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Roadmap for State Transmission Utilities (STUs) Capacity Strengthening

Prepared by
South Asia Regional Energy Partnership (SAREP)

July 2023

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FOREWORD

It is with great pleasure that I introduce this report, which addresses a significant aspect of the power sector in India – the development and strengthening of the State Transmission Utilities (STUs). As mandated by the Indian Constitution, both the Central Government and State Governments have the authority to legislate on matters related to electricity, and the Electricity Act, 2003 currently governs the power sector's development.

With diverse resource locations and load centers situated at considerable distances from each other, the need for a robust transmission system becomes paramount. The All-India Grid serves as an interconnected network, demanding meticulous planning and systematic development of the transmission infrastructure. Presently, the state sector shoulders approximately 50% of the responsibility in terms of overall assets. At 220 kV and above voltage levels we have got around 5 lakh ckm of transmission lines, and 11.5 lakh MVA transformation capacity of which 60% lies within the state sector.

Under Section 39 of the Electricity Act, 2003, the State Transmission Utility (STU) assumes the vital role of constructing, maintaining, and operating an efficient, coordinated, and cost-effective intra-state transmission system. Consequently, the STU bears the responsibility of planning, coordinating, and ensuring open access within the transmission system.

Recognizing the pivotal role of STUs in building a robust and flexible transmission system, there arises a pressing need and significant opportunity to strengthen the infrastructure, processes, and operational capacity of these utilities. In line with this objective, the United States Agency for International Development's (USAID) South Asia Regional Energy Program (SAREP) has prepared a report titled "Roadmap for State Transmission Utilities Capacity Strengthening."

The report developed by USAID's SAREP program, focused on the thematic areas of technology, infrastructure, O&M, regulations, and human capacity, pinpoints the challenges that lie ahead in the transformation of state transmission utilities and makes recommendations to alleviate the challenges faced by STUs to emerge as modernized utilities. This report is the result of consultations with various states and a national-level roundtable consultation workshop, providing a comprehensive analysis of challenges and offering appropriate recommendations to address identified gaps.

I strongly recommend that all stakeholders in the power sector, particularly the STUs, thoroughly review this report. It serves as a crucial starting point in transforming transmission utilities into modern, efficient entities. By incorporating the insights and recommendations presented within this report, we can pave the way for the development of a resilient and future-ready transmission system.

I extend my sincere thanks and appreciation to USAID's SAREP program and all the stakeholders involved in the preparation of this report. Their efforts and expertise have contributed to the production of a valuable resource that will guide and inform the transformation of STUs. I encourage all readers to embrace this report as a stepping stone towards the modernization and enhanced efficiency of the transmission sector.

A K Rajput
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FOREWORD

The Government of India has taken positive steps to accelerate clean energy transition in the country. This includes setting a bold target of achieving 500 gigawatts (GW) of non-fossil energy capacity by 2030. The country has already an installed capacity of 181 GW of renewable energy. This significant progress has been enabled by supportive policies and a regulatory framework by the Government of India. In addition, the Government of India has invested significantly to develop adequate infrastructure for evacuation of renewable energy and upgrading its power grid to address challenges arising out of integration of renewable energy, especially at the central and inter-state level. The landmark decision to allow private sector participation in development of transmission infrastructure also contributed to a more robust and reliable transmission system in the country. Similar interventions are required at the state level with replication of best practises from the central agencies. Development of the transmission network at intra-state level and having modernized transmission utilities at the state level that can adapt to the changing needs of an evolving energy sector are important advances. The state transmission utilities (STUs) must keep pace with technological interventions and adopt best practices to accelerate deployment of renewable energy. However, the STUs are faced with several challenges and barriers.

To understand these challenges and barriers, the United States Agency for International Development (USAID), through its South Asia Regional Energy Partnership (SAREP), developed the report "Roadmap for Capacity Strengthening of the State Transmission Utilities (STUs)". The report was prepared through online surveys, in person meetings, rounds of consultations with STUs, and feedback from experts from the sector. Based on analysis of the challenges, a roadmap is recommended focused on enhancing the operational and financial capacities of the STUs. This is in line with USAID's goal of a modern and efficient transmission utilities adapted to support India's clean energy transition.

I sincerely hope that this report will assist stakeholders including policy makers to understand the challenges and take suitable actions to address these. USAID on its part will take the findings of the study and will support implementation of the roadmap in its partner states.

John Smith-Sreen

John Smith-Sreen
Indo-Pacific Director
USAID/India

Acronyms

AC	Alternating Current
ACCC	Aluminum Conductor Composite Core
ADMS	Advanced Distribution Management System
AMC	Annual Maintenance Contract
ARR	Aggregate Revenue Requirement
ATC	Available Transfer Capability
BESS	Battery Energy Storage System
BOOM	Build, Own, Operate, and Maintain
BPC	Bid Process Coordinator
C2C	Concept to Commissioning
CaB	Capacity Building
CABIL	Capacity Building of Indian Load Despatch Centres
CAPEX	Capital Expenditure
CB	Competitive Bidding
CBM	Condition-Based Maintenance
CEA	Central Electricity Authority of India
CERC	Central Electricity Regulatory Commission
CoD	Commercial Operation Date
CSS	Cross Subsidy Surcharge
CSV	Comma-Separated Values
CTU	Central Transmission Utility
DC	Direct Current
DIgSILENT	Digital SimuLation and Electrical NeTwork Calculation Program
DISCOM	Distribution Company
DLR	Dynamic Line Rating
EC	Electricity Commission
EHV	Extra-High Voltage
EMS	Energy Management System
EMTP	Electro-Magnetic Transients Program
ERP	Enterprise Resource Planning
ERPC	Eastern Regional Power Committee
ERS	Emergency Restoration System
ETAP	Electrical Transient Analyzer Program
FACTS	Flexible Alternating Current Transmission System
FICCI	Federation of Indian Chambers of Commerce & Industry
FOR	Forum of Regulators
GIS	Gas Insulated Substation
GInS	Geographic Information System

GCC	Grid Coordination Committee
GENCOs	Generation Companies
GETRI	Gujarat Energy Training & Research Institute
GNA	General Network Access
GTG	Greening the Grid
HERC	Haryana Electricity Regulatory Commission
HRD	Human Resource Development
HTLS	High-Temperature Low Sag
HV	High Voltage
HVDC	High Voltage Direct Current
HVPNL	Haryana Vidyut Prasaran Nigam Ltd.
InSTS	Intra-State Transmission System
InvIT	Infrastructure Investment Trust
IPP	Independent Power Producers
IR	Industry Relation
ISTS	Inter-State Transmission System
JERC	Joint Electricity Regulatory Commission
JKERC	Jammu and Kashmir Electricity Regulatory Commission
JV	Joint Venture
KPI	Key Performance Indicator
KPTCL	Karnataka Power Transmission Corporation Limited
LDC	Load Despatch Centres
LiDAR	Light Detection and Ranging
LOA	Letter of Offer and Acceptance
MERC	Maharashtra Electricity Regulatory Commission
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MSETCL	Maharashtra State Electricity Transmission Company
NGC	National Grid Code
NEP	National Electricity Policy
NER	North-Eastern Region
NPP	National Power Policy
NREP	National Renewable Energy Policy
NTP	National Tariff Policy
NLDC	National Load Despatch Centre
NTAMC	National Transmission Asset Management Centre
NTPC	National Thermal Power Corporation
O&M	Operation and Maintenance
OHL	Over-Headline
OMS	Outage Management System
OPGW	Optical Fibre Ground Wire

OPTCL	Odisha Power Transmission Corporation Limited
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India
PoC	Point of Connection
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PSCAD	Power Systems Computer-Aided Design
PSSe	Power System Simulator for Engineering
PST	Phase Shifting transformers
PSTI	Power System Training Institute
QCA	Qualified Coordinating Agency
RCM	Reliability Centered Maintenance
RE	Renewable Energy
RFP	Request for Proposal
RFQ	Request for Quote
RLDC	Regional Load Despatch Centre
RoW	Right of Way
RPC	Regional Power Committee
RTAMC	Regional Transmission Asset Management Centre
R, M&U	Renovation, Modernization & Uprating
SANTULAN	Intra-State Reserves and Ancillary Services for Balancing
SAREP	South Asia Regional Energy Partnership
SCADA	Supervisory Control and Data Acquisition
SERC	State Electricity Regulatory Commission
SIR	System Implementation Review
SRI	Silicone Rubber Insulator
SLDC	State Load Despatch Centres
SNA	State Nodal Agency
STATCOM	Static Synchronous Compensator
STOA	Short-Term Open Access
STU	State Transmission Utility
SVC	Static VAR Compensator
TBCB	Tariff-Based Competitive Bidding
TSA	Transmission Service Agreement
TSTransco	Telangana Transmission Company
TTC	Total Transfer Capability
UAV	Unmanned Aerial Vehicle
UPERC	Uttar Pradesh Electricity Regulatory Commission
USAID	United States Agency for International Development

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Executive Summary

The United States Agency for International Development (USAID) South Asia Regional Energy Partnership (SAREP) is a regional initiative which aims to enhance energy access, improve energy security, and increase the use of renewable energy sources in the region. As development of modern and financially viable utilities is a key focus area under the program, SAREP has undertaken a market research and gap assessment study of State Transmission Utilities (STUs). The report intends to strengthen the planning and operations capacity of state transmission utilities (STUs) through a gap analysis study.

The major gaps assessed as well as the associated recommendations are as follows:

Table 1 | Gap Assessment Outcomes

Area	Identified Gaps	Key Recommendations
Technology	• Need for adoption of latest technologies • Limited R&D • Limited capacity building on latest technologies	• Encourage new technological developments such as: – Dynamic active and reactive power control (with power flow controllers, FACTS and synchronous condensers) – Storage systems (Pumped Hydro or Battery Storage) to balance the intermittency of renewables – Application of Dynamic Line Rating (DLR) technology for real-time monitoring – Digitization of infrastructure with digital substations and robust communication – Hot line maintenance practices – Drones and Helicranes in construction and O&M – Unmanned Aerial Vehicles (UAV) and satellite imagery for route survey – Reorientation of existing RoW/towers for network reconfiguration • Allocate budget for R&D and innovative pilots • Plan capacity building programs for skill building on advanced technologies and raising awareness
Infrastructure	• Requirement of additional investments • Focus on infrastructure development in cost-plus mode • Difficulty in arranging funds • Challenges in execution due to cumbersome approval processes and project delays/ cancellations • Need for enhancing disaster readiness and management capacity	• Develop optimal transmission plans to address funding limitations • Encourage TBCB to attract investment in state transmission infrastructure • Explore innovative financing models and access to low-cost debt financing • Streamline the execution process with timely release of RFQs, annual pre-qualification assessments, avoiding route surveys (generally inaccurate, costly, and time-consuming activities), and award of project • Adopt a lease policy for private land for improving the execution rate of projects • Develop disaster management plans and protocols, measure preparedness with regular mock drills and ensure availability of emergency resources systems (ERS)

Area	Identified Gaps	Key Recommendations
Tools and Techniques	• Requirement of modern planning tools • Requirement of adequate data • Need for renewed focus on grid resilience • Gaps in coordination between stakeholders	• Utilities to be equipped with following tools – Latest state-of-the-art load forecasting facilities – GInS (Geographic Information System) based planning tools – Power systems (load flow, short circuit, transient stability, etc.) and production cost models • Refinement of planning philosophies with – Market and resource scenario considerations – Techno-financial evaluation of transmission plan – Long-term planning for RE integration, green hydrogen production hubs, and reactive power planning – Inertial studies • Focus on grid resilience with vulnerability assessments, surveying operational performance, system resilience-centric planning and improving cyber security • Capacity building on project planning tools and philosophies, frequency response analysis, EMT studies, Gas Insulated Substation (GIS) and augmented reality • Support the creation of a national-level database through the updation of details on the Pradhan Mantri Gati Shakti Portal • Utilization of data captured with digitization of transmission infrastructure for better visualization of network (and its utilization) as well as for advanced analytics • Interact more frequently with CTU to enhance coordination on issues such as aligning load forecasting, transmission plans, outage planning, etc. • Interact with DISCOMs frequently to seek regular inputs for accurate load forecasting and transmission planning
Operations	• Requirement of improvement in maintenance techniques • Adherence to Indian Standard (IS)codes	• Carry out root cause analysis for any asset failure and adopt condition-based and reliability centric maintenance practices • Strive to adopt regular, data driven, energy efficient and automated methods for maintenance with advanced corona detection cameras, thermo-vision camera, drones, UAVs, sensors, etc. • Explore deployment of application-based asset monitoring similar to Powergrid's PG Darpan. • Stay updated with latest and relevant standards and codes and ensure necessary compliance
Policy and Regulations	• Need for new regulations (on resource planning, protection studies, construction mechanization, energy storage) • Requirement of monitoring of regulatory compliance • Differences in central and state regulatory practices • Need for developing in-house capacity for drafting new regulations and tariff filings	• Introduce transmission planning regulations at state level aligned to CERC's transmission planning regulations • Harmonization of recent changes at central level (such as Deviation Settlement Mechanism, General Network Access, Indian Electricity Grid Code) into state regulations by SERCs • Capacity building of STUs on regulatory framework and its implications may be undertaken.

Area	Identified Gaps	Key Recommendations
Human Capacity	• Need for skilled manpower • Requirement of training	• Regular recruitment to fill vacancies and proper incentivization to retain skilled manpower • Knowledge transfer from outgoing experts to junior staff • Allocation of budget for national and international skill development program • Development of training modules and upskilling of workforce as per annual training calendar • Defining Human Resource Development (HRD) systems and policies
Institutional Framework	• Need for autonomy • Requirement of an institutional platform for interaction between STUs	• STUs should function as independent organizations wherein the board is free to make independent decisions • A 'Forum of STUs (FoS)' may be constituted which shall operate as a platform for knowledge sharing on innovative solutions and best practices.

