CONTRIBUTIONS CONCERNING ERRORS IDENTIFICATION FOR PERFORMING THE CONNECTIONS AT THREE – PHASED ELECTRIC TRANSFORMERS

Cristina PRODAN, Elena-Daniela OLARIU, Dorel CERNOMAZU and Constantin UNGUREANU
"Stefan cel Mare" University of Suceava
str. Universitatii nr.13, RO-720225 Suceava
cristina_prodan@yahoo.com

Abstract. *The paper presents the carried out researches' results within Department of Scientific Research for domain of Machines, Devices and Electrical Controls – EMAD of "Stefan cel Mare" University of Suceava concerning errors identification of the connections drafts and imperfections diagnosis at three – phased transformers. Authors' contributions are based on the existent connection between the real configuration of the draft of connections and of mathematical sample of the index of hours, expressed under the form of code matrix. There are analyzed mathematical expressions of some errors, as circular permutation of terminals connections, reversing beginning and ending at phase windings, reversing the connections for terminals, changing the connections from N into Z at triangle connections, zig – zag, etc. There are also analyzed the using possibilities for mathematical expressions obtained through identification of mentioned errors, with computer provided help. The end of paper is intended for presenting the resulted conclusions after the experimental study.*
Keywords: *index of hours, mathematical sample, errors, three – phased transformers.*

Preliminary considerations

For the identification of an hour index after a modification of a transformer, usually, is used a vectorial construction (that claims to know a connections' scheme) or an experimental method. The authors are proposing and analysing another solution, that utilises the mathematical pattern of the hour index and its relation with the configuration of the connection schemes, belonging to the modified transformer. In [1] is presented a mathematical pattern of the hour index, expressed by a matrix, having the following form:

$$[G_k] = \begin{bmatrix} \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{bmatrix} \quad (1)$$

In the same work is presented the existent relation between the equivalent scheme of a transformer, modified by various means, and the configuration of the initial code matrix. This relation is expressed in a sugestive manner at fig.1. The effectuated studies have confirmed the possibility of identifying the hour index, resulted after a transformer's modification, by means of a matrix code.

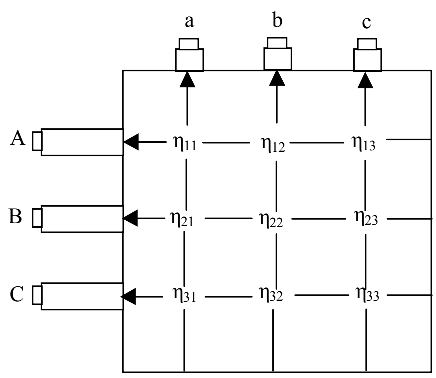


Fig. 1Relation between the equivalent scheme of a transformer and the configuration of the initial code matrix (Reproduced from [1])

The practical importance of the hour index mathematical pattern

The code matrix previously presented is faithfully displaying all the changes produced in the connections scheme of the transformer:

- circular permutation of the notations at the terminals of the transformer;
- reversing the notations at a pair of terminals of high voltage wrapping and of a pair of terminals of low voltage wrapping;
- reversing the alimentation of a wrapping (of high or low voltage);
- reversing the coiling sense of a wrapping;
- reversing the beginnig with the ending of a wrapping(of high or low voltage).

The practical signification of the correlation indicated in fig.1, consists of the fact that inter-changing the raws is equivalent with changing the coupling of the ends of the primary wrap at the line terminals A, B, C, and inter-changing the columns is equivalent with modifying the coupling of the ends of the secondary wrap at the line terminals a, b, c, of the transformer.

So, the possibilities to modify the groups of connections may be studied directly on the code matrixes, thus influencing the positions of the raws and of the columns within the matrix, and also modifying th the value of the variable η_{ij}.

In fig.2a) is presented the example of a transformer that initially had a certain hour index, expressed by the code matrix of fig.1. At the circular permutation, effectuated in a real mode, over the transformer , will be produced a modification of the initial code matrix, that will suffer a circular permutation of the raws, in a manner suggested at fig.2 b).

In order to identify the newly obtained hour index, it is enough to get the code matrix that corresponds to the new situation.

$$[G_i] = \begin{bmatrix} \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{bmatrix} \Rightarrow \begin{bmatrix} \eta_{31} & \eta_{32} & \eta_{33} \\ \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \end{bmatrix} = [G_m] \qquad (2)$$

In fig.2 c) is presented an example concerning the reversing of connections at the primary and secondary terminals, starting from the same initial transformer.

