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Transmission Capacity Development in India: A Review

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Abstract

India's transmission system is evolving from a predominantly generation-linked network into a renewable-energy-oriented and increasingly flexible national grid. This article reviews transmission-capacity development in India over the last one decade. It combines historical ckm/MVA additions with CEA plans for integration of more than 500 GW non-fossil capacity by 2030 and more than 900 GW by 2035–36. The paper also identifies key challenges and emphasizes that future development should be assessed not only through physical additions but also through transfer capability, utilisation, stability, system strength, storage integration and coordinated generation-transmission planning.

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1. INTRODUCTION

India's power system has evolved from a collection of regionally interconnected systems into a large synchronous national grid capable of transferring electricity over long distances. The importance of transmission development has increased considerably with India's commitment to expand non-fossil electricity generation. Transmission capacity is now required not only to meet conventional load growth but also to transfer renewable power from resource-rich regions to geographically dispersed demand centres.

The nature of transmission planning is therefore changing from a predominantly generation-linked approach to a more integrated framework involving generation, demand, renewable-energy zones, energy storage, system strengthening and emerging loads.

The Central Electricity Authority (CEA), through the National Electricity Plan (NEP)[1], provides the broad transmission development framework, while the Central Transmission Utility (CTU) undertakes detailed planning of the Inter-State Transmission System (ISTS). CEA's Manual on Transmission Planning Criteria provides the technical basis for system planning, including modelling, planning margins, system studies, reliability criteria and requirements associated with renewable-energy plants.

2. EVOLUTION OF TRANSMISSION PLANNING IN INDIA

Historically, transmission development was closely associated with the location and commissioning schedule of large conventional generating stations. The transmission system was planned primarily to evacuate power from generating stations and transfer it to major load centres.

With increasing regional interconnection, the objective gradually expanded towards creation of a strong national transmission network capable of facilitating inter-regional power exchange. The subsequent growth of renewable generation introduced a new dimension to transmission planning. Solar and wind generation is geographically concentrated and variable and therefore requires evacuation systems that are often required to be planned and constructed ahead of the actual generation.

The National Electricity Plan, Volume II: Transmission[1], represents an important instrument in this planning process. The plan considers transmission development over the medium-term horizon and provides a perspective for long-term system requirements. CEA's current planning framework includes the National Electricity Plan, the 500 GW renewable/non-fossil integration plan[2-4] and the recently issued transmission plan for integration of more than 900 GW of non-fossil capacity by 2035–36[5].

The NEP transmission planning exercise[1] proposed substantial additions to the transmission network during 2022–27. The published material

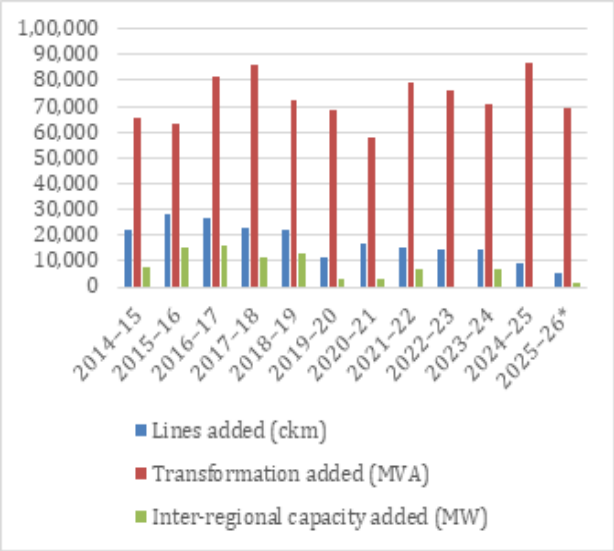


Figure 1. MoP GoI transmission sector data from 2014-15 to 2025-26.

Source: Ministry of Power, GoI, Annual Report 2025–26, Chapter 07: Transmission Sector. The 2025–26 row is reported only up to December 2025[6].

identified a requirement of approximately 1,23,577 circuit-km of transmission lines and 7,10,940 MVA of transformation capacity at 220 kV and above for the period.

These Figures illustrate the scale at which India's transmission network needs to expand to keep pace with generation and demand growth.

The Figure 1 shows the official Ministry of Power transmission-sector data for 2014–15 onward. The 2025–26 figure is explicitly reported only up to December 2025 and is therefore not a full-year value.

