IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Special Issue-18, May 2019 E-ISSN: 2347-2693

Improved Demand Response with Particle Swarm Optimization

Suparna Dey[1], Monalisa Dasgupta[2],Soumesh Chatterjee[3*], Gagari Deb[4]

[1,2,4]Department of Electrical Engineering, Tripura University, Agartala ,Tripura, India
[3]Department of Electrical Engineering, National Institute of Technology, Tripura, India

Corresponding Author: soumesh.sch@nita.ac.in

Available online at: www.ijcseonline.org

Abstract—Among all the power management strategies in smart grid, demand response is quiet popular because of its significance impact on saving in peak demand and reduced energy consumption. Electricity price revealed by utility companyis mainly accountable for the demand response to lead the consumer in electricity scheduling.The mutual benefits for both customer and supply side are ensured with the use of price conferring mechanism through demand response.This paper proposes anapproach to minimize the elastic load through price weight given by the utility company. Three types of consumers are designed as residential, industrial and commercial. The 'per day electricity use' for these consumers has been reducedby scheduling elastic loads using Particle Swarm Optimization(PSO) technique. The outcome of simulation results show that the recommended algorithm reduces the cost while balancing the peak demand.

Keywords—Demand Response, Dynamic pricing, Elastic Loads, Load Scheduling, Particle Swarm Optimization(PSO)

I. INTRODUCTION

Demand response(DR), being a part of demand side management (DSM),is prevalentlyused by electric utility companies to reduce or shift energy consumption from peak hour of the day to leaner demand periods.The purpose of using DRis to reduce electricity cost by efficiently managing the load. Efficient management of energyis possible through DR too. The main objective of DR is to precisely utilize the available energy to improve the economic property of the power system. Managing the load pattern can reduce the peak load demand and distributes the load according to the price weight given by the utility company which mutually benefits both the consumer side and the supply side.

Dynamic pricing schemes are the unique feature of DR. By usage of Automatic Metering Infrastructure(AMI) it is easy to manage the load according to dynamic pricing schemes.When these dynamic pricing schemes are used along with the DR strategies, control of customer energy usage is influenced by penalties and incentives. DR also plays a key role in the electricity market. Electricity price depends on the energy consumption of the consumer. With increase in demand the electricity price weight is also increases. This increase in electricity pricing affects the consumers in the power system. By reducing the Peak to Average Ratio (PAR), DR regulates the electricity price in an electricity price market. DR changes the customers' demand pattern to achieve the appropriate change in the existing load pattern. The DR strategy changes the shape of load pattern by shifting the controllable appliances during peak hours to an appropriate timeto reduce the cost. Some research works strongly related to this paper have been discussed below to highlight the key issues of DR.

II. RELATED WORK

There are six methods which depicts load shaping, such as valley filling, load shifting, peak clipping, flexible load shape, strategic conversation and strategic load growth as in paper [1]. Peak clipping and valley filling reduces the difference between peak load and valley load. Authors in [2] have discussed how the load scheduling problem is formulated as minimization problem. Due to intermittent nature of the electricity market, the Real Time Pricing (RTP) signal change is assumed hourly basis and hence its value is constant within one hour. Our objective is to minimize the electricity bill of user as well as reduce the Peak to Average Ratio (PAR) to increase the efficiency of the grid. Reference [3] proposes an optimal electricity scheduling framework, where customers can achieve minimum tariff objective through the proposed mechanism genetic algorithm (GA) is mainly improved in this paper, adding function of equality constraints handling, which is not in traditional GA, when control variable is against limitation conditions, penalty function will be applied. Another optimization model is introduced to adjust the hourly load level of a given consumer in response to hourly electricity prices in ref.[4]. The objective of the model is to maximize the utility of the consumer subject to a minimum daily energy-consumption level, maximum and minimum hourly load levels. The model materializes into a simple linear programming algorithm that can be easily integrated in the Energy Management System of a household or a small business. In ref. [5] the system operator (SO) implements a temporal linear pricing strategy that depends on real-time demand. Combining the real-time pricing with time-of-use pricing the pricing strategy is formulated. The announced pricing strategy sets up a non-co-operative game of incomplete information among the users with heterogeneous, but with correlated consumption preferences. The ref. [6] proposes an intelligent preemptive Demand Response Management (DRM). In this a dynamic priority-based load shedding are considered in the DRM program. The performance of the proposed DRM program is to keep the building power demand within the CC/DL and reduce the energy consumption is tested and analyzed using the building energy management system (BEMS). The ref. [7] presents PSO based DR methodology that helps to flatten the load curve of power distribution system. Load shifting DR technique is used to alter the load curve of the system.

