Emerging Issues and New Challenges in Electric Power Systems

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ABSTRACT

The huge changes facing the electric power industry cry out for bold new approaches and a number of influential organizations have formulated sweeping plans for the world's energy future. The problems in the regulated power system have grown along with increased interconnections and loading of the systems. Moreover, the unbundling of electricity supply industry into generation, transmission and distribution has given birth to several new challenges. This paper discusses various issues related to both bundled and unbundled power systems and highlights the challenges which are arising and need special attention.

1. INTRODUCTION

Change in technology, at present, is faster than ever before. This is one of the major forces of deregulations in electric supply industry (ESI). The other reasons of deregulations are high tariffs and over staffing, global economic crisis, regulatory failure, political and ideological changes, managerial inefficiency, lack of public resources for future development, rise of environmental problems, and pressures from financial institutions. Better experiences from other deregulated market such as oil, gas,and airlines industries have also prompted towards electricity restructuring [1-3].

Deregulation and restructuring of power sector is taking place in several countries with the objective of introducing competition in the electric services resulting in the replacement of former integrated organizations by more complex, unbundled organizations. The restructuring of electricity utilities has received much attention around the world due to various reasons. The ongoing restructuring in the world has forced the other countries to take suitable steps for lower price, better quality, improved reliability and higher efficiency of the system [4].

The deregulation, unbundling, and restructuring of power systems, together with the introduction of competition and market rules, have caused the traditional power system planning paradigm, operation and control to be no longer applicable. The task of planning for generation expansion and replacement has been left to the market, whereas by delegating the control of transmission systems from the utilities to the independent system operators (ISOs), the transmission-planning task has been assigned to the ISO. However, with the increased uncertainties surrounding the power markets, the task of transmission planning has become very difficult. Generation, demand and wheeling transactions are now market dependant, where market players change their bidding strategies constantly. It is assumed that the market would coordinate all of these and provide enough incentives that all transmission and generation needs would be met, reliability of the system will be maintained and improved, and efficiency will increase.

In a regulated market, the electricity prices charged to consumers is decided by the regulator, which is normally fixed for certain period of time. However, in deregulated market, the consumer has to pay the price of electricity consumption which varies half-hourly or hourly basis and has two components: generation cost and system cost which include the services provided by the transmission systems, distribution system and some other components like security and reliability charges.

Flexible AC Transmissin System (FACTS) controllers, especially series devices, can essentially control power over long-distance ac transmission. This technology has been extended by a large number of further advancement of FACTS elements, which can be effectively used for power flow control in power systems. The market for these new elements is developing which is supported by the needs in deregulated systems. A number of FACTS controllers are suitable for improving technical problems in both regulated and deregulated markets. The key issues are to select the best location and size, both from the technical and the economical point of view. From the literature, it is found that a lot of papers are published on use of FACTS devices for the suitable applications in the power systems, but still there are several challenges which must be looked upon.

This paper describes the emerging issues and challenges in both vertically integrated and unbundled power systems. Different aspects of new challenges are highlighted which are useful in research and development.

2. EMERGING ISSUES IN POWER SYSTEMS

2.1. Vertically Integrated Power Systems

Modern interconnected power system network is a highly nonlinear and stressed system. Being one of the most complex man-made dynamical systems, its operation and control in stable, secure, economic and reliable manner, has always been challenging. On-line analysis and monitoring of stability (voltage and angle) and security of the system is still a challenging task. Presence of FACTS devices also makes these analyses more complex. The available tools are limited to few bus systems. There is still a need to develop online applications of several available tools or to develop some better tools to handle these.

Besides the technical problem, regulated power systems have been facing major challenges to generate enough resources for future development to cope up with the demand growth. Also prices of electricity in several countries are rising and it is thought that vertical unbundling of the system will remove the non-technical problems. While creating the competition, it was realized that electricity is a special kind of commodity, which cannot be stored in sufficient amount and it requires better control, operation and regulation.

2.2. Distributed Generations

In recent years, the advances in technology have changed the electric power generation scenario in size, efficiency and cost. Distributed, or small generation units, typically less than 30 MW, strategically located near consumers and load centers can provide benefits to customers and support for the economic operation of the existing power distribution grid. Over the last 30 years, the cost of building and maintaining large centralized nuclear and coal-fired generating facilities has become increasingly expensive and technology has improved the efficiency and cost of smaller modular power generating options, while industry restructuring is paving the way for customers to select the optimum combinations of energy resources to fit their individual needs.

