



FREQUENCY CONTROL AS AN ANCILLARY SERVICE IN DEREGULATED POWER MARKETS

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ABSTRACT

As the penetration of energy from sustainable energy sources like wind, solar and wave are increasing gradually, the electricity market is moving towards the deregulation. Initially deregulated markets were mainly focused on the tariff structure of the power systems. After the effective participation of deregulated market in the whole market environment the technical activity like frequency control which was considered earlier as a part of integrated electricity supply, is now considered as an independent service. But in the competitive deregulated market, it is a challenging job to implement the service which is technical in nature. This paper basically identifies the technical terms of frequency control and focus on the economic features of it in the deregulated market, considering it as an ancillary service.

KEYWORDS: Deregulated power market, Transmission System Operator (TSO), Automatic Generation Control (AGC) and Different market structures.

INTRODUCTION

The successful operation of an interconnected power system requires matching the total production with the total load demand, considering the connected system losses. The operating point of a power system changes with time, and hence, systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas, which may yield unwanted effects. Frequency control is an important concern to small and medium sized power systems, having a major impact on system security, as well as on operating costs.

For secure and safe operation of a power network frequency control is a very important issue. In modern power market it is treated as an ancillary service. Recently due to the deregulation of energy market some organizations like the generation company conventionally known as

GENCOs, the transmission companies (TRANSCOs), distributed companies (DISCOs) and some independent system operators (ISOs) have emerged. They are responsible for balancing the load with the generation in real-time, so that the system can operate in a stable way in a highly competitive deregulated market. To implement the control mechanism for frequency control in the deregulated market is a very complicated task. In deregulated market the conventional energy sources like gas, thermal and hydro, have to integrate with the renewable energy sources such as wind and solar which are more dependent on nature. But considering different benefits the renewable energy sources are more encouraged to connect with the grid. But their inclusion with the grid create more complicated situation as they do not participate in frequency control services. These problems are exacerbated in areas isolated by units of renewable energy. There must be perfect coordination among the new utilities to maintain the real time power balance, regulate line flows and facilitate their bilateral contracts.

For many years, the electric power market has functioned with the vertically integrated structure, where most of the entities (GENCOs,TRANSCOs and DISCOs) are regulated by a single large utility. Because of this vertically integrated market structure, it is often difficult to separate the costs of production, transmission or distribution. As a result, the utilities charge their customers based on the supplementary average cost tariff rate for a period, sometimes causing an over electricity pricing. The other limitations with vertically integrated structure are inefficient production and use of energy, high level of losses, deteriorating infrastructure and poor management. So it has become necessary to introduce deregulation in the electric power industry, and therefore adjusted each system generation, transmission and distribution as an independent unit. So now the power market around the world is moving toward deregulated structure with market competition. The intention of this change creates retail wheel and the division of production and other services. The main benefit expected from market-based system is the reduction of energy prices, the long-term gains in efficiency, and private capital inflows. The structure of this new electric supply industry is normally based on either pool or bilateral markets for primary energy transaction [a].

APPRAISAL OF DEREGULATION

One of the major characteristics of a competitive structure is the detection and division 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.

ANCILLARY SERVICES IN MODERN POWER MARKET

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 [a].

In deregulated power markets, 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 [a].

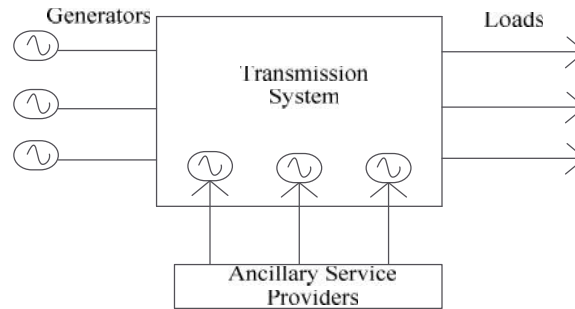


Figure-1: Ancillary service providers in modern power market.

Ancillary services can be defined as a set of actions carried out by generators, consumers and network service providers and coordinated by the system operator that have the following objectives:

- 1) Execute the outcomes of commercial transactions, to the extent that these lie within acceptable operating boundaries. That is, ensure that electrical energy production and consumption by participants match the quantities specified by the outcomes of spot markets.
- 2) Maintain availability and quality of supply at levels sufficient to validate the assumption of commodity like behavior in the main commercial markets. This can be achieved by keeping the physical behavior of the electricity industry within acceptable operating boundaries defined by planning studies in conjunction with operator experience. In a competitive power market, there are energy market and different ancillary service markets.

