India's transmission infrastructure: Status, challenges and future outlook

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Transmission infrastructure is the backbone of India's power sector, enabling the transfer of electricity from generating stations to consumers across diverse geographical regions. As we expand renewable energy capacity rapidly, we aim for energy security, robustness and reliability in an efficient transmission system.

India is one of the world's largest interconnected power grids, achieved through a harmonised network by Central Transmission Utility (CTU) and State Transmission Utility (STU). The national power grid functions at the voltage range of 132 kV to 765 kV, including high voltage direct current (HVDC) systems. The transmission system plays a vital role in guaranteeing dependable electricity supply, helping interstate power transfer and mixing of renewable energy sources.

India's transmission sector

As the transmission sector is witnessing a rapid growth in capacity and coverage across India, it provides unique opportunities and challenges to policy makers, planners, system users, developers, consumers and stakeholders. Optimal planning and development of transmission infrastructure is possible with the help of systematic and timely sharing of accurate data.

India is a country with unevenly distributed energy resources, with coal reserves in the central and eastern regions and hydroelectric potential in the northern and northeastern states, which means that coal and hydroelectric power plants are not spread out geographically. Similarly, renewable energy (RE) plants are mainly concentrated in the states of Tamil Nadu, Andhra Pradesh, Karnataka, Rajasthan, Maharashtra, Gujarat and Ladakh.

Major load centres are located in the central, northern, western and southern regions. The transmission system has expanded over the years for evacuation of power from generating stations to load dispatch centres through Inter State and Intra State Transmission Systems. The progressive integration of regional grids started in 1992 and we achieved 'One Nation, One Grid, One Frequency' in the year 2013 with synchronous interconnection of the southern regional grid with the rest of the Indian grid by commissioning the Raipur-Solapur transmission line. Since then, the transmission system in India has been continuously strengthened with the addition of transmission lines and inter-regional capacity as given in the chart.

India's transmission network comprises of three major components:

1. Inter State Transmission System (ISTS)
2. Intra-State Transmission System (InSTS)
3. Distribution networks (DISCOMS)

Source: https://www.powermin.gov.in/offerings/schemes-and-services

Evolution of transmission infrastructure in India

India's transmission sector has evolved from the foundation stage in the early 1950s to one of the world's largest synchronous national grids in 2026.

Period	Key development	Transmission sector evolution
1950–1959	State grids developed; 220 kV introduced	Foundation stage
1960–1969	State-grid interconnection and regional electricity boards	Regional integration stage
1970–1979	400 kV technology introduced	Bulk power transfer stage
1980–1989	Regional grids expanded; HVDC back-to-back systems emerged	Regional grid expansion stage
1990–1999	HVDC bipole technology; all-India planning initiated	National grid planning stage
2000–2009	765 kV introduced; Electricity Act 2003; open access; national grid integration	Market and national grid stage
2010–2014	Renewable energy integration began gaining importance	RE evacuation preparation stage
2015–2019	Green Energy Corridor (GEC) and major renewable evacuation infrastructure	Renewable integration stage
2020–2024	Large-scale renewable integration, 765 kV expansion, digitalisation	Energy transition stage
2025–2026	5 lakh+ ckm network; 1,400+ GVA transformation capacity; >500 GW RE integration planning	National renewable grid stage

The biggest shift and strategies occurred during the following years:

1950s: Transmission to supply load centre

1970s: Transmission for bulk power transfer

2000s: Transmission for national electricity markets

2010s: Transmission for renewable energy evacuation

2020s: Transmission as a backbone of India's power sector

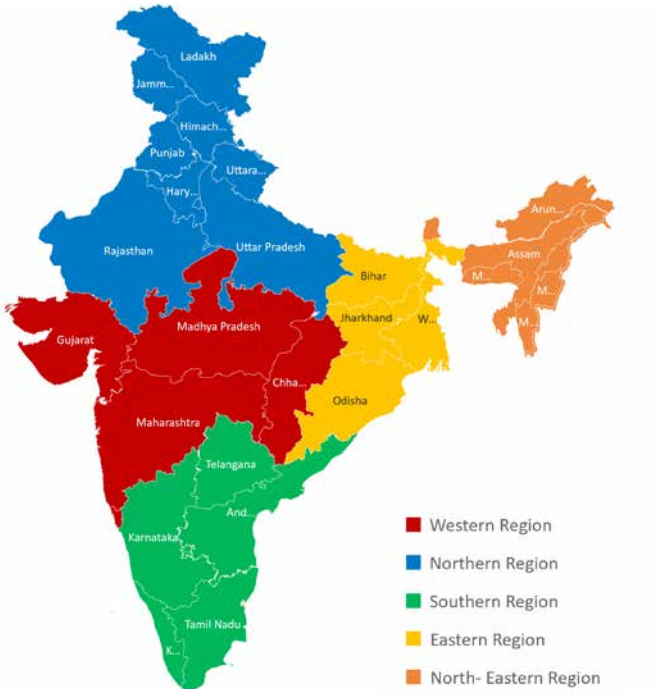
State-wise evaluation

India is divided into 28 states and eight union territories. Due to difference in electricity demand, transmission infrastructure varies considerably across the states. The following evaluation highlights the strength, challenges and future priorities in particular states and union territories.

