Electrical Generation and Distribution

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Course Description

Electrical production and distribution equipment and systems are characterized by highly sophisticated technologies that continue to develop rapidly. College and university electrical distribution systems generally consist of a switching station for receiving the electricity into the university system, switching substations (which include transformers), medium-voltage conductor circuits, electric power generation, and system protection. This class will explore electrical systems typical of university-owned facilities where electricity, whether generated on campus, purchased, or both is received and further distributed to points on campus.

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Learning Objectives

In the next 45 minutes you will be introduced to terminology that you likely hear being used on your campus. I intend to give you enough information to make you dangerous…

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Generation and Distribution

Forms of Generation (How?)
- Turbine Generators
- Solar
- Combined Heat and Power

Distribution

The Case for Self-Generation (Why?)

Cost Considerations (How Much?)
- Understand Energy Use vs. Demand
- What's your Generation Strategy?

Technology Selection (What Kind?)
- Renewable Energy Generation

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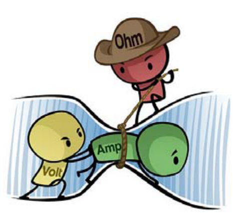
Vocab



Electricity= flow of electrons

• Voltage (volts)= potential energy created by difference in charge between two points

• Current (amps) = rate at which the charge is flowing

• Resistance (ohms) = the material's tendency to resist the flow of charge.

Plumbing analogy: Voltage = water pressure. Current = flow rate. Resistance = pipe size.

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Turbine Generators

- 80% of world's electricity generated by steam turbines driving rotary generators
- Turbines extract energy from fluid flow and convert it to useful work
  - Fluid flow acts on the turbine blades to produce rotation of a shaft (rotor) attached to generator
- Prime Mover: the mechanical means of turning the generator rotor
  - STEAM Turbine: Steam raised in a boiler which is heated by the combustion of coal, gas, or biomass
  - GAS/DIESEL Turbine: flow of gas caused by the combustion of fossil fuels
  - WIND Turbine: air flow caused by sun's uneven heating of earth's surface
  - HYDRO Turbine: water flow from run-of river, dam, or artificial pumped water storage

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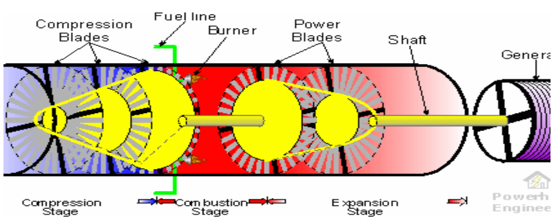

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Solar PV

- Direct conversion of solar irradiance into electricity. No generator needed.
- PV panels contain silicon layers which carry a negative and positive charge
- Silicon molecules, like copper, are prone to losing electrons
- Photons from the sun dislodge electrons in the atoms from the negative layer
- Conductors embedded in panel collect the flowing electrons
- Output from all panels is combined and sent to grid

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Combined Heat and Power

- District Energy: Central power plant distributes heating and cooling to all buildings via underground hot and chilled water pipes.
- Conserves energy & avoids need for each building to have furnace & A/C
- Standard Electric Power Plant: Energy contained in the primary fuel is used to make electricity only. On average, 66% of that energy is wasted.
- Combined Heat & Power: Primary fuel converted to multiple forms of useful energy. Only 20-25% energy wasted.

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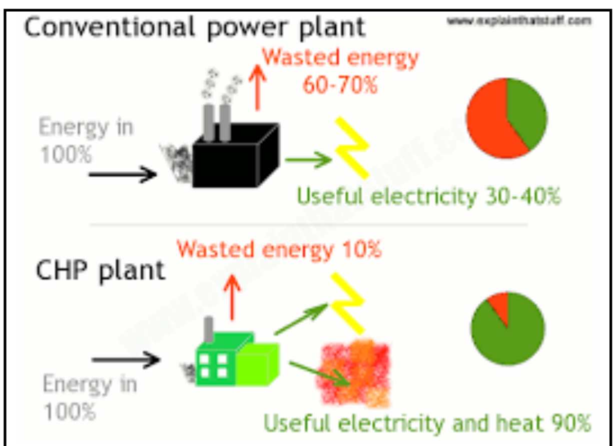

