Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF CONGESTION MANAGEMENT OF DEREGULATED POWER SYSTEM USING FUZZY LOGIC

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours**

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DECLARATION

I approve that this Bachelor Degree Project 1 (PSM1) report entitled “Development of Congestion Management of Deregulated Power System Using Fuzzy Logic” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature :

Supervisor Name : ENCIK ADAM BIN SAMSUDIN

Date : 06/02/2022

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

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Date : 4 JAN 2022

DEDICATION

To those who provide me endless affection and support as an encouragement for me to complete this report. Thank you very much for your help.

ABSTRACT

Regulated system is used in certain countries, including Malaysia. A regulated system means that the whole system of the electricity power market is own by only one organisation, mainly the government. This monopoly principle causes the market to be uncompetitive and consumers have a very little rights on the set price and no freedom to choose. Thus, this will require a system change which is the deregulated power system. This system will unbundle all the generations, transmissions, distributions into separate ownerships. The existence of the different ownership will bring a competitive power market since consumers are free to choose organisations that provide the best price and services based on their needs. However, an overly competitive market from development of deregulated system will lead to a congestion problem in the transmission lines. Congestion refers to the condition where there is insufficient power matching between generation and transmission networks. Thus, congestion management is needed to control demand for electricity and finding better methods rather than building new construction for generation. Several methods have been used to control congestion. Classical Methods are not suitable since they have complex formulation and are unable to solve real-world large power system problems. In these recent years, the implementation of Artificial Intelligence Method can solve a large-scale power system problem. The Fuzzy Logic Method is one of the methods under Artificial Intelligence Method. So, in this project, Fuzzy Logic Method is used to analyze congestion problem. The principle used by Fuzzy Logic is "IF X AND Y, THEN Z". The inputs and outputs for the Fuzzy system will be related to congestion problems. Thus, the inputs will be the value of load and the prices set for the transmission lines, while the output of the Fuzzy will be the level of congestion. Fuzzy method deals with approximation rather than precision. The data used for this project will be using data from the Reliability Test System 1996 (RTS-96). RTS-96 is used as a standard testing system that could be used to analyze and compare the results. The system will be tested using the data using the data from weekly peak load and daily week load. Then, an evaluation technique will be used to assess the system based on requirements needed.

ABSTRAK

Pasaran elektrik yang dikawal selia digunakan di dalam sesetengah negara, termasuk Malaysia. Keseluruhan sistem elektrik ini hanya dimiliki oleh sebuah organisasi, kebiasaannya ialah kerajaan. Prinsip monopoli ini menyebabkan pasaran menjadi tidak kompetitif dan pengguna mempunyai hak yang sedikit dalam penetapan harga. Justeru, keadaan ini memerlukan pengubahan, iaitu kepada pasaran elektrik yang tidak dikawal. Sistem baru ini akan mengasingkan semua penjanaan, penghantaran, pengagihan kepada pemilik yang berasingan. Kewujudan pemilik yang berasingan ini akan membawa kepada pasaran kuasa yang lebih kompetitif kerana pengguna adalah bebas untuk memilih organisasi yang menyediakan harga dan servis terbaik. Namun, pasaran yang terlebih kompetitif akan menyebabkan masalah kesesakan dalam penghantaran kuasa. Kesesakan di dalam penghantaran kuasa adalah merupakan keadaan di mana terdapat perbezaan kuasa diantara pusat penjanaan dan penhantaran kuasa. Justeru, sebuah pengurusan kesesakan ini adalah diperlukan untuk mengawal keperluan untuk elektrik dan juga untuk mencari alternatif lain selain daripada membuat pembinaan baru untuk sistem penjanaan. Beberapa kaedah telah digunakan untuk mengawal kesesakan di dalam sistem penghantaran. Namun, kaedah lama adalah tidak berkesan kerana ia mempunyai sistem yang kompleks, dan tidak mampu untuk menyelesaikan sistem kuasa realiti yang besar-besaran. Dalam beberapa tahun ini, penggunaan Teknologi Kecerdasan Buatan (AI) mampu digunakan untuk menyelesaikan masalah sistem kuasa yang besar. Fuzzy Logic adalah merupakan salah satu kaedah di dalam kategori AI tersebut. Di dalam projek ini, Fuzzy Logic akan digunakan untuk menganalisis masalah kesesakan sistem kuasa. Prinsip yang digunakan ialah "JIKA X DAN Y, MAKA Z". Input dan output untuk sistem Fuzzy akan berkaitan dengan tahap kesesakan di dalam sistem penghantaran. Justeru, nilai beban dan harga akan menjadi input, manakala output untuk sistem Fuzzy adalah tahap kesesakan. Kaedah ini menggunakan anggaran dan bukan ketetapan. Data yang digunakan adalah daripada Reliability Test System 1996 (RTS-96). RTS-96 digunakan sebagai satu sistem ujian standard yang boleh digunakan untuk menganalisis dan membandingkan data. Sistem ini akan diuji menggunakan data tertinggi mingguan dan juga data tertinggi harian. Seterusnya, satu teknik penilaian akan digunakan untuk menilai sistem tersebut berdasarkan keperluan.

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I am also indebted to my supervisor, Mr Adam bin Samsudin and co-supervisor, Madam Kamilah binti Jaafar for their precious guidance, words of wisdom and patient throughout this project. Their kindness has motivated me to perform better and widen my research boundaries in the completion of my Final Year Project.

My highest appreciation goes to my parents and family members for their love and prayer during the period of my study. An honourable mention also goes to them for all the motivation and understanding.

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CHAPTER 1

INTRODUCTION

1.1 Background

The idea of market power has gained its importance after the electric power industry initiated a transformation and reconstruction process since the early 1990s. The entirely unbundled power markets are dominated by generation companies, transmission companies, distributor companies, utility (electricity) broker and lastly an independent system (grid operator).

Deregulation of the power sector is unavoidable in today's dynamic market. The structure of the market gradually paved a way for a dynamic economy known as "Deregulated Electricity Market". It is introduced due to a number of factors, including high demand growth combined with inadequate power system managements, unreasonable tariff policies, allowing power suppliers to compete and for consumers to choose the suppliers they want. Deregulation is needed to meet the global demand for electricity at an affordable price. The wholesale electricity market is not ideal since the growing economy had resulted in a major rise in electric demand. Additionally, a lot of power sectors have been firmly developed for this purpose, where they collaborate to maximize profits, increasing electricity prices and therefore gaining market dominance which is known to be market power abuse. Owners in the competitive market initially accepted most of these risks and they are responsible for most of the outcomes – poor decisions, positive performance and management income from the power sector. Thus, deregulation is used as a method of altering the existing regulatory structure.

Mostly in developed countries, the key aim of deregulation of power system is to draw different types of investments. Deregulation of power sectors aim to increase efficiency of electricity production and usage. Simultaneously, deregulation has the potential to progressively lessen the government's role and responsibility in the power sector industries. Furthermore, deregulation brings innovation into the markets which will help to increase efficiency. This will eventually allow a high-efficiency sustainable growth of the power industries.

1.2 Problem Statement

Deregulated power system has caused those owners from the competitive power market to overly compete causing a congestion in the transmission lines which bring risks to transmission security. Congestion occurs in transmission line when too many users are using the same line, causing inadequate transmission capability to supply to all of the request from transmission companies. Congestion will affect the whole system, causing grid disruptions, which creates further outages in an integrated system. This will not only affect the power system's components but will also bring harm to the power quality. In order to avoid the system equipment from being damaged, congestion management is needed to improve power efficiency. In order to increase the reliability of the transmission services, all of the operators must re-dispatch the generation or to deny some of the requests to prevent it from being congested. The presence of congestion in the system is the key barrier in order to achieve a competitive market. Under ideal transmission-unconstrained market conditions, buyers seek to acquire energy from sellers who have the lowest offer prices. When the transmission network's physical restrictions are taken into account, the network's restricted transfer capabilities may be inadequate to accommodate the intended unconstrained market timetable without breaching the physical limits. Congestion may be reduced if lower-cost vendors are situated in places where extra transfers may be made without putting the transmission network's limited transfer capabilities under strain. Thus, one of the ways to control congestion by manipulating the prices are using Fuzzy Logic Approach. The system design used for this project is 24 Bus Reliability Test System 1996 (RTS-96) to display how Fuzzy Logic is used for congestion management. The data used from RTS-96 are the weekly and daily peak load data.

1.3 Project Objective

The objectives for this project are:

a) To make researches on deregulated power system based on its concepts and fundamentals.
b) To analyze a variety of approaches to a deregulated system that needs congestion management.
c) To monitor modelling used for Fuzzy Logic for congestion problem.

1.4 Scope of Project

Scopes for this project are:

a) Carrying out researches to find out the differences between concepts of regulated and deregulated power systems.
b) Identify possible approaches for techniques used for a congestion management.
c) Understanding the Fuzzy Logic theory and uses its application for controlling a deregulated system.
d) Usage of MATLAB to simulate Fuzzy Logic Method for controlling congestion problem caused by a deregulated power system.

CHAPTER 2

LITERATURE REVIEW

2.1 Controlled Power System

Controlled power system in an electricity market refers to a vertically integrated electric utility owned by a public regulator. The whole electric utility that involves generation, transmission and distribution system are controlled and managed by a single entity, most often – the government [1]. A regulated system is a commonly used system and is adapted in countries such as Arizona, Colorado and even Malaysia. An illustration for regulated system is as shown in Figure 2.1.

A regulated power system or known as a controlled system, has its own identity. The most noticeable element is the government dictation in many areas of electricity activity and production [2].The monopoly principle withholds pressure for price increases when end consumers have little right to set the sale price. In comparison, no third entity guarantees managerial performance and contributes to incompetent markets. Finally, cross-subsidies can exist, which means that different prices are given for different group of users. Higher prices might be given to other users to subsidize the other group with lower prices.

Since the electric market is owned and managed by a single authority, it leads to an uncompetitive market. The solution needed for this monopoly concept requires a structural change and a new set of rules. Thus, the system will be changed from regulated to a deregulated system.

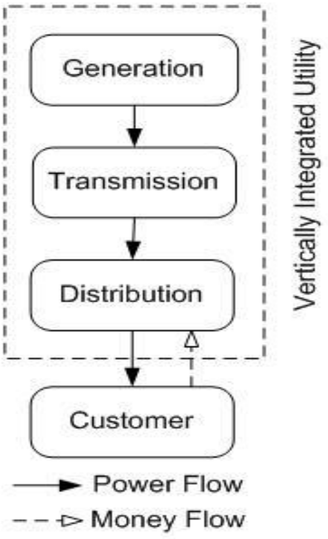


Figure 2.1 Regulated (controlled) power system

2.2 Deregulated Power System

A deregulated system is known as a vertically unbundled electricity market. The unbundled electric power market will be separated into generation companies (GENCOs), transmission companies (TRANSCOs), distribution companies (DISCOs), energy brokers and an independent operator (ISO) [3]. However, transmission firms under TRANSCOs are supposed to remain operating as a controlled monopoly, providing "free, non-discriminatory, and equivalent" access to both suppliers and customers without congestion [4]. The illustration for a deregulated power system is shown in Figure 2.2.

