DEMAND SIDE MANAGEMENT BY USING PEAK CLIPPING METHOD FOR REDUCTION OF ENERGY COSTS

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Abstract: In general, reduction of energy usage and its cost is very important to have more reliable efficient system and is one of prime factor in demand side management. Different methods are available to reduce peak demand and in turn to improve the maximum utilization of generated energy and reduction in its cost. This work presents a method of peak clipping used in demand-side management to reduce peak demand and its energy cost. In this method, firstly the values of the maximum and minimum energy demands are determined from daily load duration curve by taking the difference between hourly energy demands on a daily load schedule. Secondly peak clipping is done by the load shifting from period of maximum load to the period of minimum load at various time intervals with approval of customers.
Key Words: Demand side management, Reduction of energy cost, Reduced Peak demand.

INTRODUCTION

Demand-Side Management (DSM) is a strategy used by electric utilities to control demand by encouraging consumers to change the level and pattern of electricity consumption [1] and is nothing but active control of energy consumption. On the other side, load management, also known as Demand Side Management (DSM), is the process of balancing supply of electricity from the grid with the electrical load by regulating or controlling the load rather than the output of the power station. This often involves controlling electricity consumption based on financial requirements from the electricity market. Demand side management (DSM) has many benefits for customers and utilities [2- 4] It is successful at reducing large bills and power cuts during the peak hours of the day may cause. Technologies and initiatives that are available to help customers to reduce their energy consumption. Demand side management (DSM) may have two advantages. Firstly, by controlling when and how much electricity is consumed, consumers can lower their monthly electric bills. Second, shifting energy consumption from peak load to off-peak load hours might be profitable for the energy system. [5]. In [6-9] discuss about how to shift non-critical loads from high peak hours to low peak hours and especially during weekends and off-peak hours. DSM objective is typically to encourage consumers to spend less energy during peak load times in favour of off-peak load times [10]. By changing the system load curve, the power system can operate the lowest possible cost by controlling the amount and timing of customer energy use with the help of DSM [11].

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Demand side management techniques

Various Demand Side Management (DSM) techniques are available such as Load shifting, Peak clipping, valley filling, load building and energy conservation, flexible load are respectively, which are used to modify the utility load curve [12]. The graphical representation of DSM techniques is given in Fig. 1.

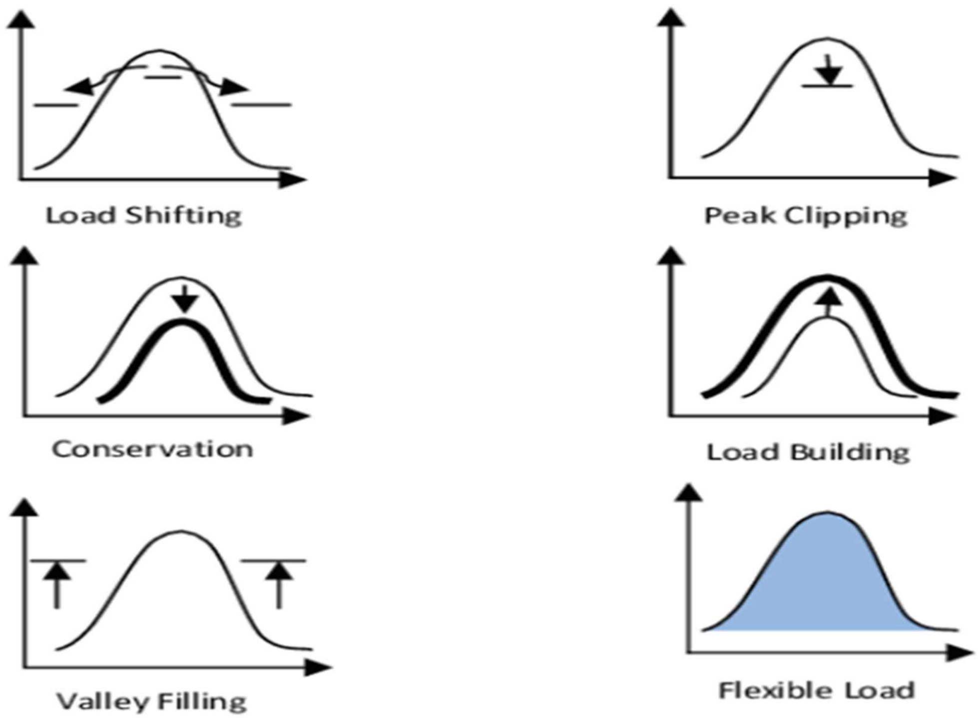

Fig. 1. Demand Side Management Technique Curves

Load shifting techniques [13] are employed and shows that cost of energy is reduced by shifting the loads from peak hours to off peak hours. Every method of DSM has its own advantages and dis-advantages. In this work peak clipping method is employed and the obtained results are compared with the load shifting method [1] results for two practical system.