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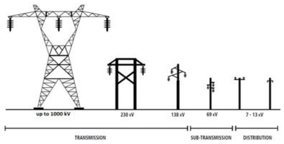
Transmission vs. Distribution

High Voltage Transmission lines:

- 69,000 volts and up
- Installed overhead for cost and efficiency.
- Not insulated.
- Insulation = resistance = wasted energy in the form of heat
- Heavy load causes lines to sag



Distribution lines (Medium Voltage):

- Common voltages: 7,200-13,800 volts
- May be overhead or underground. U/G is much more reliable but up to 10X the cost of O/H. (Campus aesthetics another consideration!)
- If U/G, conduit may be direct buried, or encased in concrete “duct bank”.
- Different utilities often share the same pole. Highest voltage electrical lines are always on top. Fiber optic, cable TV, telephone lines are installed below

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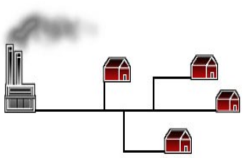
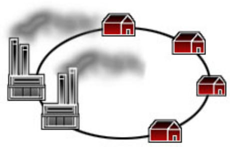
Distribution: Radial vs. Loop Topology





Radial: One feeder line from generation to each load.
- Simple, lower cost, but inflexible in the event of a line fault
- No way to divert power through other feeders to keep power on

Loop: Multiple feeder lines, allowing power to flow to load from either direction
- Managed via switchgear (breakers, switches, etc) to allow or block the flow

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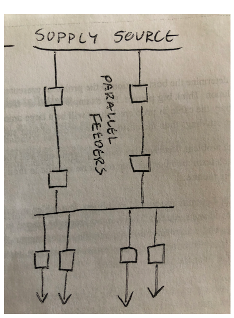
PARALLEL FEED



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SWITCH

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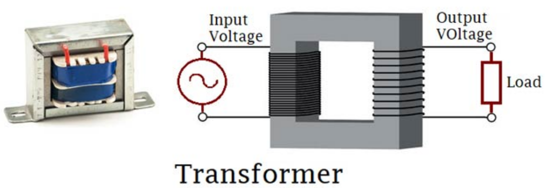
TRANSFORMER



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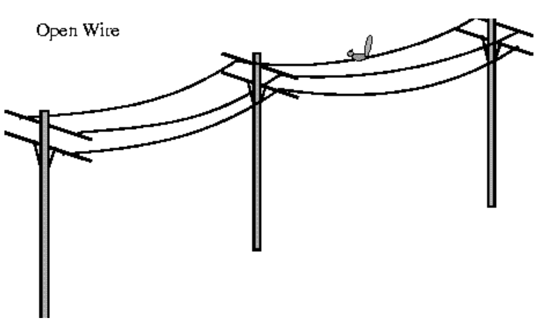
OPEN WIRE CABLE



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AERIAL CABLE

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ABOVE GROUND CONDUIT

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UNDERGROUND DUCT

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DIRECT BURY CABLE

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The Case for Self-Generation

- Continuity of service despite grid outages
- Agile response to market conditions
- Time of Day and Seasonal pricing factors
  - Rates vary by on-peak/off-peak periods, and summer/winter
- Demand Response/Curtailment Agreement
  - Lower rates/rebates utility for curtailment (load reduction)
  - Curtailment triggered by congestion, wholesale market price spikes, grid reliability concerns
- Base Load Generation vs. Peak Shaving
  - Base Load: Continuous operation serving all or most of campus demand
  - Peak Shaving: Rapid response generation to offset load during high demand hours
  - Energy Storage is another tool to achieve peak shaving—system costs rapidly coming down

