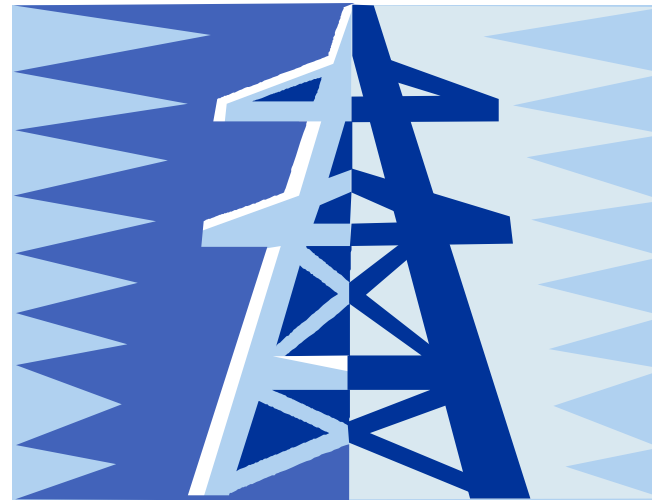


Energy 101 Tutorial



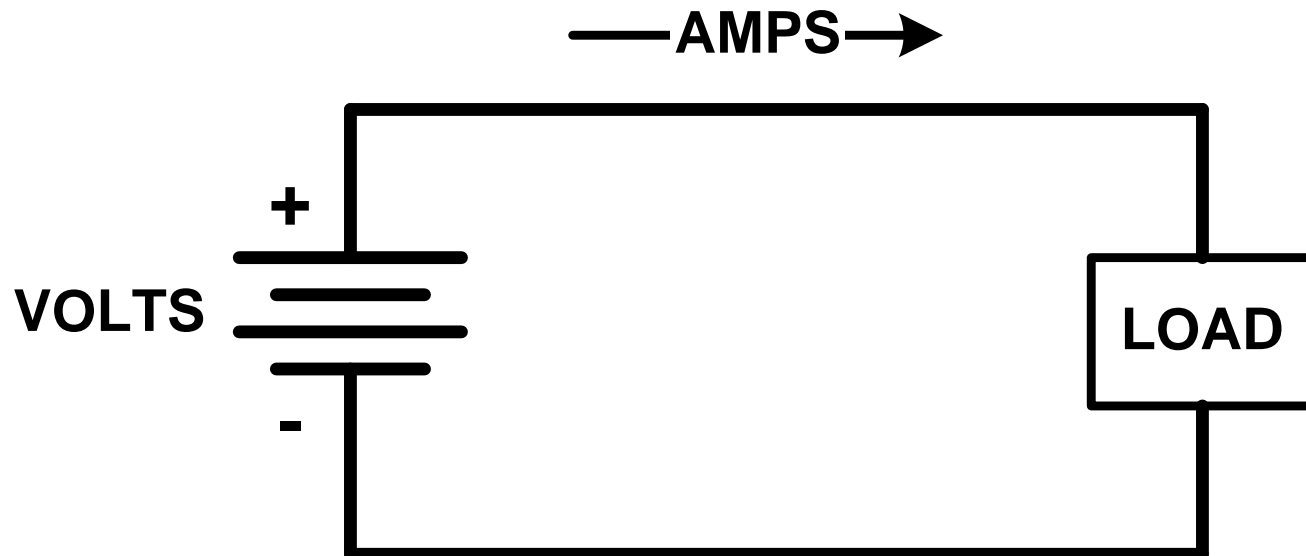
Basic Electricity

- Ampere (Amp) (I) - Unit of measure for current flowing in a circuit
- Volt (V) - Unit of measure for a potential or “pressure” that pushes current through a circuit
- Ohm (Z), Unit of measure for impedance, which resists or “impedes” the flow of current
 - Resistance (R)
 - Inductive Reactance (X_L)
 - Capacitive Reactance (X_C)