Peak clipping method

Demand-Side Management (DSM) Peak clipping means reducing the peak demand of electricity either by the utility direct control or by the tariff adjustments. Differential tariffs motivate the consumers to cut short the demand during the peak hours. Utilizing customer demand, the differential tariff balances power output and consumption [8]. For example, the peak demand for electricity can be reduced by scheduling all of the electric baseboard space heaters in public areas to turn off loads during anticipated peak hours. Peak demand costs can be reduced by making sure that high demand equipment is not operating simultaneously [14]. DSM techniques such as peak clipping are used to reduce peak demand, thereby reducing energy costs. Peak clipping is a utility-initiated load management technique by directly controlling consumer power consumption (load demand) by rescheduling the load from peak to off-peak as shown in below Fig.2. This can be done by directly controlling all consumer equipment at the time of peak demand with prior information to the consumers. Thus, peak demand is reduced during peak hours and improves the load factor of the system, which in turn reduces the peak demand cost and energy cost.

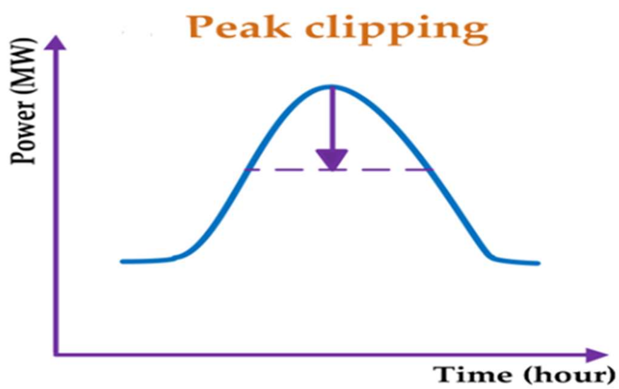

Fig 2. Peak clipping technique

To analyse the peak clipping method, initially load factor, average demand can be calculated using equations (1) - (2) from load duration curve.

Load factor is calculations using the equation (1)

L.F = P_{avg} / P_{max}

(1)

P_{avg} = Total no. of loads / Total time

$P_{avg} = \sum_{i=1}^{n} Pi \,/\, \sum_{t=1}^{24} Ti$

Where,

n = no. of loads

t = time

P = magnitude of load

L.F = load factor

P_{avg} = Average value of load

P_{max} = maximum value of load in daily load duration curve

P_{avg} = Sum of loads / Total time (24 hrs)

(2)

From equations (1) & (2), load demand cost for 24 hrs with Rs 5.88 / unit is calculated using equation (3)

Demand cost for 24 hours = L.F*Cost of energy*Total time

(3)

Cost for 33KV consumers per unit cost = 5.88Rs in the year 2021-22

The proposed peak clipping method is tested for two practical distribution systems of 33KV feeder. One feeder is connected between Narpala village to Bukkarayasamudram sub-station of 20km away each other. Second feeder is connected to Bukkarayasamudram village to Bukkarayasamudram sub-station of 1 km apart.

Illustrative examples

Example 1

Consider a practical system of 33KV feeder connected from A.P. Transco 220KV substation, bukkarayasamudram to Narpala village anantapuramu district, which is 20km away from sub-station.

