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Analysis of Load Consumption

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Abstract:- Power is one of the essential parameter for economic growth and livelihood of people. The electricity consumption is an indicator that decides the development of the nation. The increasing demand of electricity and impact of conventional energy resources on environment will have a negative impact on the economic growth of a nation. In meeting the fast growing demand and in order to achieve sustainability, the consumer should share the responsibility with the electric utilities. In this paper classification of appliances and an analysis of electricity consumption pattern of such loads is presented for effective participation of consumer's energy conservation.

***Keywords**:- Carbon Emissions, Load Classification, Load Management, On Peak hours, Off Peak hours, Peak Demand.*

I. INTRODUCTION

With the growth of local, global businesses and consumer energy systems and their dependency on electric networks has placed a great demand on the electric networks for satisfying the growing consumer needs. As electricity demand is increasing the electric utilities have tried ways and means to manage peak loads. The basic idea of the utilities was to match the consumption to generation. In order to achieve this goal an active participation of consumers was required in order to manage a peak load demand which is called as demand side management.

Active participation of consumers in order to shift their loads from on peak hours to off peak hours would help utilities meet the demand without investing on the generation of energy. The consumers are provided with incentives for managing their loads without causing much discomfort to them. The consumers can make use renewable energy resources like solar powering of certain devices and also feed the excess power generated to the grid.

Appliance Load monitoring information is an important parameter that can lead to reduction of electricity consumption and help in energy savings. Furthermore, knowledge of exact time of use of the device can also help in energy savings during the on peak hours as it would help consumers reschedule their devices to a period of the day where the electricity rates are cheaper.

This paper focuses on classifying loads based on their energy consumption pattern, their time of use. In the section I classification of electric loads in commercial, residential and industrial loads is presented. Section II presents electric load Management in all the sectors Section III presents case study of electric consumption of cement industry and energy conservation that could be achieved by adopting Demand Side Management and Demand Response strategies.

II. CLASSIFICATION OF LOADS

Electric loads can be classified basically into three categories as i. Domestic or Residential Loads ii. Commercial loads iii. Industrial Loads [2]. Domestic load consists of lights, fans, home electric appliances (including TV, AC, refrigerators, heaters etc.), small motors for pumping water etc. Most of the domestic loads are connected for only some hours during a day. For example, lighting load is connected for few hours during night time.

Commercial load consists of electrical loads that are meant to be used commercially, such as in restaurants, shops, malls etc. This type of load occurs for more hours during the day as compared to the domestic load. Industrial load consists of load demand by various industries. It includes all electrical loads used in industries along with the employed machinery. Industrial loads may be connected during the whole day. Table I gives a list of house hold consumption of electricity of various devices.

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Appliance category	Wattage	Usage hr/day	Usage hr/yr	Consumption kWh/yr
Mixer	450	0.47	172	77.20
Refrigerator	100	22.33	8150	815.05
Air cooler	170	4.8	1752	297.84
Air conditioner	1500	0.81	296	443.48
Toaster	800	1.1	402	321.20
Kettle	1500	1.1	402	602.25
Electric iron	750	0.48	175	131.40
Vacuum cleaner	750	0.7	255	191.62
Television	100	3.93	1434	143.45
Electric heater	1000	1.72	628	627.80
Battery charger	15	3.25	1186	17.79
Washing machine	325	0.71	259	84.22
Water pump	750	0.68	248	186.15
FL20	20	1.3	475	9.49
FL40	40	2.63	960	38.40
IL15	15	2.32	847	12.70
IL40	40	1.56	569	22.78
IL60	60	2.36	861	51.68
IL100	100	2.72	993	99.28
IL25	25	1.27	464	11.59
Fan	100	4.45	1624	162.43

Table 1: House hold Consumption of Electricity.

From the above table we observe that cooling devices like refrigerators, air coolers, air conditioners and heating devices like toaster, kettle form the majority of electricity consumption devices. In most of the affordable houses lighting, fans, televisions and fridges form majority of appliance composition. Lightning and television are dominating devices that are used mostly in the evening between 7-10 p.m. Fan usage peaks during night. The chart below gives house hold electricity consumption category wise.

