DOE OFFICE OF INDIAN ENERGY

Foundational Courses

Energy Basics

ELECTRICITY GRID BASICS

Presented by the National Renewable Energy Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Indian Energy

Course Outline

What we will cover…

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction
- Interconnection of Electric Power Systems
- Technology Overview:
  - Conventional Generators
  - Transmission Systems
  - Substations
  - Distribution Systems
- Policy and Tribal Utilities
- Information & Resources

Introduction

The U.S. Department of Energy (DOE) Office of Indian Energy Policy & Programs is responsible for assisting Tribes with energy planning and development, infrastructure, energy costs, and electrification of Indian lands and homes.

As part of this commitment and on behalf of DOE, the Office of Indian Energy is leading *education* and *capacity building* efforts in Indian Country.

Training Program Objective & Approach

Foundational courses were created to give tribal leaders and professionals background information in renewable energy development that:

- *Present foundational information on strategic energy planning, grid basics, and renewable energy technologies;*
- *Break down the components of the project development process on the commercial and community scale; and*
- *Explain how the various financing structures can be practical for projects on tribal lands.*

NREL's Presenter on Electricity Grid Basics is

Dr. Ravel Ammerman, Ph.D.

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Dr. Ravel F. Ammerman is a Teaching Professor in the Electrical Engineering and Computer Science Department at Colorado School of Mines. He also works as a Research Associate at the National Renewable Energy Laboratory (NREL). Dr. Ammerman received his Ph.D. degree in Engineering Systems (Electrical Specialty – Power Systems) from Colorado School of Mines in 2008. He has over 29 years of combined teaching, research, and industrial experience.

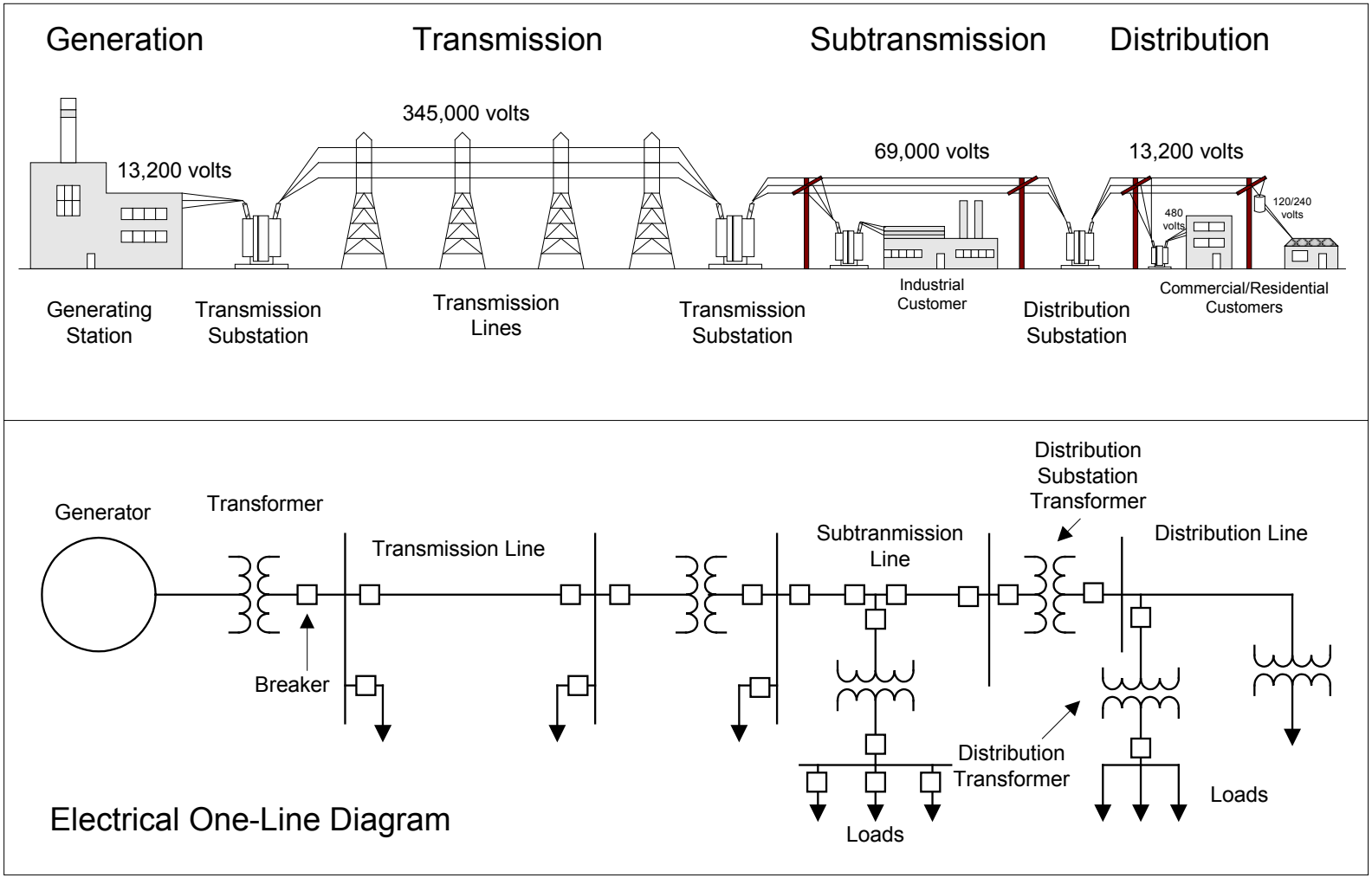
Dr. Ammerman has published in archival journals and has co-authored numerous award-winning technical articles.

