





What are Ancillary Services ?

Definition

- Ancillary services are supplementary contributions to system operation made by market participants and bought by the system operator in order to have;
- proper (secure and reliable) system operation,
- high quality, cheap and efficient power service





Application

Ancillary services are;

- <u>generally</u>, the kind of services not regularly required,
- needed by the system operator when the system enters and transits through an abnormal (emergency^(*) or restorative) operating state,

(*) A state, where the system is allowed to remain only within a certain period of time, such as few ten milliseconds to few minutes

While carrying out ancillary services, optimal system operation concern is generally ignored(**)

(**) Except Load Frequency Control





Commitment of Ancillary Services

Ancillary services are determined and committed by a central authority operated by the system Operator Service which;

- coordinates all the ancillary service markets,
- provides a regulated demand for ancillary services

This monopoly can either be in the form of;

nonprofit entity (ISO),

or

for-profit entity (Transco)

Transco is a fully regulated company, while ISO a slightly regulated company





Ancillary Services

Main Ancillary Services

- Frequency control; supply-demand balancing,
- Economic dispatch,
- Transmission system security,
- Voltage stability,
- System restoration; black start,
- Trading enforcement





Application

Ancillary services are; Karakaya HPP, 1800 MW programmed, dispatched, • followed, • logged and recorded, • changed, when necessary, • terminated, • accounted, billed and collected • by the Balancing and Settlement Center (BSC) operator.



Daily Loading Curves

Daily Loading Curves

A basic characteristics of electrical loads is that the demand is not constant, but a function of time. In other words the demand varies with respect to hours, days, weeks and season.

As seen from the figure, the peak level of demand in the winter season is about 4000 MW, while the off-peak level is 2610 MW, which is 0.65 of the peak level





Daily Loading Curves

Daily Loading Curves

- This situation creates serious difficulties in system operation, as electricity cannot be stored, hence the total supply must always be matching the total demand and losses in in the system
- The system operator therefore, spends a considarable amount of care and effort to follow the balance between the total supply and demand





Daily Loading Curves





Supply-Demand Balance

Ancillary Services

A Basic feature of electrical systems is that electricity cannot be stored

This means that;

- a) electricity is consumed immediately while it is being generated,
- b) consumed electricity must always be equal to generated electricity

The second condition is called "Supply-Demand Balance"





Supply-Demand Balance

Ancillary Services

- **Supply-Demand Balance** must always be maintained;
- in real-time,
- under all system operating conditions





Supply-Demand Balance

Ancillary Services

Frequency Control: Supply-demand balance



Supply-Demand Balance

Total Generation = Total Load + Losses $\sum P_{gi} = \sum P_{lk} + P_{losses}$



Supply-Demand Balance





Statistical Generation Patterns of Wind Turbines

Ancillary Services

Frequency Control: Supply-demand balancing





Although the unserviced and reserviced periods and the power transfer within these periods are exactly equal, the supplier is assumed to be; (a) Buying power from the pool within the unserviced period, (b) Selling power to the pool within the reserviced period



Plant Outages Resulting from Line Outages

Main Sources of Line Outages

- Physical connection of an external object, such as, tree, helicopter, human being, etc.,
- Lightning stroke,
- Incorrect switching,
- Severe weather conditions, such as wind, storm, ice and snow loading, etc.























Plant Outages Resulting from Line Outages





Plant Outages Resulting from Line Outages









Ancillary Services Purchased from Generation Companies

Ancillary Services

Frequency Control: Supply-demand balancing



Supply-demand balance is maintained by following the deviations in system frequency. Supply-demand may fall out of balance for the following three reasons;

- Loads vary in a stochastic, but in a predictable pattern throughout the day, that must be closely followed by the generators,
- b) Some generators such as wind turbines, may themselves have stochastic generation patterns,
- c) There may be generator outages and/or line outages leading to generator outages