As deregulation and restructuring sweep through the world's energy corridors, utilities and other energy service providers will see distributed power generation as either a threat or an opportunity, and will use a range of strategies and technologies to keep old customers, find new ones, and boost revenues. Used wisely, distributed power generation technologies can improve power quality, boost system reliability, reduce energy costs, and help delay or defray utility capital investments. The combined influence of growing environmental concerns and the emergence of new distributed generation technologies are changing both the scale of power projects and the way utilities think about electricity.

These trends give rise to important questions regarding the future providers of electricity and what form the service will take. It is becoming clear that any future electricity generating system, on any scale, will include distributed generation services, concepts and technologies.

As technology advances, distributed power promises to provide economic and environmental benefits well into the 21st century. Competition is becoming the rallying cry for the electric power industry. That means new opportunities for electric utilities and their customers. The future of electric power lies in distributed generation - thousands of small power systems in industrial and commercial facilities, working together as "virtual power plants." In such applications, diesel and gas engine generator sets offer the benefits of low installed cost, high efficiency at full or partial load, reliability, fuel flexibility and heat recovery potential.

With worldwide electricity consumption expected to reach 22 trillion kWh by 2020, largely due to growth in developing countries without nationwide power grids, there can be no doubt about the importance of the distributed generation market. The projected distribution generation capacity increase associated with the global market is conservatively estimated at 20 GW per year over the next decade. As utility restructuring sets in, the financial burden of new capital investments will shift from consumers to energy suppliers along with capacity additions. This favors less capital-intensive projects and shorter construction schedules. The opening up of energy markets places increased pressure on energy suppliers to increase capacity to meet growing demand and increases the probability of forced outages. Due to the distributed generations, the planning and operational rules must be modified and coordinated.

2.3. FACTS Technology

Power systems around the world have been forced to operate to almost their full capacities due to the environmental and/or economical constraints to build new generation centers and transmission lines. The amount of electric power that can be transmitted between two locations through a transmission network is limited by security and stability constraints. Power flows should not be allowed to increase to a level where a random event could cause the supply system to collapse because of angular instability, voltages instability or cascaded outages. When such a limit is reached, the system is said to be congested. Managing congestion to minimize the restrictions of the transmission network in the market of electrical energy has thus become the central activity of power system operators.

With open access to the transmission system by competing generators, the pattern of generations and flows can change drastically over a few hours. Under such circumstances, the operator needs more direct means of controlling the flows. Flexible AC Transmission Systems (FACTS) is the name given to the application of power electronics devices to the control of flows and other quantities in power system. Semiconductor technology enabled the manufacture of powerful thyristors and later on new elements such as the gate turn-off thyristors (GTO) and gate bipolar transistors (IGBT). Development based on the semiconductor devices first established high voltage dc transmission (HVDC) technology as an alternative to long distance ac transmission. HVDC technology, in turn has provided the basis for the development of FACTS equipment which can solve problems in ac transmission.

FACTS devices can improve considerably both dynamic and static performance of the system by controlling the power flows in the network without generation rescheduling or topological changes. The insertion of such devices in electrical systems seems to be a promising strategy to decrease the transmission congestion and to increase available transfer capability (ATC). Using controllable components such as static var compensator (SVC), static compensator (STATCOM), thyristor controlled series compensator (TCSC), sub-synchronous series compensator (SSSC), thyristor controlled phase angle regulator (TCPAR) and unified power flow controller (UPFC), line flows can be changed in such a way that thermal limits are not violated, losses minimized, stability margin increased, and contractual requirement fulfilled, without violating specified power dispatch. Increased interest in use of these devices is due to two reasons: development in high power electronics devices and increased loading of power systems combined with deregulation of power industry.

