CHAPTER 2

POWER INDUSTRY DEREGULATION, FREQUENCY-RELATED ANCILLARY SERVICES AND ITS MARKET MODELS

2.1 INTRODUCTION

The electric power industry has functioned with the vertically integrated structure for many years where most of the operations (generation, transmission and distribution) are regulated by a single large utility. Due to this vertically integrated structure of the electric industry, it is often intricate to separate the costs incurred in generation, transmission or distribution. Therefore the utilities charge their customers an average tariff rate based on the aggregated cost during a period which sometimes causes an over pricing of electricity. The other limitations with vertically integrated structure are inefficiency in production and use of power, high level of losses, infrastructure deterioration, and poor management. Thus it has become necessary to introduce deregulation in the electric power industry, and thus, establish each of the electricity generation, transmission and distribution system as an independent entity. Electric power industries throughout the world are now moving towards deregulated structure with market-based competition. The objectives of this change are creation of retail wheeling, and the separation between production and other services. The main advantages expected from the market-based system are reduction in energy prices, long-term gains in efficiency, and the influx of private capital. The structure of this
new electric supply industry is normally based on either pool or bilateral markets for primary energy transaction.

2.2 DEREGULATION SCENARIO

2.2.1 Overview of Deregulation

One of the principal characteristics of a competitive structure is the identification and separation of the various tasks which are normally carried out within the traditional organization so that these tasks can be open to competition whenever practical and profitable. This process is called unbundling. An unbundled structure contrasts with the so-called vertically integrated utility where all tasks are coordinated jointly under one umbrella with one common goal, that is, to minimize the total costs of operating the utility. One of the first steps in the restructuring process of the power industry has been the separation of the transmission and distribution activities from the electricity generation activity. The subsequent step was to introduce competition in generation activities, either through the creation of power pools, provision for direct bilateral transactions or bidding in the spot markets.

2.2.2 Motivation for Restructuring the Power Industry

Advantages of deregulation are,

(i) Electricity price may drop due to innovation and competition.

(ii) Expected to result in wider customer choice and more attention to improve service.
(iii) In countries where government wishes to sell state owned utilities deregulation may provide potential buyers and new producers (Lai 2001).

(iv) A competitive power industry will provide rewards to risk takers and encourages the use of new technologies and business approaches.

2.2.3 Various Entities

The introduction of deregulation has brought several new entities in the electricity market place (Shahidehpour and Alomoush 2001).

**Genco** (Generating Company): Genco is owner-operator of one or more generators that runs them and bids the power into the competitive marketplace. Genco sells energy at its sites in the same manner that a coal mining company might sell coal in bulk at its mine.

**Transco** (Transmission Company): Transco moves power in bulk quantities from where it is produced to where it is delivered. The Transco owns and maintains the transmission facilities, and may perform many of the management and engineering functions required to ensure that the system can continue to do its job. In most deregulated industry structures, the Transco owns and maintains the transmission lines under the monopoly franchise, but does not operate them. That is done by an Independent System Operator (ISO). The Transco is paid for the use of its lines.

**Disco** (Distribution Company): It is the monopoly franchise owner-operator of the local power delivery system, which delivers power to
individual business and homeowners. In some places, the local distribution function is combined with retail function, i.e. to buy wholesale electricity either through the spot market or through direct contracts with gencos and supply electricity to the end use customers. In many other cases, however, the disco does not sell the power. It only owns and operates the local distribution system, and obtains its revenues by ‘renting’ space on it, or by billing for delivery of electric power.

**Resco (Retail Energy Service Company):** It is the retailer of electric power. Many of these will be the retail departments of the former vertically integrated utilities. Others will be companies new to the electric industry that believe they are good at selling services. Either way, a Resco buys power from gencos and sells it directly to the consumers.

**Independent System Operator:** (ISO): The ISO is an entity entrusted with the responsibility of ensuring the reliability and security of the entire system. It is an independent authority and does not participate in the electricity market trades. It usually does not own generating resources, except for some reserve capacity in certain cases. In order to maintain the system security and reliability, the ISO procures various services such as frequency control services, supply of emergency reserves, or reactive power from other entities in the system.

