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Thermal Energy Storage: its prospects of Demand Side Energy Management

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Abstract:

Constrained conditions of commercial energy supply and availability; widening of the gap in Demand & Supply has become a major issue. To bridge the gap, Energy efficiency and savings programmes would be better alternative as a resource over the addition of generation capacity. Energy demand in commercial Buildings, Complexes & Offices is rapidly increasing hence effective Energy Efficiency programmes need to be adopted in 'Building 'sector. In India this sector has about 25 % of total electricity demand.

Thermal Energy Storage (TES) technology addresses critical power demand caused by Air conditioning systems, a single largest contributor to electrical peak demand and Building's energy cost. TES technology stores "cooling" energy in thermal storage mass during off- peak hours when energy cost and demand is low and supplies it during Peak hours when energy cost and demand is high. TES is proven method of reducing peak power demand and energy conservation which leads to the conservation of conventional energy resources and reduces carbon emission for Sustainable Development. TES through Demand Side Management programmes avoids the "On Peak" energy generation, reduces additional strain on Transmission & Distribution infrastructure. TES improves system Load Factor and Diversity Factor for optimum and economic operation of power system.

Potential study of peak power demand reduction, possible methods and policies of TES penetration in metro city like Mumbai are discussed in this paper. TES can be a win-win situation for owners, DISCOMs and Environment.

Introduction

Current trends in energy supply and use are unsustainable – economically, environmentally and socially. Without decisive action, global energy-related greenhouse gas (GHG) emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies [1]. In the building sector, the global number of households will grow by 67% and the floor area of service sector (commercial and institutional) buildings by almost 195% [1]. We can and must change our current energy and climate path; energy-efficient and low/zero-carbon energy technologies for heating and cooling in buildings will play a crucial role in the energy revolution needed to make this change happen.

Societal energy demands are presently increasing while fossil fuel resources, which dominate most national energy systems, are limited and predicted to become scarcer and more expensive in coming years [2,3]. It is clear that India's need for secure, affordable, and environmentally sustainable energy has become one of the principal economic and development challenges for the country. Reduction in demand through energy conservation and energy efficiency will become a key part of the solutions

Metros and Urban areas are growing very rapidly, with upgrading living standards of society. Facility centers, Multiplexes and office buildings are increasing steeply so as their energy demand causing burden on the existing supply chain. Energy demand in Building sector is rapidly increasing which demands about 25 % of Indian electricity demand [4]. Hence, there is an urgent need to address this issue.

Electricity use in Buildings sector has been growing at about 11-12% annually, which is much faster than the average electricity growth rate of about 5-6% in the economy. According to the 17th Electrical Power Survey of the Central Electricity Authority, electricity demand is likely to increase by approximately 40% in 2011-12 and 175% in 2021-22 as compared to 2006-07.

In recent years availability of power in India has both increased and improved but demand has consistently outstripped supply and substantial energy and peak shortages has continuously prevailed in the country. There are also various estimates of 25000 to 35000 MW of power being produced by diesel generation to meet the deficits which increases the carbon emissions [5]. Figure1 shows the graphical trend of increasing peak demand & shortfall of supply on the national grid.

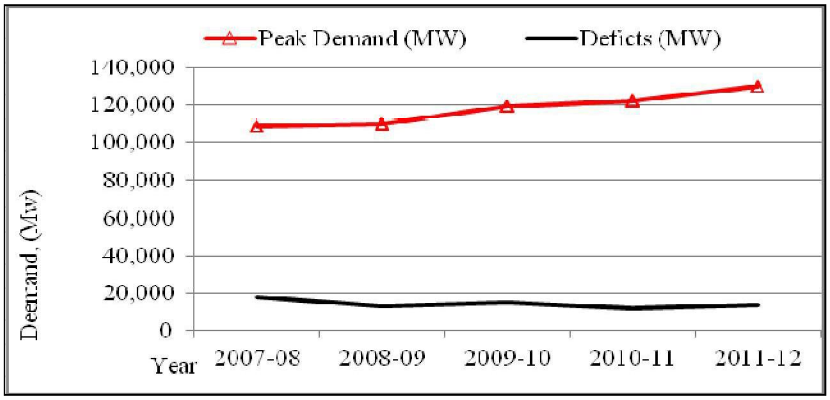

Figure 1: Power Supply Position of India

[*Source: Central Electricity Authority, New Delhi*]