Fig 3. Narpala village map

Narpala is a large village located in Narpala Mandal of Anantapur district, Andhra Pradesh with total 4876 families residing as shown in Fig 3. The Narpala village has population of 18982 of which 9466 are males while 9516 are females as per Population Census 2011. The daily total load of this Narpala village is 158.2MW and their daily load duration curve is shown in Fig. 4. The hourly load data is given in Table 1. For example, consider a washing machine of rating 2500watts is turned off during 1 to 24 hours by 880 people the total load consumed by these people is 2500w*880 = 2.2MW

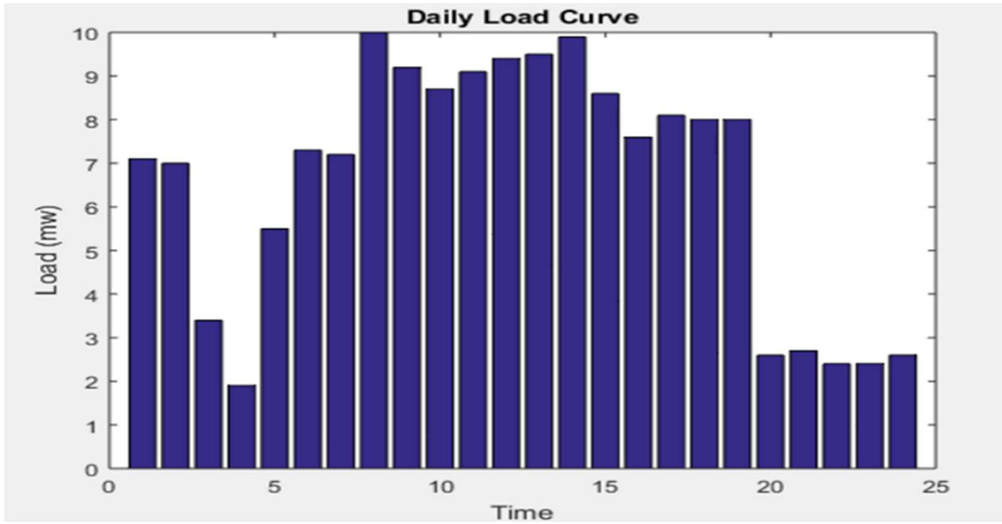

Fig 4. Daily load duration curve for Narpala 33KV feeder before peak clipping

Table 1. Load data

Hours	1	2	3	4	5	6	7	8	9	10	11	12
Load [MW]	7.1	7.0	3.4	1.9	5.5	7.3	7.2	10.0	9.2	8.7	9.1	9.4

Hours	13	14	15	16	17	18	19	20	21	22	23	24
Load [MW]	9.5	9.9	8.6	7.6	8.1	8.0	8.0	2.6	2.7	2.4	2.4	2.6

From the Fig.4, the average demand (Pavg), load factor (LF) and dialy demand cost in rupees is calculated by using equations (1) – (3). The obtained values before peak clipping are tabulated in table 2.

Table 2. Parameters Before Peak Clipping

Power system parameters	values
P_{max} (MW)	10
P_{min} (MW)	1.9
P_{avg} (MW)	6.591
$LF = P_{avg} / P_{max}$	0.6591

Daily demand cost (Rs)	930216

After application of proposed method, from Fig.4. the peak loads from 8th interval to 15th interval of time is clipped to off peak load and shifted to two intervals of 0th to 7th interval and 16th to 24th interval of time. The modified daily load duration curve with improvement of load factor to 1.0 for example the peak load of 10MW at 8th interval is reduced to 6.5MW and causes energy reduction of 3.5MW. The daily demand cost and its load factor are calculated. For modified load duration curve of Fig. 5. Using equations (1) – (3) and tabulated in Table 3.

From Table.3. It is observed that the load factor is improved from 0.6591 to 1.0 and average demand is decreased from 6.591 to 6.5, In turn the daily demand cost is reduced from Rs 930216 to 917280. The comparison of results before and after peak clipping is shown in table.3. Hence performance of the system is improved with net saving of Rs. 12936/- per day, and total load of 74.4MW clipping to off peak hours, if it is calculated per year is Rs 12936*365days = Rs 4721640.

