Demand Side Management for Power System Based on Particle Swarm Optimisation

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Abstract- Demand side management (DSM) is important tool for enabling a more efficient use of the energy resources available to a country. DSM applied to electricity systems can mitigate system problems and increase system reliability, provide relief to the power grid and generations, defer investments in transmission networks and lower pollution emissions.
The proposed algorithm evolved by the making the primitive particles and conveying the starting values, which is recognised as Particle swarm optimization (PSO). It evaluates the objective function at each particle location, and determines the best function value and the best location. It can be applied to demand side management for effective operation.

Keyword- Demand side management (DSM), Particle Swarm Optimisation (PSO), Optimum energy management,

I. INTRODUCTION

Demand-side management (DSM) has been conventionally seen as a means of reducing peak electricity demand so that utilities can delay building further capacity. In fact, by reducing the overall load on an electricity network, DSM has various beneficial effects, including mitigating electrical system emergencies, reducing the number of blackouts and increasing system reliability. Possible benefits can also include reducing dependency on expensive imports of fuel, reducing energy prices, and reducing harmful emissions to the environment.
DSM has a major role to play in deferring high investments in generation, transmission and distribution networks. Thus DSM applied to electricity systems provides significant economic, reliability and environmental benefits. When DSM is applied to the consumption of energy in general—not just electricity but fuels of all types it can also bring significant cost benefits to energy users and corresponding reductions in emissions. Opportunities for reducing energy demand are numerous in all sectors and many are low-cost, or even no cost, items that most enterprises or individuals could adopt in the short term, if good energy management is practised.

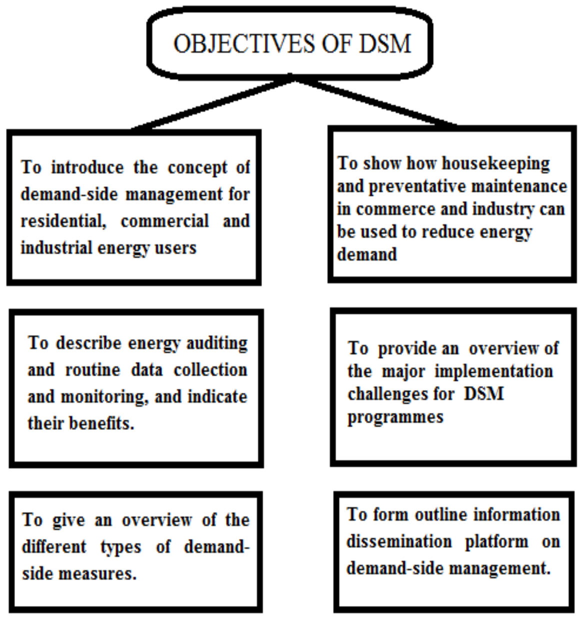

Fig.1: Objectives of DSM

An energy customer may have many reasons for selecting a certain DSM activity. Generally these would be economic, environmental, marketing or regulatory. The above points are expressed in a slightly different way, where it is argued that the benefits of DSM to consumers, enterprises, utilities and society can be realized through:

- *Reductions in customer energy bills*
- *Reductions in the need for new power plant, transmission and distribution networks*
- *Stimulation of economic development*
- *Creation of long-term jobs due to new innovations and technologies*
- *Increases in the competitiveness of local enterprises*
- *Reduction in air pollution*
- *Reduced dependency on foreign energy sources;*
- *Reductions in peak power prices for electricity*

COST REDUCTION— **DSM and energy efficiency efforts have been introduced in integrated resource planning and aimed at reducing total costs of meeting energy demand**
ENVIRONMENTAL/SOCIAL IMPACT— **Energy efficiency and DSM achieves social / environmental goals by reducing energy use, leading to reduced greenhouse gas emissions**
RELIABILITY ISSUES— **Avoiding problems in the electricity network through reducing demand which maintains system reliability and over the longer term defer the need for network augmentation**
IMPROVED MARKETS— **Short-term responses to electricity market conditions particularly by reducing load during periods of high market prices caused by reduced generation**

Fig.2: Reasons of undertaking DSM

II. ENERGY MANAGEMENT SYSTEM

The aim of energy management is to lower energy costs and bring immediate benefits to enterprises. Energy management is the structured application of a range of management techniques that enables an organization to identify and implement measures for reducing energy consumption and costs. Energy management activities typically cover:

- *Energy purchasing*
- *Metering and billing*
- *Performance measurement*
- *Energy policy development*
- *Energy surveying and auditing*
- *Awareness rising*
- *Training and education*
- *Capital investment management*

The specific tasks of an energy management department will depend on the nature of the organization and the budget and staffs kills available. Energy management is a continuous process, with continuous monitoring of energy performance and always seeks to maintain and improve t he efficient use of energy. The main types of DSM activities may be classified in three categories:

- *Energy reduction programmes*—reducing demand through more efficient processes, buildings or equipment;
- *Load management programmes*—changing the load pattern and encouraging less demand at peak times and peak rates;
- *Load growth and conservation programmes*

Advanced software programs are available to organize data on energy use and other key operating parameters, and provide a series of utility cost management applications, such as:

- *Load profiling of individual and multiple facilities to ease energy decisions;*
- *External and internal benchmarking of energy performance;*
- *Utility bill verification and budget tracking;*
- *Energy accounting, Base lining and savings analysis;*
- *Measurement and verification of energy conservation measures;*
- *Internal cost allocation by cost centres, product lines, etc.;*
- *Tenant billing for multiple occupancy buildings;*
- *Facility management reporting to senior management.*

III. PROBLEM STATEMENT

Let us assume that $load_i$ be the initial load curve or the forecasted load curve. This curve needs to be altered as per our objective curve. Let the modified load curve obtained be $load_f$, after the application of DSM. Then our objectives are as follows:

Minimize: $f : max\square load\ f\ \square$

Here, function f_1 denotes the maximum peak of the final load curve, which needs to be minimized along with function f_2 representing the total cost of electricity during H=24 hours of a day and ph is price of electricity in h_{th} hour. To solve the above minimization problems a function f is formed to obtain modified final load curve $load_f$.

$$\text{Minimize: } f_h = [\ |RLMh| - |\Delta load_h|]$$

Subjected to, for all h=1, 2… T. T is the number of time steps in hourly block. RLM is Reducible Load margin, which is simply calculated for each hour h as RLM_h ;

$$RLM_h = forecast_h - Obj_h$$

The objective curve Obj_h is inversely proportional to the expected electricity prices. At times, electricity prices are high the value of objective curve is low and vice-versa. The equation for the formation of objective curve is given as:

$$Obj_{h} = [\frac{p_{avg}}{p_{max}} \sum_{H=1}^{H=24} forecast_{h}]\frac{1}{p_{h}}$$

Where p_{avg}, is the average price during the period H and p_{max} is the maximum price throughout the day of H hours and p_h is the price of electricity at h_{th} hour and H is the total number of hours in a day i.e. 24. The forecast is the value of day-ahead forecasted load consumption, which has been taken from the data of the smart grid.

$Discon_{Lh}$ is the total amount of load which needs to be disconnected from h_{th} hour, so that our load at that hour gets reduced. It is calculated for those instants which have positive value of RLM. At other instants the value of disconnected load is zero. Disconnected load $Discon_{Lh}$ is calculated through the following equation:

$$DisconL_{\square} = \sum X_{k\square} P_{1k} + \sum_{j=1}^{l-1} . \sum_{k=1}^{D} . X_{k(\square+j)} P_{(1+j)k}$$

The above minimization problem is subjected to the following constraints:

- Number of devices of any type that are to be shifted will always be positive at any time instant.
  X k ,h kh > 0 ∀ (10)
- Number of devices that are to be shifted at any instant cannot be more than the available number of controllable devices of that particular device type.

IV. PARICLE SWARM OPTIMISATION

The flocking and schooling patterns of birds and fish provides the motivation for the evolution of, Particle Swarm Optimization (PSO) which was invented by Russell Eberhart and James Kennedy in 1995. This resulted into the progressive developments of simulations using computer software through birds flocking in the region of food sources. The algorithm is presently one of the best known optimisation solutions available in statistical solutions.

