ETM521

Lecture 4 – Fundamentals of Power System Operation

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Review

- Remember the hand dynamo?
  - More load -> slower return
  - More generation -> faster return
- Reactive (balancing of bicycle)
- History
  - Electric and magnetic understanding

Question

If there is no storage, how system matched load and supply?

Resource

Explaining Power System Operation to Nonengineers, Lennart Soder

The Grid

https://www.researchgate.net/publication/3213591_Explaining_Power_System_Operation_to_Nonengineers

Active Power Balance

- All sprockets are connected with chains, they rotate at the same speed
- Bike rpm -> system frequency
- Some pedalling (generation)
- Some braking (loads)
- To keep constant speed
  - Total force

System frequency

- Some continuously look at the speed of the bike
- When speed decreases
  - They stoke to pedals
- When speed increases
  - They loose their strokes

Reactive Power Balance

- Midpoint

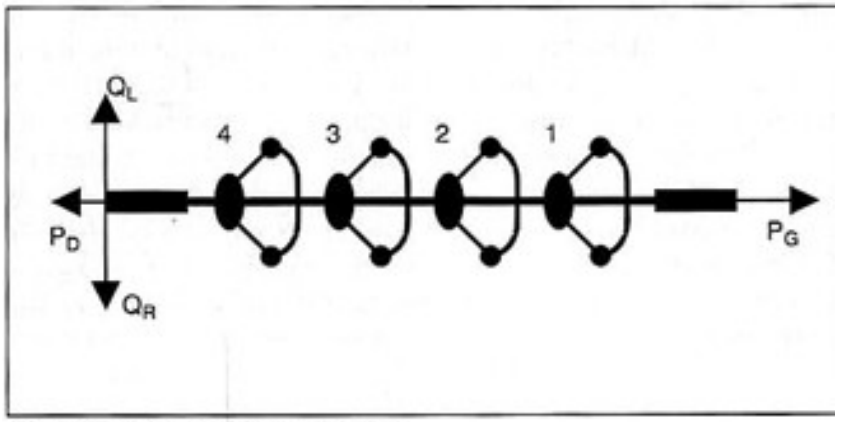


Figure 1. Forces on the tandem bike

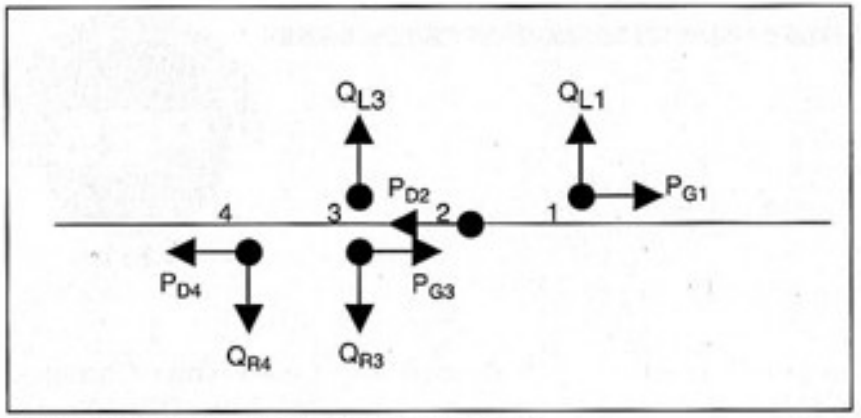
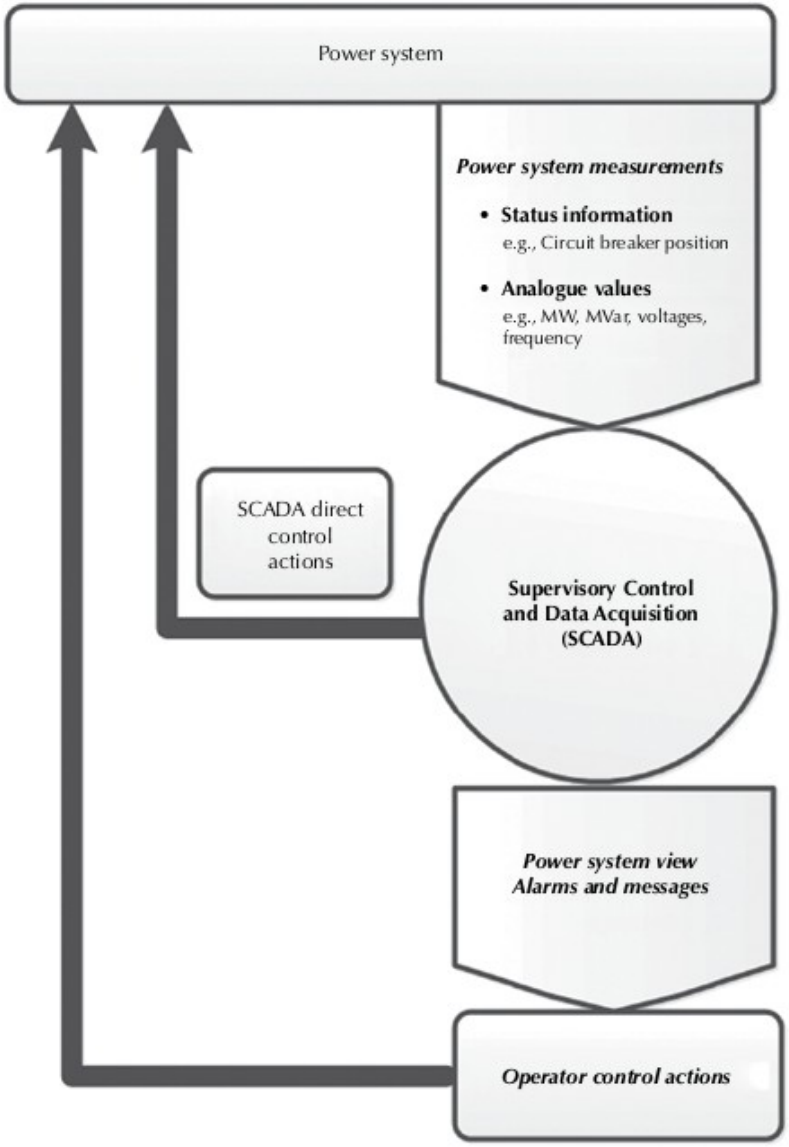