A proper methodology is required to optimally locate these devices, in power system, for various objectives such as transient and dynamic stability improvements, reduction in power system oscillations, loss minimization, power flow control and more recently for congestion management and ATC enhancement. Some of the key issues for placing the FACTS devices are:

- These can be placed at few optimal locations for improving the static and dynamic performance because the cost of FACTS devices are still very high and depend on several factors such as control parameters and the voltage rating where it is going to be installed. A suitable range must be identified for proper use of these devices for various operating conditions (both normal and contingency cases).
- In regulated market, FACTS devices are mainly used to improve the dynamic performances of the system. Some of the series devices are also used to control the power in the transmission lines. In ongoing deregulation of electric supply industries, due to the increase of unplanned exchanges/ transactions, FACTS devices can play a vital role in mitigating the congestion along with the dynamic performances.
- Presence of FACTS devices in the system causes the complexity of the optimal power flow solution where some objectives are being minimized along with the power system constraints. Conventional OPF may not converge and some advance techniques such as micro-genetic algorithm and artificial neural network can be explored.
- Netwon-Raphson method and fast-decoupled load flow methods are normally used for load flow calculations for large electric power systems. Presence of several FACTS devices may also be suitably addressed to calculate their parameters.
- For successful operation of deregulated market, fast calculation of ATC is very important which must be known online to the market participants. Location and sizing of FACTS devices may affect the ATC considerably. Suitable techniques are required to estimate the ATC and placement of FACTS for ATC enhancement.
- Role of proper pricing mechanism is a very vital issue in deregulation. FACTS devices affect both real and reactive power spot pricing considerably. A suitable method is required to recover the cost of these devices and resources for FACTS devices for future allocation.

2.4. Pricing and Wheeling Rates

From the perspective of economic efficiency, the optimal price for electricity should be set to mimic the market price in a competitive industry with many firms and minimal barriers to entry. The suitable pricing schemes will enable the firms to take decision regarding the timing, magnitude and type of fuel for new investment expenditures and can have maximum incentive to produce their output at minimum cost and can earn higher profits by cost reducing innovations.

An ideal competitive market should, in theory, allow any generator to supply any customer and should place no constraints on the transaction. In the deregulated market, regulators are continuously striving to achieve the goal of proving an efficient, reliable and economic electricity service. To support fair competition among producers, one important aspect is to treat the transmission of electrical energy as a separate business since electrical energy would become a product which could be bought or sold and transported from one place to another. In this case, it becomes important to evaluate the actual cost of transmission facilities, which provides the unbundling service.

The idea of transmission open access (TOA) alters the traditional concept of monopoly but aims to achieve a greater level of competition in electric power supply. This does not appear to have a universal model and this is a relatively recent concept whose economic, regulatory, and implementation structure continues to be adapted to the specific needs of each nation. In broad term, TOA refers to the regulatory structure which includes rights, obligations, operational procedures and economic conditions which enable two or more parties to use the transmission network belonging totally or in part to another party or parties for electricity power transfer.

Regardless of the methods used, the challenge is to develop network pricing system that provides the correct market-based economic signals to all users of the grid (supply and demand), and also to provide the correct signals to the network utility to operate, maintain, and invest in an efficient manner. The suggested pricing schemes may promote the tendency to establish the industries near the generating points. The localities, which are industrially backward, may get an advantage. The transmission pricing system has to meet multifarious requirements and is a relatively complex one. Therefore, the final implementation will and must be a compromise between economic reasonability on one hand and simplicity as well as transparency on the other hand. There are several pricing schemes such as nodal pricing, zonal pricing or flat rate pricing and different wheeling rates in different countries but still there is a need to develop a suitable model in an economical way for smooth operation of the system.

2.5. Power Quality

Power electronics is an engineering and research area that has arisen from the confluence of availability of high rating solid-state switches and needs to control power flow. Various power electronics devices such as STATCOM, TCSC, TCPAR, UPFC & SVC are real need for controlling real/reactive power of the system. Power electronics switches are also needed to implement high efficiency design in lighting, machine speed control and wide range of industrial loads. Customer concerns over reliability have escalated, particularly in the manufacturing sector. With the increased use of sensitive electronic components, the need for high quality power supplies is of paramount importance.

Power quality is another area which needs special attention. Electric power quality relates to maintain the sinusoidal voltage wave-shape at all load buses. Increasing reliability and selling power quality related services, as unbundled services are specialized niche needs in industry. Equipment manufacturers have also entered the commercial sector in the marketing of new power system components for quality enhancement. In several countries, very little attention has been given on the power quality issues. Due to more and more application of power electronics devices, the harmonic contents in the supply system are growing. Its analysis, control and mitigation are the major concerns to the utilities.