The couplings reversing at a pair of terminals belonging to a high voltage wrap, will determin the modification of the initial matrix, that will suffer a reversing of two raws, followed by a reversing of two columns:

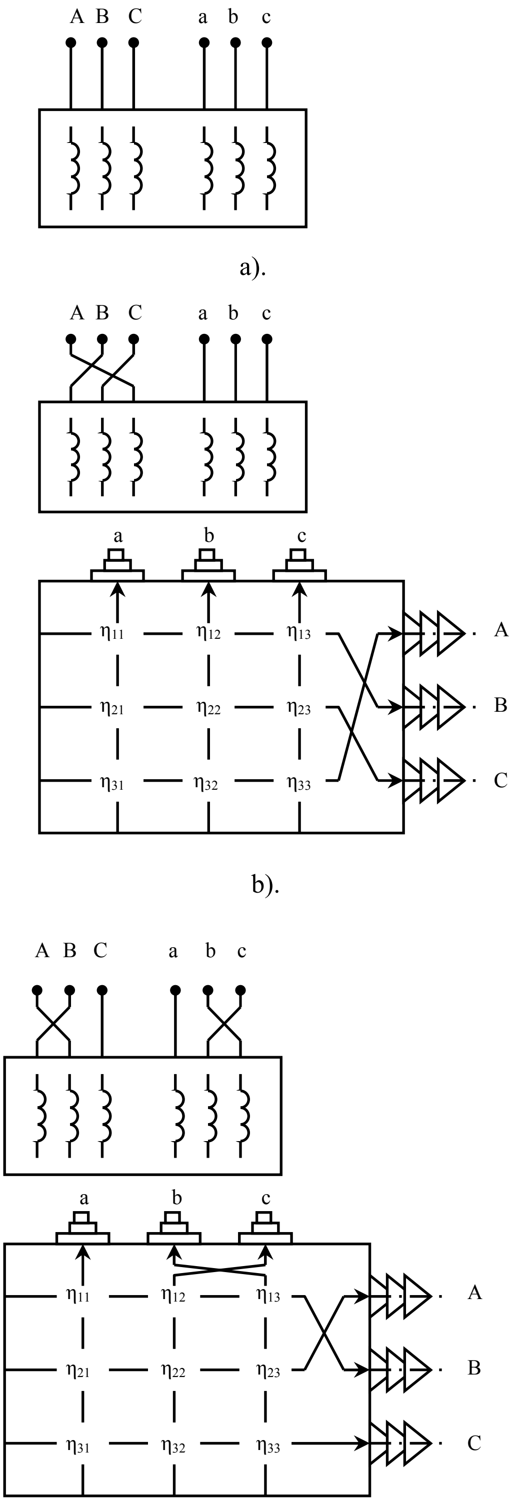
$$[G_i] = \begin{bmatrix} \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{bmatrix} \Rightarrow \begin{bmatrix} \eta_{21} & \eta_{22} & \eta_{23} \\ \eta_{11} & \eta_{12} & \eta_{13} \\ \eta_{31} & \eta_{32} & \eta_{33} \end{bmatrix} \Rightarrow \begin{bmatrix} \eta_{21} & \eta_{23} & \eta_{22} \\ \eta_{11} & \eta_{13} & \eta_{12} \\ \eta_{31} & \eta_{33} & \eta_{32} \end{bmatrix} = [G_m] \qquad (3)$$

Considerations regarding the possibility to identify the errors by using the mathematical pattern of matrixes

Previously, we highlighted the possibility of modifying the hour index of of the connections group by modifying the connections scheme of the transformer. Sometimes, these modifications, appear by chance, making the so called assembling errors.

For the purpose of their identification in a quick and secure manner, the authors are proposing to make use of an installation which is the object of an invention patent request [2].

The device, according to the invention, whose block of principle scheme is presented in fig.3, is mainly made of a nine positions switcher, that realises the succession of connections corresponding to the nine sequent measurements, concerning the constant power method; at the exit of the switcher is placed a distribution block, by which the signals resulted at the exit of the switcher are sequently distributed to the nine entrances of a memory block, so as each position of the switcher should send the signal to the respective entrance of the memory block. Whithin this block, the signals are distributed by the configuration of the code matrix, that is displayed on the display block. Then, the matrix is introduced in a decodifying block, that, at its exit, furnishes the information necessary to display, on a display block, of the



c).
Fig. 2 Examples for modifications
(Reproduced from [2])

hour index obtained experimentaly. For the purpose of identifying the errors and the faults in the transformer, the scheme has a comparison element, in which are introduced the prescribed code matrix, by means of a prescribing element, as well as the code matrix experimentaly determined, and that results at the exit of display block, of the hour index obtained experimentaly. The two matrixes are compared and analised within the computing unity, that furnishes an information at its exit, displayed on another display block.