**Customer:** A customer is an entity, consuming electricity. In deregulated markets, the customers have several options for buying electricity. They may choose to buy electricity from the spot market by bidding for purchase, or may buy directly from a genco or even from the local distribution company.
2.2.4 Functions of ISO

The independent system operator (ISO) is the central entity to have emerged in all deregulated markets with the responsibility of ensuring system security and reliability, fair and equitable transmission tariffs and providing for other system services. In any market structure, the ISO has the following basic functions laid out for it:

- System security: Operator must assure that the power system continues to operate in a stable, economical manner.
- Power Delivery: The operator should provide the power transportation services requested of it by buyers and sellers.
- Transmission pricing: System operator must determine and post the prices for transmission usage, offer to reserve or sell usage, track, bill and settle with users, and pass on revenues to transmission owner.
- Service quality assurance: The system operator must assure the quality of service it provides.
- Instantaneous match of load and supply, loss compensation bid matching and setting system price.

2.2.5 Ancillary Services

Ancillary services are defined as all those activities on the interconnected grid that are necessary to support the transmission of power while maintaining reliable operation and ensuring the required degree of quality and safety (Verbic and Gubina 2004).
In deregulated power systems, transmission networks are available for third party access to allow power wheeling, and spot markets for electricity have been developed in many countries. In such an environment, the ancillary services are no longer treated as an integral part of the electric supply. They are unbundled and priced separately and system operators have to purchase ancillary services from ancillary service providers.

The North American Electric Reliability Council (NERC) together with Electric Power Research Institute (EPRI) has identified 12 ancillary services (Hirst and Kirby 2002). They are:

1. **System Control**: The control are operator functions that schedule generation and transactions and control generation in real time to maintain generation/load balance.

2. **Reactive supply and voltage control from Generation**: Injection and absorption of reactive power from generators to control transmission voltages.

3. **Regulation**: Maintenance of the minute-to-minute generation/load balance to meet CPS1 and CPS2.

4. **Load following**: Maintenance of the hour-to-hour generation/load balance.

5. **Frequency Responsive spinning Reserve**: Immediate (10-second) response to contingencies and frequency deviations.

6. **Supplemental Reserve**: Response to restore generation/load balance within 10 minutes of generation or transmission contingency.
7. **Backup supply plan:** Customer plan to restore system contingency reserves within 30 minutes if the customer’s primary supply is disabled.

8. **Real power loss replacement:** Compensation for transmission system loss.

9. **Energy imbalance:** Accounting for the hourly discrepancy between scheduled and actual transactions.

10. **Dynamic Scheduling:** Real-time metering, telemetering, and computer software and hardware to electronically transfer some or all of a generator’s output or a customer’s load from one control area to another.

11. **Network Stability:** Use of fast-response equipment to maintain a secure transmission system.

12. **System Black Start:** The capability to start generation and restore all or a major portion of the power system to service without support from the outside after a total collapse.

### 2.3 FREQUENCY - RELATED ANCILLARY SERVICES

Among the twelve ancillary services, regulation and load following are the two frequency related ancillary services in the deregulated system. These two services are required to continuously balance generation and load under normal operating conditions (Kirby 2007).

#### 2.3.1 Regulation Service

Regulation is the use of on line generation that is equipped with automatic generation control (AGC) and that can change output quickly
(MW/minute) to track the moment to moment fluctuations in customer loads and to correct for the unintended fluctuations in generation. Regulation helps to maintain interconnection frequency, manage differences between actual and scheduled power flows between balancing areas and match generation to load within the control areas. Since this regulation service has to balance fast fluctuations in load, only ISO can provide the same through pool contract by monitoring area control error (ACE) which comprises frequency error and tie line error. It is the most expensive ancillary service compared to load following.

In the PJM region, New York, New England and Ontario, regulation is a 5-min service, defined as five times the ramp rate in megawatts per minute. In Texas it is a 15-min service and in Alberta and California it is a 10-min service (Kirby 2007).