The recommendations presented above are based on a national level gap assessment. However, gaps in present practices, and interventions required may vary for different STUs. Hence, there is need to conduct a gap assessment of a utility as individual utilities shall be at different levels of modernization. Therefore, creation of individual roadmaps is recommended through a three-step approach:

1. **As – is assessment**: An As-is assessment of utility's current practices to determine the level of modernization achieved in existing scenario. Based on the assessment, the utility shall be categorized as: foundational, mature and pacesetter
2. **Techno-commercial assessment of pathways:** Identification of measures that can be taken up based on implementation time as well as associated Cost-Benefit Analysis (CBA).
3. **Finalize roadmap:** Finalize roadmap by defining deliverables, timelines, roles and responsibilities of stakeholders, costs, performance/success indicators, etc.

1. Introduction

South Asia Regional Energy Partnership (SAREP), a five-year energy program of the United States Agency for International Development (USAID), aims to improve access to affordable, secure, reliable, and sustainable energy in six South Asian countries including Bangladesh, Bhutan, India, Nepal, Sri Lanka, and the Maldives. One of the ways through which SAREP aims to achieve this objective is through modernization of the transmission, system operation, and distribution utilities to improve their technical, financial, and operational performance, enhance grid resilience, improve customer service, and promote adaptability to new technological and renewable-related advancements.

Transmission systems in India consist of inter-state and intra-state transmission systems. Central Transmission Utility (CTU) and State Transmission Utility (STU) are responsible for inter and intra-state transmission system planning and operation respectively. With the emergence of renewable energy sources as mainstay energy resources, India is expanding the Inter State Transmission System (ISTS) to enable access to renewable energy for its consumers. While the ISTS network level is expected to expand significantly, states will need to expand the transmission capacity of the intra-state transmission system to allow efficient and unconstrained delivery of power to the distribution periphery and ultimately, to the end consumers.

The overall objective of the assessment is to identify gaps and provide a recommendation to strengthen the planning and operations capacity of state transmission utilities (STUs) to enable clean energy transition. The activities within this task are as follows:

- Analysis of current practices of STUs in areas such as transmission system planning, construction, O&M, etc.
- Understand ongoing initiatives/best practices being followed at STUs to develop the planning and operations capacity of state transmission.
- Identify gaps based on review of existing reports, consultations with central stakeholders and state transmission utilities.
- Based on the assessment and consultations, provide recommendations for improvement.

2. Approach

The report has been structured into the following sections: Present Practices of STU, Gap Assessment, Recommendations and Roadmap. The approach for each of the sections is elaborated below:

2.1. Data Collection

A three-fold approach for data collection was followed during the development of the capacity gap report. The inputs were gathered from literature survey, primary research, and stakeholder consultation.

1. **Literature Survey:** A literature survey has been conducted of reports published by central stakeholders. The following reports have been referred to understand the present practices and identification of the gaps:

   I. Manual on Transmission Planning Criteria (CEA, March 2023)

   This report describes the planning philosophy to be followed by the transmission utilities for network planning. The planning criteria discusses the routing of transmission lines by CEA (Technical standards for construction of electrical plants and electric lines) to minimize RoW, technical options, and line configurations.

   II. Transmission Reform Agenda and Action Plan (Shakti Foundation, May 2021)

   This report discusses the key challenges in terms of transmission planning, pricing, and participation related to the transmission network as well as potential solutions to address such challenges.

   III. Updating the Best Practices in Transmission Systems in the Country (CEA, April 2020)

   This report aims to consolidate the best practices in the transmission and distribution sector as well as steps to bridge the gap between existing practices and best practices.

   IV. Policy and Regulatory Environment for Utility-Scale Energy Storage: India (USAID-GTG, October 2020)

   The report analyzes the readiness of the country to deploy energy storage systems. The report suggests priority areas for regulators and policy makers to enable deployment of energy storage systems.

   V. Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study (USAID-GTG, July 2017)

   This report describes the integration study with scenarios, assumptions, and methodology to assess the RE integration into the Grid. The operational impacts of national RE targets and strategies to improve RE integration have been discussed. Finally, the findings from the analysis and policy implications to promote future RE integration have been presented.

   VI. Implementation of Tariff Policy 2016 (CEA, May 2017)

   The report analyzes the status of implementation of tariff policy 2016 through a survey of various SERCs. The report analyzes the gaps prevailing in the following areas: Electricity for All, Efficiency Enhancement, promoting environment friendly measures, ease of doing business and tariff rationalization.

2. **Primary Research:** To gather further insights, a survey was conducted with STUs in an online/telephonic mode. The entities that were surveyed are: Rajasthan, Gujarat, Karnataka, Odisha, Maharashtra, and Haryana. A total of nineteen questions were developed which catered to Infrastructure, Technology, Tools and Techniques, Operation, Policy and Regulations and Human Capacity.

3. **National Workshop:** A national workshop was organized on March 14, 2023 by USAID, through its SAREP program in New Delhi to deliberate on the inputs received from literature survey and interviews conducted. Officials from STUs and eminent industry experts were invited to express their views on the initial findings.

2.2. Gap Assessment

Based on the inputs received through the above approach, a gap analysis was carried out wherein the findings have been structured under the following categories viz. Infrastructure, Technology, Tools and Techniques, Operation, Policy and Regulations and Human Capacity.

2.3. Develop Recommendations

To address the identified gaps, recommendations have been developed, which STUs can adopt to improve efficiency in their operations. The recommendations intend to address the identified gaps in each of the categories defined in earlier sections.

2.4. Outline a Strategy for Developing Customized Modernization Roadmap for STUs

While the report presents the recommendations for a national level capacity gap assessment, the implementation roadmaps for STUs are expected to vary. Hence, an approach for developing customized modernization roadmaps for STUs is proposed. Using this approach, STUs can identify the measures that can be implemented, expected timeframe and outcomes.

3. Present Practices of State Transmission Utilities

The report has been structured into the following sections: Present Practices of STU, Gap Assessment, Recommendations and Roadmap. The approach for each of the sections is elaborated below:

3.1. Introduction

The Electricity Act 03 outlines the major responsibilities of state transmission utilities. As per the Act, STUs shall have the following functions:

1	To undertake transmission of electricity through intra-state transmission system
2	To discharge all functions of planning and co-ordination relating to intra-state transmission system with – Central Transmission Utility, State Governments, Generating Companies, Regional Power Committees (RPCs), CEA, licensees, and any other person notified by State Government
3	To ensure development of an efficient, coordinated, and economical system of intra-State transmission lines for smooth flow of electricity from a generating station to the load centers
4	To provide non-discriminatory open access to its transmission system

Based on the above responsibilities, STUs have organized the functions in the following manner:

Table 2 | **STU Organized Functions**

Area	Identified Gaps	Key Recommendations
Planning	The planning function is derived from sub-section 2(b) and (c) of Section 39 of the Act.	• Technical studies related to transmission planning and regional expansion plan • Developing substation layouts and contributing to the capital budget and regulations. • Contribute to on-site generation and operational planning studies. • Determine and evaluate transmission system upgrades to improve efficiency, reliability, and operations. • Assess the system's adequacy and reliability. • Help develop new planning strategies and tools. • Make suggestions to company management about bulk power facilities, procedures, programs, and policies.
Finance	The planning function is derived from sub-section 2I of Section 39 of the Act.	• Arranging finance for construction and operations • Preparation of accounts for the company • Overseeing audits of the company • Managing capital expenditure and operational expenses • Regulatory submissions related to tariff matters

Area	Identified Gaps	Key Recommendations
Operation and Maintenance	This function is derived from sub-section 2(a) of Section 39 of the Act	• Operation and Maintenance of transmission lines and substations • Carrying out maintenance civil works with respect to transmission network • Managing maintenance contracts and procurement of maintenance spares • Managing safety and security of the transmission assets • Managing store and inventory • Stakeholder management related to Grid Coordination Committee (GCC), State Load Despatch Centre (SLDC) and Eastern Regional Power Committee (ERPC), etc. • Providing inputs to CEA Standards and other regulatory matters
Construction/ Projects	This function is derived from sub-section(c) of Section 39 of the Act	• Managing the construction of substations and lines and related project activities • Contract Management • Project Monitoring • Managing automation projects
Regulatory/ Commercial	The department caters to compliance to regulations notified by commissions un-der Section 181 of the Act	STUs are responsible for ensuring compliance with regulations set by SERCs. These include: • Tariff Regulations • Business related regulations which include open access regulations and transmission license regulations • Operations related regulations such as state grid code
Human Resources		The human resource function carries out the following functions: • Training and development • Manpower planning, Recruitment, Promotion, Transfer, Policy formulation, • Welfare, General Administration, Estate, • Employee benefits, Industry Relation (IR) Matters, Personnel Matters, and Employee Relations. • The admin function is also observed as a sub–department under HR. The main activities under this are corporate Communication and facilities/service Management.

3.2. Present Practices of STUs

The practices of STUs are primarily guided by the Electricity Act 2003, rules introduced by central and state government and regulations introduced by state electricity regulatory commission. These department-wise practices are elaborated in subsequent paragraphs.

3.2.1. Planning

Transmission planning involves technical power system studies for future timeframes (3-5 years or longer duration) to cater to the requirements of all eligible entities (long-term applicants, distribution companies, etc.). It is driven by anticipated load growth and network constraints (such as congestion, inadequate voltage profiles and stranded condition of assets) to ensure availability of requisite transmission system for reliable and secure delivery of power to all beneficiaries. The following aspects cover the transmission planning process and practices:

1. **Planning Criteria**

   I. **Background:** The manual of transmission planning criteria published by CEA contains the planning philosophy that transmission utilities should adhere to while planning the system. The manual comprises of planning philosophy, the information required from various entities, permissible limits, reliability criteria, the broad scope of system studies, modeling, and analysis, and guidelines for transmission planning.

   II. **Present Practice:** All STUs follow the CEA transmission planning criteria for transmission planning.

2. **System Modelling Approach**

   I. **Background:** The manual on transmission planning by CEA recommends the following modelling approach:

      a. **Modeling Approach:** For the planning of the Intra-State Transmission System (InSTS) System, the transmission network may be modeled down to 66kV level or up to the voltage level, which is not in the jurisdiction of DISCOM.

      b. **System Studies:** System planning would be done based on one or more of the following studies: Power Flow Studies, Short Circuit Studies, Stability Studies (including transient and voltage stability), Electro Magnetic Transients Program (EMTP) studies (for switching/dynamic over-voltages, insulation coordination, etc.).

      c. **Time Horizon:** System studies for firming up the transmission plans may be carried out with a three-to-five-year time horizon.

   II. **Present Practice**

      a. **Modeling Approach:** STUs consider the highest to lowest voltage which is within their jurisdiction. The lowest voltage level forms the boundary of simulation studies (load lumped at lowest voltage level).

      b. **System Studies:** Most STUs predominantly utilize *Power Flow studies* for system planning. Some of the STUs also perform short-circuit studies to determine the ratings for circuit breaker rating. Very limited STUs perform studies like transient stability and voltage stability studies. Such studies are performed on a case-by-case basis.

      c. **Time Horizon:** Most of the STUs in India undertake transmission planning studies for up to 5 years to develop the five-year Capex plan; the rolling plan is updated on year-on-year basis.

3. **Coordination with central agencies and DISCOMs**

   I. **Background:** As per the Electricity Act 03, STU has the responsibility of network planning in coordination with other agencies.

   II. **Present Practice:** The Ministry of Power has notified five Regional Power Committee (Transmission Planning) viz Eastern Region Power Committee (Transmission Planning), Northern Region Power Committee (Transmission Planning), Southern Region Power Committee (Transmission Planning) and Western Region Power Committee (Transmission Planning). The main terms of these Committees are as follows:

      a. Carry out quarterly review of the transmission system

      b. Examine the transmission system requirements in the near, medium, and long term

      c. Examine applications for connectivity

      d. Examine and evaluate intra-state transmission schemes

      e. Review upstream and downstream network associated with transmission schemes

Exhibit A | **Transmission Planning Best Practices**

Gujarat Electricity Transmission Company (GETCO) has mapped the complete transmission system on a digital mapping platform through in-house web-based software developed in coordination with Gujarat Power Research & Development (GPRD) Cell, Gujarat Urja Vikas Nigam Limited (GUVNL). The GInS map of complete transmission system is beneficial in grid analysis, planning of new lines and substations based on land, centralized view of substations and RoW insights available through the GInS map.

The utility has also adopted various new technologies such as substation automation for modernizing its fleet of substations. Moreover, steps have been taken to lay optical ground wire, high temperature low sag conductors, and long rod polymer insulators for better operational efficiency in the network. Besides, GETCO has successfully adopted ester oil-fueled 66/11 kV class power transformers. Ester oil has a high flashpoint, safeguarding transformers from catching fire.

In addition to the above, GETCO has installed a 220 kV ±120 MVAR STATCOM at its Timbdi substation for dynamic reactive power support.

1. (Source: Annual Report 2021-22, GETCO; Powerline)

3.2.2. Operations and Maintenance

The key operational areas for O&M department mainly include maintenance of transmission assets, coordinate outage planning with RPCs and carry out protection and other audits. The present practices in each are enlisted as follows:

1. **Maintenance Works:** The present practices mainly include the following:

   I. Most of the STUs have appointed third party for O&M activities of transmission lines and substations.

   II. Most of the STUs follow time-based corrective and preventive maintenance. Under this methodology, assets are inspected at identified time intervals and routine maintenance works at pre-defined schedules. The STUs take help of consultants to prepare policies for patrolling.

