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IMPROVEMENT OF SAVING ON GENERATING UNITS BY USING DEMAND SIDE MANAGEMENT

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Abstract
Demand Side Management (DSM) is now an important consideration for electric power utilities. DSM in general refers to any activity adopted by an electric utility that ultimately changes the utility's system load curve. Enhancing the DSM activities will help the system operate more efficiently. Demand-side management (DSM) includes energy efficiency and demand response (DR), instead of adding more generation to the system; it pays energy users to reduce consumption. This paper presents the peak load of the system is reduced by applying DSM techniques such as Peak Clipping, Valley Filling and Load shedding. By increasing load factor, here the loads are applicable to the 6-generator system for determining the scheduling and fuel cost. These techniques are tested on the IEEE RTS 96 system and the results such as load duration curve load factors and generation cost are compared with the same system with and without DSM by using MATLAB software.

Introduction
Integrated Resource Planning (IRP) is a process of optimizing energy savings and energy producing options to minimize the total cost. IRP is a broader term which includes consideration of Demand Side Management (DSM) and social costs. DSM is actually planning, implementing, and evaluation of utility sponsored programs to influence the amount or timing of customers' energy use. A. S. Malik proposed a method on "Simulation of DSM resources as generating units in probabilistic production costing framework [1]. DSM provides the best solution between load growth and increasing constraints on new and existing generation capacity. It also provides a workable solution to some of the major problems such as high variability of load faced by the major electric utilities. Substantial benefits will increase if effective demand side participant is in place. These benefits include, but are not limited to, improvements in energy efficiency and reliability, mitigation of market power on the supply side, alleviation of transmission congestion, and reduction in the level and volatility of market prices. S.K. Nelson and B.F. Hobbs proposed "Screening demand-side management programs with a value-based test," [2]. Now a variety of DSM technologies have emerged and can be applied to achieve such goals as peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape. S. Majumdar, D. Chattopadhyay, and I. Parikh proposed "Interruptible load management using optimal power flow analysis," [3]. Strategic conservation involves reducing demand for electricity without any shift in demand to another time. Peak clipping reduces electricity demand during on-peak periods of the day, thereby lowering the peak demand that utilities must meet. Conversely, valley filling increases electric load during off-peak periods.

The process of valley filling during periods of low demand and peak clipping at times of high demand results in reduction in total costs. Load shifting is the movement of loads from peak periods to off-peak periods. The transfer of energy produced at times of low demand (hence with low marginal cost) to replace the more expensive energy at times of high demand (hence with high marginal cost) results in energy cost savings.

There is a growing concern about power system reliability under a market environment, especially after the blackouts in North America and Europe in 2003. It is generally recognized that reliability and commercial efficiency are not only compatible but also mutually reinforcing. As an index for describing the reliability and adequacy of network, DSM can bring economical efficiency in new market environments. The DSM activities might be an effective realization incorporating economical efficiency with reliability. The participation of DSM resources will enhance reliability and save money for participating customers. Operating benefits from DSM are generally calculated on the basis of long-term studies, which are directed toward determining the impact of DSM on the system adequacy assessment. E. Hirst wrote a concept on "Reliability benefits of price-responsive demand," [4]. Having important influence on system, DSM activities should be modeled for accurate evaluation. DSM was simulated as generating units in probabilistic production cost framework. M.D. Nelson, proposed a method on "Load management from a power system operator's perspective," [5]. M. Fotuhi-Firuzabad and R. Billinton proposed a paper on "Impact of load management on composite system reliability evaluation short-term operating benefits," [6]. This paper presents an efficient method to estimate the impacts of DSM resources modeling as an integrated model that incorporates peak clipping, valley filling, strategic conservation, load shifting, and strategic load growth. To investigate the impacts of DSM actions in different areas, the sensitivity analysis is adopted to guiding the key areas of implementing DSM. The study results are presented by application to IEEE-RTS79 [7].

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Objective of the work

The main objective of this work is to reduce the cost of generation by using Demand Side Management. Demand Side Management is a technique which involves various methods such as peak clipping, Strategic conservation, valley filling, load shifting, and load shedding, strategic load growth. The main goal of this technique is to encourage the consumers to use less energy during the peak loads and more energy during off peak loads.

Dsm resources modelling

The DSM load shaping objectives are realized in six generic load shaping operations: peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shaping. With the exception of flexible load shaping all the other options can be modeled within the framework of Monte Carlo simulation methodology by two operations: peaking clipping and valley filling. The flexible load-shaping objective of DSM, however, is basically meant to give flexibility on system operation and not much relevant to the case of system long-term planning.