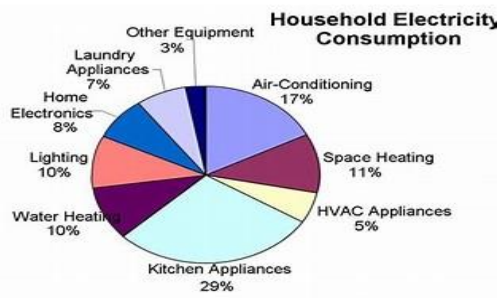

Fig.1. Household Electricity Consumption

The industrial sector uses more delivered energy than any other end-use sector, consuming about 54% of the world's total delivered energy [6].

The industrial sector can be categorized based on the types of industries. Industries like iron and steel, paper, refining, food, cement are categorized as energy-intensive manufacturing industries. Pharmaceuticals, detergents, paint and coatings, electronic products fall under non energy-intensive manufacturing, Agriculture, forestry, fishing, Mining and construction fall under nonmanufacturing category. Energy consumption in industrial sector is due to wide range of processes and assembly, steam and cogeneration, process heating and cooling, lighting, heating, and air conditioning for buildings.

Textile industry is the largest contributor in the economic growth of India, employing 35 billion people making it the second largest industry providing employability. Considering the energy perspective, textile industry consumes thermal as well as electrical energy. The major energy consumption devices are [7] Ring frame, Humidification Plant, Mercerizer, Cheese Winding, Sanforizer etc.

These processes are grouped into four subgroups based on their energy consumption in MTOE (Million tons of oil Equivalent) units. Fig.2 gives the details of these processes.

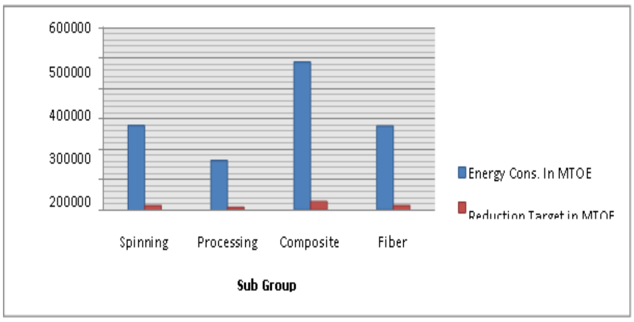

Fig.2. Energy Consumption in different Subgroups [7]

Energy usage in Commercial buildings basically comprises of HVAC loads, electronics, lighting, water heating and others.Fig.3.gives energy usage of commercial buildings.

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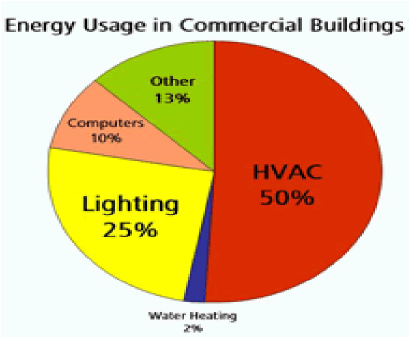

Fig.3. Energy Usage in Commercial Buildings [5]

In a nutshell the electricity consumption by sector is depicted in Fig.4.

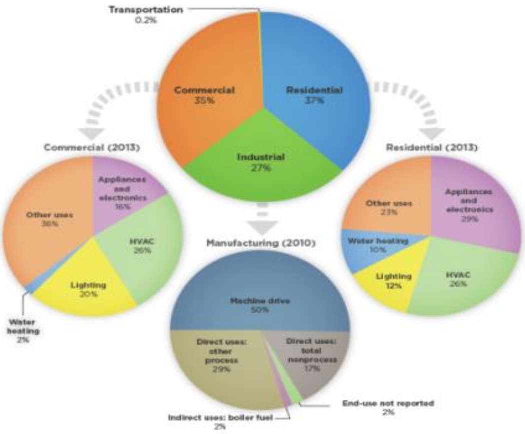

Fig.4 . Electricity Consumption by sector [4]

III. ELECTRIC LOAD MANAGEMENT

Electric load management can be defined as the action taken by utilities and/or consumers to change the load profile in order to reduce the total system peak load and meet the demand during on peak hours and effective utilization valuable resources like fuels for generation, transmission and distribution capacity [8].

To manage the load at the customer's side, the load profile must be compared with the total system demand. Some of the techniques for effective load management are

i. Rescheduling of processes
ii. Energy storage devices charged during off peak hours and used during peak hours.
iii. Use of own power production.

