Advanced Science and Technology Letters
Vol.47 (Electrical Engineering 2014), pp.290-294
http://dx.doi.org/10.14257/astl.2014.47.66

Analysis of the Effects of Temperature on the Electrical Parameters of Long Distance Cables

Seung-Jae Ryu[1], Kyung-Eun Kim[1], Byeong-Woo Kim[2]

[1] Graduate School of Electrical Engineering, University of Ulsan, Ulsan, Korea
rsj121@naver.com, gyg509@naver.com
[2] Dept. of Electrical Engineering, University of Ulsan, Ulsan, Korea
bywokim@ulsan.ac.kr

Abstract. This study examines conductive noise in long distance cables in a subsea environment. The conductive noise was caused by impedance mismatch between cables and appeared in the form of transient voltages. In particular, it is important to analyze the characteristics of transient voltages for different subsea temperature changes. To analyze the transient voltages, the effects of L, R, and C for different temperature changes were investigated. Among the analysis factors of L, R, and C, the capacitance C was identified as the factor that influences conductive noise the most. As a result, a design guideline was proposed in this study to reduce the conductive noise that occurs in the subsea-cable design stage.

Keywords: Subsea, Long cable, Inverter, Conductive noise, FEM (Finite Element Model)

1 Introduction

Recently, the use of cables for transmitting electrical energy has gradually increased in various fields. Accordingly, research on designing a cable that reduces electrical power loss at offshore plants for obtaining ocean resources is being actively conducted.

Offshore plant systems for operating induction motors consist of a three-phase power source, inverter, and long distance umbilical cables [1]. Furthermore, to smoothly control the speed of the induction motors, the PWM (pulse-width modulation) method is applied using IGBTs (insulated gate bipolar transistors), which facilitates high-speed switching [2]. However, the transient voltages generated by high-speed switching greatly affect the dielectric strength, life, and reliability of induction motors [3].

Conventional studies focus mainly on transient voltage analysis through changes in drive frequency and voltage rise time [2]. In addition, the transient voltage phenomenon was analyzed modeling the changes in the cable length using equivalent circuits. The results indicated that the transient voltage increases as voltage rise time decreases [3]. However, because few studies on the analysis of electrical parameters

ISSN: 2287-1233 ASTL

considering subsea temperature changes have been performed, one must analyze and design cables while considering temperature.

Consequently, in this study, electrical parameters were analyzed using FEM analysis of subsea cables for different temperature changes. Based on our results, the effects of temperature changes on both the electrical parameters of the cables and the conducted noise were analyzed.

2 Effects of Temperature on Capacitance

As shown by Eq. (1), the electrical characteristics of cables are expressed by the impedance (Z), and, as the cable length increases, the resistance (R) increases. However, the inductance (X_L) can be ignored because it shows smaller changes than the resistance. Furthermore, in the case of capacitance (X_C), as cable length increases, the mutual capacitance (C_m) between the three-phase cables has a greater influence on the overall impedance (Z). Moreover, as the temperature increases, the distance between the conductors (and, therefore, the mutual capacitance (C_m)) decreases. Consequently, the cable's capacitance (X_c) has a large influence on the occurrence of conductive noise. The relationship between the capacitance and temperature is shown in Eq. (4) [4].

$$Z = R + j(X_L + X_C). \tag{1}$$

$$X_C = \frac{1}{2\pi f C}. \tag{2}$$

$$C = C_m + C_i + C_g. \tag{3}$$

$$C = \frac{1}{63 \times (2.79 + 0.0158\, T) \times 10^{-5}}. \tag{4}$$

Here, T is the temperature (℃) and C is the capacitance (pF). Given that the capacitance for different temperature changes in a vacuum is considered in this study, the capacitance value is the same when the pressure is 0. When the capacitance increases owing to significant changes in the cable, the reactance and conductive noise will decrease.

3 Simulation and Results

Fig. 1 illustrates the finite element method (FEM) analysis process on the three-phase four-wire cable, and the resulting data. In this study, the simulation focused on the derivation of the R and C parameters as a function of temperature. Results showed that the structure of the three-phase cable significantly influences the reactance.

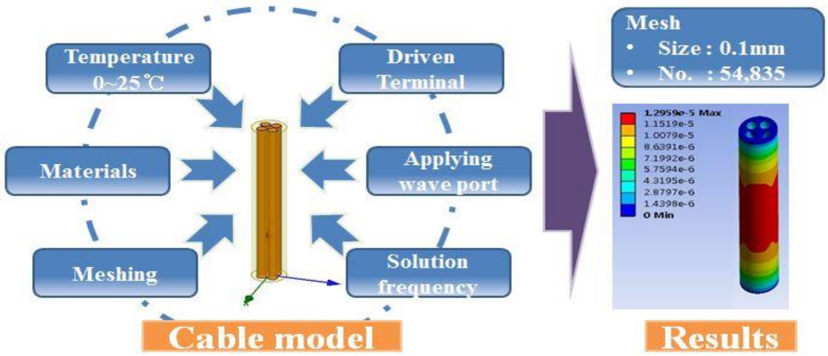

Fig. 1. Process of FEM analysis

Fig. 2 shows the changes in impedance versus temperature. As shown in Fig. 2, the impedance does not change with temperature. This is because the changes in resistance and reactance are inversely proportional to each other. In other words, if the resistance increases, the reactance decreases, and vice versa. Fig. 3 shows the reactance versus temperature. The reactance is the sum of the inductance (L) and capacitance (C). If the reactance is negative, it indicates that the reactance is capacitive. This means that as the absolute value of the capacitive reactance increases, the value of capacitance also increases.