3. TRANSMISSION AS AN ENABLER OF RENEWABLE-ENERGY INTEGRATION

The most significant change in recent transmission planning has been the increasing emphasis on renewable-energy integration.

India's target of achieving 500 GW of non-fossil installed capacity by 2030 requires transmission infrastructure to be developed in advance of generation. CEA has specifically recognised that transmission infrastructure needs to be available in advance so that renewable generation is not constrained by the absence of evacuation facilities[7-9].

The development of renewable-energy transmission corridors also reflects a geographical shift in the Indian power system. Large solar and wind resources in states such as Rajasthan, Gujarat, Tamil Nadu and Karnataka have to be connected to the ISTS and ultimately to major demand centres. This requires a combination of pooling substations, high-capacity AC corridors, HVDC links and strengthening of the existing network.

3.1 500 GW Non-Fossil Capacity by 2030

CEA's 2030 transmission plan provides a dedicated roadmap for renewable-energy integration as shown in the Table 1.

Table 1. CEA 500 GW plan

Parameter	CEA 500-GW plan
Planning horizon	2030
RE planning basis	~537 GW
Additional ISTS lines for wind & solar	50,890 ckm
Additional ISTS substation capacity	433,575 MVA
Indicative transmission investment	₹2,44,200 crore
Inter-regional transfer capability	~112,250 MW → ~150,000 MW

Source: CEA, Transmission System for Integration of over 500 GW Non-fossil Capacity by 2030 [2-4]. Values are official planning figures.

3.2 More than 900 GW Non-Fossil Capacity by 2035–36

CEA published its Transmission Plan for Integration of over 900 GW Non-Fossil Fuel Capacity by 2035–36 on 23 March 2026, as detailed in Table 2.

Table 2. CEA 900 GW plan

Parameter	**CEA 900-GW plan**
Planning horizon	2035–36
Transmission planning visibility	Over 900 GW non-fossil capacity
Additional lines for wind & solar integration	1,37,500 ckm
Additional substation capacity	8,27,600 MVA
Estimated transmission investment	₹7,93,300 crore

Source: CEA, Transmission Plan for Integration of over 900 GW Non-Fossil Fuel Capacity by 2035–36, March 2026[4].

4. GREEN ENERGY CORRIDORS

The Ministry of New and Renewable Energy (MNRE) is implementing dedicated Green Energy Corridor

(GEC) schemes- GEC Phase-I, Phase-II and the recently integrated GEC-III- to facilitate the integration and evacuation of Renewable Energy (RE) across key renewable-rich States. Under these schemes, Central Financial Assistance (CFA) is provided to States for establishing intra-State transmission infrastructure required for RE integration[10].

The transmission system under GEC Phase-I, developed for the evacuation of approximately 24 GW of RE capacity, has already been commissioned, while the transmission infrastructure under GEC Phase-II, envisaged for evacuation of around 20 GW of RE capacity, is currently under implementation.

The Inter-State Transmission System (ISTS) connections are being developed by Power Grid Corporation of India Limited (POWERGRID)

5. CEA TRANSMISSION PLANNING CRITERIA AND TECHNICAL APPROACH

CEA's Manual on Transmission Planning Criteria[11] provides the technical basis for transmission studies; CEA also published Amendment-I to the manual in January 2025.

Planning studies examine load-flow performance, contingency conditions, voltage security, thermal loading, short-circuit levels, reactive-power requirements and dynamic stability. With increasing inverter-based renewable resources, system-strength, fault-ride-through, voltage/frequency response and interactions among power-electronic resources become increasingly important.

Transmission capacity must increasingly be assessed not merely in terms of MW transfer capability, but in terms of the ability of the network to maintain secure operation under diverse system conditions.

6. CTUIL AND ROLLING TRANSMISSION PLANNING

The institutional framework for ISTS planning has also evolved. CTUIL has been assigned responsibility for planning and coordination relating to the Inter-State Transmission System[12,13]. CTUIL undertakes ISTS planning on a rolling basis, with planning activities extending over the forthcoming five-year period. The planning process is carried out continuously and involves periodic collection and updating of information from stakeholders.

A rolling planning mechanism allows transmission requirements to be revisited rather than being treated as fixed several years in advance. The CTUIL rolling-plan process therefore provides an important link between long-term policy objectives and project-level transmission development.

