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DEMAND SIDE MANAGEMENT: ENERGY PROFILE OPTIMIZATION

NURUL ASNIZA BINTI MOHD ASARI

(B011310335)

SUPERVISED BY:

EN. MOHAMAD FANI BIN SULAIMA

2017

" I hereby declare that I have read through this report entitle "Demand Side Management: Energy Profile Optimization " and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ....

Supervisor's Name : MOHAMAD FANI BIN SULAIMA

Date : 2 JUNE 2017

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A report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

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JUNE 2017

I declare that this report entitle "Demand Side Management: Energy Profile Optimization" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in a candidature of any other degree.

Signature : ....

Name : NURUL ASNIZA BINTI MOHD ASARI

Date : 2 JUNE 2016

BISMILLAHIRRAHMANIRAHIM

" In The Name of Allah, Most Gracious, Most Merciful"

For viewing,

Father and mother who is respected and loved,

MOHD AS'ARI BIN HAMZAH & MAMUNAH BT ABD RAHMAN

And supervisor, Faculty of Electrical Engineering Universiti Teknikal Malaysia Melaka, and do not forget also to my colleagues.

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ABSTRACT

The energy growth for Malaysia is rapidly increasing as the country moving forward to be the one of the industrial revolution country. During the peak hours, the energy generated is more expensive than the off peak which rises the cost of generation. Due to that 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 analyze the reduction of electricity cost by using the optimization technique. An Artificial Intelligence technique, which is Evolutionary Programming (EP) had been implemented to optimize the load profile of a commercial installation. Significant testing had been done while the proposed optimization technique shows the ability to reform the Maximum Demand from peak zone to off peak zone as to as reduce the electricity cost. The test results have been validated by using 4 cases which are conventional method for C1 ToU,C2 ToU, C1 EToU and C2 ETou tariff respectively. The impact of the EP has been analyzed while the performance of C1 and C2 EToU tariff indicate the optimum result of electricity cost for the medium voltage of installation. It is hope that the results from this study will benefits the engineer to rearrange the profile so that the demand side will enjoy significant reduction of electricity cost in the future.

ABSTRAK

Pertumbuhan tenaga di Malaysia semakin meningkat dengan pesat kerana Malaysia telah bergerak ke hadapan untuk menjadi salah satu yang terbaik dalam revolusi perindustrian. Pada waktu puncak, tenaga yang dihasilkan adalah lebih mahal daripada waktu biasa disebabkan oleh kos penjanaan yang tinggi. Oleh kerana itu, teknik DSM diperkenalkan untuk mengubah suai profil permintaan dengan melaksanakan strategi yang berbeza. Objektif kajian ini adalah untuk mengoptimumkan profil tenaga bagi sektor komersial dan untuk menganalisis pengurangan kos elektrik dengan menggunakan teknik pengoptimuman. Dalam kajian ini, teknik 'Artificial Intelligence', EP telah dilaksanakan untuk mengoptimumkan profil kuasa bagi sektor komersial. Ujian telah dilakukan untuk menunjukkan bahawa teknik pengoptimuman mampu untuk mengubah MD dari waktu puncak ke waktu biasa yang mana dapat mengurangkan kos tenaga. Keputusan ujian telah dilakukan dengan menggunakan 4 kes iaitu kaedah konvensional untuk C1 ToU, C2 ToU, C1 EToU dan C2 EToU tarif. Kesan EP telah dianalisis manakala tarif C1 dan C2 EToU menunjukkan kos optimum untuk bahagian pemasangan voltan rendah. Adalah diharapkan hasil kajian ini akan memberi manfaat kepada jurutera untuk menyusun semula profil supaya pengguna akan menikmati pengurangan kos elektrik secara ketara.

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LIST OF ABBREVIATIONS

2DPSO: 2 Dimensional Particle Swarm Optimization
ABC : Ant Bee Colony
ACO : Ant Colony Optimization
AI : Artificial Intelligence
BFA : Backtrack Free-path planning Algorithm
BFO : Bacterial Foraging Optimization
BPSO : Binary Particle Swarm Optimization
DR : Demand Response
DSM : Demand Side Management
EA : Evolutionary Algorithm
EP : Evolutionary Programming
ES : Evolutionary Strategy
EToU : Enhanced Time of Use
GA : Genetic Algorithm
GDP : Gross Domestic Product
IBR : Incentive Based Regulation
ICPT : Imbalance Cost Past Through
ILL : Incentives Load Limiting
ISO : Independent System Operator
MD : Maximum Demand
ORPP : Optimal Reactive Power Planning
PSO : Particle Swarm Optimization
RPP : Reactive Power Planning
RTO : Regional Transmission Organization
SIT : Special Industrial Tariff
TNB : Tenaga Nasional Berhad
ToU : Time of Use

CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter focused to the problem that drives the rest of the project. This chapter consist four parts which started with motivation that give an inspiration to the project followed by problem statement, objective of the project and scope of the project. The objective of this project is based on the problem stated in problem statement.

1.1 Motivation

In Peninsular Malaysia, the growing demand for electricity is driven by two main categories of the economy, the industrial and commercial sectors. For the forecast, Gross Domestic Product (GDP) growth rate for 2014 was estimated to increase from 5% to 5.3% with a bullish long-term economic projection of around 5%.

In terms of electricity sales, in 2015 an average growth rate of 2.4% was recorded. The largest customer is still the industrial sector with 42%. The commercial sector is not far behind at 35%, while the domestic sector is 21% and others comprising mining, public lighting and agriculture sectors are 2% bring up the rear. However, the commercial sector is projected to experienced higher growth and will be the largest customer, replacing the industrial sector by 2030.

Based on Figure 1.1, from the Malaysia Energy Statistics Handbook 2015 prepared by Energy Commission (ST), transportation, commercial and industrial sector are leading in their energy consumption.

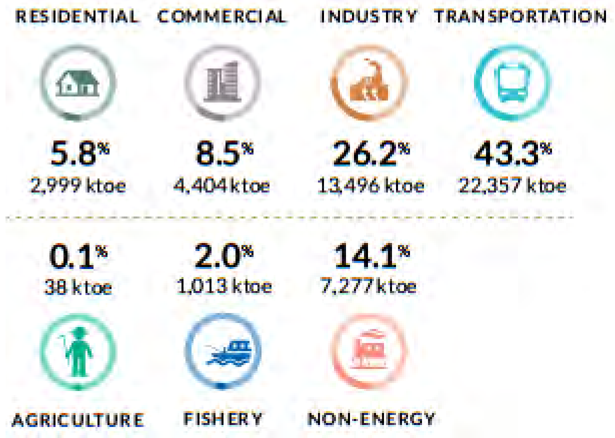


Figure 1.1: Energy consumption in every sector[1]

Sales are estimated to rise to 3.4% in 2016 and 3.8% the following year. Electricity generation is forecasted to reach 116, 813GWh in FY2015 and peak demand is estimated to reach 17, 461MW in the same year. This is a 560MW increase or 3.3% growth from that in the previous year[2].

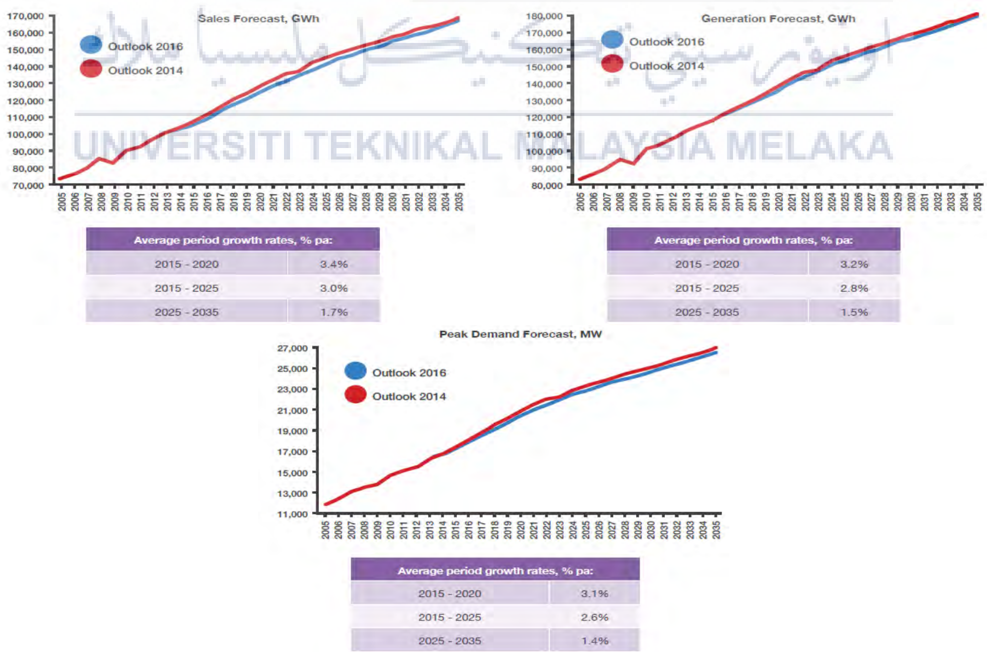


Figure 1.2: Demand forecast (2005 – 2035)[2]

As the demand for electricity is expected to grow, the generation and transmission system needs to be further upgraded and expanded. Early 2014, the electricity tariff in Peninsular Malaysia is determined through the IBR framework and the ICPT mechanism. ICPT is a structure under the IBR context allowing the government to analyze the tariff every six months to consider changes in fuel and other generation expenses.

Beginning January 2016, Suruhanjaya Tenaga established a new type of tariff category which is Enhanced Time-of-Use tariff (EToU) for users. The EToU is formed as an alternative to demand side management initiatives. It inspires consumers to use electricity more cost-effectively by lessening their electricity consumption during peak hours and having more utilisation during off peak hours. Under the new EToU scheme, the peak time zone is reduced to 4 hours from the existing 14 hours and a new mid peak zone of 10 hours is introduced for energy and demand charges at rates lower than the current peak rates. Consumers will have more ethusiasm to consume electricity at the off-peak period due to lower tariff rates[2]. By using energy more competently, consumer can reduce their energy cost and utility itself can run at higher efficiency.

1.2 Problem Statement

In 2015, government had announced, the electricity tariff for domestic and industrial will be increased in 2016 because of the price of the coal is increasing. In this case, the production sector had no choice but to increase the price of their products. It will give a burden to a consumers, especially the low-income earners. When the electricity tariff increases in industrial sector, the food production, processing and retail cost will increase simultaneously.

Demand Side Management programs offers a great advantage on both utilities and end users such that after applying DSM programs, utilities did not need to build new power plants in order to meet the load and also for customers, their electricity bill is minimized[3].

As the Enhanced Time-of-Used tariff was introduced in line to demand response program, there are three time zones in a day/24 hours. The past research only focussed on overall load profile optimization rather than determining the zoning load shape profile optimization strategies. The impact of this action, the regular activities would be sacrificed by demand side as to as the total consumption was instantly reduced.

The load profile management serves as a monitoring tool in order to find the best strategies to implement DSM. Flattening the load profile behaviour of the customers load will maximize the use of the utilities generation capacity thus dropping the load factor. This usually done by altering some customer loads from peak loads hours to off-peak hours. On the other hand, off-peak load hours can also be improved to minimize the installation's load factor[4].

Energy consumption of any building is influenced by various internal and external factors. Trial and error processes as well as the experience of the energy analyzer are mostly used to determine the most of these factors. The established factors have a certain relationship to the energy consumption of a building, which needs to be established. However this process is a time consuming process. Due to that reason optimization technique by using AI is used to determine performance correlation between power consumption and energy cost. The advantage of using AI is that it is a computerized process and is therefore much less time consuming[5]. However, the implementation of AI contributes to many problems such as results were not accurate due to trapping problem on local and global process of bio-inspired algorithm. The example of them are PSO, ABC, ACO, BFO and etc.

Due to that reason the evolutionary algorithm (EA), would be the choice because of it accuracy in considering the convergence result while leads to achieve the optimum finding when it is hybrided with others optimization method. In this study, the conventional Evolutionary Programming is used to show the capability of the EA to find the best optimal solution for the load profile in communicating to commercial tariff ToU and EToU in order to find the objective function which is electricity cost optimization.

1.3 Objective

The objectives of this research are:

1. To differentiate between TOU and ETOU tariff scheme.
2. To optimize the energy profile for a commercial installation.
3. To analyze the reduction of electricity cost by using optimization technique.

1.4 Scope

The test data had been taken from a commercial installation. The load profile data for a year had been used to be a raw data for the Matlab initialization input.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter focused on the review of the project and review of the literature. The overall goals of this chapter is to establish the significance of the general field of study, then identify a part where a new contribution could be completed. This chapter critically evaluating the varoius methodologies used in this field so as to identify the suitable approach for this project.

2.1 Demand Side Management

Demand Side Management (DSM) means, the group of measures that urge the clients to utilize less energy during peak hours (stated by 1 in Figure 2.1) or if important utilize it when the load demands are lower, for example at night (stated by 2 in Figure 2.1) or on ends of the week[6].

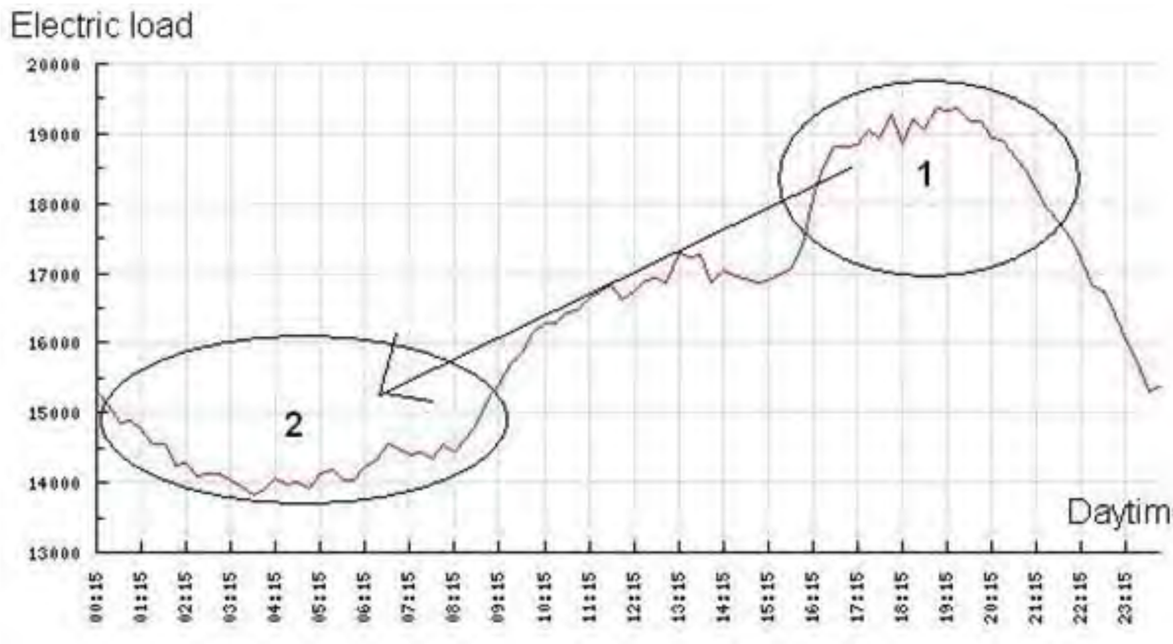


Figure 2.1: Demand Side Management[6]

The aims for Demand Side Management are:

1. Cost reduction – numerous DSM and energy effectiveness efforts have been presented with regards to incorporated asset arranging and lessening all out expenses for taking care of energy demand.
2. Ecological and social change – Energy proficiency and DSM might be sought after to accomplish ecological and community objectives by decreasing energy utilize, prompting to lessen greenhouse gas emissions.
3. Reliability and system matters – improving and deflecting issues in the power organize throughout diminishing interest in ways which look after framework dependability in the quick term and over the more drawn out term concede the constraint for organize growth.
4. Enhanced markets – Transient reactions to power economic situations (Demand Response), especially by reducing load during times of high market costs caused by reduced generation or system limit.