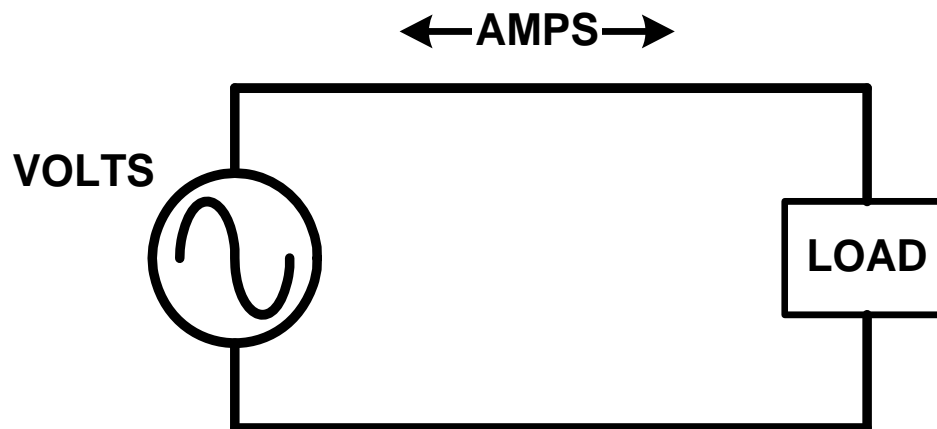
DC Circuits

- Direct Current (DC) – Volts and Amps always “push” and “flow” in the same direction



AC Circuits

- Alternating Current (AC) – Current changes direction many times per second
- Hertz (Hz) – Unit of measure for Frequency (changes of direction per second)
 - 60 Hz in USA, 50 Hz in EU



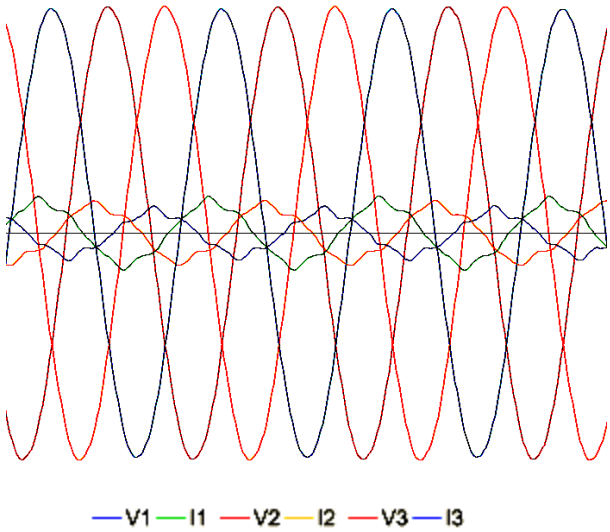
Single Phase vs. Three Phase

- Single-phase generators have a single winding
- Three-phase generator have three windings



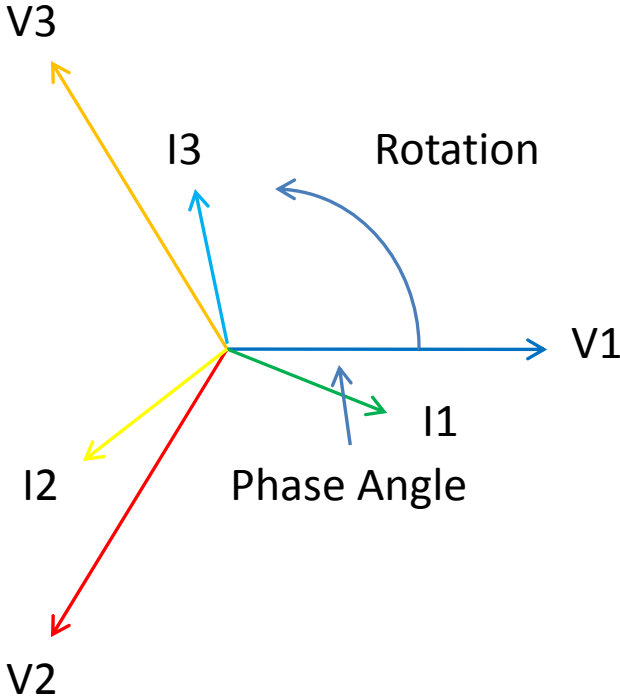
- Single-phase loads can be connected to individual phases of a three-phase power system

