ESMAP

Renewable Energy Training

Basics of Power Systems Planning and Operations

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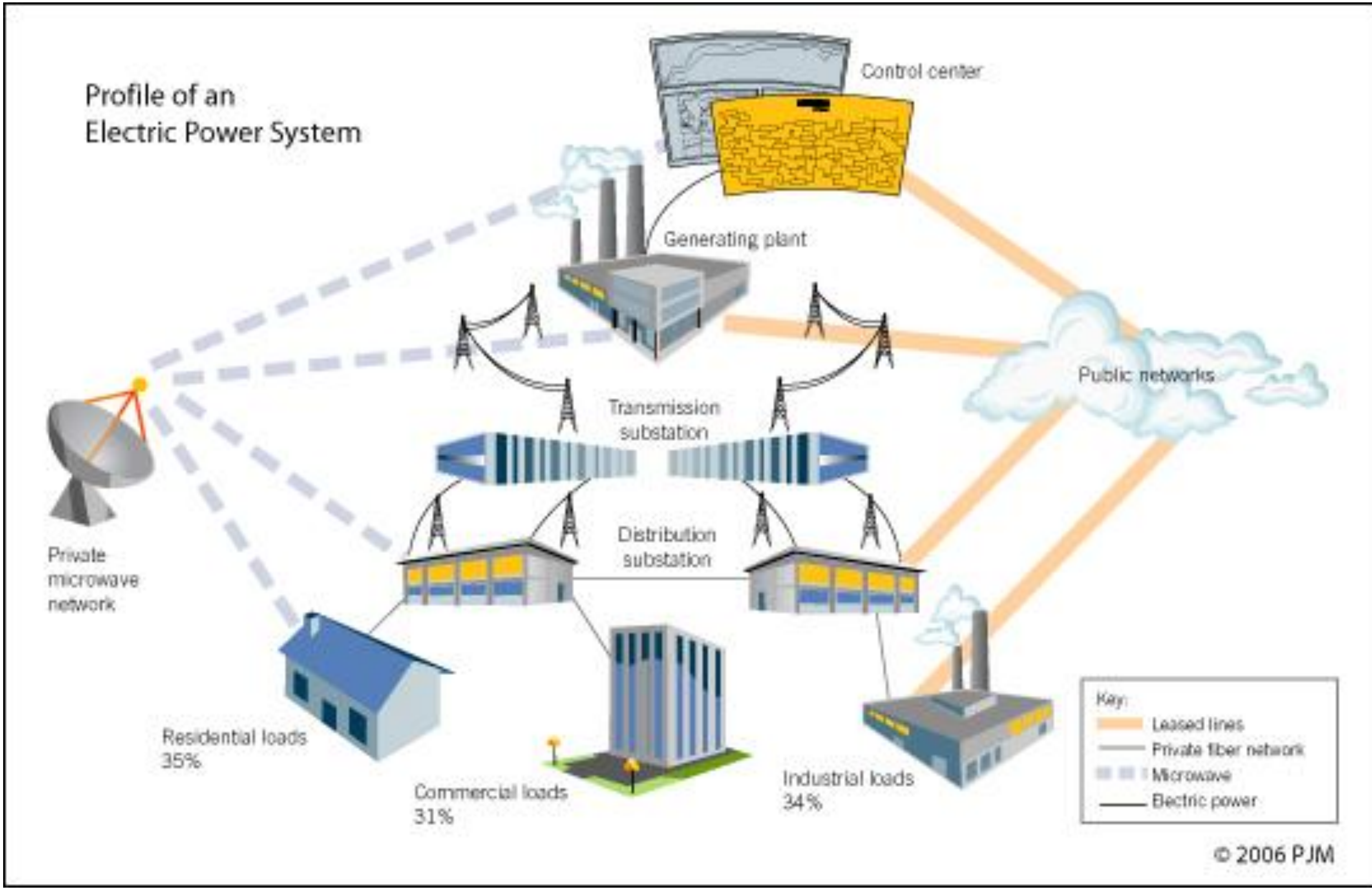
CONTENTS

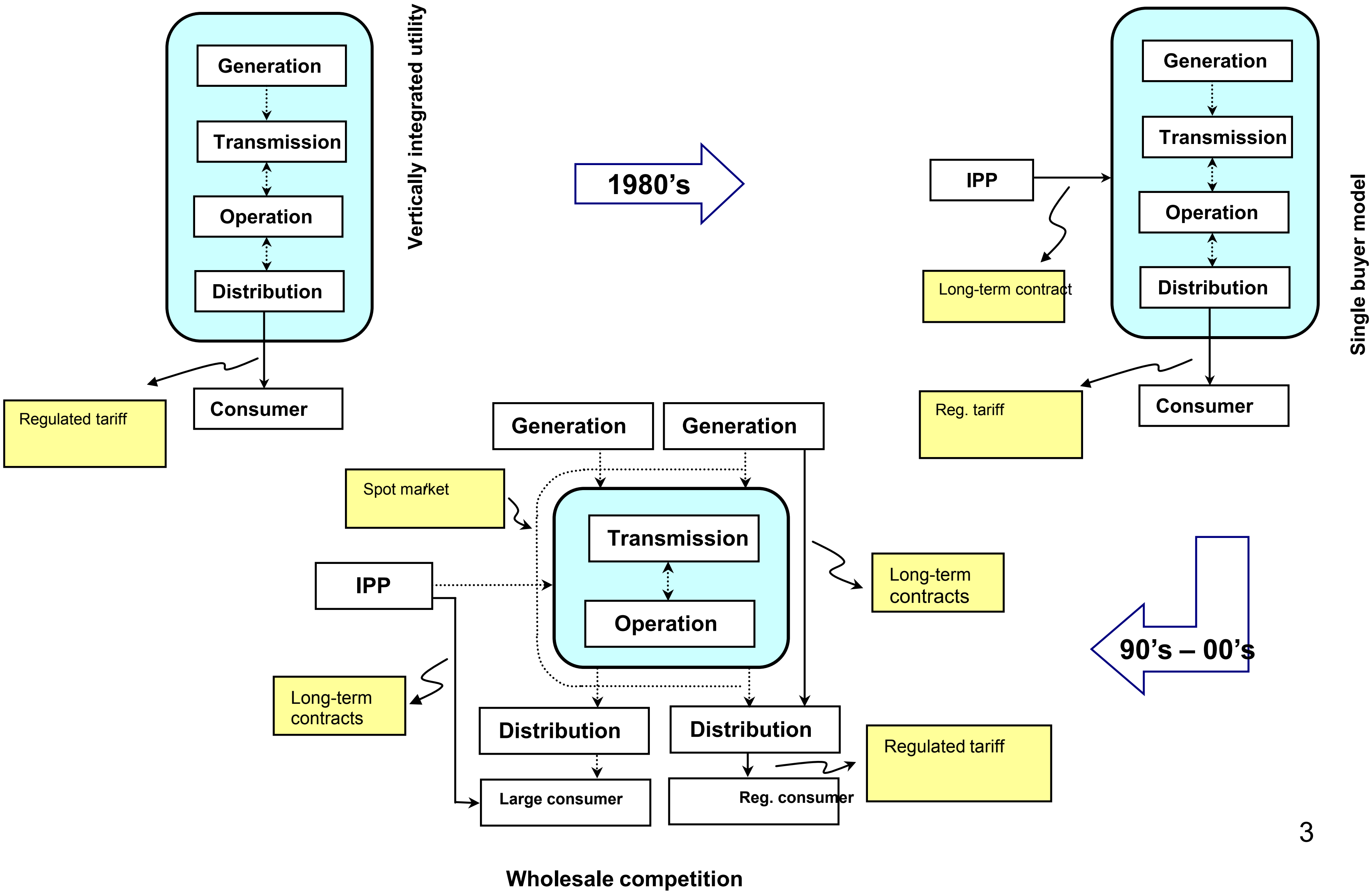
- **Overview: power system functions**
- **From planning to operations: delivering electricity at all times**
- **Basics of planning**
- **Basics of operations**
- **Renewables and planning and operations**

The physical structure



Source: PJM

Evolution of the different structures

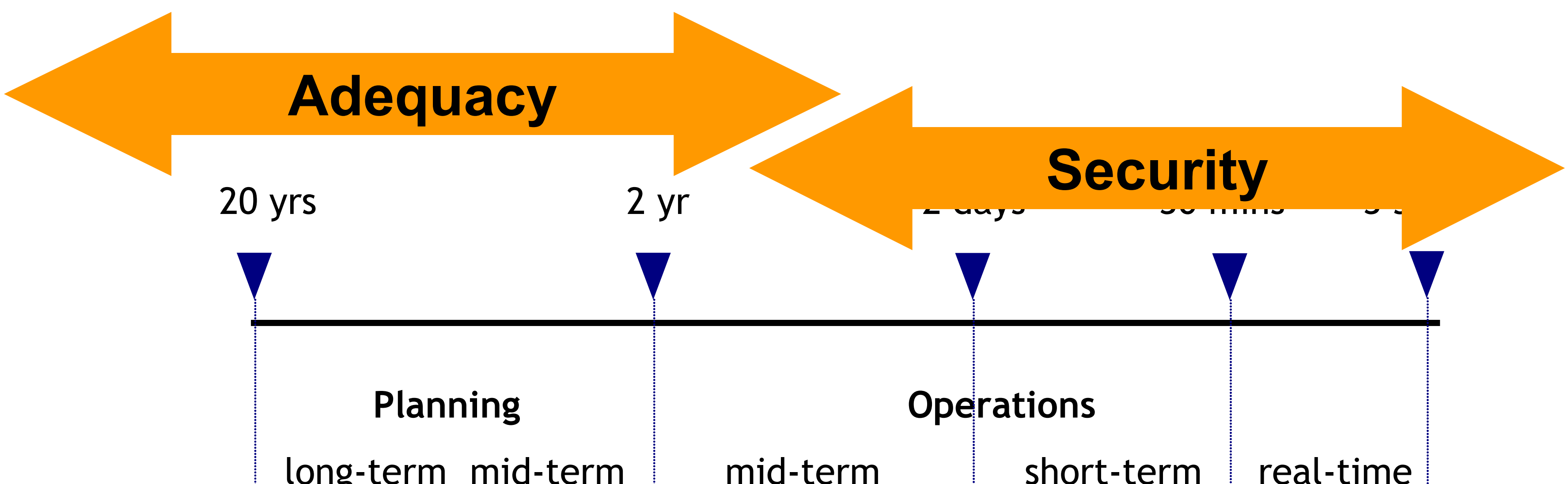


Regardless of the structure the main goal of the system is to

Ensure that demand is met **adequately** and **securely**

• **Adequate:** The system is able to meet all demand needs today and in the future

• **Secure**: The system is able to meet demand despite unanticipated events such as failures (in supply or any components in the grid)



A system is **reliable** if it is **adequate** and **secure**

Once reliability is achieved quality is the next step

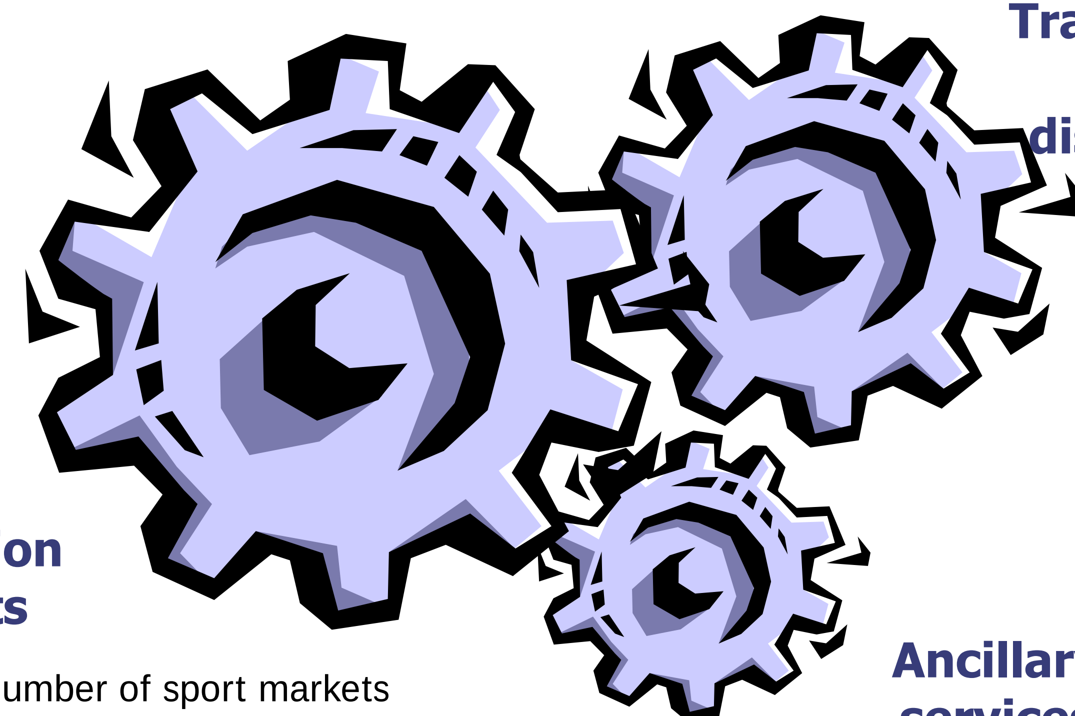
Quality of supply

Quality of service: low number, duration, and severity of supply interruptions to particular sets of costumers

Quality of energy: the technical characteristics of the current and voltage wave-forms: harmonic contents, flickering, sagging

Quality of attention: how quick the utility (usually distribution or transmission company) responds to costumer's requests: billing problems, connections, disconnections, questions, etc,.

