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Analysis of Maximum Demand of Educational Buildings and its Impact on Electricity Bills

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Abstract - ***India is a growing technological Nation and the most important role in the technological development process is played by electricity. The demand for electricity is growing manifold in comparison to the gradually increasing generation capacity. In particular, growth in electricity consumption is very much related to economic growth. The Electricity crisis is a grave problem that needs an immediate attention. Commercial educational buildings play major role in consumption of electricity on mass level to achieve the satisfaction level of their stakeholders. Since, the major concerning body being the Educational sector, this paper is dedicated on reducing electricity bill of commercial consumer without having sacrifice with satisfaction level. This paper includes practical analysis approach of the electricity bills of two consecutive years of an Engineering College of Rajasthan, following some easiest suggestion that can be implemented to save electricity cost without reducing energy consumption.***

Key Words: Connected Load, Maximum Demand, Jaipur Viduyat Vitran Nigam, Safety Margins, Demand side Management, Load Curves.

Nomenclature

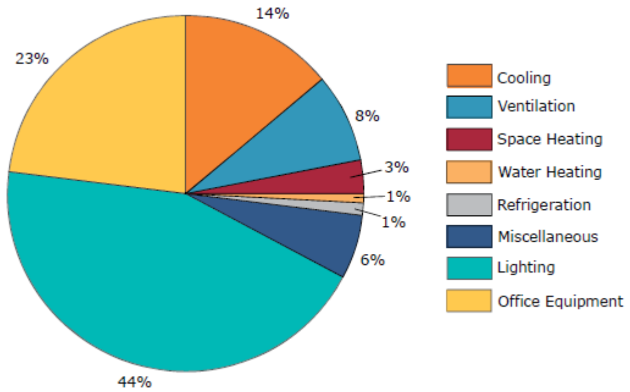
CL	Connected Load
MD_m	Minimum slab of Maximum Demand
MD_a	Actual Maximum Demand
C_{MD}	Cost per KW of Maximum Demand
T_c	Cost due to Maximum Demand
T_{cm}	Total monthly cost by Maximum Demand
T_{cy}	Total yearly cost by Maximum Demand
T_{y14}	Total annual bill of year 2014
T_{y15}	Total annual bill of year 2015
D_f	Difference between Minimum Max. Demand & Actual Max. Demand
Sv_{14}	Saving in year 2014
Sv_{15}	Saving in year 2015
S_M	Safety Margin

1. INTRODUCTION

INDIA is a growing technological and economical Nation and the most important role in the technological development process is played by electricity. The demand for electricity is growing manifold in comparison to the gradually increasing generation capacity which directly increasing the gap between demand and generation. In particular, growth in electricity consumption is very much related to economic growth. Despite India being the fifth largest producer and consumer of electricity in the world, the per capita consumption is very low and 24 hours of continuous electricity supply is still a dream for millions of Indians [8] and still electricity crisis is a grave problem that needs an immediate attention. The industrial sector of India contributed 26% of GDP in year 2013-14 [7] in which Commercial educational buildings also played a major role in consumption of electricity on mass level to achieve the satisfaction level of their stakeholders. Since, the major concerning body being the educational sector, this paper is dedicated on reducing electricity bill of commercial consumer without having sacrifice with satisfaction level of stakeholders. This paper includes practical analysis of the electricity bills of two consecutive years of an Engineering College of Rajasthan, following some easiest suggestion that can be implemented to save cost in the electricity bills without reducing energy consumption.

2. LITERATURE REVIEW

Energy use in offices has risen in recent years due to the growth in information communication techniques, air-conditioning, density of use etc. to provide high value in a comfortable workplace [1]. In organizations like Engineering Colleges, the top operating expenditure is often found to be electrical energy [2].Generally two-thirds of all energy consumed in an average commercial building is electricity. Lighting, equipment, AC's account for 90 percent of this expenditure. Certainly, the trend of high energy demand could be bounded by appropriate forecasting and the considerable improvements over the time of design, construction, insulation, lighting, and controls. Yet as energy costs continue to climb, improvements and innovation on the consumption side will not be able to keep pace [1].



In most assessments of the manageability of the cost or potential cost savings in the above component, would invariably appear as a top priority, and thus energy Audit or Periodical monitoring is can be one important parameter to be consider. The bifurcation of the consumption of electricity for different kinds of load in commercial building is shown in fig. 1. Energy constitutes a strategic area for cost reduction. A well done energy audit will always help owners to understand more about the ways, energy is used in their organizations [2], and help to identify areas where useless expenses can be suppressed and possibility of improvements exist. The energy audit would give a positive orientation to the energy cost reduction, preventive maintenance, and quality control plans which are vital for production and utility activities [2].

