"DESIGN AND CONSTRUCTION OF SINGLE-PHASE TRANSFORMATION MODULES THAT ALLOW TO ANALYZE THE UTILITY AND APPLICATION OF THE DIFFERENT THREE-PHASE CONNECTION GROUPS"

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Summary — The present project indicates the implementation of three didactic modules for the analysis of connection groups of three-phase transformers, vacuum and short circuit tests, polarity and voltage regulation. In the first part we describe all the information necessary for the training of the students, such as generalities of the transformer, vacuum test, short circuit test, and the different connection groups. A second part describes the design and construction of the three single-phase didactic transformation modules that allow us to analyze the utility and application of the three-phase connection groups. Finally, the recommendations and conclusions of the project are mentioned.

I. INTRODUCTION

The experiments of Faraday began in 1831, that is to say, half a century before the invention of the transformer. If we ask why this delay is due to its appearance, the answer is relatively simple: at the beginning of electricity, this occurred in its continuous form and in that case the transformer was not necessary.

It was not until later as when problems began to appear concerning the transportation of electricity and the energy losses that occurred in the form of heat, when the transformer appears as an extremely useful device. The electric transformer was the answer with which the technology of that time solved the problem, which allowed that it continued the impetuous development of what today is known like progress. The transformer is a device that is based on the phenomenon of electromagnetic induction. It consists of two coils of conductive material wound on a closed core of ferromagnetic material, but isolated from each other electrically. The only connection between the coils is the common magnetic flux that sets in the core. The core is generally made of a ferromagnetic material that facilitates the circulation of the magnetic field.

In the development of this project is intended to build a tool for students of electrical engineering in order to achieve practical knowledge and to obtain a more efficient development for the professional field.

II. CONTENT DEVELOPMENT

The contents in this project are structured in such a way that in a first part the generalities of the programmable automata are explained, then apply the selection parameters and perform the construction and implementation of the didactic module.

A. Overview

A transformer is a device that changes the alternating electrical power with a voltage level to alternating electric power with another level of voltage by the action of a magnetic field. *"See [1]"*

B. Transformer operation

A transformer operates with the principle of electromagnetic induction, two coils are assembled inductively, the magnetic flux passes through one of them. Also partly or wholly by the other, resulting in the two coils having a common magnetic circuit. *"See [1]"*

C. Types of transformers

- Single-phase column transformer. Has a rectangular shape and consists of two columns where windings are wound, all of the same section.
- Single-phase armored transformer consisting of a magnetic core with three columns, the central one being double section compared to the lateral ones. The two windings are wound on the central column, one on top of the other and with an intermediate insulation layer. *"See [7]"*

D. Regulation of voltage in a transformer

Voltage regulation at full load is an amount that compares the output voltage of an unloaded transformer (vacuum) to the output voltage at full load. *"See [1]"*

E. Testing of transformers

1) Open circuit test.

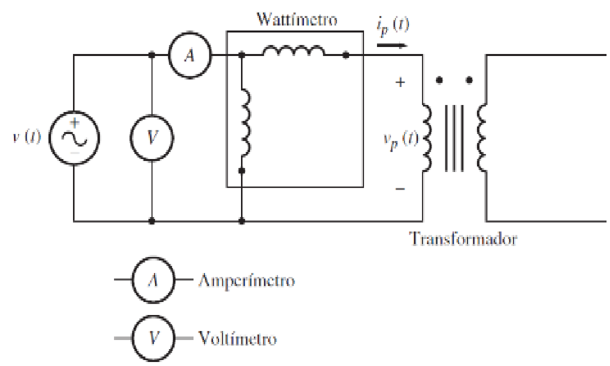

Fig. 1 Open circuit test

In the open circuit test, the secondary winding circuit of the transformer is left open and its primary winding is connected to a full voltage line.

