Basic Power System Layout

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

Generating Station
Generating Step Up Transformer
Transmission 765, 500, 345, 230, and 138 kV
Transmission Customer 138kV or 230kV
Substation Step Down Transformer
Subtransmission Customer 26kV and 69kV
Primary Customer 13kV and 4kV
Secondary Customer 120V and 240V
There are over 100 substations in the Las Vegas Valley – pic of closest substation
Substation Design

- Substation siting
- System expansion
- Substation bus schemes
Factors affecting substation expansion

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

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

\[ P_{\text{loss}} \approx I^2 R \]
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
- Commercial building
- Factory

Tomorrow

Clean, local power

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

https://www.dg.history.vt.edu/ch1/introduction.html
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

https://electrical-engineering-portal.com/communications-power-system-protection