BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES, Vol. 60, No. 3, 2012
DOI: 10.2478/v10175-012-0076-8

VARIA

The study of electronic voltage transducers operation in conditions of dips and interruptions of measured voltage

M. KACZMAREK[1]*, A. SZCZESNY[2], and R. NOWICZ

[1] Institute of Electrical Power Engineering, Technical University of Lodz, 18/22 Stefanowskiego St., 90-924 Łódź, Poland
[2] Institute of Electrical Engineering Systems, Technical University of Lodz, 18/22 Stefanowskiego St., 90-924 Łódź, Poland

Abstract. The aim of the paper is to present a response on dips and on interruptions of the measured voltage by means of electronic voltage transducers and inductive voltage transformers. Results of laboratory studies show high overvoltages generated in both a primary and secondary side of inductive VTs during the above mentioned conditions. Overvoltages in secondary circuits may damage measuring or protection apparatus connected to the secondary side of the VT. Using electronic voltage transducers enables users to avoid these problems.

Key words: voltage transducer, voltage interruptions and dips, power quality, reliability of the power supply.

1. Introduction

Basic requirements for the quality of electricity supplied by public distribution systems are defined in the international standard [1] and discussed in publications [2–4]. To ensure the proper power quality certain measurements of voltage and current parameters must be made. For the purpose of such measurements, in a public distribution system (especially medium and high voltage networks), instrument transformers or electronic voltage transducers may be used. They transform directly immeasurable, due to their high value, voltages and currents to values measurable directly by typical ammeters and voltmeters or devices used for power quality tests [5]. Both, voltage transformers and electronic transducers should ensure the accuracy of transformation also in transient states such us dips and interruptions of measured voltage [6–8].

2. Electronic voltage transducers

The electronic voltage transducer with the Hall sensor in an open loop (O/L) uses directly the Hall effect [9–11] (Fig. 1).

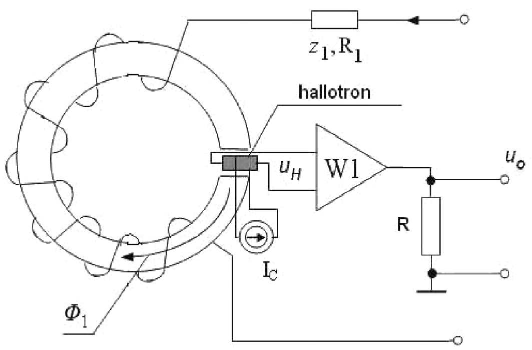

Fig. 1. Diagram of the transducer with O/L circuit after Ref. [11]

The current i_1, in an unsaturated magnetic circuit, produces the magnetic flux Φ_1, which causes the rise to the voltage u_H, on the hallotron terminals, which is placed in the magnetic core air gap, perpendicularly to the magnetic field [11]. The result of the measurement is a low voltage signal u_H requiring gaining to the useful level. An output signal is the voltage u_o measured on the resistor R.

In transducers with a closed loop the magnetic flux in the magnetic core produced by the magnetic field from the primary winding is compensated by the magnetic field from the compensation coil. In the core, as well as in the gap, where the Hall sensor is placed, the magnetic flux value which controls the electronics circuit is close to zero (Fig. 2).

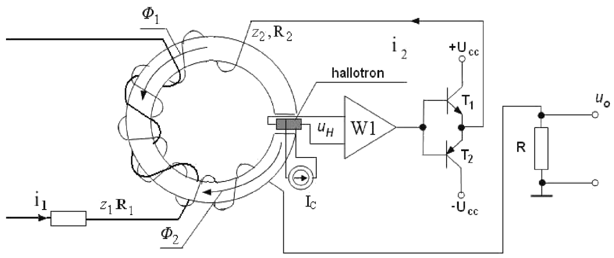

Fig. 2. Diagram of the transducer with C/L circuit [11]

Designations: z_1, z_2 – the number of turns of primary and secondary windings, i_1, i_2 – primary and secondary currents, R_2 – secondary winding resistance, Φ_1 – magnetic flux from primary current, Φ_2 – magnetic flux from the compensation circuit, $W1$ – amplifier of the hallotron signal, R – resistive load.

