

## WORKING PAPER 31 – **Electric Power Scenario in India: Challenges and Opportunities in Transmission and Distribution Sectors**

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**Abstract :** The paper delves into the current state of India's electricity landscape, whilst briefly exploring the historical context and the country's journey towards electrification. India boasts diverse power generation sources, including both conventional and renewable energies, positioning it as the world's third-largest electricity producer and consumer. Nevertheless, issues like demand-supply imbalances, uneven accessibility, and system inefficiencies persist, causing daily power cuts in certain regions.

The paper critically analyzes the challenges facing the transmission and distribution sectors and presents potential solutions for greater efficiency, resilience, and environmental sustainability. Emphasizing a need for smart grid technologies, distribution system automation, and energy storage solutions, the paper also advocates for decentralized and microgrid projects. It underscores the importance of public-private partnerships and a supportive policy regime to drive India's transformation towards clean and reliable electricity access for all. By embracing a mix of technologies, comprehensive policies, and stakeholders' involvement, India can advance toward equitable, inclusive, and environmentally sustainable electrification, fulfilling its climate goals and fostering national economic development.

**[Keywords:** Electricity, Transmission, Distribution, Challenges, India]

## **Deciphering the electricity landscape in India**

Electricity is the backbone of any modern society, for it enables industries to function. This brings about economic growth, improves living standards, and facilitates technological advancements. In the case of India, a country with a vast and diverse population, it is vital to acknowledge the historical context that has shaped the country's electricity scenario.

India has come a long way since its independence in 1947, when electric power – i.e., electricity – reached only a fraction of its population. Over the years, the country has made significant strides in electrification, with the aim of providing affordable and reliable power to all its citizens. The Bhartiya Janata Party (BJP) - led National Democratic Alliance (NDA) government has for the first time laid down rights to the electricity consumers through “Electricity (Rights of Consumers) Rules, 2020” that empowers anyone in the country to initiate legal proceedings against any Electricity Distribution Company if it resorts to willful/ gratuitous load shedding, thereby establishing that 24\*7 electricity is a right of every citizen in the country (Ministry of Power, 2020).

Regardless, the power scenario remains shrouded by many problems, both structural and functional, which cripple India's to progress in a sustainable manner. Challenges related to demand-supply dynamics, uneven accessibility, and system inefficiencies are widely prevalent in many parts of the country. It is for instance the case in the state of Meghalaya, located in Northeast part of India, where daily power cuts happen for over 6 hours even at present (Dey, 2023; The Shillong Times, 2023).

The country possesses one of the world's most diverse power sectors, encompassing a wide array of power generation sources. These include traditional sources like coal, lignite, natural gas, oil, hydro, and nuclear power, as well as promising non-conventional sources such as wind, solar, agricultural, and domestic waste. In 2021-22, electricity production was primarily dominated by coal and natural gas, accounting for 1114.75 terawatt-hours (TWh) or approximately 74 percent of the total (Powell, Sati, & Tomar, 2022). Renewable energy (RE) sources followed, with a contribution of 178.34 TWh, making up around 11.9 percent of power generation (Powell, Sati, & Tomar, 2022). Hydropower had a share of 154.64 TWh, equivalent to 10.36 percent of the total electricity generation, and nuclear energy contributed 47.110 TWh, representing approximately 3.15 percent of the power generated

(Powell, Sati, & Tomar, 2022).

India ranks as the third largest producer of electricity globally (Dale, 2021). In the fiscal year 2021-22, the country generated a total of 1,719 TWh of electricity, with utilities contributing 1,484 TWh of this overall generation (Dale, 2021). India also ranks as the third largest electricity consuming country at 1.54 trillion kWh per year (Best, 2020; International Energy Agency 2020). The International Energy Agency (IEA) predicts that India's electric power system will surpass the European Union (EU) in size by 2040 and possess a renewable energy capacity 30 percent greater than that of the United States (IEA, 2021). The power sector in the country consists of a combination of government-owned utilities, private entities, and subsidies designed to ensure affordable electricity availability to everyone, mostly at a subsidized rate (Tyagi & Tongia, 2023). It is to be noted that subsidies vary depending on targeted sections of population, businesses and even states/ areas. This is because electricity in the country is both a conduit for securing electoral votes (i.e., a political instrument for wielding influence) and a masterstroke for enhancing development, i.e., increasing the profile of any area or sector (Chadha, 2022).

