [3]. In the light of this acquisition, it is hoped that the new administration of Karachi Electric Company will take new measures, introduce new technologies, and also improve the existing standards of the sole utility company in Karachi. Along with the

replacement of infrastructure and electrical equipment, the utility company has decided to limit load-shedding in the areas of the city, where the recovery is high; i.e. the amount of bills received from the locality is in line with the number of units consumed.

The aim of this research is to offer a solution to counter the energy deficit of city of Karachi and Pakistan in general. The practices and techniques discussed in the research, if employed successfully, can contribute to the lessening of the energy demand of the city and resolve the energy crisis to some extent. The proposed solutions are general and can be employed in other cities of the country as well. It must be noted, however, that, only the residential load is considered for the purpose of this research, since it is the prime contributor to the electricity demand in the city of Karachi.

This paper considers the electricity demand and supply for Karachi for the period between the years 2008 – 2012. The work quantitatively justified how a blend of DSM techniques can be used to meet the domestic demand in Karachi, since it is the largest contributor to electricity demand in Karachi. Section 2 confers DSM approach in detail. The paper proceeds by performing a system level analysis in Section 3 to identify the supply and demand gap in a residential load of Karachi. Section 4 reflects on the DSM techniques that are capable of reducing demand in Karachi followed by Section 5 discussing the challenges and constraints that the city has in DSM implementation. Conclusion and recommendations are summarized in the final section.

II. DEMAND SIDE MANAGEMENT: ASUSTAINABLE APPROACH

Public concerns about climate change, air quality and environment are increasing with every single passing day. As mentioned earlier, even the installation of a sustainable or renewable energy power plant contributes to some sort of Greenhouse Gases (GHG) at some point during their complete life cycle. Renewable energy is the way for a cleaner and sustainable future, however, this type of energy may not be a direct substitute for base load power from conventional power plants. Solar, wind and even sometimes hydropower plants may not be available when you need them since they depend on intermittent sources in nature. Among many other approaches, Demand Side Management (DSM) was also initiated. Since the 1970s, utilities in the U.S. have devised a lot of programs to decrease residential and commercial power consumption [4]. DSM includes the implementation of practices and methods that shrink electricity demand without sacrificing the comfort. It also covers improving the system efficiency. DSM is equivalent, or sometimes even better than, spinning reserves since DSM solves the problem right at the root.

A. Reducing Electricity Consumption

DSM focuses on reducing the use of electricity using a variety of options. It may be obtained by peak clipping, load shifting, load limiting, strategic conversion etc. Utilities employ DSM methods when they see abnormal conditions in load. DSM strategies involve willingness of consumers to participate, so often such programs are supported by providing incentives to the consumers [5]. DSM strives to reduce electricity consumption in industries, offices, markets and homes. It is obtained by continuous monitoring of consumption and managing the use of electricity. Continuous monitoring is for DSM is mainly focused by researchers due to the notion of IoT. This goal can be achieved by the use of energy efficient equipment and appliances, smart metering, energy controllers, green IT etc. [6].

B. Distributed Electricity Generation Using Renewable Energy Sources

Another shade that comes under the umbrella of DSM is the distributed electricity generation using renewable energy sources. Some buildings make use of micro-generation devices that may be rooftop solar panels or wind turbines [6]. Distributed generation is getting prominent in the energy market. It includes small-scale power generation technology that generates electricity non-centrally, closer to the point of consumption. Such systems can be directly connected either to the customer or to the utility's transmission and distribution system. Additionally, these systems can generate electricity readily in a short span of time [5].

C. Transmission and Grid Management

Expensive power outages can be prevented if immediate actions are taken in the case of faults, to isolate the faulty areas in the grid. These schemes use Supervisory Control and Data Acquisition (SCADA) systems to get automatic updates of the whole network per second. In addition to that, sophisticated security measures may be implemented in the substation to avoid threats and natural disasters [6].

D. Frequency Stabilization

Frequency stabilisation in a network is also an integral aspect of DSM. Frequency variation signifies the imbalance between supply and demand. If the system demand exceeds generation, then the system frequency, falls and if the generated supply is more than the demand, then the system frequency rises. The generation maintains the system frequency within acceptable bounds by varying the output according to system frequency.

