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Manual on Transmission Planning Criteria

2023

CENTRAL ELECTRICITY AUTHORITY
NEW DELHI

Manual on Transmission Planning Criteria

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घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
GHANSHYAM PRASAD
Chairperson & Ex-officio Secretary
To the Government Of India

केन्द्रीय विद्युत प्राधिकरण
भारत सरकार
विद्युत मंत्रालय
सेवा भवन, आर,के, पुरम
नई दिल्ली–110066
Central Electricity Authority
Ministry of Power
Sewa Bhawan, R. K. Puram
New Delhi-110066

Foreword

Transmission system is the bridge between the Generation and Discoms/ Consumers. For ensuring reliable, 24x7 electricity to the consumers, a robust transmission system is necessary. It has to ensure seemless transfer of power from the source of supply to the load centre.

To achieve the transmission system capacity, especially in context with anticipated large scale renewable generation capacity addition, growth of load, increasing fault level, right of way issues, technological advancement and notification of Transmission Rules 2021, an effort has been made to comprehensively provide the details of transmission planning in the form of "**Manual of Transmission Planning Criteria, 2023**".

It is a matter of great pleasure to bring to you the new Manual on Transmission Planning Criterial prepared by CEA in consultation with the stakeholders. This Manual provides the planning philosophy, system modelling, planning margins, various system studies, reliable criteria, substation criteria, criteria for RE plants and others.

I am sure that this Manual would be quite helpful to the transmission planners to gain the technical insight to the planning and will certainly render confidence to take the decisions in a judicial manner for the betterment, expansion and strengthening of the transmission system.

(Ghanshyam Prasad)

Ashok Kumar Rajput,
Member (Power Systems)
and Ex-Officio Additional
Secretary to the
Government of India

Government of India
Ministry of Power
Central Electricity Authority

Preface

Manual on transmission planning criteria was first brought out by CEA in 1985 setting the planning philosophy of regional self-sufficiency. The Manual was further revised in 1994 and 2013 taking into account the technological advancements and institutional changes. The regional electrical grids were synchronously interconnected in December 2013 to form a single unified grid, one of the largest synchronous electrical grids in the world. The country has moved from the concept of regional self-sufficiency to bulk inter-regional transfer of power through high capacity AC and HVDC corridors forming an all-India National Grid. Further, India envisages to have more than 50% of the installed power generation capacity through non-fossil fuel based sources by the year 2030, most of which will be Solar and Wind power. Keeping in view the system needs like anticipated large scale renewable generation capacity addition, growth of load, increasing fault level, right of way issues, technological advancements, notification of Transmission Rules 2021, launch of PM Gati Shakti National Master Plan and CERC (GNA) Regulations 2021, the Manual on Transmission Planning Criteria has been revised.

For revising the Manual, a Committee was constituted on 16.11.2018 with the members from Tamil Nadu, Assam, Madhya Pradesh, West Bengal, Punjab, as well as from CEA, Grid-India and CTUIL. I would like to thank the Members of the Committee for carrying out revision of the Manual on Transmission Planning Criteria. Credit also goes to the members of the sub-groups and other experts for their co-operation and support in accomplishing of the task.

I would also like to thank Sh. Goutam Roy, Ex. Member (Power Systems), CEA; Sh. B. K. Arya, Member (GO&D), CEA; Sh. Pardeep Jindal (Chief Engineer, CEA) and Sh. Ravinder Gupta (Ex. Chief Engineer, CEA) for enriching the Manual with their experience.

I believe that this Manual on Transmission Planning Criteria, 2023 will benefit all stakeholders of the country in evolving a reliable and robust transmission system infrastructure to effectively and efficiently serve the consumers.

(Ashok Kumar Rajput)

Ishan Sharan,
Chief Engineer
(PSPA-II Division)
Central Electricity Authority

Acknowledgement

For revising the Manual on Transmission Planning Criteria, a Committee was constituted under Member (Power Systems), CEA, with members from CEA, Grid-India, CTUIL, TANTRANSCO, AEGCL, MPPTCL, WBSETCL and PSPTCL. I express my sincere thanks to all the Committee Members for their concerted efforts in preparation of the Manual.