2) Short circuit test

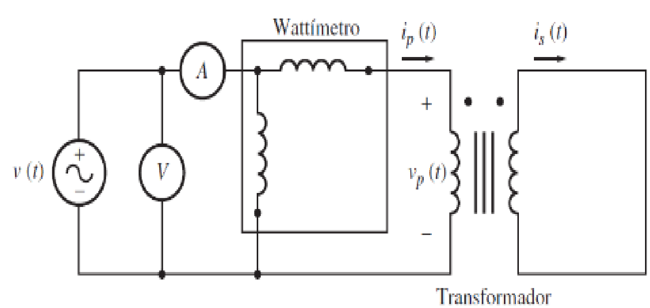

Fig. 2 Short circuit test

This test is carried out by placing the secondary winding in a short circuit and supplying the primary with an adjustable voltage, starting from zero and increasing until the nominal current is reached.

These two tests serve to make the circuit equivalent to its minimal expression. *"See [1], [7]"*

F. Transformer Polarities

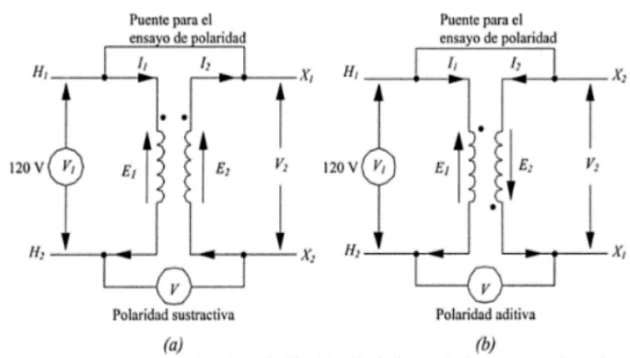

Fig. 3 Transformer Polarity

The procedure for a polarity test consists of connecting the two adjacent terminals, high and low voltage, interleaving a voltmeter V between the two remaining terminals and applying an alternating voltage V1, of convenient value, generally 120V, to the high voltage winding. If the indication of the voltmeter is V = V1-V2, it indicates that the polarity is subtractive. But if V = V1 + V2, it indicates that the polarity is additive. *"See [2]"*.

G. Three-phase transformers.

The companies generating electric power generate and transmit power in three-phase form. Within the distribution networks some loads are three-phase, while the rest are single-phase loads with connections distributed between the phases to form an almost balanced three-phase load.

TABLE I

ADVANTAGES AND DISADVANTAGES OF THE TRANSFORMER

Advantages and disadvantages of core transformer 3φ on single-phase groups	
Adventages	**Disadventages**
• They take up less space. • They are lighter. • They are cheaper. • 4. There is only one unit to connect and protect.	• Higher unit weight. • Any fault renders the whole 3φ transformation unusable, requiring a higher reserve power or unit

H. Three-phase connections

A three-phase transformer consists of three transformers, either separated or combined over a single core. The primary and secondary of any three-phase transformer can be independently connected in either (Y) or delta (D). This gives us a total of four possible connections on the bank of a three-phase transformer. *"See [1]"*

1) Star-star connection

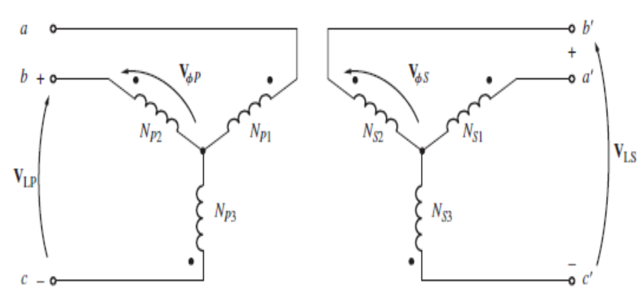

Fig. 4 Y-Y connection

Used when it is desired to have neutral at low and when large currents of imbalance (neutral phase) are not foreseen. Useful for transformers with small to moderate power at high voltages. *"See [1]"*.