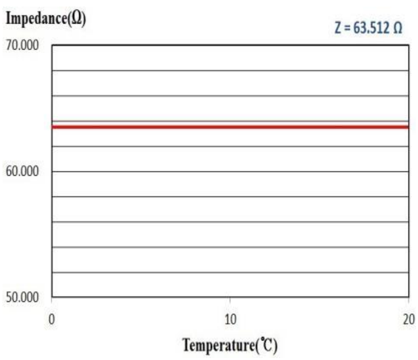

Fig. 2. Impedance variation in cable

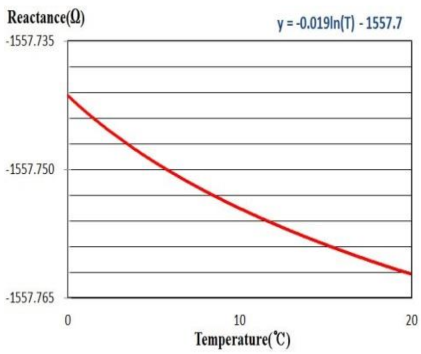

Fig. 3. Reactance variation in cable

Figs. 4 and 5 show the resistance and the capacitance of the cable versus temperature, respectively. As shown in Figs. 4 and 5, as the temperature increases, the capacitance decreases. Therefore, it can be inferred that the cable shape changes as the volume expands because of increased temperatures. Therefore, it was confirmed that reactance part plays a major role in the capacitance increase or decrease.

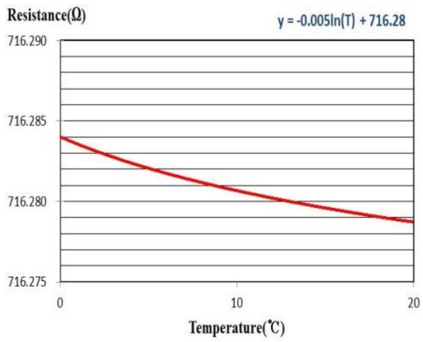

Fig. 4. Resistance variation in cable

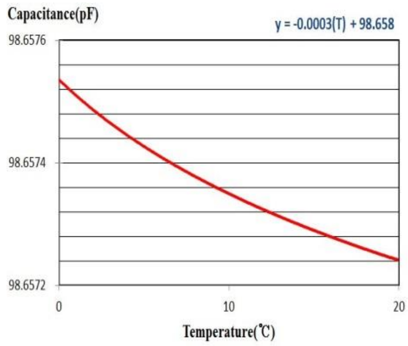

Fig. 5. Capacitance variation in cable

4 Conclusion

In this study, the electrical parameters of long distance cables as a function of temperature were analyzed. The results of deriving the parameters verified that both resistance and capacitance decreased as the temperature increased. The resistance and the capacitance appeared to be affected by the change in the distance between conductors that occur at increased temperatures. Because the conductive noise of the induction motor can be estimated by identifying the cable resistance and capacitance in advance, based on these findings, a more reliable electrical drive system (compared to conventional systems) is expected to be developed.

For a future study, the conducted noise due to an increase in the cable length with varying temperature will be analyzed as well as the capacitance change due to the rising time of noise, and the noise reduction effect will be studied.

Acknowledgments. This research was supported by the MSIP(Ministry of Science, ICT&Future Planning), Korea, under the C-ITRC(Convergence Information Technology Research Center) support program (NIPA-2013-H0401-13-1008) supervised by the NIPA(National IT Industry Promotion Agency).

References

1. Kwon, H-J., Kim, B-W.: Design of Long Distance Cable and Filter considering the Subsea Environment. J. Korea Acad.-Ind. Coop. Soc. 14(10), pp. 510--5114 (2013)
2. Kil, G-S., Ryu, K-S., Park, D-W., Cho, Y-J., Cheon, S-G., Choi, S-Y.: Measurement and Analysis of Transient Voltage for an Inverter-fed Induction Motor. Korean Soc. Railw. 10(6), pp. 650--654 (2007)
3. Han, H-S., Song, J-H., Ahn, H-S.: The Correlation Study of Factors which effect on Insulation Reliability of Inverter Motor. EESRI (Electrical Engineering and Science Research Institute), pp. 18--20 (2008)

4. Aida, K., Aiki., M.: Submarine Coaxial Cable Pressure Characteristics, IEEE Trans. Commun. 26(2), pp. 246--253 (1978)
5. McCall, D.W.: The Determination of Pressure Coefficients of Capacitance for Certain Geometries. (1955)
6. Skibinski, G., Tallam, R., Reese, R., Buchholz, B., Lukaszewski, R.: Common Mode and Differential Mode Analysis of Three Phase Cables for PWM AC Drives. In proceeding of IEEE Industry Applications Conference, vol. 2, pp. 880--888 (2006)