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Smart grid demand side management using hybrid combination of Bat and Firefly Algorithm

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ABSTRACT

A smart grid is the advanced power grid, and electricity demand is managed and controlled by it. The electricity demand is increased during the peak hours of the day. Thus, to fulfill the electricity demand either generate the extra electricity in the peak hours that increase the cost or reduce the load in the peak hours. The load during peak hours is reduced by adopting a demand-side management technique. These techniques reduce the generation cost, and the performance of the smart grid is improved. This paper provides proposed a new/latest approach known as a hybrid of BAT, and Firefly optimization is used to control the switching time of devices so that the overall load can be minimized. The experimental results are performed for different devices (3 and 5). The simulation results show that the proposed algorithm reduces the cost as compared to the original cost. In the last, we have compared the performance of the proposed algorithm over the existing Particle Swarm Optimization (PSO) algorithm and found that 47.02% and 36.48% cost reduction for 3 and 5 devices, respectively.

Keywords: *Bat, Firefly Algorithm, Load Data Management, Smart Grid*

1. INTRODUCTION

In energy management, demand-side management is the main and crucial function of a smart grid that supports functions in different sectors like management and control, constructional infrastructure, electricity marketing, managing de-centralized energy sources, and electric vehicle management [1]. The overall demand for load at peak can be decreased by influencing and controlling by reshaping demand profile and increasing the grid sustainability by decreasing overall expense and level of carbon emitted. The construction of under-utilized infrastructure of electrical appliance in means of transmitting lines, distributing networks, generating capacity that is avoided by demand-side management effectively. The present management of demand-size consists of aggregated industries that help in coordinating curtailment and shifting load for the user. Aggregating companies can be replaced by smart meters as different nations had adopted it very quickly. Smart meters used in automatic metering enable smart pricing as its unique feature of the smart grid infrastructure. In present grids demand-side management is used to handle huge controlling devices of different devices. The conversion of existing grid into smart grid provides demand-size management [2]. For instance, this should handle reusable and distributed energy resources at user property. Six generic methods for demand-side management are classified as strategic conversion, valley filling, strategic load growth, peak clipping, flexible load-shape and load shifting and categorized as TOU that is the time of use, SR that is spinning reserve, EE that is energy efficiency and Demand response (DR) policies that are used to define various load according to demand patterns [3]. Out of these, load shifting technique is most preferred to lessen the load at the time of peak. In the literature, the Genetic Algorithm (GA) load shifting technique proposed that gives a single predicted value in the output [4]. Further, the Particle Swarm Optimization (PSO) used for load shifting [4]. However, it falls to local optima and low convergence rate. Thus, in order to improve the convergence rate, two optimization algorithms hybrid.

The main contribution of this paper is to hybrid the metaheuristic algorithms such as Bat and Firefly Optimization for load shifting. To attain this goal, absolute error is used as an objective function that helps in shifting the load. The experiment connected shows the hybrid approach as outcome that gives superior results as compared to the existing. The paper presentated as follows includes Section 2 shows the related research work done in load data management, the proposed method is explained in Section 3, performance analysis and experimental results are shown in Section 4 shows, and Section 5 shows the conclusion and future scope of the proposed method.

2. RELATED WORK

In this section, the load shifting techniques used in the literature are discussed. In the literature, various methods for demand-side management are proposed that are shown in Figure 1 and explained below.

Peak clipping and Valley fillig: To increase the safety/security and decrease the divergence among valley load and peak levels demolish the peak demand burgen, the valley filling and peak clipping is focused on smart grid [6]. **Peak clipping** is used to reduce the peak load as it is a direct load controlling method, whereas direct load control is employed to construct off-peak demand by using **valley filling**. In the present distribution network, the **load shifting** is widely used as an effectual load management method as it is beneficial from the load as it independent of time and therefore shifting peak time load to off-peak [7]. Load shape optimization is attained by **strategic conversation** by reducing demand techniques at customer property directly [8]. The long term implementation for decreasing demand on operation and planning networks is to be considered by the distribution management system. Beyond the valley filling method, great demand is optimized by the strategic load growth on a daily bases that is based on expanding market share for energy conversion of load distribution or storage systems sources. To balance the exceeding demand and infrastructure that accompanies the load growth, the operations and planning are issued. The essential constructal infrastructure is for the planned load growth is required to be provided for future use. Consistency is related to flexible load shape for the smart grid. During the significant time of period, the managing system of the smart grid used to recognize clients with flexible loads that are agreeable to be controlled for exchanging different incentives. The research is conducted to recognize the anticipation load shape that consist of demand-size actions forecasted above the planning perspective [9].