All the functions should be integrated so that the system works to deliver electricity at all times: adequately, securely, with quality and desired cost and environmental characteristics



Generation markets

- Type and number of sport markets (*day ahead, intraday*)
- Bilateral contracts (*physical, financial*)
- Supply adequacy function: long-term signals for investment (*capacity payments, reliability auctions*)
- Demand Side Management (DSM) and Participation

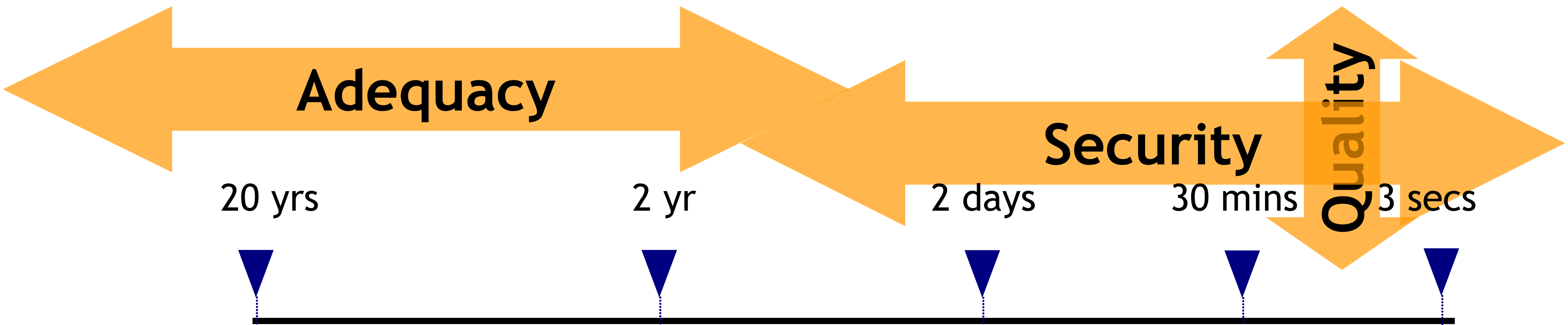
Transmission and distribution

- Expansion
- Access
- Tariff regulation
- Service quality

Ancillary services

- Real time operations
- Reserves real and reactive
- Frequency control
- Voltage control

Adequacy, security, and quality are achieved in different ways by different market structures



Structure	Adequacy	Security	Quality
Less competition	Planning	Operator manages all aspects in a central fashion	Almost to the will of the utility or to the strength if regulator
More competition	Incentives and regulation: capacity payment, long term contracts, reliability auctions	System operator + competition in some of the ancillary services	By regulation of transmission and distribution business

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The name of the functions: vertically integrated structures (pure single buyer model)

20 yrs | 2 yr | 2 days | 30 mins | 3 secs

Planning | **Operations**

long-term | mid-term | mid-term | short-term | real-time

(>1 year)
Long-term planning
Generation, transmission interconnections, demand side measures

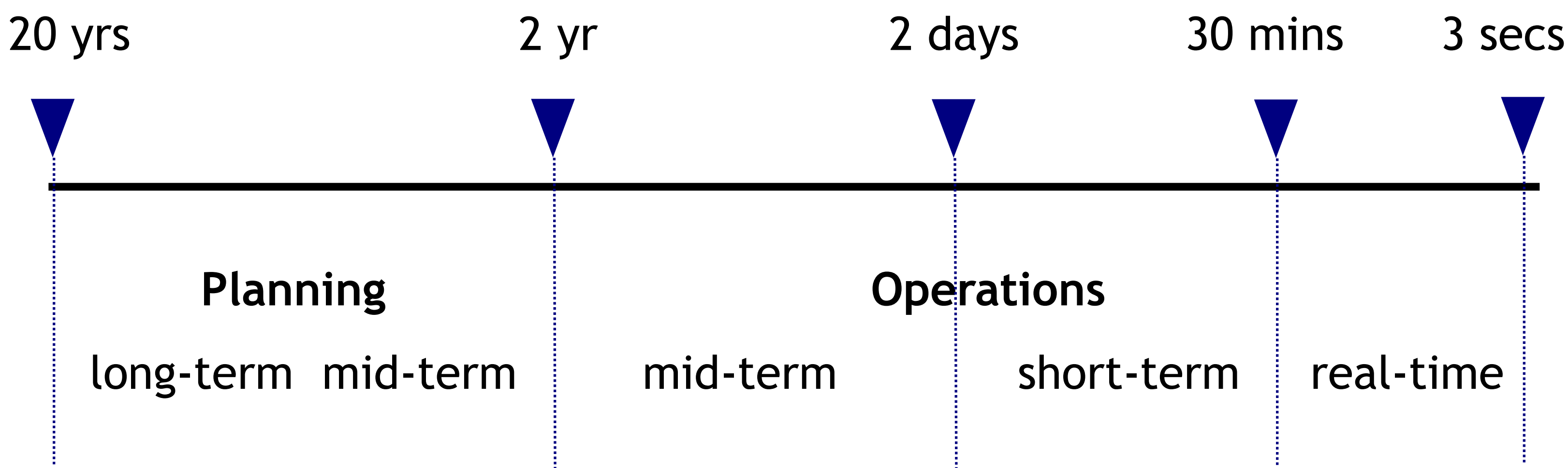
(1 ~ 3 years)
Hydro-thermal coordination
Unit-commitment
Demand forecast, fuel needs, maintenance scheduling (G+T)

(1 day head)
Operations planning or economic dispatch
Demand forecast, transmission-limited unit commitment, optimal power flows, sc-ED or OPF

Frequency control
Voltage control
Protections
Real time dispatch
Set-points to generators and AGC, Interchange scheduling

Indicative names
Activities performed

The name of the functions: systems with considerable competition in generation



Indicative integrated planning
Transmission planning
Capacity value determination
Reliability auction
Installed capacity markets
Bilateral contracts

Long-term water values
Unit-commitment

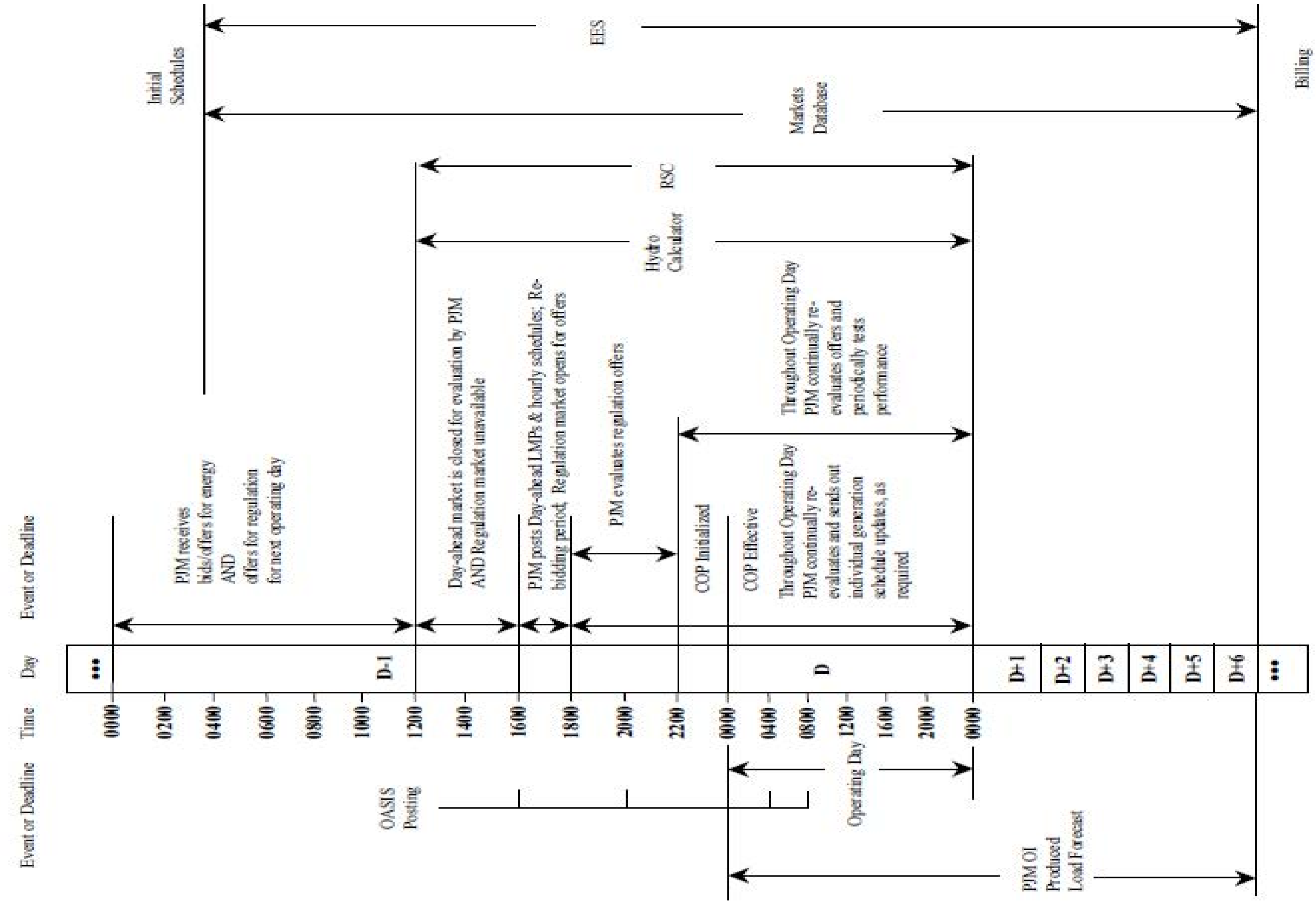
Day-ahead markets
Intra-day markets
Ancillary services
procurement: reserves

Real-time markets
Balancing mechanisms
Ancillary services
"dispatch": frequency
control, voltage contro
protections

Indicative names of some
of the functions

SHORT-TERM DISPATCH IN WHOLESALER MODELS

- **Short-term dispatch function needs be thoroughly organized from the technical and commercial perspectives**



COP – Current Operating Plant

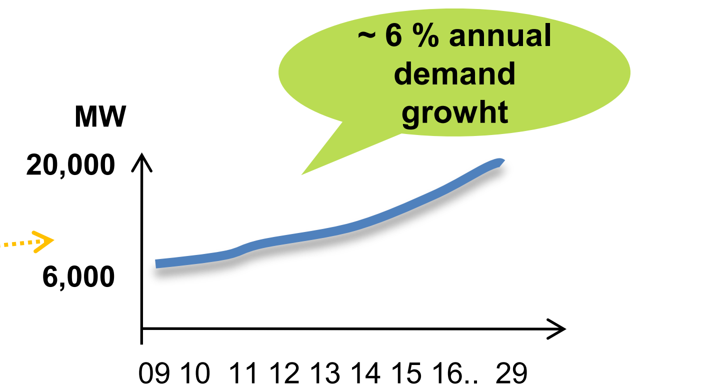
Source: PJM Manual 11: Energy & Ancillary Services Market Operations Revision: 49

Contents

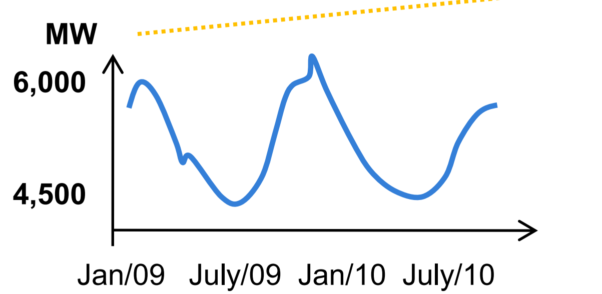
UNDERSTANDING PLANNING: SIMPLIFIED SCREENING CURVE ANALYSIS

- To define investment additions in generation that will supply demand adequately and securely, at minimum cost plus any other policy objectives of importance to the system (e.g. emissions, price volatility)

