Customer Profiling-based Optimal Load Shaving Solution Using Evolutionary Programming Technique

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Abstract- This paper presents optimal load clipping and shifting using Evolutionary Programming (EP) technique. The problem formulation is based on the basic load clipping and load shifting knowledge. This process is conducted using the data provide by Malaysian Energy Commission (EC). The study considers several load categories namely the industrial, commercial and domestic loads. Results obtained from the study are beneficial for the basic understanding of load clipping and load shifting knowledge for the society. Evolutionary Programming technique is used to solve the optimization model of load shaving. MATLAB software is needed to put into practice the actual operation of the optimization process to provide the recommended decision, thus, avoiding system peak hour shortage problem in the future.

Index Terms – Evolutionary Programming (E.P), load clipping, mutation, load shedding, load shifting, customer load profiling, load shaving optimization.

I. INTRODUCTION

Load clipping and load shifting is an important issue in power system load profiling management. This is important because its implementation can avoid the system network from the urgency to undergo load shedding leading to power blackout [1]. This requires an optimization process. There are numerous techniques which can be utilized for optimizing the load clipping and load shifting studies. Among the popular techniques are Generic Algorithm (GA), Particle Swarm Optimization (PSO), Bacterial Foraging Algorithm (BFA), Ant Colony Optimization (ACO), and Evolutionary Programming (EP) [2-4].

This paper presents Customer Profiling – based Optimal Load Shaving Solution Using Evolutionary Programming Technique. The study involved the development of optimization engine for Evolutionary Programming (EP) in order to optimize the amount for load clipping and load shifting. The load clipping only involves during the peak hours; while load shifting involves all load during the day [5]. The study considers minimization and maximization for both load clipping and load shifting. Data are provided from the Energy Commission (EC) which represents the Peninsular Malaysia load profiling. Result recorded that it is beneficial for Malaysian society.

II. EVOLUTIONARY PROGRAMMING (EP)

Evolutionary programming is based on Finite State Machine (FSM) model in its early stage, which is proposed by L. J. Fogel in 1960's when he studied the artificial intelligence. In this early model, the state of the machine is mutated by evenly distributing rules [6]. Evolutionary programming has been popular and utilized along with achievement throughout fixing quite a few kinds of optimization problem [7]. EP algorithm which is referred to the nature selection law to simulating the biologic evolution process is widely used in the aspects of real continuous function optimization, neural network structure optimization design, and pattern recognition and system identification [8].

The conventional EP technique also known as the classical EP which consist of four main section namely initialization, mutation, combination and selection. Fig. 1 below, shows the evolutionary programming (EP) flowchart for single objective optimization.

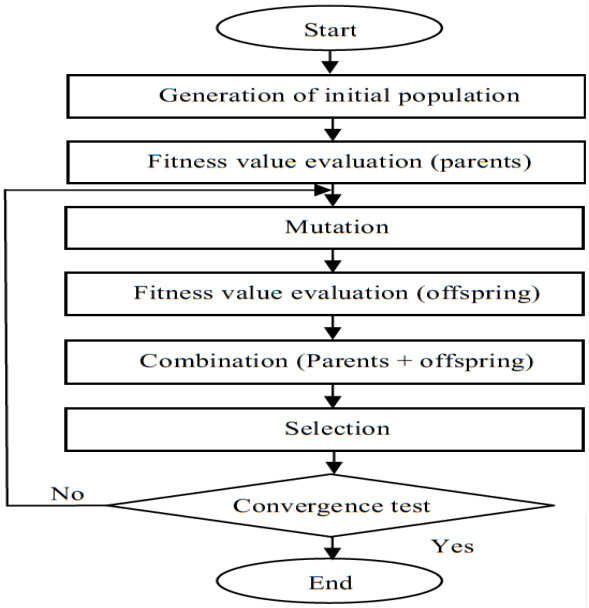

Fig.1: Flow chart of EP

In this paper, to scale back the fluctuating load shedding consequence in the power system industry, the EP technique is utilized by optimal load shaving solution to ensure that the system peak hour supply shortage could be avoided.

