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ABSTRACT

Since the mid-1980's the electrical power industry has been going through many rapid and fundamental changes. Deregulation of the power industry is a common phrase that is often used and has been a major trend in the industry. Many have come to terms with the benefit of deregulation, and the profound changes and impacts its brings along. Nations all over the world have committed to, or currently in the process of introducing more competition into their power industries. Under Transmission Open Access (TOA), unbundled transmission companies will provide power market participants with non-discriminatory access to its transmission services. As a result, the power market has seen major trends towards power retailing. This is where power wheeling comes about.

The author seeks to investigate the various methods used in the market in the pricing of wheeling transaction. Some of the commonly found methodologies such as Embedded cost-based, Incremental cost-based, Marginal cost-based will be examined closely to review their pros and cons. The author will also probe into the various power markets in the world today and provides an overview of the changes and impacts of deregulation faced by these methods.

This book present a method for allocating embedded cost of transmission to its consumers through transaction under deregulated environment of power system. There are many methods to calculate the embedded cost in different way and procedures. In this book there are comparison between those methods and try to find the fairest among them. There are IEEE 14 bus and IEEE 30 Bus system is used for the calculation with the help of MATLAB coding. For the calculation of price we take some transaction on different busses and load. This transaction is taken in MW. This transaction is bilateral in nature, active and reactive power both are considered and power factor included. We calculate the power flow a he different busses using load flow. Load flow give power in the line and this power are useful to calculate the cost of transmission. Than we calculate the cost of electricity price with transaction and without transaction.

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Chapter 1

INTRODUCTION

1.1 Introduction

Due to the rapid industrialization and subsequent increase in the power demand in India Utilities strive to provide quality power at reasonable costs. After 1947, all new power generation, transmission and distribution in the rural sector and the urban centers came under the purview of state and central government agencies. State Electricity Boards (SEBs) were formed in all the states. The customers can be majorly segmented as urban domestic, rural domestic and industrial for the explanatory purpose. But industrial segment is the major consumer of the power.

The increased power demand necessitated tariff hikes that burdened the industries. This forced the industries to build their own captive power plants and sell the excess generation to the grid. Such transactions pushed the utilities to greater strain and into losses. In order to reduce the losses, utilities moved towards restructuring of the power system. The restructuring and subsequent deregulation has made the conventional power system operational concepts irrelevant. Hence, to meet the new system conditions, studies like power quality has to be performed considering the renewed system conditions.

This dissertation presents various novel methodologies to identify the price of Electricity of the system. The presented techniques are useful to calculate the appropriate cost and methods of electricity pricing in deregulated power sector.

1.2 Motivation

The day when power system were run by vertically integrated utilities and operated with the large stability margins are all but in present climate of the deregulation and privatization, the utilities are often separated into generation, transmission and distribution so as to promote economic efficiency and encourage competition coupled with the difficulty of obtaining new rights of ways for expanding the transmission system. Power quality and energy efficiency has become more important to both electric utilities and energy customer. The purpose of this dissertation is to explore the basis for a relationship between electricity deregulation and pricing of electricity in deregulated environment of power system. On the other hand the electric system restructuring, whose main objectives are reduce & pay optimal cost to related facilities, decreasing the disturbances, and increasing energy efficiency.

During the last few decades the United States and some other countries have been restructuring their electrical power sectors, abandoning the former regulated monopolistic model which ruled the provision of electrical energy during most part of this century. The new 'deregulated' design/structures are based on free market principles (without monopoly), favoring competition among private participants and consumer choice. However, the theoretical base of deregulation in the electricity power industry is not completely developed yet, and the practical experience with electricity or power markets is still limited.

1.3 Objective

With the dawn of the competitive environment, electric power system restructuring is becoming a great concern for both electric utilities and customers. In this book, the effect of embedded cost or Pricing of Electricity on the deregulated power sector has been considered.

In the deregulated power sector 'correct' pricing of transmission facilities or services is useful for providing economic signals for efficient various short-run operations, recovery of costs with long-term capital investments and fair distribution of costs among participants.

Electricity markets with different model have been developed in many countries all over the world. This paper briefly reviews the pricing mechanism used by power market in the world. In this comparative analysis has been studied to compare the various pricing methods and effectiveness.

Chapter 2

Deregulation in Electricity Industry

2.1 Introduction

Since the mid-80s, there has been a tremendous amount of change and restructuring in the electric power industries in the world. The participants in the electric power industries have been forced to adapt to new laws and regulations which were introducing to increase competition in the industry and hence, encourage greater efficient in the management of the power companies and the system involved. This has becomes a common phenomenon in the power industry and often refer as deregulation of the power sector.

Deregulation of the power sectors has been occurring in many countries worldwide. Many reforms have been undertaken by introducing merchant incentives in generation, transmission, distribution and retailing market of electricity. There are many cause and reasons for the restructuring of the power sectors and it varies in different countries. However, some of the more remarkable benefits in a deregulated power industry are to be provided consumers with cheaper yet reliable electrical energy supply and generate financial support in the operation of power system.

Furthermore, based on the lessons learned from the experience of the deregulating the communication, natural gas and airlines industries, many have considered the necessity of deregulating the electric power industries to provide higher operation efficiency and low energy costs.

2.2 Getting Competitive

As mentioned before, there are several reasons for restructuring the electric power industries and nations worldwide are using different approaches and ways in restructuring their power sectors. Ultimately, the main issue is to find ways and means to generate and inject more competition into the power sectors, forcing the traditionally monopolized power market to become one of the competitive natures. This has been an uphill task as it involves changing many of the fundamentals involved in the management and operation of the power industries.

2.21 Monopolistic Market

In order to understand the main benefit and the approaches used in deregulated the power industries, the characteristic of a monopolistic market has to be analyzed. In a monopolistic market, competition is scarce and this often led to poor and uneconomic utilization of resources and assets available.

For many decades, the electric power industry was operating under a regulated monopoly. Power company or power utilities as commonly known, were under government protection and regulation for decades. It has been the tradition for the government to be in control of the generation and supply of the electrical energy as it is one of the basic necessities for the people. This creates a natural monopoly.

Very often, a firm will be appointed by the government to be in-charge of the generation, transmission and distribution of electrical energy to the consumers. It is often government owned and uses public money or resources to invest in assets such as generation plans and transmission grid for supply of electricity. This also means that the same firm or power entity owned and operates the generation, transmission and distribution assests. Thses entities are often referred as vertically integrated utilities and they are often the only source provider of the electrical energy in the region. Figure below shows a typical vertically integrated utility supply electrical energy to the consumers.

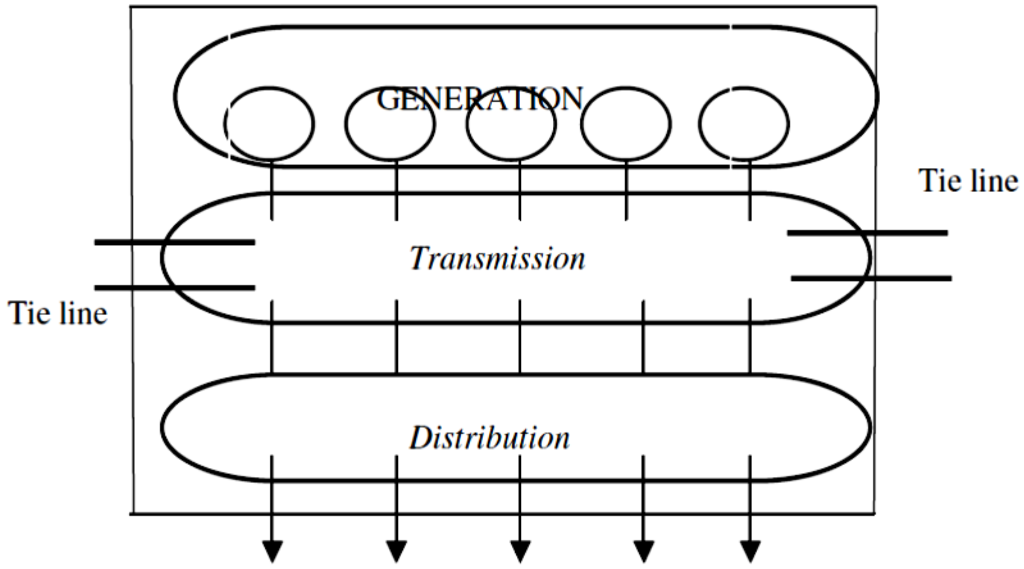

Figure 1. Structure of the Electric Power Industries in the Past

2.22 Drawbacks of Monopolistic Power Markets

It has been argued and agreed that under a zero competition and well protected environment, power utilities have the higher tendency to be operating inefficiency and as a consequence, higher tariff from consumers are usually necessary in order to cover the extra expenses incurred. Moreover, the main objective of such utilities and a deregulated and monopolistic market will be to minimize total system cost. In order to achieve this, power utilities have to operate the power system very near to its peak level, often with limited amount of backup energy resources left.

Another good example will be the transmission aspect of the power system. Old transmission lines were often poorly maintained and operating near to its saturated peak level. In the event where increased amount of transmission level required, companies tends to use low voltage transmission lines and place them in parallel to the older lines instead of installing the higher level voltage transmission lines.

2.23 Competitive Market

Hence, deregulation or restructuring of the electric power industries have been going on for past two decades in order to introduce more competition and achieve higher operating efficiency and better utilization of resources. In a competitive power market, power utilities have to compete against its competitors and operate like any other business-minded organizations.

With so many new power utilities entering the deregulated power market and without the incentives and protection enjoyed in the past under a monopolized system, restructuring of the management of the power system is a must so as to ensure continued growth and profits for the power entity. The number of generation plant increases as more generation utilities (GENCO) enters the market. This means that the amount of reserved electrical energy will be increasing also and hence there will be lower risk of having an inadequate energy supply to meet system demands during peak periods.

Furthermore, in a competitive environment, the rights, obligations and responsibilities of each party will be defined clearly. Undoubtedly, this will encourage the parties involved to make better investments to their infrastructure and improve the overall power systems. Ultimately, this will ensure higher quality and reliability in the supply of electrical energy, services and reaching the objectives of energy conservation.

2.3 Electric Power Supply Industry After

Deregulation

Generally, in a deregulated electric power industry, there has been a significant amount of trend leaning towards the unboundling of the services provided by the power utilities. One of the first steps in the process of restructuring the power industry is to separate the transmission services from the generation activities. This is because transmission of power is a natural monopoly and this has to be recognized in order to ensure fairness in the competition among the power generating utilities. Generation, transmission and distribution are independent activities. This is known as vertical unbundling.

The idea of transmission open access was introduced into the electric power supply industry to alter the traditionally monopolized industry to one with greater level of competition. Though many nations across the globe have been involved with deregulation to a certain extent, the concept of Transmission Open Access does not follow a uniform model and is often viewed and implemented based on the specific circumstances and needs of each nation. Generally, Transmission Open Access refers to having a regulatory restructure which will address the obligation, rights, operating procedures and economic conditions which ultimately and most importantly, enable two or more parties to access the transmission network (grid), which belong either partially of fully to a third party or parties for transfer of electrical power.

As mentioned before, in most deregulated and restructured power markets, transmission utilities operate independently from the other two functions in a power system. As shown in figure above, transmission utilities (TRANSCO) will be operating as an independent party. Providing access of its transmission network to the other participants in a typical power market. Under Transmission Open Access, TRANSCO should provide non-discriminatory transmission services to the power market participants and power market participants who used the transmission network of the TRANSCO for transfer of electrical energy have to pay for such usage and services.

The subsequent step in the process of deregulating the power industry is to introduce more competition into the generation activities, either through spot markets bidding, direct bilateral power transactions or creating power pool. In most restructured power industries, several generation utilities are created to introduce more competition. This is known as horizontal unbundling.

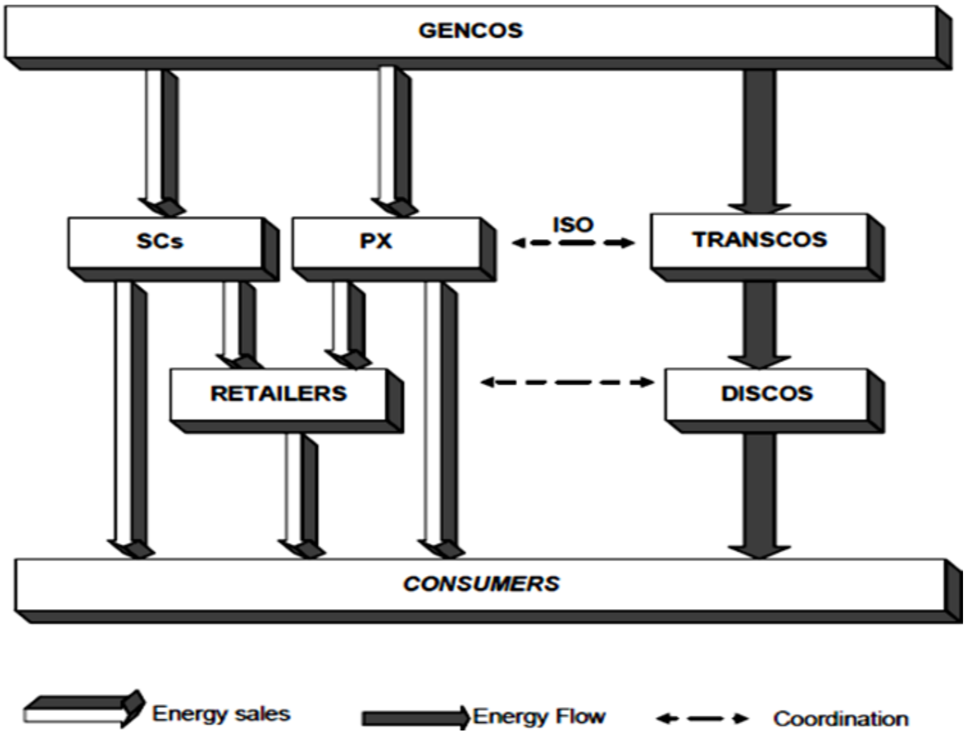

Figure 2. A typical structure of a deregulated power industry

With deregulation which brought the unbundling of the services provided in the past by vertically integrated utilities, there have been several new entities in the restructured power industries. Generally, they can be classified as follow:

Generation Companies (GENCOS): They can either be individual generating units or independent power producers (IPP) which consist of a group of generating units operating under a single company.

Transmission Companies (TRANSCOS): Entities that owned and operate the transmission networks. Main services are to provide a transmission path for the transfer of energy for their customers, be it the GENCO or the consumers.

Distribution Companies (DISCOS): Entities that owned and operate the local distribution network in an area. Electrical energy is usually purchase directly from the GENCOS or through bidding in the spot markets before supplying to the end-user consumers.

Consumers: End users which under a deregulated power market have several options in the purchase of electrical energy such as directly from GENCOS, spot markets or the local distribution companies.

Independent System Operator: Independent authority that does not involve in the market competition. Their objective is to ensure the reliability and security of the whole power system. It will not own any generation assets for commercial purpose, through it retains the right to own some capability for power generation in time of emergency.

Market Operator: Entity that will oversee the trading of electricity in the market. Bids from the market participants and the market operator will determine the market price based on certain criteria in accordance with the market structure.

Each of the above mentioned parties play a specific role in the restructured power markets. Deregulation has changed and redefined the type of activities carried out by these parties, mostly through new laws and legislation introduced by the governing body of the participating country.

At this point, it is evident that the amount of changes in the electric power industries after deregulation has been tremendous, many of which are fundamental and irreversible changes. Among all these changes, the one which is the most critical and creates a huge impact is to allow third parties non-discriminatory access to the transmission network, which results in a large increase in the number of independent power producers, non-utility generation (NUG) and wheeling contracts.

However, it is to be noted that there are variation in each country, though most follow the structure shown in above fig. Based on different needs and circumstances, the restructuring of the power sectors in each country may have started at different time, proceed at different pace and adopt slightly different approaches. The following sections will briefly describe some of the more notable restructured power market in different parts of the world.

2.31 North America

In the past, electric power industries in North American had been under a highly regulated and locally monopolized structure. Many of the regional electric utility holding companies such as Southern Company, operated under a monopolized structure within its assigned regional territory. These companies provided a total package of all electric services to their customers. In a way, they were considered as investor-owned or private companies from the very beginning.

