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Optimum Enhance Time of Use (ETOU) for Demand Side Electricity Pricing in Regulated Market: An Implementation Using Evolutionary Algorithm

M. F. Sulaima[1], N. Y. Dahlan[2], Z.M. Yasin[3], N.A.M. Asari[4], Z.H. Bohari[5]
[1,2,3]Universiti Teknologi Mara (UiTM), Faculty of Electrical Engineering, Shah Alam, 40450, Selangor, Malaysia
[1,4,5]Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100, Melaka, Malaysia
*Corresponding author, e-mail: nofriyenita012@ppinang.uitm.edu.my

Abstract

The energy growth in Malaysia is rapidly increasing as the country moves forward with the advancement of industrial revolution. Peak hours require more energy generation, thus cost is also more expensive than during off-peak. Due to this reason, Demand Side Management (DSM) through Demand Response (DR) technique is introduced to modify the demand profile by implementing different strategies of measures. The objective of this study is to optimize the energy profile for commercial sector, as well as analyse the significance of electricity cost reduction by using the optimization technique. A Meta-heuristic technique called as Evolutionary Algorithm (EA) has been implemented in this study to optimize the load profile of a commercial installation. Significant testing shows that the proposed optimization technique has the ability to reform the Maximum Demand from peak zone to off-peak zone to reduce electricity cost. The test results have been validated through 4 cases, which are conventional method for C1 ETOU, C2 ETOU, and C1 ETOU with Optimization technique, and C2 ETOU with optimization technique tariff, respectively. The impact of the EP has been analysed, while the performance of six-time segmentation of C1 and C2 ETOU tariff indicate that the electricity cost for the medium voltage of installation has been reduced. It is hoped that the results from this study can benefit consumers by giving them the flexibility to rearrange their own energy consumption profile, so that the demand side will enjoy significant reduction of electricity cost in the future.

Keywords*: demand response, Time of Use (TOU), Enhance Time of Use (ETOU), regulated market, electricity pricing, Evolutionary Algorithm*

1. Introduction

In 2013, the main energy source was gas, constituting about 50.5%, followed by coal with approximately 38% of total volume, to generate electricity in Malaysia [1]. The exhaustion of natural gas production in Malaysia has forced the government to find alternative sources for future electricity demand and security. Distribution Generation (DG) in the form of Renewable Energy (RE) is feasible, but it is challenging to generate high abundance of power, since initial cost is very expensive in Malaysia. Nuclear energy is difficulty terms of the management of nuclear waste, which is extremely dangerous. Therefore, despite of its well-known characteristic of having the highest carbon footprint, coal is still our best fuel option to replace gas. However, the dependence on imported coal has created issues on coal reserve whenever the producers change their policy on coal exports [2-3]. As a result, there is a need of other promising solution to solve energy crisis in Malaysia.

Due to that reason, Demand Side Management (DSM) unit has been established in part of the department under Malaysia Energy Commission since Efficient Management of Electrical Energy Regulation (EMEER)-2008 has been gazette [4]. There is also Electricity Supply and Market Regulation department that caters for pricing issues such as generation cost and consumers response. The main purpose of these departments is to promote demand response regulation and energy efficiency while culminating higher objective of energy security in Malaysia.

In 2014, since fuel cost is the largest contributor to the total electricity generation with subsidiaries commitment, the Malaysia government has introduced Incentive Based Regulation

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(IBR). This mechanism aims to protect energy needs by creating a balance that enables electricity providers and consumers to benefit from power generation process. While the economy majorly sees increasing energy prices, it has gradually reduced subsidies on gas and coal, which in fact, always has a cascading effect to the government [5]. The initiative began with a program called Imbalance Cost Past Through (ICPT), in 4-year duration of full monitoring from 2014 until 2017 [6]. In concept of IBR, electricity tariff has been reviewed, as the authority has set the base of the electricity rate at the beginning. This base tariff has been reconsidered, covering all costs of generation process until reaching consumers. Inclusive are CAPEX and OPEX cost, base fuel and purchasing cost, and consideration of certain forecasting of exchange rate and inflation rate congruently. In the meantime, the ICPT concept proposes the adjustment of return to consumers in per unit rate to reflect the change in uncontrollable costs base tariff.

