Using the next generation combined digital transformers

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Annotation. The paper considers and analyzes the use of new generation combined digital instrument transformers (DIT) with an optoelectronic conversion unit and a combining module or a stand-alone combining module, an external synchronization source or an internal clock generator and digital interfaces.

Introduction

The key element in the system for controlling the operating modes of electrical networks are primary instrument current and voltage transformers, which provide means of protection with measuring information, as well as measurements, accounting and registration of electricity flows in the power system [1].

Electromagnetic transformers that are in operation and production have come a long way in their development and at this time are rather imperfect devices that have their drawbacks.

They should be replaced by electronic transformers (sensors), which have great potential and operational capabilities: stability and compactness, reduction in the volume of wiring and an extended dynamic range, wide bandwidth and self-diagnostics, cost reduction, etc. Digital instrument transformers (DIT) - electronic instrument transformers with digital interfaces, supporting the protocol IEC 61850-9.2 [8]represent a new class of products based on the latest advances in optics, electronics, digital signal processing and transmission systems. These devices are distinguished by exceptional stability, high accuracy, speed, small dimensions and weight [1].

An example of building a measuring system in a high-voltage substation using combined DITs is a solution, the functional diagram of which is shown below in fig. 12].The insulating columns are installed on support structures at the open switchgear (OSG) section of the electrical substation, with the primary current sensors located on the top of the column, and the primary voltage sensors located inside the cavity of the tubular insulator of the column.

The signals (values) measured by the primary sensors are transmitted via insulating fiber-optic cables to ground level and then directed to secondary converters integrated in an optoelectronic conversion unit, usually located in the substation or switchgear of an electrical substation. The interaction between the primary sensors (meters) and the secondary converters of the optoelectronic unit, as a rule, is an important decision of a particular plant.
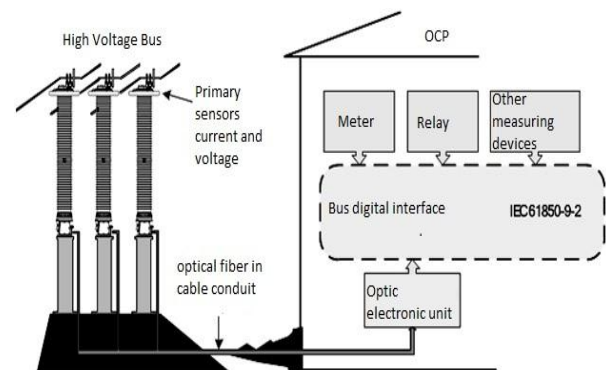
Fig. 1. Functional diagram of the measuring system[2].

In the optoelectronic unit, the data of the primary sensors are combined into a single digital data stream in accordance with the IEC 61850-9.2 protocol [8] and further distributed via the Ethernet network to the recipients of the measurement information. The functional diagram of IT with digital output (DIT) is shown in Fig. 2 [2].

The DIT does not necessarily have to include all the parts indicated in the figure. The number of primary inputs and their type (voltage or current) in an individual DIT may differ from the given example.

For comparison, Fig. 3 shows the general functional diagram of the DIT using a stand-alone combining module (SACM or field converter). SACM is a device that is not a component of DIT.

The DIT interface point must terminate with a digital output with a fiber optic or electrical connector that meets the requirements for a combiner or sensor with a communication interface. Recommended level for 100Base-FX fiber-optic communication system (full duplex, two-core fiber optic cable with connectors).
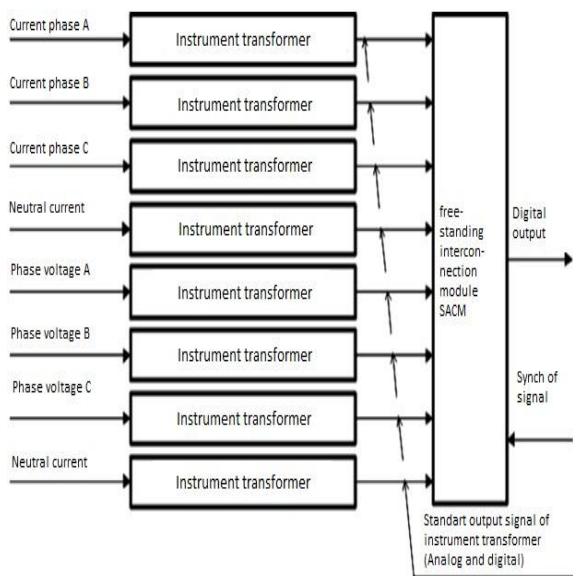
Fiber optic cables used must comply with IEC 60794 [11].