Course Outline

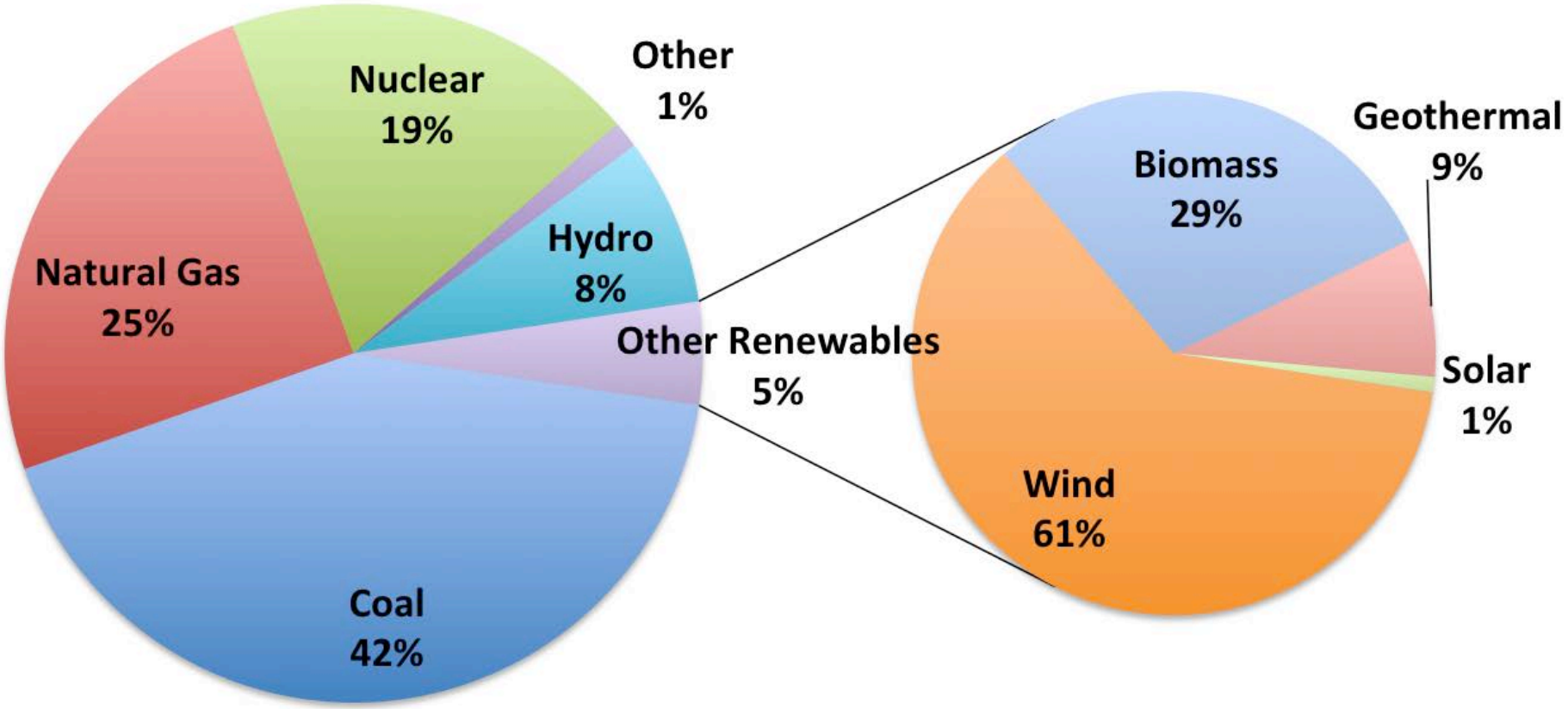
What we will cover…

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction & Key Takeaways
- Interconnection of Electric Power Systems
- Technology Overview:
  - Conventional Generators
  - Transmission Systems
  - Substations
  - Distribution Systems
- Policy and Tribal Utilities
- Information & Resources

The Electricity Grid (Overview)



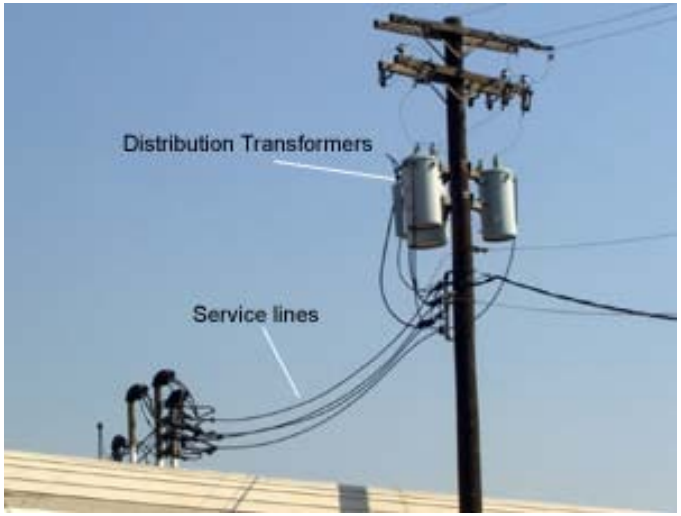
U.S. Electricity Generation



Source: U.S. Energy Information Administration (EIA), May 29, 2012

Key Knowledge Takeaways

- Fundamental understanding of the major components comprising large, interconnected electrical power systems
  - Conventional (Dispatchable) Generators
  - Transmission Systems
  - Substations
  - Distribution Systems



