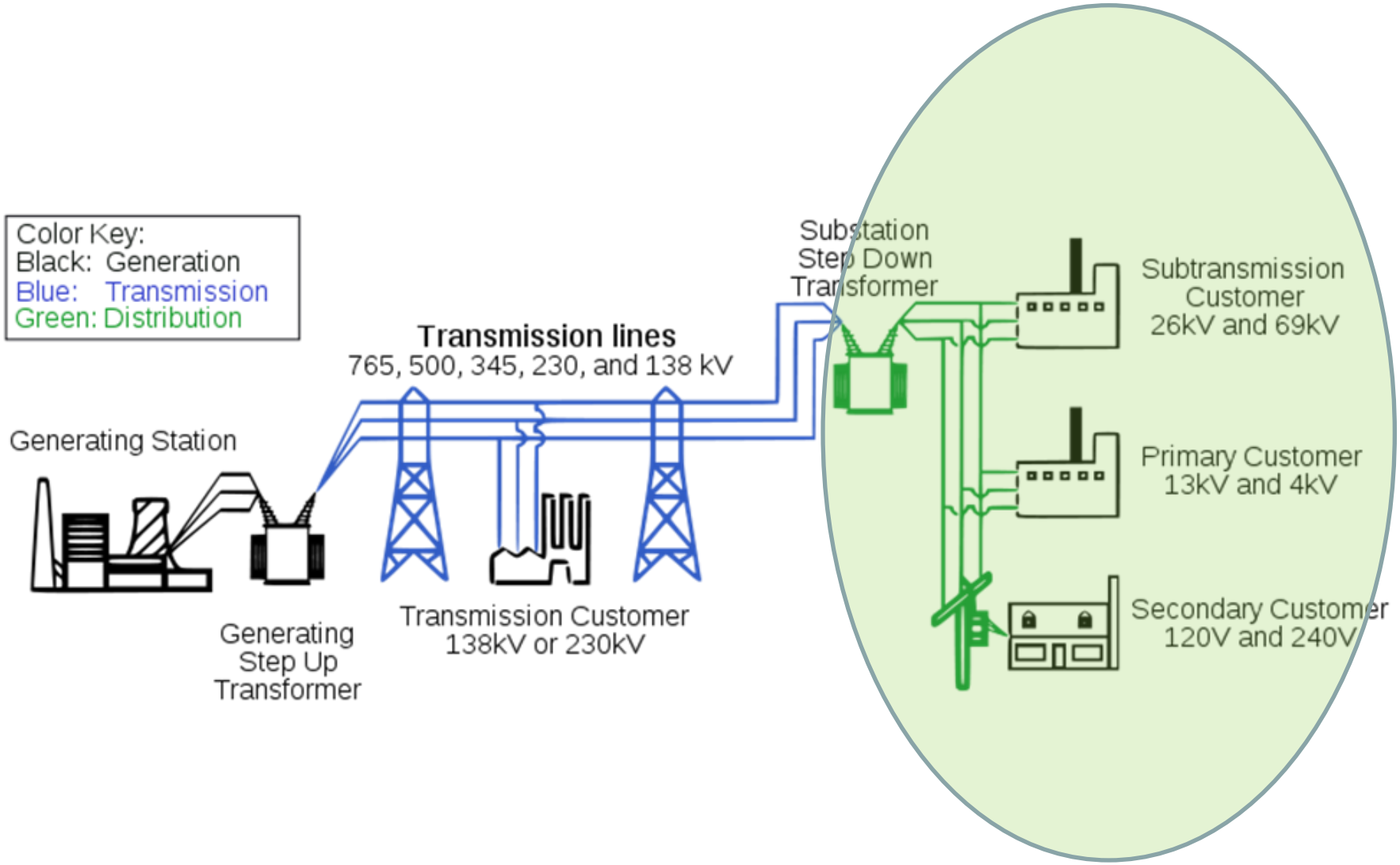
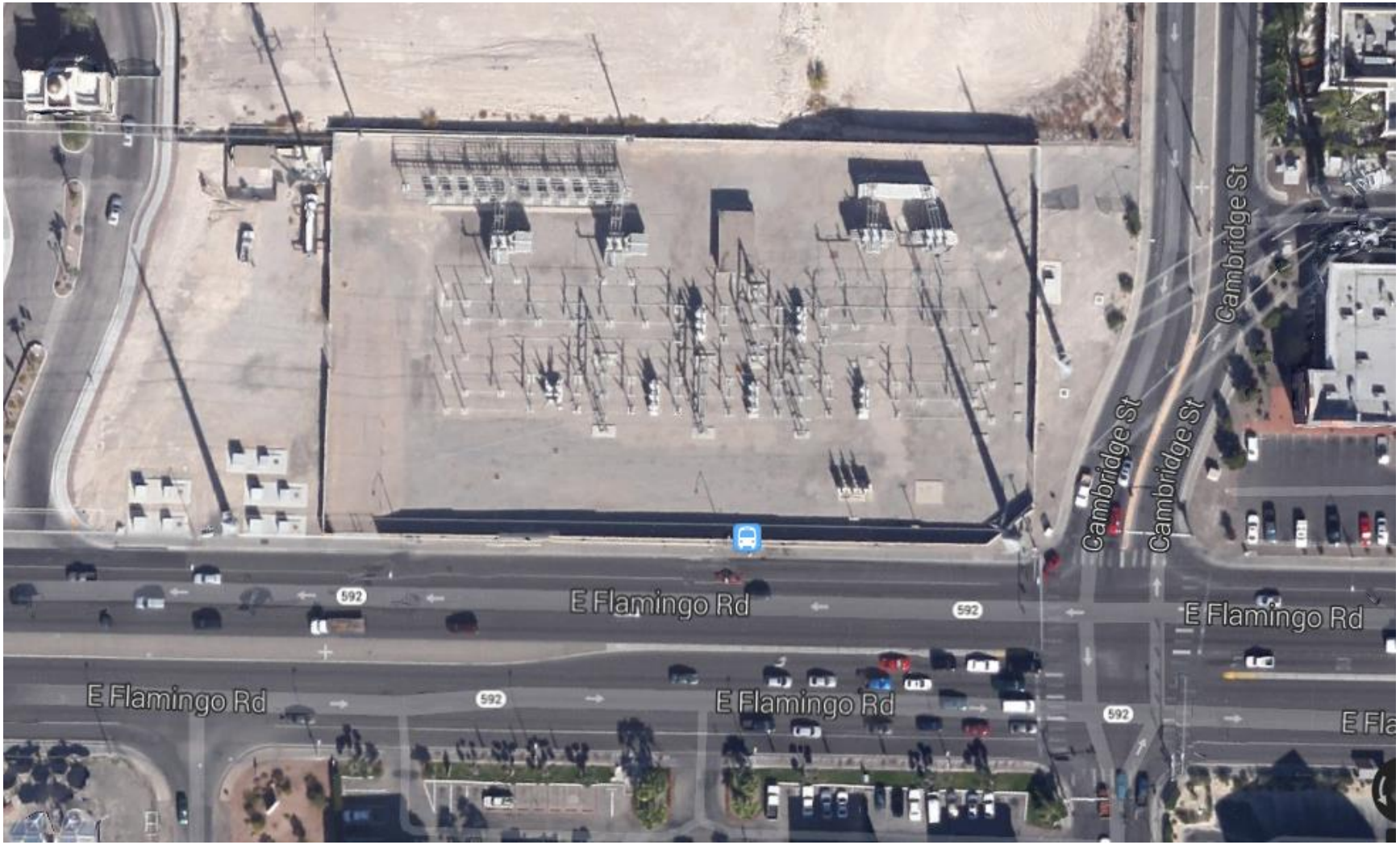
EE 741
Spring 2017

