POWER FLOW ALLOCATION IN DEREGULATED POWER SYSTEM

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Bachelor of Electrical Engineering (Industrial Power)

MAY 2010

"I hereby declare that I have read through this report entitle "Power Flow Allocation in Deregulated Power System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)".

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Date : 12th May 2010

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

Faculty of Electrical Engineering

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I declare that this report entitle "Power Flow Allocation in Deregulated Power System" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………………

Name : AIMI FARIDAH BINTI TAJUDDIN

Date : 12th May 2010

Dedicated to

My beloved parents
Tajuddin bin Kamaruddin & Salbiah bt Ahmad

My supervisor
Farhan bin Hanaffi

My friends

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All praises to the Almighty Allah S.W.T. the sustainer of the world and may there be His blessing to all messengers and his last messenger, the Prophet Muhammad S.A.W. and his family, companions and followers and the entire believer till the end of time.

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May Allah S.W.T. reward you all with the best here in this world and thereafter. Amin.

ABSTRACT

Historically, the electricity industry was a monopoly industry with a vertical structure. In a vertically integrated environment, enterprises were responsible for the generation, transmission and distribution of electrical power in a given geographical area. The last two decades, especially during the 1990s, the electricity supply service has been undergoing a drastic reform all over the world. The old monopolist power markets are replaced with deregulated electricity markets open to the competition. Deregulated power systems are unbundled in the generation, transmission and distribution which are traditionally performed in a vertically integrated manner. Viewing of market operation, it becomes more important to know the role of individual generators and loads to transmission wires and power transfer between individual generators to loads. In this project, power flow allocation is refers to power contribution of each generator to each load in deregulated power system networks. A "Commons Method" will be applied on deregulated power networks in order to determine the active and reactive power contributes from generators to the particular load. A MATLAB software will be used to construct and develop a programming that will compute the power flow allocation based on the proposed method. The simulation is based on the MATLAB programming constructed which was implemented on IEEE 9-bus system. At the end, the knowledge of the power contribution between generators and loads and flows in the power system network has become an important issue since the deregulation of the electric power industry.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Tracing the flow of electricity in power systems is an old issue, but it has become important especially after the deregulation. In deregulation, the vertically integrated structure of power industry is being replaced by market structure in the world range. In such a structure a transmission system is being used by multiple generation and load entities that do not own the transmission system. In a view of market operation it becomes more important to know the role of individual generators and load to the line and the power contributions between the generators and loads.

In this Final Year Project (FYP), a MATLAB programming will be constructing based on the selected method in determining the contribution of individual generator to loads and flows in a deregulated power system. The selected method is a "Commons Method" which is based on the power flows (active and reactive) from a solved power flow computation. This method organizes the buses and branches of the network into homogenous group. Other than that, this method provides several concepts and algorithms such as Domain of a Generator, Commons, Links and state Graph; in computing the power contribution between the generator and loads.

At the end of this FYP, by simulating the constructed MATLAB programming on IEEE 9-bus system, the power contribution between generators and loads can be determined using this MATLAB programming.

1.2 Project Objective

The objectives of this project are:

i. To study power flow allocation in deregulated power system;
ii. To develop MATLAB programming in computing the power flow allocation between the generator and load in deregulated power system;
iii. To compute power flow allocation between generators and loads in deregulated power system.

1.3 Project Scope

The main scopes of this project are:

i. To determine how much the active and reactive power output of each generator is contributed to particular load by neglecting the line losses;
ii. To analyze the power flow allocation in deregulated power system using a Commons Method;
iii. To develop a programming and simulate the power flow allocation in deregulated power system by using MATLAB software;
iv. To simulate a tests on IEEE 9-bus system of a deregulated power networks:

1.4 Problem Statement

In many parts of the world, the electricity supply industry is undergoing unprecedented changes. While these changes take many forms such as separation of traditional vertically integrated utilities into generation, transmission and distribution companies and creation of markets foe electric energy, the goal is always the introduction of competition and a lowering of the average consumer price. While competition is introduced in generation, it is widely agreed that transmission is a natural monopoly and should remain centrally controlled. It is also widely recognized that the operation of the transmission system can have enormous impact on a competitive market. Transparency in the operation of the transmission system is essential ingredient in establishing this confidence. In this respect, generators and network operating companies are likely to answers to questions such as "where the power is coming from and where is it going?"; "how far is the power generated by this unit really going?"; "which generators are supplying a specific load?"; "what are the contributions to the line of each generator?"; or "which generator is making the biggest use of this transmission line?". [6] In a competitive environment, these questions must be answer clearly and unequivocally to ensure the market are efficient and operating fairly.