Load Management Techniques are beneficial to both Consumers and Utilities. The redistribution of electrical demand from on peak to off peak hours will not require additional generating capacity during on peak hours. The investments to install generating stations are huge which will result in increased tariffs on consumers. Consumers taking part in load management have variable tariff rates during on peak hours and off peak hours or they are provided with incentives for rescheduling of loads. Integration of renewable energy resources like installation of solar panels, generating and using the power during peak hours helps reduction in peak load demand.

Residential loads can be classified as deferrable and non deferrable loads with respect to energy management. A load that requires supply for part of the day and that can be postponed in time. i,e they require energy within a given time period but exact timing is not specific. Loads associated with storage such as water pumping are deferrable loads. Loads like lightning, television, computer cannot be rescheduled over specific time period, and such loads are non deferrable loads.

Residential loads can be classified as shiftable or non shiftable loads [3] based on their time of use requirement. Air conditioning, water heater, clothes dryer fall under shiftable loads while cooking, lighting, refrigeration fall under the category of non shiftable loads.

Fig.5 shows the classification of electric appliances that would help consumers manage their load during peak hours without causing much discomfort.

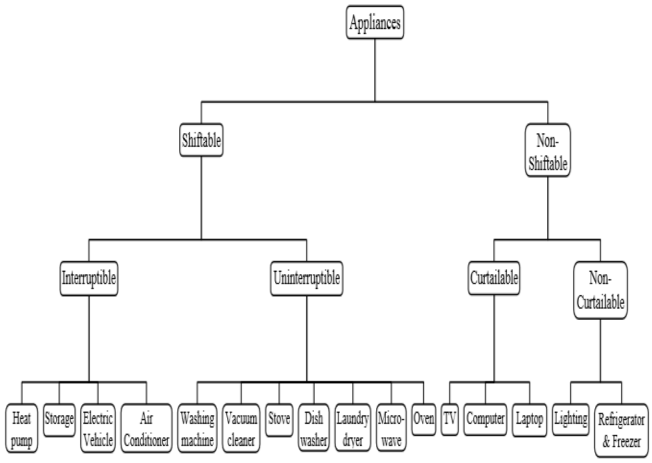

Fig.5 Classification of Electrical Appliances [3]

Industrial loads can be classified as controllable loads, fixed type loads and other loads [8]. Controllable loads can be subjected to load management strategies such process independent loads, storage constraint loads and sequential loads. Loads like furnaces, water heaters, boilers, chillers and air conditioners are example of controllable loads that work on set temperature and whose duty cycle can be varied without much discomfort to the user. Fixed time loads are those loads that cannot be subjected to any load management strategies. Such types of loads are found in metal heat treatment and in food industry for cooking, baking and sterilization. Such kind of loads when interrupted may result in useless production or even damage of device.

Other loads are those loads which are used as and when required like lightning, elevators, cranes, motors etc. The operation of some of these loads can be deferred and few may be critical i.e. they cannot be deferred like lights have to be used at night and lifts cannot be stopped while carrying people.

Load management in industries can be accomplished using operational strategies like two or three shift operations, variation of equipment size or storage capacity, adaptability to varying tariffs.

Based on the criticality of the processes involved, they can be categorized as controllable, fixed and other loads. Further Demand side management strategies like load shifting can be applied to controllable loads and hence meet the peak demand.

Commercial loads as mentioned in section II are HVAC loads, lighting, computers and other loads. The major parts of a buildings energy use are plug loads. Plug loads are those loads which contribute amount of energy usage by electrical loads like computers, printers, vending machines, coffee makers etc. Energy efficiency can be obtained by management of these plug loads. A plug load management system helps one track total plug load of a building on a day to day or hourly basis. This helps in using energy management strategies that will allow user to shut off the flow of energy to certain devices at peak times and save energy.

IV. CASE STUDY

Cement Industry production is one of the energy intensive industry. Cement manufacturing requires very large amounts of energy. It consumes 20% of total energy consumption. It is also one of the largest sources of carbon dioxide emissions. India is the second largest cement producer in the world. In this section energy consumption of various processes in a cement industry and management of these processes using DSM strategies is presented. Also the energy conservation obtained due to DSM strategy is highlighted.

