CHAPTER II

SOCIAL WELFARE AND CONGESTION MANAGEMENT

2.1. INTRODUCTION

The power flow analysis is the most essential and fundamental instrument for power system engineers. Currently vertically integrated utility (VIU) has been used for restructuring power system. VIU has primarily three utilities; generation company (GENCO), transmission company (TRANSCO) and distribution company (DISCO). The United Kingdom (UK) was the first to restructure its nationally owned power system, creating privately owned companies to compete with each other to sell electric energy. The form of deregulated power industry differs in each country and among various regions. The three main forms of power industries identified worldwide are optimal power flow (OPF), price area and transaction based models. These models operate in different ways interacting with the properties and limitations of the transmission system and also with the economic efficiency of the energy market [1-6] and [8].

In the present scenario, the market players try to find the most effective way to develop competitive electricity markets that fulfill the goals of economic benefits. The electric power industry has been seeing remarkable changes in its operation and governance after restructuring. The power market provides a good option for power engineers to promote the game of business in this industry. The purpose of introducing deregulation in power system is to create a healthy competition among the market participants and form an efficient electricity market. Also, this provides opportunity for secure, transparent and non-discriminatory economic operation of the market. After the restructuring, profit generating companies are coming up to deliver electric energy to competitive electric markets. In such cases, two important responsibilities are involved in system operations and these are accepting/awarding bids and managing the transmission system. These responsibilities are managed by two separate organizations, economic power pool or Power Exchanges (Power Ex) and the Independent System Operators (ISOs). A pool operator takes bids from suppliers and consumers and then dispatches signals for generations and loads in an economic manner based on the bids offered by the load entities. The suppliers and consumers are directly connected through the pool operator. The advantage of this arrangement is that the pool operator can internally solve the problems of congestion management, loss allocation and other ancillary services. The role of ISO has increased manifold in deregulated power system due to present trends of bilateral/multilateral contracts in the electricity market. In such a scenario, the ISO creates a set of rules that ensure sufficient control over producers and consumers to maintain an acceptable level of power system security and reliability [15]. The demand for deregulation promotes various new objective functions for economic system operations. The social welfare with congestion management can be considered as one of the important objectives of the power market. The conventional welfare is based on economic dispatch which enables minimum generation cost in a single utility environment. However, in the present work the social welfare term is benefit maximization of all the market participants. In this objective, the market operators try to provide optimal benefits for all entities with the economical growth of whole region [37] and [38].

The privatization and open access promote multi-transaction setting in power markets, wherein each transaction tries to obtain its own optimal solutions which affect the transmission system operation and sometimes this becomes a cause of congestion. Therefore, the congestion management becomes an important issue in multi-transaction model with social welfare in power market. As mentioned, the researchers have shown incredible interest in involving the consumers demand in the objective function to maximize the social welfare. In the early days of deregulation, customers did not have effective participation in power markets, and therefore they were unable to respond to the prices effectively. However, in a complete competitive market, there should be enough motivations for the customers to participate in power market operations [63, 87-89]. Thus, an open competition is established among the market participants and two approaches can be used for market operations using centralized and decentralized decision based supports. Usually the power market operators use centralized decision based system operations for an efficient and optimal solution for congestion management with social welfare. This method has some definite drawbacks over the decentralized decision based system operations. Therefore, it results into higher degree of decentralized decision making in the system operations [49-54]. A detail study and mathematical formulation of centralized and decentralized decision supports are discussed in subsequent chapters.

Before continuing further, it is useful to introduce general background of electricity market structures and to look at the operational methodologies of the electricity industry to motivate the desire for deregulation. Thus, the present chapter deals with the concepts of social welfare and congestion management in the power market [45] and [94]. It also includes a brief survey of operational methodologies adapted by different types of power markets worldwide. A brief introduction of Indian power market has also been incorporated in this chapter.

2.2. DEREGULATED POWER MARKET AND ROLE OF INDEPENDENT SYSTEM OPERATOR

The deregulation or restructuring of power system include many market players such as generation companies, demand supplying agencies and transmission system. The main objectives of deregulation are as follows

- To enable a market
- To promote competition in power markets
- To encourage investment
- To provide incentives to efficiencies.