1.5 Project Report Outline

This project report of Power Flow Allocation in Deregulated Power System is intended for BEKU 4973 Final Year Project (FYP) II. The project report is organized into 6 chapters. Each chapter begins with an introduction describing the topics that will encounter. Chapter 1 is a brief overview of the FYP which included about the objectives, scopes and problem statements of this project. Chapter 2 reviews about deregulated power system. In this chapter, deregulated power system is described as the introduction of competition in electricity supply industry and lead to the Transmission Open Access (TOA). Besides, the responsibilities of Independent System Operator (ISO) will be discussed in maintaining the operation of TOA. Chapter 3 reviews about the proposed method that being applied in allocation the power flow in deregulated power system which is Commons Method. The concepts of Commons method is also discussed in this chapter which are Domain of a Generator, Commons, Links and State Graph. Chapter 4 literates about the MATLAB Software which discussed the key features, system, language and several functions contained in MATLAB. Chapter 5 presents the methodology of software development which computes the power flow allocation in deregulated power system. It also contains the theoretical calculation of the Commons method in order to determine the contributions to the load of a Common in the IEEE 9-bus system. The calculation techniques are based on the concepts and proportional assumption stated in the previous and this chapter. In Chapter 6, a simulation and analysis for IEEE 9-bus system will be done based on the constructed MATLAB programming. Chapter 7 is a conclusion a recommendation of the FYP II including objectives that had been achieved.

CHAPTER 2

DEREGULATED POWER SYSTEM

2.1 Introduction

In 1989, the United Kingdom became one of the pioneers in privatizing its vertically integrated electricity industry. Norway and California followed in 1990 and 1996 respectively. The success of privatization in the UK and Norway has encouraged other countries worldwide to follow the trend. Countries that have been undergoing energy deregulation include Argentina, Australia, Brazil, Germany, New Zealand and Spain. Occasionally, the term ‘privatization’ is used to refer to what one would regard as ‘deregulation’ of electric utilities. Deregulation of ten starts with the sale of state-owned utilities to the private sector [6].

2.2 Deregulation

Generally, deregulation denotes breaking up the Vertically Integrated Utility (VIU) structure into Competitive Market Entities.

