Faculty of Electrical Engineering

Optimal Load Management Strategy among Residential Consumers in South Peninsular Malaysia

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Bachelor of Electrical Engineering with Honours

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DECLARATION

I declare that this thesis entitled "Optimal Load Management Strategy among Residential

Consumers in South Peninsular Malaysia" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date **:** 5/7/2021

APPROVAL

I hereby declare that I have checked this report entitled "Optimal Load Management Strategy among Residential Consumers in South Peninsular Malaysia" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name :Ts. Dr. Mohamad Fani Bin Sulaima

Date : 5/7/2021

DEDICATIONS

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I am also indebted to University Teknikal Malaysia Melaka for supporting me and their library privilege for their assistance in supplying the relevant literature. The database provided by UTeM library help me in finding the journal and papers to be cited in this research.

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ABSTRACT

Electricity cost has become a central issue in managing global energy demand. Price based program through time of use tariff (TOU) program is one of the initiative to offer, as to provide sufficient benefit for both consumers and generations. Howerver, without any awareness in implementing the optimal load management strategy with new structure of tariff design will lead to the miss perception by electricity consumers. Therefore, this study offers an investigation toward an optimal load management strategy to reflect price signal for several types of TOU tariff design from several countries. The Ant Colony Optimization (ACO) algorithm is proposed to deal with load shifting strategy to determine the best load profiles. The main objective of the proposed method is to reduce the electricity cost while defining the best time segmentation that appropriate Malaysia residential load profiles. The sample load profiles data have been obtained from various type of residential house in Melaka such as single storey, double storey, semi-D, apartment and bungalow type of houses. The significant comparison between baseline flat tariff to several types of TOU tariff has shown improvement in percentage of electricity cost saving for approximately 7 to 40%. Futhermore, the identified controlled load as the weightage for the load management was observed where the maximum load shifting weightage was set up to 30% to reflect the ability of the consumers' effort. Thus, it is hoped that this study will lead to a better offer of the TOU tariff price initiative among residential consumers in the future action by electricity provider in Malaysia.

ABSTRAK

Kos tenaga elektrik telah menjadi isu utama dalam pengurusan permintaan tenaga di peringkat global. Program berdasarkan harga melalui program tarif waktu penggunaan (TOU) adalah salah satu inisiatif yang ditawarkan, untuk memberikan manfaat yang cukup baik bagi pengguna dan generasi. Bagaimanapun, tanpa kesadaran dalam menerapkan strategi pengurusan beban yang optimal dengan struktur rancangan tarif baru akan menyebabkan persepsi yang terlepas oleh pengguna elektrik. Oleh itu, kajian ini menawarkan penyelidikan ke arah strategi pengurusan beban yang optimum untuk mencerminkan isyarat harga untuk beberapa jenis reka bentuk tarif TOU dari beberapa negara. Algoritma Ant Colony Optimization (ACO) dicadangkan untuk menangani strategi peralihan beban untuk menentukan profil beban terbaik. Objektif utama kaedah yang dicadangkan adalah untuk mengurangkan kos elektrik sambil menentukan segmentasi masa terbaik yang sesuai dengan profil beban kediaman Malaysia. Data profil muatan sampel telah diperoleh dari pelbagai jenis rumah kediaman di Melaka seperti rumah jenis satu tingkat, dua tingkat, semi-D, apartmen dan banglo. Perbandingan yang signifikan antara tarif tetap dasar dengan beberapa jenis tarif TOU telah menunjukkan peningkatan dalam peratusan penjimatan kos elektrik sekitar 7 hingga 40%. Selanjutnya, beban terkawal yang dikenal pasti sebagai bobot untuk pengurusan beban diperhatikan di mana berat maksimum peralihan beban ditetapkan hingga 30% untuk mencerminkan kemampuan usaha pengguna. Oleh itu, diharapkan kajian ini akan membawa kepada tawaran inisiatif harga tarif TOU yang lebih baik di kalangan pengguna kediaman dalam tindakan masa depan oleh penyedia elektrik di Malaysia.

