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Social spider optimization algorithm-based energy management of photovoltaic powered textile industry

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ABSTRACT

The competitive nature of business, especially in the production industries like the textile industry, increases the importance of the economic operation of the production setup. Energy management is one important tool that supports the economic operation of any industry. This paper attempts to develop an optimized energy management algorithm using Social Spider optimization in a textile industry environment. Energy management for one full day is analyzedin the environment, considering fixed, shift-able, and uninterruptible loads for energy management implementation. The benefit of implementing photovoltaic power on the premises is discussed with an appropriate calculation. The results are compared with the bat algorithm and the ant lion algorithm. MATLAB 2017b is used to program the concept.

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1. INTRODUCTION

Huge demand for energy is inevitable in the future due to industrialization, as discussed in different literature [1], [2]. Better power scheduling algorithms and distributed generation using renewable energy resources are important participants in the future of power system operations [2]. Smart metering in the smart grid operation gets information from both the power generators and the customers for better energy management implementation [3]. Optimal power delivery is assured by optimal usage of smart metering and smart grid setup between the generator and the customer. Power delivery to customers isincentivized when the customers does not use power during peak load condition [4]. The researchers discuss the application of meta-heuristic methods to demand-side management [5], [6]. The Social Spider algorithm is defined in the literature [7]. The loading time for each customer is determined by the customer in order to avoid peak load, which will be penalized by billing more charges to the customer. Communication of the load conditions and the generated power is detailed to the energy management system to decide on the energy bill charges and load shedding. At the same time, power from renewable energy is used by the customer when there is a load scheduling. A tradeoff between user comfort and energy pricing is achieved by calculating the discomfort cost using the Taguchi loss function [8]. This method does not consider the peak-to-average ratio (PAR) reduction during the optimization process. PAR reduction is considered at an optimal level while achieving a tradeoff between cost reduction and delay time [9]. Also, when the trade-off between CO2 emissions and electricity costs is achieved [10].

Higher computational costs have made the method disadvantageous since the real time pricing (RTP) computation causes discomfort to the customers due to data loss [11]. When energy management is carried out using renewable energy sources (RES) and home gateways and smart meters, the PAR is reduced while achieving a tradeoff between cost and bill reduction [12]. PAR reduction is achieved by combining both RTP and inclined block rate (IBR). Both power consumption and electricity costs are reduced in the framework, thereby achieving the tradeoff between payment and user satisfaction [13]. Higher energy cost and user comfort are considered as objectives and solved using the knapsack problem combinedwith the wind-driven optimization (WDO) algorithm [14]. Using the RTP pricing method, the genetic algorithm (GA) reduces energy costs while increasing customer satisfaction [15]. But the standalone pricing scheme introduces a deficiency in user comfort. The researchers uses the tabu search algorithm to optimize the load scheduling tasks [16]–[19]. Energy management can be implemented using the optimization algorithm usually obtained by applying metaheuristic algorithms. Energy conservation implementation in [20] is of utmost importance. A few of the examples that use the metaheuristic algorithm are discussed [9], [21]–[29]. Previous literature in the discussion above has discussed scheduling while keeping user comfort in mind, as well as the incorporation of renewable resources into the grid.This paper attempts to introduce the tradeoff between user comforts and the cost of energy with a PV generator added. Mathematically implementing the work using all the tradeoffs introduced in the formulation of load scheduling, an objective function that minimizes the cost of energy in the textile industry is formulated using the hourly load scheduling paradigm using the social spider algorithm.

2. METHOD

The energy management system for the scheduling optimization of the proposed system is given in Figure 1. It can be seen that the energy management system (EMS) is controlled by the smart meter and switch that is used to connect and disconnect the loads. According to the decision by the distribution companies the switch is used to connect different types of loads to avoid peak load or to introduce incentives to the customers who avoid power usage during peak loading conditions.

