ELECTRIC TRANSMISSION 101:

How the High-Voltage Grid Works and Who Regulates It

April 7, 2011, 10:00 am – 11:30 am
2325 Rayburn House Office Building

FACULTY:

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- ***Jay Caspary, Director of Transmission Development, Southwest Power Pool***
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Presented by WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

ELECTRIC TRANSMISSION: Operational Characteristics

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CLEAN LINE ENERGY PARTNERS

2

Objectives

Primary objective is to understand how the power system* operates in 20 minutes or less with emphasis on transmission.

- Understand the elements of the bulk power system
- Understand basic physics and control of the system
- Understand the practical limitations to the system
- Understand what options exist in overcoming the limitations and why they are important.

* Note it is the presenter's opinion that the power system is the largest, most complex machine ever designed by humans so this task is monumental

3

Basic Definitions and Components of the Power System

4

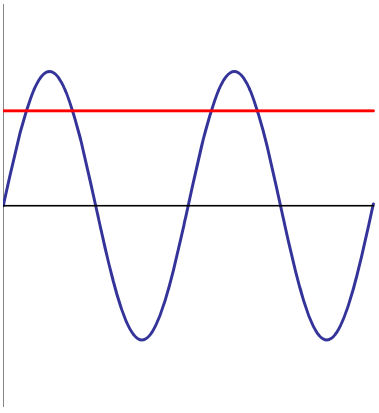
Basic Definitions

- Voltage – electrical "pressure" measured in volts. For power systems we typically measure in 1000's of volts or kilovolts (kv)
- Current – the movement of charge (electrons) through a conductor. Measured in Amperes (A)
- Power – Rate at which electricity does work. Measured in Watts or more typically kilowatts (kW) or megawatts (MW)
- Energy – The amount of work that can be done by electricity. Measured in Watt-hours or more typically kilowatt-hours (kWh) or megawatt-hours (MWh).

5

Basic Definitions

- Alternating Current – (AC). Magnitude of current varies with time. Most of grid is AC
- Direct Current (DC) – magnitude of current is constant. Applications of high voltage direct current (HVDC) in U.S. and elsewhere.



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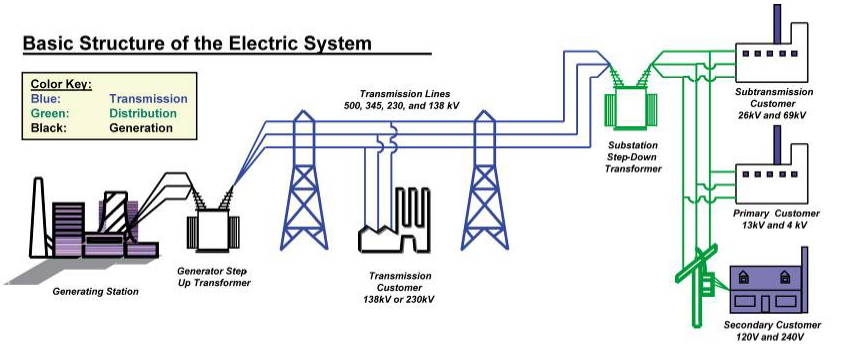
Basic Definitions

- **How much is 1 Megawatt (MW)?**
  - 1 MW is one million watts.
  - 1 MW will power 10,000 one hundred watt light bulbs
  - 1 MW will power about 800 “average” homes in North America or about 250 “average” homes during the summer in Phoenix

7

Components of the Grid: Overview



Source: www.nerc.com

- The “grid” can be broken down in to four main components: Generation, Transmission, Distribution, and Load
- This diagram is a basic overview, but does not truly illustrate the *HIGHLY* interconnected nature of the transmission system.

8

Components of the Grid: Generation




- "Creates" electric energy
- Generation is fueled by coal, nuclear, wind, gas, biomass, solar, and hydro.