   III. Mobile vehicles equipped with all equipment are generally available to carry out maintenance activities

2. **Outage Planning:** As the system is planned with n-1 contingency, it was understood that maintenance is generally corrective wherein rectification is done when there is a fault in the system. In case both lines are damaged, then rectification is done on priority.

Exhibit B | **O&M Best Practices**

Madhya Pradesh Transmission Company (MPTransco) and Haryana Vidyut Prasaran Nigam Limited (HVPNL) have initiated deployment of advanced technological solutions such as drones for patrolling, surveying, and scanning of transmission lines. Using advanced image processing algorithms, the utilities seek to draw meaningful insights on asset health, predict failures and plan maintenance actions in advance.

Maharashtra's STU Maharashtra State Electricity Transmission Company Limited (MSETCL) has deployed three unmanned and remotely controlled substations within its area of operation.

GETCO has already implemented Integrated Transmission Asset Management System (TAMS).

1. (Source: Annual Report 2021-22, MPTransco; Annual report 2021-22, HVPNL; Powerline)

3.2.3. Construction /Projects

Most of the projects are executed under Section 62 of the Electricity Act wherein the tariff is determined by the regulator. The process that is followed is elaborated below:

1. **Project Planning**

   I. **Approval:** The STUs develop a 3–5-year plan for transmission projects (construction and strengthening schemes) which is submitted to the STU board for approval. Upon receipt of board approval, the transmission plan is submitted as part of the STU Capex plan to respective State Electricity Regulatory Commission (SERC) for approval, along with the Detailed Project Reports (DPRs) and other details such as CAPEX, commissioning schedule and projected transmission charges.

   II. **Survey Techniques:** Surveys enable the identification of shortest possible route for transmission infrastructure construction, which meets the statutory obligations for clearances. STUs generally carry out route survey before procurement. The following survey techniques are generally utilized by STUs:

      a. **Desktop survey** – The desktop survey is generally used to identify potential roadblocks that may impact the project development (due to contaminated land/other geological conditions) and allows the utility to plan a detailed ground survey, if needed.

b. **Walkover survey** – It involves deployment of field team along the identified line route to collect all relevant information and update the line route on the map.

c. **Check survey** – It requires the site teams to check important locations identified based on desktop survey instead of the entire line route.

III. **Costing:** Generally, STUs develop a schedule of rates (SOR) which serves as benchmark for costing of transmission line and substations on per km and per MVA basis respectively. In some cases, benchmark rates are decided based on previous tender's rates.

2. Project Execution

I. Packaging

a. Based on the approved transmission plan, the identified assets are grouped into packages.

b. The projects are packaged such that the works for generation evacuation/ transmission strengthening are carried out by one entity in the required timeframe. However, for development of a large evacuation/ strengthening scheme, STU management may decide to split the project into several packages.

II. Award of Contract

a. Most projects are bid out as part of a competitive bidding process via engineering, procurement, and construction (EPC) route wherein the procurement is carried out through standard bidding documents (Request for Proposal (RFP), technical specifications, etc.) indicating the financial and technical requirements.

b. The tenders are approved as per the value by the chairman of the utility or by a high-powered committee.

c. Under special circumstances, the projects may be awarded as part of limited tendering/direct allotment process to cater to time constraints.

III. RoW Acquisition

a. Securing Right of Way (RoW), a critical requirement for project execution, is one of the major reasons for project delays/ cancellation. Such activities are taken up as part of project planning. The responsibility of securing RoW and forest approvals generally lies with STU.

b. Surveys provide a master list of stakeholders to be consulted with for securing RoW or permissions. For example, if the line is expected to cross a forest patch and a highway, necessary permissions from relevant departments such as the state forest department and NHAI may be required to build a transmission line along the identified route.

c. For procuring RoW, STUs exercise the power conferred under Section 164 of the Electricity Act. Generally, STUs negotiate compensation for tree and crop damage as well as any additional compensation on case-to-case basis. However, recommendations have been provided by Ministry of Power (MoP) via "Guidelines for payment of compensation in regard to Right of Way (RoW) for transmission lines in urban areas" which can be utilized by STUs to procure RoW in urban areas.

IV. Project Management

a. The construction progress is monitored at various levels. The Board of Directors monitor the quarterly progress, The Managing Director monitors the same at monthly level while the Chief Engineer monitors fortnightly.

b. Mostly project progress is tracked using excel based worksheets or through online software.

V. Testing

a. Project testing and commissioning practice includes Megger test, line continuity test, signature analysis, etc.

Exhibit C | **Construction Best Practices**

Telangana Transco (TS Transco) has added transformers with capacity of around 7000 MVA within a short duration of eleven months. Additionally, the utility has upgraded an existing transmission corridor to a higher voltage level to serve the power demand of Hyderabad city. The STU has also completed a live line reconductoring of a 220 kV line within four months for doubling the power carrying capacity of the corridor. TS Transco has also reduced the transmission losses by 50% since its inception in 2014.

GETCO has planned and constructed transmission lines with reduced land footprints by utilizing narrow base multi circuit towers. The utility has also deployed monopoles at various voltage levels to optimize RoW requirement.

Bihar State Power Transmission Company Limited (BSPTCL) adopted a lease policy for private land, which has been useful in improving the execution rate of projects.

1. *(Source: Annual Performance Review 2021-22, TS Transco; Annual Report 2021-22, GETCO; Powerline)*

3.2.4. Regulatory

The STUs are regulated by the State Electricity Regulatory Commission. The key regulations which impact the operations of STUs are Terms and Conditions of Tariff, Open Access Regulations, Transmission Licensing regulations and the Grid Code.

In terms of practice, it is observed that most STUs appoint third party contractors for regulatory filing involving approval of tariff petitions and business plans. These contractors are appointed for the control period on a retainership basis or for a limited three-to-four-month period as per the regulations. During this period the contractor is expected to carry out the following functions:

1. Preparation of tariff model and tariff petition
2. Present the findings before the senior management and the board
3. Reply to queries raised by the Electricity Regulatory Commission
4. Reply to queries raised by stakeholders
5. Analysis of tariff order issued by commission and file review petitions, if any

Exhibit D | **Regulatory Best Practices**

Similar to Central Electricity Regulatory Commission (CERC), SERCs like Maharashtra Electricity Regulatory Commission (MERC), Haryana Electricity Regulatory Commission (HERC), etc. have adopted the practice of publishing explanatory memorandum and statement of reasons along with new regulations for ease of understanding of all stakeholders.

1. (Source: MERC; HERC)

3.2.5. Institutional Framework

The background of STU's function at the institutional level and the present practices are follows:

1. **Background:** The institutional framework comprises the organization structure and corporate governance framework for the STUs.
2. **Present practice**

   I. **Board of Directors:** As STUs are governed under the Companies Act, 1956, all key decisions are entrusted with the board of directors. The composition of the board is as follows::

      a. Chairperson (a representative of the government)

      b. Managing Director of utility

      c. Directors (nominated representatives of the government)

      d. Independent directors (highly experienced professionals from the field or academicians)

   II. **Organization Structure:** The organization structure of STUs is similar in terms of the department and their roles. STUs are led by the Managing Director who is a nominated representative of the state government. The senior leadership comprises of Director (Projects), Director (Operations), Director (Finance) and Director (Human Resources) supported by executive directors, chief engineers, superintendent engineers, and assistant engineers. The projects team undertakes the responsibilities of planning and construction while the operations team is involved in operation and maintenance of STU assets. The finance team discharges the duties of financial planning, tariff related issues, etc. The HR team is responsible for recruitment, human resource policy development, employee welfare, learning and development, etc.

III. **Corporate Governance Structure:** The corporate governance structure is developed and maintained with support from following committees:

a. **Audit Committee** – The committee is responsible for overseeing financial reporting and related internal controls, risk, independent and internal auditors, ethics, and compliance.

b. **Corporate Social Responsibility (CSR) Committee** – The CSR committee is responsible for developing the CSR policy, planning CSR activities to be undertaken, recommending expenditure on initiatives, monitoring and reporting the progress to the board, etc.

c. **Nomination and Remuneration Committee** – The committee reviews, develops and provides recommendations on compensation policies, nomination of directors, performance evaluation and leadership development, corporate governance guidelines and other matters.

d. **Risk Management Committee** – The committee is intended to identify types of risks and their assessment, risk handling, monitoring, and reporting.

3.2.6. Human Resource Capabilities

The background of STU's function at the institutional level and the present practices are follows:

1. **Background**: The Human Resource department of STUs is responsible for manpower planning, regular recruitment, promotions, learning and development, development of schemes and policies for employee benefit and welfare, etc.

2. **Present Practice:** The recruitment is generally carried out at SDE level through competitive examination while Junior Engineer (JE) and other staff are recruited through state selection Commission (SSC). A coordination committee carries out all recruitment activities.

   The training is done in-house or is outsourced. The key focus areas are mainly technical such as improving supply and efficiency of power and maintenance related topics

Exhibit E | **HR Best Practices**

GETCO has taken several steps to strengthen its workforce with over 1900 new recruits and over 1700 promotions in 2021-22. Meanwhile, HVPNL has taken giant strides in learning and development of the workforce through its Haryana Power Training Institute (HPTI) in collaboration with leading academic and training institutions.

1. (Source: Annual Report 2021-22, GETCO; Annual report 2021-22, HVPNL)

4. Gap Assessment

A gap assessment of STUs was carried out across the thematic areas of technology, infrastructure, tools and techniques, operations, policy and regulations, institutional capacity, and human capacity. The findings of the gap assessment are summarized below:

Table 3 | Gap Assessment Summary

Gaps	Remarks
Technology	
Need for adoption of latest technologies	• Requirement of dynamic reactive power devices and power control devices like Flexible AC transmission (FACTS) devices. • Requirement of storage technologies to be introduced to accommodate renewable integration • Few STUs are working on technologies like High-Temperature Low Sag (HTLS) conductors and GIS-based or multistorey substation buildings • Limited digitization of transmission infrastructure
Limited R&D	• Limited R&D and innovation in planning and construction management
Limited capacity building on latest technologies	• STUs have a limited understanding of advanced technologies such as grid-forming inverters
Infrastructure	
Requirement of additional investments	• Low anticipated network utilization is observed due to decreasing load factor in electricity demand (on account of the change from deficit grid to the surplus grid) and hence more investments in transmission infrastructure. • Additional investment in transmission is required to accommodate more RE in the grid.
Focus on cost-plus methodology for implementing projects	• A limited number of projects is reported by states under TBCB (Tariff Based Competitive Bidding) route. One of the reasons for not adopting TBCB is shortage of manpower capacity to operate a separate division for Bid Process Coordinator (BPC) activities and TBCB projects.
Challenges in execution	• Securing RoW and getting forest approvals are the most important reasons for delay due to litigations/lengthy process • STUs cited tendering process and contractual challenges as a major reasons for project delay/ cancellation (Project award and commencement of work are heavily delayed because of contractual issues)
Difficulty in arranging funds	• Project Financing is a major bottleneck. STUs struggle to source debt and equity for transmission projects. • STUs source funds from banks instead of Non-Banking Financial Corporations (NBFC) created for infrastructure project financing
Need for enhancing disaster readiness and management capacity	• A proper disaster management plan is not available

Gaps	Remarks
Tools and Techniques	
Requirement of modern planning tools	• STUs are relying on demand projections provided by DISCOMs. • DISCOMs generally use excel based CAGR (Compound Annual Growth Rate) methods for projections. • Need for utilization of dynamic and transient models and enhancement of study skills. • Need for procurement/development of project planning/management tools to measure time and cost overruns, if any.
Requirement of adequate data	• Most of the states have reported that they do not have zone/cluster-level long-term demand projections for better transmission planning. • STUs reported that there is an absence of technical data for carrying out technical studies. • STUs also reported difficulties in coordination with DISCOM for gathering technical data.
Need for renewed focus on grid resilience	• Limited adoption of resilience frameworks especially in STUs which are prone to sabotage, natural disasters, cybersecurity risks, etc.
Gaps in coordination between stakeholders	• Occasional mismatch is observed between central and state level plans. • Difficulty in coordination between STU and DISCOMs with respect to data management, studies being carried out, etc.
Operational Practices	
Requirement of improvement in maintenance techniques	• Most of the STU assets are aging assets. • STUs are yet to adopt condition monitoring strategies. • Most states do not have any tools for maintenance activities and records. However, some states like Karnataka and Haryana use tools with limited features for maintenance activities.
Adherence to IS codes	• Some of the tower failure incidences note that the codes have not been followed properly
Policy and Regulations	

Gaps	Remarks
Need for new regulations	• Need for planning regulations to be issued at state level • Need for regulations regarding Integrated Resource Planning, protection studies and audits. • Limited accountability and provision of penalizing loss of availability or delays in construction. • Requirement of incentives for loss reduction by STU. • Comparative benchmarking to encourage better participation is now becoming a necessity. • Need for regulations on energy storage.
Monitoring of regulatory compliance	• STUs have reported that RE generators are not following connectivity regulations and injecting harmonics in the grid.
Requirement of harmonizing regulations between centre and state	• While sharing of transmission charges at ISTS level is done through PoC mechanism, states are still employing postage stamp method for sharing of transmission charges.