Ancillary Services Purchased from Generation Companies

Ancillary Services Fre

Frequency Control: Supply-demand unbalance





Ancillary Services Purchased from Generation Companies

Ancillary Services



Supply-demand balancing is realized in three different stages with respect to duration of time allowed;

Frequency Control: Techniques for supply-demand balancing

- a) Immediate balancing or regulation, realized by the Automatic Generation Control (AGC) system,
- b) Daily balancing with respect to daily loading conditions, realized by generator scheduling,
- c) Balancing of the disturbances arised from unexpected generator and/or transmission outages, realized by the commitment of operating reserves, i.e. hot or cold reserves



Ancillary Services Purchased from Generation Companies

Ancillary Services Frequency Control: Supply-demand balancing

Immediate balancing or regulation-Automatic Generation Control (AGC)



A mechanical system installed in each generating unit, called "speed governor" is used to follow the deviation in system frequency.

In case the frequency is;

- low, speed governor lets more power through turbine, in order to accelerate the generator shaft,
- high, speed governor reduces power flowing through turbine, in order to decelerate the generator shaft,







Ancillary Services Purchased from Generation Companies





Ancillary Services Purchased from Generation Companies

Ancillary Services Frequency Control: Supply-demand balancing

Automatic Generation Control (AGC): Speed Governor-Droop Characteristic



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Ancillary Services Purchased from Generation Companies





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Transmission system security

Transmission system security may be improved by adjusting the active and/or reactive power generation profile of the overall system.



Ancillary Services Purchased from Generation Companies

Ancillary ServicesTransmission system security:
Support for operating in Normal Operating Condition





Ancillary Services Purchased from Generation Companies

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Transmission system security: Emergency Operating Condition: Tie line open





Ancillary Services Purchased from Generation Companies

Ancillary Services

Transmission system security: Normal Operating Condition: Tie line open





Ancillary Services Purchased from Generation Companies





Ancillary Services Purchased from Generation Companies





Ancillary Services Purchased from Generation Companies

Ancillary Services

Trading enforcement

Three conditions for trading enforcement:

- All traders must be registered by the trade enforcement authority, i.e. The Regulatory Authority,
- All traders must have their connection to grid metered by proper authority, i.e. TEIAS, if connected to transmission grid, TEDAS, if connected to distribution grid,
- The trading authority, TEIAS-BSC must have the power to charge all traders for resolving the trading mismatches (residuals).



Ancillary Services Purchased from Generation Companies

Ancillary Services	Trading enforcement: Application	
	Electricity Sale Agreements (ESA) concerning power trades among all market participants are submitted to BSC for approval and recording	
	 BSE examines the agreements in terms of ; amount, feasibility, system security, (congestion possibility), system stability, load frequency control, resulting increase in system losses 	



Ancillary Services Purchased from Generation Companies

Ancillary Services



Trading enforcement: Settlement

BSC issues regular statistical reports concerning ancillary services, such as power transactions, accounts, bills and mismatches among traders.

BSC imposes penalties, such as expensive prices, to those traders who exhibits discrepancy between ESA and power flow measured in real-time



Ancillary Services Purchased from Generation Companies





Ancillary Services	Frequency Control: Load shedding
Methods of maintaining supply- demand balance;	Shed load
 Load-frequency Control (Normal method), Load shedding (Black-out), Voltage reduction (Brown-out) 	BSC System operator orders the distribution system operator to shed a certain amount of load in order to maintain Supply-demand balancing
	Transmission System Distribution System



Ancillary Services	Load shedding
BSC System operator orders the distribution system operator to shed a certain amount of load in order to maintain Supply-demand balancing	Shed load
Note that; load shedding causes a certain amount of revenue loss in the company which must be compensated by the payment through ancillary service	operator to shed a certain amount of load in order to maintain Supply-demand balancing