Electric Power Distribution Systems – An Overview

Basic Power System Layout

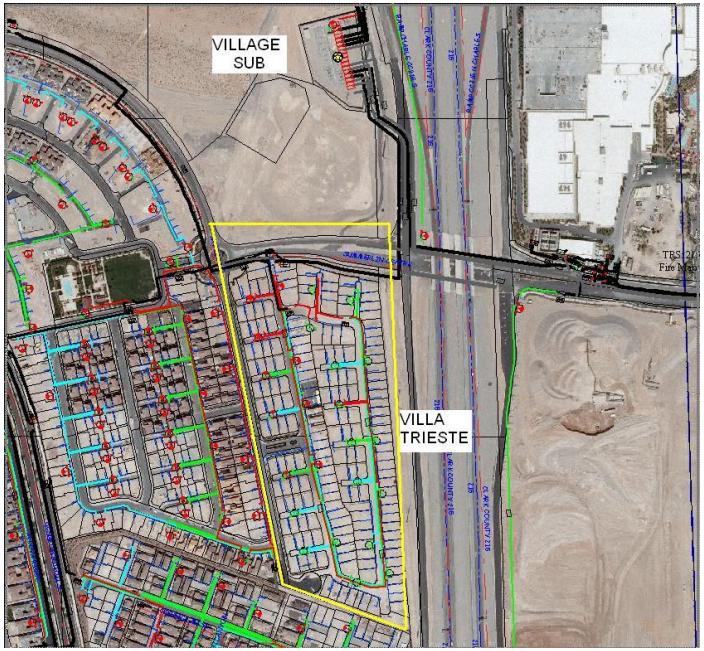


There are over 200 substations in Southern Nevada – pic of closest substation

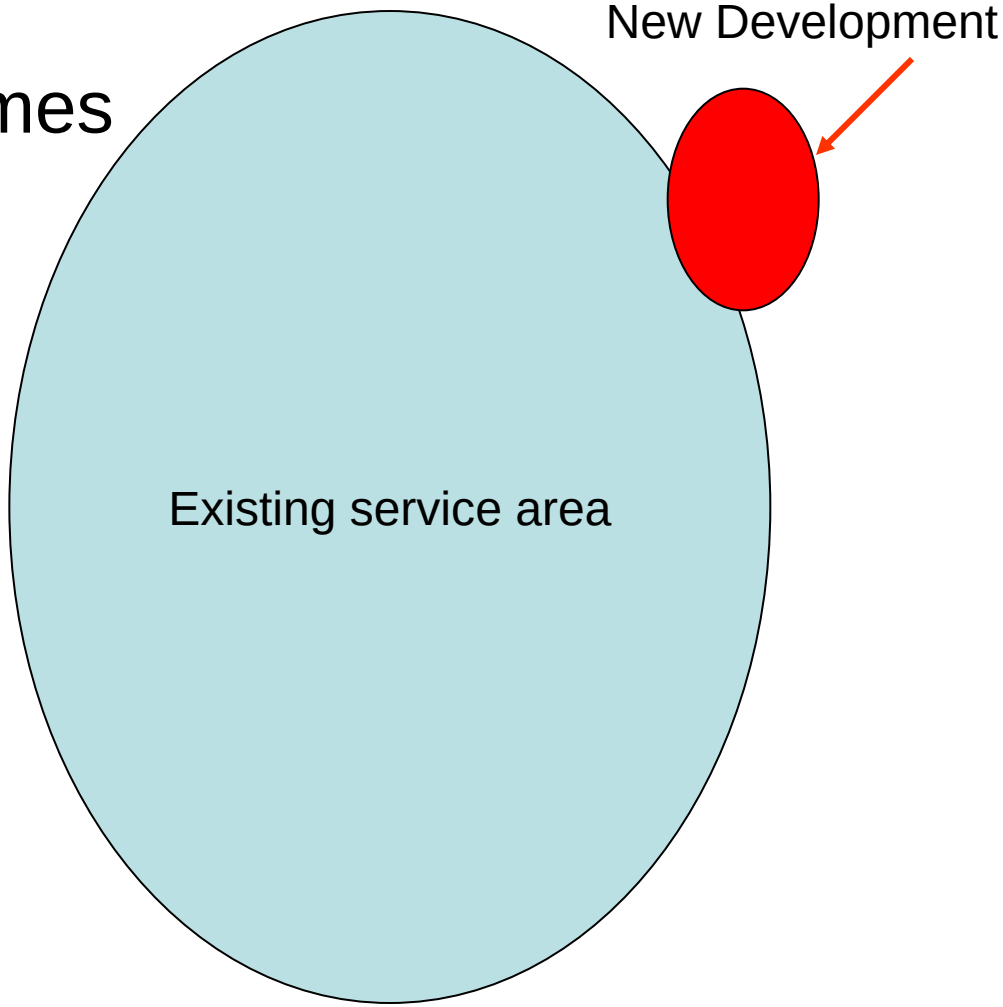


