Electric Transmission “101”
or
Everything You Wanted to Know About the Grid But Were Afraid to Ask

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Some Xcel Energy Statistics

Transmission Business
• 19,000 line miles in ten states; three NERC Regions
• $6.5 billion in transmission investment – 2012 through 2018
• #1 U.S. wind provider; #5 in solar energy
  ➢ Colorado wind near 60% of energy in some off-peak hours
  ➢ November 7, 2014, between 3 and 4 PM, served 56% of PSCO loads (2,169 MWs)

Environmental Leadership
• Since 2005 - system-wide CO₂ emissions reduced 19%
• On track for 31% CO₂ reduction by 2020
What is the “Grid?”

The networks that carry electricity from the plants where it is generated to consumers. This includes wires, towers, poles, substations, transformers, switches and other related devices.
Electricity Basics

- **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 is transferred. 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).
How much is 1 Megawatt (MW)?

- 1,000 watts is 1 kW
- 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
How Is Electricity Measured?

One 15-Watt Light Bulb  Used 5 Hours Per Day  For 30 Days

Totals 15 Watts of Power for 150 Hours or 2.25 kWh
Components of the Grid

The “Grid” can be broken down into four main components: Generation, Transmission, Distribution, and Load.
Components of the Grid – Generation

• “Creates,” or generates electric energy using a variety of fuel sources. including coal, nuclear, wind, natural gas, oil, biomass, solar, and hydro
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)
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
Components of the Grid – Transmission

- Used to move power relatively long distances from generators to load, with lower energy losses
- Highly interconnected for enhanced reliability
- The “interstate system” for electricity
- Traditionally built to enhance reliability for vertically integrated utilities
- Now critical part of the bulk or wholesale electric markets
Transmission Enables Us To…

• ...build generation in areas removed from the loads
  ‣ More desirable environmental and fuel factors

• …build larger, more efficient generators
  ‣ Economies of scale

• …get power to remote areas with lower losses
  ‣ Rural electrification

• …create robust interconnected networks
  ‣ Increased reliability
  ‣ Decreased costs
  ‣ Makes possible power pools, markets, bulk power transactions
Unlike highways, pipelines, and telecom, the flow of electricity on the AC grid cannot be easily 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.
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 the “Eastern Interconnection”
  - West of the Rockies, including B.C., Alberta, part of Baja, is the Western Interconnection
  - State of Texas is its own 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
Interconnections and Reliability Regions

North American Regional Reliability Councils and Interconnections

- NPCC
- FRCC
- TRE
- RFC
- MRO
- WECC
- SERC
- SPP
- ASCC

Source: North American Reliability Corporation
3 Major Interconnections, 8 Regions, 135 Balancing Authorities

*Bubble size is determined by acronym width

Note: The highlighted area between SPP and SERC denotes overlapping Regional area boundaries. For example, some load serving entities participate in one Region and their associated transmission owners/operators in another.

As of October 3, 2011
Submit changes to balancing@nerc.com
Supply – Demand Balance: The Goal of the System

- Electricity by nature is difficult to store
- Supply must equal demand at any given instant
  - Put another way, total generation in an area must be moved up or down constantly to match changes in customer demands
Grid Operations and Control

• Control centers are staffed 24 hours a day, 365 days a year to ensure the safety, reliability and availability of the system for electric customers
• Operating staff is licensed, must undergo hundreds of hours of initial training, as well as ongoing training, including control room simulation exercises
• The primary task of a Grid Operator is to make sure that as much power is being generated as is being used – if not, the grid’s voltage could drop, causing the grid to become unstable
# U.S. Electricity Regulation: Who is Responsible for What?

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<th>Federal Regulation (FERC)</th>
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<td>Transmission of electricity in interstate commerce</td>
<td>Low-voltage distribution</td>
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<td>(Very) Limited transmission siting authority</td>
<td>Siting of power plants and transmission lines</td>
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<td>Permitting of hydro plants</td>
<td>Resource planning; <em>i.e.</em> the generation types (coal, natural gas, renewable) used by a utility to serve customers</td>
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<tr>
<td>– Otherwise, no generation planning or facility siting authority</td>
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<td>Reliability of transmission grid</td>
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*Federal regulation is conducted by the Federal Energy Regulatory Commission (FERC), while state regulation is conducted by Public Utility Commissions (PUCs).*
Transmission Regulation Overview