The production of cement is carried out using two major processes, namely the Pyro-process [11], where lime stone the main raw material along with other additives is converted to clinker in multi stage cyclone preheater system and a rotary kiln and the grinding process, where clinker along with other additives is ground to form different grades of cement. Fig.6 shows the process flow in the manufacturing of cement.

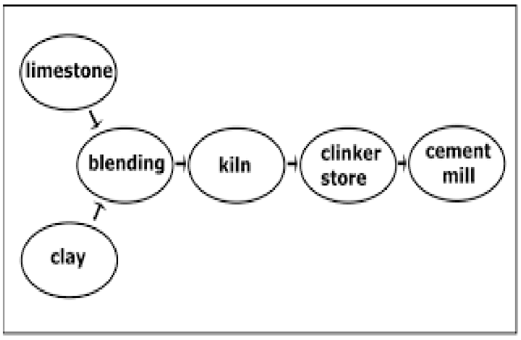

Fig.6. Manufacturing process of Cement

Most of the electric power installed in the cement industry (adopting dry or wet process) is concentrated in both rotating kiln that involves raw material transportation, crushing, screening, homogenising and ensilage and in the downstream process that is in the clinker grinding mill which is the biggest user of electricity. The pie chart below gives power consumption of the various processes for production of one tone cement [11].

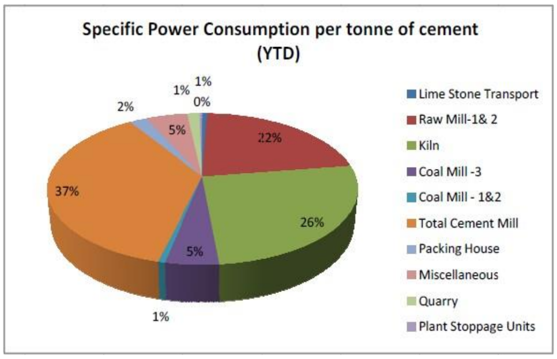

Fig 7

Load management can be applied to few processes involved in the manufacturing of cement. Based on the storage capacity of the silos that supply the rotating kiln, the preparation and homogenising facilities can be halted for longer or shorter periods. Whereas it is difficult to halt the process in dry process plants as they are equipped with heat recovery devices for predrying the raw materials. The grinding process in the clinker grinding mill may also be stopped for a time as there is usually a storage capacity available for the clinker upstream of the grinding mill and hence not affecting the operation of the klin.

Since these processes can be halted for some time duration, time of use pricing models can be implemented as one of the approaches for Demand side management.

The time of use tariff is section into time of day (i.e. peak, standard and off peak) and season(i.e. summer, winter).This would encourage large industries such as the cement manufacturing plants to shift their loads and save energy during the peak time.

The machine driven processes form the major portion of the electrical demand. If DSM strategies could be applied to the motors of these processes it would help achieve a huge energy saving potential of the total energy consumption of the plant.

Energy conservation in industrial sector can also be achieved by adopting demand response strategies through which the consumers can cut down their electricity cost significantly and also help utilities to mange peak electricity demand. DR programs have a great potential in the manufacturing sector. A DR program should have one of the four characteristics as depicted in Fig.8.

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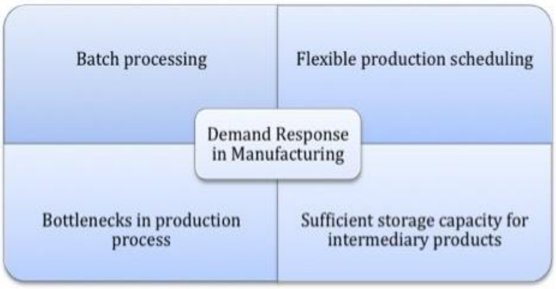

Fig.8. Demand Response in Manufacturing [9]

As discussed earlier the cement production process raw material grinding, high temperature kiln for making clinker and final finished grinding of clinker. The electricity use in a cement plant varies depending on the grinding technology, raw material properties and typically varies in the range of 90 to 150KWh/ton. Over 70% of the electricity usage is in the grinding of raw material and finish grinding process.

Batch process, large storage capacity as its output can last for hours to days, the kiln process which is the bottle neck in the manufacturing of cement when combined with large storage capacity are the DR friendly characteristics in the raw material grinding process.

Batch process, large storage capacity after the kiln for ground clinker which lasts for hours and flexible production scheduling of finish grinding process to produce the final cement product can be delayed for few hours with other processes in operation are the possible DR friendly characteristics that could be applied in the finish grinding process.