In 1978, due to the middle-eastern oil crisis, process of deregulation was initiated by the Public Utility Regulator Policy Act (PURPA) which allowed the non-utility generators (NUG) or producers of electricity to enter the wholesale power market. Non-utility generators (NUG) are privately owned entities that produce electricity for their own use and sometimes sell it to the utilities. The number of non-utility generations increased significantly, the graph below shows the increased capacity of the non-utility generation in the North America markets.

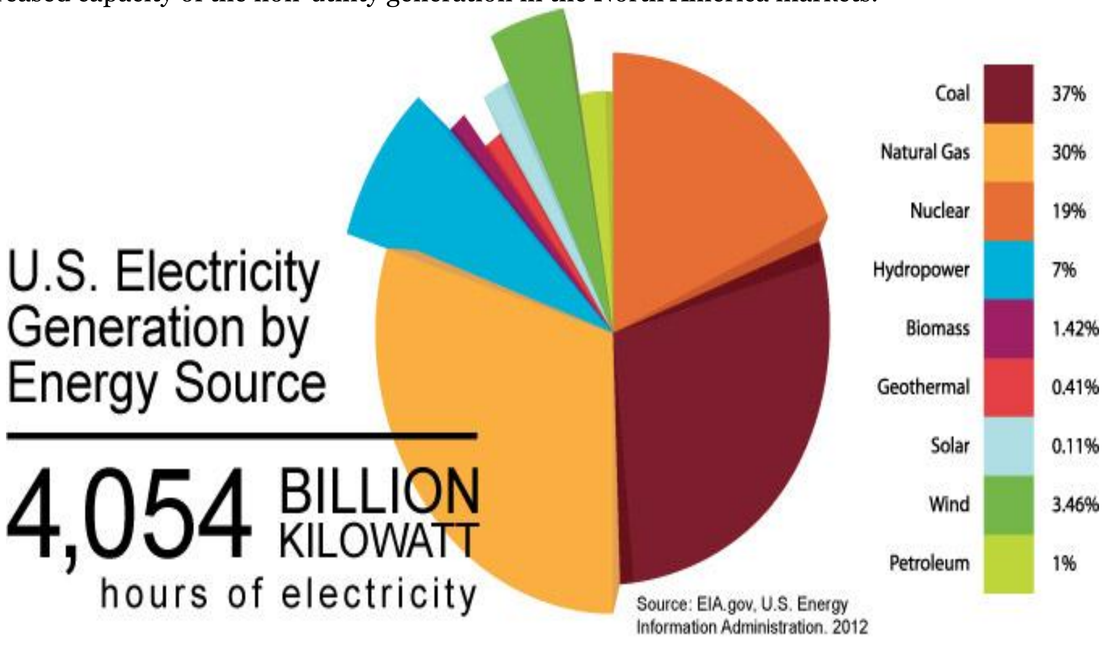

Figure 3 U.S. Electricity Generation Capacity 2012

Non-utilities generators produce power mainly for the wholesale markets. This as a significant step towards deregulation as it showed that by encouraging the growth of non-utility generators and independent power producers, generation of electricity is able to break away from the traditional monopoly structure. In 1992, the energy policy Act further enhanced the growth of non-utility generation and provides the driving mechanism to develop competitive power market in North America. The act empowered federal Energy Regulatory Authority (FERC) to facilitate the transition of the process of deregulating the electric utility industries. Based on that, the complete restructuring of the power industry begun and is still an on-going process at this point of time.

In 1996, final two ruling on Open Transmission Access were implemented by FERC which required the transmission companies (TRANSCO) to give open and equal access of the transmission grids for all electricity producers. TRANSCO are also required to adopt a non-discriminatory approach in setting tariffs, develop and maintain a same-time transmission information system for all users that the TRANSCO enjoys. These mean that non-affiliated power entities are able to enjoy non-discriminatory access to the transmission networks. This further supplement the restructuring process and customers are able to have direct access to retail power generation.

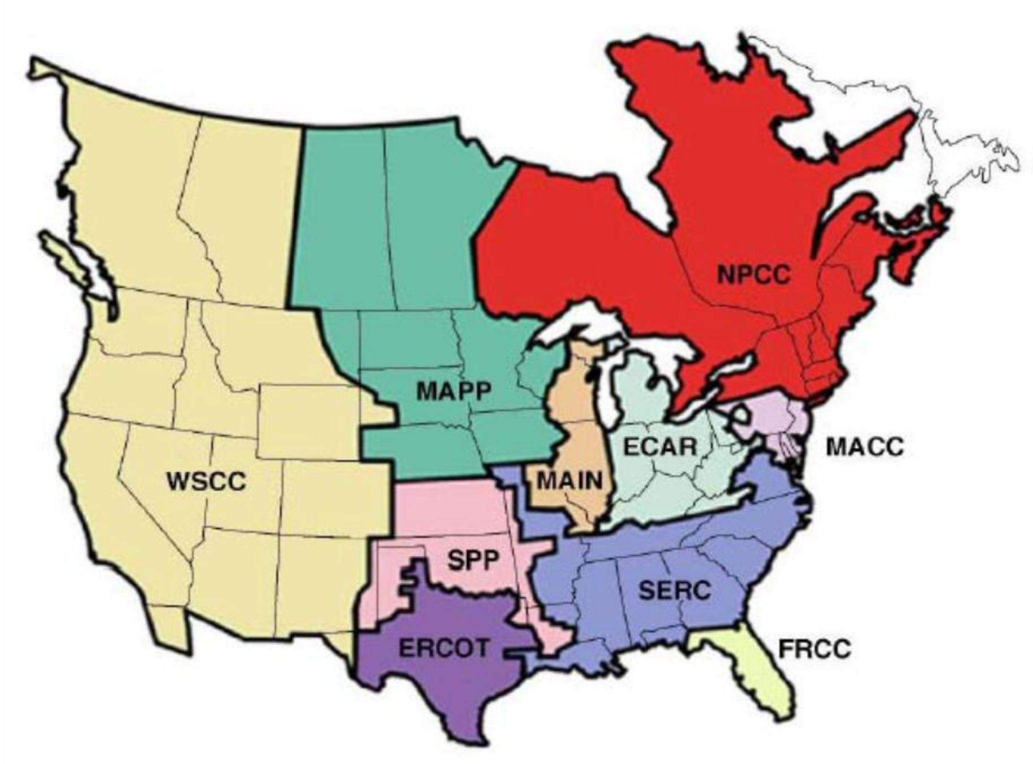

Figure 4 ISO and RTO in operation or under discussion as of april, 2000

The operational and reliability issues in transmission are some of the main concerns in a power industry. The idea of having Regional Transmission Organization (RTO) was formed in 1999 as the FERC issued Order 2000. The objective of RTO is to reform the operational practices of TRANSCO, to further reduces the discriminatory practices in the transmission services and increase the investments in transmission infrastructures. Traditional utilities that previously operated as vertically integrated and regulated monopolies are required by FERC to remove some function in order to operate in competitive power markets. By the moving the control transmission grids that these vertically integrated utilities once enjoyed, aims to break up the structures of these traditionally operated entities. However, there have been difficulties in determine the control of the transmission of electricity under a nationwide system of RTO even at the present moment.

Table 1 Information on ISO in North America

	California ISO	**ERCOT Texas ISO**	**ISO New England**	**Midwest ISO (MISO)**	**New York ISO**	**Pennsylvania New jersey Maryland (PJM) ISO**
Operating	March 31, 1998	August 1996	1997	Approved 1998.	1999	April 1998

Date						
Number of Transmission Owners	3	16	15	13	8	10
Type of Organisation	Non-profit	Non-profit	Non-profit	Non-profit	Non-profit	Non-profit
Board of Directors	24 members	18 members	10 members	8 members	10 members	8 members
Transmission Congestion management	Price based	Prioroty based	Prioroty based	Prioroty based	Price based	Price based
Ancillary services	ISO procures if not provided	ISO coordinates	ISO can provide	ISO will arrange for services	ISO can provide	ISO provide for cordinates
Transmission Planning	ISO leads coordinated process	ISO coordinates	NEPOOL has lead role	ISO develops plan with transmission owners	ISO is an active participant	ISO prepares plans

All these initiatives encourage growth of wholesale power trading and the volume of power trades have increased from 1.8 million megawatt-hours to 400 million megawatt-hours in 1999. Many new entities such as power marketers, IPP, ISO and power exchanges were born.

As the entities react and seek alternatives to survived in this competitive environment, mergers between investors-owned utilities (IOU) have been increasing. Since 1995, FERC has approved 50 mergers between IOU. Besides this, many entities have placed cost containment as a priority and as a result, there has been a dramatic staff reduction and significant slashes in the R&D budgets.

Almost half of the States in North America have passed legislations and regulations to restructure their electric power industries. In order to lower down the price of electricity, many of these States such as California, Pennsylvania and New York have opened up their retail electricity markets to competition and thus allowing customers to choose their preferred supplier, while other States also started doing so but with limited amount of customers.

Electricity rates are calculated based on the historical embedded costs. It has agreed by many analysts that rates should be dynamic and reflects the current costs providing services. It will be the common trend in the near future for utilities to unbundle their services and adopt a pricing strategy that real time and the flexible to season variations. Deregulation in the North America Power markets will eventually change the nature of the way electricity is priced, traded and marketed.

2.32 United Kingdom (UK)

The conservative government led by Margaret Thatcher came targeted many industries for privatization shortly after the election in 1979 an electric power industry was included. Privatization moved on slowly as there was several major opposition to privatization of the electric power industries. It was argued that privatizations over-benefit the customer from the industrial sectors. Moreover the full values of privatized electric assets were not attained a pay increases were given to the heads of the newly format privatized companies despite the fact that massive layoffs of the workers where conducted at the same time.

The United Kingdom started the development of a workable competitive electric power industry in 1989. The Electricity Act was passed by the parliament a started the restructuring process. There were three critical paths of restructuring. The assets of the previously state-owned electric companies which monopolized the markets and can be either vertically or horizontally enter grated were broken up. In another words, the services provided were unbundled.

The second critical process was to privatize the various states-owned area boards by turning them into regional electricity companies (RECs), each with their own share of the infrastructure, power transactions or sales. The last critical process was to recognize that transmission and distribution assets owned by the RECs are to be considered as natural monopolies where it will be subjected to an even more stringent form of regulation in terms of price controls.

Based on the restructuring phases mentioned above, the original Central Electricity Governing board (CEFB) which looked after the government controlled UK electricity system was replaced by a new regulatory authority, now known as Office of Gas and Electricity Markets (OFGEM). CEFB was broken up into three parts. Two privatized power generating companies named National Power and PowerGen were created initially. A power pool would be created to set wholesale power prices, accepting bids from generation companies. A monopolized transmission company called Nation Grid Company was also created to take over the ownership and operation of the transmission system. One of its many responsibilities was to facilitate competition, allowing open access to the transmission system. It is been directed to provide an impartial link between competing power generation companies and regional networks. It provides the main way to gain entry into the power market.

Due to this open access policy, there have been a significant increase in the amount of new generation projects and competitions in the supply of electricity to consumers have been developing rapidly. As there are more participants and power transactions going on in the market, National Grid also bears the responsibility of ensuring system security and congestion management.

The Electricity Act of 1989 was amended in 2000 with the introduction of the Utilities Act of 2000. It removed the distinction between the private and public electric supplier franchise areas. A new consumer council for the customers of gas and electricity supply was created to assist these customers in choosing an alternatives supplier for these utilities. It is compulsory for the electric supplier to meet up with the consumer councils at least six times a year in order for the consumers to serve well.

As the result of all these restructuring and privatization processes, electricity industries in United Kingdom was transformed from integrated statutory monopolies to one that displayed high degree of vertical and horizontal unbounding. The figure below shows the current structure of the industry.

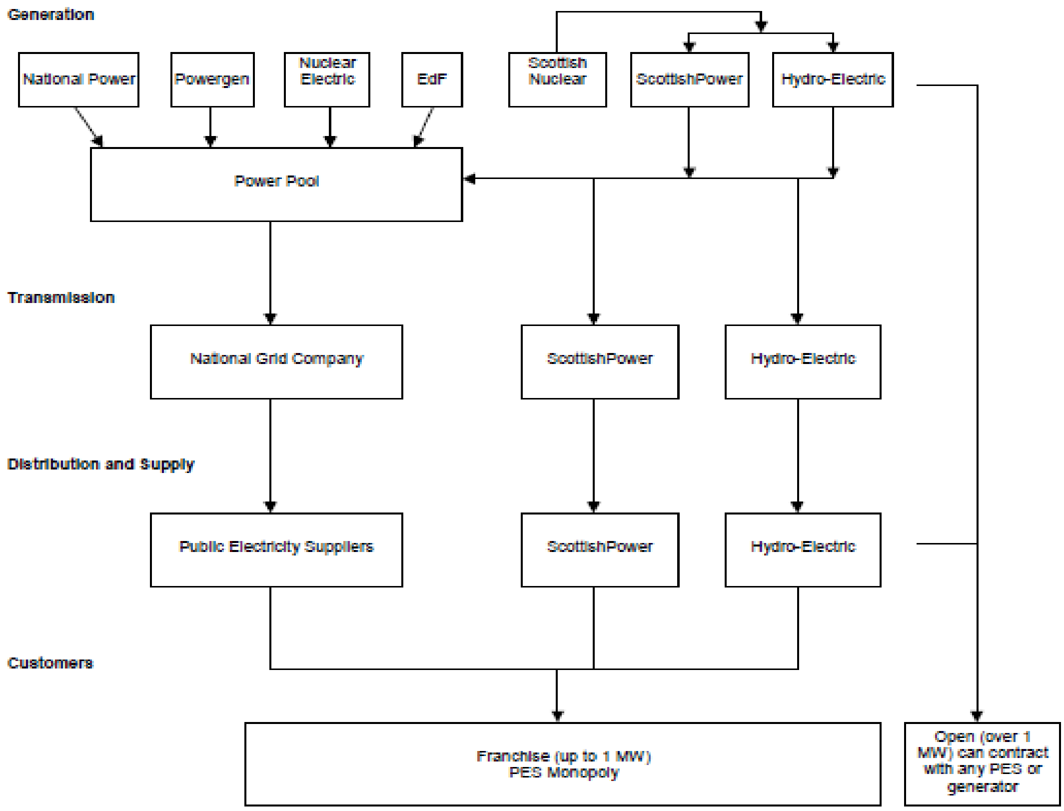

Figure 5 Electricity industry structure in UK

Figure shows the current structure of the electricity industry in United Kingdom. Participants in the market often ensure energy flows through to the ends-users, through there are some who are not involved with the physical flow but have a financial role only.

As of Oct 2003, electricity is transferred to various homes and business through two separate systems. In England and wales, much competition emerges from the power generation (wholesale) market through a single transmission network.

Competition in the generation sector is well established with 98% of the electricity freely traded in the deregulated, commodity style open market. Prices of electricity are set by the market. Since electricity is unlike any commodity as it cannot be stored, supply and load demand is balance by the National Grid Company at a second basis.

Table 2 Market shares of generating companies in a competitive market

Parent company	Supply business subsidiary	Market share
Innogy Holdings	npower npower Yorkshire npower Northern	19%
Centrica	British Gas Trading	17%
TXU	TXU Energi	15%
Scottish and Southern Energy	SSE Energy Supply	14%
Electricité de France	London Electricity	10%
ScottishPower	Scottish Power Energy Retail	10%
Powergen UK	Powergen	8%
American Electric Power	SEEBOARD Energy	6%
Other suppliers		1%

The table above shows the breakdown of the market shares by the various generation companies in UK. It shows the competitiveness of the generation sector being the results of deregulation in the power industries. Due to the intense level of competition in the market, riches of electricity have been dropping steadily over the years. The retail market is fully competitive.

However, the situation in Scotland is slightly different. Though there is competition in supply, but there is no competition in generation. The arrangement that the transmission networks are subjected to are outdated as they are drafted as early as 1989 where the privatization started. It is inefficient and hinders the wholesale market from developing. Thus, Scottish electricity customers do not enjoy the benefits of having lower prices for electricity brought on by having more competition in the electricity industry.