The response has two phases; the primary response is during the first ten seconds to stop the rise or fall in frequency, while the secondary response then regulates the frequency back to normal in a few minutes. System operators in the U.K. pay large amounts of premiums to power generators that offer

such services [7], [8]. Oak Ridge National Laboratory in the United States is doing research for U.S. Department of Energy for the use of controllable loads in the system. It proposes load reduction in the system within ten minutes of imbalance [7].

E. Reshaping Demand Curves

DSM techniques, some of which are discussed above, include the shaping of system curves. The author in [9]discuss about six types of load shapes that have different objectives as represented in Figure 1. The reduction of load and less consumption in peak hours helps to 'clip' the peak load. This prevents the need of a utility to increase capacity. The valley filling method is related to variable pricing method and it encourages the people to use electricity at times when the charges are low.

Load shifting technique requires the consumers to move their consumption timings from peak to off-peak hours, and achieves peak clipping and valley filling combined. Strategic conversion encourages consumers to reduce overall load, not only during the peak hours but an overall reduction in electricity consumption. Strategic load growth impresses upon the customers to replace inefficient technologies with efficient ones. It reduces the average cost if a large number of customers employ it so that everyone should be benefitted. Flexible load shape depends upon individual customers' choice to opt for reduced demand such as the demand subscription service and priority service pricing [9]

India, sharing an eastern border with Pakistan, also faces a shortageof electricity. In 2010, it faced a peak capacity shortage of 13% which resulted in voltage reduction and load shedding. According to a study, the peak clipping in India ranges from 837 to 4904 MW and energy saving potential is around 3311 GWh to 17852 GWh which could be achieved by using variable speed drives in the industry, motor rewinding, usage of high-efficiency motors and pumps etc. [10].

U.K. also plans to reduce its CO_2 emissions by introducing renewables and other low-carbon energy sources. Though the plan is to achieve this goal by 2020, there are still concerns about the reliability, control and flexibility of sources. So the application of DSM backing up this idea is an excellent solution. The need to increase the use of 'dual-purpose' based operation is also being emphasised. This includes the use of Combined Heat and Power (CHP) systems to facilitate heating and electricity generation. Such operation is difficult when the units are of large sizes. Balancing electricity supply and demand in distributed supply system, with the incorporation of renewables sometimes becomes challenging. For instance, wind and photovoltaic (PV) panels vary with weather conditions significantly and it becomes quite difficult to modulate the output to have a particular load shape or pattern [11].

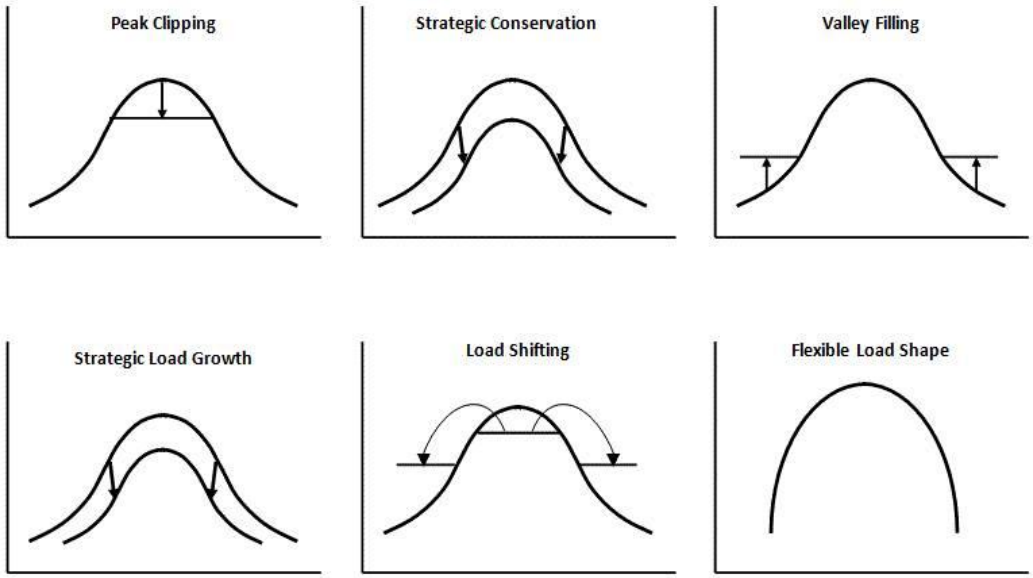


Fig. 1 Demand Management Load Curve

III. SYSTEM ANALYSIS TO IDENTIFY SUPPLY-DEMAND GAP

A. Total Supply and Demand: Ideal case Scenario

According to a report released by KESC, the demand for 2010 was 2500 MW (5% increase from last year) [2].

