Overview of Western’s Interconnected Bulk Electric System
Western Area Power Admin.
Objectives

• Describe Western Area Power Administration Region and Facilities Overview

• Explain Fundamentals of Electricity, Power Transformers and Transmission Lines

• Discuss Overview of the Bulk Electric System (BES)

• Objectives Review
Western’s Service Area

Western marketing areas and offices

Marketing area boundaries
- Central Valley and Washoe projects
- Parker-Davis, Boulder Canyon and Central Arizona Project
- Falcon-Amistad Project
- Provo River Project
- Loveland Area Projects
  - Pick Sloan Missouri Basin Program — Western Division and Fryingpan-Arkanasas Project
- Pick Sloan Missouri Basin Program — Eastern Division
- Salt Lake City Area/Integrated Projects
  - Colorado River Storage Project, Calabria, Rio Grande, Seedskadee and Dolores projects

- State Boundaries
- Regional Office
- Corporate Services Office
- CRSP Management Center
Wholesale Power Services

- Markets 10,479 MW from 56 Federal hydropower projects owned by Bureau of Reclamation (BOR), Army Corps of Engineers and International Boundary and Water Commission (IB&WC)
- 16,800 miles of high-voltage transmission line across 15 states
How is Electricity Created
What is Current and Voltage

Water analogy
Voltage = Pressure. Current = Flow
Transformers

Basic construction
- Two or more coils of wire wrapped around an iron core.
- A variation of an inductor, utilizes the magnetic field to transmit power to different voltage levels.
Transformer Operation

Primary Winding:
Ratings:
  Power = 10 MVA
  Voltage = 11.5 kv
  Current = 870 A
  Number of Windings = 23,000
Waveform:

Transformer:
  Magnetic Flux
  Primary Winding
  Iron Core

Secondary Winding:
Ratings:
  Power = 10 MVA
  Voltage = 115 kv
  Current = 87 A
  Number of Windings = 230,000
Waveform:
Substations and Transformers

- **Major Equipment**
  - **Transformers**: Transform voltage levels
  - **Circuit Breakers**: Isolate faults (disturbances) from the rest of the system
  - **Disconnect Switches**: Permit a circuit element to be safely disconnected and isolated from the system for maintenance or repair
  - **Lightning Protection**: Limit damaging transient voltage conditions
  - **Instrumentation**: Provide data needed to monitor the overall system and control the flow of power

Photo by Ravel F. Ammerman, NREL
Power System Transformers

Figure 12: Electricity Supply Chain

Hydro Generation System

Typical Hydroelectric Dam

- Reservoir
- Intake
- Penstock
- Turbine
- Powerhouse
- Generator
- Power Lines
- Outflow River

Power transmission and distribution system:

- Erection of high voltage transmission lines
- Transmission of electricity through power lines

Electricity generation and utilization:
Electrical Transmission System

Transmission Voltage Levels

Transmission
• 230 kilovolt (kV)
• 345 kV
• 500 kV
• 765 kV
• 1,000 kV and above

Sub-transmission
• 69 kV
• 115 kV
• 138 kV

Source: [http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/transmission_lines.html](http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/transmission_lines.html)
Differences: Transmission vs. Distribution Systems

- Size and scale
- Operation is fundamentally different
  - Transmission system is operated actively
  - Distribution system is operated passively

Distribution Voltage Levels

<table>
<thead>
<tr>
<th>Medium Voltage</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>4.16 kV</td>
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</tr>
<tr>
<td>6.9 kV</td>
<td></td>
</tr>
<tr>
<td>13.2 kV</td>
<td></td>
</tr>
<tr>
<td>25 kV</td>
<td></td>
</tr>
<tr>
<td>34.5 kV</td>
<td></td>
</tr>
<tr>
<td>46 kV</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Low Voltage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>480 volt (V)</td>
<td></td>
</tr>
<tr>
<td>120/240 V (single-phase)</td>
<td></td>
</tr>
</tbody>
</table>

Photo by Mike Coddington, NREL
Figure 14: Structural Variations of Transmission Towers

Transmission & Distribution Lines

Source: U.S. Department of Labor, OSHA
Transmission Line Thermal Ratings

- Transmission lines may have more than one thermal rating.
- A Continuous rating would indicate the maximum flow that can be carried under normal conditions.
- Emergency ratings for a predetermined period of time may be supplied.
- Ratings will be affected by ambient temperatures and conditions.
Transmission Line Thermal Ratings

- Sag on cold day
- Maximum sag full load on hot day

4.5 metres
How is Electricity Measured?