Substation Design

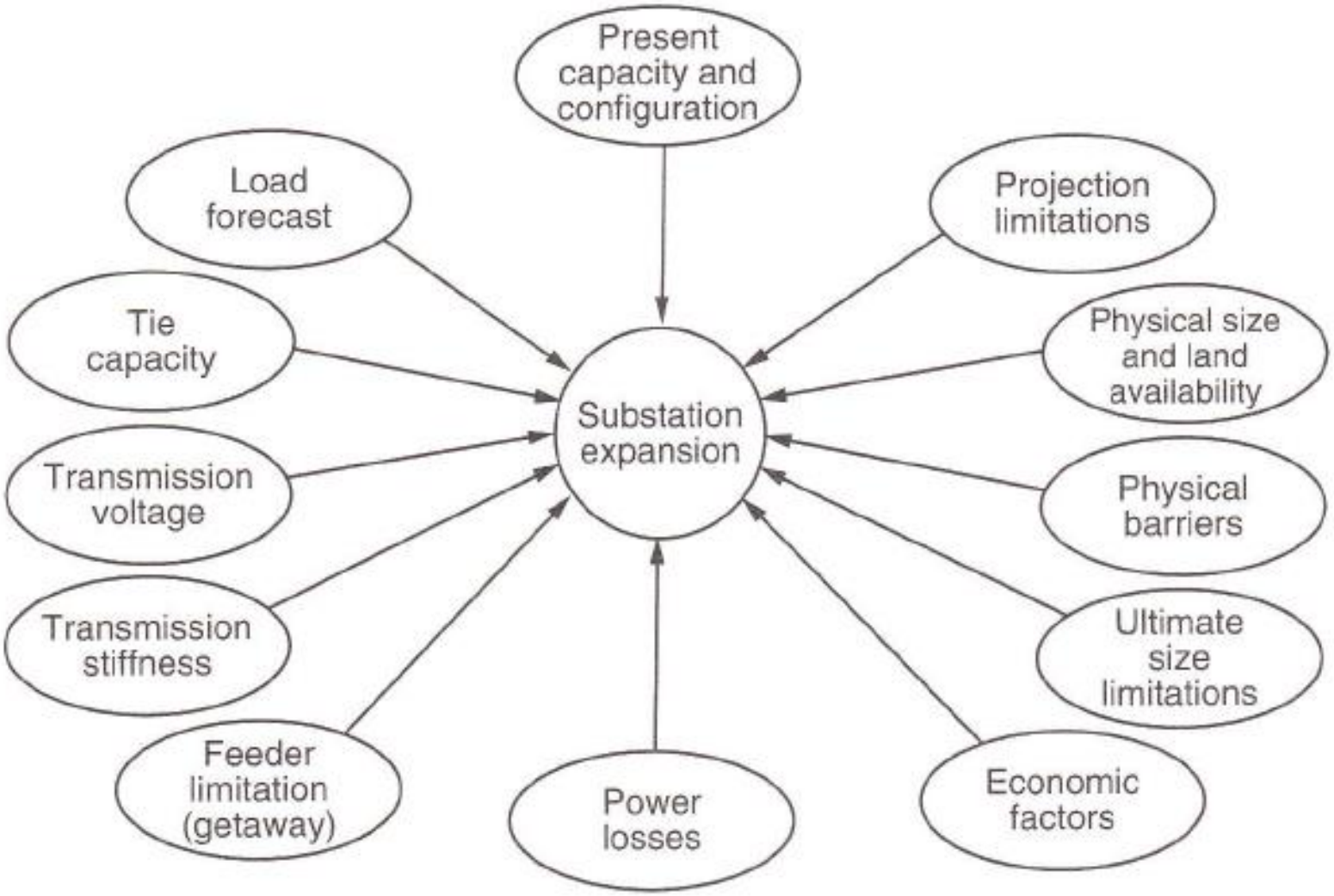
- Substation siting
- System expansion
- Substation bus schemes



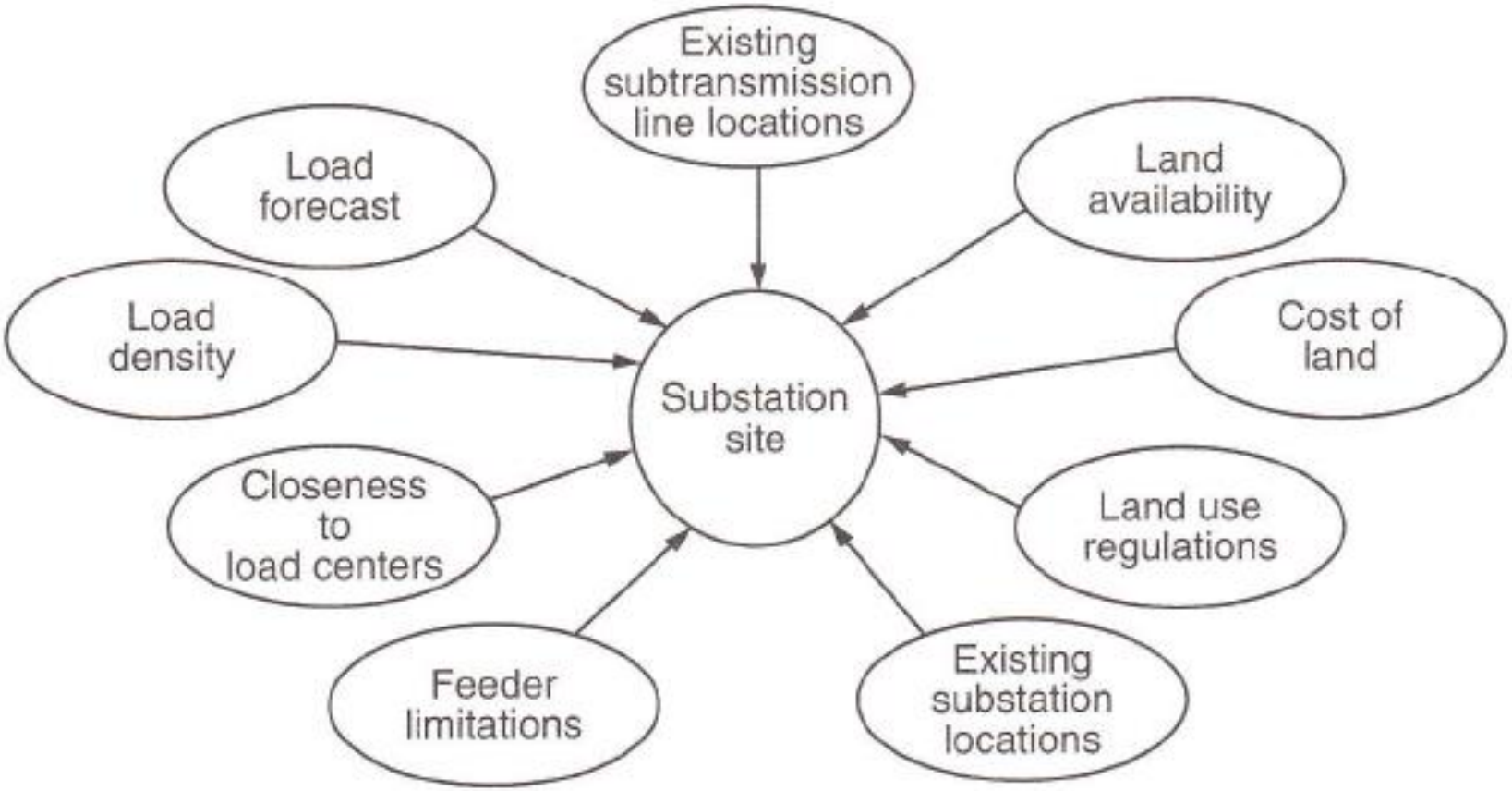
Serve from nearby substation or build new substation?



