A review on some aspects of ancillary services in a competitive electricity market

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ABSTRACT

Ancillary services (AS) defined as all those activities that are necessary on the interconnected grid which related to security and reliability of a power system. There are several activities that appear under the preview of ancillary services. In vertically integrated system the liability generation, transmission and distribution was with one organization. Ancillary services were integral part of energy generation, supply and cannot dealt separately. In a restructured power system the system operator (SO) is the entity liable for the secure and reliable operation of the power system. In this way, management of all the Ancillary services considered as an explicit function of the system operator. Under a restructured framework, ancillary services separated from the real power production, and shall be mandated or remunerated in competitive market mechanism by the system operator. This paper overviews the management and pricing of ancillary services in some of the restructured electricity markets.

Key Words: Ancillary Services, Restructured Power System, Electricity Market.

1. INTRODUCTION

The function of an electric utility is not restricted to power generation, transmission and its distribution to customers. It has to ensure the required degree of quality and safety, and perform several other functions to work under credible set of contingencies. Ancillary services defined as all those activities those are necessary on the interconnected grid which related to security and reliability of a power system. Proper execution of the energy market requires secure operation of the power system. Market players carry out their transactions and activities relating to energy on the basis of forecasts. However, forecasts remain forecasts and hence include errors. These errors have a direct influence on the balance between generation and demand and therefore on the system security. The control of frequency, voltage and reactive power, black start capabilities, management of spinning reserves are fundamental elements in the system operation and security which are considered to be 'ancillary services' [10]. In vertically integrated system where responsibility for generation, transmission and distribution is centralized, ancillary services are central part of the electricity supply and are not divided. However with the restructuring of the power system, with generation and transmission becoming separate businesses, the system operator (SO) often has no direct control over individual power stations and has to procure ancillary services from ancillary service providers. In such an environment, issues pertaining to pricing mechanisms for such services are extremely important for the accurate functioning of the structure [9] . There are many operator activities and services, which can come under the view of ancillary services. The definitions of some services and distinctions between some of them are often unclear.

The rest of the paper is organized as follows. Section 2 presents classification and definitions of ancillary services , Section 3 discusses the ancillary services management in various countries, Section 4 presents the design of ancillary services market, Section 5 presents the dispatch methods of energy and ancillary services, Section 6 concludes this paper.

2. CLASSIFICATION AND DEFINITION OF ANCILLARY SERVICES

2.1. Classification

The ancillary services are placed into three groups[7].

a) Services for normal conditions: Regulation and load following are the two services required to

continuously balance generation and load under normal conditions.

b) Services for contingency conditions: Spinning reserve, non-spinning reserve, and supplemental reserve are the reserve services which provide reserves that stand ready to respond in the event of contingency.

c). Other services: Voltage control and black start are additional ancillary services are helpful to maintain power system reliability.

2.2. Definetions

A large number of activities on the interconnected system can be treated as ancillary services. The NERC (North American Electric Reliability Council) along with EPRI(Electric Power Research Institute) has identified 12 functions as ancillary services[8]. These are

2.2.1.Regulation: The use of generation or load to maintain minute-to-minute generation-load balance within the control area.

*2.2.2.Load following***:** Service refers to load-generation balance towards end of a scheduling period.

2.2.3.Energy Imbalance: The use of generation to meet the hour-to-hour and daily variations in load.

2.2.4.Operating Reserve (Spinning): The provision of unloaded generating capacity that is synchronized to the grid and can immediately respond to correct for generation-load imbalances, caused by generation and /or transmission outages and that is fully available for several minutes.

2.2.5.Operating Reserve (Supplemental): The provision of generating capacity and curtailable load to correct for generation-load imbalances, caused by generation and /or transmission outages, and that is fully available for several minutes. However, unlike spinning reserves, supplemental reserve is not required to respond immediately.

2.2.6. Backup Supply: This service consists of supply guarantee contracted by generators with other generators or with electrical systems, to ensure they are able to supply their consumers in case of scheduled or unscheduled unavailability.

2.2.7. System Control: This activity can be compared with the functions of the brain in the human body. System control is all about control area operator functions that schedule generation and transactions and control generation in real time to maintain generation load balance.

2.2.8. Dynamic Scheduling: It includes real-time metering, tele-metering along with computer software and hardware to virtually transfer some or all of generator's output or a customer's load from one control area to another.

2.2.9. Reactive Power and Voltage Control Support: The injection or absorption of reactive power from generators or capacitors to maintain system voltages within required ranges.

2.2.10.Real Power Transmission Losses: This service is necessary to compensate for the difference existing between energy supplied to the network by the generator and the energy taken from the network by the consumer.

2.2.11.Network Stability Services from Generation Sources: Maintenance and use of special equipment (e.g., PSS, dynamic braking resistances) to maintain secure transmission system.

