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Features of the choosing insulation voltage of AC systems under increased frequency

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The article discusses the method of selecting the operating voltage and operating electric field strength inside the HV power cable insulation under increased frequency voltage. Such power cables can be widely used as part of local increased-frequency electrical power systems (IFEPS) for centralized power supply of special purpose installations (e.g. for supply devices for electrothermal processing of concrete and reinforced concrete products) with rated frequency above 10 kHz. Parametric criteria of the methodology are provision of required service life and operational reliability of power cable insulation. Preliminary conclusions were made in case of various factors influence to the level of the operating voltage with approach of this methodology.

These studies are made due to significant progress in the development of high-power converters based on IGBT transistors and transistor modules, in other hand led to the creation favorable conditions for development and application of special purpose power supply systems based on IFEPS. The authors suggest take into consideration during developing equipment and insulating components of IFEPS the following features:

- single-phase voltage application with the shape curve «trapezium» or «paused trapezium »;
- local application of IFEPS, with highest value of operational voltage due to increase maximum load supply power;
- it is highly recommended to apply special purpose power cables with polymer insulation to supply at increased frequency (their construction must be related with operation at kHz bandwidth);

The voltage selection method is based on the assumption that the most common solid dielectric materials follow the rule: constant value of the voltage frequency (f) and breakdown time (τ) corresponds to constant electrical strength (E) at this frequency. When insulation is selecting, it is necessary to consider the fact that the linear dimensions of the power cable insulation (power cable length ℓ) significantly exceeds the dimensions of test samples used for determinate the parameters of insulation lifespan, then it must be adjusted by scale coefficient.

The authors obtained expressions for determining the dielectric strength (1) and the operating voltage level (2) of power cable lines insulation operated at increased frequency:

$$E_{pl}^{f}(P) = \sqrt[m]{\frac{50B}{f\tau}} \cdot (1 - \frac{a \cdot \sigma^{*}}{100}) \cdot (1 - \frac{z \cdot \beta \cdot \sigma^{*}}{100}) \quad (1)$$

$$U_{\max} = \frac{(D-d)}{2K} \cdot \sqrt[m]{\frac{50B}{f\tau}} \cdot \left(1 - \frac{a \cdot \sigma^{*}}{100}\right) \cdot \left(1 - \frac{z \cdot \beta \cdot \sigma^{*}}{100}\right) \quad (2)$$

where z –Laplace function argument, *α и β*- scale coefficients, B и m - coefficients of insulation lifespan taken from test, determinated by experiments approach for each type of insulation, σ– breakdown voltage standard deviation, k – multiplicity overvoltage coefficient (surge factor).

The methodology was tested through experimental studies of electrical strength of radio frequency power cable (wave impedance is 50 Ohms) insulation During the tests, the breakdown voltage of the samples insulation was found by gradually increasing test voltage with 1 kV per second until breakdown. Samples of cable insulation were subjected to electrical obsolescence with applying of 50 Hz 6 kV as well as determine the insulation lifespan. It is found that with a given reliability P=0,9, deviation σ=12,5% operation voltage of increased frequency power cable with wave impedance 50 Ohms and insulation thickness about 1 mm is equal 2.5 kV. This value isn't depend of power cable length and lifecycle and correspond with the average value of operation voltage for 50 Hz power cables.

The proposed method of selecting the operating voltage of the high-voltage cable line using electrical strength of it's insulation might be applied for solving the inverse task: select an insulation type while value of the operating voltage is known. Anyway, this method of operation voltage calculation for power cable insulation should be considered as an integral part of the general methodology applicable for the design and construction increased -frequency AC systems.