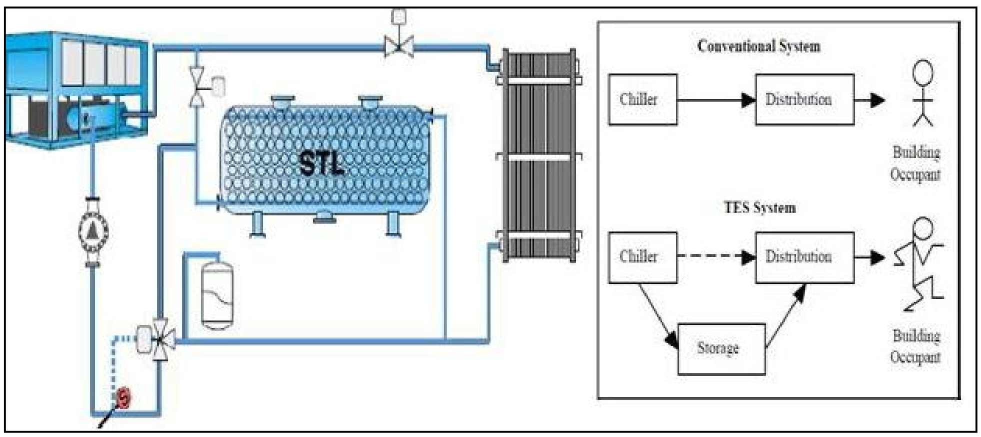

Figure 2: Typical system of TES System

[Source: TES source energy report California Energy Commission.]

TES is defined as the temporary holding of thermal energy in the form of hot or cold substances for its utilization later. The TES is not a new concept, and has been used for centuries. Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation. TES is helpful for balancing between the supply and demand of energy. Thus, TES plays an important role in commercial and economic operation of power system. A typical TES system can be shown as in Fig 2.

In this technology, the chiller's secondary coolant is usually a 25% to 30% ethylene glycol/water solution. The coolant circulates to convert the phase change liquid to ice which is kept in an insulated tank. The chillers are run in off peak (night) hours and the energy stored in ice is used for cooling in peak periods without running the chillers thus helping the load shift.

Electricity Distribution Companies (DISCOM) are licensed utilities that are responsible for giving and maintaining the electricity supply up to their consumer premises at desired voltage levels. DISCOM business is running as per rules and regulations laid under the Electricity Act 2003. DISCOM has identified TES technology for peak demand reduction on the power grid. Mumbai DISCOM's have designed the Demand Side Management (DSM) programs, offering some upfront rebate to install TES for their consumers [6].

The Metros city like Mumbai have acute shortages of power supply (600-700 MW), where DISCOM's are facing problem of costly power purchase during Peak Maximum demand. Costly power purchase increases the overall retail tariff of electricity causing dissatisfaction among consumers. Managing the peak maximum demand on the grid is the sole responsibility of the DISCOMs, hence focusing to reduce the peak maximum demand from consumer side of the meter *i.e.* consumers are encouraged to curtail or shift their electricity demand.

There are three main types of TES systems: Sensible, Latent and Chemical (sorption and thermo chemical) [7]. The selection of a TES system for a particular application depends on many factors, including storage duration, economics, supply and utilization temperature requirements, storage capacity, heat losses and available space. Thermal Energy storage has a key role for small local systems where reliability is an important feature. TES can maximize the energy savings and energy efficiency potential of other technologies, facilitate the use of renewable and waste heat, and improve flexibility, helping to minimise the overall system cost.

The TES system makes and stores ice at night during off-peak times when tariff is far less and when cleaner base load plants are used, while still providing a cool and very comfortable environment for occupants. Energy Storage lowers the relative humidity within a building and, as a result, occupants feel comfortable even if the thermostat is set at a higher level.

Figure 3 shows the typical load curve with and without TES. With TES the Load curve is smooth and levelised to improve efficiency of power system parameters. Load factor of the generating stations can be improved and effective utilization of the Transmission and Distribution infrastructure leads to better efficacy.

Peak demand and Load Curves (Mumbai)

The operation of electric power systems involves a complex process of forecasting the demand for electricity, and scheduling and operating a large number of power plants to meet that varying demand. The instantaneous supply of electricity must always meet the constantly changing demand.

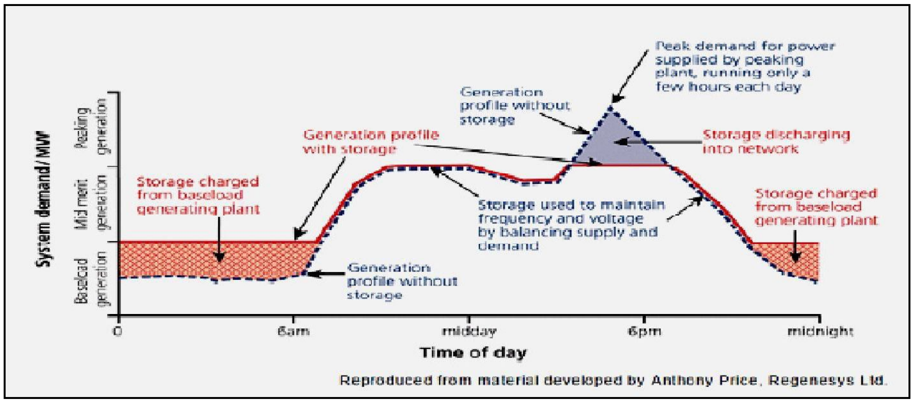

Figure 3: Typical load Curve with and without TES

[*Source: Energy ESC white paper by Energy storage council*]