2.212. System Black Start Capability: The ability of generating unit to proceed from a shutdown condition to an operating condition without assistance from the grid and then to energize the grid to help other units start after a blackout occurs.

3. ANCILLARY SERVICES MANAGEMENT IN VARIOUS COUNTRIES

3.1. New York ISO

In the New York control area the New York ISO (NYISO) coordinates the provision of all ancillary services and directly dispose the services that are not self-supplied. Either market-based or embedded cost-based prices are used to price these services. In Table.1 the service provider and pricing method for each service are given[6].

Table.1

Ancillary Service	Who provides the service? NYISO, or SS (Self-Supplied)	The pricing method For the Ancillary Service
Scheduling, System Control and Dispatch	NYISO	Embedded Cost Based
Voltage Support	NYISO	Embedded Cost Based
Regulation and Frequency Response	NYISO or SS	Market-based
Energy Imbalance	NYISO	Market-based
Operating Reserve	NYISO or SS	Market-based
Black Start Capability	NYISO	Embedded Cost Based

3.2 .California ISO

In the California system, the ISO procures reactive power support services on long-term contracts from reliable must-run generating units. The actual short-term requirement is determined on a day-ahead basis, after the real power market is settled and the energy demand and schedules are known. Thereafter the ISO determines the location-wise amount of reactive power required based on system power flow analysis. Daily voltage schedules are issued to contracted generators and the transmission operators within the region. The generators are mandated to provide reactive power within the power factor range of 0.90 lag to 0.95 lead. For reactive power absorption / generation beyond these limits, the generators are financially compensated for, including, a payment if they are required to reduce their real power output[6].

3.3. PJM Interconnection

Reactive power was recognized as an ancillary service by PJM and two distinct components were segregated. The first component was the reactive capability at rated capacity of a generator while the second was the reactive capability at reduced generator output levels. It has been mandated that reactive power supply and voltage control services will be provided directly by the individual transmission providers. The transmission providers in turn have defined the tariff rates for their customers, in this case, load serving entities either within the zone or outside. For the first component, *i.e.*, the reactive capability at rated capacity, the customer pays a charge proportional to the total generation owner's monthly revenue requirement and the amount of monthly use of the network. Regarding the second component, generators are paid for their opportunity costs incurred as a result of increasing their reactive power production by reducing real power output. This is paid only to those generators that are directed to operate in such a mode and the opportunity cost is equal to the locational marginal price less the generator's bid for each MW that they back down[6].

3.4. United Kingdom

In the UK system, National Grid Company (NGC) carries out the role of the ISO and hence is also responsible for making arrangements with regards to ancillary services. NGC contracts for ancillary services to enable voltage and frequency control standards to be maintained, as well as other services such as the black start capability. Generators, regional electricity companies, large consumers or even external members can supply these services. One of the key tasks of the ancillary services business is to encourage competition in the provision of ancillary services. The Grid Code details the technical operational requirements of NGC and defines two major categories of ancillary services, system ancillary services and commercial ancillary services[6].

3.4.1. System Ancillary Services

System ancillary services are classified in two categories. i)The services, which all generators are obliged to provide, a)Reactive Energy*(* Other than that supplied by means of synchronous or static voltage compensators) b)Operating Margin for frequency control*(*Capability to provide additional output from a generating unit with a short notice).

ii) Services that need not be provided at every site. NGC buys these services from sites based on specific contracts, a)Operating Margin for frequency control(Capability of a gas turbine or pumped storage unit to fast start) b) Black Start Capabilities

3.4.2.Commercial Ancillary Services

The other services are called the commercial ancillary services, which the generators are not obliged to provide and hence are subject to commercial agreements. Such services are as under

- Reactive energy: supplied by synchronous or static voltage compensators
- Operating margin: provided by pumped storage units, load reduction, stand-by generation, *etc.*

3.5. Finland

The Finnish ISO, Fingrid is responsible for maintenance of system voltages and accordingly, it supplies reactive power as per the general supply principles concerning reactive power. The voltage level of the main grid is controlled using reactors and capacitors. The voltage ratio between different voltage steps is controlled with tap changers of the transformers. Fingrid is also responsible for the maintenance of adequate reactive power reserves in the Finnish power system. This is done through the use of its own resources and also by acquiring reactive reserves from independent parties[6].

3.6.Australia

Initially, the ancillary services were traded through long term bilateral contracts between National Electricity Market Management

Company (NEMMCO) and the service suppliers. Since 2001, frequency control ancillary services are traded in competitive spot markets.

3.6.1.Voltage control

The energy code of Australia requires the power factor to be between 0.9 inductive and 0.93 capacitive. Optionally, generators can produce and absorb reactive power or operate the generation unit as a synchronous condenser. The service provision is managed through annual bilateral contracts.