Energy Management strategy for commercial buildings was also proposed by supermarket concept using load shedding as a viable means for reducing the electricity bills [9]. The implementation of supervision strategy was based on fuzzy logic and compared with alternative method to validate the proposed concept in terms of reduction in the electricity bills [9].

The problem of real-time estimation of occupancy in a commercial building has been addressed by development of an agent based model to extract statistical information and aid in real time estimation of building occupants [14].

3. PROBLEM STATEMENT

The data of commercial college building for which the analysis has been done was established in year 2000. Currently it is having connected load of 600KW. College is having 08 departments of UG and PG courses along with various laboratories for R&D work. As per the guidelines of Jaipur Viduyat Vitran Nigam (JVVNL), 75% of the connected load of any college building must be considered as a monthly minimum slab of Maximum Demand of consumer which must be paid as a variable part of the standard tariff equation even if the actual maximum demand of the month is very low [5]-[6]. If the consumer forecast less connected load at the time of applying for new connection and if it exceeds in a single month of a year the consumer have to bear an annual penalty for a single month.

Due to the above reason commercial consumer forecasts large connected load to prevent penalty cost, which in turn adds a significant amount in the monthly bill of the consumer.

4. PROPOSED SOLUTION

The possible solution for the above mentioned problem is the audit or critical analysis of the monthly bills and to identify the load / consumption pattern of the consumer by plotting the load curves shown in fig. 3 & fig. 6. This analysis will help in giving a transparent idea to the consumer to forecast connected load accurately and close to the actual consumption. Simultaneously consideration of new infrastructural and technological development must be considered while forecasting the load for the building.

5. MATHEMATICAL MODEL

Connected Load (CL) of building is 600 kW whereas mandatory condition as per the JVVNL is, 75% of the CL of a commercial building must be considered as a minimum slab of Maximum Demand (MDm) for the month and should to be mandatorily charged. If the MD of consumer exceeds the 75% of CL then the actual MD is charged by the JVVNL in spite of minimum slab of MD. It reflects that cost bear by the consumer for MD consumption is a function of a connected load, which can be express by eq. (1).

T_c =f (CL)..(1)

$$T_{cm}= \{MD_m * C_{MD} \text{ if } MD_a<MD_m\}$$

$$\{MD_a * C_{MD} \text{ if } MD_m<MD_a\} \ldots\ldots\ldots\ldots\ldots \text{ (2)}$$

$$T_{cy} = \{\textstyle\sum_{i=1}^{i=12}(MD_m * C_{MD}) \text{ if } MD_a < MD_m\}$$

$$\{\textstyle\sum_{i=1}^{i=12}(MD_a * C_{MD}) \text{ if } MD_m < MD_a\} \ldots \text{(3)}$$

It can be analyzed by eq. (2) & (3) that monthly and annual cost by maximum demand incorporated in the bill of consumer is directly influenced by the minimum slab of maximum demand respectively. This provided the motivation for this work.

6. ANALYSIS OF ANNUAL BILLS

In year 2015, the metering of ten months up to September has already been done so only ten months data of Maximum Demand was available, for which the analysis has been done in table no. 01. In year 2014 analysis of all twelve months is available in table no. 02. It can be seen by both the tables that rate of per KW maximum demand is also not constant, in table no. 01 it has changed from month of April and in table no. 02 it varied in the months of Feb., March and June. It can also be concluded by this varying cost per KW on Maximum Demand that T_c is not only a function of CL which defines in equation no. 01 rather in addition, it is also a function of varying cost applied by the distribution company but it is not a regular exercise so not considered in mathematical model.