Ancillary Services	Load shedding	
Initial Condition: Total Generation < Total Load + Losses $\sum P_{gi} < \sum P_{lk(old)} + P_{losses}$ Load Shedding: Prove = Prove Prove	Shed load	
Final Condition: Total Generation = Total Load + Losses $\sum P_{gi} = \sum P_{lk(new)} + P_{losses}$	Transmission System	







Ancillary Services Purchased from Distribution Companies



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Ancillary Services Purchased from Distribution Companies



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Ancillary Services Purchased from Distribution Companies



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Ancillary Services	Voltage stability
Power wheeling; Open ring operation	
These charges are paid by;	Load
Distribution Company – B to Distribution Company – A through	Supplier Transmission System
BSC accounting and billing	
mechanism	System - B



Reactive Power Market





Reactive Power Market

Reactive Power Supply

Reactive power purchased by the system operator can not be easily shared among individual customers, because its contribution to each customer, although not impossible, is rather difficult to measure.

A rather sophisticated and expensive set of measuring equipment and market structure are needed of this task in addition to that price of reactive power is low

Reactive power market is not a competitive, but a regulated market, i.e. price is determined mostly by the TSO operator and regulator

OVER VOLTAGE +C ERROR NORMAL AUTO -C == MANUEL INDUCTIVE COS (D CAPACITIVE STEP TIME PROGRAM COS () MANUEL C/k Reactive Power Control Relay RG-S 4 RESET SET DOWN

Ancillary Service: Voltage Stability



Reactive Power Market

Reactive Power Supply

Customers lack sufficient incentive to replace the reactive power that they consume

Excessive reactive power usage on the other hand, causes severe voltage drops in the system

Hence, at least, there is a need for regulation in order;

- to set prices for reactive power,
- to enforce customers to meet their own reactive power requirements, rather than supplying through the system operator

Ancillary Service: Voltage Stability





Ancillary Services Purchased from Market Participants





Ancillary Services Purchased from Market Participants



Total Generation = Total Load + Losses $\sum P_{gi} = \sum P_{lk} + P_{losses}$

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Ancillary Services Purchased from Market Participants

Ancillary Services Trading enforcement: Accounting mechanism



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Ancillary Services Purchased from Market Participants

Ancillary Services

Trading enforcement: Accounting mechanism





Accounting for Ancillary Services

Ancillary Services



Trading enforcement: Real-time measurements

All commercial and technical information concerning ancillary services, unit prices, total costs, expenses, durations, benefiting and offering participants are;

- informed,
- measured,
- recorded and logged,
- followed, monitored and analyzed,
- transmitted,
- reported,
- archieved and stored,
- accounted for,
- billed

to / by BSC in real time



Payment for Ancillary Services

Ancillary services are;

- Purchased by system operator,
 Offered by market participants
- Offered by market participants,
- Charged to and paid by the benefiting market participants,
- Paid through the accounting mechanism of the Balancing and Settlement Center (BSC)
- Ancillary services are deregulated, i.e. they are supplied (offered) by market participants competitively.
- Demand for these services on the other hand, are regulated (determined) by the system operator



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Ancillary Services

Payment for Ancillary Services

Ancillary Services

- are essential or even vital,
- casuse revenue loss on market participants, who have been influenced by or who have carried out the service,
- cannot be offered and left freely, otherwise everyone would prefer to let the others to perform them

Hence the regulator must;

- Decide on the types of ancillary services to be purchased,
- Determine the prices to be paid for these services,
- Grant authorithy to TSO for assignment of these duties to market participants,
- Make market participants to pay for them





Ancillary Services

Competition and Regulation in Ancillar Services

Duality of Ancillary and Transmission Services

Ancillary services are supplied (offered) by market participants competitively, while the demand for these services are determined (regulated) by the system operator

Service	Supplied by	Demanded by
	(Bids)	(Offers)
Ancillary	Market Participants (Competitive)	System Operator (Regulated)
Transmission	System Operator (Regulated)	Market Participants (Competitive)

For transmission Services the situation is exactly the opposite