In this paper, the DR utilizes the forecasted inelastic load data (hourly) of residential consumers, industrial consumers and commercial consumers along with the corresponding wholesale energy prices (hourly) as the inputs. Various types of controllable devices from residential area, industrial area, and commercial area are identified. In residential area approximately 10410 controllable devices from 10 different categories are available for control, in industrial area approximately 188 controllable devices are available from 6 different categories and in commercial area the number of controllable device are approximately 2160 from 7 different categories. Thus, in this paper an attempt has been taken to develop load shifting Demand Response strategy based on price weight that shows utility cost reduction along with reduced peak load pattern. The above described optimization problem has been mathematically modelled and solved with PSO and the results are compared with existing popular optimization technique i.e. genetic algorithm.

The structure of the paper is described as below. In Section I the motivation of the proposed work has been emphasized. Section II elaborates the existing works. In Section III the details of the methodology is explained. Simulation results are shown and discussed in Section IV. Conclusions are drawn in Section V.

III. METHODOLOGY

The electrical loads can be broadly classifiedinto two different categories, such as inelastic and elastic loads. The usage time of inelastic load cannot be varied according to the price weight provided by the utility company, which includes refrigerators, electric water heater, fan, lights etc.; whereas the usage time of elastic load can be changed along with the change in price weight of utility company, such as phone charger, washing machine, iron etc. which may reduce the peak load and also the energy usage cost of the end user.

A. *Particle swarm optimization technique (PSO)*

J. Kennedy and R. Eberhart in 1995 came up with a new meta-heuristic algorithm and after that it has become a popular optimization algorithm [8]. The PSO mimics the behaviour of organisms such as bird flocking and fish schooling. There are three important variables which guides the PSO algorithm, these are present movement of the particles to decide their next positions in the search space, personal best (P_{best}), and the overall best (G_{best}). Further, two factors are included as *c1* and *c2* to accelerate the solution, and an inertia factor (w) is multiplied with the present movement.

B. *Problem formulation*

The assumed power system model is mainly based on demand response strategy. In the paper, it is assumed that utility company and customers are already AMI installed.The target load consumptioncurve is prepared and compared with the existing load curve.The objective function [3] the customer's energy consumption has been modelled as a minimization problem in this paper and mentioned as (1).

$$\min f\big(e(t) + in(t)\big) = \sum_{t=1}^{24} E(t) \cdot P(e(t) + in(t)) \quad (1)$$

Subjected to,

$$e^{min} \le e(t) \le \min(L - in(t), e^{max}) \quad (2)$$

$$\sum_{t=1}^{24} e(t) = e_{total} \quad (3)$$

where

$e(t)$ →elastic load available for rescheduling at t^{th} hour,
$in(t)$ →inelastic load available for rescheduling at t^{th} hour,
$E(t)$ →electricity price weight at t^{th} hour,
$P(\cdot)$ →averaged electricity price,
e^{min} →elastic load's lower limit,
L →limit of the contract load,
e^{max} →elastic load's upper limit,
e_{total} →total amount elastic load.

The above equations describe all the required equality and inequality constraints to solve the optimization problem. Equation (2) defines the customer's hourly limitations of elastic loads and (3) represents the total limitation of elastic loads in a day. The flow chart of the proposed technique has been given in Figure 1.

IV. RESULTS AND DISCUSSION

A distribution system is modelled consisting of residential consumers, industrial consumers, and commercial consumerswhich is considered for simulation. The main purpose is to reduce the peak load demand depending on the price weight given by the utility company. This will also result in the reduction of utility cost of all the three different consumers.

