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Testing and protection of current transformer practical experiences in using the CPC 100

Mohammed Bouchahdane[a], Aissa Bouzid[b, a*]

[a]*Signals and systems laboratory,Institute of electrical and electronic engineering,University M'Hamed Bougara Boumerdes,Algeria*
[b]*Faculty of technology sciences, University of Constantine1,Algeria*

Abstract

We notice a recurrent underestimating in all transformer tests despite the huge influence of the accurate transducers on accounting systems. In addition, tests help to significantly reduce the risk of mixing up different instrument transformers or their connections. Tests can also help identify transportation damage inside a transformer. Last but not least, regularly scheduled tests are essential when it comes to detecting effects that can occur within the life cycle of a transformer such as shorted coils, loss of class accuracy due to material changes or changes to the load. Changing the power supply topology and thereby the primary time constant can lead to a situation where the transformer becomes unusable for protection, as it is saturated far earlier than desired due to transient operations. In this paper, we will look at the testing practices for current transformer used by the NATIONAL COMPANY OF ELECTRICITY AND GAS (SONELGAZ Algeria) and show that with the use of the CPC 100 many standard electrical tests for CTs can be performed with one single device saving testing time and labor costs.

Keywords: Current transformers, protection, testing, electrical power engineering, diagnostics

1. Introduction

Current transformers are very simple - yet are they so complex. A transformer ratio, a magnetization curve and similar can easily be determined. Other parameters, such as unsaturated and saturated inductance or the behavior of a protective core in a short interruption require special measuring processes. Before applying the current transformer in Oum bouaghi substation 60/30 kV in the Algerian network ,the CT has to be tested for permanence and quality evaluation to make sure that it can work with our protection system properly. These tests include the following:

Insulation resistance, Ratio and polarity, Excitation curve and Winding resistance.

In this paper we will discuss how the CPC 100 of OMICRON is applied for testing the current transformer which offers a broad spectrum of options for highly accurate testing of CT .

Experiences in that matter have been led on that subject on the Oum Bouaghi 60/30 kV substation of the Algerian network, using the 60 kV line of Khenchla [1-3].

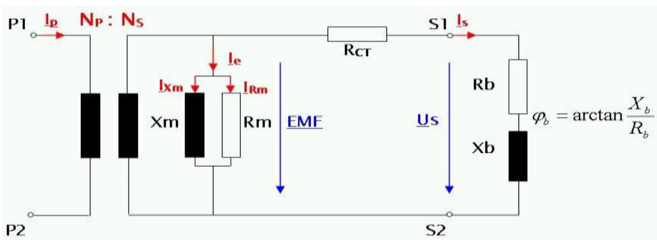

Fig. 1. Equivalent circuit diagram of current transformer.

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Corresponding author. *E-mail address*: m.bouchahdane@univ-boumerdes.dz.
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2. Current Transformer Application

Current transformers are used for relaying and metering purposes in electrical power systems. They connect the high power primary side to the protection and metering equipment on the secondary side. Depending on the application they are used for, current transformers are differently designed [4].

2.1. Protection current transformers

As it is used to feed protective relays, the CT must be accurate during normal and fault conditions. Failures in transformation could lead to misoperation of the relay along with unwanted and costly outages. To test CTs according to the requirements of modern protection systems, it is compulsory to consider transient components and auto-reclosure systems.

2.2. Protection current transformers

CTs for metering purposes must provide high accuracy up to class 0.1 to guarantee correct billing. It is therefore essential to test and calibrate the metering current transformer, as the entire metering chain is only as accurate as the instrument transformers feeding the meter. In contrast to protection CTs, metering CTs must go into saturation directly above the nominal primary current level to protect the connected metering equipment.

3. Current Transformer Testing

Testing current transformers helps to detect:

3.1. Installation related failures

Transportation damages, wiring errors and manufacturing defects.

3.2. In-service related failures

Degradation of accuracy class, shorted turns, magnetized core, burden failures in secondary circuit and insulation material failures.

4. Testing and Analyzing the Results

4.1. Insulation resistance Testing

Insulation resistance measurement is a non-destructive measurement method when carried out under normal test conditions. It is done by applying a DC voltage and the aim is to produce a result in kΩ, MΩ or GΩ. This resistance value expresses the quality of insulation between two conductive elements and gives a good indication as to the risk of leakage currents flowing. The non-destructive nature of this method is useful when tracking the ageing of insulation on a piece of electrical equipment or on an installation as time goes on, so it can also be used effectively as a means of preventative maintenance. This measurement is carried out using an Insulation Tester, otherwise known as a Megohmmeter (Chauvin Arnoux 6549).

Table 2. Current transformer insulation resistance measurement.

