International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 757

OPTIMAL SCHEDULING OF APPLIANCES IN SMART GRID ENVIRONMENT USING BPSO ALGORITHM

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ABSTRACT

In this paper, BPSO algorithm is used for DSM implementation in the SG environment. Load shifting technique is applied in the residential and industrial area and shifted the load from peak hours to off-peak hours. Load shifting technique is mathematically formulated and implemented as a minimisation form. In this paper, it has been clearly shown that BPSO based load shifting method can be able to handle a large number of devices of various types compared to the traditional DSM method. The focus of this work is to reduce the peak load demand, electricity cost, PAR as well as to achieve substantial cost savings. BPSO based load shifting method shows the better result in terms of peak load reduction when compared to GA based DSM.

Keywords: Smart grid, DSM, Algorithms, BPSO, Load shifting.

NONMENCLATURE

Abbreviations	
SG	Smart grid
DSM	Demand-Side Management
BPSO	Binary particle swarm optimization
GA	Genetic algorithm
PAR	Peak to average ratio

1. INTRODUCTION

The electricity demand is expected to increase to almost twice the current demand by the year 2020 because of the rapid electricity consumption as a consequence of quick movement of globalization and industrialization [1,2]. Therefore, effective utilization and distribution of power supply are necessary to maintain continuous economic and industrial development.

SG brings the highest opportunities to handle the future energy system. SG is an electric grid network with advanced sensing technologies, control methodologies, and communication technologies which provides bi-directional communication between the consumers and electricity suppliers [3,4].

DSM opens the new door for the efficient supply of electricity by implementing policies and measures for energy consumption [5]. In order to achieve an optimistic power consumption curve, DSM is implemented directly or indirectly by the utility companies. Moreover, an efficient DSM with SG helps to achieve an optimistic utilization and distribution of electricity by varying the price tariff of electricity between the peak and off-peak hours [6]. Generally, consumers have to spend a lot of money because of the high price of electricity. However, the integration of DSM with SG reshapes the load profile and provides the desired load curve to the utility companies. DSM manages the accessible electricity in the grid in various perspectives for example, residential, commercial and industrial. This situation leads to the reduction of peak load demand, electricity cost of the customer as well as improves the grid stability, sustainability and security.

So far, a numbers of algorithms and approaches such as dynamic programming, linear programming and heuristic evolutionary algorithm have been implemented for solving the DSM problems [7]. For example, Kurucz et al. and Shaaban et al. proposed a linear programming and nonlinear programming method respectively for scheduling the load and minimizing the peak load demand [8,9]. However, these algorithms cannot be able to handle the large numbers of various types of devices because of their system specific nature. The aim of this work is to solve a minimization problem by shifting the load from peak hours to off-peak hours employing BPSO algorithm and establish a comparison with GA. In this case, residential and industrial appliances are considered for the investigation.

2. METHODOLOGY

This paper presents a BPSO based load shifting technique for DSM. Here, day-ahead load shifting technique is applied based on the forecasted load and electricity price where controllable and uncontrollable loads are considered for the optimization problem. In this method residential and industrial appliance are considered where each device has different energy consumption.

In BPSO algorithm, number of hours in a day is represented by a particle and the particle is represented by a row vector with m variables**.** Load shifting technique is applied in a minimisation form and presented as follows.

Minimise, $\sum_{t=1}^{M}(P(t)-O(t))^2$

Where, $P(t)$= actual consumption at time t.

$O(t) =$ objective curve at time t.

P(t) can be expressed by the following equation.

P(t)=F(t)+C(t)-D(t)

Where, F(t)= forecasted loads at time t.

C(t)= loads connected at time t.

D(t)= loads disconnected at time t.

The PAR is calculated using the following equation.

PAR=$\frac{load_{peak}}{load_{mean}}$

3. SIMULATION RESULTS AND DISCUSSION

3.1 Data for simulation

Table 1 shows the hourly forecasted loads for residential and industrial areas with electricity price [7]. These loads include both shiftable and nonshiftable loads with different time steps. With the aim of comparing the BPSO based load shifting technique with GA based technique, the data for the residential and commercial appliances were taken from the previous study [6]. This makes the comparison results more reliable. The load shifting simulation was carried out for both residential and industrial loads in the MATLAB software platform.