The term deregulation does not imply the absence of laws in the system operation. The regulations will stay in force, although a new system will be established to operate the electricity industry. This is why the term ‘deregulation’ is more suitable to be said as ’re-regulation’ or ‘restructuring’ [5]. Deregulation process which includes unbundling the electric utility services into GENCOs, TRANSCOs and the other services refers to separating out the services into a basic component. Each component offers a separate sale with separate rates. This also means the separation will includes the segregation of ownership and operation. Deregulation is more about eliminating price restraint by the entry of private players into the industry.

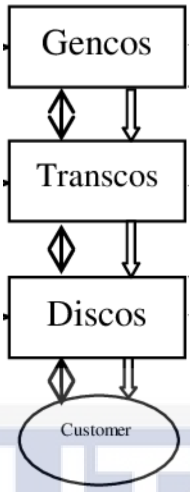


Figure 2.2 Deregulated Power System

Independent Standard Operator (ISO) managed the entire grid system to ensure the electricity is spread evenly among consumers and all the equipment is in good working order. The ISO is the driving force behind numerous plans for a deregulated, dynamic electric power market. The ISO has three main goals which are stability, service quality assurance, and economic performance and equity promotion. The ISO can be allowed to establish guidelines for transactions between vendors and customers, generator scheduling and dispatch, loads and network networks, and energy markets in order to achieve these goals [6]. The ISO's goals and authority are described differently in each proposal. There are two ISO structures that are compared which will be discussed in the next part. ISO has the term ‘independent’ which means it is not allowed to gain or own any profits from the unbundled companies [7].

The aim of a deregulation is to simplify operations. The functions of GENCO are to reduce manufacturing costs to the absolute minimum and increase returns by lowering operation and maintenance costs. TRANSCO will be able to justify distribution fees by reducing transmission delays and running more smoothly. Similarly, DISTCO will save prices and bargain with GENCO to provide the best rates and facilities [8]. Most importantly, this mechanism must be quite concrete and solid in order to avoid any power system interference in the current business flaw [9].

2.2.1 Benefits of Deregulated System

The energy market has undeniably shifted as the deregulation movement has developed. Although legislation standardizes energy provision, energy deregulation has many advantages. Since deregulation allows customers to profit from rivalry between utilities, it lets all consumers save money on their electricity and gas bills. Energy producers compete by offering better pricing and rewards to lure more customers, which helps households and businesses save money. Customers have a preference in a deregulated economy, which ensures that browsing around for the right deals is often a smart idea [2].

Other than that, a deregulated system provides a better-quality customer service. Independent electricity suppliers must do whatever they can to please and keep their consumers in the frantic rivalry of a deregulated energy sector. Customer experience is a crucial differentiator for enterprises. Next, numerous electricity companies compete for a better power market for their customer leading to more innovations made. Promotional and technological innovations are almost all made as a way for businesses to become more appealing to clients, and any electricity supplier understands that the only way to achieve that is to bring money back in their customers' pockets [10].

The aim of deregulation is to increase competition in as many areas as possible. When the generator's capacity to sell power in the new market grows, he or she has more versatility in organizing output. The involvement of a spot market suggests that fewer unused power must be maintained in order to have a certain degree of service efficiency [11]. Consumer expectations would be more precisely matched to the quality levels offered. End consumers can be given a priority deal or plan if the electricity rate schedule is equal to the degree of dependability. In comparison to state monopolies or limited power plants, a dynamic and cost-effective energy generating system will provide a far broader variety of services.

Finally, the demand for creativity would be competitive. Competition would increase a company's responsiveness to customer demands. Aside from that, the financial condition would be properly controlled, and the firm will be willing to compete for the amount to be paid to the customer. Meanwhile, the desire to be imaginative continues to rise [11]. Expansion to a cutting-edge end-user facility is a more cost-effective and faster method of dealing with problems, ensuring a favorable margin for the modernizer.

The other benefits of this system are [12]:

a) Taking some of the responsibility of controlling and managing the power grid off the government's hands.
b) There are no cross-subsidies between the market's competitive and non-competitive aspects.
c) Non-competitive element rates are non-discriminatory for all.
d) Access is guaranteed by the Independent System Operator (ISO) with no assets interests in either business.

2.2.2 Types of System

The main system used for deregulation are divided into two, which are:

a) Poolco Model

- All energy and associated contact and subsidiary services are exchanged in coordinated mode in the central auction process. The generators are scheduled by the Independent System Operator (ISO). It is often referred to as centrally manage or maximalist ISO. This model aims to cater to the needs of the customers. Since the GENCO is unaware of the transmission line conditions, transmission line restrictions may only be included in the Poolco model.

b) Bilateral Model

- Both energy, connectivity, and other related resources are exchanged on a bilateral basis. It is also regarded as a minimalist or decentralized ISO. In this sector, an ISO's job is to operate the current energy market and at the same time, offering services and congestion management. The main target of this approach is to focus the GENCOs while observing to a collection of standard restrictions.

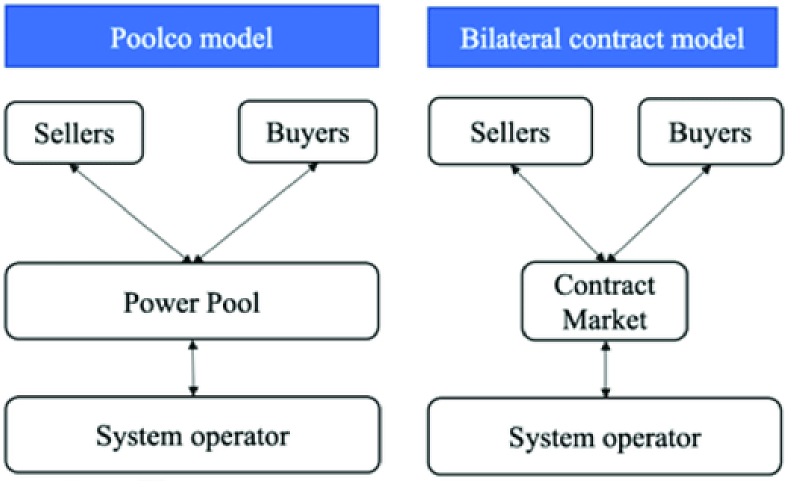


Figure 2.3 Types of Deregulated System

2.3 Congested Power System

Transmission networks have been overloaded or congested as a consequence of the growth of deregulated power systems. Since there is insufficient matching between generation and transmission networks, congestion exists. Unexpected events such as power outages, unexpected acceleration of load demand, and equipment breakdown may also trigger congestion [13]. To maintain grid security and prevent future blackouts, overload in the electricity grids should be fixed immediately.

Congestion has serious implications for power grids, including device breakdown. When transmission networks struggle to transmit power in accordance with load demand, congestion exists. Congestion management, which play an important role in today's deregulated power grids, are used to address these issues [14]. Congestion in the power grid may be caused by a variety of factors, according to technical literature. When transmission networks are unable to handle all desired transactions due to infrastructure operational limits breaches in a competitive market, congestion exists [15]. When the thermal bounds and line capacities are exceeded, congestion arises [16]. When electricity flows in the transmission line exceed the operational reliability limits, congestion arises [17].

The open access situation (deregulated power system) is one under which customers and retailers have the right to select their own generation provider via pre-established transmission lines. This is one of the most serious issues that the global energy markets face. As a result, in the evolving deregulated climate, proper congestion control is becoming increasingly necessary. To fix the congestion issue, the system operator (SO) requires an effective, non-discriminatory method [18].

In the traditional power sector, this is accomplished by re-dispatching a cheaper generator(s) usable thus alleviating restrictions [11]. Generation and transmission are divided into various firms in a deregulated setting. When consumer purchases cause congestion, they are expected to pay a premium. Since energy in the system flows in parallel paths, a single line can be overwhelmed by several transmissions [19].

2.3.1 Reasons for Congestion Management

The electricity market has experienced significant changes in today's globalized world. This is attributed to the worldwide trend of restructuring and legalization, which has a huge effect on the electricity market. The market for transmission grids has increased as a result of the power industries' reformation. In deregulated market, the electricity utility is set to be close to its ratings set through utilization of existing capital. It is to ensure that all businesses in this sector will strive for maximum growth. Because of network limitations, only a limited amount of energy is able to be transferred between two destinations in the grid system [20]. Thus, it is very important to have an ability to manage power flow in a deregulated system.

Congestion control that is successful will significantly decrease the expense of congestion. When the expense of congestion is extremely high, it is time to improve transmitting power. In general, effective congestion control reduces the economic risks of congestion to a minimal and makes efficient usage of the available transmission capacity [21]. Depending about how well the current transmission infrastructure is used, a dollar invested in transmission capacity can have a significant impact or effect. It would require years to accumulate the expense of transmission infrastructure investments [22]. As a result, unless congestion control ensures the power distribution in transmission lines is not disrupted, the only option is to invest heavily in the development of new transmission lines. However, a large group of non-government environment groups are against the development of new transmission lines. Since the building occupies such a vast amount of property, it has an effect on people's lifestyles and livelihoods. Aside from that, owing to the allocation of new power lines, many trees would need to be cut down. In order to properly use the existing transmitting power, further congestion control approaches must be explored.

Congestion control restores grid equilibrium and fixes financial difficulties created by congestion. Inattention to grid congestion may result in massive blackouts with serious social and cultural implications. Many researches have been undertaken to evaluate the best congestion control techniques for avoiding transmission line congestion amid rising power demand.

Thus, the main reasons for requiring deregulation are:

a) Rise in electricity demand
b) Price for new construction of transmission line is expensive
c) Non-government environment group are against building of new transmission lines

2.3.2 Problems Arise from Uncontrolled Congestion

Congestion on a system is allowed only for a short amount of time since it can cause cascade outages and unregulated load failure. Business ineffectiveness is indeed a product of congestion [20]. Transmission line congestion will prohibit new contracts from being signed, report significantly higher outages, escalate electricity rates in certain parts of the power market, and jeopardize grid protection and efficiency [22]. More GENCO companies will be welcomed to apply, construct, run, and distribute electricity at a set price under the new deals. Both generators are permitted to bid for the supply of retailers by tying them to short- or long-term contracts. Customers will be impacted by further outages, which are interruptions of electricity supply. As a system stability and dependability are jeopardized, it is no longer impervious to disruption. The entire electrical device would quickly fail or shut down. Thus, a management is required to reduce overload in the shortest period of time.

2.4 Methods for Congestion Management

Various power market models have been produced all around the world to control congested networks. Classical Methods have commonly been used to efficiently control congestion in transmission lines. Classical Methods, on the other hand, are inadequate to solve very complex congestion problems owing to increasing demand for energy and technical advances in software and hardware.