• Transmission is regulated 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, the economic efficiency of delivering energy to consumers, and the 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 and solar)
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 owners have turned operational control over to regional transmission operators – RTOs or ISOs
  ➢ Independent regional operators serve roughly two-thirds of electricity consumers in the United States
  ➢ Operational control also affects regulatory jurisdiction
North American RTOs/ISOs
FERC Authority

- Federal Energy Regulatory Commission regulates interstate transmission rates, terms and conditions of service for public utilities

- **General Ratemaking Principles** assure rates for service 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

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Expenses + Return On + Return Of = Revenue Requirement
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FERC Authority (cont’d)

• FERC requires “open access” to jurisdictional transmission facilities
  ➢ Basic principle: treat others as you treat yourself
  ➢ 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
  ➢ Must have transparent cost allocation methods in place for regional and interregional projects

• Adopts and enforces reliability standards
  ➢ Standards are developed by the North American Electric Reliability Corporation (NERC); apply to all users, owners and operators
RTOs and ISOs

- Regional Transmission Organizations and Independent System Operators have been created by regional stakeholders in response to FERC Orders to:
  - Facilitate competition among wholesale electricity 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)
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 (counties)

- 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
RTO/ISO-organized Electricity Markets

- A megawatt of electricity, like any other commodity, is frequently bought and re-sold many times before finally being consumed. These transactions make up the wholesale and retail electricity markets.

- Market participants include competitive marketers and suppliers, independent power producers (IPPs), and traditional vertically integrated utilities.
RTO/ISO Market Characteristics

- 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
  - Sets hourly prices for next-day’s (Day-Ahead) operations
  - Sets five-minute prices, or spot market prices, in Real-Time during the operating day
- 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
How is The Grid Planned?

A well planned system considers…

• Adequacy – Normal and Contingency
• Balance – Size and Strength
• Maintenance – Effective, Efficient, Suitable & Flexible
• Safety & Protection
• Recovery - Restoration
Primary Purpose of Transmission Planning

- To determine the transmission and substation additions which render the transmission network to be able to supply the loads and facilitate wholesale power marketing with a given criteria at the lowest possible cost and risk to the system.
Issues and Factors in a Transmission Planning Study

- Planning Period – often 10 or more years out
- Load Forecast and transmission usage projections
- Generation Resources (Location, Type, etc.)
- Discrete Transmission Capacities
- Alternative Solutions – e.g. Distributed Generation; Demand Reductions
- Economy of Scale
- Economic and Financial Constraints
- Right-of-Way Limitations, such as local opposition, environmental constraints
- New and Emerging Technology
- Various Uncertainties and Risks
- Service Reliability and Cost Considerations
- Institutional & Government Regulations
Regional Planning and Cost Allocation

- As a result of FERC Order 1000, regional planning and related cost allocation is expanding beyond ISO/RTOs to include neighboring regions – “Interregional Planning”
- Cost allocation is very challenging given complex and highly interconnected nature of the bulk power system and existing regulatory frameworks
  - Who benefits and who must pay can be highly contentious
- Certainty regarding cost allocation and cost recovery of transmission investments are critical for grid expansion
- Order 1000 also injected competition for certain new regional or interregional transmission projects – removes incumbent utilities’ exclusive rights to build certain projects within their geographic footprints
Transmission Project Development

- **Rate Based Projects**
  - Submit project and justification to ISO/ RTO
  - ISO/RTO studies the project
  - If approved, project is funded by all rate payers in the footprint and receives FERC-approved rate of return

- **Participant-Funded Projects**
  - Transmission developer has a participant(s) willing to pay to use transmission line
  - Execute contract with stated terms, payment amounts, etc.
  - Transmission developer uses contract to attract third-party financing
  - All other Rate payers are not affected

- **Merchant Projects**
  - Similar to participant funded, except no firm contract from participant; entities utilizing line pay service fees
  - Goal is to capitalize on arbitrage opportunities resulting from inefficient markets
Emerging Challenges to Transmission Planning and Development

• EPA’s proposed Clean Power Plan Rule
  ➢ Current grid configured for existing generation fleet
  ➢ Coal retirements may require drastic reconfiguration of grid
  ➢ New transmission to connect low-carbon resources can require ten+ years to site, permit, and construct – well past the 2020 interim goals for the rule

• Transmission siting and permitting
  ➢ Regional, environmental, and local land owner opposition to new transmission projects is becoming increasingly adversarial
  ➢ Political opposition to new projects
  ➢ Permitting in the west, with extensive federal lands and numerous agencies, is extremely time consuming

• Implementing FERC Order 1000
  ➢ Regional and interregional planning processes must comply
  ➢ Competitive bidding for new projects and cost allocation
Thank you

Questions?

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