Deregulation denotes breaking up of VIU structure into competitive market entities as shown in Fig. 2.1.

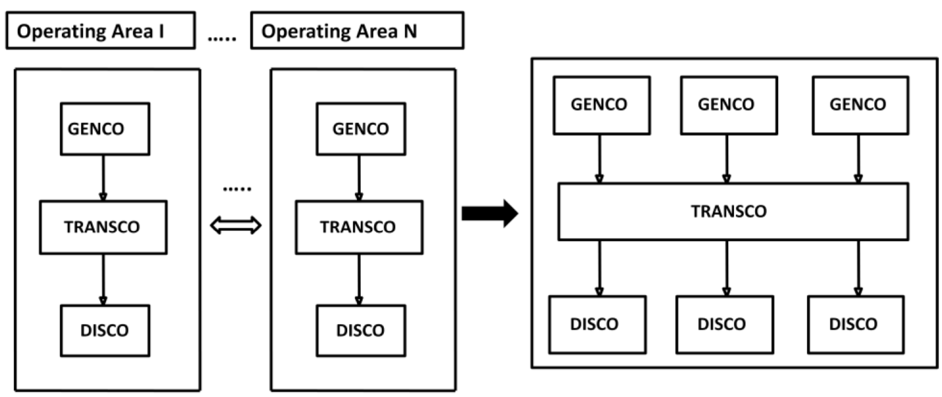


Fig. 2.1 Deregulation or restructuring of competitive market entities.

The unbundling of power system provide some more advantages in avoiding monopoly activities in transmission and system operation/distribution. It also provides a healthy competition between the participants of the power market. Although, deregulation has a large number of advantages, yet operation wise it is affected by various factors and also it requires some essential services within the restructured power industry [2-15]. These factors and requirements are as follows:

i. Addition of a large number of market players forces the system operators to take a decision, acceptable to all participants.
ii. Deregulation requires an improved information system to exchange data among those market players who can provide a reliable and efficient operation of the system.
iii. The uncertainties increase in the operation and control of the market due to the presence of a large number of participants.
iv. As renewable energy requirements are increasing day by day, interface with newer markets is becoming multifaceted.
v. Social welfare and economic operation of the market increases the pressure on the system operators.
vi. Inclusion of various factors increases the system complexity which requires new software, technologies and numerical methods for problem solution.

The ISOs are accountable for all the operations and controls of the market on daily or long term basis. The electricity markets adapt different ISOs with their operational methodologies [21] and [25]. It is important that each design fulfills its basic requirements of reliable functioning in the specified region by assuring that all the participants have open and discriminatory access to the transmission services. ISOs have been basically modeled into two types: pool model (centralized) structure and bilateral/multilateral model (decentralized) structure [44] and [50-54]. The main role of ISO is to monitor the transmission system operation in normal and abnormal conditions [15]. The major functions of ISOs have been discussed in the subsequent sections.

2.2.1. Reliability-Related Functions

The reliability-related functions have following two aspects:

i. The ISO should monitor the performance of the system security functions and re-dispatch generation to eliminate real-time transmission congestions. It should also maintain the system reliability and security in all normal and abnormal operating conditions.
ii. The ISO should carry out reliability studies and planning activities in coordination with the transmission owners and other market participants to assure the adequacy of the transmission system. The data emerging out of reliability studies may include locational congestion prices and planning related data that specifies options to be taken for reliable system operation.

2.2.2. Market-Related Functions

The market-related functions of an ISO must be carried out according to transparent, understandable rules and protocols. The following operational functions are required in a competitive market:

i. Available transmission capacity (ATC) of all paths of interest within the ISO region.
ii. Receive and process all requests of transmission services within and through the ISO region.
iii. Schedule of all transactions and their approval.
iv. Operate or participate in open access same time information system (OASIS) for information publishing.
v. Establish a clear ranking of transmission rights of all the participants of transmission system. Facilitate trading of transmission rights among participants within their own grid.
vi. Manage transmission congestion and cost allocation in accordance with the established rules and procedures for generation re-dispatch.
vii. Assure the provision of ancillary services required to support all scheduled delivery transactions.
viii. Market settlement and billing functions.

