Study Committee A3

Transmission and Distribution Equipment

Paper 10347_2022

LPIT Technology Development for 3-phase 145 kV GIS

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Motivation

- 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.
- LPIT shows compact size, low power consumption, higher accuracy and reliability. It will replace conventional instrument transformers and accelerate digitalization of substations.
- LPIT output signal was compared with that of standard Potential Transformer (PT) and Current Transformer (CT). Required accuracy (current 0.2S class and voltage 0.2 class) was satisfied. Effect of EMC and ambient temperature was also measured.

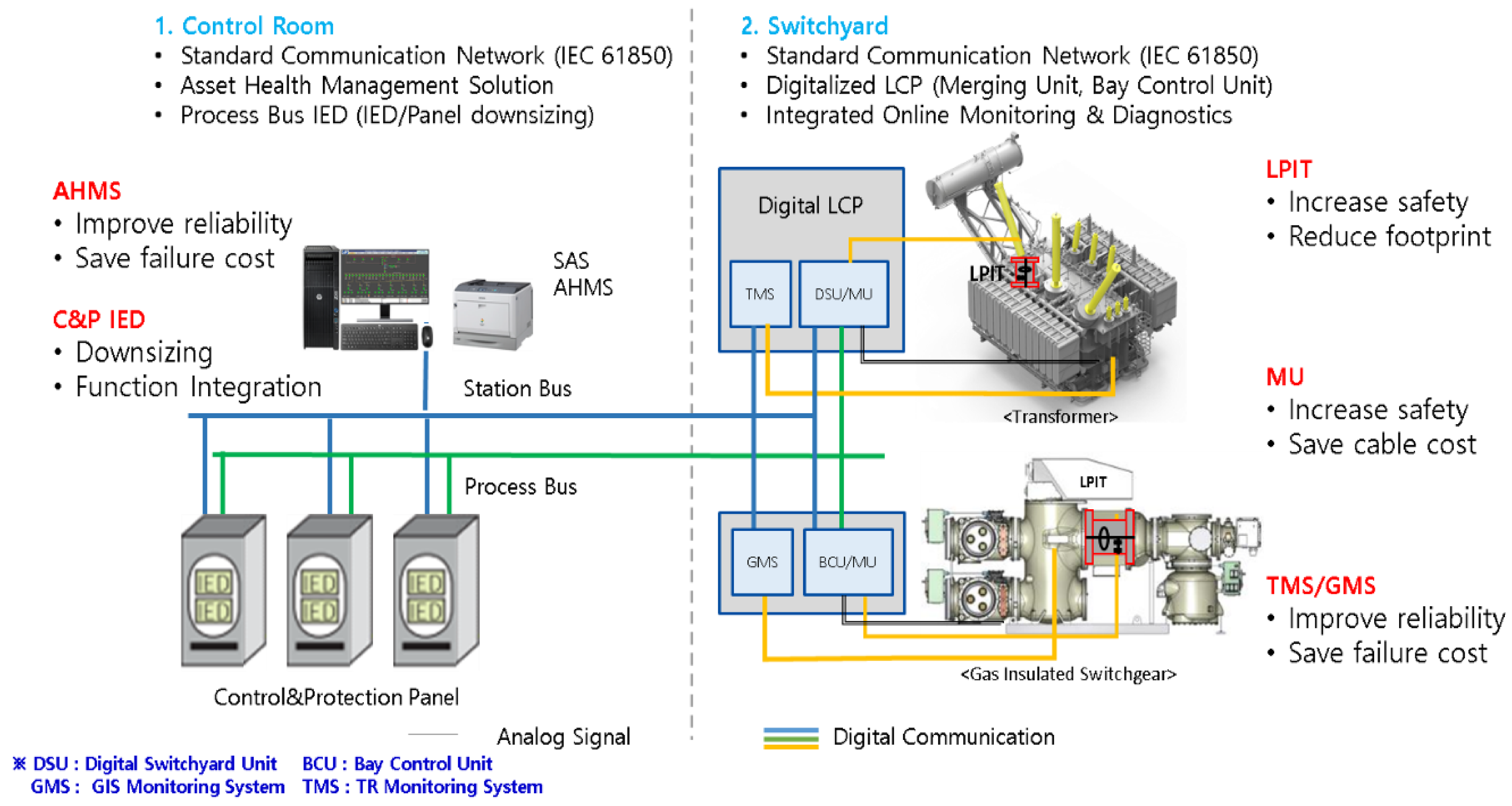

