EE 741
Spring 2017
Electric Power Distribution Systems – An Overview
Basic Power System Layout

Color Key:
Black: Generation
Blue: Transmission
Green: Distribution

Generating Station
Generating Step Up Transformer
Transmission Customer 138kV or 230kV
Transmission lines 765, 500, 345, 230, and 138 kV
Substation Step Down Transformer
Primary Customer 13kV and 4kV
Secondary Customer 120V and 240V
Subtransmission Customer 26kV and 69kV
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?

Existing service area

New Development
Factors affecting substation expansion

- Present capacity and configuration
  - Load forecast
  - Tie capacity
  - Transmission voltage
  - Transmission stiffness
  - Feeder limitation (getaway)
- Substation expansion
  - Power losses
- Projection limitations
  - Physical size and land availability
  - Physical barriers
  - Ultimate size limitations
- Economic factors
Factors affecting substation siting
Substation Site Selection Procedure

Service region

Candidate areas

Unsuitable sites

Sites held for later evaluation

Candidate sites

Proposed sites

Considerations:
- Safety
- Engineering
- System Planning
- Institutional
- Economics
- Aesthetics
Load Characteristics

- Customer load
- Diversity
- Metering
- Load control
Power Transformers

- Substation transformers
- Distribution transformers
Design of primary and secondary systems

- Three-phase primary main
- One-phase laterals
- Primary feeders
- Distribution transformers
- Secondary mains
- Consumers’ services
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

Yesterday
Centralized Power

- Transmission network
- Distribution network
- House
- Factory
- Commercial building

Tomorrow
Clean, local power

- Solar PV power plant
- Storage
- Flow control
- Power quality device
- Wind power plant
- House with domestic CHP
- Local CHP plant
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

The Smarter Grid

Sense  Communicate  Compute  Control

Markets & System Operators

Power Plants  Transmission  Substations  Distribution  Consumers
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