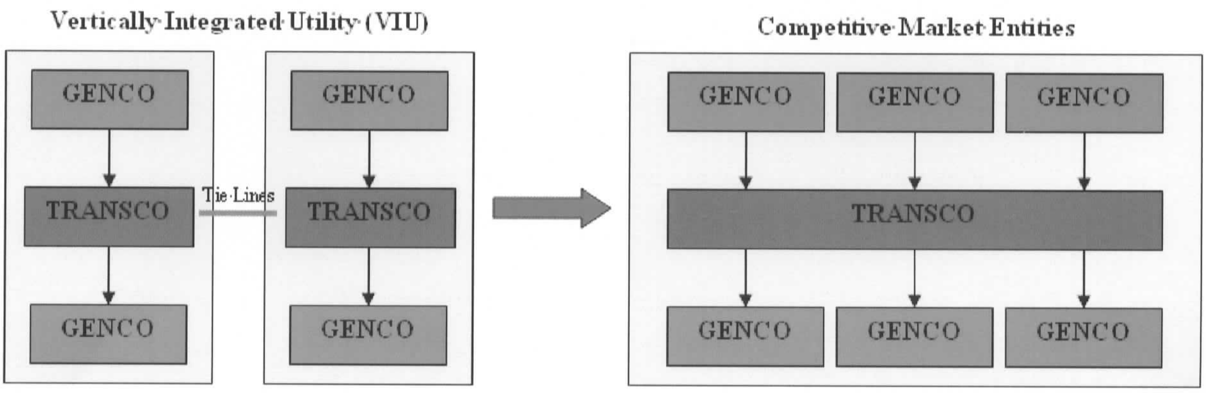

Figure 2.1: Deregulated power system

As shown in Figure 2.1, Vertically Integrated Utility (VIU) is being transformed into a market structure. VIU typically own generation, transmission and distribution over a wide area which mostly owned by the government. Each utility has one or more control centers that maintain security and reliability of a specific region. Competitive Market Entities is one in which a number of suppliers (generators) are competing to sell their electricity to a number of customers (loads). In any case, deregulation is widely adopted to refer to the 'introduction of competition'. Deregulation often involves 'unbundling' which refers to disaggregating an electric utility service into its basic components and offering each component separately for sale with separate rates for each component.

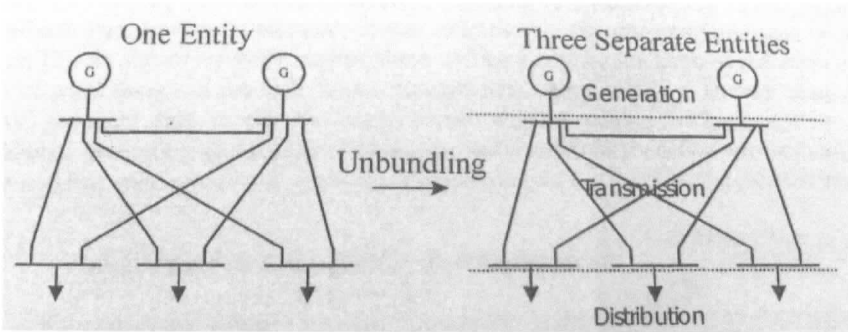

Figure 2.2: Unbundling of utilities

As shown on Figure 2.2, generation, transmission and distribution could be unbundled and offered as discrete services. However, deregulation is not only involved unbundling but also the separation of ownership and operation. In many countries, a central independent body, usually called the independent system operator which frequently called as system operator, is set up to cater for the matching of supply with demand and the maintenance system reliability and security. Sometimes the system operator is also responsible for matching the bids of generators with the demand bids to facilitate exchange. In some markets, another entity is set up just for that purpose; the so called Power Exchange.

The general success of energy privatization justifies the global trend of deregulation. In most cases, competition is introduced gradually from the wholesale market to the retail market. In most countries, retail competition is still underway; some small or residual customers have not yet benefited from the deregulation. With the existing regulations, it is difficult for new suppliers to enter market and compete with the existing suppliers. Stringent regulations are required for mandatory third-party transmission access and the recovery of utilities stranded cost. Electricity, unlike many other commodities, cannot be stored easily and supply has to match demand at all times. The transportation of electricity is constrained by physical laws which need to be satisfied constantly in order to maintain the reliability and security of the power system. It soon became obvious that the transmission network is the main impediment to energy privatization.

2.2.1 Bilateral Models

Bilateral models promote free market competition and therefore are a good way to achieve competition in an electricity market. In this model, suppliers and consumers independently arrange trades, setting by themselves the amount o generation and consumption and the corresponding financial terms, with no involvement or interference by the system operator. Economic efficiency is enhanced when consumers choose the least expensive generators. However, the unique characteristics of electric power networks make difficult to utilize the model. Problems are cased by the lack of coordination among the dependent trades, leading to the violation of transmission network constraints such as congestion and transmission system losses. In fact to manage congestion, the system operator can use one of many different objectives. These objectives can range from a least cost formulation to one that results in the minimum possible adjustments to schedule.

