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GRID / UTILITY POWER GENERATION & DISTRIBUTION

Excerpt from Inverter Charger Series Manual

BY:

VIJAY SHARMA
ENGINEER

GRID / UTILITY POWER GENERATION & DISTRIBUTION

Electrical power generation, transmission and distribution systems consist of multiple, distributed power plants (nuclear, hydro, thermal, solar, wind etc.) that operate as a grid that is linked by Transmission, Sub-transmission and Distribution Systems. Unless specified otherwise, all voltages indicated below are phase to phase voltages.

The following designations, symbols and units are used for the electrical parameters:

- **Electrical Power:** Designated by symbol "P"; measured in Watts, designated by symbol "W"
- **Electrical Current:** Designated by symbol "I"; measured in Amperes, designated by symbol "A"
- **Electrical Resistance:** Designated by symbol "R"; measured in Ohms, designated by symbol "Ω"

When very high magnitude of electrical power is transmitted over long distances, one of the major causes of power loss is heat dissipation in the conductors. This heat dissipation is proportional to the square of the current and the resistance of the conductors i.e. Power loss Ploss = I^2 x R. This equation shows that the power loss can be decreased by reducing the current, or reducing the resistance of the conductors or reducing both. The resistance of the conductors can be reduced by increasing the cross–sectional area of the conductors and reducing its length. Increasing the cross-sectional area of the conductors increases its cost and weight and hence, this option is not practical for transmission purposes. Therefore, to reduce power loss during transmission, it becomes necessary to reduce the current by some means.

Mathematically, Power (P) = Voltage (V) x Current (I). A particular value of power can be obtained by changing the ratio of voltage and current. For example, a power of 120 kW can be transmitted over a length of conductors with resistance of say 0.01 Ohm by generating at a lower voltage of 120 VAC and at a higher current of 1000 A. In this case, the power loss Ploss = 1000 A x 1000 A x 0.01 Ω = 10 kW which is a very huge loss. The same 120 kW can be transmitted at a high voltage of say 230 kV and a very low current of 0.521A using a step up transformer. In this case, the power loss Ploss= 0.521A x 0.521A x 0.01 Ω = 0.0027 W which is almost negligible. This explains why electrical power is transmitted at very high voltages and at very low currents. At the point of use, the voltage is stepped down to the required lower value of voltage and higher value of current using step down transformers

Electrical power plants generate electrical power at voltages of 2.3 kV to 30 kV. The generated power is first stepped up to very high voltages (> 110 kV) by the Step-up Transmission Sub-station and is transmitted over long distances to distant users using overhead transmission lines (See Fig 4.1). Very high voltages are used for long distance transmission to reduce losses as explained above. The specific voltages leaving a Step-up Transmission Sub-station are determined by the customer needs of the utility company supplying power and by the requirements of any connections to regional grids. Typical transmission voltages are:

- **High voltage (HV) AC:** 69 kV, 115 kV, 138 kV, 161 kV, 230 kV
- **Extra-high voltage (EHV) AC:** 345 kV, 500 kV, 765 kV
- **Ultra-high voltage (UHV) AC:** 1100 kV, 1500 kV
- **Direct-current high voltage (DC HV):** ±250 kV, ±400 kV, ±500 kV

Power for regional consumption is stepped down using Step-down Transmission Sub-stations located at switching points in an electrical grid. They connect different parts of a grid and are a source for sub-transmission lines or distribution lines. The Step-down Transmission Sub-station can change the transmission voltage to a Sub-transmission Voltage, usually 69 kV or less. The Sub-transmission voltage lines then serve as a source to Distribution Sub-stations. Sometimes, power is tapped from the Sub-transmission Line for use in an industrial facility along the way. Otherwise, the power goes to a Distribution Sub-station.