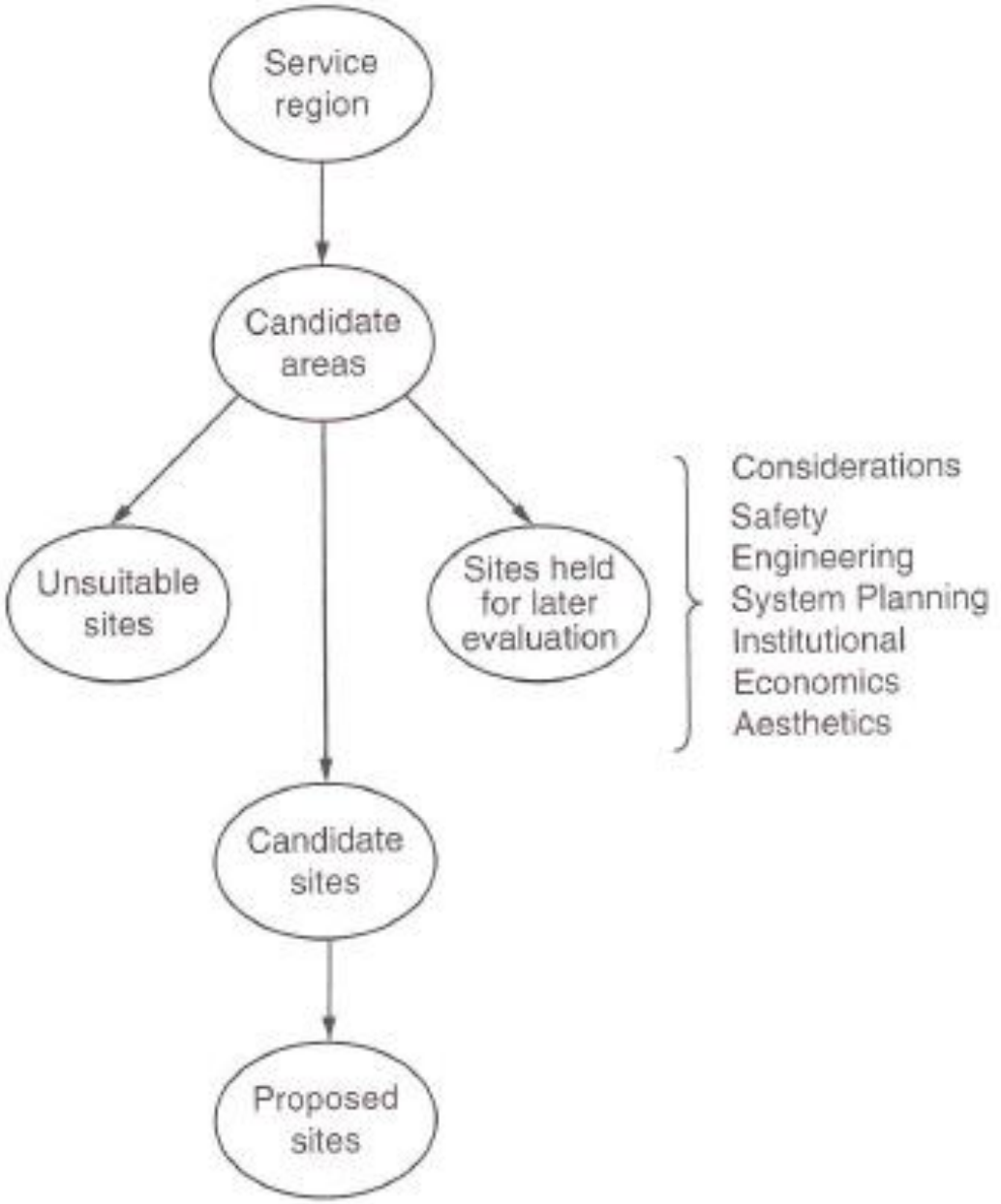
Factors affecting substation expansion



Factors affecting substation siting

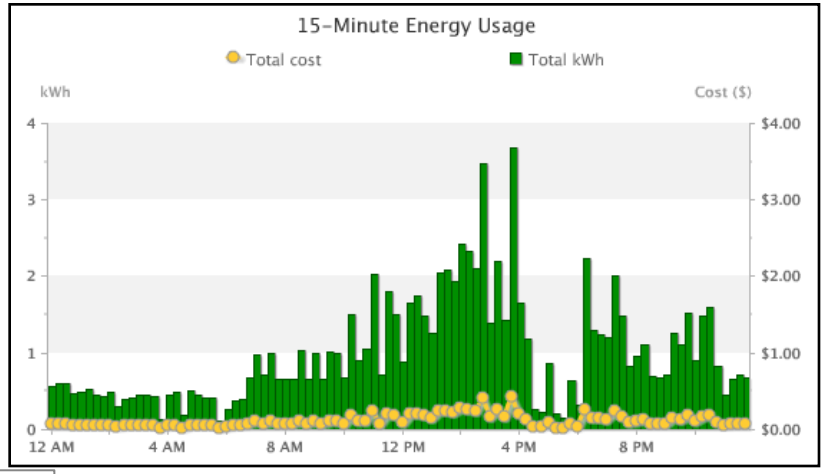


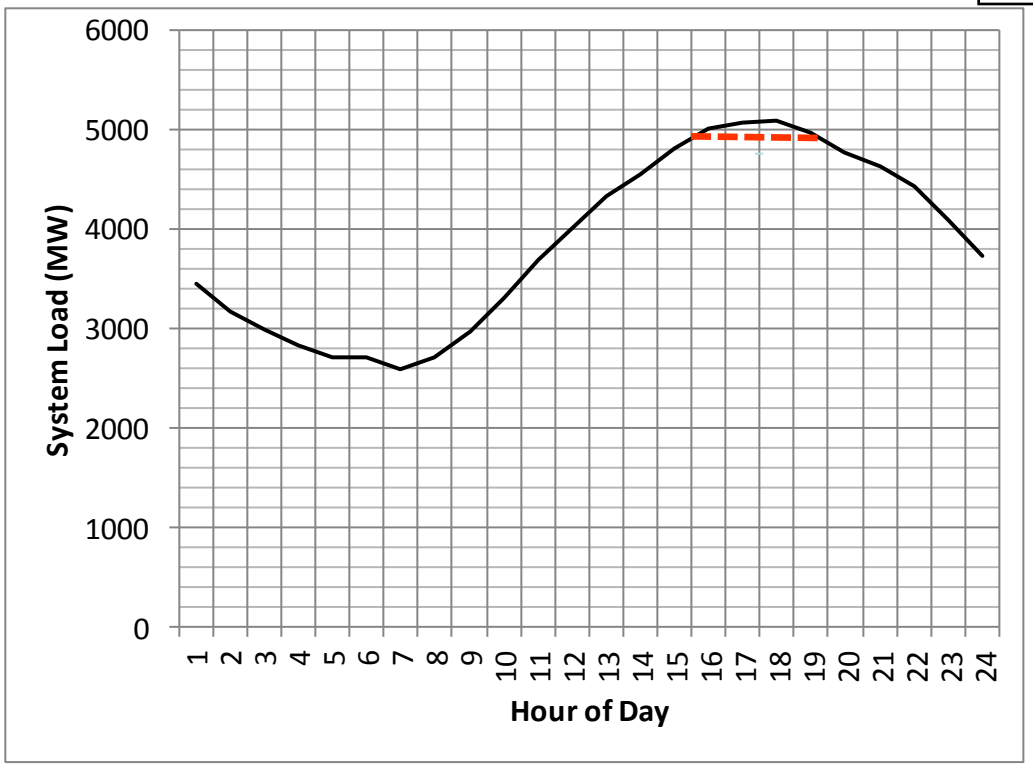
Substation Site Selection Procedure



Load Characteristics

- Customer load
- Diversity
- Metering
- Load control

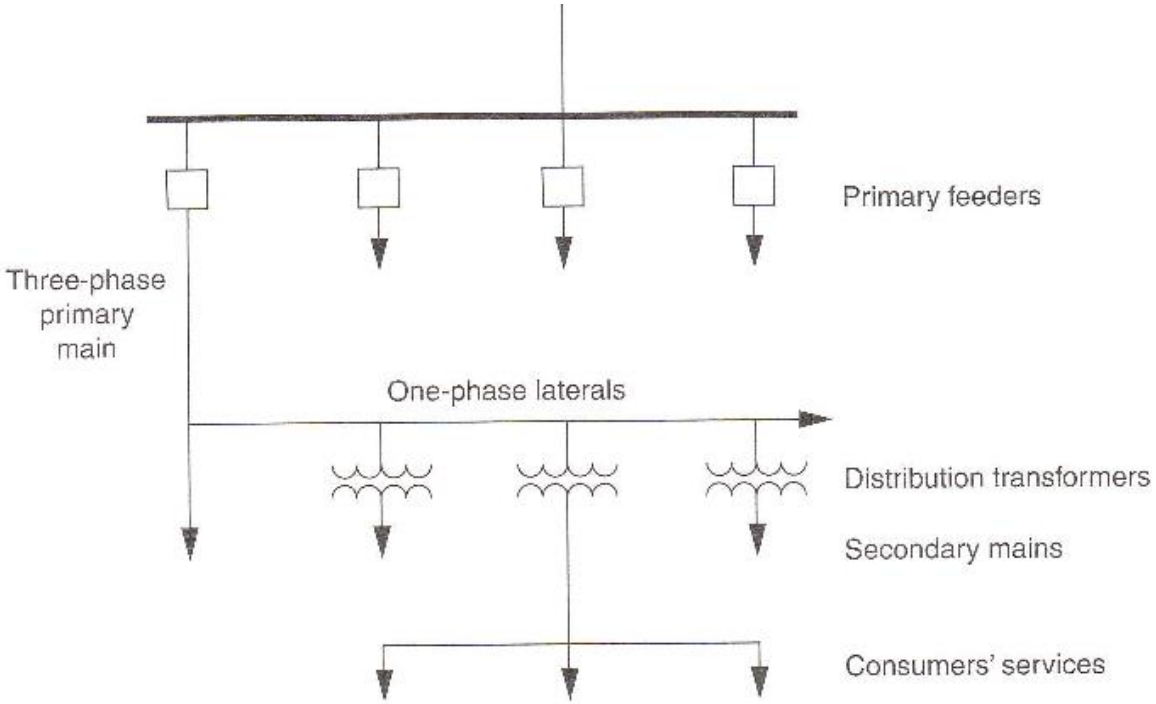




Power Transformers

- Substation transformers