In 2015, although electricity cost was crucially amplified since the IBR mechanism was run by electricity providers, Malaysian government has looked at possible ways to mitigate this situation. Introduction of new tariff schemes such as Enhanced Time of Use (ETOU) promise some beneficial factors to the demand side management program while reducing the cost of electricity. Conventional tariff scheme of Time of Use (TOU) was available only to commercial and industrial consumers with categories in C2, E2, E3 tariff and SIT; while ETOU benefits wider range of consumers with C1, C2, C3 and all types of E tariff categories [7]. By this scheme, peak and off peak with additional mid peak considered at compatible rate, consumers can adjust their activities as well as the operation hours in order to enjoy the cost saving.

In 2016, the projection of the DSM through IBR was continued by the Net Energy Metering (NEM) program inspired by Malaysia Energy Commission and Sustainable Energy Department Authority (SEDA) Malaysia. NEM is a policy to promote hybridization of the RE technology, catering solar-based electricity. This policy involves the customers in the demand response program to supply electricity energy to the grid and receive credits on their electricity bills, respectively [8]. However, this program is still new and the implementation looks to point for certain Low Voltage (LV) consumers with limitation setting of generation quota per category.

All initiatives by the government indicate the importance of DSM implementation in Malaysia. Under DSM, two general clusters of program have been taken, which are Energy Efficiency (EE) and Demand Response (DR). Demand Response is divided into several categories, which are system operation, generation, transmission, distribution, energy retailing and load [9]. In Malaysia, the price based behavior or alternative pricing in determining the Load Response (LR) has been introduced in form of TOU and ETOU based tariffs, with the objective to reduce the maximum demand in managing the total energy demand. The DSM model based on demand response segment related to LR is summarized in Figure 1.

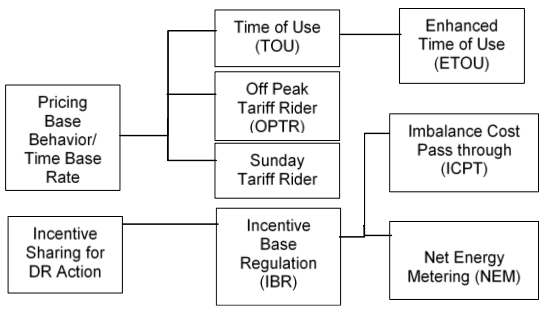

Figure 1. Load response initiatives in Malaysia under regulated market price

As stated before, the scope of implementation for time of use (TOU) tariff in Malaysia is only available for commercial and industrial types only. TOU mechanism in Malaysia has different time period which only considers peak and off peak load, while other countries consider 3 or more periods for their TOU tariff. In 2015, the Malaysia Energy Commission demanded the energy authority to regulate the optative Enhance Time of Use (ETOU) tariff modality in response to maximum demand reduction initiative by the government. Comparison of the time zones per country is presented in Table 1 accordingly.

Table 1. TOU/ETOU time zone per country

Country	Focus Consumers	Time for Off Peak	Time for Peak	Time for Mid Peak
India [13]	Industrial	10:00pm-6:00am	6:00pm-10:00pm	9:00am-12:00pm
China [11]	Industrial	12:00am-8:00am	2:00pm-5:00pm & 7:00pm-10:00pm	8:00am-2:00pm & 5:00pm-7:00pm
Brazil [10]	Residential	11:00am-5:00pm	7:00pm-10:00pm	6:00pm-7:00pm & 10:00pm-11:00am
Malaysia [12]	Commercial & Industrial	10:00pm to 8:00am	10:30am-12:30pm & 1:30pm-5:30pm	8:00am-10:30am; 12:30pm-1:30pm & 5:30pm-10:00pm

