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Data transmission from electronic current transducers to a process bus in the IEC 61850 standard

The IEC 61850 standard is used more and more commonly now in the implementation of new distribution stations or modernization of the existing ones. One of the major aspects in proper functioning of such systems is the measurement of basic electric quantities, such as current and voltage. The article features the description of a system for acquisition and transmission of instantaneous values of current with the use of coreless transformers. The major implementation issues of the system were presented, along with factors which may impact further improvement of the system technical parameters.

keywords: distribution stations, coreless transformers, data transmission, standard IEC 61850.

1. INTRODUCTION

The IEC 61850 standard is used more and more commonly now in the implementation of new distribution stations or modernization of the existing ones. One of the major aspects in proper functioning of such systems is the measurement of basic electric quantities, such as current and voltage, along with their derivatives. Nowadays, when it comes to measurements of current, classic core transformers are more and more frequently replaced by coreless transformers which use Rogowski coils. These solutions have many advantages in comparison with those employed so far. They ensure much greater dynamics of measurement and much better linearity. They have much smaller sizes and weights, which facilitates their installation. The article features the description of a system for acquisition and transmission of instantaneous values of current with the use of coreless transformers. Each of three current circuits is equipped with an intelligent measurement system which makes synchronous measurements of current in step of UCT-synchronized pulses (Universal Coordinated Time). The measurement data are sent to the data concentrator by means of optical fibres. Here the data are formed into structures in compliance with IEC 61850 in the range of Sampled Values transmission with the use of an Ethernet connection. The major implementation issues of the system were presented, along with factors which may impact further improvement of the system technical parameters.

2. INTELLIGENT CURRENT TRANSDUCER

In modern intelligent distribution stations (Fig. 1) there are the so called process buses for the transmission of information in a set digital format. In practical solutions of such system, the process bus is made on the basis of the Ethernet infrastructure. Main elements of such an infrastructure are Ethernet industrial switches and optical-fibre transmission connections or copper-twisted-pair connections (if applicable). Nowadays, IEC 61850 [1,2,3,8] is a recognized and recommended standard dealing with information exchange between distribution station elements in the realm of smart grids. This standard allows to control and monitor bays of substations by means of the MMS (Manufacturing Message Specification) server functions, to make interbay interlockings by means of

the GOOSE (Generic Object Oriented Substation Event) mechanism and to send instantaneous Sampled Values (Sampled Values) of currents and voltages. All devices connected to the process bus expose or load necessary values from the bus. One of the most important data transmitted within the distribution station are measurement values of currents and voltages. In stations constructed in compliance with IEC 61850, this information is provided by Merging Unit devices [4].