- Distribution transformers

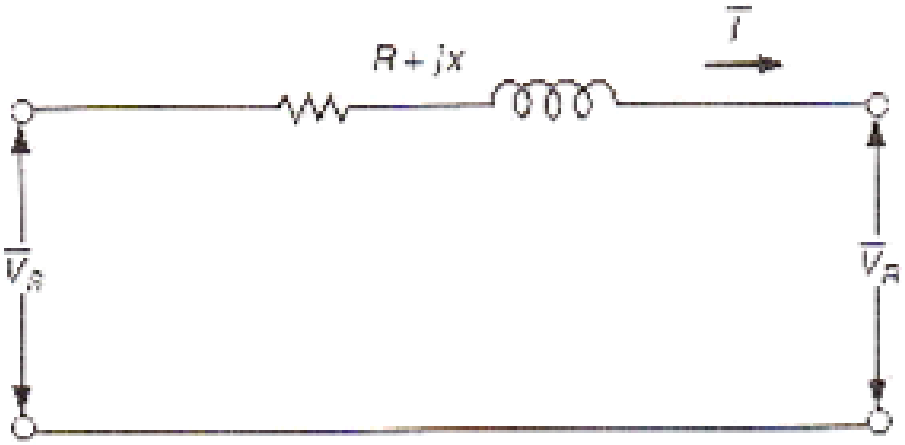
Design of primary and secondary systems



Voltage drop and power loss calculations

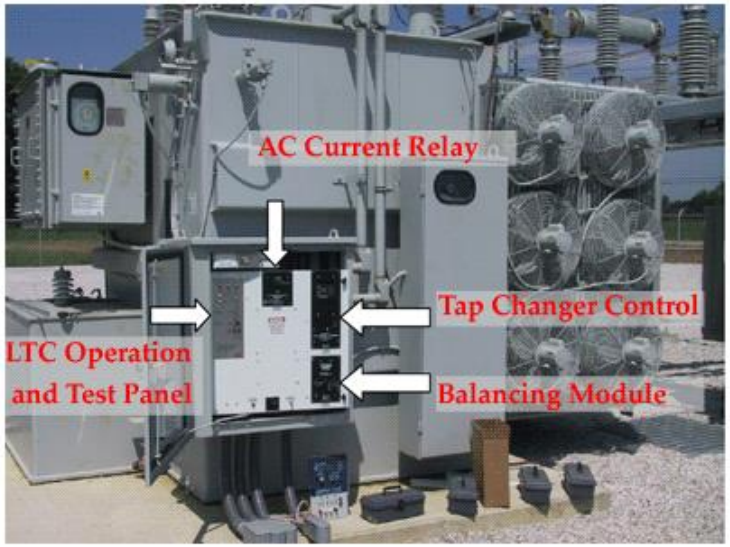
$$VD \approx I(R\cos\theta + X\sin\theta)$$

$$P_{loss} \approx I^2 R$$



Voltage regulation and capacitor application

- LTC @ substation transformer
- Voltage Regulators
- Fixed and switched shunt capacitors