Daily load duration curve for Narpala 33KV feeder after peak clipping

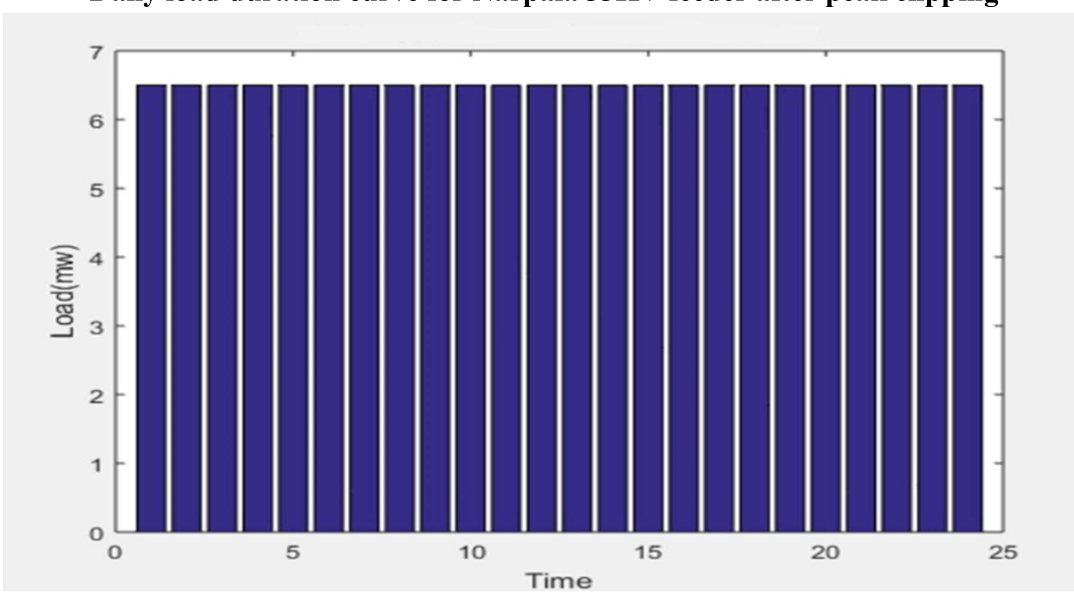

Fig 5. Daily load duration curve for Narpala 33KV feeder after peak clipping

Table 3. Parameters after peak clipping

Power system parameters	Before clipping values	After clipping values
P_{max} (MW)	10	6.5
P_{min} (MW)	1.9	6.5
P_{avg} (MW)	6.591	6.5

LF = Pavg / Pmax	0.6591	1.0
Daily demand cost (Rs)	930216	917280
Savings in Rs		12,936

4.2 Example 2

Consider a practical system of 33KV feeder connected from A.P. Transco 220KV sub-station located at Bukkarayasamudram village, anantapuramu district to Bukkarayasamudram sub-station of 1 km apart.

Fig 6. Bukkarayasamudram village map

Bukkarayasamudram has a total population of 22,000 peoples, out of which male population is 11,034 while female population is 10,966 is shown in Fig 6. There are about 5,220 houses in Bukkarayasamudram village. Anantapur is nearest town to Bukkarayasamudram for all major economic activities, which is approximately 4km away. The daily total load of this Bukkarayasamudram village is 166MW and their daily load duration curve is shown in Fig. 7. The hourly load data is given in Table 4. For example, consider a rice cooker of rating 2500watts is turned off during 1 to 24 hours by 1000 peoples it results in 2500w*1000 = 2.5MW.

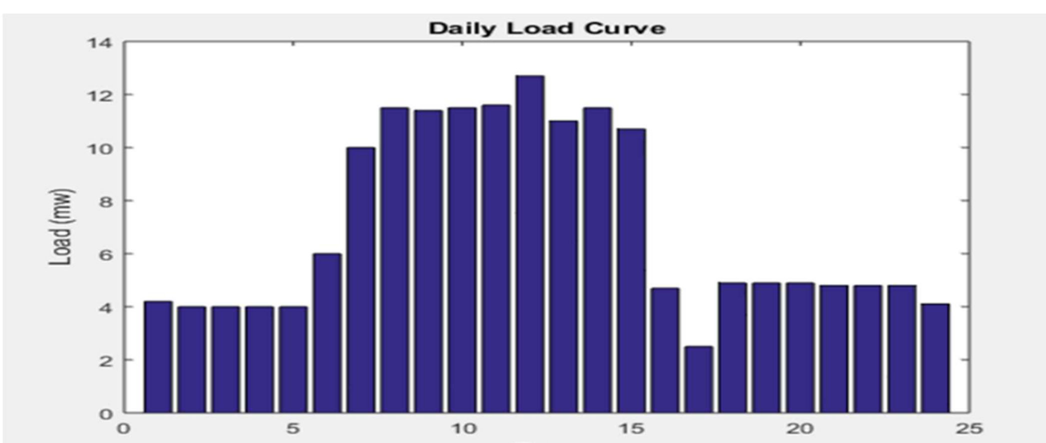

Fig 7. Daily load duration curve for bukkarayasamudram 33KV feeder before peak clipping

