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Chamber for thermo-mechanical tests of high voltage insulators

***Abstract**. Standard thermo-mechanical tests of high voltage insulators enable the assessment of their resistance to a mechanical load that occurs during their operation and maintenance and take the influence of changes in working temperature into account. A device with a thermal chamber for such tests has been designed and manufactured at the Institute for Sustainable Technologies-National Research Institute in Radom. The device enables prolonged tests to be carried out on high voltage, support and linear insulators in the temperature range of –60 to +60 ºC with the use of tensile and bending loads, according to binding norms and standards.*

***Streszczenie.** Standardowe badania termomechaniczne izolatorów energetycznych służą do sprawdzania ich wytrzymałości na obciążenia mechaniczne występujące podczas eksploatacji z uwzględnieniem wpływu zmian temperatury pracy. W Instytucie Technologii Eksploatacji – PIB w Radomiu zostało zaprojektowane i wykonane urządzenie z komorą termiczną do wykonywania takich badań. Umożliwia ono przeprowadzanie długotrwałych badań izolatorów wsporczych i liniowych w zakresie temperatur od –60 do +60 ºC z zastosowaniem obciążeń rozciągających i zginających, zgodnie z obowiązującymi normami. (**Badania izolatorów w komorze termo-mechanicznej**)*

Keywords: tests of isulators, test chamber
Słowa kluczowe: badania izolatorów, komora badawcza

Thermo-mechanical tests for power insulators

The main reason why insulators are used in overhead power lines is to isolate the lines from the transmission towers (pylons) and to enable the cables to be safely mounted. The most commonly applied insulators and insulating cross-arms made of porcelain or glass with rated voltage over 1 kV should comply with PN-EN 60383-1:2005 norms [1], whereas composite insulators should comply with PN-IEC 61109:1999 norms [2]. The aforementioned norms decide on the scope of structural, type, control and product tests, determine the methods with the use of which each of the investigations should be carried out, and define the criteria for the assessment of the test results. Crucial from the point of view of safe maintenance are creeping discharge endurance tests [3] and thermo-mechanical tests.

In thermo-mechanical tests insulators are subject to four 24h cooling and heating cycles with simultaneous application of tensile load (Fig. 1a) with the value amounting to 50-60% of the nominal tensile force, depending on the type of the insulator used. Each of the 24h cycles has two temperature levels that should be sustained for at least 8 hours for composite insulator tests and 4 hours for ceramic insulator tests. In the case of composite insulators, the temperature in the "cold" period should amount to -35ºC ± 5K, whereas in the "hot" period: +50ºC ± 5K. In the case of ceramic insulators, on the other hand, these temperatures should amount to -30ºC ± 5K and +40ºC ± 5K respectively, but remembering that the difference between the minimum and maximum temperature needs not to be lower than 70K once deviations are concerned.

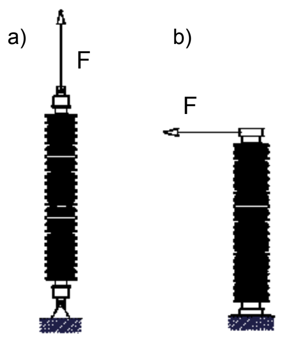

Fig.1. Means of weighing the insulators down at the time of thermo-mechanical tests: a) Line insulators, b) support insulators

The tensile load should be constantly applied to the insulator tested or periodically lowered adequately to the changes in temperature and the test method used. The test procedures also assume application of lower loads, e.g. 5% of the nominal tensile force, in order for the length of the insulator to be measured in given conditions.

Thermo-mechanical tests are intended for the verification of the endurance of line insulators to stretching in conditions resembling real operating conditions of changeable temperatures, cable loads and additional external load forces (e.g. wind, frost, etc.) [4, 5, 6].

A separate issue are tests of stationary support insulators that are mounted onto the supporting structure by means of a screwed on foot and weighed down with the use of bending forces. Their tests are carried out according to the PN-EN 60168:1999/A2:2002 norm [7]. The system for thermo-mechanical tests needs to have the option of fixed installation of the tested object with the use of the aforementioned foot and the load of the bending force directed perpendicularly to its axis (Fig. 1b).

Thermo-mechanical tests of insulators that are installed on power lines in cold climate geographical spheres (e.g. Scandinavia or Siberia) require different tests procedures to be applied. A fundamental difference consists in the application of lower subzero temperature of -60ºC. A test device composed of a thermal chamber and a mechanical-hydraulic load system was designed (Fig.1) and manufactured at the Institute for Sustainable Technologies in Radom, Poland. It is intended for thermo-mechanical tests of insulators in different load conditions and temperatures between -60ºC to +60ºC.

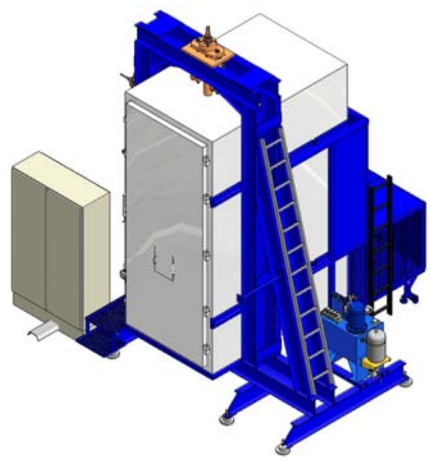

Fig.2. Virtual model of the device for thermo-mechanical tests.