Gaps	Remarks
Capacity building on regulations	• Most of the work is outsourced due to limited capacity to carry out detailed tariff studies and financial modelling.
Human Capacity	
Need for skilled manpower	• It is observed that there is shortage of skilled manpower such as transmission planners who can carry out power system analysis. • Recruitment across STUs has been very limited and continues to remain short-staffed. The manpower shortage, coupled with aging workforce, leads to fast depletion of manpower.
Requirement of training	• There is limited knowledge transfer between outgoing senior staff and junior staff. • There is a requirement of capacity building of junior staff via training and certifications.
Institutional Framework	
Need for functional independence	• The board of STUs require independence to take decisions autonomously
Requirement of an institutional platform for interaction between STUs	• There is a need for an institutional platform for promoting interaction between STUs for knowledge sharing on planning and operational best practices and enhancing coordination between STUs.

5. Recommendations

Based on the above gap analysis, the following recommendations have been enlisted which may be adopted as per the maturity level of various STUs.

5.1. Technology

From the above gap assessment, the key gaps are elaborated as follows:

1	**Need for Adoption of Latest Technologies:** It is felt that the STUs are lagging in terms of introducing advanced technologies in the grid which may enhance the operational capabilities of the transmission network. The key reasons could be on account of limited awareness of the technologies to include in system planning studies as well as limited operational experience.
2	**Limited Research and Development:** It is observed that limited research and development is taking place at STUs. This could be on account of budget limitations or inadequate incentivization to promote such innovative programs.
3	**Limited Capacity Building on Latest Technologies:** STUs have limited understanding and awareness of upcoming technologies such as grid-forming inverters.

To address the gaps, the following recommendations are proposed:

1. **Advanced Technology Adoption:** Introduce new technologies that can address the challenges on account of renewable energy integration. Some of the technologies that can enhance the network are:

Table 4 | Advanced technologies recommended for STU's adoption

Area	Technologies Available
Reactive Power Management	• FACTS devices for active and reactive power control to improve the utilization of transmission lines and voltage control, respectively
Construction Planning and Management	• Digitization of infrastructure with digital substations and robust communication systems • Introduction of drones and helicranes to expedite tower construction • Utilization of unmanned aerial vehicles for route surveys • Utilize HTLS (High Tension Low Sag) conductors to allow more power in the same infrastructure • Adoption of multi-circuit multi voltage towers • Greater adoption of HVDC and GIS substations at state level
Renewable Integration	• Adoption of Storage systems (Pumped hydro or Battery Storage) to balance the intermittency of renewables
Network Utilization	• Dynamic line rating (DLR) technology improves monitoring of the transmission system by assessing real-time capacity of power transmission

2. **Research Development, and Partnerships:** STUs may allocate a certain percentage of the annual budget to R&D/innovation/pilot projects. While the expenses may be recovered from the tariff, the benefits that accrue from innovations could be shared as defined by the regulators in order to promote innovations at STU level. STUs may also utilize the allocated budget to foster partnerships with academic institutions for conceptualizing and validating use cases of upcoming technologies:

3. **Capacity Building:** Carry out capacity building programs in advanced technologies. Some of the areas that could be considered for capacity building are grid-following and grid-forming inverter technologies and their advantages.

5.2. Transmission Infrastructure

From the gap assessment, the key gaps that can be inferred are as follows:

1	**Requirement of additional investments:** The power sector is at an inflection point where the grid has transitioned from power deficit scenario to power surplus scenario. Further, renewable energy is fast becoming the mainstay energy resource. In such a scenario, the transmission network requires fast upgradation.
2	**Focus on cost-plus route as a methodology for implementing projects:** While the predominant route for execution at central level has been Tariff Based Competitive Bidding which has led to inflow of private capital in the central sector, the same cannot be said for intra-state transmission system. STUs are still relying on cost-plus methodology wherein the SERCs determine the tariff as per tariff regulations. This also leads to fund constraints as STUs rely primarily on internal accruals for equity requirements.
3	**Challenges in execution:** The execution is also impacted on account of RoW delays and delays on account of approvals such as forest, wildlife, etc. This results in a constrained transmission system as the STU is not able to cater to the DISCOMs requirements in time.
4	**Difficulty in arranging funds:** The availability of funds further slows down the execution since STUs are primarily dependent on internal accruals and debts for funding requirements.
5	**Need for enhancing disaster readiness and management capacity:** There is a requirement to focus on disaster management to maintain the reliability of the system even during contingency.

To address the gaps, the following recommendations are suggested:

1. **Optimize transmission planning to address the funds limitation:** In view of the execution and financial constraints, the focus should now be on optimizing transmission. This can be done in the following manner:

   I. **Scenario analysis:** Before finalizing the transmission schemes, STU must publish the details of all probabilistic scenarios and suggested transmission schemes on its website and seek stakeholders' comments.

   II. **Regulator's approval:** State regulators approve CAPEX only after prudent scrutiny of the 'optimal' transmission plan proposed by the STU. An optimal transmission plan must aim at minimizing capital expenditure, shortening time to completion, limiting environmental impact, and causing minimal service disruptions to people.

   III. **Technology adoption and construction:** Utilize technologies such as multi circuit and narrow towers, HTLS conductors, monopoles, and Insulated Cross Arms (ICA) to optimize RoW.

   IV. **Adopting innovative practices:** Reorientation of existing RoW/towers for reconfiguration of networks to optimize transmission network development

2. **Encourage Tariff Based Competitive Bidding:** It is recommended to introduce TBCB at the state level to promote investments in intra-state transmission infrastructure. This can be done in the following manner:

   I. **Standardization of bidding documents:** STUs should develop standard bidding documents in line with TBCB mechanism at central level.

   II. **Defining TBCB threshold:** SERCs are required to approve the minimum CAPEX threshold limit beyond which all projects would be executed through TBCB.

   III. **Gradual scale-up of TBCB mode of execution:** Initially, a limited number of projects may be executed under TBCB to gain experience. The quantum of such projects may be increased gradually as the system achieves maturity.

3. **Maintain system reliability even during disasters:** It is essential that intra-state grid is made resilient to manage the consumer demand even during disasters. This aspect becomes even more essential since the national grid is an integrated grid and any sudden load throw off can lead to widespread frequency variations. To address this scenario, following measures are recommended:

   I. **Emergency restoration systems:** Utilize emergency resource systems (ERS) to maintain reliability in times of tower collapse. The ERS may be procured or shared between various sites.

   II. **Disaster management plans:** A disaster management system should be set up by all power utilities for immediate restoration of the transmission system in the event of major failures.

   III. **Ensuring readiness:** Mock drills should be undertaken at regular intervals to ensure readiness to react against disasters.

   IV. **Robust communication systems:** Ensure availability of communication system at the time of commissioning of a line and during normal operations

4. **Overcome shortage of funds through innovative financing:** Like the central sector, states can benefit from innovative financing. The following recommendations may be adopted:

   I. **Adopt (AOMT) model, Infrastructure Investment Trusts (InvITs) for asset monetization:** States may monetize their existing transmission assets as per the 'acquire, operate, maintain and transfer (AOMT)' model proposed by Ministry of Power. States can also utilize the InvIT model wherein the private funding maybe sought through creation of infrastructure trusts.

II. **Explore low-cost debt financing:** For infrastructure CAPEX, STUs are going with commercial banks as they get lower lending rates compared to Power Finance Corporation (PFC)/Rural Electrification Corporation (REC) Limited.

5. **Improve execution practices:** The following changes can be looked to minimize the time from concept to commission of transmission project implementation [8],

I. **Standardization of bidding documents:** Request for Quote (RFQ) can be released within one month of Electricity Commission (EC) approval. The majority of the bid documents are already standardized, and a significant time (seven months) can be saved in this step.

II. **Annual pre-qualification process:** The pre-qualification process can be held annually rather than on a project-by-project basis. Cutting the redundancy of evaluating the same technical bid by a developer for different projects differently each time can save up to 3 months.

III. **Quick award of projects:** Bids should be awarded within three months of EC approval. This process currently takes about 17 months.

IV. **Avoiding cumbersome route surveys:** STU should not conduct route surveys. This exercise can be avoided entirely because all developers conduct their own surveys during bidding. In addition to the above, STUs have also cited data quality issues in the STUs surveys of project area, making survey a redundant activity. This will save three months spent on the survey.

V. **Lease Policy:** Adopt a lease policy for private land, which can be useful in improving the execution rate of projects.

With these changes, the time for project commissioning could be cut by one-third, from 61 months to 40 months, and even shorter (18-24 months) for urgent projects [8].

5.3. Tools and Techniques

The following may be concluded from the gap assessment study:

1	**Requirement of Modern Planning Tools:** STUs are still reliant on DISCOMs projects while planning for transmission system. As the country is striving towards power for all, it is important to focus on resource advocacy wherein the planning is carried out via specialized tools and techniques.
2	**Requirement of Adequate Data:** Accuracy of any planning tool depends on availability of data. Due to difficulty in coordination between STUs and DISCOMs, the data often gets impacted which can lead to erroneous forecasts.
3	**Need for Renewed Focus on Grid Resilience:** The power system often suffers from vulnerabilities. These could be on account of natural phenomenon, cyber threats, or sabotage. The focus on transmission planning should therefore be towards grid resilience especially in zones which are vulnerable to such threats.
4	**Gaps in Coordination Between Stakeholders:** STUs encounter challenges while coordinating with various agencies and institutions

Based on the above gaps, the following recommendations are proposed:

1. **Adoption of state-of-the-art tools and techniques for planning:** The following tools are recommended for improving the performance of STUs:

   I. **Equip STU with latest tools:** All STUs must equip themselves with latest state-of-the-art load forecasting facilities for planning

   II. **Adopt GInS based planning:** It is recommended to enhance the present tools to use Geographic Information System (GInS)-based tools for more effective and implementable proposals for transmission planning, looking into various technologies, RoW issues, space, location, etc. (refer Annex I)

   III. **Detailed network studies:** It is recommended to have a detailed network model where the Utility can run and test the benefits and utilization of transmission lines with various combinations of generation dispatches. This can be achieved by having the dispatch simulation software (or production-cost models) with an AC load flow solution.

   IV. **Customization of tools:** It is recommended that Utilities should have their customized tools in hand as per their need and requirement in addition to the commercially available tools for all other technical decision-making.

   V. **Detailed technical studies for stability analysis:** The software tools at STUs should address system studies like power flow; short circuit analysis; transient stability assessment, reliability assessment, and specialist studies such as harmonic analysis, motor start-up, or electromagnetic transient studies.

2. **Refinement of Planning Philosophy:** Transmission planning should be scenario based and should incorporate the following aspects (Details in Annex I):

   I. **Scenario analysis (including markets):** Market environment scenarios, in addition to conventional scenarios (like peak demand, high hydro, high thermal, high renewables, etc.) need to be accounted for while considering neighboring STUs and CTU network in modeling and analysis.

   II. **Techno-economic transmission planning:** After the technical planning process, the decision-making for the selection of transmission schemes can be taken from multiple technical possible schemes regarding financial benefits.

III. **Renewed city transmission planning philosophy:** A renewed approach is needed for city transmission planning (Details in Annexure I)

IV. **Long-term planning view:** Design of transmission network for the next 10 years, looking into RE integration, Green Hydrogen production, and reactive power compensation.

V. **Inertia studies:** New additional inertial studies are to be introduced to verify the system stability with backdown/shutdown of conventional generation with the introduction of high RE.

VI. **Redundancy in critical loads:** Critical loads such as - railways, metro rail, airports, refineries, underground mines, steel plants, smelter plants, etc. shall plan their interconnection with the grid, with 100% redundancy and as far as possible from two different sources of supply.

3. **Focus on Grid Resilience:** STUs, especially those in the vulnerable region are recommended to incorporate the aspects of grid resilience. The following suggestions are recommended for implementation:

I. Vulnerability assessment: Carry out vulnerability assessment of the STU network: This will help identify vulnerable zones and accordingly aid in identification of measures to overcome the vulnerabilities

II. Infrastructure gap assessment: Infrastructure gaps should be assessed through proper surveys and monitoring and analysis of operational performance.

III. Resilience oriented planning: Focus on system resilience instead of installation of high-quality equipment at distributed locations

IV. Taking suitable measures towards cyber security: This can be done through cyber security posture assessment wherein utilities can gauge their vulnerabilities towards cyber threats. Some of the popular frameworks for carrying this exercise are C2M2 and NERC frameworks

4. **Capacity Building and Skill Enhancement:** STUs should focus on enhancing the skills in the following areas:

I. Skill building to include frequency response analysis, EMTP studies, etc.

II. Skill building should also focus on GIS technology, maintenance, and augmented reality.

III. Capacity building on project planning tools and best practices to be undertaken.

5. **Coordination between stakeholders:** Considering the expected large-scale RE integration, growth of markets, and the development of a more improved and coordinated central and state-level transmission infrastructure, the following recommendations can be adopted [18]:

I. Support in creation of national-level database:

   a. STUs should support the creation of a national-level database through the updation of details on the Pradhan Mantri Gati Shakti portal, to minimize efforts and costs on route survey and planning.

   b. The creation of a database should be supplemented with technological interventions such as capture of data from digitized transmission infrastructure for better visualization of transmission systems, calculation and monitoring of transmission utilization factors, etc. Such web platforms and data libraries should be made accessible to all sector stakeholders such as generation, transmission, and distribution utilities as well as power systems researchers. The availability of data will not only enhance coordination for transmission planning but will also allow the generators and system operators to plan and manage the generation connection queues in the future.

II. Regular interaction with CTU: STUs may interact more frequently with CTU to enhance coordination on issues such as aligning load forecasting, transmission plans, outage planning, etc.