9

Components of the Grid: Load



- "Consumer" of electric energy
- Loads can be smaller than your cell phone hooked to its wall charger (say 1 watt) or as large as an industrial facility (in the 10's of millions of watts)

10

Components of the Grid: Distribution

- Primary purpose is to serve loads (your house is connected to a distribution system)
- Generally radial (non-networked) in nature
- Not used for interstate commerce

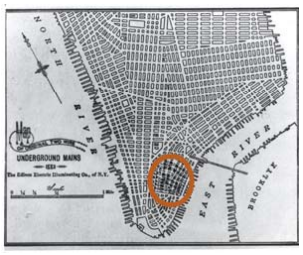
11

Components of the Grid: Transmission

- Used to move power long distances from generators to load with low losses.
- Highly interconnected for enhanced reliability
- The “interstate system” for electricity
- Traditionally built to enhance reliability for vertically integrated utilities.
- Now a critical part of the electric markets

12

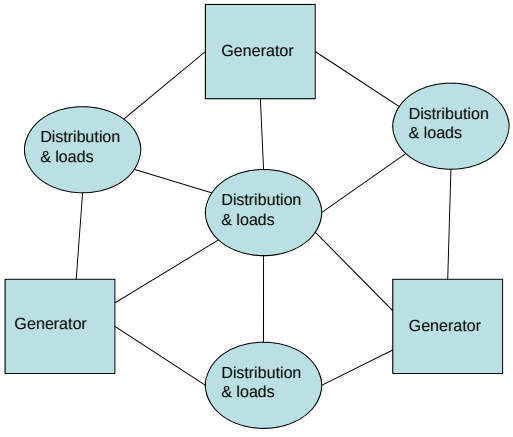
Without Transmission



- **Pearl Street Station: 255-257 Pearl Street, Manhattan**
  - First central power plant in U.S.
  - Edison Illuminating Company
  - 1882 – 1890
  - Direct current
  - 508 customers
  - 10,164 lamps

13

With Transmission

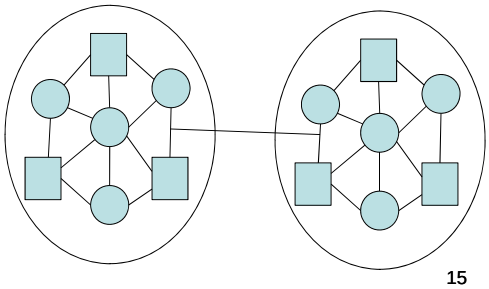


- We can build generation in areas removed from the loads
  - More desirable environmental and fuel factors
- We can build larger, more efficient generators
  - Economies of scale
- We can get power to remote areas with lower losses
  - Rural electrification

14

With Transmission

- We can create robust interconnected networks
  - Increased reliability
  - Decreased costs
  - Makes possible power pools, markets, bulk power transactions



15

Components of the Grid: Transmission

- Unlike highways, pipelines, and telecom, the flow of electricity can not be routed or controlled. Power flows via the path of least resistance. This is a critical difference in how the grid differs from other transportation mechanisms

