Testing Methodology for Continuous Monitoring of Insulation Bushings By Measuring Tg(Δ) on the Model Program in MATLAB Environment

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Abstract: The modern trend to assess the condition of the electrical insulation is to introduce systems for continuous monitoring (on-line monitoring). The advantage of monitoring systems is the ability to detect defects in insulation systems at an early stage of their development. The authors propose a methodology which is developed for continuous monitoring of the tangent of the angle of dielectric losses. The methodology provides reception of two signals proportional respectively to the voltage on the through insulator and the current through insulation. A computer simulation of the proposed algorithm in the MATLAB environment has been developed with a model of the behavior of a real energy system with a complicated variation of the voltages created within. The computer model provides filtration of signals using a Fourier transformation.

Keywords: dielectric losses, tg(δ), on-line monitoring, bushings, MatLab.

I. Introduction

The modern trend to assess the condition of the electrical insulation is to introduce systems for continuous monitoring (on-line monitoring). One of the advantages of the monitoring systems is the ability to detect defects in insulation systems at an early stage of development. This allows establishing adequate measures to remedy the defects, to predict the installation's uptime and may determine the type and volume of repair work. In previous papers, the authors propose a methodology, which is developed for continuous monitoring of the tangent of the angle of dielectric losses. The methodology provides for the reception of two signals proportional respectively to the voltage on the through insulator and the current through insulation. They are processed by Fourier transformations and the quality of the insulation of the high voltage module is estimated using the resulting value.

II. Modeling of a bushing in a programming environment Matlab

A model - file “Bushings.mdl” (Figure 1) has been developed in the MatLab programming environment. The supply power scheme is carried out by a three-phase voltage source "Tree-phase Programmable Voltage Source". of which only phase A is occupied. The signal, which is proportional to the voltage on the test object, was prepared from the external capacitive divider. It is connected to the source. It consists of two capacitors with capacitance values 15pF and 150nF. The voltage which is applied to the controlled bushing is reduced by this divider 10V. The bushing is modelled with two blocks: Bushing C1 and Bushing C2. Parallel to them the resistors are included - to C1, which has a capacity of 300 pF, a resistor with a resistance 3.109 Ω, and to that of C2 = 10000 pF - resistor with a resistance 50Ω. The Signal, which is proportional to the current through insulation of the bushing, is taken from the output after capacitor C1. It appears as PIN output of the real bushing. Both signals are shown on the oscilloscope, and are indicated with Uad, Ia (Fig.2).
Both signals are fed to the blocks for Fourier transformation. They are shown in Fig. 3 and are denoted by $U_1$ and $I_1$. These blocks act as a digital filter, which separates the first harmonic (power frequency) from the other harmonic signals. The amplitudes and the phase shifts of the first harmonics of the voltage and the current, which are applied to inputs, are obtained at the outputs. A duty cycle of 0.5 seconds is simulated. The phases of the first harmonics are fed into blocks for further processing, which calculates the tangent of the angle of dielectric losses. The display shows the measured value of $\tan(\delta)$ - in this case 0.003191.
The variation of the tg(δ) in time is given in fig. 4. The initial values are high, due to transients of the source when linking it to the scheme.

**Figure 3** Part of the model of the measuring circuit, which shows the blocks of the Fourier, blocks for the information processing and receipt of tg(δ).

![Diagram of the measuring circuit](image)

Figure 4 The variation of the tg (δ) in time.

![Graph showing the variation of tg(δ) over time](image)

Figure 5 shows the simulation of deteriorated insulation of the bushing. This is achieved through parallel inclusions of resistor "Resistor" at "Bushing C1". This inclusion changes tg(δ) at phase A (as shown in Figure 1), whose value is reduced by an order of magnitude (in this case from 109 to 108). What can be seen is that the value of tg(δ) now is 0.009045 (fig.5).

**Figure 5** The simulation of the action of the model at deteriorated insulation and display value on the display.

![Diagram showing the simulation of deteriorated insulation](image)

Figure 6 shows a dynamic model in which the deterioration of the insulation is accomplished by switching switch "Time R", which is included in the range of 0.25 to 0.5 second, and imitates the appearance of the discharge. The initial fluctuation of the value of the tangent of dielectric losses up to 0.15s was commented above. At 0.25 second when key "Time R" is included, the measured value increases sharply. This value is retained till the moment, when the switch, which imitates changes in isolation, is disconnected. The system returns to its original

![Diagram showing a dynamic model](image)
condition and value of the monitored parameter is within limits. The image of the oscilloscope in this case is shown in Figure 7.

**Figure 6** The model of the circuit in which switch Time R is incorporated.

- **Figure 7** Oscilloscope display. The values of the measured parameter \( \text{tg}(\delta) \) are at the ordinate axis.

- **Figure 8** Dynamic model that reflects the real failure bushing.

When a real discharge occurs in the isolation in one of the layers of the bushing it begins to emit products that impair its quality and this influence remains even after the discharge fades away. Another switch 30e8R (fig.8) is added to model this process. The switch activates at 0.35s and stays on until the end of the simulation. The system reacts to this change, as evidenced by the screen of the oscilloscope (fig.9).
A Saturation block is included. It solves the problem with transients, which occurs during the inclusion of the voltage source or the voltage changes which may occur during the operation.

The next task is to form a block (Figure 10) to monitor the parameter $\tan(\delta)$ change, and accumulate data. On the grounds of that data it can make an adequate decision about the status of the system. This block was built using an integrator with which to monitor the rate of change of the diagnosis parameter. So the system will be able to take a decision based on two constraints: the absolute value of the tangent of the angle of dielectric losses and the rate of its increase.

**Figure 9** The change of the monitored parameter $\tan(\delta)$ in the realization of a real breakthrough in the bushing.

**Figure 10** An expert block of the system.

**Figure 11** Output signals of the expert block. It is shown the rate of increase in the value of $\tan(\delta)$ in the middle diagram.
Figure 11 shows the screen of the oscilloscope with the introduction of the expert block. There is a visible change in readings when the Saturation block is included. The middle diagram shows the rate of change. The slope of the modification becomes steeper at the moment in which the key Time R (0.25 s) is turned on. It changes again after switching the key off (0.5 s) and returns to the previous slope.

III. Conclusion

A computer simulation of the proposed algorithm was made in the MatLab programme environment. The model of the behaviour of a real energy system with a complex voltage variation was created. Filtering signals using Fourier transform is provided in the developed model. A so-called expert block is included into the model. Its purpose is to monitor the two indicators: the rate of increase in the value of the tangent of the angle of dielectric losses and the absolute value of $\tan \delta$. On the basis of the data which were obtained, the system takes an expert decision as to whether a fault has occurred and how to react to it. In case studies it is recommended to use the experience of the standard requirements.

IV. References


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