POWER SHARING, TRACING AND PREDICTION OF LOSSES FOR DEREGULATED OPERATION OF POWER SYSTEMS

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POWER SHARING, TRACING AND PREDICTION OF LOSSES FOR DEREGULATED OPERATION OF POWER SYSTEMS

By

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LIST OF ABBREVIATIONS

IPP	Independent Power Producer
NUGs	Non-Utility Generators
TSO	Transmission service Operator
BSP	Distribution Service Provider
ISO	Independent System Operator
SRMC	Short-Run Marginal Cost
LRMC	Long-Run Marginal Cost
OPF	Optimum Power Flow
PMU	Phase measurement Unit
WAM	Wide Area Measurement Unit
AVR	Automatic Voltage Regulator
RTS	Reliability Test System
MAPE	Mean Absolute Percentage Error

LIST OF SYMBOLS

A_d	Downstream distribution matrix
A_u	Upstream distribution matrix
P_{ij}	Flow in a line joining nodes i and j
P_i	Nodal flow
P_d	Total demand at a retailer's point of receipt
C_{ji}	Proportional sharing factors
η	Set of nodes directly supplying node i
μ	Set of nodes supplied directly from node i
α, β, γ	Learning coefficients
ng	Number of generation buses
npq	Number of pq buses
$n\ell$	Number of lines

PENGKONGSIAN KUASA, MENJEJAKI DAN MERAMALKAN KEHILANGAN UNTUK PENATAAN ULANG OPERASI SISTEM KUASA

ABSTRAK

Penataan ulang operasi sistem kuasa sepenuhnya meliputi beberapa pembekal elektrik kuasa, beberapa khidmatan penghantaran dan beberapa peruncit. Kebolehan untuk meramalkan sumbangan dari setiap penjana untuk memenuhi permintaan peruncit, kehilangan dalam transaksi dan kehilangan dalam penghantaran adalah perlu untuk menyingkap transaksi dan kontrak penyawaan khidmat penghantaran. Suatu kajian perbandingan yang meliputi beberapa kaedah pembahagian kehilangan iaitu kaedah Pro rata, pembahagian berperingat dan pembahagian perkongsian dijalankan diatas IEEE TRS 24-bus dan 14-bus bagi menentukan kaedah yang sesuai untuk kajian ini, dan didapati kaedah pembahagian perkongsian merupakan kaedah yang paling sesuai. Kaedah pembahagian kuasa yang unggul pembahagian perkongsian berdasarkan kaedah kuasa jejakan dengan menggunakan persaman linear, digunakan untuk menentukan transaksi berbeza untuk membekalkan permintaan peruncit tertentu dan kehilangan berkaitan dengan setiap transaksi. Pekali pembelajaran daripada perhubungan kuadratik am menggunakan data kemasukan dari senario operasi semasa dan juga daripada senario operasi yang lepas untuk meramal sumbangan penjanaan terhadap permintaan peruncit, kehilangan kuasa transaksi, perkongsian transaksi pada peruncit dan kehilangan dalam talian yang berkaitan untuk senario operasi yang mendatang. Ramalan kehilangan kuasa bagi sesuatu transaksi dijalankan pada beban yang terdapat pada system ujian 24-bus IEEE TRS yang digunakan dalam kajian ini, dan kajian dijalankan pada musim yang

berbeza, hari yang berlainan dan masa yang berbeza. Kaedah pembahagian perkongsian yang didapati dari operasi semasa dan juga dari operasi yang lepas dan ini membolehkan kehilangan kuasa, kehilangan dari transaksi dan sumbangan dari penjana diramalkan. Pekali pembahagian dapat dikemaskini untuk senario yang akan datang. Keputusan yang diperolehi menunjukkan nilai kehilangan kuasa yang diramalkan adalah dalam julat yang dibenarkan.

POWER SHARING, TRACING AND PREDICTION OF LOSSES FOR DEREGULATED OPERATION OF POWER SYSTEMS.

ABSTRACT

Fully deregulated energy market consists of a number of generation providers, a number of transmission system operators, and a number of retailers. The capability to predict the contribution of each generator to a retailer's demand, the power loss in the transaction, the line losses associated with the transaction are necessary to frame transaction and transmission service hiring contracts. A comparative study of the different loss allocation methods namely Pro rata, Incremental allocation and Proportional sharing was carried out on the 14-bus, 24-bus IEEE RTS system, and from the results it was concluded that the proportional sharing method is the most suitable method to be used in this research. Proportional sharing based on regression and power tracing method using linear equations, was used to determine the different transactions to supply a specific retailer's demand, and losses related to each transaction. The learning coefficients from a generalized quadratic relationship and regression method using the inputs from the current and past operating scenarios is used to predict a generator's contribution to a retailer's demand, power loss for this transaction, share of transactions in a line at the retailers end and their associated line losses, for an oncoming operating scenario. Prediction of power loss in a transaction was performed for the loads given in the 24-bus IEEE RTS system for different seasons of the year, different weeks and different hours of the days. Based on the current and a few past operating scenarios Learning Coefficients were obtained and this enables the prediction of losses and contribution

of generators for oncoming scenarios. The learning coefficients can be kept updated, as and when new scenarios come up. The results obtained showed that the predicted values are within acceptable limits.