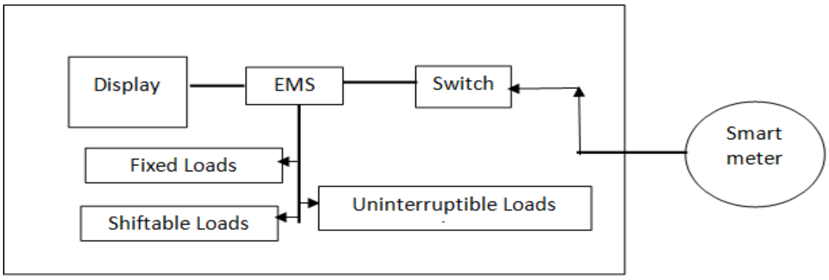


Figure 1. Proposed system

2.1. Load separation

The optimization algorithm involves three categories of loads: fixed, shiftable, and uninterruptible. Different appliances with ratings and categorical details in the textile industry are as given in Table 1 [20]. This paper schedules the equipment in Table 1 to obtain the optimized energy cost. The formulation of the proposed optimization is defined using the set of the (1) to (5).

Three types of loads according to their energy usability are termed fixed, which will work for a fixed period of time, shift-able equipment that uses energy at any time decided by the user, and uninterruptible equipment that works without any interruption for a period of time [24]. The (1) to (3) are used to define the operation of these three types of equipment in the formulation.

2.1.1. Formulation for fixed appliances

The ON state of the equipment is defined as "1" in the scheduling algorithm, while the OFF state is defined as "0." In (1), the ON/OFF state of fixed equipment is denoted as fa(t), where 't' is the time slot (t = 1, 2, ..., 24), and 'a' is the number of appliances or equipment with a total of 'n' appliances or equipment (a= 1, 2, ..., n). The power rating of the 'ath' fixed equipment is denoted by ρfa.

$$U(t) = \sum_{f_a \in F_{ap}} (\sum_{t=1}^{24} \rho f_a \times \gamma f_a(t) \quad (1)$$

The power consumption of the fixed appliances is defined as U(t) and is calculated using (1).

2.1.2. Formulation for shiftable appliances

In (2), the ON/OFF state of shiftable equipment is denoted as γsa(t), where 't' is the time slot (t = 1, 2, ..., 24), and "a" is the number of appliances with a total of "n" appliances or equipment (a= "1, 2, ..., n"). The power rating of the 'ath' shiftable equipment is denoted by ρs_a.

$$V(t) = \sum_{s_a \in s_{ap}} (\sum_{t=1}^{24} \rho s_a \times \gamma s_a(t) \tag{2}$$

The power consumption of shiftable appliances is defined as V(t) and calculated using (2).

2.1.3. Formulation for un-interruptible appliances

In (3), the ON/OFF state of shiftable equipment is denoted as γuia(t), where 't' is the time slot (t = 1, 2, ..., 24). ρui_a is the power rating of the 'ath' uninterruptible equipment.

$$\mathrm{W(t)} = \sum_{\mathrm{ui_a} \in \mathrm{UI_{ap}}} (\sum_{t=1}^{24} \rho \mathrm{ui_a} \times \gamma \mathrm{ui_a(t)}) \tag{3}$$

The power consumption of uninterruptible appliances is defined as W and is calculated using (3). F_{ap}, S_{ap}, and UI_{ap} are the sets of fixed, shiftable, and un-interruptible appliances, respectively.

Table 1. Load type and ratings in the textile industry

	Textile mill's power distribution				
	Description	Installed kW	% of usage/day	Time	Load Type
1	Ring frame	1158.88	47.12	11	Fixed
2	Autoconer	196.35	7.98	2	Fixed
3	Humidification plant	284.3	11.56	3	Fixed
4	Carding	327.6	13.32	3	Fixed
5	Blow room	58.78	2.39	6	Shiftable
6	Drawframe	61	2.48	6	Shiftable
7	Comber	59.23	2.41	6	Shiftable
8	Speed frame	68.32	2.78	7	Shiftable
9	Compressor	93	3.78	9	Shiftable
10	Winder	26.4	1.07	3	uninterruptible
11	Waste collection	45.48	1.85	4	uninterruptible
12	Buffing	7	0.28	1	uninterruptible
13	Lighting	35.15	1.43	3	uninterruptible
14	Sewage plant	7.25	0.29	1	uninterruptible
15	Water pump-hostel	18.7	0.76	2	uninterruptible
16	Admin office, QC, hostel	11.84	0.48	1	uninterruptible

