INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 6.078
(Volume 7, Issue 1)
Available online at: https://www.ijariit.com

Hybrid the bat and particle swarm optimization for demand-side management in the smart grid

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ABSTRACT

The main goal of the demand side management program is shaping the load demand from peak load period to off-load period to reduce the generation cost. In the literature, various types of load shaping objectives available such as load shifting, valley filling, and peak clipping. In this paper, two optimization algorithms hybrid for load shaping. We have considered the BAT and Particle Swarm Optimization (PSO) algorithms in our work. These algorithms turn on/off the devices in the optimal way to reduce the cost and load consumption. The algorithm is simulated in MATLAB for two case studies in which 3 and 5 devices are taken under consideration. We have measured the total load consumption, cost, and execution time for the proposed algorithm and compared with the existing algorithms. The results show that the proposed algorithm provides less load consumption and cost as compared to Normal ON-OFF and PSO algorithm.

Keywords: *Bat Algorithm, Demand Side Management, Particle Swarm Optimization, Smart Grid*

1. INTRODUCTION

There are various parameters that need to be used for the smart grid network at production, transmission as well as distribution ends. There are many works done through the usages at the users' end for the most efficient source used for good efficiency as well as economically may be stated like demand-side management (DSM) [1]. The amount of work management as well as monitoring will advantage not for the users but also utilities.

The DSM was handled the temporary parameters to decrease the work demand at the time of working hours toll that the uses are enabled to provide the working loads. Nevertheless, with increasing work demand as well as communication, other advantageous concepts have been highlighted through the DSM. It enhances the system stability through decreasing events of blackouts as well as addressing system emergency and also assists in decreasing energy rates through relieving the uses from using fuel as well as using in the new source at the time of working hours. In addition, the DSM assists usages by refraining the things from using more in storage capacity at the time of non-working hours. According to the cost advantages, it has positive surrounding effects, as decrease using of fossil fuels would decreased surrounding pollution activities. The DSM enhances the demand, as well as energy like the user, will be motivated to decrease the energy using at the time of high energy rates of period.

In the literature, numerous demand side management algorithms have been proposed in order to optimal load scheduling [2]. The most popular method is Normal ON-OFF. Nevertheless, this method is not optimally load schedule. Therefore, the optimization algorithms are used it. The most popular algorithms are Bat, firefly, and PSO [3-5]. In our work, we have studied the BAT and PSO algorithm and hybrid it in order to reduce the load and cost value for load scheduling.

The main contribution of this paper is to hybrid Bat and Particle Swarm Optimization algorithm for optimally turn on/off the devices in order to reduce the load consumption and cost. The experimental results have performed for two case studies (3 and 5 devices). The results show that the proposed algorithm provides better results as compared to Normal ON-OFF method and PSO algorithm. Thus, the proposed algorithm can be deployed for demand side management in the smart grid.

The rest of the paper is as follows. Section 2 gives an overview of Bat and Particle Swarm Optimization algorithm. Section 3 presents the proposed algorithm. Section 4 shows the experimental results for the proposed algorithm. Section 5 defines the conclusion.

2. RELATED WORK

In this section, the Bat and Particle Swarm Optimization algorithms are discussed.

2.1 Bat Algorithm

Yang suggested BA in 2010 through using the behaviours as well as the properties of the microbat. There are three main properties of the microbat are applied to build the design of Bat algorithm. The required estimates as well as the idealized rules in this approach are described which are following below [6]:

1. Most of the race of the bat usage the echo place to find out their enemy. Nevertheless, not all races do the similar process. Nevertheless, the micro bat is an illustration of extensively through the echo place. Then, the first properties are the echo place behaviour.
2. The second properties are the frequency that the micro bat accepts a fixed frequency f_{min} with wavelength λ and the loudness $_{A0}$ to find out for prey.
3. Various ways to adjust the loudness. The loudness is considered to be varied from a positive large A_0 to a minimum value A_{min}. In this method, the movement of the virtual bat is used through Eq. (1) – Eq. (3):

$$f_i = f_{min} + (f_{max} - f_{min})\beta$$

$$v_i^t = v_i^{t-1} + (x_i^t - x_{best})f_i$$

$$x_i^t = x_i^{t-1} + v_i^t$$

where f is the frequency used, the suffixes, min and max, show the minimum and maximum value of frequency respectively. x_i indicates the place of the i^{th} bat in the space, shows the velocity of the bat, t shows the current iteration, β denotes a random vector, and $\beta \in [0, 1]$, and x_{best} shows the global near best solution.