The introduction of the new tariff brings several issues to the consumers, such as difficulty to manage the load profile in order to perform the cost-saving, while the price gap of each time frame is rather huge compared to conventional tariff [10, 11, 13, 14, and 15]. Due to that reason, in recent years, many researchers have proposed many techniques of load management with regard to the new tariff load shifting, load translation, valley filling and load clipping; and most of them proposed the implementation of Artificial Intelligence (AI) techniques with different approaches. The optimization of the general load scheduling in TOU environment has been highlighted in many references as in [16]-[19]. As in [16], the Iteration Particle Swarm Optimization (IPSO) was introduced in order to optimize the contract capacity in monthly data basis. The analysis on TOU time frame reflected the reduction of the industrial consumers cost, while considering several factors to determine the optimal solution of the proposed algorithm. The sustainable program in the manufacturing process was proposed to be continued in overall optimal load scheduling by using Binary Particle Swarm Optimization (BPSO) technique. The close scheduling optimal solution for the controllable load had been discussed in detail. The proposed technique was able to accomplish the problem formulation as well as define the cost efficient for the manufacturer revenue [17]. In conjunction with the swarm based algorithm performance, Evolutionary Algorithm (EA) optimization technique was introduced to dealing with the load shifting, specifically for standard machineries in residential, commercial and industrial consumers [18]. The significant related study on evolutionary techniques was continued by [19] with the introduction of Evolutionary Integer Genetic Algorithm (EIGA). The proposed technique could analyze the desired load curve for both consumers and provider, while promoting cost-saving in practicing the newly introduced tariff, which is Time of Day (TOD). Unfortunately, the TOD is available only for those in deregulated market system, since the development of the proposed technique requires a day ahead of load forecasting and real time pricing (RTP) reputation**.** On the other hand, the complexity of the TOU design system issued for the consumers was difficult to join the variety of TOU program. References [14] and [15] addressed the issue and defined the problem formulation, while proposing the game theory algorithm in order to rectify the problem. Momentous TOU analysis had been done for the load scheduling process, but did not cover detailed discussion on the load management reflecting the DSM technique. Meanwhile, specific optimization on existing system such as water heater and heat pump with regard to TOU pricing was presented in [20] and [21], respectively. BPSO was applied in a controller to shift the schedule of water heater, while the other study compared the GA and PSO performance as to find the concurrent optimal costing for the heat pump and thermal storage scheduling.

In reference [22], the modelling method on how consumers could benefit from TOU implementation has been addressed properly. There were two constraints set in order to satisfy the importance of TOU objectives, which are: to 1) ensure costumers profit and benefits, as well to ensure the cost of the electricity not increase after TOU; and 2) to ensure energy consumption remain unchanged before and after the implementation of optimization technique. The constraints may be replicated but the electricity market is different, as presented by some references on the issues of tariff optimization with regard to TOU tariff implementation as well as ETOU in regulated market. As for today, only single paper has been published which concerns the issue of ETOU in Malaysia. The significant ETOU implementation analysis on the industrial load shifting in projection to the weightage of load changing has been presented in [23]. However, detailed discussion on the commercial tariff has not been discussed, while the opportunity to implement such optimization algorithm for load management is crucially lacking.

With regard to these reasons, this paper introduces optimal demand side (consumers) profile formulation of the Malaysia ETOU pricing, with the implementation of Evolutionary Algorithm

(EA) as optimization algorithm. The arrangement of this paper is as follows: Research Method in Section 2 discusses the problem formulation of ETOU tariff in Malaysia, together with explanation on the implementation of the EP technique. Section 3 discusses the results and finding from cases analyses, as well as comparing the issues and types of tariff offer under commercial ETOU program in Malaysia. Section 4 presents the conclusion of this study as well as the suggested future works.

2. Research Method

The data used was taken from commercial installation which is a hospital building, which has been upgraded its incoming low voltage (415V) to medium voltage (11kV), but still in dilemma to find the best commercial ETOU tariff for administrators to register with. Normal calculation was conducted to differentiate between C1 and C2 ETOU tariff. Before that, there is a more advance option to optimize the process, which is to implement Evolutionary Algorithm (EA) via MATLAB environment; with the objective to find the optimum load curve of energy profile. In this section, the new formulation for demand side ETOU program has been introduced, while the significant application of the EP concept will be improved significantly.