CHAPTER 1

INTRODUCTION

1.1 Deregulated Operation of Power System.

The electric power industry has experienced tremendous changes in the last few years, which has impacted the way power system is operated in many parts of the world. Deregulation of the electric power industry is aimed at introducing competition in the supply and retail side of the industry, while maintaining control over the transmission lines, thereby giving customers a choice of purchasing energy from the supplier of their choice without impacting reliability [1] . Similar to deregulation in any industry, this entailed in an increased competition in the electric power industry, which is now comprised of several players instead of the traditional monopoly by a single utility. This implies that consumers are presented with choices which would be determined by primarily price of energy offered by respective retail company [2],[3].

In the past, it has been assumed that electricity and its delivery has been intermingled and cannot be unbundled. Electricity has been viewed as a product used only at the point of delivery and paid for, based on a single tariff at the point of delivery. Could the electricity bill be unbundled into electricity and delivery charges, so that it can be provided for, separately from the electricity itself? Electricity becomes a product that can be bought and sold and electricity markets are opened to alternate purchases [4],[5]. With the electricity industries being restructured and liberalized around the world, electricity is now a commodity, bought and sold by generators, retailers (suppliers) and other traders. Vertically integrated utilities [6] as in Figure 1.1, are slowly giving way to the deregulated electricity market structure, Figure 1.2 [6], aiming to provide open access to generation providers as well as the retailers, which allows end-users and distributors to buy power from more distant and lower cost as well as quality competitive generators.

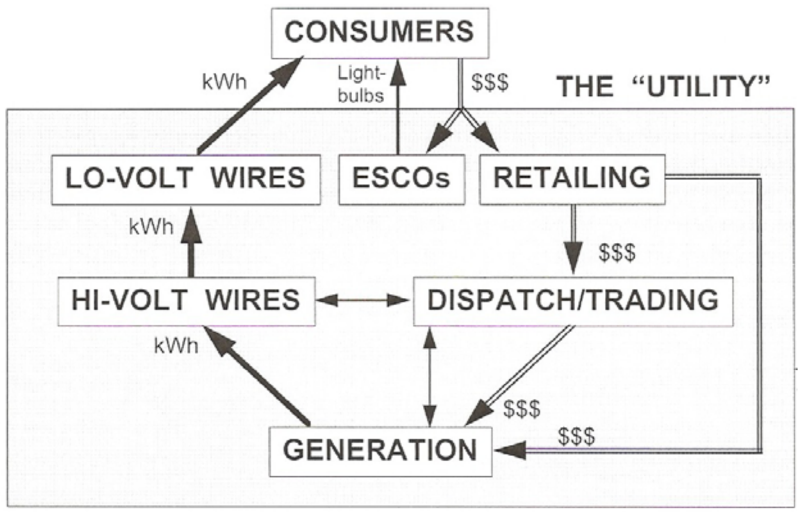

Figure 1.1 The Traditional Utility Structure.

Boxed up entities are the building blocks of an energy market, currently provided solely by the utility[1]

A closer analysis of our energy system is seen to be a formation of several basic building blocks, i.e. the individual entities within the large box with the arrow showing the principal relationships among them as shown in Figure.1.1[6]. Generation, transmission and distribution including retailing is controlled by one entity in the traditional utility structure. Having this in mind, the following question is given a thought: What is the possibility of having individual competing companies in each of the entities, reprising the role played by the traditional utility in that specific area, but with those companies in competition with each other? In this way, a retail company can choose to perform business transaction with their preferred generation company, while even be able to choose the transmission company. Consumers in turn will have a choice of retailers to purchase energy from, instead of solely from the utility in the past. This is called the deregulated energy market model, which is governed by the law of demand and supply [1],[7]. Of course the proposition is not for a total free market, especially in its inception stage but with the existence of a regulating body overlooking all market activities, and limited deregulation for starters.

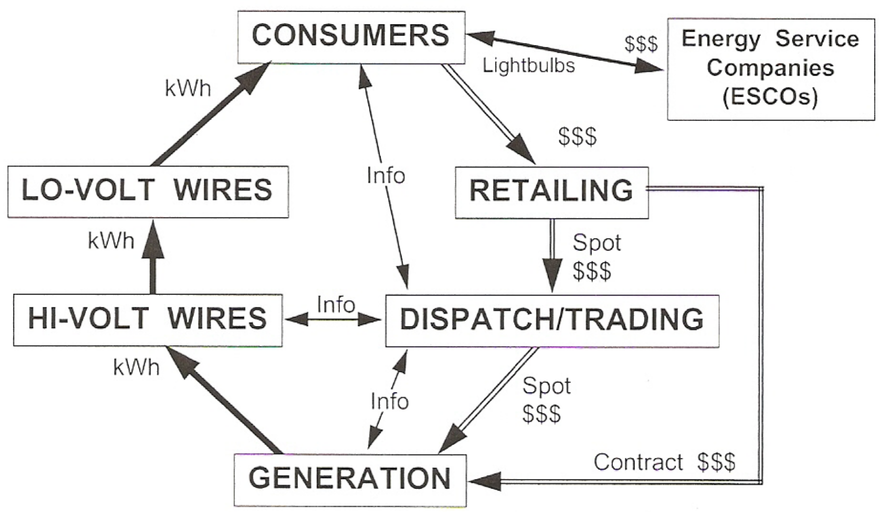

Figure 1.2 The deregulated market model

Notice the introduction of the term Spot, Contract and Info in the above diagram, which will be the cornerstone of the following discussions.

