ANALELE UNIVERSITĂŢII
"EFTIMIE MURGU" REŞIŢA
ANUL XXI, NR. 2, 2014, ISSN 1453 - 7397

Cristina Prodan, Mihaela Poienar, Ovidiu Magdin Ţanţa, Adrian Neculai Romanescu, Dan Ştefan Georgescu, Dorel Cernomazu

Contributions Concerning the Clock Hour Figure Utilization for the Power Transformer Diagnostic

The paper is based on a study for the diagnosis of power transformer through the signal configuration that are part of the clock hour figure code for a defect transformer. The investigations made have the purpose to compare the code signal before and after the transformers damage. The comparative analyzes of the signal form, course and polarity are constituted in diagnosis criteria and are formulated the conclusion about the defect location, nature and dimension.

Keywords: clock hour figure, three-phase transformer, CEUS matrix, direct current supply method

1. Introduction

One of the methods used to identify the three-phase transformer clock hour figure if the direct current supply method.

The version of this method that is used in Romania entails a succession of nine measurement as indicated by figure 1.

According to this variant the direct current source is placed high voltage winding and is connected in succession at the pair of terminals AB, BC, CA, with terminal „+" at A, B, respectively C, while, for every source position, the magneto-electric apparatus is connected successive at the terminal pairs ab, bc, ca, with the „+" terminal at a, b, respectively c [1], [2], [5].

This option is justified by the necessity to limit the impulse amplitude, in case of a transformer with a high transformer ratio.

The sequence of the nine signal will be the clock hour figure; to identify a specific clock hour figure is sufficient the experimental result comparison.

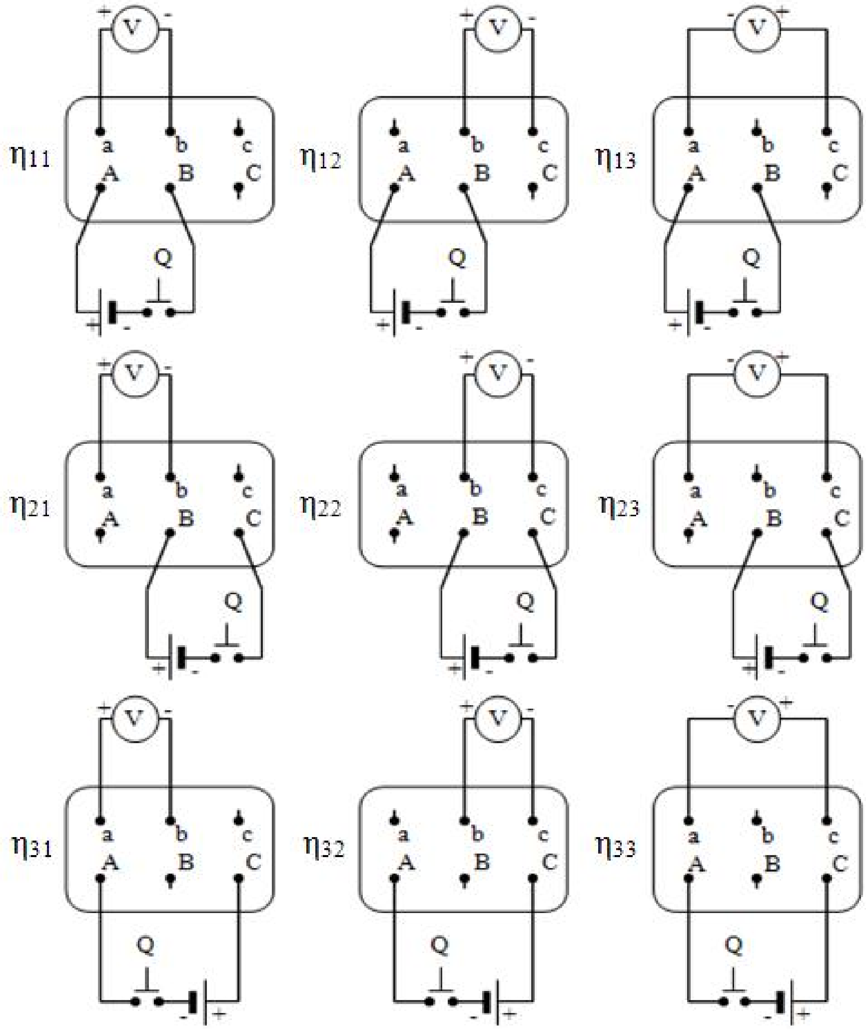


Figure 1. Explanation for getting signals that compose the clock hour figure code [5], [8], [9]

In practice are known two types of codes: analog and digital code.