16

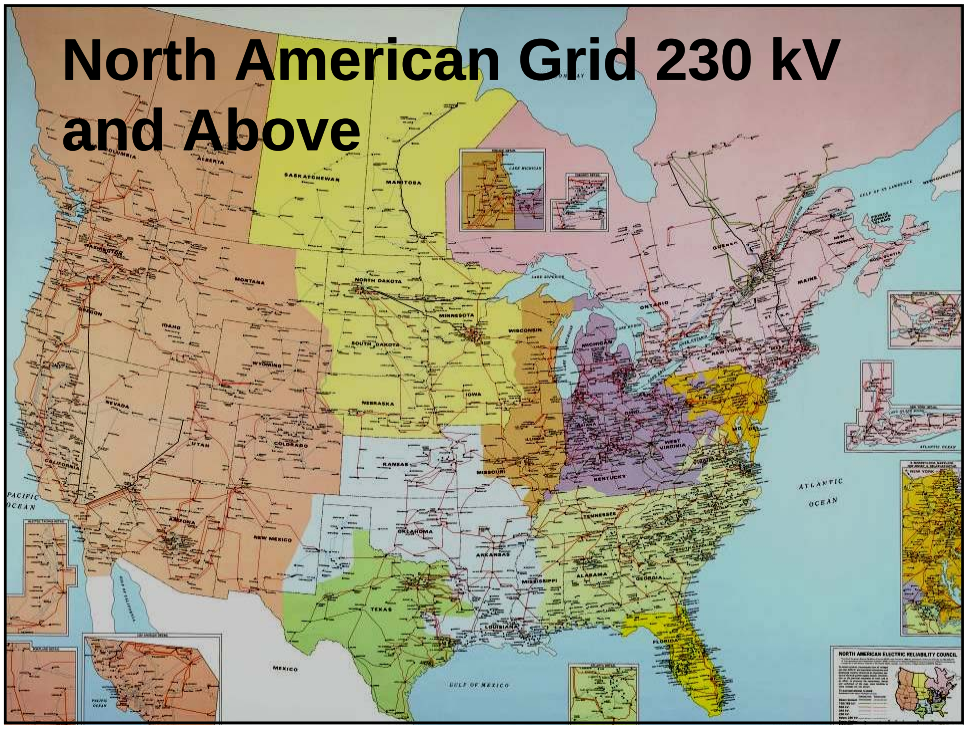
How the Grid Is Controlled

17

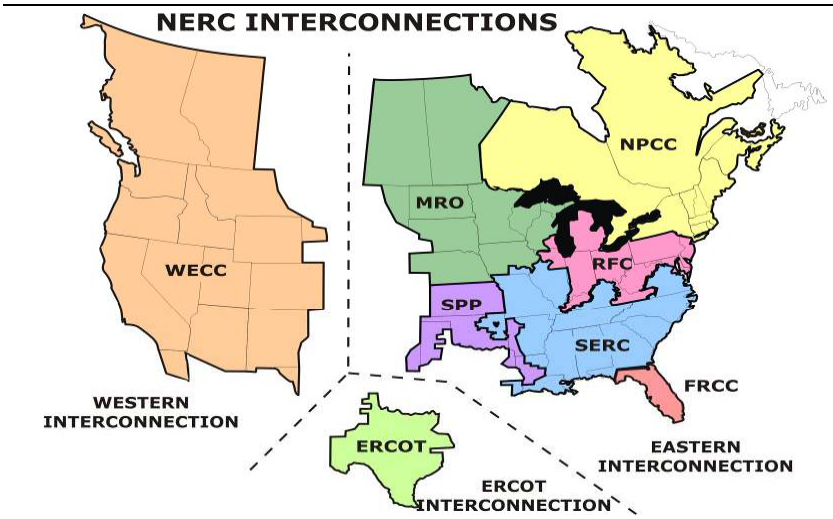
Interconnected Operation

- Power systems are interconnected across large areas. For example, most of North America east of the Rockies (with exceptions for Quebec and most of TX) is an interconnection.
- Individual utilities within each interconnection own and operate a small portion of the system (a balancing area).
- Transmission lines known as “tie lines” connect the individual utilities to each other.

18



3 Major Interconnections and 8 Regions



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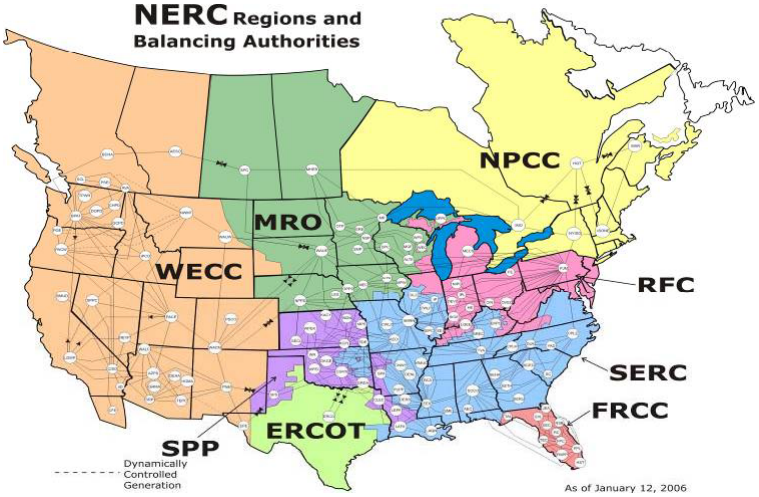
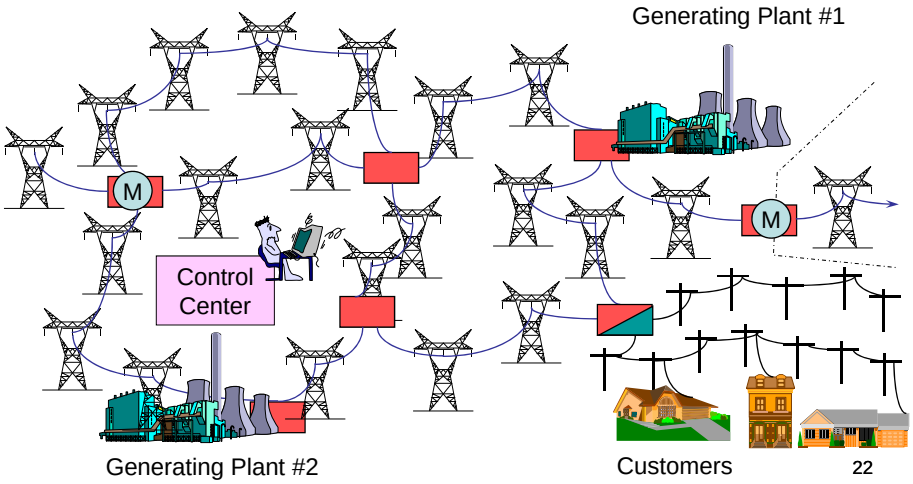
3 Major Interconnections, 8 Regions, 135 Balancing Authorities



