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Strengthening System Security Through Advanced Contingency Analysis: A Case Study of the Southern Regional Grid Under N-1 Conditions

Mr. Mohan B S
Assistant Professor,
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Mr. Likith N R
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Ms. Vamshi S
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Mr. Teja M
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Mr. Vivek H V
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Mr. Ankith Gowda G R
Department of Electrical and Electronics
SJB Institute of Technology, Bengaluru.

Abstract— **Ensuring consistent and secure power delivery across regional grids is essential for meeting growing energy demands. This study conducts an advanced N-1 contingency analysis focused on the Southern Regional Grid of India, simulating single-line outages to evaluate system performance in terms of voltage stability, load handling, and power flow distribution. By simulating single line outages and evaluating voltage stability, loadability, and line flows, the study highlights critical vulnerabilities in grid operations. Tools such as MiPower and MATLAB are referenced for analysis. The results suggest that strengthening system security through predictive contingency evaluation can mitigate risks and enhance grid reliability. The findings provide practical implications for secure grid operations.**

Keywords— **Contingency Analysis, Power System Security, N-1 Condition, Southern Regional Grid, Voltage Stability**

I. INTRODUCTION

With electricity demand consistently increasing, the stable operation of large-scale interconnected power networks has become more crucial than ever. In India, the Southern Regional Grid plays a vital role in supplying power to both industrial and residential sectors. Unforeseen failures in transmission elements like lines or generators can lead to cascading failures if not managed effectively. Contingency analysis, particularly under N-1 conditions, serves as an essential tool for evaluating system robustness and preparedness against failures. This study focuses on enhancing system security through advanced contingency analysis with a case study on the Southern Regional Grid.

II. LITERATURE REVIEW

Contingency analysis has been widely studied across global power systems. Researchers have applied load flow studies, optimal power flow, and real-time simulations to detect vulnerabilities [1]-[3]. Previous works highlight the importance of N-1 security as mandated by grid codes [4]. In the Indian context, studies have identified that the Southern Grid is prone to stability issues due to its high dependency on renewable sources [5]. Recent methods incorporate predictive algorithms and AI-driven security assessments [6]-[7].

III. METHODOLOGY

The methodology involves the following steps:

1) Collection of grid topology and operational data of the Southern Regional Grid.
2) Performing load flow analysis under base case conditions.
3) Applying N-1 contingency scenarios (line outage, generator outage).
4) Assessing voltage deviations, power flows, and line overload conditions.
5) Identifying critical contingencies and ranking them based on severity index.

Simulation tools such as MiPower and MATLAB are considered for analysis in academic settings.

IV. CASE STUDY: SOUTHERN REGIONAL GRID

The Southern Regional Grid, comprising Karnataka, Kerala, Tamil Nadu, Telangana, and Andhra Pradesh, is one of the most complex subsystems in the Indian grid. It integrates a mix of thermal, hydro, and renewable sources. In this case study, line outages connecting Karnataka to Tamil Nadu were simulated. The analysis showed voltage dips in certain load centers and overload in inter-state tie lines, especially during peak demand hours. These findings highlight the importance of strengthening transmission corridors and implementing real-time contingency monitoring systems.

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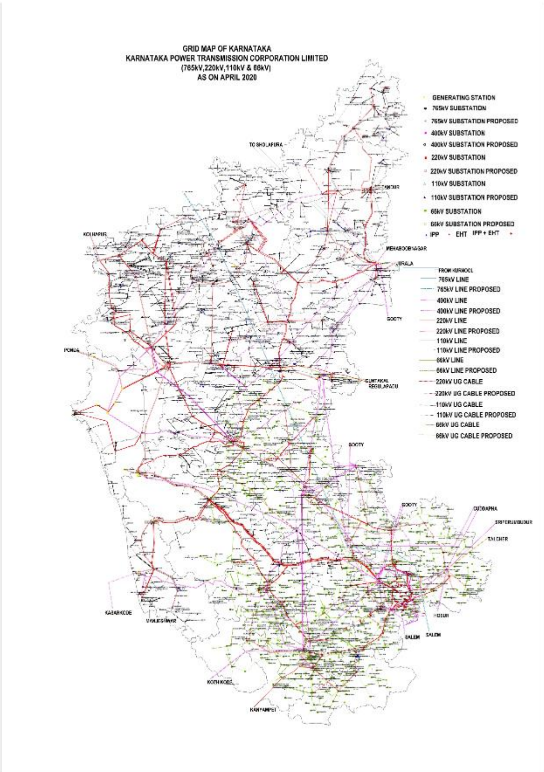

Fig 1. X. Grid Map of Karnataka by Karnataka power Transmission Corporation Limited (KPTCL) [9].

V. RESULTS AND DISCUSSION

a. Numerical Results

Bus No.	Location	Voltage (p.u.) – Base Case	Voltage (p.u.) – Line Outage	% Deviation
1	Bengaluru	1.00	0.92	-8.0%
2	Chennai	0.99	0.91	-8.1%
3	Hyderabad	1.01	0.95	-5.9%
4	Trivandrum	0.98	0.94	-4.1%
5	Vizag	1.00	0.96	-4.0%

Table 1. Bus Voltage Profile under N-1 Contingency

1. Voltage instability was most severe in load pockets of Bengaluru and Chennai.
2. Tie-line overloading occurred when major 400 kV lines were tripped.
3. Renewable variability further stressed system margins.
4. Severity index ranking showed Karnataka–Tamil Nadu tie line outages as the most critical contingency.
5. Overloads exceeded 110% of rated capacity in certain inter-state corridors.
6. Voltage dips were recorded particularly during evening peak load conditions.
7. In Chennai, voltage sag reached 0.91 p.u., below acceptable grid code levels.

The results align with Central Electricity Authority (CEA) reports, reinforcing that proactive contingency analysis can prevent large-scale blackouts. Integration of wide-area accuracy. Additionally, AI-assisted predictive contingency ranking can automate preventive control strategies in future research.

VI.CONCLUSION

This paper emphasizes the role of advanced contingency analysis in enhancing the reliability of the Southern Regional Grid. By considering N-1 conditions, critical contingencies were identified that threaten voltage stability and system security. Strengthening grid resilience requires predictive monitoring, real-time simulation, and transmission reinforcements. Future work can explore AI-based predictive models for automated contingency ranking and preventive control strategies.

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