The generation sector in Scotland is not fully competitive yet, with Scottish companies owning or contracting 98% of generation. They have their own arrangements to balance the power system, instead of using seconds by seconds load supply bidding basis. The two transmission network are run by SP Transmission plc (South Power) and Scottish Hydro Electricity Transmission Ltd (Scottish and Southern), both of which are still very much vertically integrated utilities.

Generally, there has been an increase of over 11000MW of new capacity being commissioned ever since restructuring started in United Kingdom. Customers have much more choices and options in deciding their supply of electricity energy. There has been an increasing amount of customers switching their choice of electricity supply.

2.33 Australia

Australia has been one of the several countries who are at the vanguard of restructuring and introducing various reforms into the electric power industries. The reforms and strategies used were closely guided by the reforms taken in United Kingdom to a certain extent. However, one distinct difference is the structure of the government and the way the two nations are being governed. Australia is much more a federalist nation with more emphasis on state authority, unlike United Kingdom which was more of a unitary form of government. Reforms in Australia vary from state to state as they were carried out by separate state governments with different ruling parties. For example, privatization of electricity is being emphasized in Victoria whereas other states in the country emphasized more on a corporatism form of electric utilities.

In the past, before reforms have started, vertically integrated and publicly-owned state utilities provided the supply of electrical energy to the end users, meeting the demand of individual states and territories. The whole industry had never operated on a national platform and interstate connections were weak with little transactions going on between interconnected states.

As mentioned before, there are two components in the reforms of the electric power industry in Australia, which are the national and state components. There has been dual approach to the reform, with each state government pursuing different reforms while reforms at the national level provide guidance and not direction. Due to the result of the variety of reforms in each state, the movement towards national electricity market has been more complicated than that of United Kingdom.

The Australian National Electricity Market (NEM) was scheduled to commence in 1995, developing in stages until a fully competitive electricity market for both generation and retailing is achieved in 2001. Though it is referred as a national market, the initial plan was to include Victoria, New South Wales, South Australia, Queensland and Australia Capital Territory (ACT). Subjected to the feasibility of the grid interconnection, Tasmania is likely to be included in NEM at a future date.

A national electricity generation pool was also introduced when interstate trading of electricity began between New South Wales and Victoria with ACT participating in the market through New South Wales. Each state operated under their electricity code arrangement and was responsible for the security of the system.

Several stages followed subsequently which led to the inclusion of Queensland into NEM. In 1998, NEM commenced operation and its primary objective is to inject and encourage competition into the electric power industry in Australia. The National Electricity code (Code) which includes the market rules governing the activities in NEM was drafted after much consultative and trial process. The various rules and standards listed under this Code ensure all participants of the electricity network have access to it on a fair and reasonable basis. It also listed out technical specifications and requirements for the various elements in the whole power system such as the generation plants, transmission networks and even the equipment at the point of connection at the end user or customer side.

Currently, there are five state jurisdictions in the NEM which are New South Wales, Queensland, Victoria, ANU and South Australia.

As of today, NEM has been operating on a transmission network that consists of interconnected grids which run from South Australia through to ANU, Victoria, New South Wales and Queensland. The structure, operations and regulations of the traditional Australian electricity market has changed tremendously due to the creation of NEM. An estimated $8 billion worth of energy is traded through NEM each year.

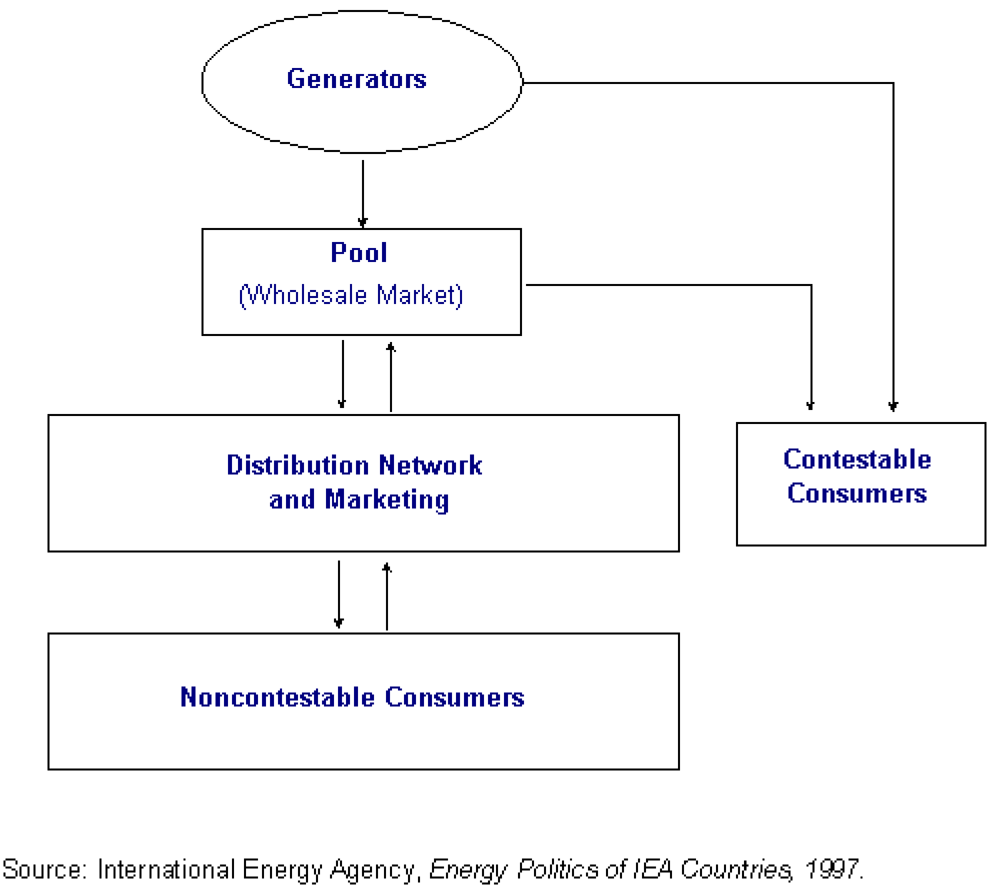

Figure 6 Electricity market structure in Australia

The figure above shows the current structure in NEM. There are several different categories of participants in the NEM. Some of them have more than one role but nevertheless, they are generally grouped as the generators, transmission networks service providers (DNSP), market customers and traders.

Among all the market participants in NEM, one which has a critical role is the Nation Electricity Market Management Company (NEMMCO). It has similar role to that of an independent system operator in other parts of the world such as North America. It was established accordingly as listed out in the Code and acts as the body corporate for the NEM.it is responsible for the management and administration of the NEM across all jurisdictions. Beside this, it is also responsible for the wholesale spot market and ensures reliability of the system by maintaining a well-balanced system between amidst load variations and supply.

Unlike other commodities, it is not possible for electricity to be stored for future use. Furthermore, in the same transmission network system, it is not possible to identify the particular generator that is responsible for the electrical energy consumed by a particular customer. A pool system is adopted to gather all electricity output from all the participating generators.

As mentioned before, NEMMCO is responsible for the daily operation and administration of the power system in the NEM. This mean NEMMCO has to achieve equilibrium between supply and demand, based on the availability of generation capacity to meet its load demand at any time in the system. This is done through a centrally dispatched process which brings the power pool into the picture. NEMMCO determines whether the total amount of generation capacity available is sufficient to meet the peak demand each day. In addition, it is necessary to have sufficient reserves so that the system will still be able to meet its demand in times of failure in any of the generating units or transmission networks.

NEMMCO does this by scheduling the generators against its load demand accordingly, bearing in mind of two important factors mentioned above. This is where the whole sale spot market comes about. It provides instantaneous matching of the supply and load demand. Generation companies offer their electrical energy supply to NEMMCO and put up bids and offers as they compete with one another. Based on the most cost-efficiency supply solution for each half hour period, NEMMCO will than decide which generators to conduct at specified time and period. Dispatch instruction will be passed down to the generators at every five minutes intervals. Generators sell their output to the pool and get paid based on the prices they bided. Whereas retailers and wholesale end-users pay for the electricity they obtained from the pool. In general, all electricity must be traded through the spot market.

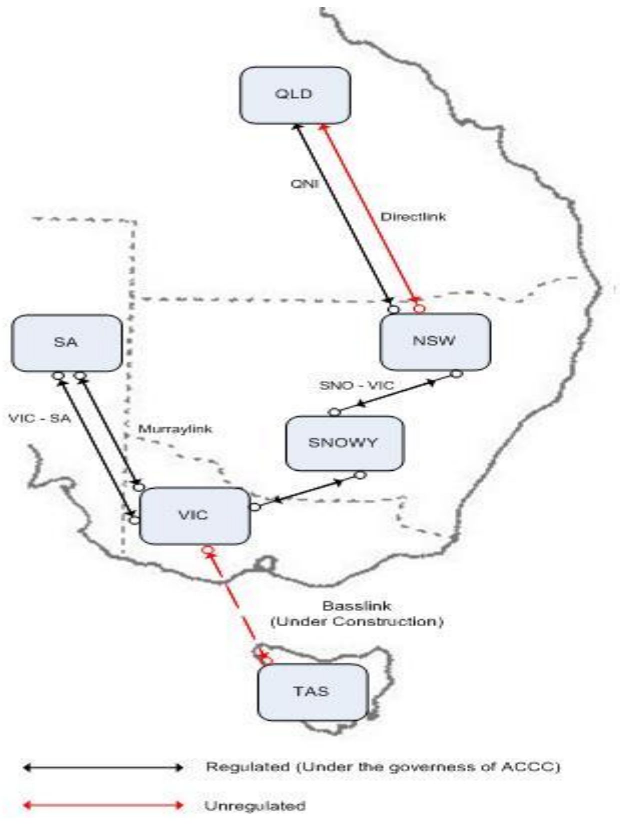

Figure 7 Interconnectors in NEM

The fig shows the interconnectors currently in the NEM. Interconnectors are used to connect and transport electrical power between adjacent electrical regions on the transmission grids. When the load demands are so high that the local generators are unable to meet, power is transmitted from the adjacent region for the system cope. Power is also transferred from adjacent regions when prices of the electricity in adjacent regions are lower than its counter parts stated by the local generators. The figure above also shows the physical transfer limit of the interconnectors in NEM. This means that there is a capacity limits in the amount of electrical power that the interconnectors can withstand. Interconnectors are traditionally regulated by state governments. However, under NEM, there has been a progressive step towards handing them over to the Australian competition and consumer association (ACCA).

2.34 Singapore

The electric power industry has a very important role in the Singapore economy. Being one of the highly industrialized nations, it relies a great deal on efficient and modern electricity system. Obtaining the supply of electrical energy at a competitive price will definitely give an extra advantage for the Singapore economy to compete both domestically and internationally. Due to the recognition of the advantage and various benefit brought by deregulation of the electric power industry, even geographically small country like Singapore is going through the restructuring process of the power industry.

At present, most of the power system assets are owned by Temasek Holdings, which is a subsidiary of the government's investment arm. The restructuring process started as early as 1995 where these assets have been adopting a complimentary approach to commercialization and privatization. The main objective was to introduce competition into the industry in several stage and allowing market forces to determine the pricing of electricity and be the driving mechanism for the investments, rather than having all of it centrally planned. The Singapore Electricity pool commenced operation in 1998 and facilitates the trading of electricity between various participants in the power market. It operated as a wholesale market and was a 'day-ahead' market. However, since the companies competing were mostly government owned, it does not have the full complication of a real-time spot market at the whole sale level. The generation companies that were involved in the wholesale market were PowerSenoko , power Seraya, Tuas power and SP Services Ltd which was a electricity supply and utilities support company. The transmission networks belonged to power Grid. Subsequently, the government reviewed the whole power industry in 1998 and announced in 2000 that deregulation of the industry is to be continued.

A new statutory board named energy Marked Authority (EMA) was established in 2001 to regulate both the power and gas industries. It also acts as the Power System Operator (PSO) which is responsible for ensuring the secure operation of the power system. The wholesale market was to be looked after by EMC, which is a joint venture between EMA and MCo from New Zealand.

Recently, a new electricity Market (NEM) has been introduced to further restructure the power industry. Its aims are to encourage efficient supply of electricity prized at a competitive level, exposed the retail market to a great level of competition, allowing privatization of the government – owned assets and encourage the private sectors to invest into the infrastructure of the power system. It is believed that with the establishment of the NEM, there will be several wide- range reforms and major change to both institutional structures and daily operations of the power industry.

The NEM consist of a wholesale market and a retail market. The operation of the wholesale spot market which runs every half-hour determines the dispatch of electrical energy. Generator offers their supply of electrical power to NEM and bid for the right to dispatch through competitive prices. Power System Operators (PSO) gives a prediction-based account of the load demand and any system constraints at that particular period. Based on the offers made by the generators, the market will determine the minimum-cost solution for both the quantity of energy to be dispatched and the market clearing prices accordingly, at the same time bearing in mind the provision of reserves, transmission systems constraints and the regulation. Nodal prices which reflect the transmission losses and physical restriction on the transmission system at various points in the network will be taken into account when determining the minimum-cost solution and dispatch schedule.

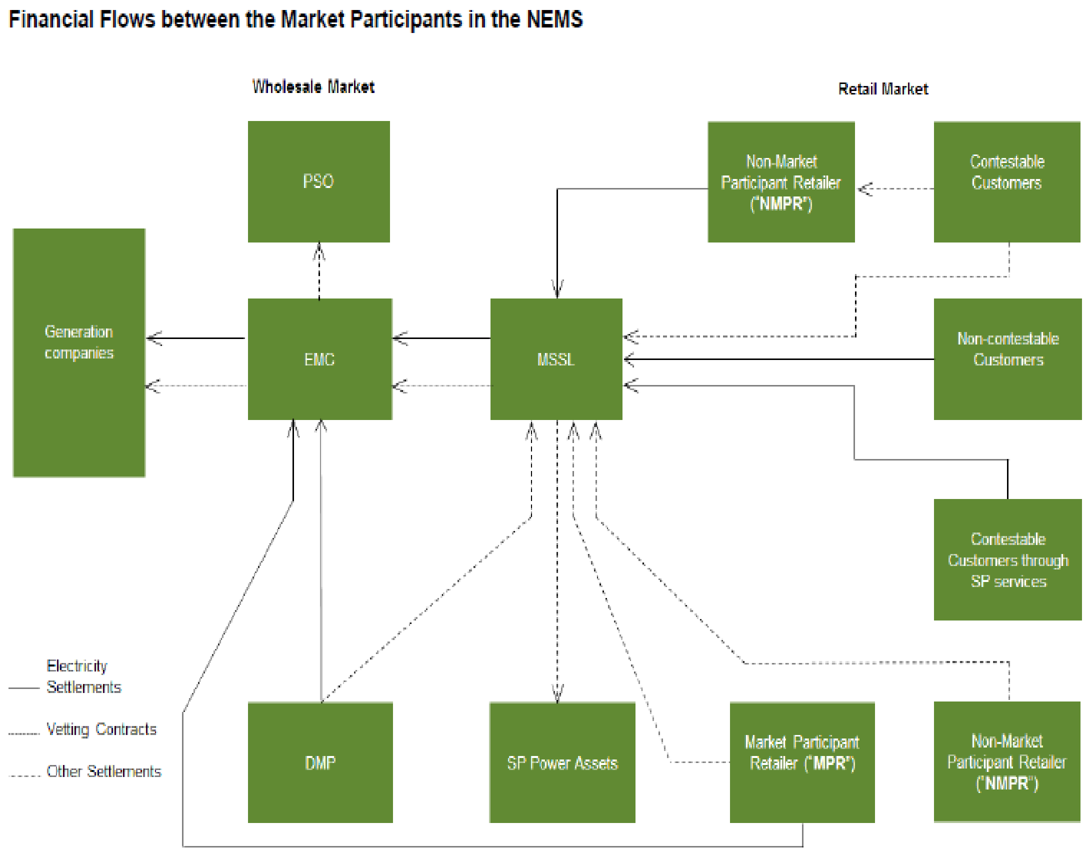

Figure 8 Structure of Singapore's New Electricity Market

The fig above shows the current market structure of NEM and indicating the financial flows between various participants in the market. Looking at the retail sector shows that there are several categories of participants such as the Market Support Services Licensees (MSSL), Retail Electricity Licensees (MPR & NMPR) and as well as contestable and non- contestable consumers. The retail market has been introduced in stage. Until recently, there is only one electricity retailer (SP Services Ltd) that provides electricity direct to all consumers. It is the only MSSL at the moment, responsible for supplying electricity to all non-contestable consumers and contestable consumers that elect not to select a retailer or purchase from the wholesale market.

