ASPECTS REGARDING THE OPERATING REGIME IN CHARGE OF SINGLE PHASE ELECTRICAL TRANSFORMERS

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Abstract

The paper presents a case study on the operating regime in charge of single-phase transformers. The case study relates to a functional model that has in its configuration a single-phase electric transformer with an apparent power of 250 VA and a transformation ratio of 230 / 27V. The monitoring of the electrical parameters in the load operation of the single-phase electric transformer was done by means of an electronic measuring block fed from an independent voltage source.

Key words:electrical transformer, secondary load, operating mode, electronic block, efficiency, single phase, relative value

1.INTRODUCTION

In the load operation mode of single-phase transformers, the impedance of the consumer connected to the secondary winding varies within the limits $Z_{sn} \leq Z_s < \infty$.

The limits of variation of the consumer impedance connected to the secondary winding terminals depend directly on the variation of the electric current transmitted by the primary winding of the transformer[1]:

$i_{10} < i_1 \leq i_{1n}$.

Where:

- i_{10}- the empty running current of the primary winding
- i_{1n}- nominal current of the primary winding

According to the law of electromagnetic induction, the electrical current in the secondary winding of the transformer (i_2) determines the magnetomotor voltage (t.m.m), respectively, the isolation $w_2 \cdot i_2$, which according to Lentz's principle is inversely oriented to the magnetomotor voltage (primary isolation) $w_1 \cdot i_1$. The equilibrium in the magnetic system of a single-phase electric transformer is realized when the current $i_1 = i_{10} + i_1'$ flows through its primary winding or when $w_1 \cdot i_1' = -w_2 \cdot i_2$.

Consequently[1]:

$$w_1 \cdot i_1 + w_2 \cdot i_2 = w_1 \cdot i_{10}$$

The equilibrium equation of the voltages for the secondary winding of the transformer, according to Kirchhoff II theorem is[1]:

$$e_{s2} + e_2 = r_2 \cdot i_s + Z_2 \cdot i_2 = r_2 \cdot i_2 + u$$

where:

$$u_2 = Z_S \cdot i_2 .$$

The load operation mode is performed when the primary winding of the transformer iis fed to the voltage $\mathbf{U_1 = U_{1n} = const}$, and load impedance $\mathbf{Z_s' \neq 0}$, adică $\mathbf{0 < Z_s' < \infty}$, and the current i_2 passes through this and the transformer's secondary offset to the secondary voltage with the angle φ_2.

2. CASE STUDY ON THE OPERATION OF A SINGLE-PHASE ELECTRIC TRANSFORMER

For the study of the loading regime of the single-phase transformers, a functional model was used in the configuration of which an electronic block (BE) was implemented, through which the nominal parameters were determined when connecting the load to the secondary transformer socket terminals.The interface of the functional layout and the principle scheme used are shown in figure 1.

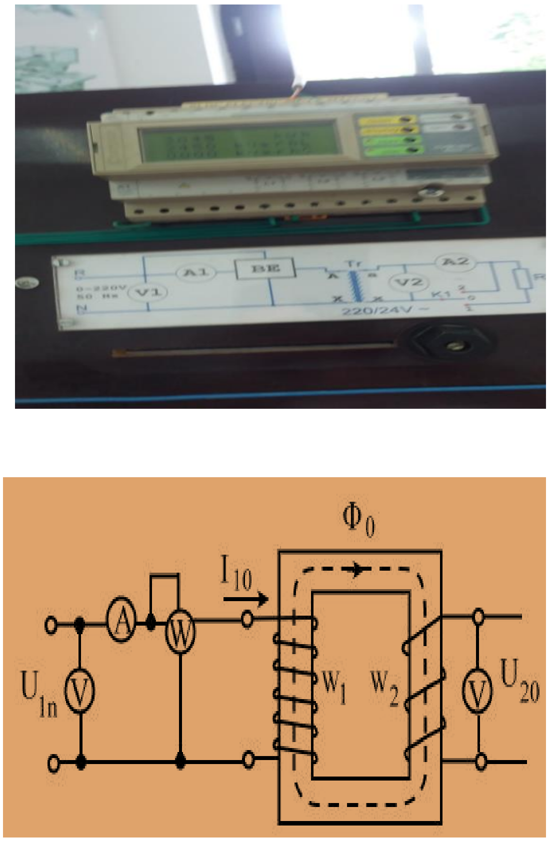

Figure 1. Experimental scheme and principle scheme used to study the load-carrying operations of the single-phase electric transformer

When applying the nominal voltage U_{1n} to the primary winding terminals of the single-phase electric transformer, the value of the nominal voltage(U_{2n}) set at the secondary winding terminals to which a load is connected can be determined. In these conditions the value of the electric current (I_{1n}) transmitted by the primary winding, the power consumption (P_{1n}) and the value of the electric current (I_{2n}) transmitted by the load resistance connected to the secondary winding terminals can be determined.