Table 1 Electricity Consumption Data of Maximum Demand of Year 2015

CL (KW)	MDm (KW)	MDa (KW)	Months	CMD (KW)	Df= (MDm - MDa)	SM= (CL-MDa)	CMD= B*D or C*D (Rs.)
600	450	128.00	Jan. 15	140	322KW	472 KW	63000
600	450	115.00	Feb. 15	140	335KW	485 KW	63000
600	450	147.00	Mar. 15	140	303KW	453 KW	63000
600	450	295.00	Apr. 15	170	155KW	305 KW	76500
600	450	334.00	May. 15	170	116KW	266 KW	76500
600	450	414.00	June 15	170	36KW	186 KW	76500
600	450	293.00	July 15	170	157KW	307 KW	76500
600	450	304.00	Aug. 15	170	146KW	296 KW	76500
600	450	423.00	Sep. 15	170	27KW	177 KW	76500
Total					**1597 KW**		**Rs. 6,48,000**

It can be seen by fig. 2 and fig. 3 that only in the month of June and Sep. the actual Max. Demand is highest among the 09 months of year. Fig. 2 is clearly indicating that all green bars are below the red bars which means not even in a single month the actual MD has exceeded the min. slab of MD, defined by the Jaipur Viduyat Vitaran Nigam Limited (based on the connected load of consumer). Consumers have to pay for min. slab of MD just for the sake of safety and prevention by annual penalty which imposed on the bill after exceeding CL.

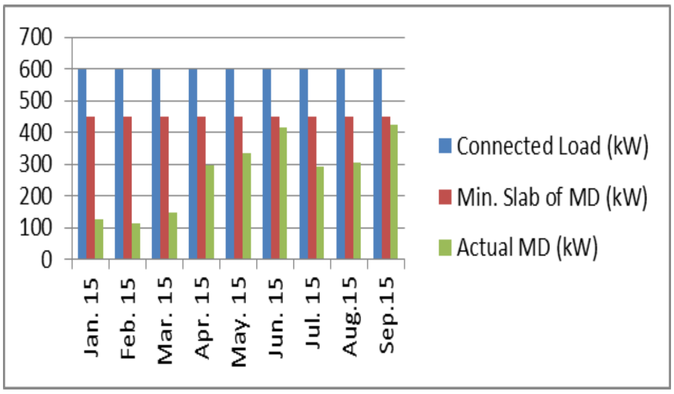


Fig.2 Comparison between Min. slab of Connected Load, and Actual Max. Demand of Commercial consumer in year 2015

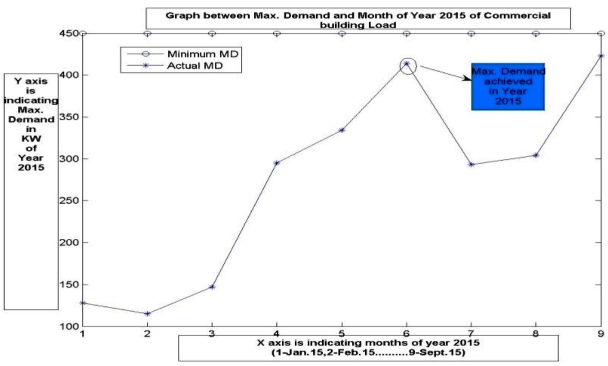


Fig.3 Load Curve showing MDa and MDm of commercial Consumer of year 2015

Fig. 4 has been plotted after the critical analysis of table 01 and by identifying safety margins after plotting fig.1.It clearly indicates that if the CL is reduced by say25% than the minimum slab MD slab imposed on consumer has also been reduced by 25%, which can provide a significant reduction in the annual bill and saving of consumer. This will encourage the consumer for the Demand side Management concept under which the electricity bill of consumer reduce without reducing the consumption.

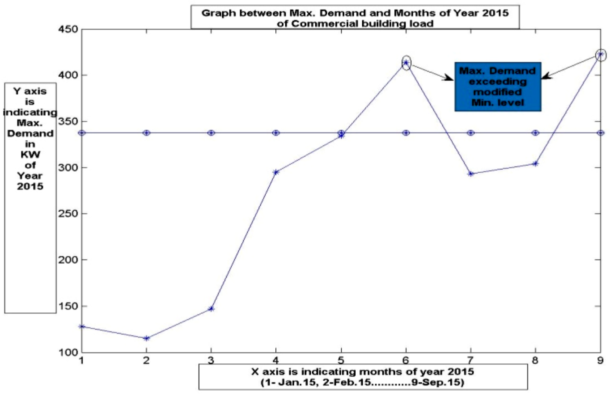


Fig.4 Load Curve showing MDm and MDa of commercial Consumer of year 2015 after reducing Connected Load

It can be concluded by Fig. 4 that even after reducing min. slab of MD by 25% the actual MD of consumer was still less than the CL in all the billing months. The benefit which consumers can achieve is only in the months when their load exceeds the min. slab of MD, in this case billing of MD will be on actual MD rather than the minimum slab of MD, and this can provide benefit to the consumer and help to reduce their electricity annual bills.