2.2. Energy consumption model

The cumulative power usage of all three categories of appliances is as given in (4).

$$P_T(t) = \sum_{f_a \in F_{ap}} (\sum_{t=1}^{24} \rho f a \times \gamma f_a(t)) + \sum_{s_a \in s_{ap}} (\sum_{t=1}^{24} \rho s_a \times \gamma S_a(t)) + \sum_{ui_a \in UI_{ap}} (\sum_{t=1}^{24} \rho f a \times \gamma f_a(t)) \tag{4}$$

A cost for the total energy usage needs to be found to optimize the cost using the metaheuristic method.

2.3. Energy cost model

The energy cost model for the formulation is given in (5). C_T denotes the total cost of energy for all the equipment consolidated.

$$C_T = \sum_{t=1}^{T} \left(P(t) \times \lambda(t)\right) \tag{5}$$

λ is the variable pricing that varies according to the peak and non-peak hours. Formulated (5) is used as the objective function to be optimised using different optimization algorithms discussed in the following section.

2.4. Solution methods

The optimization of energy cost defined in (5) is dependent on the cost of the equipment that varies according to the time of use by the equipment and the total energy at any point in time. The variation in the energy cost is plotted as shown in Figure 2. The plot shows the cost for peak and non-peak hours that is decided by the Bangalore Electricity Supply Company (BESCOM) in the city of Bengaluru, India. From Table 1, the total number of equipment that needs to be scheduled is 12 for 24 hours. Totally, around 500 combinations of the ON/OFF state that satisfy the timing given in the table are generated. That is, a 3-D matrix of 12x24x500 is generated initially before giving the input to the optimization algorithm. Since the optimization algorithm needs to start from the seed point, it randomly chooses the 2D matrix of 12×24 from among the 500 possible operations to obtain the optimized scheduling operation.

