

Bee Algorithm Optimization for Load Management Based On Load Shifting in the Textile Industry

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Abstract:-This paper proposes an application of bee algorithm (BA) with compare GA and PSO method to develop the load shifting and the same has been tried with the actual load data collected from the textile industry plant. The target of any load management is to maintain a constant level of load. The important benefits of load management are reduction in maximum demand, reduction in power loss, better equipment utilization and saving through reduced maximum demand charges. Load shifting, one of the simplest method of load management, is to reduce customer demand during the peak period by shifting the use of appliances and equipment to partial peak and on-peak periods. The objective is to minimize the total electricity cost. The methodology proposed can be used for determining the optimal response for textile industry under time varying tariffs such as flat rate and time of use (TOU). To show its efficiency, the bee algorithm is applied to solve the case studies in case of single process multi-jobs (SPMJ). The results show that the proposed method is able to achieve the best solution efficiently and easy to implement.

Key-Words: - Load management, Time of used, Bee Algorithm, Textile Industry Optimization

1 Introduction

The textile industry is one of the most convoluted contemporary industries because it is a fragmented and heterogeneous sector dominated by small and medium enterprises (SMEs) [1]. Characterizing the textile manufacturing industry is composite because of the wide variety of substrates, processes, machinery and apparatus used, and finishing steps undertaken. Different types of fibers or yarns, methods of fabric production, and finishing processes (preparation, printing, dyeing, chemical/mechanical finishing, and coating), all correlate in producing a finished fabric. Electrical energy is one of the main cost factors in the textile industry. Especially in times of high energy price

volatility, improving energy efficiency should be a primary concern for textile plants.

There are various energy efficiency opportunities that exist in every textile plant, many of which are cost-effective. However, even cost effective options are not often implemented in textile plants mostly because of limited information on how to implement such energy efficiency measures, especially given the fact that a majority of textile plants are categorized as SMEs and hence they have limited resources to acquire this information. Know how on energy efficiency technologies and practices should, therefore, be

prepared and disseminated to textile plants. An extensive literature review was conducted in this study to collect information on the energy use in and energy efficiency measures/technologies for the textile industry [2]

In recent years, various load management (LM) programs are used by electric utilities to tackle the peak load problem [3]. LM is the strategies, reported with potential reduction in system peak demand with different LM[4]. Many the utility, have the reduction in peak demand improves the utilization of base load generating stations and avoids costly peaking stations and other device in their service area [5]. The customer benefits, as there is reduction in the energy cost bill. To promote LM, utilities offer incentives like time of use (TOU) rates [6]. The textile plants being the bulk consumers, the contact of LM action like load scheduling under TOU tariff on peak demand reduction is high. The textile industries can also control their energy costs by optimal load schedule under TOU tariff [7]. The production-scheduling problem in textile manufacturing, as a multi-stage job shop scheduling problem, is also reported [8]. Most of the models for textiles are centered on process scheduling to achieve the targeted production subject to production constraints and do not give the impact on peak electricity-demand reduction. The optimal schedule to reduce the peak utility load is reported for production processes considering cost worker and process constraints. Extending this work, a production process model coupled with an optimization formulation for process industries with jobs and continuous type loads is presented here to prescribe optimal load-schedule strategies under different tariff structures.

The industries can also control their electricity costs by optimal load schedule under TOU tariff. Load shifting (LS) is a basic method for adapting load curves so as to reduce marginal costs of electric power supply. Load shifting within textile industry is based on their inhabitant behavior and in their equipment. Thus, we have to account for both [9] the practice of managing electricity supply and demand so that peak energy use is shifted to off-peak periods. Properly done, load shifting helps meet the goals of improving energy efficiency and reducing emissions by smoothing the daily peaks and valleys of energy use and optimizing existing generation assets. Load shifting may be

accomplished in several ways. Demand response programmers shift load by controlling the function of machine production, water heaters, heat pumps, and similar electric loads at maximum demand times.

The goal of this paper is to develop the BA algorithm for solving the load shifting problem. Three types of load management problems are used to evaluate the effect of BA. The load scheduling problem consisting of small jobs, medium jobs and large jobs which considers the applied to determine the start time of the process in order to minimize the total electricity cost under varying tariffs such as flat rate and time of use [11] To show its efficiency, the case studies in case of single process multiple jobs (SPMJ) are studied. The results optimized by the proposed BA are compared to those obtained by the conventional approaches, i.e. GA and PSO in terms of solution quality and computational efficiency.

2 Problem Formulation

2.1 Textile Process

Fig. 1 is a generalized flow diagram depicting the various textile processes that are involved in converting raw materials in to a finished product. All of these processes do not occur at a single facility, although there are some vertically integrated plants that have several steps of the process all in one plant. There are also several niche areas and specialized products that have developed in the textile industry which may entail the use of special processing steps that are not shown in Fig. 1.