2.2.2 Multilateral Trades

A multilateral trade is a generalization of a bilateral trade. Thos operating paradigm allows suppliers and consumers primarily to seek profits on their own while the independent system operator ensures security. It is postulated that it is essential to have coordinated trades involving three or more parties to relieve congestion or to ensure security of operation. This model has a minimal role for the system operator who has no data on costs or financial arrangements. The duties include verifying feasibility of trades 24 hours ahead, dispatching and monitoring trades in real-time and eliminating imbalances and charging commitment violations.

The drawback of this paradigm is that the congestion charge is shouldered by all participants and therefore it does not give any signals for locating or installing new transmission facilities. Also, it does not penalize any participants who constantly cause congestion to the network. The concern of fairness arises about how curtailment of trades is done initially. Furthermore, in reality, power system networks are complex, it will be difficult for participants to find the best trade and therefore it is unlikely that the optimal operating point will be achieved within a reasonable period.

2.3 Transmission Open Access

One of the main issues concerning electricity reform is the unbundling of electricity assets. Competition starts with the selling of all the government's generator to several private companies. The idea of separation of ownership and operation applies to the transmission sector. Transmission network owner and operator are separate entities so that unjust use of the network is avoided. This central body often called the system operator which is responsible for matching demand with supply. Generators are informed of the amount of power they should produce in different time slots. This ensures that the system is utilized in the most efficient way.

Access to the transmission system is one of the main issues in energy privatization. Rigid and sound regulations are required to facilitate transmission open access (TOA). TOA refers to the regulating construct such as the rights, obligations, operational procedures, economic conditions, etc., enabling two or more parties to use a transmission network. With equal rights of access to the transmission network, it has become feasible for any generators or loads to arrange transactions with each other and hence competition is enhanced. TOA is among the keys elements for facilitating competition in the energy markets.

Because of open access, entities that did not own transmission lines were granted the right to use the transmission system. The aim of TOA is introduce competition into the traditional cost-of-service regulated utilities without giving up the existing regulating structure and at the same time obtain reliable and economic electric service. There are two big issues concerning the implementation of TOA:

i. Economic issues: Marginal pricing with a supplement for revenue incentives is an economically efficient option. The different kinds of allocations are rolled-in allocation, contract path allocation, incremental cost allocation and megawatt mile allocation.

ii. Operational issues: The three different considerations are before the fact, real-time and after the fact.

The pricing of transmission services plays crucial role in the success of deregulation since it determines whether the provided transmission services are economically beneficial to both the wheelers and the customers. The rules can be divided into two main categories which are embedded-cost-based approaches and marginal-cost-based approaches. The former approaches include:

i. Postage stamp method: based on magnitude of the transacted power.
ii. Contract path method: a contract is selected to identify the transmission facilities that are actually involved in a transaction.
iii. Distance-based MW-mile method: based on the magnitude of the transaction power and the aerial distance between the points of delivery and receipt.
iv. Power-flow-based MW-mile method: Based on the extent of use of transmission facilities by the transaction. This requires set of load flow analysis associated with each wheeling transaction when multiple wheeling transactions are considered.

The latter approaches are based on the solutions of optimal power flow and include short-run marginal cost methods and long-run marginal cost methods.

2.4 Independent System Operator

The independent system operator (ISO) is a neutral entity responsible for maintaining the instantaneous balance of the grid system. The ISO performs its function by controlling the dispatch of flexible plants to ensure that the loads match resources available to the system [6]. Other major responsibility of the ISO is to ensure fair and impartial access to the transmission system for all generators, while maintaining reliable operation. Occasionally, the duties of ISO are integrated with power exchanged (PX) which act like an auction to match total demand for power with generation of power. The ISO can also operate markets for ancillary services, such as reactive power, spinning/non-spinning reserve and losses.

2.4.1 PX Functions and Responsibilities

A PX of some form is essential for efficient trading in electricity. The PX establishes an environment in which generators and consumers bid to sell and buy energy. Parties bilateral contracts can operate their own separate energy trades and schedule their transactions outside the PX's market. The primary function is to provide a forum to match electric energy supply and demand in the current and forward energy markets.