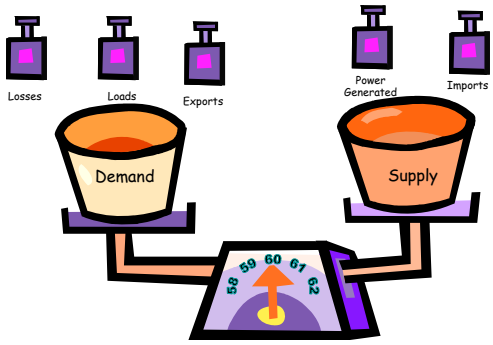
21

The Balancing Authority and System Control



22

Supply – Demand Balance: The Goal of the System

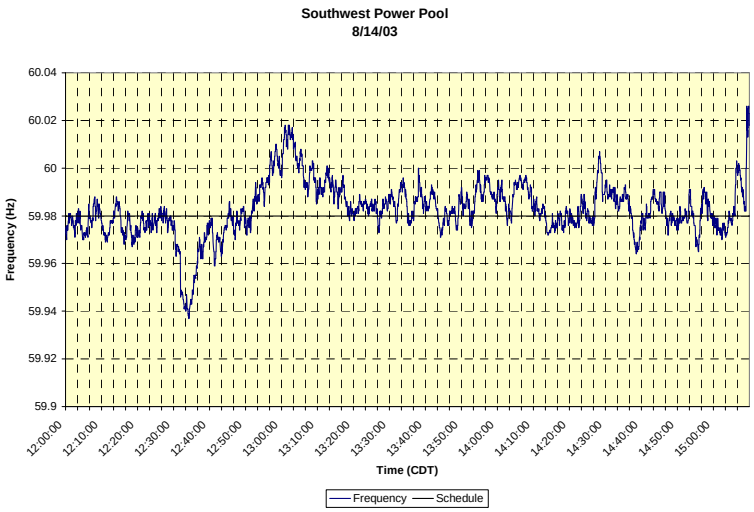


- Electricity by nature is difficult to store.
- Supply must equal demand at any given instant.

Interconnection frequency needs to be maintained close to 60 Hertz at all times (for any instantaneous demand).

23

Interconnection Allows for Reliability and Control – August 2003 Blackout example



24

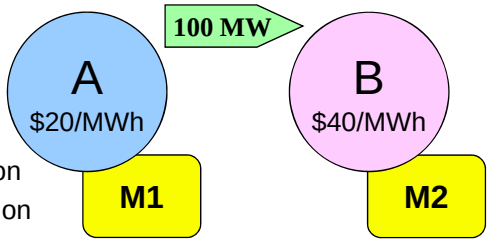
Power Flow Across the Grid

25

Simple Bi-lateral Transaction – My Best Attorneys Finalized the Contract

Sale from A to B at 4-5 pm of 100 MW

- 3:40 pm Schedule
- 3:55 pm Confirm
- 4:00 pm Begin interchange
  - Seller increases generation
  - Buyer decreases generation
- 5:00 pm End
  - Seller decreases generation
  - Buyer increases generation

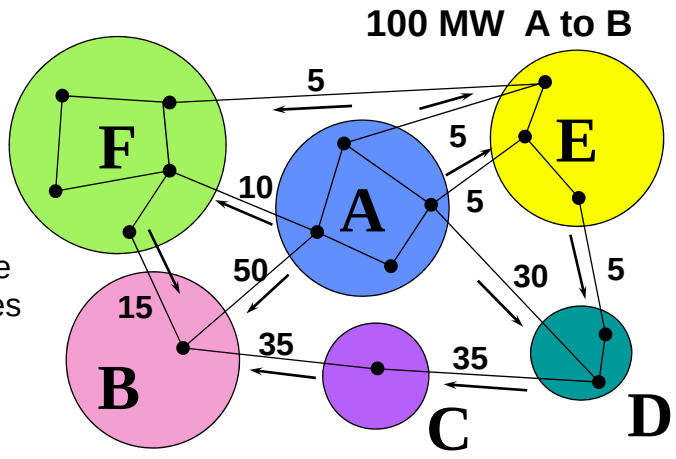


Areas A & B may be separated by thousands of miles. Price may be affected by various factors including transmission congestion

