# Quasielectrostatic Induction on Stationary Vehicles under High Voltage Power Lines

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**Introduction**: Quasielectrostatic effects from power lines induce voltages on nearby metallic objects. A person standing on the ground becomes a path for current if they touch the surface of the object. Standards require that power lines be high enough in the air to limit this current to 5 mA (below the threshold for involuntary muscle contraction). An existing method for implementing this requirement in power line design involves empirical data and mathematical and geometric simplifications.

**Study Objectives**:
1. Use COMSOL to simulate the case of a large vehicle under a high voltage transmission line (see Figure 1). Use the results to evaluate the accuracy of the existing method and determine if assumptions inherent in the existing method's simplifications are reasonable.
2. Perform parametric sweeps of study parameters and identify the sensitivity of results to those parameters.
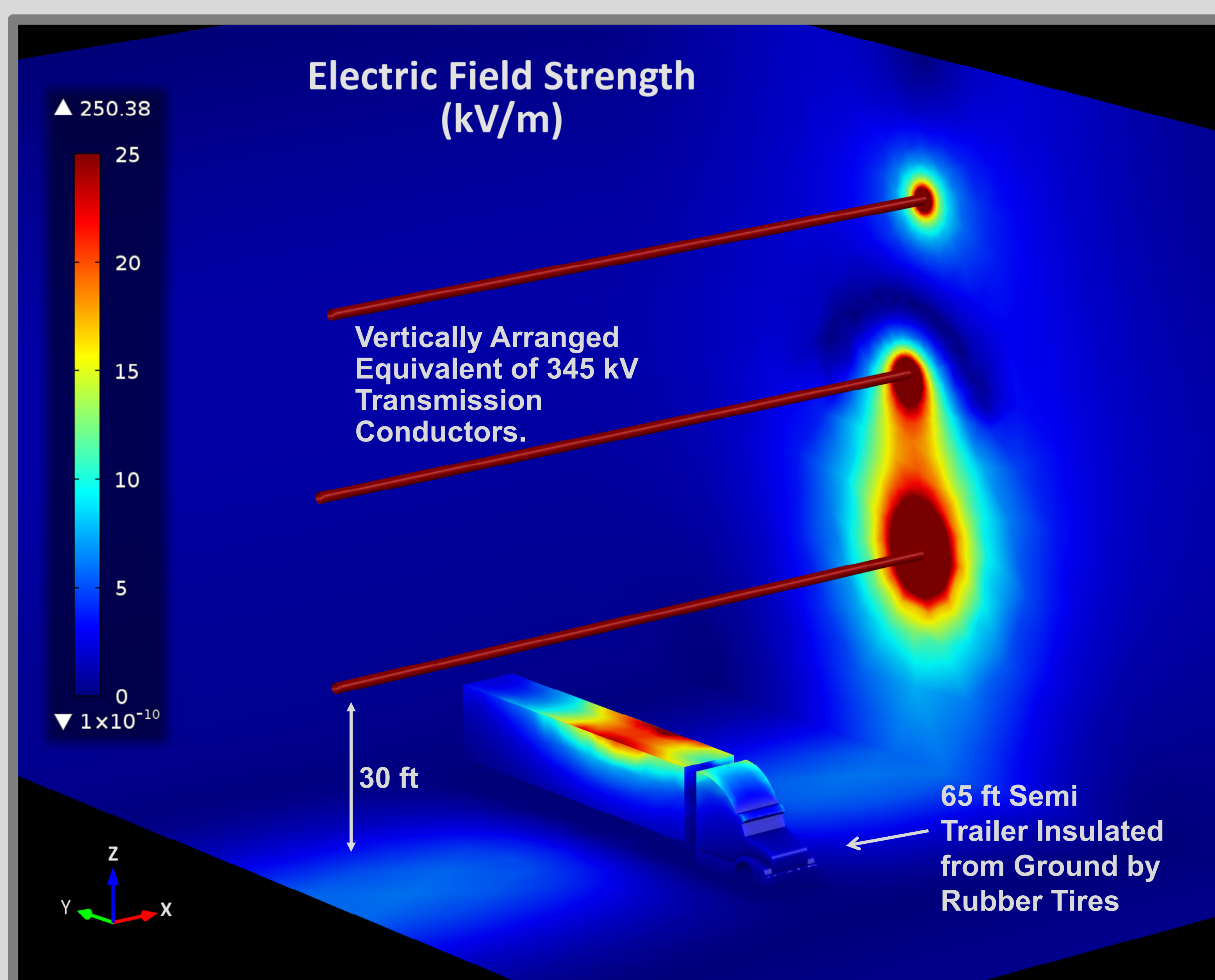
**Results for Objective 1**: Simulations were performed for the three geometric cases in Figure 2. The quasielectrostatic induced currents calculated with existing methods, COMSOL, and a non finite element analysis program are listed in Table 2.
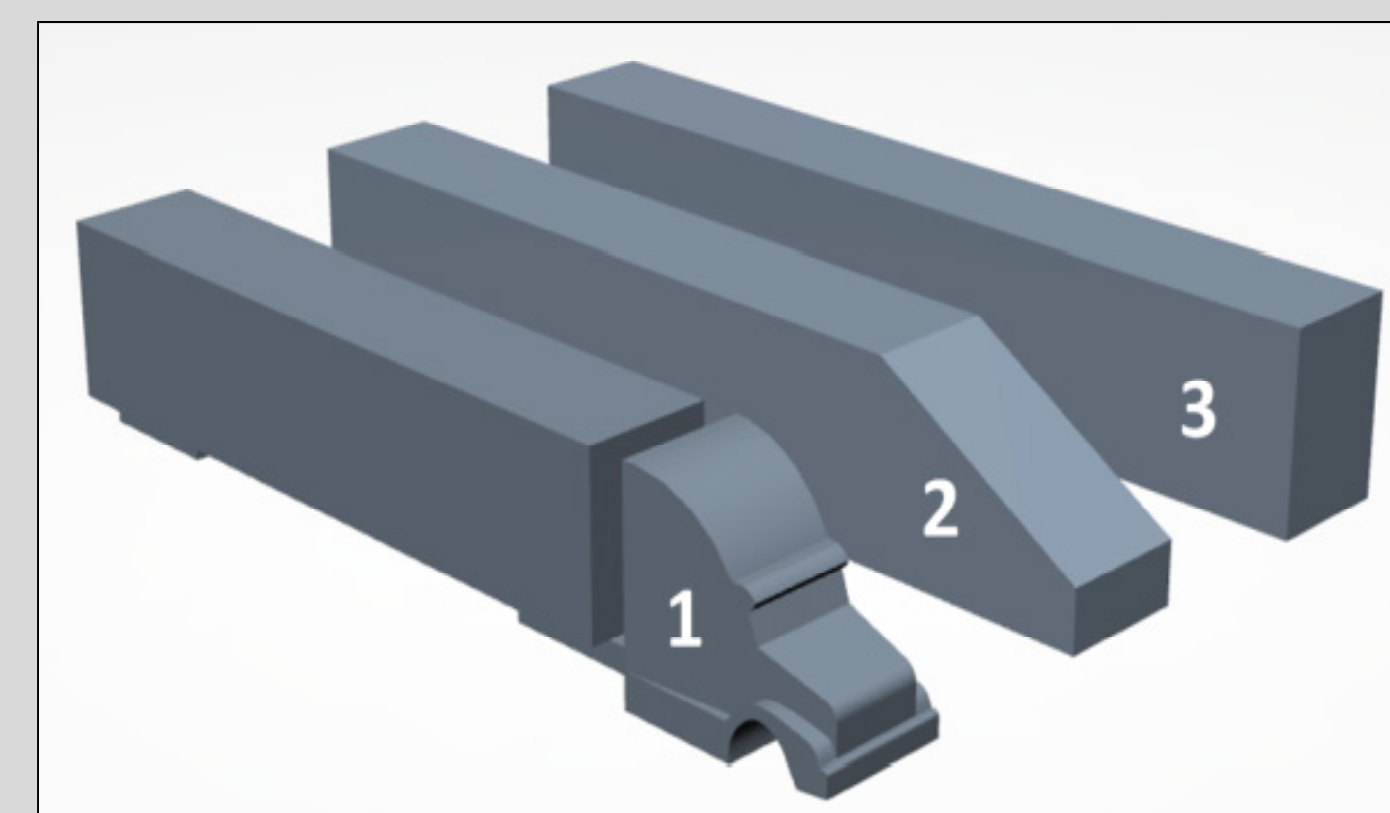


