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Power System Restructuring

Chapter 5
Ancillary Service Management

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Introduction

- **The power system infrastructure and the physical laws that govern its utilization continue to be the same, be it vertically integrated utility or the restructured industry.**
- **The activities of the system operator pertaining to operation and control of the system existed during vertically integrated era and continue to exist in the restructured era.**
- **These activities basically stem from the responsibility of the system operator to keep the system in synchronism and operate it reliably.**
- **In the restructured environment, these activities are typically known as *ancillary services*.**

Introduction

- Provision of ancillary services under the deregulated environment is not so easy.
- The main reason behind it is the entities providing ancillary services may not be under direct control of the system operator.

Case-1:

- The generators in the competitive market are scheduled as per the bids provided by them to the market.
- The system should have provision for additional generation during contingencies like generator outages.
- Total capacity of some generating units can be partly dispatched for energy and partly kept ready for reserve.
- For a particular private generating unit, the system operator is likely to schedule most of its capacity as a reserve.

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Introduction

Case-1:

- The generator, however, may not agree to this unless and until some compensation is provided to it for maintaining its capacity as a reserve.
- Thus, the development of compensation mechanism for this generator poses a challenging problem in the restructured environment.

Case-2:

- Imagine another situation where, a particular generator is operating on the boundary of its capability curve.
- An action demanded by the ISO to increase the reactive power injection for this unit needs decrease in real power injection.
- This action, though essential from the system security perspective, is against the market decision.

Introduction
Case-2:

- **But, the generator may not agree to do so without proper compensation.**
- **Ancillary services are the services which are required to be purchased by the system operator on commercial terms.**
- **The word ancillary stems from the fact that they support the main activity of the market, i.e., trading of electrical energy or power.**
- **Ancillary services are defined as all those activities that are necessary to support the transmission of power while maintaining reliable operation with quality and safety.**
- **The ancillary services may include scheduling and dispatch, frequency regulation, voltage control, generation reserves, etc.**

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Types of Ancillary Services

- **Electric Power Research Institute (EPRI) has identified 12 functions as ancillary services.**

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

2. Load Following: **This service refers to load-generation balance towards end of a scheduling period.**

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

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.**

Types of Ancillary Services

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.

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.

7. System Control: 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.

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Types of Ancillary Services

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.

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.

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.

Types of Ancillary Services

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

12. 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.

- **There is no global definition of a particular ancillary service that is applicable in all systems.**
- **There can be many other possible definitions or combinations.**

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Classification of Ancillary Services

- **There can be various ways of classifying the ancillary services.**
- **One common approach would be to identify when and how frequently these services are required by the system operator.**
- **Three groups can be formed:**

1) **Services required for routine operation**
2) **Services required to prevent an outage from becoming a catastrophe**
3) **Services needed to restore a system after blackout**

Classification of Ancillary Services

1) **Services required for routine operation:**

- **These are the services which the system operator requires quite frequently.**
- **Some of these may be required to provide corrective action on minute-to-minute basis.**
- **Following services can be grouped under this category:**
  - a) System control
  - b) Reactive power support
  - c) Regulation
  - d) Load following
  - e) Energy imbalance
  - f) Real power loss displacement

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Classification of Ancillary Services

2) **Services required to prevent an outage from becoming a catastrophe:**

- **These services prevent the system from going out of step even if a major event occurs.**
- **These do not come into picture on daily basis.**
- **Their effectiveness is sensed only under contingent situation.**
- **Following services fall under this category:**
  - a) Spinning reserve
  - b) Supplemental reserve
  - c) Network stability services

Classification of Ancillary Services

3) Services needed to restore a system after blackout:

- **Re-energizing the system after complete blackout requires support from certain generating stations.**
- **These units can pickup generation even in the absence of external electricity support.**
- **Such units provide the system black start capability.**
- **These services are very rarely used.**
- **They are either related to:**
  a) **generation-load balancing issues or**
  b) **the network security related issues**