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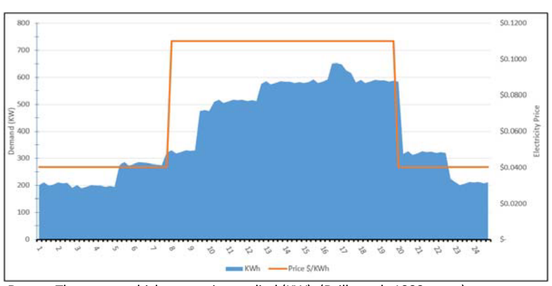
Power (KW) vs. Energy (KWh)



Power: The rate at which energy is supplied (KW). (Drill needs 1000 watts) Also called "Demand."
Energy: The amount of Power delivered over time (KWH) (Run the drill for 1 hr = 1 Kwh)
Driving Analogy: Power/Demand = miles per hour. Energy = total distance traveled.

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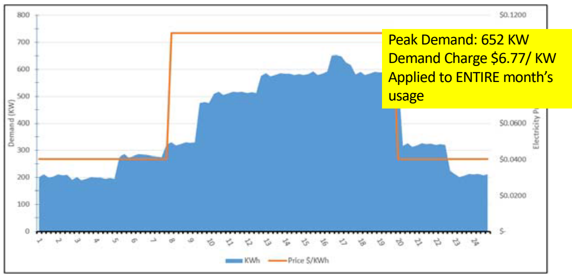
Demand and Energy



Energy Charge: $/KWh for total Energy Use (entire blue area)

On-peak Demand Charge: $/KW Charge based on your highest Demand (highest rate of energy consumption) during On-Peak hours. Demand is expensive because power plants, transmission, etc must be sized to meet peak demand.

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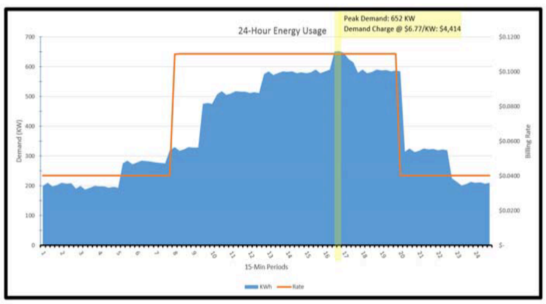

What changes might this facility take to reduce its electricity bill?
Scheduling options?
Generation options?
Load-following Generation?
Net metering?
Energy storage?

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Purchase or Generate? And Which Technologies?

Consider institutional priorities

- Utilities Cost Reduction
- Budget Stability
  - Fixed Costs – Construction & Regulatory
  - Marginal Costs – Fuel and O&M
- Energy Security
- Continuity of Services/Emergency Power
- Environmental Impacts
- University branding
- Research and Learning opportunities

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Purchase or Generate? And Which Technologies?

Consider limitations
- Available Capital
- Regional Energy Resources
- Physical Space / Existing Infrastructure
- Permitting Regime
- Community Support
- Timeline, Scalability
- Staffing & In-house Expertise
- Bring in third party operators?
- Sell utilities enterprise entirely?

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How About Renewable Energy?

- Intrinsic environmental benefits
- Branding: students expect and demand it
- Dramatic CoE reductions
- Understand available incentives and market value of
- Renewable Energy Credits
- What's your clout with your utility? Get them to do the heavy lifting!

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Solar or Wind?

Solar
- Load- following (usually)
- Less picky about siting, easier to permit
- Economics (usually) depend on tax incentives
- Scalable-- fairly easy to construct in phases
- PV Panels essentially commoditized, but supplier quality can vary

Wind
- Increasingly cost- competitive vs fossil fuels
- Siting and the wind resource are critical
- Not a load- following generation source (usually)
- Technology choice matters greatly

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Your Turn

You have been hired to design an electrical production and distribution system for a brand new campus that is located in a very sunny (hot) and windy location. Aesthetics are very important. Long term budget stability is important. Your budget for construction is very flexible as long as you can justify with TCO calculations.

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