BEYOND
SMART CITIES
ELECTRICAL POWER SYSTEMS - CEM
REFRESHER TRAINING
KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS

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SMART CITIES
ESTIMATING SAVINGS FROM
POWER FACTOR IMPROVEMENT - 1
FOR ENERGY PROFESSIONALS
KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM

WHAT SHOULD YOU LEARN
Electrical Basics (DC/AC, Single and 3-Phase Power)
Resistive and Inductive Loads, Power Factor
Voltage Imbalance, Grounding and Harmonics
Estimating Savings from Power Factor Improvement
Important 3-phase Motor Equations and Estimating Power Consumption

ELECTRIC RATES

- Utility Rate Structure Incentives
  - Demand Reductions
  - Time of day rate or real time pricing
  - Seasonal rate
  - Power Factor (Cos phi) Correction
  - Primary vs. secondary metering
  - Rebates and Rate riders (electric heat, etc)
- Potential approaches
  - High efficiency equipment
  - Scheduling uses off-peak
  - Demand limiting
  - Duty cycling

FACILITY ELECTRIC LOAD FACTOR

Definition:

Load Factor = Actual kWh Used
Peak kW ´ Time

Example: Compute monthly load factor

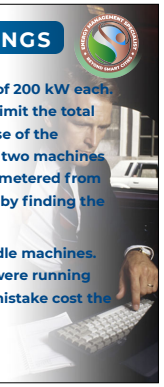
Peak kW = 1250 kW
Energy use = 500,000 kWh
Time = 720 hours

$$LF = \frac{500{,}000\ kWh}{1250\ kW \times 720\ h} = 55.6\%$$

Note: Higher load Factor will reduce unit kWh costs (more kWh per kW- i.e. kW- fixed costs, kWh variable costs.)

EXAMPLE OF DEMAND CONTROL SAVINGS

- A production facility has four large machines with a demand of 200 kW each. The machines could be controlled by a computer which would limit the total demand to 400 kW at any one time. This company limits the use of the machines by operational policy which states that no more than two machines should be turned on at any given time. This room is separately metered from the rest of the facility. Convert the electric and gas use into MJ by finding the appropriate conversion factor.
- One morning at 8:00 am, a new employee turned on the two idle machines. At 8:30 am the plant foreman noticed that too many machines were running and quickly shut down the extra two machines. What did this mistake cost the facility?



IMMEDIATE COST OF MISTAKE

The immediate cost on the month's electric bill has two components. Assuming a demand rate of $7.02/kW and an energy rate of $0.043/kWh, the immediate cost is calculated as:

Demand cost increase = 400 kW × $7.02/kW
= $2808

Energy cost increase = 400 kW × 0.5 hr × $.043/kWh
= $8.60

RATCHET PENALTY

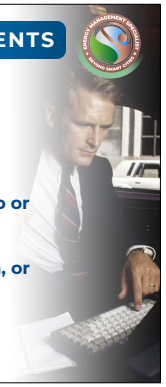
Some utility rate structures include a demand ratchet. For example, for a 70% ratchet, here would be a minimum demand assessed for the next 11 months of 70% of the highest demand in the previous 11 months, regardless of actual metered demand.

(.70 × 800 kW) - 400 kW = 160 kW

This would increase the cost of the mistake as follows: Ratchet cost increase = 11 mo × $7.02/kW mo × 160 kW
= $12,355.20

Total cost of mistake = $2808 + $8.60 + $12,355.20
= $15,171.80

REVIEW OF ELECTRIC COST COMPONENTS



Energy cost - e.g. $0.05/kWh

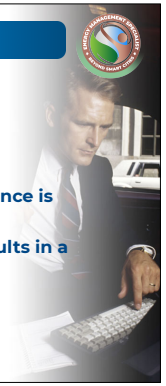
Demand cost - e. g. $6.50/kW/mo

Fuel adjustment - e.g. $0.005/kWh

Power factor (Cos phi)penalty – e.g. $6.50/kVA/mo or kW billed = kW × (0.85/PF)

Ratchet clause - e.g. Maximum of (kW this month, or 70% of maximum kW in last 11 months)

BASIC ELECTRICAL FORMULAS



1. Ohms Law
   V = I × R
   Used for AC or DC voltages where only a resistance is involved.
   For a fixed resistance, doubling the voltage results in a doubling of the current

BASIC ELECTRICAL FORMULAS +

2. Ohms Law for Power
   P = I2 × R

   For a fixed resistance, doubling the current results in power increasing by a factor of four.
   To reduce the distribution losses in a facility, higher voltages are used to supply large loads.
   At the higher voltage, Ohms Law tells us that the current is less then that at associated with the lower voltage to deliver the same power to the loads. But, the power loss in the distribution wiring is much less from its wiring resistance.

POWER COMPUTATION FORMULAS

Single-phase system
P = V × I × Cos phi
Where Cos phi = power factor

Three-phase system
P = √3 × V × I × Cos phi
Where Cos phi = power factor
√3 = 1.732

POWER COMPUTATION FORMULAS

Single-phase system

$P = V \times I \times \cos \phi$

Where Cos phi = power factor

Three-phase system

$P = \sqrt{3} \times V \times I \times \cos \phi$

Where Cos phi = power factor

$\sqrt{3} = 1.732$

POWER COMPUTATION FORMULAS +

Examples

a) For a 10 ampere, 220 volt, electric space heater

$P = 220 \times 10 \times 1.0 = 2200$ watts

b) For a three phase 380 volt, 20 ampere motor with power factor (Cos phi) of 90% at full load

$P = \sqrt{3} \times 380 \times 20 \times 0.9 = 11.85$ kW

ELECTRIC MOTOR EQUATIONS

$kW = \sqrt{3} \times kV \times I \times \cos \phi$

$kVA = \sqrt{3} \times kV \times I$

Cos phi (PF)= kW/kVA

$$kWin = \frac{kWnp \times \text{Load Factor}}{\text{Efficiency}}$$

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