The analog code requires either the comparison of the configuration, course and polarity of the signals; the digital code requires the analog code conversion through numerical indication obtained by signal modeling using the sgn function or the trivalent element algebra [1], [2], [5], [8], [9].

In the case of analog code are compared the signals directly viewed to the oscilloscope (figure 2).

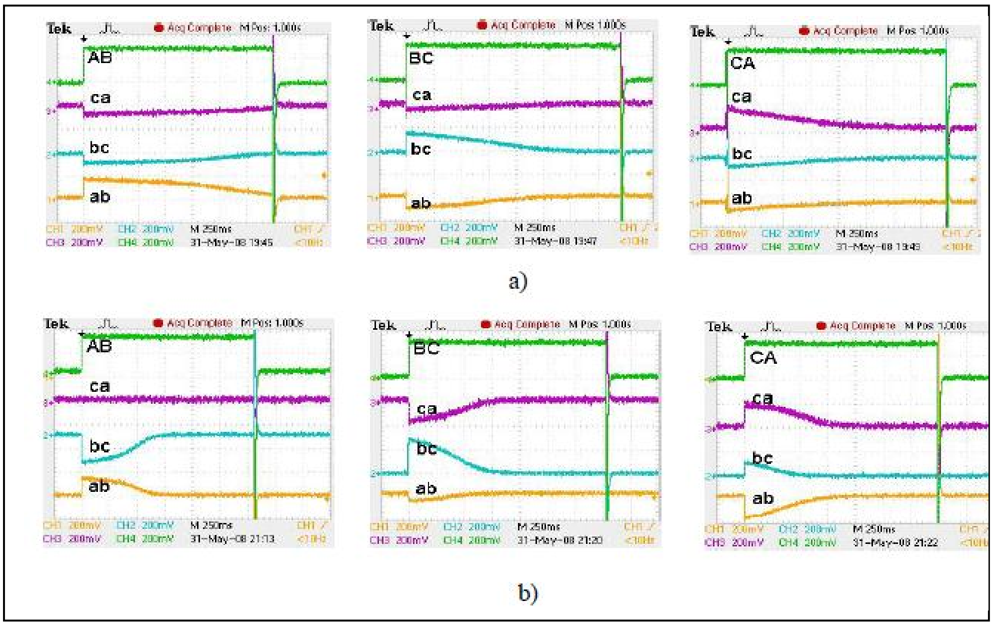


Figure 2. Oscillograms obtained for a transformer with magnetic system plan
a) Connection Y, y 12; b) connection group D, y 1

The analog code expressed in figure 2 can be simplified if we use as indicator the signal polarity instead of the real signal. The polarity is expressed related to one terminal marked with "+" when the pointer moves to the right, with "-" when the pointer moves to the left and with "0" when the pointer remains immobile or deviates only a little. As a result the analog codes shown in figure 2 assume a simplified representation illustrated in figure 3 [5], [9].

	ab	bc	ca
AB	+	-	-
BC	-	+	-
CA	-	-	+

	ab	bc	ca
AB	+	-	0
BC	0	+	-
CA	-	0	+

Figure 3. Analog code sequence obtained on the polarity of those nine signals
a) Connection Y, y 12; b) connection group D, y 1

In the case of digital code expressed through polarity are modeled by the sgn function or through the trivalent element algebra [5], [9].