III. Regular interaction with DISCOMs: STUs may interact with DISCOMs frequently to seek regular inputs for accurate load forecasting and transmission planning.

5.4 Operational Practices

The gap assessment has indicated that STUs need to improve their maintenance and design practices to improve their performance. Some of the recommendations in this regard are as follows:

I. **Operations and Maintenance:** The following practices are recommended for O&M:

I. **Condition Monitoring:** State utilities need to adopt condition monitoring of transmission systems and Reliability Centered Maintenance (RCM) practices with the ultimate aim of reducing the O&M Cost and carrying out maintenance only when necessary. Tools such as Portable Daytime Corona Detection, Corona Camera, Thermo-vision Camera, etc. can be encouraged for condition monitoring of transmission system.

II. **Modern Maintenance Practices:** Utilize UAVs for transmission line maintenance (Refer Annexure I). Practices such as Live line monitoring and maintenance, inventory control, and spare part management through software tools, failure analysis system, and System Implementation Review (SIR).

III. **Enabling efficiency in O&M practices:** The following methods can enable efficiency in O&M practices as well reduce operational costs:

a. **Regular maintenance:** Regular maintenance of transmission equipment and lines can help to identify and repair small issues before they become larger and more expensive problems. This can include things like cleaning and testing equipment, inspecting transmission lines, and replacing worn or damaged components.

b. **Improved asset management:** Using data-driven analytics to optimize asset management can help reduce operation and maintenance costs. By tracking the performance and health of equipment and components, maintenance can be scheduled only when necessary and replacement can be planned for in advance.

c. **Efficient operation**: Ensuring that the transmission system is operating efficiently can reduce costs. This can include things like reducing energy losses and optimizing voltage levels.

d. **Automation:** Automating certain tasks, such as remote monitoring and control, can help to reduce labor costs associated with operation and maintenance.

e. **Innovative technologies:** The use of innovative technologies such as predictive analytics, smart grids, and advanced sensors can help to optimize the performance of the transmission system, reduce downtime, and reduce overall costs.

f. **Training and education:** Providing training and education to personnel can help to ensure that they are equipped with the knowledge and skills to operate and maintain the transmission system in the most cost-effective and safe manner.

IV. **Periodic audits:** Carry out regular system audit and protection audit.

V. **Root cause analysis:** Carry out root cause analysis in case of tower failures, insulator failures etc.

VI. **Insulator assessment:** Carry out detailed studies regarding the use of various types of insulators e.g. porcelain, room temperature vulcanizing coating insulators, polymer insulators, and glass insulator in respect of their performance under different operating conditions, life of the insulators, life cycle cost, and environmental issues.

VII. **App-based asset monitoring:** STUs may plan to deploy application-based asset monitoring similar to Powergrid's PG DARPAN .

2. **Adherence to latest design standards:** STUs should undertake the design and engineering of assets based on the latest codes and standards.

5.5. Policy and Regulations

The requirement of new regulations at state level, harmonization of state and central regulations and monitoring of compliance are key improvement areas that have been observed at STU level. Some of the improvements in regulatory mechanism that can be recommended are as follows:

1. **Introduction of new regulations:** The SERCs may introduce regulations in the following areas-

   I. Regulations on state transmission planning aligned to CERC's transmission planning regulations

   II. Regulations on Battery Energy Storage Systems (BESS) which may include ownership rules for storage technologies, tariff determination of battery storages and safety standards to be followed.

      a. Planning of transmission system in view of increased penetration of RE

      b. Introduce generation resource adequacy planning under Integrated Resource Planning

2. **Harmonization of Regulations between Centre and State:** The regulatory system at central level has undergone a significant change with the introduction of new Deviation Settlement Mechanism (DSM), and GNA regulations as well the Grid Code. SERCs are required to harmonize the state regulations with the central regulations.

   I. Capacity Building on regulations: Capacity building of STUs on regulatory framework and its implications may be undertaken.

5.6. Institutional Framework

With the introduction of tariff based competitive bidding as well the precarious financial condition of the distribution companies, there is a requirement to increase efficiency in the overall managerial framework at the STU. In this regard, the following recommendations are suggested:

a. There is a requirement for managerial restructuring to facilitate decision making as well as ensuring complete autonomy.

b. For enabling knowledge sharing between STUs and CTU as well encouraging more pilot projects, a 'Forum of STUs (FoS)' may be constituted to allow periodic interaction between STUs.

5.7. Human Capacity

The requirement of skilled manpower and training facilities are the major focus areas for strengthening the human capacity of STUs. To address this, the major recommendations are as follows:

1. **Increasing the availability of skilled manpower:** Following remedial measures are suggested:

   I. **Recruitment drives:** Regular recruitment should be done to fill vacancies in different departments

   II. **Incentive mechanism:** Proper incentivization mechanism maybe introduced to retain skilled manpower

2. **Enhanced Capacity Building:** Following steps can be taken to address the manpower challenges:

   I. **Internal capacity building measures**

      a. Knowledge dissemination from outgoing experts to junior staff within STUs should be encouraged.

      b. Each power utility should devise different training modules for their workforce- Junior, Middle and Senior level Executives, to update their knowledge based on the latest developments in the respective fields.

      c. Regular training in a structured way and trainees in the specialized field also to be imparted to the employees.

   II. **External training and annual plans**

      a. An annual calendar covering various training programs for employees of all levels may be prepared.

      b. STUs may allocate a budget (or associate with development agencies) to provide the workforce with exposure to national and international skill development programs.

      c. STUs may mandate power system planner certification for the transmission planning team.

   III. **HRD policies and systems:** Power utilities should have well-defined HRD systems and policies.

6. Road Map for STUs

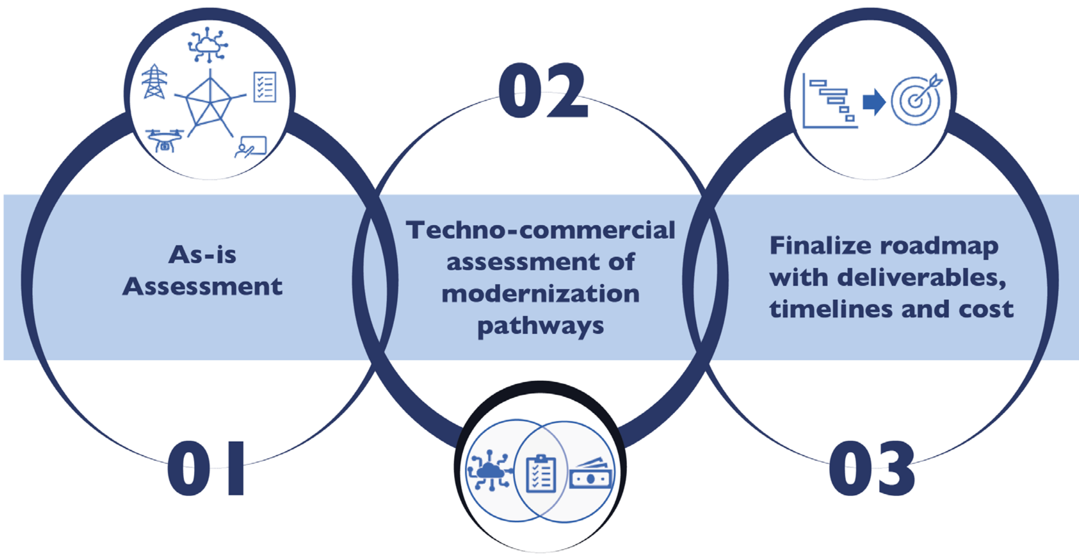
The recommendations suggested in the report are based on a national level assessment. However, the interventions required for modernization may vary for different STUs. Hence, there is need to conduct a thorough as-is assessment of a utility and develop a customized modernization roadmap, in accordance with the observed gaps, priority areas for the respective STUs, costs and implementation timelines.

For a roadmap to be effective, it is important to define the measures that can be undertaken in the short-, medium- and long-term horizons. Further, the benefits associated with the interventions should outweigh the cost incurred.

Hence, a three-step strategy is recommended for developing a customized roadmap for STU modernization:

1	**As-is assessment:** As-is assessment of utility's current practices to determine the level of modernization achieved in existing scenario.
2	**Techno-commercial assessment of pathways:** Identify measures that can be taken up in the short-, medium- and long-term horizons for modernization and carry out a Cost-Benefit Analysis (CBA) to determine the measures that are likely to have a significant impact on the performance of the utility.
3	**Finalization of roadmap:** Finalize roadmap that clearly defines deliverables, timelines, roles and responsibilities of stakeholders, costs, performance/success indicators, etc..

Figure 1 | **Strategy for developing customized roadmaps for STU**



6.1. As-Is Assessment Criteria

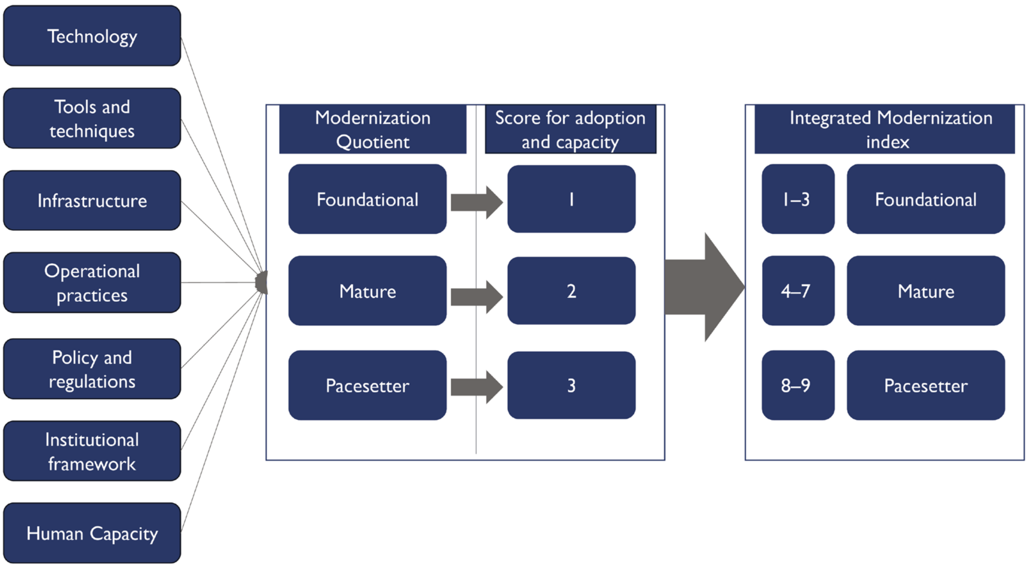
To develop the roadmap, an independent As-Is assessment of modernization level of STUs is suggested to be carried out. The STU's modernization index can assessed by mapping the current practices against three broad qualitative modernization quotients:

Table 5 | Scoring criteria for Modernization Quotients

Modernization Quotients		Score
1	Foundational	1
2	Mature	2
3	Pacesetter	3

The modernization level of STU may be graded across thematic areas in accordance with degree of technology adoption and the capacity of STU for developing/managing activities in relevant thematic areas as per the process illustrated.

Figure 2 | Modernization quotient scoring criteria and integrated modernization score



6.1.1. Modernization scoring for technology/best practice adoption in STU

The modernization level of STU may be graded in accordance with degree of technology adoption as shown in the following table.

Table 6 | Modernization scoring criteria for technology adoption

Thematic Area		Metric to Determine Modernization Quotients		
		Foundational (Score – 1)	Mature (Score – 2)	Pacesetter (Score – 3)
A1	Technology	Less than 25% of recommended technologies adopted	25%–75% of recommended technologies adopted	More than 75% of recommended technologies adopted
A2	Infrastructure	Less than 25% of practices aligned with recommended measures for planning, financing, and execution	25%–75% of practices aligned with recommended measures for planning, financing, and execution	More than 75% of practices aligned with recommended measures for planning, financing, and execution
A3	Tools and Techniques	Less than 25% of recommended tools and techniques adopted	25%–75% of recommended tools and techniques adopted	More than 75% of recommended tools and techniques adopted
A4	Operational Practices	Less than 25% of modern O&M best practices adopted	25%–75% of modern O&M best practices adopted	More than 75% of modern O&M best practices adopted
A5	Policy and Regulations	Less than 25% of regulations in place and harmonized with central policies and regulations	25%–75% of regulations in place and harmonized with cen-tral policies and regulations	More than 75% of regulations in place and harmonized with central policies and regulations

6.1.2. Modernization scoring for STU capacity

Similarly, a metric could be devised for scoring (say B) based on capacity assessment of STU across each thematic area as follows:

Table 7 | Modernization Scoring Criteria for STU Capacity

Thematic Area		Metric to Determine Modernization Quotients		
		Foundational (Score – 1)	Mature (Score – 2)	Pacesetter (Score – 3)
B1	Technology	Less than 25% of relevant staff trained in technology adoption, supply chain, costs, procurement, and integration into existing network/practices.	25%–75% of relevant staff trained in technology adoption, supply chain, costs, procurement, and integration into existing network/practices.	More than 75% of relevant staff trained in technology adoption, supply chain, costs, procurement, and integration into existing network/practices.
B2	Infrastructure	Less than 25% of relevant staff trained in optimal transmission planning, TBCB, innovative financing, disaster management, etc.	25%–75% of relevant staff trained in optimal transmission planning, TBCB, innovative financing, disaster management, etc.	More than 75% of relevant staff trained in optimal transmission planning, TBCB, innovative financing, disaster management, etc.
B3	Tools and Techniques	Less than 25% of relevant staff trained on advanced tools, techniques, techno-commercial studies, grid resilience, etc.	25%–75% of relevant staff trained on advanced tools, techniques, techno-commercial studies, grid resilience, etc.	More than 75% of relevant staff trained on advanced tools, techniques, techno-commercial studies, grid resilience, etc.
B4	Operational Practices	Less than 25% of relevant staff trained in condition monitoring based O&M, use of advanced equipment, codes, and standards to be adhered to, etc.	25%–75% of relevant staff trained in condition monitoring based O&M, use of advanced equipment, codes, and standards to be adhered to, etc.	More than 75% of relevant staff trained in condition monitoring based O&M, use of advanced equipment, codes, and standards to be adhered to, etc.
B5	Policy and Regulations	Less than 25% of relevant staff trained in regulatory frameworks and its implications, regulatory compliance, issuing amendments, etc.	25%–75% of relevant staff trained in regulatory frameworks and its implications, regulatory compliance, issuing amendments, etc.	More than 75% of relevant staff trained in regulatory frameworks and its implications, regulatory compliance, issuing amendments, etc.