TABLE I. SUPPYLY DEMAND FOR 2008-2012

Year	Demand	Without Losses		With Losses	
		Supply	Surplus	Supply	Deficit
2008	2256	2848	592	1851	405
2009	2375	2848	473	1851	524
2010	2500	2848	348	1851	649
2011	2625	2848	223	1851	774
2012	2756	2848	92	1851	905

A time span of 2008 to 2012 has been nominated for the system level analysis in this paper and demand values for these years are shown in Table 1 which has been calculated by extrapolation using the following major assumptions.

- Total power generation capacity of 2848 MW for Karachi [2] remained constant from the year 2008 to 2012.
- Constant demand throughout the year and in order to develop the understanding of the subject a linear increase of 5% in demand is assumed every year due to the unavailability of the exact data.
- Total power generation facilities in Karachi are operating at their full capacity

The low values of differences in ideal conditions indicate that even in no transmission and distribution loss conditions, it would be very difficult to meet the demand as the surplus continues to decrease every year. Figure 2 gives the graphical representation of the trend between supply and demand for the five-year under study.

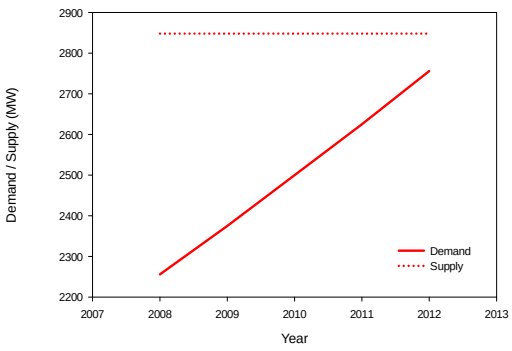


Fig. 2 Supply-Demand Curve for 2008-12 without losses

B. Actual Case Scenario

According to the same report released by KESC, losses before reaching the consumers in Karachi are approximately 35% [2]. If these losses are incorporated in the study, the situation would be more critical as shown in Table 1. The negative values of differences indicate the deficit or the inability to cope up with the demand using the existing system. Figure 3 reveals that the fixed supply failed to match the growing demand for last few years.

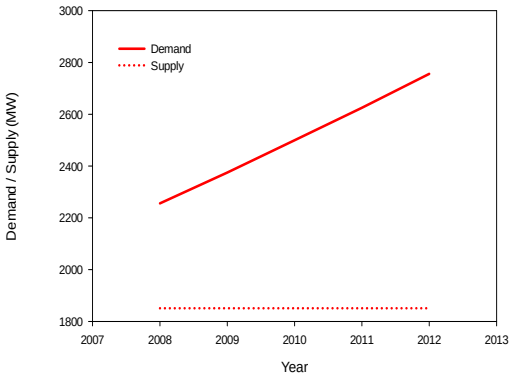


Fig. 3 Supply-Demand Curve for 2008-12 considering losses

C. Total Supply-Demand for Residential Customers

The above analysis is, however, for a total load of Karachi. If we now consider the residential or domestic load only, we find that the residential load corresponds to 77% of the total load consumption [2].

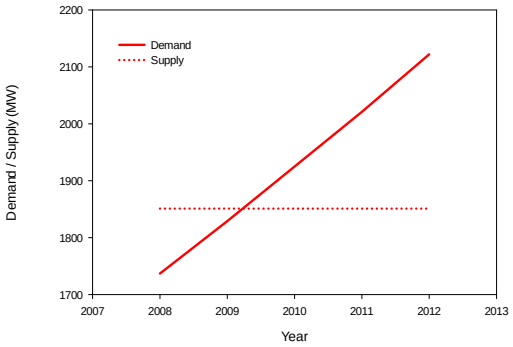


Fig. 4 Residential Supply-demand Curve with losses

Figure 4 depicts that the supply is insufficient to satisfy even the demand of residential load in Karachi. So, there is an immense need to apply DSM techniques to lessen the demand and investment can also be made in some power plants for increasing the supply as well. Even in the case where increasing the supply is inevitable, DSM can provide temporary relief and delay the construction of new power plants. This will buy time for the policymakers to make the right choices.