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LIST OF ABBREVIATION

ACO	Ant Colony Optimization
ACO- EMC	ACO based Energy Management Controller
ACOD	ACO with Dynamic-random strategy
ACON	ACO with strengthened Negative feedback
ACOS	ACO with Smaller domain-first
AMI	Advanced Metering Infrastructure
ASM	Ancillary Service Market program
CM	Capacity Market program
CPP	Critical Peak Pricing
DB	Demand Bidding/Buyback
DLC	Direct Load Control
DSM	Demand Side Management
dTOU	Dynamic Time Of Use
EDR	Emergency Demand Response
EMS	Energy Management System
ETOU	Enhanced Time Of Use
GA	Genetic Algorithm
GSO	Glow-worm Swarm Optimization
IBP	Incentive-Based Program
IL	Interruptible Load program
LS	Load Shifting
MESI	Malaysian Electricity Supply Industry
MOSTI	Ministry Of Science, Technology and Innovation
OA	Optimisation Algorithm
PBP	Price Based Program
PSO	Particle Swarm Optimisation
PV	PhotoVoltaic system
TNB	Tenaga Nasional Berhad
TOU	Time Of Use

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CHAPTER 1

INTRODUCTION

1.1 Research background

Smart meters and distributed energy are here to stay, and the emerging IoT era is bringing various new products and disrupting approaches to energy enterprise management. TNB sees communications as the key enabler in digital utility transformation. Based on figure 1.1 show that a communication platform that supports decentralised generation and bi-directional flows (of data and energy) can enable new revenue streams. Utilities can utilise smart applications to provide an automatic and remote meter reading.

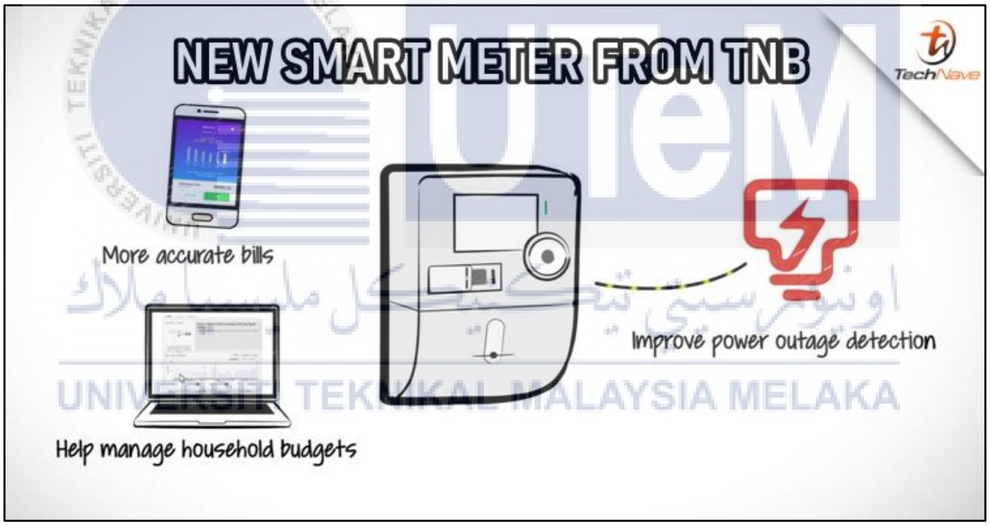

Figure 1.1: TNB new smart meter by Henry Kwan, 2020.

Customers gain easy access to accurate billing statements from a TNB smart meter where users can view a detailed monthly comparison of their electricity consumption. It’s a more user-centric experience with interactive and accurate information about their household’s energy usage. This project begins at 2014 and TNB success to install 340000 smart meter unit in Melaka and aims to expand the installation by 1.2 million smart meter unit in Klang Valley.

In 2019, an announcement made by the Minister of Energy, Science, Technology, Environment and Climate Change (MESTECC), the Malaysia electricity supply industry (MESI) said to undergo another series of reform, MESI 2.0 [1]. The MESTECC has been restructuring, and its name changed to Ministry of Science, Technology and Innovation (MOSTI) on March 9, 2020. The objectives of MESI 2.0 are to increase the industry efficiency, to future proof the industry, structure, regulations and critical processes, and to empower the consumers. Based on figure 1.2, the transformation is to provide industry efficiency is expected to be increased through greater utilisation of the market-based competition throughout the value chain, reduced government intervention. Next, increased transparency, adoption of more cost-reflective and time- based tariff, subsidisation of targeted consumers and increase in cross border trade.