Figure 2. Forces on a four-person tandem bike

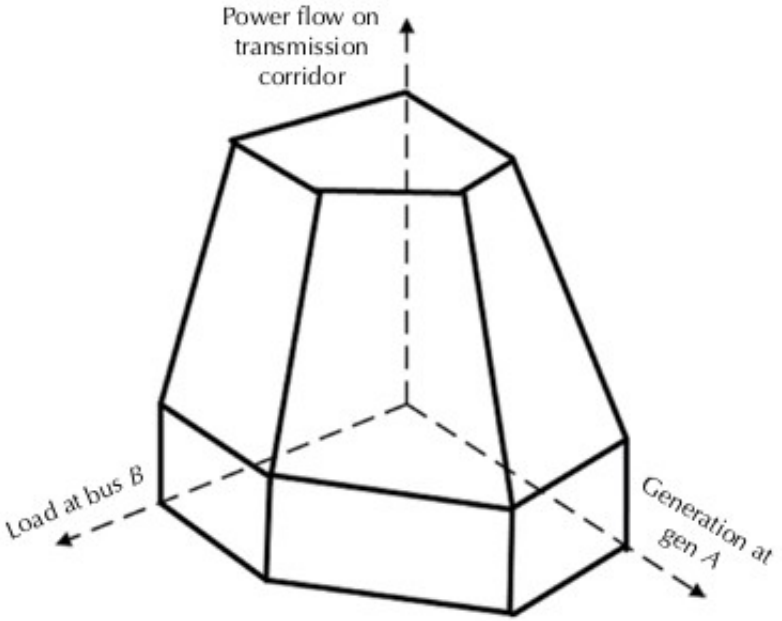
https://www.researchgate.net/publication/3213591_Explaining_Power_System_Operation_to_Nonengineers