To ensure the maximum resolution and accuracy of transducer it is required to ensure an appropriate value of currents in the primary and secondary circuits by appropriate values of the primary and secondary resistors. Typical electronic voltage / current transducers are characterized by a significant phase delay between primary and secondary signals. This may affect operation properties of measuring and protection apparatus connected to the secondary winding of these device. In

*e-mail: michal.kaczmarek@p.lodz.pl

the case of tested electronic voltage transducers (designed to operate in the protection circuits) this phase delay is comparable with a phase delay introduced to the measuring circuit by a high voltage probe used to transform high primary voltage to a measurable level by the oscilloscope. In conditions of dips and interruptions of a measured voltage the phase delay of tested electronic voltage transducers has no influence on operation of devices used to determine the power quality connected to their secondary side

3. Measuring circuit

Laboratory studies of electronic voltage transducers operation during dips and interruptions of measured voltage were made in accordance with the standard [12] in the measuring circuit presented in Fig. 3.

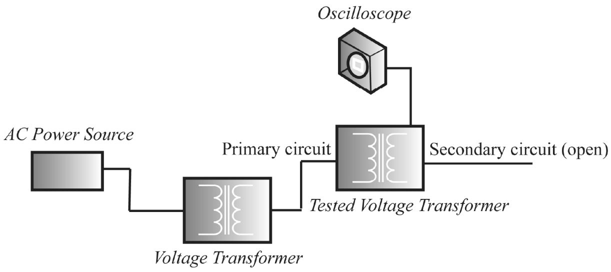

Fig. 3. Simplified diagram of the measuring circuit

Programmable AC voltage source type Chroma 61504, capable of simulating voltage dips and interruptions was used to supply the measuring circuit.

During analysis it was assumed that, voltage dip occurs when the voltage is lower than 90% of rated value, but this value should not be less than 1% of rated voltage [1]. The interruption of voltage occurs when voltage is lower than 1% of rated value. Voltage, whose rms value is above 110% rated voltage is defined as the overvoltage [2] [3]. Laboratory tests consisted of simultaneous observation, using the dual-channel oscilloscope Rigol DS5202MA, of primary and secondary voltages of tested transducers in transient states. Primary channel of the oscilloscope was additionally equipped with high voltage probe type Testec TT HVP 15HF.

4. Results for inductive voltage transformers

The obtained results of electronic voltage transducers operation in conditions of voltage dips and interruptions of measured voltage were compared to similar measurements obtained from the previously studied inductive voltage transformers [6]. Voltage transformer A with two secondary windings (2000 V / 100 V / 100 V, 0,5 class) was described in details in the scientific works [6, 7]. During laboratory studies inductive voltage transformer type UDZ 24 (2000 V / 100 V, 0,5 class) was also tested [6–8].

In Fig. 4 a primary voltage waveform of VT model A in the condition of a voltage dip equal 50% of the rated primary voltage is presented.

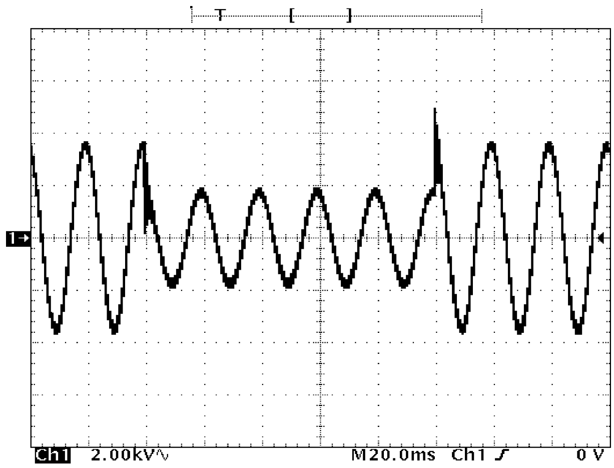

Fig. 4. Primary voltage waveform of VT model A in condition of voltage dip equal 50% of rated primary winding voltage

The peak overvoltage in the primary circuit of VT model A caused by the voltage dip equal 50% of rated primary voltage is about 5000 V (2,5 times higher than rated primary voltage). If voltage dip occurs when measured voltage reaches zero, than there were no overvoltages detected, both in the primary and secondary circuits of tested voltage transformer.