Representing AC Volts and Amps



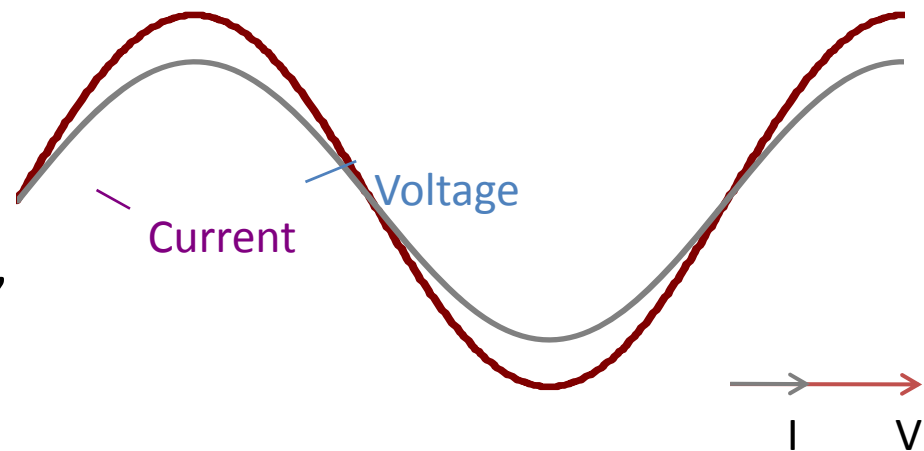
Waveform

Phasor Diagram



Real Power (P)

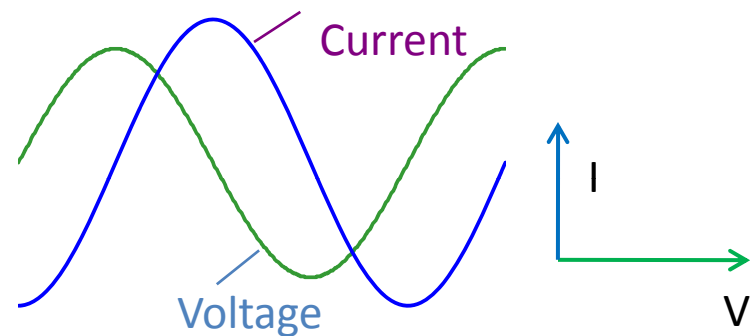
- Power = Rate of energy transfer
- Voltage and current are in phase
 - Resistive circuits such as incandescent lights & heaters
- Units of measure:
 - Watts (W)
 - Kilowatts (kW), Megawatts (MW)
- Real Power produces heat, mechanical and chemical work



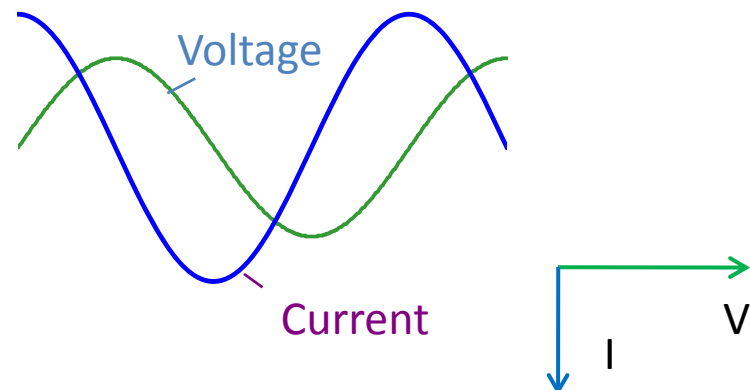
Reactive Power (Q)

- Voltage and Current are not in Phase
 - Inductive circuits such as motors & transformers
 - Capacitive circuits such as capacitor banks & certain rotating machines
- Units of measure:
 - Volt-Amperes, Reactive (VARS)
 - kVAR and MVAR
- *Reactive Power* is stored in magnetic and electric fields.