III. CUSTOMER LOAD PROFILE CATEGORY

Data of daily load profile(curve) taken from Energy Commission (EC) has been used and also analyzed in order to categorize the load profile of every sector participate on the load shaving optimization. In this paper, consideration only applies to the commercial, industrial and domestic sectors load profile to be optimized [9]. Agriculture load profile shows a constant power usage which does not contribute a significant impact on the load shedding issue. The data taken from EC was during month of July 2012. Since the data given was an overall daily load curve, it has to be categorized by sector in order to execute the load shaving optimization on a particular sector [11]. Fig.2(a), 2(b), 2(c) and 2(d) present the daily load profile for commercial load, industrial load and domestic load. From the figures shown, it is observed that the trends of load for all categories are not uniform. Commercial load experiences high demand between 8a.m to 11.am and 1p.m to 5p.m where the activities are active within these periods. On the other hand, Industrial load picks up the high demand between 7a.m to 10.am and 5p.m to 11p.m where the activities are active within these periods. For case of domestic load, two peaks are observed at around 11a.m to 5p.m and 7p.m to 10p.m. From all the three load profiles, load clipping and shifting will be conducted based on the load category.

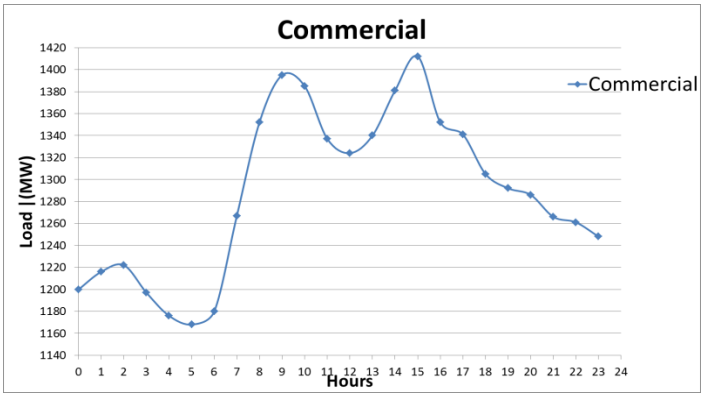

Fig.2(a): Commercial load.

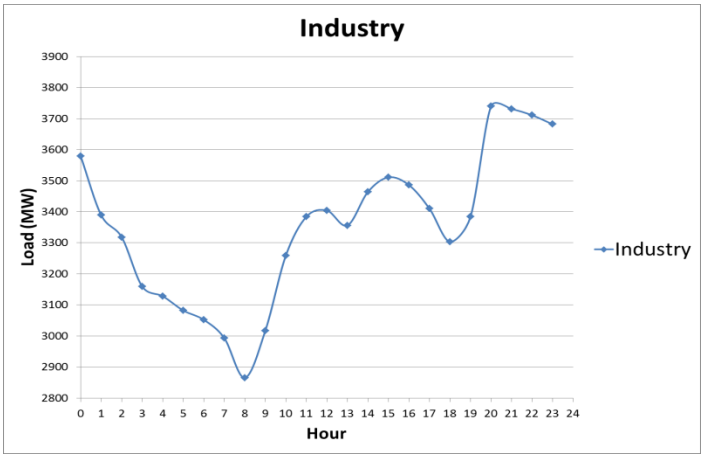

Fig.2(b): Industrial load.

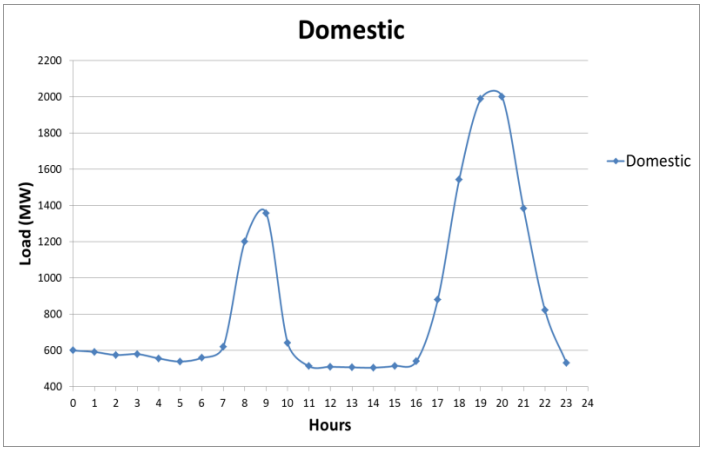

Fig.2(c): Domestic load .