2.3. POWER MARKETS AND OPERATIONAL METHODOLOGIES

The power market deregulation started through centralized dispatch pool structure with competitive bids and offers about a decade back. The pool is the only place to trade electric energy and settle the energy prices based on demand-supply movement. Hence, both suppliers and buyers are confined in their ability to hedge against potential risks. The pool structure experiences the following operational limitations:

i. Electricity demand is relatively inelastic and consumers as a whole have little influence on the prices.
ii. A large amount of energy trading provides strong incentive for the suppliers to raise prices by physical and economic withholdings.
iii. Market power can be exercised in various contingency situations.

It is difficult to monitor and correct these factors in the same time frame. Therefore, to mitigate these factors and hedge risks, the market is moved away from the pool structure towards bilateral contracts [3, 5]. The energy market provides a mechanism for market participants to buy and sell locational based marginal price (LBMP) energy and bid various types of bilateral transactions. Suppliers may sell energy directly to the market at LBMP or they become a party with purchasers using bilateral contracts. Load-serving entities (LSEs) and others may purchase energy at LBMP by submitting bids and/or they may become party with suppliers using bilateral contracts. These parties work as a firm and formulate the bilateral contracts and thus elect the bids of transactions. In this way, the parties agree to pay congestion charges for secure delivery of requested energy [83]. Power markets such as CAISO, ISO–NE, NYISO, Nordic pool, IEX, PXIL, etc exists around the world [184]. The various power market and their operational methodologies are listed in Table 2.1.

Table 2.1

Worldwide Existing Electricity Markets and Their Operational Methodologies

Operational Methodologies in Power Markets		Various Electricity Market*
Day-ahead Power Market (DAM)	-	*NYISO, CAISO, ISO-NE, PJM, MISO, Power Pool Alberta, Nordic Pool, Australia, Turkey, Spain, ATS Russian, APX-ENDEX, JEPX, GEM, SEMO, HUPX and PXE, Germany, EPEX-SPOT, Brazil, EXAA, OTE-Europe and PXIL-INDIA, IEX-INDIA*
Hour-ahead Market	-	*NYISO, Great Britain, Nordic Pool, New Zealand, IMO Ontario*
Real-Time Market	-	*NYISO, CAISO, ISO-NE, PJM, MISO, Power Pool Alberta, Great Britain, Nordic Pool, Australia, New Zealand, Southwest SPP, IMO Ontario, Singapore*
Ancillary Service Market	-	*PJM, ERCOT, Power Pool Alberta, Nordic Pool, Australia, New Zealand, IMO Ontario, ATS Russian, GEM, IMO*
Transmission Congestion Contracts (TCC) Market	-	*NYISO*
Bilateral Tractions Based Market	-	*NYISO, ERCOT, Southwest SPP, Turkey, Singapore, ATS Russian, EPEX-SPOT, Brazil, EXAA, IMO*
Reserve Market	-	*NYISO, ISO-NE, PJM, MISO, Australia, IMO*
Capacity Market	-	*NYISO, ISO-NE, PJM, MISO, IMO Ontario, IMO*
Regulation Based Market	-	*NYISO, ISO-NE, Singapore*
Financial Transmission Right (FTR) Based Market	-	*NYISO, ISO-NE, PJM, MISO, ATS Russian*
Auction Revenue Right (ARR) Based Market	-	*MISO*
Balancing Energy Market	-	*ERCOT, Nordic Pool, Turkey, Spain, ATS Russian, OTE-Europe*
Bilateral Trading Through Intercontinental Energy Exchange (EX)	-	*PJM, MISO, Southwest SPP, Spain, OTE-Europe*
Demand Response (DR)	-	*NYISO*
Market to Market Coordination Based Market	-	*PJM*
Shortage Pricing Based Market	-	*PJM*
The Financial Electricity Market	-	*Nordic Pool, IMO Ontario, ATS Russian*
Intraday Market	-	*Nordic Pool, Spain, APX-ENDEX, GEM, SEMO, Germany, EPEX-SPOT, OTE-Europe, PXIL-INDIA*