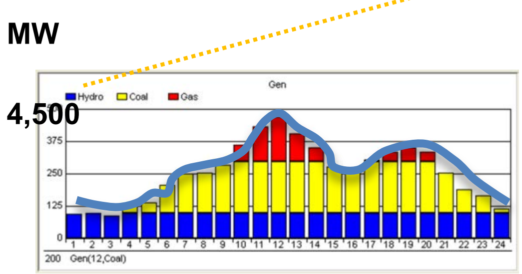
- Demand changes constantly and such variations need be taken into consideration when planning



Long-term demand projection (20 years)
Generation Planning



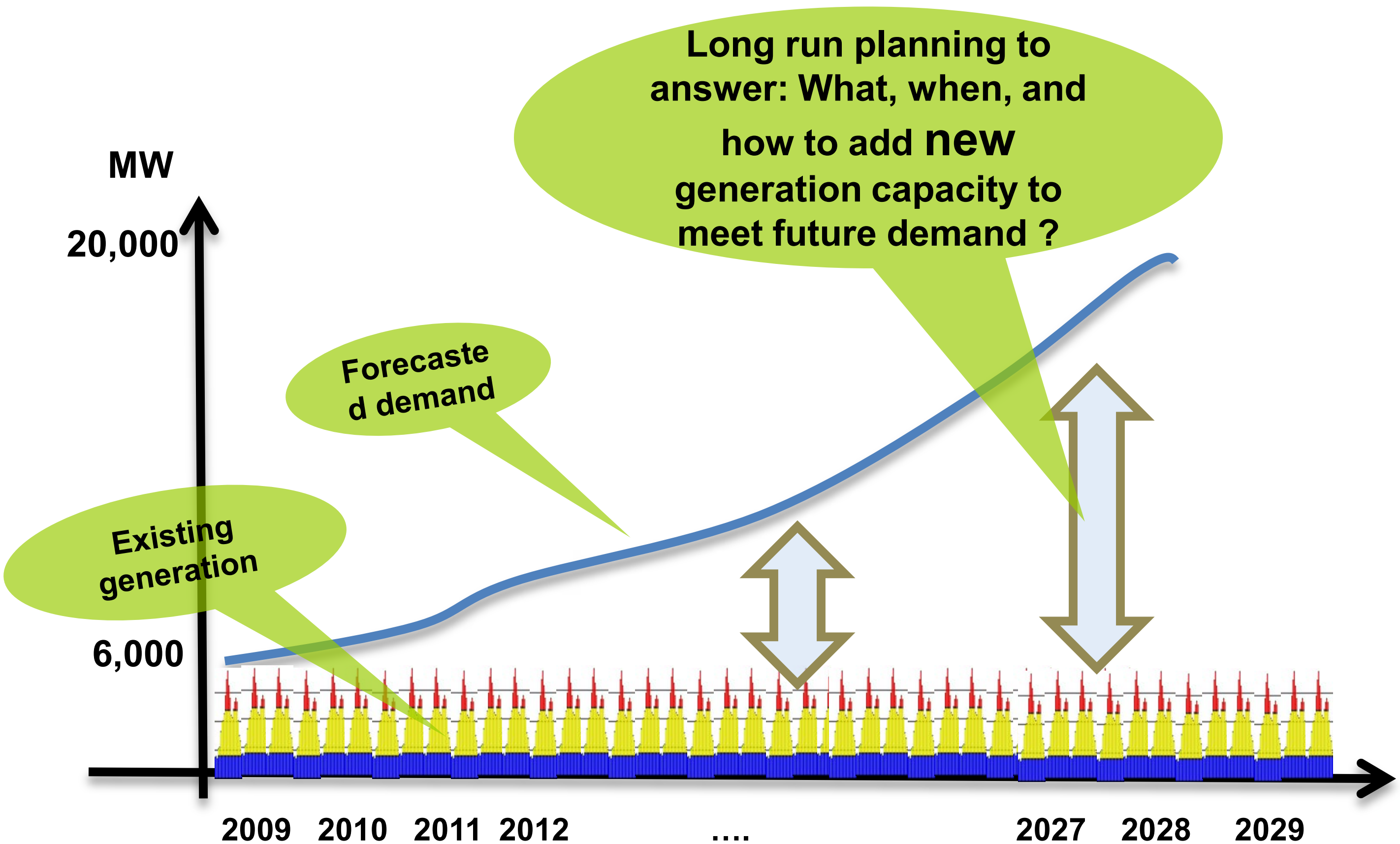
Yearly load-curve (1.5 years)
Operations planning



Daily load curve (24 hrs)
Short-term dispatch

UNDERSTANDING PLANNING: SIMPLIFIED SCREENING CURVE ANALYSIS

- Long term generation planning



UNDERSTANDING PLANNING: CONCEPTS

- Long term generation planning:
  - **What** : generation type (coal, nuclear, wind)
  - **When:** 2015, 2017 ?
  - **How:** how to combine sizes of coal, nuclear, wind, and other resources to meet changing demand patterns
- Plan should following desired objectives:
  - Minimum cost,
  - Balance emissions,
  - Increase use of local energy sources…

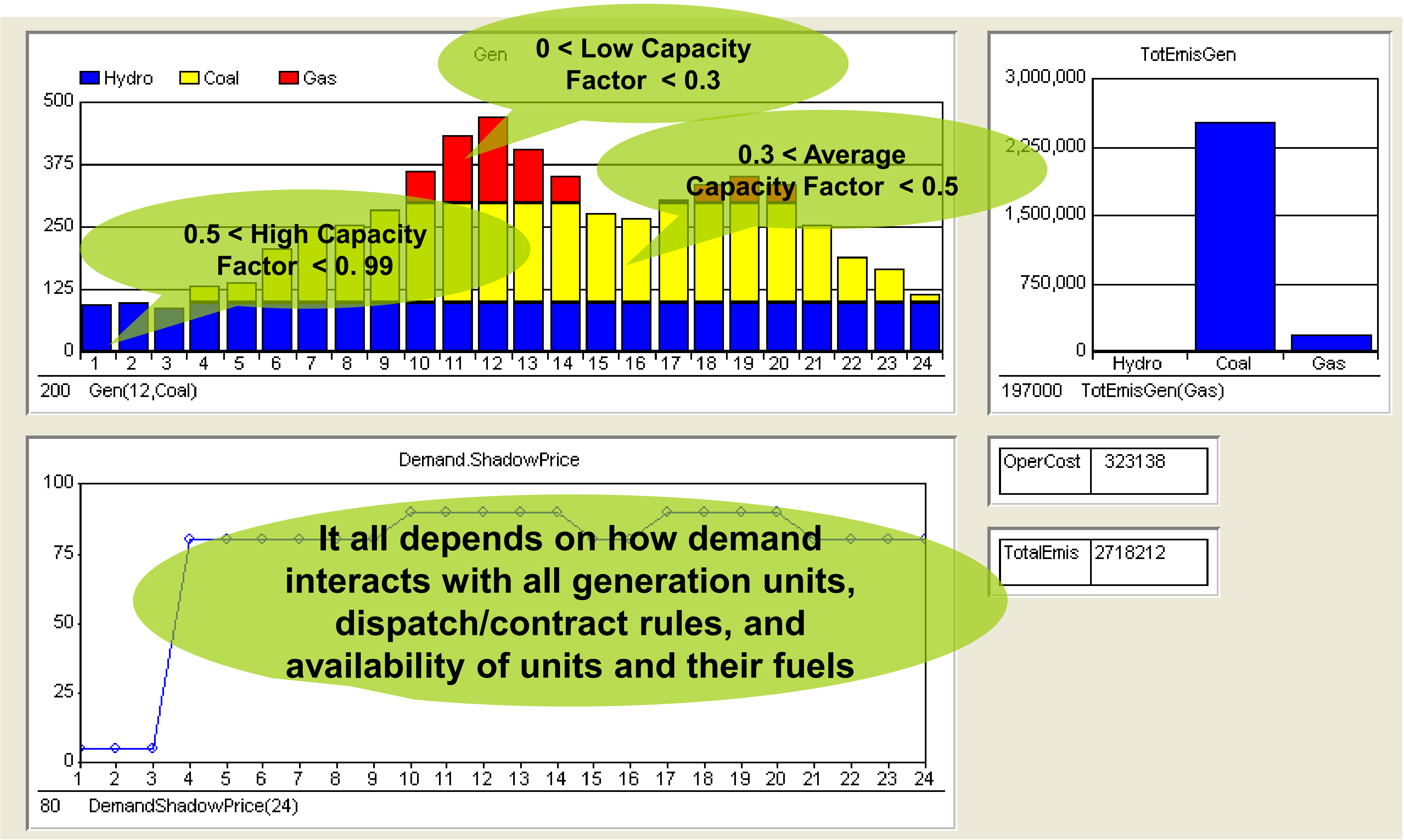
UNDERSTANDING PLANNING: CONCEPTS

- Conventionally, planning objective is to ensure demand will be met at minimum cost (other objectives or constrains can also be included)
  - Capital cost of the different generation options
  - Operational cost
    - Fixed operation costs

      Regular facilities work/maintenance) that do not depend on the power plant output
    - Variable operation cost

      e.g. Own-consumption, cooling etc, that depends on output MWh
    - Fuel cost, which is also variable on output MWh

Capacity factor (CF): Measure of the actual energy production compared to the unit's maximum production capacity



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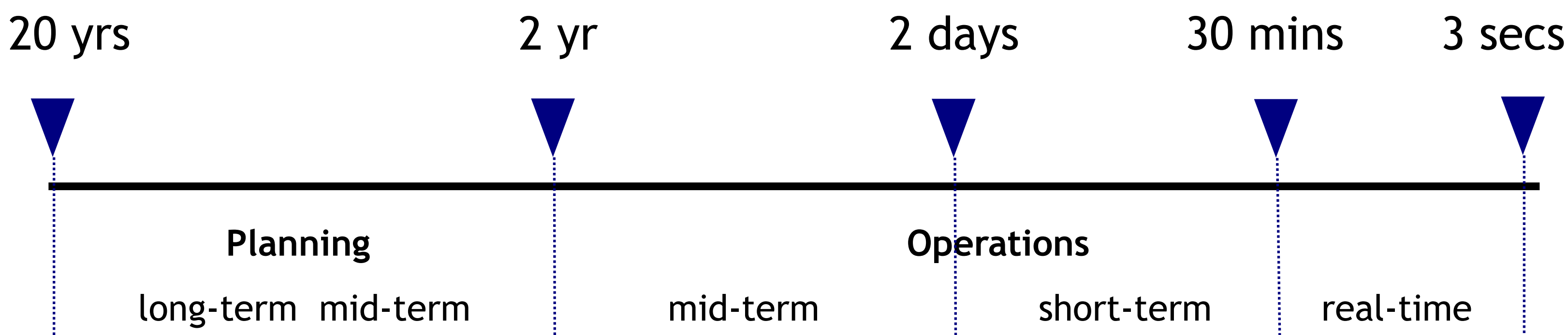
The name of the functions: vertically integrated structures (pure single buyer model)



(>1 year)
Long-term planning
Generation, transmission interconnections, demand side measures

(1 ~ 3 years)
Hydro-thermal coordination
Unit-commitment
Demand forecast, fuel needs, maintenance scheduling (G+T)

(1 day head)
Operations planning or economic dispatch
Demand forecast, transmission-limited unit commitment, optimal power flows, sc-ED or OPF

Frequency control
Voltage control
Protections
Real time dispatch
Set-points to generators and AGC, Interchange scheduling

Indicative names
Activities performed

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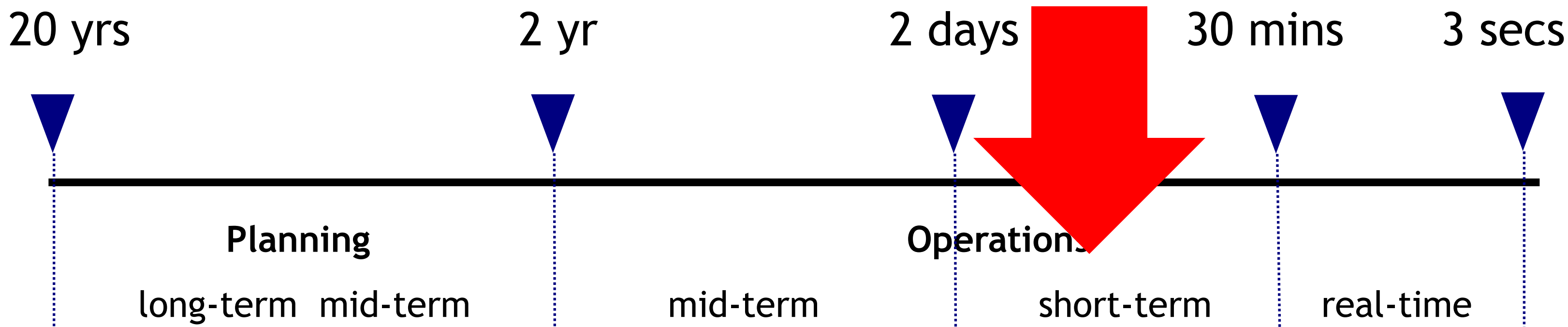