The Linear Programming Method is used to solve issues involving non-negative variables and the linearization of objective functions. The Newton-Raphson Method entails optimality and the Kuhn-Tucker requirements, which are required conditions. The Quadratic Programming Method is a special kind of nonlinear programming in which the parameters are easy to detect, however the objective function is complex. The Nonlinear Programming Approach is used to address problems with nonlinear objectives and/or constraints. The Interior Point Method is well suited to solving large-scale programming problems in detail [23].

However, Classical Methods are not the preferable method since it has quite a number of disadvantages which are:

a) Mathematical formulations are hard to understand

b) Cannot solve problems of real-world large-scale power networks

c) Convergence is weak (only one outcome can be found in a single simulation run)

d) When the number of variables is high, the system is inefficient

Artificial Intelligence Methods have been increasingly popular in recent years due to their ability to solve extremely complicated congestion problems. The science of building smart computer programs is this process. It has the potential to minimize the drawbacks of traditional approaches. As seen in Table 2.1, there are five distinct forms of this strategy. Each category does have its own range of benefits for coping with multiple forms of traffic congestion issues. The thesis in this study focused on the Fuzzy Logic methodology. The next section includes a more in-depth discussion.

Table 2.1 List of Artificial Intelligence Methods

TYPES	DESCRIPTIONS
Fuzzy Logic Method	Deals with estimations values rather than precision
Artificial Neural Network (ANN)	Interconnected of neurons that computes using a connectionist method
Genetic Algorithm Method	Using theory survival of fittest
Ant Colony Optimization	Based on the idea of ant foraging
Particle Swarm Optimization	Based on the social behaviour of organisms (fish schooling and animal flocking)

2.4.1 Fuzzy Logic Method

The term ‘fuzzy’ means the things that are not clear [24]. Most of the time, we encounter situations where we cannot decide whether the state is completely true or completely false. Thus, Fuzzy Logic is made based on the reasoning method that human made, where it provides a very flexible reasoning method [24]. The fuzzy logic set rules will be the decision we made, where all possibilities between a solid YES or NO will be taken into consideration. Thus, we are able to consider the inaccuracies and uncertainties of any given situations. In this project, we will be using this method. The detailed reasons for choosing this method will be in the next chapter.

2.4.2 Artificial Neural Network (ANN)

Artificial Neural Network is made resembling human neural networks to perform computations of data. A neural network system is made up of large number of interconnected elements, which are known as neurons that are used to solve problems [25]. Since the system is complex, as it resembles how the human brain works, the system cannot be modified easily. The data set given to be performed using ANN must be precise as it trains itself learning from the data set [26].

2.4.3 Genetic Algorithm Method

Genetic Algorithm method demonstrate a natural selection, which the fittest individuals are picked for breeding in order to create heir of the next generation. Selective breeding starts with the selection of the fittest people from a group. They have child that take over the characteristics of the parents and are passed to the next generation. For example, if the parents are athletic, their children will be fitter than the parents and have a greater chance of survival. This process is repeated indefinitely before a century of the fittest individuals is known. This concept can be used in solving problem by recognizing a collection of solutions to a problem and then choosing the best option amongst them [27].

2.4.4 Ant Colony Optimization

Ant Colony algorithm is made based on the actions of ants looking for food. Initially, the ants roam blindly. When an ant discovers a food supply, it goes back to the colony leaving "markings" known as pheromones to show to the food route. When other ants find those markings, they are expected to go after the direction. They populate the route with their own markings as they carry the food in. If more ants find the road, it gets stronger before several streams of ants migrate to different food sources nearby the colony. Since the ants drop pheromones if they carry food, short paths are often prone to be stronger, improving the "solution." However, the probability distribution of data changes after each iteration made [28].

2.4.5 Particle Swarm Optimization (PSO)

PSO applies the idea of animal social interaction for a problem solving. This system uses a number of agents (particles) that forms a swarm moving around searching for the best solution for a certain problem. Initially, the particles are set in random position and velocity, where they will swarm over the best solution at the end of the process [29].

2.5 IEEE RTS-96

The Reliability Test System 1996 (RTS-96) is an improved testing system for evaluating the dependability of large power systems. The Fuzzy Logic methods used to control congestion will be evaluated on this project. This system is a refined and revised variant of the initial IEEE RTS, which was created in 1979 to signify a change in methods of operation and to address obvious problems with the previous system.

The first edition of the IEEE Reliability Test System (RTS-79) was created in 1979 by the Power System Engineering Committee's Application of Probability Methods (APM) Subcommittee [30]. This framework was developed to establish a uniform testing system for analyzing outputs from various power system assessments. RTS-79 frequently used as a reference framework, including key details and control variables for a number of reliability assessment methods. However, this system has been updated and the second version is developed, which is RTS-86.

The RTS-86 second version was released with the aim of rendering the RTS more usable in evaluating various reliability modelling and assessment methodologies [30]. RTS-86 extended the data structure related to the generation system, which includes the amount of generating units, planned repairs, load prediction volatility, and the impact of interconnection. The value of RTS-86 is that it provided device reliability indices extracted from robust solution methods without any assumptions throughout the assessment phase [30]. These exact indexes are extremely valuable for comparing findings from various techniques. The new iteration of RTS-96 is created and implemented to satisfy the expectation of a stronger test framework that can reflect as many different innovations and configurations as possible. The RTS-96 is a hybrid and untypical model.

2.5.1 Transmission System Data

This IEEE RTS-96 24 bus system's data are provided, which includes the value of voltage for each bus, voltage used, generation and load of each bus. The data for bus and branch data of the system in RTS-96 are shown as below:

Table 2.2 Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.035	-7.278	172.00	21.47	108.00	22.00
2	1.035	-7.370	172.00	15.66	97.00	20.00
3	0.989	-5.584	-	-	180.00	37.00
4	0.998	-9.690	-	-	74.00	15.00
5	1.019	-9.964	-	-	71.00	14.00
6	1.012	-12.421	-	-	136.00	28.00
7	1.025	-7.357	240.00	51.84	125.00	25.00
8	0.993	-11.088	-	-	171.00	35.00
9	1.001	-7.435	-	-	175.00	36.00
10	1.028	-9.503	-	-	195.00	40.00
11	0.990	-2.154	-	-	-	-
12	1.003	-1.517	-	-	-	-
13	1.020	0.000*	187.25	133.99	265.00	54.00
14	0.980	2.258	0.00	-27.72	194.00	39.00
15	1.014	11.566	215.00	-3.95	317.00	64.00
16	1.017	10.449	155.00	44.40	100.00	20.00
17	1.039	14.931	-	-	-	-
18	1.050	16.292	400.00	138.73	333.00	68.00
19	1.023	8.917	-	-	181.00	37.00
20	1.038	9.530	-	-	128.00	26.00
21	1.050	17.117	400.00	106.91	-	-
22	1.050	22.766	300.00	-29.55	-	-
23	1.050	10.572	660.00	135.59	-	-
24	0.978	5.299	-	-	-	-
		Total:	2901.25	587.36	2850.00	580.00

Table 2.3 Branch Data

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	11.94	-26.92	-11.94	-22.45	0.004	0.02
2	1	3	-7.97	21.57	8.31	-26.11	0.342	1.32
3	1	5	60.03	4.83	-59.29	-4.37	0.741	2.87
4	2	4	38.44	19.15	-37.85	-20.43	0.587	2.27
5	2	6	48.50	-1.04	-47.41	-0.19	1.093	4.22
6	3	9	22.90	-17.01	-22.66	14.75	0.240	0.93
7	3	24	-211.21	6.12	212.32	34.48	1.113	40.60
8	4	9	-36.15	5.43	36.52	-6.83	0.364	1.41
9	5	10	-11.71	-9.63	11.76	7.30	0.046	0.18
10	6	10	-88.59	-130.31	89.66	-121.12	1.067	4.64
11	7	8	115.00	26.84	-112.88	-20.35	2.118	8.18
12	8	9	-36.92	3.36	37.53	-5.46	0.604	2.34
13	8	10	-21.19	-18.01	21.50	14.61	0.303	1.17
14	9	11	-105.92	-12.77	106.20	22.87	0.277	10.10
15	9	12	-120.47	-25.69	120.84	39.16	0.369	13.47
16	10	11	-151.18	36.03	151.72	-16.10	0.546	19.93
17	10	12	-166.74	23.18	167.38	0.21	0.641	23.39
18	11	13	-86.15	-54.97	86.76	49.70	0.618	4.82
19	11	14	-171.77	48.19	173.55	-42.96	1.778	13.76
20	12	13	-60.51	-33.30	60.79	25.20	0.271	2.11
21	12	23	-227.70	-6.07	234.10	34.52	6.399	49.85
22	13	23	-225.30	5.10	230.74	17.80	5.438	42.38
23	14	16	-367.55	-23.77	374.60	70.49	7.054	54.88
24	15	16	112.30	-32.60	-112.01	31.13	0.290	2.28
25	15	21	-214.92	-41.97	217.83	53.65	2.913	22.65
26	15	21	-214.92	-41.97	217.83	53.65	2.913	22.65
27	15	24	215.54	48.59	-212.32	-34.48	3.219	24.93
28	16	17	-322.68	-33.86	326.03	54.42	3.353	26.31
29	16	19	115.08	-43.35	-114.65	41.64	0.433	3.33
30	17	18	-186.94	-58.69	187.58	60.49	0.638	5.10
31	17	22	-139.09	4.28	141.54	-9.26	2.454	19.14
32	18	21	-60.29	5.12	60.40	-10.26	0.111	0.87
33	18	21	-60.29	5.12	60.40	-10.26	0.111	0.87
34	19	20	-33.17	-39.32	33.29	31.34	0.113	0.88
35	19	20	-33.17	-39.32	33.29	31.34	0.113	0.88
36	20	23	-97.29	-44.34	97.58	41.63	0.291	2.25
37	20	23	-97.29	-44.34	97.58	41.63	0.291	2.25
38	21	22	-156.46	20.12	158.46	-20.29	1.994	15.54
						Total:	51.246	454.77

2.5.2 Load Data

This IEEE RTS-96 test also provided the weekly, daily and hourly load data, where these values will be used for the congestion analysis [31]. The data are as shown below:

Table 2.4 Hourly Load Data

SUMMER WEEKS					
HOUR	PEAK LOAD (%)		HOUR	PEAK LOAD (%)	
	WEEKDAY	WEEKEND		WEEKDAY	WEEKEND
12-1am	64	74	12-1pm	99	93
1-2	60	70	1-2	100	92
2-3	58	66	2-3	100	91
3-4	56	65	3-4	97	91
4-5	56	64	4-5	96	92
5-6	58	62	5-6	96	94
6-7	64	62	6-7	93	95
7-8	76	66	7-8	92	95
8-9	87	81	8-9	92	100
9-10	95	86	9-10	93	93
10-11	99	91	10-11	87	88
11-12pm	100	93	11-12am	72	80