2.1 Problem Formulation

The formulation for determining electricity cost in ETOU is presented in Equation (1). Total power for Peak Time is $\mathrm{P_{PTE}}$, Medium Peak Time is $\mathrm{P_{MPTE}}$ and Off Peak Time is $\mathrm{P_{OPTE}}$ which have been calculated based on average energy load profile. The maximum demand, $\mathrm{P_{MD}}$ can then be identified.

$$ETOU_{TC} = (P_{PTE} \times R_{PTE}) + (P_{PTE} \times R_{PTE}) + (P_{OPTE} \times R_{OPTE}) + (P_{MD} \times R_{MDE}) \quad (1)$$

where $\mathrm{ETOU_{TC}}$ is total cost for ETOU rates, $\mathrm{R_{PTE}}$ is rate for Peak Time, $\mathrm{R_{MPTE}}$ is rate for Peak Time, $\mathrm{R_{OPTE}}$ is rate for Off Peak Time, and $\mathrm{R_{MDE}}$ is rate for Maximum Demand. In ETOU consumer profile, instead of employing three (3) time frames which are peak, off peak and mid peak (refer Figure 3), an additional sub time frame called as time segmentation has been included, which is divided by six (6), as presented in Table 1 accordingly. Thus, the optimum solution for each time segmentation load profile will be focused, while Equation (2) explains the significant formulation of the cost minimization, which involves optimal base power and desired power for each time segmentation.

$$ETOU_{\beta}(min) = \sum_{t=1}^{N}((P_{OPbase} - (P_{OPdesired} \times W_1))^2 \times R_{OPTE}) + (P_{MP1base} - (P_{MP1desired} \times W2))2 \times RMPTE) + (PP1base - (PP1desired \times W3))2 \times RPTE) + (PMP2base - (PMP2desired \times W4))2 \times RMPTE) + (PP2base - (PP2desired \times W5))2 \times RPTE) + (PMP3base - (PMP3desired \times W6))2 \times RMPTE) \quad (2)$$

where $ETOU_{\beta}$ is the minimization of actual power to the desired load curve for the total of six time segmentations of the ETOU time frame within 24 hours, represented by hourly time step,$N. P_{base}$ presents the total base power while $P_{desired}$ is the total desired power after optimal consideration of each particular segmentation; which are Off Peak Power (P_{OP}), Mid PeakPower (P_{MP1},P_{MP2},P_{MP3}), and Peak Power (P_{P1},P_{P2}) respectively. Meanwhile $W_1, W_2, W_3, W_4, W_5, W_6$ are the weighted factors of the load shifting, based on the controlled and uncontrolled load finding from the installation. In this study, the value given to each individual weight ($W_1 \sim W_6$) desired load was 0.5, equally. Constraints conditions were given as below:

a. Total six segmentation of energy before and after optimization must be equal, as maximum and minimum consideration is $\pm 5\%$. Equation (3) describes the setting of this constraint.

$$E'_{S1} + E'_{S2} + E'_{S3} + E'_{S4} + E'_{S5} + E'_{S6} \approx E_{S1} + E_{S2} + E_{S3} + E_{S4} + E_{S5} + E_{S6} \quad (3)$$

b. Total optimal cost must consider Maximum Demand (MD) cost (R_{MDE}), which are divided into two types; either in peak time frame or in mid peak time frame, in which the value of the MD must be selected. Thus, the given P_{MD} $(value\ of\ power\ demand)$ constraint is as in Equation (4) accordingly.

$$P_{P1}(max);\ P_{P2}(max) \leq P_{MD}\ \geq P_{MP1}(max);\ P_{MP2}(max); P_{MP3}(max) \quad (4)$$

c. Consideration of every day as working day with same pricing cost.