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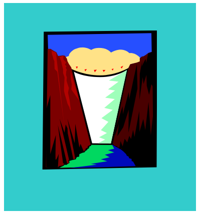
Short-term economic dispatch

- One of the most important functions before real-time operation
- Scope of the function
  - Usually performed **one day** before operations, up until a 30 or 15 minutes before real-time
  - The operator (system/market) knows what units are available to the system
  - The operator has an updated (more accurate) projection of system demand
  - The operator knows what are the conditions of the transmission system, and has good knowledge of possible contingencies
- **Objective: to schedule existing generation to economically supply short-term demand**

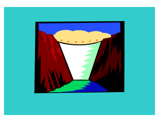
Basics: short-term generation economic dispatch

	Size (MW)	Fuel Type	Fuel Cost $/MMBTU	Fuel Consum MMBTU/MW-hr	Total Cost $/MW-hr
	100	Coal	5	15	75
	200	Hydro	-	-	5
	150	Gas	15	10	150

• Assumptions: There are no transmission limits and no losses

• Problem: at 8:00 it has been forecasted that demand at 9:00 will be 250 MW, how to supply this demand ?

Basics: short-term generation economic dispatch…

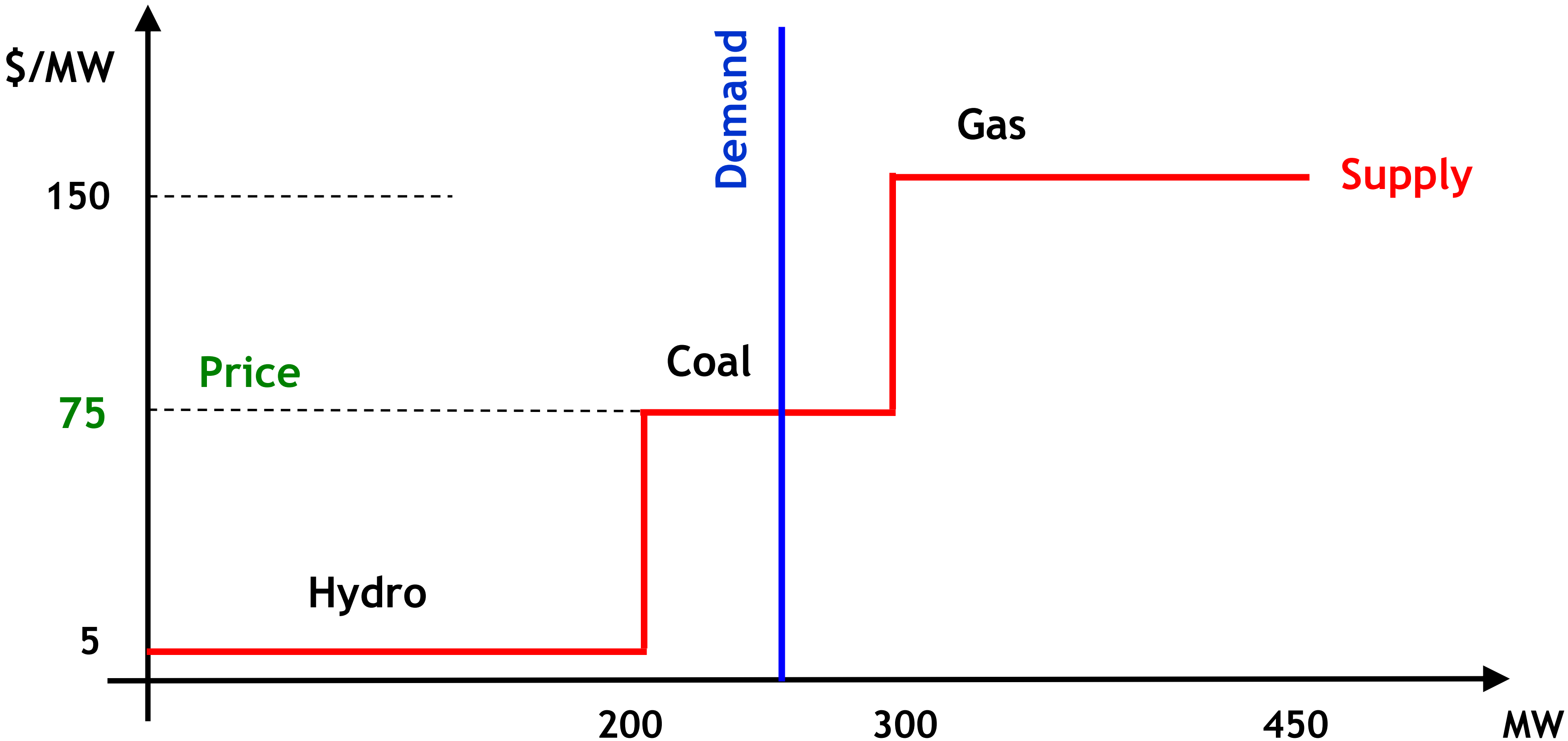


Size (MW)	Fuel Type	Fuel Cost $/MMBTU	Fuel Consum MMBTU/MW-hr	Total Cost $/MW-hr	Output MW	Cost $
100	Coal	5	15	75	50	$3,750
200	Hydro	-	-	5	200	$1,000
150	Gas	15	10	150	0	$0
Total					250	$4,750

- The minimum cost to supply 250 MW during on hour is $4,750
- Lowes cost generator is dispatched first and highest cost generator dispatches last. There is "merit order"

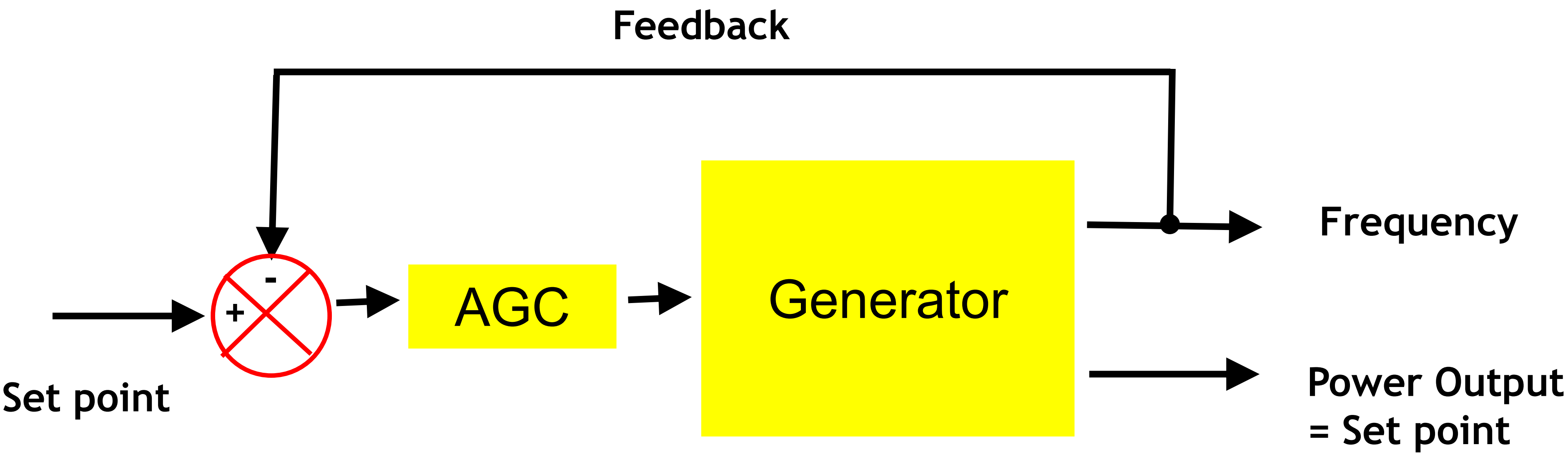
Economic interpretation

- Generators produce output if price is above cost
- Demand is inelastic
- Intersection of supply and demand = price

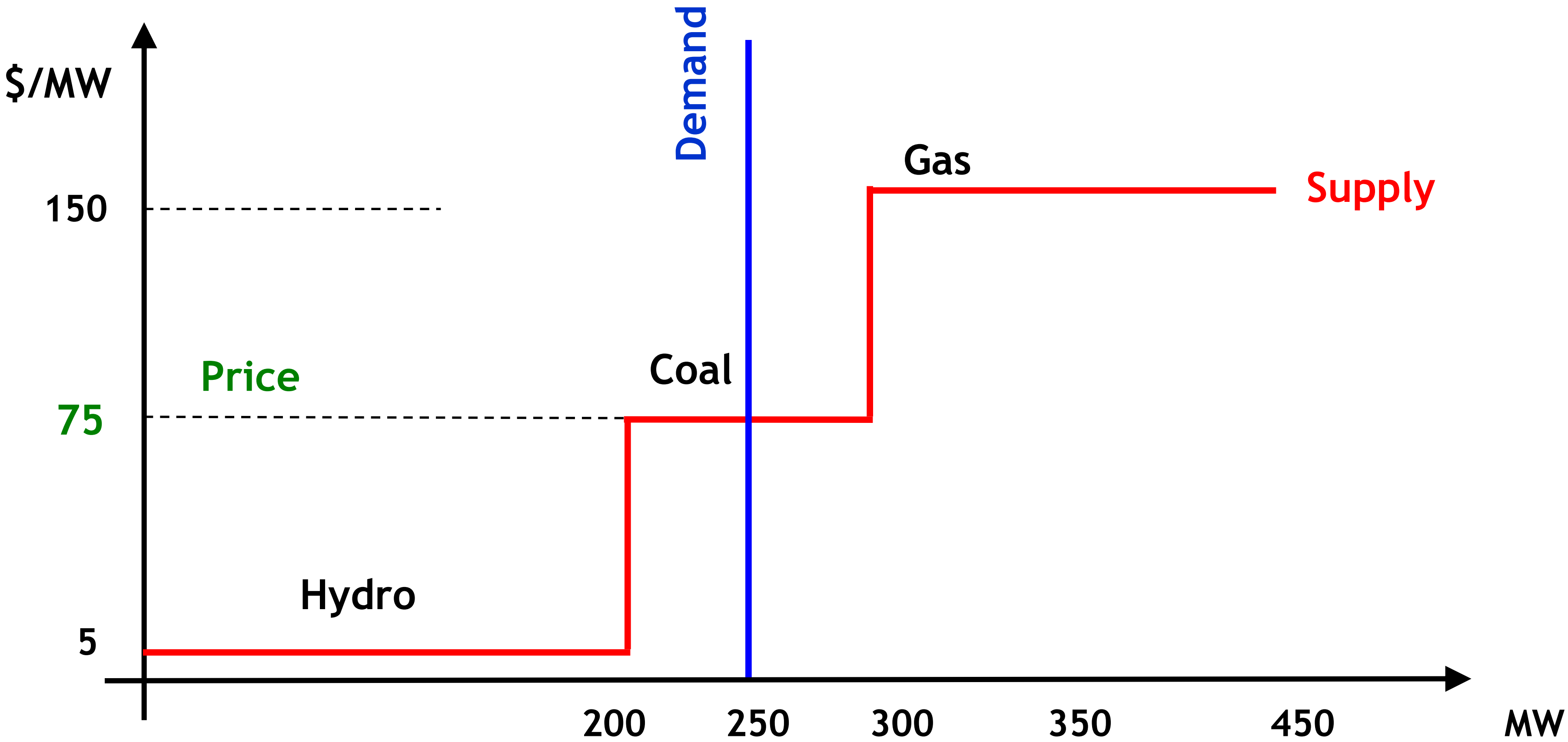


It is 8:00 am, the dispatch for 9am has been made, now what ?