For deliberating on different aspects, three groups had been formed which were coordinated by CEA, Grid-India and CTUIL. I thankfully acknowledge the valuable suggestions, assistance and cooperation received from the officers of Grid-India, particularly from Shri Rajiv Kumar Porwal, CGM; Shri Vivek Pandey, GM; Shri Priyam Jain, Manager and Shri Prabhankar Porwal, Dy. Manager. I also acknowledge the valuable suggestions, assistance and cooperation received from officers of CTUIL in the preparation of the Manual, particularly from Shri Sourov Chakraborty, Sr. GM; Shri K. K. Sarkar, Sr. GM; Shri V. Thiagarajan, Sr. GM; Shri Rajesh Kumar, GM; Shri Anil Kumar Meena, Sr. DGM; Shri Ajay Dahiya, Chief Manager and Shri Manish Ranjan Kesari, Manager.

I express my gratitude to Shri Goutam Roy, Ex Member (Power Systems), CEA, for his valuable guidance at every step in the preparation of this Manual. I also thank Shri Ravinder Gupta, Ex Chief Engineer, CEA, and Shri Pardeep Jindal, Chief Engineer, CEA, for initiating the Committee work and contributing immensely to this document.

The specific contribution made by the officers of PSPA-II Division, CEA, namely Shri B.S. Bairwa, Director; Shri Deepanshu Rastogi, Deputy Director; Shri Pranay Garg, Deputy Director; Shri Suyash Ayush Verma, Deputy Director and Shri Manish Maurya, Deputy Director, is well appreciated and acknowledged with thanks. The Manual has been brought out by the dedicated and sincere efforts of these officers.

(Ishan Sharan)

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DEFINITIONS

1. **Peak Load:** It is the simultaneous maximum demand of the system being studied under a specific time duration(e.g. annual, monthly, daily etc).

2. **Light Load:** It is the simultaneous minimum demand of the system being studied under a specific time duration(e.g. annual, monthly, daily etc).

3. **System Stability:** A stable power system is one in which synchronous machines, when perturbed, will either return to their original state if there is no change in exchange of power or will acquire new state asymptotically without losing synchronism. Usually the perturbation causes a transient that is oscillatory in nature, but if the system is stable the oscillations will be damped.

4. **Temporary over-voltages:** These are power frequency over-voltages produced in a power system due to sudden load rejection, single phase to ground faults, etc.

5. **Switching over-voltages:** These are over-voltages generated during switching of lines, transformers and reactors etc. having wave fronts of 250/2500 micro sec.

6. **Surge Impedance Loading:** It is the unity power factor load over a resistance line such that series reactive loss (I^2X) along the line is equal to shunt capacitive gain (V^2Y). Under these conditions the sending end and receiving end voltages and current are equal in magnitude but different in phase position.

ABBREVIATIONS

AC	:	Alternating Current
AUFLS	:	Automatic Under Frequency Load Shedding
BESS	:	Battery Energy Storage System
CEA	:	Central Electricity Authority
CTU	:	Central Transmission Utility
D/c	:	Double Circuit
DISCOM	:	Distribution Company
EHV	:	Extra High Voltage
EMT	:	Electro Magnetic Transient
EPS	:	Electric Power Survey
FACTS	:	Flexible Alternating Current Transmission System
GNA	:	General Network Access
HV	:	High Voltage
HVDC	:	High Voltage Direct Current
ICT	:	Inter-Connecting Transformer
ISGS	:	Inter-State Generating Station
ISTS	:	Inter State Transmission System
Intra-STS	:	Intra-State Transmission System
kA	:	kilo Ampere
km	:	kilo meter
kV	:	kilo Volt
ms	:	millisecond
MVA	:	Million Volt Ampere
MVAr	:	Mega Volt Ampere reactive
MW	:	Mega Watt
NR/WR/SR/ ER/NER	:	Northern / Western / Southern / Eastern / North Eastern Region(s)
NLDC	:	National Load Dispatch Centre
P, Q	:	P – Active Power, Q – Reactive Power

