



## Electric Power Transmission

**For Prelims:** [Bhakra Nangal Dam](#), Alternating Current (AC), Direct Current (DC) , [Distribution Substations](#), [Transmission Substations](#), [Nuclear Reactors](#)

**For Mains:** Significance of streamlining the electricity generation and transmission to achieve the renewable energy targets.

[Source: TH](#)

### Why in News?

With the rising demand for electricity in today's world, especially with increased individual and industrial needs, it's crucial to enhance the efficiency and reliability of [electric power transmission systems](#).

### What Are the Basics of Transmitting Electricity?

#### ▪ About:

- Any power supply system has three broad components: **generation, transmission, and distribution**. Electricity is generated at power plants as well as smaller renewable-energy installations.
- Then it is transmitted using a distributed network of **stations, substations, switches, overhead and underground cables, and transformers**, among other elements.

#### ▪ Transmission Efficiency:

- The efficiency of electric current transmission is **higher at lower current and higher voltage**. This is because **energy loss during transmission is proportional to the square of the current**, while voltage and current have a 1:1 relationship.
  - Transformers are used to increase voltage and reduce current for efficient transmission.

#### ▪ Resistance in Cables:

- Cables used for transmission still have some resistance, resulting in energy loss. **The thickness of the cable can be adjusted to control energy loss, with thicker cables losing less energy**, but at a higher cost.

#### ▪ Distance and Transmission Cost:

- **Longer transmission distances generally result in lower transmission costs** due to factors such as requirement of less transmission towers, substations, and maintenance efforts.

#### ▪ Alternating Current (AC):

- AC is preferred for transmission because **it can be easily modified using transformers and has higher efficiency**. However, higher AC frequencies increase resistance in the material.
  - AC power is the most common way to transfer electric power because voltage continuously changes polarity, causing the current to flow in alternating directions. **The AC frequency corresponds to the rate at which the voltage changes direction.**

## Installed Electricity Generation Capacity (Fuelwise) as on May 2023:

- Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel) is 417 GW.
- The share of various energy sources in the total Electricity Generation are:
  - Fossil fuel (including Coal) is 56.8%,
  - Nuclear fuel 1.60% and
  - Non-Fossil fuel is 41.4%.

## How is Power Transmitted?

- **Power Transmission Infrastructure:**
  - In power transmission, a **three-phase AC circuit** is employed. Each wire carries AC current in a different phase. From a power station, the wires are routed to transformers that step-up their voltage.
  - The infrastructure is equipped with safety features, **such as insulators to divert excessive current** during surges and **circuit-breakers to disconnect the circuit** in case of overload.
  - Additionally, **grounding and arresters** are used to prevent voltage fluctuations caused by external factors like lightning strikes. **Dampers** help **mitigate vibrations that could affect the stability of the towers.**
- **Substation Network:**
  - The transmission wires ultimately lead to various types of **substations**, each serving a specific role in the power distribution system.
    - **Collectors** consolidate power from different sources and channel it to transmission substations.
  - **Distribution substations** play a vital **role in stepping down the voltage in power lines, preparing the electricity for consumption in households** and businesses.
  - **Transmission substations** act as hubs, merging or branching different lines and diagnosing issues within the network.
- **Diverse Functions and Infrastructure:**
  - To perform diverse functions, the infrastructure includes a wide array of support systems, from electrical engineering expertise to advanced computerized operations.
    - Safety measures, such as fire protection, are essential to safeguard critical infrastructure.

## How Does an Electric Grid Function?

- **Grid Operation and Components:**
  - **Grids** are complex systems that play a vital role in the distribution of electrical power. They consist of three main components: **production, transmission, and distribution.**
    - The **transmission component** serves as the bridge between power production and delivery to end-users.
  - Some power sources, like coal-fired or nuclear reactors, can produce a continuous supply of energy, while renewable sources, such as wind and solar, are intermittent.
    - **In such cases, Grids become useful as Grids are equipped with storage facilities to store surplus electricity and release it when demand exceeds supply.**
- **Grid Resilience and Control:**
  - Grids must be resilient to **prevent failures in different parts of the network** from affecting others. They also need to manage voltage levels to meet varying demand and ensure a stable and reliable power supply which includes controlling the AC frequency and improving the power factor.
- **Wide-Area Synchronous Grids and Challenges:**
  - A wide-area synchronous grid is a network in which **all connected generators produce AC current at the same frequency.** An example of such a grid is the North Chinese State Grid is the world's most powerful, with a capacity of 1,700 GW. **India's national grid**

**also operates as a wide-area synchronous grid.**

- These grids have the advantage of lowering power costs due to **shared resources but require measures to prevent cascading failures** in the event of a local power supply failure.

## Electric Grid of India

- The electric grid of India, also known as the **National Grid, is a high-voltage electricity transmission network** that connects power stations and major substations across the country. It ensures that electricity generated anywhere in India can be used to satisfy demand elsewhere.
- The National Grid is owned and maintained by the state-owned **Power Grid Corporation of India and operated by the state-owned Power System Operation Corporation**. It is one of the largest operational synchronous grids in the world with **417.68 GW** of installed power generation capacity as of 31 May 2023.

## UPSC Civil Services Examination, Previous Year Questions (PYQ)

### Prelims

**Q. With reference to the Indian Renewable Energy Development Agency Limited (IREDA), which of the following statements is/are correct? (2015)**

1. It is a Public Limited Government Company.
2. It is a Non-Banking Financial Company.

**Select the correct answer using the code given below:**

- (a) 1 only
- (b) 2 only
- (c) Both 1 and 2
- (d) Neither 1 nor 2

**Ans: (c)**

### Mains

**Q. "Access to affordable, reliable, sustainable and modern energy is the sine qua non to achieve Sustainable Development Goals (SDGs)". Comment on the progress made in India in this regard. (2018)**