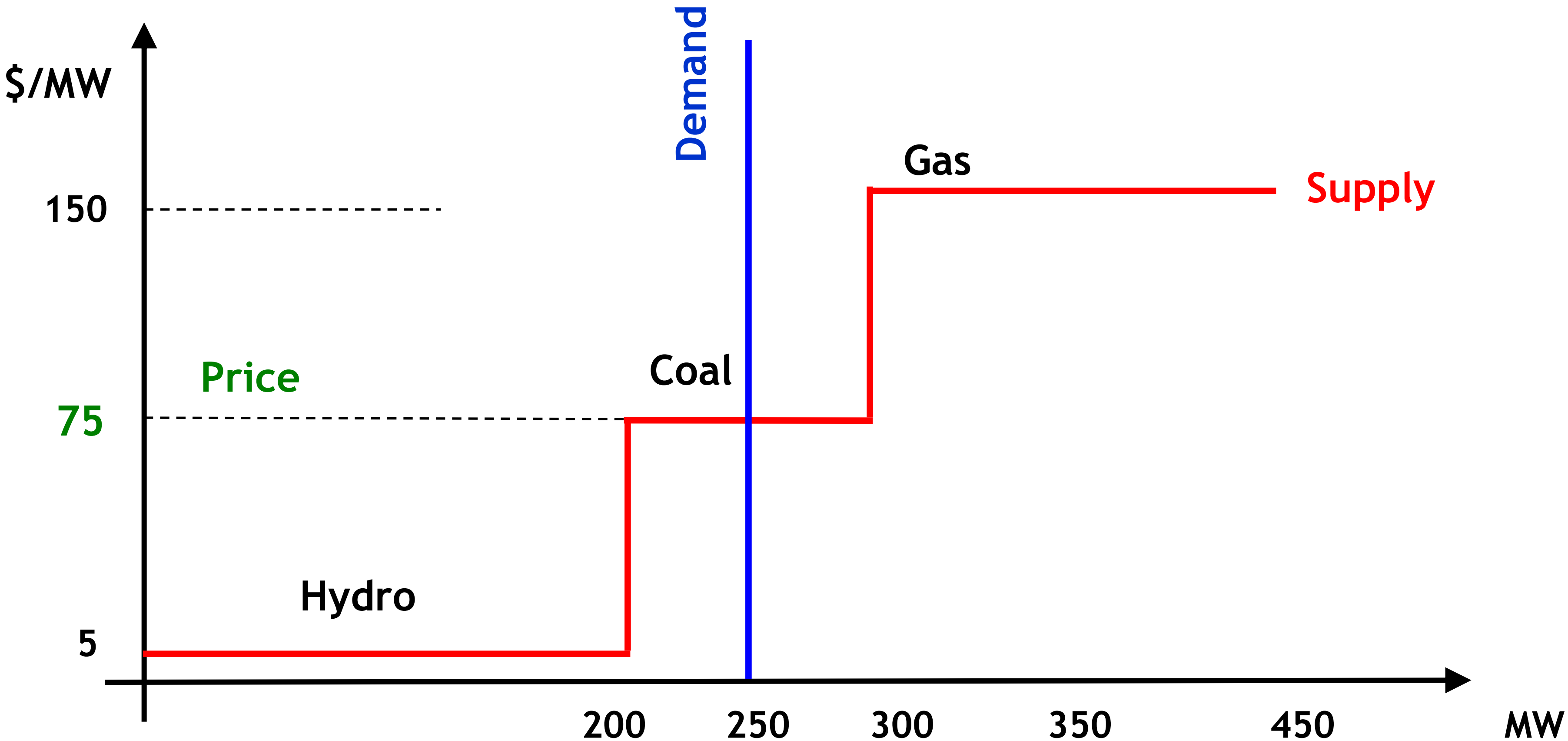
• The production output for each generator is transmitted to the each generator Automatic Generation Control (AGC) “**set-points**”

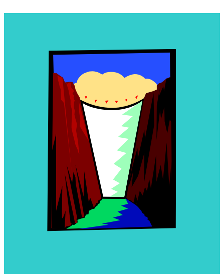


It's 9:00am, if everything is as forecasted this is the final dispatch=as planned previous day/hour=set points



What if at 9:00am Hydro run outs of water and produces only 100 MW ?





It could have been wind as well

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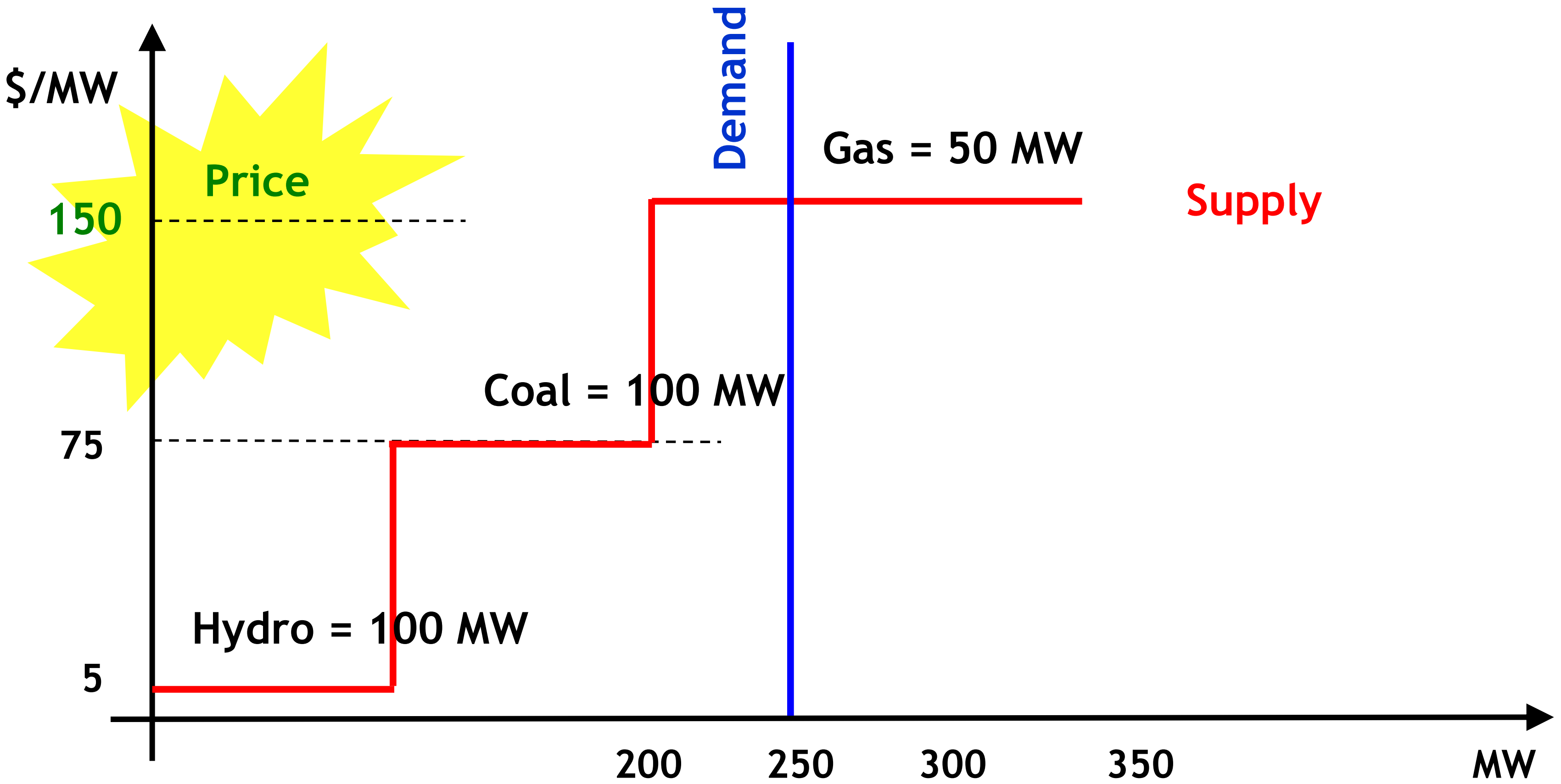
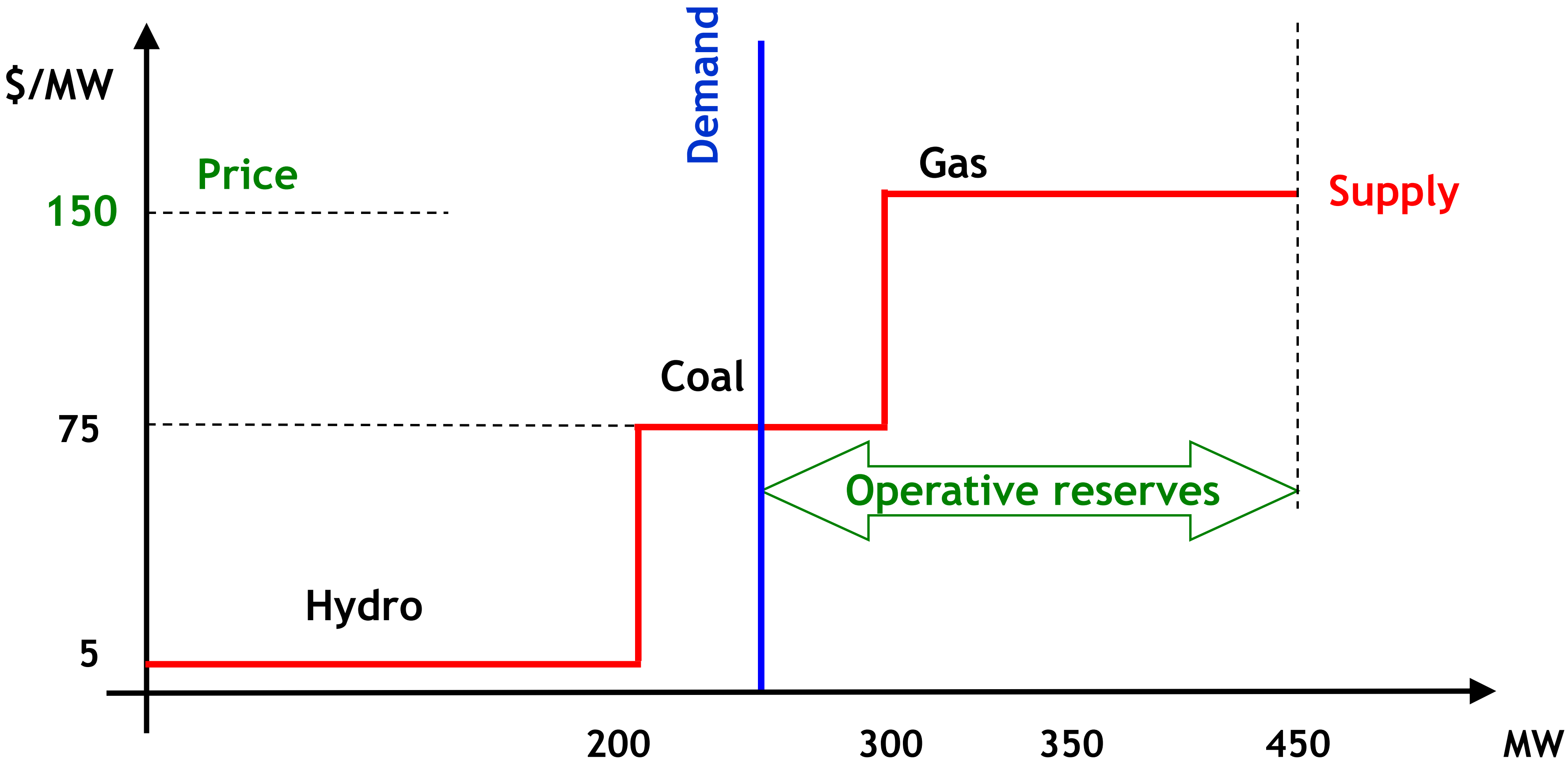
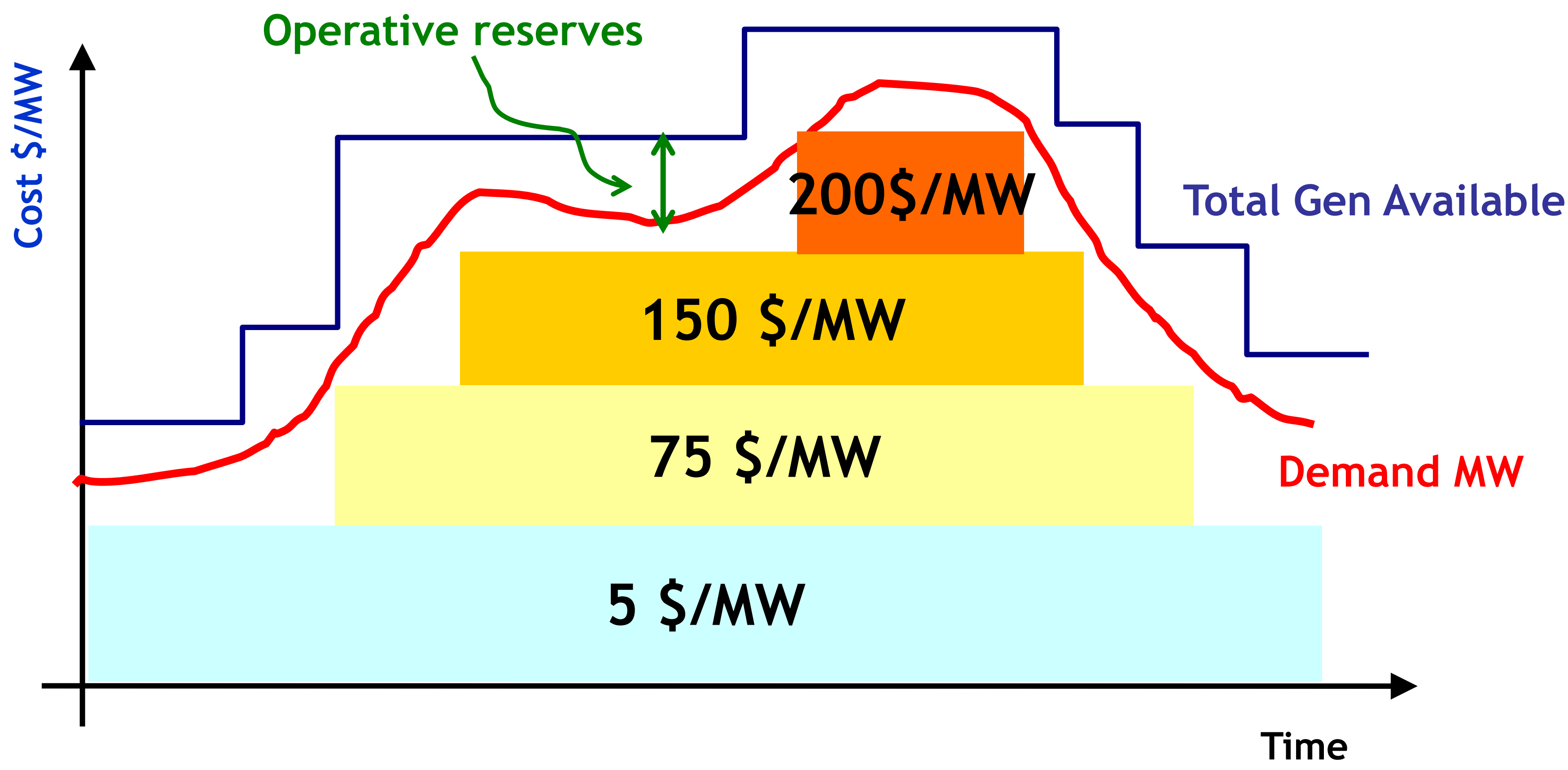