The above solution is also verified by analyzing the monthly bills of year 2014 which has shown in table 02 and comparing it with bills of year 2015 which has shown in fig. 10. It has also provided the same kind of results which produced by the analysis of year 2015. According to fig. 6 only in the month of Sept. of year 2014 the actual MD was closest to min. slab of MD but still 08 kW less to it. Fig. 7 is showing that by reducing CL, the min. slab of MD has reduced but the actual MD is still not reaching the CL which provides proper safety margin to the consumer. This was also an indicator to reduce CL for reducing the electricity bills significantly.

Table 2 Electricity Consumption Data of Maximum Demand of Year 2014

CL (KW)	MDm (KW)	MDa (KW)	Months	CMD (KW)	Df= MDm-MDa	SM= CL-MDa	CMD= B*D or C*D (Rs)
600	450	141.00	Jan. 14	140	309KW	459KW	63000
600	450	134.00	Feb. 14	172.67	316KW	466 KW	77700
600	450	128.00	Mar. 14	102.67	322KW	472 KW	46200
600	450	224.00	Apr. 14	140	226KW	376 KW	63000
600	450	308.00	May. 14	140	142KW	292 KW	63000
600	450	414.00	June 14	142.8	36KW	186 KW	64260
600	450	400.00	July 14	140	50KW	200 KW	63000
600	450	306.00	Aug. 14	140	144KW	294 KW	63000
600	450	442.00	Sep. 14	140	8KW	158 KW	63000
600	450	342.00	Oct. 14	140	108KW	258 KW	63000
600	450	334.00	Nov. 14	140	116KW	266 KW	63000
600	450	240.00	Dec. 14	140	210KW	360 KW	63000
Total					**1987KW**		**Rs. 7,53,160**

Fig. 5 is showing the comparison between CL, MD_m and MD_a. The actual MD's are very much less than the CL's. It can be seen by fig. 5 and verified by table no. 2that the minimum safety margin is 158 kW in the month of September which was an alarming figure for the work and could be reduced by taking proper measures.

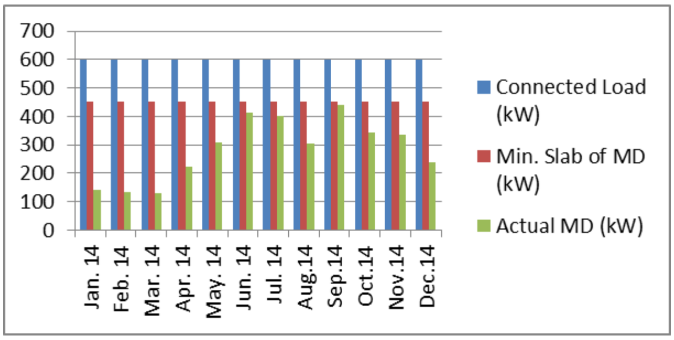


Fig.5 Comparison between CL, MDm and MDa of Commercial consumer in year 2014

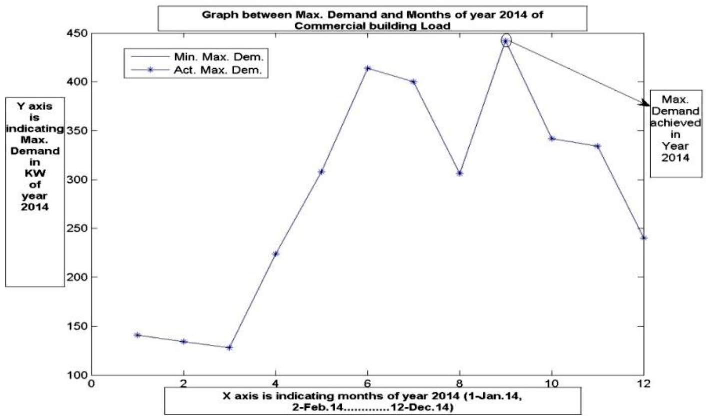


Fig.6 Load Curve showing MDa and MDm of Commercial Consumer of year 2014

As the earlier discussion CL has reduced by 25% and corresponding data was generated as per table 3 and table 4 for year 2015 and 2014 respectively. Fig 4 and fig 7 are showing the load curves exceeding the reduced minimum slab of Maximum Demand but still having considerable safety margins shown in table 3 and table 4 for year 2015 and 2014 respectively.

