Transmission 101: The Fundamentals Of High Voltage Transmission

How the Grid Works: Technology & Operations

April 21, 2015

- Donald Morrow, Sr. V. P. Corporate Strategy, Quanta Technology
- Adriann McCoy, T&D Market Strategy Manager, Burns & McDonnell

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.
Agenda

• Basic Definitions & Components of the Grid
• Grid Operations & Markets
• Grid Planning & Development
• Emerging Technologies
• Summary
• Q&A
Objectives

• Understand the Power System in 60 minutes or less
  • Understand elements of the Power System
  • Understand its basic physics
  • Understand how the Power System is controlled
  • Develop a basic understanding of energy markets
  • Understand some of the challenges in planning the Power System
Basic Definitions & Components of the Grid
The networks that carry electricity from the plants where it is generated to consumers. This includes wires, substations, transformers, switches and more.
Industry Overview - 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 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).
Industry Overview - Basic Definitions

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**

Source: [www.eei.org](http://www.eei.org)
WHAT CAN YOU POWER with one MEGAWATT HOUR (MWH)?

- Cool a refrigerator for 3 MONTHS (150 kWh)
- Download 133,320 SONGS (50 kWh)
- BREW 2,400 pots of coffee (200 kWh)
- Power a Traffic Signal for 3 MONTHS (200 kWh)

MWH = 1,000 kilowatt hours

HOST 600 Super Bowl PARTIES (300 kWh)
CHARGE 5,556 iPhones (100 kWh)

Based on a variety of sources. Numbers are estimations and may be rounded.
Industry Overview - Utility Ownership

**Private – Investor-Owned (IOUs)**
- Supported via private funds of shareholders
- Prevailing form of ownership – Nearly 75% of utility customers
- 190+ investor-owned utilities
- Holding Companies

**Public – Government-Owned**
- Funded by taxes from those directly served
- 2,000+ government-owned utilities
- Mostly communities with populations <10,000

**Cooperative – Member-Owned**
- Owned by their members/consumers
- 800+ in 47 states
- Mostly distribution only
- Provide “at-cost” service
- Every member’s share is equal
Industry Overview - Special Nature of Utilities

• “Public Utility” ≠ Publicly Owned
• Capital Intensive
  • Efficiencies
  • Economies of Scale
  • Depreciation over 30-40 yrs
• Regulated Market
• Obligation to Serve
  • “Quid Pro Quo”
Components of the Grid

**Generation**
- Fuel Source
- Energy Conversion
- Non-regulated/Competitive in most of the country

**Transmission**
- Power Transformation (Step Up)
- Demand/Supply
- 115 kV – 765 kV

**Distribution**
- Power Transformation (Step Down)
- 4 kV – 34.5 kV

**Load (Delivery)**
- Metering
- Billing
- 120 V – 240 V
Components of the Grid - Generation

• “Creates” electric energy using a variety of fuel sources including coal, nuclear, wind, gas, 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 losses
- Highly interconnected for enhanced reliability
- The “interstate system” for electricity
Components of the Grid - 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
Power Flow Across the Grid
Simple Bi-lateral Transaction - Contract View

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

- 3:40 pm   Schedule
- 3:55 pm   Confirm
  - 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
Contrary to popular belief, the power from A does NOT flow directly to B despite my best contract negotiating skills.
Grid Operations and Markets
Grid Operation

Unlike highways, pipelines, and telecom, the flow of electricity on the AC grid can not 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.
Grid Operation

• 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.

• 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.
Example: California ISO Control Center

Positions Include:

• Transmission Operators
• Market Operators
• Balancing Authority Operators
• Operational Assessment Engineers
• Maintenance Schedulers
• Supervision

Source: www.caiso.org
Grid Operation - Smart Grid

• Operators take immediate actions to isolate and mitigate issues that arise on to minimize any interruption of power

• “Smart Grid” refers to an upgraded system which would offer Grid Operators more visibility and control over the system.
Grid Operation - Smart Grid

- **Computer Control**
  - Two-way digital communication between the device in the field and the utility’s network operations center
  - Automated technology to allow remote control of devices from a central location

- **Current Smart Grid Enhancements**
  - Enhanced measurement devices and sensors to collect data
  - Improved interfaces to improve Situational Awareness
Grid Operation - Emerging Smart Grid Developments

1. **Distributed Generation** – Can sell energy surplus back to the utility and get paid as microgenerators
2. **Smart Appliances** – Can monitor cost of electricity and shut down when power is too expensive
3. **Remote Control Applications** – Utilities can control consumers’ non-essential appliances remotely
4. **Plug-in Hybrid Cars** – Can refuel using clean electricity generated locally
5. **Locally Generated Power** – Avoids the long-distance power losses
6. **Wireless Chips** – Communication between houses and utilities to swap price and usage information
7. **Web and Mobile Phone Interfaces** – Allow consumers to monitor and control appliances when away from home
8. **Energy Storage** – Can store clean solar energy for use at night when the sun isn’t shining

Source: The New York Times
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.