Distribution Sub-stations are located near to the end-users. Distribution Sub-stations use step-down transformers to change the transmission or sub-transmission voltages to lower levels for use by the end-users. Typical distribution voltages vary from 7 kV to 13 kV. A few common distribution voltages are:

- 2.4 kV, 3-phase, Delta
- 7.2 kV, 3-phase, Delta
- 12.47 kV, 3-phase, Wye (Y)
- 13.2 kV, 3-phase, Wye (Y)
- 13.8 kV, 3-phase, Wye (Y)

From here, the power is further stepped down using Distribution Transformers and is distributed to industrial, commercial, and residential customers. Figure 4.1 shows typical transmission, sub-transmission and distribution towers / poles.

Distribution Transformers step down the distribution transmission voltages fed from the Distribution Substations to lower voltages required by the end users. The step down Distribution Transformers are either Pole Mounted Type - mounted on a utility pole for overhead distribution or Pad Mounted Type - mounted on a concrete pad on the ground for underground distribution.

Typically, the output voltages from the secondary of the Distribution Transformers are:

- 120 V / 240 V Single Split Phase for residential customers,
- 480 V / 277 V, 3-phase, Y (Wye) or 208 V / 120V, 3-phase, Y (Wye) for commercial or light industry customers.

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The above stepped down output voltage from the secondary side of the Distribution Transformer is fed to the Electrical Service Entrance Panel (Also called Load Center or Breaker Panel) of the residential, commercial or light industrial customers unit for further distribution within the unit.

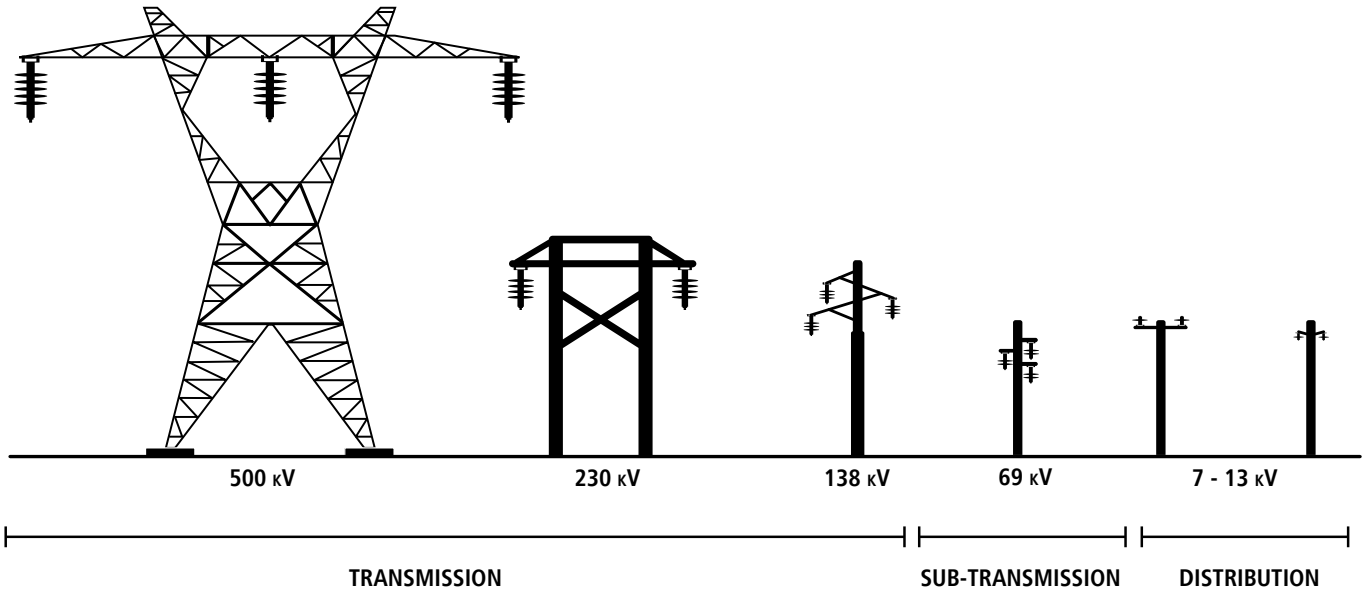

Fig 1: Transmission, Sub-transmission and Distribution Towers and Poles.
Shows typical transmission, sub-transmission and distribution towers / poles.

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