DEMAND SIDE MANAGEMENT IN SMART GRID USING HEURISTIC ALGORITHM

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***Abstract*— DEMAND SIDE MANAGEMENT (DSM) plays an important role in a smart grid that helps the consumer to make their energy utilization in an efficient way, and helps in a modification of load profile. Demand side management results in a better sustainability and reduces the overall operational cost. DSM can be enhanced by using many optimization techniques. The techniques which have been existing, uses system specific methods and algorithms. These techniques and algorithms could only be used to control limited loads of limited types. In this paper Demand Side Management deals with the load shifting technique using heuristic optimization. This optimization technique which handles large number loads of several types. This has a greater advantage for future smart grid. Here,The load shifting technique is formulated by using Genetic Algorithm. A heuristic based genetic algorithm was developed for solving the peak demand problem. Simulations were carried out on a micro grid in three service areas such as residential, commercial and industrial grids for different range of loads. From this, we could achieve substantial savings and reduce the peak load demand of smart grid.**

***Keywords*— Demand Side Management, Genetic Algorithm, Load shifting, smart grid.**

Introduction

SMART GRID is an advanced power system with integrated sensing technologies and control methodologies. The communication in smart grid is two way process (i.e.) between the transmission (operator) and distribution (consumer) levels to supply electricity in a user friendly way.

Demand side management is a key aspect towards the future smart grid which controls and influences the energy demand thereby reducing the overall peak load demand, changing the demand profile characteristics and hence increasing the sustainability over the power system. This enhances in reducing the overall cost and carbon emission levels. The new load profile and the possibilities for load reduction for each time step of next day will be informed by the DSM to the central controller. Accordingly the consumers shift their load timings. Among the various demand side management techniques used earlier most of them are system specific and as they follow dynamic and linear programming, those techniques could handle (control) only a limited number of loads of limited types. But the demand side management technique adopted in a smart grid should be able to control several loads and thereby controlling the consumers' energy consumption. The loads also have characteristics which that spread over a few hours. Hence the adopted strategy should be able to deal with a variety of controllable loads for all possible control durations. The designed Demand side management system should be able to handle communication between operator and consumer.

In this paper, a demand side management strategy is proposed for three varying load, based on load shifting technique. A heuristic based genetic algorithm is used for solving the problem. Simulations are carried out for a forecasted hourly whole sale electricity prices and forecasted hourly load consumption of each area of the smart grid. The remaining paper explains briefly about the genetic algorithm used for the energy management. The mathematical formulations are done which explains the proposed methodology. At last, the simulation results have been discussed and the paper has been concluded.

Several DSM techniques:

The main aim of Demand side management system is in reshaping the load profile of power distribution systems. This is done by altering the electricity consumption patterns of the consumers. To face the increasing electricity demand, appropriate DSM activities could help in reducing the peak load demand during peak hours of the consumers thereby shifting those loads to the more appropriate times.

Six broad methods are there for meeting the increasing energy demand: peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape.

Peak clipping: Focuses on reducing the difference between the peak load levels to solve the burden of peak demand.

Valley filling: Focuses on reducing the difference between the valley load levels to mitigate the burden of peak demand.

Load shifting: (Most effective method) Shifts the loads from peak time to off-peak time.

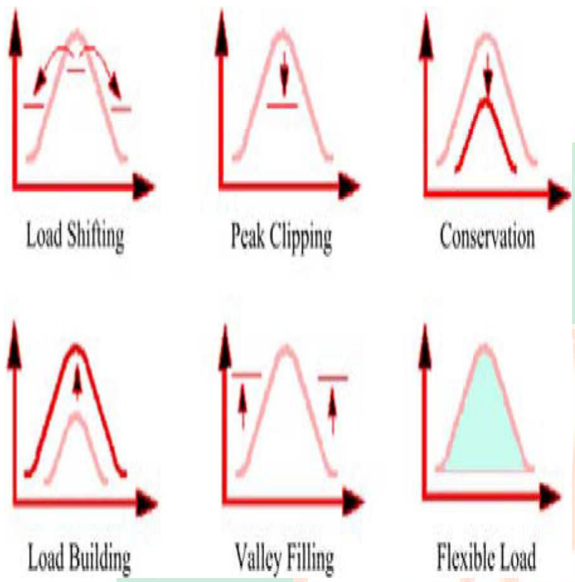


Fig 1: Demand side management techniques.