The inspiration driving the execution of DSM is clearly different for the individual social included. For service organizations, the diminishment or move of a client's energy request could mean staying away from deferrring building extra creating limit. In a few circumstances, this would prevent or defer energy costs rises that would otherwise be imposed on clients to help finance new investments in system capacity. For clients, DSM proposes the chance to diminish their energy charge over productivity and protection measures. For the situation of industrial clients, this would mean lower generation costs and a more focused item. For residential clients it implies that they would spare cash that could be spent on other family unit products[7].

There are five steps to implement Demand Side Management which started with load research. It consist of the study of load pattern of end-users, market survey, statistics survey and tariff rates. In load research it helps in figuring the significant maximum load users and also in the improvement of the load shape. Second step in implementing the DSM is by defining the load shape objective. The appropriate load shape among several is identified based on the result retrieved from the load research stage to reshape the load curve for maintaining the balance between power supply and demand. Fundamentally, there are six types of load-shape objective[8].

1. Peak Clipping: High demand periods are 'clipped' and the utility load is reduced during peak hours. It focuses on reducing highest demand.
2. Valley Filling: Low demand periods are filled by building off-peak capacities. It develops the system load factor by building the load in off-peak hours.
3. Load Shifting: It refers to shifting of the loads from peak demand periods to off-peak periods accomplishing the clipping and filling. But the clipping is different to shift in the overall demand of load is always present while in the case of clipping it is detached.
4. Strategic Conservation: Energy conservation programs aimed at reducing the whole energy consumption through reduction of electrical loads during all or most hours of the day.
5. Strategic Load Growth: Load shape modification that refers to a general increment in energy consumption during all or most hours of the day.
6. Flexible Load Shape: It involves making the load shape responsive to reliability conditions by developing specific programs to alter end-users energy consumption on required basis.

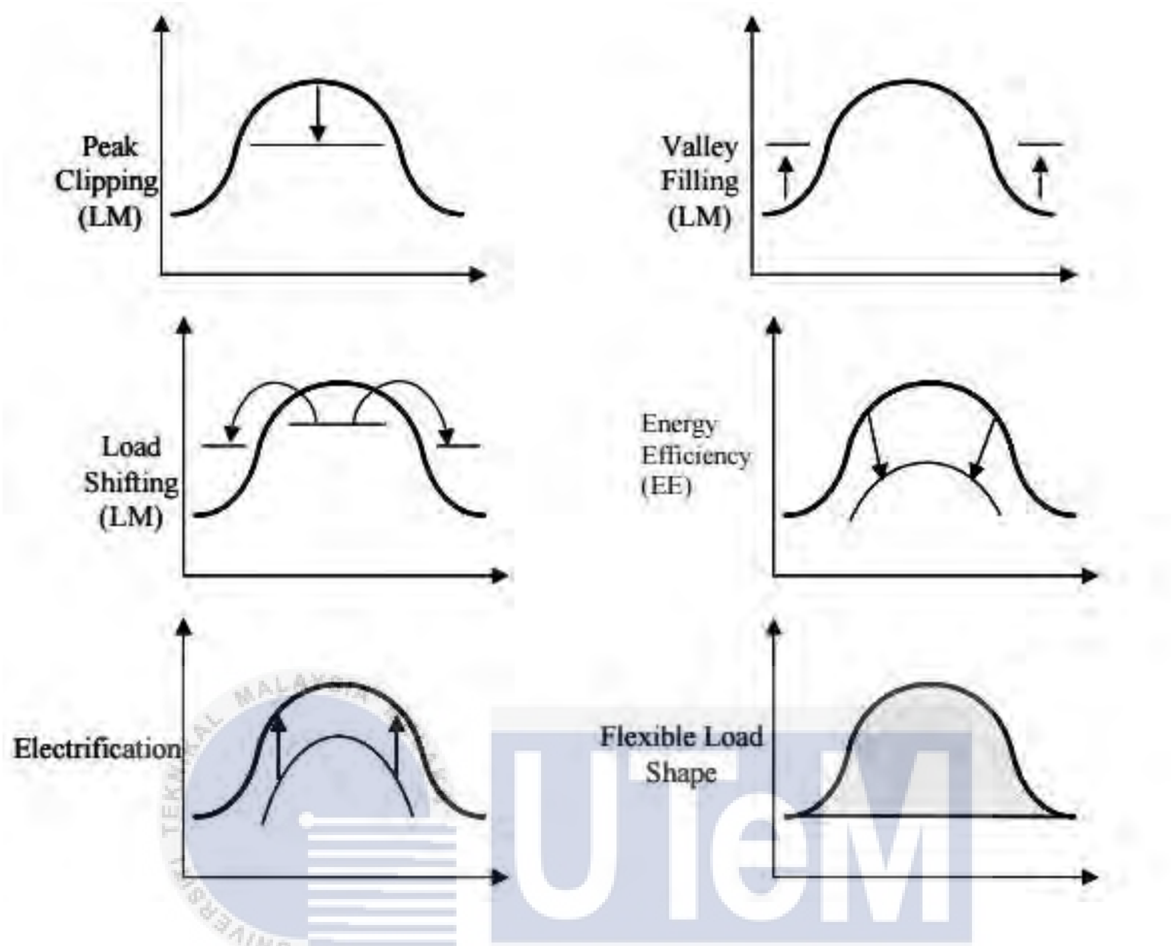


Figure 2.2: Six basic type of objective load-shapes[8]

Third step is asses program implementation strategies on the load shape objectives defined in step two, the implementation strategies for the DSM are assessed by identifying the end users applications and technology alternatives. A detailed benefit and cost analysis will also be carried out in this stage for both consumers and utilities.

The fourth step is implementation. This step involves the actual implementation of the programs designed to achieve the objectives of DSM so as to reshape the load curve in order to maintain a balance between supply and demand of electrical power.

And the last step is monitoring and evaluation. In this step, the implemented program is regularly monitored to ensure the effective and efficient adoption of DSM measures. The programs effectiveness is evaluated and compared with the DSM goals set to achieve by the utilities. Benefit and cost analysis is also done in this step to determine the actual benefits and cost incurred during the implementation process[8].

2.2 Demand Response

Demand response known as the alterations in electricity habit by end users from their regular consumption arrangements in response to changes in the charge of electricity over time. DR can be also known as the incentive outflows designed to persuade lower electricity use at times of high wholesale market charges or when system reliability is endangered. All intentional electricity utilization shape adjustments by end users that are planned to modify the scheduling, level of instant demand, or overall electricity utilization.

The advantages of DR program is divided in 3 categories which are participant, market-wide and reliability. For the consumers joining in DR programs can expect savings in electricity bills if they downgrade their electricity usage during peak periods. Meanwhile for the market-wide, an general electricity charge reduction is expected ultimately because of a more efficient usage of the available infrastructure, as an example the reduction of demand from high-priced electricity generating units. The cascaded effect of DR programs includes avoided or deferred need for distribution and transmission infrastructure implementations and upgrades.

Reliability advantages may be taken into consideration as one of the market wide advantages because they give an impact to all market participant. Through having a properly designed DR program, participant have the possibility to assist in lowering the chance of outages. Simultaneously and for this reason, participants are lowering their own risk of being uncover to forced outages and power interruption. On the other hand, the operator could have more alternatives and resources to maintain system reliability, thus reducing forced outages and their consequences.

Environmental benefits of DR programs are various and include better land utilization as a result of prevented new electricity infrastructure along with generation units and transmission/distribution lines[9].

2.2.1 Electricity Grid in Malaysia

In each nation, there is a standard framework known as National Grid System used to transmit power to everywhere throughout the nation. In Malaysia, there are three major parts in electrical power system which are generation system, transmission system and distribution as shown in Figure 2.3. The adventure of power starts at generation, the second real part of the procedure is transmission, where power is 'step-up' by substation transformer and exchanged to the National Grid. For customers to securely utilize this transmitted power, it should be 'step-down' by substation transformer proximate to end users (residential, commercial and industrial).

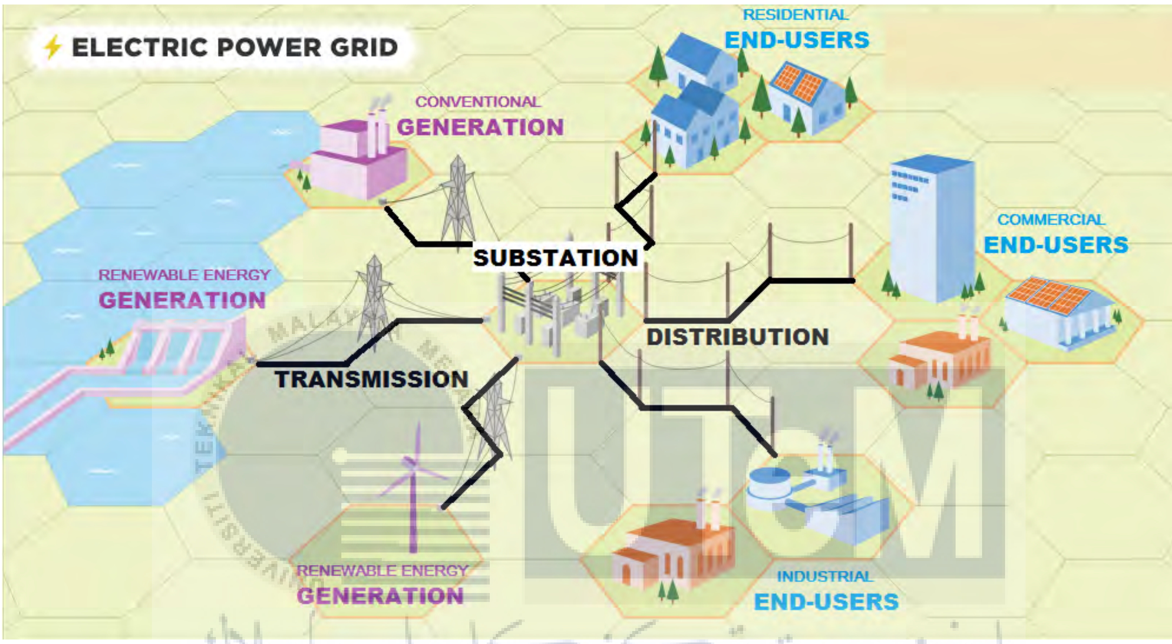


Figure 2.3: Electricity Grid in Malaysia[10]

The journey from generator to end-users happens quickly, because of the fundamental reasons which is National Grid that makes this procedure possible. The system of high voltage power lines (500kV, 275kV, 132kV, and 11kV) in the National Grid transports power from power plant to load centres (substations) or straightforwardly to sizable power customers.

2.2.2 Power generation

From the statistics made by Energy Commission from year 2006 to 2014 shown in Table 2.1, Malaysia generates about 7.14% of its electricity at Hydroelectric, 88.25% at Thermal Stations and 4.61% at Co-generation

Table 2.1: Electricity Generation in Malaysia[11]

Year	Electricity Generation (ktoe)			
	Hydro	Thermal Stations	Co-Gen	Total
2006	554	6687	499	7740
2007	558	7366	461	8385
2008	642	7321	460	8423
2009	574	7957	560	9091
2010	540	8864	387	9791
2011	656	9648	442	10746
2012	779	10253	530	11562
2013	1003	10627	424	12054
2014	1152	11075	402	12629
Total	**6458**	**79798**	**4165**	**90421**
	7.14%	88.25%	4.61%	

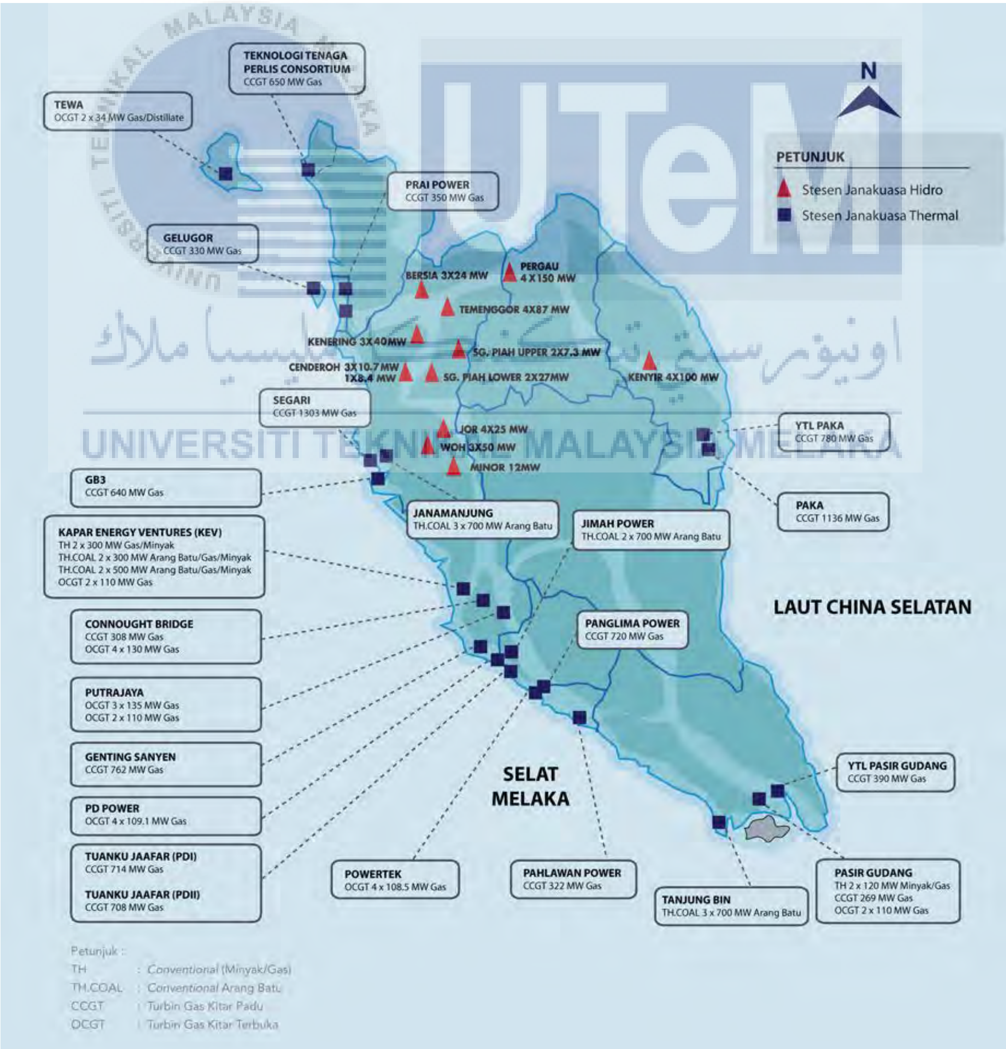


Figure 2.4: Power Station in Peninsular Malaysia[12]

Malaysia owns about 11 hydroelectric power stations and 23 thermal stations in Peninsular. Figure 2.4 shows the location and the number of power station in Peninsular Malaysia by each type. There is 13 Combined Cycle Gas Turbines (CCGT), 7 Open Cycle Gas Turbines, 5 Thermal Coal and 4 Thermal Power Station

2.2.3 Transmission, Substation and Distribution to the End-Users

Transmission Networks also known as transmission system, which comprises (entirely or principally) of high voltage electric lines (transmission lines of 132kV and above) possessed or worked by TNB Transmission and utilized to transmit power from one power station to a substation or to another power station. It can likewise be between substation or from any outside interconnection, and incorporates any plant or potentionally device and meters possessed then again worked by TNB Transmission regarding the transmission power.

Not all the power that is created at power plants reach to end users. This is by cause of that transmission and distribution losses, as well as power pilferages happen along the ways. These losses are gathered into two principle sorts as per the way of the losses – technical losses inside the distribution system, and non-technical losses, for example, power burglary. Despite the fact that these losses amount add up to a little division of total output, steps still must be taken to moderate them to build the productivity of power delivery.