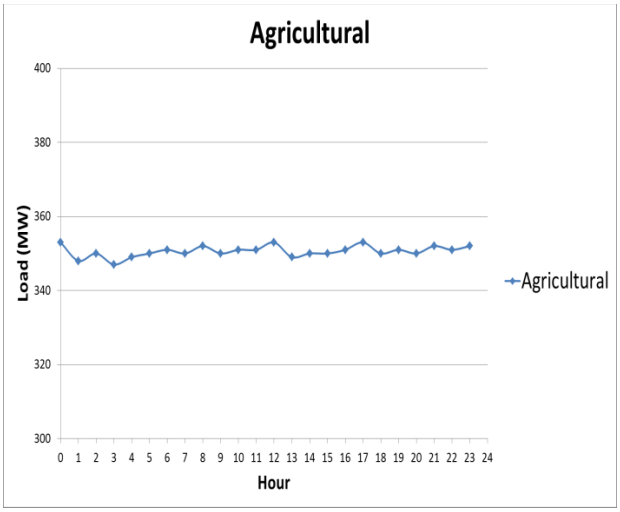

Fig.2(d): Agriculture load.

IV. OPTIMIZATION MODEL OF LOAD SHAVING

Load shaving technique would allow the reduction of fluctuations in terms of instantaneous power load as well as long-term power consumption and, consequently, contribute to the enhancement of energy efficiency of the whole grid [7]. Load management techniques involve in this research aiming to flatten the load curve of customer's load profiles. The demand-side management or load management has been used as an alternative solution for system operation in past thirty years [9]. The methods of peak clipping, valley filling and load shifting are classified as load management objectives [10]. Various load-shape objectives:

- Peak Clipping (reduction in the peak demand),
- Valley Filling (increased demand at off-peak),
- Load Shifting (demand shifting to non-peak period),
- Load Building (increased demand) are possible [8].

It is far more cost efficient to clip or shift peak demand rather than to expand the transmission network to correspond to peak demand [12].

V. PROBLEM FORMULATION

The load clipping and load shifting are implemented based on the following equation:

$$\lambda = U^{i}_{shifting} + U^{i}_{clipping} . \quad (1)$$

where: $U^{i}_{shifting} = rand(1,1)*1.0$

$U^{i}_{clipping} = rand(1,1)*1.0$

Where λ = fitness equation

$U^{i}_{shifting}$ = fraction of load shifting

$U^{i}_{clipping}$ = fraction of load clipping

The inequality constraint is:

$$U^{i}_{clipping} + U^{i}_{shifting} \leq 0.25$$

Clipping and shifting power need to be optimized:

$$\Delta P^{i}_{shifting}(t) = Pmax_i \times (U^{i}_{shifting}) \quad (2)$$

$$\Delta P^{i}_{clipping}(t) = Pmax_i \times (U^{i}_{clipping}) \quad (3)$$

A. Variable Defination

$U^{i}_{shifting}$	Shifting percentage (%) involves during all hours of the day .
$U^{i}_{clipping}$	Clipping percentage (%) involves only peak hour of the day.
$\Delta P^{i}_{clipping}(t)$	Amount of power clipped (reduced/increased) of *i*th sector at time step *t* (kW),
$\Delta P^{i}_{shifting}(t)$	Amount of power shifted of *i*th sector at time step *t* (kW),
Pi max	Maximum load of i^{th} customer (kW),
Pi min	Minimum load of i^{th} customer (kW)

VI. RESULTS AND DISCUSSION

As to determine its feasibility, the EP technique is applied to produce minimum and maximum random number as the percentage of load clipping and load shifting optimization process. The parameters of the optimization algorithms for this analysis are tabled in Table I and Table II.