According to table 3 minimum safety margin was 27 kW in the month of Sep. of year 2015 and as per table 4 it was 8 kW but the month was again same. This show that month of Sept. was having highest consumption in both the years due to the geographical conditions of Rajasthan state. The moisture content in the air is maximum in this month which in turn increases the consumption level of electricity even more than the peak summer months which can be verified by fig. 8 and fig. 9 showing comparison between Safety Margins before and after reducing CL in year 2015 and 2014 respectively.

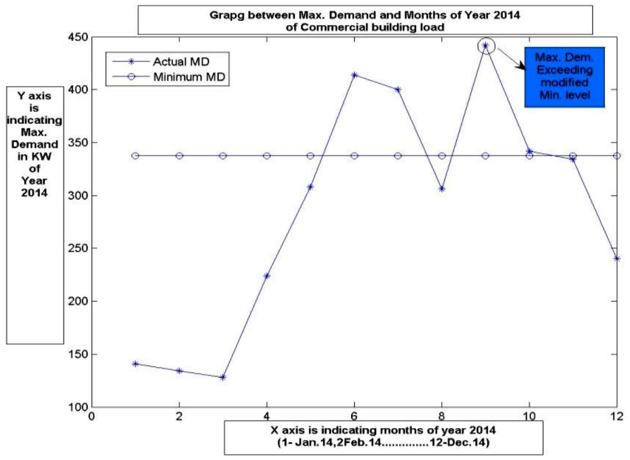


Fig.7 Load Curve showing MDa and MDm of commercial Consumer of year 2014 after reducing Connected Load

Table 3 Electricity Consumption Data of Maximum Demand of Year 2015 after modifying CL

CL (KW)	MDm (KW)	MDa (KW)	Months	CMD (KW)	Df= MDm-MDa	SM= CL-MDa	CMD= B*D or C*D (Rs)
450	337.5	128.00	Jan. 15	140	209.5	322 KW	47250
450	337.5	115.00	Feb. 15	140	222.5	335 KW	47250
450	337.5	147.00	Mar. 15	140	190.5	303 KW	47250
450	337.5	295.00	Apr. 15	170	42.5	155 KW	57375
450	337.5	334.00	May. 15	170	3.5	116 KW	57375
450	337.5	414.00	June 15	170	-76.5	36 KW	70380
450	337.5	293.00	July 15	170	44.5	157 KW	57375
450	337.5	304.00	Aug. 15	170	33.5	146 KW	57375
450	337.5	423.00	Sep. 15	170	-85.5	27 KW	71910
Total					**584.5 KW**		**Rs. 5,13,540**

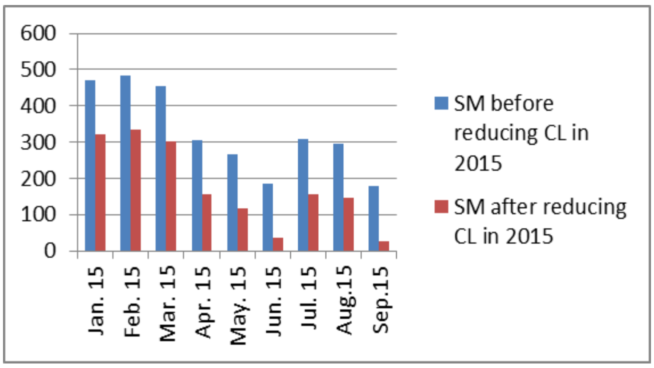


Fig 8 Graph between Comparison of Safety Margins before and after reducing CL in Year 2015

Table 4 Electricity Consumption Data of Maximum Demand of Year 2014 after modifying CL

CL	MDm	MDa	Months	CMD	Df= MDm-MDa	SM= CL-MDa	CMD= B*D or C*D
450	337.5	141.00	Jan. 14	140	196.5	309 KW	47250
450	337.5	134.00	Feb. 14	172.67	203.5	315 KW	58276.12
450	337.5	128.00	Mar.14	102.67	209.5	321 KW	34651.12
450	337.5	224.00	Apr. 14	140	113.5	226 KW	47250
450	337.5	308.00	May.14	140	29.5	142 KW	47250
450	337.5	414.00	June 14	142.8	-76.5	36 KW	59119.2
450	337.5	400.00	July 14	140	-62.5	50 KW	56000
450	337.5	306.00	Aug.14	140	31.5	144 KW	47250
450	337.5	442.00	Sep. 14	140	-104.5	8 KW	61880
450	337.5	342.00	Oct. 14	140	-4.5	108 KW	47880
450	337.5	334.00	Nov.14	140	3.5	116 KW	47250
450	337.5	240.00	Dec.14	140	97.5	210 KW	47250
Total					**637 KW**		**Rs. 6,01,306.44**

The negative signs in the difference between min slab of Max. Demand and actual Maximum Demand in table 3 and table 4 are representing the months in which the MD_a is greater than MD_m in the year 2015 and 2014 respectively. In other words it can be interpret that in these months, consumer is paying for MD_a rather than MD_m which in turn providing benefit to him in his annual expenditure on the electricity which can be seen by fig 10 which is showing annual expenses in cost of Maximum Demand in both the years.