26

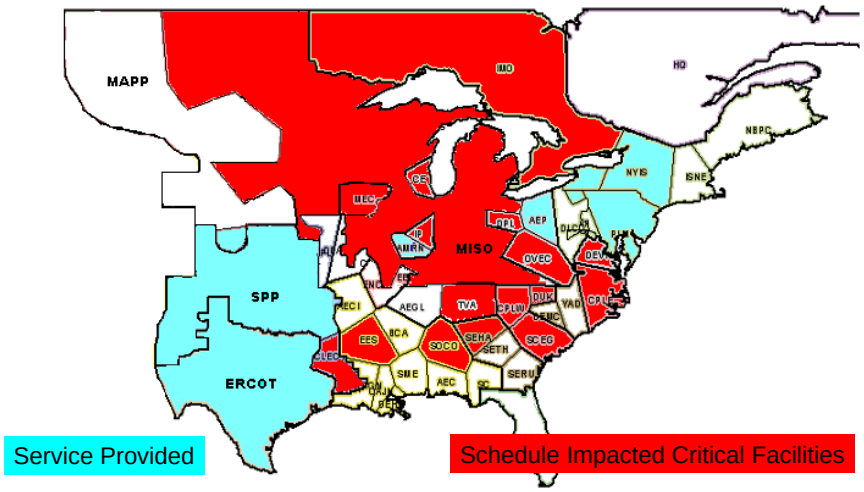
Power Flow Dictated By Laws of Physics, Not My Contract

Contrary to popular belief, the power from A does NOT flow directly to B despite my best contract negotiating skills.



27

Power Flow Dictated by Laws of Physics – Typical Power Transaction Impacts



System Limitations

29

System Limitations

- **Thermal limitations**
  - Overheating of lines, transformers, components
  - Line sag
- **Stability**
  - Angular --disturbances on the system (switching, contingencies, etc) may cause the system to become unstable. Think of controlling a car in an evasive maneuver if your shocks are gone.
  - Voltage -- High demand/loading on transmission can cause voltages to become unstable and difficult to control.
- **Contingencies**
  - Some capability left unused to handle failures

30

System Limitations Create CONGESTION

- All the aforementioned limitations are worsened by the lack of appropriate transmission.
- The limitations create *CONGESTION* on the system which results in uneconomic use of generation.
  - Re-dispatch means using less economic generators
  - Reserve margins may need to be higher to maintain reliability
  - Potential for market power increases
  - Need for ancillary services

31

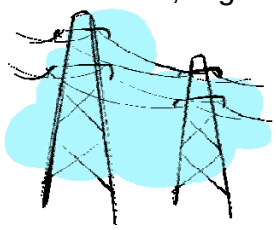
Electric Transmission: Regulation

Mason Emnett
Office of Energy Policy and Innovation
Federal Energy Regulatory Commission

32

Transmission Regulation Overview

- Transmission is regulate by a mix of federal, regional, state, and local rules
  - Ratemaking
  - Operation
  - Planning
  - Siting
  - Reliability



- Collectively, transmission-related regulations affect the ongoing reliability of the system and ability to add new generation to the overall mix of electricity resources
- A robust national electric grid is key to competitive markets and achievement of public policy goals at the federal and state level (such as the addition of renewable resources like wind)

33

Transmission Ownership/Operation

- **Ownership of the transmission grid is fragmented - hundreds of discrete owners**
  - Roughly two-thirds of U.S. transmission is owned by investor-owned utilities; roughly one-third is owned by public entities
  - Ownership affects regulatory jurisdiction
- **Many transmission owners have turned operational control over to regional operators**
  - Regional operators serve roughly two-thirds of electricity consumers in the United States
  - Operational control also affects regulatory jurisdiction