With an escalating electricity demand in the nation – projected to continue to grow in coming years – there is a pressing need to significantly expand generative capacity and optimize energy efficiency at all levels. Whilst treading in that direction, India needs to uphold its global commitments on reducing carbon emissions and decouple national economic growth and fossil fuel use in power generation.

**Big Question?** Is India, with noticeable advances in recent times, poised to achieve equity, inclusion and improvement in the power sector? Will the country be able to achieve electrification to the last mile in a cost-efficient, environmentally sustainable manner, whilst moving towards a clean (renewable) energy transition and achieving its nationally-determined climate goals?

This paper primarily examines such issues from the prism of electric power (hereupon ‘power’ refers to ‘electric power’) transmission and distribution. These are the two sectors in the country’s power sector that constitute the weakest link in the entire value chain and need wide-ranging reforms at all levels. The paper expounds what are the distinctive and overlapping challenges facing the two sectors, and how could they be addressed in a way that is beneficial for people in

the country and the country at large.

### **Challenges in the Transmission Sector**

India has a vast network of transmission lines which carry electricity from the power plants to the distribution substations. The two major transmission lines in the country are a) the North-South Corridor, a 2,000-km-long transmission line that carries electricity from the northern states to the southern states; b) the East-West Corridor, a 3,400-km-long transmission line that carries electricity from the eastern states to the western states.

Despite the recent advances towards making electricity available to all, the country faces many obstacles in power transmission. This impacts the efficiency and reliability of its electricity distribution and overall health of the power system. Some of these challenges include, but are not limited to, the following:

- **Inadequate Infrastructure:** Many parts of the transmission infrastructure are aging and require urgent upgrades or replacements (Buckley. & Shah, 2019). Older infrastructure requires more frequent and extensive maintenance to ensure its reliable operation. This has led to higher maintenance costs for power utilities and has strained their financial resources. Moreover, power utilities, especially state-owned power companies, have failed to introduce the latest and smart technologies; this has led to less efficient grid operations (Electrical India, 2018).
- **Land Acquisition and Right-of-Way Issues:** Building new transmission lines often requires the acquisition of land (like forests or private properties) linked to delays and disputes. Right-of-way issues have often hindered the timely completion of transmission projects. In recent times, there have been cases of public protests and environmental concerns in different parts of India when transmission lines were passed through ecologically sensitive areas without due consultation with the impacted local communities (Ghosal & Kumari, 2017; Rodrigues, 2021).
- **Overloading and Congestion:** The power transmission network in India has experienced overloading and congestion due to rapid growth in power demand and inadequate expansion of transmission infrastructure. Overloaded lines have occasionally led to grid instability and an increased risk of blackouts. Overloaded transmission infrastructure has caused congestion in the power grid resulting in losses of electricity (Ministry of

Power, 2023). Moreover, this poses a continuing threat to damaging equipment, like power lines, transformers, switching equipment, etc. (National Load Dispatch Centre, 2021).

- **Inadequate Grid Planning:** There have been instances of inadequate long-term grid planning and forecasting which have resulted in suboptimal utilization of existing infrastructure and delays in building new transmission lines. Also, this has led to a mismatch between electricity supply and demand, especially during peak hours (Gagal, 2022). The challenge requires a comprehensive approach, involving collaboration between government bodies, regulatory authorities, power utilities, and other stakeholders, which substantially lags at the moment.
- **Operational and Maintenance Challenges:** Proper maintenance and operation of transmission assets are essential for ensuring grid reliability. Inadequate maintenance and operational practices by power utilities have led to technical failures and disruptions in the power supply. The power failure of July 2012, which affected 700 million people (mainly in 8 states across the country) happened due to a disturbance in the Northern Grid (Pidd, 2012). It was therefore officially held that all utilities would need to adopt good operation and maintenance practices so as to avoid such mishaps in the future (Central Electricity Regulatory Commission, 2012).

To address these challenges, the Indian government and power sector stakeholders have taken various measures. These include planned investments in upgrading transmission infrastructure, implementing advanced technologies such as smart grids and grid automation, enhancing interregional connectivity, promoting renewable energy integration through grid-friendly policies, and implementing stricter measures to prevent power theft. These efforts aim to improve the efficiency, resilience, and sustainability of India's power transmission system.

