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India SMART UTILITY Week 2025

Session : Foundational Blocks for Smart Grids

TOPIC: Estimation Of Most Probable Root Cause Using Digital Tools For Inverter Dominated Power Grid

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INTRODUCTION

Target to reduce Carbon emission by 2050

Increase in integration of Inverter Based Resources (IBRs) to the grid

Integration of IBRs to the grid results in operational challenges

- Inverter Protection Settings
- Limited Control Algorithms
- Lack of Coordination between IBRs and Grid Operators
- Fault Detection and Recovery

Problem Statement:
Requirement of adaptive control algorithms for IBRs to optimize the controller settings for complying to fault ride through (FRT) regulations during voltage disturbances

Low Voltage Ride Through (LVRT)

- To maintain grid stability, IBRs are required to stay connected to the grid during contingencies.
- Recent Grid Code Compliance mandates the IBRs to follow Low Voltage Ride Through (LVRT) characteristic during transient and short-term voltage sag.
- LVRT makes the IBRs to provide voltage support to the grid during voltage disturbances by delivering reactive power which is implemented in the inverter control scheme of the IBRs.

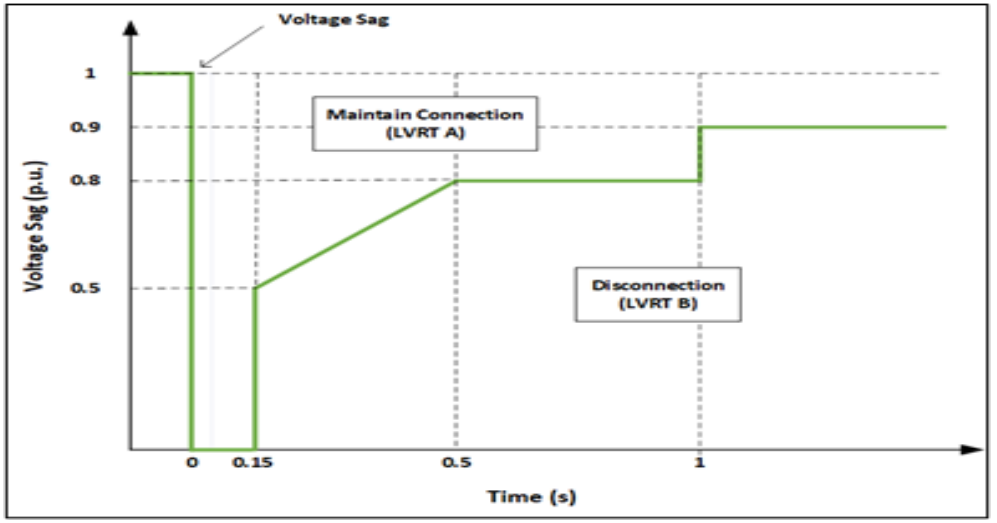

Fig. 1. LVRT Characteristic of Korean Grid

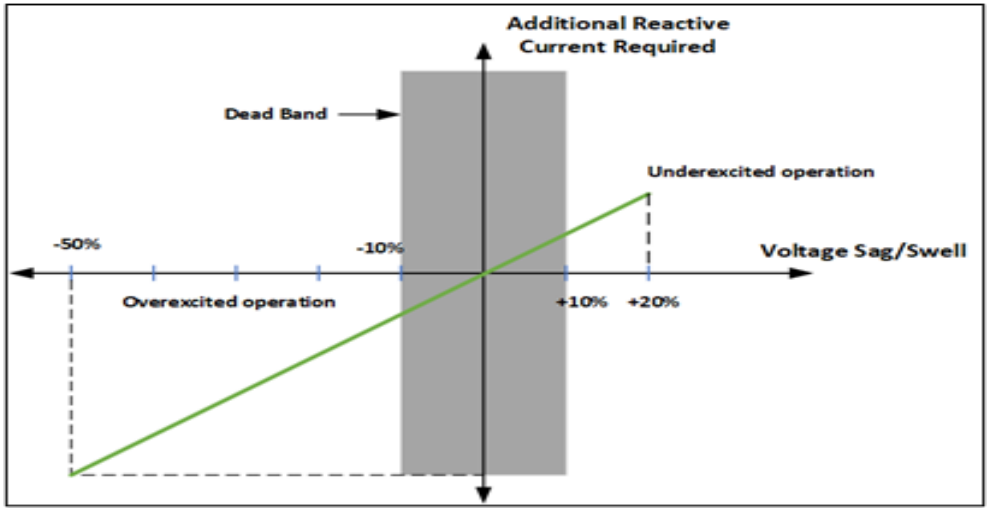

Fig. 2. Reactive Current Support Requirement During LVRT

GRID CODE COMPLIANCE FOR IBRS

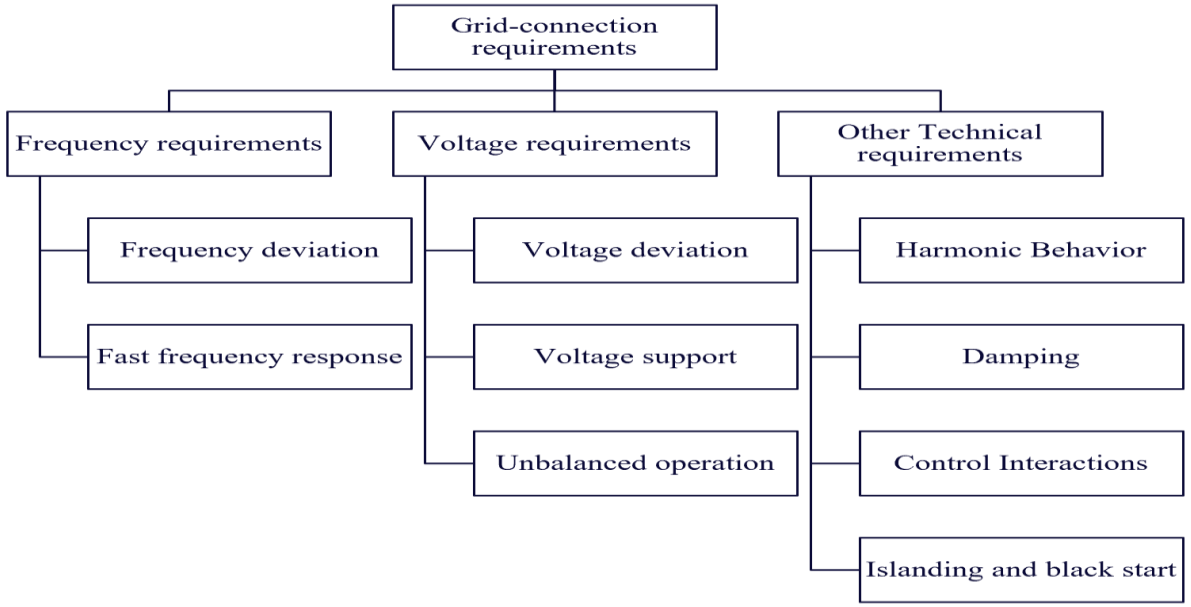

Fig. 3. Grid connection requirements for IBRs

- Frequency deviation range at the PoC - ±1%
- Voltage range at PoC – 0.9 pu to 1.1 pu
- Total Harmonic Distortion (THD) for voltage and current at PoC should not exceed 5%

- Adoption of Grid Codes ensures reliable and secured operation of current and future grid which will be dominated by IBR technologies
- Requirement of continuous improvements in the grid code compliance