P_{max}, Q_{max}, Q_{min}	:	P_{max} – Maximum Active Power, Q_{max} – Maximum Reactive Power Supplied i.e. lagging, Q_{min} – Maximum Reactive Power Absorbed i.e. leading
PMGS-NMP	:	Prime Minister Gati Shakti National Master Plan
PMU	:	Phasor Measurement Unit
POWERGRID or PGCIL	:	Power Grid Corporation of India Limited
pu	:	per unit
RE	:	Renewable Energy
RES	:	Renewable Energy Source
RLDC	:	Regional Load Dispatch Centre
RoCoF	:	Rate of Change of Frequency
S/c	:	Single Circuit
SLDC	:	State Load Dispatch Centre
STU	:	State Transmission Utility (Generally Transmission Company of the State)
SVC	:	Static VAr Compensator
STATCOM	:	Static Synchronous Compensator
X, Y, Z	:	X – Reactance, Y – Admittance, Z – Impedance
132 kV	:	132 kV System includes 110 kV System wherever used
220 kV	:	220 kV System includes 230 kV system wherever used

Chapter 1 INTRODUCTION

1.1 Background

1.1.1 As per the Seventh Schedule to the Constitution of India, the subject electricity is in Concurrent List. This implies that both central and state governments play key roles, and can regulate and operate in the electricity sector. Accordingly, electricity transmission system in India is generally categorised as Inter-State Transmission System (ISTS) and Intra-State Transmission System (Intra-STS). Optimum development of transmission system requires coordinated planning of the Inter- State Transmission Systems (ISTS) and Intra-State Transmission Systems (Intra-STS). CEA is coordinating transmission planning process under Section 73(a) of the Electricity Act, 2003.

1.1.2 Manual on Transmission Planning Criteria was first brought out by CEA in 1985 setting the planning philosophy of regional self-sufficiency. The manual was revised in 1994 considering the experience gained on EHV systems. Technological advancements and institutional changes necessitated further review of Transmission Planning Criteria.

1.1.3 The Electricity Act, 2003 has brought profound changes in electricity supply industry of India leading to unbundling of vertically integrated State Electricity Boards, implementation of Open Access in power transmission and liberalisation of generation sector, among others. The phenomenal growth of private sector generation and the creation of open market for electricity have brought its own uncertainties. Large numbers of generation projects are coming up with no knowledge of firm beneficiaries. The situation is compounded by uncertainty in generation capacity addition, commissioning schedules and fuel availability. All these factors have made transmission planning a challenging task. Adequate flexibility may be built in the transmission system plan to cater to such uncertainties, to the extent possible. However, given the uncertainties, the possibility of stranded assets or congestion cannot be entirely ruled out. In creation of very large interconnected grid, there can be unpredictable power flows leading to overloading of transmission lines due to imbalance in load generation balance in different pockets of the grid in real time operation. Reliable transmission planning is basically a trade-off between the cost and the risk involved. There are no widely adopted uniform guidelines which determine the criteria for transmission planning vis-à-vis acceptable degree of adequacy and security. Practices in this regard vary from country to country. The common theme in the various approaches is "acceptable system performance".

1.1.4 As the National grid grew in size and complexity, grid security was required to be enhanced considering large scale integration of renewable energy sources. Therefore, the transmission planning criteria was reviewed again in the year 2013.

1.1.5 The regional electrical grids of Northern, Western, Southern, Eastern and North-Eastern regions have been synchronously interconnected in December 2013 to form one of the largest synchronous electrical grid in the world. The country has moved from the concept of regional self-sufficiency to bulk inter-regional transfer of power through high capacity AC and HVDC corridors forming an all-India National Grid.