All presented results of laboratory studies of tested inductive voltage transformers operation in conditions of dips and interruptions of measured voltage were made for the case when these events occur in measured voltage at its maximum value. The rated value of measured voltage was achieved back also in the maximum value of its waveform.

In Fig. 5 the secondary voltage waveform of VT model A for measuring conditions from Fig. 4 is presented.

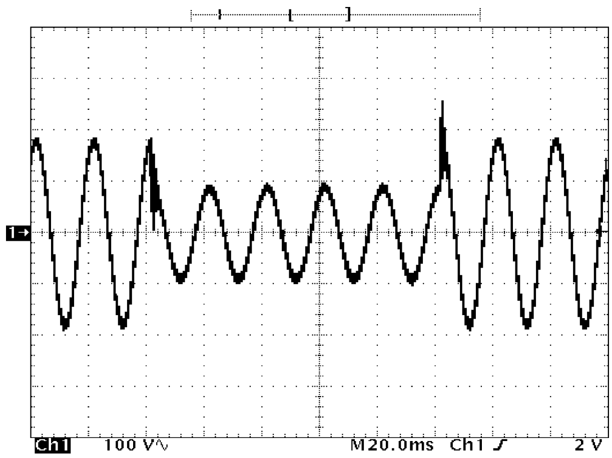

Fig. 5. First secondary winding voltage waveform of VT model A in condition of voltage dip equal 50% of rated primary voltage

The maximum value of voltage (Fig. 5), is about 260 V and is 2,6 times higher than rated secondary voltage. In comparison with the value of overvoltage in the primary winding secondary overvoltage is higher by 10%. The highest overvoltage for VT model A was detected for condition of voltage interruption of measured voltage.

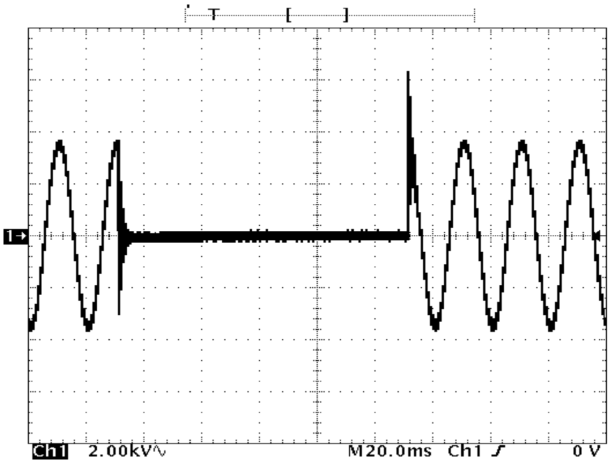

Fig. 6. Primary voltage waveform of VT model A in condition of interruption of measured voltage

Overvoltage maximum value due to the interruption of measured voltage is 6300 V, which is 315% of rated primary voltage. In the first secondary winding of VT model A for this condition overvoltage maximum value reaches about 330 V, which is about 330% of rated secondary voltage (Fig. 7).

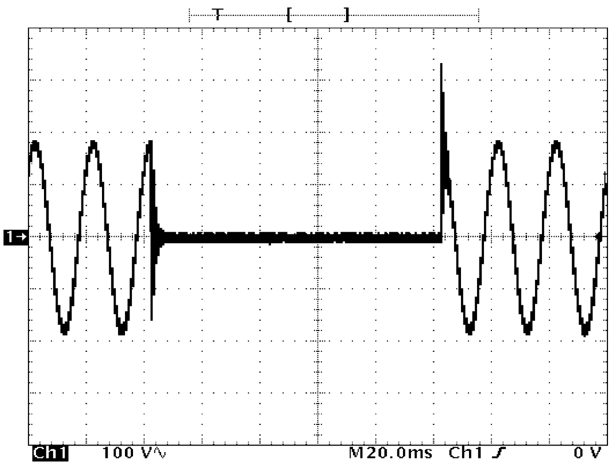

Fig. 7. First secondary winding voltage waveform of VT model A in condition of voltage interruption of measured voltage

If voltage interruption occurs when measured voltage is zero than there were no overvoltage detected both in primary and secondary circuits of tested VT.