Test System and Simulation Results

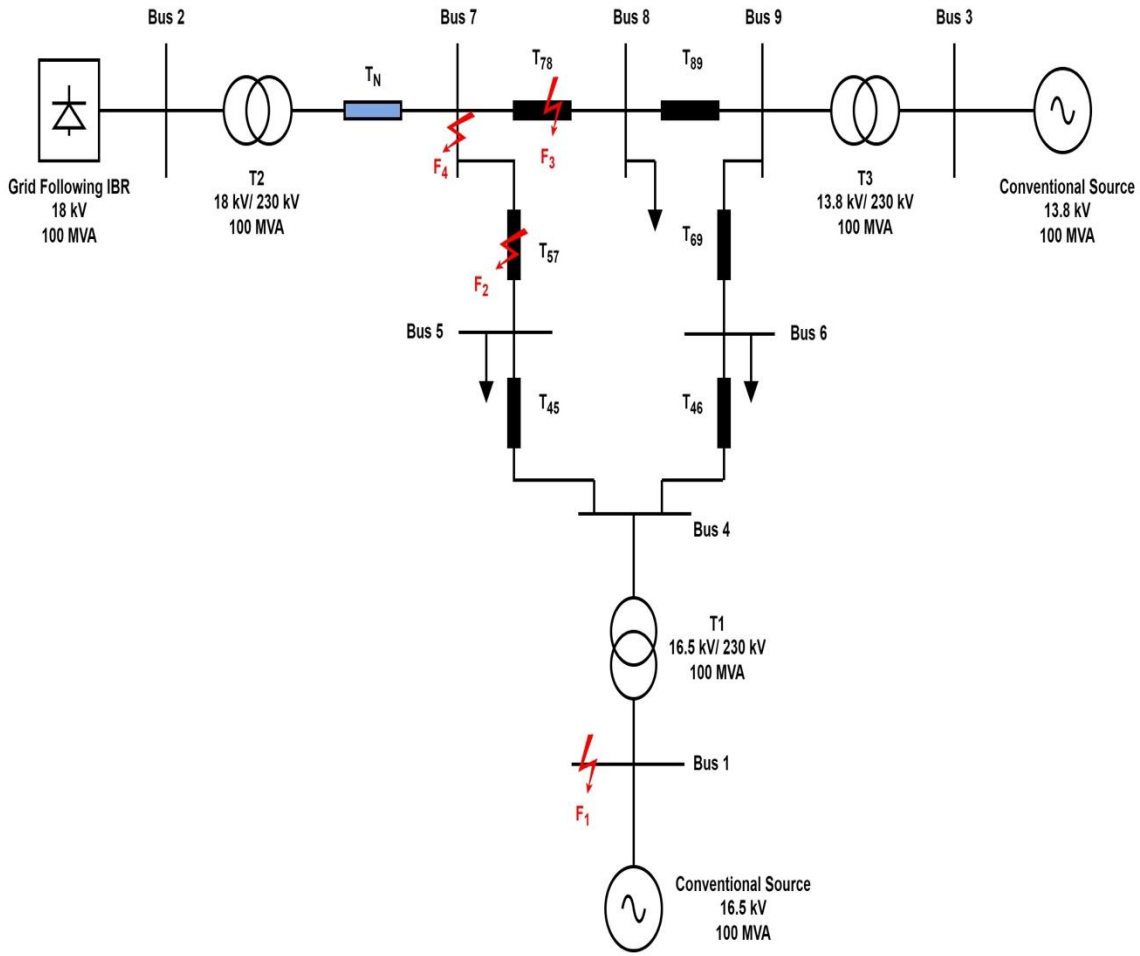

Fig. 4. Modified IEEE 9 Bus System

Two different scenarios are considered:

- *Scenario 1*: The parameters and ratings of lines and equipments of the standard IEEE 9 Bus System remains the same with only the Grid Following IBR being integrated at Bus 2
- *Scenario 2*: A new line T_N of length 10 km is inserted after the interconnecting transformer between buses 2 and 7 to realize the impact of electrical distance on the fault ride through performance of the grid following IBR