Technical losses can be freely characterized as the power lost when energy is scattered over electrical transmission overwhelmingly as heat, however energy get consumed as commotion also, generally for the inherent resistance of the conductor themselves. For instance, at the point when the electrical transmission voltage of 500kV is cast down to the domestic establishment level of 240V via a stepdown transformer, the power will go through a progression of winding channels, which are curls of wire made of copper. The size of technical loss along the distribution system is resolved by the system's architecture and typical feature, the more conceivable outcomes there are for energy scattering, the more noteworthy the technical losses.

Non-technical losses are those maintaned by means of element outside the power system, for example, meter altering and power pilferages, also called power burglary. At the point when power is misused in this way, the power dissemination system is troubled with wasted power generated and unrecorded utilization.

Despite the way technical and non-technical losses happen, they influence both the power utility and the customers. The less of these losses acquired, the more income power organizations can procure. For example, Tenaga Nasional Berhad (TNB) works under the Incentive Based Regulations (IBR), where there are altered income prerequisites. Hence, with higher benefits, electricity tariffs could be diminished, profiting the end user. Furthermore, the losses additionally require expanded power generation to meet request and make up for the decreases in the system[13].

In Malaysia, during the peak hours more electrical power would be transferred from power generation to match the load demands. The energy generated during the peak hours is more expensive than the off peak one which rises the average price of electricity. This is because when more energy was generated, the higher the fuel consumption.

2.3 Electricity Market

2.3.1 Deregulated Market

In a deregulated electricity market, market members other than utility companies own power plants and transmission lines. In such instances, generators (companies that generate electricity) sell electricity into a wholesale marketplace and retail energy suppliers purchase this electricity to sell it to customers. Transmission companies or utilities own and operate the transmission grid. This market universe is managed by an independent system operator (ISO) or regional transmission organization RTO[4].

Deregulated markets have opened up generation for competition from independent power producers in 24 states, such as California, Texas and most states in the Northeast. 18 of these states and Washington D.C have also introduced retail choice, which allows residential and/or industrial consumers to choose their own electricity provider. Customers benefit from more competitive rates and generation options, including renewable energy[4].

2.3.2 Regulated Market

In a regulated electricity market, vertically integrated control utilities cover the entire value chain with oversight from a public regulator. The utility makes sure that power is generated, sent to the grid and reaches consumers. Consumers in regulated markets cannot choose who generates their power and are bound to the utility in that area[4]. Malaysia is one of the example of electricity regulated market which is adopt the monopoli system of electricity generation until distribution by a utility. The market has been controlled by a party authorized by government who also act as policy maker.

2.4 Electricity Tariff Schedule

A tariff is the pricing structure a retailer charges a customer for energy consumption. Electricity tarif in Malaysia are divided into domestic, commercial, industrial, mining, and agriculture.

	TARIFF CATEGORY	UNIT	CURRENT RATE (1 JAN 2014)
	Tariff A - Domestic Tariff		
	For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.80
	For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.40
1.	For the next 300 kWh (301 - 600 kWh) per month	sen/kWh	51.60
	For the next 300 kWh (601 - 900 kWh) per month	sen/kWh	54.60
	For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
	The minimum monthly charge is RM3.00		

Table 2.2: Electricity Tariff for Domestic Consumers[14]

Table 2.3: : Electricity Tariff for Commercial Consumers[15]

TARIFF CATEGORY	CURRENT RATES(1 JAN 2014)
TARIFF B - LOW VOLTAGE COMMERCIAL TARIFF	
For the first 200 kWh (1 -200 kWh) per month	43.5 sen/kWh
For the next kWh (201 kWh onwards) per month	50.9 sen/kWh
The minimum monthly charge is RM7.20	
TARIFF C1 - MEDIUM VOLTAGE GENERAL COMMERCIAL TARIFF	
For each kilowatt of maximum demand per month	30.3 RM/kW
For all kWh	36.5 sen/kWh
The minimum monthly charge is RM600.00	
TARIFF C2 - MEDIUM VOLTAGE PEAK/OFF-PEAK COMMERCIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	45.1 RM/kW
For all kWh during the peak period	36.5 sen/kWh
For all kWh during the off-peak period	22.4 sen/kWh
The minimum monthly charge is RM600.00	

Table 2.4: Electricity Tariff for Industrial Consumers[15]

TARIFF CATEGORY	CURRENT RATE (1 JAN 2014)
TARIFF D - LOW VOLTAGE INDUSTRIAL TARIFF	
For the first 200 kWh (1 -200 kWh) per month	38.00 sen/kWh
For the next kWh (201 kWh onwards) per month	44.10 sen/kWh
The minimum monthly charge is RM7.20	
TARIFF E1 - MEDIUM VOLTAGE GENERAL INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month	29.60 RM/kW
For all kWh	33.70 sen/kWh
The minimum monthly charge is RM600.00	
TARIFF E2 - MEDIUM VOLTAGE PEAK/OFF-PEAK INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	37.00 RM/kW
For all kWh during the peak period	35.50 sen/kWh
For all kWh during the off-peak period	21.90 sen/kWh
The minimum monthly charge is RM600.00	
TARIFF E3 - HIGH VOLTAGE PEAK/OFF-PEAK INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	35.50 RM/kW
For all kWh during the peak period	33.70 sen/kWh
For all kWh during the off-peak period	20.20 sen/kWh
The minimum monthly charge is RM600.00	

Table 2.5: Electricity Tariff for Mining Consumers[15]

TARIFF CATEGORY	CURRENT RATES (1 JAN 2014)
TARIFF F - LOW VOLTAGE MINING TARIFF	
For all kWh	38.10 sen/kWh
The minimum monthly charge is RM120.00	
TARIFF F1 - MEDIUM VOLTAGE GENERAL MINING TARIFF	
For each kilowatt of maximum demand per month	21.10 RM/kW
For all kWh	31.30 sen/kWh
The minimum monthly charge is RM120.00	
TARIFF F2 - MEDIUM VOLTAGE PEAK/OFF-PEAK MINING TARIFF	
For each kilowatt of maximum demand per month during the peak period	29.80 RM/kW
For all kWh during the peak period	31.30 sen/kWh
For all kWh during the off-peak period	17.20 sen/kWh
The minimum monthly charge is RM120.00	

Table 2.6: Electricity Tariff for Agriculture Consumers[15]

TARIFF CATEGORY	CURRENT RATES (1 JAN 2014)
TARIFF H – LOW VOLTAGE SPECIFIC AGRICULTURE TARIFF	
For the first 200 kWh (1 -200 kWh) per month	39.00 sen/kWh
For the next kWh (201 kWh onwards) per month	47.20 sen/kWh
The minimum monthly charge is RM7.20	
TARIFF H1 - MEDIUM VOLTAGE GENERAL SPECIFIC AGRICULTURE TARIFF	
For each kilowatt of maximum demand per month	30.30 RM/kW
For all kWh	35.10 sen/kWh
The minimum monthly charge is RM600.00	
TARIFF H2 - MEDIUM VOLTAGE PEAK/OFF-PEAK SPECIFIC AGRICULTURE TARIFF	
For each kilowatt of maximum demand per month during the peak period	40.80 RM/kW
For all kWh during the peak period	36.50 sen/kWh
For all kWh during the off-peak period	22.40 sen/kWh
The minimum monthly charge is RM600.00	

2.4.1 Maximum Demand

Maximum demand is the top level of electrical demand supervised in a particular period usually for a month period or the peak load appointed by the consumer to electricity provider system at any point of time. To reflect the time of day it is used, Maximum Demand tariffs are structured. For these reasons most tariffs for outsized consumers are designed to encourage consumers to regulate their electricity demand at daytime peaks.

2.4.2 Enhanced Time of Use

With the Special Industrial Tariff (SIT) being phased out,the Enhanced Time of Use (EToU) scheme is being introduced to further encourage greater efficiency in industrial and commercial usage of electricity. EToU scheme is introduced as an expansion to the Time Of Use (TOU) tariff. TOU tariff scheme offers various tariff rates at a different times of the day.

Under the EToU scheme, there will be three time regions for Energy charge with Peak, Mid-Peak and Off-Peak rates. On the other hand, Maximum Demand charge will have two time regions with Peak and Mid-peak rates. This scheme is also classified in two categories which are, Monday to Friday and Saturday,Sunday and Public Holidays.

- Monday to Friday
  - 3 time regions with 3 energy rates for Energy charge. Peak, Mid-Peak and Off-Peak
  - 2 time regions with 2 rates for Maximum Demand. Peak and Mid-Peak
- Weekends and Public Holiday
  - 1 time region with 1 energy rate. Off-Peak rate
  - Maximum Demand Charge is diminished during Saturday, Sunday and Public Holidays.

The differentiation of TOU scheme versus EToU tariff scheme shown in Table 2.7. EToU has three time zones meanwhile TOU only have two time zones.

Table 2.7: The differentiation of TOU scheme versus EToU tariff scheme[16]

Time Of Use		Enhanced Time of Use	
Time Zone	Hours	Time Zone	Hours
Peak	08:00 – 22:00	Mid-Peak	08:00 – 11:00
Off-Peak	22:00 – 08:00	Peak	11:00 – 12:00
		Mid-Peak	12:00 – 14:00
		Peak	14:00 – 17:00
		Mid-Peak	17:00 – 22:00
		Off-Peak	22:00 – 08:00

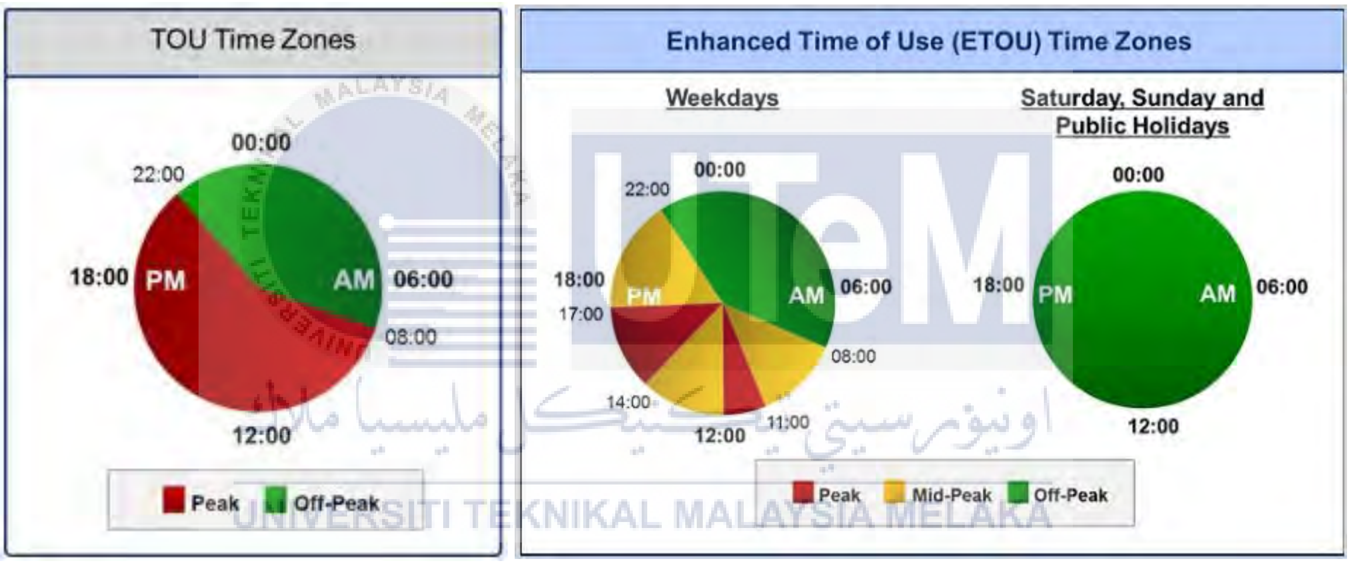


Figure 2.5: The differentiation of a time zone between TOU scheme and EToU scheme[17].

Starting from 1st January 2016, EToU tariff scheme will be offered to commercial customers at medium voltage (tariff C1 and C2) and industrial customers at medium and high voltages (tariff E1, E1s, E2, E2s, E3 and E3s). And starting from 1st January 20017, the tariff scheme will be offered to industrial customers at low voltage (tariff D and Ds). However, low voltage industrial customers may optional for the EToU scheme starting from 1st January 2016, provided that they would upgrade voltage tariff at their own cost.

Tariff Category	Demand Charge (RM/kW/Month)		Energy Charge (sen/kWh)		
	Peak	Mid-Peak	Peak	Mid-Peak	Off Peak
Commercial C1 MV ETOU	34.00	28.80	58.40	35.70	28.10
Commercial C2 MV ETOU	48.40	42.60	63.60	33.90	22.40
Industrial D LV ETOU	42.10	37.20	48.40	32.70	24.90
Industrial E1 MV ETOU	35.50	29.60	56.60	33.30	22.50
Industrial E2 MV ETOU	40.00	36.00	59.20	33.20	21.90
Industrial E3 HV ETOU	38.30	35.00	57.60	32.70	20.20

Figure 2.6: EToU Tariff Scheme[16]

Tariff rates differ with time periods because demand for electricity will be different throughout the day, therefore the electricity production cost will also change with time. The objective of EToU is to inspire Demand Side Management. EToU allows customers to control their electric consumption efficiently by using a lesser amount of electricity during Peak hours. EToU is a self-regulating tool for customers to manage their electricity usage and bill. By shifting and optimization of their consumption to Mid-Peak and Off-Peak hours, when the rates are cheaper, customers will enjoy the reduction in monthly bill.

2.5 Related Previous Work in Demand Side Management

Adia Khalid [18] define DSM for Home Management electric appliances arrangement is very helpful in the framework of load management by changing or balancing. Most users shift load on renewable resources but it is insufficient to totally facilitate the user. To handle such condition underlying research work adopted the Artificial Intelligence based optimization techniques. The proposed method is based is on a hybrid BFA and GA. Simulation results clearly establish that hybrid method results are better than BFA and GA. The load was balanced as per demand and shifted the load toward off peak hours without generating the peak load. It is also noted that there is tradeoff between the cost and PAR where when the author reduce the cost by shifting the maximum load during the off-peak hours that often cause increase in PAR. As in case of BFA, where cost is low but PAR is high as compared to other techniques. The simulation results also show that algorithm performance is highly affected by the fitness function too.

Mohammed Y. Morgan [19] develop a DSM technique that modify the demand profile through implementing different DSM measures (load shifting and load shedding). The function to develop DSM technique is to create greater flexibility in demand and better facilitate the integration of renewable energy technologies within the built atmospheres. The propose optimization for DSM technique was Genetics Algorithms. The objective of the algorithms are to create optimal demand profiles for the operation of renewable energy systems. To achieve the objective of the research is by using the methodology that based on building short term load forecasting model for each load profile to asses having real estimation of the profiles needed to be reshaped. The result from the reseach shows the huge benefits of using Genetics Algorithms. In this case, the load are optimized based on the load profile.

Ishan Gupta [20] stated demand side management is obtaining a lot of importance due to its advantages to the entire smart grid. It trim down the excess demand of power during peak hours and along with that it also cuts the utility bill of the consumers. New approach has been adopted by the author using the particle swarm optimization algorithm which has come out with the reduction in peak demand and also results in substantial savings in utility bills. The research has been carried out on three area loads which are residential, commercial and industrial of a smart grid.

J. Agneessens [21] used the technique of binary particle swarm for optimization. The main objetive of the author is to create curtailment schedule that takes into account both the voltage profile along the line as well as the demand consumers. The methodology of the research contain three step. The first step is determining the consumption in each node. The second step are executing the simulation and the last step are determine the new power. But in the end of the research, the athor stated ,in order to increase optimization results, subdivisions could be established. This means that applications would still have the similar barrier constraints, yet they can be turned on and off at various circumstances. This would have an instantaneous impact on the optimization outcomes. As the results, the load could not be fully optimized as to as PSO always ssss the step in order to achieve the minimum time for convergence.

