Measurement 46 (2013) 4114–4120

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

A non-conventional instrument transformer

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ARTICLE INFO

Article history:
Received 15 March 2013
Received in revised form 1 July 2013
Accepted 2 August 2013
Available online 13 August 2013

Keywords:
Extended merging unit
High-voltage power network
IEC61850
Low-power current transformers
Non-conventional instrument transformer

ABSTRACT

The paper describes a non-conventional instrument transformer (NCIT) offering the possibility of adapting the measuring points in the high-voltage power network to new states as a result of the impact of intermittent renewable energy resources, harmonic distortions evoked by switching apparatus and smart-grid systems, enabling prompt and accurate measurements in a wider frequency range at a higher dynamics, and providing more reliable operation of the power network. The features of the proposed NCIT are in using the low-power current transformers (LPCT) and in the measuring and processing electronics which are situated partially on the potential of high voltage (HV) line and partially on earth potential.

1. Introduction

The measuring points in the HV power network have to adapt to new states evoked by the impact of intermittent renewable energy resources, harmonic distortions caused by switching apparatus and smart-grid systems [1]. The existing conventional instrument transformers, which have been reliably performing their tasks for many decades, are no longer a suitable choice for the today's electric power system. The need for prompt and accurate measurements in a wider frequency range, higher dynamics, safer and more reliable operation calls for a new generation of the instrument transformers.

The major issues being copped with when using the conventional instrument transformer are:

- Many design variations necessitated to meet different purposes (transient, differential, metering, etc.).
- Demanding insulation.
- Environmentally hazardous technology (oil).
- Hazardous faults (explosions as a results overheating).
- Heavy and expensive for using copper and other precious metals.
- Many secondary wires and hazardous handling (open current terminals).

The NCIT, which is shown in Fig. 1, solves all the listed issues. In the NCIT electronic measuring part there is no environmentally hazardous transformer oil or precious metals used. The employed current sensors of a wide frequency and dynamic range allow for different measuring and protection [2] operations. NCIT monitors all the power quality indices [3] and analyses the harmonics. It can be easily connected to digital protection systems implemented according to the IEC61850-9-2 standard [4] thus avoiding heavy wiring and additional signal conversion.

The biggest concern when using the electronic instrument transformers is of course their operational reliability. A NCIT prototype was therefore thoroughly tested in a HV laboratory to prove its resistance to heavy disturbances taking place in the power network. The testing being positive was then installed in a substation connected in series with the conventional instrument transformers to be further tested under real network operating states. Having been in operation for one year its reliability is now proven. There are still some further tests to be made particularly to

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http://dx.doi.org/10.1016/j.measurement.2013.08.011

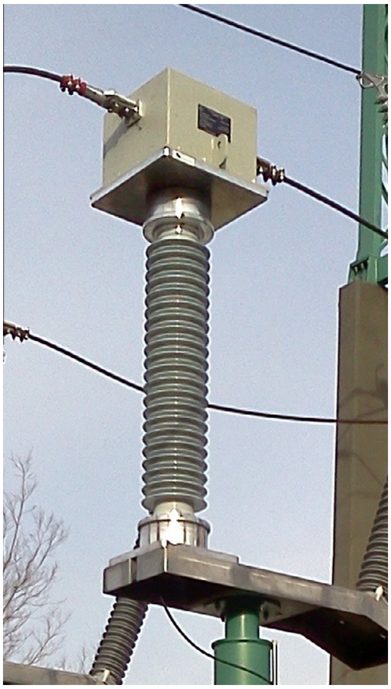

Fig. 1. Non-conventional instrument transformer.

meet specifications of the IEC61869 standard [5] and other applicable standards imposed on the digital instrument transformers.

2. NCIT structure

The traditional current and voltage HV measuring transformer consists of a bottom part (using aluminum part which is the core of the current transformer with secondary connections and is usually filled with oil), middle insulation part (made of ribbed porcelain or silicone) and upper connection part (HV cable bushing). To measure the voltage a RC divider is used enabling undistorted measurements at higher frequencies and harmonic analysis based on them.

The NCIT is similar to the conventional voltage-measuring transformer, using a capacitive divider and the current measuring part floating on the HV line.

In Fig. 2, the key NCIT components are shown. On the top of the insulator there is a metal-shielded head (1) with the HV wire-connections bushings. Inside the head there are used current transformers (CT (2)), more precisely the low-power current transformers (LPCT) [6] which are normally used for the measuring and protection purposes on the low-voltage level. They require no extra insulation since they are electrically "floating". The used LCPTs (IEC60044-8) design to meets all the metering requirements such as accuracy, phase displacement resistance immunity to external disturbances and is even able to accurately measure the instantaneous peek consumption without damaging the used measuring instrument which is not possible when using the standard current transformer. LPCT is also used for protection purposes. It allows for fast response, very high dynamics (full-load current of 2500 A, max current >40 kA) and high accuracy. Another advantage of using LPCT is its low-voltage output (up to 9 Vrms). This type of CT outperforms the standard CT in terms of its price, weigh, dimensions and handling.

In NCIT, there are two identical LPCTs used; one for protection and the other for measuring purposes, though just one would suffice because of its high accuracy and linearity in its extremely wide operation range. The auxiliary-supply CT (3) is used to energize the electronics (when the primary and secondary power units fail to provide power).

The auxiliary power-supply unit (4) provides the power for the electronics. It uses three different power inputs (3, 6 and 8) and is a reliable power source for the measuring and communication electronics. In a normal operation state, the auxiliary power supply used for measuring the electronic and communication systems (<100 mW) is derived from the capacitive voltage divider (8). In short-circuit or ground-fault state decreasing the primary voltage, the additional power is obtained from CT (3). To allow for a very fast response time the power is supplied to the measuring electronics even when the power transmission lines have not been energized for a longer period of time (e.g. used as a reserve power supply). If such be the case, the power is fed to the measuring electronics over optical fibers to assure proper HV insulation. The energy received over the laser suffices for a short period of time if the fault happens immediately after the transmission line has been energized and when a fast response is required.

(5) Shows the main measuring unit providing fast and accurate sampling of the voltage and current to be measured as well as time stamping of the derived samples. Its internal reference is stable, A/D conversion is very fast and accurate and its power consumption is low. It delivers 1000 samples/period (20 ms) for metering, protection and power quality (PQ) evaluation (transients and events). At the same time it also sends out 80 samples/period for the protection purposes in a stand-by mode. For safety reasons, the measuring unit is equipped with a redundant dual-processor having a self-checking mechanism for fail-safe operation. The device also measures some other parameters such as temperature and additional capacitive current (7). The optic fibers, which are used for the communication purposes in the communication interface (6) provide adequate insulation between the ground and the HV potential where the measuring electronics resides. The optic fibers are also used for delivering an auxiliary-power supply to the measuring electronics (4). A very fast communication system sends readings in real-time as well as receives settings (internal clock synchronization).

In (7) there is an additional current sensor measuring the current through the capacitive divider (8) to assess the capacitor health. (8) Marks the main capacitive divider inside insulator with two main terminals (HV and GROUND). One is a measuring terminal and the other is used for auxiliary-power supply electronics supporting different HV levels (110 kV and 400 kV). The last component in the NCIT system is a merging unit (9) which will be described below.