The following characteristics can be observed when operating the single-phase electric transformer[1]:

- external feature
- variation of secondary voltage
- the performance variation characteristic

The external feature highlights voltage variation at the secondary terminals depending on the load current (secondary), the voltage applied to the primary and its frequency being the nominal ones.

The external feature is defined by the relationship[1]:

$$U_2 = U(\beta) \text{ pentru: } U_1 = U_{1n} = \text{const.}; \cos\varphi = \text{const.}; \beta = \frac{I1}{I2n} = \frac{I2}{I2n} \qquad (1)$$

In the transformer operation, the voltage U_2 must be constant or vary very little within the limits allowed by the consumer. The voltage drop in the transformer Δu from empty to load is [1]:

$$\Delta u_2 = \frac{\Delta U_2}{U_{20}} = \frac{U_{20} - U_2}{U_{20}} = \frac{U'_{20} - U'_2}{U'_{20}} = \frac{U_{1n} - U'_2}{U_{1n}} \qquad (2)$$

The secondary voltage variation of a two-winding transformer for a given power factor is the difference between the nominal secondary voltage at the secondary secondary terminals and the voltage at the same terminals when the transformer is operating at load if $\mathbf{U_1}$ and $\mathbf{f_1}$ remain constant.

$$\mathbf{\Delta U_2 = |\underline{U}_{20}| - |U_2| = U_{20} - U_2} \qquad (3)$$

or as a percentage of the nominal secondary voltage

$$\mathbf{\Delta u_2 = \frac{U_{20} - U_2}{U_{20}} \cdot 100 = \frac{U_1 - U'_2}{U_1} \cdot 100 = \Delta u'_2} \qquad (4)$$

By marking $\beta = \frac{I1}{I2n} = \frac{I2}{I2n}$ the relative value of the secondary load, the expression of the voltage drop in relative units will be[1-5]:

$$\Delta u_2 = \beta(U_{ka}\cos\varphi_2 + u_{kr}\sin\phi_2)[\%] \qquad (5)$$

Figure 2 shows the variance curve of the secondary voltage according to the character of the load.

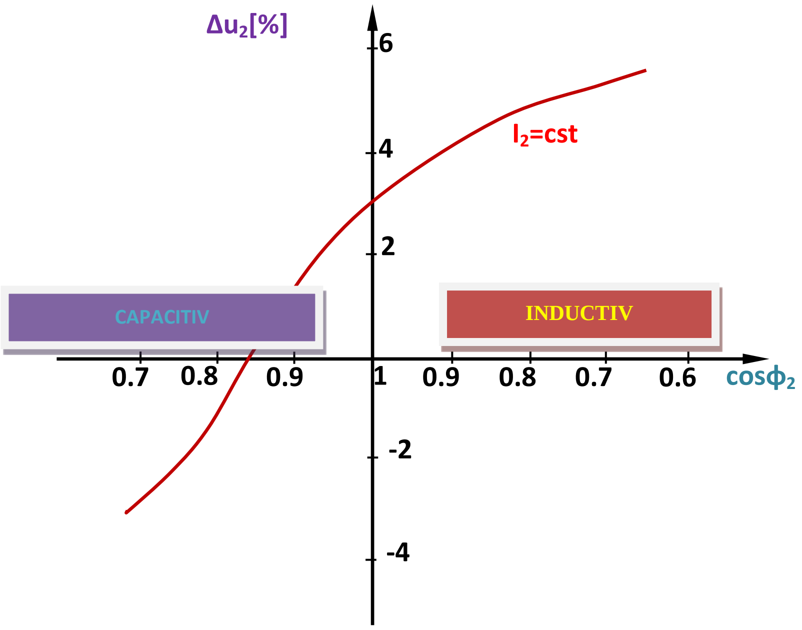

Figure 2.
Secondary voltage variation curve in function
by the character of the load (inductive / capacitive).

