doi: 10.4302/plp.v14i2.1158 PHOTONICS LETTERS OF POLAND, VOL. 14 (2), 37-39 (2022)

Optoelectronic system for detecting short-circuits in low voltage networks

Kamil Barczak,* Janusz Juraszek

Department of Optoelectronics, Silesian University of Technology, Krzywoustego 2, 44-100 Gliwice

Received May 29, 2022; accepted June 24, 2022; published June 30, 2022

Abstract—The paper presents the concept of using a fiber-optic current sensor with external conversion (OFCS-EC) in a power system. The sensor was developed in the Department of Optoelectronics and was tested in a laboratory. The focus was on the use of OFCS-EC in a real low voltage network. The main purpose of the presented measurement system will be to record network disturbance states with high accuracy. The experiment is to answer the question whether the recorded current waveforms in fault states and measurement transmission speed will be useful enough to be able to predict, identify and, consequently, prevent losses and damage sustained by devices, caused by disturbances in low voltage networks.

The methodology of measuring electrical quantities in all electric power areas is very important. The measurement methods used in the system by means of direct and indirect methods of electrical quantities, e.g. current, have their limitations. A particular imperfection of measurement concerns the use of traditional instrument current transformers measurement sensitivity and transmission speed of measurement data, which are important in some areas.

The proposed new solutions for measuring electrical quantities use the magneto-optical phenomenon. Current sensors constructed on this basis can have enormous application in transmission, distribution and industry. These sensors are characterized by high insulation, insensitivity to electromagnetic interference, high response speed and small size. In addition, they are resistant to excess range, current surges, and in the event of damage caused by e.g. physical influence of current (e.g. high temperature) they minimize the risk to people and property [1–2].

Most of the short circuits occur in low voltage networks. The above are also related to the fact that these networks have the highest number of accidents involving people, including fatalities. This fact is the main motivation behind the attempt to use fiber optic current sensors in networks of this type. Full insulation and full galvanic separation are then of utmost importance.

The measuring stand for testing the optical system (optical transformer) for measuring the current value was built on the real system of a low voltage lighting network. The network consists of 194 70-W sodium luminaires. For testing, two parallel current measurement systems were built, the first one using traditional inductive current transformers (in the indirect method) and the second – an optical current transformer. The purpose of the tests was to check the accuracy of current measurement by showing differences in the obtained measurement results in the two systems used. Knowing approximately the actual values of load current flow which, depending on the time of day and year, vary from 0.1 A to 50 A, it is possible to check the deviations of measurement made from two measurement methods in the entire range. These measurements are also intended to verify the linear characteristics of the measurement methods over the entire expected range for the optical transformer [3].

* E-mail: kamil.barczak@polsl.pl

The proposed solution uses an optical fiber current sensor with external conversion (OFCS-EC) developed at the Department of Optoelectronics of the Silesian University of Technology. The construction of the transformer is based on the use of a glass rod made of magnetooptic glass with a high Verdet constant. This rod is the sensor head. The light is led via a core-core optical fiber. There is a polarizer at the input. The twist of the plane of polarization is converted into a change in light intensity at the output by using an analyzer (Fig. 1). The recorded signal is linear in a wide range because the operating point is optimally set (according to the Malus law). The sensor uses light with a wavelength of 650 nm. This wavelength results from the sensitivity of commercially available detectors and the dependence of the Verdet constant on the wavelength of the glass used (Verdet dispersion).

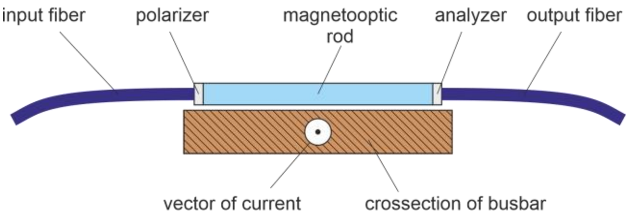

Fig. 1. Schematic view of OFCS-EC.

OFCS-EC is characterized by a compact and simple structure and is suitable for mounting on busbars with rectangular cross-sections. This transformer has been extensively tested and is the result of many years of research [4–6]. In particular, it has a linear characteristic over a wide range of currents (Fig. 2). Moreover, its insulating properties have been experimentally confirmed [7].