TABLE II

Y-Y TRANSFORMER RELATIONSHIP

Relationship	$\frac{V_{LP}}{V_{LS}} = \frac{\sqrt{3} * V_{FP}}{\sqrt{3} * V_{FS}} = a$

2) Star-delta connection

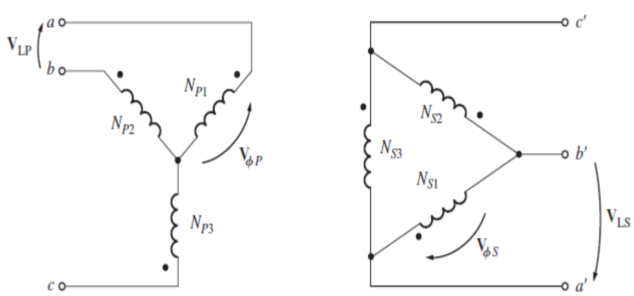

Fig. 5 Y-D connection

Suitable as a transformer (when grounding is not required in the secondary). It does not generate voltage harmonics. It is mostly recommended for relatively low secondary voltages that drive high currents. *"See [1]"*

TABLE III

Y-D TRANSFORMER RELATIONSHIP

Relationship	$\frac{V_{LP}}{V_{LS}} = \frac{\sqrt{3} * V_{FP}}{V_{FS}} = \sqrt{3} * a$

3) Delta-star connection

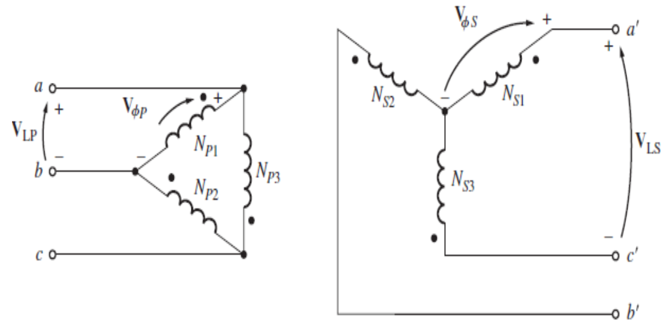

Fig. 6 D-Y Connection

Used as an elevator transformer. It is not a generator of third harmonic voltages. It does not motivate flows through the air in case of unbalanced loads (c.c.) or neutral transfers (surges). Supports unbalanced loads and the possibility to take neutral at low voltage. *"See [1]"*

TABLE IV

D-Y TRANSFORMER RELATIONSHIP

Relationship	$\frac{V_{LP}}{V_{LS}} = \frac{V_{FP}}{\sqrt{3} * V_{FS}}$ $\frac{V_{LP}}{V_{LS}} = \frac{a}{\sqrt{3}}$

4) Delta delta connection

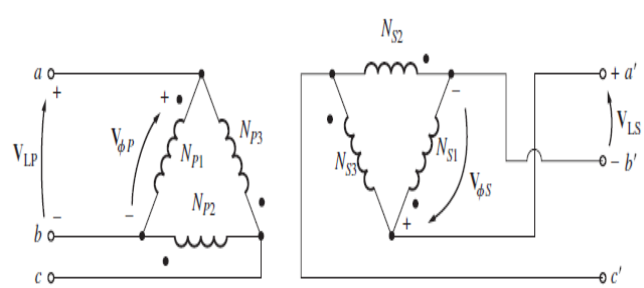

Fig. 7 conexión D-D

This type of connections is used a lot in autotransformers, when you want to recover the voltage drop by length of the feeders, due to some distance of the feeder circuit you have a drop in the supply voltage so you need to transform that energy to recover Somehow those losses for which these transformers are used with delta-delta connection. *"See [1]"*

TABLE V

D-D TRANSFORMER RELATIONSHIP

Relationship	$\frac{V_{LP}}{V_{LS}} = \frac{V_{FP}}{V_{FS}} = a$

According to the above connections there are other combinations of three-phase connections.

TABLE VI

THREE-PHASE CONNECTION GROUPS

Group	Connections		
0	Yy0	Dd0	Dz0
6	Yy6	Dd6	Dz6
5	Yd5	Dy5	Yz5
11	Yd11	Dy11	Dz11

III. DEVELOPMENT OF THE PROPOSAL

Here we explain the construction of the didactic modules: the materials that were used with selection criteria, the design of the modules, as well as the practices to be carried out.

A. Transformer Selection

The type of transformer to be selected must have suitable characteristics for the applications of the modules in the laboratory of electrical machines, these can be selected according to the functions for which they are required. Some of the general characteristics of the modules are:

- Easy handling
- Convenient power supply
- Compact physical space

Fig. 8 Single-phase transformer LAYRTON 120V-12V

B. Transformer Characteristics

Voltage in Primary	120V
Voltage in the Secondary	12V
Apparent Power	250 VA
Frequency	50-60 Hz
Current (Primary)	3.15 A

C. Design of the modules

The modules have a design based on technical engineering criteria in which the protection of the different devices and the safety of the people are taken into account; Without reducing efficiency.