Distribution System Protection

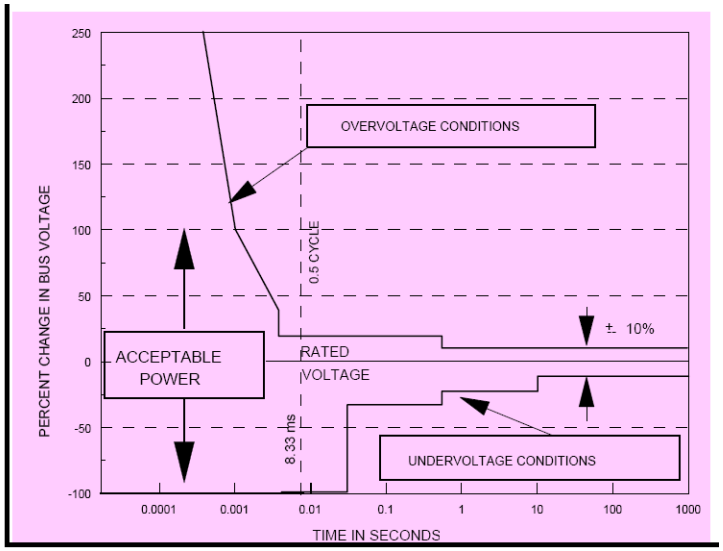
- Overvoltage Protection
- Overcurrent Protection

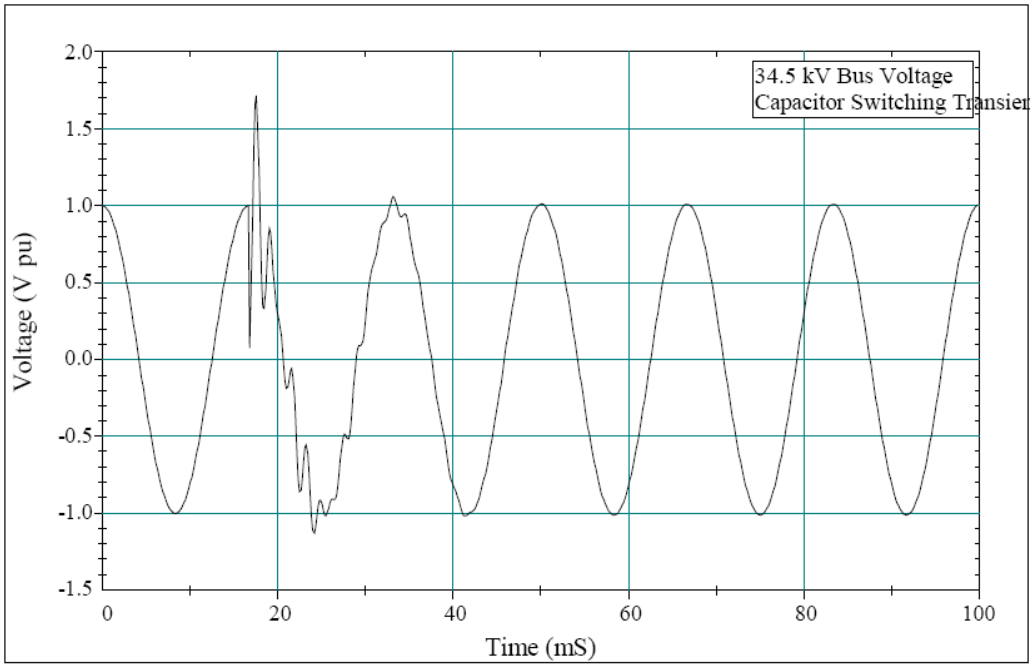
Distribution System Reliability

- Sustained interruption indices (e.g., SAIDI, CAIDI, …)
- Other indices (momentary)
- Load and energy based indices

