10347 Session 2022
A3 TRANSMISSION AND DISTRIBUTION EQUIPMENT
PS3 – Digitalisation of T&D Equipment
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LPIT Technology Development for 3-phase 145 kV GIS

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SUMMARY

With regard to the digitalization of power equipment, the process bus has been discussed as the latest trend in Digital Substations. And future power system will be transformed from one-way to decentralized, bi-directional structure. So, the power system will become more complex and larger than before. The substations must be digitalized in order to operate the grid efficiently and stably. Conventional substations used copper wires to transmit electrical signals for mutual protection, control, and monitoring. However, digital substations convert electrical signals into digital signals, thus enabling fast and efficient operation.

It is important to measure the voltage and current of the devices in a digital substation. Conventional measuring instruments have to be used separately for instrumentation and protection because of the magnetic flux saturation of the iron core. And their weight and size are also very large. Therefore, in order to overcome the disadvantages of conventional measuring instruments, the techniques for measuring current and voltage without an iron core has been studied for a long time.

This paper deals with the Low Power Instrument Transformer (LPIT) applied to the non-segregated phase type three phase Gas Insulated Switchgear (GIS) with the rated voltage 145 kV, the rated operating current 3150 A, and the rated short circuit current 40 kA. The test result of the sensor developed in this paper according to the standards were presented.

KEYWORDS

LPIT – Low Power Instrument Transformer
GIS – Gas Insulated Switchgear

1. Introduction

Applying digital technology expands customer selectivity through securing interoperability of digital equipment in substations, while improving safety and optimizing asset management by applying proven products. Through the application of LPIT, which has low secondary output, the safety of the operator is dramatically improved and range of the measurement is expanded due to the linear characteristic of the sensors.

The measured values are collected by the Merging Units (MUs), converted into Sampled Values (SVs) based on IEC 61850-9-2 and distributed between Intelligent Electronic Devices (IEDs) over the communication network. In addition, all signals in the field are also collected and transmitted by the MU and Bay Control Units (BCUs). Existing many copper cables are replaced by safe and standard fiber optical communication so digital substations can connect entire substations using networks without complicated wiring. Through this process bus solution, it is possible to reduce cabling and trench materials by up to 80% and relay room by up to 50% which provides the reduction of space and increasing the stability through the optical communication network.

The LPIT can replace conventional instrument transformers because of its small size and advantages in terms of power consumption, stability, accuracy and signal reliability. The use of LPIT in GIS will increase as digital communications are introduced in substations according to the IEC61850-9-2 standard.

The performance of LPIT is verified by the measurement of the magnitude and phase angle of the voltage and current applied to the GIS. Measurement results of LPIT are compared with those of the standard Potential Transformer (PT) and Current Transformer (CT). The accuracy standards of LPIT, current 0.2S class and voltage 0.2 class, were satisfied. In addition, the accuracy of sensors was measured according to temperature change, and EMC test was carried out.