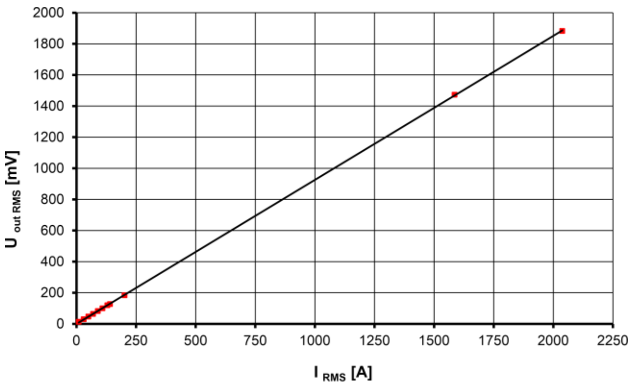

Fig. 2. Effective value of a voltage output signal registered by OFCS-EC as a function of effective electric current intensity.

As mentioned, the sensor is to be built in and tested in a real system. For this purpose, a special box was constructed, equipped with appropriate protection and current busbars, on which fiber optic current sensors and classic current transformers were to be installed (Fig. 3a and Fig. 3b).

Fig. 3a. Photo of the switching box with installed one OFCS-EC sensor.

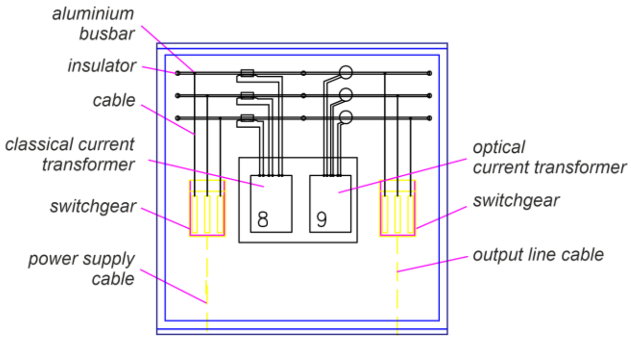

Fig. 3b. View of the box for current measurement tests with an optical instrument current transformer.

The first stage of the research was to verify the sensor operation in laboratory conditions. The tests were performed with the use of a high-current source of alternating current with a frequency of 50 Hz (the same as for the real system). Figure 4 shows a diagram of the test stand. The FLUKE i400s current clamp with an accuracy of 2% was used for reference measurement. The waveforms were recorded using an oscilloscope with properly set triggers.

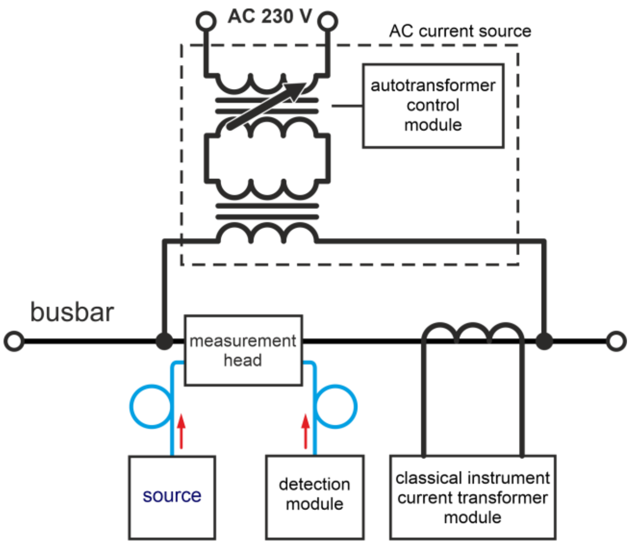

Fig. 4. Scheme of the laboratory measurement stand.

Figure 5 shows the results of the current measurement using a fiber optic sensor and a classic current transformer. It is a time waveform showing the time of shutdown. As can be seen, the waveform recorded by the optical transformer was well reproduced. The differences in the maximum values of the recorded waveforms do not exceed 3%. This value is close to the accuracy of the current clamps used, which is 2% as mentioned above.