An overall modernization score can be obtained by combining individual scores in each of the above areas using the following formula:

$$\text{Integrated modernization score} = \frac{\sum_{i=1}^{5} (A_i \cdot B_i)}{5}$$

Table 8 | Categorization of STU Based on Integrated Modernization Score

Modernization Level	Integrated Modernization Score
Foundational	1–3
Mature	4–7
Pacesetter	8–9

This integrated modernization score can be used to assess the modernization level for each of the STUs and accordingly prepare the roadmap for each of the STUs.

Illustrative calculation for a sample utility

For instance, if a utility is assigned the following scores based on an as-is assessment for its modernization status:

Table 9 | Illustrative Scoring and Calculation of Integrated Modernization Score for a Sample Utility

Thematic Areas		Adoption Score (A)	Capacity Score (B)	$A_i * B_i$
1	**Technology**	2	1	2
2	**Infrastructure**	2	2	4
3	**Tools and Techniques**	3	3	9
4	**Operational Practices**	2	2	4
5	**Policy and Regulations**	1	1	1
6	**Integrated Modernization Score** ($\frac{\sum_{i=1}^{5} (A_i \cdot B_i)}{5}$		4	

Hence, the utility X with an integrated score of ~4 is a 'mature' utility when it comes to initiatives related to modernization. The low-scoring areas may be prioritized for development of modernization roadmap.

6.2. Techno-commercial Assessment of Pathways

Based on the as-is assessment, an implementation roadmap, outlining the broad timeline, cost of implementation, and benefits is suggested for adoption. The priority areas for STU can be ranked based on the cost of implementation and potential benefits.

An illustration of techno-commercial assessment of pathways is shown below:

Table 10 | Illustrative Techno Commercial Assessment of Pathways

Thematic Area	Recommendations	Implementation Horizon			Tentative Cost (INR Cr.)	Potential performance improvement	Rank
		Short (< 2 years)	Medium (3 – 5 years)	Long (Beyond 5 years)			
1 Technology	DLR	•	•				
	FACTS		•				
	UAV, Satellite imagery, Drones, Helicranes	•					
	GIS S/S, MCMV, HTLS			•			
	HVDC			•			
	Storage		•				
2 Infrastructure	Optimal transmission planning	•					
	TBCB		•				
	Innovative financing instruments		•				
	Disaster management	•					
3 Tools and Techniques	Adopting advanced tools	•	•				
	Refinement in planning philosophy	•	•				
	System resilience focused approach		•				
	Skill building on advanced tools and techniques	•	•	•			
4 Operational Practices	Condition monitoring		•				
	Advanced technologies in maintenance		•	•			
	Efficient maintenance practices		•				
	Regular audits	•					
	Adherence to latest codes and standards	•					
5 Policy and Regulations	Develop new regulations		•				
	Harmonize existing regulation with central level	•					

Thematic Area		Recommendations	Implementation Horizon			Tentative Cost (INR Cr.)	Potential performance improvement	Rank
			Short (< 2 years)	Medium (3 – 5 years)	Long (Beyond 5 years)			
6	**Institutional Framework**	Frequent interaction with central agencies	●					
		Frequent interaction with DISCOMs	●					
		Providing data support for creation of national level data repository	●					
7	**Human Capacity**	Regular recruitment drives	●					
		Incentives for retaining skilled workforce		●				
		Training and certification courses for junior staff	●					
		HRD policies and systems		●				
		Annual training calendar		●				

6.3. Finalized Modernization Roadmap

A customized modernization roadmap can be prepared with identification of the measures to be implemented. These shall include the following:

Table 11 | Illustrative Roadmap for STU Modernization

STU Modernization Roadmap					
Proposed Intervention		Stakeholders	Output	Timeline	Performance Standard
1	**Intervention 1**	Relevant STU department, Technology service provider, etc.	Installation of equipment	T + N1 months	Equipment installed with SLA, performance improvement of XX % over 2 years
2	**Intervention 2**	Relevant STU department, Technology service provider, etc.	Procurement of tools	T + N2 months	Procurement completed performance improvement of XX % over 2 years
3	…………….	…………….	…………….	…………….	…………….
4	…………….	…………….	…………….	…………….	…………….
N	**Intervention N**	Relevant STU department, Technology service provider, etc.	Training material developed	T + N3 months	Training imparted to XX number of employees

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Annexure I

AI.1 City Transmission Planning

Existing and developing mega-cities share in common the requirement for supplying, at high levels of reliability and quality, concentrated electrical loads, exceeding in some cases 5-10 GW at voltage levels of 400-765 kV; these loads and voltage levels are comparable to mid-sized states, amply justifying the application of a transmission, sub-transmission and distribution system hierarchy.

The exceptionally high load growth rate of some developing mega-cities, like a sustained growth rate of 15% [25] and confinement of power generation to relatively small areas, is challenging the conventional approach to planning transmission and distribution networks, facing, as a rule, the following problems [25]:

- Excessive short circuit levels, approaching the limits of any presently manufactured switchgear and interrupting devices
- Scarcity of land for power line/cable corridors and substations.

Due to the continuous expansion of city boundaries, Over-Head Line (OHL) transmission corridors between power plants and consumers become a real obstacle to urban development, occupying valuable construction land, visually impacting high-profile residential or business areas, and raising electromagnetic compatibility concerns.

A typical problem faced in the conceptual design phase is the conflict between reducing short circuit levels by splitting the system and contingency analysis under normal peak operation, which essentially requires a high degree of meshing of the transmission network.

The vast majority of metropolitan networks now apply AC technology for reasons of flexibility and ease of transformation between hierarchical voltage levels. As a rule, in such a system, major power additions are connected directly to the Extra-High Voltage (EHV) grid. As large loads are connected at concentrated locations the transmission voltage levels increase from 33 kV to 66 kV to 132 kV.

Most utilities apply the classical static-deterministic N-1 criterion, starting with "all lines in service" and peak load condition for transmission planning performed at the State level or country level.

In the past decade, efforts have been put into adding a probabilistic dimension to the N-1 criterion and relegating the use of the N-2 criterion to special planning cases, notable evacuation of critical power to the city.

When planning metropolitan transmission networks, it is recommendable to consider generally an N-1 outage criterion supplemented by probabilistic attributes or a discriminative application of the N-2 outage criterion, featuring [25]:

- Acceptance of light overloading of a particular transmission line (for example, above 5-10% of the continuous rated capacity), situations which can be mastered in practical operation by immediate actions like re-dispatching or mobilization of stand-by generation resources
- Simulation of double outages only if these are conceivable as the consequence of a single event, like bus section protection operation or simultaneous loss of a double circuit line for electrical or mechanical reasons.

Since a meshed transmission topology inherently reduces the efficiency of conventional fault-limiting methods and rating upgrades of switchgear and other equipment are not possible, various Direct Current (DC) technologies can be considered. If location and size are carefully selected, a DC back-to-back link offers another attractive solution possibility in the congested environment of the metropolitan system, with better control of the parallel active and reactive power flows.

If DC technologies are not sufficient to cope with the short-circuit problem, the ultimate medium and long-term planning goals should be [25]:

- Segregation of the transmission system into two or more AC subsystems with little or no power exchange and interconnected by DC links for keeping open any mutual support options
- A higher voltage level

AI.2 Power System Planning Procedures

Transmission planning studies, which often consist of the three analyses shown in Figure A1-1, help the system planners identify transmission expansion options that meet their objectives.

Production cost analyses help planners to understand the operational cost and performance of transmission expansion options and prioritize project options. Also, emission reduction options should be given priority along with optimal cost while planning future generation mix in States. And load-flow and stability analyses help planners ensure the feasibility and reliability of the transmission system and refine cost estimates.

The overall aim of such studies is outlined in Table 0 1. The three specific main goals for conducting each analysis are [22]:

1	Assess whether an option is technically feasible from a reliability perspective
2	Identify necessary refinements to meet reliability goals
3	Understand how these refinements may influence production costs.

Figure AI-1 | Transmission Planning Studies Analysis (22)

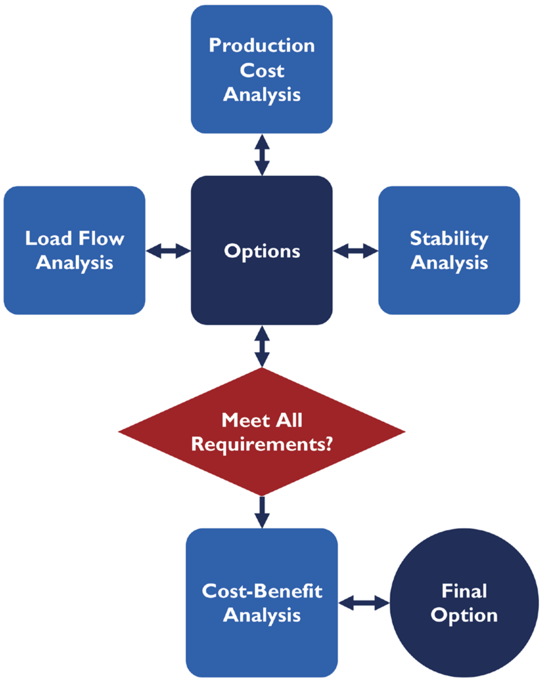


Table AI-1 | Overview of Transmission Planning Study Analysis (22)

	Production Cost Analysis	Load Flow Analysis	Stability Analysis
Purpose	Estimate operational cost and performance impact on the power system that results from Transmission expansion options	Identify Limitations of System operational feasibility and reliability given scheduled and reasonably expected unscheduled outages; refine cost estimates	Identify reliability limitations and contingency needs of the transmission system to withstand unexpected disturbances and recover to a steady state; refine cost estimates
Inputs	Detailed Data on: • Generator Parameters • Storage Parameters • Load (Profiles and forecast) • Transmission Parameters • Substation Bus Parameters • Electricity Market Details • Energy or Fuel resources • Time-synchronous generation and load data	Detailed Data on: • Generator and storage commitment and dispatch for a period of interest • Contingency events • Load • Transmission Parameters • Substation Bus Parameters	Detailed Data on: • Generator Dynamic models • Inverter control models • Contingency event list • Load • Transmission Parameters • Substation Bus Parameters
Outputs	Detailed Data on: • Generation • Operational Costs • Electricity Prices • Transmission System Congestion • Expected renewable energy curtailment • Reserve holding • Lost Load Probability • Emissions	Detailed Data on: • Voltage Levels and Phase angles at buses • Active and Reactive Power Flows in transmission lines • System Losses	Detailed data on the dynamic performance of the system in the seconds after simulated faults: • Rotor Angle Stability • Frequency Stability • Voltage Stability
Key Institutions that may perform or contribute to the analysis	• Ministries of Energy • Regulators • System Operators or Planners • Utilities • Research institutes or Consultants	• Regulators • System Operators or Planners • Utilities • Research institutes or Consultants	• Regulators • System Operators or Planners • Utilities • Research institutes or Consultants
Tools	• PLEXOS, ORDENA, MiPSO, and Renewable Procurement Optimization and Smart Estimation (REPOSE)	• Power System Simulator for Engineering (PSSe), DIgital SImuLation and Electrical NeTwork calculation program (DIgSILENT), MiPower and Electrical Transient Analyzer Program (ETAP)	• PSSe, DigSilent, MiPower, ETAP, Power Systems Computer Aided Design (PSCAD) (EMTP studies)

The following planning aspects can be encouraged in the transmission system:

Market environment scenarios, in addition to conventional scenarios (like peak demand, high hydro, high thermal, high renewables, etc.) needs to be accounted for while considering neighboring STUs and CTU network in modeling and analysis.	After the technical planning process, the decision-making for the selection of transmission schemes can be taken from multiple technical possible schemes regarding financial benefits.	Design of transmission network for the next 10 years, looking into RE integration, green hydrogen production, and reactive power compensation.	New additional inertial studies are to be introduced to verify the system stability with losing of conventional generation with the introduction of high RE.

AI.3 Geographical Information System (GInS) for Transmission Utility

GInS is used to visualize, digitize and analyze data on a geographical map for transmission utility planning and operation. GInS gives a basic idea of geographical features and acts as a decision support system for the utilities.

Most European countries and the US have a well-equipped GInS system with all spatial analysis packages. Light Detection and Ranging (LiDAR) technique are widespread in these areas where they use scanning devices that are attached to aircraft for transmission maintenance and operation.

In India, a few distribution utilities are already in the implementation stage, whereas a few utilities (Punjab and Gujarat) have initiated the GInS implementation.