Fig.1 Configuration of Digital Substation based on IEC-61850

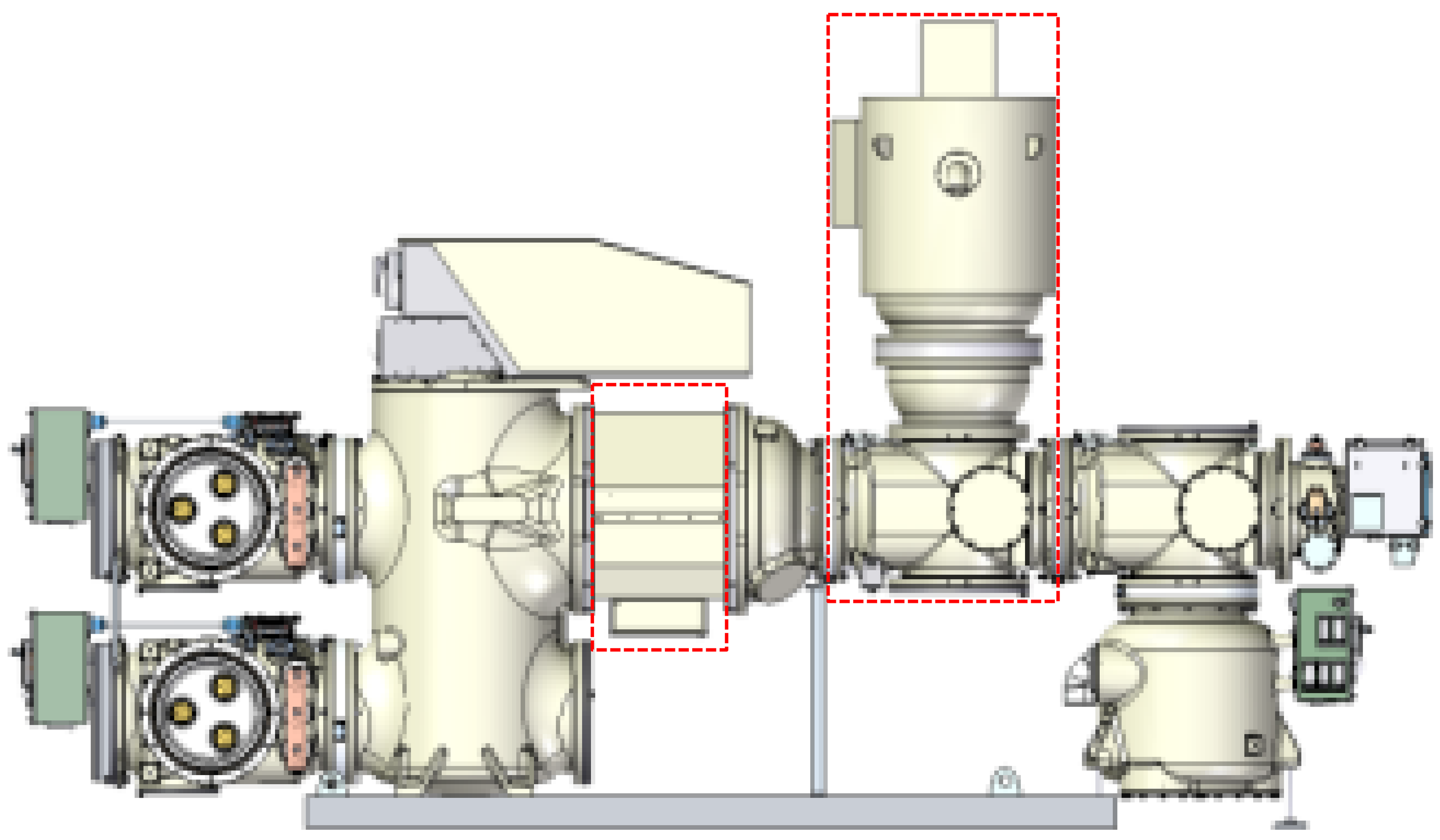

Fig.2 GIS configuration with conventional instrument transformers

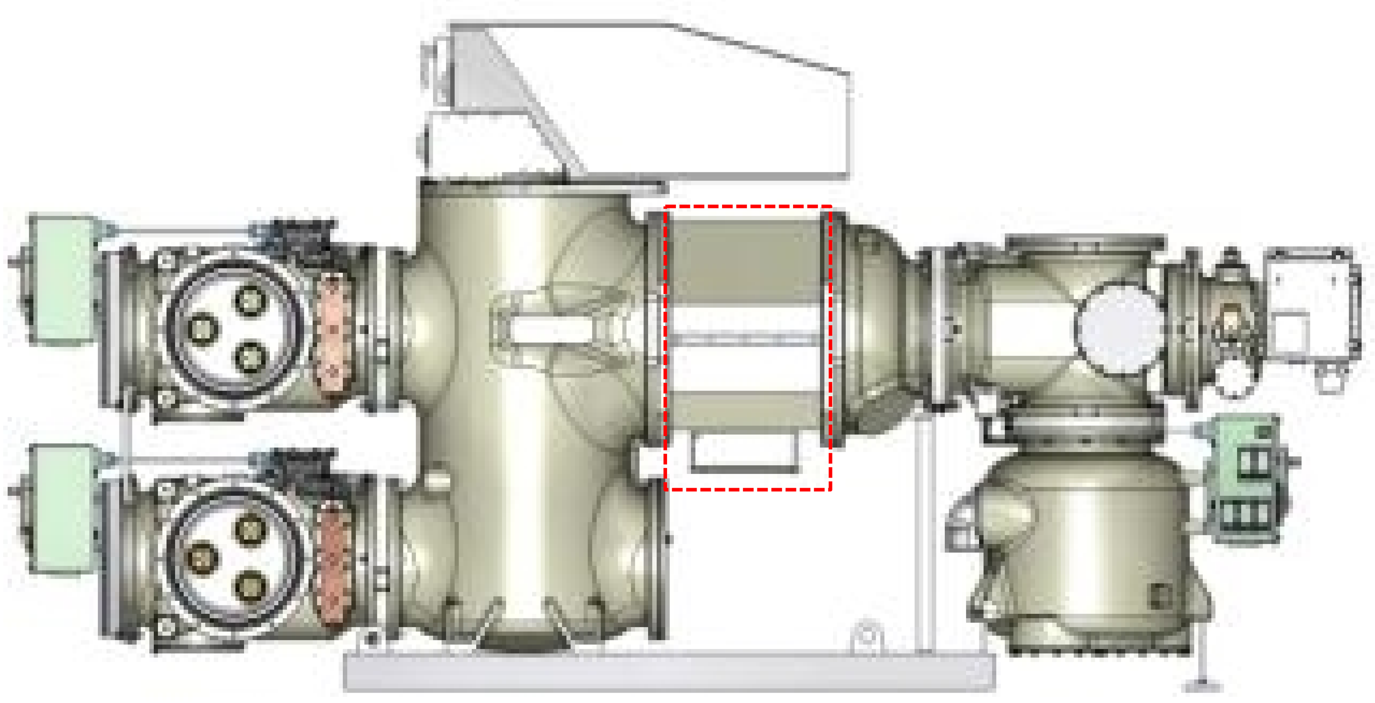

Fig. 3 GIS configuration with LPIT

Specification 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.

Table 1. 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

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Accuracy test results

- 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 4 shows the accuracy limit and measurement value according to voltage.
- 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 5, the accuracy limits and the measurement value of the magnitude according to the current were compared.