Table 4. Load data

Hours	1	2	3	4	5	6	7	8	9	10	11	12
Load [MW]	4.2	4.0	4.0	4.0	4.0	6.0	10.0	11.5	11.4	11.5	11.6	12.7

Hours	13	14	15	16	17	18	19	20	21	22	23	24
Load [MW]	11.0	11.5	10.7	4.7	2.5	4.9	4.9	4.9	4.8	4.8	4.8	4.1

From the Fig.7, the average demand (Pavg), load factor (LF) and dialy demand cost in rupees is calculated by using equations (1) – (3). The obtained values before peak clipping are tabulated in table 5.

Table 5. Parameters Before Peak Clipping

Power system parameters	values
P_{max} (MW)	12.7
P_{min} (MW)	2.5
P_{avg} (MW)	7.020
LF = P_{avg} / P_{max}	0.552
Daily demand cost (Rs)	990780

After application of proposed method, from Fig.7. the peak loads from 7th interval to 15th interval of time is clipped to off peak load and shifted to two intervals of 0th to 6th interval and 16th to 24th interval of time. The modified daily load duration curve with improvement of load factor to 0.9 for example the peak load of 12.7MW at 7th interval is reduced to 7.03MW and causes energy reduction of 5.67MW. The daily demand cost and its load factor are calculated, for modified load duration curve of Fig. 8. using equations (1) – (3) and tabulated in Table. 6. From Table.5. it is observed that the load factor is improved from 0.6591 to 1.0 and average demand is decreased from 7.020MW to 6.916MW, in turn the daily demand cost is reduced from Rs 990780 to 976080. The comparison of results before and after peak clipping is shown in table.6. Hence performance of the system is improved with net saving of Rs. 14700/- per day, and total load of 101.9 MW clipping to off peak hours, if it is calculated per year is Rs 14700*365days = Rs 5365500.

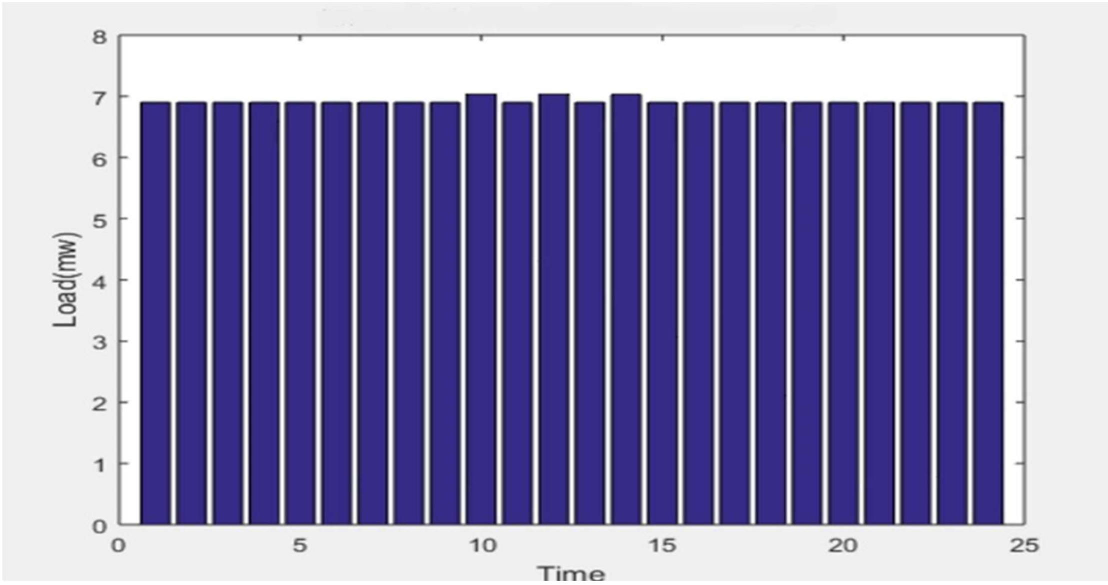

Fig 8. Daily load duration curve for bukkarayasamudram 33KV feeder after peak clipping