The grouping of contestable and non-contestable and non-contestable consumers is based on the electricity energy they required. Contestable consumers are those that required minimum energy consumption of 2 MW and above. There are plans for to include consumers that required energy consumption as low as 240 MWh per annual.

The transmission network in Singapore consist of the high voltage network and low voltage networks which both belong to Power Grid, the only transmission licensee due to the geographical size of Singapore. It is a natural monopoly and is subject to regulation rather than market forces. The high voltage transmission network (HVTS) stretches 4611 km long through all the three 400 kv, sixteen 16 kv and seventy-three 66 kv substations. The low voltage distribution network is 10644 km long and runs through the 22kv and 6.6 kv substations. The next few figures below show some of the facts and figures regarding the power market in Singapore.

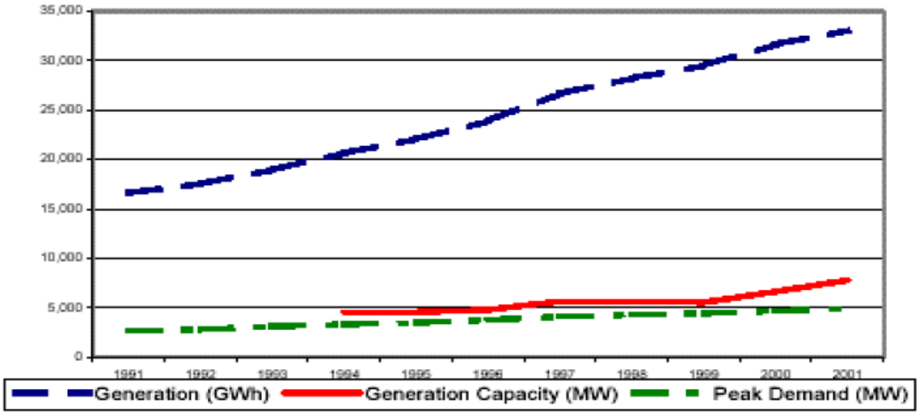

Figure 9 Energy generation, Generation Capacity and Peak demand in Singapore

2.35 India

Restructuring of State Electricity Boards (SEBs) in Uttar Pradesh

In Uttar Pradesh, in the early 1990s, the World Bank (Washington D.C.) funded a study commissioned by the state government and conducted by consultants from the United Kingdom (UK) to analyze Uttar Pradesh State Electricity Boards (UPSEB's) situation and suggest improvements. The study, submitted in 1995, concluded that: (a) There was high political interference in Uttar Pradesh State Electricity Boards (UPSEB's) functioning, (b) its financial losses were due to the existence of high subsidies, low tariffs rates, high transmission losses and distribution losses and poor bill collection system, and (c) causes of UPSEB's very poor efficiency included poor financial policies, poor revenue collection system and losses, over-staffing, poor service quality and political interference in the board. Not surprisingly, the study reflect the recommendations of the 1994 NDC study that the Uttar Pradesh State Electricity Boards (UPSEB's) be split into three separate entities: Thermal Electricity Generation, Hydro Electricity Generation, Transmission and Distribution.

Uttar Pradesh passed its Electricity Reforms Bill in 1999, and on January 14, 2000, the Board was dissolved and divided into three independent corporations – UP Power Corporation (UPPCL), Uttar Pradesh Rajya Vidyut Utpadan Nigam (UPRVUNL) and Uttar Pradesh Jal Vidyut Nigam (UPJVNL) – responsible for transmission and distribution, thermal electric generation, and hydroelectric generation, respectively. The World Bank (Washington D.C.) sanctioned a loan of $150 million for the Uttar Pradesh power sector restructuring project.

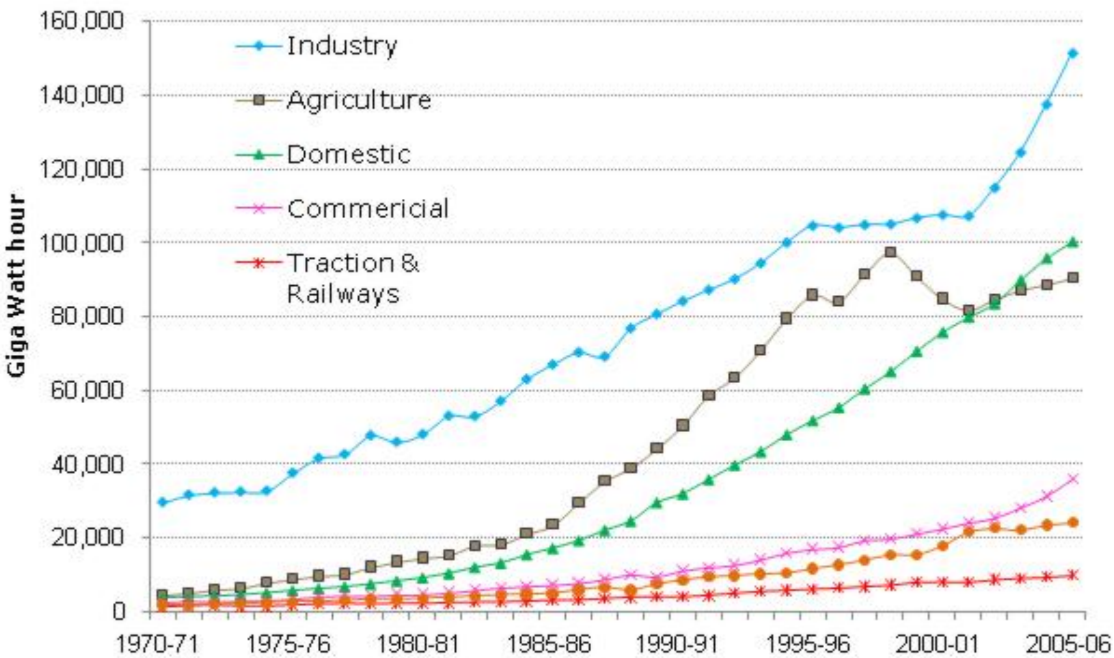

Figure 10 Power consumption in India

Power Sector Reform in Orissa State

1. **April-1992 -** Government of Orissa, Orissa State Electricity Board and World Bank (Washington D.C.) discussed the feasible solution to Orissa Electrical Power Sector problems.

2. **Nov-1993-** Government of Orissa undertook a process Reforms and Restructuring of the Electrical Power Sector in the State. The Electrical Power Sector restructuring process included (a) Restructuring: by unbundling of generation, transmission and distribution of the system. (b) Privatization: Through private sector participation in electrical power generation and distribution activities. (c) Competition: Through competitive auction for new generation.(d) Regulation: By transparent and independent Regulatory system or Body (e) Tariffs: By tariff reforms at Bulk power transmission and Retail levels.

3. **January-1994-** ECC engaged by the World Bank (Washington D.C.) for a review of the reform proposals put forth for Orissa's electrical power sector.

4. **March 1994-** The Steering Committee, chaired by the Chief Secretary and Task Force, chaired by the Energy Secretary for Electrical Power Sector Reform are constituted through a Government of Orissa Resolution.

5. **May 1994-** KPMG begins Financial and Management consulting work on the reform project for the World Bank (Washington D.C.).

6. **July 1994-** (9) Working Groups are constituted for implementation of the reform programme.

7. **June 1995-** The Working Group Reports are finalized. The 9 Working Groups are

Merged and 7 Working Groups are created. The work is internalized in OSEB.

8. **Nov. 1995-** The Legislature of Orissa State passes the Orissa Electricity Reform Act, 1995.

9. **03.01.1996-** The Orissa Electricity Reform Act, 1995 was assented by the President of India.

10. **March 1996-** The State Government Notified 1st April, 1996 as the date on which the Orissa Electricity Reform Act, 1995 shall come into force.

11. **01.04.1996-** Orissa State Electricity Board was split into GRIDCO and OHPC. GRIDCO takes over the transmission and distribution business and OHPC takes over the hydroelectric generation business of OSEB.

12. **July 1996-** Orissa Electricity Regulatory Commission was constituted.

13. **19.11.1997-** GRIDCO divided its distribution functions into four geographical zones in Orissa, namely Western Zone of Orissa, Northern Zone of Orissa, Southern Zone of Orissa and Central Zone of Orissa. GRIDCO incorporated four wholly owned subsidiaries namely WESCO, NESCO, SOUTHCO and CESCO under the Companies Act, 1956.

14. **28.11.1997-** The process of privatization of distribution business was initiated with the issue of press advertisements inviting Request for Qualification (RFQ) in connection with disinvestments of 51% equity share capital held by GRIDCO in the Distribution Companies.

15 Feb**-1998 to Nov-1998-**

- 54 companies purchased RFQ from GRIDCO..
- 13 companies/consortium submitted Statement of Qualification
- 11-companies/consortium qualified to participate in the privatization.
- Due diligence process completed.

16. **26.11.1998-** Section 23 of the Orissa Electricity Reform Act was amended empowering the State Govt. to draw Transfer Scheme to transfer and vest in a subsidiary Company of GRIDCO, any undertaking or part thereof comprising property, interest in property, rights and liabilities and personnel etc. on such terms and conditions as may be specified in the Transfer Scheme.

22. **29.03.2004-** A new Public Limited Company under the name of "Orissa Power Transmission Corporation Limited" was incorporated to carry on the business of electrical power transmission, STU and SLDC functions of GRIDCO.

23. **31.03.2004-** The new company obtained the Certificate for Commencement of business of electrical power, which entitles the company to carry on any business.

24. **01.04.2005-** OPTCL became functional. GRIDCO continue to carry on its Bulk Supply and Trading functions.

2.4 Conclusion

Upon reviewing some of the power markets in the world that have gone through deregulation and restructuring process, it is noted that reform and restructuring focus mainly on privatization and bringing more competition into the local power industry. However, this is not a straight forward issue as there are many factors to consider when implementing these change and furthermore, reform need not necessary be just introducing competition into the market. It has to consider that whole system in terms of reliability, security, economic impacts, technical constraints, prejudices and unfair practices, contingency management, ancillary services, inter-region power transaction, wheeling of power, and one of the very important aspects which is congestion management. Participants in any power markets in the world expect a fair, justified and profitable mechanism to be incorporated into the process of restructuring the power markets and the necessary reform to be introduced.

This is important especially when power retailing becomes more of a norm in the electric power industries. In most of the deregulated power markets, transmission of electrical energy has been unbundled from the other services, often viewed as a natural monopoly. In order to support a competitive but yet fair and profitable power market for the participants in term of power retailing, pricing for the transmission of electrical energy has to be accurate, reasonable and be justified in its course of recovering the necessary costs involved when performing power retailing. This has a significant impact in encouraging power retailing as cost is one of the important aspects to be considered in a highly competitive market.

Furthermore, in order to ensure reliability in the transmission system for any of these retailing to take place, adequate investment has to be injected into the maintenance and upgrading of the system.

Chapter 3

TRANSMISSION PRICING

Irrational pricing in the supply of electricity is one of the many reasons that promoted the call for deregulating the power industry. For a long period pf time, the power sectors of various countries have been under the direct supervision of the government. Power utilities in the past often have no commercial autonomy in both managerial and financial aspects. This means that these utilities relied on the subsidies that have been generated from the public based on the policies implemented by the government. This has been one of the reasons for the existence of irrational pricing and tariff policies in the past. Moreover, these tariff policies have often failed to recover the total costs incurred by the system.

3.1 Introduction

As more and more countries understand the importance and accepted the fact that deregulation of the power industry is vital to the growth of the power sector, there have been a tremendous increase of the unbundling of services once provided by the vertically integrated utilities. Transmission of the electrical energy become a separate entity by itself, providing access to its transmission networks to generation companies and power retailers, while charging them for the use of its networks accordingly. In this highly competitive market, cost is one of the many important consideration for all the participants in the power market. Therefore, a fair, competitive and reasonable transmission pricing is imperative, yet at the same time must be able to recover the various costs incurred by the transmission utility when providing such services to its customers.

The following sections will look into the types of transmission services, the cost components to be accounted, the principles and the objectives of transmission pricing.

3.2 Type of Transmission services in TOA

As mentioned before in TOA, transmission utilities should be able to recover all the incurred costs when providing transmission services and other necessary associated services. In a competitive environment, the types of transmission services vary. Consequently, each different type of transaction will have different bearing on the cost of transaction. In order to adopt a competitive pricing strategy, one has to understand the different types of transmission services provided and the various cost components involved. The types of transmission services can first be classified as either:
Point-to-Point services – they are transmission of power that include specific delivery and receipt point.

Network services- this allows the transmission user a complete access to the system without specifying the point of delivery and receipt, or any additional charge for the change of schedules.

The point-to-point transmission services can be further subdivided to different categories which are the firm transactions and its counterpart, non-firm transactions.

Firm transactions- one distinctive feature is these transmissions are not subjected to discretionary interruption. They are also known as reserve transmission transactions since they require the reserve capacity of the transmission facilities to be able to meet the transaction needs. Arrangements are made by the transmission utilities to ensure this.

Non-Firm transactions- in contrast to its counterpart, these types of transaction are affected and subjected to curtailment when in times of network congestion, outage, overload and even the surface of better economic opportunities. It can also be as-available transactions which are short term and take place when capacity becomes available at specific areas and particular times.

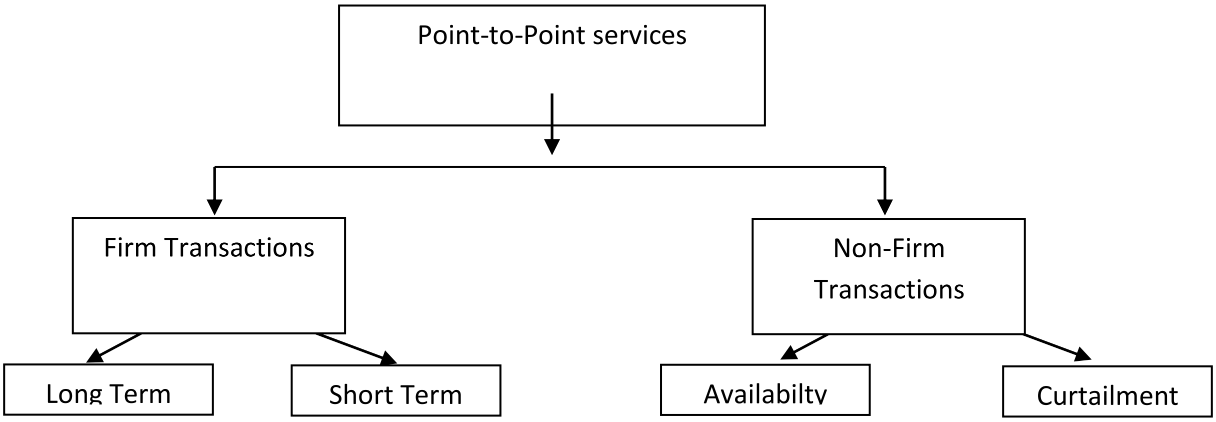

Figure11 Categories that fall under point-to-point transmission services

Firm transactions can be further classified as long term firm transactions or short term firm transactions. Long term transactions are those that take place over several years. As the duration is usually lengthy, it is sufficient for new transmission amenities to be built. An example will be long term wheeling transactions which are the result of agreements between the wheeling utility (transmission) and the customers in contractual basis. It is to be noted that curtail-able type of transmission which falls under non-firm transaction can be either long or short term basis.

In contract, short term transactions can last for a period of time ranging from few hours to one or two years. This short period of time is insufficient for much new facilities to be built and therefore these transactions are usually not associated with any transmission reinforcement. Short term transactions can happen when there is a bilateral contract or when required as part of the arrangement in a power pool.

Upon understanding the type of transmission service provided by the transmission company, the next section will described the various cost components to consider in transmission pricing.