- Spun yarn spinning
- Weaving
- Wet-processing (preparation, dyeing, printing, and finishing)
- Man-made fibre production

2.2 Type of Energy Used in Textile Industry

In general, energy in the textile industry is mostly used in the forms of electricity, as a common power source for machinery, cooling and temperature control systems, lighting, office equipment, etc.; oil as a fuel for boilers which generate steam; liquefied petroleum gas; coal; and city gas. The rational use of energy calls for a broad application of energy conservation technologies in the various industrial

sectors where energy is wasted. One of these energy intensive industrial sectors to be considered to improve efficiency through the introduction of modern energy conservation technologies is the textile industry. In the textile industry, appreciable amounts of energy could be saved or conserved by regulating the temperature in the steam pipes, adjusting the air/fuel ratio in the boilers, and installing heat exchangers using warm waste water.

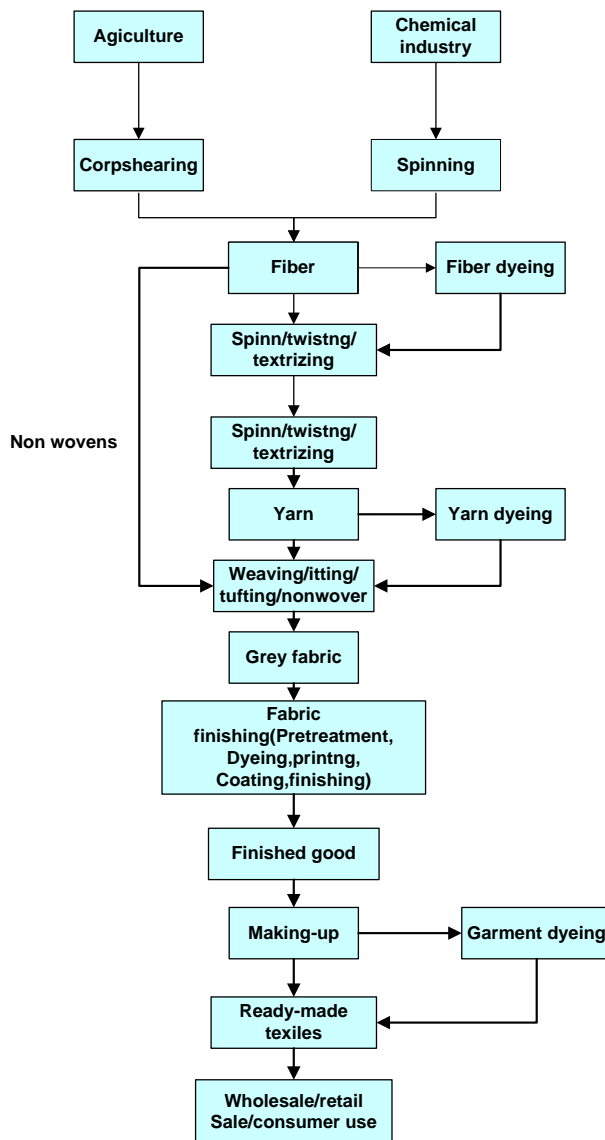


Fig. 1 Textile Process[7]

2.3 Load Pattern and Electrical Tariffs in Thailand

Domestic consumption in 1991 could be divided into three periods of time, i.e. during the evening time hours of 6:30 to 9:30 pm when the power consumption was highest (peak period), during the daytime hours of 8:00 am to 6:30 pm when the consumption was moderate (partial-peak period), and during the night-time and early morning hours of 9:30 pm to 8:00 am when the consumption was low (off-peak period). During the peak period, the Electricity Generating Authority of Thailand (EGAT) had to use its full generation capacity until the minimum reserve margin was reached, the Provincial Electricity Authority (PEA) had to use its full dispatching capacity in the same period, whereas the Metropolitan Electricity Authority (MEA) had to maximize its dispatching capacity in the afternoon when the consumption nationwide was at moderate level. Therefore, if the demand had increased during the peak period, the power sector would have been required to increase the investment in power generation and distribution. Both from an energy efficiency perspective and from equity of rates perspectives, large consumers during the peak period should pay a higher tariff than small consumers during the off-peak period of the system. One way to determine a fair tariff was to use a formula to automatically adjust the electricity charges in different periods of a day, i.e., implement a Time-of-Day (TOD) Rate. However, this method could not be applied to all individual consumers because the expense for meter installation was rather high.

2.3.1 The TOD Rate or Flat rate

The TOD Rate is the electricity tariff rate that varies with the time-period during which electricity has been used during the day. Its objective is to shift consumption from the peak to off-peak periods. The TOD Rate was first used in Thailand in 1964 as an alternative rate applied to the industrial sector. In 1966 it became one of the alternative rates for customers that were served directly by EGAT. In practice, only a few customers opted into this rate.

2.3.2 Time-of-Use (TOU) Rate

The Time-of-Use Rate (TOU) was established as an alternative for users who currently use the TOD rate so that the tariff structure would reflect the costs and load curve of the system. As of September

1998, 167 customers were on TOU rates, of which 11 were in MEA and 156 in PEA. The TOU rate differs from the TOD rate in the following: TOU will increase tariff categories for consumers whose consumption is at or greater than 115 kV, the tariff will be lower than that of the previous 69 kV. TOU will be divided into two periods of time, i.e. peak, from 9 am to 10 pm on Mondays through Saturdays and off-peak during all other hours. Under the TOU rate, the energy charge varies according to voltage levels and periods of time. Under the TOU rate, there is no demand charge during the Off-Peak period. The newly established TOU rate will be compulsory for new consumers who have to use the TOD rate. The TOU rate best reflects actual costs

of the current power system. This will provide more incentives for consumers to change their consumption behaviour, whereas those whose consumption is consistent and who do not change their consumption behaviour will not be harmed. The research for electrical tariff to major industrial sector may consist of a charge for the total kWh consumed, a power factor charge and a KW maximum demand charge. The costs of the total electrical energy before shifting and after shifting are calculated with the TOU tariff rate applying by the MEA rated voltage is 24 kV connected grid. The tariff for the industrial sector is TOD rate or flat rate as shown Table 1 and TOU rate shown in Table 2.