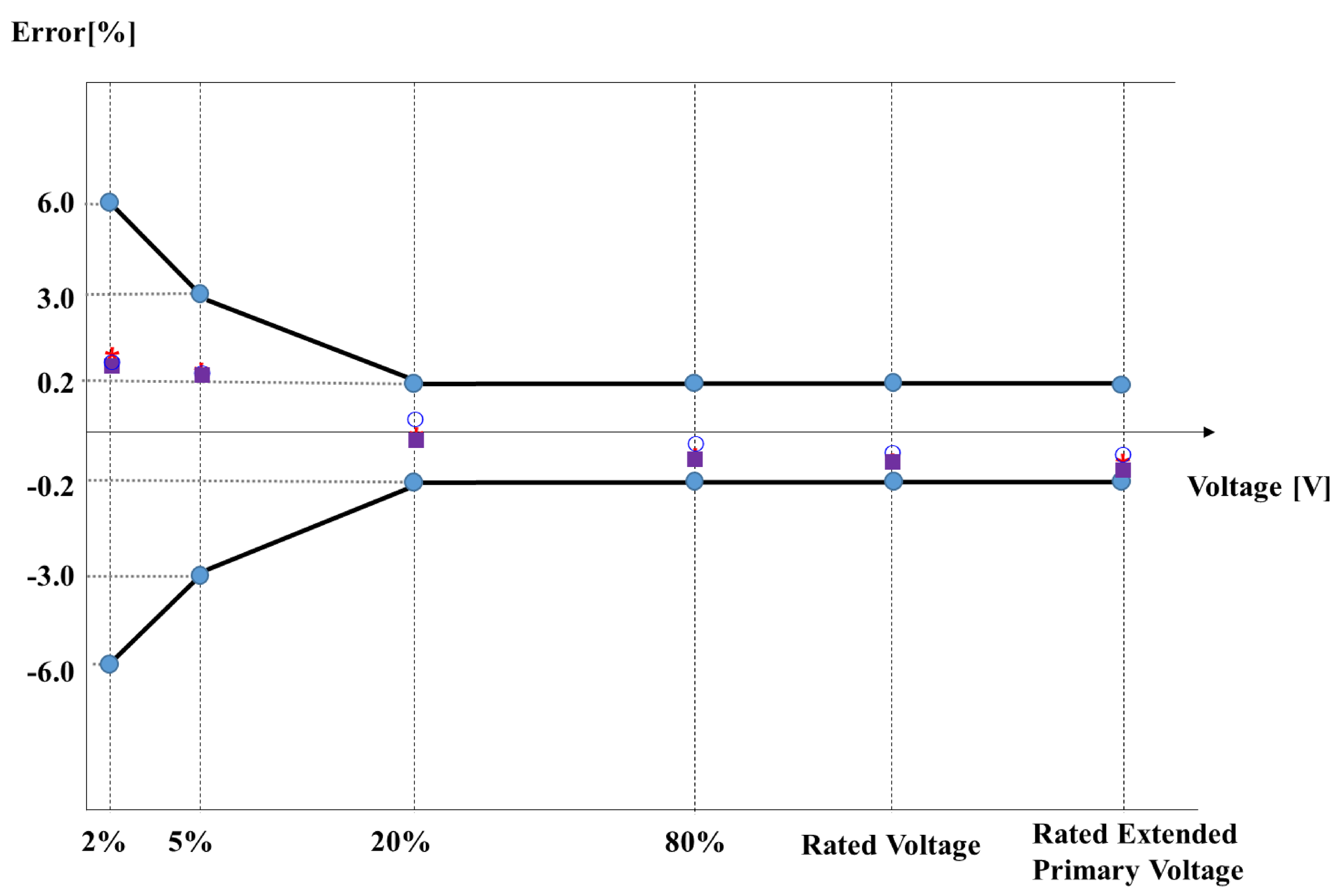

Fig.4 Accuracy test results of the voltage sensor according to the IEC60044-7

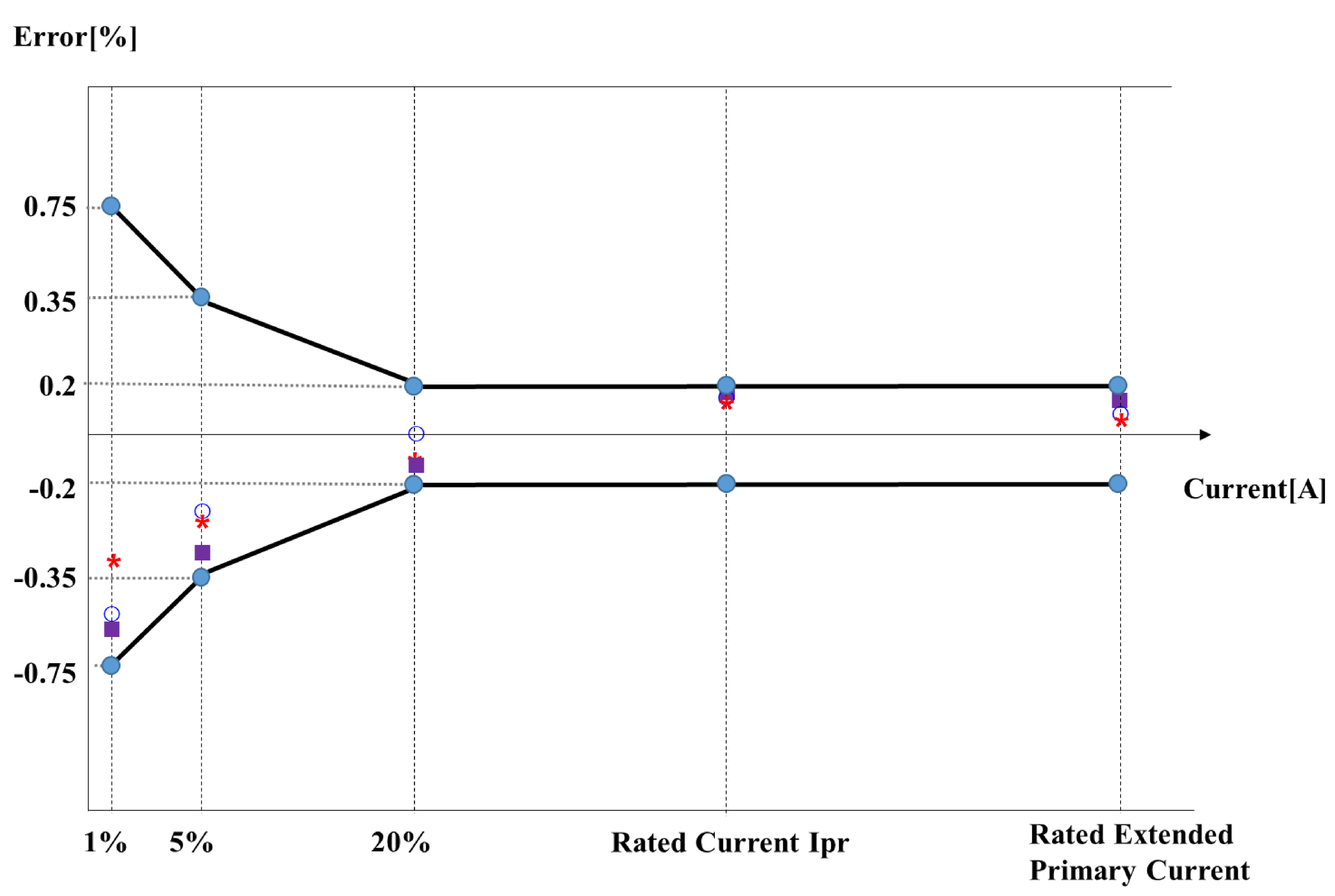

Fig. 5 Accuracy test results of the current sensor according to the IEC60044-8

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.