2.6. Operation and Control

Due to unbundling of generation and transmission, the system operator has to contract with the generators to obtain the resources needed to operate the system and in particular to manage congestion, to continuously match generation and load and to keep voltage within acceptable limits. These are called ancillary services. There is a need to precisely define clear and unambiguous cooperation between the system operator and the generators. In order to maintain stable operation of large networks, reserves are necessary. In a deregulated energy market, the question of who provides these reserves and under what conditions, is not naturally resolved and has to be addressed. Large variation and peaks in consumption are technically and economically undesirable. The question is how to develop policies and incentives for power producers and consumers to flatten the consumption.

Maintenance has been relatively simple in vertically integrated system where it was planned centrally for all the units but in competitive power market each generating unit is to be maintained by each individual generator. Due to lack of coordination, system reliability and security may be hampered. Similarly the unit commitment problem, scheduling the on/off status, is also difficult in the deregulated market because the individual generator has to perform these.

A new layer, the independent system operator (ISO), is being added above the control area by ongoing deregulation activities. The ISO is responsible for the grid security of the power system and has to operate the system in market driven rules. In competitive power market, independent generators and utility generators may or may not participate in the load frequency control of the system that is done by ISO based on the parameters defined by the participating power producers. ISO buys the power to maintain the frequency of the system but this power should be as less as possible for reliable and economic operation of the system. Thus, it is always required to make strategies for better load frequency control economically.

In regulated market, there is a reasonable degree of flexibility in scheduling supply to serve customer load reliably and economically. Due to rigid bidding system and different ownerships of transmission and generation, flexibility in operation is reduced. Different types of contracts have also made the problem complex. All suppliers must accept the contracts, if awarded. Failure of a supplier to perform some contracted services could result in serious consequences in the power system. In these cases, a non-performance penalty may need to be assessed.

2.7. Planning and Environmental Impact

In competitive electric market, generation companies invest in new generation plants when it is profitable to do so (just as in any other competitive market). Since competitive generators do not have public service obligations or rights, they will be better motivated by profit concerns. The usual measure of profit is return on the investment. A generating company, evaluating a new plant, will forecast the expected revenues (from the sale of electricity services in deregulated market), and net of expected operating costs (fuel, staffing, property, etc.). This stream of future net revenues will be compared to the net investment in the plant. If the resulting internal rate of return for the project exceeds the company's hurdle rate for such investments, the company would likely pursue the project. Thus, it all depends on the projected returns, and not the anticipated reserve margin. This results in the decline of reserve margin.

Within traditional regulation, it is possible to share transmission facilities and to coordinate planning or operations of interconnected utilities on a voluntary basis. In a fully competitive market, transmission access is intrinsic to the market mechanism. The uncertainty resulting from the increasing transactions makes transmission planning more difficult than in the vertically integrated system. As new ones at other locations replace old generators, the loading of transmission system changes. Furthermore, the grid users (generators and consumers) require that the transmission access tariff be kept at a low level, which implies a reduction in transmission investments. Grid users are more critical towards rigid planning criteria and more focused on actual reliability. Therefore, an assessment of interruption costs should be included in the cost-benefit analysis for new investments. The transmission access tariff should reflect the reliability of the transmission service provided. Requests for use of the transmission network by third party is extending the traditional analysis of transmission capability far beyond traditional institutional boundaries.

Given these significant policy shifts, the electric utility industry is moving to new planning criteria where broader engineering considerations of transmission access and risks must be explicitly addressed. Specifically, the likelihood of the occurrence of worst possible scenarios must be recognized in the analysis and acceptable risk levels incorporated in the decision-making process. In general, planning criteria should address the following issues:

- Suitable electricity energy forecasting methods in meeting the future demand for socio-economic growth of the country.
- Optimal ratio of primary energy sources for electricity generation over reasonable period of time.
- Making suitable connections for system stability and security; ability to exchange power between regional areas or neighboring countries.
- Maintaining service reliability with the planned load growth while being financially feasible.
- Uncertainties associated with deregulation, wheeling and transmission access and disintegration of the distribution systems.
- Integrated generation and transmission system modeling.
- Accessing environmental costs and implication of electricity.