Source: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/index.html

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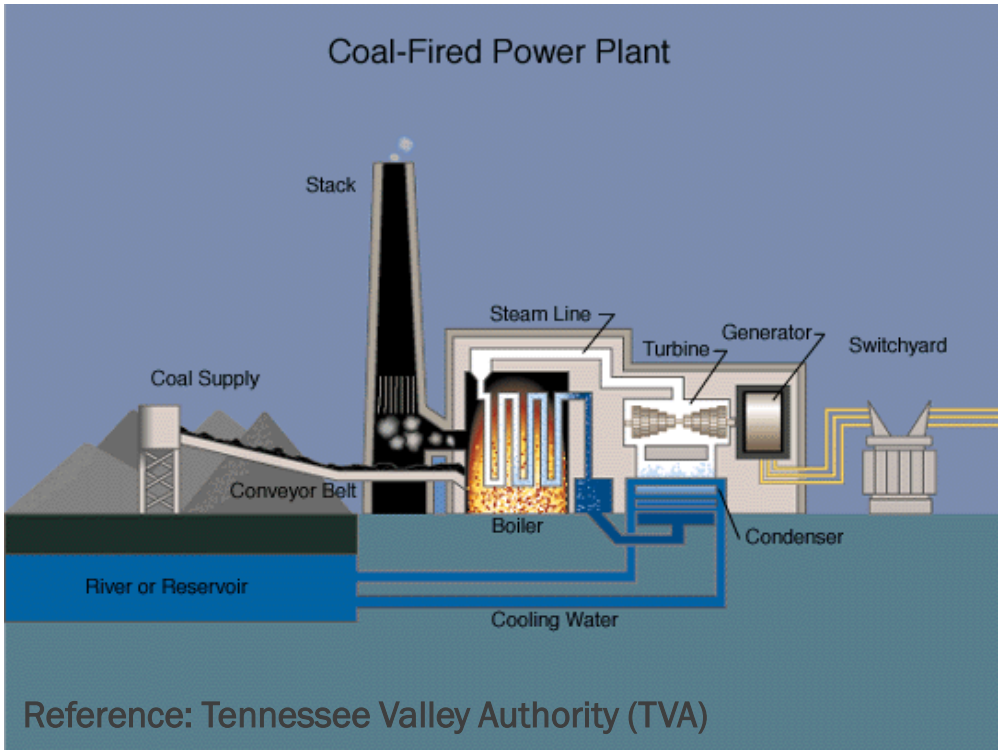
Conventional Power Generation Systems - Coal

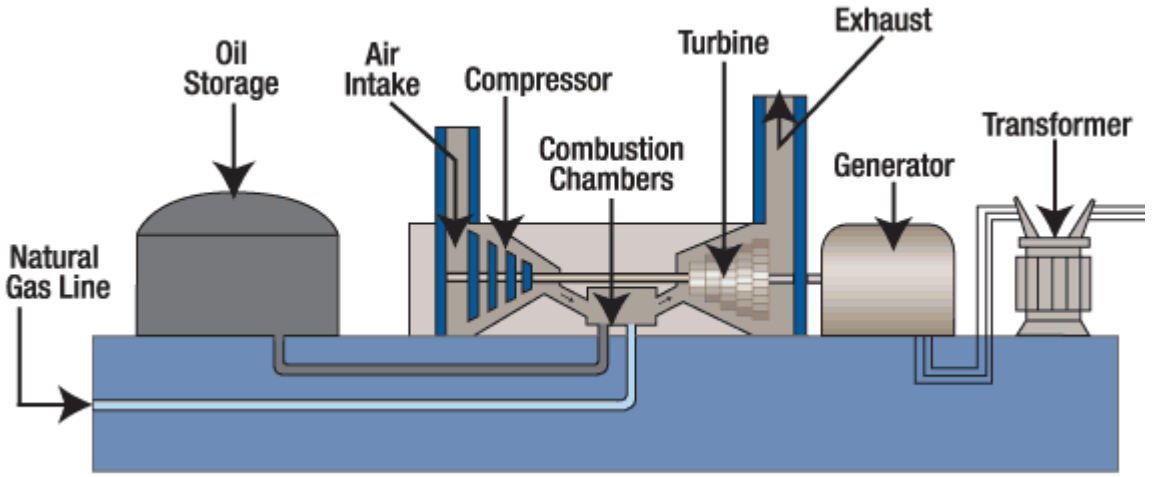


Source: http://www.tva.gov/power/coalart.htm

Characteristics:

- Low thermal efficiency (35%)
- Thermal pollution (condenser)
- Air pollution (CO_2, SO_2, NO_X)
- Long time required to start and stop

Conventional Power Generation Systems – Combustion (Gas) Turbines



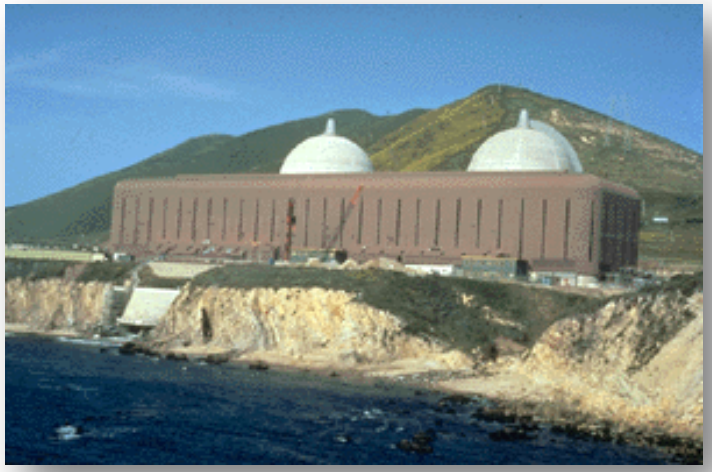
Reference: Tennessee Valley Authority (TVA)

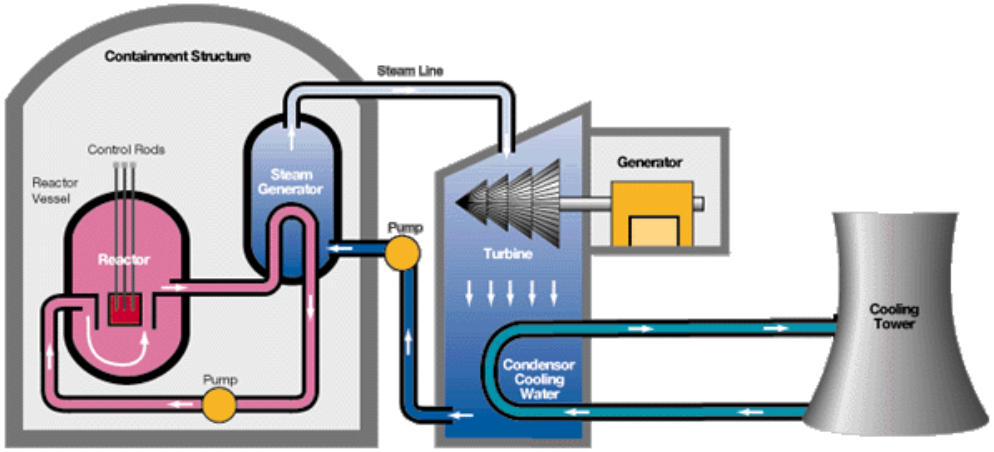
Characteristics:

- Turbine draws in air, compresses it, mixes with fuel and ignites
- Hot gases expand driving a generator
- Quick starting

Source: http://www.tva.gov/power/comb_cycle_video.htm

Conventional Power Generation Systems - Nuclear



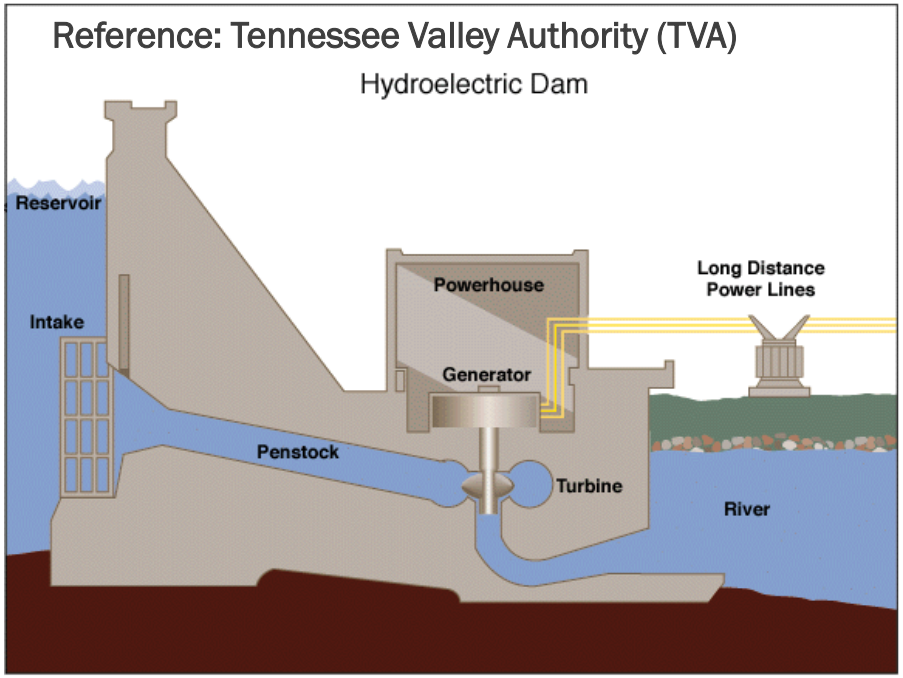


Source: Tennessee Valley Authority (TVA)

Characteristics:

- Low thermal efficiency (35%)
- Thermal pollution (condenser)
- Concerns about radioactive waste disposal
- No smoke stack (no emissions)
- Long time to start and stop

Conventional Power Generation Systems - Hydroelectric

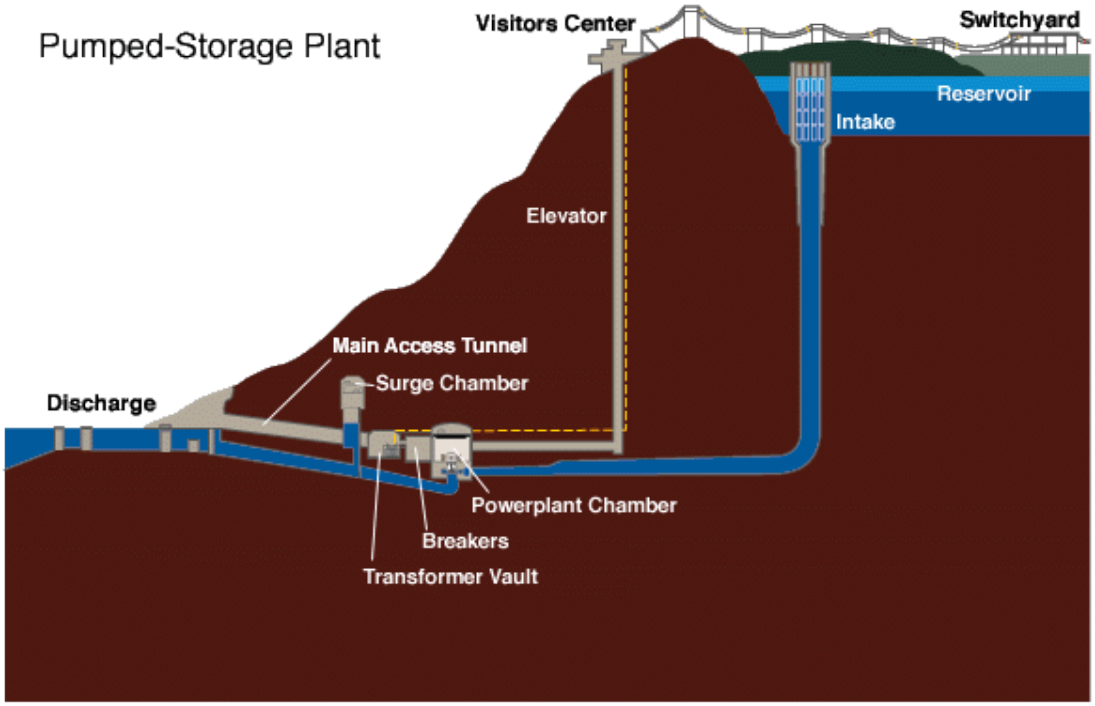


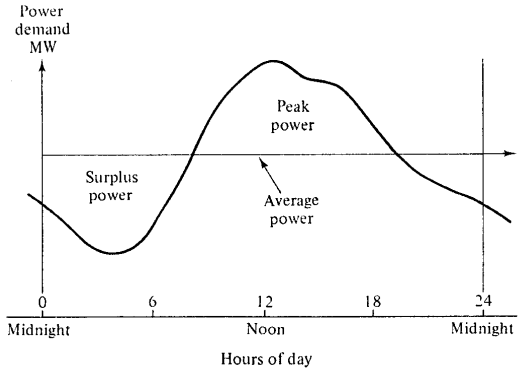
Characteristics:

- High efficiency (85-90%)
- Considered a renewable energy source
- Easy to control
- Environmental concerns (water flows and siltation)

Source: http://www.tva.gov/power/hydro.htm

Conventional Power Generation Systems – Hydroelectric Pumped Storage



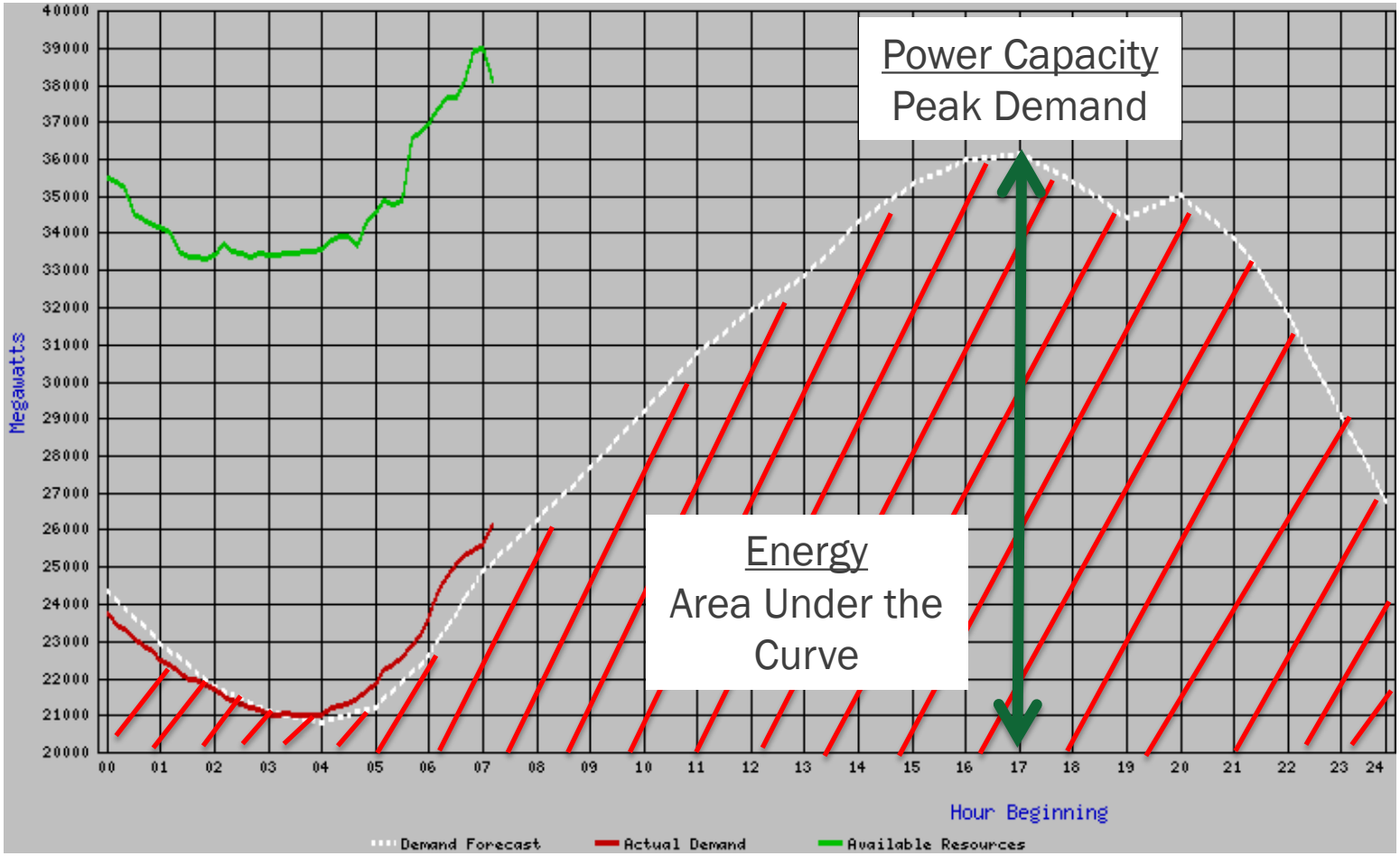


Characteristics:

- Uses electricity during low demand times to pump water from the low-elevation reservoir to the high-elevation reservoir
- During peak power demands the water flows back down acting like a conventional hydroelectric facility