Gas power plant responds and quickly produces 50 MW, short-term generation cost (price) grows up to 150 $/MW

Short-term (operative) reserves are required to anticipate this situations:

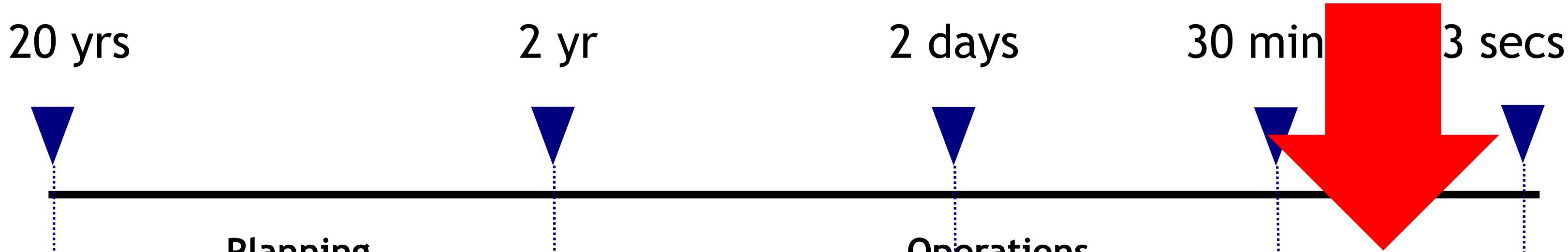


In general short-term operation will look like:



Simplified representation

The name of the functions: vertically integrated structures (pure single buyer model)



Planning **Operations**

long-term mid-term mid-term short-term real-time

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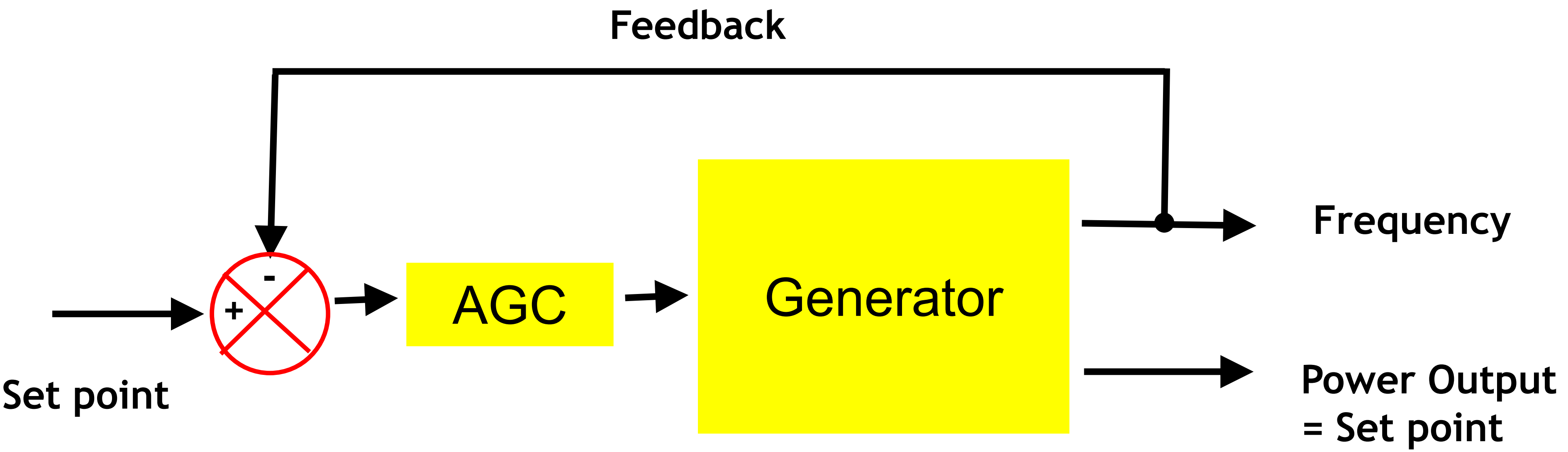
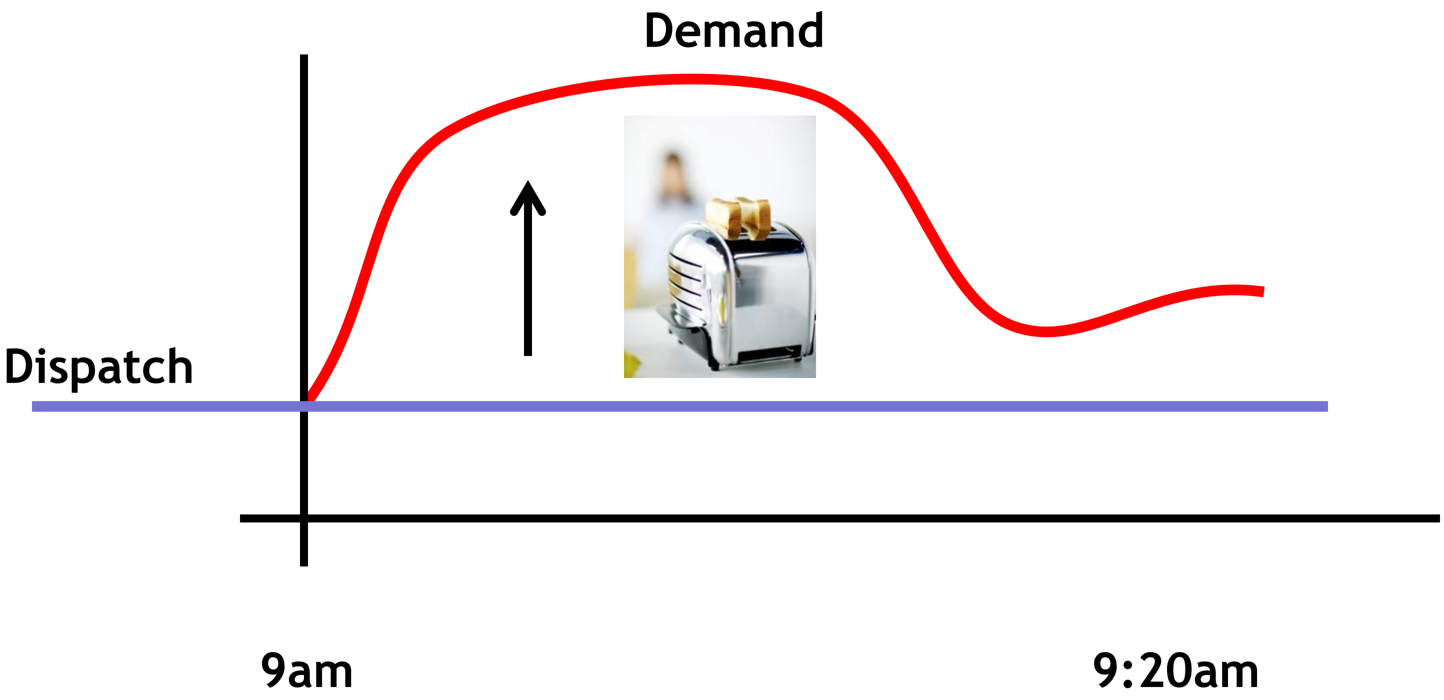
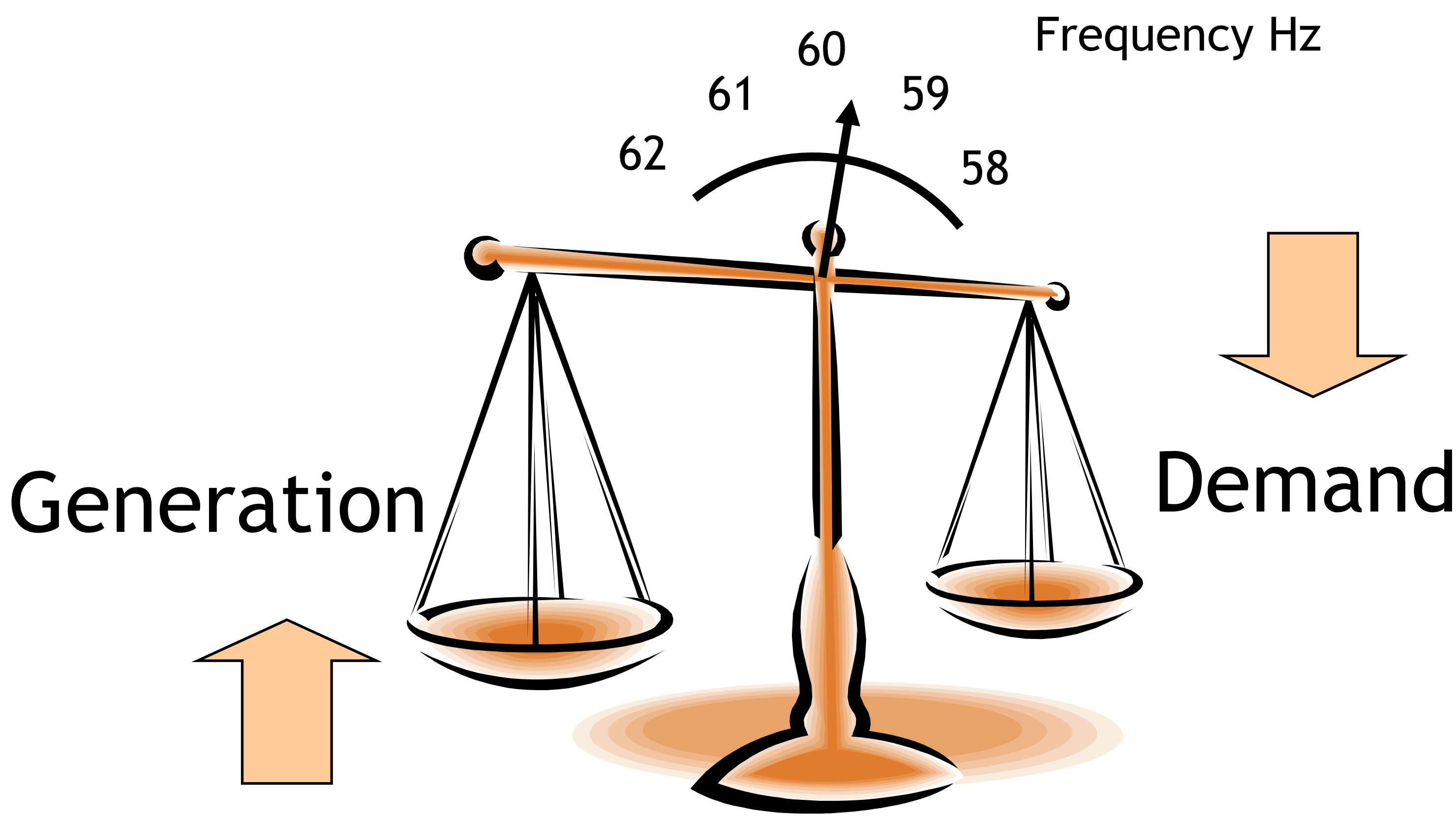


What happens when demand increases (beyond dispatch level) ?