Peak clipping and valley filling modeling

DSM peak clipping is the fact that peak energy is clipped by the DSM actions, and this clipped energy is completely or partly filled during off-peak hours as required. Therefore, DSM peak clipping and valley filling objectives can be modeled as a pumped-storage hydro plant, which shaves the peak energy of high marginal cost with the replacement of the hydro plant operation, in turn, to fill the energy with low marginal cost by pumping operation. In this case, the peak load is limited to a specific value and part of the energy not supplied during peak hours is moved to off-peak hours if possible. According to [7], the peak clipping and load filling is modeled using (1), where P is the pre-specified peak demand of the system that results from the implementation of DSM actions.

$$\overline{L}(t)=\begin{cases}P & t\in\Omega \\ L(t)+A & t\in\Psi=[t_1,t_2]\end{cases} \qquad (1)$$

$$A=a\left[\frac{\sum_{t\in\Omega}(L(t)-P)}{h}\right] \qquad (2)$$

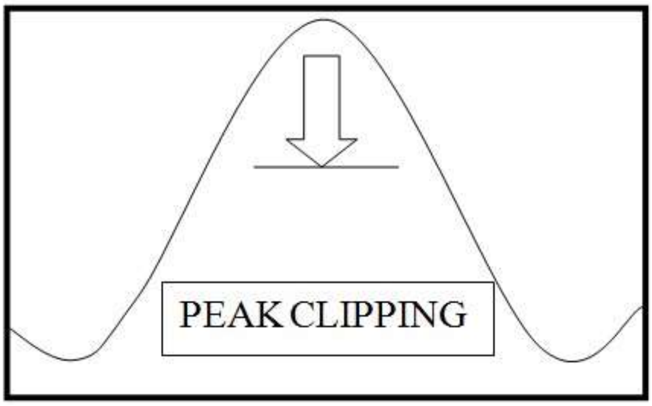

Fig: 1 Peak Clipping

where $L(t)$ is the basic load model; $L(t)$ is the modified load model;Ψ is the set of off-peak hours during which the energy is recovered, and $t1$, $t2$ denotes the starting time and ending time, respectively; Ω is the set of on-peak hours during which the energy is removed; h is the number of off-peak hours in Ψ; A is the MW load added to each off-peak hour of Ψ; and a is the percentage of the energy reduced during on-peak hours and recovered during off-peak hours, which depends on the customers' need for energy during off-peak hours.

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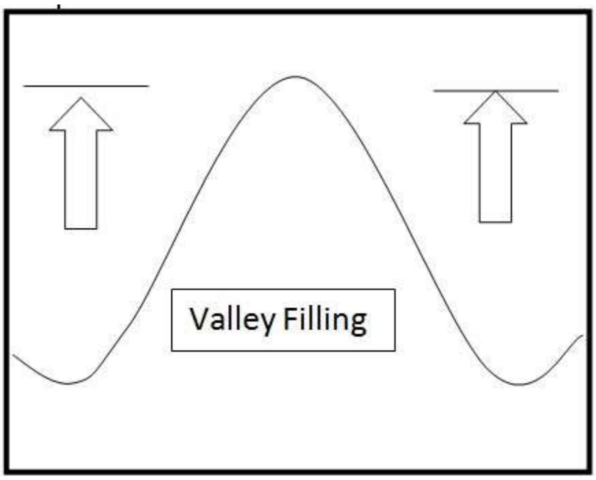

Fig: 2 Valleys Filling

Strategic conservation and load growth modelling
The strategic conservation and strategic load growth can be similarly modelled by (3).

$$\bar{L}(t)=\begin{cases} L(t)+bB & t\in[t_3,t_4] \\ L(t) & t\in others \end{cases} \qquad (3)$$

where B is the MW load added or reduced to each hour between t_3 to t_4; b is either +1 or −1, b=+1 refers to strategic load growth; b=−1 refers to strategic conservation. The equations (1) and (3) can be utilized to model all load shaping actions of DSM except flexible load shaping. The equations can be extended to different time length load curve: daily, weekly, seasonal, or yearly load curve by adjusting the parameters t_1 to t_4, A and B. Correspondingly, a variety of load management models (LM) can be obtained.