2.3.2 Load Following Service

Load following is the use of on line generation to track the intra- and inter-hour changes in customer loads. It occurs over longer time intervals, that is 10 minutes or more rather than minute to minute. Load following changes are often predictable (e.g., because of the weather dependence of many loads) and have similar day to day patterns. Even when not predictable by the control area operator, the customer can inform the control center of impending changes on its electricity use.

This service can be provided either through bilateral contract or by ISO through pool contract.
2.3.3 Comparison of Regulation and Load Following Characteristics

Loads can be decomposed into three elements as shown in Figure 2.1. The first element is the average load (base load) during the scheduling period, 85 MW over the one hour shown in this case. The second element is the trend (ramp) during the hour and from hour to hour (the morning pickup in this case); here that element increases from -5 MW at 7 a.m to +9 MW at 8 a.m. The third element is the rapid fluctuations in load around the underlying trend; here the fluctuation ranges over +/- 2MW. Combining the three elements yields a load that ranges from 78 to 96 MW during this hour. The system responses to the second and third components are called load following and regulation. Table 2.1 shows the comparison of load following and regulation characteristics (Kirby and Hirst 2000).

![Figure 2.1 Components of hypothetical load](image-url)
Table 2.1 Comparison of load following and regulation characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Regulation</th>
<th>Load following</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns</td>
<td>Random and uncorrelated</td>
<td>Highly correlated</td>
</tr>
<tr>
<td>Control</td>
<td>Requires AGC</td>
<td>Can be manual</td>
</tr>
<tr>
<td>Maximum swing</td>
<td>Small</td>
<td>10-20 times regulation</td>
</tr>
<tr>
<td>Ramp rate (MW/min)</td>
<td>5-10 times load following</td>
<td>Slow</td>
</tr>
<tr>
<td>Sign changes per unit time</td>
<td>20-50 times load following</td>
<td>Few</td>
</tr>
</tbody>
</table>

2.4 MARKET MODELS FOR FREQUENCY - RELATED ANCILLARY SERVICES

Three structures are proposed in the literature (Christie et al 1996) for providing regulation and load following ancillary services: (i) charged structure, (ii) bilateral structure and (iii) charged-cum-bilateral structure.

2.4.1 Charged Structure for pool market

In the charged structure which is used in pool market, there are two main entities participating in the market, i.e. customer and supplier. The independent system operator (ISO) considers electricity bids and offers (the quantity and the price) from these two entities and dispatches the demand in an economic manner depending on the price and MW biddings. In general, the customers and suppliers do not directly interact with each other, but only indirectly through the ISO. It executes the control algorithm, measuring ACE comprising the frequency deviation and the net interchange deviation, and issues control signals to gencos who are willing to provide generation shift.
up/down for a price to meet the demand. Charged structure can provide both load following and regulation services.

Charged structure can adopt any of the following two market settlement strategies:

a) Single Auction Power Pools: In this type of market only suppliers submit their offers (the quantity and the price) and these bids are then stacked in the increasing order of prices. The highest priced bid that intersects with the system demand forecast determines the market clearing price. This arrangement is found in Australian system.

b) Double Auction Power Pools: In double auction pool market, both supply and demand offers are invited from participants. The supply side participant submit an offer (the quantity and associate price) for selling energy to the pool, while the demand side participant submits an offer (the quantity and associate price) for buying from the pool at a price. The system price is obtained by stacking the supply bids in increasing order of their prices and the demand bids in decreasing order of their prices. The system price and the amount of power cleared for trading is obtained from the crossing point of these curves. This market settlement strategy is used in New Zealand, California and NordPool (Norway, Sweden, Finland, Denmark and Iceland) markets.
2.4.2 Bilateral Structure

Bilateral market has two main participants, i.e. customers and suppliers who make the contracts. This structure provides only load following service. Figure 2.2 shows the bilateral market structure. In this market the electricity prices for providing load following service is decided by the participants, not by the independent system operator (ISO). Once the dealings are settled, the ISO needs to be informed about the trade since ISO is responsible to ensure that the services do not endanger the system security. With this type of market, there is no centralized control.