- Capacitive circuit

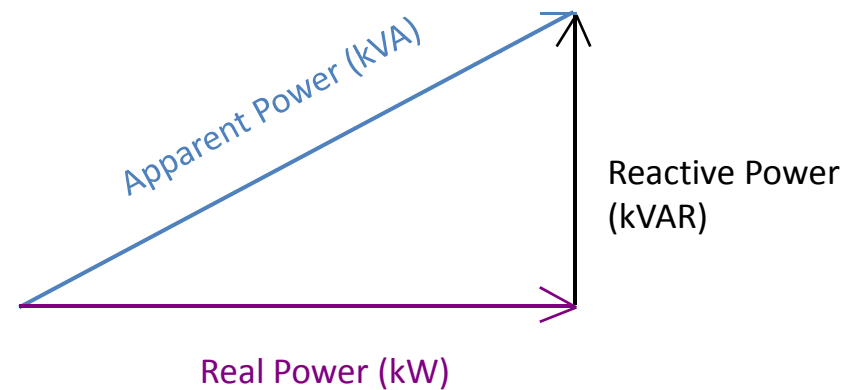


- Inductive circuit



Apparent Power (S)

- Units of Measure:
 - Volt-Amperes (VA's)
 - kVA and MVA
- *Apparent Power* dictates the capacity requirements of the system
 - Generators and transformers rated in kVA or MVA



Power Factor

- Ratio of Real to Apparent Power

$$PF = \frac{\textit{Real Power (P)}}{\textit{Apparent Power (S)}}$$

- Power factor can be Leading or Lagging
 - Lagging means the load is more inductive
 - Leading means the load is more capacitive
- Leading Power Factor can be undesirable
 - Can cause voltage control problems
- Utilities may impose a Power Factor Penalty

Energy

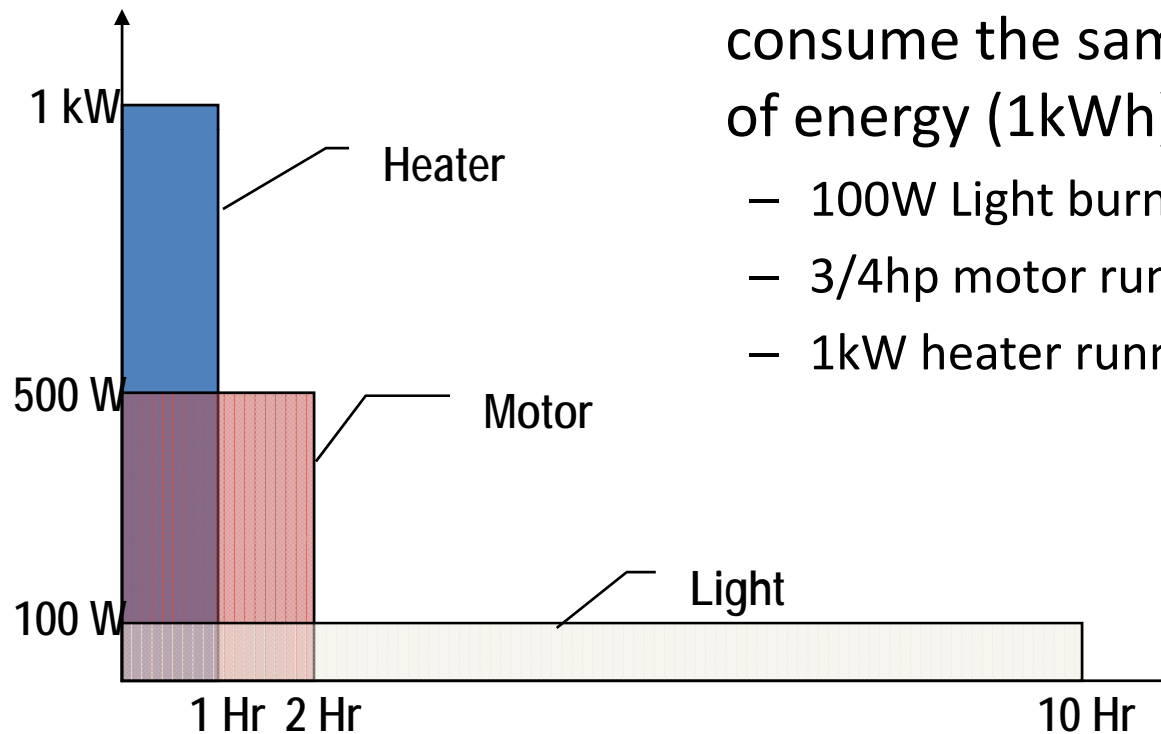
- Power = Rate of Energy Transfer
- Energy = Power * Time Interval
- Units of measure:
 - Watt-hours (Wh)
 - kWh, MWh
- A little “weird” since time is part of the energy unit