The algorithm keeps track of three global variables:

- *Target value or condition*
- *Global best (gBest) value indicating which particle's data is currently closest to the Target*
- *If the target is not achieved, then the Stopping value must be indicated to stop the algorithm*

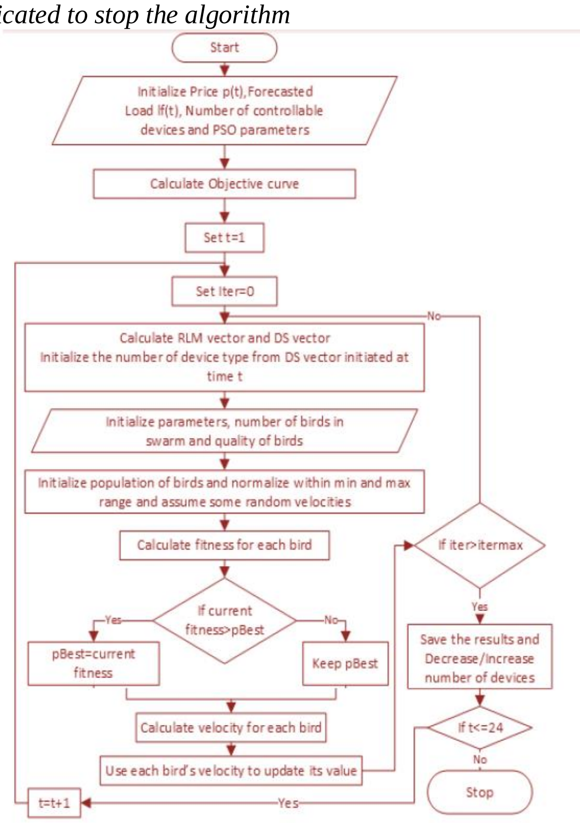

Fig.3: PSO algorithm

Each particle consists of:

- *Data representing a possible solution*
- *The amount of Data can be changed by the signal of velocity value*
- *A personal best (pBest) value indicating the closest the particle's Data has ever come to the Target*

V. RESULT AND DISCUSSIONS

The strategy for DSM using the Particle Swarm Optimization technique has been applied in three areas comprising residential, commercial and industrial. These areas have a different set of devices with different characteristics like different operating hours, schedule and power consumption. The algorithm has been able to handle such complexities efficiently and has modified the load curve in such a way that it has come close to objective curve as much as possible.

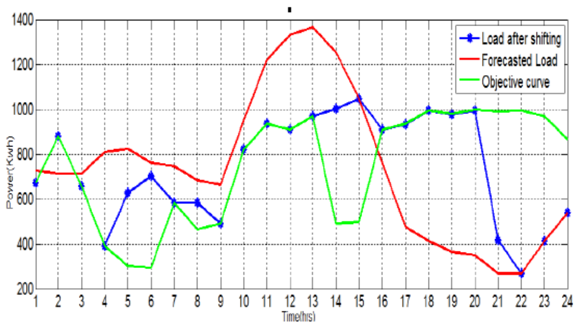

Fig.4: DSM results for Residential Areas

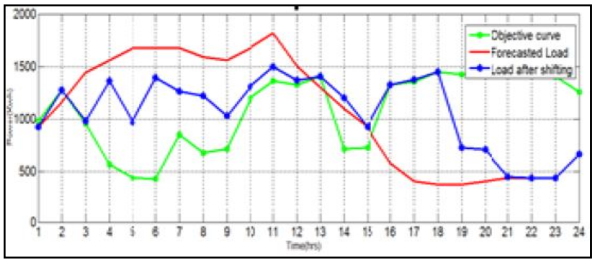

Fig.5: DSM results for Commercial Areas

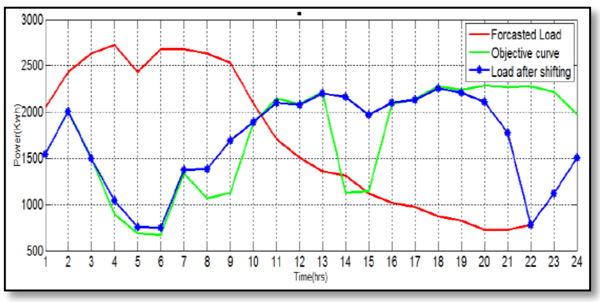

Fig.6: DSM results for Industrial Areas

DSM strategy has not only reduced the peak load but also the cost which will result in reduction of consumer's bill. The peak load has reduced for all residential, commercial and industrial respectively. Similarly for cost, a reduction of 7.24%, 9.65% and 18.72% for residential, commercial and industrial area load has been observed. The results also justify the improvement in load factor. There is a lot of improvement in load factor of approximately 30.3%, 22.69 and 19.96% respectively.