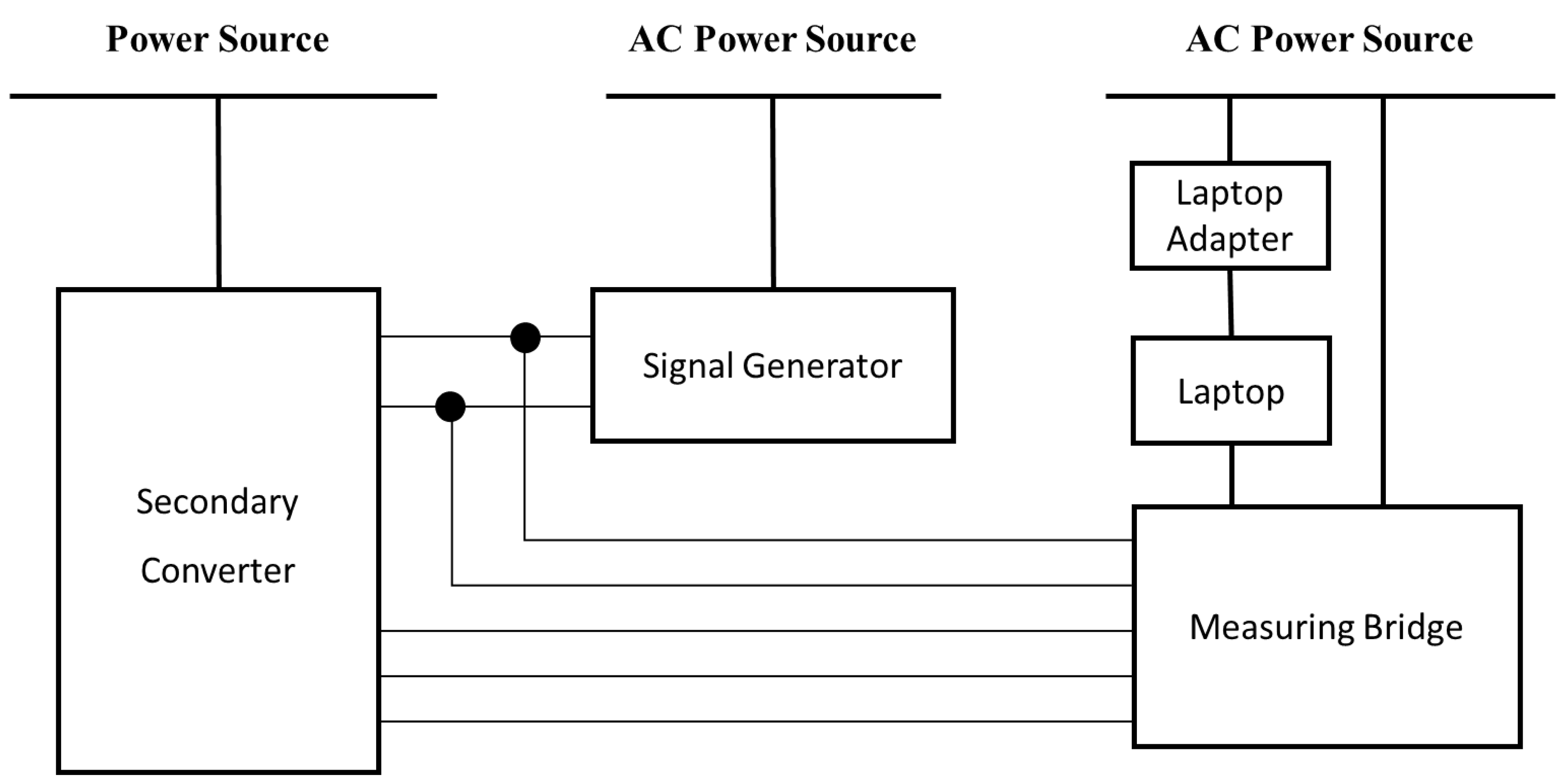

Fig.6 Configuration of the EMC test

Table 2. 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

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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.
- 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.