States/UTs	Key strengths	Major challenges	Future focus
Gujarat, Maharashtra, Rajasthan, Delhi	Extensive 765 kV network, strong renewable integration, high grid reliability	Rapid demand growth and right-of-way (RoW) constraints	Green Energy Corridors, HVDC, smart substations
Tamil Nadu, Karnataka, Andhra Pradesh, Telangana	Strong wind and solar evacuation, modern substations	Renewable congestion during peak generation	Grid automation, storage integration, transmission expansion
Uttar Pradesh, Madhya Pradesh, Odisha, Chhattisgarh, Haryana, West Bengal, Goa	Strong industrial and interstate connectivity	Increasing demand and aging assets	Capacity augmentation and digital monitoring
Kerala, Punjab, Himachal Pradesh, Uttarakhand, Assam	Stable grid with sector-specific strengths (hydro/agriculture)	Terrain, seasonal loading, limited corridors	Climate-resilient infrastructure and additional EHV lines
Bihar, Jharkhand, Arunachal Pradesh, Jammu & Kashmir, Ladakh, Sikkim, Manipur, Meghalaya, Mizoram, Nagaland, Tripura	Government-supported transmission expansion	Difficult terrain, sparse network, low transmission density	New 220/400 kV corridors, renewable and hydropower evacuation
Andaman & Nicobar Islands, Lakshadweep, Puducherry, Dadra & Nagar Haveli and Daman & Diu, Chandigarh	Reliable local supply	Geographical isolation or land constraints	Renewable microgrids, underground cables, battery storage

State-wise Evaluation

Indian Region Divided by Central Transmission unit



Regional grid structure

India's national grid is managed through five Regional Load Dispatch Centres, coordinated by the National Load Dispatch Centre (NLDC)

1. Northern region – RLDC is located in New Delhi
2. Western region – RLDC is located in Mumbai
3. Southern region – RLDC is located in Bengaluru
4. Eastern region – RLDC is located in Kolkata
5. North eastern region – RLDC is located in Shillong

Region	States covered	Key observations
Northern region (NR)	Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Ladakh, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand, Chandigarh	Rajasthan is a major renewable energy hub with extensive 765 kV transmission. Delhi and Haryana have highly reliable urban networks, while Himalayan states require additional evacuation corridors due to challenging terrain and growing hydropower integration.
Western region (WR)	Gujarat, Maharashtra, Madhya Pradesh, Chhattisgarh, Goa, Dadra & Nagar Haveli and Daman & Diu	The strongest transmission network in India with multiple 765 kV AC and HVDC corridors. High interstate power transfer capability supports industrial demand and large-scale RE integration, particularly in Gujarat and Maharashtra.

Southern region (SR)	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Telangana, Puducherry	Strong transmission backbone supports India's largest wind and rapidly expanding solar capacity. Major investments have enhanced interstate connectivity, although renewable energy congestion occurs during peak generation periods.
Eastern region (ER)	Bihar, Jharkhand, Odisha, West Bengal, Sikkim	Rich in thermal and mineral-based generation with increasing renewable integration. The region is strengthening interstate transmission and expanding GECs to support industrial growth and future power evacuation.
Northeastern region (NER)	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura	Significant hydropower potential but relatively sparse transmission infrastructure due to difficult terrain and dispersed load centres. Ongoing investments are focused on strengthening interstate connectivity and hydropower evacuation.

CTUIL ISTS capacity allotment in RE rich states

With introduction of General Network Access (GNA) Regulation and Renewable Energy Connectivity Framework, Central Transmission Utility of India Limited (CTUIL) has emerged as the nodal agency for granting ISTS connectivity and transmission capacity to RE developers.

State	Major renewable resource	Estimated CTUIL ISTS capacity allotted*	Key renewable energy zones
Rajasthan	Solar & wind	**Highest (>90 GW)**	Bhadla, Jaisalmer, Fatehgarh, Pokhran
Gujarat	Solar, wind & hybrid	**>65 GW**	Khavda, Kutch, Dholera, Banaskantha
Karnataka	Wind & solar	**~20 GW**	Pavagada, Chitradurga, Bellary
Tamil Nadu	Wind	**~18 GW**	Tirunelveli, Thoothukudi, Coimbatore
Andhra Pradesh	Solar & wind	**~15 GW**	Kurnool, Anantapur, Kadapa
Maharashtra	Solar & wind	**~10 GW**	Solapur, Ahmednagar, Dhule
Madhya Pradesh	Solar	**~12 GW**	Rewa, Neemuch, Agar
Telangana	Solar	**~8 GW**	Mahabubnagar, Nalgonda
Odisha	Offshore wind & solar (emerging)	**~5 GW**	Coastal renewable zones
Uttar Pradesh	Solar	**~4 GW**	Bundelkhand solar region

Conclusion

The expansion of India's transmission infrastructure in the past decade has significantly improved electricity reliability and supported rapid renewable energy growth. States like Gujarat, Maharashtra, Rajasthan, Tamil Nadu and Karnataka now feature advanced transmission systems ready to meet future energy demands. Meanwhile, eastern and northeastern states are progressing through focused investments and central government support.

To achieve long-term energy goals such as net zero targets and extensive renewable integration, India needs ongoing investment in high-capacity transmission corridors, smart grid technologies and climate-resilient infrastructure. Success will depend on coordinated efforts among the Central Electricity Authority, Power Grid Corporation of India, state transmission utilities and private sector stakeholders to build an efficient and future-ready national transmission network.

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