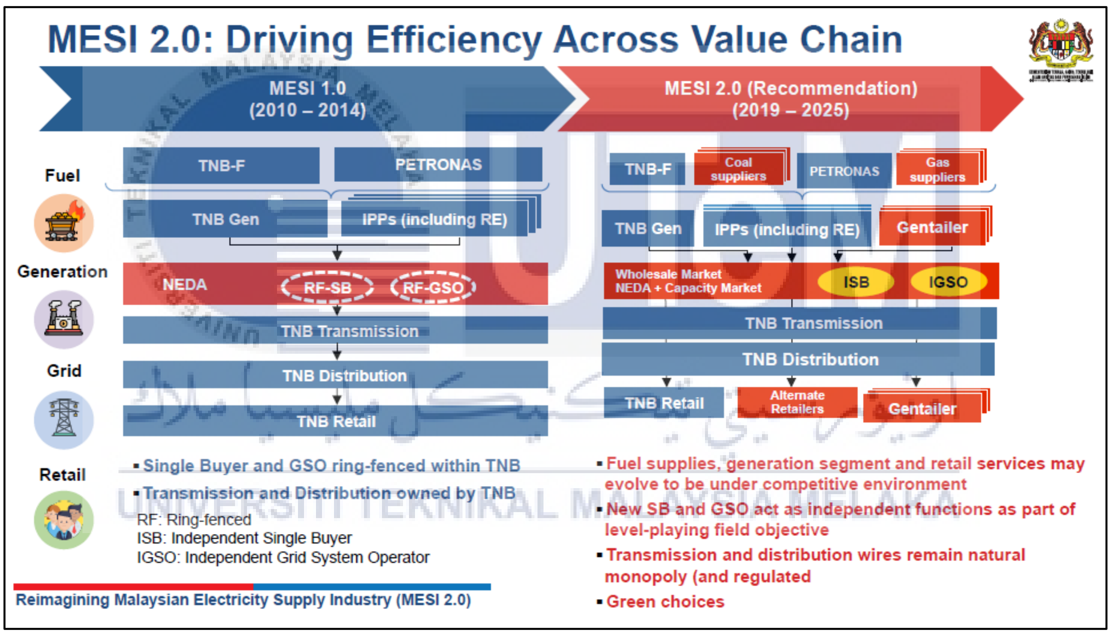

Figure 1.2: Reimagining Malaysian Electricity Supply Industry (MESI 2.0), by MESTECC, 2019.

Both initiative of smart meter from and MESI 2.0 is providing benefit to the consumer through digitalisation as a platform to facilitate an intelligent energy network using digital technologies. The primary key of both ideas is about efficiency, sustainability, security and customer experience. The consumer must take action, such as able to know how to manage and monitor their smart meter information to achieve the entire objective proposed by MOSTI and TNB.

Based on the journal of “Building energy consumption in Malaysia: An overview”, state that the building consumes 40% of global energy. The energy building energy consumption expected to increase to 50% by the year 2030. The building energy consumption is divide into a residential building and commercial building. In 2012, based on table 1.1, the Energy Commission highlight that building structure consumes 54% of the total electricity in this country [2].

Table 1.1 Regional and sectorial electricity consumption in Malaysia, by Energy Commission[2], 2012.

Region	Peninsular	Sarawak	Sabah	Total
Industry (GWh)	45,357 (44%)	5,554 (60%)	1,504(30.5%)	52,414 (45%)
Commercial (GWh)	34,696 (34%)	2,026 (22%)	1,923 (39%)	38,645 (33%)
Residential (GWh)	21,536 (21%)	1,657 (18%)	1,516 (31%)	24,709 (21%)
Transportation (GWh)	241 (0%)	- (0%)	- (0.5%)	241 (0.5%)
Agriculture (GWh)	344 (0%)	- (0%)	- (0.5%)	344 (0.5%)
Total (GWh)	102,174 (100%)	9,237 (100%)	4,943 (100%)	116,353 (100%)

Based on the journal of “From residential electric load profiles to flexibility profiles – A stochastic bottom-up approach”, the author says there are four factors that can influence and reduce the residential energy consumption. Based on other literature, the author of the journal “Optimal household energy management based on smart residential energy hub considering uncertain behaviours” said that the consumer’s utility plays an essential role in evaluating consumer’s residential electricity consumption [3].