34

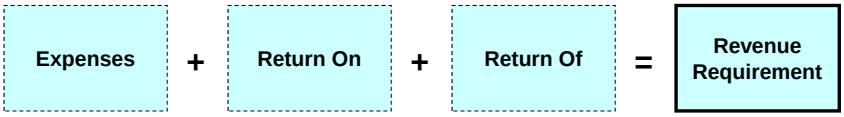
Federal Regulation

- **A number of federal entities have authority over transmission related matters depending on location and market structure, including:**
  - Federal Energy Regulatory Commission
    - regulation of utility corporate matters, rates for some transmission owners, reliability
  - Department of Energy
    - policy, data collection and analysis
  - Department of Agriculture/Forest Service, Department of Interior/ Bureau of Land Management
    - rights of way and land use management
  - Federal Utilities
    - ownership and operation of facilities

35

FERC Authority

- Federal Energy Regulatory Commission regulates interstate transmission rates for public utilities
- General Ratemaking Principles assure rates and terms are just and reasonable and not unduly discriminatory
  - Largely driven by embedded system costs, not cost of serving the next user
  - Based on “cost of service” principles
  - Revenue requirement is the amount needed to cover operating expenses, taxes, interest, and a reasonable rate of return



36

FERC Authority (cont'd)

- **Uses ratemaking authority to ensure open access to transmission facilities**
  - Non-discriminatory access by generation seeking to deliver to the market
  - Open access applies to transmission used in interstate commerce (including unbundled retail transmission, but not bundled retail transmission)
  - Transmission planning subject to open and transparent rules
  - Pending rulemaking on further planning reforms and cost allocation for new transmission lines
- **Adopts and enforces reliability standards**
  - Standards are developed by the North American Electric Reliability Corporation (NERC)

37

FERC Authority (cont'd)

- Backstop siting authority for "national interest electric transmission corridors"
- Monitors energy markets to protect customers from market manipulation
- Authorizes public utility asset dispositions and mergers over $10MM
- Oversees issuance of certain securities
- Resolves disputes among market participants

38

State Regulation

- A number of state entities play a role in transmission issues:
  - Public Service/Public Utility Commissions (retail rates, siting)
  - Environmental agencies (land use, siting, environmental standards)
  - Legislatures
  - Local Authorities (siting)
- States rules and requirements for transmission siting are not uniform and there are no formal compacts; many states have no siting rules and may be governed by local authorities
- Most states regulate retail electric rates that end use customers pay, including the collection of transmission revenues
- Land use, contracts, corporate matters (e.g., public utility status) eminent domain are usually under state law
- There are entities that are not under state regulation, such as municipal utilities, cooperative utilities and others

39

Regional Operators

- Regional Transmission Organizations and Independent System Operators have been created by regional stakeholders in response to FERC's Orders 2000 and 888, respectively, to:
  - Facilitate competition among wholesale suppliers
  - Provide non-discriminatory access to transmission by scheduling and monitoring the use of transmission
  - Perform planning and operations of the grid to ensure reliability
  - Manage the interconnection of new generation
  - Oversee competitive energy markets to guard against market power and manipulation
  - Provide greater transparency of transactions on the system
- RTOs and ISOs are subject to FERC jurisdiction
  - Participation by public entities in an RTO or ISO results in FERC jurisdiction over RTO/ISO-related activities
  - RTO/ISO market structure can affect state jurisdiction (e.g., resource adequacy)