Figure 3 shows the connection between the external characteristic and the voltage variation, and in Figure 4 a family of external characteristics for different values of cosφ_2 is represented.

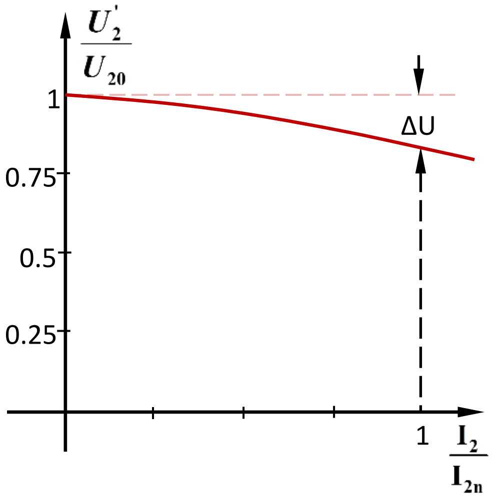

Figure 3. Dependence of external characteristic and voltage variation.

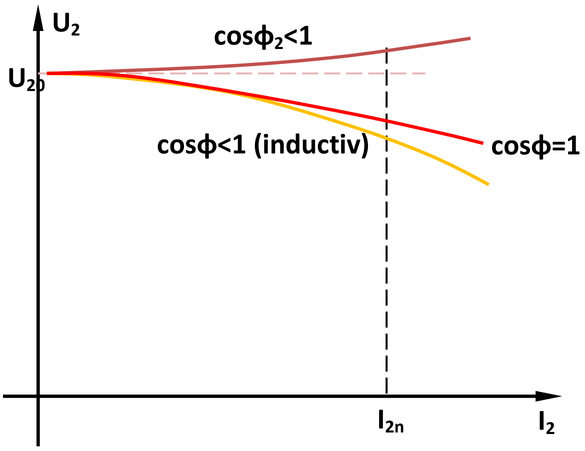

Figure 4. External features of transformers for different values of cosφ_2

With the variable autotransformer (ATR) entering the experimental scheme configuration shown in Figure 1, seven supply voltage values ranging from 0-U_{1n}, were set, and the parameters of the primary and secondary circuit of the transformer indicated on electronic block display[6-9]:

The measured values are listed in Table 1.

Table no.1 Experimental data on load operation.

No. Crt.	$U_{1=}U_{1N}$ [V]	I_1 [A]	I_2 [A]	$U_{2=}U_{2N}$ [V]
1.	80	6,96	8	8,9
2.	110	7,4	8,5	11,8
4.	140	9,44	10,85	15
5.	170	11,14	12,8	18
6.	200	13,92	16	21,5
7.	230	16,54	19	27

Table no. 2 The correlation values between β şi η

No.crt.	β	η [%]
1.	0,5	1
2.	0,75	0,9
3.	0,8	0,88
4.	1	0,85

Generally β_m= 0,4 – 0,75 having low distribution transformer values that work longer at low loads and higher values at transformers built to work at loads close to rated load. Figure 5 shows the variance characteristic η=f(β).

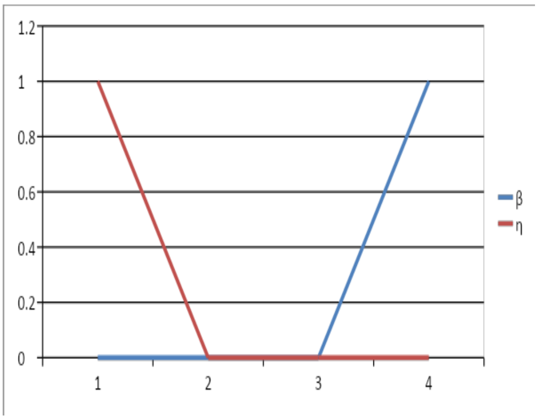

Figure 5.Variation feature η=f(β)

4.CONCLUSIONS

1. The maximum yield value is obtained when the winding losses are equal to the losses in the ferromagnetic core, ie when the variable losses (from the windings) are equal to the constant losses (from the iron).
2. For values of I_2 between 0 ÷1,2 I_n results values of $\beta = I_2/I_{2n} = 0÷1,2$;
3. The external feature highlights voltage variation at the secondary terminals depending on the load current (secondary), the voltage applied to the primary and its frequency being the nominal ones.

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