A. Load clipping and load shifting during minimization process:

Table I
Results of load clipping and shifting fractions of minimization process.

Sector		Commercial	Domestic	Industry
$U^{i}_{shifting}$	0.1627 (5.34%)	All hour	All hour	All hour
$U^{i}_{clipping}$	0.0521 (5.21%)	Hour (8-11) & (13-17)	(7-10) & (17-22)	(11-17) & (19-23)

Results for load shifting using minimization process are shown in Fig3(a), 3(b), 3(c).

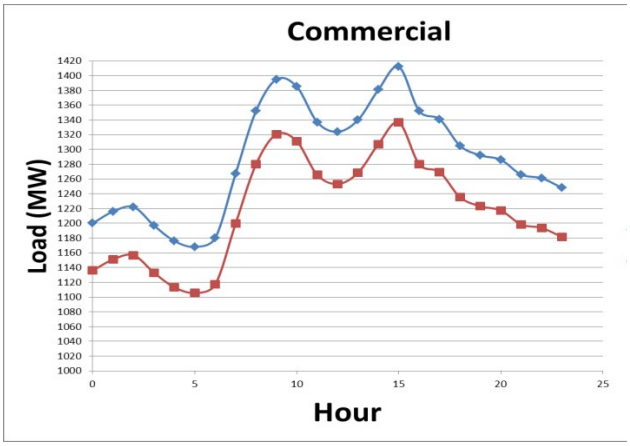

Fig.3(a) : Result of commercial load profile before and after load shifting by minimization. Series1 indicates system load after optimization process.

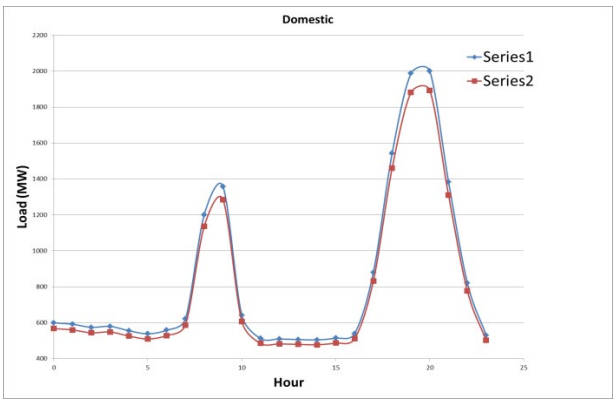

Fig.3(b): Result for the domestic load profile. Series2 indicates system load after optimization process.

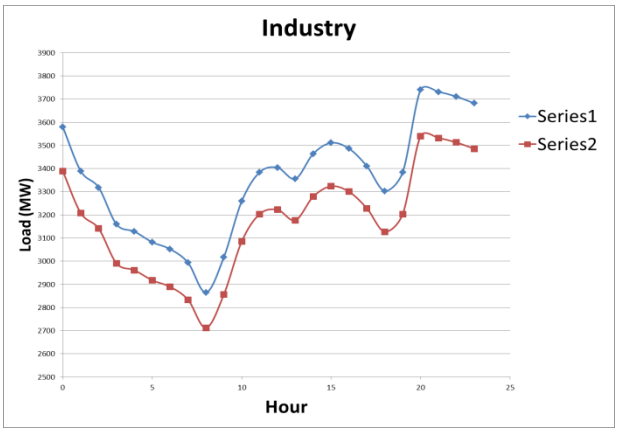

Fig.3(c): Result for the industrial load profile. Series2 indicate system load profile after optimization.

Results for load clipping using minimization process are shown in Fig4(a), 4(b), 4(c).