The main issue in this structure is Contract violation committed by the participants of the market either knowingly or unknowingly. The frequency control service of limited capacity provision by ISO becomes essential to take care of the generation/load deviation caused by contract violations.
2.4.3 Charged-cum-Bilateral Structure

This hybrid model, Charged-cum-Bilateral Structure combines various features of the previous two models. It is likely to be adopted in many countries and provides more freedom to the participants. The discos opted for bilateral contract send the signal to respective gencos. All other discos opted for pool structure is taken care by ISO.

2.5 FREQUENCY CONTROL PRACTICES IN VARIOUS COUNTRIES

In this section various practices concerning frequency control in different power systems and the impact of market development are discussed (Amott et al 2003).

2.5.1 Australia

In Australia the National Electricity Market Management Company (NEMMCO) is the ISO. The frequency control service is the pool market where single Auction power pool pricing structure is adopted. Frequency standards are set by a panel which tries to assess the costs and benefits of frequency standards. There are eight ancillary services related to regulation spot markets. Two services are regulating services delivered over a 5 minute period. Six services are for the management of disturbances caused by contingency events, measured by the average amounts of response delivered in 6, 60 and 300 second time periods. NEMMCO determines the amount of each service needed to comply with the frequency standards, and dispatches the amount every five minutes, based on the bids for each service.
2.5.2 Continental Europe

Union for Coordination of Transmission of Electricity (UCTE) has one of the largest interconnected power systems in the world, covering 21 countries with installed capacity of 512GW. Thirty five Transmission System Operators (TSO) perform system control. Primary regulation is mandated by the grid code of most of the participating countries of UCTE. Each country or control block keeps primary reserves of roughly 1% of its load. Secondary control through AGC is a major part of the balancing services. The system operator can order these services directly from the power plant operator who has offered them. Usually, a direct set point signal is sent to the power plant to raise or lower the generation within limits. In the UCTE system individual countries maintain their own frequency response capability and each block controller monitors the regulation offered and delivered in its market.

2.5.3 Great Britain and Ireland

In both Britain and Ireland the frequency standard is lodged with the Regulator. Any changes require the Regulator’s approval, which involves consultation with the industry. In practice, the system operator (SO) reviews the standards from time to time and proposes any changes to the Regulator. The guidelines are developed further by the SO to determine the definition of the events to be secured, depending on the system characteristics.

In England and Wales, Primary response is defined as the response provided within 10 seconds and maintained for a further 20 seconds. Secondary response is defined as the response provided within 30 seconds and maintained for 30 minutes. High frequency response is defined as the response to high frequency provided within 10 seconds and maintained
thereafter. These responses are a mandatory requirement of connection paid for on a cost recovery basis.

2.5.4 Nordic Countries

The interconnected power system in the Nordic countries comprises the power systems of Sweden, Norway, Denmark and Finland. The nominal frequency in the Nordic system is 50 Hz and it is stipulated that fluctuations during normal system operations should not exceed 0.1 Hz. At frequencies higher than 51 Hz, the thermal units are set to reduce their outputs automatically. Charged structure with double action power pool bidding structure is adopted. The generation scheduling and dispatch were decentralised to the main power producers. By agreement, the system operators in Sweden and Norway take responsibility for secondary frequency control.

Sweden operates a balance service for secondary regulation, to continuously balance the country’s electricity generation and consumption. It accept bids–quantity (power in MW) and price from generators willing to quickly (max 10 minutes) increase or decrease generation or even consumers willing to increase or decrease consumption.

