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An Analytical Study on the Influence of Cable Parameters on Screen Voltage and Fault Current in EHV Cables

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ABSTRACT
Extra High Voltage (EHV) power cables are a critical component in modern power transmission systems. One of the important considerations in the design and protection of these cables is the screen-to-earth voltage and the magnitude of fault currents during electrical faults. This paper presents an analytical study on the effect of cable parameters—resistance (R), inductance (L), and capacitance (C)—on screen voltage and fault current in 132 kV solid insulated EHV cables. Using MATLAB simulations and theoretical formulations, this study investigates how varying R, L, and C values per kilometer affect screen voltage during faults. Screen voltage waveforms are generated for different parameter sets using MATLAB. Results indicate that both screen voltage and fault current are sensitive to cable impedance, and optimal parameter selection can significantly reduce transient voltages and improve system protection.

INTRODUCTION

The expansion of electrical power systems and the increasing demand for uninterrupted power supply have led to the widespread use of EHV underground cables, especially in urban and environmentally sensitive areas. These cables must be designed not only for efficient power transmission but also for safe operation under fault conditions. One such safety consideration is the screen-to-earth voltage, which develops across the cable's metallic screen during faults. This voltage can lead to insulation stress and potential failure if not properly accounted for.

The magnitude of fault current and the resulting screen voltage are directly influenced by the cable's electrical parameters—resistance (R), inductance (L), and capacitance (C) per unit length. Understanding the interaction of these parameters is essential for effective grounding, protection system design, and insulation coordination.

This paper focuses on analyzing how different combinations of R, L, and C values influence the screen voltage and fault current in a 132 kV EHV cable.

2. Objectives

- To analyze the influence of R, L, and C parameters on screen voltage in EHV cables.
- To evaluate the effect of cable impedance on fault current magnitude.
- To simulate and plot screen voltage waveforms for different parameter sets using MATLAB.
- To recommend optimal parameter ranges for minimizing screen voltage and fault current.

3. Methodology

The methodology includes both analytical calculations and MATLAB-based simulations:

3.1 System Model

- Cable voltage: 132 kV (line-to-line)
- Frequency: 50 Hz

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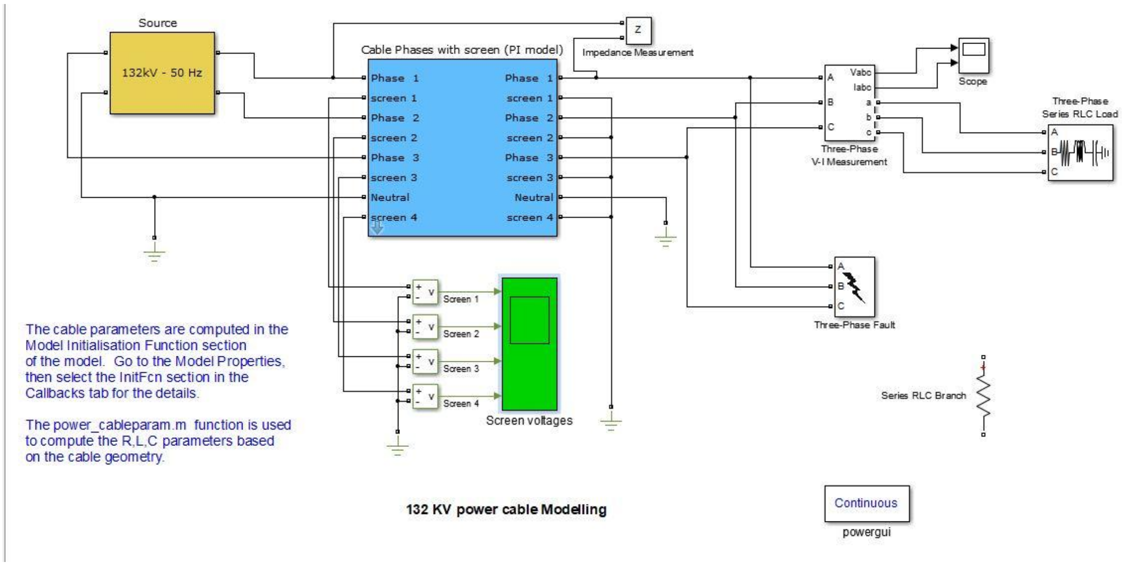
- Fault current range: 2000 A to 3000 A (symmetrical fault)
- Three parameter sets were considered:



Case	R (Ω/km)	L (mH/km)	C (μF/km)
A	0.05	0.3	0.05
B	0.10	1.0	0.12
C	0.15	1.5	0.30

3.2 Screen Voltage Calculation

The screen voltage was computed using the magnitude of the cable impedance:

The screen voltage was computed using the magnitude of the cable impedance:

Z = √(R^2 + (ωL)^2)

V_screen = I_fault × |Z|

Where ω = 2πf and f = 50 Hz.