Table 6. Parameters after peak clipping

Power system parameters	Before clipping values	After clipping values
P_{max} (MW)	12.7	7.03
P_{min} (MW)	2.5	6.9
P_{avg} (MW)	7.020	6.916
LF = P_{avg} / P_{max}	0.552	0.9
Daily demand cost (Rs)	990780	976080
Savings in Rs		14700

Load shifting method (Existing method):

By using this existing method [1], the load is shifted from peak hours to off-peak hours as shown in Fig 9. without consultation of consumers, which in turn reduces daily demand cost and improves load factor. The effect of this method is tested with same 33KV feeder connected between Narpala village to bukkarayasamudram sub-station. The load duration curve of Fig 4. is used to find the effectiveness of the existing method. From Fig 4, Some of deferrable loads from 8th interval to 15th intervals are shifted [1].

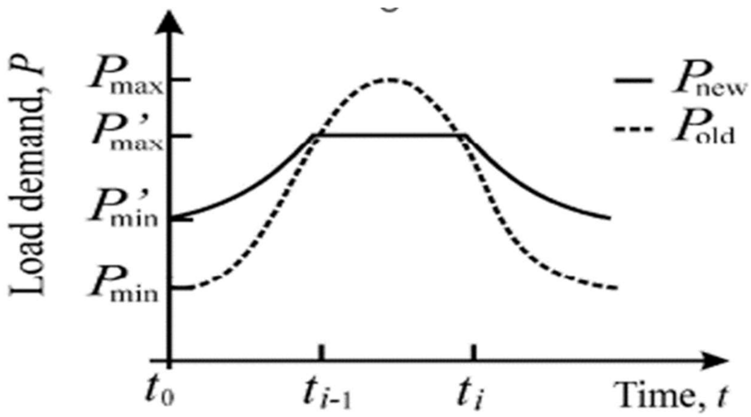

Fig 9. Load demand before (Pold) and after (Pnew) the applied load shifting technique.

For comparing the result obtained from proposed method and result obtained from existing method, the same 33KV feeder connected between Narpala village to Bukkarayasamudram sub-station is considered. The results of existing method [1] for the same system is given in Table 7. and the resultant daily load duration curve is shown in Fig 10. The comparison of results of both methods are shown in Table 8. From the Table 8. it is observed that maximum, demands has been reduced from 7.5 to 6.5 and minimum, demand is maintained constant. Also load factor is improved from 0.8788 to 1.0, daily demand cost is reduced from Rs 930216 to 917280. Hence performance of the system is improved with Table 8. observed net saving of Rs. 12936/- per day, and total load of 74.4MW clipping to off peak hours, if it is calculated per year is Rs 12936*365days = Rs 4721640.

Hence, the proposed method is better than existing method in terms of cost of energy load factor and maximum demand, Fig. 10 using equations (1) – (3) and tabulated in Table. 7.