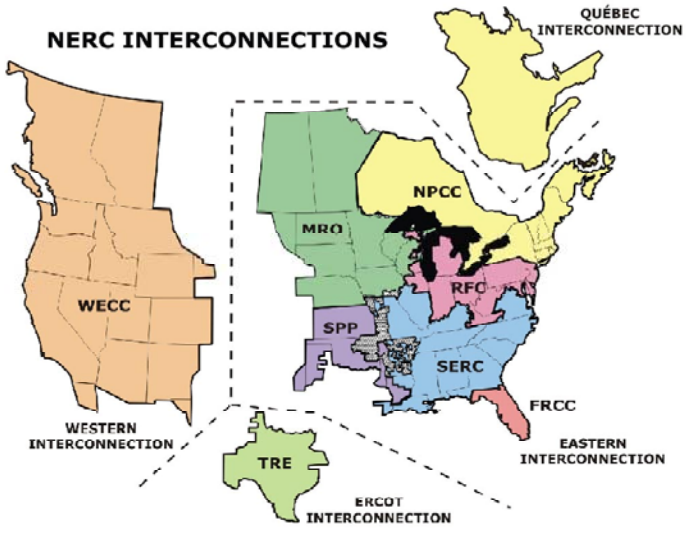
40

Markets, ISO/RTOs and Grid Planning/Operations

Jay Caspary
Director, Transmission Development
Southwest Power Pool

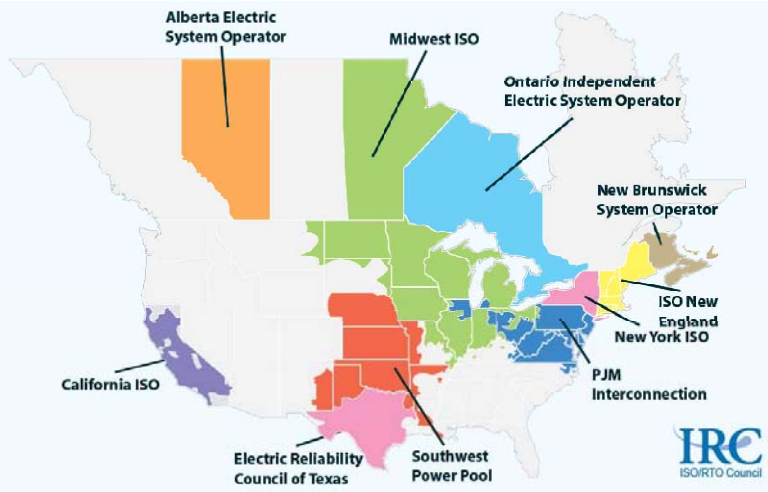
41

3 Interconnections / 8 NERC Regions



42

ISO / RTO Map



43

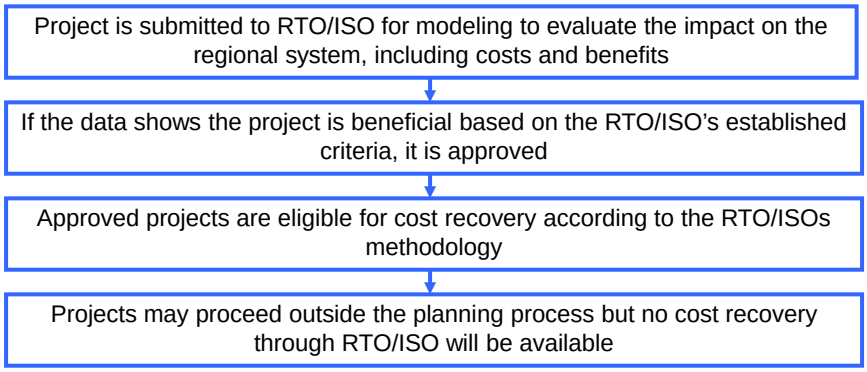
Regional Transmission Organizations Independent System Operators

- No standard market design for every ISO/RTO
- Manage and provide a central clearing house for transactions (transmission and generation) versus bilateral markets with parties working directly to establish terms and conditions
- Includes allocation of transmission rights, day ahead and spot market purchases
- Participants still negotiate bilateral arrangements as appropriate for business needs
- Provides more efficient grid management
- Participation is officially voluntary though FERC provides incentives to encourage membership

44

Regional Planning Process

RTO/ISO planning encompasses the regional footprint; stakeholders can provide input and advocate positions throughout the process



45

Bilateral vs. Organized Markets

- Bilateral contract – a buyer and seller negotiate directly and sign a two-party contract to trade electric power.
- Outside the RTOs/ISO—mainly the Southeast, the upper Great Plains, and the West outside of California, wholesale power trades occur through bilateral contracts.
- Areas outside RTOs and ISOs are often called "bilateral market" areas.
- In the RTOs and ISOs, there are both bilateral markets and "organized" markets that pool all sellers and buyers.
- In the RTOs, FERC's oversight of transmission is stronger because all transmission owners follow the RTO's or ISO's transmission policies approved by the Commission.

46

Regional Grid Enlargement in Bilateral Market Areas

- Outside RTOs and ISO, there are many types of transmission owners, only some regulated by FERC.
- FERC regulates only wholesale transmission by "public utilities."
- One-third of U.S. transmission is not owned by public utilities nor subject to full FERC wholesale regulation.
- States regulate most transmission for retail power sales.
- Transmission not fully regulated by FERC includes transmission owned by public power (governments), by most cooperatives, and by most of the utilities in Texas.
- Outside RTOs and ISO, FERC's ability to promote coordinated enlargement of the interconnected grid is weaker than in RTOs and ISOs because its policies to do not apply to all the owners of the interconnected system.