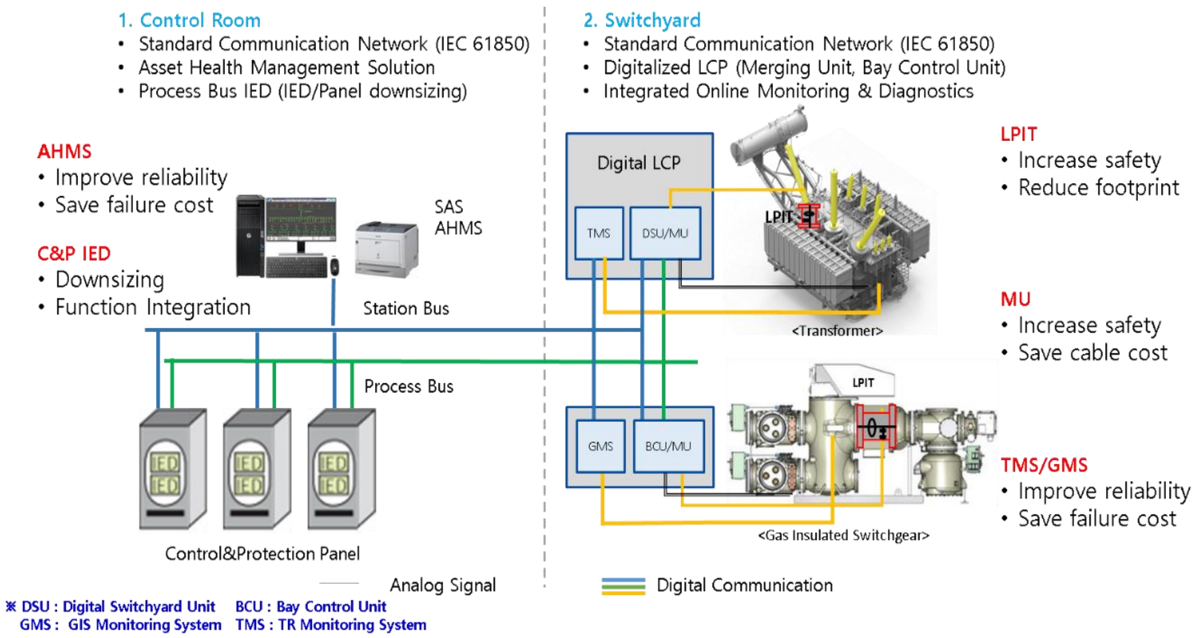

Fig. 1 Configuration of Digital Substation based on IEC-61850

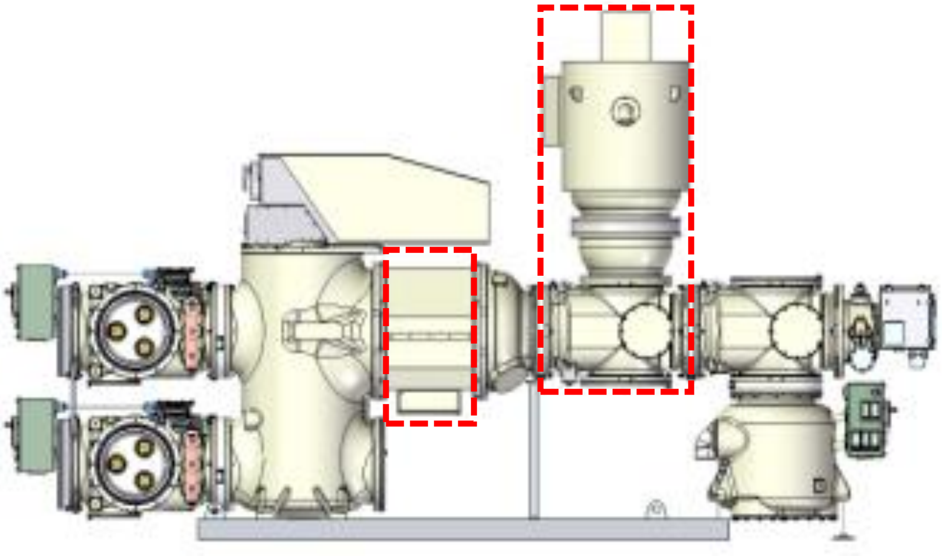

Fig.2 GIS configuration with conventional instrument transformers

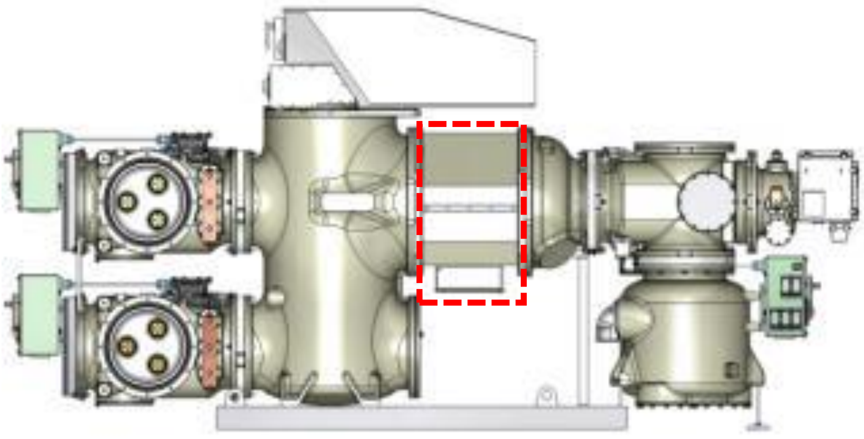

Fig. 3 GIS configuration with LPIT

2. Experimental results of LPIT

The detailed specifications of the LPIT are as follows. The LPIT consist of a voltage and current sensors, a secondary converter, and a MU. Various types of voltage and current transducers applied for LPIT have been developed. For current measurement, the Printed Circuit Board (PCB) type Rogowski coil has been used. Because the Rogowski coil output is a voltage, it needs a function to convert it into a current.