Table 2.5 Daily Load Data

DAY	PEAK LOAD (%)
MONDAY	93
TUESDAY	100
WEDNESDAY	98
THURSDAY	96
FRIDAY	94
SATURDAY	77
SUNDAY	75

Table 2.6 Weekly Load Data

WEEK	PEAK LOAD (%)	WEEK	PEAK LOAD (%)	WEEK	PEAK LOAD (%)	WEEK	PEAK LOAD (%)
1	86.2	14	75.0	27	75.5	40	72.4
2	90.0	15	72.1	28	81.6	41	74.3
3	87.7	16	80.0	29	80.1	42	74.4
4	83.4	17	75.4	30	88.0	43	80.0
5	88.0	18	83.7	31	72.2	44	88.1
6	84.1	19	87.0	32	77.6	45	88.5
7	83.2	20	88.0	33	80.0	46	90.9
8	80.6	21	85.6	34	72.9	47	94.0
9	74.0	22	81.1	35	72.6	48	89.0
10	73.7	23	90.0	36	70.5	49	94.2
11	71.5	24	88.7	37	78.0	50	97.0
12	72.7	25	89.6	38	69.5	51	100.0
13	70.4	26	86.1	39	72.4	52	95.2

2.6 SUMMARY

Deregulated system can be said to bring beneficial to the countries that used it. Since the consumers can choose electricity suppliers that are beneficial to them, it brings a lot of competition into the market. These companies will provide better services to their consumers to make sure they are following the consumers preferences. In this project, the congestion problem will be tested using the data in RTS-96 to show how Fuzzy Logic will be used to control congestion.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section includes an overview of the research methodology used in the review. It contains details about the samples, such as the study's eligibility requirements and how they were collected. This part examines why the design and methods are selected for the research. The instruments that would be used to collect data is also listed, as are the protocols that were implemented to conduct this analysis. The techniques used to interpret the data are often discussed and analysed. The flowchart below is the detailed flow for the implementation of Final Year Project (FYP) throughout the year.

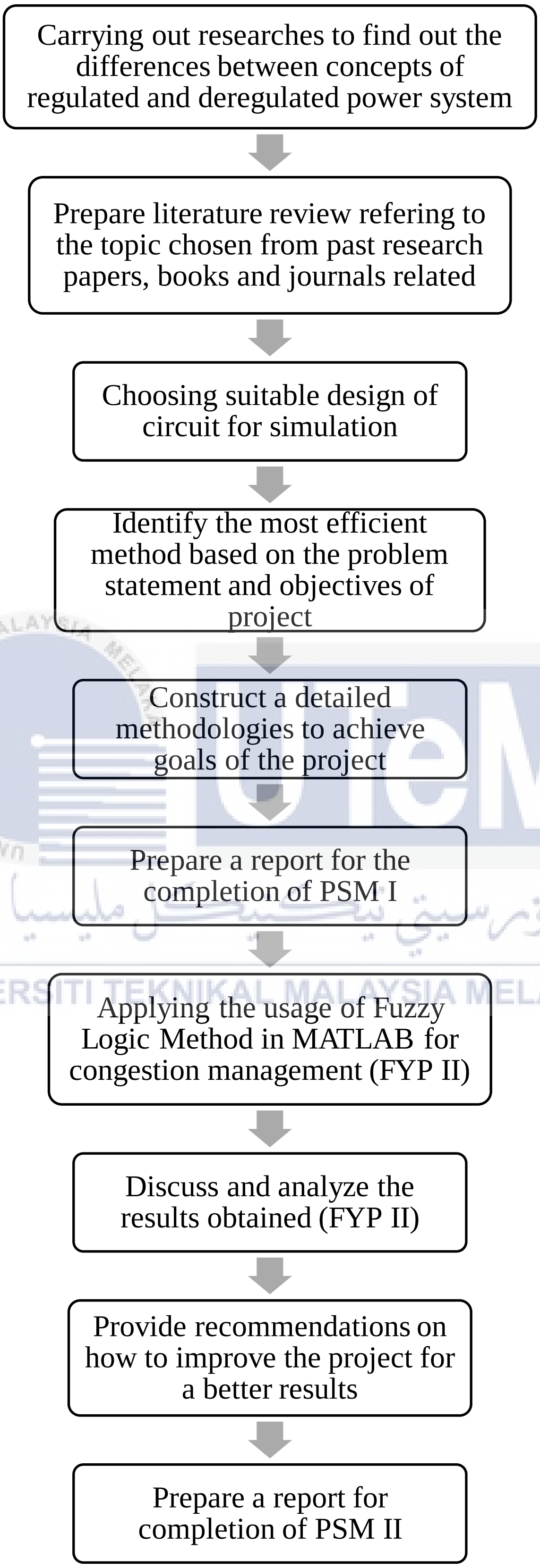


Figure 3.1 Flowchart of FYP throughout the year

3.2 System Design

The design of circuit used in this project will be using the RTS 1996 24-Bus System. The IEEE Reliability Test System was created by the IEEE reliability subcommittee in 1979 to produce a standard testing system that could be used to analyse and compare the results from different approaches used.

The transmission system of this design is consists of 24 buses connected to 38 transmission lines and transformers. The transmission lines used are at the rate of 138kV and 230kV. The top part of the design is using 230kV system while the lower part uses a 138kV system. The buses that use a 230/138 kV are bus 11, 12 and 24. The data for all the lines, generators and transformers are stated in the data system of the design in the previous chapter.

The system contains a voltage corrective device which is a synchronous condenser (at Bus 14) and a reactor (at bus 6). Synchronous condenser is the other name for compensator, which is used to produce or absorb reactive power, Q. Meanwhile, reactor is acomponent that comes with a a coil that has large number of turns and its ohmic resistance value is high. Reactor is used to compensate line capacitance, mitigate voltage transients, and to limit fault currents, thus increasing the systems protection.

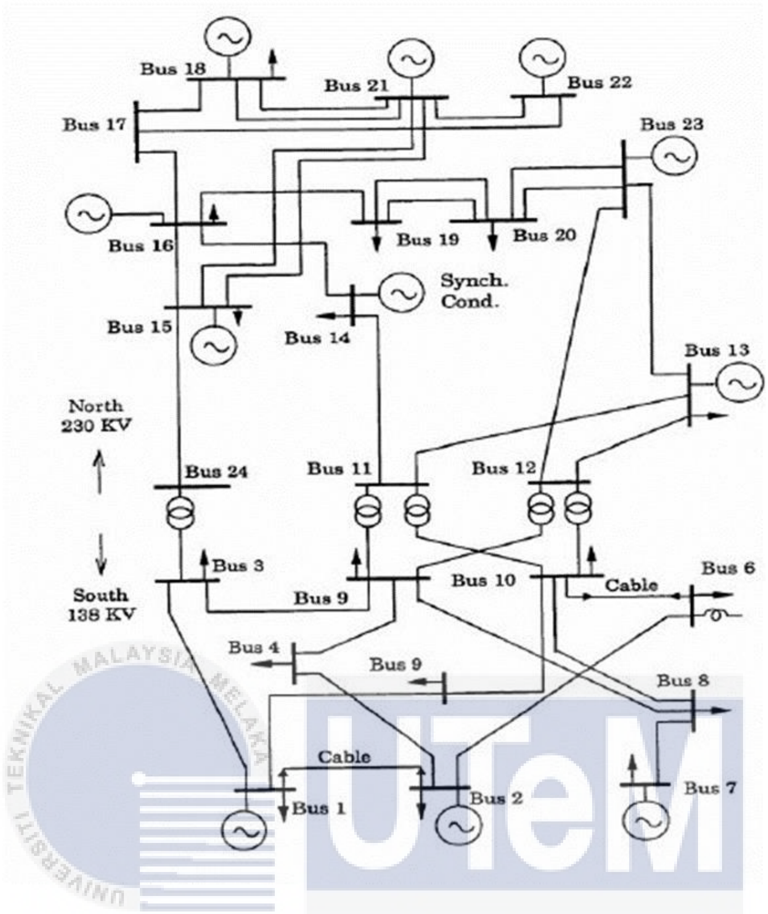


Figure 3.2 IEEE RTS-96 24 Bus System

The system will be tested using the data using the data from weekly peak load and daily week load. Then, an evaluation technique will be used to assess the system based on requirements needed. In this project, we will be using Fuzzy Logic Approach for analysis of congestion problem.

3.3 Fuzzy Logic Approach

Generally, binary sets are made up of two values of logic whether it is true or false, whereas fuzzy logic parameters will be in the intervals of 0 until 1, implying that they are somewhere between absolutely true and absolutely false. Fuzzy logic is a multivalued logic that deals with nearness instead of exact values. It allows ones to function through unclear and contradictory contexts and thus overcome poorly done or unfinished issues.

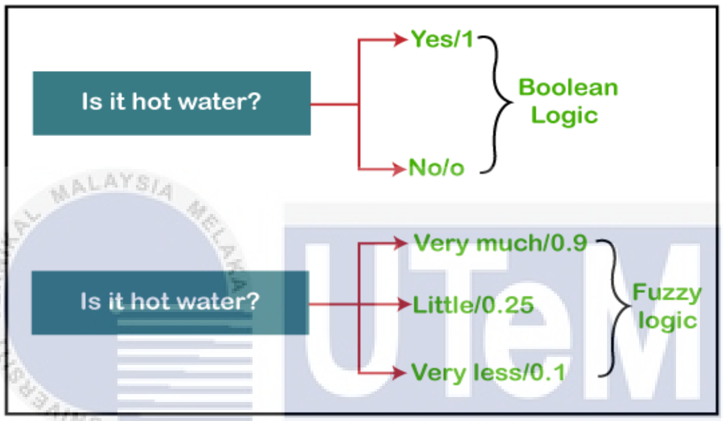


Figure 3.3 Example for Fuzzy Logic Reasoning Method

Operational constraints can be represented by this technique. Fuzzy logic may be used with either hardware or software, or a hybrid of the two. Fuzzy reasoning has the advantage of making it easier to arrive at an understandable inference when supplied with indistinct, inaccurate, noisy, or incomplete data. It behaves much like a person might react, except that it responds much quicker. The easy and clear rule-based technique is known as “IF X AND Y than Z”. Fuzzy logic is a simpler way of handling and structuring results.

Fuzzy Logic are divided into two types, that are Type 1 and Type 2. Type 1-fuzzy logic working method is shown in Figure 3.4. Fuzzy Type 2 is used if the user is dealing with any uncertainties with the intervals to be set. However, since there are no uncertainties in this paper, Fuzzy Type 1 is used.