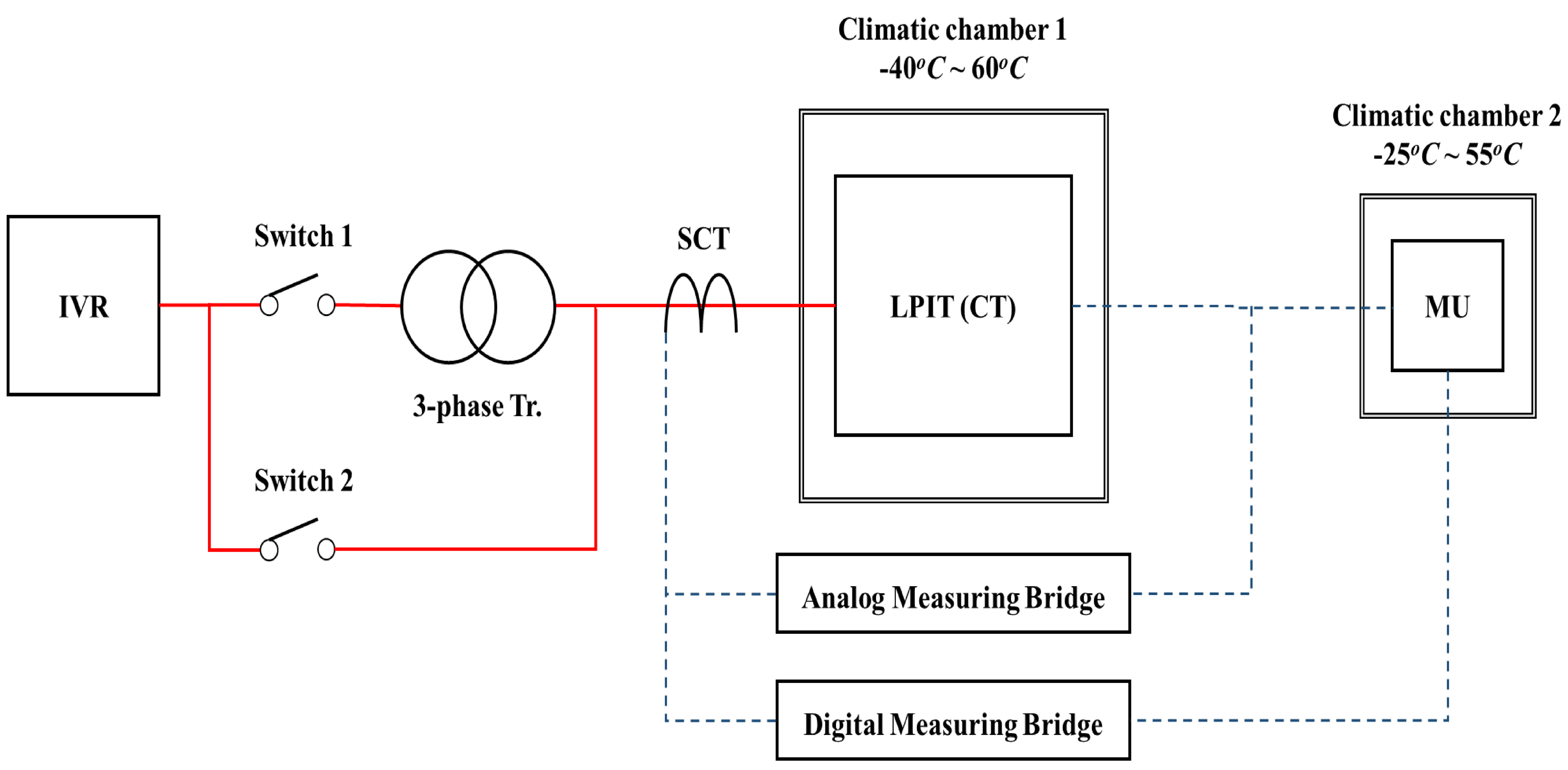

Fig.7 Configuration for the temperature cycle test of the current sensor

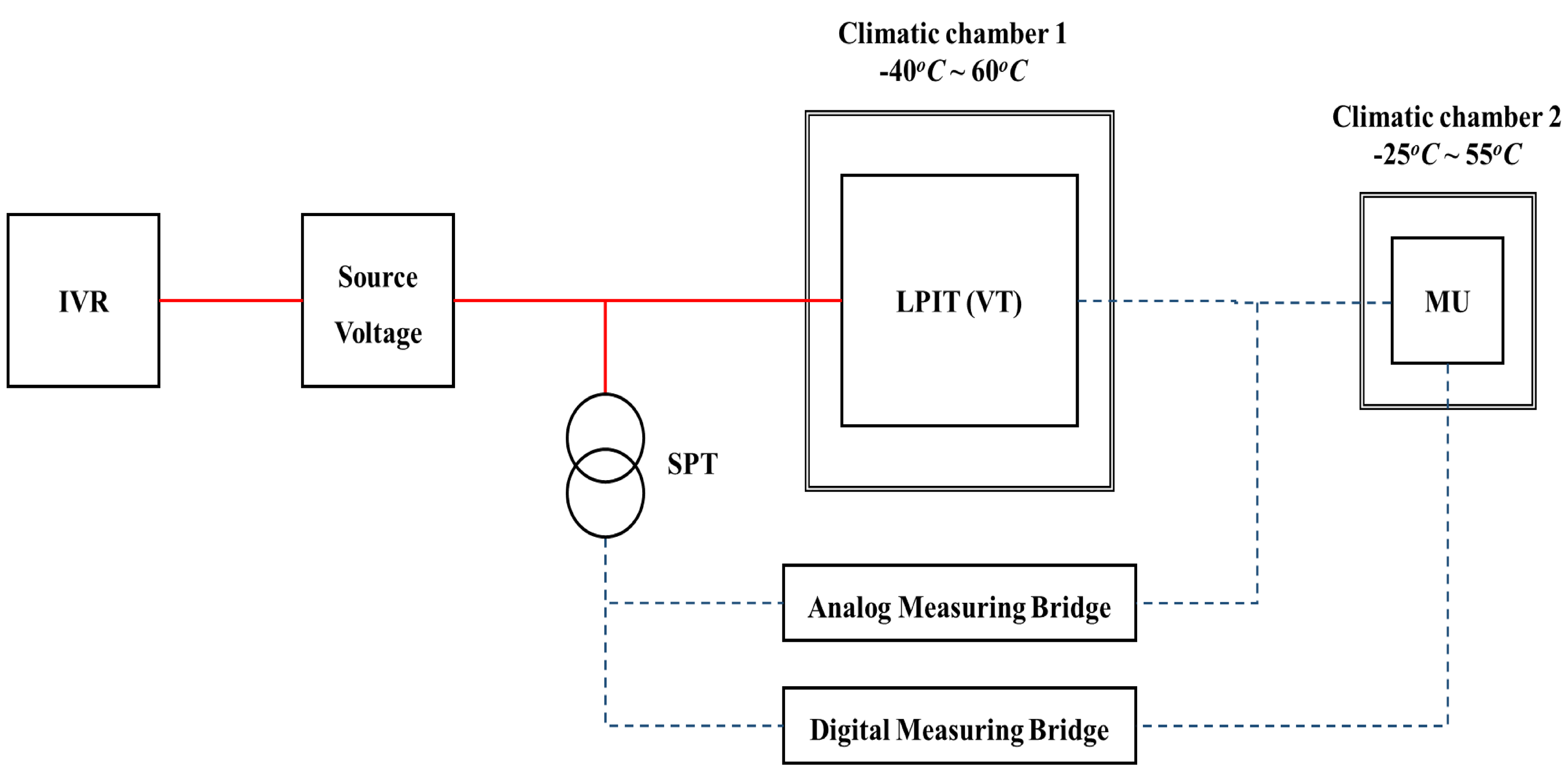

Fig. 8 Configuration for the