Synchronization. The DIT or the combiner must be able to receive an external synchronization signal.

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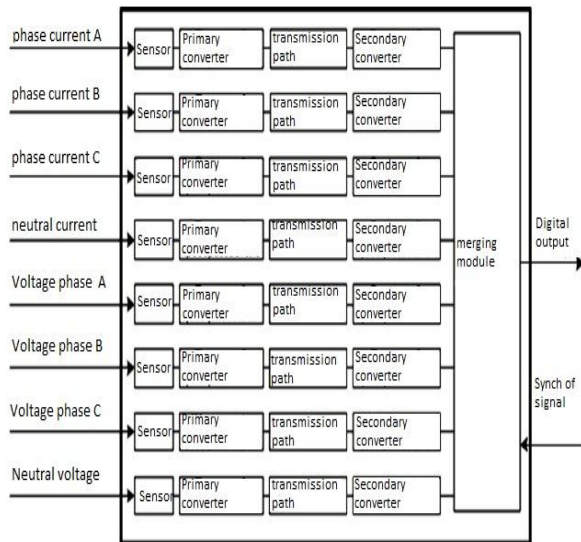
Fig. 2. General functional diagram of instrument transformers with digital output.

Fig. 3. An example of building a digital instrument transformer with a separate combining moduleю

The sync signal must be a 1PPS input signal as required by IEC 60044-8 [3]. If desired, synchronization can be performed via Ethernet in accordance with IEC 61588 [12].The 1PPS rise time value can affect the timing of the combiner's internal clock. This parameter can be neglected if the maximum trigger time deviation is no more than ± 2 μs, with a rise time of no more than 200 ns. The synchronization source must have an accuracy of ± 1μs. Samples from the combiner must be time stamped with class 4 accuracy in accordance with IEC 61850-5 [7] (± 4 μs). For this reason, the clock input of the combiner can have a jitter of ± 2 μs. The synchronization source must have an accuracy of ± 1μs. Samples from the combiner must be time stamped with class 4 accuracy in accordance with IEC 61850-5 [7] (±

4 μs). For this reason, the clock input of the combiner can have a jitter of ± 2 μs.

Functioning without synchronization

If the combiner does not receive a sync signal and exits holdover as described above, the "SmpSynch" attribute in the SV message shall be FALSE. SmpCnt should continue to read as if a sync pulse were present at its input.

Synchronization sources that generate a 1PPS signal are usually implemented with GPS receivers. The 1PPS pulse has an accuracy of ± 1 μs compared to absolute time (GPS time reference). If the GPS receiver loses signal, the internal clock of the synchronization source will begin to drift from the ideal GPS time. There are two possibilities to handle this situation: calculations performed in the combiner module, and in case the current and / or neutral voltage is not measured by a real sensor, the combiner must calculate these values as the sum of the phase values. However, since the recipient needs to know whether the values are being calculated or measured, the merging module must show this in the appropriate quality descriptor.

In case of automatic detection of a malfunction of the DIT, the flag on the invalid data on the digital output must be raised. Failure of the transmission system should be automatically detected with the generation of a corresponding fault signal. In the event of a power outage or input voltage out of range, data output must be stopped and digital output disabled. After the restoration of the power supply, the functioning of the DIT should be automatically restored. In accordance with IEC 60044-8 [3], the maximum allowable latency for signal processing to the combiner is 3 ms (+ 10%, - 100%). The signal processing delay is defined as the time interval between the moments of measurement on the primary side of the DIT until the moment when the frame containing this measured value is published on the communication interface of the DIT. The measurement of the delay associated with signal processing is carried out when the DIT is synchronized from an external reference time source using precision time marking / fixing of individual frames sent from the communication interface of the DIT.