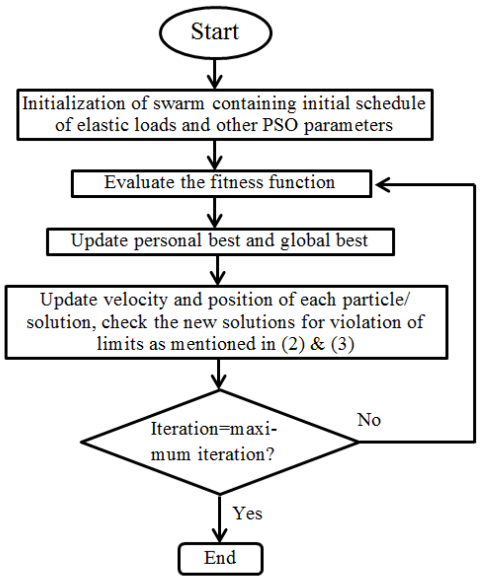

Figure 1. Flowchart of the proposed technique based on PSO

The target loadcurve is basically inversely proportional to wholesalemarket energy prices, that is when the price weight is low the electricity demand is high and vice versa.Figure 2 shows the hourly price weight provided by the utility company.

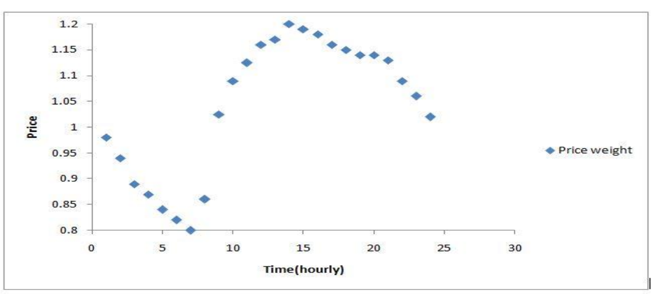

Figure 2. Hourly price weight

The three distribution system such as residential, industrial, and commercial consumers has various types ofcontrollable devices, with different consumption patterns, the details of which are given below in Table 1, Table 2, and Table 3 respectively.

Table 1. Details of elastic loads for residential consumers

Sl. no	Devices	Rating (kW)	Number (Nos.)	Unit Total (MW)
1	Washing machine	0.5	750	0.375
2	oven	1.3	650	0.845
3	Vacuum cleaner	0.4	250	0.100
4	kettle	2	700	1.400
5	Hair dryer	1.5	700	1.050
6	blender	0.3	960	0.288
7	iron	1	1000	1.000
8	Phone charger	0.005	4000	0.020
9	Laptop charger	0.08	800	0.064
10	Dryer	1.2	600	0.720
Total5.860 MW/DAY				

Table 2.Details of elastic loads for industrial consumers

Sl .no	Devices	Rating (kW)	Number (Nos.)	Unit Total (MW)
1	Water heater	12.5	70	0.875
2	Welding machine	25	60	1.500
3	Fan/ac	30	24	0.720
4	Arc furnace	50	14	0.700
5	Industrial motor	100	8	0.800
6	DC motor	150	12	1.800
TOTAL6.395 MW/DAY				

Table 3. Details of elastic loads for commercial consumers

Sl. no	Devices	Rating (kW)	Number (Nos.)	Unit Total (MW)
1	Water dispenser	2.5	200	0.500
2	dryer	3.5	240	0.840
3	kettle	3	240	0.720
4	oven	5	180	0.900
5	Coffee maker	2	200	0.400
6	Fan/ac	3.5	300	1.050
7	light	2	800	1.600
TOTAL6.970 MW/DAY				

Thus the residential, industrial, and commercial consumers can preferto shift their loads from peak to off-peak period by changing their controllable devise usage time. Simulationswere performed and the forecasted hourly load consumption of residential, industrial, and commercial consumersare noted down. The elastic load limits for the three distribution system are different. The values are listed below in Table 4.

Table 4. Details of operational limits

Consumer type	Lower limit of Elastic Load (MW)	Upper limit of Elastic Load (MW)	Total Elastic Load / Day (MW)
Residential	0	0.6	6
Industrial	0	0.5	6.5
Commercial	0	0.55	7

The PSO for this optimization problem has been modelled in MATLAB coding environment with swarm size 50. The comparison of GA [3] and PSOhas been drawn for reduction of system peak loadand tabulated in Table 5.It can be seen from Figure 3-5, that there is a huge saving in energy and hence cost for residential, industrial, and commercial consumers with the load scheduling ($e(t)$) using PSO. From the simulation results it also can be stated that the load shifting DR strategy manages to achieve significant reduction of the load pattern and also reduces the utility operational costs at the same time. Thus the PSO algorithm provides much better reduction of load pattern from the existing GA algorithm. The comparison tables for all the three distribution system are given below in Figure 3-5.