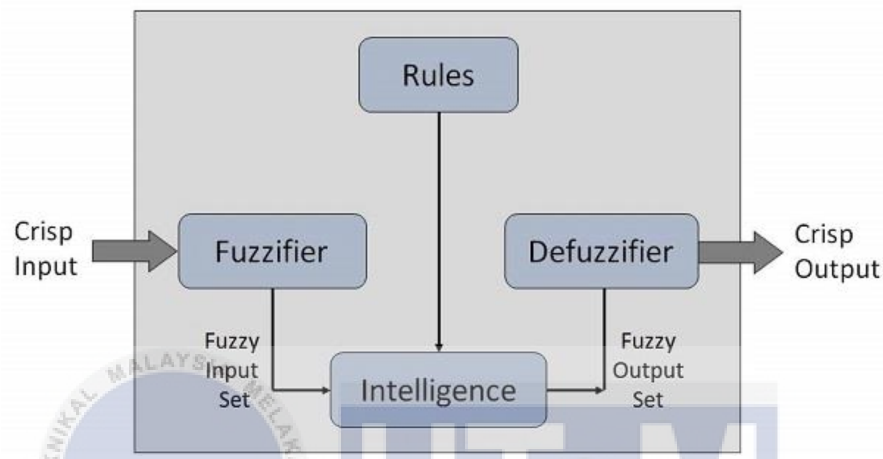


Figure 3.4 Type 1-Fuzzy Logic

a) Fuzzification refers to the mechanism of changing real input parameters into fuzzy values.
b) Defuzzification refers to the mechanism where the output parameters undergo the opposite of fuzzification process. (Converts fuzzy value to a crisp value).
c) Parameters for the inputs are known as “Membership Functions”.
   - Each input is divided into a set of values
   - Each input is to be defined
   - Output values will be depending on the values set for inputs

If the functions have been concreted, expanded, and joined, these become defuzzified to provide a crisp output that controls the whole activity of the system. As seen in Figure 3.5, there are numerous types of membership function for the input and output parameters, such as triangular or bell-shaped functions.

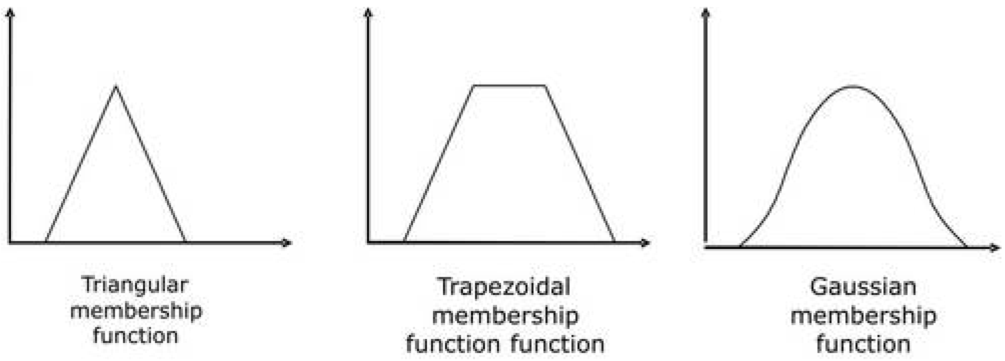


Figure 3.5 Types of Type 1-fuzzy logic Membership Functions

3.3.1 Fuzzy Set Rules

Fuzzy Logic Rules uses the principle of "IF X AND Y, THEN Z". In this project, we are going to use fuzzy logic rules which are:

Table 3.1 Fuzzy Set Rules

LOAD LEVEL	PRICE	CONGESTION
LOW	HIGH	NO CONGESTION
	AVERAGE	
	LOW	
NORMAL	HIGH	LOW
	AVERAGE	MODERATE
	LOW	HIGH
HIGH	HIGH	MODERATE
	AVERAGE	HIGH
	LOW	VERY HIGH

The inputs and outputs for the Fuzzy system will be related to congestion problems. Thus, the inputs will be the value of load and the prices set for the transmission lines (high, moderate, low), while the output of the Fuzzy will be the level of congestion. The range set for load level will also be low, normal and high. However, since Fuzzy uses principle of "IF X AND Y, THEN Z", if the load level is low, the condition will be no congestion regardless of the price (low, normal or high). This is due to low load will not cause any congestion happening on the transmission line.

Fuzzy Logic used for this system is used in MATLAB, known as "FUZZY LOGIC TOOLBOX". The results obtain will be based on the inputs and the rules set above. The design for fuzzy logic using MATLAB will be shown in the next chapter.

3.4 Gantt Chart for FYP

Gantt charts are useful for project planning and scheduling. They help us to analyze how progress of the project, identify the resources needed, and organize our workflow. They're also beneficial for task dependencies. Gantt chart of this project is shown in Appendix A and Appendix B.

3.5 Summary

This chapter proposed method that can be used for this project. The software to be used is MATLAB, where we will use the Fuzzy Logic Toolbox for the congestion management. The data used will be Weekly Load Data and Daily Load Data.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter provides the findings on relevant results and discussion on Fuzzy Logic to control congestion. This will prove the third objective – monitor modelling of used for Fuzzy Logic for congestion problem caused by a deregulated system. In this study, the results are obtained from Fuzzy Logic system followed by related discussions. Overall, this chapter presents the experimental results and discussions from data obtained.

4.2 Results and Analysis

4.2.1 Fuzzy Logic Results

The Fuzzy Logic Approach is designed by using MATLAB Fuzzy Toolbox where the inputs and outputs are as mentioned the previous chapter. The membership functions used in the design of fuzzy are combination of both triangular and trapezoidal form. The initial step for developing fuzzy logic for this system is by adding list of inputs and output depending on the requirements. Then, the next step is to declare each input and output and setting the range for each parameter.

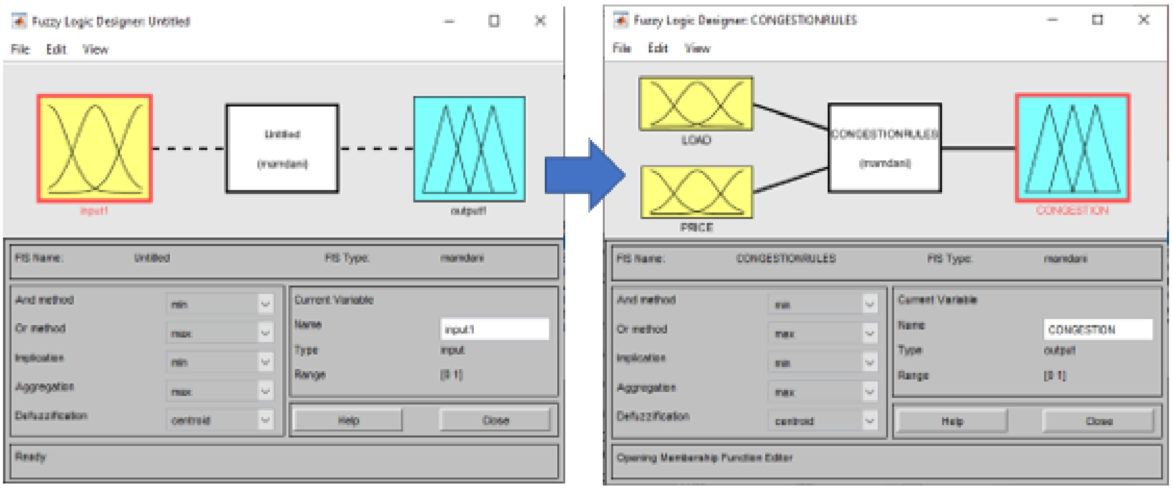


Figure 4.1 Initial Step for Fuzzy Design

As mentioned in the previous chapter, the membership functions for load and price are set to three main ranges which are low, average and high.

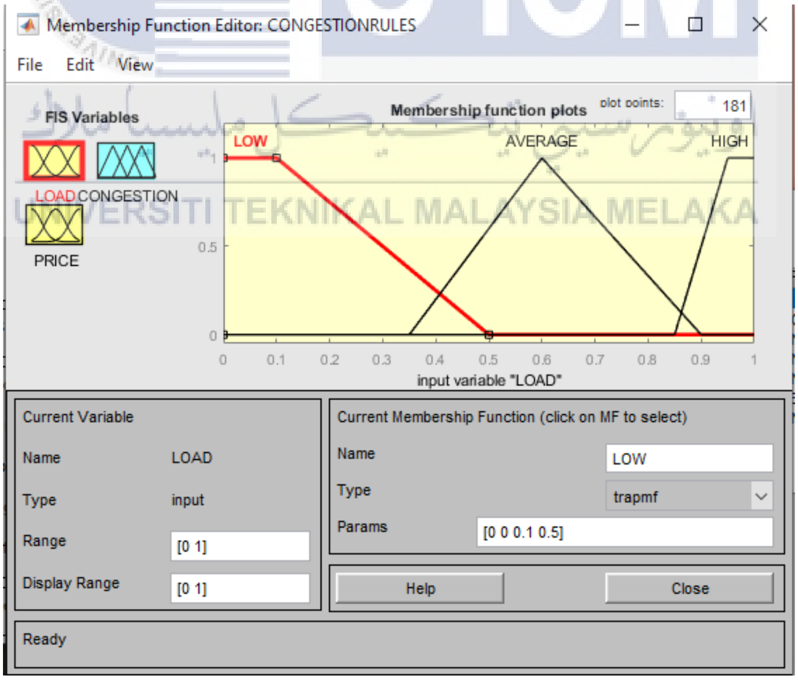


Figure 4.2 Load Membership Function

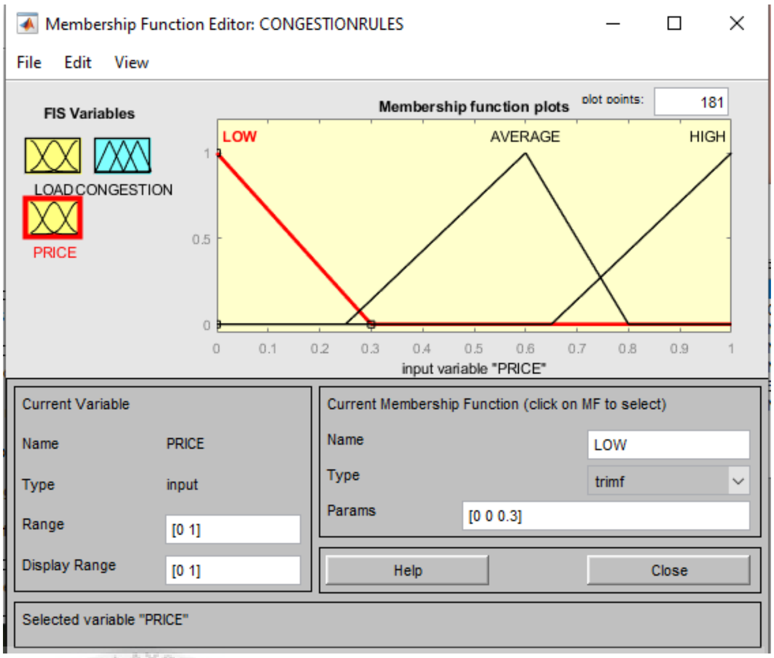


Figure 4.3 Price Membership Function

The range set for congestion level is set to no congestion, low, average, high and very high congestions.