Trend towards deregulation and unbundling of transmission services proliferated in the US and Europe with the rest of the world jumping onto the bandwagon [7]. Electricity is now a commodity bought and sold by generators, retailers (suppliers) and other traders to end consumers like home users and the industries. Cross-border trades are taking place even as of now in Europe, where a generator in Norway can be supplying power to Denmark [8],[10]. No commodity can be traded however, unless there are appropriate arrangements for its delivery and pricing. This is represented in Figure 1.2, by the 'Info' and 'Spot' arrows depicting this scenario of how energy is to be priced and delivered.

Deregulation gives customer a meaningful choice to select their supplier, although the term 'customer' is confined only to bulk or retail buyer. This has a big impact on the industry as it requires not only a host of ownership, organization, and functional changes, but also a change in perspective that leads to changes in power industry management. Contrary to traditional vertically integrated power system, monopoly is fully intended to be removed from generation, transmission and distribution (including the retail service) sectors in a deregulated power system [8],[9]. As a result, generation, bulk transmission and distribution are expected to be competitive, with many different companies vying for these businesses. The prices and operational practices are expected to be based on sound commercial practices and are not regulated anymore. Although the original concept of deregulation was that it will introduce competition at both the generation and retail level, retail competition has been rather rare.

Fully Deregulated System

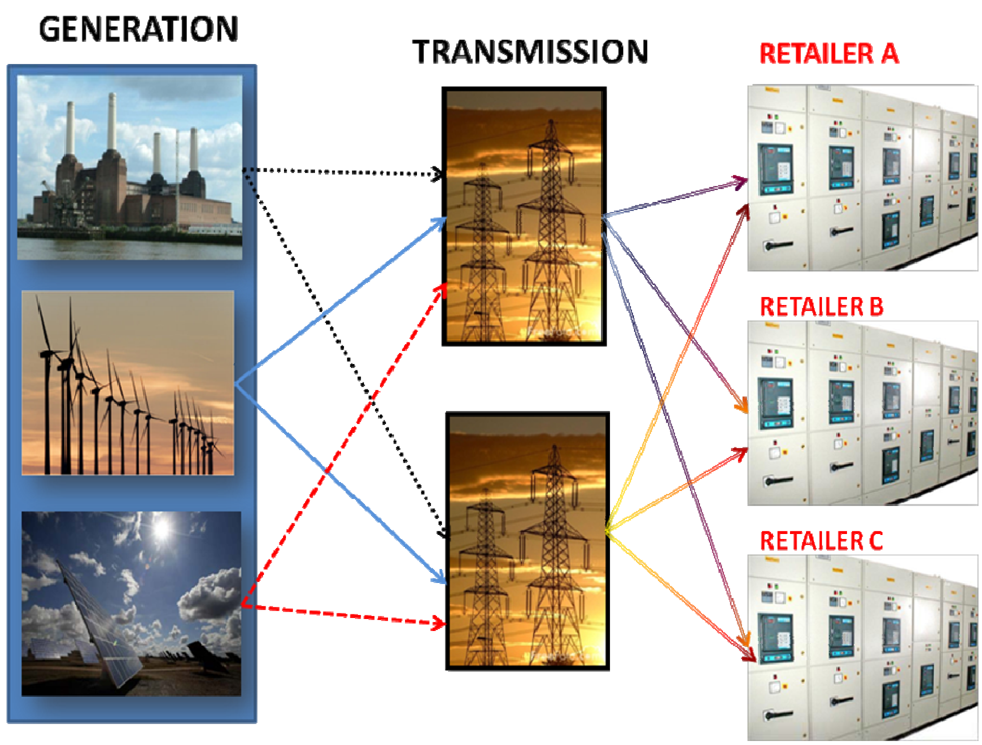

Figure 1.3. A Fully Deregulated System

A fully deregulated system shown in Fig.1.3, is a conglomeration of a number of generation providers, a number of transmission system operators (TSO), a number of retailers who serve the customers, and also an independent system operator (ISO) overseeing coordinated operation between these elements and carrying out arbitration when required [9]. A customer has the choice of choosing which retailer he wants to buy his power from, based on best price.

The ISO's are required to publish the hourly load forecasts and actual loads [10]. To facilitate market transparency the ISO operators must calculate hourly requirements 24 hrs in advance and post the information for the market. The ISO will facilitate a mechanism that allows a process of bidding to take place. This process continues from 24 hours prior to the hour up to real time. The ISO will conduct bid-based auction where participants will bid for capacity and will present their self-schedules to the ISO operators. ISO will determine the resources based on predetermined rules agreed upon by all participants [11]. This information is publicly posted for all participants to review.