### **Challenges in the Distribution Sector**

India's distribution sector is responsible for delivering electricity from power plants to consumers. The two main categories of distribution companies in the country are: first, a) State Electricity Boards (SEBs) –government-owned distribution companies that operate in most Indian states. An example is the Maharashtra State Electricity Distribution Company Ltd (MSEDCL), which supplies power to over 2.6 crore consumers in the state of Maharashtra and was awarded the "Best state

power utility award' during the 15<sup>th</sup> India Energy summit (Sen, 2022). Second, b) Private Distribution Companies are private companies that operate in some states of India. An example is the Tata Power Company Ltd (the nation's largest private sector power utility, with an installed generation capacity of over 13,735 MW)

The country faces several challenges in power distribution<sup>1</sup> that impact an effective and reliable delivery of electricity to end consumers. The major power distribution challenges, some of which are interrelated, include:

- **High Aggregate Technical and Commercial (AT&C) Losses:** AT&C losses refer to the combined losses incurred during the transmission and distribution of electricity, including technical losses and commercial losses due to theft, billing inefficiencies, and non-payment. High AT&C losses have put financial strain on power utilities and have resulted in inadequate revenue collection. The Central Electricity Authority (CEA) has set a limit of 15 per cent Aggregate Technical and Commercial (AT&C) losses (Central Electricity Authority, 2021); however in some states, like Uttar Pradesh – the largest state in the country – AT&C losses account for over 30 per cent (Goswami, 2022).
- **Inadequate Last-Mile Connectivity:** Certain areas, especially in rural and remote regions, have limited access to the power distribution network. Lack of last-mile connectivity makes it challenging to provide reliable electricity supply to all households and businesses. Border states in India, especially Arunachal Pradesh – that China refers as "Zangnan," ("South Tibet") and Jammu and Kashmir – rank at the bottom for power availability in rural areas as per data of the Indian Ministry of Power in 2021 (Ministry of Power, 2021). Vast parts of these states remain unelectrified, though certain (unverified) sources claim that these states have achieved 100 percent rural electrification ("Arunachal Pradesh Achieves Remarkable Milestones In Rural Electrification," 2023).
- **Overload of Distribution Infrastructure:** Distribution networks are unable in some areas to handle the increasing load demand. Overloading of transformers, substations, and distribution lines has led to frequent power outages and voltage fluctuations. This is now manifested in several states in

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<sup>1</sup> Power distribution includes the distribution substations and the distribution network that delivers electricity to the end-users.

north India, like Uttar Pradesh, Punjab, Bihar, even Delhi, as they experience a severe heatwave that has resulted in surges in power consumption (Baruah, 2023).

- **Inaccurate Metering and Billing:** Inaccurate metering and billing systems have contributed to revenue losses for power distribution companies. Issues persist, such as faulty meters, billing errors, and inefficient collection processes affect revenue collection and financial viability. In the Northeastern state of Assam, which has recently introduced smart prepaid meters in Guwahati city and plans to expand that across other districts (Jones, 2022), there have been reports regarding faulty meter readings, resulting in a steep rise in electricity bills of consumers (Singh, 2022; The Sentinel Assam, 2023).
- **Voltage Fluctuations and Power Quality:** Voltage fluctuations, low power quality, and frequent voltage surges impact the performance of electrical appliances and machinery. Inconsistent power supply affects the productivity of industries and the overall consumer experience. As per a joint study by Smart Power India (SPI), NITI (National Institute for Transforming India) Aayog and the Rockefeller Foundation said that 63 percent of customers in the country experienced more than one voltage fluctuation in a week, while 10 percent encountered over 10 voltage fluctuations per day during the past week (NITI Aayog, 2020).
- **Lack of Consumer Awareness and Engagement:** Limited awareness among consumers about their rights, responsibilities, and energy conservation measures hampers effective energy management and demand-side participation. Indian power consumers are often not given the opportunity to participate in decision-making about the power sector. This puts them in a position where they feel they have no control over matters related to power supply. This is especially the case in Electric Vehicle (EV) sector; though there is a boom for EV cars across states in the country, people at large remain in oblivion about interconnected EV technology, policy, and social issues (Vadera, 2023).

### **Complete overhaul or progressive advancements?**

There is a school of thought that claims the existing power system in India needs a

paradigm restructuring in order to achieve parity with Western and other developed countries. Another school of thought is satisfied with the incremental progress the country has been making in the power system over the years, and especially after the NDA government won general elections in 2014.

The first school of thought mainly contends that a nation-wide power grid, officially named as ‘National Power Grid’, cannot be an economically optimal solution for the government or a sustainable recourse for the country, as transmission over long distances creates significant power losses. Advocates of this school further contend this is more of a political scheme substantiating BJP’s ‘one nation’ theory and aims of establishing a strong national government in New Delhi.