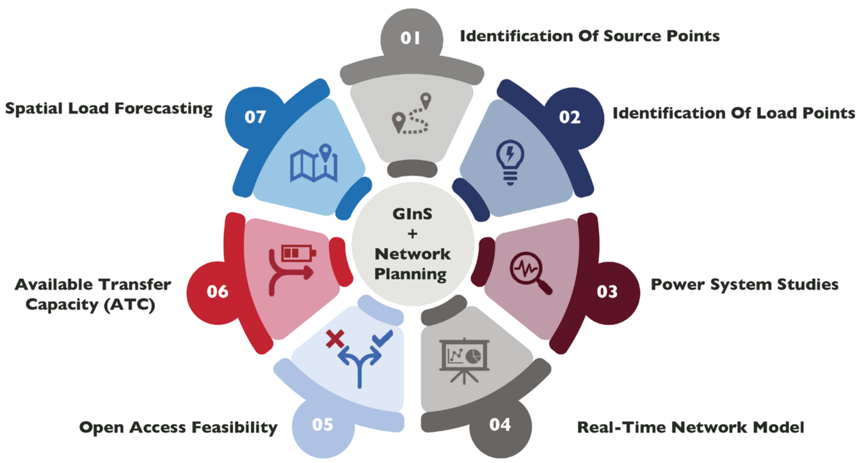
The GInS-based system can be used for the following applications.

Asset management	Outage management	Network analysis and planning	Transmission line siting

GInS-based application for outage management and network analysis is presented in Figure AI-2 and Figure AI-3.

Figure AI-2 | Outage Management Using a GInS-based System

Figure AI-3 | Network Analysis and Planning Using GInS-based System

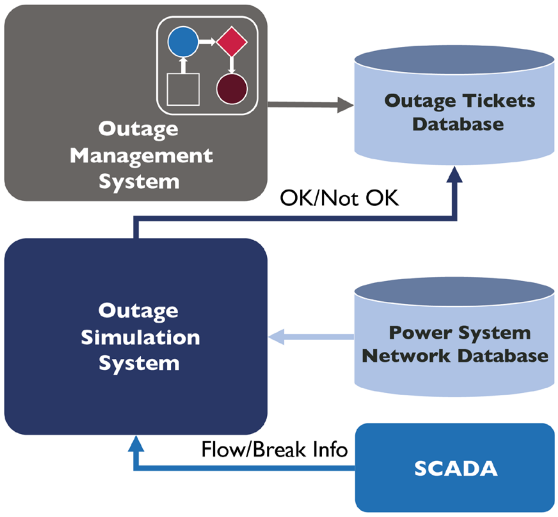


AI.4 Outage Management System (OMS) integrated with SCADA

To ensure that all planned outages are tracked and well managed/controlled, a system must be in place that enables the utilities to plan and take actions based on scientific calculations rather than on individual experience. Hence, a system is required that manages the end-to-end workflow associated with Outage Management System (OMS) and provides them with a system using which outage impact simulations can be performed near-real time for well-controlled outage events, thus improving the availability and reliability of the power system.

OMS solution consists of two components: a web-based system and a network simulation tool integrated with the SCADA system, as shown in Figure AI-4

Figure AI-4 | Outage Management System with integrated SCADA System



The components are:

Outage Management System – It is a Workflow System (Ticketing System) to log and track various outage tickets till their completion. As a web-based workflow solution, it enables utilities to work from anywhere and manage their respective tasks as assigned by the workflow engine in a secure manner (Access Controls).

Outage Simulation Tool – This is a desktop application used by power system engineers to perform various simulations to aid the outage process. This tool integrates with the SCADA system (through Comma-Separated Values (CSV) or Database Views) for real-time data to enable near-real-time simulation studies and understand potential risks before giving the go-ahead for the actual restoration work.

AI.5 Unmanned Aerial Vehicle for Transmission Line Maintenance

An Unmanned Aerial Vehicle (UAV) is a type of aerial vehicle that is piloted using radio remote control equipment and software. It is a complicated system integration involving electronics, aviation, electric power, reconnaissance, geographic information, image recognition, and other components. UAVs can be utilized in a variety of industries, including air photography, surveying and mapping, sports, military concerns, and scouting for natural disasters, due to their capacity to work fast in the upper air from a considerable distance. This improvement enables it to be managed via telemetry data link, GPS satellite potential, and geographical matching, displaying stability, simplicity, reliability, extreme economic performance, weather-proofing, and long-lasting cruise power. The technology is more scientific and efficient than manual inspection methods, consistent with modern science and engineering concepts. [23].

In transmission and distribution line inspection, UAVs can carry all sorts of detection devices instead of artificial visuals for automated checking of the electric line [23]. The main advantages of UAVs are as follows:

1	It improved patrol efficiency by overcoming terrain restrictions. It can capture 360-degree images for analysis and reduce manual labor intensity and risk.
2	UAVs with infrared imagers can detect latent bottle defects and weaknesses more easily than manual patrols (insulators, hardware, and bottle defects).
3	Unlike robots, UAVs can patrol 765 kV, 400 kV, 220 kV, 132 kV, and 66 kV transmission lines without modification.
4	Its speed is dozens of times faster than artificial patrols and robots. It can quickly obtain image data and make real-time decisions.
5	Unlike satellite remote sensing, it is not affected by cloud cover and revisits the cycle.
6	Low-cost use and maintenance, easy-to-use technology.
7	Patrol costs little after an initial investment. Self-patrol is optional. (Deploying a helicopter and other equipment is expensive and not as reliable as it is impeded by the weather.) Helicopters can't cross rivers, forests, etc.
8	It detects transmission line defects. With the advancement of science and technology, drones can identify the key parts of overhead transmission line accidents, including the tower body, conductor and insulator, and shock hammer.

Annexure II – Questionnaire

Table AII-1 | Questionnaire for STUs

Sl. No	Category	Discussion Point	Concerned Stakeholder
1	General	What are the top five issues faced by your Utility?	STU/SLDC/Central
2		What top five initiatives will your utility take up for the next decade?	STU/SLDC/Central
3		What are your observations on utility transformation in the last decade?	STU/SLDC/Central
4	Planning	What are the issues that you are facing while planning the power system with varying generation mix (more renewable on the grid)	STU
5		What are the initiatives taken at STU for more clean energy integration in the coming decade	STU
6		What is the planning criteria being followed in your utility? CEA/CERC-Grid code/ State Grid code	STU
7		List the measures being taken in your utility to make the transmission system Resilient to Extreme Weather.	STU
8		How periodically are you conducting the Transmission system Protection studies	STU
9		What are the technological innovations utilities have taken up in recent times?	STU/SLDC
10	Regulatory	Are there any specific concerns about the CTU transmission charges procedure/calculations?	STU
11		What are the regulatory issues (policies/regulations) faced in STU activities?	STU
12		What are the best practices you can propose for better coordination between the electricity stakeholders (STUs, DISCOMs, Generation Companies (GENCOs), Regulators) among state and central utilities	STU/SLDC/Central
13	Execution/ O&M	What measures are taken to improve the reliability of important lines through O&M activities?	STU
14		What measures are taken for O&M for cables in cities for aged cables and dielectric breakdown accidents?	STU
15		Please list the issues faced in delay in transmission line additions (planning/ decision making/tendering/RoW etc.)	STU
16		What are the criteria for selecting a project for execution through the TBCB route (if any)?	STU

Sl. No	Category	Discussion Point	Concerned Stakeholder
17	Human Resource Training and Capacity Building	Please list the present human resource practices in terms of availability, capabilities, capacity-building requirements, etc.	STU/SLDC/Central
18		What are topics (advanced technologies or others) on which the utility workforce needs training?	STU
19	Financials	How is the financial planning being done in your utility?	STU

Annexure III – Survey Outcomes

AIII.1 State Transmission Utility

The detailed response for each question from survey outcomes is as follows:

1. **What are the top five issues faced by your Utility?**

   The majority of the STUs mentioned that Right of Way (RoW) in urban areas and forest grant from the forest department is the main issue in transmission line project implementation. The other challenges or issues reported are the shortage of manpower in the STU planning department; facing high and low voltages at the same substation at various time instants; reactive power compensation issues with underground cable systems and renewable integration. Because of government policies regarding agricultural power supply, there is a shift in load to daytime, and load management is another issue as the designed transmission network is not intended to handle more demand in the daytime. Due to this, the power flows in transmission lines are changed and overloading on transmission lines is increased at various locations. Some STUs have been confronted with financing and regulatory issues. Network expansion will be a major challenge for STUs without having area/zone-wise peak demand forecasting as present demand forecasting are only available at the state level or DISCOM level. Some interviewees believe that capacity building and skill development is also a barrier for them.

2. **What are the top five initiatives that will be taken up by your utility for the next decade?**

   The majority of the STUs mentioned initiatives are taken up in recent years. However, some of the non-RE state utilities opinioned there are no major initiatives in recent times. The initiatives reported by STUs in India are: upgrading existing transmission line conductors with HTLS conductors; expanding the network to have more connections with the CTU network, which will improve the states' import capacity; planning new renewables generation for RPO compliance; installing real-time data acquisition systems at all substations via OPGW; STATCOM and SVC are planned to address reactive power issues. And to generate equity for financial assistance, one of the STUs has created InvIT (Infrastructure investment trust: An infrastructure investment trust, simply put, is a pooled investment vehicle like a mutual fund. While mutual funds invest in financial securities, an InvIT invests in real infrastructure assets such as roads, power plants, transmission lines, and pipelines).

3. **What are your observations on utility transformation in the last decade?**

   All STUs agreed that with the various technologies available over the last decade, there has been a significant transformation happening in the recent decade with the addition of more renewables, increased expectations from consumers, and faster response expectations from developers and stakeholders.

4. **What are the issues that you are facing while planning the power system with varying generation mix (more renewable on the grid)?**

   The majority of STUs opinioned that accommodating the number of load-generation scenarios is very high due to the diverse generation mix especially accounting for renewable variability. Transmission line transfer capacity limitations, large voltage variation, overloading found only for a few hours in some places, generators not adhering to CEA connectivity regulations, harmonics being injected into the grid and resulting in the damage of a 400 kV transformer, and power quality issues encountered by some STU at the interface points of RE generators are some issues highlighted.

5. **What are the initiatives taken at STU for more clean energy integration in the coming decades?**

RE-rich states are planning to increase their clean energy integration in the coming years. New substations are being planned to handle and transfer RE generation, existing lines are being upgraded with HTLS conductors to transfer more power, some utilities have planned for green hydro generation in the coming years, and synchronous condensers are being planned to improve the reactive power control, energy storage options are being explored to charge during RE availability and discharge when required in the evening and other grid services. STUs also highlighted the potential usage of the Battery Energy Storage System (BESS) to fill the gap of reduced inertia in the grid due to more renewables.

6. **What is the Planning Criteria being followed in your utility? CEA/CERC-Grid Code/State Grid Code**

All STUs in India plan their networks following the CEA transmission planning criteria. Most of the STUs are planning their transmission network plan based on the CEA demand projections and some states are using their demand forecasting values for transmission planning. All STUs are equipped with network analysis tools like PSSe and MiPower. There is no independent verification of the transmission plan carried out by a third party in the form of an audit.

7. **List the measures being taken in your utility to make the transmission system Resilient to Extreme Weather.**

STUs located in the coastal part of India are focused recently on the design of resilient transmission systems for extreme weather conditions. The resilient measure includes underground cables for distribution systems up to 33kV and 11kV, and the transmission lines design included wind zone 6, which can handle wind speeds of up to 200 kmph. In areas with heavy rain, some STUs have deployed Emergency Restoration Systems (ERS).

8. **How periodically are you conducting the Transmission System Protection studies?**

STUs stated that as per the requirement, transmission licensees are required to submit the protection settings, as well as the calculation sheets, coordination study reports, and input data, to the respective regional power committee by the first week of each month. It was stated that the State Regulatory Commission can request that the STUs conduct protection audits whenever necessary.

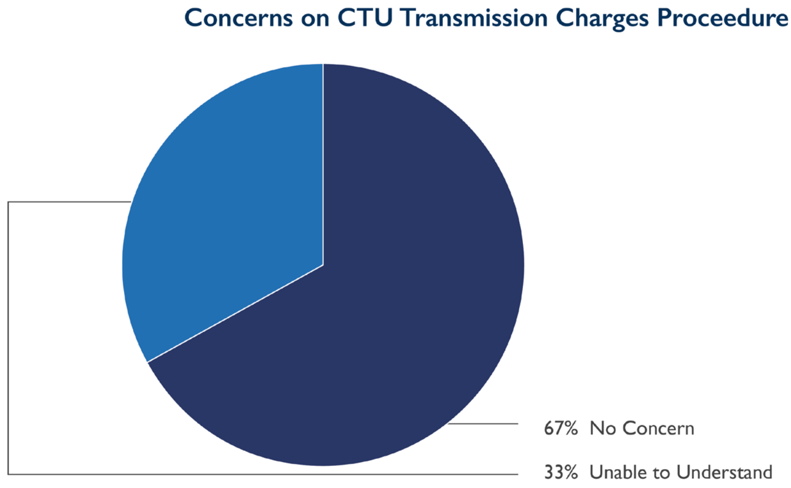
9. **What are the technological innovations utilities have taken up in recent times?**

The following technological innovations are listed: upgradation of existing lines with HTLS; adopting dynamic compensation techniques like Static VAR Compensator and STATCOM; some STUs have planned more than one control center with EMS, ADMS, and Asset Management System for most of the substations; power control devices for power flow control for 220kV lines. Energy storage systems are planned by some STUs for various applications. Some STUs have started analyzing the remaining life of the critical equipment.