3.3 MATLAB Simulation

A time-domain simulation was carried out using MATLAB for a sinusoidal fault current. The screen voltage waveform was plotted for each parameter set:

- Time span: 0 to 40 ms
- Time step: 10 μs
- Fault current: 3000 A peak sinusoidal (symmetrical)

4. Results and Discussion

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4.1 Tabulated Results

R (Ω/km)	L (mH/km)	C (μF/km)	2000 A (V)	2250 A (V)	2500 A (V)	2750 A (V)	3000 A (V)
0.05	0.3	0.05	213.38	240.05	266.72	293.40	320.07
0.10	1.0	0.12	659.38	741.80	824.23	906.65	989.07
0.15	1.5	0.30	989.07	1112.71	1236.34	1359.97	1483.61

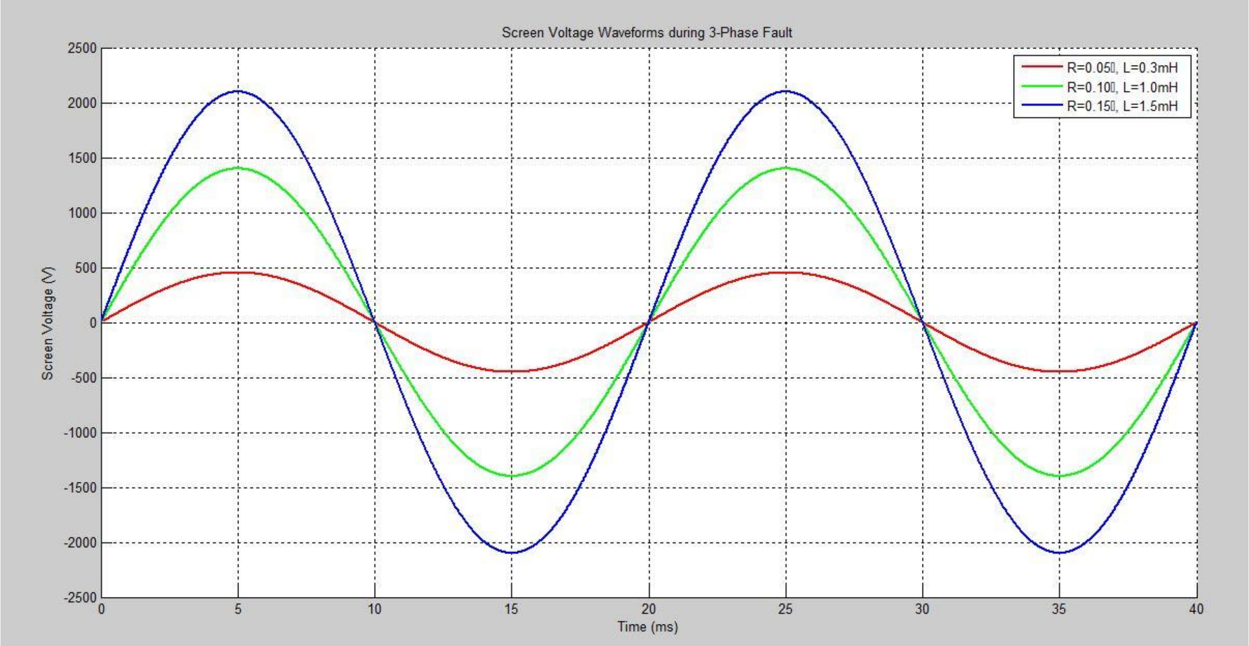
4.2 Waveform Analysis

Screen voltage waveforms for each case were plotted using MATLAB. It was observed:

- Case A (low R and L): Lower peak screen voltage and faster rise.
- Case B (moderate R and L): Higher screen voltage with slower rise.
- Case C (high R and L): Maximum screen voltage among all, indicating higher insulation stress.

MATLAB Plot Code (Excerpt):

```
If_peak = 3000 * sqrt(2);
omega = 2 * pi * 50;
t = 0:1e-5:0.04;
If = If_peak * sin(omega * t);
Z = sqrt(R^2 + (omega*L)^2);
V_screen = Z * If;
plot(t*1000, V_screen);
```



5. Conclusion

This study demonstrates the critical influence of cable parameters on screen voltage and fault current in EHV systems. Increasing resistance and inductance values lead to higher screen voltages and reduced fault currents. However, excessively high screen voltage can stress cable insulation, potentially leading to failure. Therefore, an optimal balance must be achieved based on system protection, thermal limits, and insulation coordination.

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Key Findings:

- Screen voltage increases with both R and L.
- Lower R and L reduce screen voltage but allow higher fault currents.
- Capacitance plays a minor role during short-term faults but impacts transient and surge behavior.

6. Recommendations

- Adopt cable parameters with moderate resistance and inductance (e.g., R = 0.10 Ω/km, L = 1.0 mH/km) to balance fault current and screen voltage.
- Implement cross-bonded or single-point earthing to manage screen potential.
- For critical installations, simulate screen behavior under different grounding and parameter configurations using MATLAB/Simulink.
- Extend future work to include surge analysis and thermal modeling under fault conditions.

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