Measurement and modeling of long multi-conductor shielded cable based on fast vector fitting algorithm

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Abstract

The transmission lines need to be modeled accurately to predict the voltage reflections and EMI levels of the converter system. In this paper, a transmission line model based on fast vector fitting algorithm is proposed. At high frequencies, the parasitic capacitance of the cable conductor causes the cable impedance to resonate. Due to skin effect and proximity effect, the cable parameters change with frequency. The frequency equivalent model is used to characterize the effect of cable parameters varying with frequency. When cable is open-circuited and short-circuited, and the high-frequency impedance characteristics of the cable are measured using an impedance analyzer. Through the relationship between measured impedance and model impedance, the impedance of the model is obtained. The impedance is fitted by fast vector fitting algorithm. Finally, the feasibility and validity of the proposed model are verified by comparing the simulation and measurement results in the frequency and time domains.

Introduction

With the development of power electronic converter, variable frequency speed regulation system is widely used in new energy vehicles, elevators, rail transit, industry and other fields. When the converter is directly interconnected with the motor through a long transmission line, mismatch between the cable impedance and the motor impedance, cause overvoltage impact. In the range of 150kHz to 30MHz, the magnitudes of voltage and current signals in the transmission line vary spatially. Under AC excitation, the cables show skin effect, leading to significant deviations in amplitude and phase.

In this case, according to the transmission line theory, the cable high-frequency distribution model is established on the traditional transmission line model. The impedance analyzer is used to obtain the short-circuit and open circuit impedance of the cable through appropriate measurement methods. After analysis, the relationship between the measured impedance and the model parameters is obtained. The impedance in the model is modeled based on the fast vector fitting algorithm.

High frequency model of multiconductor power cable

The Figure 1 is a circuit model of a uniform transmission line. The excitation source voltage is u(t), u(x, t) and i(x, t), which represent the voltage and current at a point x in the cable respectively. Z_S is the internal impedance of the excitation source and Z_L is the load impedance.
Figure 2 is a cross-sectional view of four core power shield wire. There are five transmission paths in the cable, including U, V and W three-phase wires, P ground wire and S shield wire. According to the derivation in the previous section, the low-frequency circuit of the four-conductor shielded wire is shown in Figure 3. M represents the mutual inductance between conductors, R and L represent the impedance of the core wire itself, and C represents the distributed capacitance between conductors.

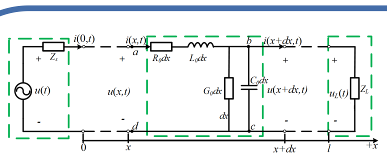


Figure 1. The Low frequency circuit model of uniform transmission line

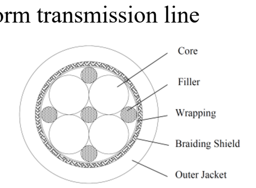


Figure 2. Cross section of four core shielded wire

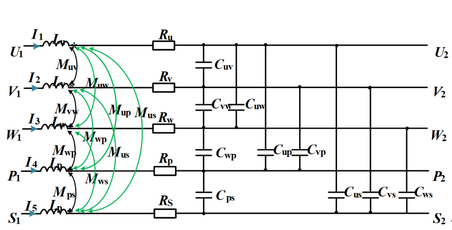
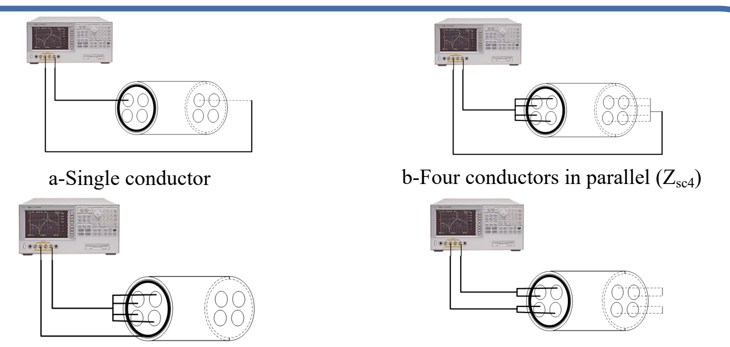


Figure 3. Laminated Structures

Frequency variation effect of cable parameters and Multi conductor cable impedance measurement

Using the measurement method in the figure below, the high frequency impedance of the cable can be modeled. Using figures 7(a)(b), the impedance of the conductor itself and the coupling impedance between the conductors can be obtained by measuring the impedance of a single-core wire and the parallel impedance of a four-core wire. With figures 7(c)(d), the impedance between conductors and conductors and between conductors and shields can be measured separately.Based on the cable model circuit topology, the model impedance can be calculated from the impedance measured by the impedance analyzer.

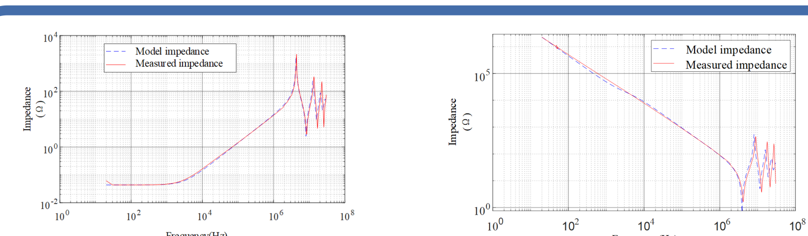


a-Single conductor b-Four conductors in parallel (Z_{sc4})

c-Impedance between conductor and shield (Z_{cs}) d-Impedance between conductors (Z_{cc})

Figure 7. Cable Impedance Measurement

With the fast vector fitting algorithm, the impedance can be fitted very accurately in the frequency domain. As shown in figure 8(a)(b), the open circuit impedance and short circuit impedance of the circuit model are consistent with the real measurement in the range of 20Hz to 30MHz.
Figure 10 shows the comparison between the measured motor side voltage and the simulation data. The simulation results of overvoltage are in good agreement with the measured data and have good accuracy.



a-Short Circuit Impedance Fitting b-Open Circuit Impedance Fitting

Figure 8. Cable high frequency model

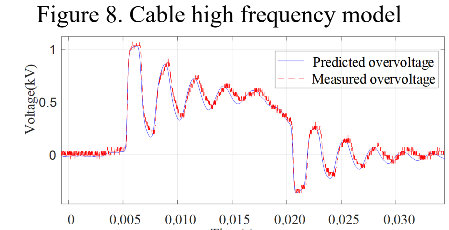


Figure10. overvoltage simulation

Conclusion

In this paper, broadband model for transmission lines is proposed, which not only shows the frequency change effect of cable inductance and resistance, but also fully expresses the parasitic capacitance of the core. Using four test methods, the cable impedance was tested by impedance analyzer. A fast vector fitting algorithm is used, which allows the model to be fitted and imported into the simulation software. The feasibility and validity of the proposed model is verified in simulation software by time domain.