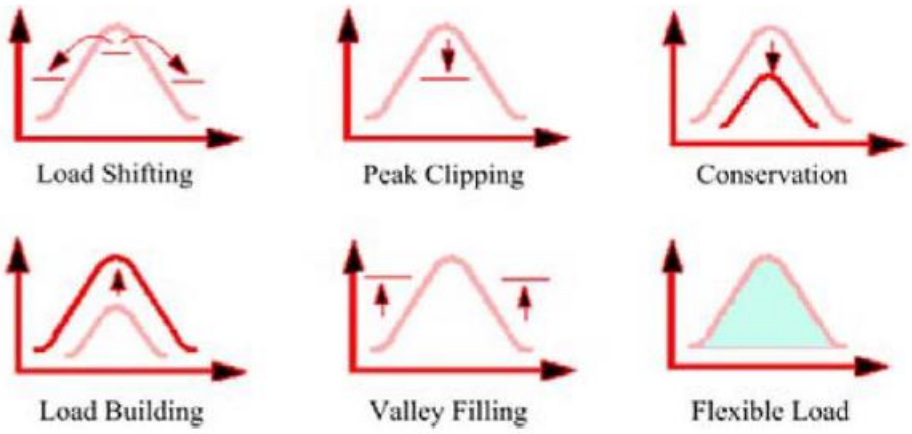


Fig. 1 Method for Demand Side Management [5]

3. TECHNIQUE PROPOSED

The proposed technique is hybrid two optimization algorithms that is used to enhance the convergence rate for load shifting. In figure 2 the proposed block diagram is shown.

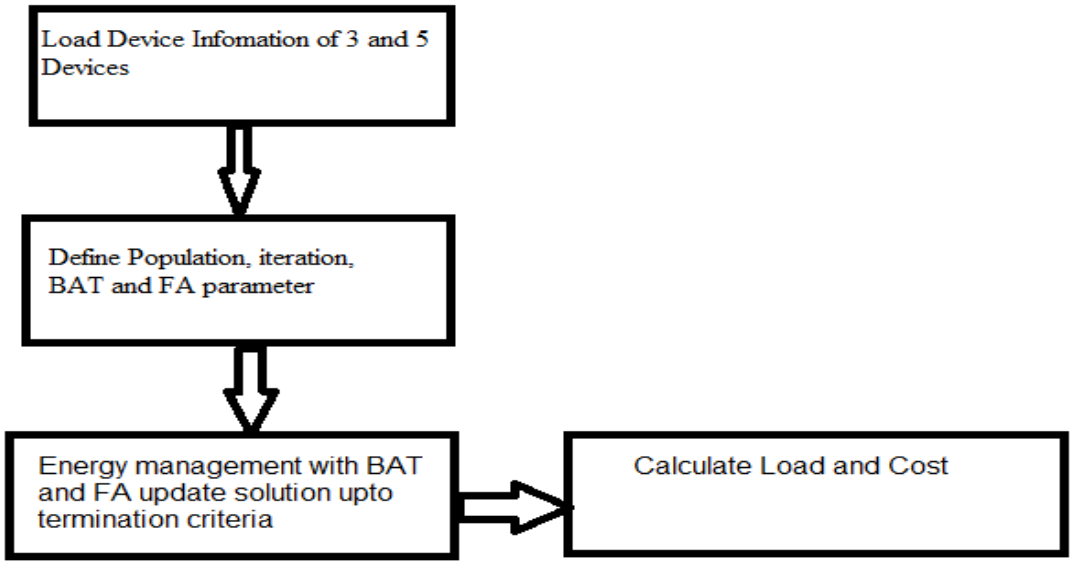


Fig. 2: Proposed Technique Block Diagram

3.1 Bat Optimization Algorithm

Bat algorithm is a modern method of providing good results as compared to many conventional and interrogative algorithms used to resolve the complicated and complex engineering issues. It is utilized for the echo-location of micro-bats. Etiolation or echolocation is a sonar wave that is produced by micro-bats, which helps them in finding prey, and also, with the help of this, sometimes they are able to differentiate the barriers or danger caused on their path in darkness. The loud and high-frequency ultrasonic waves are produced by bats, and the reflecting back echo from the object in the surrounding is heard by them. The rules used by bat algorithm are simple and listed below.

- To sense/ feel the prey, any obstacle or predator on the way, echolocation is used by bats.