1) External

It is the frontal profile of the didactic modules, with which the personnel will be able to operate to the equipment in the different practices to realize; For that reason the respective signaling and identification in each one of its parts is necessary.

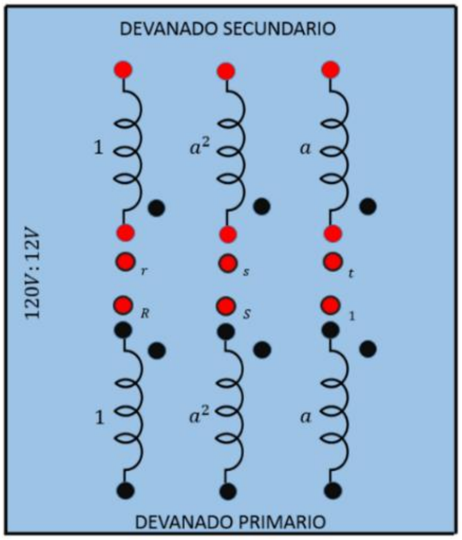

Fig. 9 Outside the module

On the outside is the configuration of the elements connected internally:

- Primary windings
- Secondary windings
- Input voltage
- Output voltage
- "Banana Jack", to make various connections
- Three-phase supply "R, S, T"
- Its positive polarity

2) Internal part

It is the cover of the metal cabinet, which contains the different work elements, assembled in the most convenient way to save as much space as possible.

The ease of manipulation of the teaching modules is due to the correct internal structure in both the connection points and the wiring.

Fig. 10 Internal part of the module

D. Construction of the modules

The modules consist of local standardizations so that the didactic module has an aesthetic presentation, according to other existing boards in the Technical Education laboratory.

3) Construction of the cabinets

Fig. 11 Construction of the modules

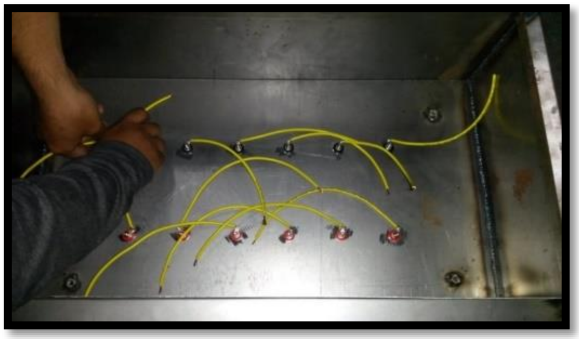

Fig. 12 Holes and placement of bananas

Fig. 13 Module wiring

Fig. 14 Assembly of transformers

Fig. 15 Construction of pedestals and assembly of modules

Fig. 16 funcionality test

ACKNOWLEDGMENTS

A special thanks to God, the supreme being and creator of all things, to our Fathers, an infinite thank you to Ing. Hernán Pérez, career director and this investigative work. Thank you very much for each of the participating engineers, with the necessary training information.

REFERENCES

[1] CHAPMAN S. J. (2012). *Maquinas Eléctricas 5ED*. En S. Chapman, Maquinas Eléctricas (págs. 49-103). Mexico: McGraw-Hill.

[2] AVELINO PÉREZ (2001). *Transformadores de distribución*. segunda edición Printed Mexico.

[3] NORBERTO A. LEMOZY (2015) *transformadores trifásicos*

[4] CASTRO J., GARCIA D. (2011) *(Tesis de ingeniería en electromecánica).* Universidad Técnica de Cotopaxi. Latacunga, Ecuador.

[5] RECALDE S. (2012), *Didáctica general*. Cotacachi, Ecuador.

[6] YANES SALAZAR (2010). (*Tesis de escuela de formación tecnológica*). Escuela Politécnica Nacional. Quito. Ecuador.

[7] RODRÍGUEZ MIGUEL ÁNGEL. *Transformadores trifásicos*. Universidad Nacional Del Santa. Chimbote. Perú