As a matter of fact, a pan-India electricity grid is more susceptible to ‘systemic instability’ arising due to decreased inertia, rise in power demand causing stressed out grids and higher penetration of variable renewable energy sources. Even from a national security perspective, such a national electricity grid could be more vulnerable to cyber-attacks and other “disaster” scenarios that can disrupt power supply to large areas (Rising, 2022; Parida et al., 2023; The Business Standard 2015).

The second school of thought, which is more accepted within government circles, contends that fringe additions and modifications to the existing power system will create a unique, indigenous power system that will take care of both needs – maintaining electricity supply to countrymen and meeting other associated socio-economic (and political) goals of the national government representing the country at large.

It is to be noted that electricity constitutes a subject in the concurrent list found in the Constitution of India, meaning that both the central government and any state government can make laws related to its management. However, the BJP-led central government is diligently striving to bring this subject under its full control by introducing new laws, enacting policies and redesigning the power apparatus. It cannot be denied that a national grid provides certain advantages, for instance increased reliability, enhanced efficiency and standardized environmental performance; however, these advantages need to be gauged vis-a-vis the inevitable drawbacks.

A common ground that can be derived from these schools of thought is that the existing power system in India is not full-proof; there is scope for improvement.

The trajectory chosen by both central and state governments will be crucial in determining whether the power scenario in India emerges as a centralized, directed system or as a set of decoupled, dynamical systems comprising a mix of on-grid and off-grid power structures and associated distributions, all loosely connected over a countrywide power network.

### **Proposed Way Forward**

At present, India is struggling to meet its power needs from conventional sources – mainly coal, which has remained the backbone of the country’s baseload. The country’s annual electricity demand is projected to grow at an average of 7.2% by the end of March 2027 (Innovation Centre Denmark, 2023), whereas its present installed capacity can only add 25,000 MW per year (Thakur, 2019). This is insufficient to support the 7-8 percent annual economic growth that India witnessed prior to Covid-19 outbreak; insufficient also to meet the needs of a fast-developing country at the world stage.

At this juncture, we must radically re-think how to revamp the power system in the country, so that electricity no longer remains a prized item – and becomes an everyday commodity of use that is readily available and can be converted (smart grid). There are several opportunities for improvement in power transmission and distribution sectors to enhance the efficiency, reliability, and sustainability of the electrical grid. Some key opportunities include:

➤ **Smart Grid Technologies:** Implementing smart grid technologies can revolutionize power transmission and distribution. Smart grids enable real-time monitoring, control, and automation – thereby improving energy management, reducing losses, and enhancing grid resilience. In May 2015, the Government of India launched the National Smart Grid Mission with a total project cost of USD 135.1 million (INR 980 crore) and received budgetary support of USD 46.6 million (INR 338 crore), which became operational in January 2016 (Ministry of Power, 2015). Both India’s national grid and (mainly) the regional grids have changed since then, but not enough (Choudhary, 2022). There is great scope and depth to digitalize the grids by introducing technologies such as SCADA systems, which come with a self-correcting mechanism allowing them to gather and store data and identify potential issues that may require troubleshooting and maintenance, thereby making the power systems more intelligent and resilient.

➤ **Distribution System Automation:** Automation can allow utilities to monitor

the distribution network in real time, thus enabling them to identify and address issues promptly. It can manage dynamic load – balancing and optimizing the distribution of electricity across the network to prevent overloads and voltage fluctuations. Such distribution systems can detect faults and outages more accurately and efficiently. Moreover, automation can help detect energy theft and unauthorized usage, thus reducing revenue losses for utilities and ensuring a fair and transparent billing system.

The ‘Guidelines on Introduction of Automation in Distribution Sector’ (2018) highlights a philosophy about its application that ‘20% (automated) control can restore 80% of the network’ (Central Electricity Authority, 2018). At present, the government is deliberating whether to adopt technologies such as Advanced Metering Infrastructure, Enterprise Service Bus (a method that allows accommodation of multiple ESB domains to communicate across the operation center, enterprise and substation) and Home Automation (Central Electricity Authority, 2018); however, much of these are still in their projection phase (Tejaswi, 2023; “How is Automation changing the Indian Power Sector,” 2020).