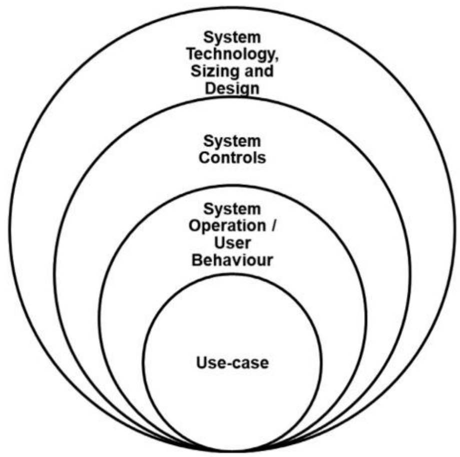

Figure 1.3 Parameters were influencing and reducing the usable flexibility of a given technology[4], 2020.

While, another researcher identified four major factors that influence energy such as weather and location, the physical characteristic of the building, appliance and electronics stock and lastly occupancy and occupant's behaviour towards energy consumption[5]. The result from their experiment state that weather and physical characteristics of the building illustrate more influence on residential electricity consumption compared to other categories such as occupant behaviour [5].

In Malaysia, residential contribute 21% from 54% building energy consumption[2]. For several residences, depending on the culture, the number and status of the residents, the number of possible appliances or devices that are present could vary[6].

Based on table 1.1, the most residential energy usage is in peninsular Malaysia 21,536 Gwh by donating 87.16% from total residential energy usage in Malaysia. At the same time, the total on residential energy usage in Sabah and Sarawak combined only 3,173 Gwh, 12.84% from total residential energy usage in Malaysia.

1.2 Problem statement

1. Electricity consumption has become a central issue in managing global energy demand growth [7]. In Malaysia, buildings consume a total of 48% of the electricity generated in the country. Commercial buildings consume up to 38,645 Gigawatts (GWh), while residential buildings consume 24,709 Gwh [2]. Many residential consumers use electricity inefficiently because, in their everyday lives, they are not aware of ways to use energy effectively. Air-conditioning and heating appliances led to about 60 per cent of overall energy usage, where consumer scheduling planning coordination was insufficient to control during critical peak hours. After the meter conversion, there is a lot of complaint from the consumer in Melaka. The problem is the electrical provider is billing the energy consumption for over 30 days. The problem occurs because the standard procedure required the utility firm to issue bills for 30 days and suddenly rise of electricity bill.

2. Without any effort towards load management as well as Demand-side Management (DSM) strategies implementation, the dedicative consumers' electricity bill has increased significantly to approximately 0.5%–12% during ETOU tariff shifting [8]. DSM encompasses the entire range of activities such as planning, implementation and monitoring that influence the pattern and magnitude of a utility's load. DSM program is a means of reducing operating cost, increasing profit and remaining competitive[9].

3. An optimal algorithm is needed to give the best result reducing the electricity of the consumer. The method of ant colony optimisation (ACO) is employed to process a large amount of data and eliminate redundant information[10]. The advantage of ACO is the problem can find the central problem easily and overcome it by describing in a set of nodes and edges between nodes to form a graph[10]. ACO also have high speed and high accuracy but can also find a quasi-optimal solution quickly[11].

1.3 Objective

The objective of this study is to analyse and proposed smart load management by integrating improve residential energy audit procedure to the simulation programming application. Following are the objective proposed for this study:

i. To analyse a baseline of residential load profile in Melaka from TNB Smart Meter
ii. To investigate the energy consumption reduction for several TOU design in various country reflecting several types of houses.
iii. To reduce the electricity cost based on the proposed load shifting strategy by applying ACO algorithm.

Table 1.2: Problem statement and objective mapping.