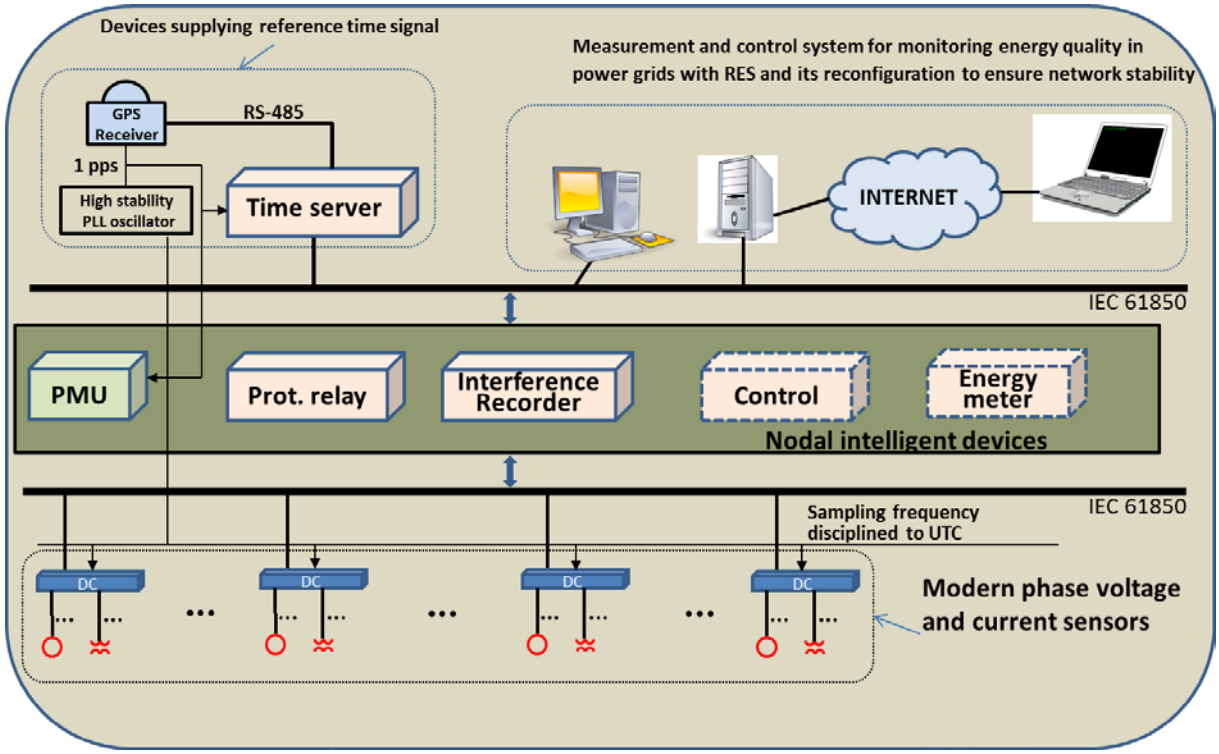

Fig. 1. Intelligent distribution station

The intelligent current transducer was developed in two versions:

– with autonomous power supply (Fig. 2.),
– with external power supply.

In both versions the same current transducer and electronic circuit are used [6]. The transducer is responsible for measuring the current, converting the values into a standardized format, and sending them to the concentrator in accordance with synchronization signals. The measurement circuit placed near the transducer reduces the impact of electromagnetic-field disturbances on the measured signal [5].

The ISP version with power supplied from operating currents has a limitation related to the supply of the device at currents which are small with respect to the nominal value. A partial solution to this problem is to select a proper current supplying transformer in relation to the nominal current, i.e. in such a way that the system could work at 5% value of the nominal current.

The ISP solution with external power supply does not have the above limitations. The transducer is smaller and lighter. Still, it is necessary to ensure continuous power supply.

Fig. 2. ISP transducer with autonomous power supply

2.1. Merging Unit

Merging Unit (MU) is an intelligent electronic device which plays a role of a data concentrator and an interface between the analogue and digital worlds. The source of signals are current and voltage transformers/transducers. MU provides access to data in the form of time-synchronized Sampled Values (SV) packages. According to the requirements of the standard, the data transmission stipulates two variants of data access: 80 or 256 sample packages per period [7]. An SV package is composed of: I_1, I_2, I_3, I_o, U_1, U_2, U_3, and U_o, synchronized to UTC with the accuracy of 4μs.

In the presented solution, called Data Concentrator (KD), which performs the functions of Merging Unit, only the values of phase currents are accessible (Fig. 3) in the form of synchronized sequences of samples coming from intelligent current transducers (ISP). The samples can be exposed by KD to the process bus in the variant of 80 or 256 samples per period. Downloading data from ISP and their synchronization is carried out through optical fibres – transmitters FT 1, FT 2 and FT 3 as well as receivers FR 1, FR 2 and FR 3 (Fig. 3). Time synchronization in KD and time synchronization of current transducers ISP is carried out with the accuracy of 3.5μs.