D. Power Calculation for an Average Household in Karachi

The population of Karachi is around 21.2 million people. The power requirement per capita can be estimated by considering the residential demand of Karachi in 2012.

The assumption is that the whole city population contributes towards the residential demand although a small percentage of people living in the city do not have access to electricity. So, based on safe assumption that users are 21.2 million, power requirement per capita can be determined, this is the ratio of total residential demand and the total users of the city, and found out to be ~154 watts (W) per person. Since Karachi is a densely populated city, it may be inferred that at an average of 7 people are living in each household [12]. This makes the total power requirement per house as 1078 W. It is an average measure of the total consumption that one house has. Since the population is very high, this amount seems fairly low, so in the next subsection, a hypothetical model of a house is presented, with typical types of load considered

E. Hypothetical model of a house in Karachi to apply DSM and identify the potential saving

Table 2 shows the average power consumption of a regular house in Karachi based on a survey conducted in some prominent localities of the city.

TABLE II AVERAGE POWER CONSUMPTION PER HOUSE

Load	Before DSM		After DSM	
	Power Rating (W) [13]	No. of Units	Power Rating (W) [11]	No. of Units
Light Bulb	40	2	14	4
	60	2		
	100	2	22	5
Air Condit.	1750	3	1500	1
Tube Light	60	1	-	-
Iron	1000	1	1000	1
Toaster	750	1	750	1
Refrigerator	200	1	200	1
Ceiling Fan	100	4	100	4
Machine	700	1	700	1
TV (CRT)	200	1	25 [14]	1
Computer	200	1	55 [15]	1
Grinder	200	1	200	1
Water Pump	740	1	740	1
Total	6720	-	5736	-

If simple DSM techniques are applied to these households, then the load may be reduced to a greater extent. For instance, the energy efficient equipment can reduce the demands to the levels presented in Table 2. By replacing energy efficient appliances with the conventional shown in Table 2, it is possible to lessen huge amount of power consumption of a single house, around 950 W.

The application of this technique to all houses of Karachi can reduce the overall consumption and demand of the city. With a total population of 21.2 million and 7 people per household, 2 million houses are estimated to be present in the city capable of reducing 1900 MW from the total power supply

IV. DEMAND REDUCING DSM TECHNIQUES

A. Smart Metering

Real-time pricing arrangements are required for efficient allocation of DSM resources and also inform them about the value of electricity at each time. Sophisticated customers can incorporate the pricing in their energy management system. If there are big differences in pricing, then the energy usage will become more optimised and better.

The smart metering idea can be backed up with the use of intelligent appliances [11]. Smart metering prevents theft and tampering and is better for fault detection. It also improves customer satisfaction and trust [16]

B. Load Limiter

Load limiters limit the power for consumers. The consumers can decide for themselves which appliances they should use and which they may delay using. If there is a limit to their load, people will be careful in using electricity [11]

C. Frequency Regulation

If there is a loss of a large generator, the frequency drops significantly and this problem signals to reduce the load to regulate frequency. Some development needs to be done in the area where frequency regulation can be incorporated into electrical appliances [11].

V. FUTURE PROSPECTS OF POWER GENERATION IN KARACHI

The current installed capacity of Karachi stands at 2848 MW and the government is planning to set up a new nuclear power plant of 1000 MW capacity in Karachi, to overcome the shortfall. So, an additional 1000 MW will increase the capacity to 3848 MW which is more than enough to overcome the demand. The government has already released 475 million PKR (~4.9 million USD) for the feasibility and design study for Karachi Nuclear Power Plant (KANUPP-2). The government is planning to set up the plant near another nuclear plant at Hawksbay and the land already has been acquired [17]

There are some benefits associated with the use of nuclear energy in Pakistan because it will reduce per unit price of electricity to as low as 5 PKR per unit while Currently, it is around 20 PKR for electricity produced from burning fossil fuels [17]. But the problem is that nuclear is not regarded as totally 'clean' energy due to the waste it produces. If the government promotes and introduces DSM to the citizens, the demand can greatly be reduced at the expense of some money, as seen by the calculations for a model house in Karachi. So, if more DSM techniques are implemented and the program is efficiently executed then there is a huge potential to reduce the demand and may be the government does not have to spend so much money on power generation using conventional methods. The introduction of renewables and the concept of distributed generation may be an option to increase capacity, however as mentioned earlier renewables, due to their intermittency, do not exactly provide a secure supply of electricity