Table 1. The Time-of-Day (TOD) Rate in Thailand

Time of Day Rate (Tariff)		Demand Charge (Baht / kW)			Energy Charge (Baht /kWh)
		1*	2*	3*	
1	69 kV. and over	224.30	29.91	0	1.6660
2	12 – 24 kV.	285.05	58.88	0	1.7034
3	Below 12 kV.	332.71	68.22	0	1.7314

Flat rates or Time-of-Day (TOD Tariff): Demand charge: 1.7034 Bath /kWh or (0.052 \$/kWh),
Energy charge: 58.88 Bath/kWh or (1.84 \$/kWh), (Note: present transaction rate 1 US\$:bath. 32.0)

1* On Peak: Everyday from 06.30 PM to 09.30 PM

2* Partial Peak: Everyday from 08.00 AM to 06.30 PM (only the amount of maximum demand that is out of the On -Peak period will be charged at this rate)

3* Off Peak: Everyday from 09.30 PM to 08.00 AM (No demand charge)

Table 2. Time of use tariff (TOU tariff)

Time of Use (Tariff)		Demand Charge (Baht /kW)	Energy Charge (Baht / kWh)		Service Charge (Baht/month)
			1*	2*	
1	69 kV and over	74.14	2.6136	1.1726	228.17
2	12 - 24 kV.	132.93	2.6950	1.1914	228.17
3	Below 12 kV.	210.00	2.8408	1.2246	228.17

Time of use tariff (TOU tariff), Demand Charge: 132.93 Bath/kW or (4.15 \$kWh), Energy Charge: 1.1914 Bath/kWh or (0.037 \$/kWh), On Peak: Monday – Friday from 09.00 AM to 10.00 PM off Peak: Monday – Friday from 10.00 PM to 09.00 AM, Saturday – Sunday and normal public holiday (excluding substitution holiday) from 00.00 AM to 12.00 PM.

1* On Peak: Monday – Friday from 09.00 AM to 10.00 PM, 2*Off Peak: Monday – Friday from 10.00 PM to 09.00 AM Saturday – Sunday and normal public holiday (excluding substitution holiday) from 00.00 AM to 12.00 PM.

2.3 Load Shifting Problem Formulation.

In this section, the load management based on load shifting for the textile process is presented. The problem can explain in 3 parts; systematic model, feasible solution structure, fitness function.

2.3.1 Systematic model

2.3.1.1 Input parameter: The input parameters consist of the step of textile production process, process and transfer time, number of machine and man power of each step, rated power each of machines. The input varies depending on the of production process type.

2.3.1.2 Decision variables: The starting time of each job are assigned to decision variable .This variable will be used to determine the time schedule to minimize total energy cost.

2.3.1.3 Production constraints: Normally, the textile industries have the specific machine and man power .The process cannot operate if the machine and man power are not available. Therefore, the constraints of time dispatching are limited by the machines and manpower of industry.

2.3.1.4 System output: The objective of load shifting scheduling is to minimize the total energy cost of process time schedule.

2.3.2 Feasible solution structure

In this paper, the structure of an solution for load shifting problem is composed of a set of starting time number each job .Therefore, size of solution is $1 \times n$ matrix where n is number of jobs. Note that it is very important to create a set of solution satisfying the constraints. It is called a feasible solution.

The feasible solution of candidate solution is related to the of possible jobs, which can be found by

$$FS = T^n \quad (1)$$

where FS is number of feasible solution, T is number of time periods.

2.3.3 Fitness function

In order to evaluate fitness function of load shifting problem, firstly define indices, parameters and decision variables as follows.