The use of the mentioned installation, claims the usage of computer, and using the computer claims the usage of analitical relations which should express the main modifications that may a[...] [...]ons s[...]

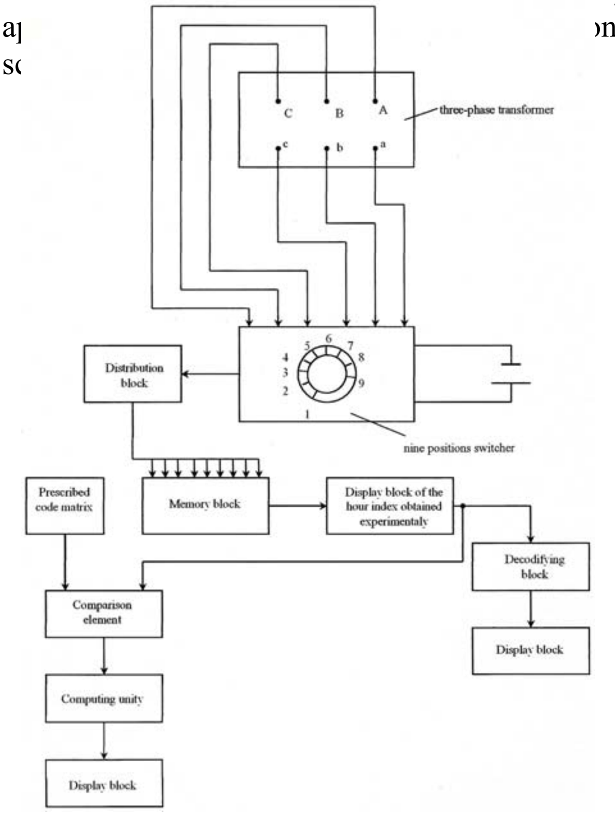


Fig 3 Block of principle scheme to device
(Reproduced from [2])

Starting with the main changes previously enumerated, the authors have managed to express analiticaly the following changes:

- circular permutations in direct sense of the terminals' couplings in the primary:

$$G_x = G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad (4)$$

- circular permutations in inverse sense of the terminals' couplings in the primary:

$$G_x = G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}^2 \quad (5)$$

- circular permutations in direct sense of the terminals' couplings in the secondary:

$$G_x = G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}^2 \quad (6)$$

- circular permutations in inverse sense of the terminals' couplings in the secondary:

$$G_x = G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad (7)$$

- changing the alimentation from the high voltage wrap to the low one:

$$G_x = T_{G_k} \quad (8)$$

- modifying the initial scheme through a type 3I variant (3I- reversing the coiling sense, reversing the terminals' couplings, reversing the terminals' notations):

$$G_x = (-1) \cdot G_k \quad (9)$$

- modifying the couplings between the phase wrappings at the connections d (triangle) and Z (zig-zag):

1. modifying the couplings from N to Z at the high voltage wrappings:

$$G_x = (-1) \cdot G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad (10)$$

2. modifying the couplings from Z to N at the high voltage wrappings:

$$G_x = (-1) \cdot G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}^2 \quad (11)$$

3. modifying the couplings from N to Z at the low voltage wrappings:

$$G_x = (-1) \cdot G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}^2 \quad (12)$$

4. modifying the couplings from Z to N at the low voltage wrappings:

$$G_x = (-1) \cdot G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad (13)$$

- reversing the couplings between two terminals in the primary and two in the secondary:

1. reversing the couplings between A and B, respectively a and b:

$$G_x = T_{G_k} \quad (14)$$

This relations is the same like when we reverse the conections between B and C, respetively b and c, and also, when we reverse the conections between A and C, respetively a and c.

2. reversing the couplings between A and B, respectively a and c:

$$G_x = \left\{ G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \right\}_T \quad (15)$$

This relations is the same like when we reverse the conections between B and C, respetively b and a, and also, when we reverse the conections between A and C, respetively b and c.

3. reversing the couplings between A and B, respectively b and c:

$$G_x = \left\{ G_k \cdot \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}^2 \right\}_T \qquad (16)$$

This relations is the same like when we reverse the conections between B and C, respetively c and a, and also, when we reverse the conections between A and C, respetively b and a.

Conclusions

Establishing the analitical expressions that define the various modifications wich may appear in the connections scheme of a transformer opens the possibility to establish a diagnosis of the assembling errors in the transformer's scheme.
It is possible to make use of an apparatus for identifying the hour index on the basis of the method of the constant power, associated to an electronical computer, connected to the appararus by means of an interface.
Considering the performances offered by the computer, as well as a series of solutions used by the authors to realise the indicating device, it is. possible to rapidly and securely obtain some pieces of information about the diagnosis of the assembling errors at the electrical three-phase transformers.

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