Table 5. Simulation results and comparison with GA

Hour	Load Value (GA)	Load Value (PSO)	Load Value (GA)	Load Value (PSO)	Load Value (GA)	Load Value (PSO)
	Residential Consumer		**Industrial Consumer**		**Commercial Consumer**	
1	0.20	0.2306	0.38	0.2809	0.40	0. 3024
2	0.29	0.0168	0.39	0.0921	0.40	0.0797
3	0.48	0.0008	0.50	0.2986	0.40	0.3421
4	0.50	0.0042	0.50	0.15	0.32	0.1930
5	0.60	0.1007	0.50	0.0671	0.58	0.2823
6	0.60	0.0903	0.50	0.1063	0.57	0.2210
7	0.59	0.3093	0.50	0.4475	0.55	0.0418
8	0.57	0.2513	0.50	0.0357	0.57	0.1320
9	0.30	0.3563	0.38	0.1212	0.38	0.0678
10	0.05	0.1662	0.23	0.0269	0.18	0.1011
11	0.00	0.3557	0.12	0.2209	0.20	0.1320
12	0.10	0.3511	0.12	0.0066	0.20	0.2295
13	0.10	0.073	0.10	0.4486	0.15	0.0273
14	0.08	0.0472	0.05	0.0983	0.02	0.2700
15	0.13	0.0192	0.19	0.0467	0.22	0.2691
16	0.16	0.1009	0.02	0.1537	0.08	0.1857
17	0.23	0.3145	0.19	0.228	0.08	0.2031
18	0.12	0.5048	0.23	0.0508	0.26	0.0612
19	0.28	0.1838	0.28	0.4977	0.02	0.2144
20	0.10	0.1147	0.25	0.166	0.16	0.1329
21	0.19	0.0391	0.02	0.1487	0.21	0.2222
22	0.02	0.1469	0.20	0.031	0.22	0.0530
23	0.01	0.3752	0.12	0.1491	0.37	0.0726
24	0.05	0.124	0.10	0.0232	0.40	0.5181
Total	**5.75 MW/day**	**4.2766 MW/day**	**6.37 MW/day**	**3.8962 MW/day**	**6.94 MW/day**	**4.3543 MW/day**