2.5.5 North America

The North American grid extends over Canada, the contiguous states of the United States of America (USA), and portions of Mexico. They all use the planning and operating practices developed by the North American Electric Reliability Council (NERC). The industry in the USA is regulated by various government statutes and the Federal Electricity Regulatory Commission (FERC). Similar structures are used in Canada and Mexico. No
markets have been developed for primary or governor control. Some regulation reserve or a balance reserve markets have been developed for secondary control. The payment is for capacity made available, up and down, the energy supply being compensated at spot market rates. In some areas, there is no separate regulation market and part of the spinning reserve is used for secondary frequency control. For example, in PJM, a secondary frequency control ancillary service market operates for generators under PJM AGC control. Primary governor control is mandatory and no market has been developed.

2.5.6 Southern Africa

The Southern Africa Power Pool (SAPP) is a co-operative pool of combined peak demand of 35 GW, with three control areas (Chown and Coker 2002). (i) Eskom’s control area includes South Africa, Botswana, Namibia, Lesotho, Swaziland and Mozambique. (ii) Zimbabwe has its own control area. (iii) Zambia’s control area includes all the interconnected countries further north. In the SAPP, frequency performance is measured using NERC standards with a target standard deviation of 75 mHz. Eskom vertically integrated system is one of the control areas of SAPP. It uses 4 second data, and is assessed after each hour or frequency excursion. Participants can see their performance via the Eskom Power Pool web. Poor performance results in non-payment for the service and in some cases in penalties. The system operator has incentives for reducing AGC usage but penalties for not maintaining the agreed frequency performance (Chown and Coetzee 2000).

The South African Government has established the framework for further deregulation. In South Africa, the services used to control frequency are provided through ancillary service markets. Instantaneous reserve is the
generation capacity or demand side managed load, which is available to respond fully within 10 seconds, and sustained for at least 10 minutes. Regulating reserve is reserve that is under AGC and can respond within 10 seconds and be fully active within 10 minutes. This reserve is used for second-by-second balancing of supply and demand and also to restore instantaneous reserve within 10 minutes of the disturbance. Ten-minute reserve is used to restore regulation reserve.

2.6 INDIAN SCENARIO OF DEREGULATION

In India, the power sector was mainly under the government ownership (> 95% distribution and 98% generation) under various states and central government utilities, till 1991 (Khaparde 2004).

In mid 1990s, Orissa began a process of fundamental restructuring of the state power sector. Under the World Bank (WB) loan, the state decided to adopt, what is known as WB-Orissa model of reform. This consisted of a three pronged strategy of 1) Unbundling the integrated utility in three separate sectors of generation, transmission and distribution, 2) Privatization of generation and distribution companies and, 3) Establishment of independent regulatory commissions to regulate these utilities. Soon afterwards, several other states such as Andhra Pradesh, Haryana, Uttar Pradesh and Rajasthan also embarked on similar reforms and also availed loans from multilateral development banks such as WB and Asian Development bank, etc. Meanwhile, some moderate steps were taken towards reforms until the Electricity Bill 2003 was approved by Parliament in May 2003. The Bill now replaces the previous three acts on electricity of 1910, 1948 and 1998 with their amendments.
The Electricity Act 2003 also seeks to consolidate, update and rationalize laws related to the generation, transmission, distribution, trading and use of power. Some of the major provisions of the Electricity Act 2003 are:

- Provision of ‘Open Access’ with respect to transmission
- Introduction of a spot market for bulk electricity
- Unbundling of the SEBs on the basis of functions (Generation, Transmission and Distribution)
- Compulsory metering of all consumers in order to improve accountability.

2.7 CONCLUSION

The electricity industry is to become completely deregulated in the presence of significant market competition. One of principal characteristics of a competitive structure is the identification and separation of the various tasks which are normally carried out within the traditional organization so that these tasks can be open to competition whenever practical and profitable.

Procurement of various ancillary services is a complex task for the ISO in deregulated electricity markets. Among the various ancillary services, the two frequency-related ancillary services regulation and load following are presented in this chapter. To provide the frequency-related ancillary services three market structures such as charged structure, bilateral structure and charged-cum-bilateral structure are also discussed. Subsequently the frequency control practices in various countries and the impact of market development are discussed. Finally the Indian scenario of deregulation is discussed.