

HISTORICAL POWER SYSTEM ARCHITECTURE



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TECHNOLOGY CHANGES



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WHAT IS CONTROLLED? AND HOW?

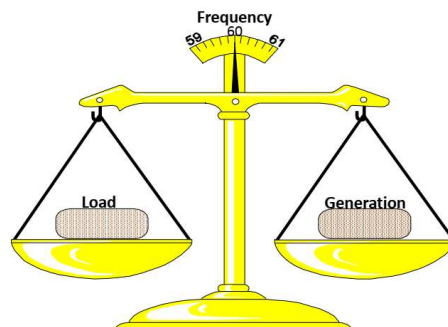


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FREQUENCY INDICATES ENERGY BALANCE

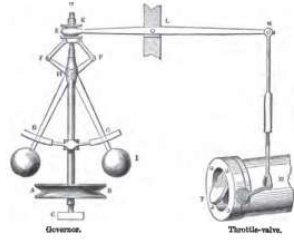


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GENERATOR GOVERNOR



REAL-TIME OPERATIONS



GENERATOR DISPATCH: CLASSICAL APPROACH

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- Base load
- Intermediate (mid) load
- Peaking units



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MEASURES OF PERFORMANCE PLANNING VERSUS OPERATIONS

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REMOTE GENERATION



GENERATION SOURCES (HISTORICAL)



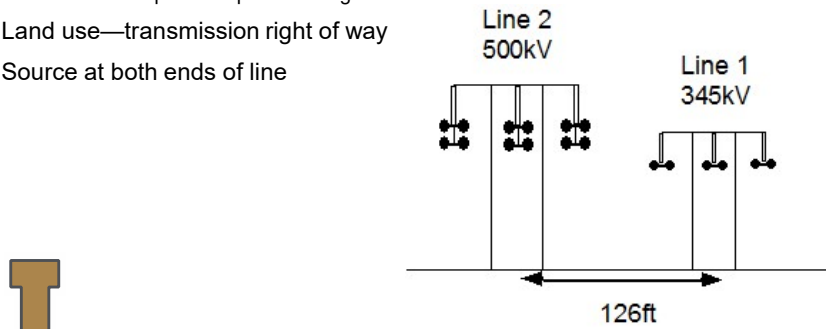
POWER LINES

Voltages approx. 132kV and up

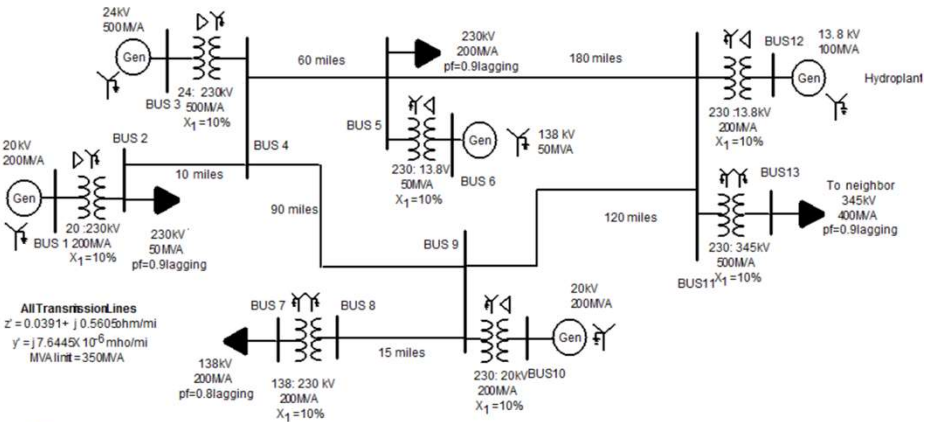
- EHV 345 kV and above
- This is RMS phase to phase voltage

Land use—transmission right of way

Source at both ends of line



TRANSMISSION



SUB TRANSMISSION

- Definition voltage level varies by utility
- Typically 34.5-132kV
 - Shorter lines
 - Connect transmission to distribution substation
- Often connected such that have an equivalent source at each end



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DISTRIBUTION

- Typically, below 24kV
- Mostly radial systems with normally open switches that can be closed
- Often unbalanced
- Traditionally design assuming no power sources connected to system
- Extensive facilities for most utilities