Boat race

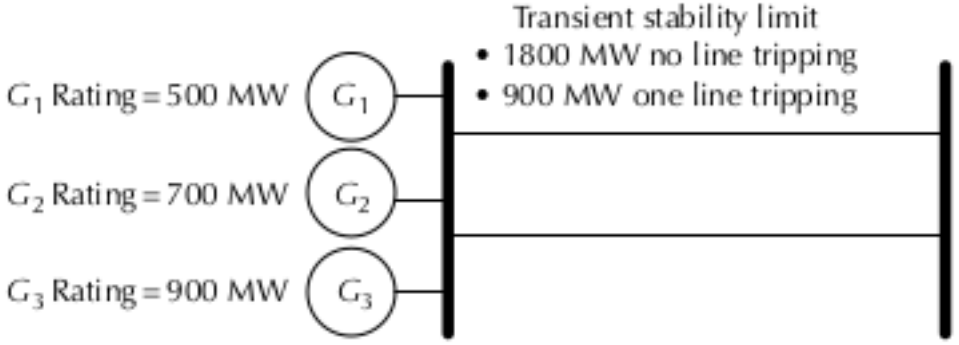
System operation



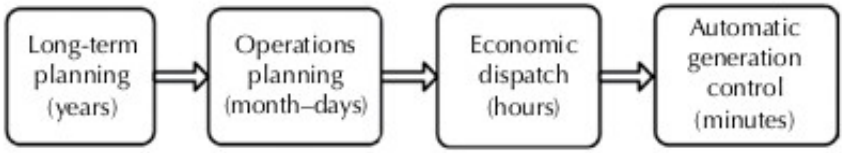
Acceptable operating conditions

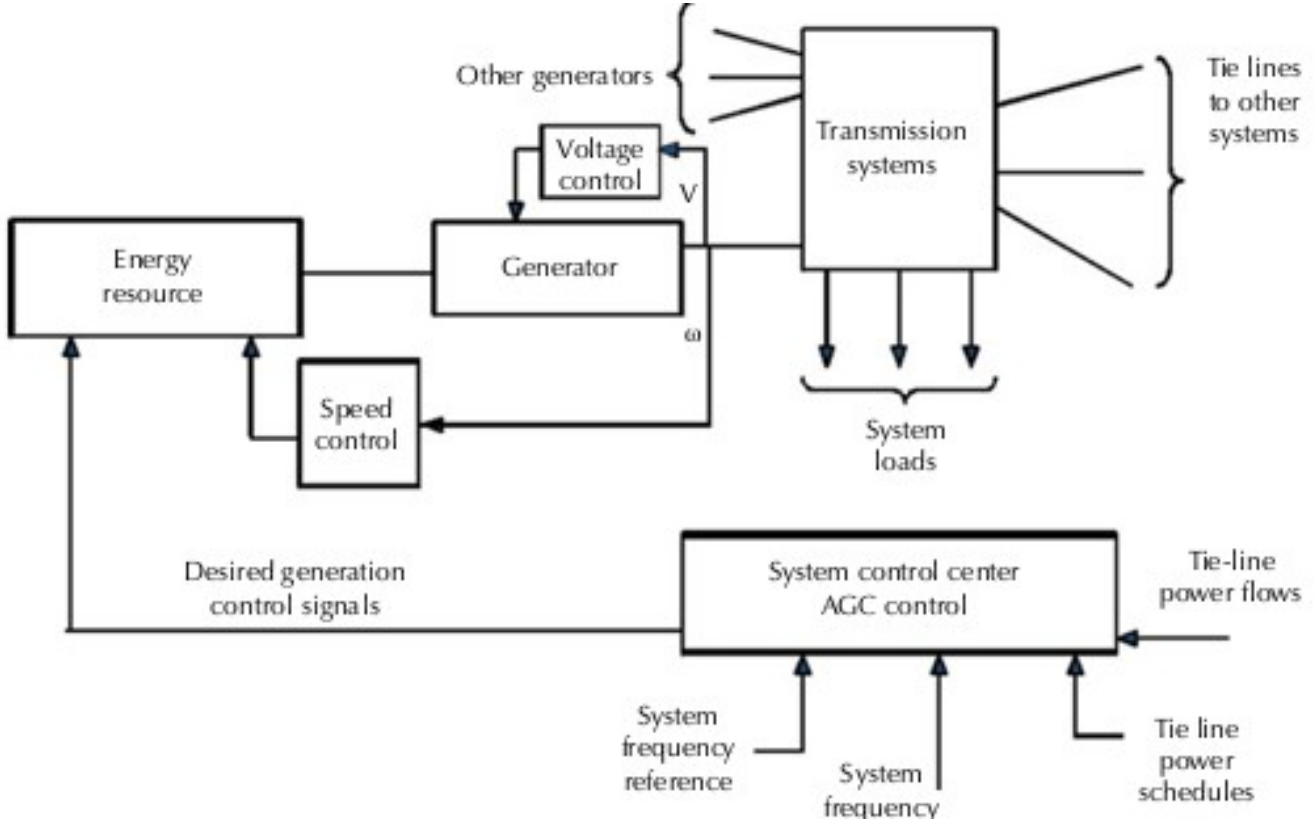


re 6.1 Acceptable operating conditions under normal conditions to avoid trans

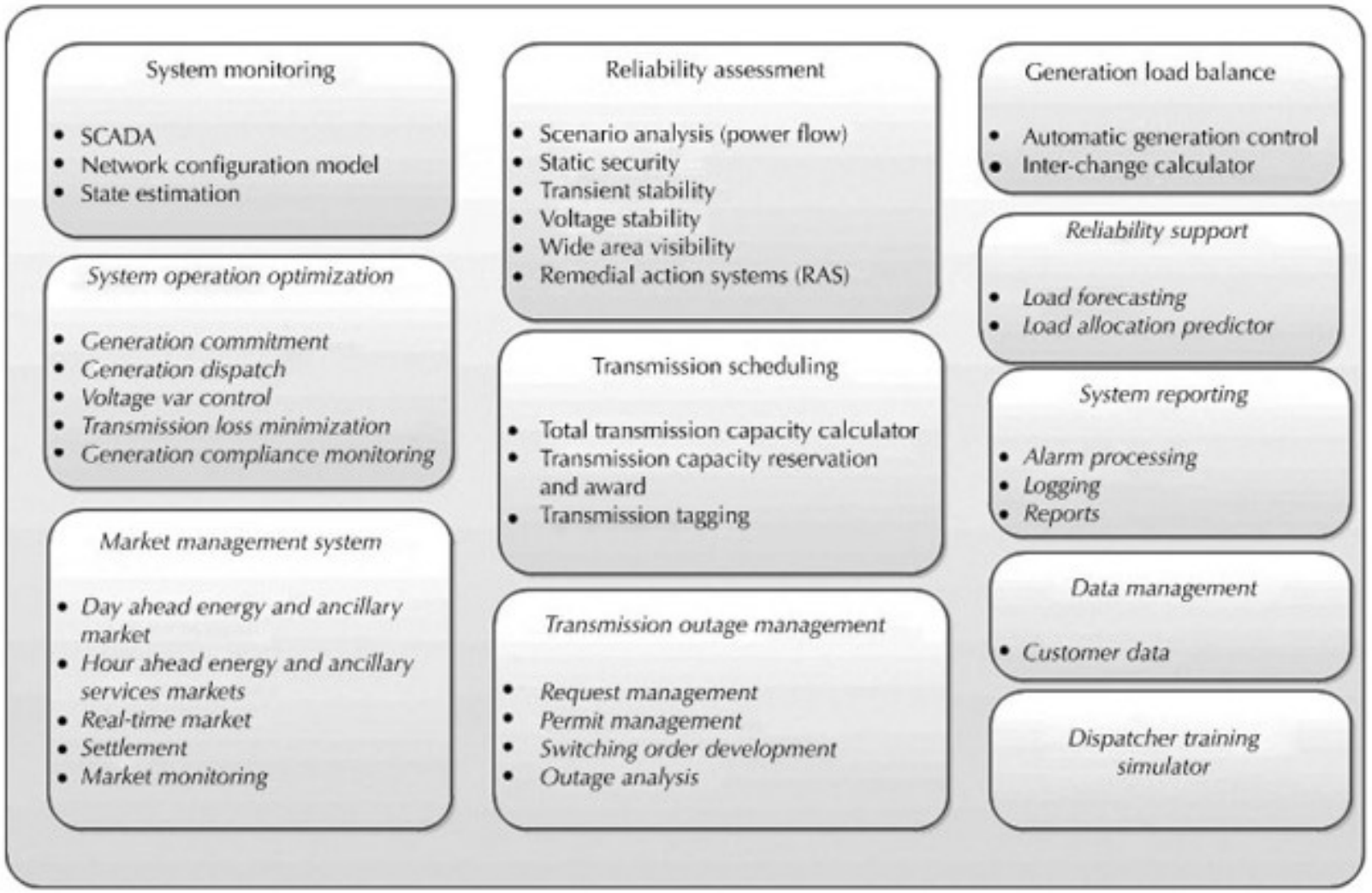


Generation planning & control





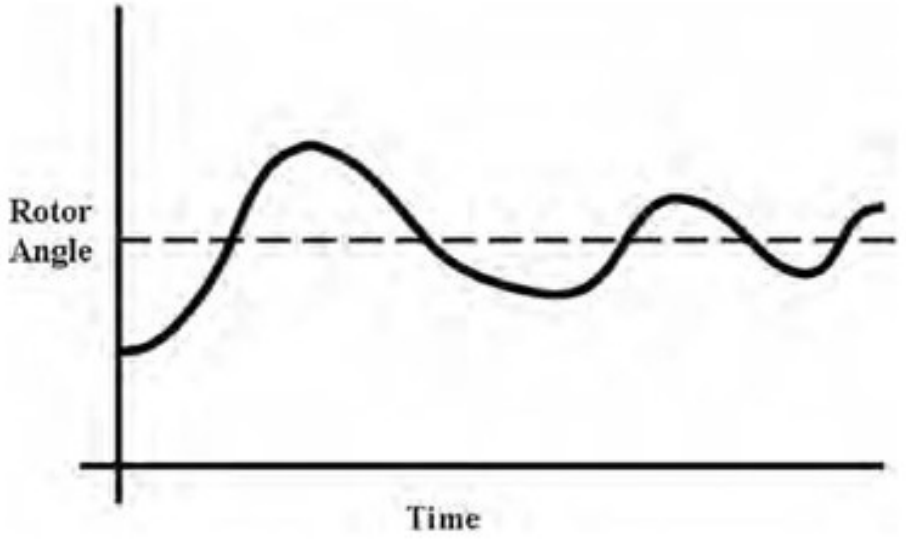
EMS

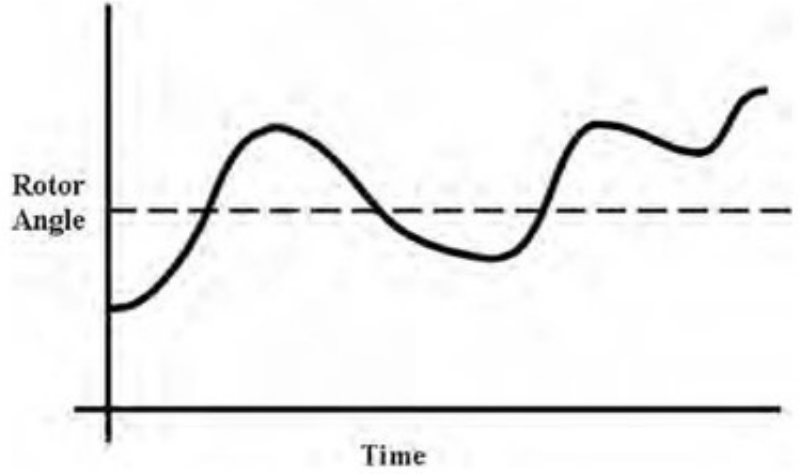

System monitoring
SCADA
Network configuration model
State estimation
System operation optimization
Generation commitment
Generation dispatch
Voltage var control
Transmission loss minimization
Generation compliance monitoring
Market management system
Day ahead energy and ancillary market
Hour ahead energy and ancillary services markets
Real-time market
Settlement
Market monitoring
Reliability assessment
Scenario analysis (power flow)
Static security
Transient stability
Voltage stability
Wide area visibility
Remedial action systems (RAS)
Transmission scheduling
Total transmission capacity calculator
Transmission capacity reservation and award
Transmission tagging
Transmission outage management
Request management
Permit management
Switching order development
Outage analysis
Generation load balance
Automatic generation control
Inter-change calculator
Reliability support
Load forecasting
Load allocation predictor
System reporting
Alarm processing
Logging
Reports
Data management
Customer data
Dispatcher training simulator