Meanwhile, Sanjaya Kumar Nayak used 2D Dimensional Particle Swarm Optimization (2D PSO) algorithm [22]. The objective of the research is to program the electrical appliances of consumers in such a way that overall electric cost is to be reduce which also decrease the peak power demand. His research contains 4 steps which started with initial particle/solution formation. The second step is, fitness function evaluation which to flat the load curve by changing the peak load to off peak. The third step is, velocity and position updates. This is to make sure that the solution should not fall in local optimum value. And the last step is checking the validity of solution. The result for his research show of 13.05% of saving in price and 17.44% of saving in power. However, ToU only have peak and off-peak meanwhile EToU have additional time zone which is mid peak. However the work done in [17], [20] and [21] are only focused on low voltage installation.

Jagruti Thakur [23] analyzed the hourly demand data of residential customers for two different DSM methods, one of which is the existing price based strategy and another is the proposed incentive based method. The objective of the research is to investigate the dynamics of demand response based tariff mechanisms on user load profiles as well as the effect on the monthly bill. The methodology used in this research are analysis of time of use (TOU) program and incentiv8ed load limiting (ILL). The steps for implementation of TOU in india was described in Figure 2.7.

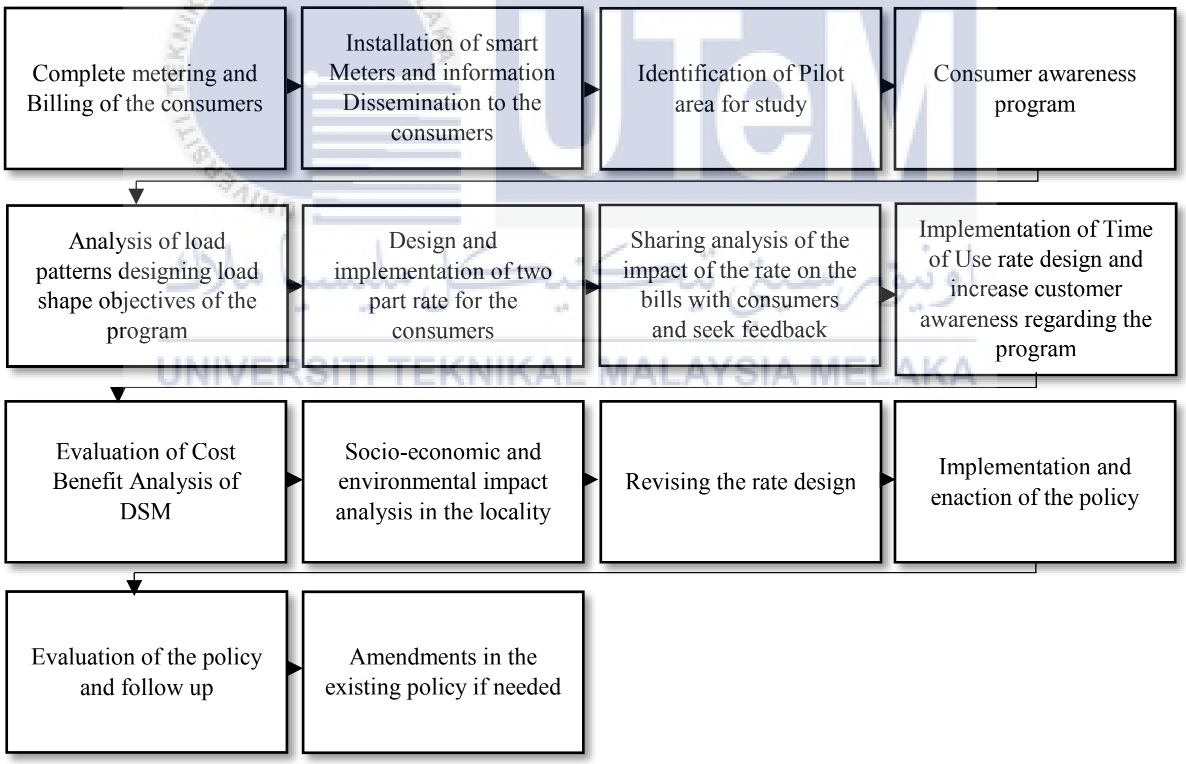


Figure 2.7: Steps for implementation of TOU DSM in India [23]

The results in this research shows, the flatter curve can be obtained in the analysis of time of use pricing mechanism in ideal situations which shows that alternative price mechanism can lead to efficient usage of resources.

In a survey of 500 households in Sweden [24], it was found that after the introduction of time of use tariffs (TOU), the average demand for electricity reduced by 12.65% in two years. This study has demonstrated that households are generally sympathetic to being charged according to a demand-based tariff, seeing as how the distribution system operator's motive for introducing it relates to environmental issues.

In survey of 15 experiments, it was concluded that, residential consumers reduce their consumptions in response to higher electricity prices [25]. In a research of 483 households in California [26], it was found that significant average response was achieved for differential pricing. It was discovered that residential users definitely give some potential of load shifting to demand response programs and that larger users responds more.

Md Aminur Rahman [27] define demand side management has the ability to provide many advantages to the entire smart grid community, particularly at distribution network level. The suggested strategy is a generalized technique based on load shifting and energy efficiency advancement. Results shows that along with multiple benefits for generation as well as utility company, this framework would offer economic benefits to various commercial customers. Scaling-up this framework will enable intelligent load management for a city, which should be the objective of any smart of efficient grid system.

Majid Ali [4] in his research thesis suggest that DSM is the only way out to overcome the current energy crisis to some extent. Our system does not allow us to keep energy at a large scale. So there has to be a suitable solution to produce, transmit, distribute and use it immediately. In simple words here it is being suggested that energy crisis can be controlled significantly using DSM technique. The DSM is a viable option to meet the future electricity demand through implementing DSM strategies.

Similarly, M.D. Murphy [28] applied a DSM algorithm for the optimization of ice storage in a dynamic real time electricity pricing environment. The results from his research succeed in reducing the cost of electricity. Rim Missaoui, [29] analyzed the act of global model based anticipative building energy management system (GMBA-BEMS) in managing household energy consumption. The results also succeeded in reducing the cost of electricity by practicing the model to manage home appliances. However, not all customers can change the schedule of use solely to reduce electricity bills. It is because, every equipment has its own interest.

Other than that, B Priya Esther [30] have conducted a survey on residential DSM, which can help people to have a view of the issue which includes the architecture, formulation of optimization problems and its different approaches. Besides, A.S.O Ogunjuyigbe [31] proposed a demand side load management method that is able of managing loads within the domestic building in such a way that the consumer satisfaction is maximized at lowest price.

2.6 Evolutionary Programming

Ismail Musirin [32] had made a research of optimization by using Evolutionary Programming. The study was focused on solving reactive power planning in power system. To identify the most suitable Reactive Power Planning (RPP) technique for minimising transmission loss in power system, comparative studies was performed in this study while maintaining the voltage profiles at reasonable voltage levels and avoiding overcompensating to the system. Results obtained from the study can be utilised by the power system engineers to perform any remedial action in an attempt to reduce transmission loss. The only problem involved optimization process is utilizing the ideas of EP to identify the optimal solution for RPP.

Meanwhile, [33] presents a comparative study for three evolutionary algorithms (EAs) to the Optimal Reactive Power Planning (ORPP) problems which are Evolutionary Programming, Evolutionary Strategy and Genetic Algorithm. The EA is a powerful optimization technique analogous to the natural selection process in genetics. In theory, this technique converges to the global optimum solution with probability one. It gives a big impact especially when other optimization methods fail in finding the optimal solution. The results show the ORPP problem was solved by minimizing the total cost. However, the ES needs less generations to converge but it has a higher probability to fall into a local minimum and the EP needs more generations to converge, and less likely to fall into a local minimum.

2.7 Summary

It is observed that the existing methodologies and programs of DSM may not turn out to be feasible for many of the developing nations. A mix of various pricing mechanisms would help to achieve the target of flat rate more easily. Along with this, the awareness regarding the usage of data and benefits of DSM among the consumers is a necessity to make this program successful. Figure 2.8 shows the summary of the demand side management in this study.

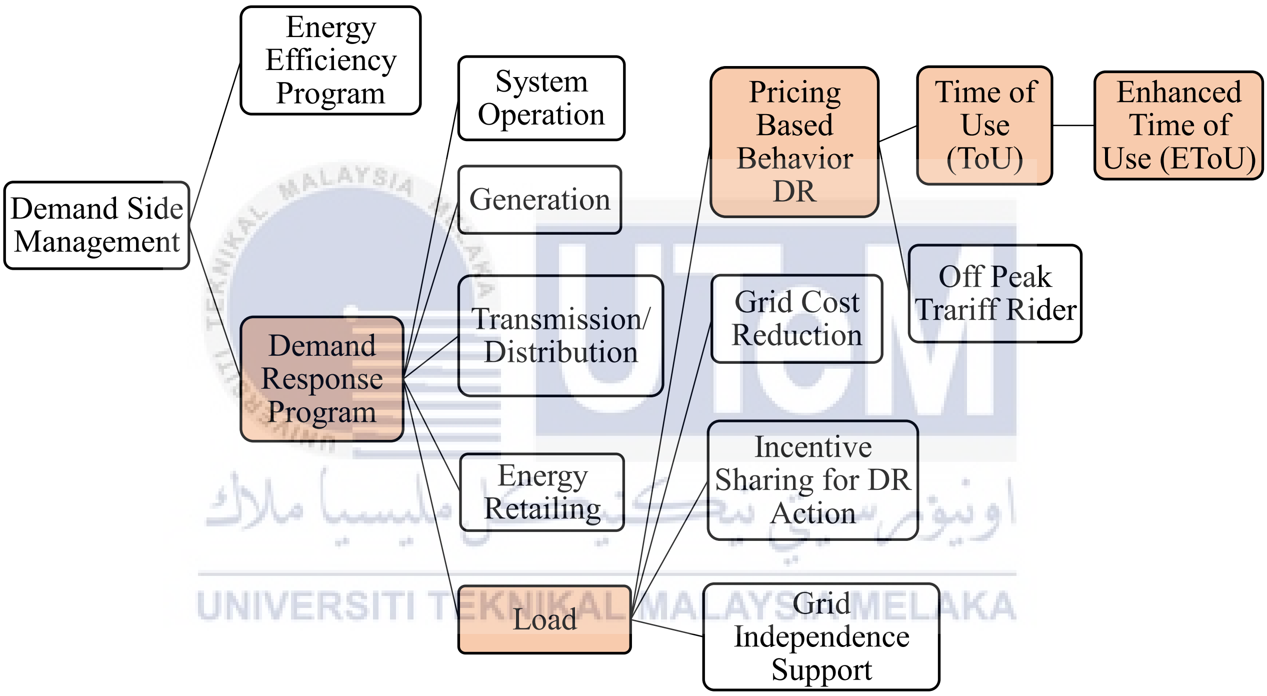


Figure 2.8: Summary of demand side management route

Table 2.8: Comparison between past research technique

Ref.	Optimization Method	Objective	Test Market	Algorithm	Weakness
[17]	Algorithm	Cost minimization and load management.	Residential	Hybrid BFA & GA	The optimization is focused only on low voltage installation.
[20]		To create curtailment schedule that takes into account both the voltage profile along the line as well as demand consumer.	Residential	BPSO	
[21]		To program the electrical appliances of consumers to decrease the peak power demand.	Residential	2D PSO	
[18]		To create optimal demand profiles for the operation of renewable energy system.	General	GA	The method used not focussing to tariff mechanism.
[19]		To minimize the peak demand and reduce the utility cost.	Residential/ Commercial/	PSO	The study focused on overall consumption

			Industrial Smart Grid		
[22]	Tariff Mechanism	To investigate the dynamics of demand response based tariff mechanisms on user load profiles.	Residential	Implementing TOU	Cannot handle a complexities efficiently rather than using algorithm.
[23]	General	Represent a strategy on load shifting technique for DSM.	Commercial	Load Shifting and Energy Efficiency Improvement	

CHAPTER 3

METHODOLOGY

3.0 Overview

This chapter will discuss the methods that will be used from the beginning to achieve the objectives of the research until the end. Project flow and system overview will be discussed briefly to give more understanding of the development concept of this research. The data used will be taken from a commercial installation which is a hospital building. Normal calculation was conducted to differentiate between ToU and EToU tariff. Optimization process was conducted using EP via Matlab environment to find the best energy profile in order to get the optimum load curve of energy profile. Lastly, the cost reduction has been analyzed while the optimum load profile has been compared between conventional ToU, EToU and EP EToU.

3.1 Project Flow of the Research

The project started from the literature review. A few research had been study in order to get the best method to optimize the load profile. The second step was data collection. The data was collected in commercial sector. The data used in this research is an average of one year data for a month. After the data was collected, a normal calculation was conducted. This is to differentiate between ToU and EToU tariff scheme. Tariff C1 and C2 were used to compare for the best tariff

The total electricity cost were determined by the normal calculation and the differences between ToU and EToU were analyzed. The optimization was done by using Evolutionary Programming. The reduction of electricity cost was analyzed and the percentage of reduction was determined after the optimization has been done. The flowchart of the project flow was shown as Figure 3.1.

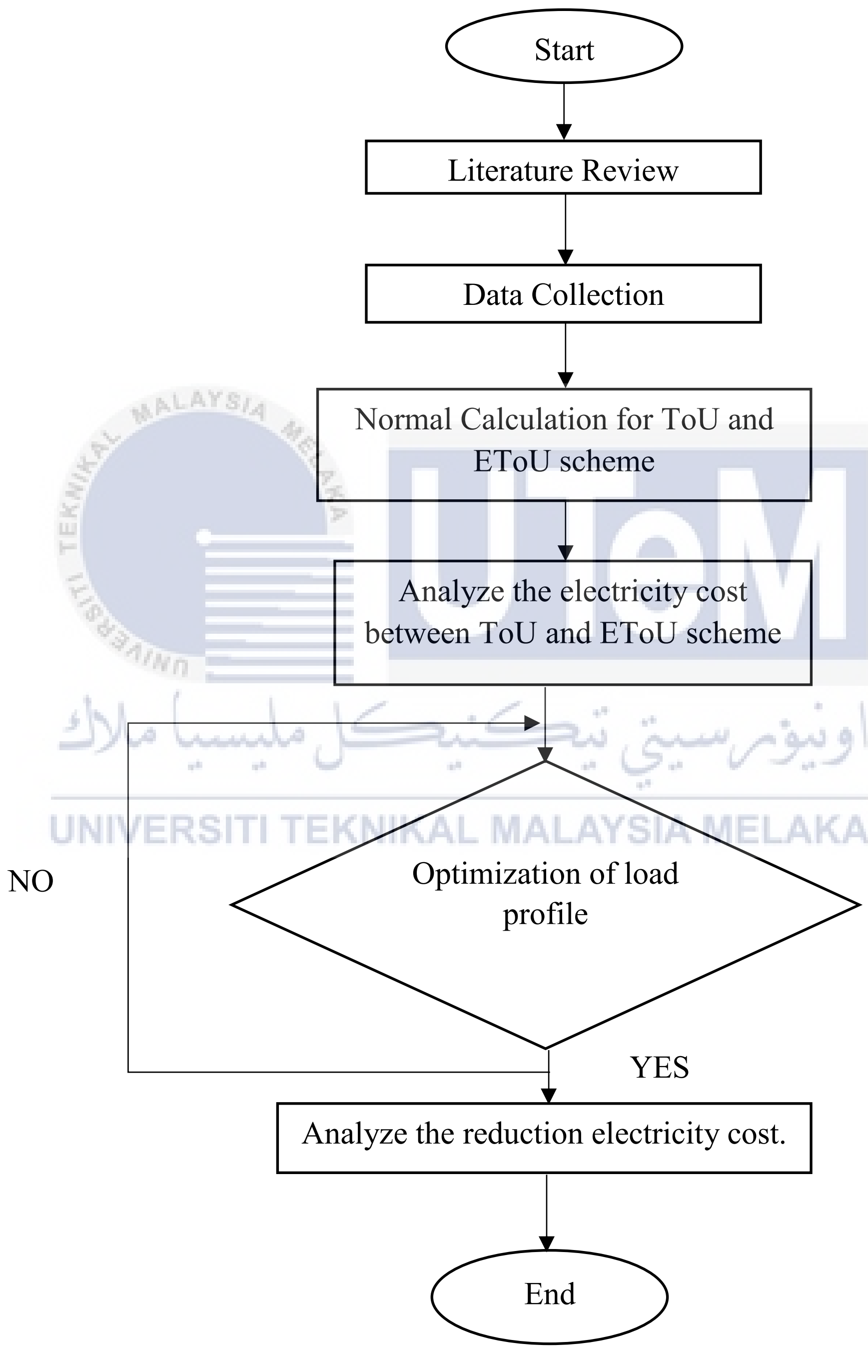


Figure 3.1: Flowchart of the project flow

3.2 Formulation of ToU and EToU Scheme

3.2.1 ToU scheme

Steps for calculating electricity cost in ToU scheme:

1. The total power for Peak Time, P_{PTT} and Off Peak Time, P_{OPTT} are calculated based on average energy load profile.
2. The maximum demand, P_{MD} is identified.
3. The total cost for 24 hour energy load profile data are calculated.

$$ToU_{TC} = (P_{PTT} \text{ x } R_{PTT}) + (P_{OPTT} \text{ x } R_{OPTT}) + (P_{MD} \text{ x } R_{MDT}) \quad (1)$$

Where:

ToU_{TC} = Total cost for ToU rates

R_{PTT} = rates for Peak Time in ToU scheme

R_{OPTT} = rates for Off Peak Time in ToU scheme

R_{MDT} = rates for Maximum Demand in ToU scheme

3.2.2 EToU scheme

Steps for calculating electricity cost in EToU scheme:

1. The total power for Peak Time, P_{PTE} , Medium Peak Time, P_{MPTE} and Off Peak Time, P_{OPTE} are calculated based on average energy load profile.
2. The maximum demand, P_{MD} is identified.
3. The total cost for 24 hour energy profile load data are calculated.

$$EToU_{TC} = (P_{PTE} \text{ x } R_{PTE}) + (P_{PTE} \text{ x } R_{PTE}) + (P_{OPTE} \text{ x } R_{OPTE}) + (P_{MD} \text{ x } R_{MDE}) \quad (2)$$

Where:

$ETOU_{TC}$ = Total cost for EToU rates

R_{PTE} = rates for Peak Time in EToU scheme

R_{MPTE} = rates for Peak Time in EToU scheme

R_{OPTE} = rates for Off Peak Time in EToU scheme

R_{MDE} = rates for Maximum Demand in EToU scheme

The flowchart of the normal calculation are shown in Figure 3.2.

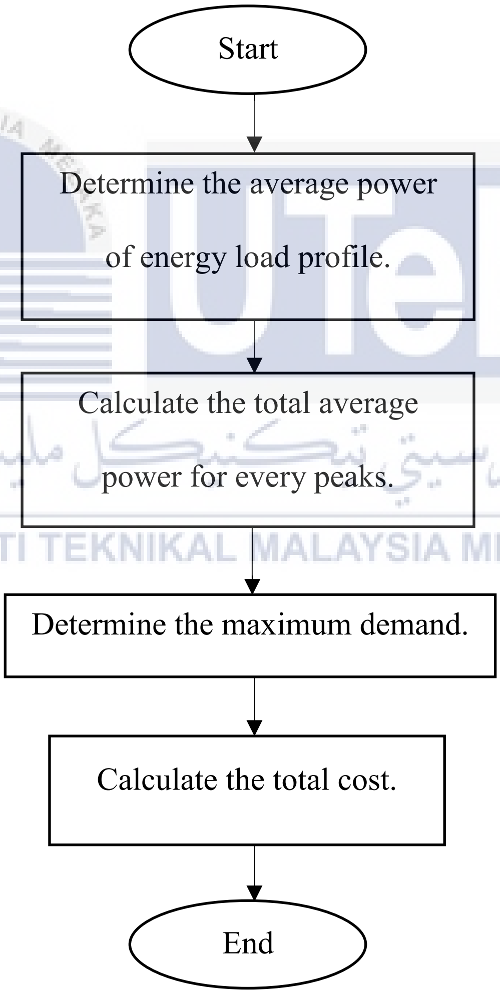


Figure 3.2: Flowchart of the normal calculation for ToU and EToU

3.3 Optimization of Load Profile using Evolutionary Programming (EP)

There are several steps to develop EP. The steps are:

1. Random generation of initial population
   a. The procedure for the optimal solution is done by deciding a population of candidate solution over a number of generations randomly.
2. Fitness computation
   a. The strength of each candidate solution is determined by its fitness function which is evaluated based on the constraint in the objective function of the optimization process.
3. Mutation
   a. Others will combine through a process of mutation to breed a new population.
4. Combination
   a. Combination process will occour after the mutation that will combine the parent and offspring.
5. Tournament selection
   a. Tournament selection is choosing the survival to next generation
6. Convergence test
   a. The new population is evaluated and the process repeated until it reaches the convergence state.

The mathematical formulation of DSM techniques as optimization problem where the optimization problem is generally determined by clarifying the following question:

1. What does the objective needed to be achieved of the load profile?
2. What are the variables of the problem?
3. What constraints must be imposed on variables to simulate properly actual variables?
   a. Total optimization power ≥ actual power
   b. Everyday is consider as a weekdays = same tariff charges

Figure 3.3 shows the flowchart of the optimization process using Evolutionary Programming.

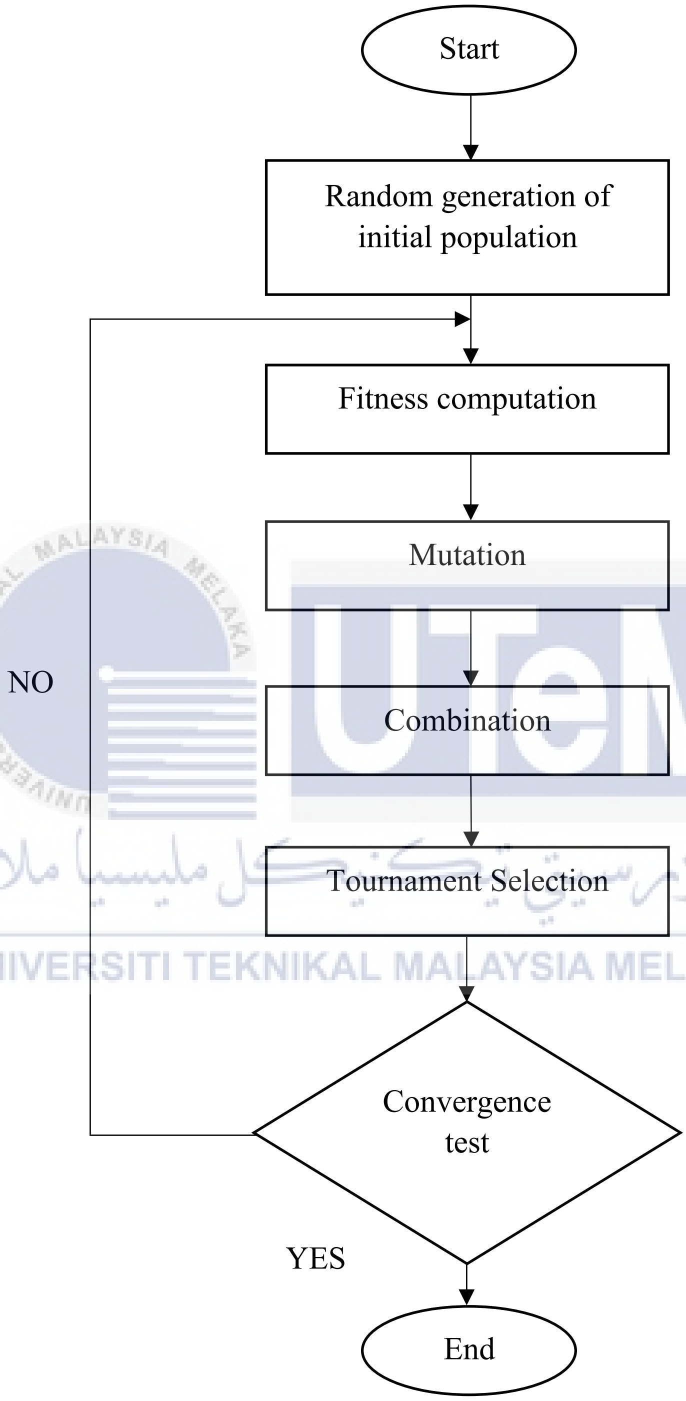


Figure 3.3: The optimization process using EP

3.4 Implementing of EP to determine the optimum price

1. Random generation of initial population

Input system data includes load profile for one month power consumption were used. The constraints for this data is, everyday is consider as weekdays. Any public holidays and weekends will be ignore.

2. Fitness computation

For the fitness calculation, the equation (1) and (2) were used to achieve the objective function that need to be optimized. The objective function in this study is to reduce the electricity cost.

3. Mutation

The mutation scale determine the convergence rate. Large search step will lead to large computation time.

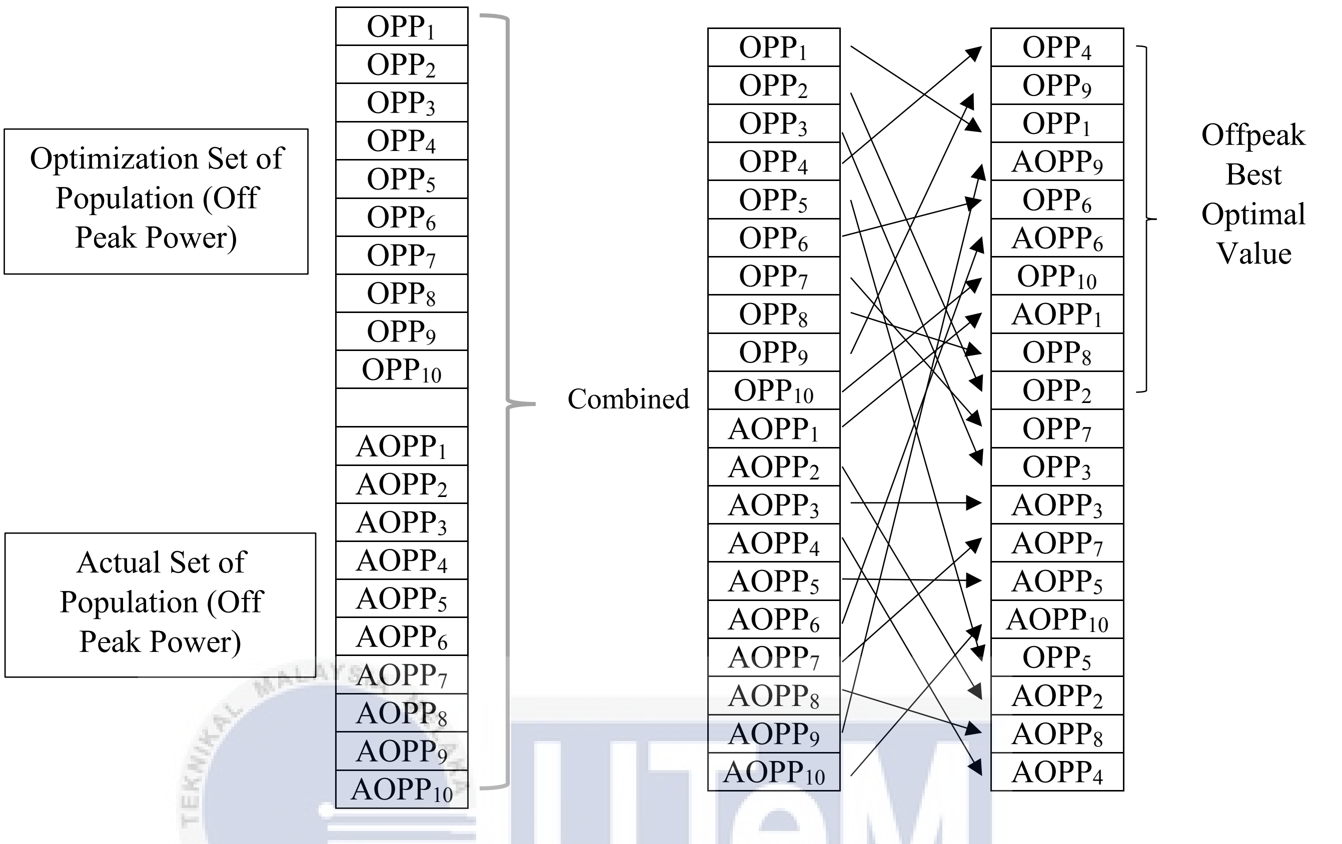
4. Combination

At this stage, the fitness calculation is recalculated to calculate the electricity cost in order to get new fitness value based on the new generate state variables during mutation process. The actual and optimization power were combined together and this combination of actual and optimization were contested in a tournament.

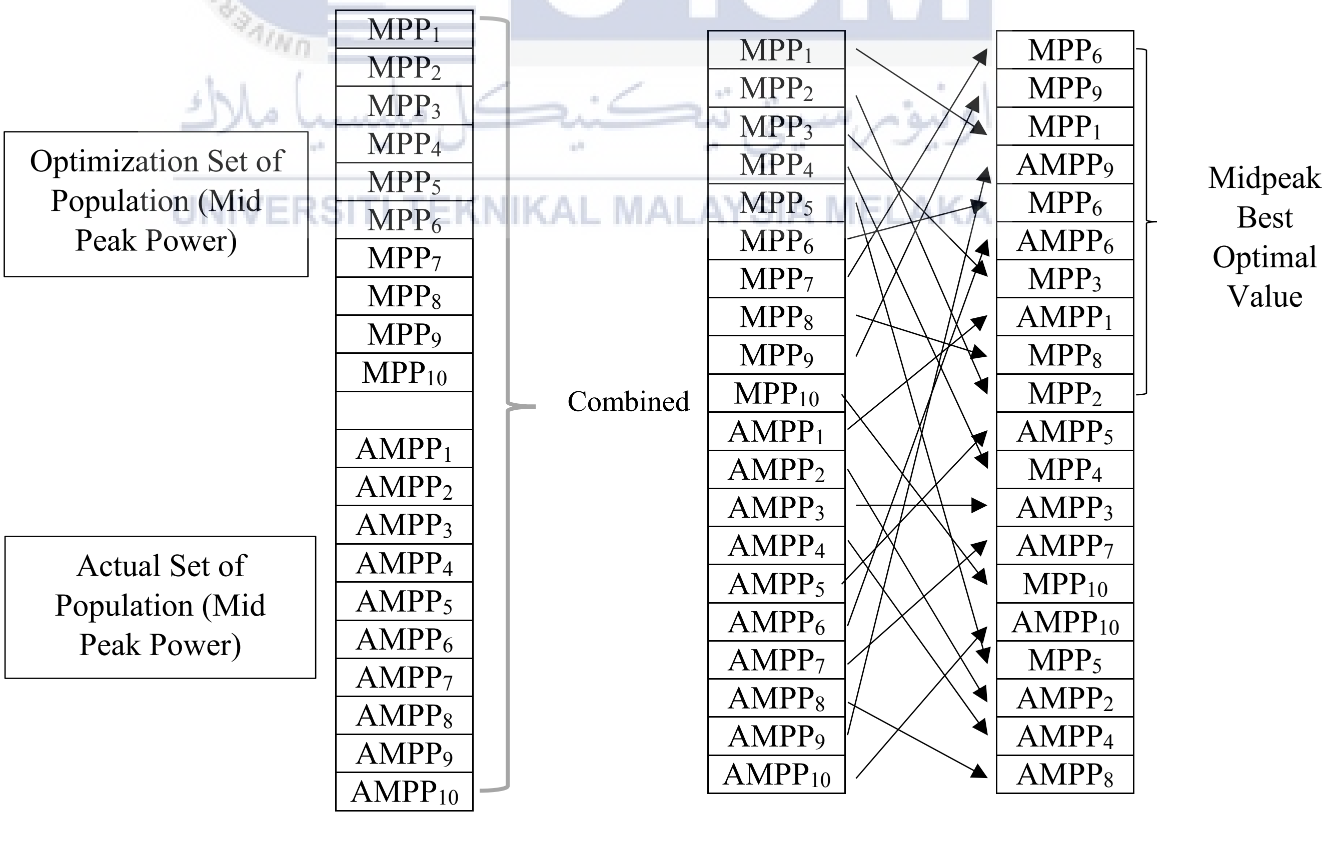
5. Tournament selection

To choose the survivals to 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 was contested randomly. The priority selection strategy is used throughout the selection strategy process based on the objective function.