- Position and velocity is used by bats to fly. The loudness and frequency f is used to approach the prey. The pulse emission frequency r is adjustable.
- When the approaches near to the prey, the loudness reduces, and the pulse increases [10].

3.2 Firefly Optimization Algorithm

At night the blinking indication and light are generated by insects or beetles with wings called fireflies. Bioluminescence is generated from the lower abdomen of fly chemically that does not employ any infrared or ultraviolet frequency. The flashlight is utilized to attract prey or mates, and it is also used as a reminder for fireflies regarding possible predators known as protective warning mechanisms. It is stimulated as a flashing nature of fireflies as a firefly algorithm called a metaheuristic algorithm and the occurrence of bioluminescent communicating technique. The assumptions made for the firefly algorithm are as below.

- Being unisexual, fireflies are attracted to all.
- Their brightness is proportional to attractiveness, so flies with less brightness will be attracted to flies with high brightness, and therefore, the attraction reduces with increasing distance between the two flies.
- Random motion is caused due to the same brightness among flies.

The newly generated solutions have produced random movement and attraction between fireflies. The brightness is associated with functional aim related to issue with fireflies. They are divided into sub-groups depending on their attractiveness, and swarming in the region of local models is performed by every sub-group [11].
The hybrid FA and BAT algorithm is proposed for home energy management. HEM is utilized in the environment. ESS that is energy storage system is incorporated as EV that is electric vehicle and demand response (DR) is utilized for reducing electricity consumption bill for homes by using UPS that is the uninterrupted power supply.

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. These home appliances are programmed by FA and BAT algorithms in MATLAB software.

4. EXPERIMENTAL RESULTS

The performance and simulation analysis parameters for the proposed technique is shown in this part. We have written code and simulated in MATLAB. The hybrid BAT and Firefly parameters are described Table 1.

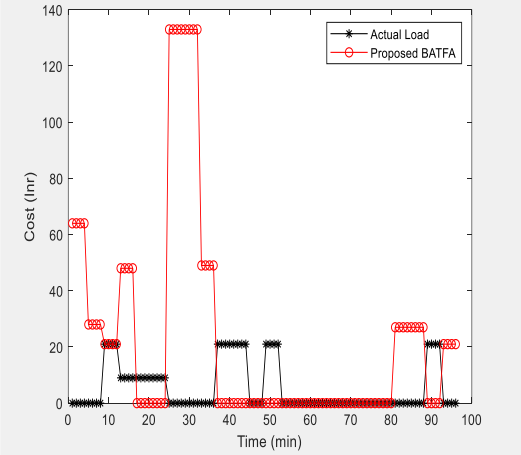
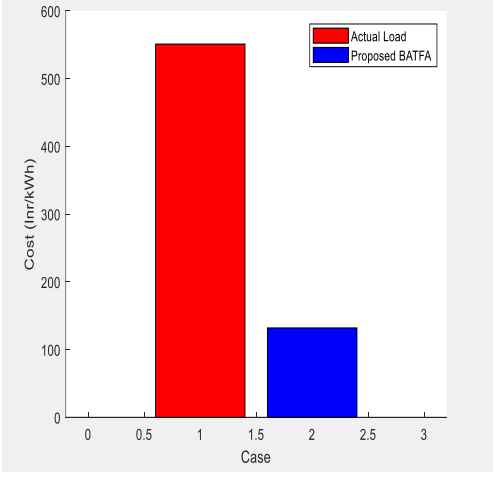
Table 1: Hybrid BAT and Firefly Algorithm Parameters