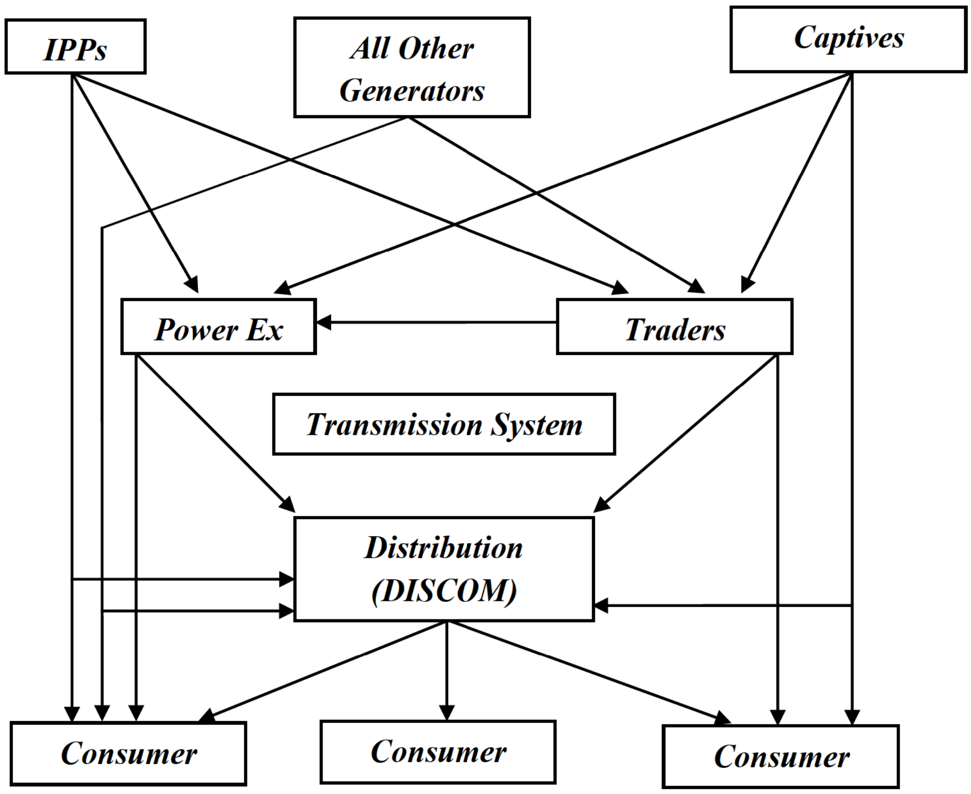
APX-ENDEX – *Power Spot Exchange Europe* ***EXAA*** – *Energy Exchange Austria* ***MISO*** – *Electric Power Exchange in Canadian Province of Manitoba* ***OTE-Europe*** – *Czech Electricity and Gas Market Operator* ***Southwest SPP*** – *Southwest Power Pool Electric Exchange Network North America*	***ATS Russian*** – *Russian Whole Cell Electricity Market* ***EPEX-SPOT*** – *European Power Exchange* ***HUPX*** – *Power Exchange Hungary* ***IEX-INDIA*** – *Indian Energy Exchange Ltd.* ***PXIL-INDIA*** – *Power Exchange India Ltd.* ***NYISO*** – *New York Independent System Operator* ***PXE*** – *Power Exchange for Central and Eastern Europe* ***GEM*** – *Germany Electricity Market*	***CAISO*** – *California Independent System Operator* ***ERCOT*** – *Electric Reliability Council of Texas* ***IMO/IESO Ontario*** – *Independent Electricity Market Operator/ Independent Electricity System Operator* ***JEPX*** – *Japan Electric Power Exchange* ***Nordic Pool*** – *Power Pool of Nordic Countries* ***PJM*** – *PJM interconnection Pennsylvania* ***ISO-NE*** – *Independent System Operator New England*

Apart from these methodologies, some supporting services and market products also play a vital role in market operations. Some of the electricity market support services are generator scheduling, ancillary services, residual unit commitment, congestion revenue rights, convergence bidding, network modeling, resource modeling, outage management, metering and telemetry, settlements archive and dispute processes, transmission operations, power contracts bulletin board, market monitoring and rules and regulations. These products establish a trade in the electricity market which allows meeting reliability related issues to serve the load by providing balancing energy with sufficient capacity and allow participants to meet their own business objectives. The ISO also offers services including mechanisms for entities to obtain and trade congestion revenue rights and engage in convergence bidding activities. All products and services are developed and implemented in full collaboration with the stake-holders.