2.2 Proposed Algorithm

Demand response optimization algorithm in reflecting to load profile needs to be flexible enough to handle a number of parameters. Any proposed algorithm should be able to address the complexity of nature of various tariff pricings in the market. Various optimization techniques such as linear and dynamic programming are commonly used in this field. However, these approaches have limitations in dealing with such intricacy of the simulation nature. Evolutionary algorithms have shown potential in solving such complex problems, such as Evolutionary Algorithm (EA), which offers many advantages in obtaining optimal solutions for complex objectives functioning. Thus, in this work, Evolutionary Algorithm (EA) has been proposed. The steps to implement optimal solution for demand side electricity cost minimization with regard to ETOU tariff are described below.

a. Step 1-Random generation of initial population: Input system data covering average 24 hours load profile for one month power consumption are to be used. All constraints need to be considered, including Equation (3) and Equation (4). Any public holiday and weekend shall be ignored.
b. Step 2-Fitness computation: For fitness calculation, Equation (1) and Equation (2) shall be used to achieve the objective function that needs to be optimized. The objective function in this study was to reduce the total demand side electricity cost of the $ETOU_{TC}$ and $ETOU_{\beta}$ pricing, respectively.
c. Step 3-Mutation: Implementation of mutation scale to determine the convergence rate. Large search step will lead to large computation time. For this study, the mutation rate was set to 0.05.
d. Step 4-Combination: At this stage, the fitness calculation needs to be recalculated by implementing optimal electricity cost $ETOU_{\beta}$ so that the new fitness value based on the new generate state variables during mutation process would be produced. The base and desired power (in set of fitness function) must be combined together, and these combined individuals must be contested in a tournament (the set of power values are called candidates).
e. Step 5-Tournament selection: To choose the survivals for the next generation, EP employs a selection through the tournament scheme. This selection is used to identify the candidates that can be transcribed into the next generation from the combined populations of the parent and offspring. This tournament will be contested randomly. Priority selection strategy shall be used throughout the selection strategy process based on the objective function.
f. Step 6-Convergence test: Convergence test is required to determine the stopping criteria of the evolution. In this study, the convergence test was set below 21. After the 21 iteration, the process shall stop.

3. Results and Analysis

This section presents analyses of two categories of tariff, which are Medium Voltage General Commercial Tariff (C1) and Medium Voltage Peak/Off-peak Commercial Tariff (C2). Data from the hospital, inclusive of energy usage in 24hrs for 12 months, and pricing for average daily operation data to a month average data, had been collected. In this study, the analyses were focused on 4 cases as given below.

Case 1: C1 ETOU tariff without optimization technique
Case 2: C2 ETOU tariff without optimization technique
Case 3: C1 ETOU tariff with EA optimization technique
Case 4: C2 ETOU tariff with EA optimization technique

The baseline had been set as one-month profile in terms of hourly power consumption, as presented in Figure 1. The base profile reflects normal commercial load profile by representing two time frames, which are peak and off peak time frame. Figure 2 illustrates the monthly load curve after optimization method had been applied. As comparison, the optimization technique produced better load curve, reflecting three time frames of ETOU tariff, which are off peak, mid peak and peak, respectively.

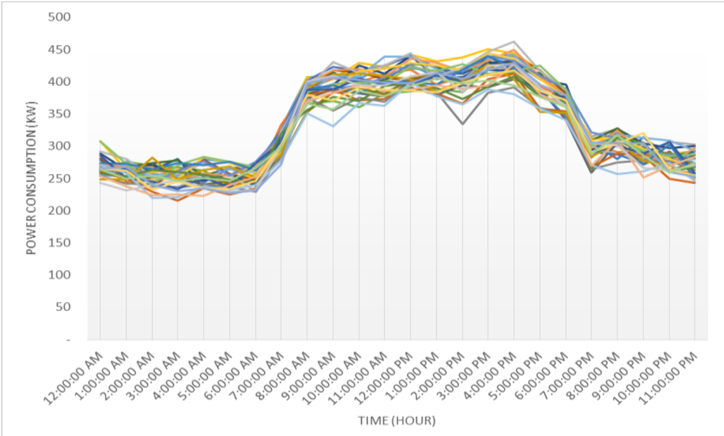

Figure 2. Baseline power profile (1 month average)