3.3 Cost components in pricing

There are many different cost components that one needs to consider when it comes to performing a transmission transaction. These are the costs that the transmission companies incurs in order to while providing a satisfactory transmission laid down in the contractual terms. The major components of the cost of transmission transactions are:

- Operating Cost

The operating cost of a transmission transaction is the production (Fuels) costs that the transmission utility incurs in order to accommodate the transaction. It is associated with the rescheduling and re-dispatch of generation in which the latter is probably caused by change in losses and some other operating constraints such as transmission flow and limits of the bus voltage. Beside these, the need for reactive power support which in the end will add on to the operating cost has to be considered as well. Other factor such as start-up time, start-up costs and requirement of the spinning reserve play a part in influencing the rescheduling of generation.

However, if the performed transaction is able to reduce losses or as well as mitigate the operating constraint which led to the improving the generation dispatch, the overall production cost will be reduced. When the performed transaction is able to reduce the production costs, this means that the operating costs of that particular transmission will be negative.

Calculation of the operating costs on a hourly basis can be approximated by using an optimal power flow (OPF) model which accounts for all operating constraints including transmission system constraints, generation scheduling constraint and security of the system.

- Opportunity cost:

Basically, opportunity cost of a transmission transaction corresponds to the benefits which the transaction utility has to forego due to operating constraints caused by the transaction. The unrealized benefits may arise from the fact that the transmission utility could not use cheaper generation resources due to the possibility of transmission overloads. The benefits could also come from unrealized revenue form the firm transaction which the transmission transactions that caused such operating constraint and result in unrealized benefits will inure some cost. However, if the transaction is able to mitigate transmission congestion and enable additional transactions to take place, it will provide some benefits and reduces cost.

Though opportunity cost seems to have been clearly defined, in the day to day operation, opportunity cost is the most elusive component among all the other costs in a transmission transaction.

- Reinforcement Cost

The reinforcement cost of a transmission transaction refers to the capital cost of all new facilities needed by the transmission utility in order to accommodate the transaction. Reinforcement cost only applies to firm transactions. Reinforcement cost can also be the cost of planned new installation of transmission facilities being deferred by the transmission transaction.

Though the concept of reinforcement cost is straight forward, evaluating this cost component prove to be a task with great difficulty. The main challenge is to be able to identity and attributing the reinforcement cost to the transactions that trigger the reinforcement.

3.4 Principles and objective of Transmission pricing

In any transmission pricing scheme lays a fundamental principle which is to allocate all or part of the existing and new cost of transmission system to the customers. However, since the power market is operated based upon the policies and directives set by the respective government in each country, different approaches have been adopted. These pricing schemes should adopt similar principle listed below when determining the pricing schemes.

Transparent & simple: - pricing system should be able to transmit the right economic signals to all consumers, traders and producers of electrical energy and therefore, should be as transparent and simple as possible.

Recover Costs: - Revenue obtained from the tariffs charged for the usage of the transmission services should be adequate to recover all expenses incurred in investments, operation and maintenance of the transmission network and also a regulated level of profit. Cost recovery is very important in the maintenance of the assets used for any power transmission.

Encourage efficient usage: - the price system should provide incentives to encourage efficient use of the transmission system. Efficient usage of the system can be attributes to technical efficiency which means minimizing losses in transmission or economic efficiency.

Independent: - the pricing system should be fair and justifiable. This means it should be steering clear from any transmission network owners and should not owned any interest in any transmission network.

Encourage investment:- the pricing scheme and the dividends paid to various transmission owners should provide an incentives for investment in new infrastructure as and when necessary .

3.5 Conclusions

In the past, no serious efforts have been undertaken to calculate the cost of providing transmission services separately from the overall cost of supplying electricity. Upon reviewing the various impacts brought by the deregulation of the power industry, it can be clearly seen that there is one very distinctive approach in all the power industries world-wide. That is the unboundling of the services once provided by the vertically integrated electric utilities.

As a result, utilities that provide transmission services are separated from other functions in a typical power system. In fact, there are companies in the world today that the sorely provide wheeling services for its customers. One example will be the National Grid Company in United Kingdom. The growth of wheeling transactions and the expansion of facilities needed to accommodate such power transactions have been rapid in recent years, largely due to the policy of providing non-discriminated third party access into the transmission system.

Therefore, pricing of transmission services has become an important aspect to be considered in this new and restructured power industry. Several cost components which basically make up the overall transmission cost have been introduced. It is to be noted that the pricing of transmission services is not entirely the result of engineering analysis. Undoubtedly, engineering analysis will help to determine the technical achievability in providing such transactions and also evaluate the costs incurred when doing so. However, market influence and political consideration are some of the factors that may be included when it comes to the process of pricing such transmission services.

Chapter 4

WHEELING

As we have mentioned in the last section, deregulation of the power industry has to a huge increase in the number of wheeling transaction among the participants in the power markets. The following sections serve to provide a better understanding of power wheeling in the power industry.

4.1 Introduction

There is several definitions for the term wheeling in the power industry. Basically, wheeling is a term which described the situation where the transmission of electrical power takes place between a seller and a buyer using a transmission network that belongs to a third party. For example, Buyer B intends to purchase electrical power from Seller S. However, they have no direct transmission links of their own between each another. Therefore, they have to engage wheeling Utility W to provide the transmission path for the flow of electrical energy between them.

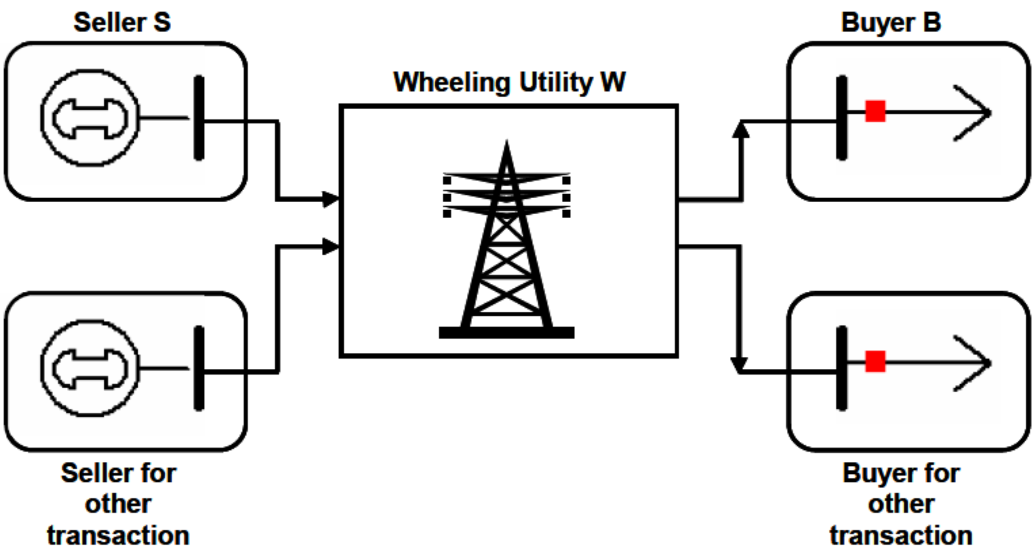

Figure 12 A simplified diagrams of two wheeling transactions going on

It can be seen that from fig that there are more than one wheeling transactions going on at the same time. In real life situation, this is possible as transmission network are often interconnected with one another and more than one wheeling transaction may be going on as long as the transmission capacity is not exceeded.

Very often, wheeling causes a variety of physical and economic impacts on the wheeling utility. The following issues have to be considered whenever a wheeling transaction is to be conducted.

- Determine the actual economic costs and benefits of wheeling when looking from the perspective of the wheeling utility.
- Established a set of justifiable wheeling rates which enable cost recovery, profit-taking and yet at the same time, competitive and fair.

Looking at fig above, when wheeling transactions take place, proper allocation of the costs incurred during transmission among all wheeling transaction is needed. Wheeling utility W has to be paid for providing wheeling services for both seller S and Buyer B. It is to compensate the wheeling utility for the use of its transmission system. Wheeling utility should obtain adequate revenue to cover the impacts of wheeling transaction on its operation costs. These costs are incurred when facilitating generation re-dispatch and providing services such as metering, billing and computations. Since wheeling utility bear the costs of losses which resulted from the wheeling transactions, they should be remunerated adequately.

However, determining the costs of wheeling is not an easy task, especially when there is more than one party using the transmission system. Wheeling rates are the prices charged by the wheeling utility for the use of its network. It determines the payments made to the wheeling utility by the seller and the buyer.

From the viewpoint of the wheeling utility, finding an appropriate way to determine wheeling rates is of great importance as it encourage optimal use of the existing transmission capacity and attracts investment in expansion of the transmission facilities. Many researches have been conducted to find a justified and appropriate method in determining wheeling rates. Several methods have been proposed and debated.

4.2 Types of Wheeling

There are different types of wheeling transaction that can take place in a power system. Based on the relationship between the parties involved, they can be categorized into four broad categories stated below:

(a) **Bulk Power wheeling-** This is also known as utility to utility wheeling as power transaction takes place between one regulated utility to another regulated utility via the transmission network of an intervening utility.

(b) **Customer Wheeling-** This happen when a private user or customer who requires power purchase it from a regulated utility which does not provide service to that particular area. In such cases, an intervening transmission network of another utility has to be used to wheel the purchased power across.

(c) **Private Generator to Utility Wheeling-** Regulated utility whose transmission network is not connected to the private generator purchase power from the latter through the network of a third party.

(d) **Private Generator to Customer-** Private Generator sells its output power to the private user or customer who requires power using a transmission network that belongs to a transmission utility.

Since wheeling can takes place either between individual buses or between areas, the different types of wheeling mentioned in the previous page can also be explained in term of buses and areas. Type (a) refers to area to area wheeling in which the selling and buying utilities are located in different geographical areas and each is interconnected to the transmission network of the intervening utility by multiple tie lines. Type (b) and type (c) are typical examples of area to bus wheeling and bus to area wheeling respectively. The last type of wheeling transaction which is type (d) illustrated bus to bus wheeling as the seller and the buyer are located at two different buses.

4.3 Summarizing the need to determine wheeling rates

Wheeling is among the most important electrical supply option available to transmission utilities. The growths of wheeling transactions have grown so rapidly, and in some cases, at a much faster rate than the increment of new transmission capacity. There is this possibility of having amount of power to be wheel exceeding the transmission capacity limit. In such cases, the wheeling utility has no choice but to forgo the benefits which could have been obtained if the transmission infrastructure is able to accommodate the wheeling.

Thus, it is important for the wheeling utilities to know the costs in providing such services, set the correct wheeling prices so as to make economic and engineering decisions in issues pertaining to upgrading and expanding their transmission facilities. And in today’s open and deregulated power industry, setting fair and competitive prices for wheeling through a simple and transparent pricing scheme is an imperative to ensure continued growth for the wheeling utility.

Chapter 5

METHODOLIGIES IN EVALUATING WHEELHING RATES

There are several methods proposed of currently in practice in determining wheeling rates for power wheeling in a competitive market. Many debates have been going on in the process of deciding the best method and it is almost impossible to review all the methods intensively. This chapter attempts to review some of the commonly practiced methods in determining wheeling rates in a competitive market.

5.1 Losses in Wheeling

It is imperative to understand the impacts on losses caused by wheeling transaction when determining wheeling rates. When a wheeling transaction takes places, there is always the possibility of extra power losses attributes to it. From the wheeling utility point of view, losses incurred from the wheeling transaction may either be included as a part of the inflow from the seller or make a request that both selling and buying parties contributes to the extra power losses due to wheeling are included in the incoming flow from seller S and the output power flow to buyer B is W out, the total input power flow coming from sellers S will be Win=Wout+ΔW , where ΔW is to be included in part the wheeling agreement where it will be supplied by seller S. ΔW is the component used to compensate for the losses incurred during wheeling.

However, wheeling power may either increase or decrease the transmission losses, depending on the direction of the flow of wheeled power when compared to the base load (native load) on the transmission lines of the wheeling utility. In addition, when subjected to the same amount of wheeled power, a heavily loaded transmission network causes more energy losses when compared with a lightly loaded transmission network.

5.2 Marginal cost-based Methodology

It is generally accepted that services provided by wheeling utility should be compensated based on short-run cost of wheeling. Short-run of wheeling refers to the marginal costs of the last KWh of wheeled power. Marginal cost is the cost incurred in having one additional units of transmission capacity on the transmission system. When there is more than one wheeling transaction going on at the same time with the same wheeling utility involved, they are physically impossible to differentiate. Therefore, one way to compute short-run cost of wheeling is form the difference between the marginal costs of electricity at the entry bus and exit bus of the wheeling. Thus,

Ideal Wheeling Rate* = *Marginal Cost of Wheeling

Marginal cost based pricing has always been regarded by economists to be the ideal method in determine the tariffs for transmission of electricity. An ideal wheeling rate should be able to recognize transmission constraints. For example, if wheeling transaction would cause an overload in the system, the wheeling rate should rises to discourage it. Similarly, wheeling rate can even be negative if the wheeling transaction causes a reduction in the losses in the system. It varies accordingly to the change in spot prices of electricity.

Marginal cost of wheeling is able to reflect the losses, lodes levels, amount of wheeled power, network constraints, location and operating costs of power plants. It is a characteristic of marginal cost-based pricing to be able to recover the wheeling utility's incremental operating costs. Unfortunately, marginal cost based pricing methods does not guarantee that the appropriate share of the embedded capital investment will be recovered which led to problems in revenue reconciliation. It does not provide the capital cost needed for any transmission reinforcements.

5.2.1 Marginal operating costs

Marginal operating cost is the cost incurred in order to facilitate a marginal increase in the amount of transacted power. It can also be defined as the incremental costs of the last unit (MWh) of wheeled power in optimal operating conditions. With the help of OPF model, it is possible to the solution for optimal operating state and thus, obtains the marginal operating cost of real and reactive power.

Thus, the marginal costs real power at Bus i:

$$MCp_i = \frac{\partial[\text{total generating and wheeling costs subject to operating constraint}]}{\partial[\text{amount of real power being wheeled}]}$$

And the marginal cost of reactive power at Bus i:

$$MCQ_i = \frac{\partial[\text{total generating and wheeling costs subject to operating constraint}]}{\partial[\text{amount of real power being wheeled}]}$$

These marginal costs are equal to the Lagrange multipliers of the corresponding load-flow equation (Kirchhoff) when OPF is solved as a non- linear programming problem. The Lagrange function is also defined as the augmented objective function which is formulated to produce an optimal solution that minimizes costs and satisfies the constraints at hand.

5.22 Marginal cost-based wheeling rates

In any wheeling transaction, one thing to take note is the reactive power flow. This is important as reactive power flow has a direct impact on transmission losses and the stability of the voltage levels. Thus, it is included in the calculation of wheeling prices. Revenue collected from marginal- cost based pricing includes the cost of wheeling for both real power and reactive power. For example, if there is a wheeling transaction going on between seller S and buyer B, the total wheeling charge (w) is :

W= WP+WQ

= PBωp+QBωq

= (MCPB-MCPS)+(MCQB-MCQS)

Where Pb, Qb refers to amount of real and reactive power wheeling respectively; Wp is the wheeling price for real power which is the difference between marginal cost of real power at buying bus (MCpb) and the marginal cost of real power (MCps) at the selling bus.

It is true that the marginal costs of real power are much greater than the marginal costs of reactive power. However, the difference between MCpb and MCps is comparable to the difference between MCqb and MCqs. As mentioned earlier, an OPF model which can handle reactive power balance and handle the reactive constraints as well as voltage limits at bus bars is needed for evaluation of reactive power wheeling costs.

5.23 Methods in practice

The section in the following pages intends to introduce the commonly used marginal cost-based pricing methods.

5.231 Short-Run marginal cost (SRMC)

As mentioned before, short-run cost of wheeling refers to the marginal costs of the last MWh of energy wheeled. In other words, short-run marginal cost of a transmission utility is the cost incurred in supplying an additional 1 MW of power in a wheeling transaction. In order to use this method to determine wheeling rates, the marginal operating cost at the bus where the wheeled power enters (supply bus) and the marginal operating cost at the bus where the wheeled power leaves (delivery bus). The difference between the two is then multiplied by the magnitude of the wheeled power to evolve the short-run marginal cost (SRMC).

$$\text{SRMCt} = \sum_{i\in B}[BMCi * Pi, t]$$

Where BMCi refers to the marginal cost at Bus I, Pi, t refers to power at bus I due to transaction t (negative for generation or supplying, positive for load or receiving) and Bt the set of buses involved with transaction t.