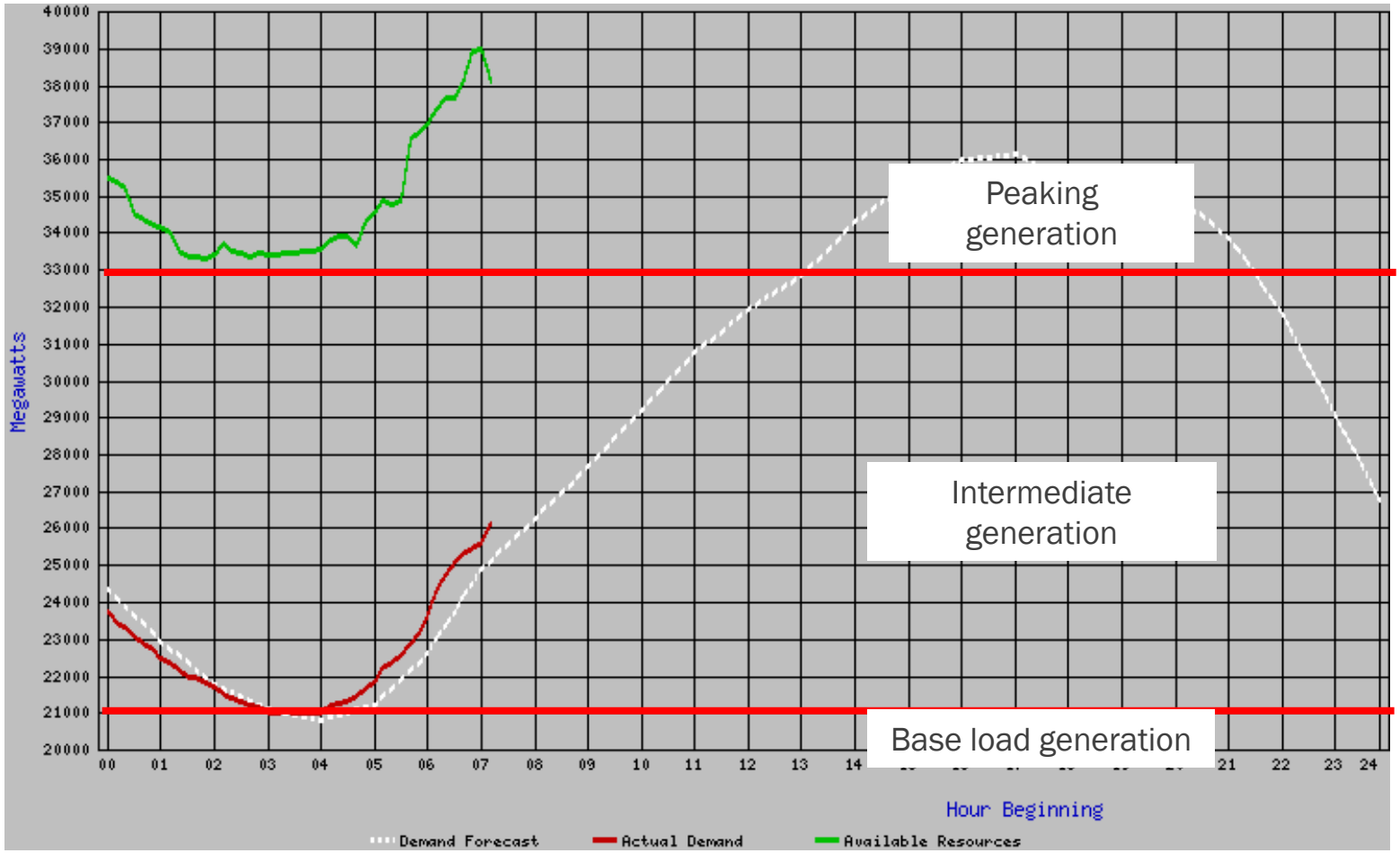
Source: TVA

Power (MW) vs. Energy (MWh)



Source: California ISO (http://www.caiso.com/Pages/TodaysOutlook.aspx)

Daily Demand Curve and Generation Mix



Source: California ISO (http://www.caiso.com/Pages/TodaysOutlook.aspx)

Dispatchable vs. Non-Dispatchable Generation

- 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

Source: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/index.html

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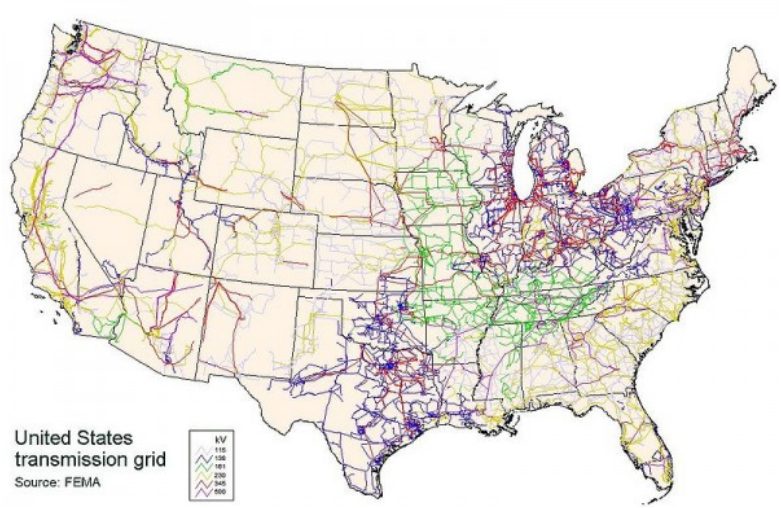
Electricity Transmission System



69 kV

345 kV

230 kV

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

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Transmission Substations

- 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

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Major Differences between Transmission and Distribution Systems