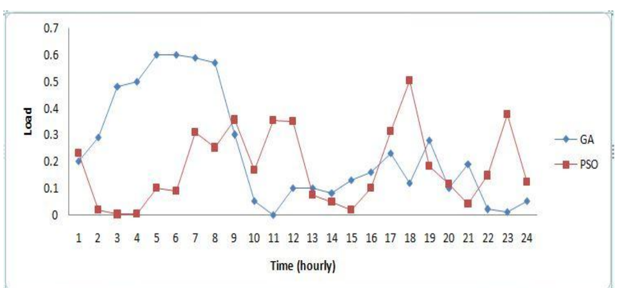

Figure 3. Comparison between GA & PSO for residental consumers

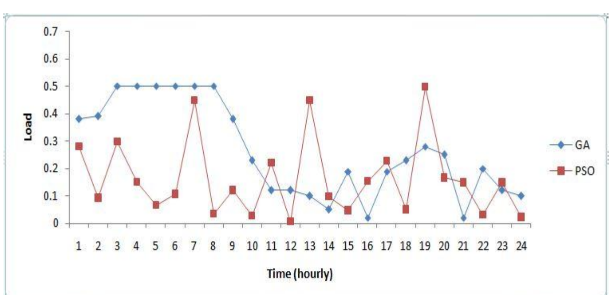

Figure 4. Comparison between GA & PSO for industrial consumers

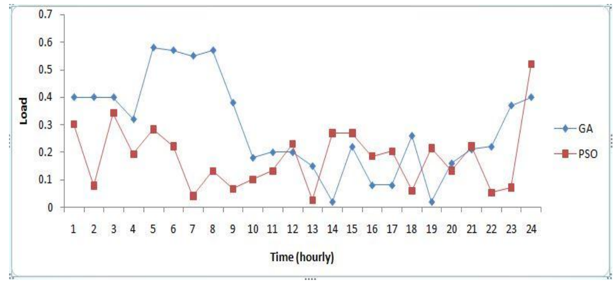

Figure 5. Comparison between GA & PSO for commercial consumers

V. CONCLUSION AND FUTURE SCOPE

A simple approach to solve the elastic load scheduling problem has been demonstrated in this paper. The minimization and economic scheduling of elastic loads has been modelled as a simple optimization problem. The hourly and daily limits of elastic loads have been included too. Three different sectors of consumer e.g. residential, industrial and commercial consumer have been identified and modelled for the above said problem. The proposed demand response strategy is based on PSO. The outcome of the proposed method gives satisfactory results and it is compared with one of the popular meta-heuristic technique i.e. GA. It is seen that PSO is giving better results for this case. The difference between the result of GA and PSO are demonstrated by several graphs which prominently shows the improved result with the PSO technique.

In future work, the recent meta-heuristic techniques like symbiotic organism search (SOS), moth flame optimization (MFO), sine-cosine algorithm, grey-wolf optimization (GWO) etc. can be modelled for elastic load scheduling problems. Some new constraints can be added for more practical realization of the problem.

REFERENCES

[1] G. Gaur, N. Mehta, R. Khanna, and S. Kaur, "*Demand Side Management in a Smart Grid Environment*", IEEE International Conference on Smart Grid and Smart Cities, India, pp. **227-231**, 2017.

[2] M. Awais, N. Javaid, N. Shaheen, Z. Iqbal, G. Rehman, K. Muhammad, and I. Ahmad, "*An Efficient Genetic Algorithm Based Demand Side Management Scheme for Smart Grid*", IEEE International Conference on Network-Based Information Systems, pp. **351-356**, 2015.

[3] C-R Chen, M-J Lan, C-C Huang, Y-Y Hong, and S. H. Low, "*Demand Response Optimization for Smart Home Scheduling Using Genetic Algorithm*" , IEEE International Conference on Systems, Man, and Cybernetics,pp. **1461-1465**,2013.

[4] A. J. Conejo, J. M. Morales, and L. Baringo, "*Real-Time Demand Response Model*", IEEE Transaction on Smart Grid, Vol.**1**, No.**3**, pp. **236-242**, 2010.

[5] C. Eksin, H. Delic, and A. Ribeiro, "*Demand Response Management in Smart Grids With Heterogeneous Consumer Preferences*", IEEE Transaction On Smart Grid, Vol. **6,** No. **6**, pp. **3082-3094**, 2015.

[6] B. Sivaneasan, K. Nandha Kumar, K. T. Tan, and P. L. So, "*Preemptive Demand Response Management for Buildings*", IEEE Transactions on Sustainable Energy, Vol. **6**, No. **2**, pp. **246-256**, 2014.
[7] N. Kinhekar, N. Prasad Padhy, and H. Gupta, "*Particle Swarm Optimization Based Demand Response for Residential Consumers*", pp. **1-5**, IEEE Power & Energy Society General Meeting, 2015.
[8] R. Poli, "*An analysis of publications on particle swarm optimization applications*", Technical Report CSM-469, 2007.

Authors Profile

*Ms. S. Dey*received the B.Tech degree in Electrical and Electronics Engineering from Lovely Professional University, Punjab, in 2017. Currently she is pursuing M.Tech in Electrical Engineering from Tripura University, Tripura. Her research interests include power system, energy management system.

*Ms. M. Dasgupta*received the B.E degree in Electrical and Electronics Engineering from Sathyabama University, Chennai, in 2016. Currently she is pursuing M.Tech in Electrical Engineering from Tripura University, Tripura. Her research interests include power system, energy management system.

*Mr. S. Chatterjee*has received his B. Tech from WBUT, in 2010 and M. Tech from NIT Agartala, in 2013. He is currently pursuring PhD at NIT Agartala. His current research interest covers PMU application in power system, protection schemes for micro-grids, and demand side management.

*Mrs. G. Deb*received the B.E degree in Electrical Engineering From Tripura University, Tripura, in 2004 and M.tech in Electrical Engineering from Tripura University, Tripura, in 2008.She in pursuing Ph.D From NIT Agartala. Currently she is working as a lecturer in Tripura University at the department of Electrical Engineering. Her research interests include power system, energy management system, Artificial Neural Network, FACTS Device.

