Validation Of A High-voltage Relay For Deep-sea Applications Using COMSOL Multi-Physics®

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Abstract

Abstract

High-voltage relays currently used for deep sea applications must be designed for extreme underwater conditions. So, pertinent materials used, and the design procedures adopted are novel, innovative but expensive. Alternatively, the existing high-power electric switches, relays and pertinent components for air can be suitably modified to meet the high-voltage and high-pressure requirements of deep-sea applications [1]. Such an attempt would emerge as a reliable and cost-effective solution. In any case, a detailed investigation on understanding the electric field distribution, localized electric field enhancements and other relevant design parameters are essential. The crucial parameters that define the operating conditions, efficiency, lifetime and reliability of such modified components in an extremely challenging environment must be identified prior to their deep-sea commissioning. A suitable way to achieve this is to perform a simulation study on such modified components to identify and/or estimate the expected numerical values, i.e. electric field, of such crucial parameters that defines their operating condition and reliability. In this context, a numerical simulation model of a high-power relay for the environmental conditions air modified to meet the high-voltage requirements of deep-sea conditions using COMSOL Multi-Physics® software is initiated.
Initially, a generic 5 kV high-power relay that are commonly used for switching applications in air is selected and the environmental conditions is modified to enhance its operating voltage from 5 kV to 15 kV respectively [1]. Figure 1 shows the high-power relay, the possible critical location of localized electrical field enhancements. Subsequently, the changes made in the material arrangements and structural modifications made are noted and converted into a numerical simulation model. In order to enhance the voltage rating, the structural arrangements of the high-voltage contacts are smoothened and the distance in between is adequately increased. In addition, the modified relay is placed inside insulating liquid to increase its breakdown strength.

Use of COMSOL Multiphysics

Figure 2 shows the three-dimensional (3D) numerical model of the high voltage relay. It is created with Inventor professional version 2021 and is imported and simulated using the COMSOL Multiphysics® 5.5 simulation software including the module AC/DC, electrostatic and stationary case. The active relay is simulated under two different environmental conditions, air and insulating liquid, and the corresponding electrical field conditions are investigated. Further the different calculating points are defined, according to figure 1, to show the electric field conditions in critical areas.
For this reason a numerical simulation model is prepared in order to be able to carry out qualitative considerations with respect to optimizations. In this context, FEM based numerical electric field simulation have been initiated.

Conclusions

This paper presents a FE study of a 5 kV power relay that is modified to meet the requirements of higher voltages up to 15 kV. Numerical simulations compared to real case studies of electrical components are senseful techniques to validate operating conditions for deep water applications.
The presented procedure can be used as a qualitative technique to show different implementation situations.

References

[1] S. Arumugam, Y. Haba, G. Körner, D. Uhrlandt, M. Paschen, "Understanding partial discharges in low-power relay and silicone cable modified to suit high-voltage requirement of deep sea electrical system," Int'l Trans. on Electr. Ener. Sys., vol. 28, Iss. 6, June 2018, pp. 1 - 18.

Figures used in the abstract

Figure 1 : Figure 1. Pictorial description of the high-power relay (rated 5 kV, enhanced to 15 kV) and possible locations of electric field enhancements.

Figure 2 : Figure 2. Top view of calculating point’s definition (blue) according to figure 1 (left) and electric potential example (right).