In the first case:

$$\text{sgn a} = \begin{cases} 1 & when \quad a < 0 \\ -1 & when \quad a < 0 \\ 0 & when \quad a = 0 \end{cases} \tag{1}$$

For the trivalent element algebra defining case:

$$k = \begin{cases} 2 & when \quad a < 0 \\ 1 & when \quad a < 0 \\ 0 & when \quad a = 0 \end{cases} \tag{2}$$

It is obtained an array with three rows and three columns expressed by the matrix shown below and that represent the matrix that configure the clock hour figure for a three-phase transformer [4], [5], [9].

$$G_i = \begin{pmatrix} \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{pmatrix} \tag{3}$$

The matrix shown above is known in the literature as the code matrix and the authors, to indicate its origin propose the acceptance of CEUS matrix trade name.

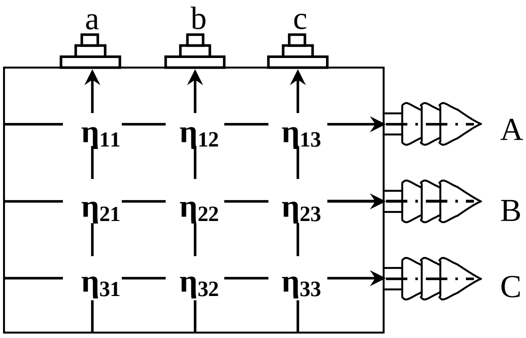


Figure 4. The interdependence between matrix code configuration and the configuration on the terminal connection [5], [9]

The relation existing between the matrix code configuration and the transformer terminal connection configuration is expressed in a suggestive manner in figure 4. The rows position reflect the modification at the terminal of high voltage winding while the columns position reflect the modification at the terminal of low voltage winding.

2. Contributions to identify the transformation equation

In realisation of the three-phase transformer connection diagram can interfere modification made intentionally or accidentally. The changes that may occur in the connection diagram of the transformer are summarized in table 1.

Table 1.

Nr. crt.	Changes in the trasformer connection group		$G_x = (-1)^m \cdot (T)^n \cdot G_i$	
			m	n
1.	Permutations in direct sens of terminal connection to the transformer primary		2	1
2.	Permutations in reverse sens of terminal connection to the transformer primary		2	2
3.	Permutations in direct sens of terminal connection to the transformer secondary		2	2
4.	Permutations in reverse sens of terminal connection to the transformer secondary		2	1
5.	Supply change from the high voltage winding on the low voltage winding, for the following connection group :	1, 7	1	1
		5, 11		2
		3, 9		3
		4, 10	2	1
		2, 8		2
		6, 12		3
6.	Modification of the original diagram by a variant of 3I type (reversing the winding, reversing conections to terminal, terminal notation inversion)		1	3
7.	Modification of the N connection in Z connection at the high voltage winding		1	1
8.	Modification of the Z connection in N connection at the high voltage winding		1	2
9.	Modification of the N connection in Z connection at the low voltage winding		1	2
10.	Modification of the Z connection in N connection at the low voltage winding		1	1
11.	Reversing the connections to the two terminals in the primary and terminals in the secondary, namely: - A şi B, respectively a şi b; - B şi C, respectively b şi c; - C şi A, respectively c şi a, for the following connection group:	1, 7	1	1
		5, 11		2
		3, 9		3
		4, 10	2	1
		2, 8		2
		6, 12		3

12.	Reversing the connections to the two terminals in the primary and terminals in the secondary, namely: - A şi B, respectively c şi a; - B şi C, respectively a şi b; - C şi A, respectively b şi c, for the following connection group:	5, 11	1	1
		3, 9		2
		1, 7		3
		2, 8	2	1
		6, 12		2
		4, 10		3
13.	Reversing the connections to the two terminals in the primary and terminals in the secondary, namely: - A şi B, respectively b şi c; - B şi C, respectively c şi a; - C şi A, respectively a şi b, for the following connection group:	3, 9	1	1
		1, 7		2
		5, 11		3
		6, 12	2	1
		4, 10		2
		2, 8		3

In literature these modification occurred intentionally or accidentally over the three-phase transformer connection diagram are summarized by a relation known as the transformation equation:

$$G_x = (-1)^m \cdot (T)^n \cdot G_i \tag{4}$$

Where the notations have the following meanings:

G_x - the matrix resuling from the changes;
G_i - the initial matrix;
m -constant that can have two values: “1” or “2”;
n - constant that can have three values: “1”, “2” or “3”;
T - transfer matrix.

$$T = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \tag{5}$$

The equation presented above is valid only if the code matrix is defined by the sgn function. In the first chapter was highlighted the possibility that the code matrix can be defined through the trivalent element algebra.