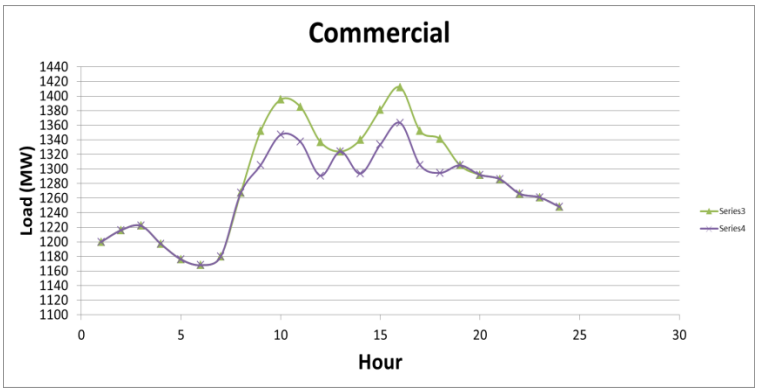

Fig.4(a): Result of commercial load profile undergone load clipping optimization process. Line series4 indicates after optimization process.

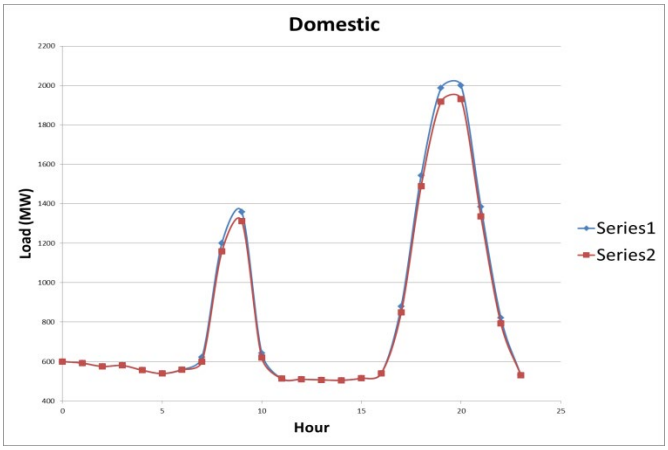

Fig.4(b): Result of domestic load profile undergone load clipping optimization process. Line series2 indicates after optimization process.

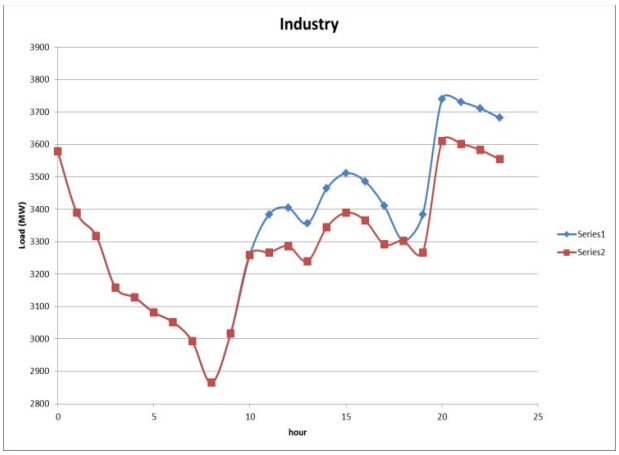

Fig.4(c): Result of industrial load profile undergone load clipping optimization process. Line series2 indicates after optimization process.

Load clipping and load shifting during maximization process:

Results for load shifting using maximization process are shown in Fig5(a), 5(b), 5(c).

. Table II
Parameters of maximization process

Sector		Commercial	Domestic	Industry
$U^{i}_{shifting}$	0.1627 (16.27%)	All hour	All hour	All hour
$U^{i}_{clipping}$	0.0521 (5.21%)	Hour (8-10) & (14-17)	Hour (7-10) & (17-22)	Hour (11-17) & (19-23)