10. **Are there any specific concerns about the CTU transmission charges procedure/calculations?**

The views of the interviewees are presented as stats in Figure AIII-1. Some of the STUs mentioned that they don't understand the transmission charges calculation by CTU and they expect more transparent calculation procure to be shared and discussed with stakeholders.

Figure AIII-1 | Stats on Views of STUs on CTU Transmission Charges Procedure



11. What are the regulatory issues (policies/regulations) faced in STU activities?

The majority of STUs do not experience any problems, but a few of them have experienced problems complying with orders from regulators, and as a result, they are requesting additional time from the regulator to abide by the compliance requirements for integrated resource planning, a protection audit, tools, and maintenances.

12. What are the best practices you can propose for better coordination between the electricity stakeholders (STUs, DISCOMs, GENCOs, Regulators) among state and central utilities?

In response to the question, the majority of STUs gave their opinions, saying that the coordination between the various stakeholders is running very smoothly. However, a few STUs brought up the fact that they do not receive reliable data from the distribution licensees.

13. What are the measures taken to improve the reliability of important lines through O&M activities?

The majority of STUs agreed that there is no software tool available for maintenance activities. Some STUs use condition monitoring outage management tools. Part of STUs handles their maintenance at the zone level, whereas others outsource their O&M activities to a third party, resulting in a financial benefit for the STU. Some STUs and 132kV substation O&M activities are outsourced to a service provider. Some STUs have signed agreements with service providers to maintain 765kV, 400kV, 220kV, and 132kV lines with one vehicle and 4-5 people for patrolling and preventive maintenance every 250-300 kilometers of transmission lines.

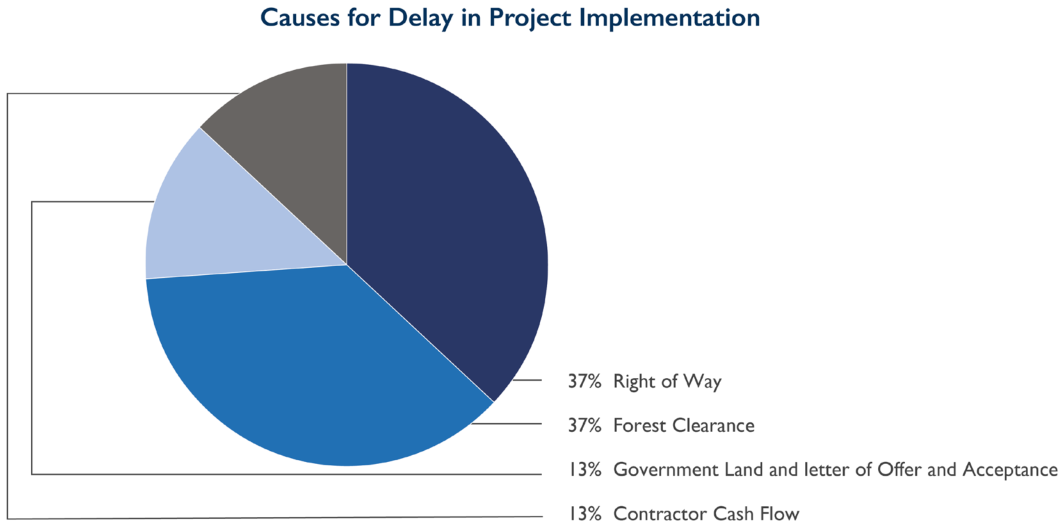
14. What are the measures taken for O&M for cables in cities for aged cables and dielectric breakdown accidents?

Mostly, this activity is outsourced to the developer with Annual Maintenance Contract (AMC) contact for the maintenance activities whenever required.

15. Please list out the issues faced in delay in transmission line additions (planning/decision making/ tendering/RoW etc.)

STUs highlighted the major reasons for transmission project delays are Right of Way (RoW) and Forest Clearance. The other issue is the government's restriction on using only government land for project implementation. The problem with using government land is that sometimes the government agrees to provide the land, but when the Letter of Offer and Acceptance (LOA) is issued, the government says this land cannot be provided and they provide an alternate, which may be very far away. The final issue is contractor cash flow; sometimes, due to market fluctuations, material rates change, affecting contractors' cash flows, which leads to project abandonment. The stats for causes of transmission project delay are presented in Figure AIII-2.

Figure AIII-2 | Causes for Delay in Project Implementation



16. What are the criteria for selecting a project for execution through the TBCB route (if any)?

In most STUs, the regulatory commission has set a cost threshold above which all projects will go through the TBCB route. The majority of STUs have begun to implement projects via the TBCB route. Some STUs have suggested only green field projects, raising the TBCB threshold limit, connecting one grid to another grid, and only time-consuming projects should use the TBCB route.

17. Please list out the present practices on human resources in terms of availability, capabilities, capacity-building requirements, etc.

It is observed that the majority of STUs have training institutes. Some utilities have outsourced O&M activities to service providers, resulting in financial savings for STUs. Some STUs noted a shortage of skilled personnel with knowledge of both software and power systems.

18. What are topics (advanced technologies or others) on which the utility workforce needs training?

When asked about the requirement of training for the workforce at the STUs, they were divided on their opinion. Some of the STUs feel work education comes from experience. Some STUs mentioned that capacity building is required on software and power systems knowledge. And some mentioned that they have separate training departments led by Superintendent Engineer for providing technical and non-technical training activities. Some also mentioned that training on international training will be beneficial for all.

19. How is the financial planning being done in your utility?

Most STUs follow the same process, after the approval from the technical team, the financial department makes the estimate for the new infrastructure or upgrades, and accordingly the same is submitted to the regulator in terms of Aggregate Revenue Requirement (ARR).

Annexure IV – Stakeholder Consultation Workshop

The roundtable consultation on modernization of STUs was organized on March 14, 2023 by USAID, through its SAREP program in New Delhi. The objective of the consultation is to receive the inputs to finalize the report and support the goal of developing a roadmap to prepare Indian states for a clean energy transition, especially in dealing with the challenges of increased renewable energy in the power system.

The consultation with STUs has focused on deliberating the gaps identified and recommendations listed in the gap assessment undertaken by SAREP program. The event started at 10:30 AM IST with transmission utilities from different states, Central Transmission Utility, Central Electricity Authority, Power Grid and many experts.

Further, the round table consultation has been structured into three themes shown below:

1 **Theme–1:** Infrastructure and Technology

2 **Theme–2:** Tools & Techniques and Operations

3 **Theme–3:** Policy & Regulations, Institutional Framework and Human Capacity

Based on the deliberations in the roundtable consultation with STUs, PGCIL, CEA and external experts, the summary of gaps and relevant recommendations to address such gaps have been summarized in Table AIV-1.

Table AIV-1 | Workshop – Summary of Gaps and Recommendations

Sl. No	Thematic Area	Gaps	Recommendations
1	**Institutional Framework**	STUs do not have functional and financial independence.	STUs sought a Ministry of Power (MoP) directive towards: • Defining a standard organization structure (chart with department names) for STUs. • Appointment of Independent board of directors to strengthen governance practices.
		There is a need for enhancing coordination between states and center on transmission planning and charges calculation.	• STUs may interact more frequently with the central agencies to enhance coordination. • STUs may discuss and deliberate with central agencies on aligning the central and state transmission plans. • STUs should support in creation of national level database through updation of details on PM Gati Shakti portal, to minimize efforts and costs on route survey and planning. • STUs may participate in capacity building programs on transmission charges calculation.
		Need for enhancing coordination between STU and DISCOMs.	STUs may interact with DISCOMs frequently to seek regular inputs for accurate load forecasting and transmission planning.

Sl. No	Thematic Area	Gaps	Recommendations
2	**Human Capacity**	Need for enhancing coordination between STU and DISCOMs. • Most STUs have an aging workforce. • STUs struggle to retain skilled members. • Knowledge transfer between outgoing senior staff and junior staff is limited. • Capacity building of junior staff via trainings and certifications is limited within the STUs. • Recruitment across STUs has been very limited and continues to remain short-staffed.	• STUs may seek independence to recruit a workforce capable of discharging its duties. • STUs may undertake regular recruitment to fill vacancies at all levels. • Knowledge dissemination from outgoing experts to junior staff within STUs should be encouraged. • STUs may provide incentives and promotions to workforce. • STUs may allocate budget (or associate with development agencies) to provide workforce with exposure to national and international skill development programs. • STUs may mandate power system planner certification transmission planning team (if not already specified in grid code).
3	**Policy and Regulatory interventions**	Limited policy and regulatory interventions on BESS, Insulated Cross Arm (ICA) and Transmission Asset Management Centers.	• Policy or regulatory interventions are required to promote the use of BESS as a transmission element. • There is a requirement of regulations/guidelines on use of ICA solutions (used to minimize RoW requirement). • Mandating creation of institutions like NTAMC and RTAMC at state level would be helpful in reducing manpower requirement for O&M.
		Project Financing is a major bottleneck. STUs struggle to source debt and equity for transmission projects.	• STUs may seek support from central level for issuance of a directive which promotes project financing support from power sector lending institutions like PFC and REC
		Benchmarks that can serve as end goals for STUs are yet to identified and utilized for performance measurement/improvement	• STUs may identify KPIs for Transmission network in state such as, per capita circuit km of Transmission line in collaboration with central stakeholders. • STUs may seek the development of guidelines on maximum possible utilization factor of Transmission line from relevant agencies (or at least considerations for evaluating this parameter).
4	**Infrastructure**	STUs cited tendering process and contractual challenges as a major reason for project delay/cancellation. (Project award and commencement of work is heavily delayed because of contractual issues).	• STUs may develop standard bidding development in consultation with market players to expedite the award process. • STUs may streamline internal process for reducing delays in project approvals.
		STUs have not adopted Tariff Based Competitive Bidding (TBCB) route for project execution because of shortage of manpower capacity to operate a separate division for Bid Process Coordinator (BPC) activities and TBCB projects.	• STUs may implement pilot projects through TBCB route to gain TBCB experience. • STUs may look to increase manpower capacity to effectively carry out studies, TBCB, bid process management, payment settlements and address regulatory challenges.

Sl. No	Thematic Area	Gaps	Recommendations
5	Technology	STUs encounter a lot of challenges in reactive power management.	• Dynamic reactive power management devices (such as synchronous condensers and STATCOMs) should be studied and installed within state networks
		STUs have limited understanding of grid-forming inverters.	• STUs should participate in knowledge dissemination and capacity building programs on grid-following and grid-forming inverter technologies and its advantages.
		• There is a shortage of funds and resources for R&D and innovation in planning and construction. • Mechanization in construction is yet to become a core priority area.	• STUs may allocate a certain percentage of annual budgets to R&D/innovation/pilot projects. • STUs may explore the use of: – Unmanned Aerial Vehicles (UAV) and satellite imagery for route survey. – GInS mapping for integrated transmission planning. – Reorientation of existing RoW/towers for reconfiguration of networks
		Planning department is understaffed.	• STUs may recruit more engineers for system planning.
6	Tools and Techniques	Long-term planning is less effective because of project delays; requires re-planning.	Bifurcation of system planning department into short-term and long-term planning: • Short-term planning team to coordinate with SLDCs for immediate network requirements. • Long-term planning team to interact with central agencies for ensuring alignment with ISTS plans.
		• Softwares used for network modeling and analysis varies across STUs • Network models are non-uniform and inconsistent • Shortage of dynamic and transient study skills. • Asset failure due to design based on obsolete codes/standards.	• STUs are recommended to: – Use of steady state and dynamic tools/ software's for network planning. – Develop models or tools based on planning philosophy as per CEA transmission planning criteria to ensure uniformity in network models/tools. • Skill building to include frequency response analysis, EMTP studies, etc. • STUs should undertake design and engineering of asset based on latest codes and standards. • Root cause analysis should be undertaken along with R&D to mitigate such failures (especially on metallurgical front).

Sl. No	Thematic Area	Gaps	Recommendations
7	Operation & Maintenance (O&M)	Best practices manual is not developed/updated.	• STUs may develop a best practice manual. • STUs may interact and learn from best practices of other states.
		GIS substation maintenance and inventory remains an issue.	• Skill building should focus on this GIS technology, maintenance, and studies apart from frequency response analysis, EMTP studies and augmented reality.
		Development of (or adherence to) disaster mitigation plans is a challenge.	• STUs may develop state-specific disaster mitigation plans. • Mock drills should be undertaken at regular intervals to ensure readiness to react against disasters.
		Limited advanced technologies deployment is observed within STUs.	STUs may explore use of the following: • Digitalization for improving O&M. • Data analytics for asset management. • Virtual/Augmented reality.

ABOUT SAREP

The South Asia Regional Energy Partnership (SAREP) is the flagship regional energy program of the United States Agency for International Development (USAID) mission to India (USAID/I). This five-year initiative (2021-26) will improve access to a-ordable, secure, reliable, and sustainable energy in six countries Bangladesh, Bhutan, India, Maldives, Nepal, and Sri Lanka — in line with these countries' climate and clean energy priorities.

The program is a key activity under the U.S. Government's Asia Enhancing Development and Growth through Energy (EDGE) initiative and aligns with USAID's climate change priorities to advance equitable and ambitious actions to confront the climate crisis. The program helps the U.S. Government's Indo-Pacific Vision and facilitates collaboration among the six countries in South Asia to accelerate the transition to clean energy, mitigate climate change, and promote energy security

SAREP will enable modernization of transmission, system operation, and distribution utilities in the region to improve their technical, financial, and operational performance, grid resilience, enhance customer service, and promote adaptability to new technical advancements. The expected outcome is modern and financially viable utilities that enable clean energy transition and efficient energy markets

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