2.3.1. Indian Power Market

The Indian power sector has undergone extensive changes and has made significant progress over the years. The installed capacity of generation has been upgraded from 1,361 MW in 1947 to 211,766 MW as on March 2013. Fundamentally, the Indian power market is an unbundled/decentralized structure. A typical structure of Indian power market is shown in Fig. 2.2.

After the constitution of electricity acts, some supporting bodies have been established to support and guide the power system participants. These bodies are basically government bodies such as central electricity authority (CEA), central electricity regulatory commission (CERC) and state electricity regulatory commissions (SERCs). They are governed by the ministry of power (MoP). These bodies govern the whole power market and provide an efficient operation in Indian power sector. After the establishment of different electricity acts and regulations, significant changes have been adopted by Indian power sectors at different intervals [22-25]. These regulations and their impacts on Indian power sector are given in Table 2.2. After the enactment of the Electricity Act 2003 and implementation of open access, the market structure in the power sector has changed from the old single buyer structure to multi-buyer model [33]. The generator can sell power to any buyer using the open access provision in transmission and users have the choice to choose their supplier. This enactment has increased competition among generators and suppliers, which improve the sector's performance. Currently day-ahead and intraday based methodologies have been adopted by the Indian power market structure.



** All the arrows shows the contract between participants*

Fig. 2.2 Indian power market structure.

Table 2.2

The Regulations and There Impacts for Indian Power Market: An Overview

Laws/Polices	**Objective**	**Impact**
The Electricity Act, 1910	Infrastructural framework for supply of electricity	Attracted private capital
The Electricity Act, 1948	Mandated creation of State Electricity Boards (SEBs)	Ownership in the hands of SEBs
Independent Power Producers (IPP) Process, 1991	Private investment in power generation	Projects from private players came into generation
Mega Power Policy, 1995	Setting up of Mega power plants	Mega power plants get benefited

The Electricity (Amendment) Act, 1998	Making transmission a separate activity	Central Transmission Utility & State Transmission Utilities were setup
The Regulatory Commission Act, 1998	Provision for setting up of Central/State Electricity Regulatory Commission	Independent regulatory mechanism
Electricity Act, 2003	Providing reliable and quality power to customers at reasonable rate	Investments in capacity addition
National Electricity Policy, 2005	Competition and protection of consumer	More players influenced to invest and more efficient consumer service
National Tariff Policy, 2005	Tariff structuring	Attractive tariff for players
Power Exchange, 2008	Establishing the power market in India	The process of organizing the electricity market by realizing the staff paper for developing a common platform for trading electricity
Power Market Regulation, 2010	The Electricity Act aims at taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and enhancing supply of electricity.	To promote development of markets in electricity (including trading) through regulations and in accordance with National Electricity Policy.

Presently, many states have unbundled the SEBs and have reported the improvements in their operational efficiency [27, 30]. Although the SEBs are handling the regulatory operations, the Act has mandate for the creation of regulatory commissions in each state. These commissions have passed numerous regulations and provided a legal framework for players for carrying their business in the industry. This is a well known fact that the system operators also play an important role in the power market with these regulatory commissions. Therefore, different regional load dispatches centers (RLDCs) such as NRLDC, WRLDC, SRLDC, ERLDC and NERLDC are working as ISOs in India. The RLDCs look after the operation of power system in their respective regions and report to the National Load Dispatch Centre (NLDC). These bodies try to establish a better competition among all the profit making entities. In spite of all this, the Indian power sector is still lagging on several issues such as power shortages, transmission and distribution losses. A concrete market structure where consumers can also participate in market competition and also get some benefits with minimum controversy is the need of the hour.