Spotting	**Test voltage and duration**	**Phase 0**	**Phase 4**	**Phase 8**
Primary / Earth	5000 Vdc – 1 mn	231.8MΩ	475MΩ	333.4MΩ
Primary / Secondary 1	1000 Vdc – 1 mn	19.39GΩ	547GΩ	432GΩ
Primary / Secondary 2	1000 Vdc – 1 mn	600GΩ	705GΩ	539GΩ
Secondary 1/ Earth	500 Vdc – 1 mn	378GΩ	485GΩ	370GΩ
Secondary 2 / Earth	500 Vdc – 1 mn	461GΩ	626GΩ	500GΩ

4.2. Winding resistance

After entering the test current and pressing the Start button, the test card.

- displays the deviation of the measurement over time during the period of charging the winding.
- automatically performs a discharging of the winding after saving the measurement.
- measures the DC voltage
- measures the resistance
- (optionally) compensates the temperature behavior of copper, where the applied temperature compensation calculates the resistance for working temperature.

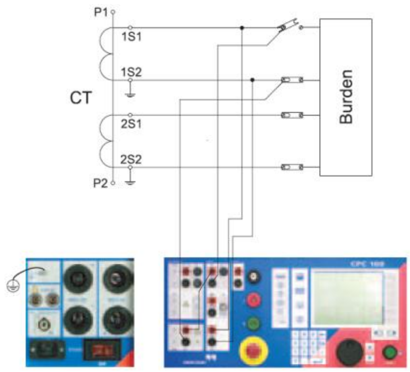


Fig. 2. Connection diagram of CPC100 to CT.

The reference resistance (Rref,temperature-compensated winding resistance) is calculated:

$$R_{ref} = (V_{DC}/I_{DC}) \times (235\,^{\circ}\mathrm{C} + T_{ref}) / (235\,^{\circ}\mathrm{C} + T_{meas}) \quad (1)$$

Tmeas: Ambient temperature

Tref: Operating temperature of test object, that is, the power transformer's secondary winding

235 ℃ for Cu and 225 ℃ for Al .

Note: Formula according to IEC 60076-1.

Table 3. Results of a current transformer winding resistance measurement.

Winding	Idc test	Phase 0	
		Temperature measurement	**Resistance measurement**
Measurement Circuit	2A	10.00 ℃	**3.8458 Ω**
Protection Circuit	2A	10.00 ℃	**1.7308 Ω**

4.3. Ratio and polarity

Supplied from a single phase wall outlet, the CPC 100 can generate up to 800 A AC (2000 A with CP CB2 current booster) for injecting into the CT's primary side and testing its ratio and polarity.

Tests ratio, polarity with direct injection to CT primary current input and measuring of secondary output. After entering I primary, I secondary and test current, and pressing the Start button, the test card measures:

- Secondary current.
- Ratio with error in percent.
- Polarity on the CT terminals.

Iprim: actual current output at the 800A AC output that is injected into the CT's primary side

Isec: measured secondary current and phase angle ϕ relative to Iprim

Ratio: ratio Iprim /Isec (2)

The value Isec is calculated as follows: Isec act x (Iprim nom / Iprim act) (3)

and deviation of current ratio in %.

((Kn x Isec - Iprim) / Iprim) x 100% (4)

Kn = rated transformation value. Polarity: displays the status of the polarity.

OK = phase Isec – phase Iprim = $-45° < 0° < +45°$ (5)

NOT OK = all other cases

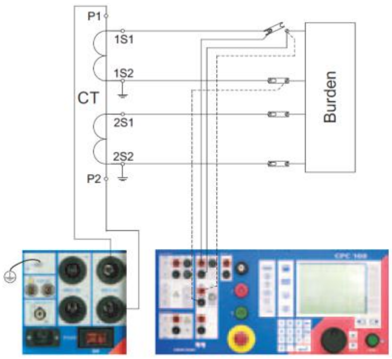


Fig. 3. Connection diagram of CPC100 to CT.

Table 4. Results of a current transformer ratio.

Winding	**Theoretical ratio**	**Phase 0**				
		I injected HV side	**I injected LV side**	**Ratio calculated (A)**	**Error**	**Polarity**
Measurement Circuit	600 /1	150.0 A	249.91 mA	**600A /0.9998 A**	**-0.02 %**	OK
Protection Circuit	600 /1	150.0 A	249.61 mA	**600A / 0.9986 A**	**-0.14 %**	OK

4.4. Excitation curve

For excitation curve measurement, the CPC 100's output is connected to the secondary terminals of the core. Within an automatic test run, the CPC 100 measures the excitation curve and displays the knee point voltage and knee point current (according to the relevant IEC or IEEE / ANSI standard). The CPC 100 also automatically demagnetizes the CT core after the test. The test is done using a regulated voltage source [5][6][7].

