Power Delivery System: A brief Overview

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What is the Power Delivery System?

"The power delivery system, named as the **transmission and distribution (T&D) system** consists of thousands of transmission and distribution lines, substations, transformers, and other equipment scattered over a wide geographical area and interconnected so that all function in concert to deliver power as needed to the utility's customers."

Goals of the Power Delivery System

- Cover the **utility's service territory**, reaching all consumers who wish to be connected and purchase power.
- Have **sufficient capability** to meet the peak demands of those energy consumers.
- Provide satisfactory **continuity of service (reliability)** to the connected energy consumers.
- Provide **stable voltage quality** regardless of load level or conditions.
- Maintain the desired **Power Quality** to the customers.

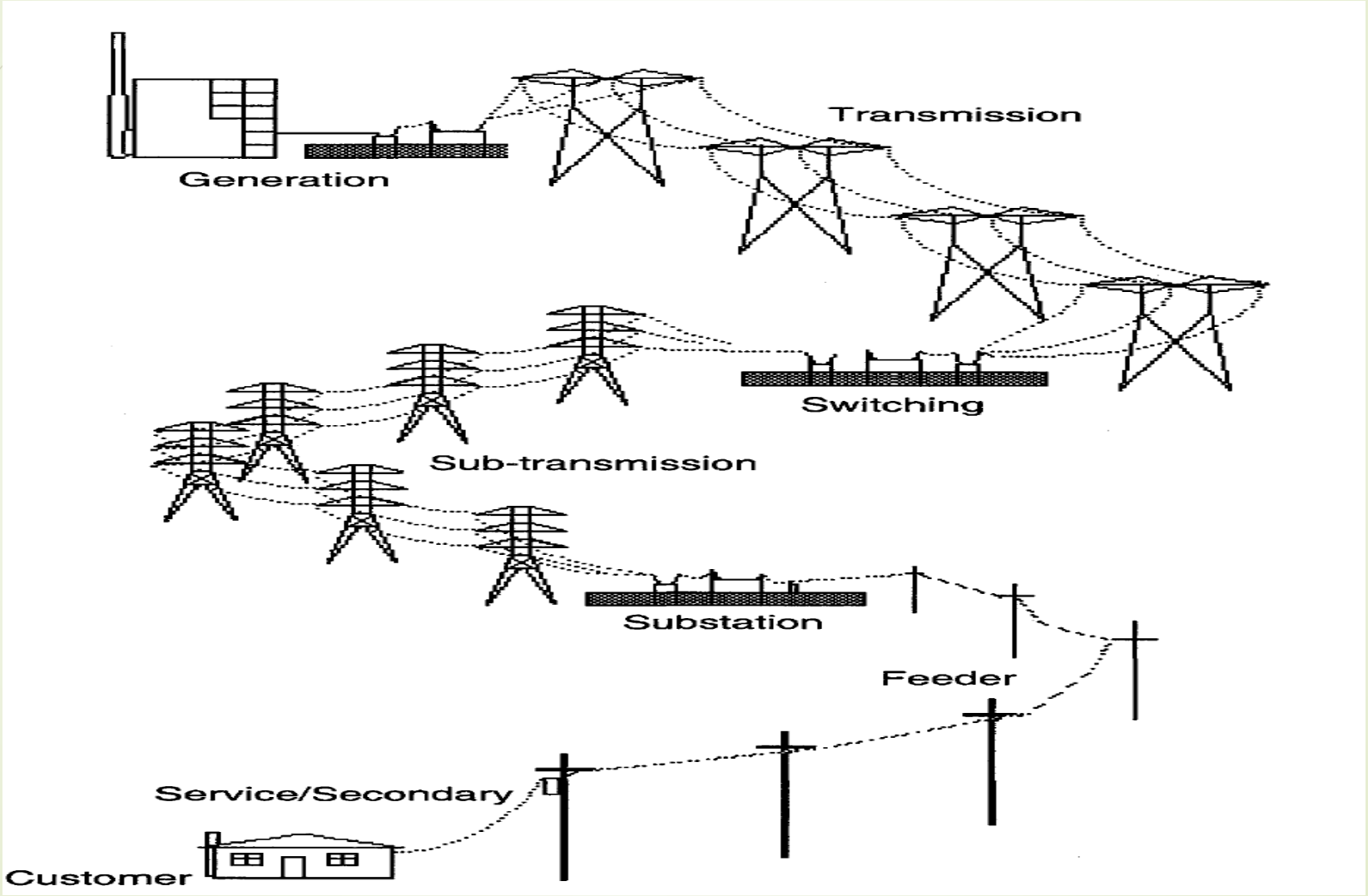
The History of the development of the Transmission and Distribution Systems

- In the early part of the electric era (1890 - 1930) most electric utilities viewed interruptions of service primarily as interruptions in revenue.
- The mindset of the utilities changes during the 1930s -1960s due to the inception of the Digital computer.
- The utilities adopt several measures to measure and quantify the reliability level during 1970 -1990, which leads to the development of supervisory control and data acquisition (SCADA) system, outage management system etc., to determine which customer is out of service, and when, and why.
- After 1990, the power delivery system undergoes the supervisions of regulatory commission. In India, This happens after the implementation of the **Electricity Act 2003**.