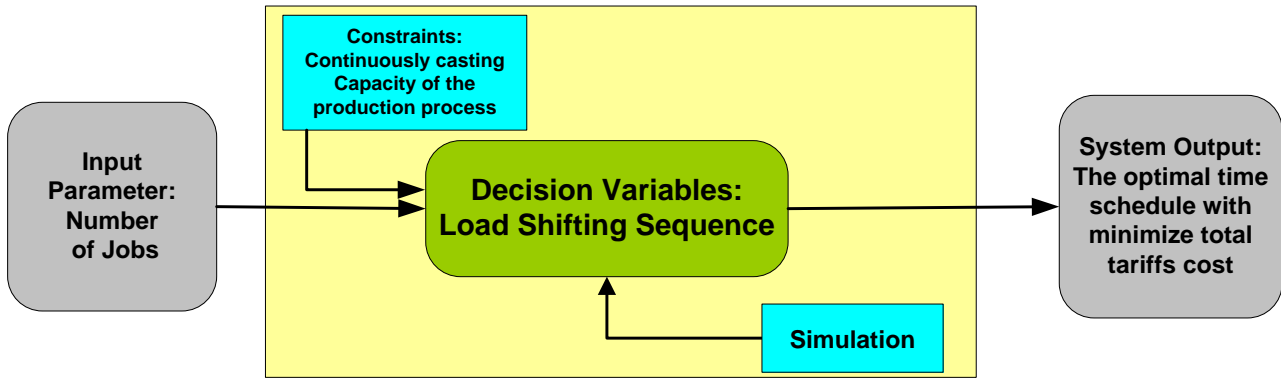


Fig. 2 Systematic model of load shifting problem

Indices

- i : Index of job $i, j \in \{1, n\}$
- j : Index of the production process, $j \in 1, m\}$
- t : Index of load shifting time schedule from job i to production process $j, t \in \{1, n\}$

Variables

- m : Number machine of production process.
- n : Number of job.
- PT_j : Process time of production process j
- NM_j : Number of machines of production process j
- NE_j : Number of manpower of production process j
- TT_j : Transfer time of production process j
- MP_j : Rated power machine of production process j
- ST_j : Start time of job i
- ST_{j-1} : Stop time of job _{$j-1$}

- $Start_time_{ij}$: Start time of job i and process j
- $Stop_time_{ij}$: stop time of job i and process j
- T : Time interval
- R_T : Tariffs cost rate of time interval

The $Start_time_{ij}$ of m_n machines are set as:

$$Start_time_{ij} = \begin{cases} ST_i & j = 1 \\ Stoptime_{ij-1} + TT_j & j = 2 \dots m \\ & i = 1 \dots n \\ & j = 2 \dots m \end{cases} \quad (2)$$

The $Stop_time_{ij}$ of m_n machines are set as:

$$Stop_time_{ij} = Start_time_{ij} + PT_j \quad (3)$$

Total energy consumption of machines is obtained by summing the energy consumptions of all machines operating in the textile manufacturer. Certain machines processes have the feature of having multiple duty cycles. These machines have the capability to operate for different levels of power consumption. Energy consumption of given equipment for a particular period of time can be stated as:

$$E_{NMj} = P_{NMj} \times T \times R_T \quad (4)$$

where E_{NM_j} is the energy consumption of the NM_{ij} machines P_{NM_j} is its power consumption at T time interval is the time at which the NM_j machines are set operational. The cost of electricity consumption of given equipment is dependent on various factors including locality, watts, time of consumption and the cost-rate (peak versus non-peak hour) for that particular time of the day.

The procedure of fitness function is given as follow. The information data for load shifting management problem is shown in Table 3. Here, the production process has 10 processes for plant textile in Thailand. This information will be used to

convert a feasible solution or sequence to a time schedule for reduces energy power consumption.

Step 1: Determine starting time and stop time of job i and process j . The step to find starting time of job i start with the computing equation (2) and to find stop time as equation (3)

Step 2: Determine time interval of each process and evaluate rate of tariff based on Tariff of use.

Step 3: Evaluate tariff cost by equation (4) and energy cost of process at time interval.

Table 3.The dyeing machines of production process for 10 processes

No	Process	Process time (min)	No. Machine plant	Transfer time(min)	Machine kW/No.
1	Fabrics Prepare	75	2	15	84
2	Dyeing , Thies	60	3	10	105
3	Preset	100	4	15	123
4	Fabric Prepare	90	2	10	94
5	Dyeing	150	4	20	117
6	Ring Spinning	130	2	10	100
7	Rewinding	60	2	15	94
8	Heat setting	100	4	20	134
9	Inspection	60	3	10	78
10	Packing	95	4	15	85

(Table 3 shown the textile process in Thailand)

2.3.4 Case Study

To illustrate the model proposed, a case study has been worked out for a typical the dyeing machines of production process for 10 steps of textile matrix $4 \times 10 =$

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$

checked condition , If the total status of machine job i and process the column shown status is $1 \geq 1$,status is available ,but the total status of machine

job i and process $i_s = 0$, defined the machine cannot operated.

Step 1: determine starting time and stop time of job i and process j . The step to find starting time of job i start with the computing equation

$$Start_time_{ij} = \begin{cases} ST_i & j = 1 \\ Stoptime_{ij-1} + TT_j & j = 2 \dots m \end{cases} \quad \begin{matrix} i = 1 \dots n \\ j = 2 \dots m \end{matrix} \quad (5)$$

Step 2: Determine time interval of each process and evaluate rate of tariff based on Tariff of use. The results are shown in Fig. 3.

Step 3: Evaluate tariff cost by equation (4) and energy cost of process at interval time. The results of this step 3 are shown in Table 4.

Time Scheduled of jobs 1, 2, 3 after load shifting technique are shown in Table 5 and the result of energy cost power consumptions load-shifting technique for case study are shown in Table 6.