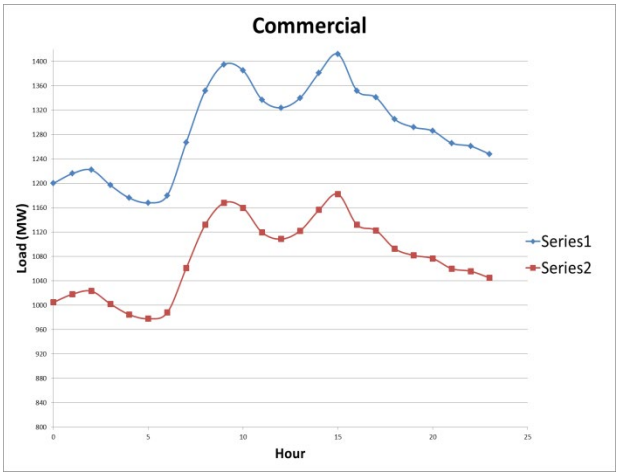

Fig.5(b): Result of commercial load profile undergone load shifting optimization process. Line series2 indicates system load after optimization process.

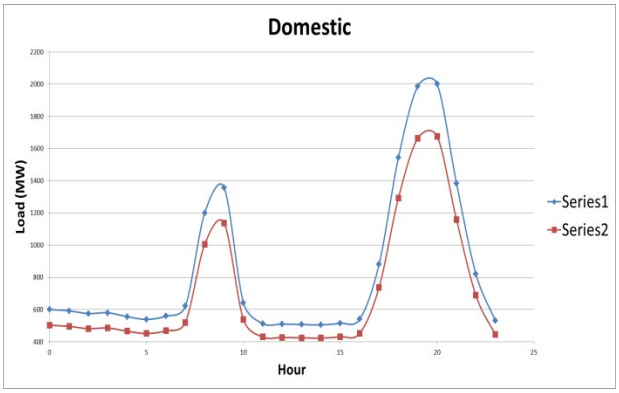

Fig.5(b): Result of domestic load profile undergone load shifting optimization process. Line series2 indicates system load after optimization process.

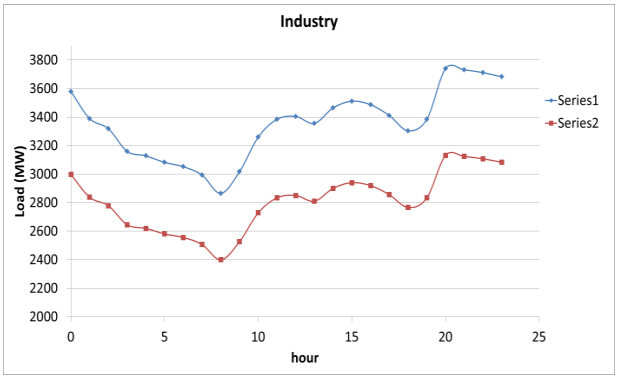

Fig.5(c) : Result of industrial load profile undergone load shifting optimization process. Line series2 indicates system load after optimization process.

Results for load clipping using maximization process are shown in Fig6(a), 6(b), 6(c).

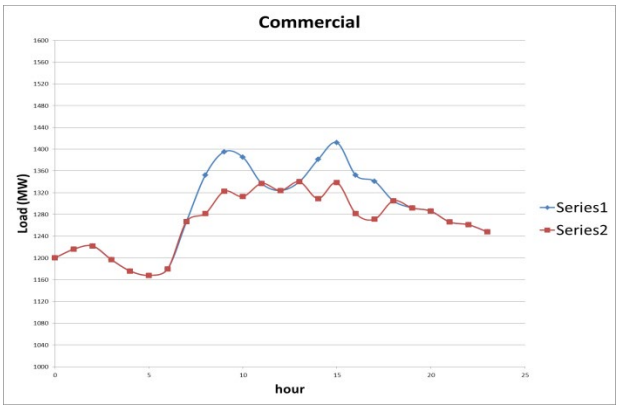

Fig.6(a): Result of commercial load profile undergone load clipping optimization process. Line

series2 indicates system load after optimization process.