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Sources of Reactive Power

- **Reactive power support can be provided by active sources like generators and synchronous condensers, as well as by locally installed passive elements like capacitors or inductors.**
- **Power electronics based family of devices called Flexible AC Transmission System (FACTS) can also act as reactive power support devices.**

Generators

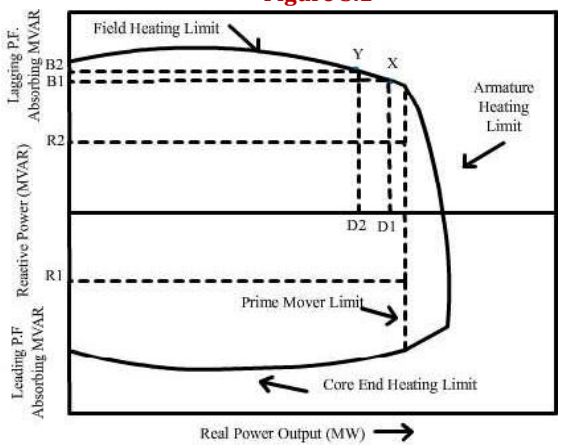
- **The synchronous generators are very fast reactive support devices.**
- **The ability of a generator to provide reactive support depends on its real-power production.**
- **Figure 5.1 shows the limits on real and reactive production for a typical generator.**

Sources of Reactive Power

Generators

- This is also called as a capability curve of a generator.
- The output of generators are limited by their current-carrying capability.

Figure 5.1



- Near rated voltage, this capability becomes an MVA limit for the armature of the generator rather than a MW limitation.
- This is shown as the armature heating limit in the figure.

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Sources of Reactive Power

Generators

- Production of reactive power involves increasing the magnetic field to raise the generator's terminal voltage.
- Increasing the magnetic field requires increasing the current in the rotating field winding.
- This too is current limited, resulting in the field-heating limit shown in the figure.
- A synchronous generator is mandated to absorb or produce reactive power in a band bounded by limits R_1 and R_2, shown by dotted lines in Figure 5.1.
- However, outside this band, it is entitled for opportunity costs if real power output is required to be reduced in order to produce more reactive power.

Sources of Reactive Power

Synchronous Condensers (SC)

- Synchronous machines that are designed exclusively to provide reactive support are called synchronous condensers.
- SCs have all of the response speed and controllability advantages of generators without the need to construct the rest of the power plant.
- As compared to the static alternatives of reactive power support, due to presence of moving parts and system auxiliaries, they require more maintenance.
- They also consume real power equal to about 3% of the machine's reactive-power rating.

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Sources of Reactive Power

Capacitors and Inductors

- Capacitors and inductors are passive devices that generate or absorb reactive power.
- They accomplish this without significant real-power losses or operating costs.
- The output of capacitors and inductors is proportional to the square of the voltage.
- The capacitor banks are often configured with several steps to provide a limited amount of variable control.
- Inductors are designed to absorb a specific amount of reactive power at a specific voltage.
- They can be switched on or off but offer no variable control.

Sources of Reactive Power

Static VAR Compensators (SVCs)

- An **SVC** combines conventional capacitors and inductors with fast switching capability so as to provide a continuous range of control.
- The range can be designed to span from absorbing to generating reactive power.
- Consequently, the controls can be designed to provide very fast and effective reactive support and voltage control.
- Because SVCs use capacitors, they suffer from the degradation in reactive capability as voltage drops.

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Sources of Reactive Power
Static Synchronous Compensators (STATCOMs)

- The **STATCOM** is a solid-state shunt device that generates or absorbs reactive power and belongs to **FACTS** devices.
- The **STATCOM** shows similar performance as that of **SVC**, when compared on the basis of response speed, control capabilities and the use of power electronics.
- The basic difference is that the STATCOM uses power electronics to synthesize the reactive power output, without employing capacitors and inductors.
- The STATCOM ensures very fast and efficient voltage control by virtue of its solid state nature.
- **STATCOMs** are current limited - so their **Mvar** capability responds linearly to voltage as opposed to the voltage-squared relationship of **SVCs** and **capacitors**.

