Simulation of Electric Field Distribution in the Insulation of a HVDC XLPE Cable

Ying LIU*,1, Shendong ZHANG1, George CHEN2
1Xi’an Jiaotong University, Xi’an, China; 2University of Southampton, Southampton, UK
Ying LIU*: Ying.Liu@soton.ac.uk; candlyy@mail.xjtu.edu.cn

Introduction:
- A 2D model is set up to simulate the electric field distribution in the XLPE insulation of a 320 kV DC cable by the software COMSOL without consideration of the space charge effect.
- The electric field distribution of the steady state is computed under the thermal equilibrium and rated DC voltage, with two parameters in XLPE conductivity expression being changed.
- Simulation of time-varying states is performed under thermal equilibrium and several typical voltage forms, including the continuous rising DC voltage, polarity reversed DC voltage and superimposed impulse voltage.

Model:
- The computing model of the cable buried in the soil is shown in Fig.1.

![Fig.1. Computing model of the 320kV DC cable buried in the soil](image)

- The conductivity of XLPE is described as

\[
\gamma = A e^{-\frac{\varphi}{kT} \cdot \sinh (B|E|)} \quad |E|
\]

Where: \( \varphi \) is the thermal activation energy; \( B \) is the electric stress coefficient; \( E \) is the electric field.

Results:
A. Steady state
- Insulation temperature difference is about 8.4 °C and electric field is reversed when full-loaded.

![Fig.2. Electric field distributions across the dielectric with different thermal activation energies or electric stress coefficients](image)

(b) different electric stress coefficients

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B. Time-varying states
- The continuous rising DC voltage

![Fig.3. Electric field at the inner border of the insulation under continuous rising voltages of different speeds as a function of time (semi-log)](image)

- The polarity reversed DC voltage

![Fig.4. Electric field at borders of the insulation under polarity reversal voltage applied](image)

- The superimposed impulse voltage

![Fig.5. Electric field at the borders of the insulation under a superimposed switching impulse voltage of the opposite and same polarity to the DC voltage applied](image)

Conclusions:
- The field simulation in DC cable insulation can be performed as a one way coupling question.
- Lower thermal activation energy or higher electric stress coefficient helps to uniform the field distribution under the steady state.
- Climbing rate of the continuous rising voltage is the key parameter for the maximum field, with the higher rate leading to the larger electric field at the inner border of the insulation.
- The maximum electric field in the insulation under the polarity reversed DC voltage and superimposed impulse voltage can be estimated by the resistive and capacitive field under the continuous rising DC voltage.