47

Some Obstacles To Carrying Out Regional Transmission Plans

- **Cost allocation**
  - A major obstacle to carrying out a regional plan is deciding "Who pays?" for it.
- **Transmission Siting**
  - Local transmission siting can be another obstacle to realizing a regional transmission plan.
  - EPAct 2005 gave FERC "backstop" siting authority in DOE designated areas.
- **Inter-Regional Planning is next frontier**
  - DOE funded efforts for each interconnection in process
  - FERC RM10-23 should provide guidance and direction.

48

A Western State Government Perspective

Rich Halvey
Energy Program Director
Western Governors Association

49

The Governors' Perspective

- New high voltage, interstate transmission is contemplated in support of renewable energy
- Decide on the appropriate generation mix and design transmission to accommodate it
- All potential clean generating technologies are on the table, including fossil fuels and nuclear
- While reliability and congestion management on the transmission grid are important, governors are as concerned about safety, cost, and state policy

50

The Changing Policy Landscape

- While states in the past were generally willing to let PUCs and the reliability authorities lead on transmission planning, the emergence of larger policy concerns (RPS, water, wildlife, lands issues) has stimulated engagement in current planning efforts such as the Regional Transmission Expansion Planning Project
- Governors and legislatures need to lead on balancing state interests against regional needs

51

State Perspectives

- Most states would prefer to use in-state sources of renewable energy before considering out of state sources because of the economic benefits associated with green energy
- There are states with tremendous export potential who would like to see transmission developed in a way that would allow them to market their renewable energy

52

Current Paradigm for Building New Renewable Energy Generation

- The current paradigm for renewable energy and transmission will not accelerate the current rate of renewable development; that will require policy or technology changes, or greater incentive
- Small projects on private land with no environmental concerns, near load centers
- Many minimally capitalized companies
- Disconnect between the time it takes to approve/build renewable energy and the time to approve/build transmission

53

Regional Perspective

- Every entity with an interest in a project expects their concerns to be satisfied (States, PUCs, utilities, developers, NGOs, land owners, financers)
- It is critical not to see individual projects in isolation, but to understand the larger implications of not doing a project
- If you take a regional perspective, it may be that there are not limitless combinations to meet any potential greenhouse gas emission limits, maintain reliability, meet demand, keep prices reasonable, and protect natural resources and wildlife

54

Regional Transmission Plans

- The need to build new transmission has to be driven by the outcomes related to environmental, natural resource, price, and engineering considerations agreed upon by policy/decision makers
- In other words, generation decisions need to precede transmission decisions, and generation decisions need to be based on more than just demand, system reliability and congestion management
- FERC necessarily has a much narrower focus than the states

55

Federal Lands

- Public lands issues in the West are enormous. All states have significant tracts under federal management (e.g., Nevada is 80% federally managed)
- There is growing sentiment that public lands should be considered before private lands for the location of renewable generation and transmission
- Approvals on public land take too long in part because there are time-consuming requirements with little value added

56

Policy Collisions

- Renewable energy has substantial land requirements (e.g., 500 MW of solar would need approximately 4,000 acres of land) and often the best resources are in areas with wildlife sensitivities
- Water is always in short supply in the West, and energy projects will compete with agricultural and municipal users

57

Right Sizing

- Lines need to be sized to accommodate current and predictable future demand
  - PUCs are generally unwilling to upsize lines and make existing ratepayers foot the bill
  - Federal government has an opportunity to pay the differential to right size lines and receive cost recovery when demand materializes

58

Cost Allocation

- Current cost allocation approaches in the West are acceptable to states
- WGA will examine future generation/transmission scenarios to determine if there may be alternative cost allocation schemes that work

59

Federal Pre-emption

- Generally, states either do not favor federal pre-emption for the construction of new transmission, or would only accept it in a few narrow circumstances

60

Closing
Jim Hoecker

Themes To Think About

- The transmission system is:
  - A massive, highly integrated machine
  - A basic component of a vibrant economy
  - Regional in operation
  - Impacted by many federal, state and local authorities
  - Essential to delivering remote clean energy resources
- Today's challenges to investment:
  - Planning
  - Cost recovery
  - Cost allocation
  - Siting

Questions? Contact us at www.wiresgroup.com

62

Contact Our Faculty

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63