The impact of environmental degradation caused by electric power generation is spread out widely and it is experienced not only locally and nationally but also internationally such as in the case of global warming phenomenon. The recent move to a competitive electricity market has intended to call for environmental attention and regulation in electricity industry. The various environmental externalities involved in electric power generation may be categorized as air pollutants, greenhouse gases, water and noise pollutions.

Due to competitive environment, power producers will try to minimize the costs of electricity production to get more profit and they may ignore the environmental issues. Most regulatory and restructuring issues do not reflect any caution for environment in their decision regarding fuel quality. Furthermore, competitive power market may discourage many of the most economic environmental initiatives such as funding for cost effective energy and renewable energy source development. Some arguments that deregulated market will increase emission are:

- The prices of electricity will decrease, as expected, and this will lead to increase in consumption of electricity, which may increase the environmental degradation.
- Demand-side management programs may become less effective and doubtful in application.
- Power producers may opt for low quality fuels and thereby increase in emissions.
- Competition will result in reduction of market share for cleaner and renewable power, as they may not compete with other sources of power. Therefore, there may be increase in emission.

2.8. Reliability and Security

Deregulation and competitive pricing make possible for consumers to select their supplier based on cost effectiveness and reliability. Traditional reliability criteria based on the deterministic considerations will become increasingly difficult to apply, as the traditional utility functions are unbundled. This is true in the system operation domain where security constraints are deterministically based. In planning domain, there is a long history of probabilistic techniques and applications. In order to appreciate the reliability issues arising in the present deregulated power supply industry, it is necessary to recognize the forces and actions, which are shaping this environment.

The reliability analysis [5] for a reinforcement project may include prediction of the expected load and capability of system for delivering the power without violating the ratings. With incorporation of probability demand levels, contingency scenarios and possible operating practices, the predicted index become the measure of the degree that the demand will exceed the transmission capacity. Competitive electric energy systems provide strong motivation to re-evaluate the traditional approach and consider a risk-based security assessment approach, where risk is defined as the product of probability and consequence. In addition, unlike the traditional environment of the regulated industry, where rate of return is fixed, competitive electric systems create incentive for a multiplicity of players to take operating risks in order to maximize their profits. Unmanaged risk-taking may very well lead to degradation of security levels specially true in dynamic security aspects and the consequence of instability can be costly.

As consequence of the increase of transactions and of the reduction in the transmission investments, transmission systems are operated closer to their limits and reliability is at risk, as evident from some recent blackouts in restructured systems. This requires new security monitoring and control systems to be developed. It can be clearly seen that the thrust towards privatization and deregulation of the electric supply industry will introduce a wide range of reliability and security issues. These issues require new system reliability and security criteria and analytical tools that recognize the residual uncertainties associated with the power system planning and operation.

2.9. Energy Efficiency and Conservation

Supply-side efficiency improvements have been the major focus of electricity generation industry ever since the start of their commercial use. Now energy efficiency [6] or conservation programs are widely implemented in form of demand-side management (DSM) programs. Demand-side management has gone a long way since its beginning in the wake of the oil crisis. The early programs were intended to increase customer awareness of energy issues and available conservation options. By the late 1980s, the interest of utilities to reduce or eliminate the needs for additional resources has increased. Generally energy savings are achieved through the substitution of technically more efficient DSM measures to produce the same level of end use services with less consumption of electricity.

There were two opinions about the energy efficiency in deregulated environment. It was argued that deregulated market would force the customer to use energy efficiency options when the cost of energy increased during peak hours. On the other hand, it was believed that average energy prices would decrease and customer would not bother about energy efficiency measures, as these devices were expensive compared to the non-efficient devices. It was also thought that the government may not support the energy efficiency options. Before restructuring, utilities were generally more prepared to invest in energy efficiency programs because of, primarily, the institutional link between generation, transmission and distribution; and the natural monopoly status that enabled some degree of public-benefit investment. Since competition has been introduced, the DSM programs have declined due to two reasons:

- Restructuring generally seeks to harness competitive forces to improve the economic efficiency of the system. Achieving this goal makes more difficult for the market participants to invest in these types of energy efficiency programs and remain price-competitive.
- Restructuring tends to fragment the electricity supply industry and there are no potential market play benefiting from the investments in end use energy efficiency.