Thumb-rules of the Power Delivery systems

- It is more economical to move power at high voltage.
- Utilization voltage is useless for the transmission of power.
- Power must be delivered in relatively small quantities at a low voltage level

A typical Power Delivery system Schematic



Hierarchical Systems

- **The transmission systems**: These are used to evacuate power from the generating stations to the load centers. The transmission grid also provides a strong electrical tie between generators, so that each can stay synchronized with the system and with the other generators.
- **The sub-transmission Systems**: These are usually of reduced capacities and voltage levels. These are used to take power from the transmission switching stations or generation plants and to deliver it to distribution substations.
- **The primary distribution systems**: These are the basically power networks used to carry power from substations to distribution transformer.
- **The secondary distribution systems**: These networks are used to supply power to the end-user/customer.

Hierarchical Voltage and Power Levels

- **Transmission System**: Transmission lines usually operate at voltages of between 69 kV and 1,100 kV and have capacities between 50 and 2,000 MW.
- **Sub-transmission system**: Normally, sub-transmission lines are operating at voltages from 34.5 kV to as high as 230 kV.
- **Primary distribution system**: The primary distribution feeders usually operate between 2.2 kV and 34.5 kV and have capacities somewhere between 2 and 35 MW.
- **Secondary distribution system:** These usually operate at a voltage level of 110-120 V single phase or 220-230 V single phase.

Generic features of T&D systems

- Each level is fed power by the one above it, in the sense that the next higher level is electrically closer to the generation.
- Both the nominal voltage level and the average capacity of equipment drops from level to level, as one moves from generation to customer.
- The net capacity of each level (number of units times average size) increases as one moves toward the customer. A power system might have 4,500 MVA of substation capacity but 6,200 MVA of feeder capacity and 9,000 MVA of service transformer capacity installed.
- Reliability drops as one moves closer to the customer. A majority of service interruptions are a result of failure (either due to aging or to damage from severe weather) of transformers, connectors, or conductors very close to the customer.

Difference of transmission and distribution networks

Difference in features	Transmission network	Distribution network
Topological	Meshed	Radial
Load	Relatively balanced	Unbalanced
Lines	Transposed	Non-transposed
Power Losses	Low	High
Fault occurrence	Less	More