Table 1 Hourly forecasted loads for different areas and electricity price [7]

Time (h)	Price (Ct/kWh)	Forecasted load (kWh)	
		Residential	Industrial
1	8.11	412.3	876.6
2	8.25	364.7	827.9
3	8.1	348.8	730.5
4	8.14	269.6	730.5
5	8.13	269.6	779.2
6	8.34	412.3	1120.1
7	9.35	539.1	1509.7
8	12	729.4	2045.5
9	9.19	713.5	2435.1
10	12.27	713.5	2629.9
11	20.69	808.7	2727.3
12	26.82	824.5	2435.1
13	27.35	761.1	2678.6
14	13.81	745.2	2678.6
15	17.31	681.8	2629.9
16	16.42	666	2532.5
17	9.83	951.4	2094.2
18	8.63	1220.9	1704.5
19	8.87	1331.9	1509.7
20	8.35	1363.6	1363.6
21	16.44	1252.6	1314.9
22	16.19	1046.5	1120.1
23	8.87	761.1	1022.7
24	8.65	475.7	974

3.2 Analysis of residential appliances

In the case of residential loads, the simulation was carried out in a total of 1547 device of 7 types. Compared to industrial area, residential appliances have lower electricity consumption rating and short period of operation. It can be seen from the Fig. 1, the implementation of DSM shifts the loads from peak hours to off-peak hours and provides a load curve close to the objective curve. Without DSM strategy the value of peak demand was about 1363.6 kWh at 20th hour and reduced to 967.1 kWh when DSM was implemented. With DSM the peak load shifted to first hour with a value of 1018 kWh. The hourly cost curve (Fig. 2) depicts that the electricity cost reduced significantly in the peak hours with DSM and remained nearly constant from third hour. Table 2 presents the comparison between the results with DSM strategy and without DSM strategy in terms of peak demand, PAR and electricity cost. As can be seen, the DSM strategy reduces the PAR, peak demand and total electricity cost by 25.41, 25.35 and 16.87% respectively.

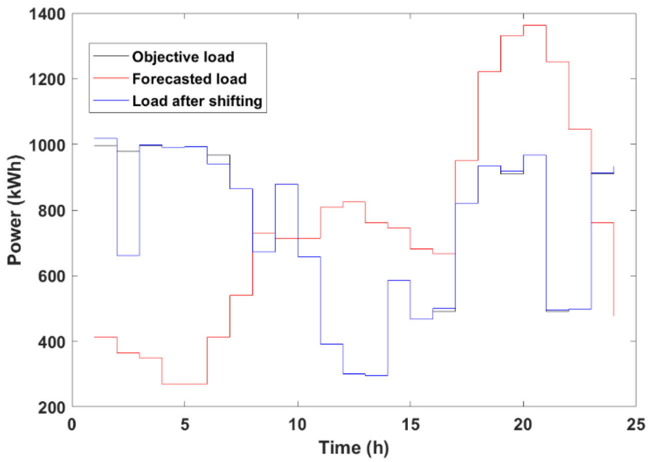

Fig 1 Load curve for residential area

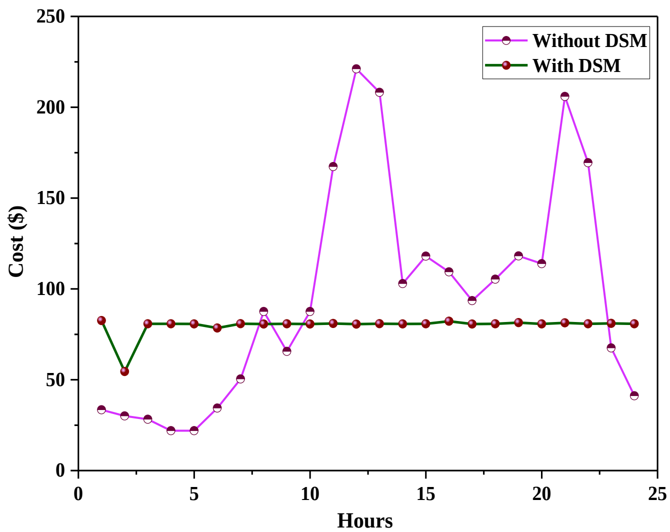

Fig 2 Hourly cost curve for residential area

Table 2 Simulation results of BPSO based load shifting

	Without DSM	With DSM	Reduction (%)
Residential area			
PAR	1.85	1.38	25.41
Peak demand (kWh)	1363.6	1018	25.35
Total cost ($)	2302.88	1914.4	16.87
Industrial area			
PAR	1.62	1.53	5.56
Peak demand (kWh)	2727.3	2225	18.42
Total cost ($)	5712.05	3923.48	31.31

3.3 Analysis of industrial appliances

A total of 133 devices of 6 types were considered for the simulation in case of industrial area. As can be seen from the Fig. 3, the load curve after shifting closes to the objective curve except the first 8 hours. At 11th period the peak demand was 2727.3 kWh without DSM and reduced to 727.3 kWh with DSM. In the case of DSM strategy, the peak demand was 2225 kWh and shifted to 9th hour. Fig. 4 shows the hourly cost reduction for the industrial area. In the peak periods, the hourly cost with DSM significantly reduced with slight fluctuations. The results of the simulation suggests that the proposed DSM scheme reduces the peak demand, PAR and electricity cost by shifting the load from peak hours to off peak hours. In this case, the reduction of peak load, PAR and total cost was 18.42%, 5.56% and 31.31% respectively.