1.1.6 Ministry of Power have promulgated Electricity (Transmission System Planning, Development and Recovery of Inter-State Transmission Charges) Rules, 2021 in Gazette of India on 01 .10.2021 paving the way for complete overhauling of transmission system planning to give power sector utilities easier access to electricity transmission network across the country. These Rules underpin that electricity transmission planning shall be done in such way that the lack of availability of the transmission system does not act as a barrier on the growth of different regions and the transmission system shall, as far as possible, be planned and developed matching with growth of generation and load. While doing the transmission planning, care shall be taken that there is no wasteful investment. These rules also introduced General Network Access (GNA) in the inter-state transmission system.

1.1.7 In view of above, there was need to update the Manual on Transmission Planning Criteria issued by CEA in January, 2013 especially in context with anticipated large scale renewable generation capacity addition, growth of load, increasing fault level, right of way issues, technological advancement and notification of Transmission Rules 2021. Accordingly, the planning criteria has been revised again. This planning criteria may be referred as Central Electricity Authority (Manual on Transmission Planning Criteria), 2023.

1.2 Scope

1.2.1 The Central Electricity Authority is responsible for preparation of perspective generation and transmission plans and for coordinating the activities of planning agencies as envisaged under Section 73(a) of the Electricity Act 2003. The Central Transmission Utility (CTU) is responsible for development of an efficient and coordinated inter-state transmission system (ISTS). Similarly, the State Transmission Utility (STU) is responsible for development of an efficient and coordinated intra-state transmission system (Intra-STS). The ISTS and Intra-STS are interconnected and together constitute the electricity grid. It is therefore imperative that there should be a uniform approach to transmission planning for developing a reliable transmission system.

1.2.2 The planning criteria detailed herein are primarily meant for planning of Inter-State Transmission System (ISTS), Intra-State Transmission System (Intra-STS) and dedicated transmission lines down to 66 kV level.

1.2.3 The manual covers the planning philosophy, the information required from various entities, permissible limits, reliability criteria, broad scope of system

studies, modelling and analysis, and prescribes guidelines for transmission planning.

1.3 Applicability

1.3.1 These planning criteria shall be applicable from 1st April, 2023.

1.3.2 These criteria shall be used for all new transmission systems planned after the above date.

1.3.3 The existing and already planned transmission systems may be reviewed with respect to the provisions of these planning criteria. Wherever required and possible, additional system may be planned to strengthen the existing system. Till implementation of the additional system, suitable defence mechanisms may be put in place.

Chapter 2 PLANNING PHILOSOPHY

2.1 General guidelines

2.1.1 The transmission system forms a vital link in the electricity supply chain. Transmission system provides 'service' of inter-connection between the source (electrical energy sources) and consumption (load centres) of electricity. In the Indian context, the transmission system has been broadly categorised as Inter-State Transmission System (ISTS) and Intra-State Transmission system (Intra-STS). The ISTS is the top layer of National Grid below which lies the Intra-STS. The smooth operation of power system gets adversely affected on account of any disturbance in these systems. Therefore, the criteria prescribed here are intended to be followed for planning of both ISTS, Intra-STS and dedicated transmission line.

2.1.2 The transmission system is generally augmented to cater to the power transfer requirements posed by eligible entities, for example, for increase in power demand, generation capacity addition etc. Further, system may also be augmented considering the feedback regarding operational constraints and feedback from drawing entities.

2.1.3 The principle for planning of the ISTS shall be to ensure that it is available as per the requirements of the States and the generators, as reflected by their General Network Access (GNA) requests. As far as possible, the transmission system shall be planned and developed matching with growth of generation and load and care shall be taken that there is no wasteful investment.

2.1.4 The transmission customers as well as utilities shall give their network access requirement well in advance considering time required for implementation of the transmission assets. The transmission customers are also required to provide a reasonable basis for their transmission requirement such as size and completion schedule of their generation facility, demand and their commitment to bear transmission service charges.