**Figure 2**. Vehicle Cases

| Approach | Short Circuit Current | | |
|---|---|---|---|
| | Truck 1 | Truck 2 | Truck 3 |
| Semi-empirical | n/a | n/a | 4.2 mA |
| COMSOL | 3.8 mA | 4.1 mA | 4.2 mA |
| Non FEA Software | n/a | 4.1 mA | 4.2 mA |

**Table 2**. Results

**Results for Objective 2**: Figure 3 shows vehicle short circuit current results for parametric sweeps of vehicle length, vehicle position (Y axis), conductor height, and human body resistance.
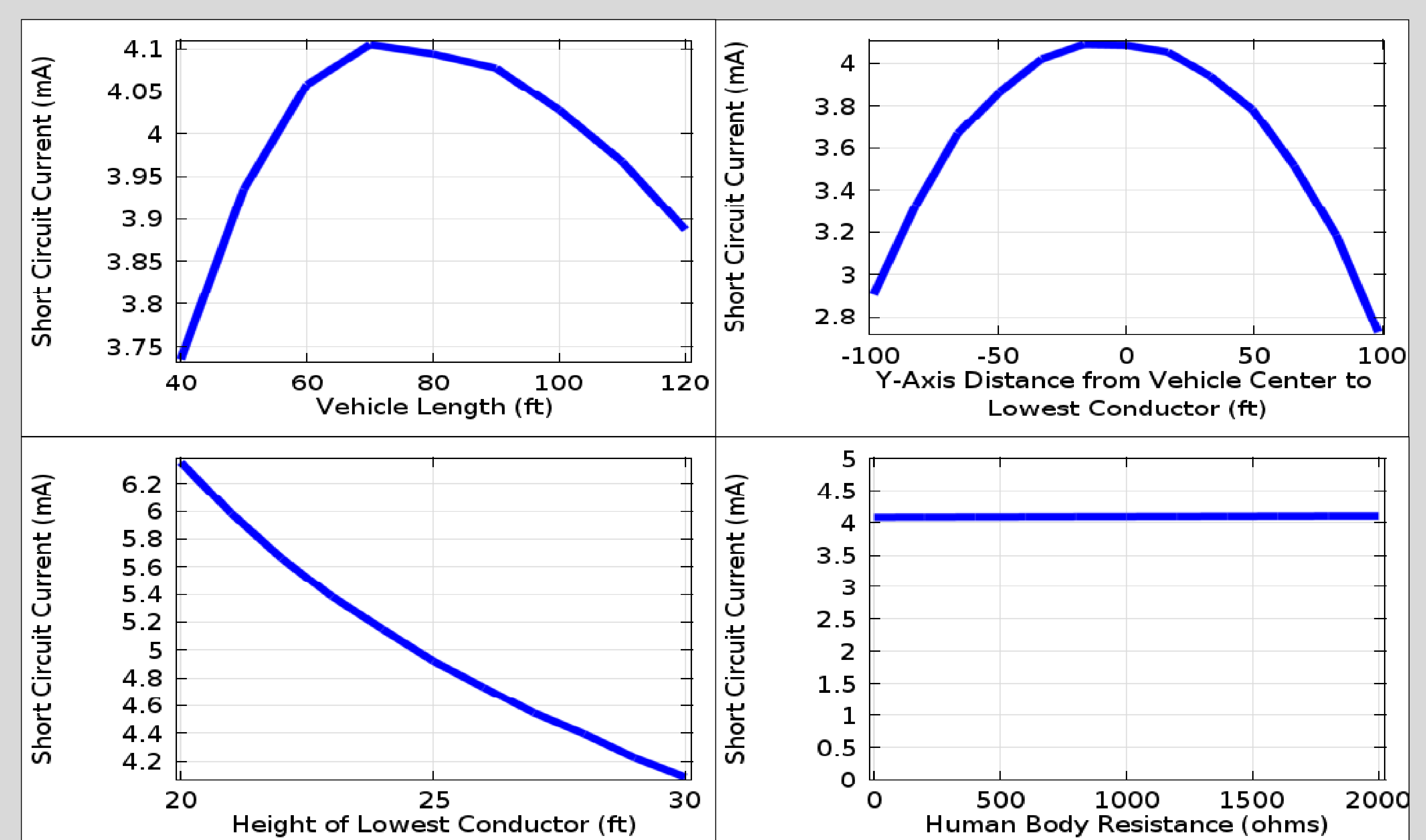