- Energy like an odometer



- Power like a speedometer

Energy example

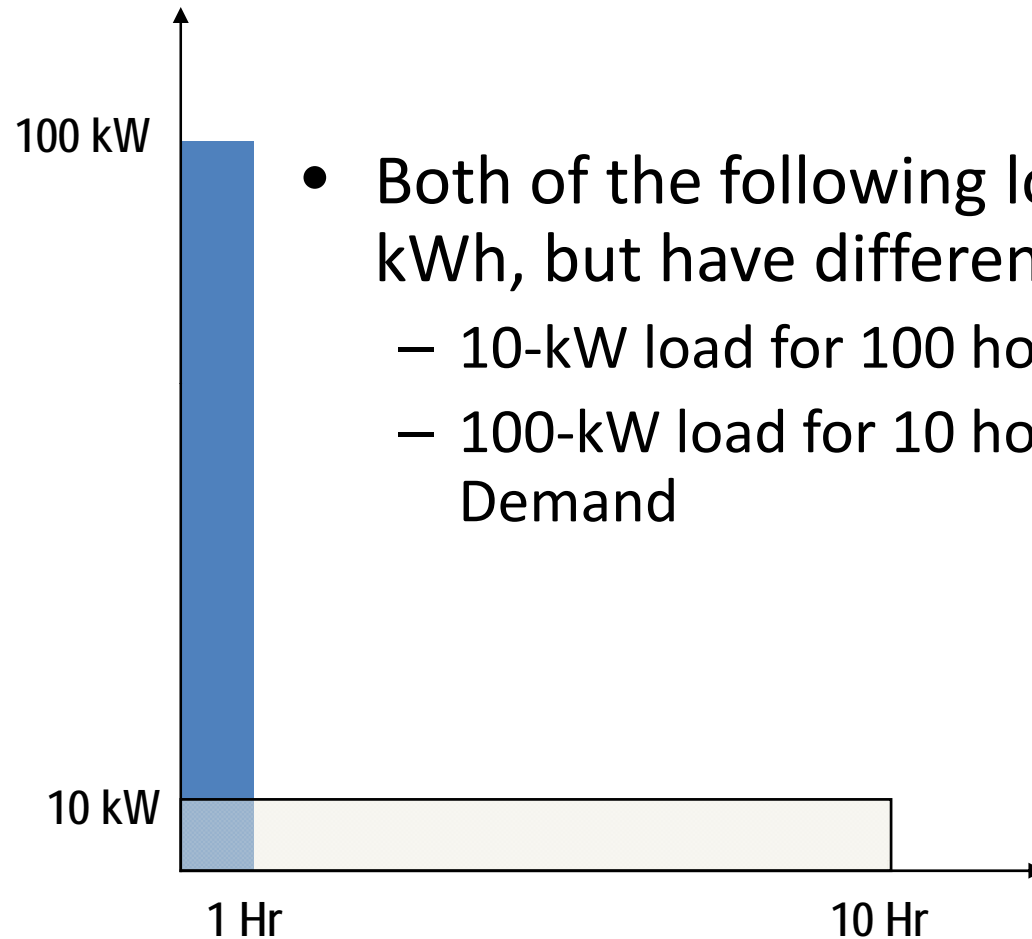


- All of the following loads consume the same amount of energy (1kWh):
 - 100W Light burning for 10 hrs
 - 3/4hp motor running for 2 hrs
 - 1kW heater running for 1 hr