CONCLUSION

The government of Pakistan and utility company of Karachi (KESC) need to devise a proper plan and strategy to reduce the electricity demand. Through policy changes, DSM incentives and other demand side related plans, the government and the power company can make a difference. They should also create awareness among the people and conduct seminars and sessions to induce the need to change their old ways of perceiving things and emphasise using energy efficiently by using simple DSM techniques. Karachi has a lot of potential in demand reduction and if properly executed, such a program may eliminate, or at least delay, the need to install

new power plants. The government, instead of investing in a generation, may look towards sustainability and introduce efficient equipment and technology to cope up with the rising demand. This will greatly help the country and it will also be appreciated on a global level. Sustainability cannot be achieved without considering the demand side of the problem. This paper showed how the help from the demand side management programs can be quantified and used in mitigating the supply-demand mismatch. This kind of analysis can help policy makers plan a better energy future for their country

ACKNOWLEDGEMENT

The authors wish to acknowledge Mr. M. Arslan Tariq and Mr. Saleh Rashid for the survey conducted in residential area of Karachi and for providing key figures from KESC, necessary for study.

REFERENCES

[1] PAKISTAN: Karachi City.. Retrieved from available: http://www.citypopulation.de/Pakistan-Karachi.html (2016)
[2] Karachi Electric Supply Company (KESC). (2016). Retrieved from http://www.pc.gov.pk/hot links/PSR/5th OCT/2-KESC Presentation.pdf.
[3] Dinesh Nair, Faseeh Mangi, and V. C. (2016). Shanghai Electric Power Said to Near Deal to Buy K-Electric.
[4] Auffhammer, M., Blumstein, C., & Fowlie, M. Demand-Side Management and Energy Efficiency Revisited. The Energy Journal, 29. (2008)
[5] M. Fahrioglu, F. L. Alvarado, R. H. Lasseter, and T. Y. Supplementing demand management programs with distributed generation options. Electr. Power Syst. Res, 84, 195–200. (2012)
[6] Frye, W. Transforming the Electricity System to Meet Future Demand and Reduce Greenhouse Gas Emissions. Smart Grid, CISCO White Paper. (2008)
[7] J. A. Short, D. G. Infield, and L. L. F. Stabilization of Grid Frequency Through Dynamic Demand Control. IEEE Trans. Power Syst, 22(3), 1284–1293. (2007)
[8] Seneviratne, C., & Ozansoy, C. Frequency response due to a large generator loss with the increasing penetration of wind/PV generation–A literature review. Renewable and Sustainable Energy Reviews, 57, 659-668. (2016)
[9] Bellarmine, G. T. Load management techniques. In IEEE Southeastcon 2000 (pp. 139–145) (2000).
[10] Rajput, S. M. and A. K. Demand side management and load control #x2014; An Indian experience. In IEEE Power and Energy Society General Meeting (pp. 1–5) (2010).
[11] Strbac, G. Demand-sideManagement: Benefits and challenges. Energy Policy, 36(12), 4419–4426. https://doi.org/10.1016/j.enpol.2008.09.030 (2008).
[12] Hasan, A., & Mohib, M. The case of Karachi, Pakistan (Understanding Slums: Case Studies for the Global Report On Human Settlements) (2003).
[13] Calculate your monthly Electricity consumption. (2017). Retrieved from http://www.pepco.gov.pk/bill_consumption.php
[14] EHow. (2012). CRT TV vs. LCD TV Power Consumption | eHow. Retrieved from http://www.ehow.com/about_5398279_crt-lcd-tv-power-consumption.html
[15] III, J. M. (2016). Approximate Desktop, Notebook, & Netbook Power Usage. Retrieved from http://www.upenn.edu/computing/provider/docs/hardware/powerusage.html
[16] Openshaw, D. Smart Metering at Energy Networks Perspective, In IET Smart Metering (2008).
[17] Ahmadami, A. (2012). Karachi to have another N-plant. The Nation. Retrieved from http://www.nation.com.pk/pakistan-news-newspaper-daily-english-online/editors-picks/10-Sep-2012/karachi-to-have-another-n-plant

★★★