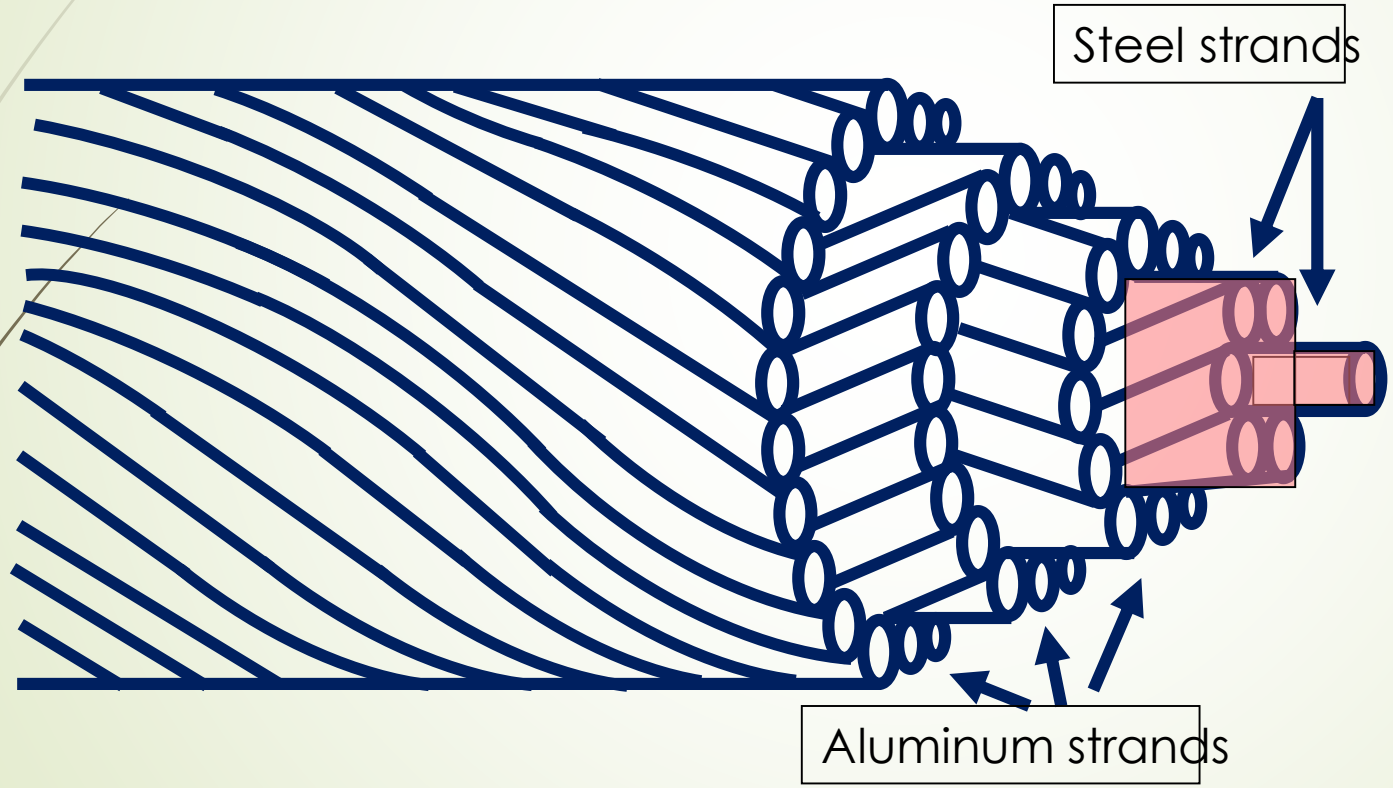
Utility T&D Equipment

- Transmission and distribution lines
- Switching station/substations
- Service transformers
- Measuring and Protective devices
- Reactive power compensators
- FACTs in Transmission systems (Ex. STATCOM, SSSC, UPFC)
- Custom power devices in distribution systems (Ex. DSTATCOM, DVR, UPQC)

Transmission and Distribution Lines

- Transmission and distribution lines are made of electrical conductors available in various capacity ranges.
- Conductors can be all steel (rare, but used in some locations where winter ice and wind loadings are quite severe), all aluminum, copper, or a mixture of aluminum and steel.
- Lines are either of overhead conductors or of underground cables
- Overhead lines are economical compared to the underground cables.
- Underground cables are more reliable. They are used in cities with high population density.

Stranded conductors



Specification of ACSR conductors

- Conductor size is standardized in circular mils (*cmils*).
- One mil is equal to 0.001 inch.
- For a solid round conductor, the area in circular mils is defined as the square of diameter in mils.
- For example, 1,000,000 *cmils* represents a solid round conductor of 1 inch in diameter.
- Diameter in inches= $\frac{\sqrt{cmils}}{10^3}$

Switching Stations/Substations

- Substations are the meeting points between the transmission grid and the distribution feeder system.
- Substation equipment consists of high and low voltage racks and busses for the power flow, circuit breakers for both the transmission and distribution level, metering equipment, and the "control house," where the relaying, measurement, and control equipment is located.
- The most important equipment – what gives this substation its capacity rating, are the substation ***transformers***, *which converts the* incoming power from transmission voltage levels to the lower primary voltage for distribution.

T&D Planning cost

- A T&D system is an expensive to design, build, and operate. Equipment at every level incurs two types of costs. They are: (i) Capital investment cost and (ii) Operational cost.
- The **Capital costs** include the equipment and land, labor for site preparation, construction, assembly and installation, and any other costs associated with building and putting the equipment into operation.
- The **Operating costs** include labor and equipment for operation, maintenance and service, taxes and fees, as well as the value of the power lost to electrical losses.
- Usually, capital cost is a one-time cost (once it's built, the money's been spent). Operating costs are continuous or periodic.

Total T&D Costs

- The following table shows the cost of providing service to a "typical" residential customer in an example power system. These figures are *representative* of all systems, but costs, practices, and accounting systems vary so that these are not general values applicable to all utilities.

Level	Cost Components	Cost
Transmission	4 kW x 100 miles x $.75/kW mile	$300
Substation	4 kW x $60/kW	$240
Feeder	4 kW x 1.5 miles x $10/kW-mile	$60
Service	1/10th of 50 kVA local service system	$300
	Total Initial cost (Capital)	$900
All	Operations, Maintenance, and Taxes (PW next 30 years)	$500
All	Cost of electrical losses (PW next 30 years)	$700
	Estimated cost of power delivery, 30 years, PW	$2,100

Reference

H. Lee. Willis. *Power Distribution Planning Reference Book*; CRC press; 2nd Edition, Revised and Expanded, 2004.

Thank You….