Regarding transmission sector, though in most of the cases transmission systems still remain regulated by regulators and state owned agencies, deregulation in transmission sector is also being witnessed, wherein sections of the transmission sections are leased out to different service providers. Although the reasons for these changes are not always the same, their expected impacts are the same [11]. Transmission of power will invariably incur losses in the transmission lines [3],[4]. The retailer will need to pay for the losses incurred in the transmission of power. In a fully deregulated system, where there are a number of transmission system operators, a retailer may choose to wheel (transmit) power through a transmission line with the minimum transmission loss to reduce his wheeling cost. As the various transmission system operators are competing with each other to get a bigger share of the retail market. This will encourage the TSOs to improve their efficiency by reducing losses, since a retailer will choose a TSO with the minimum losses in order to reduce its own off take power cost. As a number of retailers can wheel power through the same transmission line at any one time, a retailer need not pay for all the losses incurred in the transmission as the TSO will be wheeling power not only for one particular retailer or serving one particular transaction, and the retailer need to pay wheeling charges only for that percentage of power transmission facility that he uses. The transmission charges payable to a TSO in addition to the fixed one may include variable operating cost including losses as well [12].

To achieve this, the electric distribution service provider (DSP) or retailer must have an idea of the loss taking place and what is the reasonable loss allowed to have a reasonable purchasing price bid. In order to be able to prepare a purchase price bid in a fully deregulated system, a retailer will need to have complete transparency on the possible generation providers, the contribution of each generator in retailer's power demand, cost of generation for a generation provider on certain time of a day, possible alternate bulk transmission routes to transfer the power together with route utilization by a retailer from respective generation provider, and a complete picture of losses for each possible transmission routes.

1.2 Problem Statement.

In a fully deregulated system, the retailer to remain competitive both pricewise and power qualitywise to his customers, needs to decide at any particular time of a day, which generation provider/providers is fit to supply his requirements from quantum, quality and price aspect, what percentage of his requirement is to be supplied by a specific generation provider, which are the contract paths to be used for wheeling the supplies and what is the utilization of each contract path for his supply requirement.

In order to be able to prepare a purchase price bid in a fully deregulated system, a retailer will need to have complete transparency on the possible generation providers, the contribution of each generator in retailer's power demand, cost of generation for a generation provider on certain time of a day, possible alternate bulk transmission routes to transfer the power together with route utilization by a retailer from respective generation provider, and a complete picture of losses for each possible transmission routes.

Since a purchase bid needs to be prepared by a retailer for a power demand to come up at a time later in the day, based on the current network flow distribution, it is required to predict generations participating in meeting a retailer's future demand, predict capacity utilization of the generation providers involved in meeting a demand and losses associated with the power transaction. As there are no previous references available in the area, and the capability to predict the stated inputs is necessary for the efficient operation of the deregulated power system, learning coefficients from a generalized quadratic relationship and regression method is proposed in this research to achieve the desired objectives.

1.3 Objective and Scope of this Thesis.

The objectives and scope of the research carried out are:

i. To propose a methodology that based on the current and past operating scenarios, could help to predict:

   (i) The contribution of each generator to a retailer's demand.

   (ii) Power loss for this transaction.

   (iii) To determine the extent of use of a line related to a transaction sharing a line with other power transactions.

   (iv) The line losses associated with a transaction using a transmission path.

   (v) To frame a power purchase contract and a transmission hiring contract in a fully deregulated operation, especially when sections of the transmission lines are operated by different lease holders.

ii. To frame a real time implementable procedure identifying the tasks therein, that will help in carrying out the fully deregulated operation and enable to make either a transaction contract or a transmission contract operational.

Once these relationships are stored in the computer memory through the related learning coefficients, it is possible to predict the above for an oncoming (future) transaction.

1.4 Proposed Procedure

For a transaction contract bid to take shape, apart from the cost elements discussed in Chapter 2, inputs such as power required by a retailer and its corresponding required generation at the generation end, taking into account the expected overall power loss in the transaction, is essential. Similarly, for a transaction to be feasible, it must be complete with its power delivery plan. Since a transaction may use a number of transmission lines, which may even be owned or on lease by different TSOs' in a fully deregulated open access system, for framing of the transmission services hiring contract, inputs such as extent of use of a transmission circuit for a transaction and the associated power loss in the said transmission circuit are also required.

Foreseeing this requirement, the thesis proposes a learning coefficient based on (regression method) quadratic curve learning procedure which enables learning of the relationship between a demand and the contributions to this demand from the generations through each possible flow path at both ends of the path, and also relationship between a demand at a point of receipt and associated losses related to this demand in a line. For this the electricity tracing algorithm [13]-[15], and proportional tracing algorithm [16]-[21], is adapted into the proposed procedure. With the availability of wide area network monitoring system (WAM), Phase measurement units (PMU) [22], distributed computing facility to generate validated state estimated real time complex network bus voltages and real time line flows available thereby, it is feasible to carry out the electricity tracing in real time [23].

The procedure further enables the learning of the relationship between a line flow and a generation's contribution to this flow. Based on the current and few past operational scenarios, once these learning coefficients are obtained, they are used to predict contribution of each generation to a future retailer demand, contribution of each line to a future retailer demand, contribution from each generation to a line flow corresponding to a future retailer demand, and also losses related to a transaction in a line [10]. A quantum of power agreed to be supplied by a generation provider to a retailer is termed a transaction. The learning coefficient can be kept updated, as and when new operational scenarios come up. To have more confidence in the learning coefficients, a higher number of past operating scenarios were generated using the 24-bus RTS system. The accuracy of the method in performing prediction is first examined through the trends of the learning coefficients generated with increasing number samples employed.