For voltage measurements, a Capacitive Voltage Divider (CVD) has been used. The voltage sensor shall ensure that the parameter can be adjusted according to the variation of the ambient temperature, so that the compensation should be done appropriately depending on the temperature change.

Table1. Specification of the LPIT

List	**Value**
Rated Primary Voltage	132 / √3 kV
Highest Voltage	145 kV
Lighting Impulse Withstand Voltage	650 kV
Rated Power Frequency Withstand voltage	275 kV
Rated Short-Time Thermal current	40 kA – 3s
Rated Extended Primary Current Factor	1.2
Voltage Factor	1.2
CT Accuracy	0.2S / 5P
VT Accuracy	0.2 / 3P
Ambient Temperature	-40 ~ 60°C
Reference Standard	IEC60044 - 7/8

2.1 Accuracy test result of voltage sensor

The voltage sensor uses a long-term stable SF6 compressed gas capacitor $C1$ and a precision capacitor $C2$ as main sensing element. $C1$ is the capacitance between the sensor electrode and the centre conductor, typically a few picofarad. The output signal is approximately proportional to the first derivative of the primary voltage. The figure below shows the accuracy limit and measurement value according to voltage.

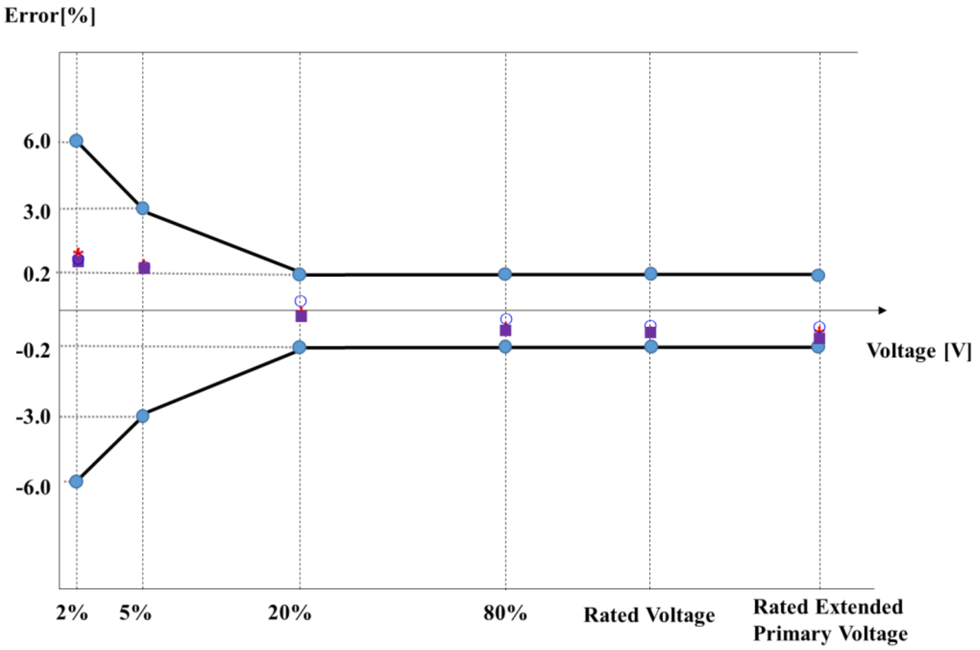

Fig. 4 Accuracy test results of the voltage sensor according to the IEC60044-7

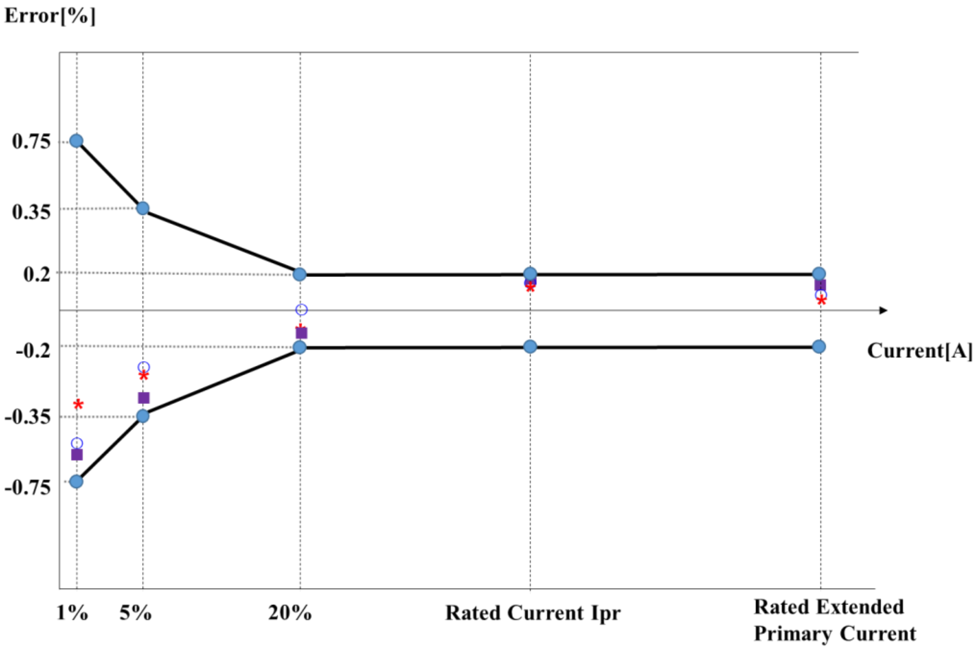

Fig. 5 Accuracy test results of the current sensor according to the IEC60044-8

2.2 Accuracy test result of current sensor