5.2311 Strength and Weakness in SRMC

The main advantage of SRMC pricing is that the wheeling charges for any particular wheeling transaction changes accordingly to the variations in the optimal economic signals for short term operation. Marginal costs are also known as spot prices. Therefore, this pricing method is able to reflect the actual operating conditions of generation and transmission facilities such as network congestion, line losses and other constraints. On the other hand, when the magnitude of the base loads (native) is small when compared with the wheeled power, SRMC prices may not be anywhere near the actual operating cost for the wheeling transaction. Revenue collected generally falls short in recovering the cost of lumpy transmission reinforcement, thus does not promote the expansion of the transmission facilities.

5.232 Long Run Marginal cost Methods

The long-run marginal cost (LRMC) pricing method seeks to determine the present value of the cost of future operation and investments required to accommodates a marginal increase in demand at any point in the system, based on forecast of peak demand in the future and growth. In other words, long-term transmission planning analysis is included within the transaction.

There are two elements in determining the wheeling prices using long-run marginal cost pricing.one of it is the marginal operating cost which can be determined using the same approach mentioned in the last section. The other requires much exhaustive calculation which is the marginal reinforcement cost.

In order to determine the marginal reinforcement cost, all the future plans regarding the expansion of transmission facilities have to be identified and taken into account. This means over a future time span of several years, any cost that is due to facilitating the expansion of transmission facilities have to be noted. The costs for such these expansion project are then totaled and divided by the total amount of power for all new-planned wheeling transaction.

5.2321 Strength and weakness in LRMC

Long-run marginal cost pricing incorporates both capital and operating costs. A single value of LRMC can be developed for a time period which reflects the cost of system expansion. Many have also argued that calculation is simpler than SRMC as values in LRMC are calculated based on long term plan and not as volatile as those in SRMC. However, on a year basis, exhaustive efforts are required in the process of computation. Furthermore, uncertainties in the future values of important factors such as fuel costs; demand growth etc. which will have an impact on marginal cost calculation are ignored.

5.24 Revenue Reconciliation

A distinctive characteristic of marginal cost-based pricing is its incompetence in recovering the embedded capital investments in the transmission facilities which are used for wheeling tractions. The capital costs of providing transmission reinforcement may not be recouped. In other words, there is this possibility where the funds needed for providing reinforcements to the facilities are nowhere to be obtained. This is clearly shown in short-run marginal cost pricing.

As the result of this problem, modification to the ideal wheeling rate obtained based on marginal cost-based pricing are deemed necessary. Change has been made which is to include a revenue reconciliation adjustment factor.

Revenue Reconciled Wheeling prices = Ideal Wheeling Rates (obtained from margin cost-based pricing)+Revenue Reconciliation Adjustment

However, this concept has a problem at hand even before the revenue adjustment can be calculated. Determining the actual amount of the capital cost to be recovered proves to be one of great difficulties. The capital cost to be recovered could come either from the recovery of the embedded transmission investments (existing) or to allocate incentives for future investments. As a result, such revenue reconciliation could create great distortion in prices and leads to unjustified pricing.

5.3 Embedded cost-based methodology

This section addresses all the embedded cost-based methods in determining wheeling rates. Embedded cost-based methods are commonly throughout the transmission utility industry.

5.31 Features

The embedded capital costs, average annual operation costs, as well as the maintenance costs of the existing transmission facilities are considered when determining wheeling charges for a particular wheeling charge for a particular wheeling transaction. Based on the amount of usage of the transaction facilities or resources, these transmission system costs are allocated to the various system users accordingly.

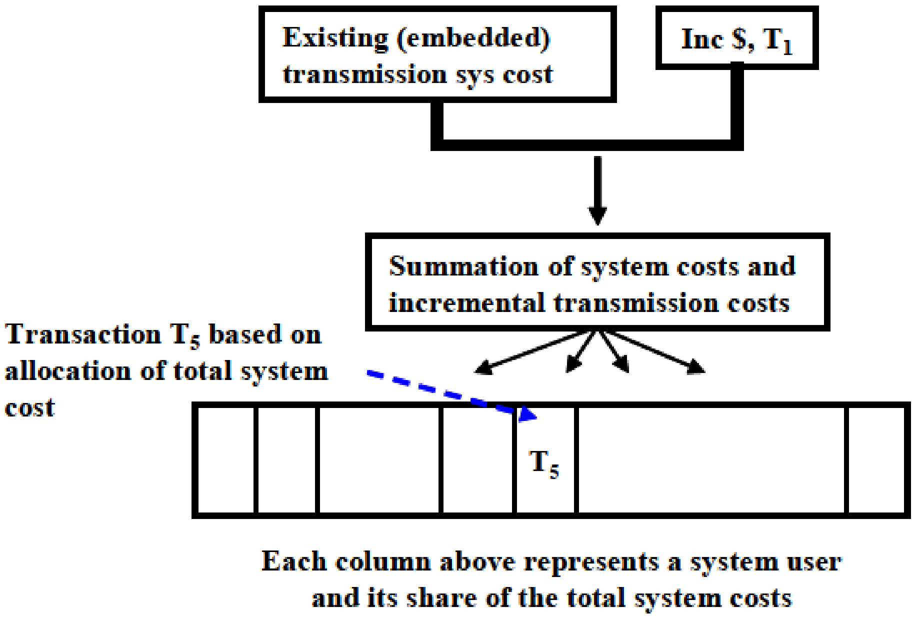

Figure13 Transmission costs to various transactions through Rolled-In Paradigm

Figure 14 above illustrate the approach of the embedded cost-based methods towards allocation of the overall system costs or in other words, the wheeling charges to be paid by each wheeling transaction.

5.32 Methods in practice

Four of the commonly known embedded cost-based methods used for allocating wheeling charge (determine the wheeling rates) are discussed. The two traditional methods which do not require power flow execution are known as Contract path method and Rolled-In-Embedded, also known as Postage Stamp method. The other method is the line by Line-by-Line method or MW-Mile method and the Boundary Flow method. These two methods the power flow modeling in order to allocate the wheeling charges accordingly.

5.321 Rolled-In Embedded Method (Postage Stamp)

The rolled-in embedded method allocates the wheeling charges based on the magnitude of the wheeled or transacted power. It is considered as the simplest method among all as it assumes the whole transmission system is involved in the wheeling transaction. This means that it does not take account of the actual power flow path of the wheeled power. There is no distinction being made between the supplying and receiving points, the power flow path or time of transaction.

One important characteristic of rolled-in-embedded method is the disregard of the distance of the wheeling path. As mentioned, only the magnitude of the wheeled power is considered in the computation of the wheeling charges for each wheeling transaction.

where
P_w = Transacted power
C = Annual fixed cost
P_{peak} = Peak load of the system

$$C_{aT} = \frac{P_w}{P_{peak}} * \frac{C}{8760}$$

5.3211 Strength and weakness in Rolled-in-Embedded Method

The main attractive factor about using this method is the absence of power flow executions and associated studies to identify the involved parties. Thus, evaluation of the wheeling charges is easy to handle and compute.

However, the simplicity of these methods led to a lot of drawbacks. The main drawback is the disregard of the actual system operation. The wheeling charges allocated are not related to the pattern of the actual power flow. As a result, it is very likely to send the incorrect economic signals to the transmission customers. For example, a particular wheeling transaction that will incurs high costs due to the much needed extensive reinforcement or upgrades of the system might still be able to carry on doing so as it only have to pay a fraction of the actual cost.

Moreover, as distance of the actual power path flow is disregard when applying the rolled-in-embedded method, a wheeling transaction between two buses with a shorter distance between each other might end up paying much more when compared to another transaction that has buses which are much farther apart if the system peak load (Ppeak) in the case is more.

In addition, the increased transmission losses due to a particular transaction are not taken into account. This means that each transaction is assumed to have an equal impact on the transmission system which is a far cry from the actual truth. Therefore, even though this method is simplistic in nature and far less complicated in its computational process, it is economically unsound as many have argued. In order to overcome the limitations of the rolled-in-embedded method when it comes to allocating the wheeling charges, some other methods have been proposed and used in many of the wheeling utility.

5.322 Contract path method

The second traditional embedded cost-based method is named as contract path method. In this method, it is assumed that wheeling of power for a particular transaction can only take place along a specified electrical path belonging to the wheeling utility. As in the same case in rolled-in-embedded method, a power flow study is not conducted to identify the actual transmission facilities or resources that are used for the wheeling transaction. Any variations in the power flow of other lines that are not listed to be within the contracted path are not considered. Hence, only those embedded capital costs that belong to the facilities included in the contracted path are accounted. If new facilities are built for the wheeling transaction, they are usually included in the contract path.

In order to calculate the wheeling charge based on the contract path method, the MW or the transmission capability of the specified path has to be identified. The annual wheeling cost per MW has to be determined. The net plant cost (NP) and the annual fixed charge rate (AFCR) will have to be computed. Subsequently, the annual wheeling costs per MW will be:

$$C_{bT} = \frac{P_w}{P_{min.\ path}} * \frac{C}{8760}$$

Where

P_w = Transacted power

C = Annual fixed cost

$P_{min.\ path}$ = minimum power path

5.3221 Strength and weakness in Contract Path method

The contract path method overcomes some of the limitation found in rolled-in-embedded methods. However, it also ignores the actual system operating condition. Large portion of the transacted power may actually flows outside the specified contracted path and thus makes use of transmission facilities not included in the computation of the wheeling rates. In fact, there is the possibility of having the transacted power flowing on the transmission grids of the neighboring utilities. Transmission facilities that are not included in the contract path might require costly upgrades in order to accommodate the flow of the wheeled power. The wheeling utility will face uphill task in obtaining the revenue needed for the upgrades as these facilities are not included in the contracted path in the first place.

5.323 Boundary Flow Methods

The boundry flow method is also known as Power Allocation Methods (PAM). Changes in the MW boundary flow of the wheeling utility due to a wheeling transaction are included in the cost of wheeling either on a line basis or net interchange basis. The changes in either individual boundary line or net interchange are obtained after performing the two power flow executions successively with and without wheeling for every year. The base load levels of the system in the power flows execution can be at peak load or any appropriate level. Using the ratio of the change in the real power outflow to the magnitude of the wheeled power, the PAM factor is obtained and this factor is usually a unity factor.

5.3231 Strength and weakness of boundary flow methods

Since boundary flow method has the advantages of using power flow executions, it has the capability to overcome the limitation of the rolled-in-embedded method. However, one drawback about this method is the lack of recovery of revenue for reinforcement costs and change in production costs due to generation re-dispatch and rescheduling. Furthermore, reactive power flow is not considered when using this method. Reactive power flow can have significant impacts on line losses and stability of the magnitudes of bus voltages. For example, when the peak load demand is high or heavy, reactive power flow can influence the bus voltages, tab changes in transformer setting or circuit loading to be near their operating limits and bring them away from their operating limits when oppositely oriented. The wheeling charges determined using the boundary flow method does not take this into consideration.

5.324 MW-Mile Methods

The Mega Watt-MILE method is also known as line-by-line method. The power magnitude is change of power flow on the system caused by the wheeling transaction is taken into consideration in order to abet in the allocation of the wheeling costs to each of the wheeling transaction of electrical power. One distinct feature is the length of the transmission lines used in the transaction is also known into consideration when determining the wheeling costs. This attempts to solve the fault in the rolled-in-embedded method where the distance between the location of supply and the location of the recipient has no effect in determining the usages of the transmission system by the wheeling transaction. Mega Watt-Mile method attempts to allocate the wheeling costs based on the actual system usages as close as possible. Therefore, two (2) power flow implementation are needed with one having native loads only and with the wheeling transaction comes into play.

The power flow-mile on each transmission line of the system due to a particular wheeling transaction is calculated by obtaining the product of the transmission line length and the change in the magnitude of the power flow caused by the transaction. The power flow-miles of each transmission line are totaled up to represent the amount of the transmission resources used by the corresponding transaction. The total system capacity is obtained by totaling up the product of each transmission line length and some measures of the contribution made by the transmission facility towards the capacity of the system. This contribution can be measure by several alternatives such as measuring the temperature based rating, surges impedance loading, actual power flows at criteria.

$$C_{aT} = \frac{C \sum_f (\triangle MW_f)_T L_f}{8760 \sum_T (\sum_f (\triangle MW_f)_T \ L_f)}$$

Where

$\triangle MW_f = \left| MW_f(with\, T) \right| - \left| MW_f(without\, T) \right|$

$L_f = Length\ of\ transmission\ facility\ f$

$(MW_f)_T$ = Mega Watt flow in facility f due to transaction T

5.3241 Strength and weakness in MW-Mile Method

The advantage about MW-mile method is that it overcomes some of the limitations of the rolled-in-embedded methods. It seeks to allocate the cost of wheeling based on the actual operating system usage as close as possible. However, there have been some concerns raised regarding the insufficient recovery of its embedded capital costs. This is because the total circuit power flows are usually smaller than the full system capacities. Hence, Mega Watt-mile method is only charging for a base case network and not taking the system reserve into consideration.

5.325 MW-Cost Methods

According to proposed MW-cost method, embedded costs of transmission system are allocated proportionally to the change in MW flows of each facility caused by the transmission transaction and cost of that facility.

$$C_{aT} = \frac{C \sum_f (\triangle MW_f)_T C_f}{8760 \sum_T (\sum_f (\triangle MW_f)_T \ C_f)}$$

Where

$\triangle MW_f$ MW_f= $\left| MW_f(with\, T) \right|$ - $\left| MW_f(without\, T) \right|$

$C_f = Cost\ of\ transmission\ facility\ f$

$(MW_f)_T$ = MW flow in facility f due to transaction T

5.326 MVA-Mile Methods

In all the above methods reactive power change in the transmission facilities caused by transaction party are not considered. Mega Volt Ampere-mile method can take into consideration both active and reactive power loading of the transmission network caused by the transaction and hence allocates embedded cost of transmission accordingly. Hence a transaction causing more reactive power loading will be allocated more cost than other transaction.

$$C_{bT} = \frac{C \sum_f (\Delta MVA_f)_T L_f}{8760 \sum_T (\sum_f (\Delta MVA_f)_T L_f)}$$

Where

$\Delta MVA_f = |MVA_f(with\ T)| - |MVA_f(without\ T)|$

$L_f = Length\ of\ transmission\ facility\ f$

$(MVA_f)_T$ = MVA flow in facility f due to transaction T

5.326 MVA-Cost Methods

According to proposed MW-cost method, embedded costs of transmission system are allocated proportionally to the change in MW flows of each facility caused by the transmission transaction and cost of that facility.

$$C_{aT} = \frac{C \sum_f (\Delta MW_f)_T C_f}{8760 \sum_T (\sum_f (\Delta MW_f)_T C_f)}$$

Where

ΔMW_f MW_f= $|MW_f(with\ T)| - |MW_f(without\ T)|$

$C_f = Cost\ of\ transmission\ facility\ f$

$(MW_f)_T$ = MW flow in facility f due to transaction T

5.4 Incremental cost-based methodology

Expressing in simple terms, incremental costs are the difference between the transmission costs with wheeling transactions and those without wheeling transactions. The next section will describe the feature of the incremental cost-based pricing scheme.

5.41 Features

The concept of incremental cost-based pricing is to consider only the new transmission costs caused by new wheeling transaction when evaluating charges for these transactions. In other words, only new transactions that forced the construction of the new facilities are charged the full increment cost of those facilities. This is a distinctive difference from the embedded cost-based pricing scheme. The existing system costs or the embedded costs will remain the responsibility of the utility's current transactions. This is shown in the fig below.