	Problem statement 1	**Problem statement 2**	**Problem statement 3**
Objective 1	X	X	
Objective 2		X	
Objective 3			X

1.4 Project scope

i. Residential load profile sample focus on single-storey terrace house, double-storey house, bungalow and semi-detached house taken from myTNB smart meter electrical usage data

ii. Demand-side management strategy based on load shifting technique to reduce the electricity cost

iii. Analysis of the residential load profile by simulation on Matlab M-file programming based on Ant Colony Optimization algorithms in reducing the electrical cost

iv. Appliance unit, power rated in kW per unit, and consumption hours only based on the ceiling fan, fluorescent lamp, washing machine, water heater, water dispenser, television, WIFI router, air conditioning and phone (charging).

v. Data obtained from one unit per different type of residential in Melaka

vi. Data obtained daily for 14 days of each residential through myTNB smart meter

1.5 Flow of the report

This report is a study about Optimal Load Management Strategy among Residential Consumers in South Peninsular Malaysia. The first chapter is discussing the research background and problem statement. The objective of this study is to achieve from the problem statement with some scope of the study.

The second chapter is focusing on discussing the previous literature review related to the task. The information obtains from the various researcher that has studied about this related topic. The related issue and term are describing deeply in this chapter.

Chapter three explains the methodology of the study. This chapter is explaining the formula relating, design, and the limitation of the proposed method. The engineering parameter of the study also indicates in this chapter. This chapter will explain the process to find a solution from the problem statement. The propose strategy is discussing in detail for this chapter.

The fourth chapter of the report is orienting about the result and the analysis of the study. The element of analysing and discussing the output is base from the simulation by using Matlab. All the work is visualising in graph, table or the diagram. The difference result of the optimisation is analysing by varying the load shifting weightage and time zone. The best optimal result also reviews in this chapter.

The last chapter five is about the conclusion and recommendation of this study. This chapter is a summary of the entire research, including methods, results and significant recommendations arising from the study. The list of recommendation is for future improvement related to this project. At the end of the report is the list of the reference that has been citing in this report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is focusing on the previous study relating to this research. Section 2.2 is about what is the demand-side management from the researcher's point of view. It concludes that there are two main categories of the DSM approach, like energy efficiency or demand response. For this, sub-topic is focusing on the method that can be approach in direct-load control method.

Next section is focusing on Demand Response. DR is a flexibility mechanism that enables consumer participation to demand modulation in response to a system operator's signal. Furthermore, in section 2.4 is discussing the Incentive-Based Program. IBR programs implemented due to load shortages, distributed generation penetration, and other reliability issues in the electrical provider side. The other researcher state that there is six IBR program that can be offered to the consumer.

Next section is discussing Price Based Program or also call as Time-based Program. PBP depends on consumers' choice to minimise or adjust their consumption in response to changes in electricity price over 24 hours. The program discusses such as ToU, dTou and CPP. Section 2.5.1 is focusing on Time of User tariff. It can conclude that the ToU rate and zone depend on the country geography or season weather.

Next section is discussing Load Shifting method. Load shifting method is one of the DSM strategies under Direct Load Control. Basically, load shifting is shifting electricity consumption from one period to another to reduce the electricity cost. In section 2.7, it is discussing the Advanced Metering Infrastructure. AMI is also called digital power meter or smart meter that one of the equipment needed in the smart grid. AMI is a bidirectional communication device that can track energy consumption over 24 hour period.

Section 2.8 is discussing Optimisation Algorithms. This topic is focusing on OA that have been applied in DSM application. Difference OA will give difference optimisation performance. The last section in this chapter is about Ant Colony Optimization. It will explain the flow and parameter in detail for general ACO optimisation algorithms.

2.2 Demand-side management

Demand-Side Management (DSM) is the selection, planning, and implementation of measures intended to influence the demand or customer-side of the electric meter. DSM technique mainly relies on matching present generation values with demand by controlling the energy consumption of appliances and optimising their operation at the user side[12]. Based on figure 2.1, there are two main categories of DSM.