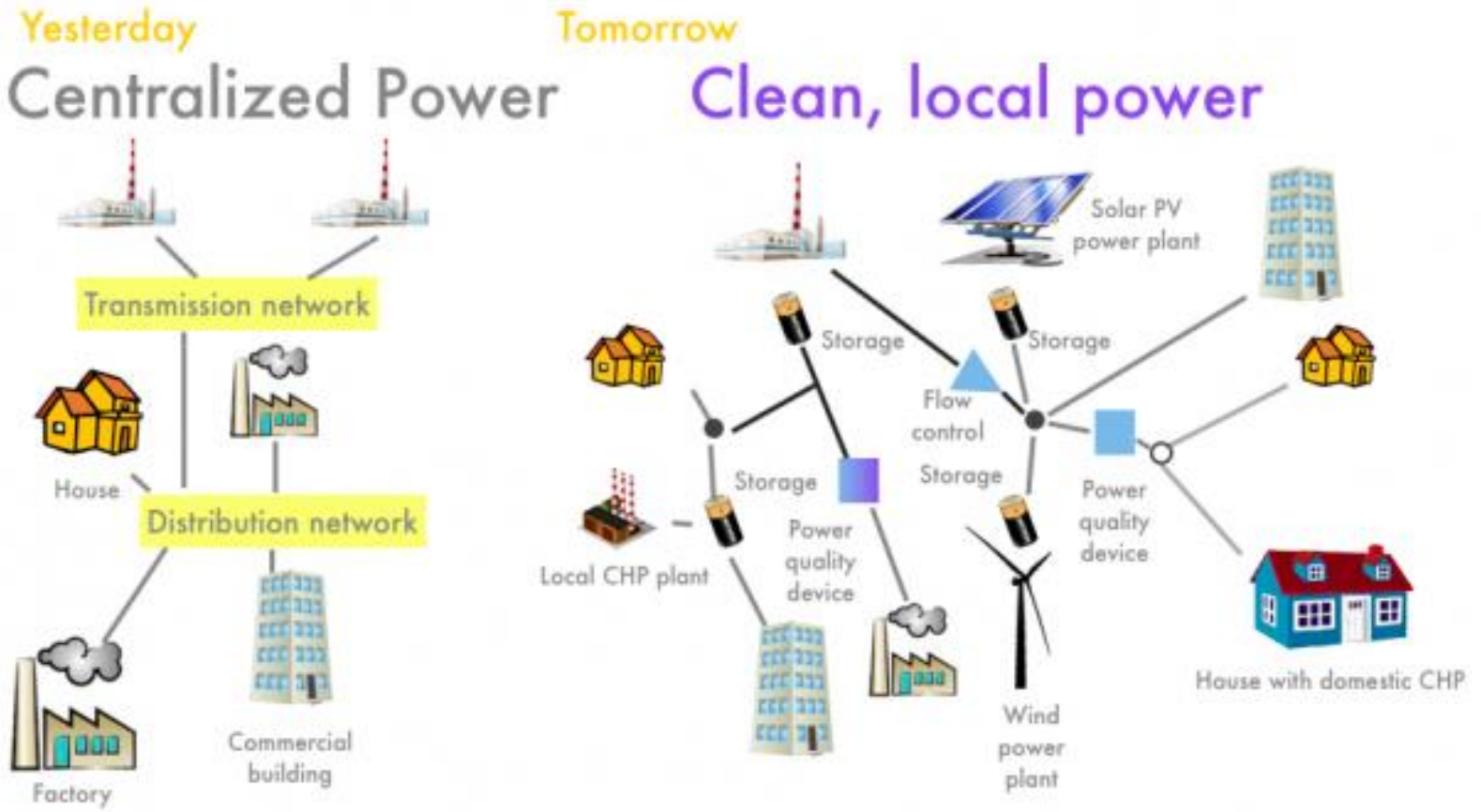
Electric Power Quality

- Continuity of service
- Variation in voltage magnitude
- Transient voltages and currents
- Harmonic content in the waveforms
- Power Quality Indices



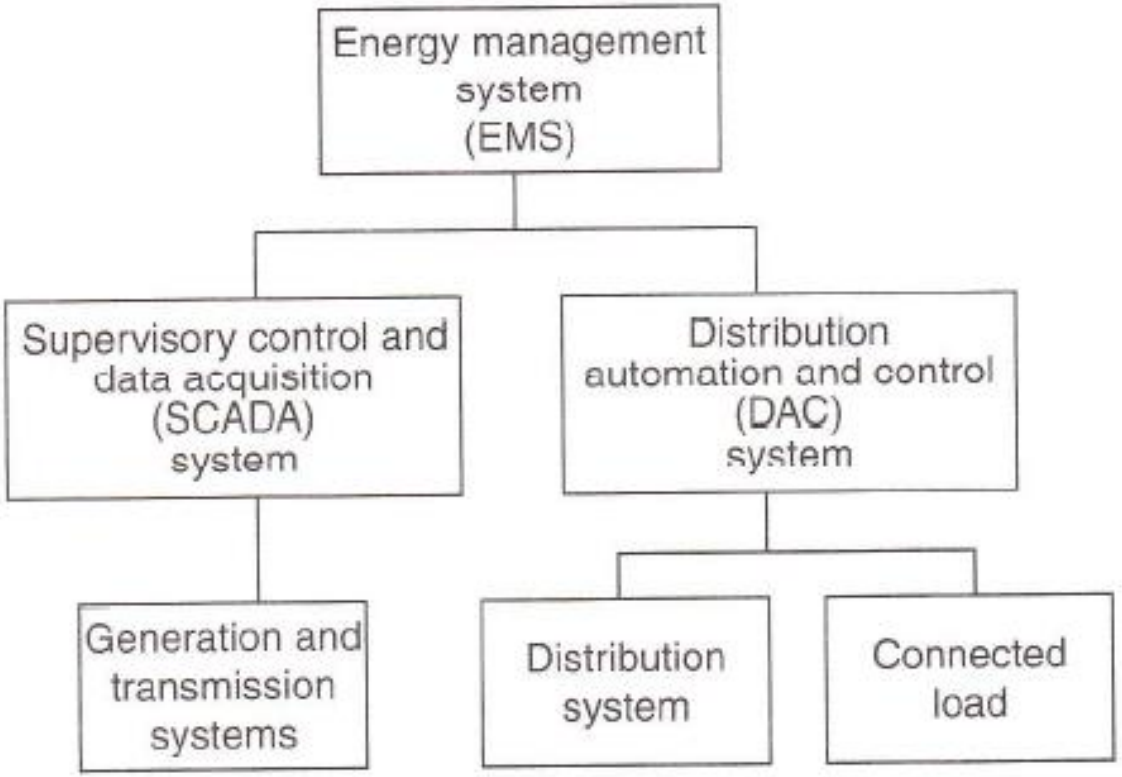


Distributed Generation



Distribution Automation

- Generation and transmission systems have been automated for some time through SCADA.
- Distribution Automation is relatively new – now part of the utility Energy Management System (EMS)



Distribution Automation

- Distribution automation has a broad meaning and additional applications are added on a regular basis:
  - It is an integrated concept of the automation of distribution substations, feeders and loads.
  - It includes communication, control, monitoring, protection, load management, and remote metering of consumer loads.
  - It is fueled by increased reliability reporting requirements, need to operate the system closer to its design limits, increased efficiency requirements, and tendency to monitor customer load behavior.
- The benefits include improved quality and continuity of supply, voltage level stability, reduced system losses, reduced investment, reduced workforce.

Automation and Control Functions

- Load management
  - direct load switching,
  - peak load pricing,
  - load shedding,
  - cold load pick-up (loss of diversity and inrush)
- Operational management
  - feeder load re-configuration,
  - transformer load management,
  - voltage regulator and control of switched capacitors,
  - fault detection-location-isolation
- Remote meter reading
  - automatic customer meter reading,
  - dispersed storage and generation