2.3.2. Establishment of Power Exchange in India – IEX & PXIL [33]

The power sector in India is undergoing various structural transformations after the enactment of Electricity Act, 2003. One of the important transformations is the creation of "Power Exchanges". The objective of creating a power market is to unleash market forces to improve efficiencies, stimulate technical innovation and promote investments. Currently, 95% of the capacity is tied up with long term power purchase agreements. In order to supply the seasonal demand, it is necessary for the distribution utilities to look for short term contracts. The latest addition is bilateral contracts, traders and unscheduled interchange (UI) of short term contracts in power exchanges. The recent trends of power exchanges in the power sector are in operation in India for about five years and they are taking place of conventional methods of long term trading and bilateral contracts. The Electricity Act, 2003, in India passes two power exchanges, "Indian Energy Exchange (IEX)" and "Power Exchange of India Limited (PXIL)". These exchanges provide platforms for automated and online electricity trading. In addition, these exchanges are supposed to supply and modernize the electricity sector in India by introducing a transparent and neutral market through a technology enabled electronic trading platform. In India, disparity in the power demands of different states and regions result into seasonal surpluses in some areas and deficit in some other areas. This demand–supply mismatch can be improved by introducing a bidding platform that brings power industry participants together to buy and sell electricity in an auction based system. On 9th June 2008, CERC accorded approval to IEX for commencing its operations and on 27th June 2008, IEX started its functioning. The IEX was the first power exchange in India and today it controls about 95% of the market of the country. Another exchange, PXIL had also started its operation in India on 22nd October 2008. After the establishment of these exchanges, the Indian power sector has become a modern power market and is playing an important role in the overall development of the country.

2.4. SOCIAL WELFARE AND OPTIMAL POWER FLOW IN POWER MARKETS

In the previous section a brief review has been reported on the world wide established power markets. The most important aim for establishing the markets in the power system is to promote the competition among participants and improve the economy. Therefore, a term social welfare has been introduced in the power markets. The meaning of this term is to increase the individual benefits of all participants as well as to improve the economy of whole market [40]. The market clearing price (MCP) and the generation and demand of all bidders are normally determined to obtain the maximum social welfare under the competitive power pool. In this scenario, the power dispatch in between supplier and consumer is based on any one of the two theories, the last accepted bid method and the spot pricing method [45, 60]. The last accepted bid theory is shown in Fig. 2.3.

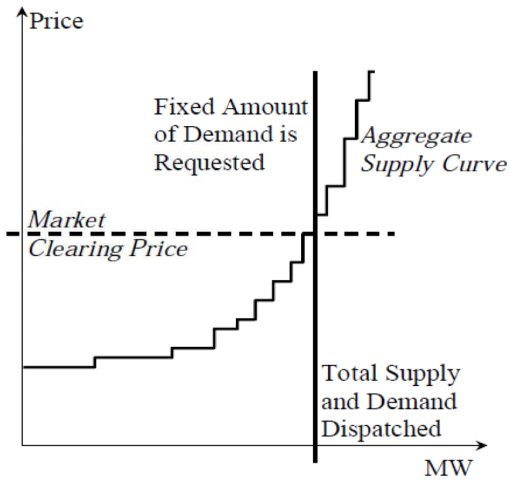


Fig. 2.3 Fixed demand requests or inelastic demand bid model.

In the last accepted bid method, the market participants submit blocks of generation and load along with associated prices. All the supply bids are aggregated and sorted by price in ascending order to create the aggregate supply curve in this method. If the consumer bidding is included, then all the demand bids are aggregated and sorted by price in descending order to create the aggregate demand curve. The curves are then plotted against one another, and the point where they cross defines the market clearing price (MCP). All bids to the left of this point are then accepted and all suppliers are paid the MCP for the blocks of generation bids. Moreover, all consumers must pay the MCP for the blocks of demand bids.

The spot pricing method is shown in Fig. 2.4 [35]. In this method, suppliers and consumers submit bid curves to the pool operator and an optimization routine is used to determine the dispatch results. Suppliers are then paid a price according to their bids and consumers must pay a price according to their bids. In such a case, OPF based solutions play an important role in maximization of social welfare in terms of utilities profits. Congestion management problem can also be easily handled using this method based on OPF technique. A brief discussion of OPF, social welfare and congestion management has been reported in the subsequent sections.

