Investigation of Maintenance Standards of Instrument Transformers

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I. Research Background and Objectives

The instrument transformer is often applied for the scenario when encountering a large magnitude of voltage and current, leading to the difficulty of direct measurements. Hence, this type of transformer can effectively convert the voltage or current to the value, allowing for a safe measurement. While the current transformer is given for lowering the magnitude of current, the potential transformer is designed for the voltage reduction to the appropriate level. Fig. 1. shows the photograph and schematics of the through-type current transformer, and Fig. 2 illustrates that of potential transformer. Both transformers are used for instrumentation and measurement, which are critically important in the electrical power transmission and distribution system.

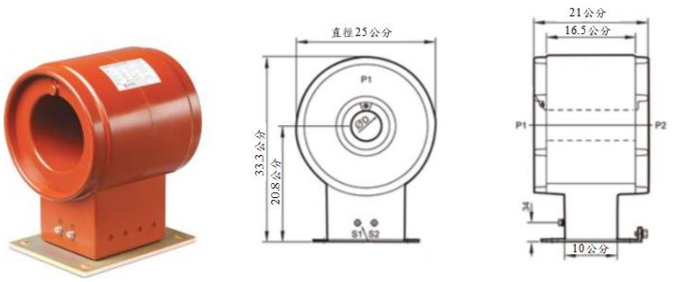

Fig. 1 Schematics of through-type current transformer

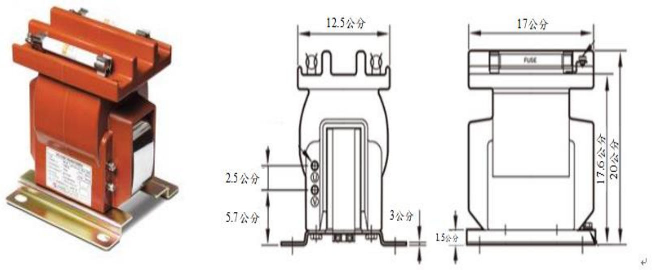

Fig.2 Schematics of potential transformer

With the recent development of insulating materials, the insulating strength of instrument transformer is increased to be applicable for more applications, which results in the crucial need to investigate the management and maintenance of this equipment. Yet, under the restriction of existing regulations and limited personnel for coping with such a large number of instrument transformers of various manufacturing companies which have been used for a long hour of operation, it becomes necessary to examine the inspection work for further improvement. Particularly, following the swift development of industry, the measurement accuracy and the reliability of power supply are most concerned. The issue of the testing, inspection, and maintenance of instrument transformers has become more important than ever, which also motivates the study made in this direction of research.

The operation of the potential transformer varies with the environment, the degree of climate change, and the instrument transformer. For example, the coastal area may accelerate the deterioration of the instrument transformer due to the sea breeze and salinization. It is noted that when the instrument transformer is placed in a relatively high humid environment, then the insulating properties may be degraded in a sudden temperature change. In addition, for the transformer allocated at the place containing dust, smoke, or corrosive gas, the creepage distance of this instrument transformer will be largely increased. This also illuminates the importance of regular maintenance to prolong the life duration of this equipment.

It is also worth mentioning that the instrument transformer purchased by Taiwan Power Company may not be immediately allocated on-field. There exists a certain possibility that the instrument transformer may deteriorate before operation, which results from an inappropriate maintained environment. Therefore, in order to ensure electrical safety, this study is devoted to collecting the existing literature survey of inspection methods, maintenance specifications, implementation methods, and practical applications of foreign electric power companies. With this study, we can contribute to high stability of electricity consumption and residential safety.

II. Contents of Study

During the operation of instrument transformers, there are three major reasons that may cause damage: defective insulation, body rupture, and improper maintenance. Defective insulation is usually caused by shortened creepage distance, low insulation resistance, and deterioration of insulation between interturn or interlayer after long-term use. The body rupture often occurs when the instrument transformer is installed under an unpleasant installation environment, resulting in partial damage to the appearance or deterioration of moisture absorption. During the period of maintenance, it is necessary to confirm that the terminals are firmly locked and to prudently check whether the appearance has burrs because of unexpected scratches.

To improve the safety of operation and reliability of equipment, the maintenance work of instrument transformers can be divided into scheduled maintenance and routine maintenance. For routine maintenance, aside from routine inspection of equipment operation, confirmation of appearance, and partial discharge detection, it needs to clean the instrument transformer at least once a year such that those contaminations causing partial discharge or breakdown of insulation can be better prevented. For scheduled maintenance, it is performed based on the inspection records, condition of occurrence, lifetime of equipment, and the importance of the area. Particularly, more attention should be paid to the outdoor transformer. For example, the damage to the outdoor converter caused by typhoons or the coastal environment may further lead to the discharging of the insulated case or corrosion of the shell. Under the considerations of cost and maintenance of equipment reliability, the number of samples used in destructive tests can be appropriately increased to boost the reliability of test.