Next the operation of VT type UDZ 24 in condition of voltage interruption of measured voltage is analyzed. Figure 8 shows that the overvoltage maximum value in a primary winding is about 5000 V, which is 2.5 times higher than the rated primary voltage.

Overvoltage in secondary winding (Fig. 9) is about 260 V and is 10% higher than in primary circuit (Fig. 8).

If dip or interruption of measured voltage occur in the waveform maximum value, both in primary and secondary windings of tested inductive voltage transformers, overvoltages were detected. The increase of the voltage dip causes the increase of the overvoltages maximum value in tested voltage transformers windings. The highest value of overvoltage is detected for voltage interruption of measured voltage.

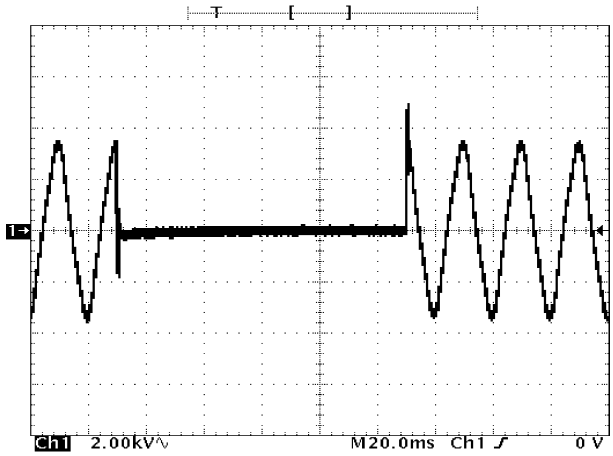

Fig. 8. Primary voltage waveform of VT type UDZ24 in condition of interruption of measured voltage

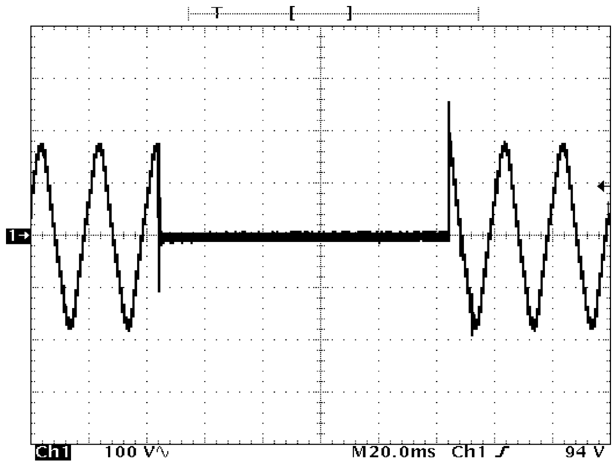

Fig. 9. Secondary winding voltage waveform of VT type UDZ24 in condition of voltage interruption of measured voltage

5. Results for electronic voltage transducers

Figure 10 shows voltage waveforms on the primary and secondary sides of the electronic voltage transducer type LV 25-P in the presence of 30% voltage dip which occurred at the time when voltage achieves zero [12].

Comparison of the voltages in Fig. 10 shows that, secondary voltage correctly reflects the primary voltage. Furthermore, it should be noted that there are no overvoltages in the primary and secondary voltages.

In the next part of laboratory studies the accuracy of transformation of the VT type LV25-P in condition of 30% voltage dip of measured voltage when voltage achieves its maximum value is presented (Fig. 11).

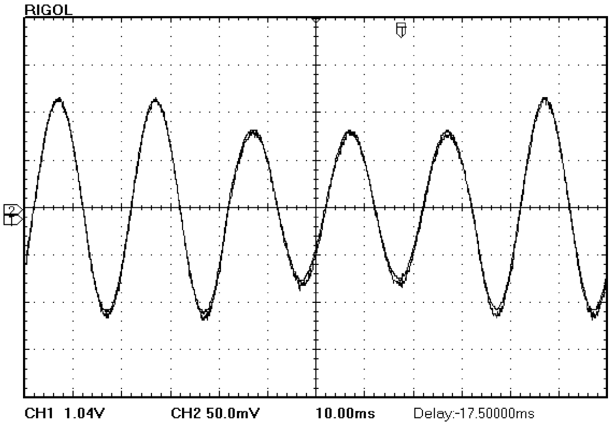

Fig. 10. Voltage waveforms on the primary and secondary sides of the electronic voltage transducer LV 25-P in the presence of 30% voltage dip which occurred at the time when voltage achieves zero