7. COMPETITIVE DEVELOPMENT AND IMPLEMENTATION OF TRANSMISSION PROJECTS

The expansion of transmission infrastructure has also been accompanied by increased private-sector participation. Tariff Based Competitive Bidding (TBCB) has become an important mechanism for implementation of several ISTS projects.

The National Electricity Plan reported that, up to September 2023 [1], 133 ISTS schemes had been identified for implementation through the TBCB route. Of these, 92 schemes, with an estimated cost of approximately ₹1.24 lakh crore, had been awarded, while 41 were under bidding.

Competitive bidding has introduced a wider group of transmission developers into the sector and has created a framework in which transmission projects can be awarded through a competitive process. At the same time, successful implementation depends on factors extending beyond the award of a project, such as Right-of-way acquisition, land-related issues, forest and environmental clearances, local opposition and coordination with associated generation or transmission projects

Thus, improving transmission capacity requires attention not only to planning and investment but also to project execution and coordination.

8. TECHNOLOGICAL GAPS AND EMERGING REQUIREMENTS: STORAGE, HVDC AND NEW LOADS

Slow deployment of Flexible AC Transmission Systems (FACTS) and Dynamic Line Rating (DLR) restricts existing lines from handling 20–30% extra throughput. Also, limited adoption of digital technologies such as GIS, drones, LiDAR and wide-area monitoring systems is constraining opportunities to enhance transmission planning, construction, and operational efficiency[14].

The next phase of transmission development will be influenced by changes in both generation and demand.

Large-scale Battery Energy Storage Systems (BESS) and pumped-storage projects are expected to become increasingly important as renewable penetration increases. Storage can modify the timing and direction of power flows and can therefore influence the design and utilisation of transmission corridors.

HVDC transmission will also remain important for long-distance bulk power transfer from remote renewable-energy zones to major demand centres.

Transmission planning must also increasingly consider not only traditional load forecasts but also emerging demand clusters due to new electricity-intensive applications such as green hydrogen production, data centres, large industrial loads and EVs.

The result is a more complex planning problem in which generation, transmission, storage and demand need to be considered together.

9. THE 2035-36 PERSPECTIVE

India's transmission requirements are expected to increase substantially beyond 2030. In view of CEA's plan for integration of over 900 GW Non-Fossil Fuel Capacity by 2035–36, future transmission development will need to address several simultaneous objectives:

- Evacuation of renewable generation from resource-rich regions;
- Strengthening of inter-regional transfer capability;
- Integration of storage resources;
- Maintenance of voltage and frequency ;
- Management of changing short-circuit levels;
- Integration of inverter-based resources;
- Efficient utilisation of existing transmission assets; and
- Development of resilient and digitally monitored networks.

The transmission system of the future will consequently need to be more flexible and actively managed than the conventional network designed primarily around predictable synchronous generation.

10. KEY CHALLENGES AND WAY FORWARD

India has made substantial progress in transmission planning and network expansion. However, the scale and speed of future requirements will require improvements in both planning and implementation. Following is an indication of how the challenges related to Right-of-way, forest and environmental clearances, coordination with associated generation or transmission projects etc. can be handled to ensure fast growth:

- Synchronise generation, storage and transmission commissioning.
- Use rolling planning to update forecasts and network requirements.
- Strengthen dynamic and stability studies for high inverter-based-resource penetration.
- Improve utilisation of existing assets through advanced monitoring and grid-enhancing technologies where justified.

- Reduce right-of-way and approval delays through early coordination.
- Use AC and HVDC solutions according to system studies and transfer requirements.
- Complement ckm/MVA statistics with transfer capability, utilisation and congestion indicators.

11. CONCLUSION

India's transmission sector is entering a phase in which the challenge is not simply adding more lines, but developing the right network at the right location and at the right time. The 500-GW and 900-GW planning exercises demonstrate the scale of infrastructure required for renewable-energy integration.

The next phase will require coordinated generation-transmission-storage planning, rigorous power-system studies, HVDC development, improved system monitoring and efficient project implementation. India's transmission network will remain the physical backbone of its electricity transition and the quality of its planning will strongly influence how effectively the country's growing and increasingly renewable generation resources can be converted into reliable electricity.

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AUTHOR CONTRIBUTION

Dr. Tulika Bhattacharjee is the sole author of this manuscript. She conducted the literature survey, prepared and drafted the manuscript and carried out the proofreading and final review of the manuscript.