However, public benefit energy efficiency investment can be continued through various ways such as:

- Innovative regulatory efforts,
- Financing energy efficiency investments, and
- Independent institutional arrangements.

3. NEW CHALLENGES

3.1. Change in Professional Interest

Structural changes in the electric supply industry (ESI) business have resulted in several changes in professional interests. The industries requiring only core power engineers are now switching towards the economists, business administrators and law professionals. There is also a shift of interest in research and development activities. Even in the regulated ESI period, the interest in power engineering education was declining and restructuring may further decrease this interest. Research and development will also be hampered especially in transmission and distribution operations, as small market participants will not like to invest in R&D activities.

3.2. Suitable Environmental Rules

The deregulation of power industry may lead to more emission, if it is not properly regulated with environmental rules. Thus, utility regulators must understand the environmental implications while making decisions in resource selection and in reform process. The green power in generation mix may decline and may give a threat to the environment. Electricity regulator should establish a close, consultative relationship with environmental regulators to achieve the environmental objectives. Economic development is absolutely necessary for any country but cleaner environment is also important to achieve the desired economic objective.

3.3. Suitable Electricity Code

Market rules and market structures in the restructured electricity supply industries in different countries are not the same. The interaction of these market rules and the market structures of the various industries may enable to determine whether these markets set economically efficient prices. The questions to be answered are:

- What are the effects of the current market rules on all these objectives?
- How do the current planning paradigms used by the ISOs affect system reliability and efficiency?
- What new paradigms should be introduced to accommodate the current market and to encourage the use of Distributed and/or Renewable Energy Resources?

The challenge is to design market rules that would meet these objectives to run electricity market in healthy and transparent manner.

3.4. Quick Settlement Issue

It is expected that market will operate in non-discriminatory manner and each market participant has the right to do business in equitable manner. In regulated market, there was only one utility for generation, transmission and distribution. There was no dispute but in the vertically unbundled system, the number of participants is high and there may be dispute on several issues and on several occasions market may be stalled or suspended. Therefore, there must be a quick settlement mechanism for the smooth operation of the market. The settlement issues may be cleared in each month and/or on each day.

3.5. Information Technology

Large-scale transactions, covering long distances, can impact many system operators, either directly or due to the effect of loop flows or parallel paths. Therefore, system operators need to have data not only on their own system but also on the other connected systems. New communication systems must be developed. There are some data which should be accessed by everybody and some data are to be made available online such as network status, available transfer capacity of the system, and pricing. A strong communication link is necessary which is possible through information technology. Failure of flow of interaction may cause several disputes and to a greater extent, failure of energy market.

3.6. New Black Start Standards

The power system must be prepared for the rare occasions when all or a major portion of the system is forced out of service. This might be the result of a particularly severe disturbance resulting in the loss of stability and requiring many generators to shut down. Although this occurs rarely but whenever it occurs, the system must be able to be restored to normal operation as quickly as possible. The current system of indirect regulatory pressure on black start services planned for vertically regulated market may not work under the deregulation [7]. This is called system black start capability.

The lack of specificity in black start requirements, coupled with different market participants such as generators, transmission owners and operators, may impose a fundamental problem under restructuring. The system operator could buy black start capability competitively from generators. The technical restrictions (e.g., speed of response, control capability, voltage control, reactive power capability) and locational capability may reduce the number of units that can provide this service. Within a region, restoration plans should be adjusted to accommodate changes in the location of black start units. Therefore, new standards and rules are required to deal with restoration problem.

3.7. Software Suitability

Deregulation of the energy industry has resulted in the emergence of software that coordinates the functions in power systems. The quality of software [8] should meet the customer's expectations and be easily adaptable to changes. A detail and accurate representation of system is required for performing functions such as congestion management, determining transmission congestion prices, forecasting transmission loss responsibilities and evaluating transmission capability. Slight error may not give the optimal solution and may lead to dispute.

With the evolving power market scenario and the emergence of diverse software requirement, software quality is bound to invite more attention than ever before. This poses strong challenges to companies who are involved in developing deregulated energy system software. The other challenges are due to changing market policies, operating platforms, diverse software makes. The range of available power system software packages is increasing and compatibility between the software packages can be an issue.