If process can not available to find stop time as equation, minimize

$$\{Stop_time_{ki}\}, i = 1 \dots n, k \neq i$$

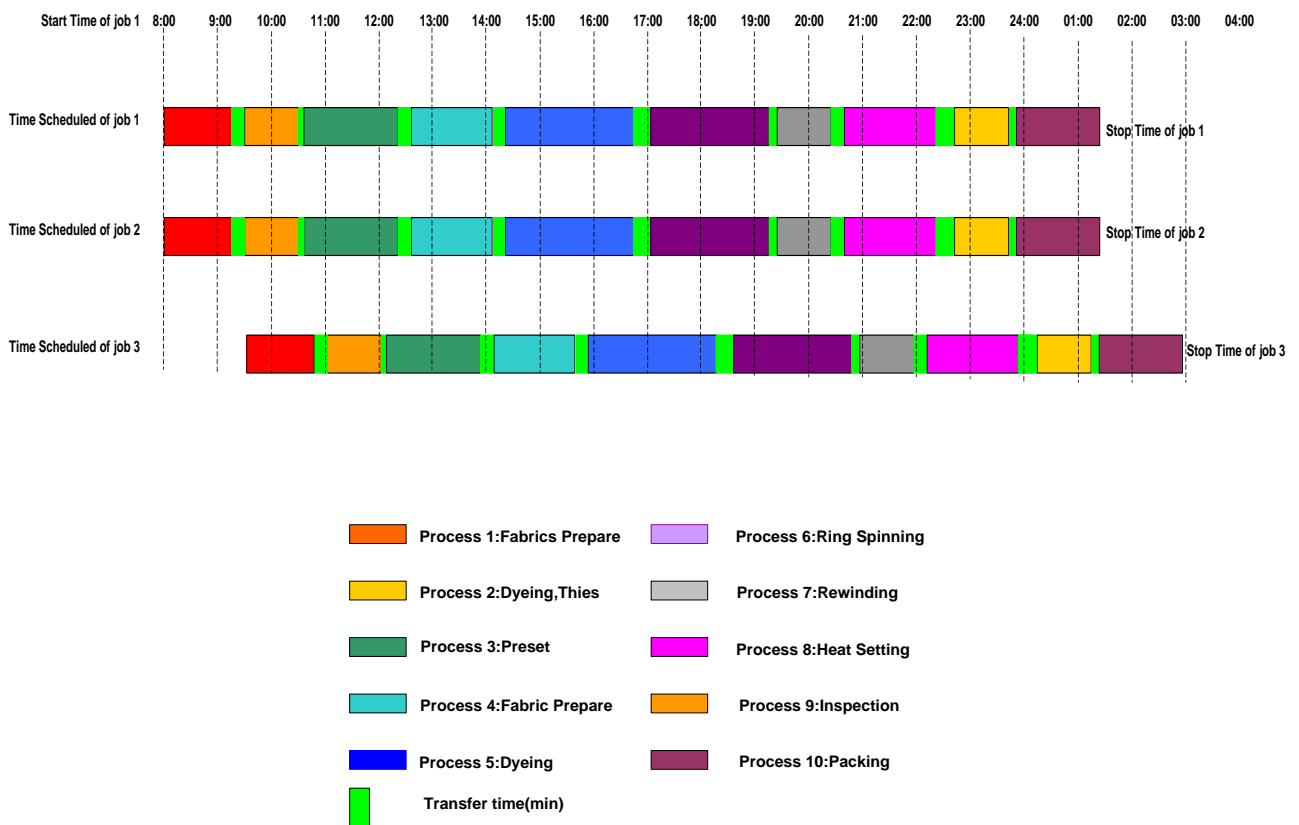


Fig.3 Time Scheduled Diagram of jobs 1, 2, 3 for load shifting technique

Note: All colures are remark each of production processes.

Table 4. The Result of energy cost power consumptions load-shifting technique for case study

Job& process	1	2	3	4	5	6	7	8	9	10	Total energy cost (Baht)
Job#1	155.6762	282.9750	552.4750	379.9950	788.2875	583.9167	253.3300	534.7225	92.9292	160.3426	3785.6
Job#2	155.6762	282.9750	552.4750	379.9950	788.2875	583.9167	253.3300	534.7225	92.9292	160.3426	3785.6
Job#3	282.9750	282.9750	552.4750	379.9950	788.2875	583.9167	147.3262	266.0793	92.9292	160.3426	3537.3
Total energy cost (Baht)											11109.5

Table 5. Time Scheduled of jobs 1, 2, 3 after load shifting technique

Job process	1	2	3	4	5	6	7	8	9	10
Job#1										
Start time	16:00	17:30	18:40	20:35	22:15	01:05	03:25	04:40	06:40	07:50
Stop time	17:15	18:30	20:20	22:05	00:45	03:15	04:25	06:20	07:40	09:25
Job#2										
Start time	17:00	18:30	19:40	21:35	23:15	02:05	04:25	05:40	07:40	08:50
Stop time	18:15	19:30	21:20	23:05	01:45	04:15	05:25	07:20	08:40	10:25
Job#3										
Start time	23:00	00:30	01:40	22:15	23:55	02:45	05:05	06:20	08:20	09:30
Stop time	10:45	12:00	03:20	23:45	02:25	04:55	06:50	08:00	09:20	11:05

Table 6. The Result of energy cost power consumptions load-shifting technique for case study