Daily load duration curve for Narpala 33KV feeder after peak clipping

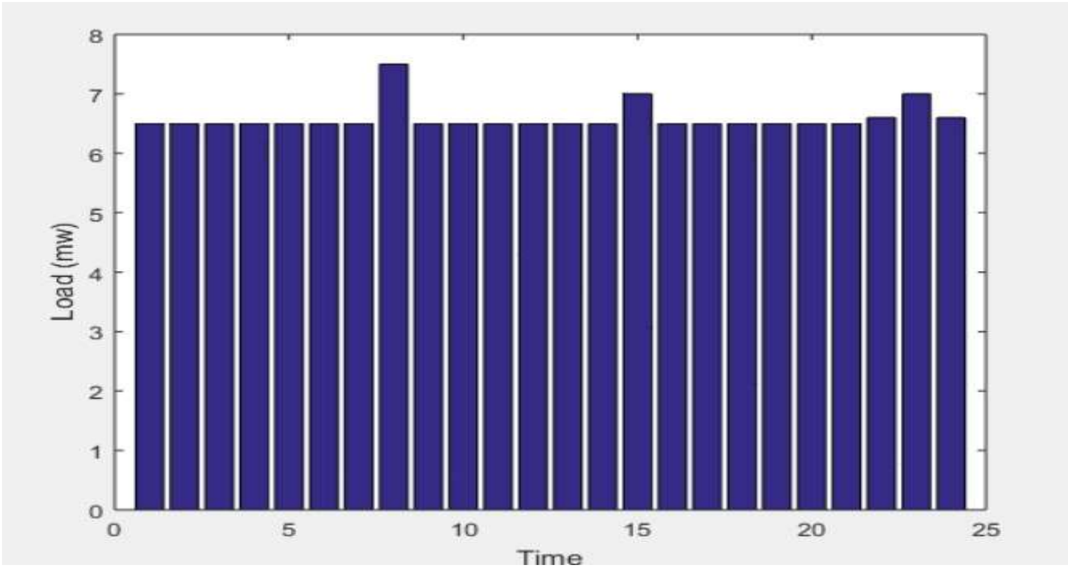

Fig 10. Daily load duration curve for Narpala 33KV feeder after peak clipping

Table 7. Parameters after load shifting

Power system parameters	Before load shifting values	After load shifting values
P_{max} (MW)	10	7.5
P_{min} (MW)	1.9	6.5
P_{avg} (MW)	6.591	6.591
LF = P_{avg} / P_{max}	0.6591	0.8788
Daily demand cost (Rs)	930216	930216

Table 8. Parameters after load shifting method and after peak clipping method values

Power system parameters	After load shifting method values	After peak clipping method values
P_{max} (MW)	7.5	6.5
P_{min} (MW)	6.5	6.5
P_{avg} (MW)	6.591	6.5
LF = P_{avg} / P_{max}	0.8788	1.0
Daily demand cost (Rs)	930216	917280

Savings in Rs		12936

CONCLUSION:

Peak clipping method is a control technique for demand side management. To minimize the maximum demand at times of high load, it is a direct controlling method on all consumer appliances. By shifting peak loads to off-peak loads at suitable periods of time. The proposed peak clipping method is one of direct control technique for managing peak demand in the area of demand side management and in turn reduce the cost of energy. It shows that obtained results for two practical systems after peak clipping is better than before peak clipping and load shifting method (existing method). The savings in cost of energy per year is Rs 4721640 for Narpala load & Rs 5365500 for Bukkarayasamudram load per yearly and is better than saving in cost of energy per year with the existing method.

REFERENCES:

- D. Javor and N. Raicević, "Two-Steps Procedure in Demand Side Management for Reducing Energy Costs," 2020 19th International Symposium INFOTEH-JAHORINA(INFOTEH),2020, pp.1-4, doi:10.1109/INFOTEH48170.2020.9066311.
- C. W. Gellings and J. H. Chamberlin, Demand-Side Management: Concepts and Methods, PennWell Books, USA, 1993.
- L. Y. Seng and P. Taylor, "Innovative Application of Demand Side Management to Power Systems," Proceedings of the First International Conference on Industrial and Information Systems, Sri Lanka, 2006, pp.185-189.
- M. M. Salama, E. M. Saied, H. M. Mahmoud, and H. A. Abdelhadi, "Residential loads and Application of Demand Side Management (DSM) Techniques," Conference of Saudi Arabia Grid 2013 (5ASG), Geddah, Saudi Arabia, 2013, pp. 1-7.
- https://www.ema.gov.sg/Demand_Side_Management.aspx
- R. K. Yadav, P. N. Hrishikesha and V. S. Bhadoria, "A Nature Inspired Strategy for Demand Side Management in Residential Sector with Smart Grid Environment," 2020 9th International Conference System Modeling and Advancement in Research Trends (SMART), 2020, pp. 235-239, doi: 10.1109/SMART50582.2020.9337101.
- T. Logenthiran, D. Srinivasan, A. M. Khambadkone, and H. N. Aung, "Multiagent System for Real-Time Operation of a Microgrid in Real-Time Digital Simulator," IEEE Transactions on Smart Grid, vol. 3, no.2, 2012.
- Mahmood, A., Ullah, M. N., Razzaq, S., Basit, A., Mustafa, U., Naeem, M., et al. (2014). A new scheme for demand side management in future Smart Grid networks. Procedia Computer Science, 32, 477–484.
- Gellings, C. W. (1985). The concept of demand-side management for electric utilities. Proceedings of the IEEE, 73(10), 1468–1470.
- https://kalyan07.wordpress.com/2014/04/12/introduction-to-demand-side-management-benefits-challenges-and-barriers.
- H. Yang, Y. Zhang and X. Tong, "System Dynamics Model for Demand Side

Management," 2006 3rd International Conference on Electrical and Electronics Engineering, 2006, pp. 1-4, doi: 10.1109/ICEEE.2006.251854.