With this information available, a retailer is provided with all the inputs to enable him to formulate his purchase price bid, comprising of usual two part tariff charges, i.e. demand and energy as well as charges on account of power losses incurred while generating and routing the retailer's demand through the power network. Since power losses can be directly related to voltage quality and hence power quality, the deviation of power losses from its reasonable level can be factored into the purchase price bid.

The procedure discussed is shown in Figure 1.4. With the developments coming up in the area of smart grid and grid computing, it is feasible to implement the proposed procedure in real time.

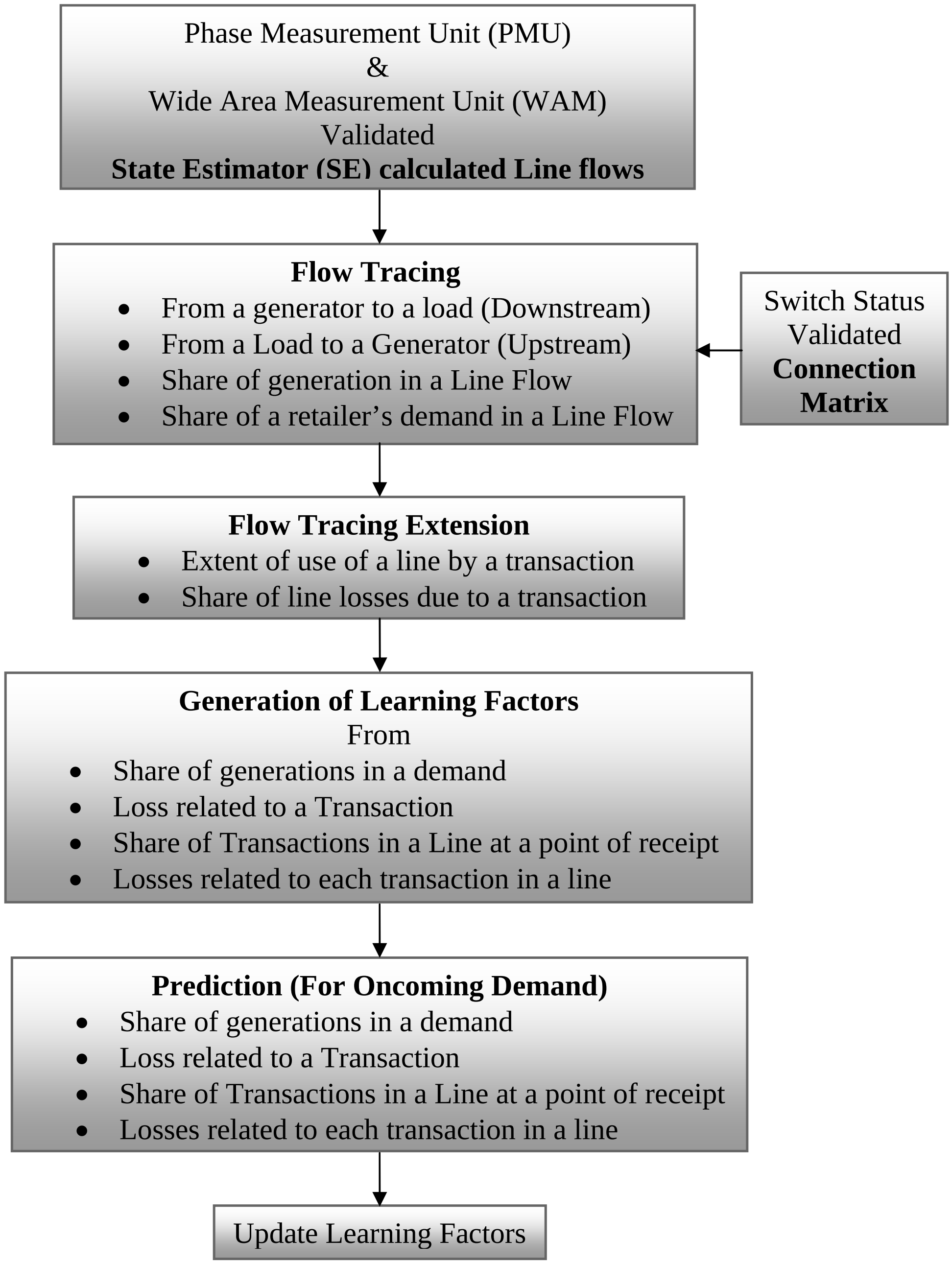

Figure 1.4 Online Assessment and Prediction of Power flow & losses for a Transaction.

1.5 Outline of the Thesis

Chapter 1 describes the overall real time implementable procedure proposed in the thesis. The procedure includes tracing of the power flows together with the transactions, transmission losses associated with a transaction, the different transactions sharing a line, and share of losses associated with a transaction sharing a line with other transactions in a current operating scenario. The procedure uses the state estimation derived line flows, generates learning coefficients based on the current as well as few past scenarios, and generates relevant inputs for framing transaction as well as transmission hiring contract, using prediction.