Simulation Results and Inferences

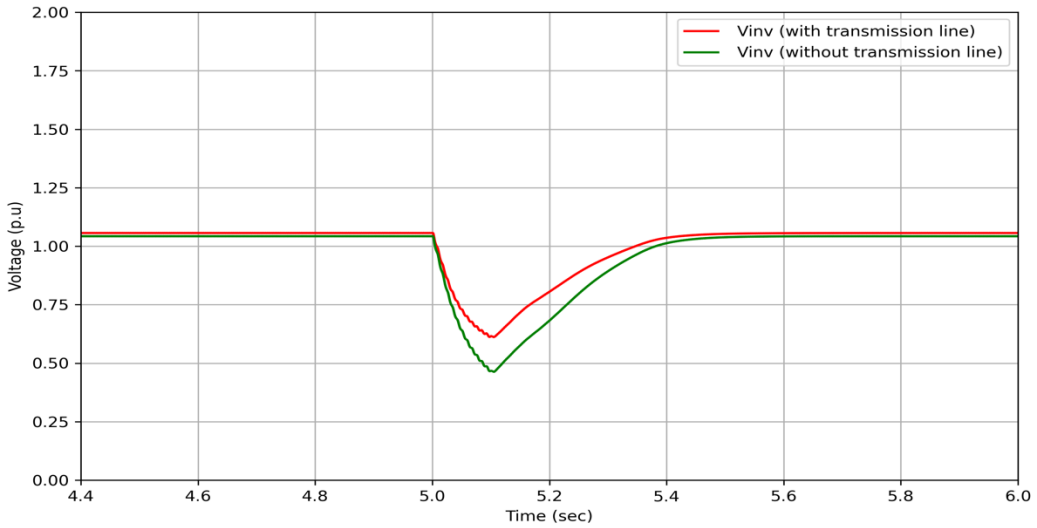

Fig. 5. Voltage at inverter terminal for ABG Fault at Bus 1

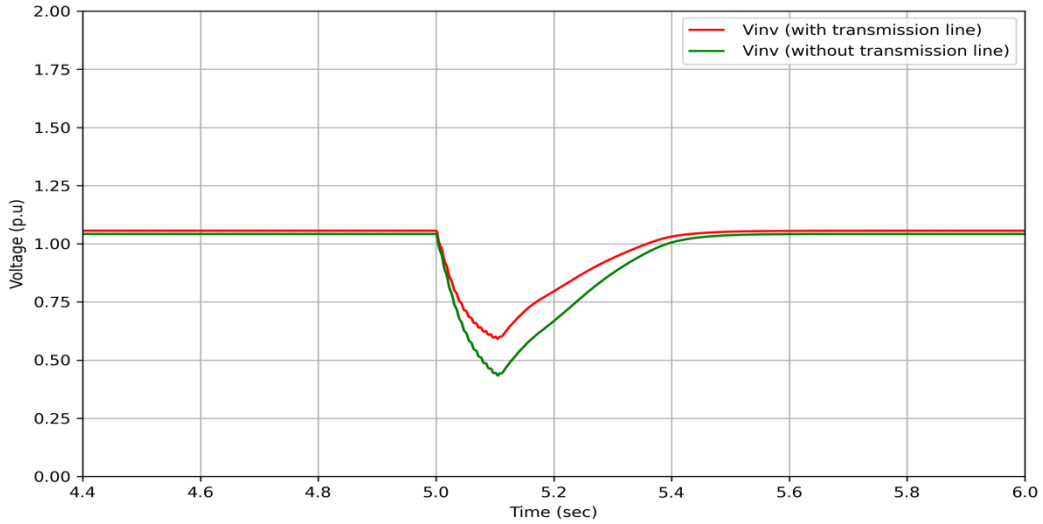

Fig. 6. Voltage at inverter terminal for ABG fault on the transmission line present between bus 5 and bus 7

- Presence of transmission line makes the IBR incapable of providing the required voltage support to the grid
- Sluggishness in the voltage dip in the presence of transmission line has led to introduction of time delay which may affect the ability of the inverter based resource to respond quickly to voltage sags during faults