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

Distribution Voltage Levels

Medium Voltage

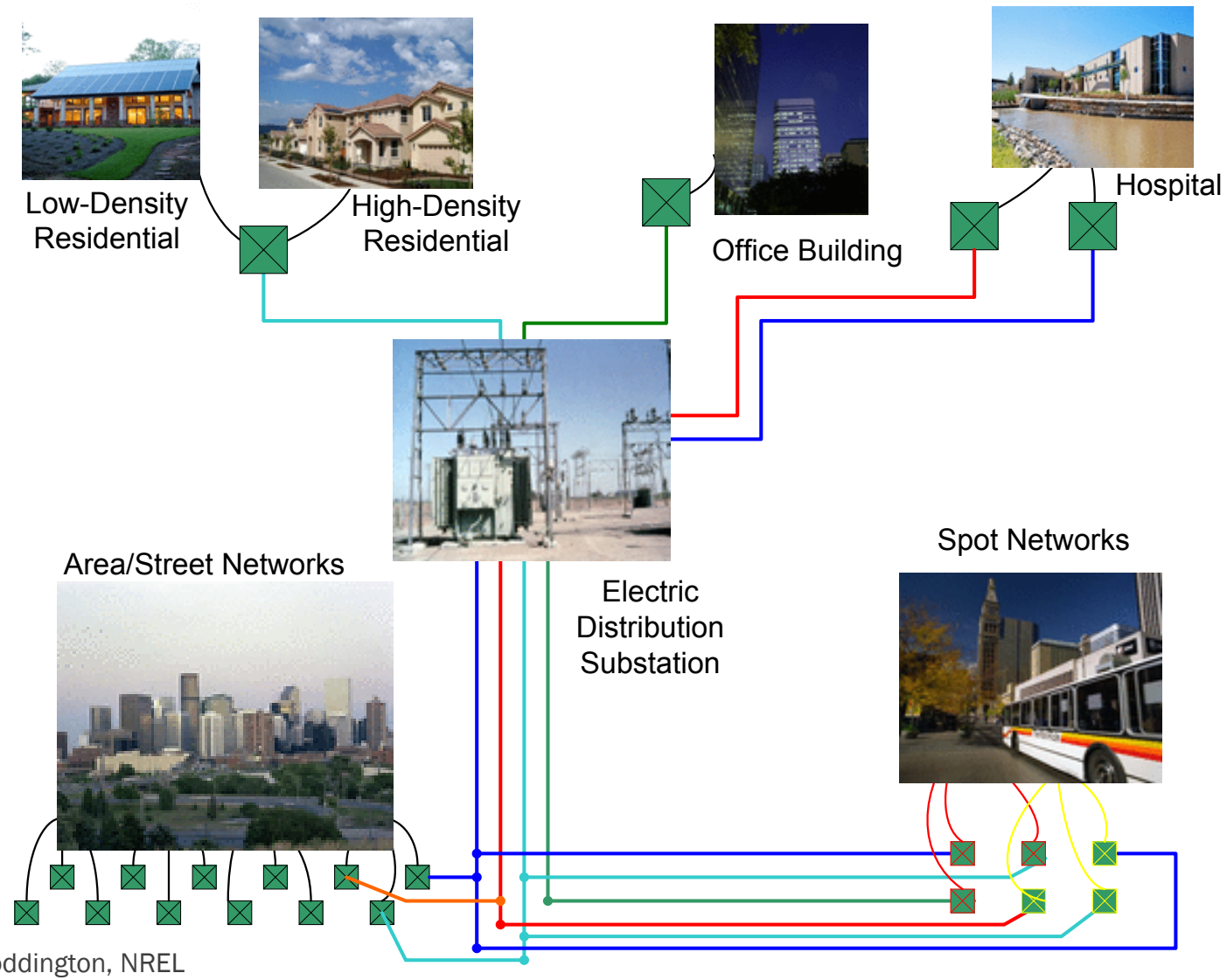
4.16 kV
6.9 kV
13.2 kV
25 kV
34.5 kV
46 kV

Low Voltage

480 volt (V)
120/240 V (single-phase)

Photo by Mike Coddington, NREL

Electric Distribution System Types



Photos by Mike Coddington, NREL

Distribution Substation

13.2 kV Side

13.2 – 230 kV Transformer

230 kV Side

Photo by Ravel F. Ammerman, NREL

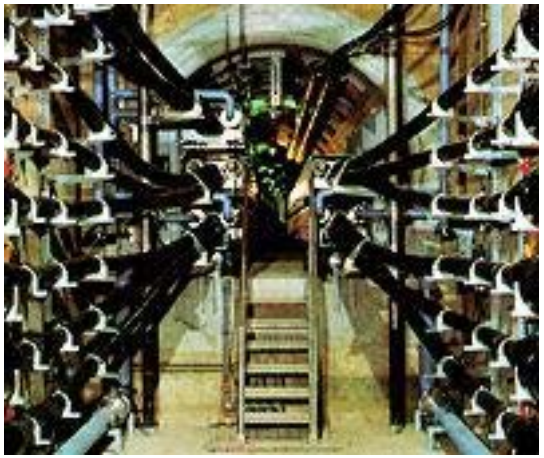
Electric Distribution Systems – Overhead Lines, Insulators, Conductors

Characteristics

- Bare conductors
- Lower cost
- Aesthetics

Photos by Mike Coddington, NREL

Electric Distribution Systems – Conductors (Underground)

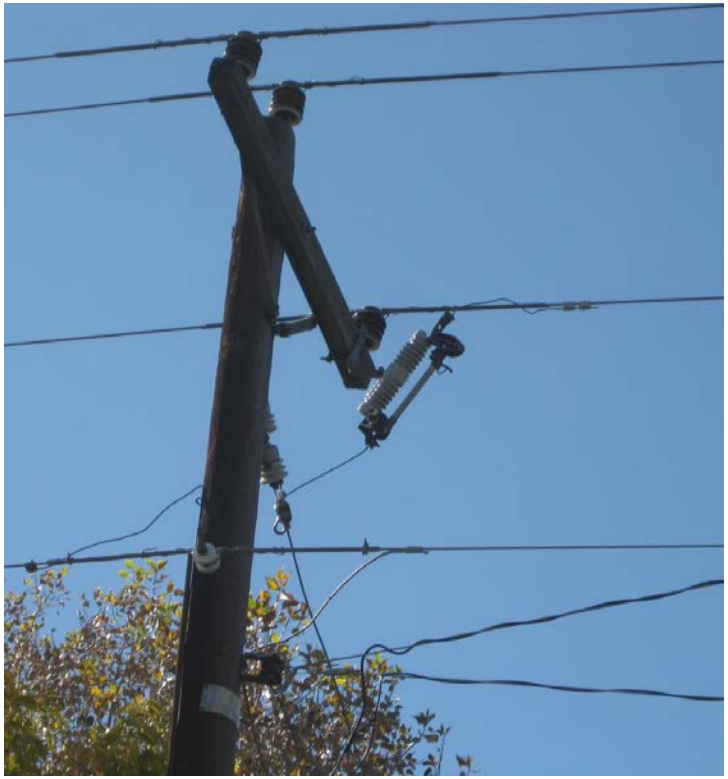


Characteristics

- Higher cost (3 to 10 times higher)
- Aesthetics
- Reliability in stormy weather
- Maintenance costs reduced