temperature cycle test of the voltage sensor

Fig.9 Test setup of the LPIT in climatic chambers

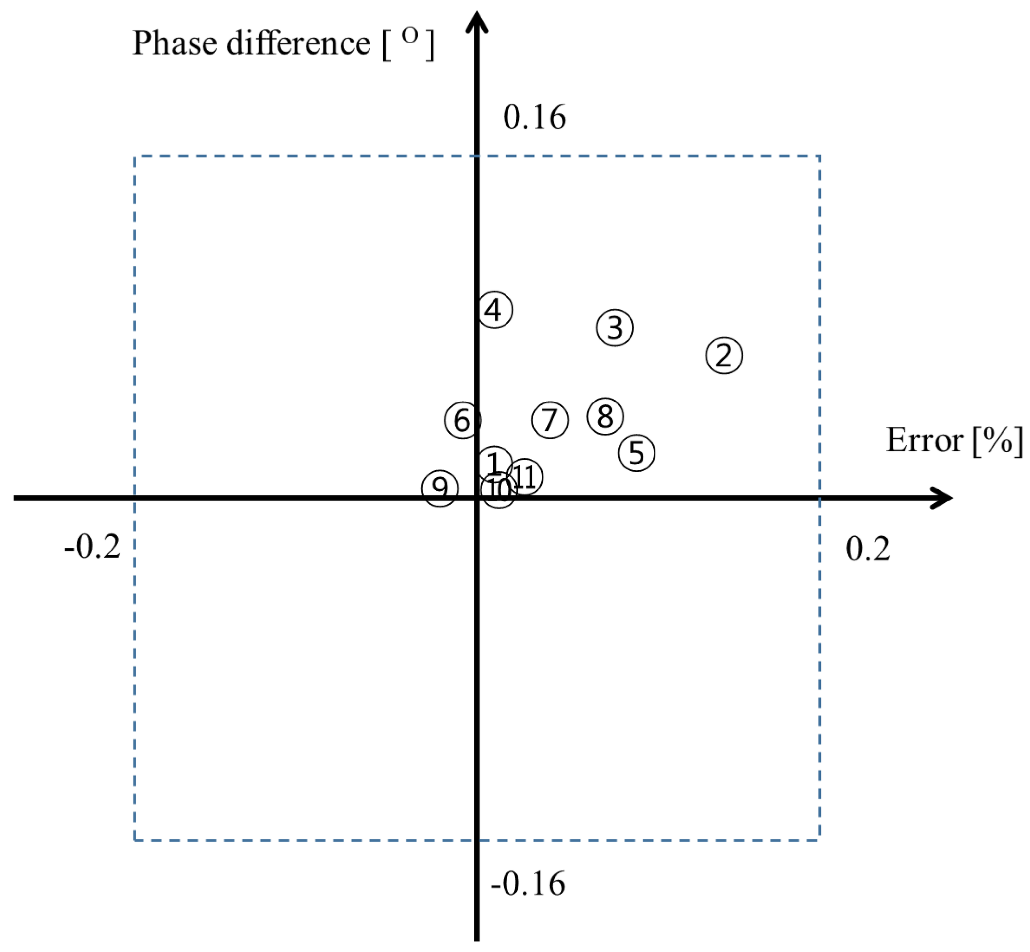

Fig.10 Results of the temperature cycle test