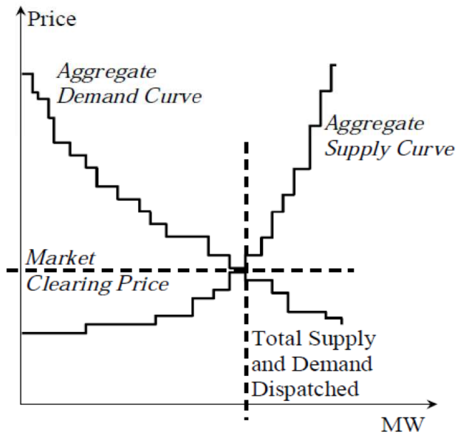


Fig. 2.4 Variable demand bidding or elastic demand bid model.

2.4.1. Optimal Power Flow [5]

The traditional OPF with the objective of minimizing the generator cost is described in this section. The consumer demand has been considered as fixed demand biding and it is not included in the problem objective. The various objectives, controls and constraints of OPF are given in Table 2.3.

The Optimal Power Flow may be formulated as follows:

$$minimize \quad f(x,u) \tag{2.1}$$

$$subject\ to \quad g(x,u) = 0 \tag{2.2}$$

$$h_{min} \leq h(x,u) \leq h_{max} \tag{2.3}$$

where

u	set of control variable
x	the set of dependent variables
$f(x,u)$	a scalar objective function
$g(x,u)$	the power flow equations
$h(x,u)$	the limit of the control variables and operating limits of power system components.

In present work, two objectives have been considered as a mutual problem in the problem formulation. These two objectives are minimum cost of generations and maximum benefit of consumers.

Table 2.3

The Objectives, Controls and Constraints of OPF Problems

Objectives	• Minimum cost of generation and transactions • Minimum transmission losses • Minimum shift of controls • Minimum number of controls shifted • Minimum number of controls rescheduled • Minimum cost of VAr investment • Determines the system marginal cost • Maximum social welfare has been added as a new objective
Equality Constraints	• Power flow constraints • Other balance constraints
Inequality Constraints	• Limits on all control variables • Branch flow limits (Amps, MVA, MW, MVAr) • Bus voltage variables • Transmission interface limits • Active/reactive power reserve limits • Demand limits are also consider as a new constraints
Controls	• Real and reactive power generation • Transformer taps • Generator voltage or reactive control settings • MW interchange transactions • HVDC link MW controls • FACTS voltage and power flow controls • Load shedding

2.4.2. OPF Based Social Welfare Maximization [37]

In ISO, the supply-demand bids are collected by generator and load serving traders on hourly/half-hourly/minutes basis. The ISO tries to maintain a schedule of both demands and generations for maximizing the social welfare of the market. The conventional benefit optimization is mainly based on economic dispatch in a single utility environment which enables to achieve minimum generation cost. Presently, worldwide the multi-transaction structure based power market has been preferred. Therefore, the consumers also participate in the main objective of social welfare maximization. In order to maximize the social welfare in a power market, the objective function of conventional OPF is modified by including a consumer benefit function $B(P_D)$ in the objective. The congestion management becomes one of the important problems by adding consumer's benefits. The OPF based social welfare can provide a better solution for congestion management. In order to analyze the congestion problem in power system, the line limits are also included as constraints in the optimization problem formulation. The social welfare based market model can be represent as

Maximize {Total benefits obtained by demands (B_j)–Total generation cost (C_i)}

Subject to Equality Constraints of power balance in market (P_D, P_G, P_{losses})

and Inequality Constraints related to power system components $(P_G, P_D,$ *Line limits, etc.)*

In this objective function, B_j and C_i denote the consumers benefit and generators cost functions respectively. In next chapter, these two terms are explained in detail. The equality constraint denotes the power balance for each transaction considering the losses. Also, the inequality constraints include the active and reactive power limits of generators, demands and the line limits. For simplicity, the transmission lines are supposed to be congested only in one direction.