Source: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/transmission_lines.html#Underground

Electric Distribution Systems – Protection Equipment



Overhead Fuse

Three-Phase Overhead Recloser

Photos by Mike Coddington, NREL

Electric Distribution Systems – Transformers

Single-Phase Overhead (7.62 kV to 120/240 V)

Three-Phase Pad-Mount (13.2 kV to 277/480 V)

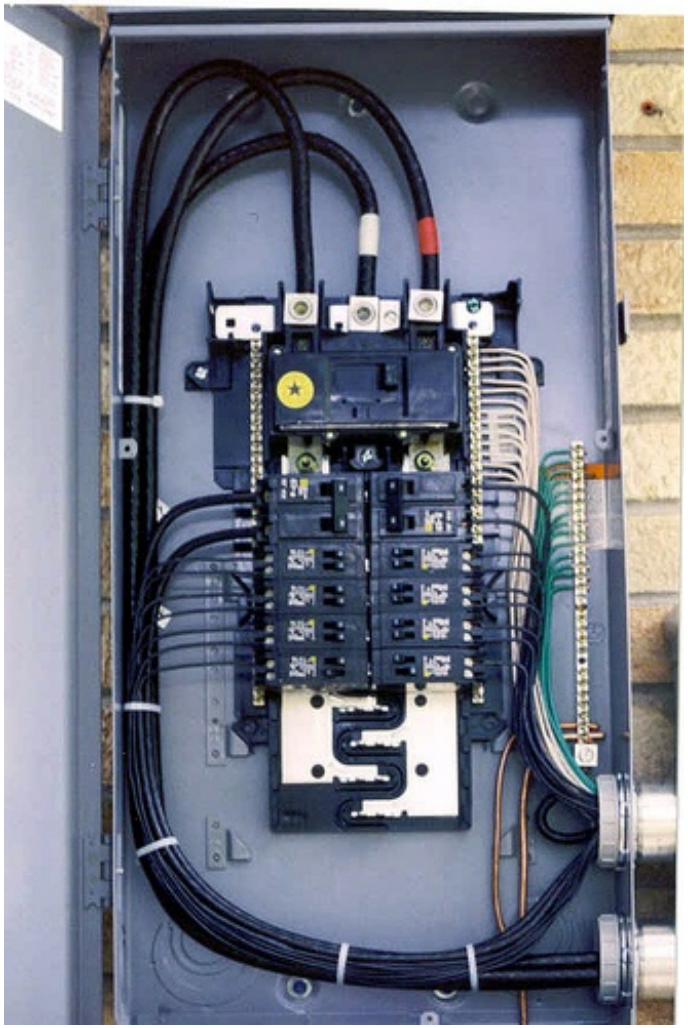
Function:

Distribution transformers convert the primary voltage levels to secondary voltage levels for utilization by consumers

Photos by Mike Coddington, NREL

Electric Distribution Systems – Utilization Equipment

Residential Meter and Disconnect



Main Disconnect Panel

Photos by Mike Coddington, NREL

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Policy: Regulatory Bodies for the Electricity Grid

- Federal Energy Regulatory Commission (FERC)
- North American Electric Reliability Corporation (NERC)
  - Regional Reliability Councils
- 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)

Tribal Utilities

- Western Area Power Administration (WAPA or Western)
  - Fulfilling requirements for open access transmission service, reliable operations, and transmission development for renewable energy
  - DOE and Western include Tribes and stakeholders as playing a central role to the electricity system in the future of the country
- Electric Tribal Utilities
  - Eight tribal electric utilities
  - One natural gas utility: Southern Ute in Colorado
- Handbook by Leonard S. Gold: *Establishing a Tribal Utility Authority*, 2012 Edition
  - 56-page guide to evaluate the feasibility of forming a tribal utility

Useful Resources

RESOURCE	• U.S. Energy Information Administration (EIA): http://www.eia.gov/electricity/ • Paper: *Case Studies: The Conversion of On-Reservation Electric Utilities to Tribal Ownership and Operation* by Western Area Power Administration; Sept, 2010: http://apps1.eere.energy.gov/tribalenergy/pdfs/tribal_authority.pdf • Handbook: *Establishing a Tribal Utility Authority*; by Leonard S. Gold, President, Utility Strategies Consulting Group, LLC: http://www.utility-strategies.com/downloads/Web-TUA%20Formation%20Handbook.pdf
TECHNOLOGY	• Occupational Safety & Health Administration (OSHA) offers reliable grid information: http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/ • Western Area Power Administration (WAPA) electric grid expansion in collaboration with Tribes and other stakeholders focused on Western states: http://ww2.wapa.gov/sites/Western/Pages/default.aspx
POLICY	• American Council for an Energy-Efficient Economy: http://www.aceee.org/topics/utility-regulation-and-policy • Western Electric Coordinating Council has two Tribal reps for policy deliberations: http://www.wecc.biz/Pages/Default.aspx • Inter-Tribal Council on Utility Policy: http://www.intertribalcoup.org/

Thank you for attending this webinar on Electricity Grid Basics

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DOE Office of Indian Energy Website:
www.energy.gov/indianenergy

NREL Technology Websites:
www.nrel.gov/learning/re_basics.html

INFORMATION ON THE CURRICULUM PROGRAM & OFFERINGS

Curriculum Structure & Offerings

Foundational Courses

- Overview of foundational information on renewable energy technologies, strategic energy planning, and grid basics

Leadership & Professional Courses

- Covers the components of the project development process and existing project financing structures

Foundational Courses

Energy Basics

- Assessing Energy Needs and Resources
- Electricity Grid Basics
- Strategic Energy Planning

Renewable Energy Technology Options

- Biomass
- Direct Use
- Geothermal
- Hydroelectric
- Solar
- Wind

All courses are presented as 40-minute Webinars online at
www.energy.gov/indianenergy