**Figure 1**. System Model and Electric Field Results



**Figure 3**. Parametric Sweep Results

**Conclusions**:
- Geometric simplifications and empirical data of existing analysis methods give reasonably accurate results, biased appropriately on the side of safety. The detailed COMSOL model with a high resolution mesh produced a short circuit current result that was about 10% lower than the existing method. Future work will determine if different transmission line configurations have similar results.
- The current delivered through a person who touches the vehicle is essentially independent of resistance in the typical range of the human body.
- The largest vehicle will not necessarily produce the worst case result.

**Computational Methods**: Power system frequency in the U.S. is 60 Hz. The charge relaxation times of earth and metallic objects in the model are much lower than the period of the power line voltages and currents. Therefore, the system can be solved using the Electric Currents interface of COMSOL. Governing equations are listed in Table 1.

| Equation | Summary |
|---|---|
| $\boldsymbol{E} = -\nabla \boldsymbol{V}$ | Relationship between electric potential and electric fields |
| $\nabla \cdot \boldsymbol{E} = \dfrac{\rho}{\varepsilon_0}$ | Gauss' Law: Electric flux through a surface is proportional to the enclosed charge |
| $\mathbf{n} \cdot (\varepsilon_0 \boldsymbol{E^a} - \varepsilon_0 \boldsymbol{E^b}) = \sigma_s$ | Relationship between surface charge density and electric at the surface boundaries |
| $\nabla \cdot \boldsymbol{J} = -\dfrac{\partial \rho}{\partial t}$ | Law of conservation of charge: Current in or out of a volume is equal to the rate of change of charge |
| $\boldsymbol{J} = \sigma \boldsymbol{E} + j\omega \boldsymbol{D} + \boldsymbol{J_e}$ | Equation for current density given a steady-state frequency domain problem |

**Table 1**. Governing Equations

**References**:
1. *National Electrical Safety Code C2-2012*, pp. 92-93. Institute of Electrical and Electronic Engineers, Inc., New York, NY (2011)
2. *EPRI AC Transmission Line Reference Book: 200 KV and Above, Third Edition*, pp. 7.34-7.42. EPRI, Palo Alto, CA (2005)
3. Haus, Hermann A., and James R. Melcher, *Electromagnetic Fields and Energy*, (Massachusetts Institute of Technology: MIT OpenCourseWare). http://ocw.mit.edu (accessed September 20, 2011). License: Creative Commons Attribution-NonCommercial-Share Alike.