2.5. CONGESTION MANAGEMENT [5]

A power system is said to be congested if the transmission network is operated at or beyond one or more transfer limits. In other words, transmission congestion can be defined as the condition that occurs when there is insufficient transmission capability to simultaneously implement all preferred transactions in the electricity market [93]. If the congestion is not properly managed, congestion can impose a significant barrier with respect to trading of electricity. The form of congestion management is dependent on the form of the energy market, and congestion management itself cannot be separated from market considerations. There are at least two main reasons for transmission congestion management which are for adjusting the preferred transactions to keep the power system operation within its security limits and to collect congestion charges from market participants and pay the transmission grid owners to compensate their investment on the grid. The fundamental methods for congestion management used in power networks are

i. Transaction curtailment
ii. Transmission capacity reservation
iii. System re-dispatch

iv. Congestion management using Financial products

(Contract for Differences (CfDs) and Financial Transmission Rights (FTRs)

v. Congestion management by VAR support

These methods are generally adopted for the congestion management in various types of power systems. The different methods have their merits and demerits. The implementation of these methods depend upon the operations of the power system. In the present work, the system re-dispatch method has been used to solve the congestion problem with social welfare. The system re-dispatch is a real-time operation for managing the congestion. In this method, the system control operator directs for the generation and demand adjustments (incremental/decremental) to relieve congestion and avoid undesired transaction interruptions. The cost of these adjustments may be allocated to the responsible participants by either established tariffs or by equal shares among all the participants. Financial instruments may be developed to provide transmission users with the opportunity to hedge against the possible high cost of congestion management. The main advantage of this method over other methods is that there is no delay between the identification of a constraint and implementation of re-dispatch to satisfy the constraints. Moreover, in this method, the bid based auction mechanism is used which makes a market-based system. Also, the congestion management is accomplished by the market participants who offer their willingness to protect their transactions during congestion in the system. Almost all the market participants can contribute in system re-dispatch by following approaches:

i. *Generators:* Generators submit incremental/decremental adjustment bids to the ISO. The generators are selected by the ISO to relieve transmission congestion and they are paid for their contributions.

ii. *Consumers:* Demand elasticity against spot price signals is an efficient way to alleviate congestion and social welfare. Thus, the adjustments of loads provide re-dispatch services with demand elasticity and get profit from it.

iii. *Transmission companies:* Many transmission devices, like transformers, FACTS devices and reactors/capacitors can be controlled by the ISO resources for system security. However, in a competitive market environment they need to be priced properly to encourage transmission companies to improve the power grid.

iv. *Power marketers:* Power markets can adjust their transaction according to the ISOs commands and system information for re-dispatch.

In order to efficiently manage the transmission congestion in the real-market, the participants must have freedom to engage in various mechanisms to protect their business. The best solution might always be a combination of several of the basic methods in different time scales as shown in Fig. 2.5.

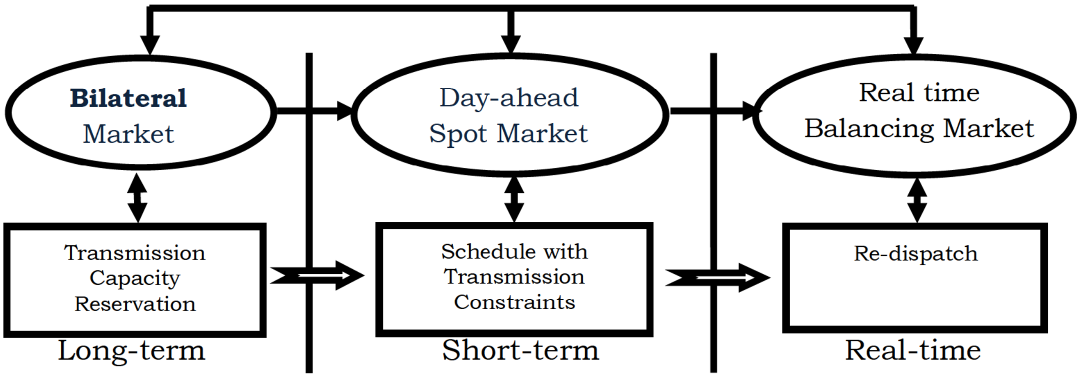


Fig. 2.5 Overall congestion management processes.

2.6. CONCLUSION

This chapter gives an overview of the concept of worldwide deregulated power market operation and Indian power market structure. The chapter also presented an introduction about social welfare maximization using optimal power flow based approach. The discussion in this chapter gives the importance of benefit maximization in power markets with multi-transaction setting using bilateral contract structure. A brief introduction of congestion management methodologies have also been discussed in this chapter.