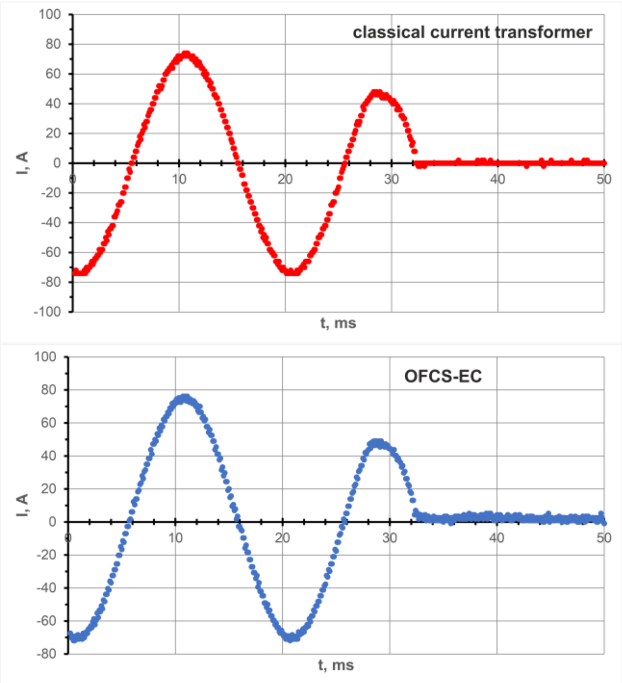

Fig. 5. Time waveforms registered at the time of shutdown (red – classical transformer; blue – OFCS-EC).

The next stage of the research will be to test the sensor in a real lighting system. The aforementioned system consists of 194 park lamps. The diagram of this network is shown in Fig. 6. It is planned to use three sensors in these studies (one for each phase). In the first place, tests will be carried out when switching the lighting on and off, and during steady state operation. The next step will be to leave the measuring system and record all disturbance states that occur during the system operation (several months). This stage is planned in order to register potential short-circuits that may happen - such events in the tested facility do not happen more often than a few times a year. For this reason, there is a need for long-term monitoring. The tests planned in this way will also show possible influence of temperature on the currents recorded by the fiber optic sensors.

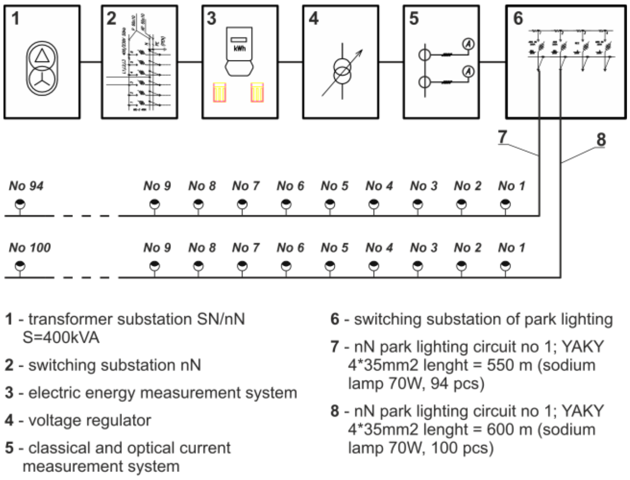

Fig. 6. Block diagram of the current measurement in the park's lighting circuits.

Tests on a real object are to answer the question whether the use of optical transformers will allow to obtain the required accuracy of measurement data in a wide measuring range and will allow to increase the data transmission speed. The confirmation of positive results will allow for further research on the optical transformer in protection systems in industry and distribution of low and medium voltage switchgears.

References

[1] S. Ziegler, R.C. Woodward, H.H.C. Iu, L.J. Borle, IEEE Sens. J. **9**, 354 (2009).
[2] R.M. Silva, H. Martins, I. Nascimento, J.M. Baptista, A.L. Ribeiro, J.L. Santos, P. Jorge, O. Frazão, Appl. Sci. **2**, 602 (2012).
[3] K. Barczak, K. Mazniewski, Proc. SPIE **10455**, 104550R (2017).
[4] K. Barczak, T. Pustelny, D. Dorosz, J. Dorosz, Eur. Phys. J.: Spec Top. **154**, 11 (2008).
[5] K. Barczak, T. Pustelny, D. Dorosz, J. Dorosz, Acta Phys. Pol. A, **116**, 247 (2009).
[6] K. Barczak, Proc. SPIE **10034**, 100340A (2016).
[7] K. Barczak, D. Duda, K. Mazniewski, Proc. SPIE **10830**, 108300K (2018).