Demand

- Average rate of energy transfer during each **Demand Interval**
 - Demand Interval set by the energy provider
 - Usually fixed interval but may be a “sliding window”
 - Typically 15 minutes long but may be 30 or 60 minutes
- Single highest interval Demand occurring in the billing period is the **Peak Demand**
- Units of measure same as Power (kW)
- Demand dictates the minimum capacity of the electrical system
 - Energy providers charge for peak demand to recover costs associated with maintaining a larger system capacity
- Ratchet clauses prolong the financial penalty
 - Example: charge for highest demand in previous 12 months

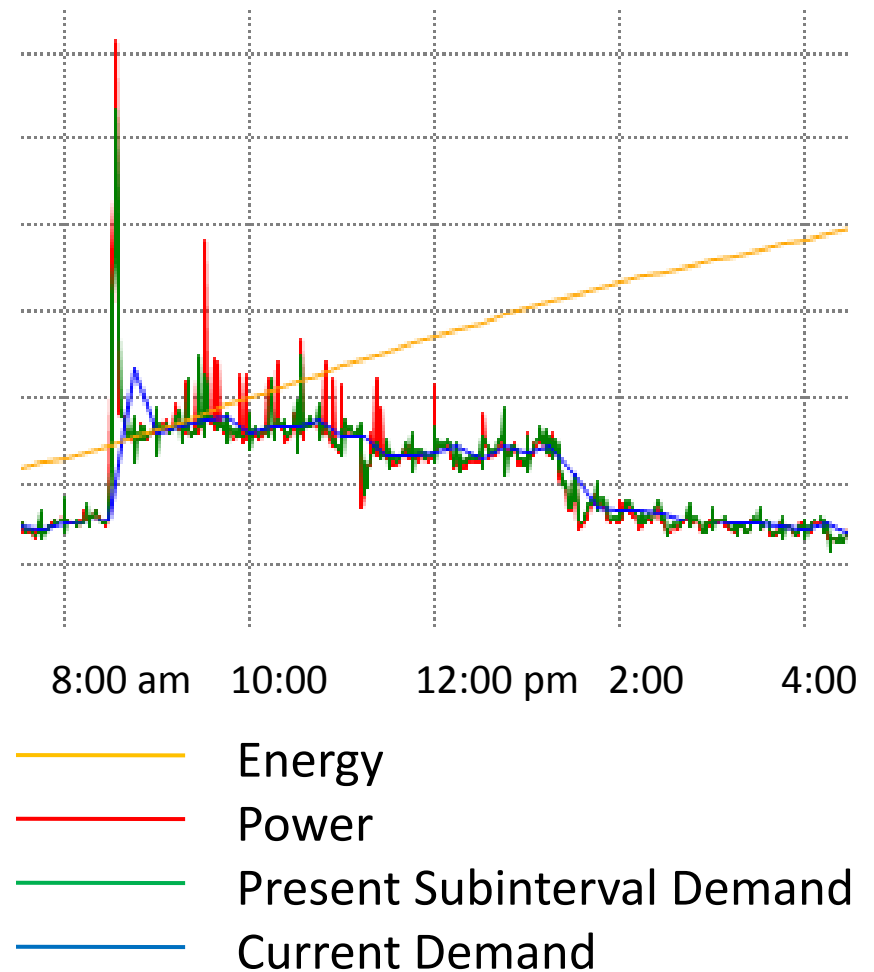
Peak Demand Example



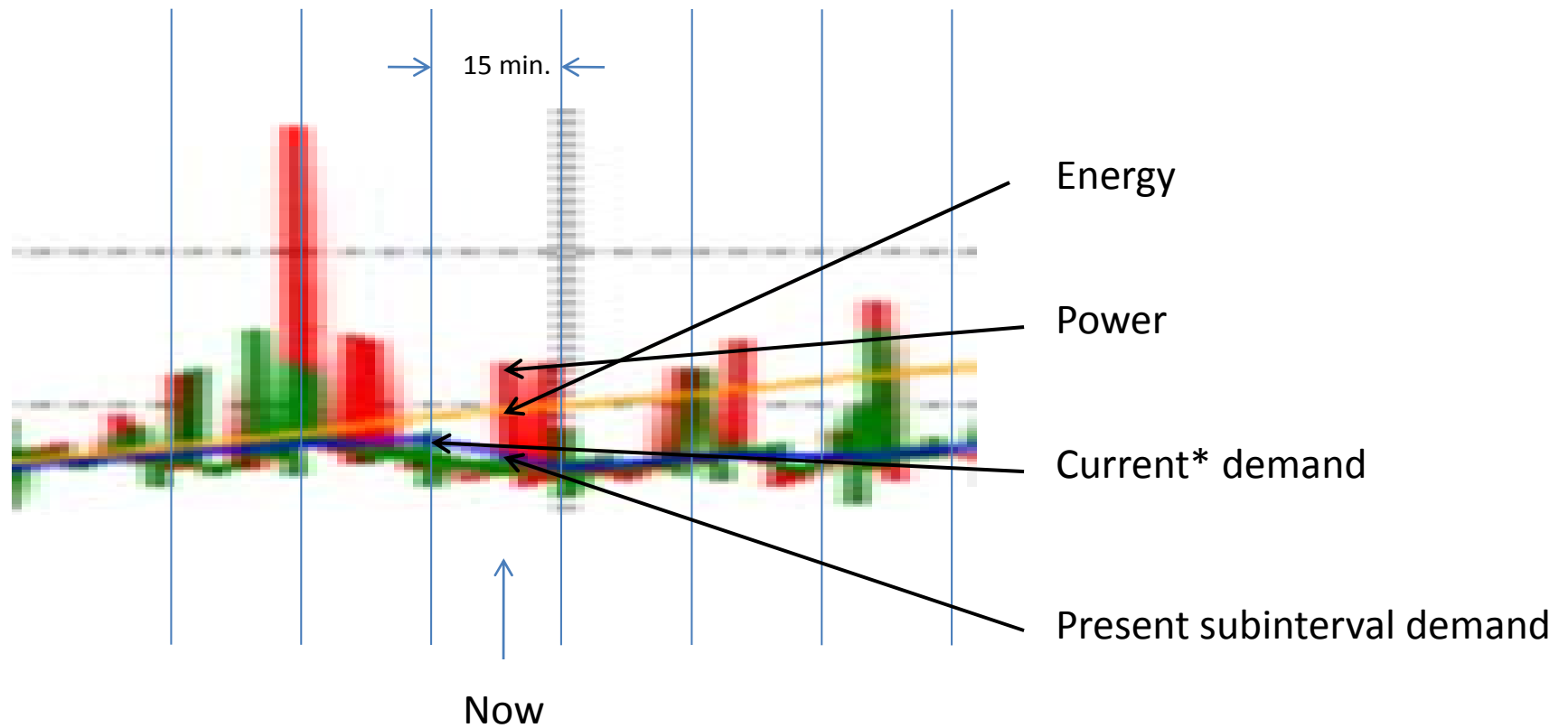
- Both of the following loads consume 100 kWh, but have different peak demands:
 - 10-kW load for 100 hours = 10 kW Demand
 - 100-kW load for 10 hours = 100 kW Demand

Demand, Power and Energy

- ANSI definitions
 - Current Demand = most recent interval demand
 - Present Subinterval Demand = average energy used over portion of demand interval