The author’s research aim is to indetify a general equation that is valid if the matrix code is defined by the sgn function and if the code matrix is defines by the trivalent element algebra.

In these direction was obtained the expression presented below:

$$G_x = \beta^m \cdot (T)^n \cdot G_i \tag{6}$$

Where:

$$= \begin{cases} -1 & \text{when the matrix code is modeled through the sgn function} \\ 2 & \text{when the matrix code is modeled through the trivalent element algebra} \end{cases}$$

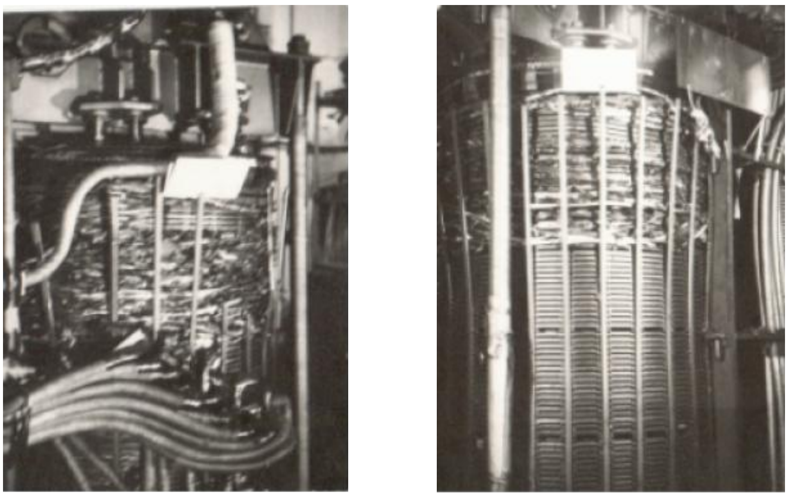
The digital indices m and n takes values according to changes occurred in the transformer connection diagram; those values are summarized in the Table T1.

The notations: m, n and T keep the meaning shown in the formula presented above.

3. Contribution concerning the three-phase transformer diagnosis through the clock hour figure

The major defect of the transformer windings are caused of short circuits occurred in interior or in the transformer utilization circuit as well as phase winding circuit disjunctions.

This paper aim to diagnose the phase windings short circuit.



a) b)

Figure 5. A transformer damaged following an external circuit (transformer 4 MVA; 15/6,3 kV) .
a - detail 1; b - detail 2

The studie and investigations of the authors for power transformer diagnosis led to the finding that the majority failure are related either to the windings circuit cut-off either the short circuit of a winding or a portion of that winding.

The investigations show that the clock hour figure code has a particulat importance in transformer faults diagnosis. This code can be interpreted as a transformer stamp for the failure cases that lead to einding short circuit.
Comparing the analog code, obtained when the transformer is without defects with the damaged transformer can provide clues as to: the nature, location an extent of the damage. Referring to damage that lead to a short circuit, which can be identified by the shape, duration, amplitude and signal polarity that make up the clock hour figure code.

An important finding is the fact that on the occurrence of a short circuiton on the phase winding placed on a column of the magnetic system, two signals of the analog code are converted from half-wave aperiodic signals in two half-wave signals of different amplitude and polarity as shown in figure 6.

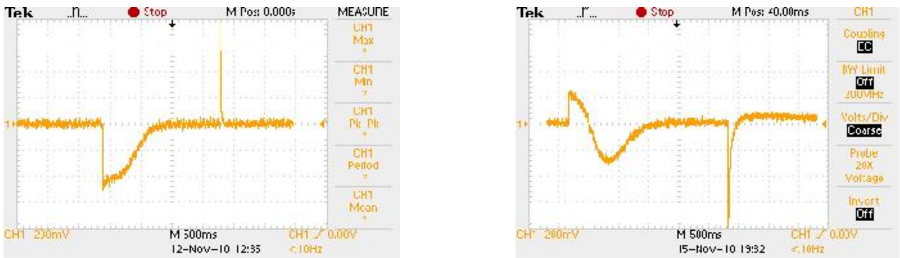


Figure 6. Explanation for analog code signal evolution
a) before failure; b) after failure

The pace of proving fault signals (double-wave signals) in code configuration depends of: transformer connection group, the membership on even or odd index group and of connection type for „delta“ and „zig zag“ connection (with connection in N or Z).