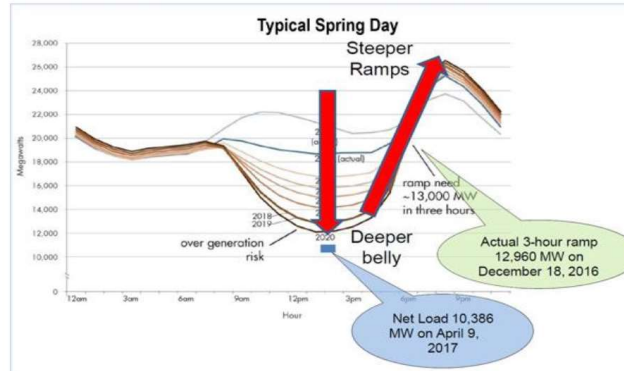
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CAL ISO "DUCK CURVE"

- Net load falls in middle of the day
- Peak in evening
- Potential for steep ramps

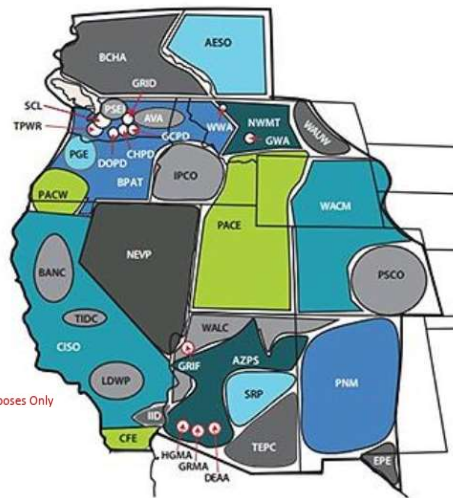


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BALANCING AUTHORITIES



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BALANCING AUTHORITY RESPONSIBILITIES

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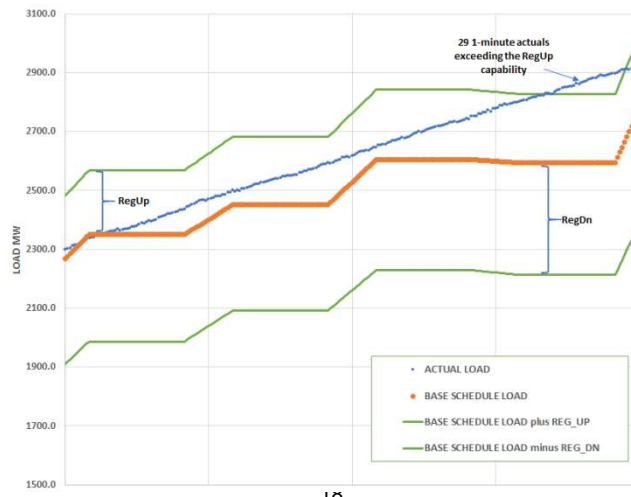
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MAINTAINING REGULATING RESERVES

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POLICY AND REGULATION

- Public Utilities Regulatory Policy Act (PURPA)
 - Federal rule requires utilities to buy output of qualified facilities regardless of need
 - Implemented state by state
 - Varies by state
- Renewable portfolios



FERC ORDERS 888/889

- Functional separation of merchant and transmission functions
- Transmission service equally available to all players in market
- Open access same-time information system



EMERGING ARCHITECTURES

Traditional Power Grid Arch

- Still largely used in states that haven't embraced reregulation

Emerging Architectures

- Impact of markets
- Ownership of gen, trans, dist
- Distributed generation-wind, PV (large/small)
- Merchant transmission
- Storage (past, present and future)
- Control of load (demand response)



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ABNORMAL SITUATIONS - POWER OUTAGES

- Natural disasters
 - Example:
 - Destructive Northwest windstorm (Nov 16, 2015)
 - 522,000 customers lost power in the territory
 - Around 181,000 customers lost power in the central business district
 - Failure of generation or transmission equipment
 - Misoperation of the protective equipment
 - Cyberattacks can bring down parts of the system
 - Entire system less likely unless larger coordinated attack



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EXAMPLE