Simulation Results and Inferences

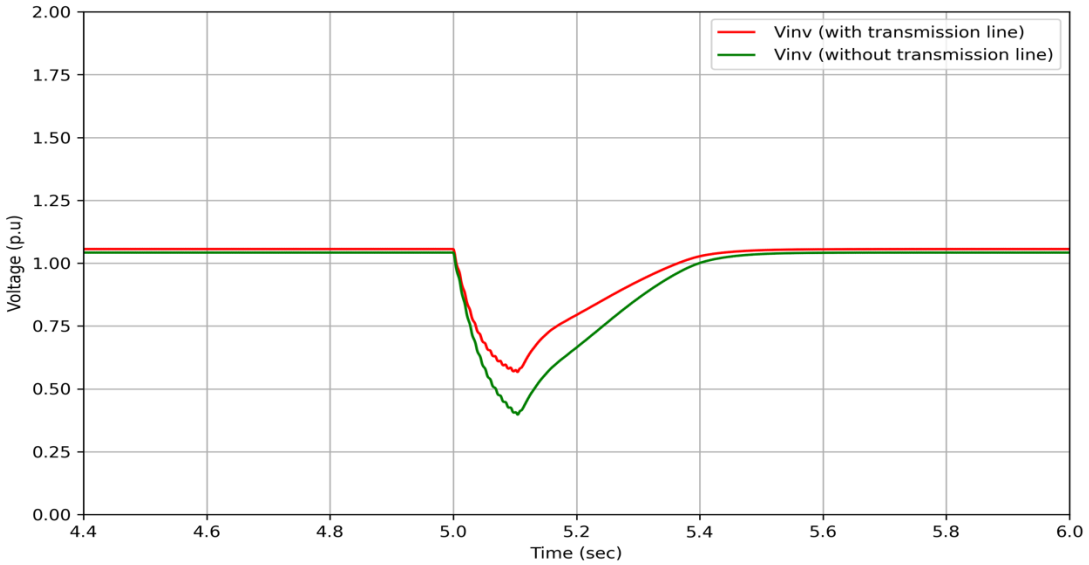

Fig. 7. Voltage at inverter terminal for ABG Fault on the transmission line present between bus 7 and bus 8

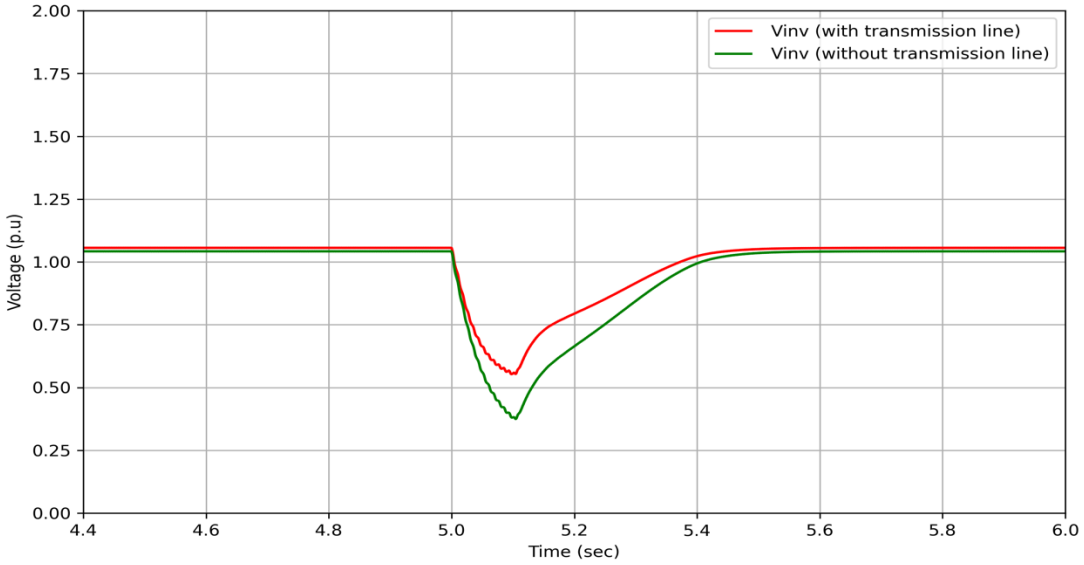

Fig. 8. Voltage at inverter terminal for ABG Fault at Bus 7

- Uncertainty in the inverter's response time in the presence of transmission line causes a deviation from the protection settings in legacy protection schemes, resulting in unreliable behavior of the protective equipment, affecting the ability of the inverter based resource to respond quickly to voltage sags during faults.

- Inverter may remain connected to the grid for a longer time duration which can result in damaging inverter components.

Conclusion and Future Scope

- LVRT response of IBRs defines the immunity of the renewable generation plants to voltage disturbances
- LVRT non-compliance by IBRs can lead to unpredictable scenarios in the grid making it more vulnerable to instability
- Need of adaptive LVRT settings for IBRs to adjust to the network topology available in the software like DERMS
- Accurate modelling and analysis of network topology and inverter controls in digital simulation tools for estimation of most probable root cause of the unpredictable responses by IBRs

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THANK YOU

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