4. Moreover, the rate of pulse emission is showed through the symbol r_i and $r_i \in [0, 1]$, where the suffix i indicates the i^{th} bat. In iteration, a random number is produced and contrast with r_i. In the iteration, the random number is greater than r_i, a local search method is indicated. A good solution is produced through Eq. (4):

$$x_{new} = x_{old} + \varepsilon A^t$$

Where $\varepsilon, and\ A^t$ is a random number and $\varepsilon \in$ [-1, 1] and shows the average loudness at the current time step. After upgrading the x, A_i , and r_i of the bats, the loudness, and the pulse emission rate when the global near best solution is upgarde and the random produced number is smaller than A_i . The upgarde of A_i and r_i are executed through Eq. (5) and Eq. (6):

$$A_i^{t+1} = \alpha A_i^t$$

$$r_i^{t+1} = r_i^0[1 - e^{-\gamma t}]$$

In this experiment, α=γ=0.9 is used.

2.2 Particle Swarm Optimization

The PSO method is a stochastic optimization method originated on swarm, which was suggested through Eberhart and Kennedy (1995) as well as Kennedy and Eberhart (1995). This method simulates animal's behavior, involving herds, birds, insects, and fishes. It maintains a co-adjustor method to detect the food, and each member keeps varying the search structure according to their learning ways as well as other family members [7].

The equation followed in the PSO approach. Each recitation, the value of position of the each particle is upgarde through its velocity which is shown in below equation [8].

$$v_i(t+1) = w \times v_i(t) + c_1 \times r_1 \times [pbest_i - x_i(t)] + c_2 \times r_2 \times [gbest_i - x_i(t)]$$

$$x_i(t+1) = x_i(t) + v_i(t+1)$$

Where p, t, and r1, r2 is the number of particles, the iterations number, and the random numbers between [0,1], and c1,c2 are denoted as the constants of acceleration. The w is denoted as the inertial constant.

3. PROPOSED ALGORITHM

The proposed technique is hybrid two optimization algorithms that is used to optimal scheduling of the loads. The block diagram of the proposed algorithm is shown in Figure 3.

Initially, the load devices information is initially. The main load in homes is consumed by appliances like HVAC that is heating ventilating and air conditioning, electric water pump (EWP), and EWH that is an electric water heater.

After that, initial parameters for the BAT and PSO algorithm is defined. The BAT and PSO optimization are using for management home appliances to reduce load and cost. Optimization algorithm turn on/ off the home appliances for best time which suitable to reduce overall load. In the last, total load consumption, load cost, and execution time is determined for it.

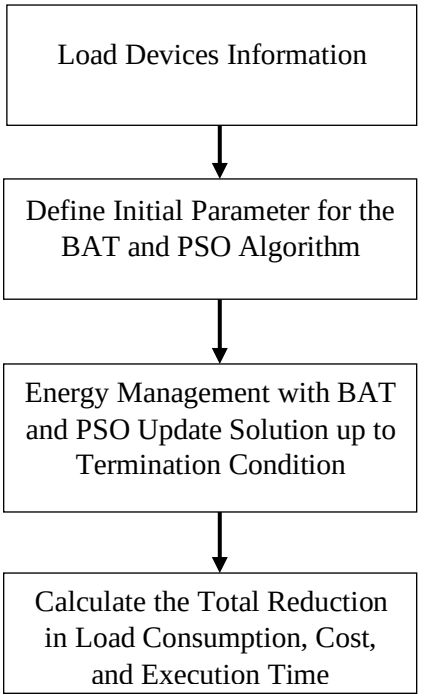

Fig. 3: Block Diagram for the Proposed Algorithm

4. EXPERIMENTAL RESULTS

In this section, experimental results from the proposed algorithm are presented to validate with existing algorithms. The algorithm is simulated in MATLAB. In our work, we have taken two cases studies. In the case studies, we have considered 3 and 5 energy consuming devices. In the proposed algorithm, we have hybrid the BAT and PSO algorithm. The initial parameters considered for it is shown in Table 4. Next, we have measured number of performance parameters for it, as explained below.