Job&process	1	2	3	4	5	6	7	8	9	10	Total energy cost (Bath)
Job1	282.9750	282.9750	552.4750	368.2168	348.4845	258.1367	111.9916	266.0973	92.9292	281.1078	2,845.4
Job2	282.9750	282.9750	552.4750	368.2168	348.4845	258.1367	111.9916	266.0973	92.9292	408.9138	2,831.8
Job3	125.0970	125.0970	244.2370	167.9874	348.4845	258.1367	111.9916	266.0973	193.9756	362.7021	2,203.8

Total energy cost (Bath)												7,811.0
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3 Bee Algorithm Optimization

Bee Algorithm Optimization (BA) [12] algorithm was proposed by Karaboga for optimizing numerical problems in 2005. The algorithm mimics the food foraging behaviours of swarms of bees algorithm use several mechanisms like waggle dance to optimally locate food sources and to search new ones. This makes them a good candidate for developing new intelligent search algorithms. It is a very simple,

robust and population based stochastic optimization algorithm. In BA algorithm, the colony of artificial bees contains two groups of bees are scout and employed bees. The scout bees have the responsibility is to find a new food source. The responsibility of employed bees is to determine a food source within the neighbourhoods of the food source in their memory and share their information with other bees within the hive.

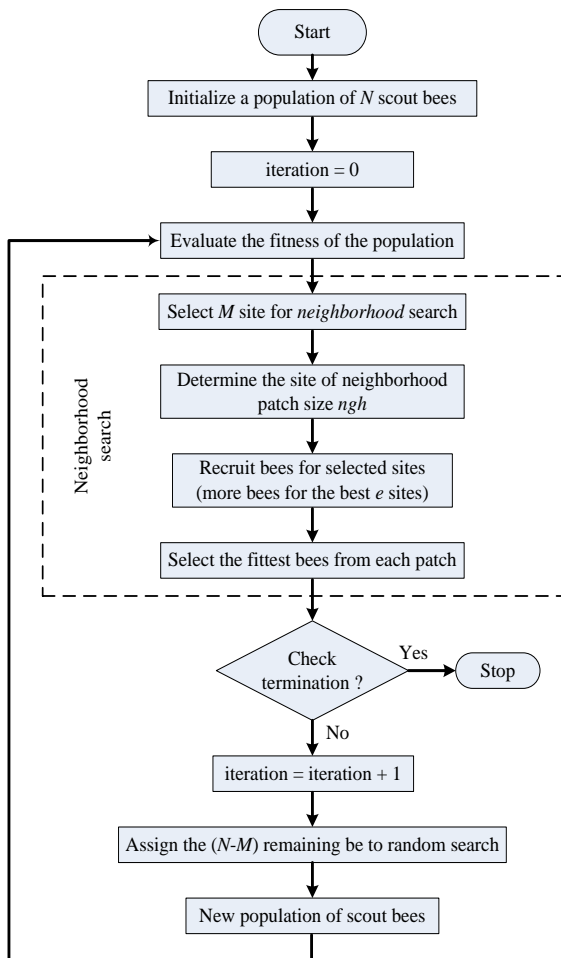


Fig.4 Flowchart of BA algorithm

The procedure of the BA algorithm is given as below:

Step 1: Generate randomly the initial populations of n scout bees. These initial populations must be feasible candidate solutions that satisfy the constraints. Set $NC=0$.

Step 2: Evaluate the fitness value of the initial populations.

Step 3: Select m best sites for neighbourhood search.

Step 4: Separated the m best sites to two groups, the first group has e best sites and another group has $m-e$ best sites.

Step 5: Determine the size of neighbour search of each best size (patch size, ngh).

Step 6: Recruit bees for selected sites (more bees for the best e sites).

Step 7: Select the fittest bees from each patch.

Step 8: Check the stopping criterion. If satisfied, terminate the search, else $NC=NC+1$.

Step 9: Assign the $n-m$ remaining bees to random search.

Step 10: New population of scout bees. Go to Step 2.

where NC is number of iteration, n is number of scout bees, m is number of the best selected sites, e is number of the best site, ngh is neighbour size.

4 Experiment and Results

To assess the feasibility solution of the swarm intelligence techniques i.e. GA, PSO and BA, three take load sizes problems (small, medium and large problems) are applied. All optimization methods (GA, PSO, and BA) were implemented in MATLAB[®] package and the simulation cases done on a Intel Core i5-430M, 2.26GHz laptop computer with 4 GB RAM under Windows 8. Each studied systems was run 30 times with differential random initial solutions. In order to evaluate the performance of each technique, the best, worst, average, and standard deviation of the generation costs and the average of computational time to get near optimum solution are used for evaluation. Unfortunately, the number of initial solutions and the computational time for an iteration of these techniques are different. Therefore, the execution of search was done by the same iterations. This method is not suitable for comparison. Consequently; this work uses the time limit as the stopping criterion. The search processes of all techniques are executed by the same time period; therefore, the maximum iteration of each technique depends on the time limit. When the search satisfies the stopping criterion, the best, worst, average, and standard deviation of the generation costs and the average of computational time to get near optimum solution are reported.

4.1 Case study

There are 3, 7 and 10 jobs of dyeing production process of a textile industry. These processes consist of 10 processes as shown in Table 3. That needs to

find the starting time of each job. So, the number of the feasible solutions is 1.3824×10^4 , 4.5865×10^9 and 6.3403×10^{13} respectively.

