

SC D1 Materials and emerging test techniques
PS 1: Testing, monitoring and diagnostics**X-ray inspection of operating high-voltage oil-filled circuit breakers****L.A. DARIAN^{1*}, P.V. GOLUBEV¹, P.V. GONCHAROV², R.M. OBRAZTSOV¹,
F. SCIOCCHETTI³****¹JSC «Technical Inspection UES», ²IDGC of the South, ³CAMLIN Power Ltd.
Russia, Italy
ldarian@rambler.ru**

The article presents the fundamental studies of the X-ray inspection capabilities of high-voltage oil-filled circuit breakers. Also proposed an instrument and analytical system for the equipment inspection, which was tested in field conditions. The main advantage of the proposed method is the possibility of operational control of the high-voltage oil-filled equipment internal elements at site without dismantling and disassembling.

By now, several countries already have an experience of using X-ray for monitoring high-voltage equipment in laboratory as well as in field conditions. However, this experience is related to small homogeneous objects (for example, linear insulators) and objects with a heterogeneous structure (gas dead tank circuit breaker and GIS) with a relatively small equivalent radiation thickness. An application of the X-ray method for homogeneous objects has alternatives – ultrasound and visual methods. In this area of research, the authors posed and solved the problem of inspection high-voltage oil-filled circuit breakers as large complex structures consisting of elements with highly different properties of materials (steel, copper, oil, porcelain, etc.). To obtain informative images of such heterogeneous structures with massive porcelain or polymer insulators, it is necessary to use specialized technical means and techniques of X-ray inspection.

The Russian experience in the field of creating an X-ray apparatus allowed the authors to develop and test a mobile X-ray system for inspection high-voltage oil-filled equipment in field conditions. Inspection of such equipment for assessment of geometric dimensions and location of internal structural elements cannot be performed by other non-destructive methods. It should be noted that oil-filled equipment with massive external insulation has a large equivalent radiation thickness.

The article presents the method proposed by the authors for controlling the internal elements of high-voltage oil-filled circuit breakers at site without dismantling and disassembling. This method is a mobile X-ray system with high resolution. The system includes:

- an X-ray monoblock (X-ray emitter) with collimator;
- a power supply panel;
- a remote control panel;

- a pad with an X-ray film (X-ray receiver);
- a positioning system of monoblock and a pad for X-ray film (platforms, rods, winches);
- an automatic developer and a scanner for X-ray film;
- an X-ray images processing software.

It should be noted that the positioning system is designed in such a way that the X-ray emitter and the receiver can rotate around the circuit breaker pole to change the angle of the X-ray shooting and move vertically along the pole.

For investigation of the X-ray method possibilities to control the internal elements of high-voltage oil-filled equipment, a special defective sample (SDS) based on a minimum oil circuit breaker 110 kV was developed. The selection of defects for SDS development was based on the analysis of statistics for minimum oil circuit breaker failures. The developed SDS has 12 defects on 9 internal structural elements.

The obtained X-ray images of SDS were compared with the actual defects. Based on these results, the authors were able to evaluate the information content of X-ray images – 75% of the defects were found. The resolution of the X-ray image is not worse than 1 mm [in the original scale of the equipment].

The influence of the spectral energy characteristics of X-ray on the X-ray images information content was assessed by the example of a SF₆ live tank circuit breaker. It was confirmed that the main source of leakage radiation that do not carry useful information and distort [interference] the resulting X-ray image is a circuit breaker porcelain insulator. "Interference" in the image can be up to 80% – which causes a deterioration of the X-ray image contrast.

Increasing the X-ray images information content of structurally complex objects with large metal elements or with the presence of massive polymer/porcelain insulators and transformer oil is possible with a significant reduction of leakage radiation influence on the detector. In the article authors also proposed to use a scanning X-ray system with slit collimation of a radiation source and an X-ray receiver for solving this problem.

Testing of the developed system was carried out at 3 substations 110 kV. The results confirmed the possibility of carrying out a full cycle X-ray inspection of internal elements of high-voltage oil-filled equipment with porcelain external insulation.