Comparison between Various Reactive Power Sources

➢ The comparison can be based on three parameters: voltage support ability, costs and means of procurement.

Reactive Power Source	Speed of response	Ability to support voltage	Costs	
			Operating	Opportunity
Synchronous Generator	Fast	Excellent	High	Yes
Synchronous Condenser	Fast	Excellent	High	No
Capacitor	Slow, Stepped	Poor	None	No
SVC	Fast	Poor	Moderate	No
STATCOM	Fast	Fair	Moderate	No

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Black Start Capability Service

➢ A blackout is a rare contingency, but it nevertheless does occur.

➢ In order to reduce the economical and social consequences, it is important to restore power as fast as possible.

➢ The system operator is then restore the system to normal operating state as soon as possible.

➢ However, restoration of the system after a major blackout needs a methodic sequential approach.

➢ Restarting of large thermal power plants requires major chunk of electric power for its auxiliaries.

Black Start Capability Service

- The electric power resources like hydro plants, diesel generators, etc., can be started without help from the grid.
- During the restoration process, the energization of long transmission lines and the capability of generators to support reactive power creates major problem.
- In deregulated environment, the restoration may involve private generators and multiple transmission companies.
- The overall coordination of network facilities owned by different entities and allocation of costs of various support entities is hard to determine.
- The system operator can make long term contracts so as to procure black start capability.

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Provisions of ancillary services

- The system operator lays down the rules to be followed by the participants.
- The rules for the connection to the grid can be:
  - The generator should be equipped with droop characteristics of 5%. This helps in frequency regulation.
  - The generator should be able to operate in a power factor range of 0.85 lead to 0.9 lag. It should be equipped with Automatic Voltage Regulator (AVR).
- These types of compulsions act like the rules existing in the vertically integrated utility.
- This will ensure that enough resources will be available towards system security.

Provisions of ancillary services

➢ Some of the problems associated with this approach are as follows:

- ❖ There is a chance that more than sufficient sources are likely to be developed, which is not desired.
- ❖ The participants may think that they are denied the profits of the market just because they are forced to supply services at an additional cost.
- ❖ The approach does not leave room for technological or commercial innovation.
- ❖ Some units may be unable to provide some of the services.

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Markets for Ancillary Services

➢ Due to some demerits and difficulty of implementation of compulsory services necessitates introduction of competition in at least some of the ancillary services.

➢ The preferred form of mechanism depends on the type of the ancillary service.

➢ Services like black start capability can be procured on long term basis.

➢ These are the services in which the amount of service provided does not change much with the time.

➢ Also, this amount does not depend on the activity of the spot market.

Markets for Ancillary Services

- The system operator may run a separate market for regulation asking generators to submit their up and down regulation bid.
- The reserve capabilities can be a mix of two approaches.
- The system operator may make a long term contract for some part of the reserve requirement.
- It can obtain remaining reserve requirement through short term market mechanism.

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Co-optimization of Energy and Reserve Services

- In all the power markets of the early days, energy and reserve were traded in different markets.
- The market for reserve would clear first and then the energy market would be cleared.
- The resources which were not cleared in one market would be offered in the other market.
- Bids that were successful in one market would not be offered in the next market.
- The natural choice of allocating various products is to go for a joint optimization of all products.

Co-optimization of Energy and Reserve Services

- **Energy and reserve should be offered in joint markets and these markets should be cleared simultaneously to minimize the overall cost of reserve and energy.**
- **If the energy and reserve are obtained through separate markets instead of joint optimization, following situation may arise:**
  - **Partially loaded generators cannot sell as much energy as they might otherwise do.**
  - **Out of merit order dispatch is done to meet the load.**
- **The joint-optimization (co-optimization) will take dispatch decision taking into consideration the availability of resources and the overall cost.**

Reference: Restructured Power System by A. R. Abhyankar, S. A. Khaparde, ww.nptel.iitm.ac.in/courses/108101005/

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