4.1.1 Simulation Result

After performed 30 trials, the best solutions of three methods are given in Tables 7, 8, 9. The results of the BA method in comparison with those of GA and PSO in terms of maximum, average, minimum generation cost, the standard deviation (SD), and average computational time are provided in Table 7, 8, 9. Clearly, the BA method has always better solutions than other methods.

4.2 Comparison of Three Methods

4.2.1 Solution quality

For three size are 3 jobs of production cost process system, the best solutions of three methods are given in Tables 7,8,9 after performed 30 trials. Table 7 shown the GA, PSO and BA method get max cost, average cost and min cost is 7,836.41 baht. The percent get optimal is 100 and CPU time the BA fast more than PSO and GA. Table 8 shown the PSO, GA and BA method get max cost 18,950.20, 18,192.50, 18,066.20 average cost 18,321.20, 18,078.70, 18,066.20 and min cost is 18,066.20 baht. The percent get optimal is 33.33%, 90.00%, 100 % and CPU time the BA express more than PSO and GA. Table 9 shown the PSO, GA and BA method get max cost 27,962.90, 26,717.00, 26,232.40 average cost 27,027.30, 26,268.00, 26,232.40 and the min cost of BA is 25,912.50 baht. The percent get optimal is 33.33%, 90.00%, 100 % and CPU time the BA express more than PSO and GA

The results of the BA method are compared with those obtained by GA, and PSO in terms of maximum, average, minimum tariffs cost, the standard deviation, and average computational time, as provided in Table 7, 8, 9. Obviously, all methods have succeeded in finding the near optimum solution presented in with a high probability of satisfying the equality and inequality constraints. In order to demonstrate the efficiency of the BA method, the distribution outlines of the best solution of each trial are considered. Fig. 5, 6, 7 shows the distribution outlines of the best solution of each trial in case of 3, 7 and 10 number of jobs. Almost all tariffs costs obtained by the BA method are lower.

This verifies that the BA method has better quality of solution.

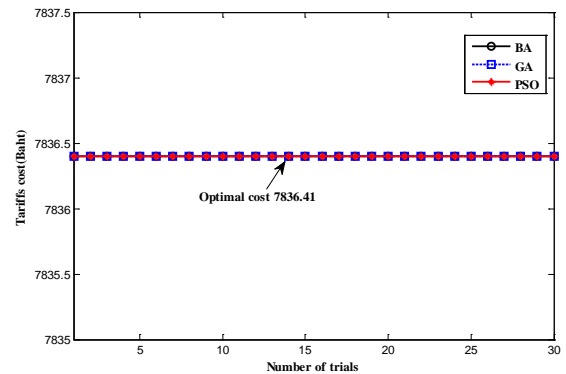


Fig. 5 Distribution of tariffs cost of three methods of 3 jobs for 10 processes of production process system

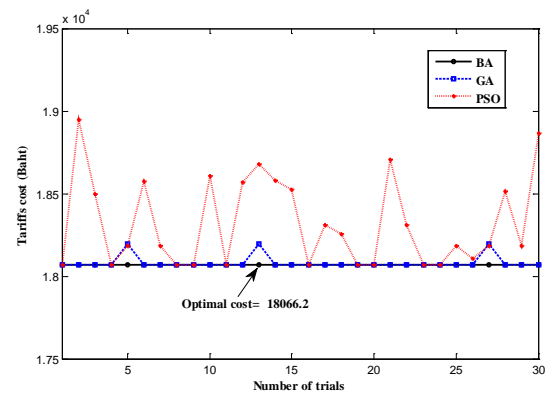


Fig. 6 Distribution of tariffs cost of three methods of 7 jobs for 10 processes of production process system

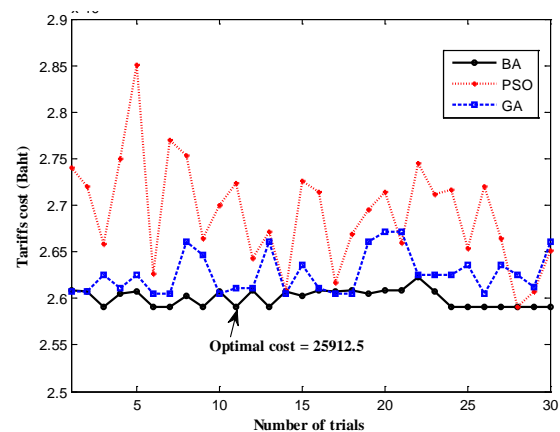


Fig. 7 Distribution of tariffs cost of three methods of 10 jobs for 10 processes of production process system

4.2.2) Computation efficiency

The convergence characteristics of the BA compared with other methods for three case studies are shown in Fig. 8, 9, and 10. Clearly, the BA converges to the optimum solution much faster than other methods. Furthermore, the comparisons of computation time of three methods for three studies system are already given in Table 8, 9 and 10. The BA methods has better quality of solution. For the Table 10 are result after load shifting 3,7,10 jobs comparative flat rate for 3, jobs more than 3jobs TOU tariffs cost 29.306%;7jobs saving is 25.120 % and 10 jobs to be saving 21.57%. Fig. 5, 6 and 7 shows the distribution outlines of the best solution of each trial in case of 3,7,10 jobs for production process 10 processes.