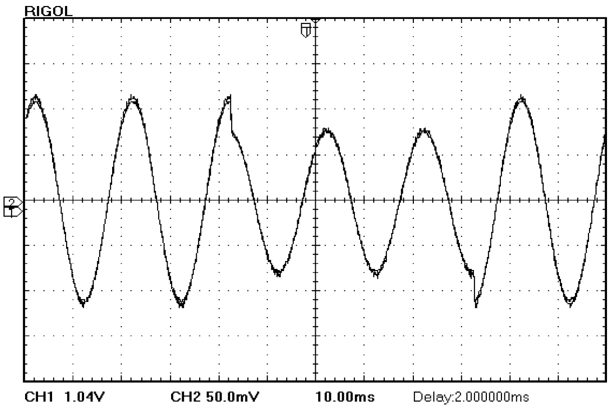

Fig. 11. Voltages waveforms of LV 25-P in the presence of 30% voltage dip when voltage achieves its maximum value

In the case presented in Fig. 11 there were no overvoltages detected. In this condition in the windings of tested inductive voltage transformers high overvoltages were present.

In inductive voltage transformers the highest values of overvoltages were observed for primary voltage interruption which occurred when voltage waveform achieved its maximum value. Figure 12 shows primary and secondary voltage waveforms of the electronic voltage transducer LV 25-P under these conditions.

Again, there was no overvoltage detected in primary and secondary circuits of the electronic VT under test.

In the last stage of the laboratory studies operation of the electronic VT type AV 100-2000 in conditions of dips and interruptions of measured voltage was tested.

Analysis of waveforms in Fig. 13 shows that in both primary and secondary circuit of the AV 100-2000 voltage transducer there are no overvoltages. This is confirmed by the results of harmonics content analysis and their levels measurements presented in Fig. 14 made for primary and secondary voltages waveforms from Fig. 13.

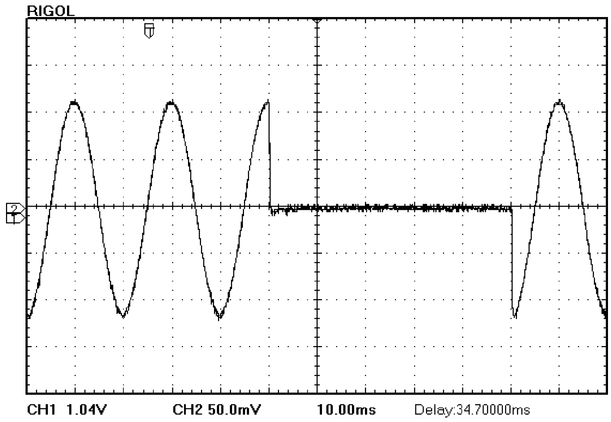

Fig. 12. Voltage waveforms of LV 25-P in the presence of voltage interruption when voltage achieves its maximum value

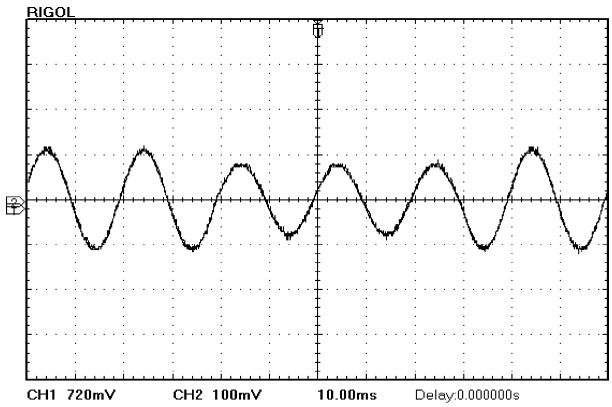

Fig. 13. Voltage waveforms of AV 100-2000 in the presence of 30% voltage dip when voltage achieves zero

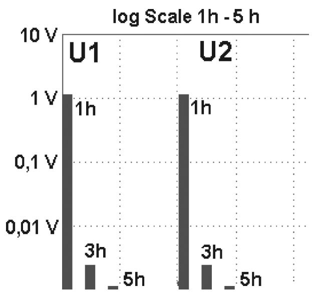

Fig. 14. Results of harmonics content analysis and their levels measurements made for voltages from Fig. 13

Presence of harmonics 3. and 5. is caused by little distortion of the supply voltage from the AC source. Same harmonics content and equal levels of responding harmonics are the evidence of high transformation accuracy of tested electronic VTs in this test condition.

