Abstract
This work estimates the ground potential rise (GPR) of the multi-grounded neutral and shield wires in the joint transmission and distribution configuration, and compares the safety impacts of transmission line faults and distribution line faults. Basic procedure governing the GPR mechanism is illustrated. A multi-phase EMTP based computer tool was used for the simulation.

Objectives
Fig. 1 shows the conductor positions and schematic diagram of transmission and distribution configuration. The neutral wire is insulated from the tower and grounded with dedicated ground rods. The shield wire contacts the tower’s body, which provides the grounding of this wire. The objective is to investigate the safety impact of a parallel circuit in the same tower, by quantifying the GPRs of the shield and neutral wires.

Analytical methodology
Step 1: Get the fault characteristics (type, location, fault current)

Step 2: Convert the induced voltages into current sources

Step 3: Identify the current injection locations and amounts

Step 4: The product of equivalent impedance and injected current gives the GPR of the current injected node

Step 5: Location of maximum GPRs in multi-grounded wire

Results

Basic data
• 477 Pelican (D-line); 288 Partridge (T-line)
• 3/0 Pigeon (Neutral); 5/8” Steel (Shield)
• 15 ohm neutral and shield grounding resistance
• 75 m interval between two grounding nodes
• 0.15 ohm substation grounding resistance
• 4 km parallel section between D-line and T-line
• 12.5 kA T-line and 2.5 kA D-line fault currents

The GPR profiles of the neutral and shield wires
• Line-to-shield fault occurs in the parallel section
• Neutral GPR (NGPR) is maximum at parallel end
• Shield GPR (SGPR) is maximum at fault location
• When bonded, the GPR of neutral wire increases to the level of GPR of shield wire in the parallel exposure section

The GPRs of different configurations
• The D-line with or without neutral wire does not affect the GPR of the shield wire
• Bonding of neutral and shield wires increases the NGPR and reduces the SGPR
• The SGPR is significantly higher than NGPR for the unbounded configuration
• The D-line has no adverse effect on T-line GPR

Comparison of GPRs for T-line and D-line faults
• The NGPR is significantly higher for a T-line fault than that for a D-line fault, in all configurations
• The SGPR is negligible for a D-line fault compared to that for a T-line fault (Fig. 10)

Effect of parallel length between D-line and T-line
• The NGPR increases with the parallel exposure length in an unbounded circuit
• In the bonded circuit, the shield wire impedance and fault current determine the GPR and are unaffected by the parallel length. So, the NGPR does not increase with parallel length

Conclusions
• If the D-line is built under the T-line, it does not increase the GPR level of T-line system. Also the presence of neutral wire has no negative impact.
• The NGPR values for D-line increase significantly due to the large fault currents of T-line faults
• The bonding of shield wire with neutral wire helps to reduce the SGPR, but worsens the NGPR, compared to single circuit configuration
• The GPR of the parallel circuit will increase with the increase in parallel length only until a certain length is reached

Fig. 1. Conductor positions and system configuration
Fig. 2. Single-phase fault
Fig. 3. Voltage source to current source conversion
Fig. 4. Current injection locations in multi-grounded wire
Fig. 5. Location of maximum GPRs in multi-grounded wire
Fig. 6. The GPR of neutral wire (T-line fault)
Fig. 7. The GPR of shield wire (T-line fault)
Fig. 8. The GPRs for different configurations (T-line fault)
Fig. 9. The NGPR for T-line fault and D-line fault
Fig. 10. The SGPR for T-line fault and D-line fault
Fig. 11. The GPRs for different parallel lengths (T-line fault)