ALLOCATION OF SECURITY COST IN A PURE POOL-BASED ELECTRICITY MARKET DESGIN BASE ON LOAD CONTRIBUTION TOWARDS SECURITY PROBLEM

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To my beloved mak, ayah and abg

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ABTRACT

Transmission congestion management in pool market model has become the main issue of the debate in competitive electricity markets over the years. This happened due to a lot of problems and associated issues which need serious attention from all participants; suppliers, pool operator and consumers. Previously the UK pool handled the cost of transmission constraints by an uplift charge and used a uniform price for transaction between suppliers and consumers. However, it is some kind of nondiscriminatory auction since it gives incorrect signals for sitting new power plants. Then, nodal pricing is introduced in pool market as another alternative to solve the security cost allocation. The approach is able to reflect the locational value in accounting for losses and congestion. Though, it contributes towards merchandizing surplus. In order to assure the security cost allocation satisfies the economic efficiency and provides fair prices, a study on this issue is being conducted. Several comparisons are made between uniform pricing, nodal pricing and game theory methods by testing them in pool system under different case studies. In order to realize it, MATLAB programs have been developed for three bus system and IEEE-14 bus system applications. The results obtained are analyzed for further improvements and recommendations.

ABSTRAK

Pengurusan kesesakan di talian penghantaran di dalam model pasaran kelompok (*pool market*) telah menjadi isu utama perdebatan di dalam pasaran elektrik sejak bertahun-tahun dulu. Ini berlaku kerana begitu banyak masalah dan isu-isu berkaitan yang memerlukan perhatian yang serius daripada semua pihak; tidak kira sama ada pembekal, operator kelompok dan pengguna. Sebelum ini, pihak pengurusan kelompok UK mengendalikan kos penghadan penghantaran sebagai harga bayaran angkatnaik *(uplift)* dan menggunakan harga yang sama untuk tranksaksi di antara pembekal dan pengguna. Walau bagaimanapun, ini merupakan seperti pendiskriminasian jual beli memandangkan ia memberikan isyarat yang tidak betul untuk mendirikan sebuah loji kuasa baru. Kemudian, harga nod diperkenalkan di pasaran kelompok sebagai alternatif lain untuk menyelesaikan peruntukan kos sekuriti. Pendekatan ini mampu mengembalikan nilai lokasi dalam mengambilkira kehilangan dan kesesakan. Namun, ia menyumbang kepada lebihan dagangan. Dalam memastikan peruntukan kos sekuriti memenuhi kecekapan ekonomi dan memberikan harga yang adil, satu kajian tentang isu ini dijalankan. Beberapa perbandingan dibuat antara kaedah harga seragam, harga nod dan teori permainan dengan mengujinya di sistem kelompok dengan kajian kes yang berbeza. Untuk merealisasikannya, program MATLAB telah dibangunkan untuk aplikasi sistem tiga bas dan sistem IEEE-14 bas. Keputusan yang diperolehi dianalisis untuk penambahbaikan dan cadangan lebih lanjut.

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CEGB	-	Central Electricity Generating Board
DisCo	-	Distribution Company
h	-	hour
ISO	-	Independent System Operator
MP	-	Market Price
MW	-	Megawatt
MWh	-	Megawatt-hour
OPF	-	Optimal Power Flow
SMP	-	System Marginal Price
SRMCC	-	Short Run Marginal Congestion Cost

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CHAPTER 1

INTRODUCTION

1.1 Project Background

In competitive electricity market, a wide access to networks that connect customers and suppliers is required. The access to the transmission system by generators and loads is expected to be traded in a non-discriminatory and equitable manner. It shows the transmission networks play an important role in power system operation.

However, one characteristic of electric power networks has become a major concern in order to achieve transmission open access. The transmission congestion became a serious issue since the past few decades because of its effects to the power system operation. This special phenomenon may prevent the system operators from dispatching additional power from a specific generator and hence increases in cost which can be much greater than in the case of transmission losses.

The increase in cost is due to re-dispatching the cheapest available generators. Generation re-dispatch would cause the power generated by the cheaper generator not being delivered to the desired load and thus increasing the cost of energy production. This increase in cost is considered as the cost of having a secure system or in other words, a security cost.

A relevant problem related to the competitive electricity markets operating under the pool model is the allocation of the security cost among the consumers.

Typically, this cost is charged to the consumers as an uplift charge. However, this approach cannot give the correct signals to the consumers. Despite that, another approach is implemented in certain countries to reflect the locational value of the consumers. Yet, it still has weaknesses in the transaction between suppliers and consumers.

Therefore, there are many methods available and have been proposed with the purpose of solving the security cost allocation. Some of them are traceable flow method, new-user oriented, multi-stage method, Lagrange multiplier method, uniform pricing, nodal pricing and game theory. However, this project only concentrates on uniform pricing, nodal pricing and game theory. Several comparisons will be done between them by monitoring each performance in three bus system and IEEE-14 bus system applications. For that purpose, a MATLAB programs will be developed for application in pool model market.