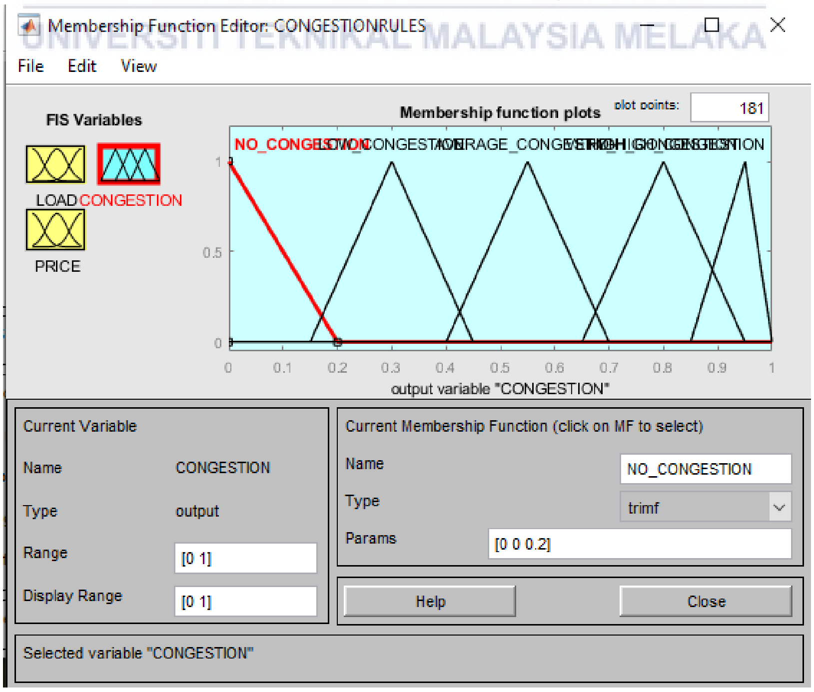


Figure 4.4 Congestion Level Membership Function

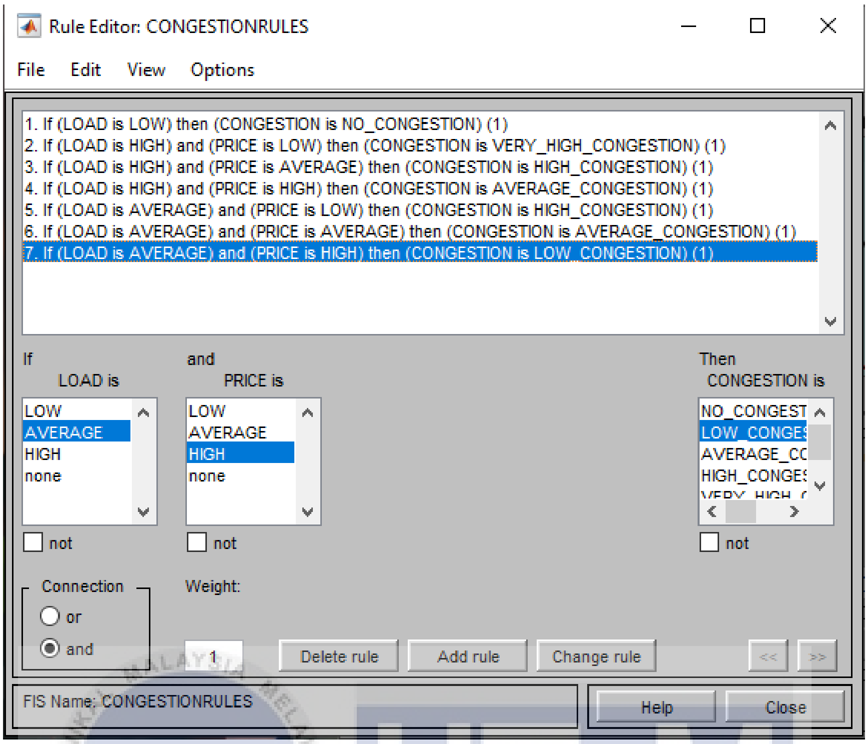


Figure 4.5 Fuzzy Set Rules

From the completion of the fuzzy logic design, the membership functions of load, price and congestion level can be tested. The results will be shown on the Fuzzy Rule Viewer and also Fuzzy Surface Viewer.

Fuzzy Rule Viewer will analyze the results based on the values set for the inputs which are load level and price, and the results will show the congestion level. The level of each parameters needed are displayed in a graph as shown in Figure 4.6. While for the Surface Rule Viewer, the results are shown in a three-axis graph as in Figure 4.7. However, the parameters shown are still similar as those in Fuzzy Rule Viewer.

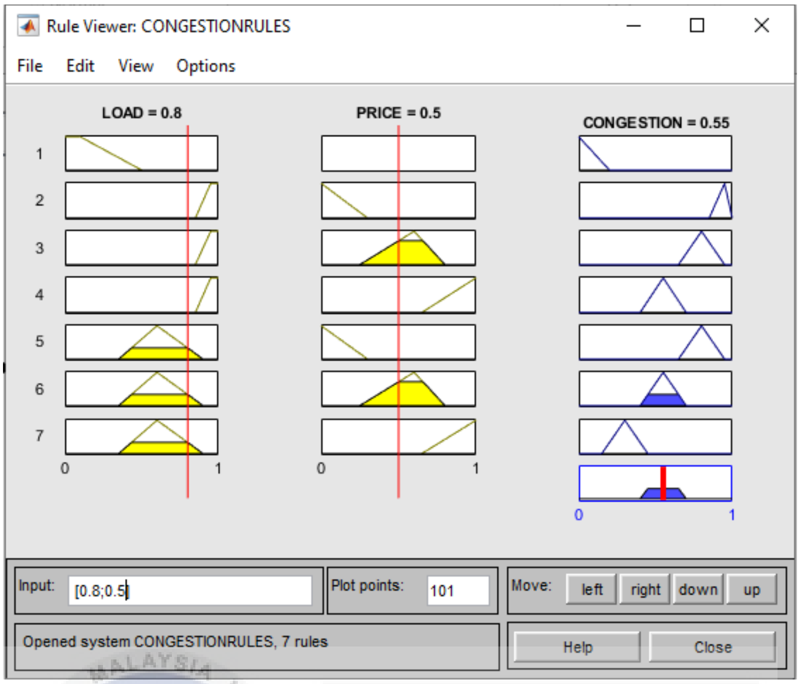


Figure 4.6 Fuzzy Rule Viewer

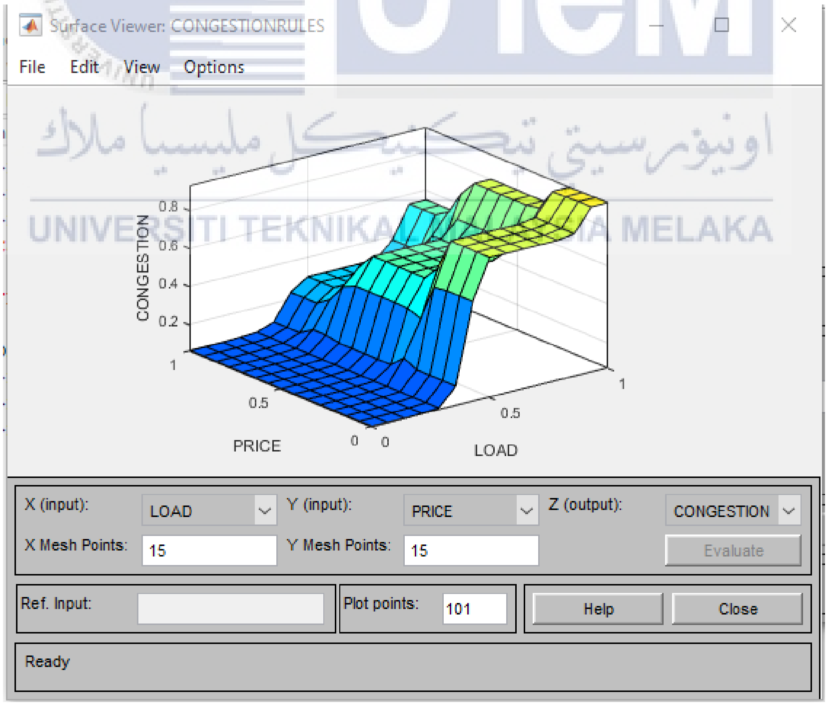


Figure 4.7 Fuzzy Surface Viewer

4.2.2 Simulation Result

The testing results from Weekly Load Data and Daily Load Data are tabulated below:

Table 4.1 Congestion Level for Weekly Peak Load Data

WEEK	PEAK LOAD	PRICE		
		CHEAP (0.150)	AVERAGE (0.525)	EXPENSIVE (0.900)
1	0.862	0.682 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
2	0.900	0.688 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
3	0.878	0.685 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
4	0.834	0.935 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
5	0.880	0.685 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
6	0.841	0.901 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
7	0.832	0.935 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
8	0.806	0.938 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
9	0.740	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
10	0.737	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
11	0.715	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
12	0.727	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
13	0.704	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)

WEEK	PEAK LOAD	PRICE		
		CHEAP (0.150)	AVERAGE (0.525)	EXPENSIVE (0.900)
14	0.750	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
15	0.721	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
16	0.800	0.938 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
17	0.754	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
18	0.837	0.934 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
19	0.870	0.683 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
20	0.880	0.685 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
21	0.856	0.682 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
22	0.811	0.937 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
23	0.900	0.688 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
24	0.887	0.686 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
25	0.896	0.688 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
26	0.861	0.682 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
27	0.755	0.942 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
28	0.816	0.937 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)

WEEK	PEAK LOAD	PRICE		
		CHEAP (0.150)	AVERAGE (0.525)	EXPENSIVE (0.900)
29	0.801	0.938 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
30	0.880	0.685 (Moderate congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
31	0.722	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
32	0.776	0.941 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
33	0.800	0.938 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
34	0.729	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
35	0.726	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
36	0.705	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
37	0.780	0.940 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
38	0.695	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
39	0.724	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
40	0.724	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
41	0.743	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)

Table 4.2 Congestion Level for Daily Peak Load Data

WEEK	PEAK LOAD	PRICE		
		CHEAP (0.150)	AVERAGE (0.525)	EXPENSIVE (0.900)
1	0.930	0.688 (Moderate congestion)	0.800 (High congestion)	0.500 (Moderate congestion)
2	1.000	0.688 (Moderate congestion)	0.800 (High congestion)	0.500 (Moderate congestion)
3	0.980	0.688 (Moderate congestion)	0.800 (High congestion)	0.500 (Moderate congestion)
4	0.960	0.688 (Moderate congestion)	0.800 (High congestion)	0.500 (Moderate congestion)
5	0.940	0.688 (Moderate congestion)	0.800 (High congestion)	0.500 (Moderate congestion)
6	0.770	0.941 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)
7	0.750	0.943 (Very high congestion)	0.800 (High congestion)	0.550 (Moderate congestion)

4.3 Discussion

Based on the result, we can see the variation of the congestion level. It can be seen that, the congestion level is very high if the price is cheap, high congestion if price is average, and lastly moderate congestion when price is high. Thus, it can be said that the congestion level depends on the price. Consumers might have high consumption if price is too cheap, and low consumption if price is too expensive. These kind of variation in prices will need a particular pricing method in order to benefit both parties (electricity supplier and consumer).