The operation of electric power systems involves a complex process of forecasting the demand for electricity, and scheduling and operating a large number of power plants to meet that varying demand. The instantaneous supply of electricity must always meet the constantly changing demand. The seasonal and daily patterns are driven by factors such as the need for heating, cooling, lighting, etc. To meet this demand, utilities build and operate a variety of power plant types. Base load plants are used to meet the large constant demand for electricity. These are often nuclear and coal-fired plants, and utilities try to run these plants at full output as much as possible.

Variation in load is typically met with load-following or “cycling” plants. These units are typically hydroelectric generators or plants fueled with natural gas or oil. These peaking units, which meet the peak demand often, run less than a few hundred hours per year.

In addition to meeting the forecasted and/or unpredictable daily, weekly, and seasonal variation in demand, utilities must keep additional plants available to meet unforeseen increases in demand, losses of conventional plants and transmission lines, and other contingencies (frequency regulation, load-forecasting errors).

Metro city like Mumbai which also called as financial capital of the country, has typical load pattern throughout the day. Being a financial hub & Center for Bollywood, most corporate offices, facility centers, Multiplexes and Multispecialty Hotels & Hospitals are established in the city and its suburbs. Cooling and lighting load from Commercial buildings contribute to the Peak on the Mumbai Load curve.

Fig.4 shows the typical Load curve for the Mumbai DISCOM's (Mumbai system has three DISCOMs viz. BEST Undertakings, TATA Power Company and Reliance Energy Ltd.) Fig 5 shows Summer Peak of 2012 for Mumbai system on full load day. Typically Peak load starts at 10:00 Hrs when all the offices starts working & reaches its maximum at 16:00 Hrs, when most of the centralized A/C systems are fully operational. Demand starts reducing from 18:00 Hrs, and forms valley on the curve during (01:00 to 06:00 Hrs) when demand is minimal. There is opportunity to shift day time peak demand to this valley by aggressive adaptation of TES system. Fig.5 also shows that the shortages of about 700 MW needs to be managed from outside power purchase during peak hours. Due to Humid climate conditions throughout the year, the difference in maximum peak demand during summer and winter season is only about 15 – 20 % which indicates that operation and usage of Centralized air-conditioning load is less dependent on the climatic and atmospheric conditions.

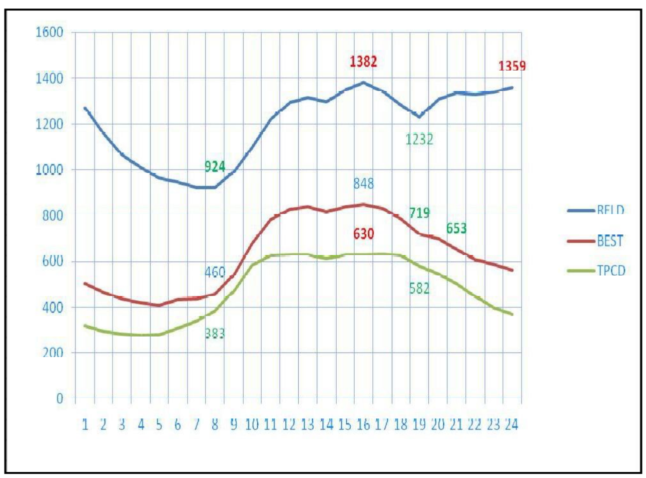

Figure 4: Typical Individual load curves for Mumbai DISCOM'S

[Source: Maharashtra Electricity Regulatory Commission, Mumbai]

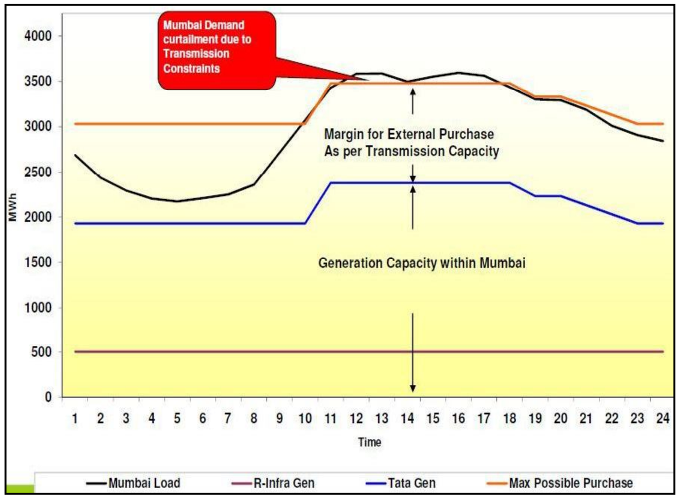

Figure 5: Mumbai Summer 2012 Peak Demand

[Source: -MERC SAC Committee, Mumbai.]