Chapter 2 discusses the regulated and deregulated operation of power system, examining the need for open access to increase competition in the energy market. Congestion in the deregulated system is discussed. It further reviews transmission pricing methodologies in practice to overcome congestion and establishes the need to be able to quantify the losses associated with a transaction and also the share of the line losses associated with a transaction sharing a line with other transactions. A detailed analysis of the various methods of loss allocation in deregulated power system was done, identifying the advantages of the proportional sharing method as the method to be used in this research. It first derives the power sharing relations in parallel circuits based on the current sharing rule in parallel circuits, extends the same to multi generation and multi load configurations, reviews the power tracing methodology proposed and extends this methodology to determine the extent of use and share of the line losses associated with a transaction, sharing a line with the other transactions.

Chapter 3 proposes a quadratic curve learning procedure through learning coefficients, which enables learning of the relationships between a retailer's demand and (i) the generation contributions to this demand through each possible flow path at the point of receipt, (ii) the power losses associated with a transaction, (iii) share of transactions in a line at the retailers end and the (iv) line losses associated with a transaction using a specific transmission path. These learning coefficients can be generated by using canonical form involving square matrices or method used in over defined systems involving rectangular matrices. The learning coefficients are used in determining the stated inputs for an oncoming operating scenario. It also describes the prediction procedure using the learning coefficients to predict a generator's contribution to a retailer's demand at the point of receipt, power loss for a transaction, share of transactions in a line at the retailers end, and the share of the line losses related to a transaction for a retailer's demand.

Chapter 4 carries out the performance assessment with results and discussion on the proposed procedure using a six bus network and the IEEE 24 bus reliability test system. The effectiveness of the proposed procedure is demonstrated on two buses of the six-bus system, assuming that the load changes on the bus-5 and bus-6 do not take place simultaneously. This is considered to be a fair assumption, since it relates to predicting an oncoming operating scenario for contract framing purposes. Though both the test systems employed are meshed systems, the 24-bus system is typically radial in structure. The 24-bus IEEE reliability test system was used for trend analysis to establish the validity of the learning coefficient method used. Effectiveness of the procedure on both the systems demonstrates the general applicability of the procedure.

Chapter 5 mentions the conclusion arrived out on the basis of the research done. The main contribution of the research work and the proposed future work is also discussed in this chapter.

A detail analysis of the various loss allocation methods in given in Appendix 1, and the power tracing and prediction of values of upstream trace and losses are given in Appendix 2.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Electrical Power System.

Today, electric power systems have become common entities all over the world. A massive industry and infrastructure has developed worldwide to support the production, transportation, use, and business of electrical energy. The electric power industry is one of the largest industry in the world. Thousands of electric utility and companies are supplying power to billions of consumers. People cannot imagine living without electricity. It has become an essential commodity in our every day life and billions of equipment and accessories are being used in the world today that are solely dependent on electric power.

2.2 The Evolution of The Natural Monopoly.

Early leaders recognized that electric companies suffered from high fixed costs as a result of heavy investment needed to finance central generating plants and transmitting system. Utilities frequently found that it was difficult to maintain investor confidence and attract adequate capital. This was attributable to both the dubious franchise process, which made operation of the utility over the long term an uncertain prospect, and the low returns investors received. Early industry leaders began to think that if the franchise granting process and the rates charged by utilities were overseen by a nonpartisan state agency instead of a city council, financing might be easier and cheaper to obtain. Early regulation of the industry proved beneficial to both the electric companies and their customers, who got reliable, reasonably priced service without the uncertainties caused by duplicate services and inefficient operations. Later electric industry was developed as regulated industry all over the world [24]-[27].

2.2.1 Regulated Power System [24],[26],[27]

Figure 2.1, below depicts the general power flow in any traditional vertically integrated utility diagram.

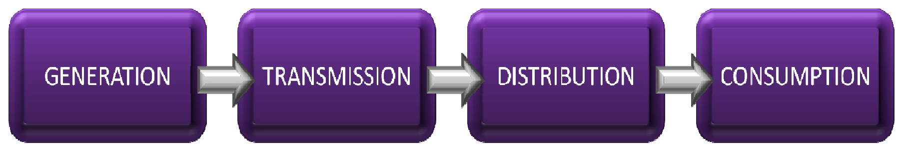

Figure 2.1 : Traditional vertically integrated utility diagram

Electricity industry is recognized as a natural monopoly in a vertically integrated and regulated entity. They own facilities and manage all the functions of producing, transmitting, delivering and selling of electric power. Vertically integrated means that all the functions needed were intertwined into one system and company. Almost all electric utilities prior to 1990s fall into these category [28]. They were granted a monopoly franchise by the state or government, which granted them exclusive rights to produce and sell electric power. In return they were obliged to provide power to all customers who wanted it. Regulated industry is one in which the government has set down laws and rules that put limits on and define how a particular industry can operate, it is only with laws that constrain them to do business under fair or fully disclosed business practices and to operate their facilities within recommended safety guidelines. Regulation refers to a more rigorous set of rules and include [26], [29]:

Monopoly franchise: A franchise guarantees utilities that it will have customers. The government grants one company the sole right to sell electricity to consumers in a certain area, its franchise territory. No other company can sell electric power within its territory. This is to attract investors, because electric utility systems requires large investments. By granting monopoly franchise, someone else's money pays for the electric power system and its operation. By regulating it correctly, the government gets what it wants, electric power available to all its citizens at a reasonable cost, and the investing company get what it wants, profit from its investment.