3.8. Market Power

Electricity market is not a perfect competitive market where the number of suppliers is not high and there is always a chance of making market power, which is an abuse to the deregulation. Market power is the ability to profit by moving the market price away from the competitive level. Most of the firms have some market power and this causes no significant problem if the amount is small. Market power raises price and thereby transfers wealth from consumers to all the suppliers in the market and leads to inefficiency of the market. Factors that determine the market power are the market concentration, demand elasticity, style of competition, forward contract, and geographical extent of the market. The different approaches to study the market power may be the ex-post analysis of recently restructured market, market concentration analysis, market simulation and equilibrium modeling. Market power must be studied properly and should be reduced as much as possible for better competition.

3.9. Price Volatility and Existing Utilities

Vertically integrated power system is categorized as a fixed price system where the price of electricity is decided by the government regulators and is fixed for a particular period of time. However, in competitive electricity market, the price of electricity is decided by the market at any particular instant of time. Each market participant acts according to its own to make profit from the market and therefore the price of electricity fluctuates throughout the day. There are several mechanisms, such as future and forward contracts, financial and physical rights, to reduce the price volatility but they are still unable to completely flatten the price in the deregulated market. Network constraints are also a root cause of price volatility. In a perfect competition, the price of commodity should remain almost constant throughout the day. There is a need to design the market and to have some mechanisms to safeguard against spiraling prices.

Some suppliers may be at a competitive disadvantage due to operating or economic constraints such as significant start up time and costs; minimum output levels, run time and down time, and restrictive fuel contracts. Their operating efficiencies may also not be as high as the new units. To the extent possible, these suppliers should be accommodated so that they have a more realistic opportunity to compete.

3.10. Congestion Management

Congestion in a power system is a consequence of network constraints characterizing a finite network capacity that limits the simultaneous transfer of power from all required transactions. Congestion in a transmission system, whether vertically integrated or unbundled, cannot be tolerated, since this may cause cascade outages with uncontrolled loss of load. The main tool used for dispatch in a vertically organized power system where generation, transmission and distribution control functions are within the control of the energy management system, is an optimal power flow. In addition to its role in minimizing production cost, it also provides the possibility of avoiding congestion in a minimum cost manner. In deregulated electricity market, congestion management has been debated much for increasing competition of electric power generation in both pool and bilateral dispatch models. Congestion management, furthermore, becomes even more complex in the event that dynamic security is taken into consideration.

There are several ways to eliminate congestion including cost-free (outage of congested branches, operation of FACTS devices and operation of transformer taps) and non-cost-free (re-dispatch of generation and curtailment of pool loads and/or bilateral contracts) means. In some cases, congestion can be avoided by using a costlier generator, which increases the nodal prices of the system. The presence of new market participants and changing the demand patterns means that the power system is now being operated in states far away from those contemplated during planning. In practice, it may not be possible to deliver all bilateral and multilateral contracts in full and to supply all pool demand at least cost due to violation of operating constraints such as voltage limits and line over-loads (congestion).

Congestion management essentially has to do with rationing transmission access. Rationing has to follow a user-pay philosophy "willingness-to-pay" so as not to be constrained which is an indicator of the importance that the parties to a transaction place on unfettered dispatch. The objective function of the dispatch problem in a system with bilateral and multilateral dispatches only, that is without pool, would be:

$$\min f(u, x) = F + [(u - u^o) A]\, w\, [(u - u^o)^{\mathrm{T}} A] \tag{1}$$

subject to:

$$\tilde{L}(u, x) = 0 \tag{2}$$

$$\tilde{G}(u, x) \leq 0 \tag{3}$$

where:

F	=	social benefit function of pool
w	=	a diagonal matrix whose elements are "willingness-to-pay" price premiums to avoid transaction curtailment
u	=	a set of control variables consisting of active power injected or extracted at generator buses and load buses, respectively
u^o	=	the desired or target value of u (pool loads, bilateral and multilateral contracts)
x	=	the set of dependent variables
A	=	a constant matrix reflecting curtailment strategies used by market participants

Equality constraints, Eq. (2), are the real and reactive power balance equations along with the contracts but Eq. (3) is a set of inequality constraints indicating the magnitude (mathematically upper limits) of pool demands in addition to the usual system operating constraints such as bus voltage levels and line overloads.