3.6.2.Frequency control

In this service, it is expected that the system's frequency varies only in the range of 50 +/- 0.1 Hz. The system operator can request additional amounts of primary frequency regulation, up or down. A response period from 6 to 60 s is required and the service should be supplied during 90 s. Generators with AGC are in charge of the service provision which is managed through annual bilateral contracts. The suppliers get payments for enabling and compensation. Secondary frequency regulation is provided by generators, load shedding or fast connection generation units. This service is required in a period of 5 min and the period by which the service should be supplied is not specified. The provision of the service is managed through annual bilateral contracts. Payments are carried out for enabling and compensation[6].

4. DESIGN OF ANCILLARY SERVICES MARKET

Two important issues regard to the ancillary services are cost of providing these services and the value of these services to the power system .In the electricity industry ancillary services can be provided either by the ISO or may be purchased through contracts. Ancillary services are the same components that produce energy , charging ancillary services using a bundled rate may not be equitable to users. To reflect the actual usage of these services , a competitive market based ancillary service is an appropriate scheme regarding procurement and charging users. The operation of real time market and day-ahead market for ancillary services is one of the responsibilities of the system operator. The ISO must ensure that there are sufficient capacities among generators to participate in the balancing market[4].

In the design of ancillary market there are a number of choices that can be considered. They are

- The time frame for the market can be long term or short term
- Procurement can be sequential or simultaneous
- The market can be bilateral or competitive bidding
- Settlement rules can be i. Price based on bid type ii. Price based on usage type iii. Marginal price or pay as bid
- Recovery can be i. Energy uplift ii. Use of the system charge or other methods.

5. JOINT OPTIMIZATION OF ENERGY AND ANCILLARY SERVICES

In many of the existing power markets, both energy and ancillary services are permitted for competitive bidding. The reason is that the same resource and capacity could be used to provide multiple products, and AS market operation should be closely coordinated with the energy market. This close coordination is achieved through joint optimization of ancillary services and energy markets, which optimizes the total market cost of meeting system demand and AS requirements by satisfying network security constraints.

In the development of Ancillary service markets, different market models have attempted. The models can be categorized in to three groups: independent merit order dispatch, sequential market clearing, and joint optimization[4].

5.1. Independent merit order dispatch

Independent merit order based market clearing overlooks the capacity correlation between energy production and supply of ancillary services. Each product is cleared independently from other products based on a separate merit order. This approach is easy, but it leads to solutions that are physically infeasible.

5.2. Sequential market clearing

The sequential method recognizes that energy and reserves compete for the same generating capacity. In this method a priority order is defined for each product. Available capacity of a resource is progressively reduced as higher priority products are dispatched from that resource. While the sequential dispatch is an improvement over independent merit order dispatch, it needs further improvements for handling interdependencies among the coupled products. Explicit evaluation of costs associated with lost opportunity, production cost impacts,

value of lost load (VOLL) etc. are mechanisms that are used to provide quantitative indices for analyzing tradeoff decisions. They also help reduce the arbitrariness in the dispatch sequence.

5.3.Joint optimization

In the joint optimization approach, the objective is to optimize the total cost of providing ancillary services along with energy offers to meet estimated demands as well as Ancillary Service requirements. The allotment of limited capacity among energy and ancillary services for a resource is determined in terms of its total cost of providing all the products relative to other resources. The effective price for a resource to provide multiple products depends on its quoted prices as well as the product substitution cost. Product substitution cost arises when a resource has to reduce its use of capacity for one product so that the capacity can be used for a different product (leading to an overall optimal solution). The product substitution cost is determined internally as part of the joint optimization. This product substitution cost plus its bid price reflects the marginal value of a specific product on the market. The marginal value, which is typically the market clearing price, represents the price for an extra unit of the product that is consistent with the marginal pricing principle for the energy product. Market clearing prices for ancillary services reflecting product substitution costs create price equity among the multiple products. Price equity refers to the fact that a market participant can expect to receive equivalent amount of profits no matter which kind of service the participant is assigned to provide. Price equity is an incentive for participants to follow dispatch instructions. Without the price equity, participants would tend to provide those services that produce the most profits, which could deviate significantly from dispatch instructions. Significant deviations from dispatch instructions could seriously degrade dispatcher ' s ability to maintain grid reliability. Therefore, joint optimization of energy and AS market has been accepted in many competitive electricity markets, including New York – ISO, PJM - RTO, ,ISO - New England, Australian, and New Zealand markets.

6.CONCLUSION

Deregulation and competition is moving forward at a rapid speed in many countries. Competitive electricity markets require competitive markets for ancillary services. This paper over views the practices of some deregulated electricity markets. The definitions for ancillary services are not clear-cut and each country adapts them to specific characteristics of its own power system, there is certain number of services which appear in related forms in almost all countries which have liberalized systems. The goal of the paper is to give a brief on definitions, over view on some aspects of ancillary services in some markets, design of markets, & mechanisms for dispatch of energy and ancillary services.

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