FREQUENCY CONTROL FRAMEWORK

In brief frequency deviation in a system is due to the power imbalances. The active power production must be regulated accordingly, as the power consumption varies. The overall frequency control frame work has been represented in **Figure-2**. Frequency regulation acts in three successive steps. Primary frequency control adjusts the active power generation automatically based on frequency deviation. The primary frequency deviation can be measured by comparing nominal frequency and common frequency of the interconnected network as shown in **Figure-3**. Its response time is usually less than 30 seconds [d]. In order to share the regulation between different generators a permanent droop, which results is a frequency deviation is used [d]. The aim of secondary frequency control is to restore primary frequency

control capacity, return back the frequency to its desired value and decrease unscheduled power flows between neighboring control areas. It is usually automatic and centrally controlled in so-called *AGC* (Automated Generation Control) scheme [d], which is shown in **Figure-4**. It is response time up to 15 minutes.

Tertiary control is usually manual, e.g. through telephone calls or faxes from the control center to the service provider. Its goal is to re-dispatch the generation in order to free the regulating bands of the generating units that took part in the secondary regulation [d]. The frame work for tertiary control is shown in **Figure-5**.

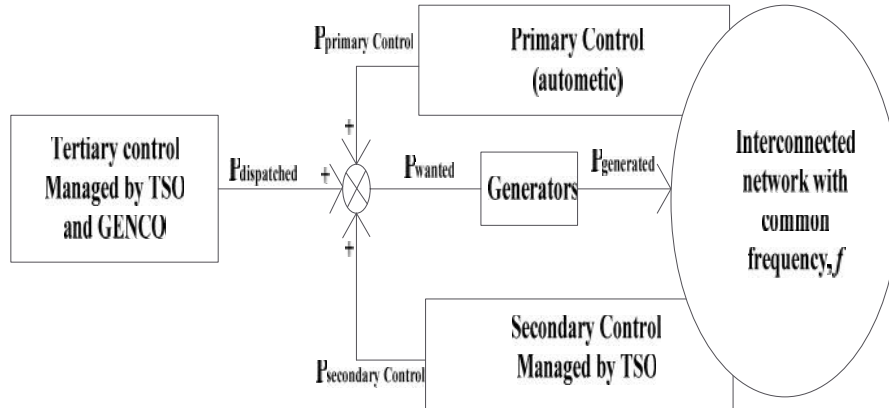


Figure-2: Frequency control frame work

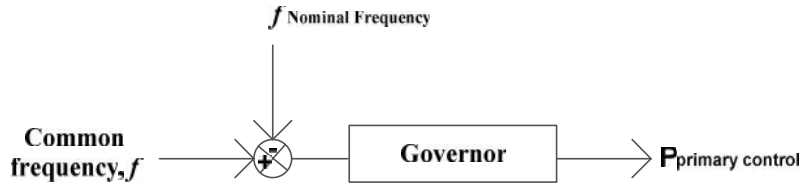


Figure-3: Primary frequency control.

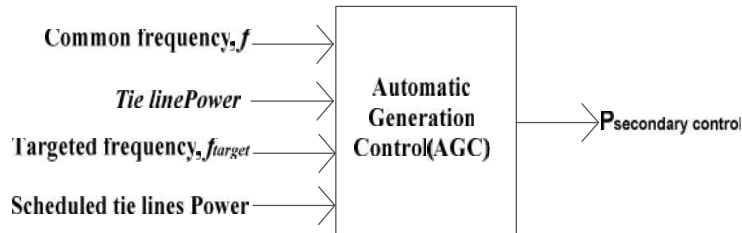


Figure-4: Secondary frequency control.

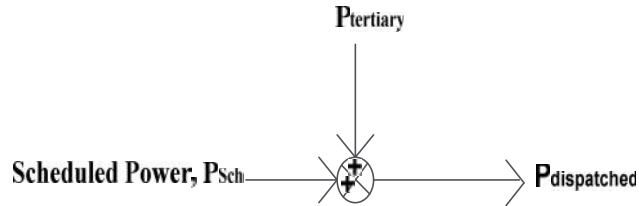


Figure-5: Tertiary frequency control.