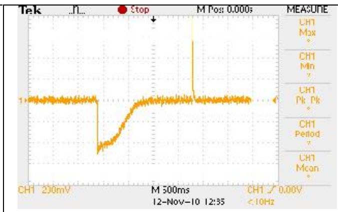
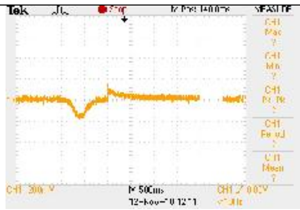
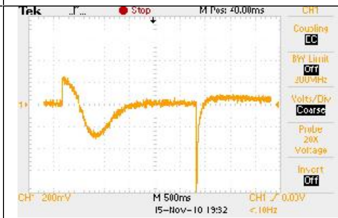
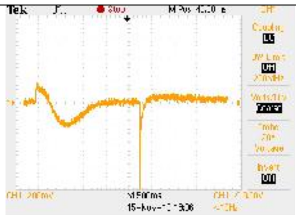
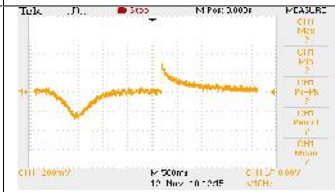
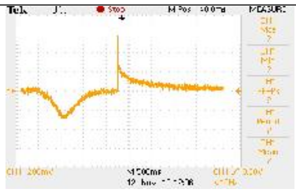
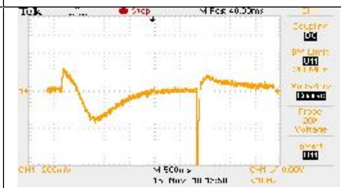
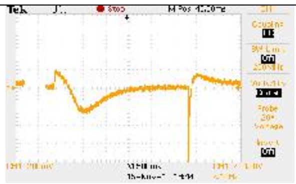
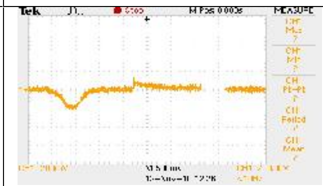
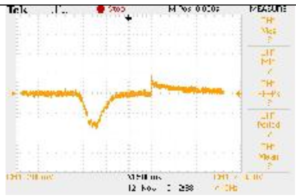
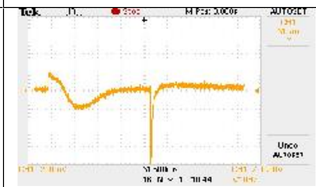
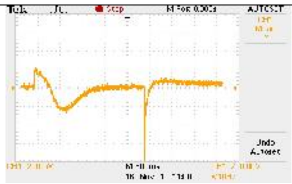
An interesting remark is related to the odd clock hour figure, where the double-wave signals occur within the analog code, in signals location interpreted as signals „0“. The locations of analog code signals are shown in figure 7 [5], [7], [9].