The potential of DR program in a typical cement plant can be illustrated by simple calculation [9]:

Let us assume that an cement plant uses 100 kWh/ton cement of which 70% (70 kWh/ton cement) used in raw material grinding and finish grinding, and produces 2400 ton cement per day (100 ton/hour), every hour of shift in the operation of both raw material grinding and finish grinding in response to a DR signal will result in 100*70=7000kWh reduction in electricity demand. If the shift was applied to any one of the process i.e raw material grinding or finish grinding the reduction achieved would be half i.e 3500kWh which is a huge DR potential which when adopted by utilities and cement companies reduces peak energy demand. The major limitation of implementing a DR program in the cement industry is the kiln that is always operated at 100% and also puts limitations on other process.

The choice of a suitable power curtailment strategy is a complex task that needs considering the multiple, disproportionate, and probable conflicting objectives. These objectives might include the minimizing peak power demand, without compromising on maximizing profits, customer discomfort and ensuring quality by minimizing losses.

Cement production is a major source of CO2 emissions. Cement manufacturing generates CO2 and the industry as a whole represents around 5% of global CO2 emissions. These CO2 emissions are produced as a byproduct of a chemical conversion process used in the production of clinker, the primary component of cement in which calcium carbonate is heated in a rotary kiln that results in conversion of carbonates to oxides i.e. CaO(lime).CO2 is also emitted during cement production by fossil fuel combustion. The carbon footprint is nearly 1.3 kg/kWh for Captive Thermal Power plants in India. The overall CO2 emission is 866 kg/ ton clinker produced. The CO2 emission is around 670 kg/ ton of cement (PPC).

Power plants based on renewable sources such as wind and solar energy can be an integral part of new cement plants adopting green processes and green power generation to reduce Green-House-Gas (GHG) emissions.

Solar energy harnessed can serve a great source of powering cement plants as most of the plants in India are located in dry and hot areas with enormous solar radiation. This makes cement sector very ideal for deployment of solar power generation plants as huge amount of unused land is available for installation of Solar Power Plants. Several cement manufacturers like Aditya Birla Group, Zuari Cement, Birla Corp and Ambuja Cement, Dalmia Cement[12] etc. have all ventured into solar power generation in India. Aditya Birla Group was one of the pioneers, having set up a 100 kW solar power plant in its Rajashree cement plant in Karnataka in 2012. Zuari Cement set up a solar power plant in Yerraguntla district in Andhra Pradesh in 2013.Cement companies such as Emami cement, OCL India, Ultratech cement, Birla Corp at Satna works have installed the solar power plants of 10.06 MW, 5.5 MW, 2.5 MW, and 1.5 MW capacities respectively.

Let us take an example of a cement plant that produces 2 million tons of cement per year. The power requirement of such plant is 198GW/year [12]. Say a solar power plant of 10MW capacity produces18-24GWh/year which accounts to 9 to 12% of power needs and avoids 15,000-20000 ton CO2 emissions per year.

Demand side management has the potential not only to reduce electricity costs but also reduce carbon emissions. Using Demand side management strategies these renewable energy resources can be integrated to the existing power grids hence achieving eco-friendly energy saving techniques.

Using Demand side management like load shifting approach the consumers can prepare the factory schedule partly based on the electricity prices. As discussed earlier few processes can be halted during peak hours and operated during off peak hours. The other approach of DSM is medium to store energy. The storage is charged during off peak hours[10] where the electricity prices are low and discharged during peak hours to reduce consumption from the grid at high price times.

V. CONCLUSION

Energy management includes engineering, design, application, operation and maintenance of electrical power systems for efficient use of electrical energy. The basic aim of energy management is to optimize the energy usage and reduce the overall electricity cost. In this paper a theoretical framework of electrical loads in different sectors, residential, commercial and industrial and possible load management strategies that could help achieve efficient and optimal use of electricity without investing on new infrastructure was presented. Because of increasing costs of burning fuels and large investments installing new generation capacity, most factories face raised cost of production. A case study of Cement industry was presented highlighting the possible DSM strategies for reducing the overall electricity costs, reducing peak power demand and reduced carbon emissions.

Conflict of Interest:

The authors declare that there is no conflict of interest regarding the publication of this research work.

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