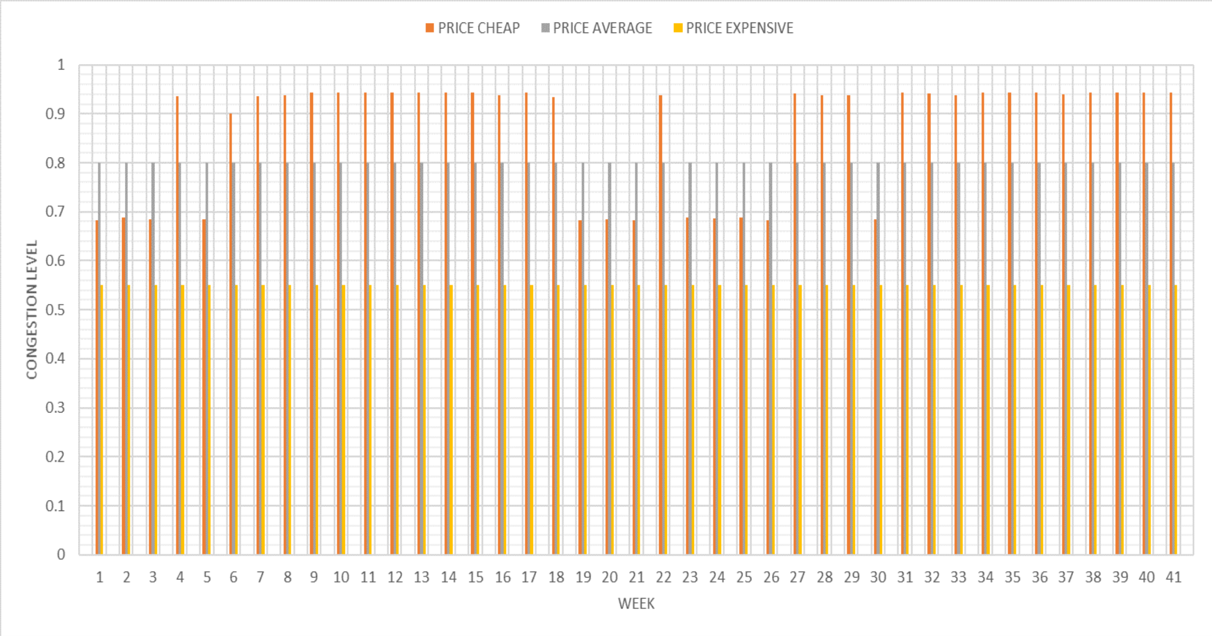


Figure 4.8 Graph for Weekly Load Data

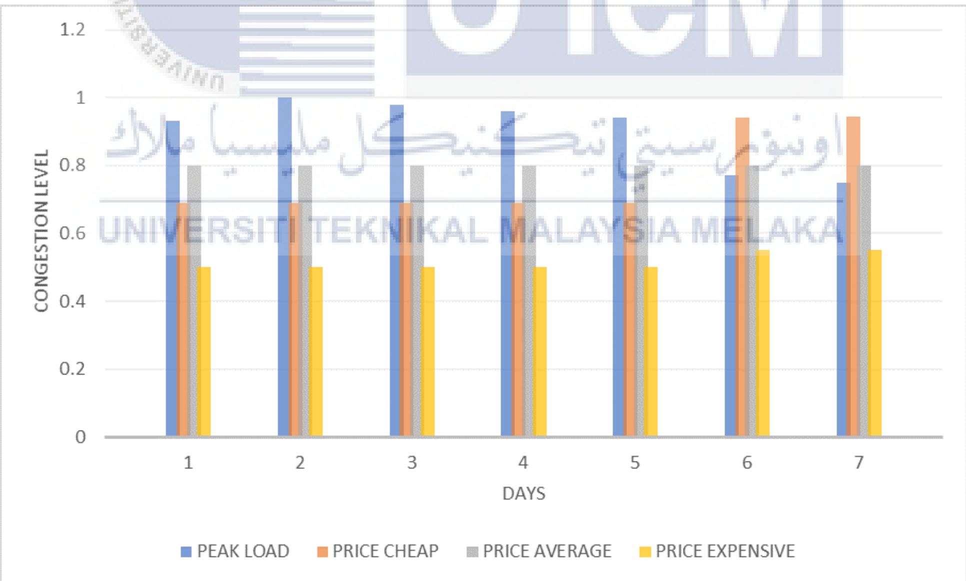


Figure 4.9 Graph for Daily Load Data

Based on the results obtained, congestion in transmission line might leads to price divergence in different submarkets. Efficient congestion managements are important for both short-term and long-term transmission and generation investments. The two widely used methods in controlling congestion are Nodal Pricing Method and Zonal Pricing Method [32].

Concept of Nodal Pricing is charging different prices at different individual buses. The price for a node is basically the price difference between the generator and the destination place. Nodes in the transmission lines are priced respectively according to their measured power flow [33]. Prices would differ if congestion occur in the system. Locations which cause congestion will need to pay extra according to their respective nodes. Consumers are priced individually and does not pay extra fees due to usage from commercial businesses that consume higher energy. Nodal Pricing offers better pricing system that strives to transparency [32].

The basic idea of Zonal Pricing Method is charging uniform prices inside a zone. Network nodes are combined into one zone which share the same price, known as Zonal Pricing [33]. In zonal pricing, zones with high congestion are those who consume high energy while zones with low congestion are those who consume less energy. Zonal Pricing is less transparent when it comes to pricing. Consumers that fall under the same zone will have to pay high electricity bills regardless of the usage [32]. This will be unfair for those in industrial zones since they have to pay higher values even though the congestion is mainly caused by commercial businesses.

Malaysia current tariff for electricity can be improved better according to customers usage. Among the three main electric companies in Malaysia (TNB, SEB and SESB), TNB have the highest charges for their consumers, followed by SESB and lastly SEB. These differences in tariff can be changed to be uniform in order to promote better services to consumers.

If a deregulated system is applied fully in Malaysia, the generation and distribution companies can charge the price to the consumer according to the congestion level in the transmission line. If there is high demand in a highly congested line, higher price will be charged to the consumer that uses the electric utility which transmit through that line. This pricing strategy that is based on Fuzzy Logic is a better way to control energy usage.

4.4 Summary

The simulation using Fuzzy Logic is done by referring to any range set for the data which are prices, congestion levels and load values from RTS-96. It can be seen that the congestion levels are either between very high and high if the prices set are too cheap, high and moderate congestion if price is average and lastly congestion is moderate if price is expensive. Thus, this pricing method will be set based on Nodal and Zonal pricing so that consumers can have their benefit with either the two methods.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

Conclusion will be made on this chapter, referring to the objectives that are aimed to be done in this project. Next, recommendations will also be stated to improvise this project in the future.

5.2 Conclusion

In conclusion, a deregulated power system is a reliable system that can be used in worldwide application to increase quality of the current controlled system used. Mainly, the concern of utility suppliers is the incident of congestion on the transmission system. Since congestion is a result from poor managements between generation and transmission companies, it is vital that a better management is required. These poor management might end up causing frequent disruption of electricity, sudden escalation level of loads or equipment defects. Since power system is large, a better method is needed, which is the Artificial Intelligence Method. In this paper, one of the ways to control congestion is by using Fuzzy Logic Approach. Managing congestion problems involve dealing with approximation, since the level of congestion can be predicted and divided into a certain interval.

In this paper, the usage of Fuzzy Logic Approach can be used to identify the congestion level in transmission lines. Since the congestion level are known, it is easier for utility brokers to decide on the charges set for consumers. Thus, the first and second objectives of this project are completed in Final Year Project 1. Finally, the last objective is to monitor the modelling used for Fuzzy Logic Approach, which is discussed in Chapter 4. The results used are from energy usage in IEEE RTS96, which are the weekly and daily load. In order to manage congestion, the pricing methods suggested are Zonal and Nodal Pricing method. Thus, the objectives of this project is achieved.

5.3 Recommendations

Based on this project, there are some recommendations that can be improvised to obtain a better result. These improvements can be done in terms of implementing a more reliable results or include the system as a part of component in a system.

Firstly, the intervals for Fuzzy Logic can be set to a certain fixed range so that it is easier to monitor and to obtain better results. These uneven intervals causes the reading for congestion level to be having only slight differences and unchanging results for most of the reading in this project.

Secondly, a better simulation method can be used to display the reading along with the congestion level. In this project, the congestion levels were manually written based on range of the congestion set after obtaining the results.

Next, a larger set of data can be used instead of only using Weekly and Daily Load Data in RTS-96. These sets of data can be used to obtain more variety of reading for congestion levels.

Lastly, usage of Fuzzy Logic can be applied to hardware in order to demonstrate how it works in power system. Fuzzy Logic can be used in exicitation control of syrnchonous machines, identifying fault location and service restoration in distribution lines anf also used in reactive power planning and control [34].

Instead of using Fuzzy Logic Approach, there are some other methods that can be used. The first one is flexible different current transmission system (FACTS) devices. FACTS devices works by controlling the power flow in the network for reducing flows in heavily loaded lines, leading to increased lodability, low system losses, network improvement, and lower production costs. Next method is the optimal power flow (OPF). The role of optimal power flow technique is to reduce the generation pricing and provide benefit to consumer with respect to power system parameters. The OPF can be utilized effectively when the system is congested helps in analyzing overloading issues. A complete matrix for congestion management comprises in pool markets environment, bilateral markets and multilateral markets for power balance conditions and curtailment strategies. The basic objective of curtailment policies is to minimize deviations from scheduled transactions. In the multilateral transactions reliability of the system assessed by congestion management which in turn results in reduced curtailments and congestion charges comparatively bilateral transactions. The next method is genetic algorithm. This method is used as a powerful tool in obtaining an optimal power flow under certain operating conditions compared to other computational techniques. Thus, genetic algorithm is demonstrated as an intelligent definition in resolving optimal power flow in a congested system. It works by using differential technique by examining congestion problems dubbed large scale mixed integer algorithm for identifying optimal power flow in a crowded network.

REFERENCES

[1] "Renewable Energy 101: Regulated & Deregulated Energy Markets," July 2020. [Online]. Available: https://www.customerfirstrenewables.com/resources/energy-101.php.

[2] O. A. Alsayegh, "Restructuring Kuwait Electric Power System: Mandatory or Optional?," World Academy of Science, Engineering and Technology, 2008.

