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

2021

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek **DEVELOPMENT OF CONGESTION MANAGEMENT FOR A DEREGULATED POWER SYSTEM USING FUZZY LOGIC**

Sesi Pengajian : SEM 1 (2021/2022)

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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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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.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for giving me the chance to complete my Final Year Project I and II in partial fulfilment of my course.

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.

Finally, I would like to thank my friend for the continuous support and assists along the completion of this project.

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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.

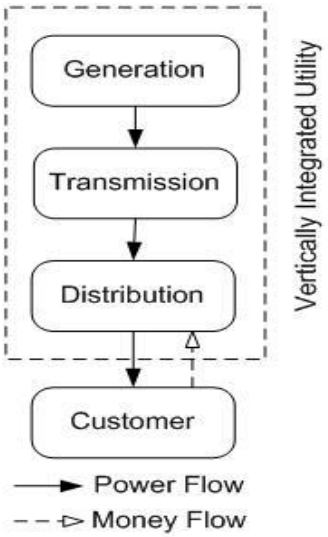

Figure 2.1 Regulated (controlled) power system

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.

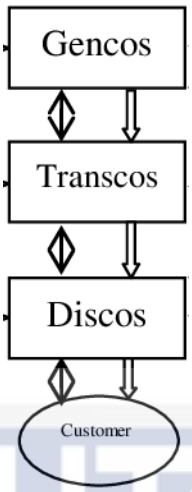

Figure 2.2 Deregulated Power System

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.

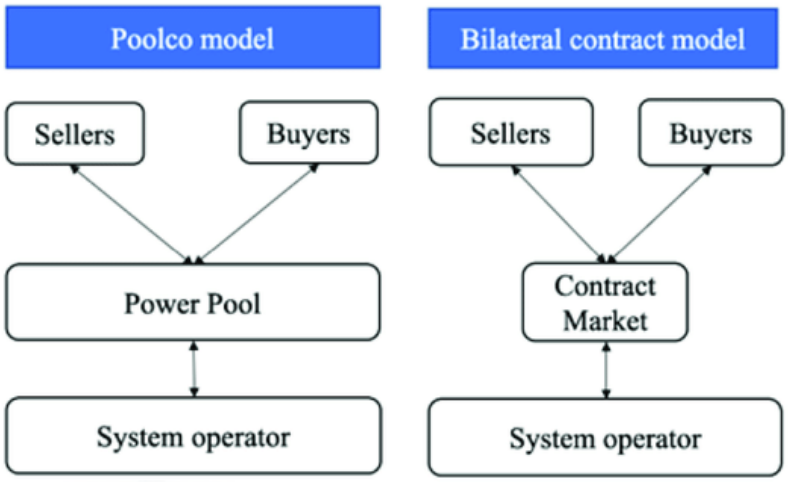

Figure 2.3 Types of Deregulated System

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