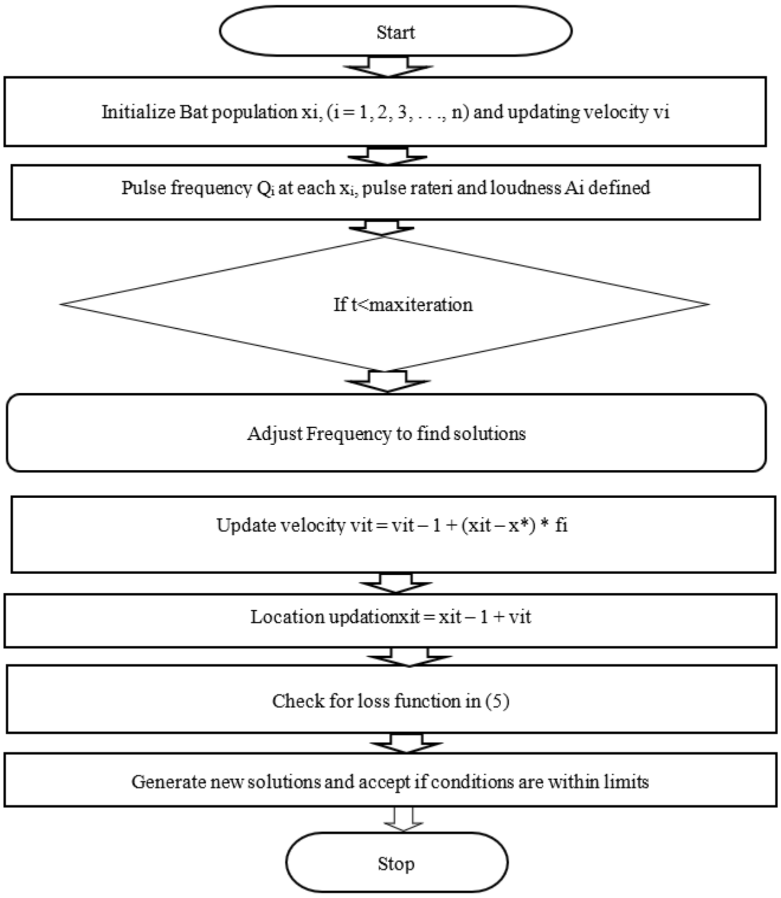


Figure 2. Bat algorithm flowchart

2.4.1. Bat algorithm

The bat algorithm is the mathematical emulation of the echolocation behavior prevalent in bats [25]. The ability of bats to discriminate different types of insects even in complete darkness is converted into a mathematical optimization formulation. Since fixed equipment works at a particular time, the optimization algorithm does not indicate the fixed equipment. Only shiftable and uninterruptible equipment is set up for optimization.

2.4.2. Ant lion optimization (ALO)

Similar to the bat algorithm, the ant lion algorithm is an emulation of the hunting behavior of ant lions [24], [25]. Preying on the ants is the objective of the ant lion algorithm while minimising the energy cost is the objective of the proposed problem. Random walks by the ant lion to prey on the ants are emulated as the iterative increment in the position updating function in the algorithm. Control traps that the ant lion algorithm develops for preying on the ants, and their updating is iteratively emulated to obtain the best preying options in its hunting behavior. Similarly, this behavior is emulated to obtain the best energy cost in the proposed algorithm.

Step1: The population value between 0 & 500 is populated
Step2: Calculate fitness function (cost)
Step3: The population that can find the optimization faster is chosen and named as elite
Step4: While cost reduction not satisfied,

Do for all ant lions, Roulette wheel selection of antlion. Minimum value C and maximum value D is updated in the population using (6) and (7).

$$c^t = \frac{c^t}{I} \quad (6)$$

$$d^t = \frac{d^t}{I} \quad (7)$$

Apply random search and normalize using (8).

$$X(t) = [0, cumsum(2r(t_1) - 1), cumsum(2r(t_2) - 1), .., cumsum(2r(t_n) - 1)]$$
$$X_i^t = \frac{(X_i - a_i)X(d_i - c_i)}{(d_i^t - a_i)} + c_i \quad (8)$$

Ant position is updated using (9).

$$Ant_i = \frac{(R_A^t + R_E^t)}{2} \quad (9)$$

End (for loop).
Cost function calculated for all variables
$Antlion_j^t = Ant_i^t \ if \ C_T(Ant_i^t) > C_T\left(Antlion_j^t\right)$ Replace Antlion using (10).
Update the elite member
End the while
Step5: Display elite

2.4.3. Social spider optimization

The social spider algorithm [26], [27] developed emulates the preying technique of spiders by observing the vibration in the web. Social spiders forage the location of their prey by using vibrations on the web. This process of foraging is emulated as a mathematical model in the simplified swarm optimization (SSO) algorithm. The steps involved in developing the SSO algorithm are as given.

i) Parameter initialization of SSO (population, maximum iteration, random integer (rain range(0, population)), iteration probability (pc in range (0, 1)), vector probability (pm in range (0, 1),).
ii) Fitness function is evaluated for all the initial population as defined in (11) with C_T (Pa) the fitness value. Position of the spider is P_a for ‘a^{th}’ spider. Random number ‘r’ is also generated. For each spider in the population set, repeat from step 4 to 8.

$$I\left(p_{a,}p_a, t\right) = \log\left(\frac{1}{C_T(P_a) - c} + 1\right) \quad (11)$$

$$D(P_a, P_b) = |P_a - P_b| \quad (12)$$

$$I(P_a, P_b, t) = I(P_a, P_a, t) \times \exp\left(-\frac{D(P_a, P_b)}{\sigma \times r_a}\right) \quad (13)$$

iii) The (12) and (13) define the intensity of vibration absorbed by every spider. I (Pa, Pb, t) is the observed vibration by ‘a’ due to the prey ‘b’ at a time ‘t’.
iv) Compare the maximum intensity value and previous value to reset C and if the previous value is larger replace that as the maximum intensity, else increment C. C is the number of iterations.
v) Random number generated ‘r’ is compared with the ‘pc’ value. If ‘r’ is found to be less than or equal to ‘pc’ then go to step 7, else proceed to step 8.
vi) The mask $m_{a,i}$ changes from 0 to 1 or 1 to 0 by comparing ‘r’ with ‘pm’. If ‘r’ is greater, the mask becomes ‘0’ else it will be ‘1’.
vii) Repeat steps 4 to 7 until the termination criterion is satisfied. Position is updated using (14)-(16).