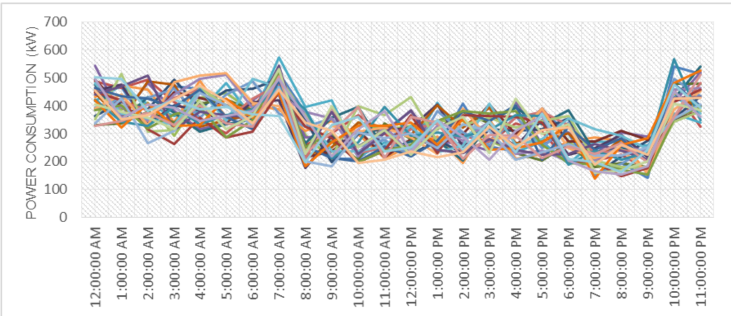

Figure 3. Desired power profile (1 month average) after optimization

The monthly bases before and after optimization are presented in Table 2 accordingly. Maximum Demand (MD) for baseline line had been reduced from 462kW to 362kW, while the relative differential of the total energy before and after optimization was 0.5%, which followed the constraint.

Table 2. Energy Profile Before and After Optimization

Monthly	Baseline profile	Optimization profile
Total Off Peak Energy (kWh)	79 233	122 848
Total Medium Peak Energy (kWh)	109 246	80 268
Total Peak Energy (kWh)	49 321	35 920
Maximum Demand (MD)	462	362
Monthly Total Energy (kWh)	**237 800**	**239 036**

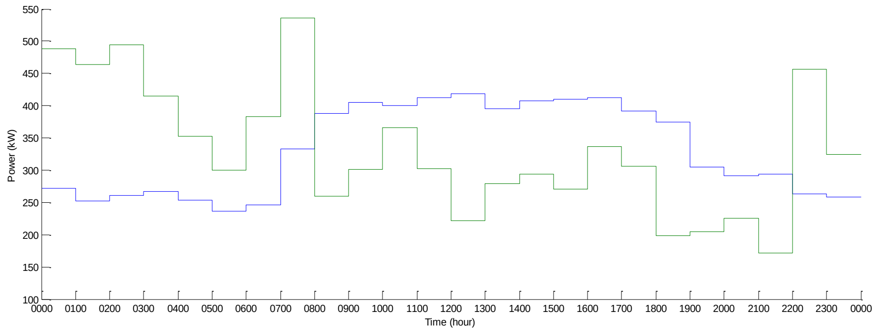

Figure 4. Actual load profile (24 hours: blue line is baseline; green line is after optimization)

With regard to ETOU tariff program, Figure 4 shows the comparison between conventional and optimal per day load profiles. By using the Evolutionary Algorithm technique, the optimization focused on the time zones. The blue line indicates the actual power while the green line indicates the optimization power. From 0000 to 0800 and 2200 to 0000; which was in off-peak time zone, the optimization load profile was higher than the actual load profile because of the application of DSM strategies such valley filling load strategy. By improving the off peak power, it also improved the system load factor while increasing controlled load activities by 35.5%.

Meanwhile from 0800 to 1100, 1200 to 1400, and 1700 to 2200; which were in mid-peak time zone, the optimization load profile was lower than the actual load profile due to the application of the clipping load shape strategy. High demand periods were 'clipped' and the utility load was reduced during three times of segmentation. It was a reduction of approximately 26.5% power immediately after load optimization.

This was similar to duration from 1100 to 1200 and 1400 to 1700 for peak time period, when clipping load shape was applied. At this period, 27.2% load was cut down after the optimization. However, even after the optimization process, the total power consumption did not reduce significantly, which fulfilled the constraint significantly.

The differences between total energy pricing in each time zone based on four cases are tabulated in Table 3 accordingly. The table shows that in off-peak time zones, the optimization pricing value of Case 3 and Case 4 (EP-ETOU) increased, while in total mid-peak and peak time zones, the pricing values after optimization significantly decreased (Case 3 and Case 4).
On the other hand, there were significant reductions of maximum demand cost for Cases 3 and 4 compared to Cases 1 and 2. Hence, for total ETOU with optimization technique performance, Case 4 showed the most reduction (12.1% compared to Case 2) in terms of total electricity cost in a month, while being able to balance the MD value and reduce the total mid peak cost concurrently, as shown in Figure 5. The commercial C2 ETOU tariff, in terms of EP algorithm, was able to reduce the total cost; which reflects the effectiveness of demand response program as well.