Thermal chamber with a load system

The structure of the device for thermo-mechanical tests of insulators is presented in Fig. 2. The device has a steel frame that transfers mechanical loads applied to tested objects and plays a role of the body of the entire device.

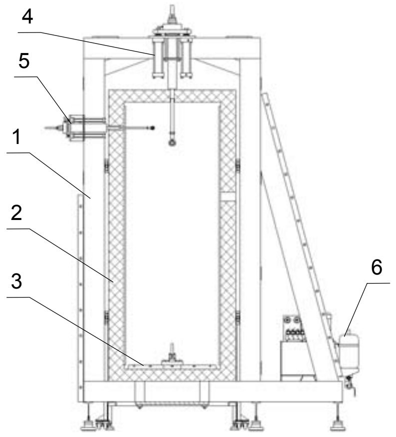

Fig.3. Structure of the device for thermo-mechanical tests of insulators: 1 – frame, 2 – thermal chamber, 3 – plate for the fixing of the insulator, 4 – hydraulic system of vertical load, 5 – hydraulic system of horizontal load, 6 – hydraulic unit.

In the frame of the device a 1.1 x 1.1 x 3.1 m thermal chamber, with built-in heating and cooling systems, built from multilayer insulating boards secured with stainless steel was placed. The inner sides of the walls of the chamber, the evaporator of the cooling system and the heater were all equipped with shields protecting them from damage that may be caused by the breakage of the tested object. One of the walls of the chamber is entirely constituted by the doors that enable the assembly of the insulator tested and its connection with a proper load system. A steel plate with T-grooves intended for the mounting of the bottom end of the insulator in the case of both tensile and bending load was installed at the bottom of the chamber. The hydraulic load units with the stroke of 300 mm create a vertical tensile force in the range of 10 to 220 kN or horizontal bending force of 1 to 20 kN. The units were installed on the outer frame of the device and the loads they cause are transferred to the inside of the chamber via the ties that go through its walls. The load units are supplied from a joint hydraulic unit in which proportional valves were used to regulate the pressure of the agent.

a) b)

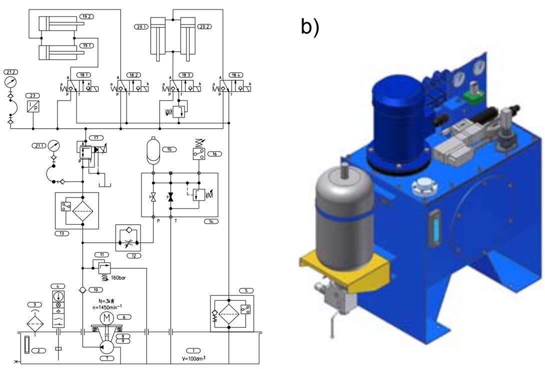

Fig.4.Hydraulic unit: a) draft, b) virtual model

This enables smooth regulation of the value of the pressure posed with the speed of up to 1.5 kN/s in full working range with the use of the computer and the PLC controller. The real value of the loading force is measured with the use of legalized strain gauge measuring tracks with sensors located on hydraulic actuators. The connection of the insulator with the loading unit is realized with the use of adaptation elements (chains, joints, extenders) depending on the its structure, dimensions and the kind of the load.

The preparation of the thermo-mechanical tests consists mainly in the installation of the tested insulator inside the chamber and t he connection with the load system. Support insulators are mounted directly onto the T-groove plate according to the producer's recommendations concerning the number and diameter of the mounting screw. The top end of the insulator needs to be equipped with a suitable extender allowing for the extension of the bending force at the distance of 2750 mm from the base. The value of the loading force has to be calculated in a way creating exactly the same bending moment at the base of the insulator as the required test force. Line insulators should be mounted onto the plate with the use of the holder ending with a joint. The bottom end of the sample is connected with the joint with the use of a ready-made ear, whereas the top one with the tie of the loading system with the use of certified chain of suitable endurance. Such connection results in automatic alignment and the presence in the tested object of tensile force only. Once the insulator is installed in the chamber and the backlash in the tie of the loading unit eliminated, the chamber is closed and the rest of the test is conducted automatically according to the course programmed in the system controlling the work of the device. Fig. 3 presents the chamber with the installed line insulator prepared for the test.

a) b)

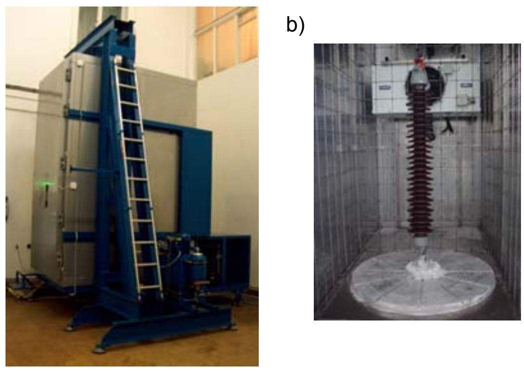

Fig. 5.Thermal chamber: a) view, b) with the installed line insulator prepared for a thermo-mechanical test.