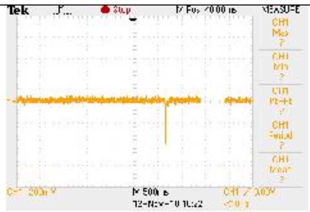
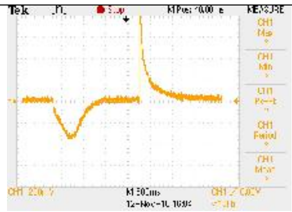
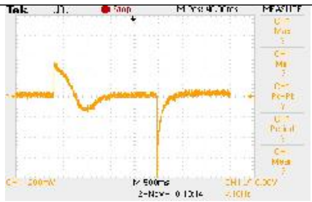
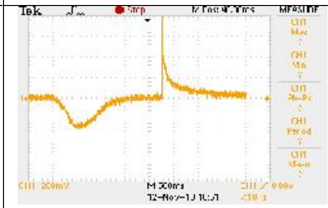
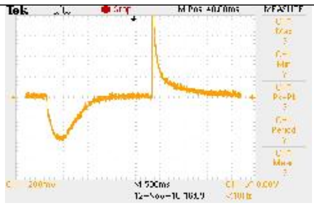
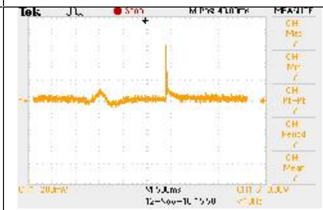
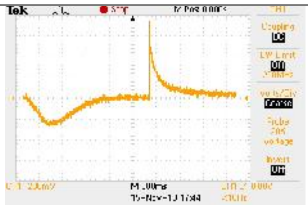
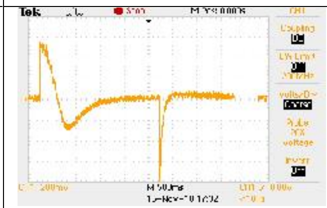
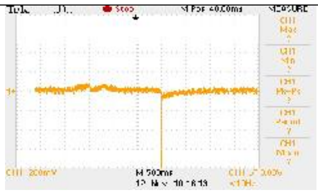
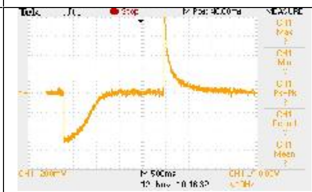
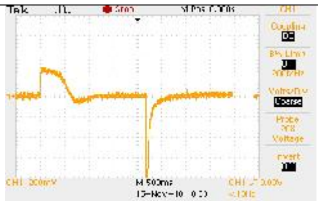
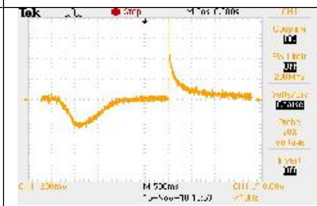
	ab	bc	ca
AB	η_{11}	η_{12}	η_{13}
BC	η_{21}	η_{22}	η_{23}
CA	η_{31}	η_{32}	η_{33}

Figure 7. Explanatory for analog code signals location

In table 2 are presented the double-wave signals for two three phase transformers eith short circuit on low voltage windings, one with Y y 12 connection group and other with D y 5 connection group.

Table 2

Y,y 12	short circuit on a column	before failure	 Caab	 ABca
		after failure	 Caab	 ABca
	short circuit on b column	before failure	 BCab	 ABbc
		after failure	 BCab	 ABbc
	short circuit on c column	before failure	 BCca	 CAbc
		after failure	 BCca	 CAbc

Y,d 5	short circuit on a column	before failure	 Caab	 ABca
		after failure	 Caab	 ABca
	short circuit on b column	before failure	 BCab	 ABbc
		after failure	 BCab	 ABbc
	short circuit on c column	before failure	 BCca	 CAbc
		after failure	 BCca	 CAbc

4. Conclusions

1. The verification of clock hour figure for a three phase transformer can be effectuated by direct current supply method through a table and represent the clock hour figure code [5], [7].

2. The clock hour figure code can be numerical code represented through a matrix code with three rows and three columns noted in literature as matrix code and the autors of the paper, to emphasize its origin, propose the term CEUS matrix [5], [9].

3. The matrix code can be modeled by the sgn function or theough the trivalent element algebra. The main changes mais, intentionally or accidentally, in the connection diagram can be expressed analytically by a relation known as: transformation equation.

4. The current state of knowledge for transformation equation is valid only if the matrix code is defined by the sgn function. The paper analyze and propose a new form, more general, for transformation equation with validity in both variants used for defining matrix code (through sgn function or through trivalent elements algebra).

5. In the last chapter the authors highlight and prove the importance and applicability of the clock hour figure analog code, that it considers a true stamp of power transformers. Converting after a fault (a short circuit) the analogue code initial signals, represents an indication of the new location and extent of the defect. From this point of view, the shape, amplitude, duration and polarity of signals converted from the defect may be very important clues for diagnosis of damaged transformer.