The frequency control frame work can be summarized in the **Table-1** from [h].

	<i>Primary Control</i>	<i>Secondary control</i>	<i>Tertiary Control</i>
<i>Why is this control used?</i>	It stabilizes the frequency in the case of any imbalance	To bring back the frequency and the interchange program to their target	To restore the secondary control reverse, to evaluate congestion and to bring back the frequency and interchange program to their target, if the secondary control is not enough
<i>How to achieve this control?</i>	Automatically		Manually
<i>Where is this control performed?</i>	Locally	Centrally(ISO)	
<i>Sender of the control signal to the source of reserve.</i>	Local sensor	ISO	GENCOs, Consumer or other TSOs (after receiving instruction from the ISO)
<i>Time to achieve this control</i>	Immediately	Immediately(sec onds)	Depends on the system
<i>Sources of reserves can be used.</i>		Depends on the system	

Table-1: Frequency control frame work summery.

PROVIDERS OF FREQUENCY CONTROL SERVICE

In the deregulated market the primary frequency control automatically provided by the generation companies. But for secondary and tertiary control the generation company with higher capacity like the thermal power plant with the full output, pump storage station and even the larger consumer can participate in the control action. Large consumers can contribute by interrupting some their loads.

FREQUENCY CONTROL AS AN ANCILLARY SERVICE

In the deregulated environment the frequency control is treated as separate ancillary service. The necessary condition for the successful operation of the ancillary service market is a significant number of potential participants. It is difficult to fulfill this condition so there is a great risk that some market players may take advantage of their market power. This would certainly lead to unwanted high prices of ancillary services. These types of incidence always happen in the small power systems where the deregulation in ancillary service is not properly established. In such

cases much more reasonable option is to procure required ancillary services through long-term contracts [d]. Because of all these facts it is understandable enough that deregulated markets for ancillary services are not spread worldwide. They exist to some extent in the Nordic countries, England and Wales, Spain and in California to name just a few examples [d].

ROLE OF TSOS IN FREQUENCY CONTROL

As with any commodity, establishing a market for ancillary services is a way of resolving the disagreement between buyers and sellers to their mutual benefit. To manage frequency control as an ancillary service the TSOs have to play the central roles. They would like to obtain the resources at minimum cost to maintain the security of the system. At the same time the service providers seek to maximize the profit from the sale of ancillary services. **Table-2** represents some of the world renowned TSOs and regulators.

From the procurement methods of frequency control, it can be seen quite clearly that the transmission system operator mainly (TSO), act basically in the secondary and tertiary frequency control. They can acquire this service through four procurement methods: compulsory provision, bilateral contracts, tendering, and spot market.

System	Abbreviation	Regulator	TSO
Australia	AU	AER	NEMMCO
France	FR	CRE	RTE
Germany	DE	BNA	EnBW, E.ON, RWE and VET
Great Britain	GB	Ofgem	NGET
New Zealand	NZ	Electricity Commission	Transpower
PJM	PJM	FERC	PJM ISO
Spain	ES	CNSE	REE
Sweden	SE	Stem	SvK

Table-2: World renowned TSO's and their regulators.

	Compulsory provision	Bilateral contract	Tendering process	Spot market
Primary frequency control	ES, PJM	AU, FR, NZ	SE, DE, GB, NZ	AU, NZ

Secondary frequency control	-	FR	NZ, DE	AU, ES, PJM
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Table-3: Procurement methods for frequency control service.

Compulsory provision means that a certain class of network users (typically large generators) is required as part of their connecting conditions to provide upon request from the TSO up to a certain amount of a given ancillary service [e]. Compulsory provision is “fair” because all the users belonging to a certain class must supply the similar amount of services. However, because of the fairness and transparency, the requirements for compulsory condition are often spoken in a manner that does not catch all the complexity of the issue. But it has two main consequences. First, the volume of services provided may exceed what is needed, imposing unnecessary costs on the providers. Second, compulsory provision does not necessarily minimize costs because potentially low cost providers are treated on the same basis as more expensive ones [e].

When a TSO purchase frequency control service using bilateral contracts, it negotiates with each provider the quantity, quality, and price of the service to be provided. Such negotiations remove the two problems associated with compulsory provision because the TSO can buy only the amount it needs and can deal only with the cheaper providers [e]. But the bilateral contract has some problems. First, it contains lacks of transparency. Second, it can be long, complex, and costly. Third, because of the high transaction cost of bilateral contracts, price and volume are often fixed for a long time [e].