Strategic conservation: Demand reduction method is directly applied at the consumer premises.

Strategic load growth: This is the planning of the operations to meet the demand in case when it is very huge, with necessary infrastructure that enhances load growth.

Flexible load shape: For achieving the desired load, the customer's loads will be controlled during the critical periods. The customers who are willing to change their load profile will be identified by the smart grid management system and in turn the customers would get some incentives. Reliability can thus be assured with the smart grid.

Genetic algorithm (a heuristic approach)

Genetic algorithm is a natural selection process based on the human genetics. It uses the random search heuristic approach to solve the constrained and unconstrained optimization problems. Though random search is made, they are not so since the algorithm uses the data which were collected at earlier days (historical data) to proceed the search into the search space. This search space consists of several individuals of better performance. Repeated modification of the population of individual solution is done here. The individuals of a particular population will be considered (using random search) as the parents for generating the children of consecutive generation. The process will be continued until an optimal solution is found.

The techniques followed in genetic algorithm generally follow the principle "survival of the fittest" given by Charles Darwin. This principle is based on the fact that, fittest individuals will be produced when the individuals in the search space compete for the limited resources.

Genetic algorithm is more robust in sense that the process is insensitive to any change in input or any noise. Also the algorithm is not subjected to a particular search space like the typical optimization techniques. Instead the search space may be in any order (larger, multi-modal or n-dimensional).

Brief overview:

Genetic algorithm is similar to hierarchy of human beings. Among the individuals of a particular population, the GAs simulates the survival of the fittest. As we see the chromosomes in our DNA, the character string will be present in the population. Each and every individual in the population represents the point in the search space and will be made to undergo the process of evolution to get the optimal solution.

Genetic algorithms optimization technique had been made based on the genetic structure and from that the following foundations have been made:

Every individual in the population find for particular resource and performs mating.

After competing among the population to find the best offspring, the most successful individual would be obtained.

Better offspring individual will be produced when both parents represents a good genes.

Now a population of best individuals each represents a possible solution to the given problem which will be within the search space. Usually, the individuals will be coded as the binary digits (0, 1). These binary digits are the genes within the chromosomes (individuals). Each solution has a '*FITNESS SCORE'*, according to their competing ability. The most optimal solution giving individual will be obtained.

The population of chromosomes in genetic algorithm will be maintained within in their allotted fitness values. Parents that can produce best offspring are selected for mating.

Once the old mating is exhausted, individuals in that particular population die. That particular individual is replaced by the new generation produced by then new mating. The generations thus produced consists of solution which is better than previous generations by using this genetic algorithm technique.

Process in genetic algorithm:

Selection process:

Selection process involves the selection of genome .By performing the better selection, better off springs can be obtained. By evaluating the process with genomes, fitness value is allocated. The best individual is identified by their fitness value. By this selection process best individual is selected for mating.

Cross over process:

Once the selection process is completed, next process in the genetic algorithm is cross over process. It is the type of process in which both parent individuals are mated for production of offspring from them. For this crossover process, two individuals had to be selected from the selection process. The selected individual is in the form of bits, which then undergo cross over. The crossed bits are considered to be the better solution but not the optimal solution.

Mutation:

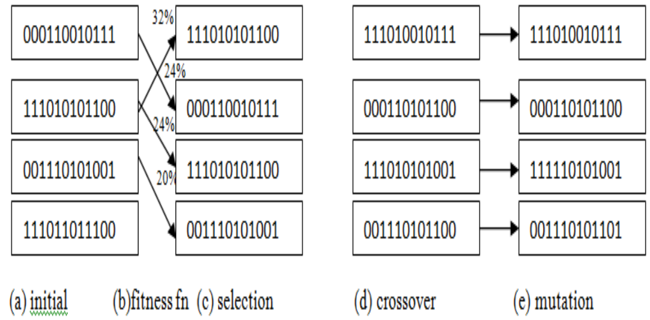
In mutation process, the portion of the new individuals will have some of their bits flipped with some low probability. Its purpose is to maintain within the population and inhibit premature convergence. Mutation alone induces a random walk through the search space.