Inertia

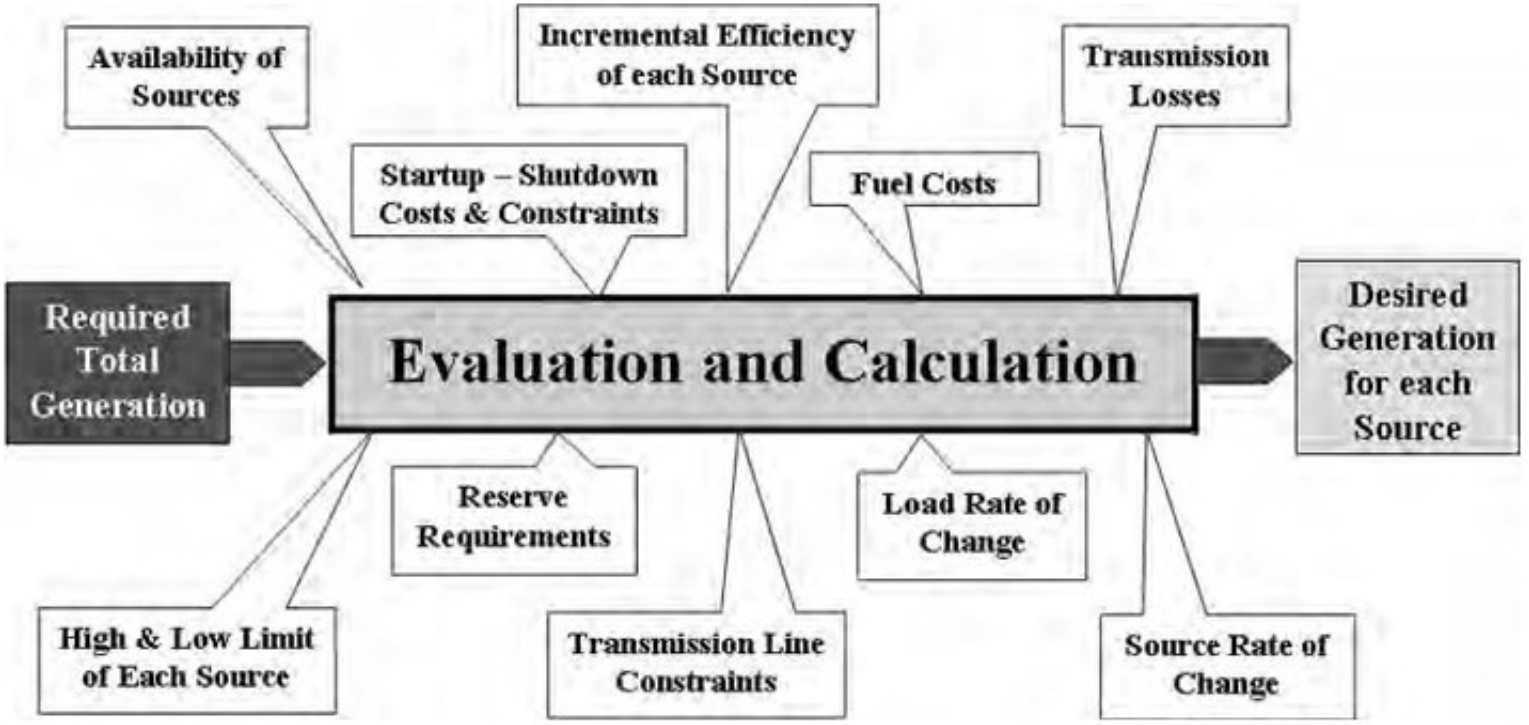
- Tendency to stay at rest or remain in motion
- The larger the object the more inertia
- Rotating machines not generator
- Power System Stabilizers (PSS)
  - Installed on gens
  - Governors control (the amount of steam/water to turbines)