Maximum peak demand reaches up to 3500 MW during the summer season and average peak demand remains in the range of 3000 to 3100 MW. Load research study carried out in Mumbai DISCOMs shows that major load responsible for maximum Peak is the Air conditioning & Ventilation Load. Air condition demand comprises of Centralized A/C chillers, Compressors, Air handling Units (AHU), Window & Split A/C, whereas ventilation load is of Ceiling Fans & Coolers. It has been estimated that one third of the peak maximum demand (about 1100 MW) is due to A/C system only.

It is estimated that, there are about more than 200 high rises commercial buildings using centralized Air conditioning chillers, AHU, and lighting load contribute to Mumbai demand during 10 am to 6 pm by about 1100 MW. Also it is normal practice that working places at commercial buildings are used to maintain cooling temperature around 20°C, which is much less than the temperature prescribed (26 °C) by BEE for Indian Tropical Conditions. Every 1 deg. rising temperature will save about 3% of input electrical energy.

Critically identified consumers (contributes to system peak) Central Air Conditioning commercial and industrial consumers has connected load of around one lakh Tonnes of Refrigeration.

Peak demand for the Mumbai system is growing faster than energy consumption and trend of increasing the electricity Demand above 10% on the Mumbai system will be continuing further in line with the economical developments and Govt. policies in India.

Demand Shifting Potential Through TES Technology

The problem of peak power demand can be overcome either by curtailment of Peak Load or Shifting to non peak hours. TES technology supports the shifting of Peak Load and conservation of energy as well. Opportunity to shift the Peak Demand to Non – peak hrs in Mumbai city is about 100 MW (1,00,000 TR is approximately equal to 100 MW , assuming 1TR load is equal to 1 KW), if all the critically identified Central Air Conditioning systems are aggressively retrofitted with TES system. There are few success stories in the country, by adopting the TES system, load demand and electricity bills are managed to curtail. National Stock Exchange Building at Bandra Kurla Complex Mumbai has put 4800 TR-Hrs (Tonnes of Refrigeration multiplied with Hrs of operation), TIDEL Park Chennai has put TES of 24140 TR-Hrs.

In Mumbai approximately annually electricity saving (assuming 20 % saving potential) [12] at consumer end will be 27 MU (million units) and reduction in carbon emission would be about 22,000 tones (estimation based on L.F of 0.75 and load running for 6 Hrs per day for 300 days in year. Average carbon emission for1Kwh is 0.80 kg).Due to reduction in Peak Load the DISCOMs will be benefited by avoiding costly Peak power purchase. Thus Mumbai system would be benefited by voiding peak power purchase of 31 MU and Rs. 15.5 Cr for Peak power Purchase. (T&D Losses taken into consideration are 15 %. Peak Power Purchase is considered at Rs. 5 per KWh). Consumers adopting TES System are benefited by reduced electricity bills due to ToD tariff (Time of Day) incentive during off- peak period.

Conclusion

TES has win-win situation for building owner, DISCOM and Environment as well. It is satisfied technology for shifting of peak demand on the grid. Shifting of Peak demand avoids peak power purchase there by less impact on rise of retail electricity tariff.

The detailed study report “Source Energy & Environmental Impacts of TES” (1996) carried out by California Energy Commission has found that, TES system can reduces cooling cost up to 40 % and the size and cost of air handlers, motors, ducts, and pumps can be reduced by 20 to 40 percent.

Building owners can use TES as a load shifting response tool and reduce peak demand in response to price signals with little, if any impact on building occupants. This will support new energy efficiency market through Demand Response programme. Use of TES increases a utility's load factor by better utilization of existing power plants & natural resources. It also avoids expansion of Transmission & Distribution (T&D) infrastructure & Networks, their by improving T&D losses.

Mumbai city has typical load demand pattern and power crisis (about 600-700 MW shortages), about 100 MW demand shifting potential can be tapped through TES. There is urgent need of Regulatory & DISCOM support for TOD tariff so that TES projects shall have attractive paybacks for owner. Although there are few success stories on TES, TOD tariff signal advantage will encourage Energy efficiency Market and Energy Service Companies (ESCO market) for better penetration of TES technology for sustainable development.

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