A measure of degree of curtailment, along with the spot prices, is required for market participants to respond in the event of congestion. The degree of curtailment can be defined as:

$$d(C) = \sqrt{(u* - u^o)^{\mathrm{T}} \;\; (u* - u^o)} \tag{4}$$

where $u*$ is the optimal value obtained from the above minimization.

3.11. Strategic Biddings

An open power market place envisages competition in both investment and supply. The former is concerned with the prospect of several entrepreneurs competing to obtain regulatory franchise to build, operate and market profit from investment in future plant. On the other hand, competition in supply is concerned with how owners of existing plant price their outputs for commercial gain. The bid price is an internal decision of the seller which depends upon several factors.

An appropriate bidding structure is very important for both suppliers and the consumers in electricity market since their underlying objective is to maximize their profits. In the bids, suppliers have freedom to bid above their actual cost but there is no guarantee for getting the dispatch cleared in the market which is decided by other market participants' strategies. The net revenue received from market is based on their strategic bids whereas in the vertically regulated market, suppliers have been getting the fix rate for their power produced. Several factors which affect the bidding strategies are technical constraints of the unit operation, bilateral/multilateral contracts, market clearing prices of the previous days, and hydro energy availability. It is an optimization process with all constraints where some are probability based. Suitable bidding models are required in the deregulated market so that the market operates near the marginal cost of generators.

3.12. Load and Price Forecasting

Load forecasting [9] has reached a comfortable state of performance in the years preceding the recent waves of power system restructuring. Competitive power market, however, has been associated with the expectation of greater consumer participation and efficiency gains for both consumers and other market participants. The major differences of load and price forecasting in competitive power market compared to regulated market are:

- Price response has to be considered.
- Forecast errors have significant implications on profit, market shares, etc.
- Day-ahead, weather-based forecasting is becoming the most crucial activity.
- Some other information is required.
- Pricing in the past period is also necessary.

The demand-side forecasting is an evolution of conventional load forecasting and is also used with an added emphasis on the separate hourly (or half-hourly) periods, more stringent requirements for weather forecasts and a need to cope with additional non-linearities. Thus, there is a need to have computational intensive method. Forecasting the strategic behavior on the supply-side is a new area of research and not yet formulated.

Price forecasting is an important issue for both the supplier and consumers for decision-making activities. The price forecast includes the future and forward market prices forecasts. Since price forecasting is directly coupled with load forecasting, a comprehensive model is required to deal with these in electricity market.

3.13. Allocation of FACTS

It is important to ascertain the optimal location for placement of FACTS devices because of their considerable costs. There are several methods for finding optimal locations of FACTS devices in both vertically integrated and unbundled power systems. Moreover, these works do not suggest a simple and reliable method for determining the economic location in the deregulated environment. Mathematically, the optimization problem, subjected to power system constraints, can be formulated as:

$$\min F + C_{FACTS}(r, n, X) \tag{5}$$

where C_{FACTS} is the cost of FACTS devices which should be recovered in n years at the interest rate r. X is the control parameters of FACTS device. It is not possible to locate the FACTS in all lines, therefore, some potential lines can be identified and/or determined. One such way to determine this is the sensitivity factor approach [10]. At the same time, it is also important to devise a suitable mechanism to recover the cost of these devices from the market.

4. CONCLUSIONS

The changes taking place in the corporate environment of electricity supply industry are described in terms of deregulation, restructuring, privatization, and third party access, but the main common feature to all these is to create competition at some levels. This paper highlights several emerging issues and key challenges in the power system. There is no doubt competition would bring several advantages but, at the same time, create several problems. Therefore, a number of questions should be answered before moving towards deregulation:

- Is the deregulation good for the benefit of the society?
- What are the implications to the current industry participants?
- What types of new participants will be seen and why?
- What should be the structure of the market and its operation?
- What might an electricity transaction of the future look like?
- What are the key issues in moving towards deregulation?

In a competitive power market, a commercially transparent and technically justifiable operation of market is very important. Some of the technical challenges are also discussed in this paper, which should be properly analyzed and a suitable mechanism is to be developed to handle these issues. The paper provides a bridge between traditional utilities methodologies that are effective and efficient and the need to make the electricity market place more inclusive and competitive.

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