Conclusions after genetic operations:

i. When selection alone is used, the population will be filled with the copies of best individual.
ii. When crossover operator is used along with selection, a good but sub-optimal solution will be achieved.
iii. When mutation alone is performed, the search space will be randomly walked through.
iv. When selection is used along with mutation, it will become a parallel and noise-tolerant process.

Summary of genetic algorithm process:

a) Initialize the population in a random fashion.
b) The fitness score must be calculated for the population.
c) Through the selection process, the parents must be selected.
d) Then crossover must be performed on parents creating population next to the actual population selected.
e) On that new population, the mutation process should be performed.
f) For the same population, fitness score is to be calculated.
g) Repeat steps (c) to (f) until the best individual is attained.



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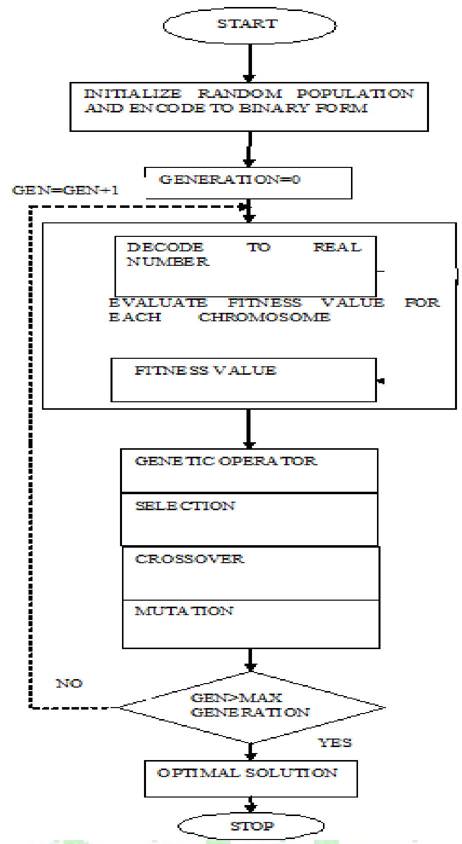


Data used for the simulation:

The simulations were carried out based on the forecasted load demands and wholesale energy prices and the hourly forecasted loads of each area of smart grid as given in the table below. As seen in the table, the maximum demand of each sector residential, commercial and industrial sectors is 1.5, 2 and 3MW respectively. In a usual day for zero to 24 hours it will be difficult to shift the peak load since it occurs after the valley of load consumption. Hence to mitigate this problem, control duration is taken from 8th hour of the particular day till the 8th hour of next day. There will be different loads connected to a particular grid which are given in the table below.

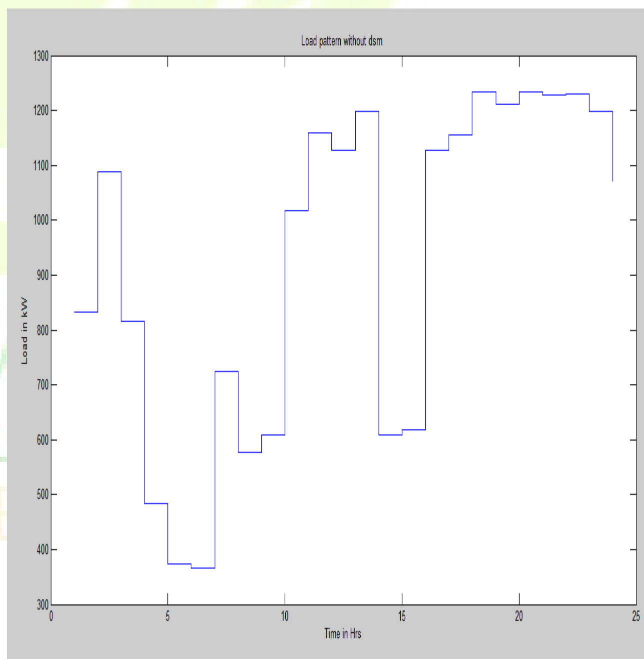
Table 1: forecasted load demand and whole sale prices