Table 3. Comparison of the optimization results for different cases

Monthly	Case 1	Case 2	Case 3	Case 4
Total Off Peak Cost (RM)	22,264.47	17,748.19	34,520.29	27,517.95
Total Medium Peak Cost (RM)	39,000.82	37,034.39	28,655.68	27,210.85
Total Peak Cost (RM)	28,803.46	31,368.16	20,977.28	22,845.12
Maximum Demand (MD) Cost (RM)	13,305.60	19,681.20	10,425.60	15,421.20

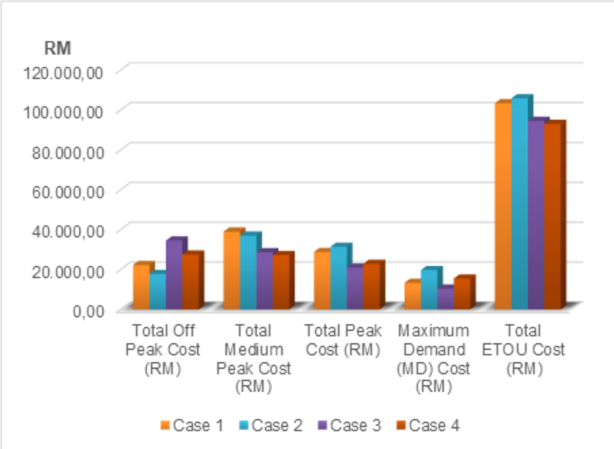

Figure 5. Summary of the ETOU tariff of four cases analysis

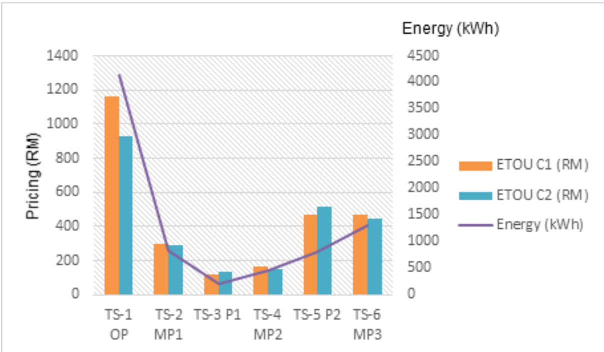

Figure 6. Time segmentation pricing for optimal ETOU tariff

The derivation of the objective function, which was to minimize the total electricity pricing cost for ETOU profile, had correlated to the arrangement of the six (6) time segmentation of the profile consequently. Therefore, the effect of the optimal arrangement of the energy cost of each segmentation had led to the reduction of total cost, reflecting single pricing of the three (3) time frames of off-peak, peak and mid-peak correspondingly. As shown in Figure 6, the price signal for the C2 types in ETOU program had been selected due to the balance of the pricing profile to energy profile after optimization. Time Segmentation 1 off-peak (TS-1 OP) presented higher cost for both classes of tariffs C1 and C2. The C2 tariff pricing was higher at TS-5 P2 while C1 tariff pricing was at TS-6 MP3, respectively. The rest of time segmentations (TS-2 MP1, TS-3 P1, and TS-4 MP2) were balanced between both tariffs.

4. Conclusion

This paper presented a method to optimize the demand-side of ETOU pricing with the implementation of Evolutionary Algorithm optimization technique. The proposed method has been proven capable in reducing the total electricity energy cost by adjusting the desired load curve significantly. The electricity cost can be saved in a month if the owner of the installation follows the load curve as suggested by the optimization algorithm. Other than that, it looks possible for commercial buildings to employ the desired load curve with 50% changing; thus future works will take into account the possible controlled load to be shifted. The test data and optimization method also could be extended to industrial implementation, while employing the demand side management load strategies to minimize electricity cost congruently.