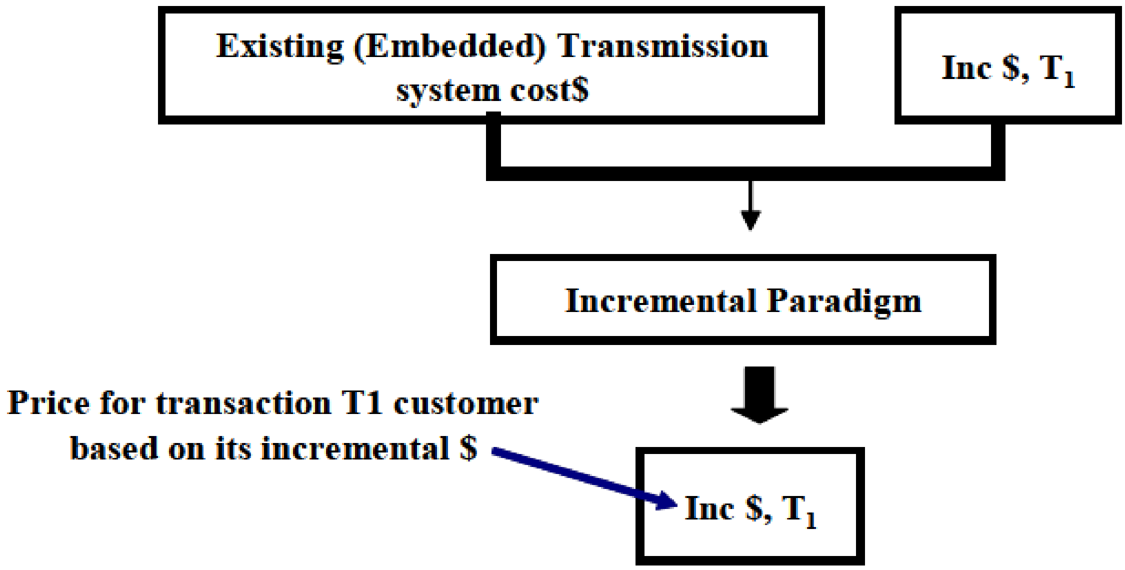

Figure 14 Transmission costs to various transactions through Rolled-in Paradigm

5.42 Methods in practice

It can be seen from the diagram that any revenue requirements needed for payment of any new transmission facilities are allocated to the transmission services customers distinctively. Some of the commonly used method in determining wheeling costs is:

1] Short-run incremental cost pricing (SRIC)

2] Long-run incremental cost pricing (LRIC)

The next section will be dedicated to address these two method and list out their strengths and weaknesses.

5.421 Short-Run Incremental Cost Method

In the short-run incremental cost pricing method, the operation cost of a new wheeling transaction is computed and allowed to that transaction. Operating cost of a new wheeling transaction can be approximated using an OPF model with the constraints specified. These constraints could be the transmission system constraints (static or dynamic security) and generation constraints.

Therefore, short-run incremental costs are the incremental costs of the variable costs, including transmission losses, congestion costs and cost of ancillary services. Ancillary services are the services provided to assure security of the power system operation and the quality of supply of electricity. Congestion costs are out-of-merit production costs due to constraints in the transmission system.

5.4211 Strength and weakness in Short-Run Incremental Cost method

There are several considerations associated with short-run incremental cost pricing. As timely and correct economic signals are needed to be feedback to the transmission customers, forecasting of the operating costs are deemed necessary. The accuracy of the forecasting of the operating costs will be reduced as the forecast of the operating costs go farther into the future. Secondly, the problem in allocation of short-run incremental costs arises when there are several wheeling transaction that are collectively responsible for the variation in the operating costs. In addition, the volatility of the transmission prices is a area of concern when using this method is applied in long term wheeling transaction. The revenue collected using this method is able to compensate for the operating cost insured by a wheeling transaction only. This tends to discourage the wheeling utility to expand the transmission system.

5.422 Long-Run Incremental Cost Method

In long-run incremental cost pricing method (LRIC) all long run costs that are necessary to facilitate a wheeling transaction is being considered. This means incremental costs of both variable costs which is the operating costs and fixed costs (reinforcement costs) are included. The reinforcement costs come from the investment made to either accommodate the wheeling, credit for delaying or avoiding reinforcements. The change in operating costs comes from the variation in production costs, incremental operation and maintenance costs. Thus, the two factors to consider in long-run incremental cost are the operating costs and operating costs and the reinforcement costs. Reinforcement cost is negative if the corresponding transaction has resulted in the deferment of the planned reinforcements. This is in contrast to the embedded cost-based method which the investment costs for each wheeling transaction are not considered separately.

The LRIC can be further split up into two different methods based on the way the reinforcement of the transmission system is handled. The two method which have been developed are the standard long-run increment cost and long-run fully incremental cost methods. The difference in these two method lies in the adopted approach in computing the reinforcements. The standard long-run incremental method uses a more traditional system planning approach to decide the reinforcement and the schedules of investment for these reinforcements with and without the wheeling.

Traditional planning procedures determine the reinforcement project throughout the study years and identify the capital investment needed from each company or region considered in the study period. When there are more than one wheeling transaction going on during the study period, the costs of the reinforcement and the changes in the operating costs have to have to be allocated appropriately to the each wheeling transaction.

5.5 Conclusions

Upon reviewing several of the method used for determining the costs of wheeling, it can be noted that none of the discussed method mentioned has been able to fully fulfill the criterions of a good pricing or tariff structure whereby the revenue collected is able to recover all the expenses incurred in investment, operation and maintenance of the transmission network and also a regulated level of profit. Furthermore, most of the method failed to provide an incentive to encourage efficient use of the system or encourage investments to be made in upgrading the transmission facilities.

Chapter 6

CHARACTERITICS AND LIMITATION

This chapter intends to summaries the distinctive characteristics and limitation face in the determining wheeling rates based on Marginal, Embedded and Incremental cost-based methods.

6.1 Marginal cost based methods

Marginal cost-based pricing methods have been commonly used when it comes to determine the transmission costs or the costs of wheeling. The following list out some of the limitations which one is facing when marginal cost-based method is used.

1] A load flow program which is able to simulate a generation dispatch model with economic constraints is needed in determining the costs of wheeling due to the high complexity involved.

2] As marginal wheeling costs can even be negative when the flow of the wheeled power is travelling in opposite direct against the prevailing network flows.

3] Marginal wheeling costs are able to reflect actual system operating condition as they are sensitive to network constraints, outages in transmission and generation, magnitude of load demand or loads levels and operating cost of generating units.

4] Marginal wheeling costs are different when the utilities are jointly dispatched as compared to those that dispatched as a single power pool.

5] Limitation in the recovery of the capital costs proved to be difficult as the revenue reconciliation method have its flaws and reservation.

6.2 Embedded cost based methods

As embedded cost based method allocate the cost of new reinforcement evenly among the wheeling transaction, it is considered as economic inefficient. This is because it does not take into account of scarcity of the resource of the transmission system. Two of the embedded method which are rolled-in-embedded cost method and the contract path method ignore actual system operating condition. This led the possibility of sending the wrong economic signals to its customers.
The limitations of the embedded costs based methods are summarized as below.

- Costs of new reinforcements which may be required due to a particular wheeling transaction are not a direct part of the embedded costs methods. A revenue reconciliation factor has to be added on in order to recover the reinforcement costs.
- The factor does not view the change in production costs as a result of required changes in dispatch and/or unit commitment due to the presence of wheeling.

6.3 Incremental cost methods

Although many of the economists argued that incremental cost-based pricing method is able to promote economic efficiency, there have been some problems in getting the right charges for the wheeling transactions using incremental cost-based methods.

The implementation of the incremental cost-based methods is difficult and one of great computational complexity. This is because forecasting of the operating cost in necessary in order to send the timely economic signals to the wheeling utility and determine the area of expansion to be needed. Consequently, inaccurate evaluations of the costs involved have a high tendency to occur.

An incremental cost-based method makes use of the difference between the transmission costs with wheeling transaction and those without wheeling transactions. It requires one or more of these transactions to be operating “at the margin” which means there will be a ranking of these transactions. This could result in higher and lower prices for the calculations of such transactions. Furthermore, many subjective arguments could arise when it comes to the ranking of these transactions.

Case study - IEEE 14 Bus System

A case study involving the use of MATLAB coding to provide an optimized load flow calculation was conducted.

Introduction

An IEEE 14-Bus system is used in this case study.

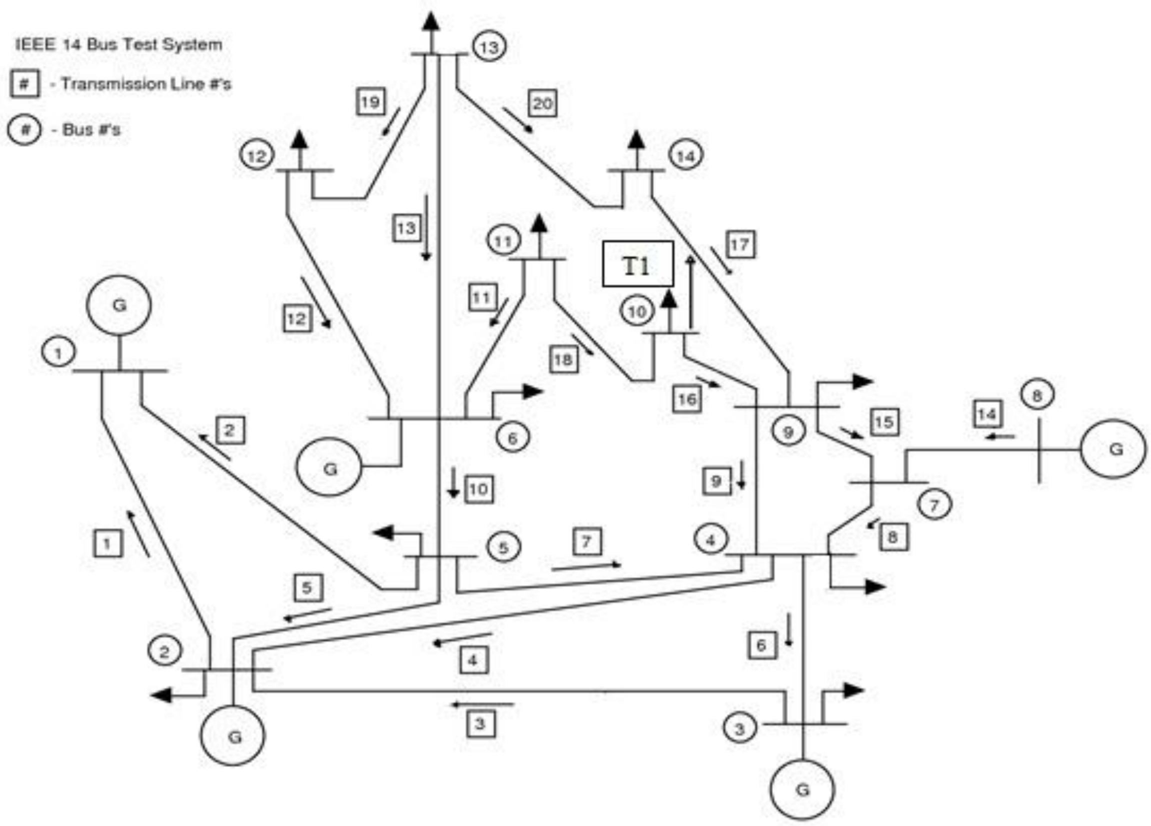

Figure15 An IEEE 14-Bus system with base case

Five generators with a total generation capacity of MW are found at Bus 1,2,3,6 and 8. The figure above shows the IEEE 14-Bus system with its native load, without any wheeling transactions going on.

The length of the transmission lines are shown in the table below.

Table 3 Length of Transmission lines and cost of transmission lines

From Bus	To Bus	Length (km)	Cost (lacks)
1	2	40	16
1	5	50	12
2	3	80	20
2	4	110	12
2	5	45	20
3	4	20	8
4	5	90	20
4	7	30	4
4	9	70	16
5	6	50	12
6	11	10	24

6	12	80	20
6	13	60	8
7	8	40	20
7	9	120	4
9	10	30	24
9	14	90	16
10	11	40	12
12	13	70	20
13	14	20	12

And the system network parameter are shown in the table below.

Table 4 System network parameters

From Bus	To Bus	R	X
1	2	0.01938	0.05917
1	5	0.05403	0.22304
2	3	0.04699	0.19797
2	4	0.05811	0.17632
2	5	0.05695	0.17388
3	4	0.06701	0.17103
4	5	0.01335	0.04211
4	7	0	0.20912
4	9	0	0.55618
5	6	0	0.25202
6	11	0.09498	0.1989
6	12	0.12291	0.25581
6	13	0.06615	0.13027
7	8	0	0.17615
7	9	0	0.11001
9	10	0.03181	0.0845
9	14	0.12711	0.27038
10	11	0.08205	0.19207
12	13	0.22092	0.19988
13	14	0.17093	0.34802

Objective

As mentioned before, a load flow was calculated using MATLAB coding. The transmission utility will have to accommodate three on-going wheeling transactions and thus, the operating costs will be subjected to change brought by these three transactions. The objective of this case study is to help the transmission utility in allocating the wheeling charges to the three wheeling transactions accordingly.

Table 5 Values of Different Transactions

Transaction	From Bus No.	To Bus No.	Value of Transaction		
			MW	MVAR	Power Factor
T1	8	10	10	5.27	0.85
T2	6	4	20	8.72	0.9
T3	1	13	30	18	0.8

Procedures

The procedures for the calculation of the wheeling charges are shown as below:

1. Using the length of the transmission lines and cost of the transmission line given in the table, the cost is calculated.
2. By using MATLAB coding IEEE 14 Bus system, the parameter can be found given in table.
3. Without including any of the wheeling transactions, the base case power flow on all the transmission lines are obtained.
4. The wheeling transaction T1 is included in the system. The transaction takes place between the seller at Bus and Buyer at bus. The new optimal power flow solution for all the transmission lines are obtained using MATLAB coding.
5. Find the new power flow solution with the wheeling transaction T2 and T3. The transaction takes place between the seller at Bus and the buyer at Bus.

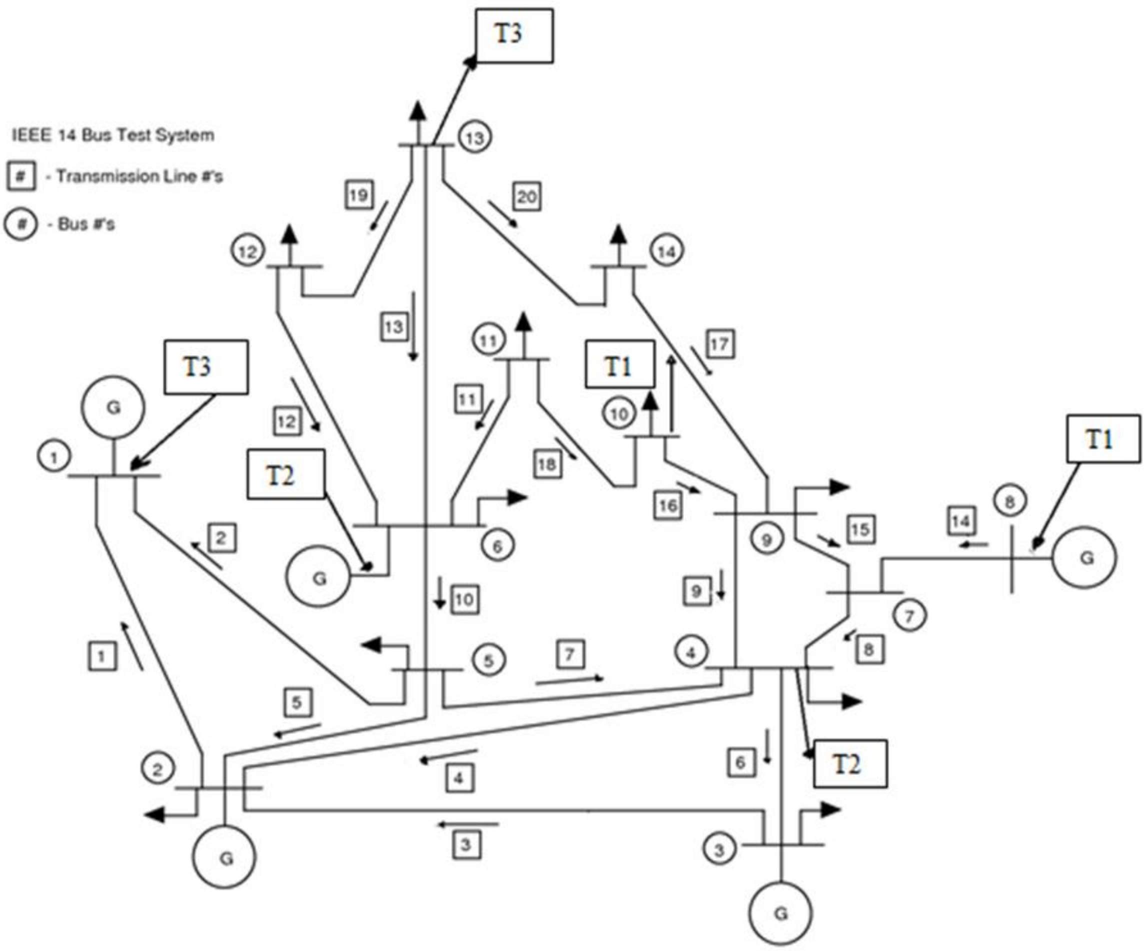

Figure 16 An IEEE-14 Bus system with Three Transaction T1, T2 & T3

6. The increment in power flow in each of the transmission lines due to wheeling transaction T1 is calculated.
7. Similarly calculate the wheeling transaction for the Transmission line for the transaction T2 & T3 and also calculate the increment power flow.
8. Power flow in the line may be increase or decrease in the line during wheeling transaction. This may depend on the nature of the transaction.
9. Now using of Postage Stamp method, Contract Path method, MW-mile, MW-cost, MVA-mile and MVA-cost method calculate the electricity pricing of the transmission system and then compare to find out the fairest among them.
10. For the MVA-mile and MVA-cost method we consider the reactive power flow in the line but for the other methods reactive power is not considered and losses are not considered for the simplicity.
11. Electricity pricing is obtained by this can be compare and then final conclusion obtained.

