Validation of a High-Voltage Relay Modified for Deep-Sea Applications Using COMSOL Multiphysics®

Y. Haba[1$], S. Krohmann[1], S. Arumugam[1], S. Kosleck[1]
1. Institute of Ocean Engineering, University of Rostock, Rostock, Germany
[$]E-Mail: yvonne.haba@uni-rostock.de (Corresponding author)

INTRODUCTION

- High voltage relay used for deep-sea applications must be designed for extreme conditions.
- Pertinent materials, procedures adopted are novel, innovative, but expensive.
- Alternatively, the existing high-voltage electric switches and relays can be modified to meet high-voltage, high-pressure requirements [1].
- An experimental study of a standard 5 kV high-voltage relay has already been investigated and the crucial points, which decides the operating condition and reliability has been identified [1].
- As a next step, a simulation study that validates the design modification made to adopt the chosen high-voltage relay is initiated.

COMPUTATIONAL METHODS

The FEM model is developed (figure 1) and the stationary case is simulated including crucial locations of field enhancements (figure 2).

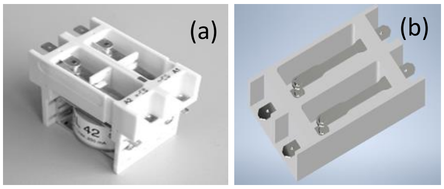

Figure 1. High-voltage relay (a) Actual (b) 3D representation

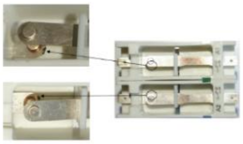

Figure 2. Crucial locations of field enhancements [1]

RESULTS

The magnitude of simulation voltage is set in steps (5 kV, 8 kV, 10 kV, 15 kV, 20 kV) and the electric displacement field, is observed, shown in table 1 and figure 3.

Table 1. Electric displacement field (norm) at the crucial points 1 to 4

Medium	Simulation Voltage	Electric Displacement Field (norm)			
		Crucial point 1	Crucial point 2	Crucial point 3	Crucial point 4
	kV	pC/mm²	pC/mm²	pC/mm²	pC/mm²
Silicone oil	5	12.2	10.1	31.9	62.8
	8	19.5	16.2	51	100.4
	10	24.3	20.2	63.7	125.5
	15	36.5	30.4	95.6	188.3
	20	48.6	40.5	127.5	251.1
Pure water	5	693.2	577.1	1817.3	3578.8
	8	1109.1	923.3	2907.7	5726.1
	10	1386.4	1154.2	3634.6	7157.6
	15	2079.7	1731.3	5451.9	10736
	20	2772.9	2308.4	7269.2	14315
Sea water	5	606.57	504.95	1590.1	3131.4
	8	970.5	807.93	2544.2	5010.3
	10	1213.1	1009.9	3180.3	6262.9
	15	1819.7	1514.9	4770.4	9394.3
	20	2426.3	2019.8	6360.5	12526

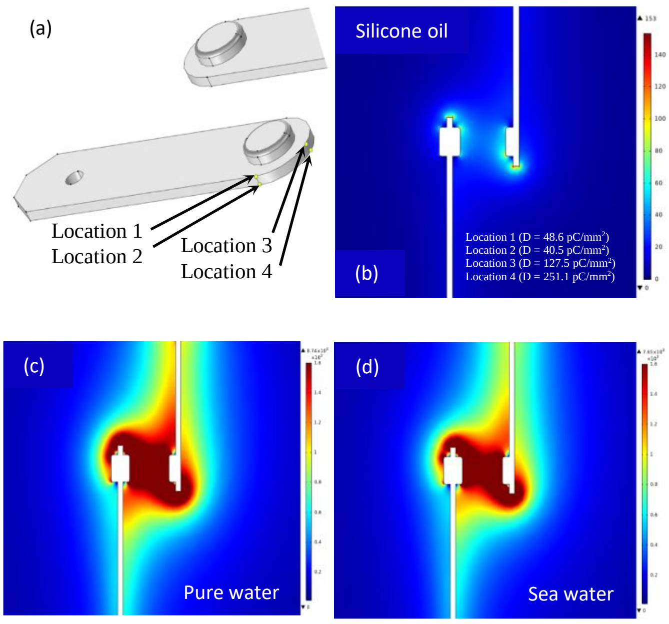

Figure 3. Electric displacement field (norm) at the switching terminals
(a) Model (b) Silicone oil at 20 kV (c) Pure water at 20 kV (d) Sea water at 20 kV

CONCLUSIONS

The presented procedure can be used as a qualitative technique to validate various implementation situations. In addition, the technical pre-requisites for the insulation materials, employed for high-pressure and underwater applications can be optimized.

- Silicone oil mitigated field enhancements and increased operating voltage from 5 to 20 kV.
- Water, despite being a dielectric suffers random movement of molecules.
- Mild dissociation of H^+ and OH^- ions, makes it less feasible solution.

ACKNOWLEDGEMENTS

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