Figure 15 shows primary and secondary voltage waveforms of electronic VT type AV 100-2000 in the presence of voltage interruption, which occurred at the time when measured voltage achieves its maximum value.

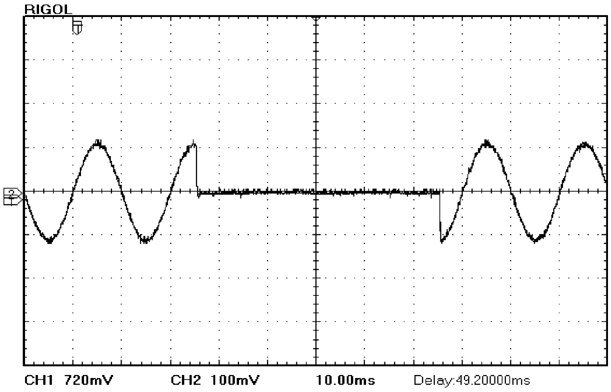

Fig. 15. Primary and secondary voltage waveforms of the VT type AV 100-2000 in the presence of voltage interruption, which occurred at the time when measured voltage achieves its maximum value

In test conditions from Fig. 15 in the windings of tested inductive voltage transformers measured overvoltages had the highest values. In primary and secondary voltages of electronic VT type AV 100 - 2000, there were no overvoltages detected, as well as in voltages of previously tested electronic VT type LV25-P.

6. Conclusions

The presented in the paper comparison between operation of tested electronic voltage transducers and inductive voltage transformers in conditions of dips and interruptions of measured voltage shows the high transformation accuracy of electronics VTs with no overvoltages detected in both primary and secondary voltages of tested electronics VTs. However, it should be noted, that typical electronics transducers are characterized by a significant phase delay between primary and secondary voltages.

REFERENCES

[1] EN 50160, *Voltage Characteristics of Electricity Supplied by Public Distribution Systems*, CEN, 1999.

[2] R.C. Dugan, M.F. McGranaghan, S. Santoso, and H.W. Beaty, *Electrical Power Systems Quality*, McGraw-Hill, London, 2003.

[3] J. Schlabbach., D. Blume, and T. Stephanblome, *Voltage Quality in Electrical Power Systems*, Ins. of Electrical Engineers, New York, 2001.

[4] E. Acha and M. Madrigal, *Power Systems Harmonics; Computer Modelling and Analysis*, Wiley&Sons Inc., London, 2002.

[5] R. Nowicz, *Classical, Unconvetional and Special Voltage Transformers,* Publishing House of Lodz Technical University, Łódź, 2003, (in Polish).

[6] M. Kaczmarek, D. Brodecki, and R. Nowicz, "Analysis of operation of voltage transformers during interruptions and dips of primary voltage", *Proc. Electrical Power Quality and Utilisation – EPQU 2009* 1, CD-ROM (2010).

[7] M. Kaczmarek, "Transfer of interference by voltage transformers", *PhD Dissertation*, Technical University of Lodz, Łódź, 2009, (in Polish).

[8] M. Kaczmarek and R. Nowicz, "Application of instrument transformers in power quality assessment", *Proc. Modern Electric Power Systems – MEPS 2010* 1, CD-ROM (2011).

[9] T.C. Schot, H. Blanchard, E.S. Popovic, R. Racz, and J. Husja, "High-accuracy analog Hall probe", *IEEE Trans. Ins. and Meas.* 46 (2), 613–616 (1997).

[10] Z.L. Warsza, "Hallotron as a circuit element controlled by a magnetic field", *El. Rev.* 83 (1), 57–64 (2007), (in Polish).

[11] A. Szczęsny, "Analysis of frequency properties of compensated current transformers" , *PhD Dissertation*, Technical University of Lodz, Łódź, 2007, (in Polish).

[12] IEC 61000-4-11, *EMC. Testing and Measurement Techniques – Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests*, IEC, 2004.