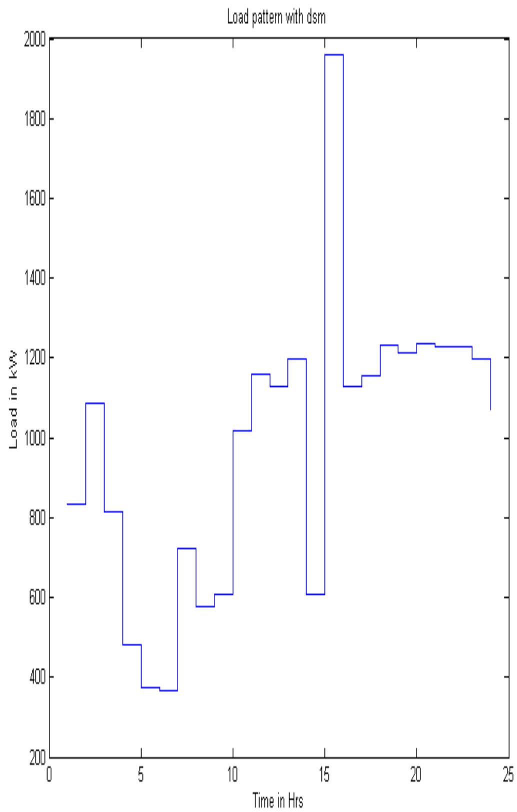
Time	Wholesale Price (ct/kWh)	Hourly Forecasted Load (kWh)		
		Residential Microgrid	Commercial Microgrid	Industrial Microgrid
8hrs-9hrs	12.00	729.4	923.5	2045.5
9hrs-10hrs	9.19	713.5	1154.4	2435.1
10hrs-11hrs	12.27	713.5	1443.0	2629.9
11hrs-12hrs	20.69	808.7	1558.4	2727.3
12hrs-13hrs	26.82	824.5	1673.9	2435.1
13hrs-14hrs	27.35	761.1	1673.9	2678.6
14hrs-15hrs	13.81	745.2	1673.9	2678.6
15hrs-16hrs	17.31	681.8	1587.3	2629.9
16hrs-17hrs	16.42	666.0	1558.4	2532.5
17hrs-18hrs	9.83	951.4	1673.9	2094.2
18hrs-19hrs	8.63	1220.9	1818.2	1704.5
19hrs-20hrs	8.87	1331.9	1500.7	1509.7
20hrs-21hrs	8.35	1363.6	1298.7	1363.6
21hrs-22hrs	16.44	1252.6	1096.7	1314.9
22hrs-23hrs	16.19	1046.5	923.5	1120.1
23hrs-24hrs	8.87	761.1	577.2	1022.7
24hrs-1hrs	8.65	475.7	404.0	974.0
1hrs-2hrs	8.11	412.3	375.2	876.6
2hrs-3hrs	8.25	364.7	375.2	827.9
3hrs-4hrs	8.10	348.8	404.0	730.5
4hrs-5hrs	8.14	269.6	432.9	730.5
5hrs-6hrs	8.13	269.6	432.9	779.2
6hrs-7hrs	8.34	412.3	432.9	1120.1
7hrs-8hrs	9.35	539.1	663.8	1509.7

Table 2: different controllable devices in residential area

Device Type	Hourly Consumption of Device (kW)			Number of Devices
	1st Hr	2nd Hr	3rd Hr	
Dryer	1.2	-	-	189
Dish Washer	0.7	-	-	288
Washing Machine	0.5	0.4	-	268
Oven	1.3	-	-	279
Iron	1.0	-	-	340
Vacuum Cleaner	0.4	-	-	158
Fan	0.20	0.20	0.20	288
Kettle	2.0	-	-	406
Toaster	0.9	-	-	48
Rice-Cooker	0.85	-	-	59
Hair Dryer	1.5	-	-	58
Blender	0.3	-	-	66
Frying Pan	1.1	-	-	101
Coffee Maker	0.8	-	-	56
Total	-	-	-	2604

***Simulation results and discussions*:**





The simulation results show that the proposed demand side management using genetic algorithm has managed to reduce the peak load demand by shifting it during the off-peak hours. Here the simulation has been done for the residential grid which consists of different types of controllable loads.

Conclusion:

Demand side management has made the entire smart grid at the distribution level to get the benefits. The strategy used is demand side management will be more helpful in the future smart gird. The strategy used here is generalized and is based on load shifting technique. It could be mathematically formulated as a minimization problem. Heuristic based genetic algorithm is employed for solving this problem. Simulations were carried out based on the data collected from a smart grid which focuses on the different types of controllable loads in residential area. Simulation outcome increases the sustainability of the smart grid and reduces the overall operational cost and carbon emission levels.

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