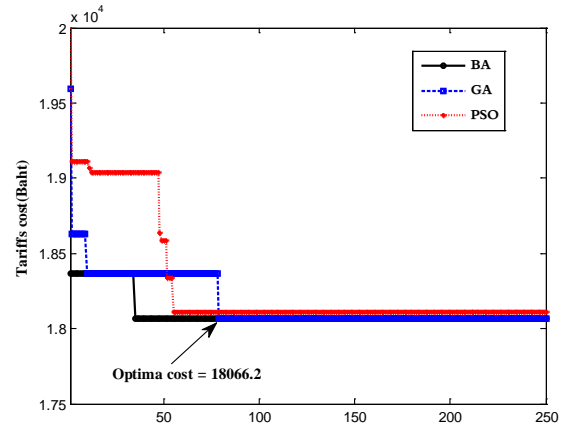


Fig. 9 Convergence curve three methods of 7 jobs for 10 processes of production process system

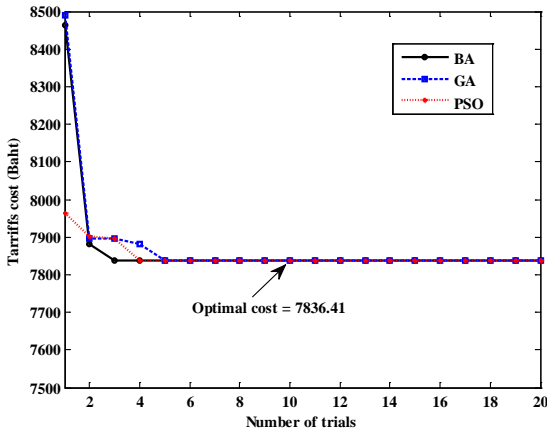


Fig. 8 Convergence curve three methods of 3 jobs for 10 processes of production process system

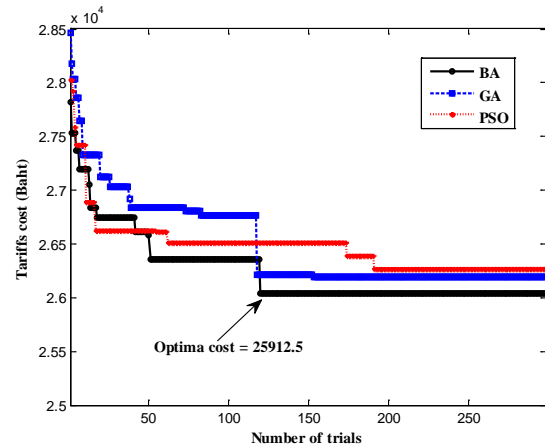


Fig. 10 Convergence curve three methods of 10 jobs for 10 processes of production process system

Table 7. Best results obtained 10 processes for small jobs (3 jobs) production process system using GA, PSO, and BA

Methods	Max cost (Baht)	Average cost (Baht)	Min cost (Bath)	SD (Standard Deviation)	CPU time (sec)	%Get optimum
GA	7,836.41	7,836.41	7,836.41	0.000000000027751	1.892	100
PSO	7,836.41	7,836.41	7,836.41	0.000000000027751	1.382	100
BA	7,836.41	7,836.41	7,836.41	0.000000000027751	1.069	100

Table 8. Best results obtained 10 processes for medium jobs(7jobs) production process system using GA, PSO, and BA

Methods	Max cost (Baht)	Average cost(Baht)	Min cost(Baht)	SD (Standard Deviation)	CPU time (sec)	%Get optimum
PSO	18,950.20	18,321.20	18,066.20	272.30	96.666	33.33
GA	18,192.50	18,078.70	18,066.20	0.00213168	26.922	90.00
BA	18,066.20	18,066.20	18,066.20	0.0000000000074003	10.8348	100

Table 9. Best results obtained 10 processes for large jobs(10 jobs) production process system using GA, PSO, and BA

Methods	Max cost (Baht)	Average cost(Baht)	Min cost(Baht)	SD (Standard Deviation)	CPU time (sec)	%Get optimum
PSO	27,962.90	27,027.30	26379.00	568.84	121.34	0
GA	26,717.00	26,268.00	26,054.00	0.00856645	302	0
BA	26,232.40	26,035.10	25,912.50	0.003246387	78.50	43.33

Table 10. The Result for 3, 7 and 10 jobs of load-shifting technique for case study

Job& process	Flat rate cost (Baht)	After shifting with TOU tariffs cost(Baht)	% Saving
3jobs	11,085	7,836.41	29.306
7jobs	24,127	18,066.20	25.120
10jobs	33,040	25,912.50	21.57

5 Conclusion

In this paper, the BA algorithm has been proposed to solve the LS problem by taking the three size problem (small, medium and large scale) and load shifting effects into the case studies in case of single process multiple jobs (SPMJ) to minimize the total electricity cost under varying tariffs such as flat rate and time of use (TOU) consideration. The consequence jobs of load-shifting technique for 3, 7, and 10 jobs saving 29.306%, 25.120% and 21.57% with compare flat rate tariffs. Numerical testing and

a comparative analysis show that the proposed BA algorithm outperforms computed time for other methods and i.e. GA, and PSO in terms of high-quality solution, stable convergence characteristic and good computation efficiency.

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