Composite DSM Resources Modelling
In practice, load-shaping operations of DSM are usually functioning simultaneously in different areas of bulk power system. Suppose there are N areas where different load shaping operations of DSM are active, the effect of these composite DSM resources can be modelled by (4).

$$\bar{L}(t)=\bar{L}_1(t)+\bar{L}_2(t)+\cdots+\bar{L}_i(t)+\bar{L}_N(t) \qquad (4)$$

Where $L(t)$ (i=1, 2,……, N) is the modified load model of the ith area where any actions described in (1) or (3) may be active. Taking peak clipping in the whole system as example, suppose t_{peak} is the peak time before peak clipping action, after peak clipping action the peak time shifts to peak $\bar{t}_{peak}$, then the clipped peak power, denoted by C_P (MW), can be calculated by (5).

$$C_p = L(t_{peak}) - \bar{L}(\bar{t}_{peak}) \qquad (5)$$

And the peak-clipped power of the ith area can be determined by (6).

$$C_{Pi} = L_i(t_{peak}) - \bar{L}_i(\bar{t}_{peak}) \qquad (6)$$

Need for dsm

1. Cost reduction—many DSM and energy efficiency efforts have been introduced in the context of integrated resource planning and aimed at reducing total costs of meeting energy demand.
2. Environmental and social improvement—energy efficiency and DSM may be pursued to achieve environmental and/or social goals by reducing energy use, leading to reduced greenhouse gas emissions.
3. Reliability and network issues—ameliorating and/or averting problems in the electricity network through reducing demand in ways which maintain system reliability in the immediate term and over the longer term defer the need for network augmentation.

4. Improved markets—short-term responses to electricity market conditions ("demand response"), particularly by reducing load during periods of high market prices caused by reduced generation or network capacity.

Case study

The correctness and effectiveness of above approach are verified by IEEE-RTS79 test system. This test system includes 24 buses, 33 transmission lines, five transformers, one reactor and 32 generators, the total generator capacity is 3405MW and the peak load is 2850MW. The network configuration and parameters can be found in [7]. All quantities in this paper are in per unit, and the base is 100MW. The basic Bus 23 is the slack bus, and the installed capacity is 660MW. The fixed value C is 1100MW.
The results in fig 1 explain about chronological hourly load curve with and without demand side management for peak clipping and valley filling. The graph shows about the peak clipping and valley filling by demand side management. The x-axis shows the time duration for one year in hours and y-axis shows the load demand in MW. The curve with DSM explains that during peak loads the load demand is adjusted by peak clipping and load demand is increased during low load duration by valley filling.

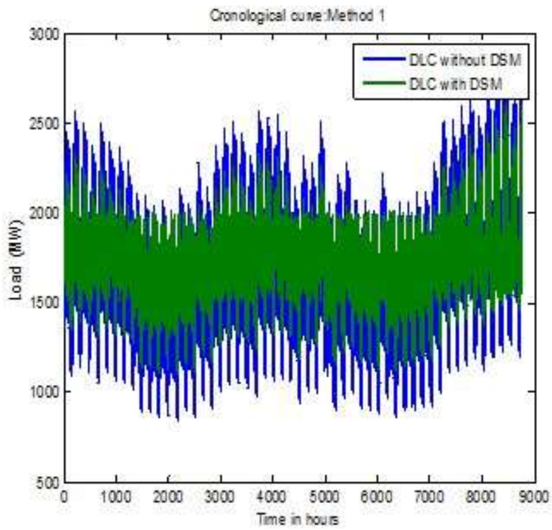

Fig 3 Chronological logical hourly load curve for peak clipping and valley filling with and without DSM

The results can be analyzed by determining average load, diversity factor, and utilization factor and so on. The analysis is made based on load fore casting.
The results in fig 2 explain about chronological hourly load curve with and without demand side management for load shifting. The graph shows about load shifting by demand side management. The x-axis shows the time duration for one year in hours and y-axis shows the load demand in MW. The curve with DSM explains that during peak loads the load demand is adjusted by peak clipping and load demand is increased during low load duration by valley filling.

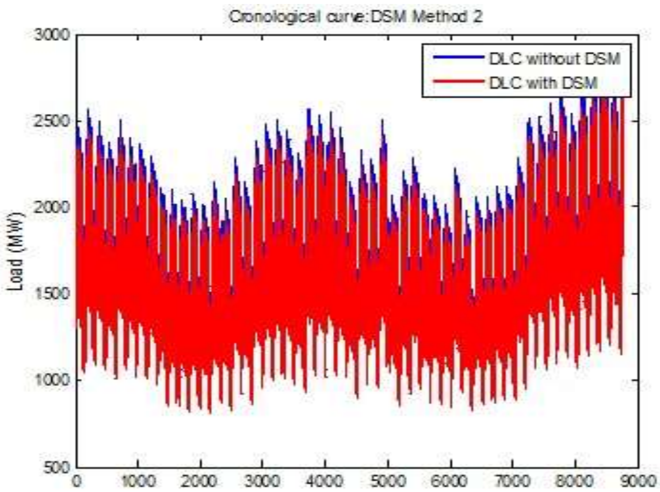

Fig 4 Chronological logical hourly load curve for load shifting with and without DSM

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The above figure shows the daily load curve with-out DSM and with DSM by applying the peak shifting method i.e. the total load which is present in the peak hours is shifted to another time. Peak shifting is one of the traditional approaches of demand side management technique. The load is going varies from time to time as shown in the above figure. By applying the peak shifting method the results are as follows