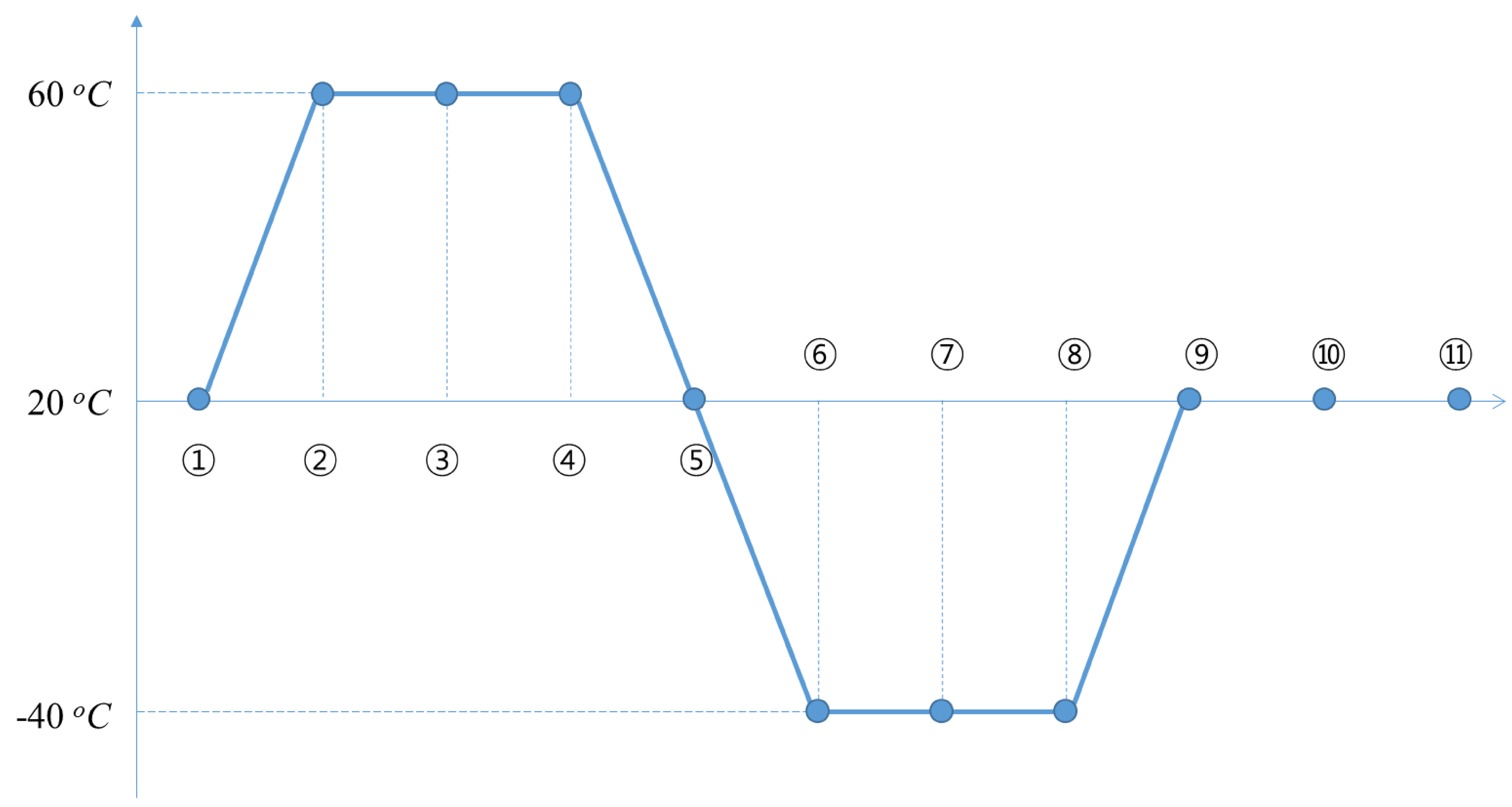

Fig.11 Temperature cycle according to the IEC 61869-6 and 60044-8

Conclusions and future works

- 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.