Table 4: Parameters for Hybrid Bat and PSO Algorithm

S no.	Parameter	BATPSO
1	Population	10
2	Iteration	100
3	A (Loudness)	0.5
4	r (Pulse rate)	0.5
5	Fmin	0
6	Fmax	2
7	C1	1
8	C2	0.5
9	W	0.9

4.1 Total Load Consumption

In this analysis, we have measured how much total load reduction with scheduling of the devices.

Case Study1: In the case study1, we have considered 3 energy consuming devices. Table 4 shows the total load reduction using the normal on-off, PSO, and proposed algorithm. The proposed algorithm provides 54.74% and 47.02% better load reduction as compared to the existing algorithms (normal on-off and PSO). It shows that the proposed algorithm is better approach as compared to the existing algorithms.

Table 4: Comparative Analysis based on the Total Load Consumption

Calculation Methods	Consumptions of Total Load (KWh)
Normal ON-OFF Method [8]	384.50
With PSO [8]	328.44
Proposed Algorithm (HPSOBAT)	**174**

Case Study2: In the case study2, we have considered 5 energy consuming devices. Table 4 shows the total load reduction for different algorithms such as normal on-off, PSO and proposed algorithm (HPSOBAT). The proposed algorithm provides 51.86% and 40.49% better load reduction as compared to normal on-off and PSO algorithm, respectively.

Table 4 Comparative Analysis based on the Total Load Consumption

Calculation Methods	Consumptions of Total Load (KWh)
Normal ON-OFF Method [8]	444.50
With PSO [8]	365.78
Proposed Algorithm (HPSOBAT)	**214**

4.2 Cost

In this parameter, we have measured how much reduction in the cost with scheduling of the devices with the proposed algorithm.

Case Study1: In the case study1, we have considered 3 energy consuming devices. Table 4 shows the cost for scheduling the devices for normal on-off, PSO, and proposed algorithm. The cost for normal on-off method is Rs. 714.05, PSO is Rs. 568.33, and proposed algorithm is Rs. 455. The total cost reduction due to proposed algorithm is 36.28% and 19.94% as compared to the existing algorithm.

Table 4: Comparative Analysis based on the Total Cost

Calculation Methods	Costs of Total Load (in Rs)
Normal ON-OFF Method [8]	714.05
With PSO [8]	568.33
Proposed Algorithm (HPSOBAT)	**455**

Case Study2: In the case study2, we have considered 5 energy consuming devices. The cost in the scheduling of Normal ON-OFF approach, PSO, and proposed algorithm approach is Rs. 843.08, Rs. 630.74, and Rs. 391. The total decreased of the price through proposed algorithm is 53.62% and 38.01% as compared to Normal On-Off and PSO algorithm, respectively.

Table 5: Comparative Analysis based on the Total Cost

Calculation Methods	Costs of Total Load (in Rs)
Normal ON-OFF Method [8]	843.08
With PSO [8]	630.74
Proposed Algorithm (HPSOBAT)	**391**

4.3 Execution Time

The total time spent for the proposed algorithm for determine load consumption and cost. In the MATLAB, tic and toc commands used for determine the execution time. Table6 shows the execution time for case studies (3 and 5 Devices).

Table 6: Execution Time for the Proposed Algorithm

Case Study (Devices)	Execution Time (in Seconds)
3	1.1086
5	1.1416

5. CONCLUSION

This paper gives a basic home energy management system by the real-time price scene of the uses through a heuristic optimization approach. In the proposed algorithm, we have hybrid the two optimization approaches like BAT and PSO algorithm for load scheduling. These algorithms in the optimal way switch on/off the devices for reduce the load consumption and cost. We have considered two case studies (3 and 5 devices) for load scheduling and measured the total load consumption reduction, cost reduction, and execution time for it. The proposed algorithm provides better results as compared to the normal ON-OFF and PSO algorithm [8].

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