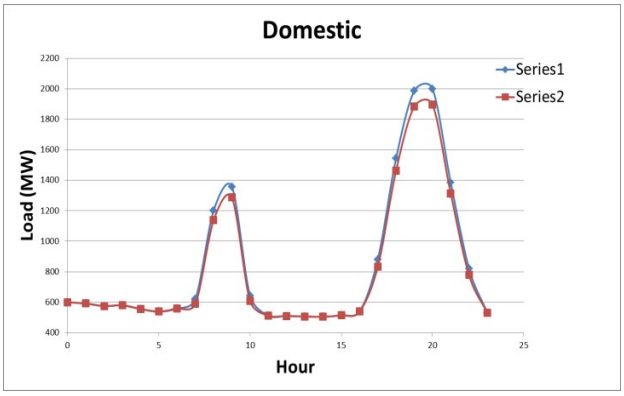

Fig.6(b): Result of domestic load profile undergone load clipping optimization process. Line series2 indicates system load after optimization process.

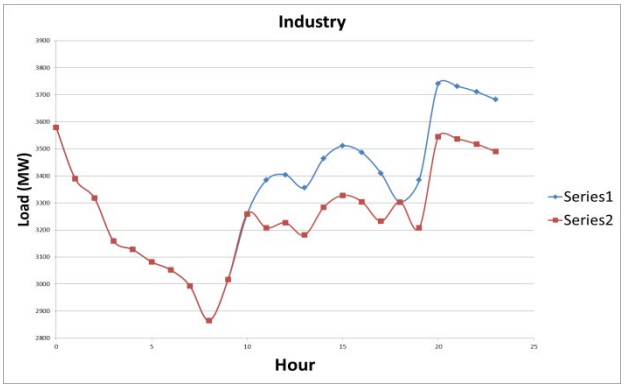

Fig.6(c): Result of industrial load profile undergone load clipping optimization process. Line series2 indicates system load after optimization process.

Comparison of Minimization and Maximization process on the Optimization Model.

The optimization formulation results as shown above is based on the maximization and minimization processes. The typical system load profile of each categorized sector had undergone an optimization process which altered the portion of power (MW). Based on the observation on the data plotted, there are significant differences between both processes, which can be obtained by the objectives of each process. Minimization process executed in the programming should be to find the lowest value of random number generated. In this case, the summation $U^{i}_{shifting}$ and $U^{i}_{clipping}$ variables must not be greater than 0.25, which is 25% for both load clipping and load shifting of the system load profile of each category. The objective of setting the 25% is to avoid insufficient power supply to the consumers. In contrast, the intention of maximization process is to generate random number and produce the highest value from the generated numbers. The results obtained in this paper are based on parameters shown in Table 1 and Table 2.

Sector that involves in the optimization solution were selected based on their capability of load clipping and load shifting. The agricultural sector is neglected due to the constant or flat load profile curve which did not give a significant impact on its load profile. The load shifting process involves all 24 hours of the day. Whereas, for load clipping is optimized at peak hour only as shown in Table I and Table II. It is superior to have high percentage of clipping to minimize the impact of load shedding. Fig.6(a) proven to have better load clipping portion compare to Fig.4(a) clipping of system load profile by minimization process.

Impact of load shifting and load clipping on the load profiling selected.

From the results, it is discovered that load shifting is much less useful as compared to load clipping. The reason for this inefficiency is due to the unnecessary reduction of system load at inconvenient time. The obvious difference can be identified through the maximization process in Fig.5(b) and Fig.6(a) On Fig.5(b), at every hours in the day, the system load reduced or shifted ±200MW which is unnecessary and very poor system load management. This approach can be chosen to identify the load to be clipped.

VII. CONCLUSION

This paper introduced the purpose of Evolutionary Programming (E.P) technique to find the optimal load shaving solution and categorizing the load profile of participated sector to avoid the load shedding in the system. This process is conducted using the data provide by Malaysian Energy Commission (EC). The study considers several load categories namely the industrial, commercial and domestic loads. Results obtained from the study are beneficial for the basic understanding of load clipping and load shifting knowledge for the society.
A relevant mixed integer evolutionary programming model is designed and programmed in order to

resolve the load shaving optimization issue. The actual numerical results indicate the potency of your recommended optimization model such as EP. Results obtained from the study are beneficial to the society.

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