[3] S. S.C. and K. Perveen, "Congestion Management in Deregulated Market - A Case Study on an Indian Power System," Indian Institiute of Technology Kanpur, Bangalore, India, 2000.

[4] N. P. Padhy, "Congestion Management Under Fuzzy Environment," IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies (DPRT2004), Hong Kong, 2004.

[5] H. S. Joshi, "Deregulation in Power System to Improve Its Quality with Different Models Formulated," International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Amravati, India, 2015.

[6] P. Varaya and F. Wu, "MinISO: A Minimal Independent System Operator," Berkeley, California, 1997.

[7] 11 November 2020. [Online]. Available: https://www.yesenergy.com/yeblog/2020/introduction-of-isos-yes-energy-101.

[8] K. Vijayakumar, "Multiobjective Optimization Methods for Congestion Management in Deregulated Power Systems," Journal of Electrical and Computer Engineering, 2012.

[9] B. Kuri and F. Li, "Effective design for competitive electricity markets," 39th International Universities Power Engineering Conference, Bristol, UK, 2004.

[10] P. R. Energy, "How does a deregulated energy market benefit you?," 30 September 2015. [Online]. Available: https://www.plymouthenergy.com/how-do-deregulated-energy-markets-benefit-you/.

[11] L. L. Lai, "Power System Restructuring and Deregulation," John Wiley & Sons Ltd., New York, USA, 1998.

[12] S. Dhanalakshmi, "Market Modes for Deregulated Environment - A Review," IEEE Computer Society, 2011.

[13] A. Y. T. T. N. H. Z. and O. M. , "Congestion management using demand response and facts devices," International Journal of Electrical Power & Energy Systems, 2012.

[14] N. I. Yusoff, A. U. Mohd Zin and A. b. Khairuddin, "Congestion Management in Power System: A Review," IEEE, Skudai, Johor, 2015.

[15] S. N. P. S. and K. M. L. , "Congestion Management In Transmission Lines Considering Demand Response and FACTS Devices," International Journal of Innovative Research in Science, Engineering and Technology, 2014.

[16] H. M. C. C. L. S. and C. K. W. , "Dispatch of Generation and Demand Side Response in Regional Grids," IEEE Transactions, 2015.

[17] M. B. N. and A. A. , "Network Losses-Based Economic Redispatch for Optimal Energy Pricing in A Congested Power System," 3rd International Conference on Power and Energy Systems Engineering (CPESE), 2016.

[18] K. K. e. al., "Topics on The Deregulation Of The Power Industry," ECE Technical Reports , 1992.

[19] E. Z. Zhou, "XML and Data Exchange," IEEE Power Engineering Review, 2000.

[20] V. S. S. and T. J. , "A Congestion Line Flow Control In Deregulated Power System," Serbian Journal of Electrical Engineering, 2011.

[21] J. W. V. D. and B. J. K. , "Congestion Management Requirements, Methods and Performance Indices," California Energy Commision, 2002.

[22] N. K. and S. B. , "Congestion Management In Deregulated Power System using Real Coded Genetic Algorithm," International Journal Of Engineering Science and Technology, 2010.

[23] K. S. P. and S. J. , "A Survey Of Optimal Power Flow Methods," Journals of Theoritical and Applied Infromation Technology, 2005 - 2008.

[24] "Difference between Neural Network And Fuzzy Logic," GeeksforGeeks, 17 July 2020. [Online]. Available: https://www.geeksforgeeks.org/difference-between-neural-network-and-fuzzy-logic/. [Accessed 28 May 2021].

[25] "Real-Life and Business Applications of Neural Networks," smartsheet, 17 October 2018. [Online]. Available: https://www.smartsheet.com/neural-network-applications. [Accessed 27 May 2021].

[26] "What Is a Neural Network?," The MathWorks, Inc., [Online]. Available: https://www.mathworks.com/discovery/neural-network.html. [Accessed 28 May 2021].

[27] A. Agrawal, "Particle swarm optimization," 9 September 2016. [Online]. Available: https://www.slideshare.net/LaRageVenom/particle-swarm-optimization-65856059. [Accessed 28 May 2021].

[28] W. K. Macura, "Ant Colony Algorithm," Wolfram Mathworld, 18 May 2021. [Online]. Available: https://mathworld.wolfram.com/AntColonyAlgorithm.html. [Accessed 28 May 2021].

[29] B. S. G. d. A. and V. C. Leite, "Particle Swarm Optimization: A Powerful Technique for Solving Engineering Problems," 3 December 2019. [Online]. Available: https://www.intechopen.com/books/swarm-intelligence-recent-advances-new-perspectives-and-applications/particle-swarm-optimization-a-powerful-technique-for-solving-engineering-problems. [Accessed 28 May 2021].

[30] I. R. T. F. o. A. Subcommittee, "The IEEE Reliability Test System-1996," IEEE Transactions on Power Systems, 1999.

[31] I. T. o. P. Systems, "The IEEE Reliability Test System - 1996," Vols. 14, no.3, 1999.

[32] M. WEIBELZAHL, "Nodal, zonal, or uniform electricity pricing: how to deal with," Higher Education Press and Springer-Verlag Berlin Heidelberg 2017, 2017.

[33] M. S. M. R. H. and P. H. , "Production efficiency of nodal and zonal pricing in imperfectly competitive," in *Energy Strategy,* ELSEVIER, 2019, pp. 193 - 206.

[34] D. Srinivasan, A. Liew and C. Chang, "Applications of Fuzzy Systems in Power Systems," ELSEVIER, 1995.

[35] L. M. B. L. M. G. L. Z. A. L. M. C. F. M. M. &. S. J. J. “. o. T. i. h. I. a. s. i. i. C. (. I. I. C. 2. p. 6. Tarouco.

[36] O. &. F. P. “. o. t. c. t. f. s. e. a. i. e. D. R. P. 2. Vermesan. [Online].

[37] S. &. B. P. T. V. “. b. r.-t. r. e. m. m. s. i. T. i. I. M. a. A. (. p. 1.-5. J. 2. Karthikeyan. [Online].

[38] "http://compassrosebooks.blogspot.se/2010/11/pee-genie-how-were-all-at- risk.html [Accessed: 2012-10-15]," [Online].

[39] J. T. J. C. A. &. P. L. Lloret, “An Integrated IoT Architecture for Smart Metering.”, IEEE Communications Magazine, vol. 54, no. 12, pp. 50-57,, Dec. 2016.

[40] L. B. M. R. G. S. M. S. M. N. K. M. G. &. I. M. R. Labib, Design and implementation of low-cost universal smart energy meter with demand side load management.”, IET Generation, Transmission & Distribution, vol. 11, no.16, pp. 3938-3945, Jul. 2017..

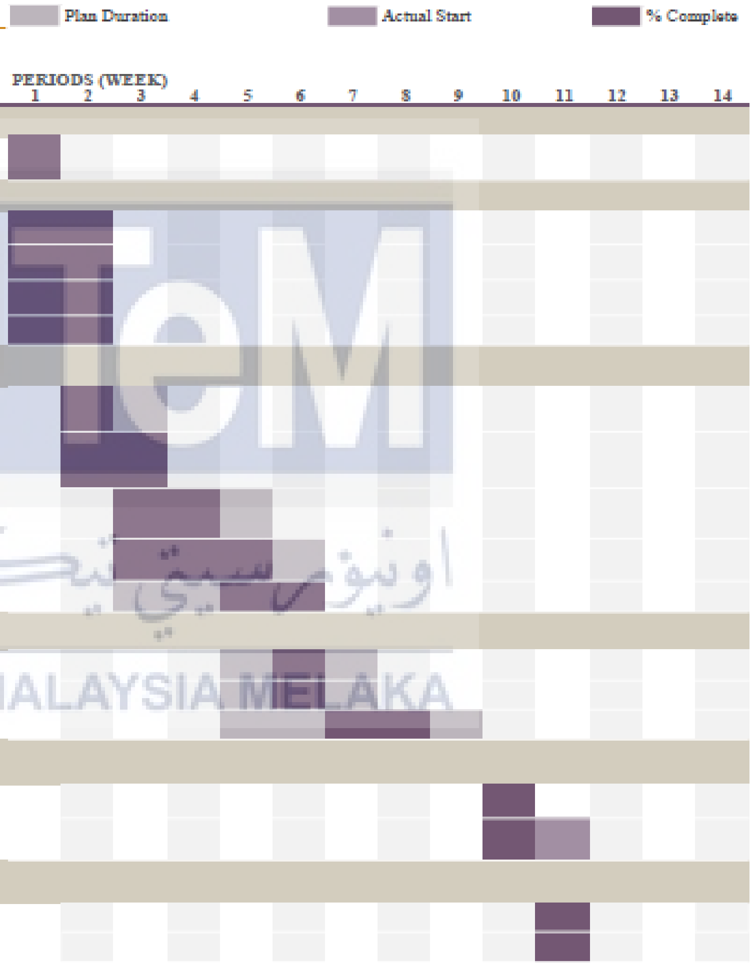
[41] E. F. Livgard, "Electricity customers' attitudes towards Smart Metering," *IEEE International Symposium on Industrial Electronics (ISIE)*, pp. 2519-2523., 2010.

[42] [Online]. Available: http://www.Smartgrid.gov/the_Smart_grid#Smart_home [Accessed: 2012-10-09].

APPENDIX A Gantt chart FYP I

FINAL YEAR PROJECT I GANTTCHART

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
PSM 1 Briefing					
Title Selection and Confirmation	1	1	1	1	100%
Chapter 1 (Introduction)					
Background	1	2	1	2	100%
Problem Statement	1	2	1	2	100%
Objectives	1	2	1	2	100%
Scope of Research	1	2	1	2	100%
Chapter 2 (Literature Review)					
Controlled Power System	2	2	2	1	100%
Deregulated Power System	2	2	2	2	100%
Congested Power System	3	3	3	2	100%
Methods for Congestion Management	3	4	3	3	100%
IEEE RTS-96	3	4	5	2	100%
Chapter 3 (Methodology)					
Introduction	5	3	6	1	100%
System Design	5	3	6	1	100%
Fuzzy Logic Approach	5	5	7	2	100%
Chapter 4 (Results and Discussion)					
Introduction	10	1	10	1	100%
Results and Analysis	10	2	10	2	40%
Chapter 5 (Conclusion and Recommendations)					
Introduction	11	1	11	1	100%
Conclusion	11	1	11	1	50%



APPENDIX B Gantt chart FYP II

FINAL YEAR PROJECT II GANTTCHART

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
PSM 2 Briefing					
Chapter 4 (Result and Discussion)					
Introduction	1	2	1	1	100%
Results and Analysis	2	6	2	6	100%
Discussion	6	2	6	1	100%
Chapter 5 (Conclusion and Recommendations)					
Introduction	8	1	8	1	100%
Conclusion	8	2	8	1	100%
Recommendations	8	2	8	1	100%