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References

[1] Energy Commision. *Malaysia Energy Statistics Handbook 2015*. 2016.
[2] Energy Commision. *Peninsular Malaysia Electricity Supply Industry Outlook 2014*. 2016.
[3] Ministry Coordinator of Strategic Sectors. *National Energy Balance 2014*. *Energy Comm.* Page Number: 218, 2014.
[4] Z Umar. *Efficient Management of Electrical Energy Regulations 2008 Energy Manager ' S Roles and Functions*. 2013.
[5] ARI Azhar Omar, Othman Omar, Asma Aini Mohd Nadzri. Towards A World-Class Energy Sector Spark of Efficiency. *Energy Malaysia*, 2014; 1(1): 48.
[6] Suruhanjaya Tenaga. *Review on Electricity Tariff in Peninsular Malaysia under the Incentive-based Regulation Mechanism (FY2014-FY2017)*. Page Number:16; 2013.
[7] Tenaga Nasional Berhad. *Enhanced Time of Use (ETOU) Tariff Scheme*. Consult. Sess. With Key Stakeholder; 2014.
[8] S Chemud. *The Impact of Roof Top Solar PV Under Net Energy Metering*. Tenaga Nasional Berhad; 2016.
[9] M Behrangrad. A review of demand side management business models in the electricity market.*Renew. Sustain. Energy Rev.*2015; 47: 270–283.
[10] RS Ferreira, LA Barroso, PR Lino, P Valenzuela, MM Carvalho. *Time-of-use tariffs in Brazil: Design and implementation issues*. IEEE PES Conf. Innov. Smart Grid Technol. ISGT LA. 2013
[11] Z Tan, M Wang, J Qi, J Hou, X Li. Time-of-use Price Optimizing Model And Fuzzy Solving Method. *Syst. Eng. - Theory Pract.* 2008; 28(9): 145-151.
[12] Energy Commission. *Enhanced Time of Use (ETOU) Tariff Scheme*. 2014.
[13] S Ashok. Peak-load management in steel plants. *Appl. Energy*. 2006; 83(5): 413-424.
[14] H Chen, Y Li, RHY Louie, B Vucetic. Autonomous Demand Side Management Based on Energy Consumption Scheduling and Instantaneous Load Billing: An Aggregative Game Approach. *IEEE Trans. Smart Grid*. 2013; 5(1): 1-11.
[15] Y Peng, T Gongguo, A Nehorai. A game-theoretic approach for optimal time-of-use electricity pricing. *Power Syst. IEEE Trans.* 2013; 28(2): 884-892.
[16] TY Lee, CL Chen. Iteration particle swarm optimization for contract capacities selection of time-of-use rates industrial customers. *Energy Convers. Manag.* 2007; 48(4): 1120-1131.
[17] Y Wang, L Li. Time-of-use based electricity demand response for sustainable manufacturing systems. *Energy*. 2013; 63: 233-244.
[18] T Logenthiran, D Srinivasan, TZ Shun. Demand side management in smart grid using heuristic optimization. *IEEE Trans. Smart Grid*. 2012; 3(3): 1244-1252.
[19] N Kinhekar, NP Padhy, HO Gupta. Multiobjective demand side management solutions for utilities with peak demand deficit. *Int. J. Electr. Power Energy Syst.* 2014; 55: 612-619.
[20] A Sepulveda, L Paull, WG Morsi, H Li, CP Diduch, L Chang. *A novel demand side management program using water heaters and particle swarm optimization.* IEEE Electr. Power Energy Conf. 2010; 1–5.
[21] H Molavi, MM Ardehali. Utility demand response operation considering day-of-use tariff and optimal operation of thermal energy storage system for an industrial building based on particle swarm optimization algorithm. *Energy Build.* 2016; 127: 920-929.
[22] Z Tan, M Wang, J Qi, J Hou, X Li. Time-of-use Price Optimizing Model And Fuzzy Solving Method. *Syst. Eng. - Theory Pract.* 2008; 28(9): 145-151.
[23] N Azrina, M Azman, P Abdullah, MY Hassan, DZ Said. Enhanced Time of Use Electricity Pricing for Industrial Customers in Malaysia. *Indones. J. Electr. Eng. Comput. Sci.* 2017; 6(1): 155–160.