The current sensor is PCB type Rogowski coil, which has some advantages compared to the coil wound type. The PCB type Rogowski coil is suitable for applications that require precision measurement because it can compensate errors due to shape deformation or installation location. As shown in the figure below, the accuracy limits and the measurement value of the magnitude according to the current were compared.

2.3 EMC test results

Electromagnetic Compatibility (EMC) tests should be conducted whether the equipment or system can operate satisfactorily in an electromagnetic environment without issuing any electromagnetic interference. In this paper, the EMC test was tested based on 61869-6.
Because it is difficult to apply a rated current and voltage to the LPIT, the EMC test was carried out by applying a signal instead of the rated voltage and current. The test configuration is shown in the figure, and the test results are shown in the table.

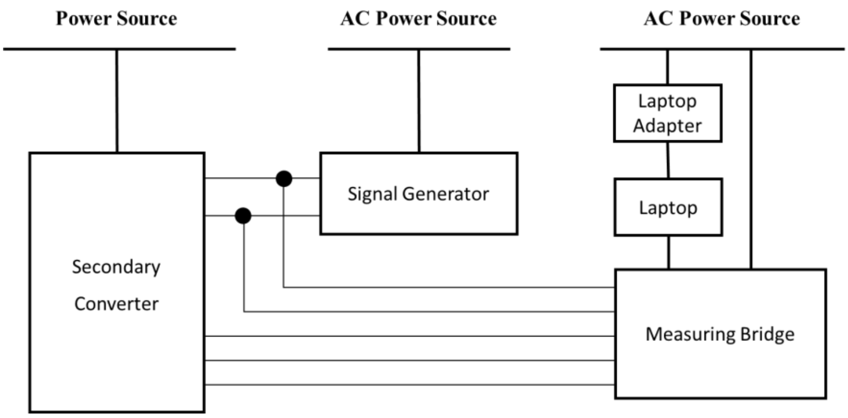

Fig. 6 Configuration of EMC test

Table2. Summary of EMC test results

	Test item(s)	Results
6.11.3.602	Harmonic and interharmonic disturbance test	Pass
6.11.3.603	Slow-voltage variation test	Pass
6.11.3.604	Voltage dips and short interruption test	Pass
6.11.3.605	Surge immunity test	Pass
6.11.3.606	Immunity to conducted disturbances, induced by ratio-frequency fields test	Pass
6.11.3.608	Electrical fast transient / burst test	Pass
6.11.3.609	Oscillatory wave immunity test	Pass
6.11.3.610	Electrostatic discharge test	Pass
6.11.3.611	Power frequency magnetic field immunity test	Pass
6.11.3.612	Pulse magnetic field immunity test	Pass
6.11.3.613	Damped oscillatory magnetic field immunity test	Pass
6.11.3.614	Radiated, ratio frequency, electromagnetic field immunity test	Pass
6.11.601	EMC emission tests	Pass