1.2 Problem Statement

A main problem associated with competitive electricity market especially in pool-based market is allocation of the security cost among the consumers. Typically, uniform pricing approach is applied in allocation cost to consumers. However, the uniform pricing does not reflect economic efficiency since it does not consider which consumer contributes more towards congestion in the transmission networks. Also, the nodal pricing approach which is applied in certain regions results surplus in the transaction. This approach causes the revenue collected are in excess of the cost incurred.

Therefore, it is necessary to investigate other method of security cost allocation which satisfies the properties of economic efficiency and provides fair prices.

1.3 Objective

The purpose of this project is to compare between practical security cost allocation methods with other available method. In this project, the comparison on performance towards security cost allocation is made between uniform pricing, nodal pricing and game theory approach. The analysis will lead to advantages and disadvantages of each method.

This project also targets to develop a MATLAB program which able to solve security cost allocation problem in pool market. Therefore, the analysis can be made numerically and effectively.

1.4 Scope of Project

Basically, this project will cover the security cost allocation methods such as uniform pricing, nodal pricing and game theory. Those methods will be applied to three bus system and IEEE-14 bus system in order to monitor each performance. Afterwards, the pro and cons of each method are highlighted. Finally, a MATLAB program will be developed to test the method in simple and large system of pool model.

1.5 Thesis Outlines

This research project is divided into six chapters. Generally, some basic principles, theories, equations, previous researches references, case study and discussion were included in these five chapters based on the contents requirements of each chapter.

In chapter 1, the author has included the project overview, the problem statement for this research project, the objective of the project and the scope of

project. Chapter 2 presents the literature review on pool market model. This chapter briefly explains two types of pool market. This chapter also explains the transmission congestion which occurs in pool-based electricity market. Come to the end of the chapter, the author will present three methods on security cost allocation. The methods which include pro rata, nodal pricing and game theory will be explained in details in this chapter. Some methods are already applied in certain countries which their electricity markets are pool-based model and the remaining are the previous research works done by other researchers.

Chapter 3 presents the methodologies of carrying out the research as well as the procedures for MATLAB programming and power system network testing. The method will be presented in flow chart fort together with a brief explanation.

The MATLAB programming that developed by using MATPOWER will be covered in Chapter 4. There are five case studies will be presented which involving three bus system and IEEE-14 bus system. Each method; pro rata, nodal pricing and game theory will be applied to the same system in order to obtain the security cost allocation between consumers. Also, there will be additional part which attempting to allocate the security cost to both generators and loads. The developed programs will be shown in flow charts. Meanwhile, the MATLAB programs are attached in appendices.

Chapter 5 will discuss on the results from the simulation. The performance of each security cost allocation method in every system will be discussed in detail. The final section of this chapter will compare the results from each method. Some pros and cons for the security cost allocation methods will be pointed out.

Finally, Chapter 6 will conclude all the works, studies and comparisons that had been presented in the previous chapters. Besides, some recommendations for future work will be mentioned.

REFERENCES

[1] E.L da Silva, J.C. Morales and A.C.G. de Melo, "Allocating Congestion Cost Using Game Theory," *Power Tech Proceedings, 2001 IEEE Porto* , vol.1, no., pp.5 pp. vol.1-, 2001.

[2] A.G. Bakirtzis, "Aumann-Shapley transmission congestion pricing," *Power Engineering Review, IEEE* , vol.21, no.3, pp.67-69, Mar 2001.

[3] A. Brandenburger, "Cooperative Game Theory," Apr 2007.

[4] H. Singh, S. Hao and A. Papalexopoulos, "Transmission congestion management in competitive electricity markets," *Power Systems, IEEE Transactions on Power Systems*, vol.13, no.2, pp.672-680, May 1998.

[5] D. Kirschen and G. Strbac, "Fundamentals of Power System Economics, " John Wiley & Sons, Ltd, 2004.

[6] M. Y. Hassan, "Teaching Module: Power System Control," 2nd Edition, FKE, UTM, 2007.

[7] L. A. Barroso, T. H. Cavalcanti, K. Purchala, and P. Giesbertz, "Classification of Electricity Market Models Worldwide", IEEE 2005.

[8] H. S. Jung, D. Hur and J. K. Park, "Congestion Cost Allocation Method in Pool Model," IEE, 2003.

[9] A. R. Shirani and H. Siahkali, "Traceable Flow Method in Determination of Congestion Cost in Open Access Power System Network," IEEE, 2002.

[10] H. Jiang, Y. Q. Zhou, and J. C. Peng, "A New User-Oriented Method for Congestion Cost Allocation," IEEE, 2002.

[11] http//:en.wikipedia.org/wiki/coordination_game

[12] M. P. Abdullah, M. Y. Hassan and F. Hussin, "Congestion Cost Allocation in a Pool-Based Electricity Market," PECon 2008, IEEE, Dec 2008.

[13] R. D. Zimmerman and C. E. Murillo-Sanchez, "MATPOWER User's Manual," Cornell University, 2007.

[14] M. Z. Mat Cha and W. A. G. Wan Abdullah, "Modul Sains Komputer," Kementerian Pendidikan Malaysia, 1999.