$$P_{a,i}^{fo} = \begin{cases} P_{a,i}^{tar}, m_{a,i} = 0 \\ P_{a,i}^{r}, m_{a,i} = 1 \end{cases}$$
$$r = rand(1, pop) \quad (14)$$

$$P_a(t+1) = P_a + \left(P_a - P_a(t-1)\right) \times r + \left(P_a^{C_T} - P_a\right)R \quad (15)$$

$$P_a(t+1) = \begin{cases} (x_i - P_{a,i}) \times r \; if \; P_a(t+1) > x_i \\ (P_{a,i} - x_i) \times r \; if \; P_a(t+1) \le x_i \end{cases} \quad (16)$$

$P_a(t+1)$ is the particle generated for the next iteration. All three algorithms discussed above in the previous section are used for the implemeting energy management system.

3. RESULTS AND DISCUSSION

The industrial tariff of BESCOM used for energy management systems in the proposed formulation is as given in Table 2. A MATLAB-based simulation is carried out on the proposed formulation of cost optimization. Optimization with and without PV generation in the power system is also discussed. The tariff fixed by the distribution company, BESCOM, in Bengaluru, India is shown in Figure 3 for hourly variation. Power generation from the PV for the period of 24 hours considered for the implementation is as shown in Figure 4. The optimized scheduling obtained from the bat algorithm for the 12 equipments considered for the optimization in the proposed formulation is given in Table 3. The optimised scheduling obtained from the ALO algorithm for the 12 equipments considered for the optimization in the proposed formulation is given in Table 4.

Table 2. Tariff in Karnataka, India

Hours	Tariff
22.00 hrs to 06.00 hrs	(-) 100 paise per unit
06.00 hrs to 10.00 hrs	(+) 100 paise per unit
10.00 hrs to 18.00 hrs	0 paise per unit
18.00 hrs to 22.00 hrs	(+) 100 paise per unit