Maximum load after DSM (Day Shifting) is 2730.82 MW

Load factor after DSM (Day Shifting) is 0.634

Table:1 Max load and load factor with and with-out DSM

S.No	DSM Methods	Max Load	Load Factor
1	Without DSM	2850.0	0.614
2	Peak clipping, valley filling	2606.56	0.674
3	Day Shifting	2730.82	0.634

Table:1 Calculation of generation scheduling without DSM

Hour (Hrs)	Load (MW)	PG1 (MW)	PG2 (MW)	PG3 (MW)	PG4 (MW)	PG5 (MW)	PG6 (MW)
1	1787.3	564.65	264.65	364.65	214.65	264.65	184.65
2	1695.9	548.09	248.09	348.09	198.09	248.09	168.09
3	1627.4	535.73	235.73	335.73	185.73	235.73	155.73
4	1604.6	531.63	231.63	331.63	181.63	231.63	151.63
6	1947.3	593.86	293.86	393.86	243.86	293.86	213.86

Table: 2 Calculation of generation cost with-out DSM

S.No	Hour (Hrs)	Load (MW)	Cost (Rs/MW-Hr)
1	1	1787.3	25432
2	2	1695.9	23727
3	3	1627.4	22485
4	4	1604.6	22079
5	6	1947.3	28559

The Tables 1 & 2 shows the scheduling of six generators and calculation of generation cost at each and every load without using DSM. The total generation cost with-out applying the DSM technique is 122282 Rs/MW-Hr.

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Table: 3 Calculation of generation scheduling with using DSM(Peak Clipping And Valley filling)

Hour (Hrs)	Load (MW)	PG1 (MW)	PG2 (MW)	PG3 (MW)	PG4 (MW)	PG5 (MW)	PG6 (MW)
1	1530.8	518.39	218.39	318.39	168.39	218.39	138.39
2	1439.4	502.07	202.07	302.07	152.07	202.07	122.07
3	1370.8	482.71	198.85	282.03	147.97	190.03	107.84
4	1348	477.66	195.16	278.29	144.27	186.09	103.7
6	1690.7	547.15	247.15	347.15	197.15	247.15	167.15

Table: 4 Calculation of generation cost with using DSM (Peak Clipping And Valley filling)

S.No	Hour (Hrs)	Load (MW)	Cost (Rs/MW-Hr)
1	1	1530.8	20787
2	2	1439.4	19235
3	3	1370.8	18107
4	4	1348	17738
5	6	1690.7	23631

The Tables 3 & 4 shows the scheduling of six generators and calculation of generation cost at each and every load with using DSM methods (Peak Clipping and Valley Filling). The total generation cost with applying the DSM methods (Peak Clipping and Valley Filling) is 99498Rs/MW-Hr.

Table: 5 Calculation of generation scheduling with using DSM (day shifting)

Hour (Hrs)	Load (MW)	PG1 (MW)	PG2 (MW)	PG3 (Mw)	PG4 (MW)	PG5 (MW)	PG6 (MW)
1	1466.8	506.96	206.96	306.96	156.96	206.96	126.96
2	1379.2	484.63	200	283.44	149.29	191.53	109.41
3	1313.5	470.02	189.58	272.63	138.76	180.12	97.44
4	1291.6	465.18	186.05	269.05	135.27	176.33	93.46
6	1620	534.39	234.39	334.39	184.39	234.39	154.39

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Table: 6 Calculation of Generation Cost with Using DSM (Day Shifting)

S.No	**Hour (Hrs)**	**Load (MW)**	**Cost (Rs/MW-Hr)**
1	1	1466.8	19695
2	2	1379.2	18244
3	3	1313.5	17186
4	4	1291.6	16839
5	6	1620	22353

The Tables 5 & 6 shows the scheduling of six generators and calculation of generation cost at each and every load with using DSM method (Day Shifting). The total generation cost with applying the DSM method (Day Shifting) is 94317Rs/MW-Hr. By applying the DSM method (Day Shifting) the generation cost is reduced from 122282 to 99317. The difference in the generation cost is 27965 Rs/MW-Hr.

Conclusions

Enhancing DSM actions could help not only the system operate more efficiently, but also benefit to the system reliability and adequacy improvement. This paper presents an efficient approach to estimate the impacts of DSM resources. The sensitivity analysis is adapted to finding the key areas of DSM activities. The algorithm based on the above approach is developed for IEEERTS79 system is used to verify the proposed approach. The results show those DSM actions; especially peak clipping, valley filling and load shifting have obvious contributions. The results also demonstrate that DSM activities on different buses have different effects by reason of the network topology structure.

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