System Stability/Instability



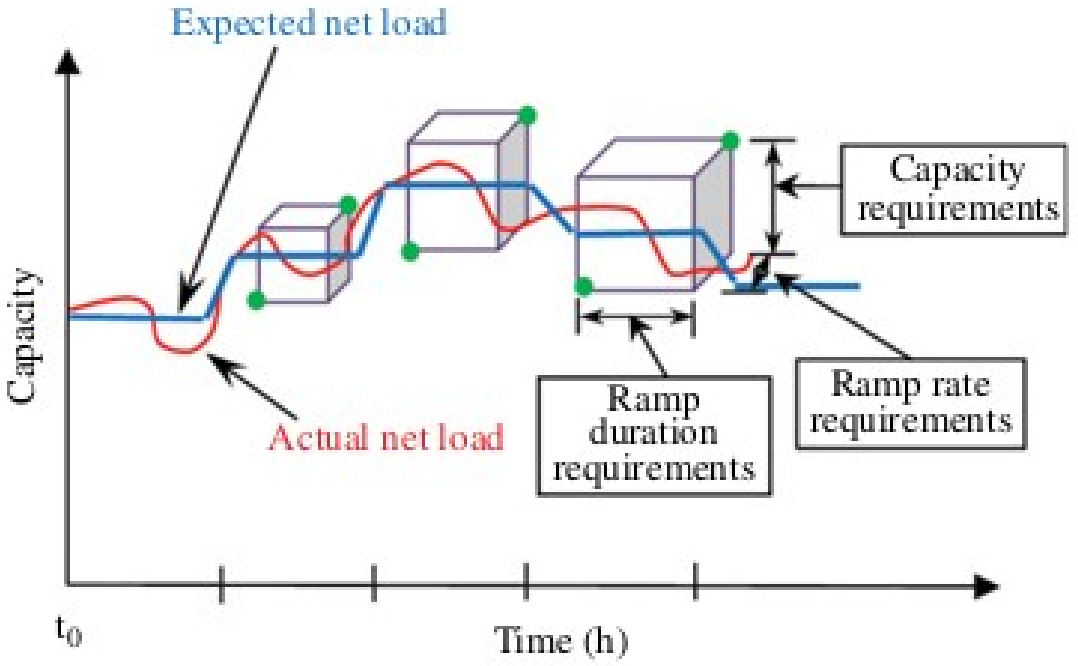


Generator Dispatch Factors



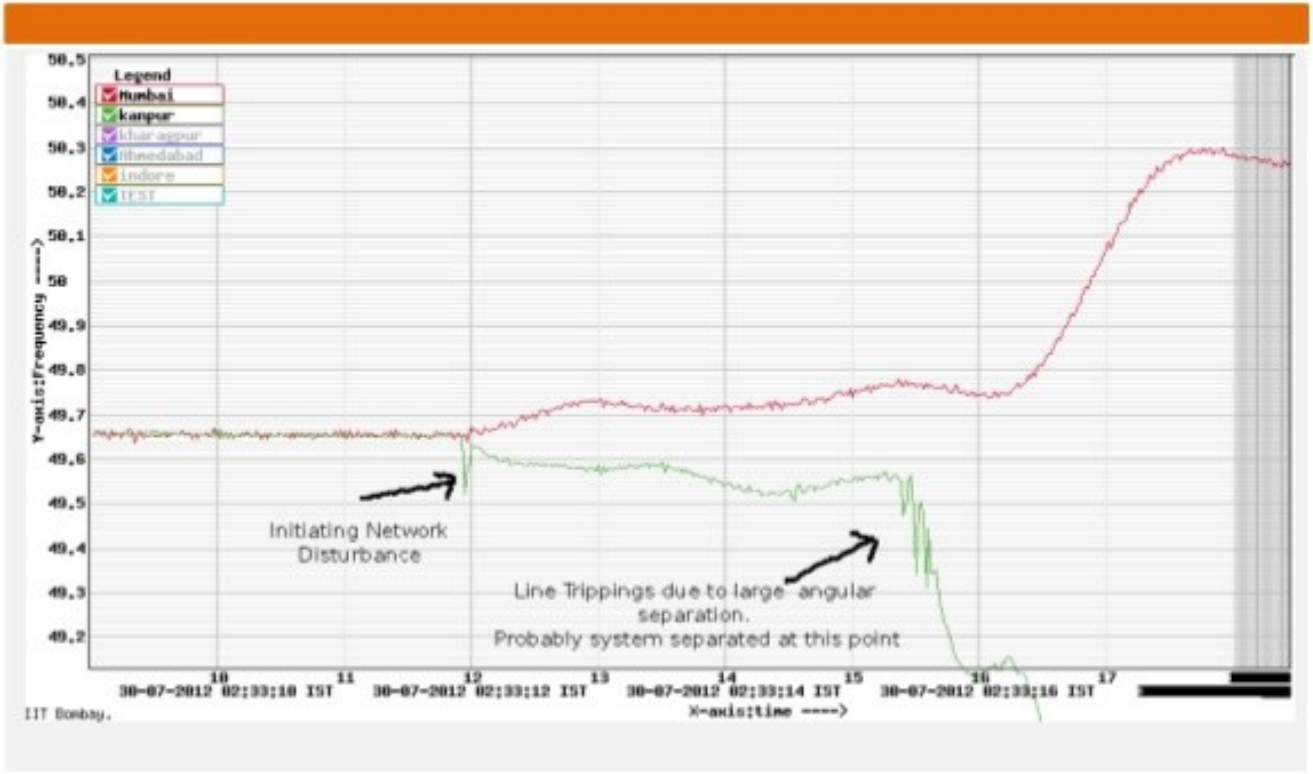
Three uncertainty

- Capacity
- Ramp rate
- Ramp duration



31 July 2012 – India Blackout

Frequency profile as captured by IIT Bombay



RESOLVE

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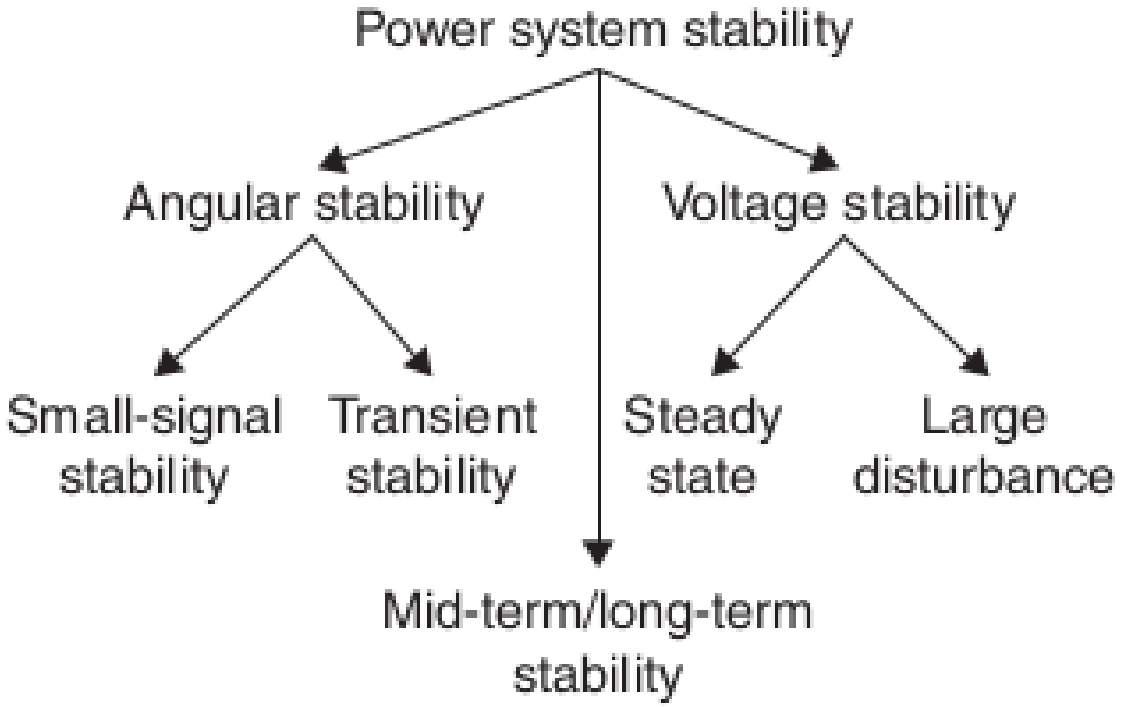
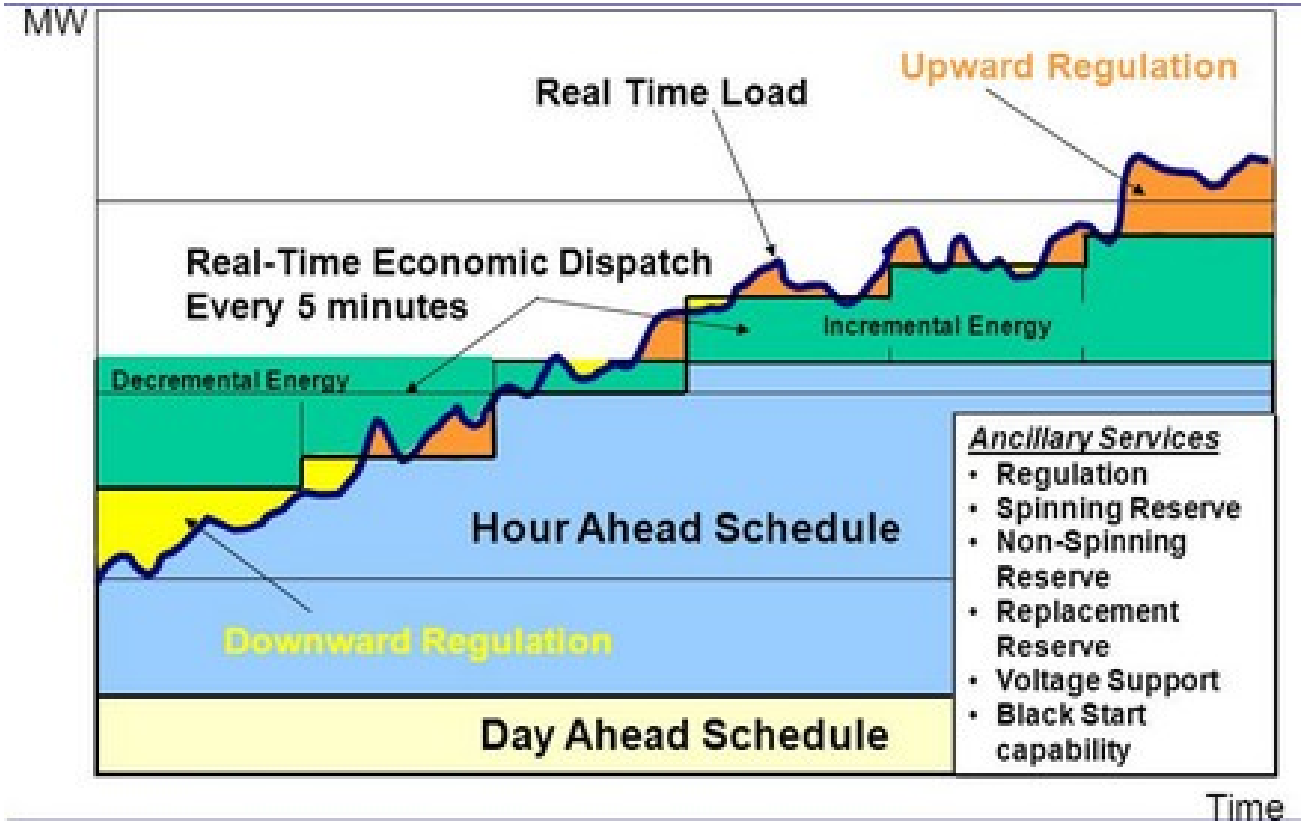
Power system stability