It is also suggested to establish a

standard procedure for the type test and provide the testers as a reference to improve the reliability of the type test. It is recommended that the test of the transformer can be sequentially arranged as structure inspection, power-frequency withstand voltage, error experiment, induced voltage (or open circuit) test, temperature rise test, impulse voltage test, partial discharge test, wet withstand voltage test, mechanical short-circuit capability test, error (including polarity) test. Among them, the low-voltage through-type current transformer needs to be tested by an open-circuit test, while the medium-voltage current transformer needs to be tested through the induced voltage. To ensure higher accuracy of potential transformers, the error test is also required to carry out following the power-frequency withstand voltage test and the mechanical short-circuit capability test. Note that the polarity test of the transformer will also be conducted during the error test.

This study also collects the related content of type tests from several countries. Table 1 and 2 individually lists The analysis and comparisons of potential transformers and current transformers type tests of different countries are shown in Table1 and Table2, respectively.

Table 1: Analysis and comparisons of potential transformers type tests of different countries

Country (Standard)	Type tests of potential transformer
Taiwan (CNS 11437)	1. Structure inspection 2. Power-frequency withstand voltage 3. Error test 4. Induced voltage test 5. Temperature rise test 6. Impulse voltage test 7. Partial discharge test 8. Wet withstand voltage test 9. Mechanical short-circuit capability test 10. Erorr test (including polarity)
Japan (JIS C1731-2)	1. Temperature rise test 2. Short circuit test 3. Lightning impulse test 4. On/off impulse voltage test 5. Outdoor water injection withstand voltage test 6. Error test
U.S. (IEEE C57.13)	1. Partial discharge test 2. Excitation voltage and current measurement 3. Resistance measurement 4. Impedance measurement 5. Short time thermal rating 6. Temperature-rise test 7. Impulse voltage test 8. Wet-voltage withstand test 9. Grounded shield check
Sweden (SS-EN61869)	1. Temperature Rise Test 2. Accuracy of Instrument Test 3. Short-Circuit Current Capability Test 4. Insulation Resistance Test 5. Wet Test for Outdoor Type Transformers 6. Primary-Side Surge Voltage Test

Table 2: Analysis and comparisons of current transformers type tests of different countries

Country (Standard)	Type tests of current transformer
Taiwan (CNS 11437)	1. Structural inspection 2. Power frequency withstand voltage 3. Error test 4. Induced voltage test 5. Temperature rise test 6. Impulse voltage test 7. Partial discharge test 8. Wet withstand voltage test 9. Mechanical short-circuit capability test 10. Error test (including polarity)
Japan (JIS C1731-1)	1. Withstand current test 2. Temperature rise test 3. Lightning impulse test 4. On/off impulse voltage test 5. Outdoor water injection withstand voltage test 6. Error test
U.S. (IEEE C57.13)	1. Partial discharge test 2. Interturn overvoltage 3. Impedance measurement 4. Short time thermal rating 5. Temperature-rise test 6. Impulse voltage test 7. Wet-voltage withstand test 8. Grounded shield check
Sweden (SS-EN61869)	1. Temperature Rise Test 2. Wet Test for Outdoor Type Transformers 3. Primary Side Surge Voltage Test 4. Insulation Resistance Test 5. Short Time Current Tests 6. Accuracy of Instrument Test

III. Conclusions and Suggestions

The short-term feasible solutions can be divided into two parts. The first part lies in the consideration of the billing modular smart electric meter that comes with a 10-year warranty given by the manufacturers. Therefore, it is recommended that this warranty of the instrument transformer can be also extended to more than 10 years during purchasing. In this way, both warranties of the electric meter and instrument transformer can be consistent. The second part is to suggest that for those instrument transformers that have been stored for longer than two years, they are required to be re-tested before operation so as to ensure the electrical safety of this equipment.

The medium-term feasible solutions can be divided into two parts. One is to formulate a proper maintenance plan for the instrument transformer daily inspection without power interruption and regular inspection with power interruption. The inspection cycle can be performed once a year or based on the reliability requirements of connected customers. The other part is to change the replacement period of the instrument transformer by referring to the recommended manuals of Takaoka Toko and Fuji Dengyo. When the instrument transformer has been used for longer than 15 years, the frequency of inspection and maintenance should be increased to at least once a year. In addition, an electromechanical consulting company or personnel shall be commissioned to conduct electrical characteristic tests such as dielectric absorption characteristic test and power factor test for the instrument transformer to determine the degree of insulation deterioration of the instrument transformer and the aging level of the equipment.

The long-term feasible solutions can be divided into two parts. The first part is to increase the test specification of the materials selected for the instrument transformer. The manufacturers of the instrument transformer can check and attach the partial discharge initial voltage test results of the enameled coil and the accelerated life test results of the insulating resin, serving as the purchase certificate of primary materials used inside the equipment.

The second part is to consider the factors affecting the aging of instrument transformers or leading to the deterioration of insulation. In addition to taking high voltage into consideration, the surrounding environment that accelerates the degrading of the instrument transformer should be also considered. Based on the accelerated stress life test, it is also suggested to carry out the research and collection of those influences of environmental factors on the aging of instrument transformers. Meanwhile, an in-depth comparison of different insulating papers, iron cores, coils, and resins that may affect the life of instrument transformer under different environments should be extensively performed. In this way, the service life of the instrument transformer can be extended, and the efficiency can be simultaneously improved.