TITLE OF THE TUTORIAL: Transmission Utility Perspectives on System Protection Challenges and Opportunities in Large-Scale Renewable Energy Integration

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OBJECTIVES OF THE TUTORIAL:

1. To highlight the challenges faced by transmission utilities in protecting power systems amidst large-scale renewable energy integration.
2. To explore the impact of inverter-based resources (IBRs) on fault currents and the limitations of conventional protection systems.
3. To discuss the ambiguities in existing grid codes (e.g., IEEE-2800) and the challenges posed by inconsistent interpretation and implementation.
4. To examine power quality issues at the Point of Connection (POC) and the difficulties in implementing IEEE-519 standards for IBR integration.
5. To provide real-world case studies from the Indian Power Sector, illustrating protection failures and the need for clear international standards.
6. To offer strategies for adapting protection systems to RE-rich grids and improving coordination between utilities and inverter owners.

TARGET AUDIENCE: Transmission Utility Engineers, Power System Protection Engineers, Renewable Energy Integration Specialists, Grid Code and Standards Developers, Academics and Researchers, Utility Managers and Decision Makers

TUTORIAL SUMMARY: The rapid integration of renewable energy (RE) into the Indian Power Grid has introduced significant challenges, particularly during transient events like transmission line faults and shunt reactor switching. The large-scale deployment of inverter-based resources (IBRs), combined with inadequate and inconsistently interpreted grid codes, has exacerbated grid disturbances. IBRs produce fault currents within overload ranges, with responses varying by inverter controller design, often rendering conventional protection systems ineffective near IBRs.

This tutorial will address the challenges faced by transmission utility engineers in protecting transmission lines, transformers, and bus bars near IBR systems. Currently, no comprehensive standards exist for Grid-IBR interconnections, and IEEE-2800 leaves protection requirements to transmission system owners, creating ambiguity. I will explore issues arising from unclear standards and challenges posed by inverter owners, which shape protection philosophies at Grid-IBR interfaces.

Increasing IBR penetration has also led to power quality issues at the Point of

Connection (POC). Utilities face challenges in implementing IEEE-519 standards to manage voltage and current harmonics. Additionally, shifting loading patterns in RE-dominated regions have introduced dynamic reactive power requirements, straining the EHV system and depleting STATCOM reserves.

The tutorial will feature real-world case studies from the Indian Power Sector, highlighting misinterpreted grid codes, protection failures, and the need for clear international standards. It will also examine challenges with coordinating protection functions and the limitations of conventional relays near IBRs, offering insights into addressing these issues.

OUTLINE FOR THE TUTORIAL:

1. Introduction

- Overview of renewable energy (RE) integration in India
- Key challenges in grid operations due to large-scale RE deployment

2. Impact of Inverter-Based Resources (IBRs)

- Characteristics of IBR fault currents
- Limitations of conventional protection systems near IBRs
- Variability in inverter controller designs and its impact on protection

3. Protection Challenges in Grid-IBR Interconnections

- Protection issues for transmission lines, transformers, and bus bars
- Ambiguities in interpretation of grid codes (IEGC-2023) and limitation of international standards (e.g., IEEE-2800)
- Influence of inverter owners on protection philosophies

4. Power Quality Challenges at the Point of Connection (POC)

- Voltage and current harmonics issues
- Implementation challenges with IEEE-519 standards

5. Reactive Power and Loading Challenges

- Shifting loading patterns in RE-dominated areas
- High reactive power demand during peak loads

- High voltage challenges during zero solar generation
- Impact of frequent switching of shunt reactors, capacitor banks, and transmission lines
- Depletion of STATCOM reserves

6. Real-World Case Studies from the Indian Power Sector

- Examples of misinterpreted grid codes leading to protection failures
- Role of STATCOMs in addressing grid challenges
- Insights into protection coordination beyond distance protection

7. Recommendations and Way Forward

- Need for clear international standards for Grid-IBR interconnections
- Strategies for adapting protection systems to RE integration
- Enhancing coordination between utilities and inverter owners

8. Conclusion

- Summary of challenges and solutions
- Key takeaways for transmission utilities

9. Q&A Session

- Open discussion with participants to address specific queries and challenges