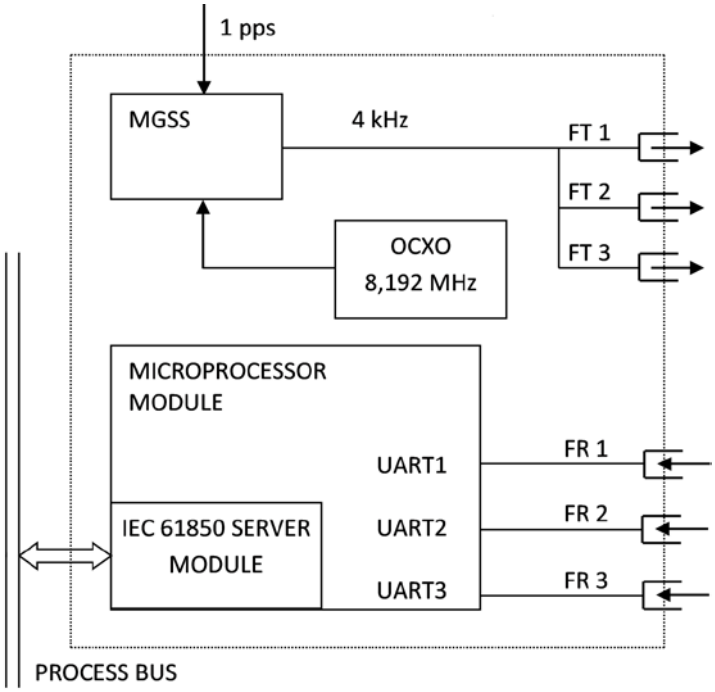

Fig. 3. Block diagram of Data Concentrator

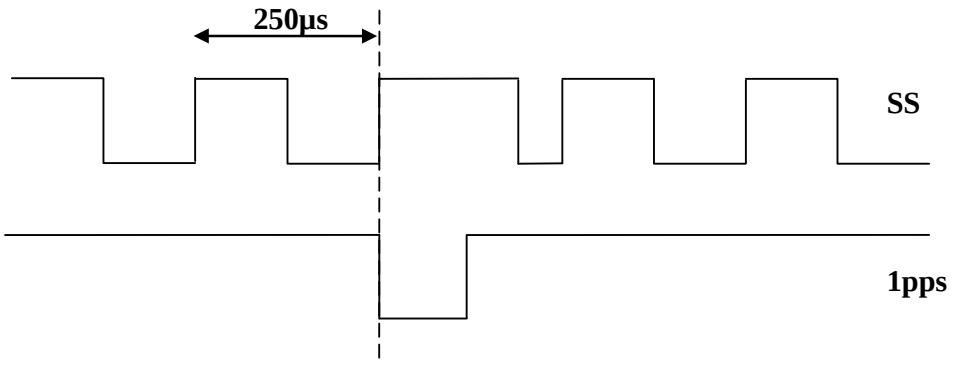

Fig. 4. Shape of synchronization signal (SS) which synchronizes ISP transducers

The central unit of the device is the ARM Cortex – A8 microprocessor with the Linux operating system installed. Data exchange between ISP and the IEC 61850 Server Module is conducted through shared memory. The Synchronization Signal Generation Module (MGSS) is responsible for time synchronization. The module generates a synchronization signal which is connected, in terms of time, to the UTC time scale sourced by a GPS receiver – a time signal from GPS is provided in the form of 1 pps pulses. Figure 4 features the shape of the signal which synchronizes ISP transducers. It is a rectangular signal with a 50% duty cycle and 4kHz frequency. Every second the pulse corresponding to a 1 pps signal edge has a duty cycle of 75%. Based on this information, ISP transducers adjust the synchronization of the samples loading to UTC.

2.2. Data transmission to process bus

The model of Sampled Values transmission from the current transducer to other users is based on a fast and reliable data distribution system which uses a data publication and subscription mechanism in the form of the so called Sampled Values according to the IEC 61850 standard. The transmission of Sampled Values is conditioned in time, that is why the path related to the data transmission from the transducer to an external system has to be very fast, yet reliable. The central unit of the controller is equipped with several functional modules which are responsible for data (samples) acquisition, placing them in suitable buffer structures and sending them to the communication process bus, to the recipient. In order to make the process very fast, inter-process communication (IPC) mechanisms were employed by using shared memory in the form of a circular buffer. In addition, the access interfaces were defined, along with the completeness control of the operations of recording and reading to the memories of particular functional modules (Fig. 5.).

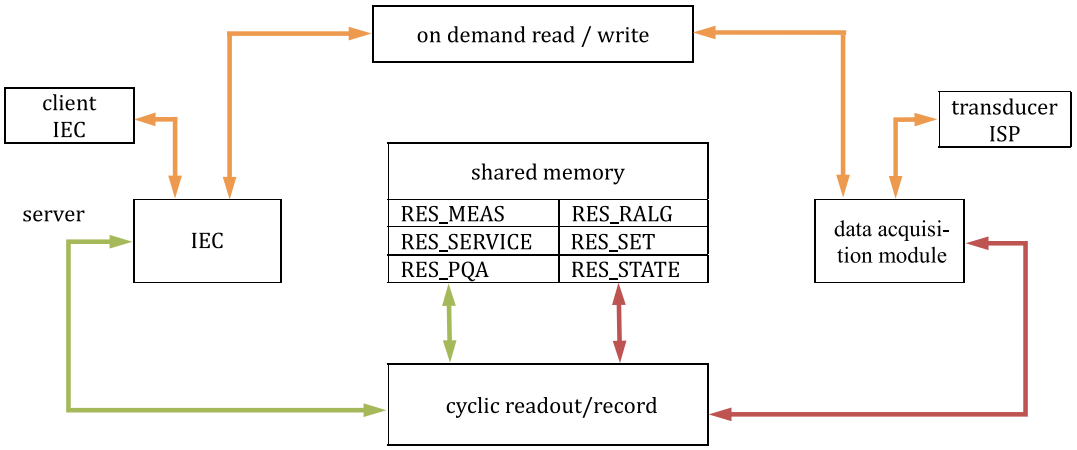

Fig. 5. Diagram of inter-process communication mechanism applied in KD microprocessor module

The publication of Sampled Values through a module of the IEC 61850 server, which acts as a publisher, can be conducted in two ways:

- with the use of MULTICAST-APPLICATION-ASSOCIATION – multicasting mechanism controlled by the MSVCB logical node,
- with the use of UNICAST SAMPLE VALUE CONTROL BLOCK – unicasting mechanism controlled by the USVCB logical node.