References

[1]. Cernomazu D., Consideraţii privind verificarea grupei de conexiuni aferentă transformatoarelor electrice trifazate, prin metoda curentului continuu, Energetica, Nr. 9, Septembrie 1981, p. 396 – 401.

[2]. Cernomazu D., Consideraţii privind propeităţile codurilor de conexiuni determinate prin metoda curentuui continuu, Energetica, Nr. 9, Septembrie 1982, p. 440-446.

[3]. Cernomazu D., Consideraţii privind legătura între proprietăţile codurilor grupelor de conexiuni determinate prin metoda curentului continuu şi posibilităţile de utilizări pentru schimbarea grupelor de conexiuni la transformatoarele trifazate, Volumul Conferinţei Naţionale de Electrotehnică şi Energetică, Timişoara, 1982, vol. 3, p. 159 – 170.

[4]. Cernomazu D., Étude du modèle mathémathique de l'indice horaire d'un transfromateur triphasé – ouvrage de stage à l'Université des

Sciences et Tehnilogies de Lille, France, 1995, Coordonateur Philippe Delarue, professeur à l'EUDIL.
[5]. Prodan C., Contribuţii teoretice şi experimentale privind conexiunile şi grupele de conexiuni la transformatoarele electrice de forţă – Teză de doctorat. Suceava: Universitatea "Ştefan ce Mare", Facultatea de Inginerie Electrică și Știința Calculatoarelor, 2008.
[6]. Prodan C., Poienar N., Olariu E.-D., Cernomazu C., Contributions for the identification of the errors to the connections making to the three-phase transformers, 4th International Conference on Modern Power Systems, Cluj-Napoca, Romania, May 17-20, 2011.
[7]. Prodan C., Cercetări postdoctorat: Proiect PRIDE - contract POSDRU/89/1.5/5/57083. Suceava: Universitatea "Ştefan ce Mare", Facultatea de Inginerie Electrică și Știința Calculatoarelor, 2013.
[8]. Poienar N., Contribuții teoretice și experimentale privind conexiunile și grupele de conexiuni speciale la transformatoarele trifazate, Teză de doctorat. Suceava: Universitatea "Ştefan ce Mare", Facultatea de Inginerie Electrică și Știința Calculatoarelor , 2012.
[9]. Poienar N., Creţu N.C., Olariu E.D., Cernomazu D., The contribution concerning the algebra applications of trivalent elements in the study of possibilities for modifying the clock hour figure to the connection group, 3rd International Symposium on Electrical Engineering and Energy Converters ELS 2009. Suceava, România, 23-24 septembrie 2009, p.
[10]. Poienar N., Cretu N.C., Olariu E.D., Cernomazu D., The graphical representation of clock hour figure mathematical model through the algebra trivalent elements, 7-th International Conference on Electromechanical and Power Systems, SIELMEN 2009 vol. II, Iaşi, România, oct. 8-9, 2009, p. 280-283.

Addresses:

- Prof. dr. ing. Dorel Cernomazu, Ştefan cel Mare University of Suceava, str. Universităţii, nr. 13, 720229, Suceava, dorelc@eed.usv.ro
- Şef lucrări dr. ing. Cristina Prodan, Ştefan cel Mare University of Suceava, str. Universităţii, nr. 13, 720229, Suceava, cristinap@eed.usv.ro
- Drd. ing. Mihaela Poienar, Ştefan cel Mare University of Suceava, str. Universităţii, nr. 13, 720229, Suceava, mihaela_poienar@yahoo.com
- Drd. ing. Dan Ştefan Georgescu, Ştefan cel Mare University of Suceava, str. Universităţii, nr. 13, 720229, Suceava, dangrig@eed.usv.ro
- Drd. ing. Ovidiu – Magdin Ţanţa, E-ON Servicii Tehnice SRL, str. Parcului, nr.2, 720037 Suceava, ovidiu.tanta@yahoo.com
- Drd. ing. Adrian Neculai Romanescu, E-ON Servicii Tehnice SRL, str. Vadu Bistriţei, nr. 40, Bacău, adrian73ran@yahoo.com