Obligation to serve: The power company must provide for the needs of all electric consumers in this region. The utility is required to provide electric service in any for needed, to anyone who wants it and is willing to pay its standard regulated rates anywhere in the franchise territory. Obligation to serve is included in all franchise agreements to ensure that all customers are offered service in a non-discriminatory way, and to assure that the grid is eventually extended to all places where it is needed.

Guaranteed rate of return: The government guarantees the company that its regulated rates will provide it with a reasonable profit margin above its costs. The government define a rate schedule of prices the utility must charge to ensure that the utility, which has a local monopoly, does not charge too much. The prices set are to cover the utility's costs, and provide a reasonable profit. The concept behind these prices are cost recovery and guaranteed rate of return. This means that the prices are set so that the utility is certain to recover all its costs and its permitted profit. The monopoly franchise is given to convince its stockholders to invest in utility facilities and equipments needed by the public, so that the utility will cover the other cost necessary to cover the other costs necessary to run the electric system in the franchise area. No businessman would invest in a system designed to serve all the customers, as opposed to only a portion deemed profitable, unless he is given assurance that his cost would be covered with at least a small profit.

Prescribed operating and business practices: The government may put stringent limitations on how the local power company functions. These includes standard operating procedures, service standards and perhaps rates.

Least-cost operation: The government will define how the utility computes costs and sets its prices. Since a monopoly franchise holder is in a position to deliberately increase the cost in its operation so as to make more money, the regulatory procedures governing its activities is designed to limit its ability to do so.

In a regulated monopoly, an electric power system can be divided into four main functional zones; generation, transmission, distribution and retail service.

Generation – generation is the conversion of electric energy from other forms of energy like chemical (gas, coal, hydrogen), nuclear, solar, hydro energy, geothermal energy, wind and wave energy. Electric generators vary in sizes, and generally larger and newer ones are more efficient and cost less to run per unit of electricity produced. A generating station includes one or more generators along with the ancillary equipment needed to provide operation and control of the generators.

Transmission – transmission is the transfer of bulk electric energy from one place to another through some transmission network. Transmission lines operate at high voltages. High voltage lines cost more, require bigger towers and equipments but carry much more power. A line with twice the voltage carries four times as much power. Utilities prefer high voltage as it costs less and avoids the need for greater number of lines. These are linked together in a transmission power grid or transmission network. It connects the generator network and distribution network.

Distribution – distribution is the process of delivering electric power from the local network to the consumers. Distribution lines called feeders take power from substation and route it to every neighborhood.

Retail Service – retail service can broadly called retail customer service. Its main function is measuring and billing customers for the power delivered.

In a regulated monopoly, these four functions of generation, transmission, distribution and sales are controlled by one single entity. As today's power system networks are very large in production volume and geographical area, their operation became a complex phenomenon which does not only depend on the state of technology but also on complex issues like economy, social advancement, environmental impact and political decisions. In traditional monopoly, one company is allowed to generate, transmits and distribute electrical power to the consumers in one jurisdiction. The service area is primarily determined by political map and jurisdiction. In some cases, distribution is divided among two or more electric utilities, e.g. city corporation or other private distribution companies. Price of electricity is determined by the same utility which is justified by cost of generation, transmission and distribution.

2.2.2 Deregulated Energy Market.

Regulated electric utilities provided the industry with stable growth and good service for more than a century and brought several important benefits. It legitimized the electric utility business, it gave utilities recognition, it assured a return on investment and established a local monopoly. To meet the ever increasing demand for electrical energy, and ensure that the customers needs of a reliable, stable and affordable electric supply is met, the electrical industry worldwide is undergoing major changes, as it shift from regulated to de-regulated structure for the government valued the advantages of competition among energy suppliers and a wide choice for electric consumers [25],[26],[27].

All power systems in the world were running as vertically integrated monopoly system. Later it was realized that the electric power industry was not necessarily a natural monopoly at least when it came to generating electricity. It was proven that open access and competition in business lowers the unit price. The same is believed to happen in electric power industry. Therefore, bringing competition in power sector in generation and retail consumer level became essential. The regulatory process and lack of competition gave electric utility no incentive to improve on yesterday's performance or to take risk on new ideas that might increase customer value. The main argument used to support deregulation is that a free market promotes efficiency. In a regulated environment, for example, wholesale and retail electricity power prices are calculated based on a utility's costs. If a utility invests in what turns out to be an uneconomical project, it can still add the costs of the investment to the price it charges for electricity. Thus, the risks and economic consequences of a poor investment are passed to the electricity customer. Competition will encourage new technologies for generating electricity with better efficiency and inefficient generating plants will die out [24],[28],[29].

In many of the countries where electric utility deregulation first occurred the government was privatizing the industry. By deregulating i.e. by privatizing the power sector, government can withdraw huge amount of money. It has also been proved in many cases that a private organization can serve better than a government organization. Competitions also increase customer focus [30]. Another reason for deregulation is to give customer a meaningful choice to select their supplier, although the term 'customer' is confined only to bulk or retail buyer.