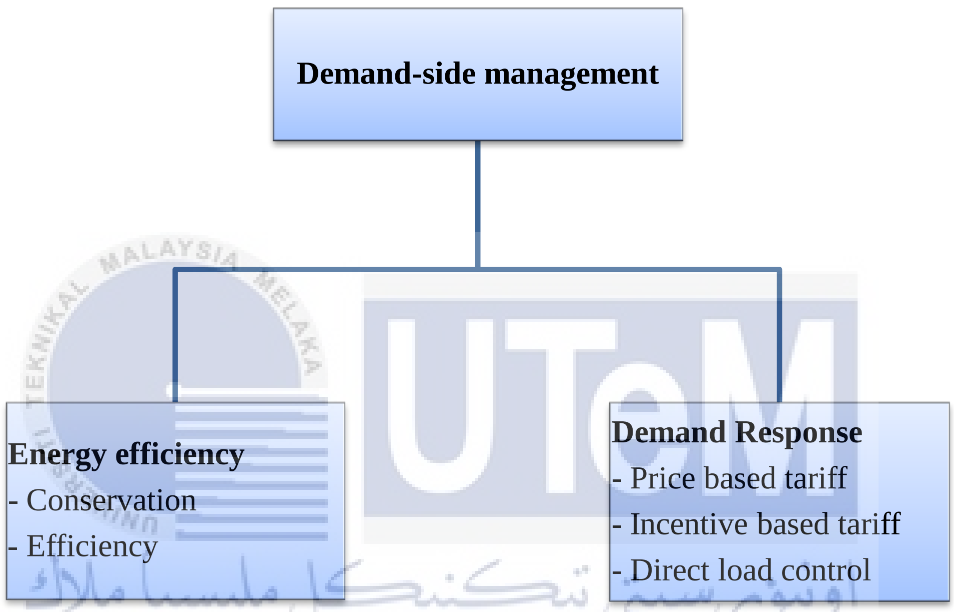

Figure 2.1 : Demand-side management category[13].

From other literature, there are several DSM strategies can be proposed. Such as forecasting of residential energy[12], using direct load control [9], using optimization and artificial intelligence[14], incentive-based demand response program [15], load shifting [16], Energy Management Systems (EMS), Photovoltaic Systems (PV)[17]. In this research are focusing on direct load control strategy by using load shifting technique. There is several other direct load control technique based on figure 2.2.

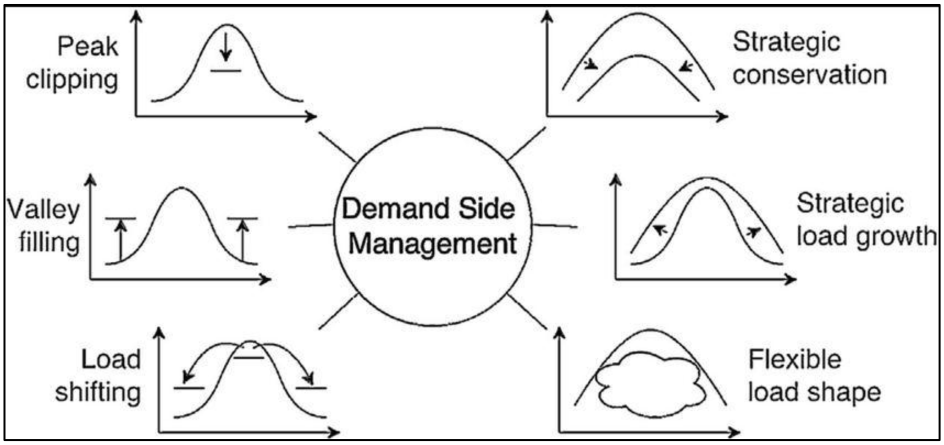

Figure 2.2: Type of direct load control [18].

2.3 Demand Response

The demand response (DR) is defined as a tariff or program developed to motivate the change in energy consumption of end-users, in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability jeopardised [19]. Another researcher state that Demand response (DR) is a flexibility mechanism that enables consumer participation to demand modulation in response to a signal from the system operator[20]. Therefore, a key concept to reduce the electricity bill and decrease CO2 emissions by reducing the need for polluting peaking power plants[20]. To achieve the DR program objective, the consumer must have to volunteer into the program, and some of the programs are mandatory. The lateral category is shown in figure 2.3.