2.4 Results of temperature cycle test

The temperature cycle test for current sensor was performed using two separate climatic chambers in manufacturer's test laboratory. Because the environmental conditions including operating temperature of the LPIT and the MU are different, the test condition should be distinguished. In the test, two different temperature classes were applied at the same time:

- for sensor in GIS test setup in the first climatic chamber: -40…+60ºC
- for Merging Unit in the second climatic chamber: -25…+55ºC

In addition to the rise of the chamber temperature, the current was applied to raise the temperature of the test product. And the accuracy of LPIT was measured when the temperature was in steady state. In contrast, the current did not apply to decrease the temperature. And the accuracy of the LPIT was measured when the temperature was in steady state.

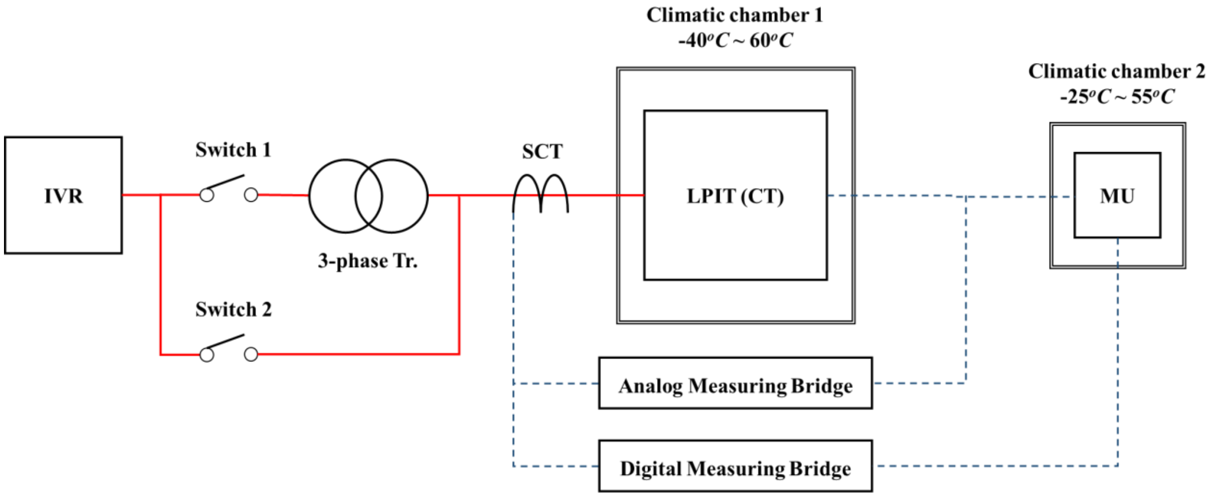

Fig. 7 Circuit configuration for the temperature cycle test of the current sensor