- B. Priya Esther, K. S. Sathish Kumar, (2016), A survey on Residential Demand Side Management Architecture, Approaches, Optimization models and methods, in 'Renewable and Sustainable Energy Reviews', Elsevier, 59, 342-351.
- J. Prasad, T. Jain, N. Sinha and S. Rai, "Load Shifting Based DSM Strategy for Peak Demand Reduction in a Microgrid," 2020 International Conference on Emerging Frontiers in Electrical and Electronic Technologies (ICEFEET), 2020, pp. 1-6, doi: 10.1109/ICEFEET49149.2020.9186983.
- https://www.enertiv.com/resources/blog/4-peak-demand-reduction-strategies
- https://en.wikipedia.org/wiki/Energy_demand_management.
- https://en.wikipedia.org/wiki/Differential_tariff.
- H. A. Attia, "Mathematical formulation of the Demand Side Management (DSM) problem and its optimal solution," Proceedings of 14th International Middle East Power Systems Conference MEPCON'10, Paper ID 314, Cairo, Egypt, 2010, pp. 953-959.
- Gelazanskas, Linas, and Kelum AA Gamage. "Demand side management in smart grid: A review and proposals for future direction." Sustainable Cities and Society 11 (2014): 22-30.
- Gellings, Clark W. "The concept of demand-side management for electric utilities." Proceedings of the IEEE 73.10 (1985): 1468- 1470.
- Esther, B. Priya, and K. Sathish Kumar. "A survey on residential demand side management architecture, approaches, optimization models and methods." Renewable and Sustainable Energy Reviews 59 (2016): 342-351.
- Haider, Haider Tarish, Ong Hang See, and Wilfried Elmenreich. "A review of residential demand response of smart grid." Renewable and Sustainable Energy Reviews 59 (2016): 166- 178.
- Panda, S., Rout, P. K., & Sahu, B. K. (2021). Demand Side Management by PV Integration to Micro-grid Power Distribution System: A Review and Case Study Analysis. Green Technology for Smart City and Society, 417-432.
- Cherukuri, S. Hari Charan, B. Saravanan, and G. Arunkumar. "An overview of residential demand side management strategies." 2019 Innovations in Power and Advanced Computing Technologies (iPACT). Vol. 1. IEEE, 2019.
- Barbato, Antimo, and Antonio Capone. "Optimization models and methods for demand-side management of residential users: A survey." Energies 7.9 (2014): 5787-5824.
- Haney, Aoife Brophy, et al. "Demand-side management strategies and the residential sector: lessons from international experience." The future of electricity demand: Customers, citizens and loads (2010): 337-378.
- Elma, Onur, and Uğur S. Selamoğullar. "A survey of a residential load profile for demand side management systems." 2017 IEEE International Conference on Smart Energy Grid Engineering (SEGE). IEEE, 2017.

- Tascikaraoglu, Akın, A. R. Boynuegri, and Mehmet Uzunoglu. "A demand side management strategy based on forecasting of residential renewable sources: A smart home system in Turkey." Energy and Buildings 80 (2014): 309-320.
- Warren, Peter. "A review of demand-side management policy in the UK." Renewable and Sustainable Energy Reviews 29 (2014): 941-951.
- Zhang, Qin, et al. "Survey of demand response research in deregulated electricity markets." Automation of Electric Power Systems 32.3 (2008): 97-106.
- Siano, Pierluigi. "Demand response and smart grids—A survey." Renewable and sustainable energy reviews 30 (2014): 461-478.
- Meyabadi, A. Fattahi, and Mohammad Hossein Deihimi. "A review of demand-side management: Reconsidering theoretical framework." Renewable and Sustainable Energy Reviews 80 (2017): 367-379.
- Zhang, Qin, et al. "Survey of demand response research in deregulated electricity markets." Automation of Electric Power Systems 32.3 (2008): 97-106.
- Samad, Tariq, Edward Koch, and Petr Stluka. "Automated demand response for smart buildings and microgrids: The state of the practice and research challenges." Proceedings of the IEEE 104.4 (2016): 726-744.
- Warren, P. (2014). A review of demand-side management policy in the UK. Renewable and Sustainable Energy Reviews, 29, 941-951.