The manufacturer shall provide information in accordance with standards such as IEC 60812 [10] and IEC 61025 [6] on the functional and operational reliability of electronic instrument transformers, including mean time to failure (MTTF), mean time between failures (MTBF) and analysis. Failure Mode and Effect (FMEA) associated with the main part subject to service. Functional diagram should be provided that describes the relationship between the subsystems and shows how the redundancy is performed, if any. The DIT nodes for which the corresponding maintenance operations are carried out must be identified.

The materials used in the construction of transformers must meet the requirements for explosion hazard and fire safety.

Comparative results of instrument transformers

Table 1. Comparative results of instrument transformers.

Electromagnetic:	Electronic:
Advantages:	
1.Highaccuracyclass 2.Simplicity and reliability 3.Temperature stability of CT characteristics.	1.Corresponds to the innovative concept of the development of the electric power industry in the direction of "Digital substation" [4,5]; 2.Compatible with both traditional and advanced microprocessor-based power and relay metering devices; 3.Accurately reproduce the shape of the current curves in normal and transient modes (not saturated, not subject to the phenomenon of remanent magnetization); 4.There is a possibility of using optical communication cables; 5.Safefromfireandexplosion 6. Small-sized;
Disadvantages:	
1.Saturation of the magnetic circuit of the electromagnetic CT with the aperiodic component of the short-circuit current (SC) and the lack of transmission of information about the primary current in the first periods of the emergency transient process; 2.High voltage insulation problems; 3.Explosion and fire hazard	-

Conclusion

The use of digital combined current and voltage transformers at substations will speed up the transition of electric power facilities from traditional analog signals to digital signals, where all information flows circulate and are digitally processed, which in turn will increase the reliability and selectivity of protection and automation equipment, as well as metering devices electricity.

Literature

1. Chichev, SI, Kalinin VF, Glinkin EI System of control and management of electrical equipment of substations. Moscow: Publishing House "Spectrum", (2011)

2. Korsunov P. Yu., Morzhin Yu. I., Popov S. G. Development of the Concept "Digital substation". Contract No. I-11-41 / 10 / OJSC NTTSE. Moscow, (2011)

3. GOST R IEC 60044-7-2010. Measuring transformers Part 7. Electronic voltage transformers. M .: Standartinform, (2012)

4. Kalinkin, S. Yu. Technical solutions in the field of process control systems for digital substations 110/35 kV. Turnkey Energy / S.Yu. Kalinkin, (2010)

5. Morzhin, Yu.I. Digital substation UNEG / Yu.I. Morzhin, S.G. Popov, P.A. Gorozhankin, V.G. Narovlyansky, M.A. Vlasov, A.A. Serdtsev // EnergoExpert, (2011), No. 4 (27), pp. 27-32.

6. GOST R 51901.13-2005 (IEC 61025: 1990) Risk management. Analysis of the Fault Tree), Moscow: Standartinform, (2005)

7. GOST R IEC 61850-5-2011. Communication networks and systems at substations. Part 5. Requirements for communication for functions and device models. Moscow: Standartinform, (2013)

8. Zakonshek J. Digital substation // Complex RTDS for modeling digital substations in real time: electronic journal. 2013, [Electronic resource]. URL: https://web.archive.org/web/20130628013600/http://xn--61850-txen0l.xn--p1ai/ (date of the application: 25.02.2020).

9. GOST R IEC 61850-7-2-2009. Communication networks and systems at substations. Part 7. Basic communication structure for substations and line equipment. Section 2. Abstract Communication Services Interface (ACSI)), Moscow: Standartinform, (2011)

10... GOST R 51901.12-2007 (IEC 60812: 2006) Risk management. Method for Analysis of Types and Consequences of Failures), Moscow: Standartinform, (2008)

11. GOST R IEC 60794-1-2-2017 Optical cables. Part 1-2. General technical requirements. Basic test methods for optical cables. General Guide), Moscow: Standartinform, (2011)

12. Chichev S. I., Kalinin V. F., Glinkin E. I. Ch-72 Methodology for designing a digital substation in the format of new technologies. Moscow: Publishing House "Spectrum", (2014)