System frequency is the signal that second by second tells if demand and generation are being matched

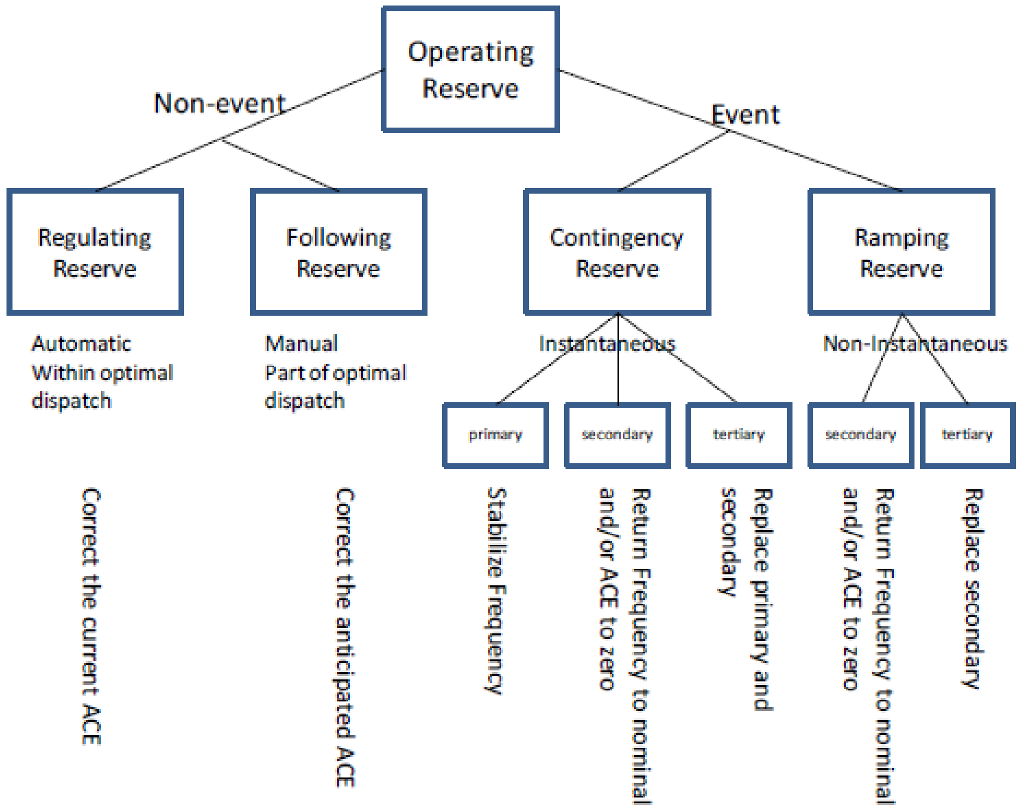


Different generation technologies/controls provide frequency control in the millisecond, seconds, and minute time frame
Such services can all be called “operating reserves”

Operating reserves: power output increase or decrease that can be achieved within prescribed time frames.

There is no standard to name reserves, each system may need different types o reserves. The following are typical types of deserves in a system

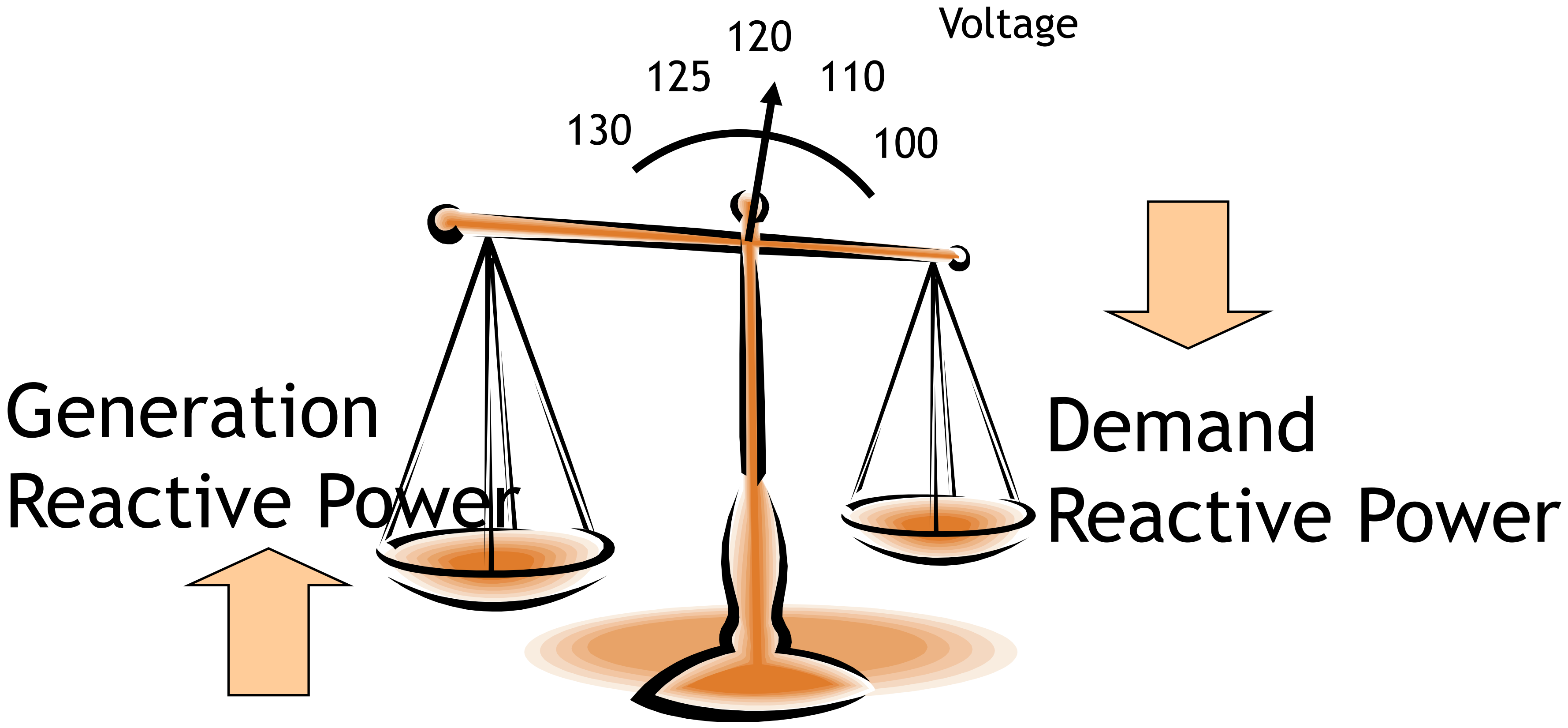
seconds



to minutes

*Source: **Operating Reserves and Variable Generation** *A comprehensive review of current strategies, studies, and fundamental research on the impact that increased penetration of variable renewable generation has on power system operating reserves..* Erik Ela, Michael Milligan, and Brendan Kirby . NREL aug. 2011

Voltage. Same as frequency, voltage needs to be within prescribed limits to ensure both quality and reliability



Devices that consumer reactive power: motors in pumps, fridges, anything that has a coils on it. Devices that produce reactive power: generator, capacitors, var compensators, lines

In real time operations Frequency and Voltage are the main variables to control to ensure system security

Virtually any device in the system has and impact on F and V

Generation assess are specially important to mange F, and also (but to a lesser degree degree) V.

Frequency a system issue, while voltage is a local issue (in a given region, substation, street area)

Operators have rules to use the different devices so that F and V are always witting prescribed limits

Source: PJM

VARIABLE RENEWABLE ENERGY TECHNOLOGIES AND PLANNING

- New generation technologies such as Wind and Solar power have characteristics that make them different to other technologies

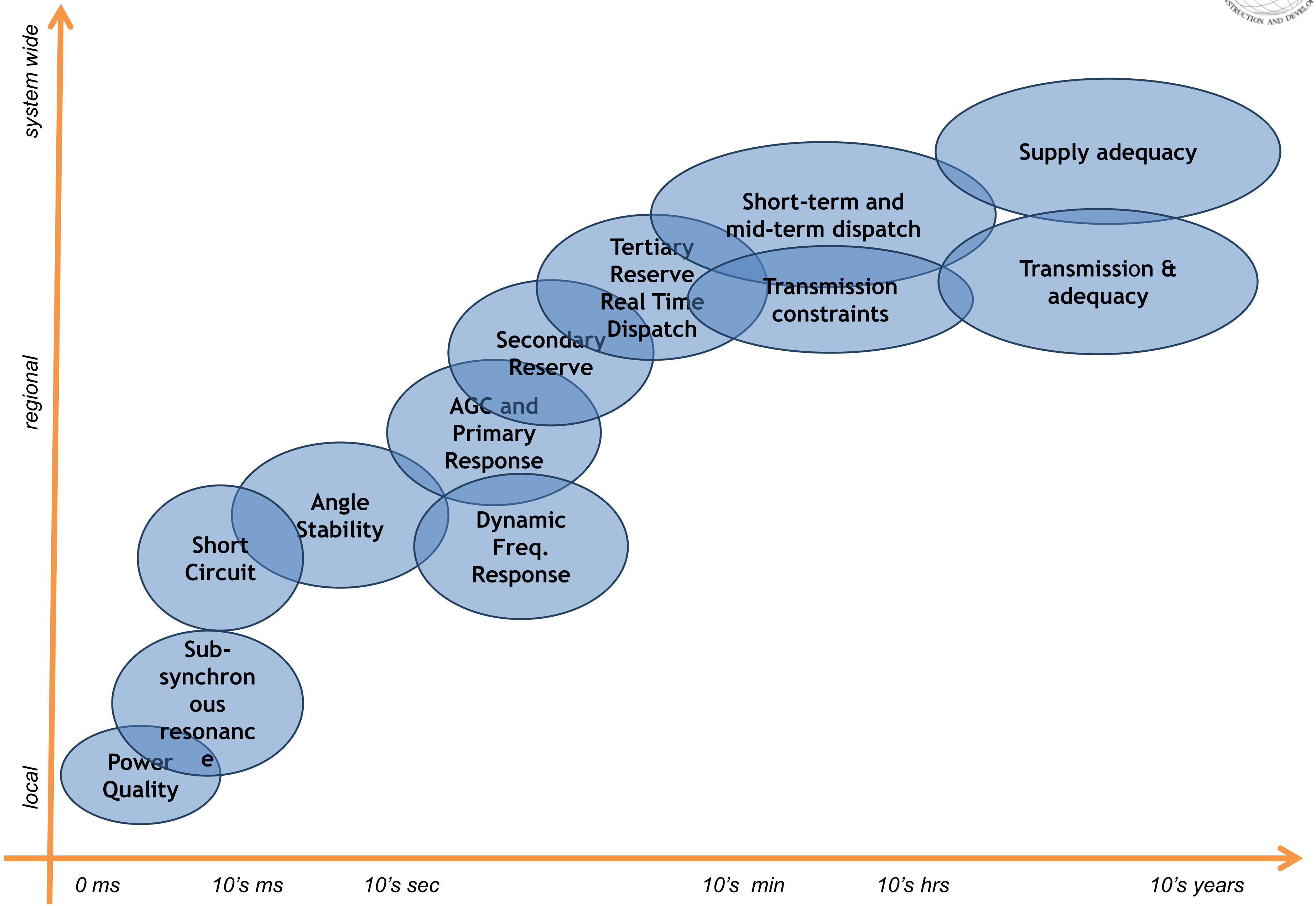
- These sources have variability in their power output some what different to the variability our systems are used to

- Their location is more sparse and their average size is some how "smaller" than conventional power plants

- Almost all variables in the system (generation/demand) are variable in the short- and long-term.