Table I – Result Load Factor Calculation

Type of Area	Load Factor without DSM	Load Factor with DSM	
		in[10]	*PSO*
Residential	0.53975	0.6604	0.7033
Commercial	0.58795	0.7197	0.7214
Industrial	0.61829	0.7195	0.7417

Table II – Forecasting's of 1st 12 Hours

Time (hr.)	Wholesale Price (cents/kWh)	Hourly Forecasted Load(kWh)		
		Residential	*Commercial*	*Industrial*
1	12.00	540.9	661.5	1170.5
2	9.19	593.8	892.4	1560.1
3	12.27	593.6	1181.0	1274.9
4	20.69	594.1	1293.0	1372.3
5	26.82	558.8	1257.4	680.1
6	27.35	545.6	1257.4	898.6
7	13.81	535.4	1139.8	898.6
8	17.31	529.6	1318.6	842.4
9	16.42	513.8	1338.4	1145
10	9.83	866.4	1301.7	706.7
11	8.63	1085.6	1446.0	917.0
12	8.87	1196.6	1246.1	809.7

VI. CONCLUSION

Demand side management is gaining a lot of importance due to its benefits to the entire smart grid. It reduces the excess demand of power during peak hours and along with that it also reduces the utility bill of the consumers. Using the particle swarm optimization algorithm, which has come resulted in the reduction in peak demand and also results in substantial savings in utility bills. This approach has been carried out on three area loads, i.e. residential, commercial and industrial of a smart grid.

VII. REFERENCES

[1]. Javaid, N., et al.: A hybrid genetic wind driven heuristic optimization algorithm for demand side management in smart grid. Energies 10(3), 319 (2017)

[2]. Merrikh-Bayat, F.: A numerical optimization algorithm inspired by the strawberry plant. arXiv preprint:1407.7399 (2014)

[3]. Samadi, P., Wong, V.W.S., Schober, R.: Load scheduling and power trading in systems with high penetration of renewable energy resources. IEEE Trans. Smart Grid 7(4), 1802–1812 (2016)

[4]. Ma, J., et al.: Residential load scheduling in smart grid: a cost efficiency perspective. IEEE Trans. Smart Grid 7(2), 771–784 (2016)

[5]. Khan, M.A., et al.: A generic demand side management model for smart grid. Int. J. Energy Res. 39(7), 954–964 (2015)

[6]. Jalali, M.M., Kazemi, A.: Demand side management in a smart grid with multiple electricity suppliers. Energy 81, 766–776 (2015)

[7]. Ma, K., et al.: Residential power scheduling for demand response in smart grid. Int. J. Electr. Power Energy Syst. 78, 320–325 (2016)

[8]. M. AboGaleela, M. El-Sobki, and M. El-Marsafawy, "A two level optimal DSM load shifting formulation using genetics algorithm case study: Residential loads," IEEE Power Energy Soc. Conf. Expo. Africa Intell. Grid Integr. Renew. Energy Resour. PowerAfrica 2012, no. July, pp. 9–13, 2012.

[9]. S. Bu and F. R. Yu, "A Game-Theoretical Scheme in the Smart Grid With Demand-Side Management: Towards a Smart Cyber-Physical

[10]. Power Infrastructure," IEEE Trans. Emerg. Top. Comput., vol. 1, no. 1, pp. 22–32, 2013.

[11]. N. Kunwar, K. Yash, and R. Kumar, "Area-load based pricing in DSM through ANN and heuristic scheduling," IEEE Trans. Smart Grid, vol. 4, no. 3, pp. 1275–1281, 2013.

[12]. L. Yao, W.-C. Chang, and R.-L. Yen, "An Iterative Deepening Genetic Algorithm for Scheduling of Direct Load Control," IEEE transactions Power Syst. PWRS, vol. 20, no. 3, pp. 1414–1421, 2005.

[13]. T. Logenthiran, "Demand side management in smart grid using heuristic optimization," IEEE Trans. Smart Grid, vol. 3, no. 3, pp. 1244–1252, 2012.