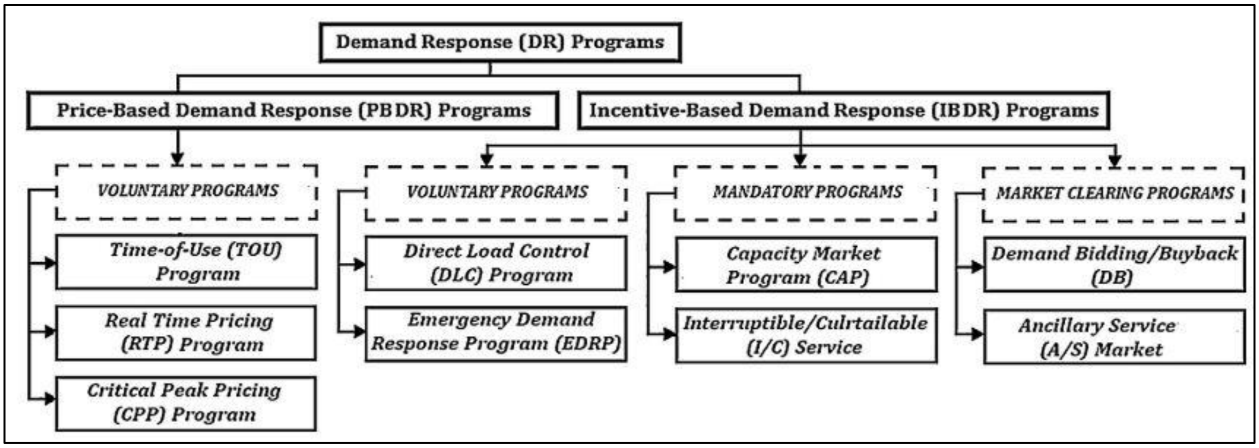

Figure 2.3: DR programs divided into primary and lateral categories[21].

To apply for this program, the consumer must have the AMI (Advanced Metering Infrastructure). The smart meter data will provide three critical applications: load analysis, load forecasting and load management[22]. Considered the impact of external benefits and established an advanced system dynamics simulation model: price-based program and incentive-based program[23]. Figure 2.4 show that there are two main classifications on the DR program such as PBP and IBP.

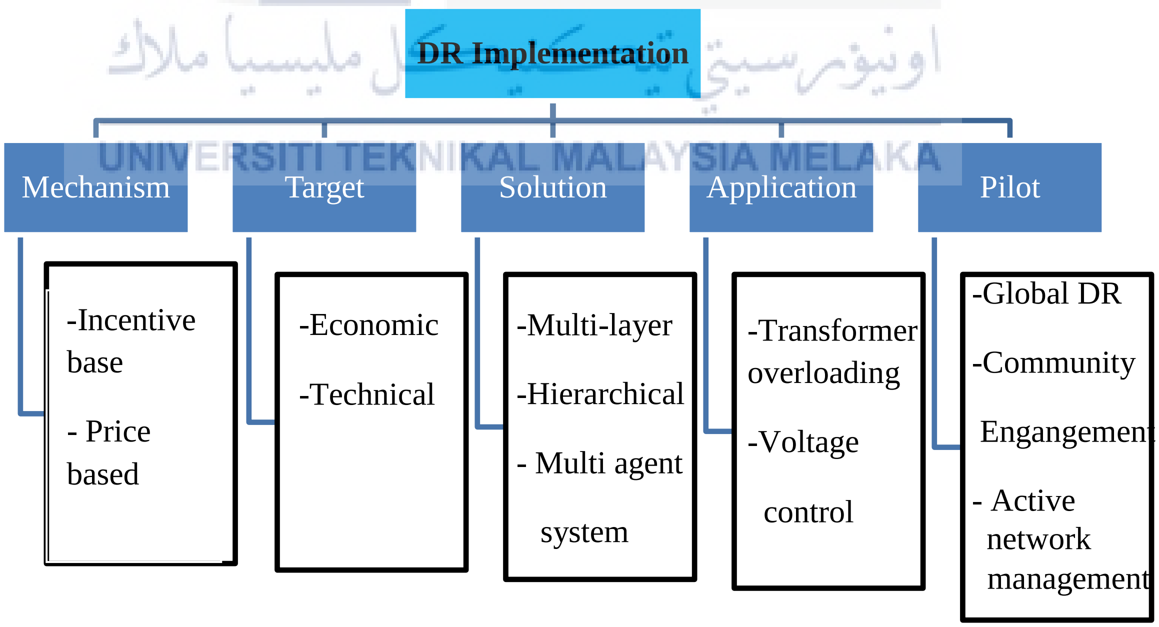

Figure 2.4 : Classification of DR implementation[22].