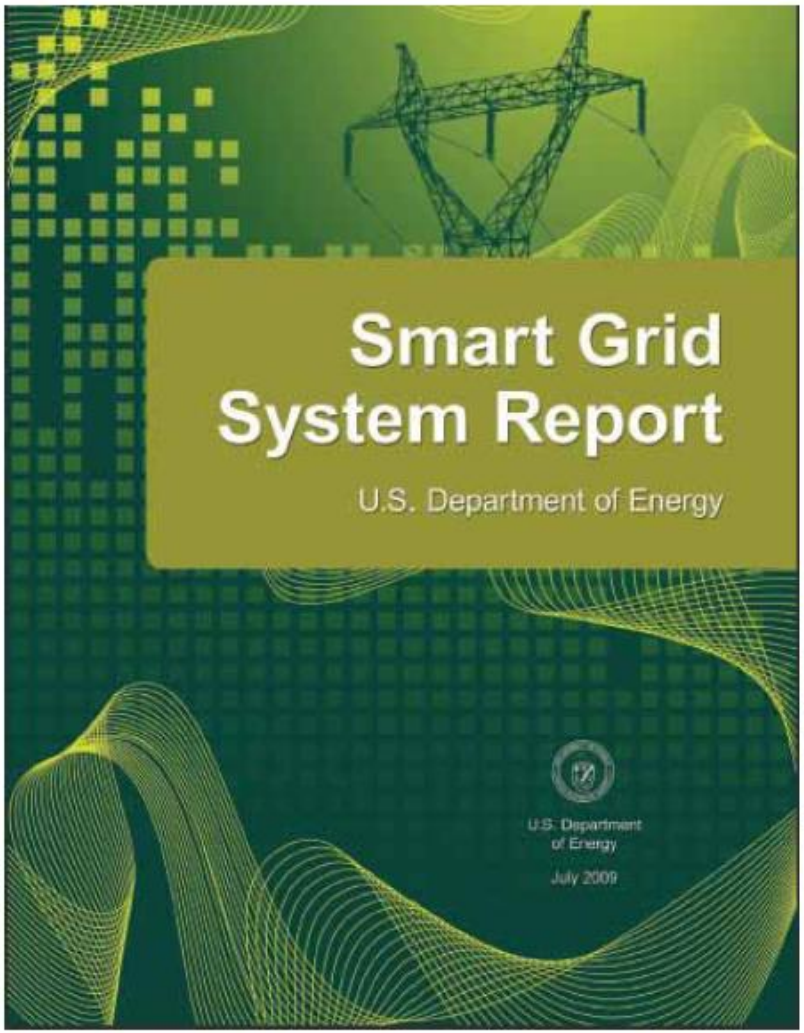
Communication

- Many communication methods are available:
  - Dial-up and dedicated leased telephone lines
  - Power Line Carrier
  - Radio control (UHF point-to-point and multi-address system, VHF radio (one-way), packet switching network, cellular radio)
  - Fiber optics
  - Microwave
  - Satellite communications

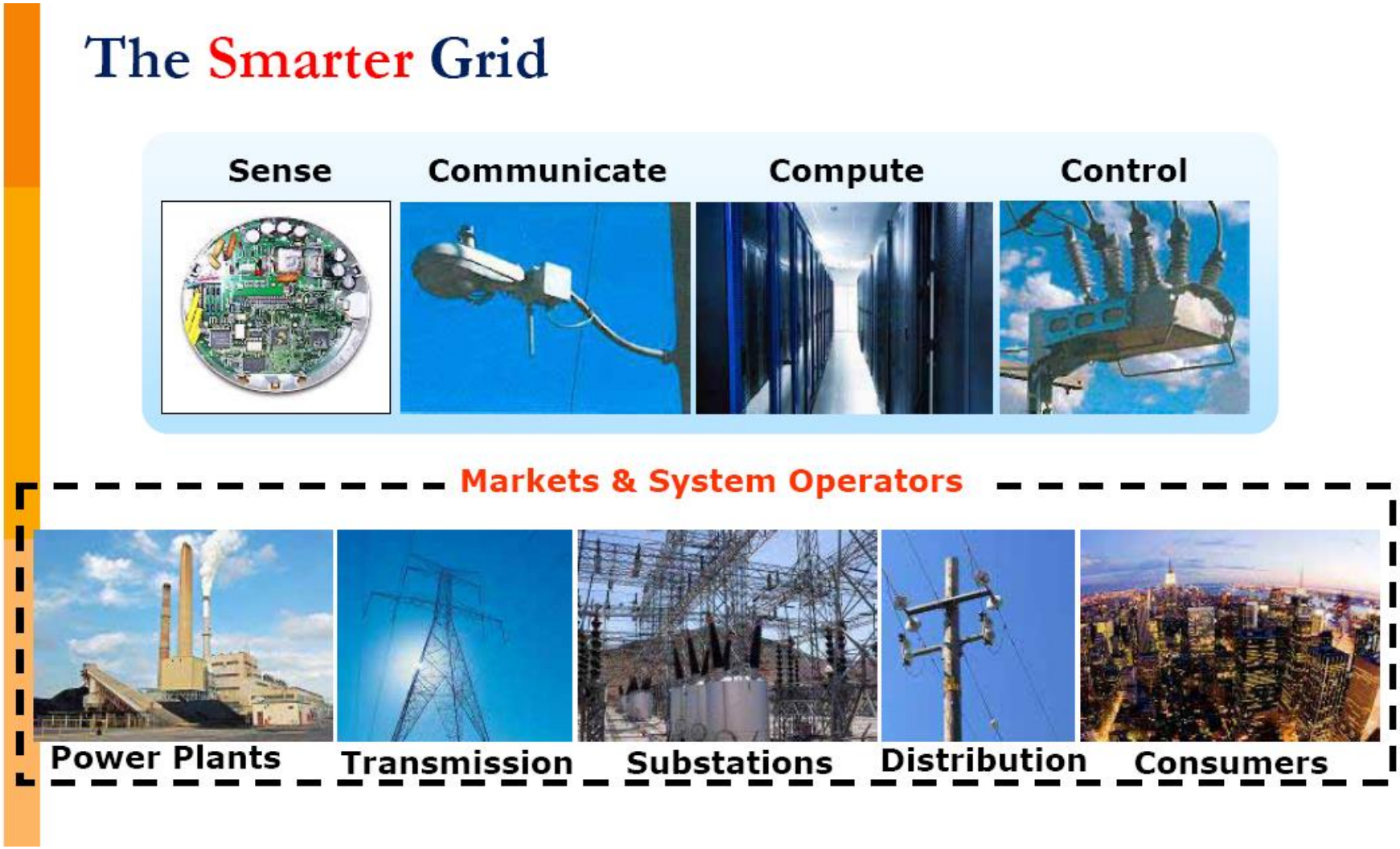
Future Smart Grid

Smart(er) Grid Objectives

- Enables informed participation by customers
- Accommodates all generation and storage options
- Enables new products services and markets
- Provides required power quality
- Optimizes asset utilization and operations efficiency
- Operates resiliently to disturbances, attacks, and natural disasters



Overall Picture of Smart Grid

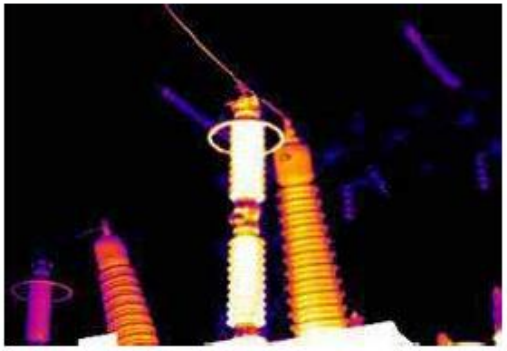


Sensors also critical to managing the power grid infrastructure (ageing)

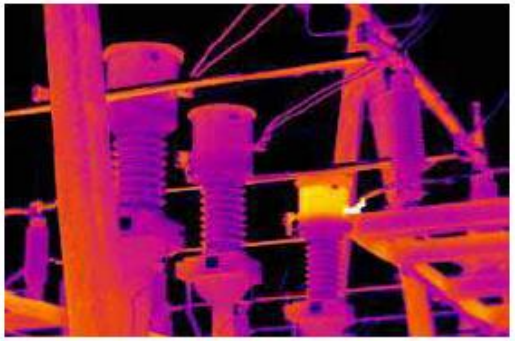
Transmission Lines

Circuit Breakers

Transformers



Surge Arrester Failure



Overheating CT

Internal Arcing

Automating Condition Assessment Key to Preventing Failure