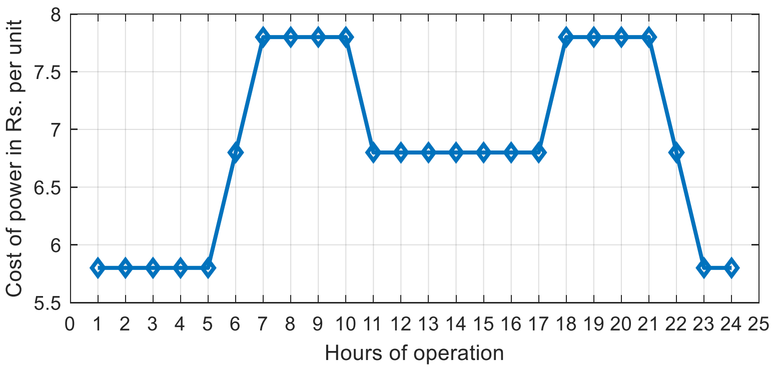


Figure 3. BESCOM electricity tariff

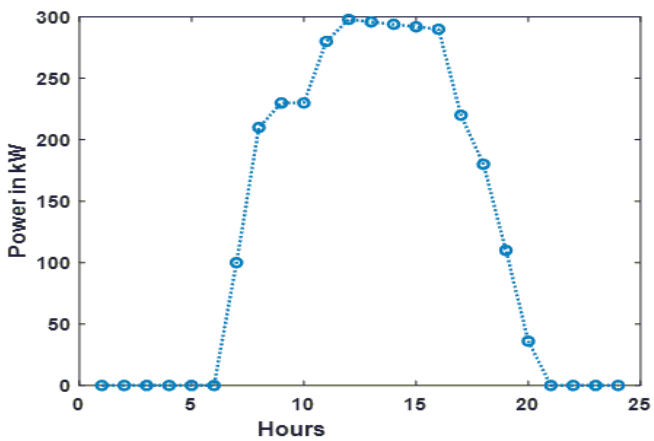


Figure 4. The PV power available in the premises in a day

Table 3. Result of bat for shift-able and un-interruptable load

Hours	Equipment Number											
	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1	0	0	0	1	1	0	0	0	0	0
2	0	1	1	1	0	1	1	1	0	0	0	0
3	0	1	0	1	1	0	1	0	1	0	0	0
4	1	0	0	0	0	0	1	0	1	1	0	0
5	0	0	1	1	1	0	0	0	1	1	0	0
6	1	0	1	0	1	0	0	0	0	0	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	1	0	0	0	0	0	0	0
11	0	0	0	0	1	0	0	0	0	0	0	0
12	0	0	0	0	1	0	0	0	0	0	0	0
13	1	0	1	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	1	0	0	0	0	0	0	0	0
16	0	0	1	0	1	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	1	0	0	0	0	0	0	0	0
19	0	0	0	1	0	0	0	0	0	0	0	0
20	0	1	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	1	0	0	0	0	0	0	0
23	0	1	0	0	1	0	0	0	0	0	0	0
24	0	1	0	1	0	1	0	0	0	0	0	0

Table 4. Schedule of ALO for shift-able and un-interruptable load

Hours	Equipment Number											
	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	1	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	0	0	1	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	0	0	0	0	0
8	1	0	1	1	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	0	0	0	0	0	0
10	1	0	0	1	1	0	0	0	0	0	0	0
11	0	0	0	1	0	0	0	0	0	0	0	0
12	0	0	0	0	1	0	0	0	0	0	0	0
13	0	0	1	0	0	0	0	0	0	0	0	0
14	0	1	0	1	0	1	0	0	0	0	0	0
15	0	0	0	0	0	1	1	0	0	0	0	0
16	0	0	0	0	0	1	1	1	0	0	0	0
17	0	0	0	1	1	0	1	0	1	0	0	0
18	1	1	0	0	0	0	1	0	1	1	0	0
19	0	0	0	1	0	0	0	0	1	0	1	0
20	0	1	1	0	0	0	0	0	0	0	1	1
21	1	0	0	0	1	0	0	0	0	0	0	0
22	1	0	0	0	1	0	0	0	0	0	0	0
23	0	0	1	0	0	0	0	0	0	0	0	0
24	0	0	1	0	0	0	0	0	0	0	0	0

The optimized scheduling obtained from the SSO algorithm for the 12 equipments considered for the optimization in the proposed formulation is given in Table 5. The optimized scheduling obtained from the SSO algorithm for the 12 equipments incorporating the PV generation considered for the optimization in the proposed formulation is as given in Table 6.

Table 5. Schedule of SSO for shift-able and un-interruptable load

Hours	Equipment Number											
	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	0	1	0	1	0	1	0	0	0
2	0	0	1	1	1	0	1	0	1	1	0	0
3	0	0	0	1	1	0	0	0	1	0	1	0
4	0	0	0	0	0	0	0	0	0	0	1	1
5	1	1	1	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	0	0	0	0	0	0
10	0	0	1	0	0	0	0	0	0	0	0	0
11	1	1	0	0	1	0	0	0	0	0	0	0
12	0	0	0	0	1	0	0	0	0	0	0	0
13	0	0	0	1	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0	0	0	0
19	1	1	0	1	1	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	1	0	0	0	0	0	0	0
23	1	1	1	1	1	1	1	0	0	0	0	0
24	0	0	1	1	0	1	1	1	0	0	0	0

