

Definition and Purpose of Substations (Part 1)

Milav Dabgar

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- Course: Substation Engineering (DI04009011)
- Unit 1: Introduction
- Lecture 1

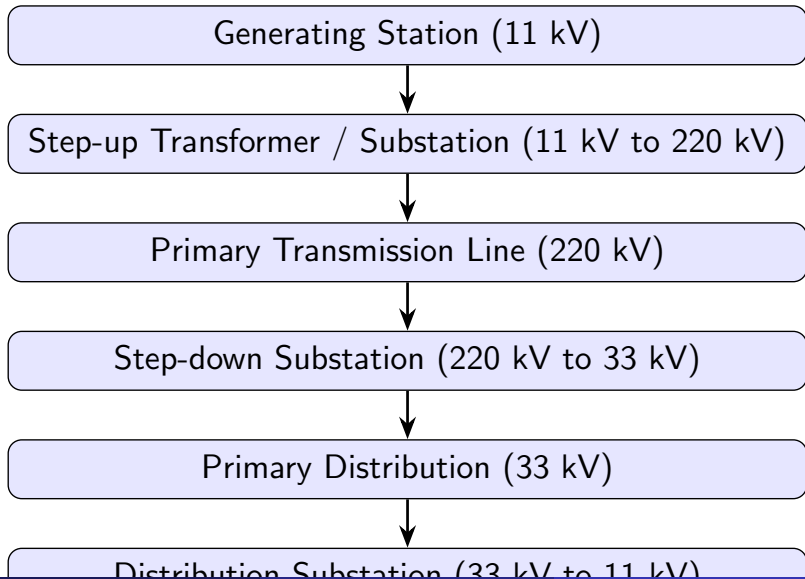
Agenda

- Introduction to Electrical Power Systems
- The Concept of a Substation
- Formal Definition of a Substation
- Primary Purposes: Voltage Transformation
- Primary Purposes: Switching and Isolation
- Summary and Q&A

Overview of Electrical Power Systems

- Power systems consist of Generation, Transmission, and Distribution.
- Electricity is generated at relatively low voltages (11 kV - 25 kV).
- It is stepped up to high voltages (132 kV, 220 kV, 400 kV, 765 kV) for efficient long-distance transmission.
- It is stepped down again for distribution to consumers (33 kV, 11 kV, 415 V, 240 V).

Power System Network Diagram



What is a Substation?

- A substation is a critical node in the power grid.
- It serves as an intersection where power lines meet and voltage levels are changed.
- It houses transformers, switchgear, protective relays, and control equipment.
- Substations do not generate power; they route and condition it.

Formal Definition of an Electrical Substation

- An assembly of electrical apparatus such as transformers, switchgears, buses, etc.
- Situated in a specific location.
- Designed to change electrical characteristics (voltage, AC/DC, frequency).
- Used to switch power circuits on and off for grid management and maintenance.

Why Do We Need Substations?

- Generators cannot be connected directly to consumers.
- Long-distance transmission requires very high voltages to reduce losses.
- Consumers require low, safe voltages to operate appliances and machinery.
- Faults must be isolated to prevent whole-grid collapse.

Primary Purpose 1: Voltage Transformation

- The most recognizable function of a substation.
- Step-Up Substations: Increase voltage for transmission (e.g., 11 kV to 400 kV).
- Step-Down Substations: Decrease voltage for sub-transmission or distribution (e.g., 220 kV to 33 kV).
- Utilizes power transformers to perform this function efficiently.

Voltage Levels Table (Typical Indian Grid)

Grid Segment	Typical Voltage Levels
Generation	11 kV, 21 kV
Primary Transmission	400 kV, 765 kV
Secondary Transmission	132 kV, 220 kV
Primary Distribution	33 kV, 66 kV
Secondary Distribution	11 kV, 415 V, 240 V

Primary Purpose 2: Switching operations

- Substations provide the ability to switch equipment in and out of the system.
- Allows for routine maintenance without disrupting the entire grid.
- Facilitates load shedding or load transferring between different feeders.
- Done using Circuit Breakers and Isolators (Disconnectors).

Primary Purpose 3: Isolation of Faults

- Power systems are subject to faults (short circuits, lightning strikes).
- Substations contain protective relays that detect these abnormal conditions.
- Relays send signals to circuit breakers to open and isolate the faulty section.
- Protects expensive equipment (transformers) from catastrophic damage.
- Ensures stability of the remaining healthy grid.

Other Purposes: Power Factor Correction

- Industrial loads are highly inductive, causing poor power factor.
- Poor power factor reduces system capacity and increases losses.
- Substations may house Capacitor Banks or Synchronous Condensers.
- These devices inject reactive power to improve the power factor.

Other Purposes: Voltage Regulation

- Voltage drops along long transmission lines due to line impedance.
- Substations help regulate voltage to keep it within statutory limits.
- Accomplished using On-Load Tap Changers (OLTC) on transformers.
- Static VAR Compensators (SVC) are also used in modern substations.

Summary of Substation Purposes

- Voltage transformation (Step-up and Step-down).
- Switching for maintenance and load management.
- Protection and fault isolation.
- Power factor correction.
- Voltage regulation.