Source: www.learn.pjm.com
Wholesale Electricity Markets

- The price for wholesale electricity can be predetermined by a buyer and seller through a bilateral contract or by organized wholesale markets.

- The clearing price for electricity in these wholesale markets is determined by an auction in which generation resources offer in a price at which they can supply a specific number of megawatt-hours of power.

Source: [www.learn.pjm.com](http://www.learn.pjm.com)
Wholesale Electricity Markets

Many regions organize their markets under an ISO/RTO as a result of FERC Orders 888-889 which aimed to ensure non-discriminatory open access to the transmission system.
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
• 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
Wholesale Electricity Markets

- **Spot Markets** (aka Day 1 or real-time)
- **Day Ahead Markets** (aka Day 2)
Example: MISO Real-time LMPs
4/14/15 @ 10:15am
Grid Planning and Development
Regional Grid Enlargement

- 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.

  - 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 ISOs, 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.
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 & Factors in a Transmission Planning Study

- Planning Period
- Load Forecast and transmission usage projection
- Generation Resources (Location, Type, etc.)
- Discrete Transmission Capacities
- Alternative Solutions
- Economy of Scale
- Economic and Financial Constraints
- R-O-W Limitations
- New and Emerging Technology
- Various Uncertainties and Risks
- Service Reliability and Cost Considerations
- Institutional & Government Regulations
Regional Planning

- Per FERC O. 1000 (in conjunction with O. 890), all public utility transmission providers must participate in a regional transmission planning process.

- Public utility transmission providers in neighboring transmission planning regions must coordinate to determine if there are more efficient or cost-effective solutions to their mutual transmission needs.

- Stakeholders can provide input and advocate positions throughout the process.

- Processes vary by region as dictated by individual transmission planning tariffs.
Regional Planning - FERC Order 1000

Competitive Bid Model

Sponsorship Model
Regional Planning - Cost Allocation

• As a result of FERC Order 1000, regional planning and related cost allocation is expanding beyond ISO/RTOs to include other regions

• Cost allocation is very challenging given complex and highly interconnected nature of the bulk power system and existing regulatory frameworks, not considering merchant transmission developments and opportunities which can transcend regions

• Certainty regarding cost allocation and cost recovery of transmission investments are critical for grid expansion
Transmission Project Development

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

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

• Merchant Projects
  • Similar to participant funded, except no contract from participant
  • Goal is to capitalize on arbitrage opportunities resulting from inefficient markets
Emerging Grid Technologies
Storage

5 MW Energy Storage System at the Salem Smart Power Center in Salem, OR

Source: www.energy.gov
Synchrophasors/ Phasor Measurement Units (PMUs)

- A synchrophasor is a sophisticated monitoring device that can measure the instantaneous voltage, current and frequency at specific locations on the grid.

- They give operators a near-real-time picture of what is happening on the system, and allows them to make decisions to prevent power outages.
Synchrophasors/ Phasor Measurement Units (PMUs)

- Synchrophasors are measured by high-speed monitors called PMUs that are 100 times faster than existing SCADA technology.

- PMU measurements record grid conditions with great accuracy and offer insight into grid stability or stress.

- Overall = Improved grid reliability, efficiency and lower operating costs.
Superconductors

- Superconductors are made of alloys or compounds that will conduct electricity without resistance below a certain temperature, thus eliminating inefficiencies
  - National electricity transmission and distribution losses average about 6% of the electricity that is transmitted and distributed in the United States each year

- Could enable the transfer of power over long distances at residential voltages

- Huge cost impacts!
Smart Wires Technology

- Smart Wires react in real time to grid needs, adjusting the impedance of each line to optimize the flow of power on the grid.

- Can limit the number of customers affected by the outage by re-directing power around the outage using alternative routes.

- Has ability to transform the way power systems are planned and operated.
Summary

• The power system is:
  • Composed of generation, distribution and transmission
  • Relies on transmission to deliver cost effective generation to load centers
  • Uses the transmission backbone to support energy markets
  • Is complicated to operate and requires constant monitoring and control
  • Regional in operation

• Today’s challenges to investment:
  • Planning to meet stakeholder needs
  • Integration of competitive transmission development
  • Getting agreement on cost allocation
  • Emerging technologies
Questions?

Donald Morrow
Dmorrow@Quanta-Technology.com

Adriann McCoy
Armccoy@Burnsmcd.com
Sources:

• www.eei.org
• www.ferc.gov
• www.epsa.org
• www.learn.pjm.com
• www.energy.gov
• www.misoenergy.org
• www.caiso.com