The tendering third and spot market enhance transparency and foster competition. On the other hand, they have high data management costs and may help the exercise of market power by some participants.

Table-3 summarizes the procurement methods chosen for the frequency control service. Primary frequency control wide choice of procurement methods exists. Secondary frequency control is never compulsory and only France uses bilateral contracts. Indeed, Sweden and Great Britain do not use this service, while other countries rely on spot market and tendering methods.

REMUNARATION METHODS FOR FREQUENCY CONTROL

The remunerated methods for frequency control can be different. They can be paid according to one of three types of price: a regulated price (RP), a pay as bid price (PBP), or a common clearing price (CCP).

A regulated price is set by the regulator or the TSO and is usually the same for all providers. This form of remuneration is particularly justified when market power is an issue.

In a pay as bid system, the supplier receives the price of its accepted offer. This type of remuneration method is preferable when the quality services offered is highly differentiated and those offers are thus not easily comparable. But, a pay as bid price does not encourage providers to bid their marginal cost, except when market concentration is low.

In a common clearing price system, all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer [e]. This form of pricing gives real inspiration to the suppliers to offer their marginal cost. While the offers have to be comparable, it is not adapted to differentiated products.

From the survey of [e] **Table: 4** can be constructed. It gives the idea about the different remuneration method used in different TSO's.

Types of frequency control	None	Regulated price	Pay as bid price	Common clearing price
Primary frequency control	PJM, ES	NZ	AU, FR, GB, DE, NZ, SE	AU
Secondary frequency control	-	-	PJM, GB, AU, FR, DE, NZ, SE, ES	AU, ES, PJM

Table-4: Remuneration methods for frequency control.

From the **Table-4** it is clearly seen that in PJM and Spain are the only systems where primary frequency control is not remunerated. When this service is remunerated, a pay as bid policy is preferred because it is a differentiated product [g]. Secondary frequency control services are remunerated in all the systems that use it. But again the choice goes towards a pay as bid price. Only AU, PJM and ES use the common clearing price.

ECONOMIC FEATURES PF FREQUENCY CONTROL

This subsection discusses some important economic features of markets for frequency control services.

- 1) Duration of the Contracts: The contract of TSO with the service providers of frequency control basically two types: long term and short term contract. Long term contracts are mainly done for several years, so there is no more competition until it comes up for renewal. This can be either a disadvantage or an advantage for the TSO if the contract is, respectively, worse or better than the other offers on the market. Short-term contracts (e.g., five minutes) increase competition but also risks.
- 2) Frequency of Review of Needs: By reviewing on a frequent basis the amount of ancillary services that it needs, a TSO can ensure that it only purchases what it really needs to maintain security. This parameter should be considered separately from the duration of the contracts because the available resources can vary during the day, even if the needs are constant [e].

- 3) Price Cap: It can be applied to mitigate the effect of market power. A purchase cap is the maximum offer price that the TSO can purchase, whereas an offer cap is the maximum offer price that a supplier can propose. However, since ancillary services markets are linked to other electricity markets, the consequences of imposing price caps should be considered carefully [b].
- 4) Market Concentration: It is usually measured using indicators such as the Herfindahl–Hirschman Index (HHI) or the Residual Supply Index (RSI) [c], but these indicators have only an indirect link with the potential for abuse of market power. For primary and secondary frequency controls are generally less concentrated because participants located anywhere can provide this service as long as transmission capacities are sufficient. However, primary frequency control has to be uniformly spread around the network and technical requirements are more demanding for primary frequency control than for secondary frequency control [g], so more units are able to participate in this last market.

CONCLUSION

This paper has analyzed the important economic features of Frequency control as an ancillary service in the perspective of deregulated market. No consensus has yet been reached on the details of the market for any ancillary service. However, some common features have been identified. Primary frequency control is a differentiated product, so pay as bid policies are preferred in most of the cases. For the case of secondary frequency control, it is always remunerated and is regularly sold using a spot market. Furthermore, this service is always at least partly compulsory. Lastly, frequency control ancillary services are commonly remunerated with a capacity and a utilization payment. Payments for opportunity cost or the frequency of calls are hardly used. The costs of ancillary services vary widely between countries (from 0.5 to 5% of the cost of energy), depending mainly on the technology used to provide the ancillary service and the policy of the system operator.

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