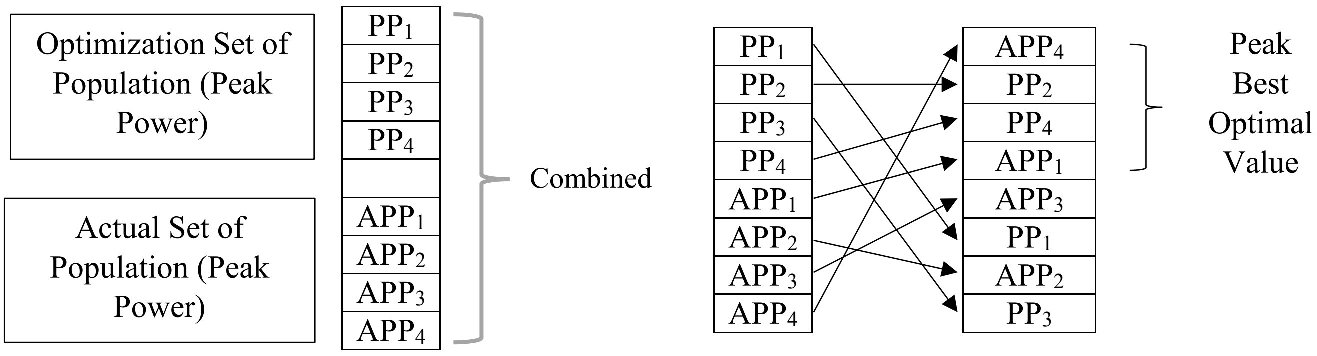
The illustration of mutation, combination and tournament selection were described by the Figure 3.4(a), Figure 3.4(b), and Figure 3.4(c).


Optimization Set of Population (Off Peak Power)
Actual Set of Population (Off Peak Power)
OPP1 OPP2 OPP3 OPP4 OPP5 OPP6 OPP7 OPP8 OPP9 OPP10
AOPP1 AOPP2 AOPP3 AOPP4 AOPP5 AOPP6 AOPP7 AOPP8 AOPP9 AOPP10
Combined
OPP1 OPP2 OPP3 OPP4 OPP5 OPP6 OPP7 OPP8 OPP9 OPP10
AOPP1 AOPP2 AOPP3 AOPP4 AOPP5 AOPP6 AOPP7 AOPP8 AOPP9 AOPP10
OPP4 OPP9 OPP1 AOPP9 OPP6 AOPP6 OPP10 AOPP1 OPP8 OPP2
OPP7 OPP3 AOPP3 AOPP7 AOPP5 AOPP10 OPP5 AOPP2 AOPP8 AOPP4
Offpeak Best Optimal Value

(a)


Optimization Set of Population (Mid Peak Power)
Actual Set of Population (Mid Peak Power)
MPP1 MPP2 MPP3 MPP4 MPP5 MPP6 MPP7 MPP8 MPP9 MPP10
AMPP1 AMPP2 AMPP3 AMPP4 AMPP5 AMPP6 AMPP7 AMPP8 AMPP9 AMPP10
Combined
MPP1 MPP2 MPP3 MPP4 MPP5 MPP6 MPP7 MPP8 MPP9 MPP10
AMPP1 AMPP2 AMPP3 AMPP4 AMPP5 AMPP6 AMPP7 AMPP8 AMPP9 AMPP10
MPP6 MPP9 MPP1 AMPP9 MPP6 AMPP6 MPP3 AMPP1 MPP8 MPP2
AMPP5 MPP4 AMPP3 AMPP7 MPP10 AMPP10 MPP5 AMPP2 AMPP4 AMPP8
Midpeak Best Optimal Value

(b)



(c)

Figure 3.4: The process of tournament selection for off-peak,mid-peak and peak power

The set of the Offpeak, Midpeak and Peak best optimal value were tabulated to be a set of load profile for a day as show in Table 3.1.

Table 3.1: Load profile

OFF-PEAK								MID-PEAK			PEAK
12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am
OPP_4	OPP_9	OPP_1	$AOPP_9$	OPP_6	$AOPP_6$	OPP_{10}	OPP_8	MPP_6	MPP_9	MPP_1	APP_4

MID-PEAK		PEAK			MID-PEAK					OFF-PEAK	
12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
$AMPP_9$	MPP_6	PP_2	PP_4	APP_1	$AMPP_6$	MPP_3	$AMPP_1$	MPP_8	MPP_2	OPP_8	OPP_2

6. Convergence test

Convergence test is required to determine the stopping criteria of the evolution. In this study, the convergence test was set below than 21. After the 21 iteration, the process will stop.

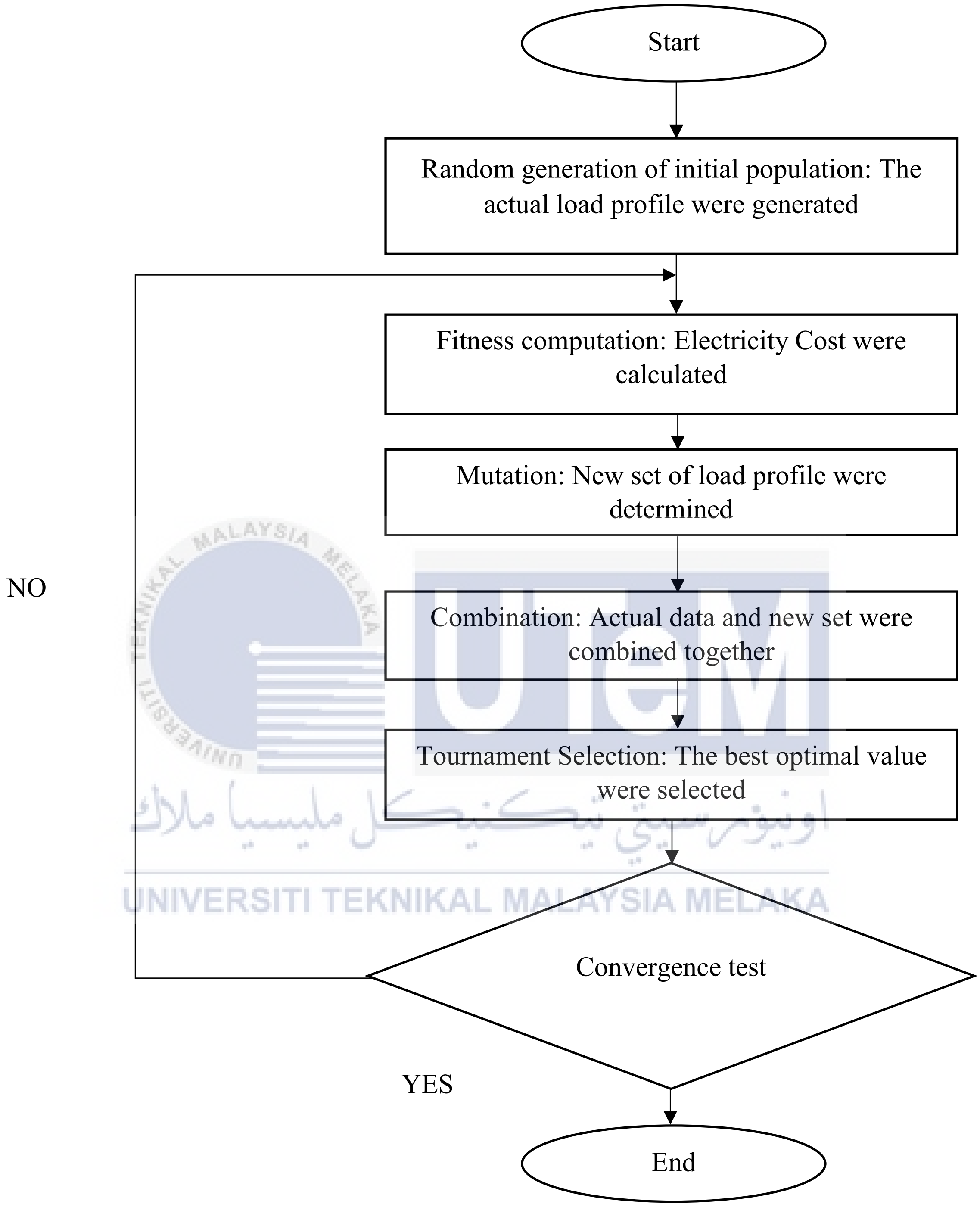


Figure 3.5: The flowchart of optimization method

CHAPTER 4

RESULT

4.0 Overview

This section have three parts where Part 1 shows the results of using normal calculation to differentiate the electricity cost. Two types of tariff (ToU and EToU) were used. Two category of tariff were analyzed which are Medium Voltage General Commercial Tariff (C1) and Medium Voltage Peak/Off-peak Commercial Tariff (C2). For Part 2, the results present the optimization load profile for EToU by each day using the Evolutionary Programming while the analysis of cost reduction discussion will be the last sub-sectioned.

4.1 Case Study

This study focused on 4 cases. The conventional method on these cases were compared with optimization result. The cases are:

- Case 1: C1 ToU
- Case 2: C2 ToU
- Case 3: C1 EToU
- Case 4: C2 EToU

4.2 Normal Calculation between ToU and EToU scheme

Figure 4.1 shows the graph for average power consumption in a year for a month versus time. The graph shows the power fully consumed during peak time zone. From the graph, the maximum power was determined which is 462kW at 4.00 PM which is considered as maximum demand. The position of maximum demand is in peak hour for both tariff.

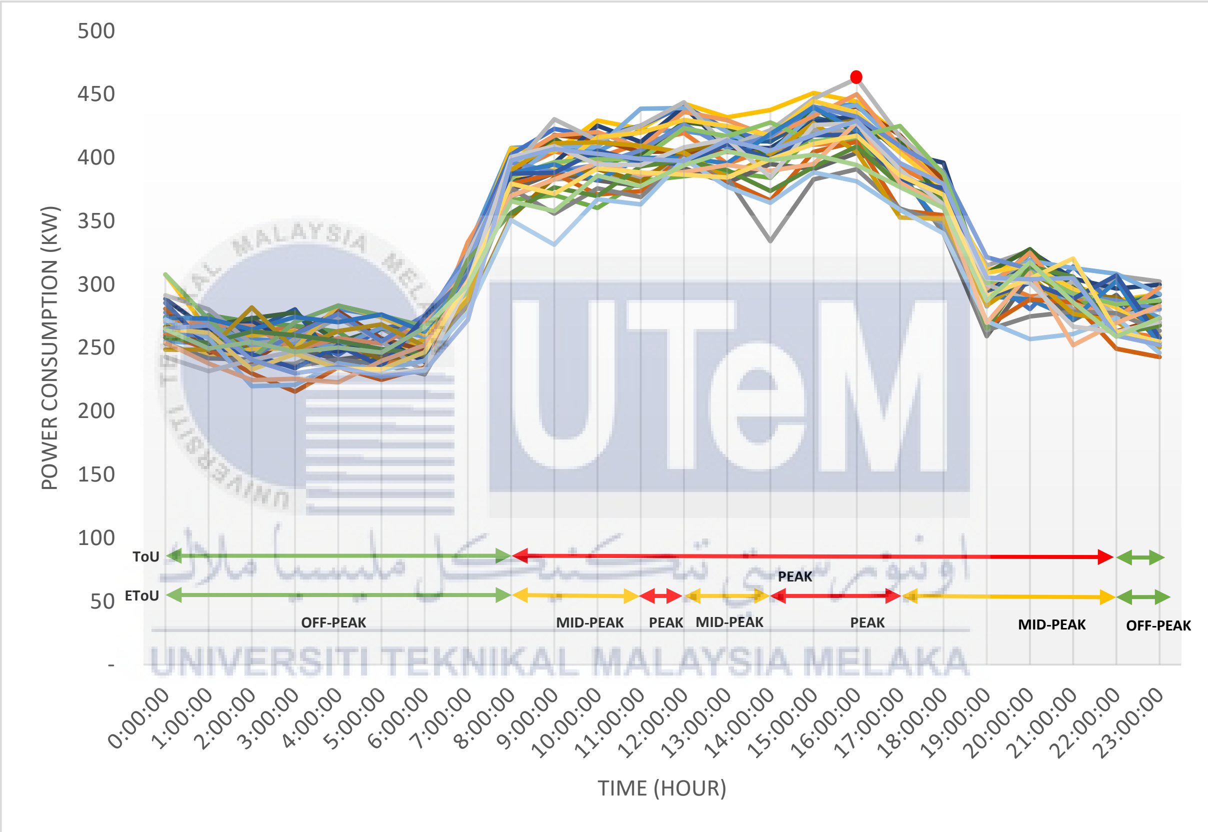


Figure 4.1: Power consumption versus time

The average power for one month of load profile from hospital and the total power consumption is summarized in Table 4.1. Based on load profile refered on Appendix A, total off peak, medium peak and peak power were calculated. For Case 1 since ToU in tariff category C1 defined as flat tariff, there is no time zone in this category. For Case 2, tariff category C2 in ToU tariff scheme only offered two tariff, so there is no power in medium peak zone. For Case 3 and 4 which are EToU, there is three time zones in both category (C1 and C2), so the power tabulated is divided by three time zones.

Table 4.1: Total power for different tariff category

	Case 1	Case 2	Case 3	Case 4
Total Off Peak Power (kW)		79 233	79 233	79 233
Total Medium Peak Power (kW)	237 800	-	109 246	109 246
Total Peak Power (kW)		158 567	49 321	49 321
Maximum Demand (MD)	462	462	462	462
Total (kW)	**237 800**	**237 800**	**237 800**	**237 800**

Based on the Table 4.1, the total electricity cost were calculated using formula (1) and (2) and tabulated in Table 4.2.

Table 4.2: The differences of electricity cost for ToU and EToU tariff scheme

	Case 1	Case 2	Case 3	Case 4
Total Off Peak Electricity Cost (RM)		17 748	22 264	17 748
Total Medium Peak Electricity Cost (RM)	86 797	-	39 001	37 034
Total Peak Electricity Cost (RM)		57 877	28 804	31 368
Maximum Demand (RM)	14 011	20 836	15 722	22 381
Total EC (RM)	**100 808**	**96 461**	**105 791**	**108 531**

Figure 4.2 shows the comparison for electricity cost between ToU and EToU tariff. From the graph, ToU tariff shows lower electricity cost than EToU tariff in both tariff

category (C1 and C2). In ToU tariff scheme, C1 leads by 4.31% than C2 meanwhile in EToU tariff scheme, C1 lags by 2.59% than C2.

