Strategic Roadmap for Reliable Energy Distribution: Operational Planning in 220 kV Receiving Transmission Substations

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Abstract: ***Electricity is generated at power stations, typically situated at a distance from population centers. To transport this electricity efficiently, high-voltage transmission lines are employed, connecting the power stations to the areas of demand, or load centers. Along this journey, various substations are necessary for voltage transformation and switching. Substations, integral to the power system, serve as intermediaries between power generation, transmission, and distribution networks. Their primary role involves receiving high-voltage electricity from the generating stations and lowering the voltage to levels suitable for distribution. The stability analysis of the power system relies heavily on the performance of these interconnected substations. Utilizing the MATLAB PSAT tool, a comprehensive study is conducted to ensure the secure operation of receiving substations, with recommendations provided accordingly.***

***Keywords**- Steady state, PSAT, NR load flow*

I. INTRODUCTION

The power system in India comprises a variety of utilities, including:

- Indian State Electricity Boards
- National Thermal Power Corporation
- Power Grid Corporation of India
- Power Corporation
- National Hydro Power Corporation

Interconnected state transmission lines link all these utilities, each state having its own power grid [2]. Deregulation processes are underway in many states. Some inter-state power transmission lines are built and operated by PGCL (Power Grid Corporation Limited). Additionally, the operation of hydro, thermal, and nuclear power stations is overseen by the National Grid Corporation, such as the *National* Hydro Corporation, National Thermal Power Corporation, and NPC. The Power Grid Corporation of India holds the responsibility of the central transmission utility. The CERC approves Grid codes, which delineate the planning and operation protocols for various interconnected state transmission lines and power stations situated centrally.

The current power grid system in Karnataka is operated by KPTCL (Karnataka State Power Transmission Corporation Limited), recognized as a transmission utility under Section 27-B of the Indian Electricity Act 1990 [3]. KPTCL fulfils various roles, including:

- Transmitting energy across state transmission systems to supply both retail and bulk distribution consumers.
- Coordinating and planning activities in collaboration with entities such as CEA (Central Electrical Authority), CTU (Central Transmission Utility), Southern Regional Electricity Board, Generating Companies, and Distribution Supply.
- Monitoring and implementing control measures within the state grid.

- Providing regular updates and information to the grid in compliance with CTU regulations.

To streamline these operations, KERC (Karnataka Electricity Regulatory Commission) [2] [3] has established the "Karnataka Electricity Grid Code," applicable exclusively to Karnataka and its neighbouring inter-state transmission networks.

The structure of the grid is outlined as follows:

- Introduction: Provides an overview of the grid code's key features.
- Definitions: Clarifies various terms used throughout the code.
- Management of the grid code: Details the document's current status and periodic review process by the competent panel.
- System Planning code: Describes procedures for design, technical criteria, and planning activities.
- Connectivity condition: Specifies technical criteria and standards to be met by transmission licensees, distribution and retail supply licensees, and generating companies.
- Operation planning and security: Covers operational planning activities, parameter fixing for operating margins, reserve and contingency control, and demand management.
- System operation metering, protection dispatch, and control code: Emphasizes scheduled dispatch of generating units, demand-supply balance, frequency control, and management of extra high voltage in transmission lines.
- Monitoring of Generation and drawl: Monitored by the state load dispatch center, which tracks generation output, real and reactive reference capacity, and plan evaluation.
- Contingency Planning: Addresses power supply recovery and normalization in the event of partial or total collapse of Karnataka Grid or neighbouring Grid.
- Cross boundary safety: Specifies operating margins of equipment and step-by-step procedures for equipment condition checks.
- Accident reporting systems: Requires recording of accidental issues and actions taken for analysis.
- Safety and Line Clear permits: Outlines procedures for obtaining line clear permits and safety operation guidelines.

II. OBJECTIVES

The primary aim of this paper is to:

[1] Conduct Line Flow Analysis of transmission substations.