- New RE, such as wind and solar have a different form of variability – one to which grid operators where not used too –In that such sources are more uncertain and offers less (or non) controllability.

IMPACTS IN DIFFERENT TIME/SPACE FRAMES AND THE ARE OF FOCUS IN THIS PRESENTATION



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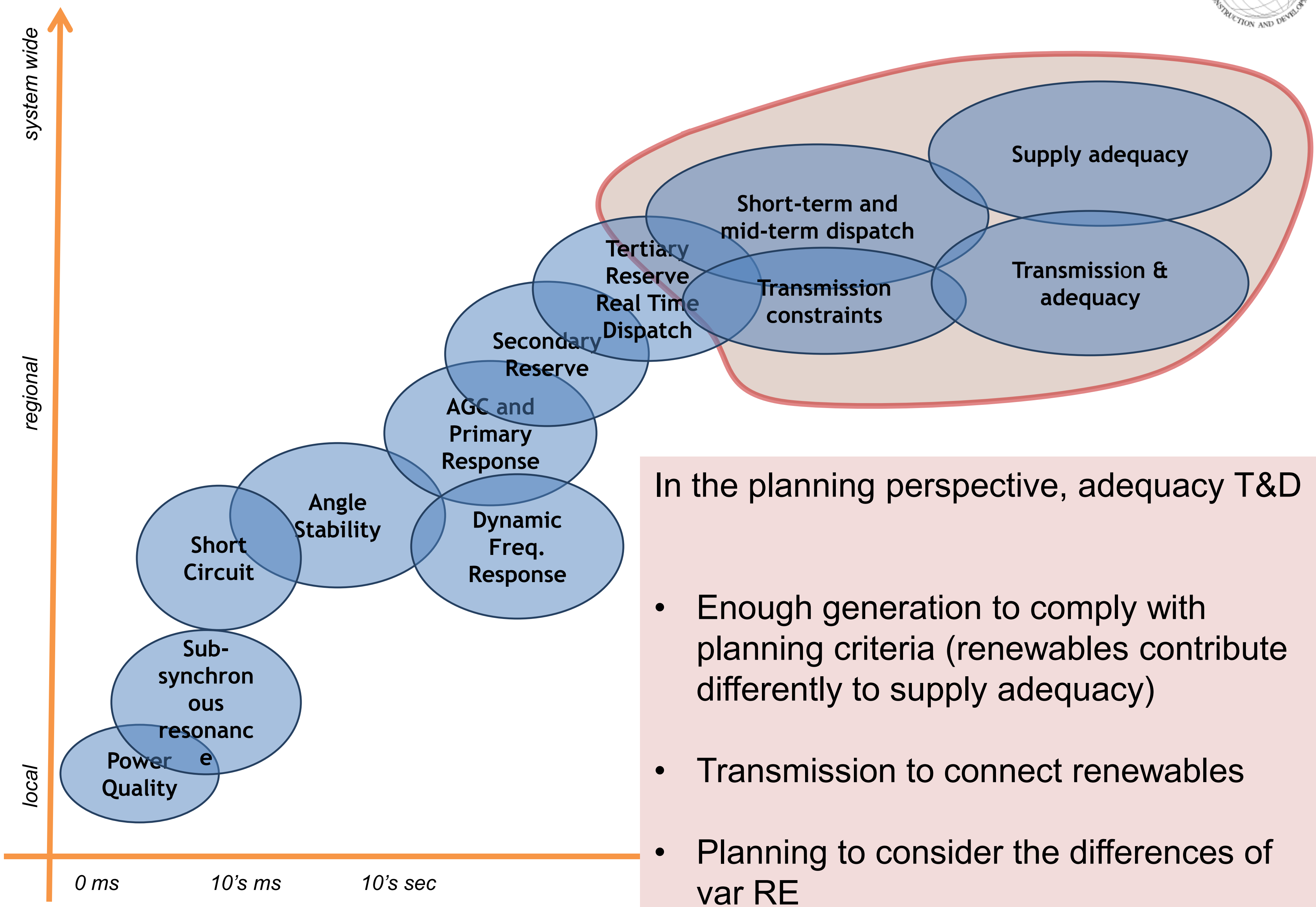
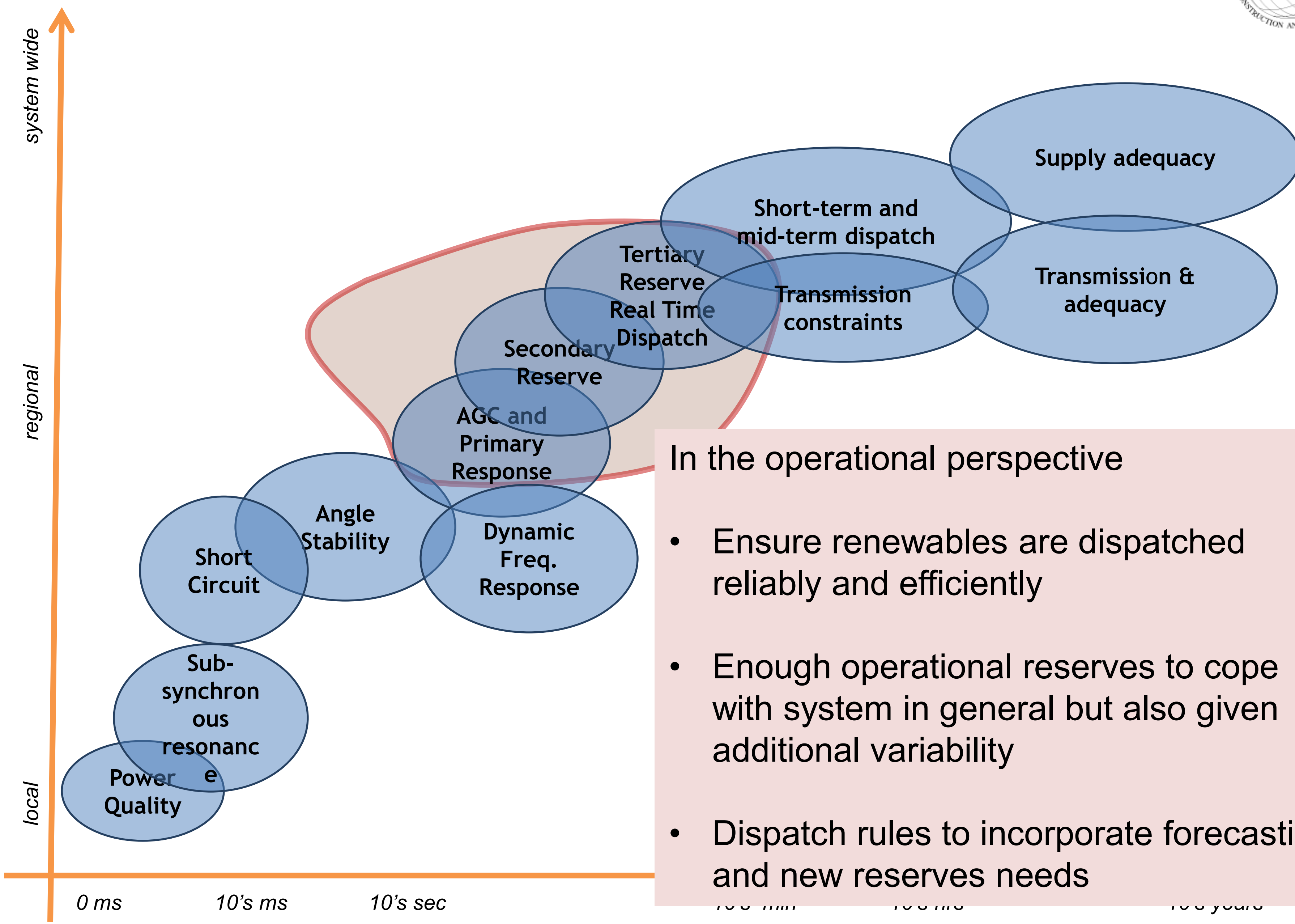


In the planning perspective, adequacy T&D

- Enough generation to comply with planning criteria (renewables contribute differently to supply adequacy)
- Transmission to connect renewables
- Planning to consider the differences of var RE

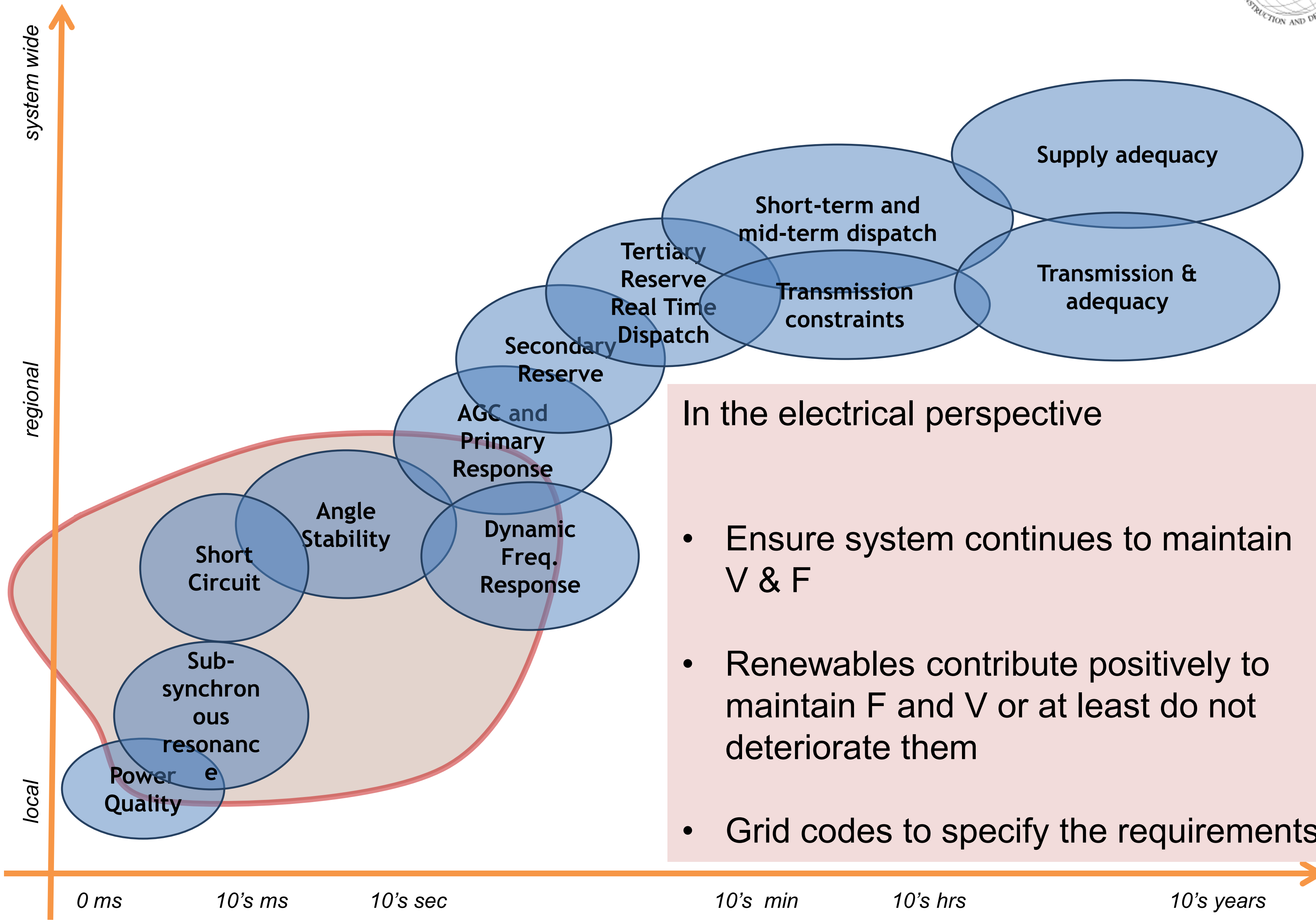
IMPACTS IN DIFFERENT TIME/SPACE FRAMES AND THE ARE OF FOCUS IN THIS PRESENTATION



In the operational perspective

- Ensure renewables are dispatched reliably and efficiently
- Enough operational reserves to cope with system in general but also given additional variability
- Dispatch rules to incorporate forecasting and new reserves needs

IMPACTS IN DIFFERENT TIME/SPACE FRAMES AND THE ARE OF FOCUS IN THIS PRESENTATION



In the electrical perspective

- Ensure system continues to maintain V & F
- Renewables contribute positively to maintain F and V or at least do not deteriorate them
- Grid codes to specify the requirements