Demand, zoomed view



* Current indicates time, not flow of electricity

Utility Billing

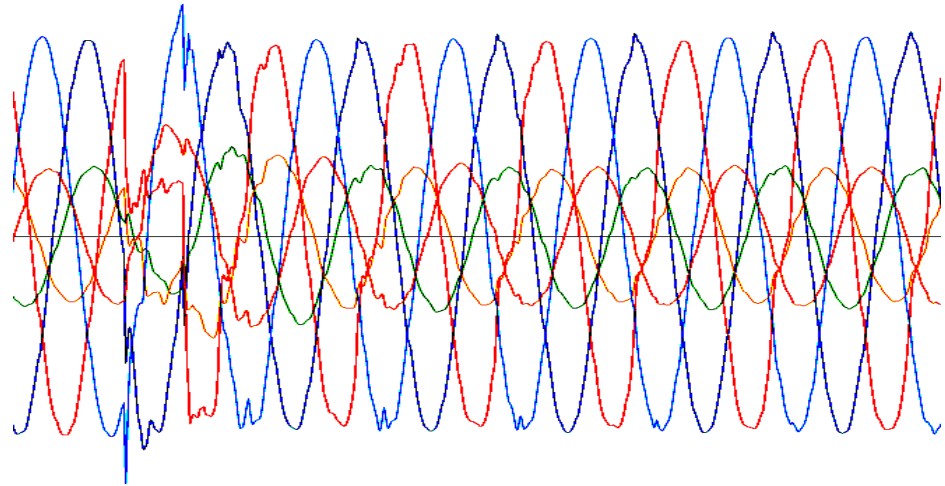
- A **Tariff** is filed by the utility with the controlling body in the state
- A power delivery **contract** exists between a user and the utility
- A electric power **bill** will usually consist of the following parts:
 - Energy usage charges (cents per kWh)
 - Demand charges, on peak / off peak (\$ per kW)
 - Power factor penalty
 - Taxes, special charges or credits (also known as “riders”) & other miscellaneous charges

A few words about power quality

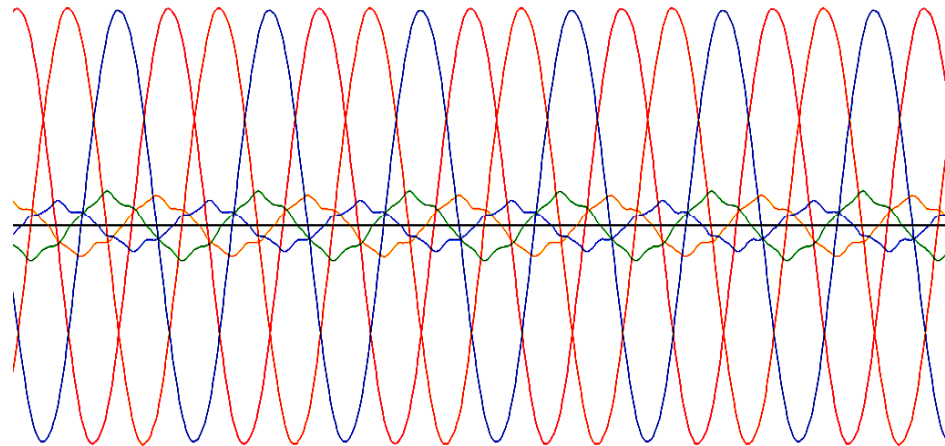
- Power quality is the absence of malfunctions or failures caused by power anomalies
- A misnomer; should be “voltage quality”
- Examples of power quality events
 - Sags: voltage dips $> 10\%$
 - Swells: voltage rises $> 10\%$
 - Interruptions
 - Noise, harmonics, unbalance

Power quality

- Bad power quality



- Good power quality



NAESB model

- Power quality summary
 - Statistical counts of various power quality events
- User who wants detail needs to invest in power quality metering.

Questions, comments?

Thank you!