In its simplest form a PX provides a bulletin board type of environment for energy suppliers and energy customers to engage in bilateral forward contracts. However, the more usual function is to act as a pool for energy supply and demand bids and to establish a market-clearing price (MCP). The MCP is the basis for the settlement of forward market commitments. Regardless of asking prices all selected bidders are paid the MCP. This approach encourages bidders in a competitive market to price energy close to their marginal production costs.[6]

Basically, the working process of the PX is:

i. Receive bids from power producers and customers;
ii. Match bids, decide the MCP prepare scheduling plan;
iii. Provide schedules to the ISO or transmission system operators;
iv. Adjust the scheduling plan when the transmission system is congested.

2.4.2 ISO Functions and Responsibilities

The system operator plays a critical role in both the traditional utility environment and the emerging unbundled systems, although some activities and responsibilities have changed considerably. In the traditional utility environment the system is vertically integrated and the operator, as the top manager, takes over the entire business so far as operating the physical system is concerned. In vertically integrated traditional utilities the range of operator responsibilities as well as the ownership of the system is maximized in one corporate entity.

In a new market structures there are a variety of arrangements for the system operator and since the operator must be disassociated from all participants the name independent system operator is a natural choice. The ISO has three objectives which are security maintenance, service quality assurance and promotion of economic efficiency and equity. To achieve these objectives the ISO performs one or more of the following functions: [6]

i. Power system operations function:

This fundamental function includes the operation-planning function and real-time control.

The operation-planning function includes:

- Perform power system scheduling.
- Co-ordinate with energy markets.
- Perform power system dispatch.
- Determine available transfer capabilities (ATCs).
- Determine real-time ATCs.
- Pre-calculate short-run costs and prices for transmission-related services.

The real-time control includes:

- Monitor power system operation status.
- Monitor system security.
- Conduct physical network operations and network switching.
- Deal with outages and emergencies.
- Coordinate real-time system operation.

ii. Power market administration function:

There are two types of energy markets: the pool market and the contract (bilateral and multilateral transactions) market. The former could be run by the PX or an ISO-PX combine while the latter may be coordinated by one or more SCs.

The pool market includes:

- Run a power pool where parties can bid to buy and sell energy.
- Develop a preferred schedule for pool.
- Submit the supply and load schedule to the ISO according to pre-specified protocols (this is for case when the PX is separated from the ISO).

The contract market includes:

- Manage bilateral and multilateral transactions.
- Manage and coordinate submissions from SCs.
- Submit preferred schedules to the ISO according to pre-specified protocols.

iii. Ancillary services provision function:

- Own certain ancillary services for satisfactory grid operation.
- Purchase ancillary services transactions from market participants according to pre-specified protocols.
- Provide ancillary services to transmission users.
- Allocate cost of ancillary services among all users.

iv. Transmission facilities provision function:

- Maintain the transmission network.
- Provide transmission facilities for all supplies and loads.
- Plan transmission,, reactive power and FACTs expansion and ensure that resourcse for future investment are generated.
- Plan and commission own ancillary services.

2.5 Methods of Power Flow Allocation

Tracing the flow of electricity becomes an important issue under transmission open access. In practice, power flow follows the physical laws of electricity and therefore it is not straightforward to map out how the participants make use of the system. In a competitive market environment, a transmission system is being used by multiple generation and load entities that do not own the transmission system. In view of market operation it becomes more important to know the role of individual generators and loads to transmission system and power transfer between individual generators to loads.

Continuing trend towards deregulation and unbundling of transmission services has resulted in the need to assess what the impact of a particular generator or load is on the power system. A new method of tracing the flow of electricity in meshed electrical networks is proposed which may be applied to both real and reactive power flows [1]. The method allows assessment of how much of the real and reactive power output from a particular station goes to a particular load. It also allows the assessment of contributions of individual generators or loads to individual line flows. A loss-apportioning algorithm has also been introduced which allows the break down of the total transmission loss into components to be allocated to individual loads or generators. The method can be useful in providing additional insight into power system operation and can be used to modify existing tariffs of charging for transmission loss, reactive power and transmission services.

Because of the introduction of competition in the electricity supply industry, it has become much more important to be able to determine which generators are supplying a