Electric Power Systems

Electricity

Energy is the ability to do work

Power
- Instant "Demand"
- Watt (W) or kilowatt (kW)

Energy
- Power x Time
- Watt hour (Wh) or kilowatt hour (kWh)

Power vs. Energy

Power X Time = Energy

100 watts X 10 hours = 1 kWh
Energy vs. Demand

100 watts X 10 hours
=> 1 kWh energy
=> 100 W demand

1000 watts X 1 hour
=> 1 kWh energy
=> 1 kW demand

California Generation

California Power Plants

1999 CA Power Mix
Natural Gas 31%
Liquefied Hydro 26%
Coal 20%
Nuclear 16%
Renewables 12%
Other 1%

*Large proportion imported

Gas Turbine Generator

- Simple Cycle
  - Combustion gases turn turbine
  - One pass
- Combined Cycle
  - Heat captured creates steam
  - Powers second generator
- Higher efficiency
- Less expensive to build
- Less emissions
Cogeneration

- Waste heat from industrial or manufacturing process is used to generate electricity
- Increase efficiency
- Reduce emissions

- Issues
  - Is excess electricity needed?
  - Installed costs
  - Operations and maintenance costs
  - Fuel savings for making steam

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Transmission

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Transformers

Step down transformer.
Utility Transformers

Utility Power Meters
- Types
  - Electromechanical meters
  - Electrical meters
- Data output
  - kWh over demand periods
  - kW over demand periods
  - Power Factor
  - Can provide real-time kW

Power Quality Issues
- Voltage should be sustained within +5% of nominal
- Frequency deviation is +1%
- Potential PQ problems
  - Transients/Notches
  - Sag/Swell
  - Momentary interruption
  - Interruption/Outage
  - Noise/Harmonic Distortion
- Grounding issues
Power Factor

- A measure of how effectively an electrical load converts power into useful work.

- \( PF = \frac{\text{active power}}{\text{rms V} \times \text{rms A}} \).

Lighting
De Anza ES 74

- Lighting consumes 20% of the electricity generated in the US.

- Lighting represents approximately 40% of the electrical consumption for a typical office building.
Pollution Prevention

- EPA estimates that for every kWh per year saved the following amounts of pollution are prevented:
  - 1.0 lbs/yr CO2
  - 1.1 g/yr S02
  - 1.5 g/yr Nox

  For CA, Numbers are aggregated by US region

Importance of Lighting Quality

- Operating Cost per square foot (sqft)*
  - 85% Wages and benefits
  - 6% Space
  - 5% Services and Supplies
  - 3% Furniture and Equipment
  - 1% Lighting!

  *From EPA Green Lights Program

Compact Fluorescent Lamps

- Energy Efficient Substitute for incandescent lamps
  - Modular
  - Integral
  - Dedicated
- Good color rendering
- Flexible
- Limitations
  - Light can be "trapped" in a recessed can fixture
  - Retrofits are not usually dimmable
  - Output is affected by temperature and orientation
Compact Fluorescent

- Wattage: 5 to 40
- System Efficacy: 50 to 80
- Average rated life: 10,000 to 20,000
- CRI: 82 to 86
- Life Cycle Cost: moderate
- Fixture size: compact
- Start to full brightness: 0-1 minute
- Restrike time: immediate
- Lumen Maintenance: good

Halogen Torchiere

- 300 to 500 watts with dimming
- $20 first cost
- 2,000 hours lamp life

Compact Fluorescent Torchiere

- 65 watts two level
- $70 first cost
- 10,000 hours lamp life
What is a Motor?
- Machine that converts electrical power into mechanical power.

% of National Energy Use
- 60% of Nation's electricity as input

“A sizable percentage (15-25%) of U.S. electricity can be saved by optimizing the performance of electric motors and their associated wiring, power conditioning equipment, controls, and transmission components” (American Council for an Energy Efficient Economy 2002)

How Are Motors Used?
- Residential
  - “Fractional” small motors for appliances
- Commercial/Industrial
  - Pumps, fans, compressors for HVAC.

Energy Efficient Motors
- Energy Savings! 20 hp premium efficient running full time uses $14,000 of energy per year. First cost is around $1,200.
- Improved design, materials, and manufacturing reduces losses.
- Other benefits include:
  - Increased reliability
  - Higher service factor
  - Longer insulation and bearing lives
  - Less waste heat and vibration
  - Often longer warranty
  - Improved power factor
Energy Efficient Motors Applications

- New Construction
- Large Renovation projects
- Frequently used motors (hrs/yr)
  - We’ll do payback analysis!
- Improperly sized motors
- Failed motors

Variable Frequency Drives (VFDs)

- VFDs, also called Adjustable Speed Drives (ASDs), are the dominant speed control technology.
- Pumps, fans, and compressors are the most common applications.
- VFDs can provide precise control for other applications such as conveyor belts.
- Significant energy savings can accrue where part load conditions repeatedly exist.

Variable Speed Drives – Cost Benefit

- VFDs cost around $100 to $150 per hp
- Installation is around 15% of equipment cost
- Energy Savings are approximately 15 to 50%.
Renewable and Alternative Energy Systems
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Steve Murphy's Slides...
Solar Heating and Power Systems
- Space Heating/Cooling
- Domestic hot water heating/swimming pools
- Photovoltaic (PV) Power
Wind Turbines/Energy Systems
Ground Source Heat Pumps
Fuel Cells
Biomass

Renewable and Alternative Energy Systems

Solar Heating/Power systems:
- Solar "insolation" (incident solar radiation)
  - Energy balance
  - Greenhouse effect
  - "Solar constant" - 430 Btu/ft²/hr @ top of atmosphere
  - Solar geometry CRITICAL!
    - Altitude angle
    - Azimuth angle

Renewable Power Generation (cont.)

Photovoltaic Power:
- Principal of operation: photoelectric effect
- Systems converts light directly into DC electricity
- Components:
  - Cell → Module → Panel → Array
Renewable Power Generation (cont.)

**PV System Configurations:**
- Batteries used for electrical energy storage
- Inverters needed for AC power
- Regulators needed to ensure no overcharging of batteries
- Co-generation capabilities for excess power (i.e. California is req'd to purchase surplus power !!)

Solar Heating/Power Systems

"Active Solar" heating systems

**Solar Collectors**
- Low tech - i.e. swimming pool (coiled plastic piping)
- FPC design (Flat Plate Collector)
  - Efficiency of collector is critical factor!
    - Copper sheet with black selective surface; high absorptivity/low emissivity
- South facing
- Tilt angle = latitude
  - i.e. San Jose @ 37° tilt angle

Active Solar Heating Systems

**System Types/Classifications:**
- **Forced air:**
  - Rock bed thermal storage with forced convection fans
  - Preheating for domestic water heating possible
- **Hydronics:**
  - Domestic hot water/swimming pool
  - Space heating systems