2.1.5 Planning of transmission system for evacuation of power from hydro projects shall be done river basin wise considering the identified generation projects and their power potential.

2.1.6 In case of highly constrained areas like congested urban / semi-urban area, very difficult terrain (including hilly terrain) etc., the transmission corridor may be planned by considering long term perspective of optimizing the right-of-way and cost. This may be done by adopting higher voltage levels for final system and operating one level below voltage level in the initial stage, or by using multi-circuit towers for stringing circuits in the future, or using new technology.

2.1.7 Routing of the transmission line may be planned in accordance with Central Electricity Authority (Technical Standards for Construction of Electrical Plants

and Electric Lines) Regulations, 2022 and its amendments or re-enactment thereof, to minimise Right of Way (Row), technical options and line configurations.

2.1.8 PM Gati Shakti National Master Plan (PMGS-NMP) was launched on 13th October 2021 for providing multimodal connectivity infrastructure to various economic zones. It provides a digital platform for integrated planning and coordinated implementation of infrastructure connectivity projects. The information available on this platform to be used while planning of transmission system. For planning of any new transmission lines or substations, the portal of PMGS-NMP to be used to identify preliminary feasibility of the same.

2.1.9 In line with Section 39 of the Electricity Act, 2003, STU shall act as the nodal agency for Intra-STS planning in coordination with distribution licensees and intra-state generators connected/to be connected in the STU grid. The STU shall be the single point contact for the purpose of ISTS planning and shall be responsible on behalf of all the intra-State entities, for evacuation of power from their State's generating stations, meeting requirements of DISCOMs and exchange of power with ISTS commensurate with the ISTS plan with due consideration to the margins available in existing system.

2.1.10 Normally, the various intra-state entities shall be supplied power through the intra-state network. Only under exceptional circumstances, the load serving intra-state entity may be allowed direct inter-connection with ISTS on recommendation of STU provided that such an entity would continue as intra-state entity for the purpose of all jurisdictional matters including energy accounting. Under such situation, this direct interconnection may also be used by other intra-state entity(ies). Further, STUs shall coordinate with urban planning agencies, Special Economic Zone (SEZ) developers, industrial developers etc. to keep adequate provision for transmission corridor and land for new substations for their power transfer requirements.

2.1.11 The system parameters and loading of system elements shall remain within permissible limits. The adequacy of the transmission system should be tested for different probable load-generation scenarios as detailed in chapter-3 of this manual.

2.1.12 The system shall be planned to operate within permissible limits both under normal as well as after probable credible contingency(ies) as detailed in subsequent chapters of this manual. However, the system may experience extreme contingencies which are rare, and the system may not be planned for such rare contingencies. To ensure security of the grid, the extreme/rare but credible contingencies should be identified from time to time and suitable defence mechanism, such as - load shedding, generation rescheduling, islanding, system protection schemes, Automatic Under Frequency Load Shedding (AUFLS) schemes (AUF Relay & df/dt), etc. may be worked out to mitigate their adverse impact.

2.1.13 For strengthening of the transmission network, cost, reliability, right-of way requirements, transmission losses, down time (in case of up-gradation and re-conductoring options) etc. need to be studied. If need arises, addition of new transmission lines/ substations to avoid overloading of existing system including adoption of next higher voltage may be explored.

2.1.14 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.

2.1.15 The planned transmission capacity would be finite and there are bound to be congestions if large quantum of electricity is sought to be transmitted in direction not previously planned.

2.1.16 Communication system for new transmission system shall be planned and implemented in accordance with Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022 and its amendments or re-enactment thereof, Central Electricity Authority (Technical Standards for Communication System in Power System Operations) Regulations, 2020 and its amendments or re-enactment thereof and CEA Manual of Communication Planning in Power System Operation 2022 and its amendments such that the communication system is available at the time of commissioning of the transmission system.