In practice, both mechanisms have a certain functionality that makes them different from each other. With the former mechanism it is possible to transmit the values to more than one subscriber, yet the communication between the publisher and the subscriber is carried out in a multicast mode. Only authorized subscribers can control the publishing mechanism. The publication of Sampled Values as such is carried out irrespective of whether these values are taken by any subscriber or not.

In the case of the latter method, Sampled Values are transmitted to one subscriber only. The subscriber initiates communication with the publisher by establishing a bilateral connection of the application. Then the subscriber can configure the logical node responsible for the publication mechanism of Sampled Values. Next, the subscriber can launch the publication of these values by changing the SvEna attribute to Active. During the transmission of Sampled Values

between the subscriber and the publisher, it is necessary to have a connection on the application level. When the connection is closed/broken, the publisher stops to publish the values automatically.

The data coming from Merging Unit are used by the following devices: field controllers, fault recorders, analyzers of energy quality. As the transmission of Sampled Values has special time conditions, in practice this type of transmission between the publisher and the subscriber is carried out on a separate process bus – a separate communication network. SV messages are marked with a special heading which is used in virtual-network transmission. The heading contains the network identifier and the message priority. A transmission system which fulfils time requirements related to the transmission of a great number of messages must have proper intermediary devices. These devices must be able to queue a large number of messages and to provide service for their priorities.

3. CONCLUSIONS

In traditional solutions the connections between transformers and field controllers are established and run by means of electric cables. These cables transmit information in the form of an analogue signal. The signal can be subject to disturbances from an electromagnetic field which is present in distribution stations. Modern technologies and the IEC 61850 standard allow to change the approach to the transmission of information between devices which are part of the station and information exposed and downloaded from the process bus. Thanks to the Ethernet connection with optical fibres in the physical layer, which are resistant to electromagnetic disturbances, it is possible to transmit data in a standardized format and to use them by an intelligent device installed in the station. The solution presented in this article has a wide range of applications and high resistance to electromagnetic disturbances. It ensures reliability and high quality of the delivered data. One has to remember that in order to improve reliable functioning of such devices, it is necessary to equip them with redundant transmission connections.

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References

1. Gacek A., Książek L.: *Modelowanie systemu automatyki stacji w standardzie IEC61850 (Modeling of substation automation system in the IEC 61850 standard).* „Elektornika" 7(51) 2000, pp.71-74.
2. Dolezilek D., Whitehead D., Skendzic V.: *Integration of IEC 61850 GSE and Sampled Value Services to Reduce Substation Wiring*. Schweitzer Engineering Laboratories 2010.
3. IEC 61850 International Standard. Communication Networks and Systems in Substations. Part 5 to 9-2, 2003-2004.
4. Lee H.H., Kim G.S., Lee J.H., Kim B.J.: *Real-Time Communications on IEC 61850 Process Bus Based Distributed Sampled Measured Values Applications in Merging Unit.* Lecture Notes in Computer Science 5226, Springer 2008.
5. Lisowiec A.: *Wpływ parametrów cewki Rogowskiego na wartości pomiarowe w stanach dynamicznych (Impact of parameters of Rogowski coil on measuring values in dynamical states).* „Mechanizacja i Automatyzacja Górnictwa" 8(427) 2006, pp.7-11.
6. Przybysz R., Wlazło P.: *Inteligentne przetworniki prądowe w automatyce elektroenergetycznej (Intelligent current-mode converters in automatic control of electrical power engineering).* „Mechanizacja i Automatyzacja Górnictwa" 5(519) 2014, pp.5-11.
7. UCA International Users Group. Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2, July 2004.
8. Weiss S., Graeve P., Andersson A.: *Benefits of Converting Conventional Instrument Transformer Data into Smart Grid Capable Process Data Utilizing IEC 61850 Merging Unit*. CIRED - 21st International Conference on Electricity Distribution, Frankfurt, 6-9 June 2011.

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