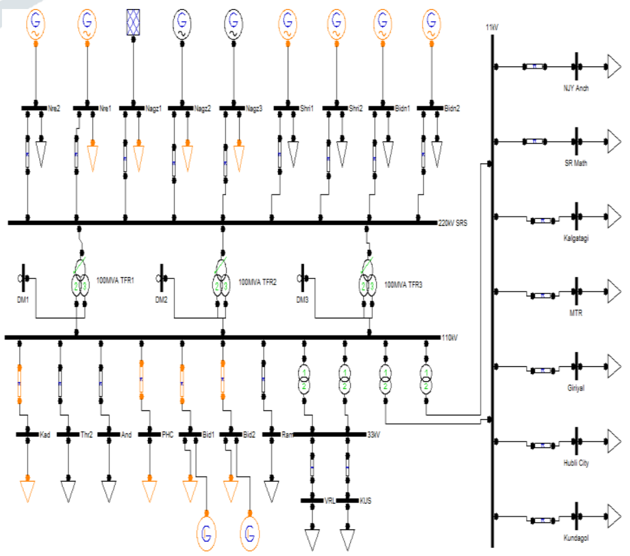
[2] Provide recommendations for enhancing operational planning to boost performance.

[3] Assess the feasibility of integrating distribution generation at the distribution level.

III. METHODOLOGY

Operational planning incorporates conventional methods for conducting line flow analysis. The NR method is selected for its efficiency in minimizing iterations and providing accurate results. Analysis is conducted across various load conditions and system configurations using the Power System Analysis Toolbox (PSAT) within MATLAB [4].

The study focuses on real-time 220/110kV receiving stations and their interconnected substations. Performance analysis aims to offer recommendations for enhancing operational planning and assessing the feasibility of integrating distribution generation at the distribution level.



IV. CASE STUDY

Considering a receiving station under the jurisdiction of KPTCL, a state government body in Karnataka [5], the mission statement of Karnataka State Power Transmission Limited articulates its commitment as follows:

- Ensuring the delivery of reliable and high-quality power to customers by implementing optimal systems and establishing a robust transmission network.
- Aiming to excel as the foremost transmission utility nationwide, KPTCL pledges to optimize its human and technical resources for the collective benefit of its clientele.

Given that the company solely undertakes transmission responsibilities, it serves as a vital link between generation plants and load centers. Maintenance of all 220 kV, 110 kV, and 33 kV infrastructure falls under the purview of the receiving substation. The generated power is transmitted over long transmission lines, with distribution activities managed by distribution substations under distribution companies, which assume responsibility for maintaining 11 kV lines up to households.

The proposed study is conducted at the KPTCL receiving substation, with its single-line diagram depicted in Figure 1. The station receives power from nine 220 kV lines originating from various locations, all of which are linear input and output transmission lines. The received power is distributed to 110 kV substations through three 100 MVA step-down transformers. Subsequently, the 110 kV power undergoes further step-down transformations to 33 kV and 11 kV using 20 MVA and 10 MVA transformers, respectively.

Fig.1 Single line diagram of the 220/110/33/11kV receiving station

The various configurations are outlined as follows:

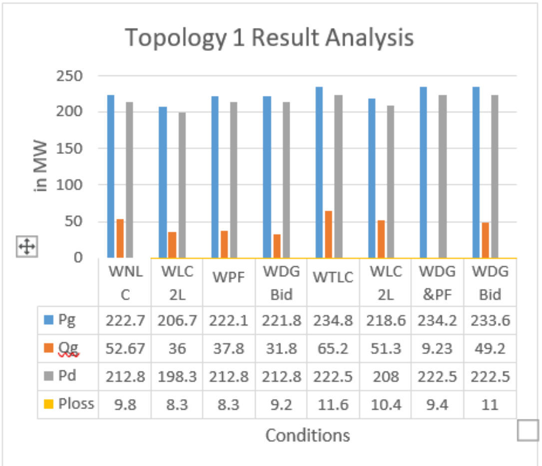
Topology 1: During the rainy season, only hydro power feeds into the grid. Despite generation meeting demand, load curtailment occurs due to overload and outages.