IEC/BS According to IEC 60044-1, the knee point is defined as the point on the curve where a 10% voltage increment increases the current by 50%.

ANSI 45° According to IEEE C57.13, the knee point is the point where, with a double logarithmic representation, the tangent line to the curve forms a 45° angle. Applies to current transformer cores without an air gap.

ANSI 30° Like ANSI 45° but forming a 30° angle. Applies to current transformer cores with an air gap.

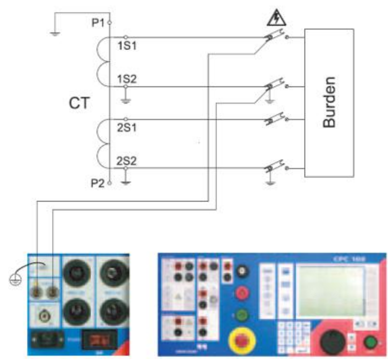
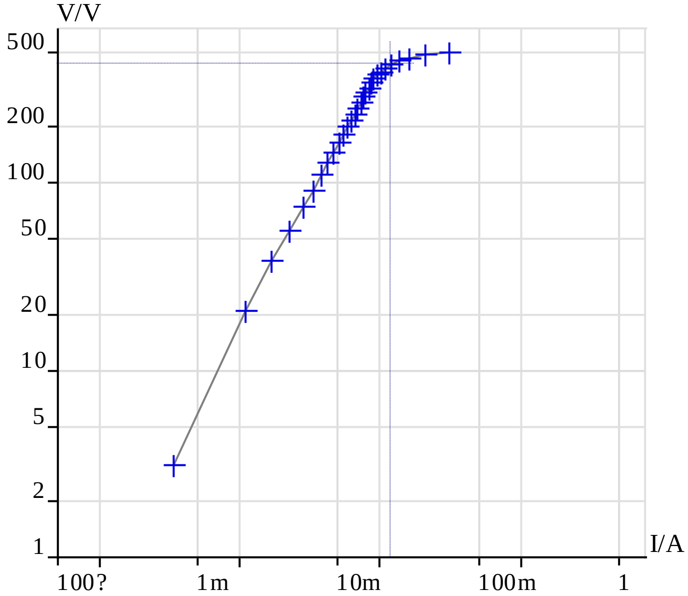


Fig. 4. Connection diagram of CPC100 to CT



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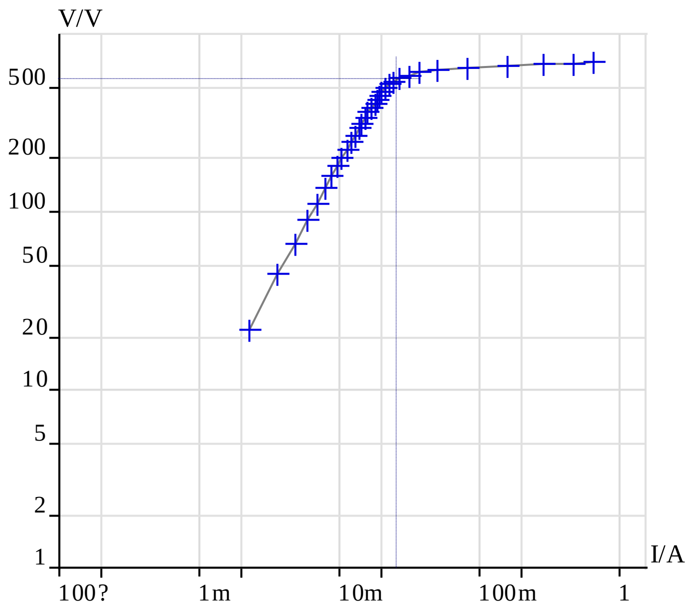

(b)

Fig. 5. Excitation curve of current transformer (phase 0): (a) Measurement circuit and (b) Protection circuit.

Table 5. Results of a current transformer excitation curve measurement (phase 0).

Winding	**Frequency**	**Phase 0**			
		Imax injected	**Vmax injected**	**V knee point**	**I knee point**
Measurement Circuit	50Hz	1A	600V	**428.03 V**	**24.086 mA**
Protection Circuit	50Hz	1A	900V	**557.07 V**	**26.114 mA**

5. Conclusion

This paper illustrates with some practical examples in the use of testing CT under actual testing conditions. The measurement results show a very good matching with the values measured by manufacturer. By the time passing and transformers getting older, we need a far more recurrent and regular checks of the operating conditions. In using the omicron CPC 100, the most important current transformer, measurements allow a faster and far more efficient performing. Automatic test procedures enable simple operation and the report is created automatically.

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