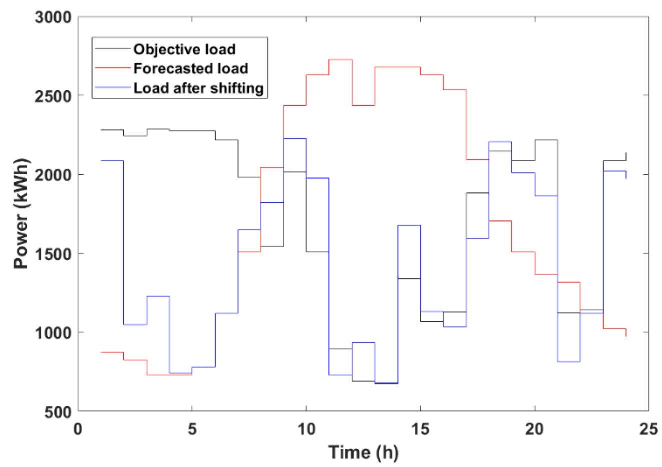

Fig 3 Load curve for industrial area

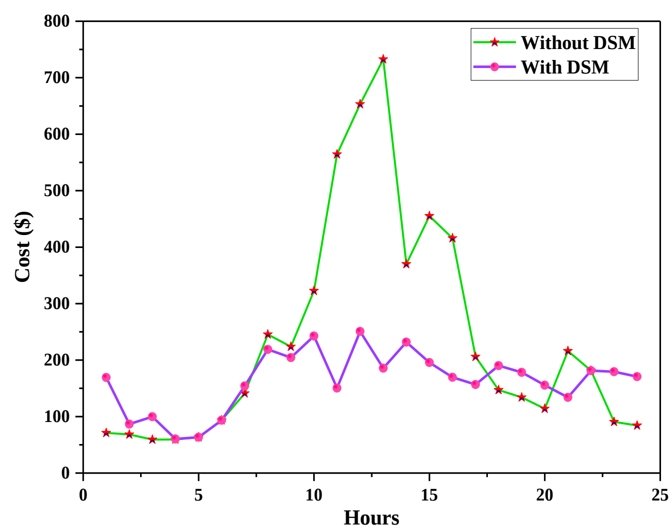

Fig 4 Hourly cost curve for industrial area

3.4 Comparative analysis with GA-DSM

Fig. 5 shows the comparison between the proposed BPSO based and GA based DSM method. GA based DSM method used “flexible load shape” technique while BPSO method used “load shifting” technique. It can be observed from the Fig. 5 that the GA based DSM method reduced peak demand by 23.81 and 17.49% residential and industrial area respectively [6]. On the other hand, proposed BPSO based DSM method reduced the peak demand by 25.35 and 18.42% for residential and industrial area, respectively. Therefore, the BPSO based DSM method improves the performance by 1.54 and 0.93% for residential and industrial area, respectively. In addition, the proposed BPSO based load shifting method is simple in mathematical formulation and provides the maximum efficiency and successive rate compared to GA based method.

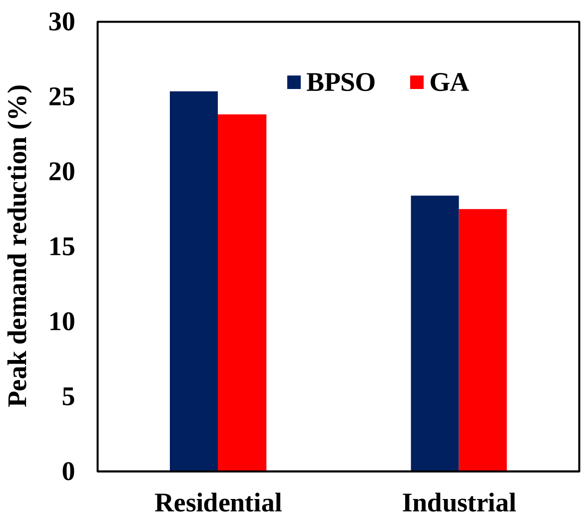

Fig 5 Comparison between BPSO and GA based DSM

4. CONCLUSIONS

In this work, a BPSO based load shifting strategy is proposed which has the potential to bring the benefit for both customer and supplier. This method is able to provide a stable cost reduction curve. Simulation is carried out with a number of appliences of various types in residential and industrial area. It has been shown that the proposed BPSO based method finds an optimal load schedule in terms of reduction of peak demand, electricity price and PAR. In addition, a comparitive study has been carried out with GA based DSM method and found that the proposed BPSO based DSM method perform better.

ACKNOWLEDGEMENT

This work was supported by the School of Software and Electrical Engineering, Swinburne University of Technology, Melbourne, Australia. The first author is indebted to the Swinburne University of Technology for the TFS scholarship.

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