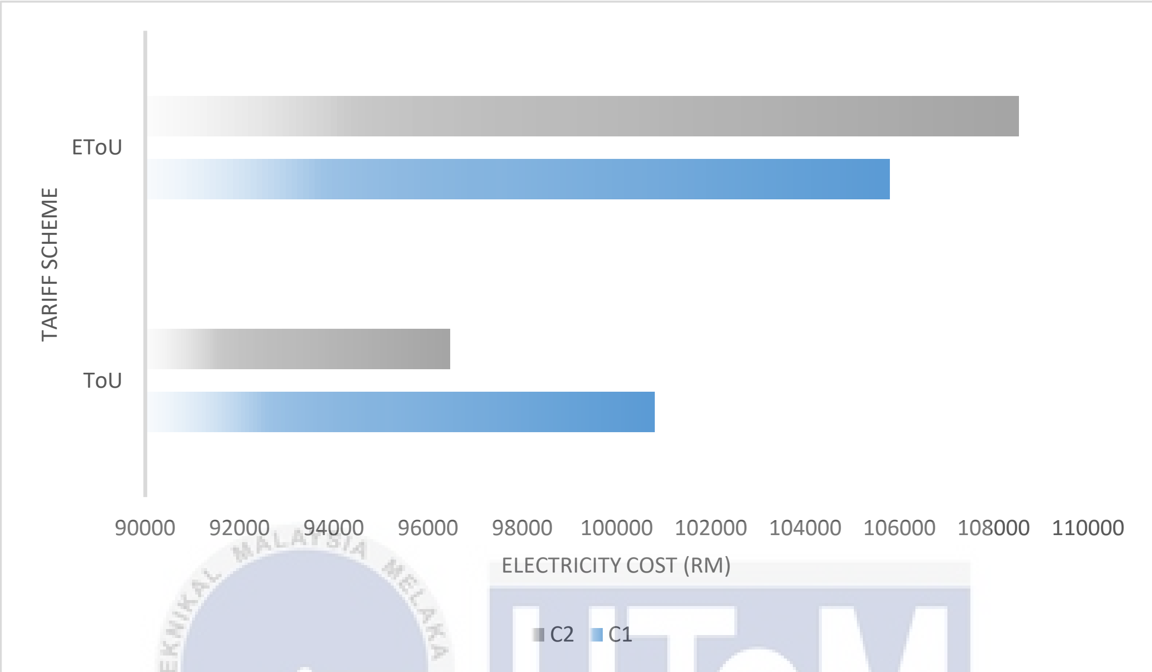


Figure 4.2: Electricity Cost for ToU and EToU tariff scheme in category C1 and C2

4.3 Optimization of Load Profile in EToU tariff scheme using EP

Enhanced Time of Used (EToU) have three time zones which are off-peak, mid-peak and peak zones. By using the evolutionary programming, the optimization focused on the time zones. Figure 4.3 shows the average per day load profile after optimization was done. The blue line indicate the actual power while the green line indicate the optimization power.

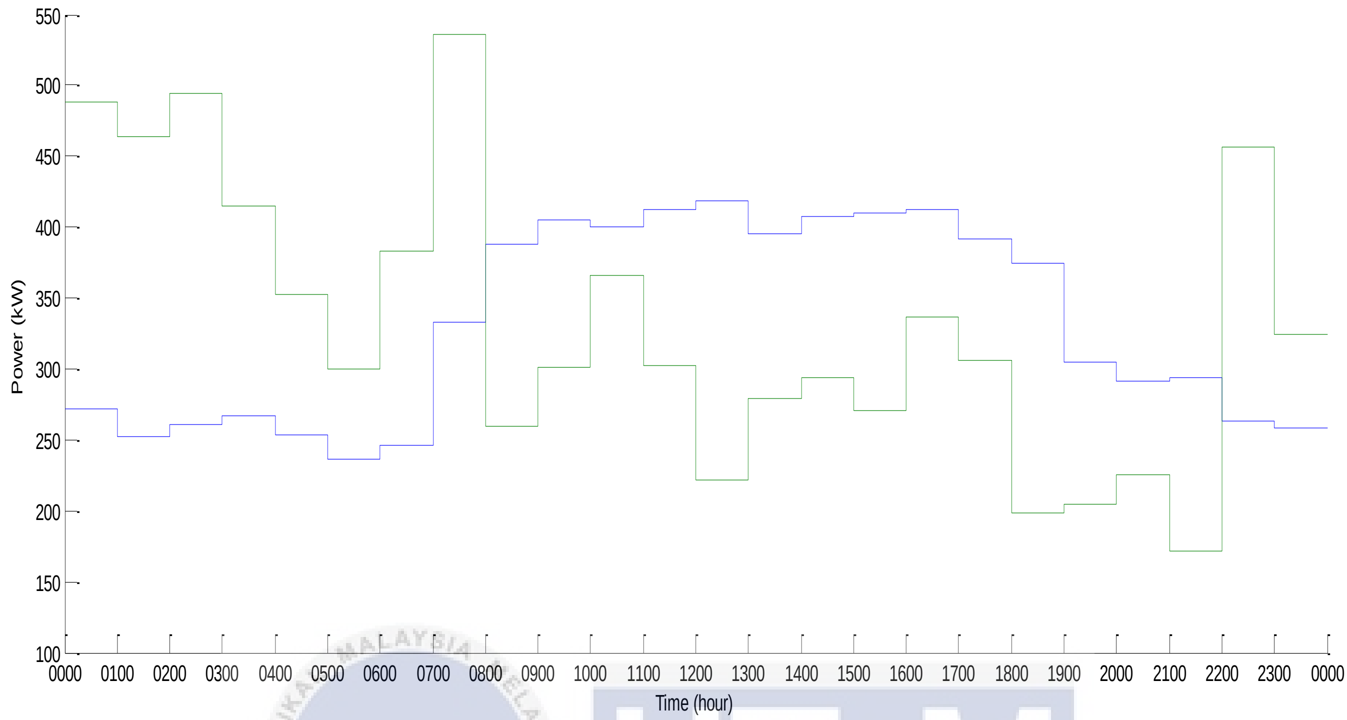
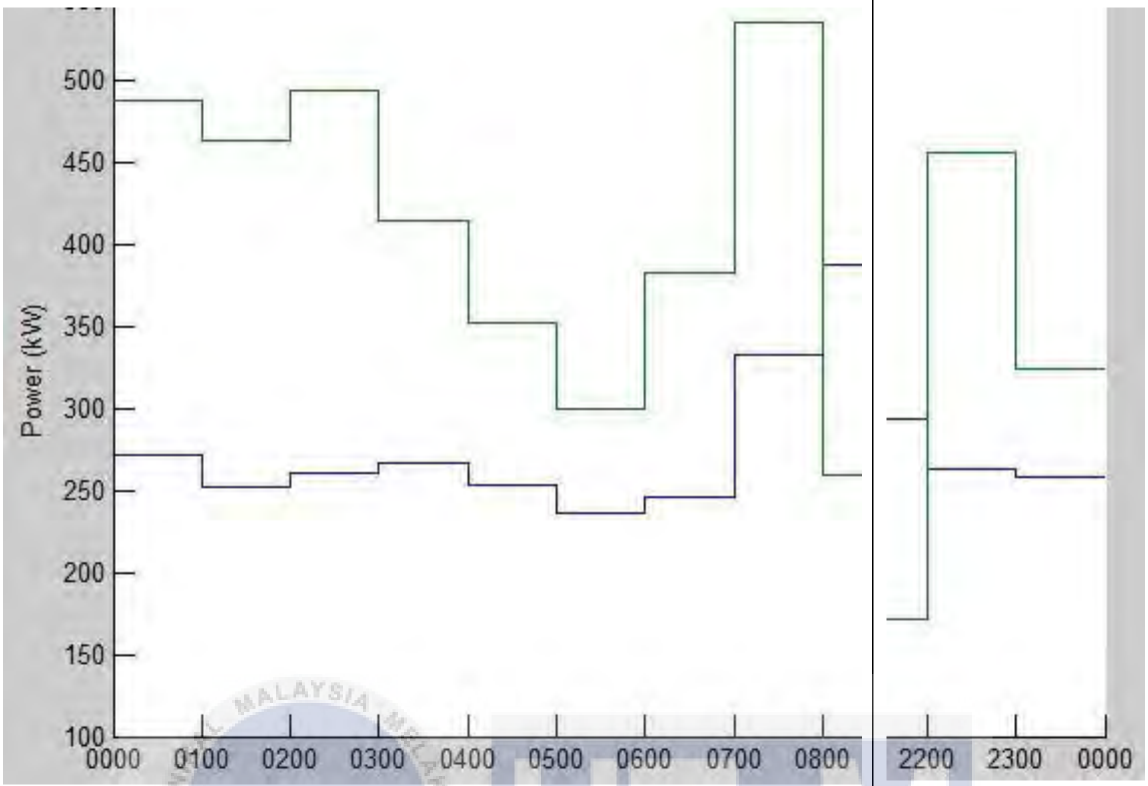


Figure 4.3: The actual load profile compare with the optimization load profile

From 0000 to 0800 and 2200 to 0000 show in Figure 4.4 (a) Figure 4.4(b) which is in off-peak time zone, the optimization load profile is higher than the actual load profile because the valley filling load shape was applied. Low demand periods are filled by building off peak capacities. By improving the off peak power, it will also improve the system load factor. The graphs show the increasing of load profile by 35.5% before the optimization was done.



(a) (b)

Figure 4.4: Optimization power based on time zoning (offpeak)

Meanwhile from 0800 to 1100, 1200 to 1400, and 1700 to 2200 show in Figure 4.5(a), Figure 4.5(b) and Figure 4.5(c) which are in mid-peak time zone, the optimization load profile are lower than the actual load profile because the clipping load shape were applied. High demands periods are ‘clipped’ and the utility load is reduced during this hours. 26.5% power from the actual was decreased using this hours.

Same goes to 1100 to 1200 and 1400 to 1700 show in Figure 4.6(a) and Figure 4.6(b), the clipping load shape were applied. At this hour, 27.2% were cut down after the optimization. But even after the optimization process, the total power consumption does not reduce.

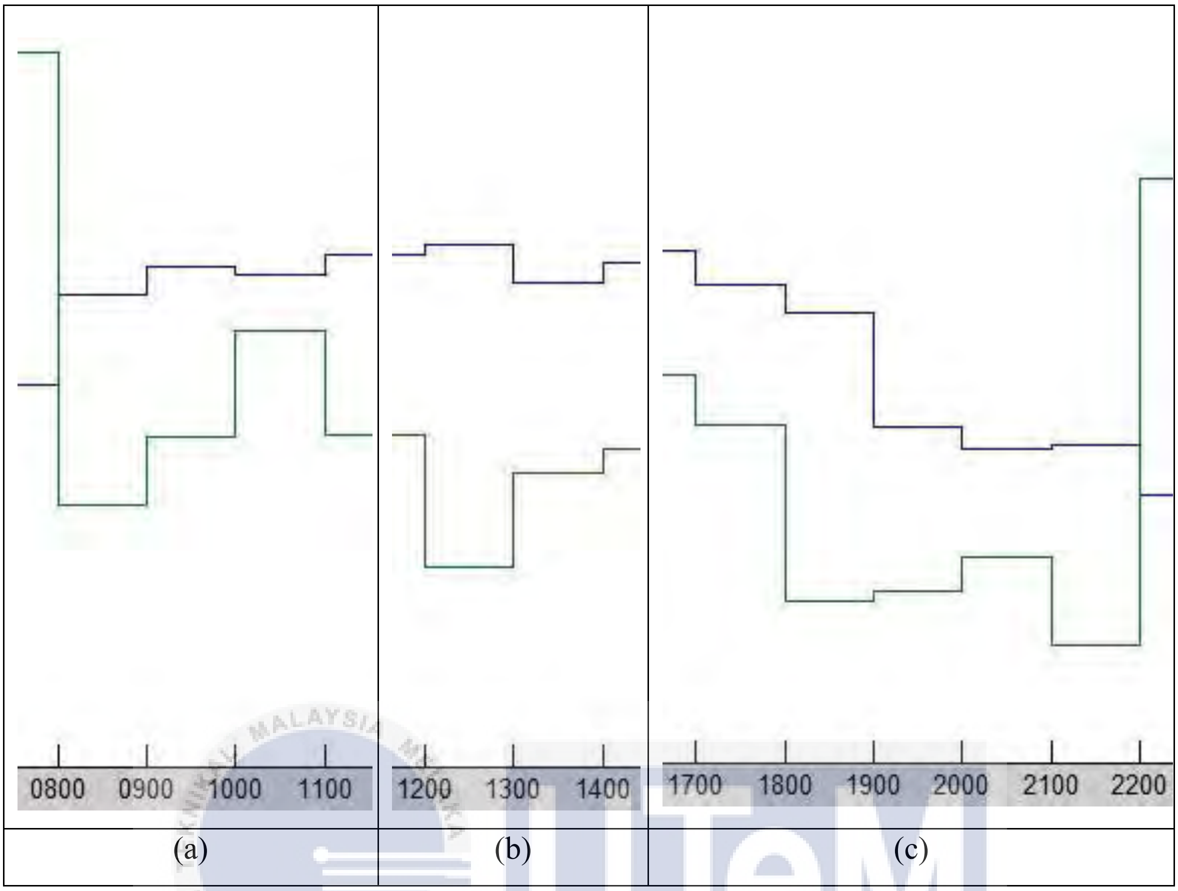


Figure 4.5: Optimization power based on time zoning (midpeak)

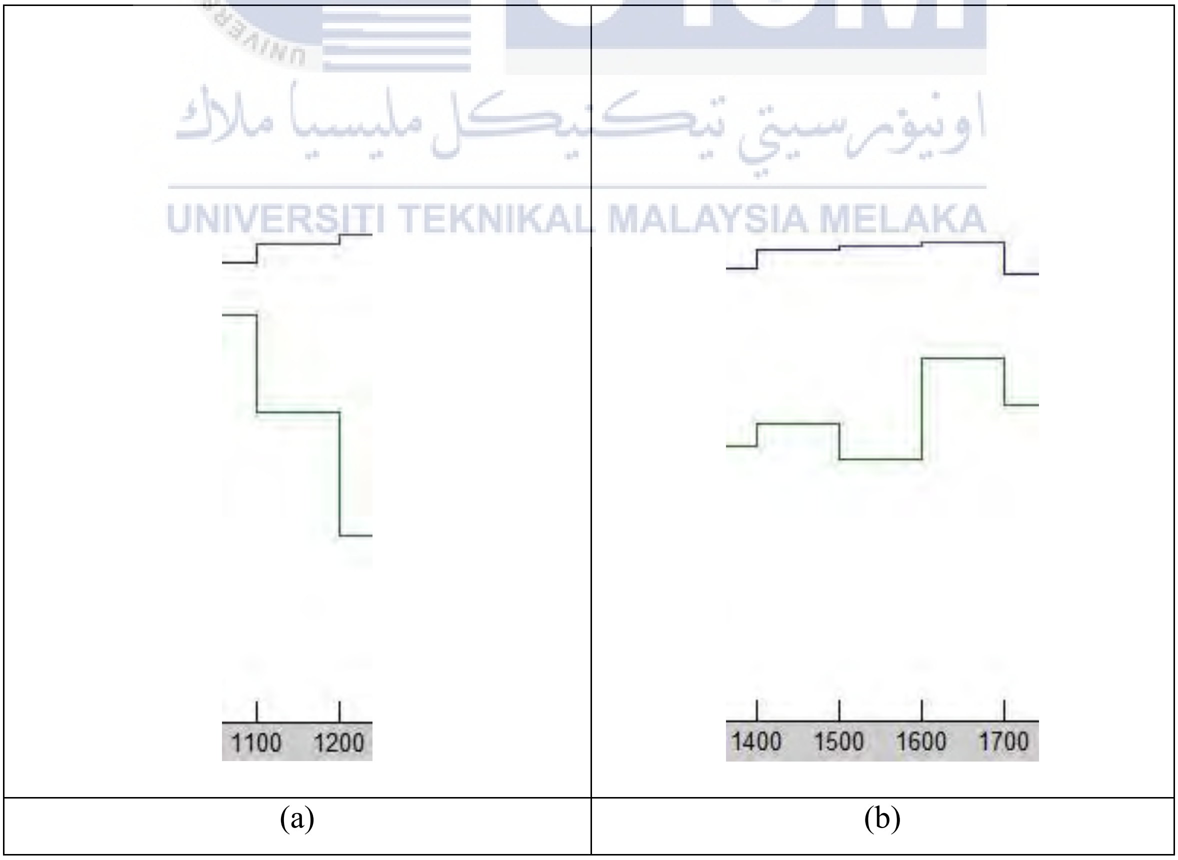


Figure 4.6: Optimization power based on time zoning (peak)

4.4 Analysis of Electricity Cost Reduction using Optimization Technique

The differences of total energy load in each times zones were tabulated in Table 4.3. The table shows at the off-peak time zones, the optimization value (EP EToU) increased, and at the mid-peak and peak time zones, the optimization value (EP EToU) decreased. This can effect the energy cost because the tariff scheme in off-peak time zones is much cheaper than mid-peak and peak time zone. The maximum demand after optimization process is more higher than the actual data but the value falls in off-peak region so it will not be charged. This leads to lower energy cost.