Deregulation and re-structuring of electric power industry is occurring in most part of the world. Some are rapidly progressing towards full deregulation while others are re-structuring their power industry to allow some types of deregulation. Although the reasons for these changes are not always the same, their expected impacts are the same [6],[31].

Basic features in favor of a deregulated power system are discussed below.

a) ***The electric utility is being privatized*** in many countries where the government sells its state-owned electric utility to private owners, as it was felt that the private industry could run it in a more efficient manner as the risk-free investment for electric infrastructure development that was necessary in the early years of development does not exist.

b) ***Competition.*** The fundamental goal of deregulation was to remain and foster competition among energy producers. As deregulation was intended to make the electric utility more competitive, and competition will undoubtedly lead to innovation and efficiency. This not only will lead to lower rates for electricity but also improvement of customer value.

c) ***Incentives*** to improve performance and service. Deregulated structure provided incentives on improved profits or bigger market share This encouraged competitors to invest in technology that is needed for deregulated operation and competition and to track and coordinate their forces in the field to optimize customer service quality. This also promotes customer focus and increases customer choice.

d) ***Open Access***. Under open access, all qualified parties, not just the delivery system owners have comparable rights to use the power system to move power from one point to another to assure fair competition.

2.2.3 Deregulated Electric Utility Structure

Unbundling of the traditional vertically-integrated electric utility structure is being implemented in many countries of the world. This had a big impact on the industry as it required not only a host of ownership, organization, and functional changes, but also a change in perspective that led to changes in power industry management [4],[30]. Contrary to traditional vertically integrated power system, monopoly is fully removed from generation and distribution (including retail service) sectors in a deregulated power system. As a result, generation and distribution are competitive, with many different companies vying for those businesses. Their prices and practices are not regulated anymore [6]. On the other hand, most governments and regulators realized that it is best to have only one transmission system [10]. Therefore, in most cases transmission sector remained regulated. Although the original concept of deregulation was that it will introduce competition at both the generation and retail level, retail competition is rather rare.

The deregulated electricity market is being perceived as a conglomeration of independent power producers (IPP) or non-utility generators (NUGs) as well as utility generators collectively termed as generation providers, transmission service operators (TSO) and distribution service providers (DSP) or retailers, wherein both generation and retailing may have open access to the transmission grid for negotiated power transfer and thus electricity, a commodity may be traded as shown in Figure 2.2 [30].

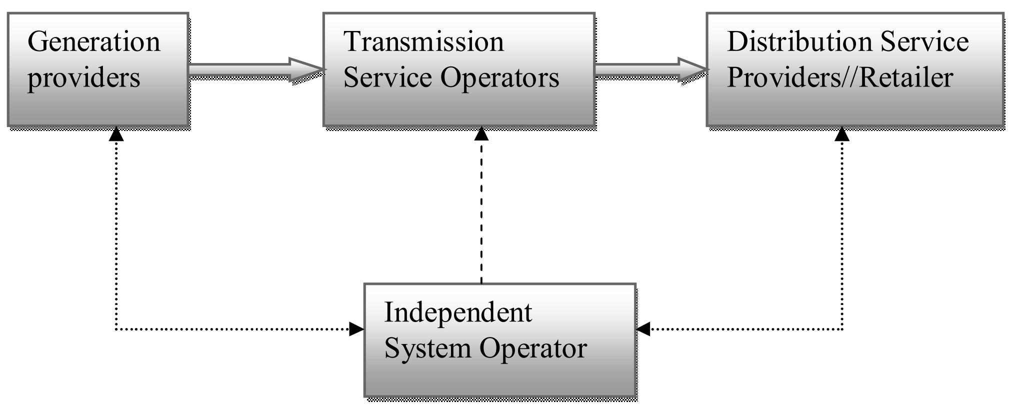

Figure 2.2 Electrical Energy Market

The coordination between the generation providers, TSOs' and retailers for technical operation of these sub-entities and the commercial arbitration among them may be carried out by an Independent system operator (ISO) for effecting power wheeling through agreed upon contract paths, while addressing vital attributes such as system security, voltage profile, losses and VAR reserves [31].

The major issues a deregulated power environment may keep on encountering are [6],[12]:

(i) Stability and viability crisis related issues leading to the need of congestion management.

(ii) Pricing together with methodology of locating and sharing investments on both real and reactive power operating reserves, assuring reliability as well as power quality.

(iii) Appropriate loss allocation and revenue reconciliation adjustment methodologies associated with power wheeling, ensuring appropriate return on investments to the provider.

(iv) Devising an open access charging system, recovering common costs in a fair manner.

(v) Logical development of metering, monitoring and protection system in line with the system expansion and deregulated operation needs.

Independent System Operator (ISO) [26],[29] - An independent system operator plays the role of a supervisor for system operation, planning and security. It has operational control authority over the whole power system and normally operates and maintains the transmission lines. An ISO normally performs the following functions:

• provides open and comparable access to similarly situated customers to the transmission facilities,

• operates exclusively the ISO Controlled Grid in an efficient and reliable manner,