Topology 2: In the summer season, with reduced hydro power generation, a combination of hydro and wind power feeds into the grid. Load curtailment occurs due to power scarcity.

Topology 3: In the winter season, power from wind, IPPs (independent power producers), and hydro power stations is supplied to the grid to meet demand. Despite this, load curtailment occurs due to outages.

Line flow analysis is conducted using the NR method load flow analysis, and observations from different topologies aid in understanding load curtailments. Based on this information, operational planning suggestions are provided [6] [7].

Expected results for different topologies during periods of light load demand are as follows:



	WNLC	WLC 2L	WPF	WDG Bid	WTLC	WLC 2L	WDG &PF	WDG Bid
Pg	222.7	206.7	222.1	221.8	234.8	218.6	234.2	233.6
Qg	52.67	36	37.8	31.8	65.2	51.3	9.23	49.2
Pd	212.8	198.3	212.8	212.8	222.5	208	222.5	222.5
Ploss	9.8	8.3	8.3	9.2	11.6	10.4	9.4	11

Fig.2 Topology 1 results

Figure1 illustrates the graphical representation of Topology 1. Referring to the scenario described above, where the load demand at the receiving station is 212.1 MW, and the injected power to the station is 198 MW, there exists a shortfall of 14.9 MW in load. Without load shedding (WNLS), this would lead to voltage dips at some bus points and violations of thermal limits in certain transmission lines. To ensure secure operation, operators must curtail 14.9 MW from rural lines.

The analysis was conducted using the conventional NR method load flow. To address the shortfall in generation, integration of Distributed Generation (WDG) at the 110 kV substation can be implemented, achieving similar results as load shedding.

Similarly, analysis was conducted for power factor improvement (WPFI) in Topologies 2 and 3, as depicted in Figures 3 and 4 respectively.

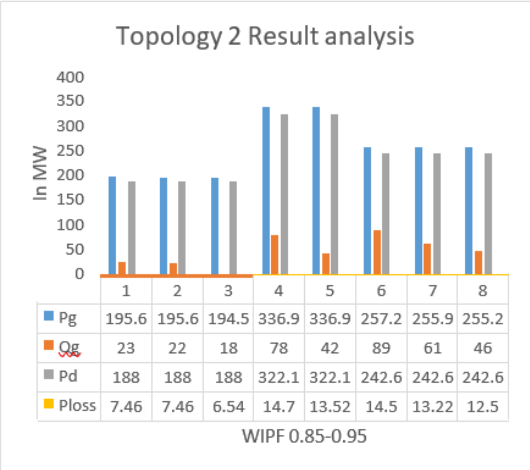


Fig.3 Topology 2

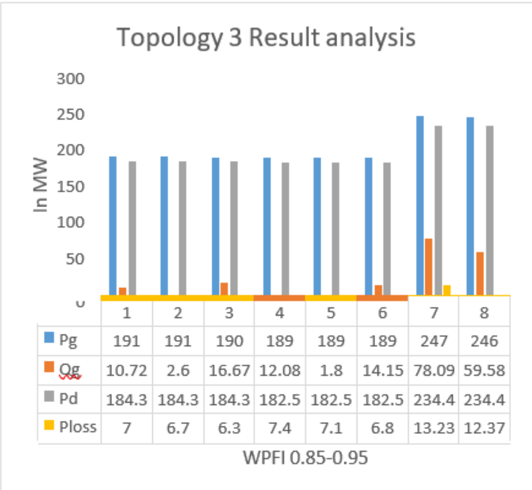


Fig.4 Topology 3

V. CONCLUSION

1]. Performance analysis will provide recommendations for enhancing operational planning and conducting a feasibility study on integrating distribution generation at the distribution level.

2]. Assists in enhancing the security system of transmission substations.

3]. Aims to achieve increased reliability of transmission substations.

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