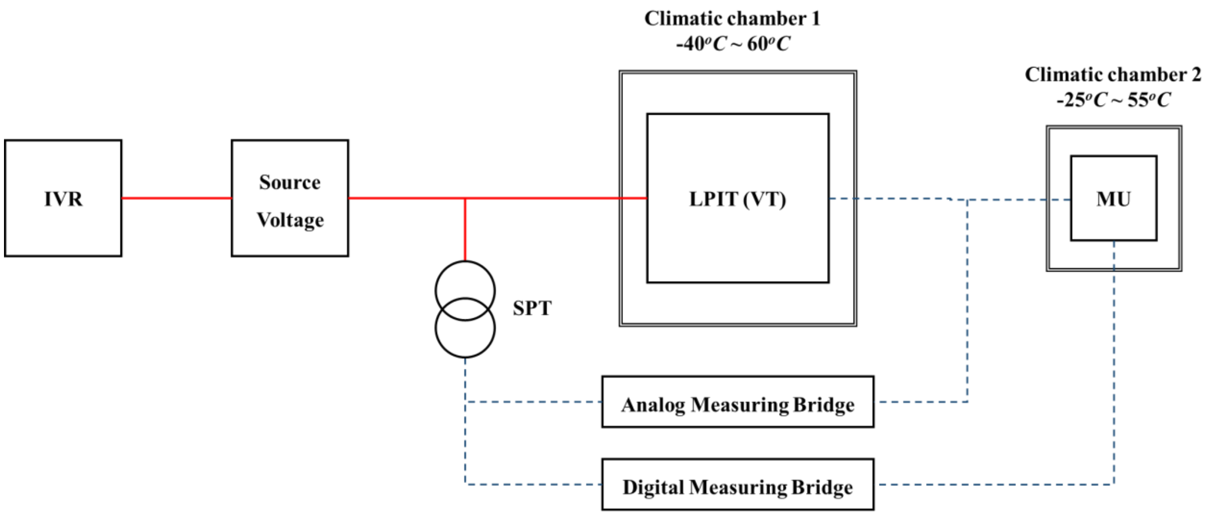

Fig. 8 Circuit configuration for the temperature cycle test of the voltage sensor

The temperature cycle test results of the voltage sensor were performed according to the IEC60044-8 and the accuracy was measured at maximum and minimum temperatures.

3. CONCLUSIONS

LPIT will be a key element that constitutes a digital substation in the future. This paper presents the accuracy, EMC, temperature cycle results of the LPIT installed in 145kV GIS according to the IEC60044-7/8. In addition, the reliability test of the LPIT was also performed, and the required performance criteria was satisfied according to the IEC standards. We have used sensors and converter to confirm that there is no problem by using a variety of tests, such as temperature cycle test and vibration test. However, for the lifetime test of the sensor, we have not yet acquired enough data because it takes a long time.
In the future, the application of the LPITs in the substation will increase with various voltage classes. Many studies will be necessary to reduce the cost of LPIT and size of the GIS.

Fig. 9 Test setup of the LPIT in climatic chambers

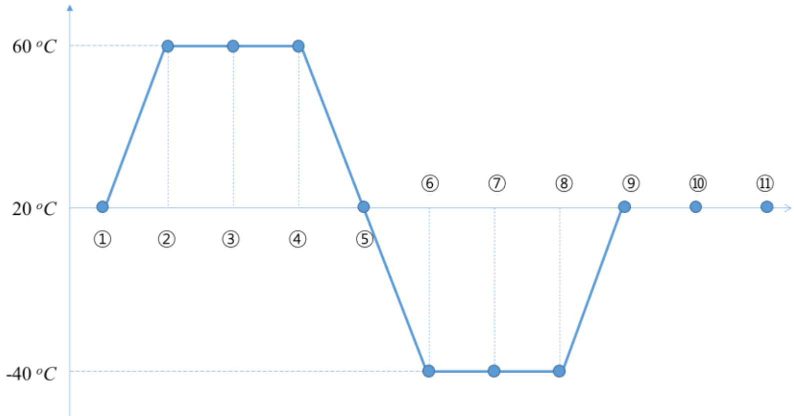

Fig. 10 Temperature cycle according to the IEC 61869-6 and 60044-8

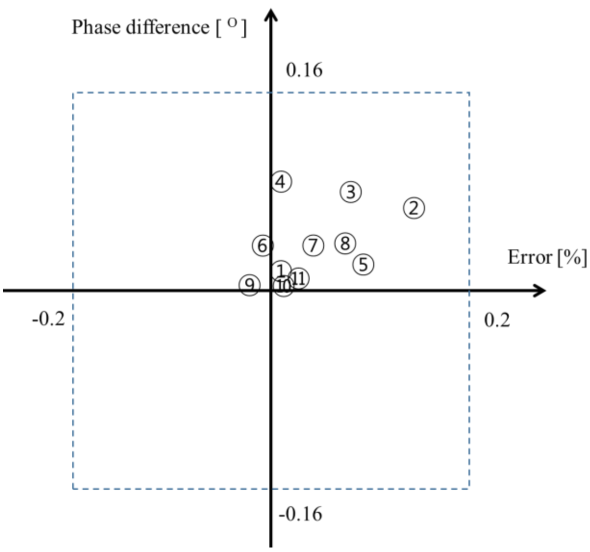

Fig. 11 Results of the temperature cycle test

BIBLIOGRAPHY

[1] Lj. A. Kojovic "Non-Conventional Instrument Transformers for Improved Substation Design", CIGRE 2016 conference B3-1021 August 2016

[2] W. OLSZEWSKI, G. CHAROT, N. PRESSER, M. KUSCHEL "Customer process for technical qualification of Non-Conventional Instrument Transformer products for high-voltage GIS applications", CIGRE 2016 conference PS1-111 August 2016