➤ **Energy Storage Solutions:** These solutions involve the capture and storage of energy for later use, which can enhance grid stability, support renewable energy integration, and improve overall efficiency. Investing in energy storage technologies can help manage fluctuations in electricity demand and supply. Integrating energy storage systems into the grid can improve stability and enable a better use of intermittent renewable energy sources.

In March 2022, the Ministry of Power issued guidelines to promote the growth of energy storage and achieve India's 2030 target of installing 500 GW of non-fossil energy. These guidelines focus on the procurement and utilization of battery energy storage systems in various aspects of power generation, transmission, and distribution, including ancillary services. With such aims in sight, the country’s Union Budget 2023-24 focuses on clean energy storage and the power transmission sector (PIB, 2023),<sup>2</sup> which is likely to introduce batteries of scale to store power across the countrywide network.

➤ **Decentralized and Microgrid Solutions:** Encouraging decentralized power

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<sup>2</sup> In the Union Budget 2023-24, the Ministry of Power has formulated a Scheme on Viability Gap Funding for development of Battery Energy Storage Systems with capacity of 4,000 MWh.

generation through small-scale renewable energy projects and microgrids (closer to the point of consumption) can improve energy access in rural and remote areas. This can also reduce dependency on long-distance transmission lines. Furthermore, decentralized power generation can encourage the integration of various distributed energy resources (DERs) such as solar panels, wind turbines, and battery storage, thus creating a more diverse and resilient energy ecosystem.

Brookings has claimed that “Many Indian microgrids have been a response to “bad quality” or unavailable grid supply – this model faces an existential threat as the grid improves.” (Tongia, 2018). In 2016, the Indian government introduced a Draft National Policy on Mini and Micro-grids that aimed to implement a minimum of 10,000 renewable energy-based micro/mini-grids with a total capacity of at least 500 MW within the following five years; however, this draft plan was shelved and microgrids have failed to materialise over these years.

At present, the Indian government does not have a clear plan and a working strategy on how to build mini and microgrids that could sustainably meet the energy needs of local communities. Despite of that, private players are enthusiastically entering in this segment – one can mention for instance a partnership between Tata Power and Rockefeller Foundation, which plans to set up of 10,000 microgrids across the country by 2026 (Tata Power, 2019).

➤ **Public-Private Partnerships (PPPs):** Since the power sector, including transmission and distribution, requires substantial investments in infrastructure development, technology upgrades, and capacity expansion, private sector participation through PPPs can bring in additional funding and expertise, easing the financial burden on the government. PPPs can result in more efficient project implementation due to streamlined decision-making processes and reduced bureaucratic hurdles. They can also allow risks to be shared between public and private partners, thereby minimizing the financial burden on the government in case of unforeseen challenges or project delays. It is interesting (rather confusing) to see that the NITI (National Institute for Transforming India) Aayog – a think tank owned by the central government – has reported that during the financial year 2021-2022, out of 125 appraised central government projects (including 2 by state governments) not one regards the power sector (NITI Aayog, 2023). The power sector has traditionally shown a strong track record of PPP projects. There is a clear need to increase collaboration at this front.

➤ **Supportive and responsive policy regime:** Such a policy framework is urgently necessary to cope with different challenges, both unprecedented and existing, as well as to foster growth and development in the country's power sector. Some key elements include an investor-friendly and enabling environment, real-time demand response programs, effective financial and regulatory support for Distribution Companies (DISCOMs) and state of art research and development (R&D) initiatives. The policy regime now in place for the power sector is considerably disjointed and incoherent. This needs to be recalibrated and redesigned in consultation with other stakeholders, including small consumers of power, whilst keeping all actors at a level playing field.

### **Conclusion**

With India aiming to achieve carbon neutrality by 2070 and meet fifty percent of its electricity requirements from renewable energy sources by 2030 (Ellis-Petersen, 2021; Birol & Kant, 2022 ), it is imperative that the country urgently reforms its power system – mainly the transmission and distribution sectors – so as to meet these goals whilst protecting the environment and sustaining its national economic development. It can achieve this not merely through a centralized scheme of plans, policies and actions, but simultaneously driving up a 'bottom-up approach' of fostering (niche) innovation and stakeholders' participation in decision making, starting from a grassroot level to wider society and central-government ministries. By focusing on a mix of technologies, modernizing the transmission and distribution network, implementing inclusive government policies and a greater use of clean energy (both renewables and cleaner use of fossil fuels), India can strive towards universal access to reliable and sustainable electricity.

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