- Electricity is measured in terms of watts, typically in kilowatts (1,000 watts) or megawatts (1,000 kilowatts). One MW is enough capacity to instantaneously light approximately 750 – 1000 homes.

- A kilowatt (or megawatt) is the amount of energy used, generated or transmitted at a point in time. The aggregation of megawatts possible at a point in time for a power plant, for example, is its capacity. The aggregation of kilowatts used at a point of time is the demand at that point.
How is Electricity Measured?

• One kilowatt of energy consumed over an hour is called a kilowatt-hour (or kWh). Meters measure the kWh usage over a month. Billing rates are established as ¢/kWh.

• One megawatt generated, delivered, or consumed over an hour at the wholesale level is called a megawatt-hour (or MWh). Wholesale transactions are priced at $/MWh.
Electricity is Unique

- Is generated and consumed at nearly the same time
- Storage has been impractical on a broad scale although that’s beginning to change
- Requires an extensive delivery infrastructure (Bulk Electric System)
Balancing Generation and Load

Maintaining a reliable grid requires a constant balancing between generation (supply) and load (demand)
U.S. Power Generation Mix

Figure 3: U.S. Power Generation by Fuel Type in 2014
- Renewables (Excluding Hydro): 7%
- Hydroelectric: 6%
- Nuclear: 19%
- Natural Gas: 27%
- Petroleum Liquids: 1%
- Coal: 39%
- Other: 1%

Figure 4: U.S. Generation Capacity in 2013
- Renewables (Excluding Hydro): 7%
- Hydroelectric: 9%
- Nuclear: 9%
- Natural Gas: 42%
- Coal: 28%
- Petroleum: 4%

Sources: U.S. Department of Energy, Energy Information Administration (EIA)

Figure 2: Conceptual Flow Chart of the Electricity Supply Chain
- Generation Plants
- Step-Up Substations
- Transmission Power Lines
- Step-Down Substations
- Distribution Power Lines
- Customer End Use
Power Generation in the West

Generation in the Western U.S. AK, AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY

Source: ACORE

United States Generation Mix

Source: U.S. Department of Energy
Transmission and the Grid

North American Interconnections

Western Area Power Administration
Power Flow on the BES

Figure 11: Daily System Demand Profile

Peak Demand 6.6 kW for 15 minutes

Maximum kW usage

Source: U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability
Seasonal Power Flow on the BES
Daily Demand Curve and Generation Mix

Source: California ISO (http://www.caiso.com/Pages/TodaysOutlook.aspx)
Generation Energy and Capacity

- Dispatchable
  - Conventional generation sources
  - Energy is inherently stored within source of fuel
  - Use when needed

- Non-Dispatchable
  - Renewable energy resources (wind and solar)
  - Characterized by variability and uncertainty
  - Energy source must be used when available

Generation Energy and Capacity
Regulation of the Interconnected Bulk Electric System (BES)

- **Federal Energy Regulatory Commission (FERC)** – Regulates the transmission and wholesale sale of electricity. Monitors energy markets.
- **North American Electric Reliability Corporation (NERC)** – Establishes reliability standards that grid operators must adhere to.
- **Regional Reliability Organizations (RRO)** - are the enforcement arm of NERC. They perform periodic audits of grid operators and can levy financial fines for non-compliance.
Regional Reliability Organizations
Electric Industry Regulation

- Utility commissions and districts regulate privately and publicly owned electricity providers
  - Utilities Commission
  - Utility Regulatory Commission
  - Public Utilities Commission
  - Public Service Commission (may be civil service oversight body rather than utility regulator)
  - Public Utility District (tribal, state, or government owned utility, consumer owned and operated, small investor owned)
  - Publicly owned utilities include cooperative and municipal utilities
  - Cooperative utilities are owned by the customers they serve (farmers and rural communities)
Balancing Authority Areas in the West
Reserves

Operating Reserves

*Diagram of Reserve Generation, as Defined in NERC Glossary of Terms*
Information Resources


Objectives Review

• Describe Western Area Power Administration Region and Facilities Overview

• Explain Fundamentals of Electricity

• Discuss Overview of the Grid
Questions?

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