Table 4.3: The differences of power consumption for ToU and EToU tariff scheme

	Case 1	Case 2	Case 3	Case 4	EP EToU C1	EP EToU C2
Total Off Peak Power (kW)		79 233	79 233	79 233	122 848	122 848
Total Medium Peak Power (kW)	237 800	-	109 246	109 246	80 268	80 268
Total Peak Power (kW)		158 567	49 321	49 321	35 920	35 920
Maximum Demand (MD)	462	462	462	462	-	-
Total (kW)	**237 800**	**237 800**	**237 800**	**237 800**	**239 036**	**239 036**

Table 4.4 shows the overall energy cost for both tariff category compared with optimization cost and Figure 4.7 shows graph of comparison between actual cost and optimization cost. For tariff category C1, the energy cost for EP EToU is 20.45% and 16.52% cheaper than energy cost for Case 1 and 3. And for tariff category C2, the energy cost for EP EToU is 28.52% and 19.58% cheaper than energy cost Case 2 and 4 correspondently. The average reduction is estimated between RM15 000 to RM20 000 for a month. If the significant reduction is happened in a year, more money will be saved.

Table 4.4: The differences of energy cost with optimization load profile

	Energy Cost (RM)
Case 1	100 808
Case 2	96 461
Case 3	105 791
Case 4	108 531
EP EToU C1	84 153
EP EToU C2	77 574

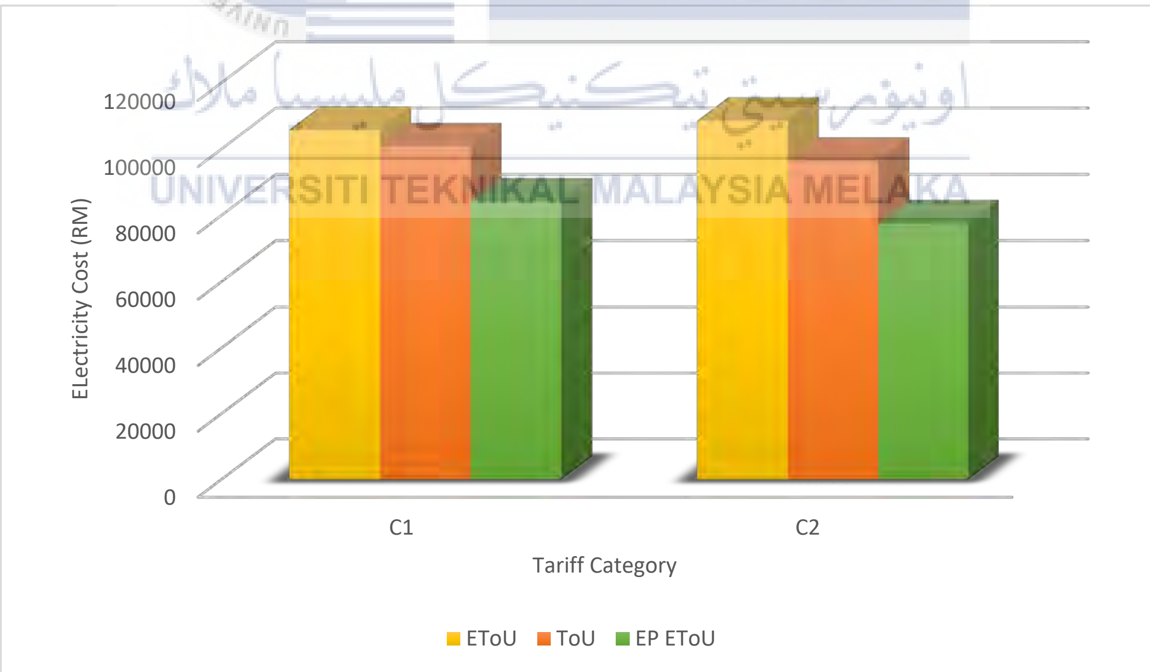


Figure 4.7: The comparison of energy cost between actual and optimization load profile

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion & Recommendation

As mentioned earlier in the introduction chapter, the intent of this project is to differentiate between TOU and EToU tariff scheme and to optimize the energy load profile for a commercial installation. The first objectives have been achieved through normal calculation by using commercial sector data. The research shows TOU tariff scheme give lower electricity bill than EToU tariff scheme. Optimization process using Evolutionary Programming of energy load profile has been made and the results shows changes in load profile. This results shows significant bill reduction, therefore energy profile optimization is needed. In average, RM15 000 to RM20 000 saving can be made in a month when optimization has be done. One of the limitations of the research is when using the average data, the public holidays and the weekend should be ignore while the days give big impact in reducing electricity cost.

In future works, the data used should be in various energy profile and not using one type of profile data only to get the more convincing solution. The other method should be used in order to compare with the existing method to optimize the energy load profile. As the data research is a hospital's power profile, subclasses will be made for optimization in order to divide the type of load.

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APPENDIX A

Table 7.1: Actual average power (kW) in a day for day 1 to day 10

	1	2	3	4	5	6	7	8	9	10
0:00:00	255	272	266	308	278	262	264	281	263	267
1:00:00	254	252	250	263	264	276	264	244	249	262
2:00:00	257	261	237	260	248	270	264	239	274	251
3:00:00	255	267	237	263	261	267	280	261	250	251
4:00:00	281	253	252	237	244	263	236	279	241	256
5:00:00	275	236	265	244	265	240	241	257	245	241
6:00:00	263	246	249	257	271	252	248	248	242	245
7:00:00	328	333	300	319	324	304	310	295	288	281
8:00:00	408	388	369	407	402	366	379	383	375	353
9:00:00	410	405	383	405	423	370	395	418	388	384
10:00:00	405	400	384	429	417	360	402	414	382	391
11:00:00	422	412	385	423	425	382	397	405	377	381
12:00:00	421	419	399	443	441	385	403	405	392	405
13:00:00	416	395	412	432	422	389	413	405	380	412
14:00:00	416	407	405	438	412	384	413	404	395	402
15:00:00	439	410	422	451	438	419	432	437	391	426
16:00:00	443	412	421	444	426	414	424	440	404	431
17:00:00	409	392	388	417	409	379	411	418	390	407
18:00:00	383	374	368	376	373	382	371	382	340	372
19:00:00	283	305	315	311	305	298	289	301	259	300
20:00:00	325	291	327	317	281	313	319	319	306	309
21:00:00	272	294	279	299	314	286	297	288	272	291
22:00:00	289	263	307	287	282	285	283	263	292	290
23:00:00	274	258	302	292	268	292	292	273	254	270

Table 7.2: Actual average power (kW) in a day for day 11 to day 20

	11	12	13	14	15	16	17	18	19	20
0:00:00	289	274	270	273	292	274	262	308	274	260
1:00:00	264	267	271	268	280	243	259	272	273	249
2:00:00	270	273	252	268	253	249	243	241	265	230
3:00:00	253	278	254	248	257	250	261	271	274	215
4:00:00	247	254	251	258	274	283	277	283	270	235
5:00:00	257	265	266	253	255	274	255	276	276	225
6:00:00	239	263	259	271	230	260	275	267	263	234
7:00:00	313	309	297	317	324	290	317	294	309	302
8:00:00	380	379	383	397	390	385	396	385	388	379
9:00:00	396	415	409	417	430	391	389	396	395	388
10:00:00	425	394	408	420	414	416	394	399	382	371
11:00:00	412	403	439	408	425	420	406	399	400	374
12:00:00	440	428	439	436	444	430	426	423	400	401
13:00:00	408	424	420	430	408	425	408	417	395	382
14:00:00	407	400	403	416	422	418	417	428	419	366
15:00:00	428	439	435	433	447	445	440	413	440	405
16:00:00	433	419	441	450	462	436	432	416	421	413
17:00:00	404	414	409	408	416	404	409	425	386	358
18:00:00	396	363	378	378	388	376	389	387	345	355
19:00:00	294	309	301	297	300	309	321	301	291	267
20:00:00	326	328	319	325	287	315	312	310	288	288
21:00:00	305	298	313	285	302	297	291	293	273	286
22:00:00	297	273	308	274	276	282	287	284	303	249
23:00:00	300	286	292	297	280	260	281	287	252	243

Table 7.3: Actual average power (kW) in a day for day 21 to day 30

	21	22	23	24	25	26	27	28	29	30
0:00:00	254	248	285	258	272	254	243	265	265	265
1:00:00	242	249	251	254	257	238	232	262	268	250
2:00:00	241	282	245	263	220	224	240	233	240	255
3:00:00	236	248	234	260	221	226	247	245	230	247
4:00:00	241	263	252	255	238	223	235	234	235	250
5:00:00	237	269	235	249	232	240	229	233	227	246
6:00:00	229	251	274	245	240	252	233	246	232	266
7:00:00	287	288	307	319	278	303	301	301	272	300
8:00:00	376	390	387	356	351	370	401	379	398	366
9:00:00	356	411	388	377	331	383	409	371	407	358
10:00:00	376	412	406	370	367	396	395	392	403	386
11:00:00	369	409	397	393	363	387	394	388	399	378
12:00:00	400	404	395	398	399	389	408	387	397	394
13:00:00	384	385	411	390	377	394	415	384	414	405
14:00:00	334	402	399	374	365	390	385	399	406	398
15:00:00	383	427	418	393	388	395	426	411	418	402
16:00:00	391	404	418	409	381	428	427	417	429	394
17:00:00	360	353	382	378	359	380	390	386	396	377
18:00:00	349	352	376	367	340	362	363	371	379	360
19:00:00	264	283	290	265	271	270	305	291	305	287
20:00:00	275	307	301	314	257	309	301	305	304	317
21:00:00	279	277	289	306	261	252	267	321	305	286
22:00:00	277	271	307	261	273	270	262	263	260	259
23:00:00	263	250	258	267	246	283	271	255	252	273

APPENDIX B

Table 7.4: Optimization average power (kW) in a day for day 1 to day 10

	1	2	3	4	5	6	7	8	9	10
0:00:00	451	488	389	545	418	433	363	495	331	454
1:00:00	466	464	388	360	473	474	415	395	336	475
2:00:00	331	494	411	481	406	458	387	341	377	334
3:00:00	469	415	293	380	363	340	493	450	340	401
4:00:00	462	352	430	317	381	492	394	428	408	383
5:00:00	349	300	448	336	483	359	455	401	423	341
6:00:00	367	383	379	419	358	401	460	381	383	413
7:00:00	519	536	482	488	575	386	497	442	457	419
8:00:00	376	260	296	288	396	310	345	215	256	178
9:00:00	211	301	207	294	421	346	198	235	272	290
10:00:00	211	366	341	232	215	298	298	313	208	255
11:00:00	284	302	312	311	269	212	318	215	337	311
12:00:00	319	222	327	380	245	257	225	282	280	322
13:00:00	250	279	345	269	412	289	279	260	317	405
14:00:00	409	294	345	267	288	194	231	299	379	253
15:00:00	253	271	276	240	339	351	316	405	338	314
16:00:00	236	337	236	416	232	210	309	298	229	258
17:00:00	380	306	372	260	272	228	315	389	203	348
18:00:00	302	198	274	305	191	272	354	271	265	223
19:00:00	153	205	184	223	272	288	149	272	181	248
20:00:00	196	225	179	305	269	274	220	309	196	296
21:00:00	142	171	178	291	258	156	274	279	180	217
22:00:00	541	456	441	415	374	438	355	348	479	348
23:00:00	514	325	398	520	340	382	435	381	480	403

Table 7.5: Optimization average power (kW) in a day for day 11 to day 20

	11	12	13	14	15	16	17	18	19	20
0:00:00	475	447	393	465	352	387	482	389	463	449
1:00:00	344	349	426	417	516	395	374	440	436	421
2:00:00	431	488	428	383	307	347	355	330	426	316
3:00:00	375	475	460	428	314	440	332	485	395	264
4:00:00	306	324	359	461	465	497	460	509	457	358
5:00:00	333	348	440	349	402	512	345	517	362	288
6:00:00	352	370	488	427	360	393	497	412	316	307
7:00:00	476	462	372	477	503	441	468	398	492	451
8:00:00	265	222	324	211	368	379	383	238	253	326
9:00:00	357	251	355	395	217	355	236	327	212	285
10:00:00	395	340	253	231	400	220	236	307	202	198
11:00:00	241	324	279	250	368	328	258	321	253	239
12:00:00	271	296	221	316	431	226	328	288	219	368
13:00:00	275	403	381	338	273	329	234	226	276	231
14:00:00	204	322	303	233	331	276	256	390	381	366
15:00:00	346	394	259	274	357	342	408	282	346	364
16:00:00	392	267	363	359	322	228	260	286	401	360
17:00:00	335	275	249	377	345	240	281	391	207	340
18:00:00	385	300	341	331	363	201	354	249	325	198
19:00:00	232	206	152	231	205	205	316	214	242	197
20:00:00	251	280	191	239	180	257	292	243	283	148
21:00:00	223	197	247	235	180	237	245	163	200	178
22:00:00	425	429	496	359	344	457	436	386	480	415
23:00:00	540	398	435	481	381	465	373	452	400	457

Table 7.6: Optimization average power (kW) in a day for day 21 to day 30

	21	22	23	24	25	26	27	28	29	30
0:00:00	384	440	424	420	338	327	405	498	503	454
1:00:00	401	470	343	323	427	346	377	354	498	353
2:00:00	318	509	327	407	267	375	358	404	381	366
3:00:00	371	312	396	327	310	331	316	394	423	423
4:00:00	396	378	334	330	448	402	416	347	387	472
5:00:00	287	367	368	426	403	337	315	363	396	416
6:00:00	350	357	386	357	329	326	363	381	371	336
7:00:00	522	544	468	451	466	506	531	498	363	459
8:00:00	252	226	387	184	201	231	228	362	199	340
9:00:00	304	377	212	268	182	303	398	218	330	309
10:00:00	197	226	268	327	303	396	251	316	362	195
11:00:00	239	301	396	329	283	212	314	381	236	206
12:00:00	261	383	293	340	302	360	224	237	252	237
13:00:00	345	242	304	259	249	340	319	350	349	216
14:00:00	381	229	290	353	335	210	361	291	243	232
15:00:00	372	282	312	241	311	295	229	206	343	324
16:00:00	381	241	367	247	206	294	426	311	233	250
17:00:00	260	224	363	270	233	214	299	365	373	312
18:00:00	196	226	189	331	262	253	335	203	211	323
19:00:00	190	264	238	138	222	227	158	164	199	189
20:00:00	172	239	207	261	221	265	169	153	161	261
21:00:00	154	207	232	283	251	197	202	182	242	223
22:00:00	355	429	567	483	354	362	408	453	477	426
23:00:00	397	431	349	526	404	512	383	360	393	428