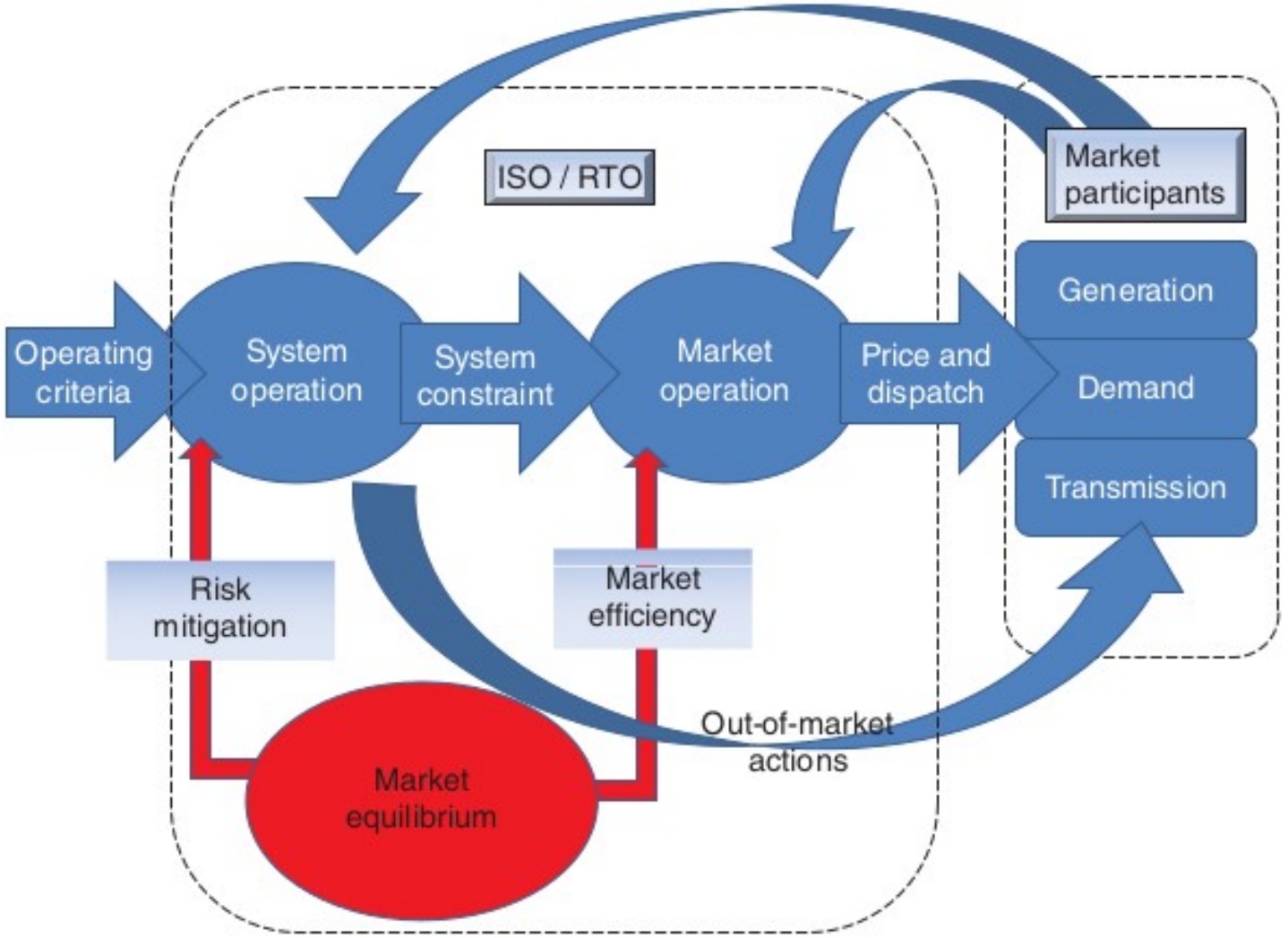
Ancillary Services

1. **Energy**
2. Regulation & Load Following Services – AGC/Real time maintenance of system's phase angle and balancing of supply/demand variations.
3. Synchronised Reserve – 10 min Spinning up and down
4. Non-Synchronised Reserve – 10 min up and down
5. Operating Reserve – 30 min response time
6. Voltage Support – RPS, Locational Specific
7. Black Start – (Service Contracts)