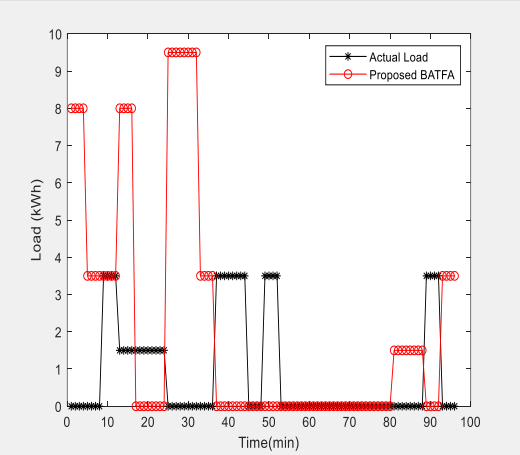
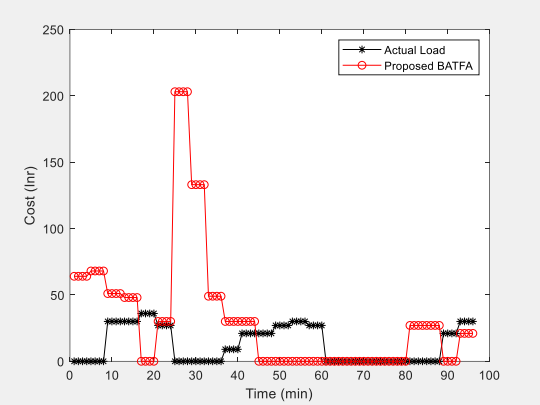
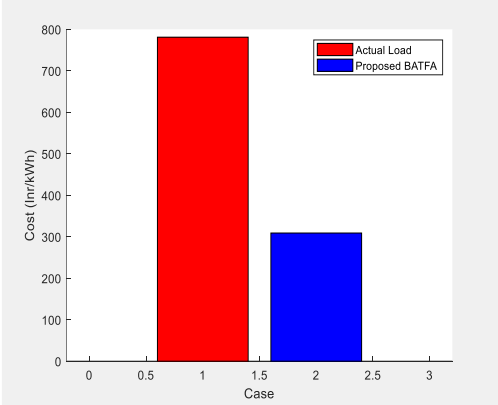
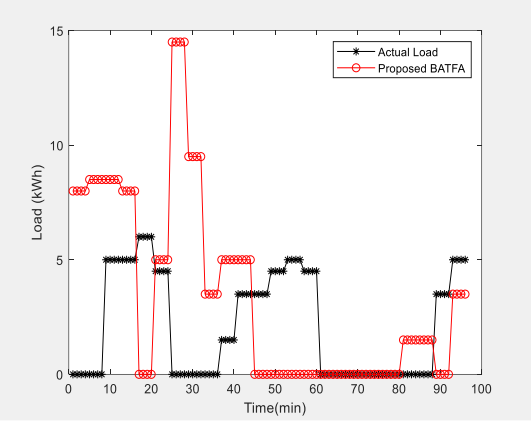
S no.	Parameter	BATFA
1	Population	10
2	Iteration	100
3	A (Loudness)	0.5
4	r(Pulse rate)	0.5
5	Fmin	0
6	Fmax	2
7	Gamma	1
8	Alpha	0.5

4.1 Simulation Results

For the experimental purposes, 3 and 5 devices of the home equipements are taken under consideration. The experimental results are shown in Table 2. The results show that the total cost reduction in the proposed BATFA as compared to the actual load.

Table 2: Simulation Results for Different Devices

Devices	Analysis	Cost Reduction
3	 Time vs. Cost	

	 Time vs. Load	
5	 Time vs. Cost	
	 Time vs. Load	

4.2 Analysing Performance

We have measured the following performance parameter for the proposed technique.

- **Total Cost:** The chief motive is to decrease the expense of electricity by load shifting for the customers. In Table 3, the cost factor is compared.

Table 3: Total Cost Reduction Percentage between Original and Predicted Cost

Device	Original Cost	Predicted Cost	Reduction Percentage
3	551	174	68
5	781	361	53
Average	666	268	59

- **Execution Time:**The total time is taken by the proposed technique to predict the optimal solutions. In the MATLAB, to determine the execution time of the algorithm, two inbuilt commands available known as tic and toc. The *tic* command is written at the start of the algorithm and toc at the end of the algorithm. The proposed technique used to calculate the execution time is depicted in tabular form below in table 4.

Table 4: Various Devices with their Execution Time

Device	Execution Time (in Seconds)
e	2.59
5	2.69

4.3 Comparative Analysis with the Existing Techniques

In this part of the paper, the comparison between the proposed BATFA technique and the current technique is examined that is shown in Table 5 given below. The outcomes depict that the suggested method has fairly decreased the expense in comparison to the current PSO algorithm.

Table 5: Comparative Analysis with the Existing Technique

Devices	PSO [4]	Proposed BATFA	Reduction Percentage
3	328.44	174	47.02
5	568.33	361	36.48

5. CONCLUSION AND FUTURE WORK

It is concluded that to manage the load data, the load shifting method is utilized in this research paper. This primary aim is achieved using a metaheuristic algorithms BAT and Firefly Optimization algorithm. The experimental results are performed for different devices and determine the load distribution and cost reduction. The simulation results show that the proposed algorithm reduces the cost as compared to the original cost. In the last, we have done the comparative analysis and found that the hybrid approach reduces 47.02% and 36.48% cost as compared to the existing PSO algorithm for 3 and 5 devices, respectively.

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