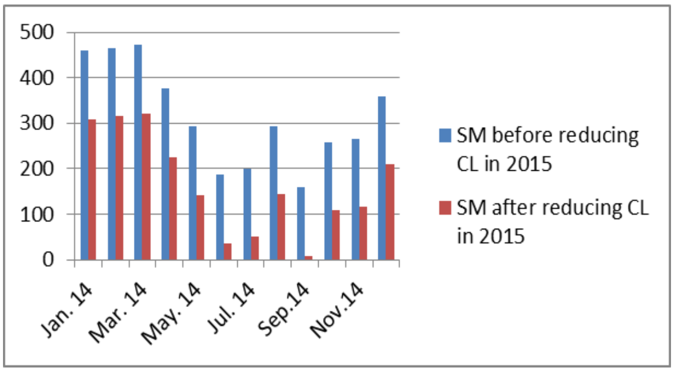


Fig.9 Graph between Comparison of Safety Margins before and after Reducing CL in Year 2014

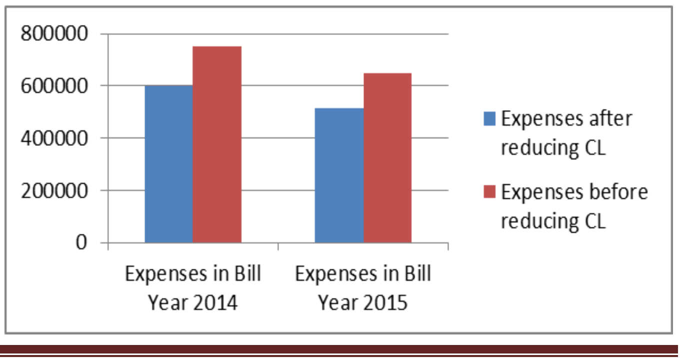


Fig.10 Expenses on Maximum Demand in Year 2014 & 2015 in INR

7. RESULT ANALYSIS

The total saving in the electricity bill can be realized annually due to monthly fluctuations in maximum demand. In fig.8 & 9 blue bars are showing the safety margins before reducing the CL and red bars are showing safety margins after reducing CL as per the data in table no. 3 & 4. It can be easily judged that even after reducing CL, safety margins were not reduced beyond the threshold value (value of CL), which means reducing CL by 25% was still safe to prevent consumer by imposing annual penalty. After reducing CL, the monthly saving on bill cannot be guaranteed but annual saving on bill must be ensured and verified by the calculation done below for year 2014 and 2015 respectively.

$\%Sv_{14}$= [Sv_{14} / Ty_{14}]*100...(4)

$\%Sv_{14}$= (601306.44 / 7942266.86)*100= **7.57%**

$\% Sv_{15}$= [Sv_{15} / Ty_{15}]*100.. (5)

$\%Sv_{15}$= (513540/ 6448641.28)*100= **7.96%**

Results derived from equation (5) and (6) are clearly indicating the considerable financial benefits of 7.57% and 7.96% in the bills of year 2014 and 2015 respectively. According to table 2, 4, 1 & 3 financial benefits which the consumer could get was Rs. 1, 51,853.56 in year 2014 and Rs. 1, 34,460 in year 2015. The benefit of year 2015 was only considering nine months. This proves the feasibility of work done.

8. CONCLUSION

In this paper critical monitoring and proper identification of load pattern in a structured manner were the keys of reducing the electricity bills of commercial building. There could be still further scope of work by deeply analyzing the bills of commercial consumers having large consumption in the context of demand side management. Many parameters can be identified in the tariff structure of commercial consumers which can help in energy conservation. It can be concluded that auditing or monitoring is also a part of Demand side Management which can provide a significant benefit to consumers and encourage them for the energy conservation by various means like technological advancements, replacing equipments by better star rating, shift their peak demand periods to the off peak demand periods etc. All these kind of works are proposed for the future expansion of commercial tariff structure.

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BIOGRAPHIES

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