System for the control of the work of the device and the examples of the tests recorded

The system for the control of work parameters of the chamber is composed of two systems: force setting system and the temperature regulation system inside the chamber, as well as computer software for the visualization and archiving of force and temperature characteristic in time.

The force setting system sets different values for different types of forces applied, and in the case of the tensile force it amounts to 220kN, whereas in the case of bending force to 20 kN. This is realised by the hydraulic system that mainly allows the following:

- Stabilization of the force applied,
- Alignment of the ties of hydraulic actuators,
- Initial strain of the insulators with the possibility of their tare.

The force is measured with the use of strain gauges. The signal from the gauge controls the pressure of the oil in hydraulic actuators by means of a PLC controller and a proportional valve. The hydraulic feeder is equipped with pressure accumulator, which allows for a cyclical and energy-saving work of the pump of the feeder. Such a way of realization of the force regulation system, contrary to the frequently applied pressure stabilization only, enables temperature compensation for strains resulting from changes in geometry of the tested insulator measuring even up to 2500 mm during temperatures ranging from 60ºC to +60ºC.

The temperature regulation system is composed of two separate subsystems including:

- Cooling system ensuring subzero temperatures to be obtained,
- Heating system ensuring plus temperatures to be obtained.

The cooling subsystem, depending on the value of the applied temperature, can work as a one or two-stage system. The first of the stages of the cooling unit works in the temperature up to 30ºC, whereas the second stage, the high pressure one that uses the low temperature cooling agent ensuring the temperature of -60ºC to be obtained, is switched on in the case when the temperature drops below -30ºC. The working mode of the cooling unit is set by the selection of the number of stages and alternately of the threshold for the initiation of the second unit. Two sections of resistive heating elements for the procurement of the temperature of +60ºC inside the chamber were installed next to the evaporator of the cooling unit. In order to intensify the heat exchange and homogenize the arrangement of temperatures inside the chamber, inner fans were used to direct the air towards and through the evaporator. The system allows the temperature to be lowered from +60ºC to -60ºC within 240 minutes.

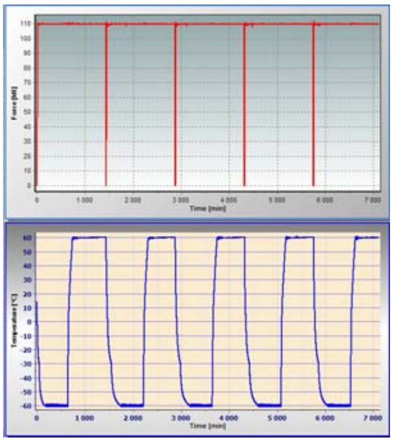

Fig. 6.Window of the control system with recorded parameters of the tests, temperature and load characteristics at the time of chamber tests.

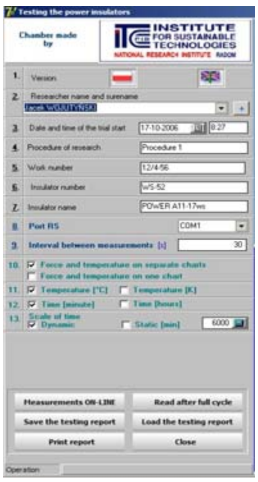

Fig.6. Dialog of the programme supervising tests procedures.

The computer software for the visualization and archiving of force and temperature characteristics in time (fig. 6) ensures the transfer of data between the PC and the PLC controller monitoring the work of the regulation system. The serial transmission protocol supported by the RS232 port, with which the PC and the PLC controller are equipped, was used for communication.

The designed software (fig. 7) has options allowing the following:

- Providing all information required by the norms for each of the tests,
- On-line monitoring of the state of the chamber,
- Reading temperature and force once the tests is finished (off-line mode),
- Automatic record of measured force and temperature values to the temp file (this prevents data loss in the case of emergency states);
- Print-out of measurements taken at the time of insulator tests.

The software was made with the use of Delhi pack.

Conclusions

Application of the device enables the realisation of thermo-mechanical tests of ceramic and composite insulators according to PN-EN 60383-1:2005, PN-IEC 61109:1999 and PN-EN 60168:1999/A2:2002. Due to the need for thermo-mechanical endurance tests of insulators used in extremely cold climatic conditions in Siberia and Scandinavia, technical possibilities of the chamber were extended in relation to those required by the norm, particularly in the case of subzero temperatures. Technological solutions applied enable stabilization of temperatures in the range of ±2ºC and the step or smooth extortion of the change of tensile and bending force. The chamber can work automatically with no computer software, which constitutes additional equipment and allows for the visualization, archiving and processing of measurement data obtained at the time of insulator tests. The application of programmable PLC controllers enables possible change of control algorithms for force and temperature characteristics in the time function, which allows the change in technological possibilities of the chamber, with no structural changes to be made.

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