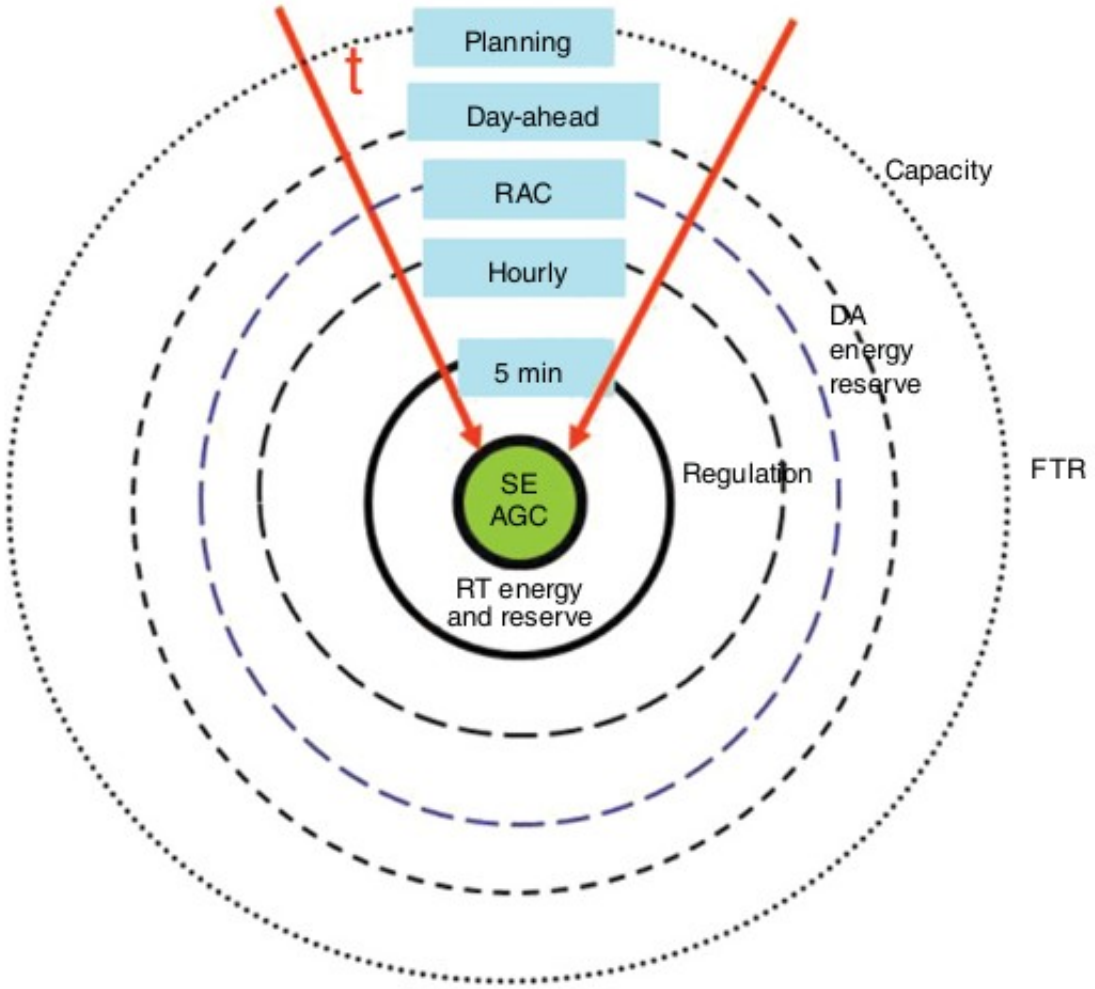
CAISO - balancing functions



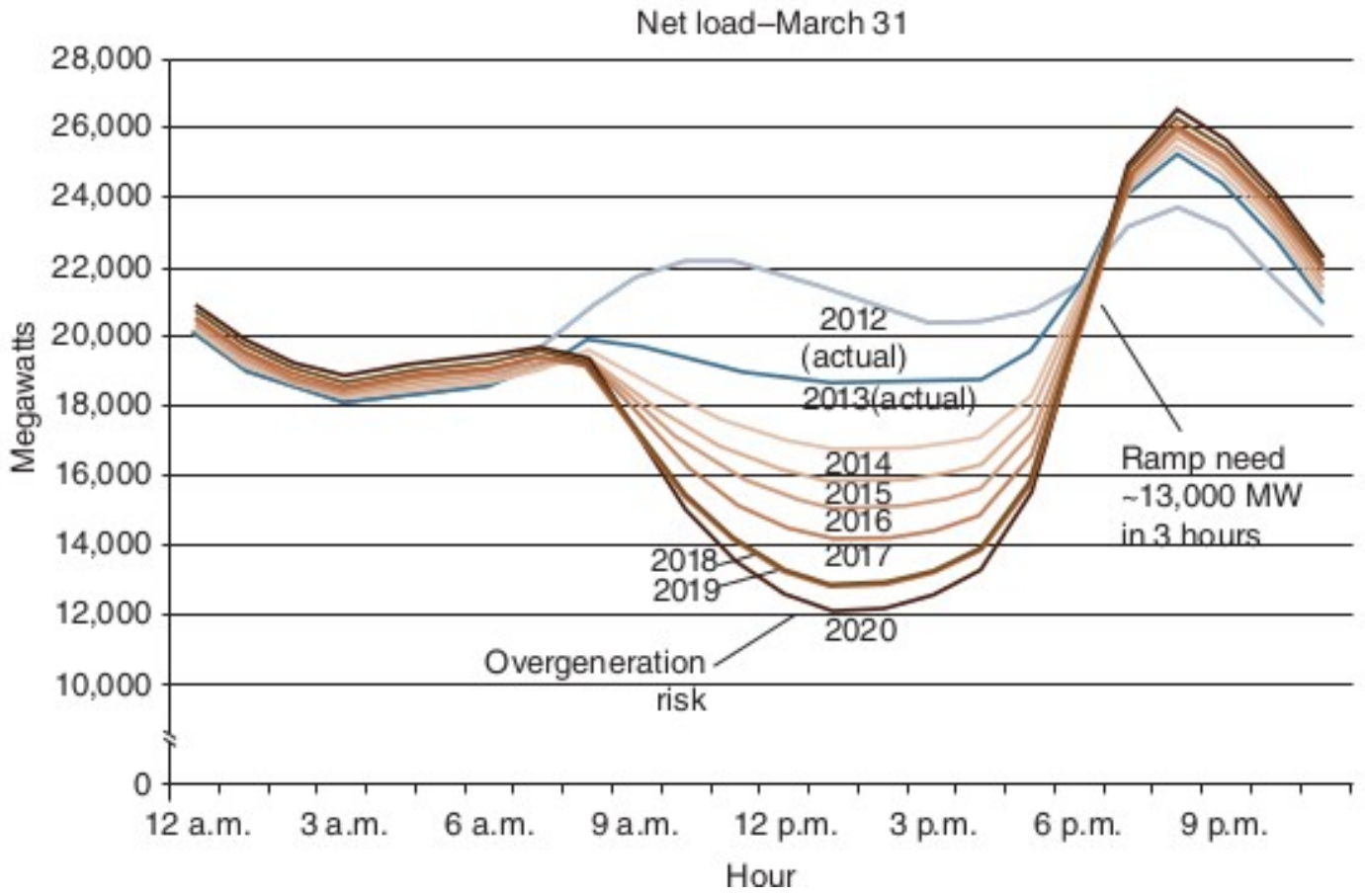
Integrated Operation



Multi-settlement market design

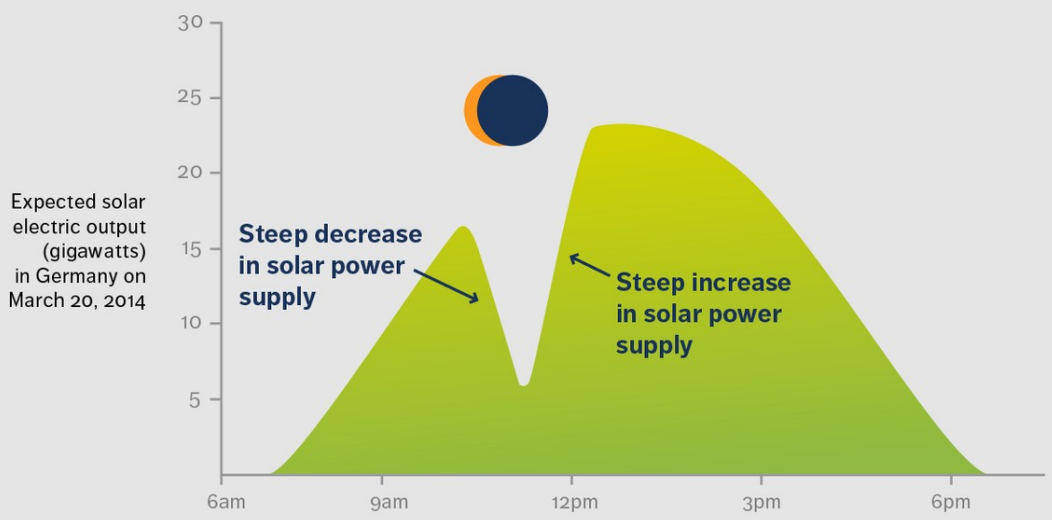


Duck Curve


Net load–March 31
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
0
Megawatts
12 a.m.
3 a.m.
6 a.m.
9 a.m.
12 p.m.
3 p.m.
6 p.m.
9 p.m.
Hour
2012
(actual)
2013(actual)
2014
2015
2016
2017
2018
2019
2020
Ramp need
~13,000 MW
in 3 hours
Overgeneration
risk

Solar eclipse

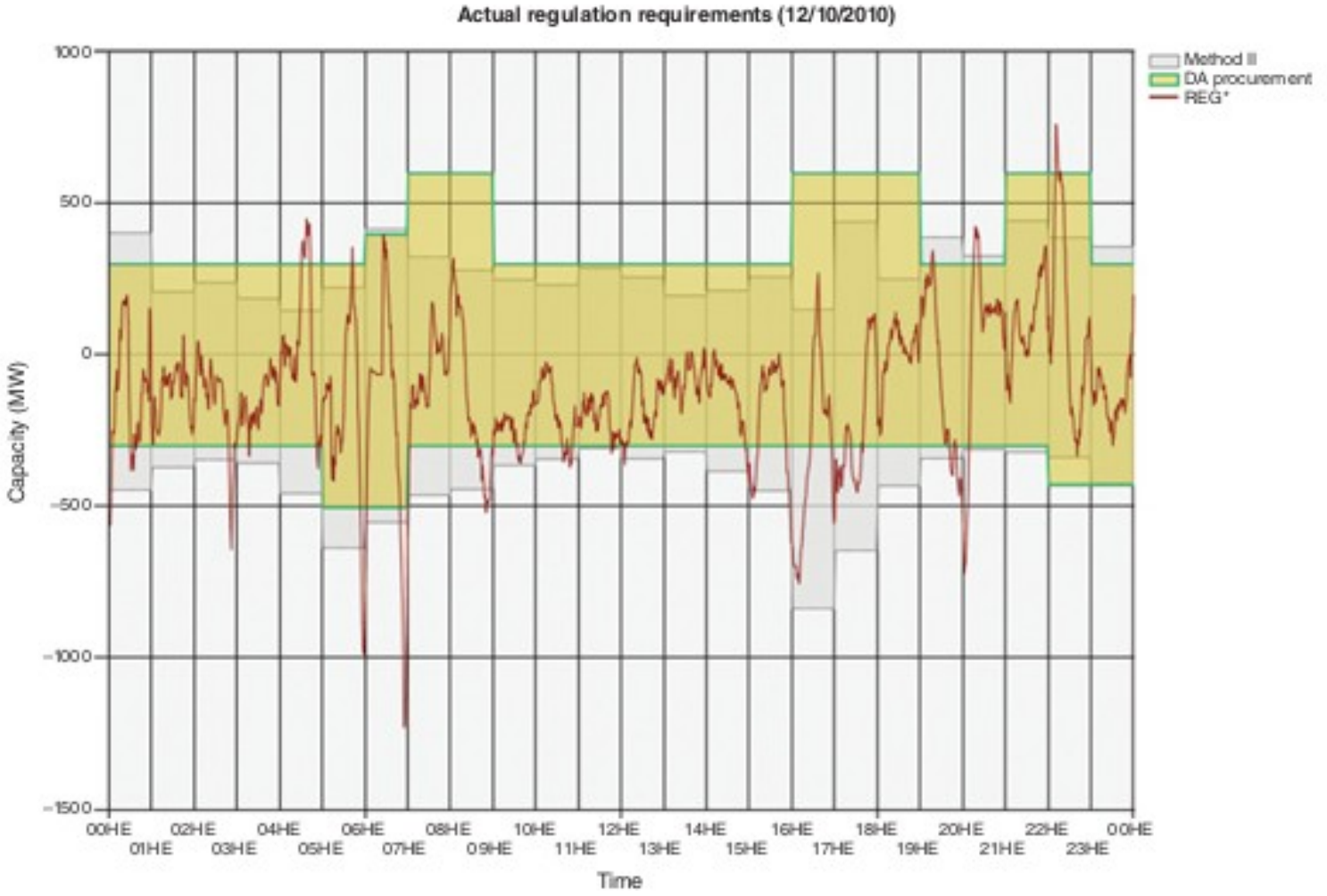
Germany's eclipse is poised to cause a rapid decrease in solar power supply, followed by a rapid increase.



Modeled values assume clear-sky (i.e. cloudless) conditions.
Adapted from source: Hochschule für Technik und Wirtschaft Berlin (October 2014).

OPOWER 2015

How regulation works



ACE (Area control error)

- Certain typles of generating units can move up and down in 4s. (regulation units)
- AGC (Automatic generation control)
  - Output of regulation units adjusted (secondary)
- Governors are primary frequency controls

In Europe

- Primary freq reserves
  - 30 seconds
- Secondary freq reserves
  - 15 minuts
- Tertiary freq reserves
  - Slower, take primary&secondary back to reserve

Network Security

- Contingency
  - N-1
- Facility Thermal Limitation
  - Can cause conductors to sag or stretch

Thank you

- For more info

  www.barissanli.com