Table 6. Schedule of SSO for shift-able and uninterruptable load using PV

Hours	Equipment Number											
	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	0	1	0	1	0	1	0	0	0
2	0	0	1	1	1	0	1	0	1	1	0	0
3	0	0	0	1	1	0	0	0	1	0	1	0
4	0	0	0	0	0	0	0	0	0	0	1	1
5	1	1	1	0	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	1	0	0	0	0	0	0	0	0
10	0	0	1	0	0	0	0	0	0	0	0	0
11	1	1	0	0	1	0	0	0	0	0	0	0
12	0	0	0	0	1	0	0	0	0	0	0	0
13	0	0	0	1	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0	0	0	0
19	1	1	0	1	1	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	1	0	0	0	0	0	0	0
23	1	1	1	1	1	1	1	0	0	0	0	0
24	0	0	1	1	0	1	1	1	0	0	0	0

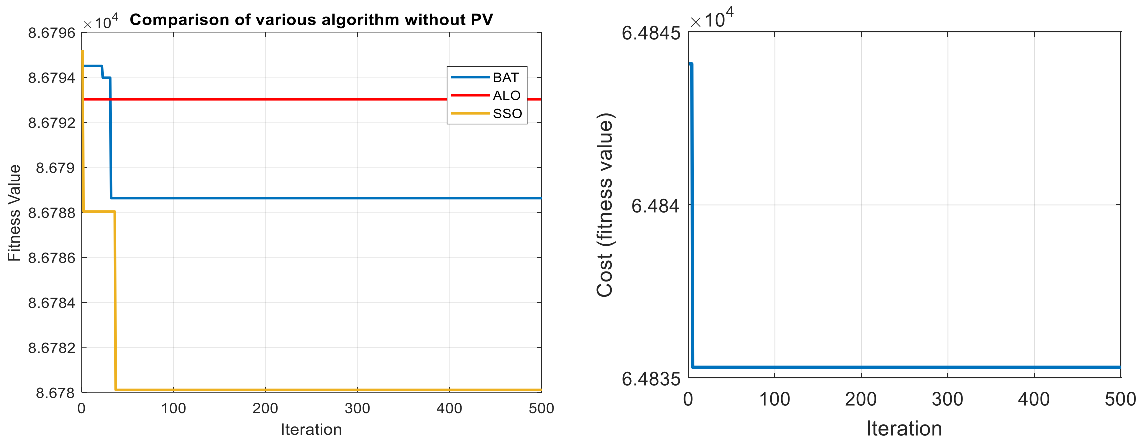
The non-optimal operating schedule of all the appliances is given in Table 7. It can be observed from Table 8 that the cost reduction is found to be better in the SSO algorithm, although it uses more execution time. Also, the cost reduction provides better performance by introducing photovoltaic (PV) generation into the distribution system for the SSO algorithm [28], [29]. The convergence curve of the algorithms is as given in the Figure 5. It's also visible in the convergence graphs of all the algorithms used in cost-optimized energy management systems, as shown in Figures 5(a) and (b). It is evident from the suggested implementation of cost optimization in the energy management system for the textile industry that cost reduction in the textile industry can be achieved by incorporating PV generation into the distribution system. Among the algorithms used, the SSO algorithm fared the best.

Table 7. Schedule of non optimal operation

Hours	Equipment Number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0
18	1	0	1	1	1	1	1	1	1	1	1	0	1	0	0	0
19	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0
20	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0
21	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table 8. Comparative cost of different algorithms

Algorithms	Cost in Rs.	Time in sec
	Without PV	
Non-optimal operation	86884	-
Bat	86789	42.03
ALO	86793	97.37
SSO	86780	103.15
	With PV	
SSO	64835	102.5



(a) (b)

Figure 5. Convergence curve (a) cost comparison of three algorithms without PV and (b) cost curve of SSO with PV

4. CONCLUSION

Energy cost optimization using metaheuristic algorithms has shown better optimization performance by introducing PV generation into the algorithm. Among the meta-heuristic algorithms implemented for the proposed energy management formulation, the SSO algorithm performed better with and without PV power in the distribution system that supplies the textile industry. The proposed tariff, followed by distribution company BESCOM, used in the proposed formulation, gives a better real-time scenario of the energy management system in the textile industry. The MATLAB simulation thus carried out gave satisfactory results for the SSO algorithm with PV generation included in the power system.

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