Result

The results of each method are given below. First table shows the electricity price using Postage stamp method and second table shows the contract path methods.

Table6Electrcity price using Postage stamp method

Transaction (MW)		Postage stamp (Rs/hr)
T1	5	16
T2	15	49
Pool	315	1034

Table 7Electricty price using Contract path method

Transaction (MW)		Contract Path (Rs/hr)
T1	5	220
T2	15	687.5
Pool	315	192.5

Table 8 Electricity price using MW-mile, MVA-mile, MW-cost and MVA-cost

Transaction (MW)		MW-mile (Rs/hr)	MVA-mile (Rs/hr)	MW-cost (Rs/hr)	MVA-cost (Rs/hr)
T1	5	365	359	399	359
T2	15	367	370	368	369
Pool	315	368	371	332	372

IEEE 30 Bus Systems

A case study involving the use of MATLAB coding to provide an optimized load flow calculation was conducted.

Introduction

An IEEE 30-Bus system is used in this case study.

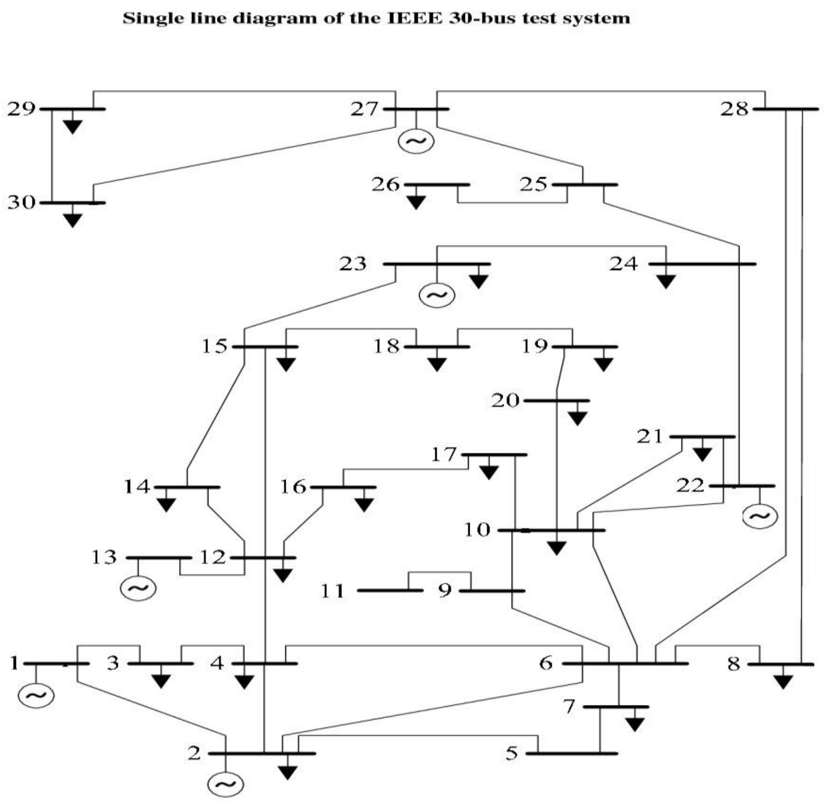

Figure 17 An IEEE 14-Bus system with base case

Five generators with a total generation capacity of MW are found at Bus 1,2,3,6 and 8. The figure above shows the IEEE 14-Bus system with its native load, without any wheeling transactions going on.

The length of the transmission lines are shown in the table below.

Table 9Length of Transmission lines and cost of transmission lines

Facility No.	Bus	Length in mile	Cost Of facility (lakh)
F1	1-2	40	34
F2	1-3	50	42
F3	2-4	54	29
F4	3-4	61	57
F5	2-5	34	46
F6	2-6	54	59
F7	4-6	53	44
F8	5-7	61	38
F9	6-7	52	29
F10	6-8	53	74
F11	6-9	64	37
F12	6-10	46	22
F13	9-11	29	32
F14	9-10	53	41
F15	4-12	63	43

F16	12-13	61	54
F17	12-14	26	43
F18	12-15	51	68
F19	12-16	54	65
F20	14-15	67	54
F21	16-17	26	47
F22	15-18	39	61
F23	18-19	40	63
F24	19-20	61	43
F25	10-20	64	54
F26	10-17	56	64
F27	10-21	73	39
F28	10-22	62	56
F29	21-22	65	63
F30	15-23	46	54
F31	22-24	67	65
F32	23-24	54	43
F33	24-25	64	56
F34	25-26	56	45
F35	25-27	57	65
F36	28-27	75	54
F37	27-29	45	65
F38	27-30	69	76
F39	29-30	56	65
F40	8-28	65	76
F41	6-28	46	65

And the system network parameter is shown in the table below.

Table 10System network parameters

From Bus	To Bus	R	X
1	2	0.02	0.06
1	3	0.05	0.19
2	4	0.06	0.17
3	4	0.01	0.04
2	5	0.05	0.2
2	6	0.06	0.18
4	6	0.01	0.04
5	7	0.05	0.2
6	7	0.03	0.08
6	8	0.01	0.04
6	9	0	0.21
6	10	0	0.56
9	11	0	0.21
9	10	0	0.11
4	12	0	0.26
12	13	0	0.14
12	14	0.12	0.26
12	15	0.07	0.13
12	16	0.09	0.2
14	15	0.22	0.2
16	17	0.08	0.19
15	18	0.11	0.22
18	19	0.06	0.13
19	20	0.03	0.07
10	20	0.09	0.21
10	17	0.03	0.08
10	21	0.03	0.07
10	22	0.07	0.15
21	22	0.01	0.02
15	23	0.1	0.2

22	24	0.12	0.18
23	24	0.13	0.27
24	25	0.19	0.33
25	26	0.25	0.38
25	27	0.11	0.21
28	27	0	0.4
27	29	0.22	0.42
27	30	0.32	0.6
29	30	0.24	0.45
8	28	0.06	0.2
6	28	0.02	0.06

Objective

As mentioned before, a load flow was calculated using MATLAB coding. The transmission utility will have to accommodate three on-going wheeling transactions and thus, the operating costs will be subjected to change brought by these three transactions. The objective of this case study is to help the transmission utility in allocating the wheeling charges to the three wheeling transactions accordingly.

Table 11 Values of Different Transactions

Transaction	From Bus No.	To Bus No.	Value of Transaction		
			MW	MVAR	Power Factor
T1	27	10	10	5.27	0.85
T2	1	8	20	8.72	0.9
T3	22	30	30	18	0.8

Procedures

The procedures for the calculation of the wheeling charges are shown as below:

1. Using the length of the transmission lines and cost of the transmission line given in the table, the cost is calculated.
2. By using MATLAB coding IEEE 14 Bus system, the parameter can be found given in table.
3. Without including any of the wheeling transactions, the base case power flow on all the transmission lines are obtained.
4. The wheeling transaction T1 is included in the system. The transaction takes place between the seller at Bus and Buyer at bus. The new optimal power flow solution for all the transmission lines are obtained using MATLAB coding.
5. Find the new power flow solution with the wheeling transaction T2 and T3. The transaction takes place between the seller at Bus and the buyer at Bus.

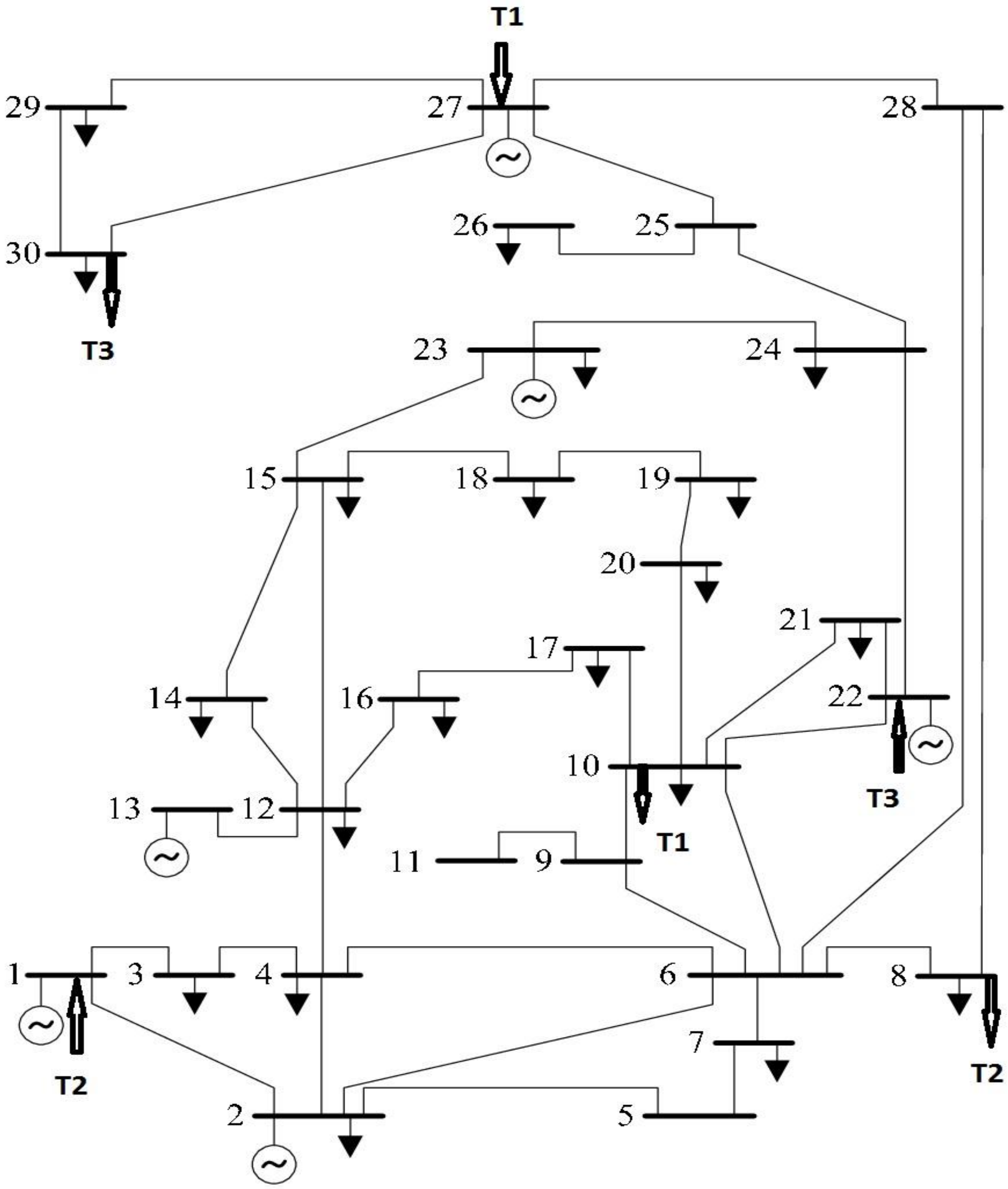

Figure 18 An IEEE-30 Bus systems with Three Transaction T1, T2 & T3

6 The increment in power flow in each of the transmission lines due to wheeling transaction T1 is calculated.

7 Similarly calculate the wheeling transaction for the Transmission line for the transaction T2 & T3 and also calculate the increment power flow.

8 Power flow in the line may be increase or decrease in the line during wheeling transaction. This may depend on the nature of the transaction.

9 Now using of Postage Stamp method, Contract Path method, MW-mile, MW-cost, MVA-mile and MVA-cost method calculate the electricity pricing of the transmission system and then compare to find out the fairest among them.

10 For the MVA-mile and MVA-cost method we consider the reactive power flow in the line but for the other methods reactive power is not considered and losses are not considered for the simplicity.

11 Electricity pricing is obtained by this can be compare and then final conclusion obtained.

Result

The results of each method are given below. First table shows the electricity price using Postage stamp method and second table shows the contract path methods.

Table 12Electrcity price using Postage stamp method

Transaction (MW)		Postage Stamp (Rs/hr)
T1	10	144.5
T2	20	289
T3	30	433
Pool	189.2	2730

Table 13Electrcity price using MW-mile, MW-cos, MVA-mile and MVA-cost tmethod

Transaction (MW)		MW-mile (Rs/hr)	MVA-mile (Rs/hr)	MW-cost (Rs/hr)	MVA-cost (Rs/hr)
T1	10	542	1150	1222	136
T2	20	1833	1329	822	1203
T3	30	3958	5554	971	645
Pool	189.2	987	1650	634	1666

Conclusion

In this dissertation, the reasons for restructuring and deregulation the power industry have been reviewed. The main motive behind the call for deregulating the power industry has been consistent in most of the power industries in the world. That is to achieve greater efficiency in system management and promotes better tariff pricing policies. It is widely believed that by opening up the electricity sector to competition, electric utilities are forced to innovate and operate in the most efficient and economic manner in order to survive and recover their costs. Moreover, end-users will have more choices and options in deciding their supply of electricity which means there will be pressure for the pricing of electricity to stay low and competitive.

It is believed that the right transmission pricing strategy will help to improve the transmission facilities and infrastructure as more funding will be made available. However, there are great difficulties in determining the competitive transmission prices. This is due to the non-linearity of power flow functions when it comes to transmission of electrical energy. This explains why the need for intensive research made into this area in recent times. Furthermore, the rapid increase in the number of wheeling transactions after deregulation has led to an even urgent urge in finding the economically sound and technically feasible transmission pricing methodologies.

All the methods reviewed have both its advantages and disadvantages. The justification of the optimal method to be used depends on the situational factors. For example cost-based methods are unable to recognize transmission resources scarcity. This means that any new costs of reinforcements required due to transmission capacity bottleneck caused by a particular wheeling transaction is not recovered "correctly". The pricing method is unable to point out the wheeling transaction which causes this inefficiency and charges the adequate wheeling transaction which causes this inefficiency and charges the adequate wheeling charges accordingly. Instead, embedded methods charges based on the extent of the usage of transmission resources. An incorrect economic signal will be sent out. Therefore, embedded cost-based methods are more suitable for vertically regulated utilities where transmission access is not common.

The flow of reactive power in the transmission system is also not considered in many of the methods mentioned. Reactive power flows can have a great impact on the transmission losses and voltage magnitudes. The revenue obtained from wheeling of reactive power and the changes in charge of the wheeling of real power caused by wheeling of reactive power and the changes in charges of the wheeling of real power caused by reactive power wheeling are of economic importance especially in a competitive market.

The dissertation concludes with an example showing the calculation and procedure in using Postage stamp, Contract Path, MW-mile, MW-cost, MVA-mile and MVA-cost pricing method to allocate the wheeling charges accordingly.

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