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TESTING ALGORITHM FOR NEGATIVE ASYMMETRY COEFFICIENT CALCULUS FOR A STEINMETZ SYMMETRIZING CIRCUIT

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ABSTRACT

In case of the currents asymmetry analysis for an induction furnace – symmetrizing circuit connected in a Steinmetz scheme, one of the most important aspects is represented by the negative asymmetry coefficient. This one can be determined knowing the positive sequence and the negative sequence components and the initial parameters R_0 and X_0 of the induction furnace.

The testing algorithm follows the negative asymmetry coefficient determination function by knowing the input data, the final values being the same indifferently which way is chosen for the calculus.

Keywords: Steinmetz, symmetrizing, algorithm

1. ASYMMETRICAL STATE INDICATORS

Like the other aspects of Electrical Energy Quality, the asymmetrical state knows a dynamics looking the indicators effectively used and proposed indicators. Such as, from the scalar expressions we have passed to the complex expressions and indicators related to the powers have been attached to the indicators of the voltages and currents. The characterization of the multi-phased system asymmetry is realized, mainly, through the calculated indicators like ratio between the negative sequence or zero sequence, and positive sequence component or the corresponded nominal value, on the other side.

a). The negative asymmetry factor is defined through the ratio between the effective value of the negative sequence component Y^- and the effective value of positive sequence component Y^+, conformal with next relation:

$$k_s^- = \frac{Y^-}{Y^+} . \quad (1)$$

b). Zero asymmetry factors are defined through the ratio between the effective value of zero sequence component and positive sequence component, conformal with next relation:

$$k_s^0 = \frac{Y^0}{Y^+} . \quad (2)$$

c). The complex negative asymmetry factor is determined through the reported complex values of the negative sequence components and positive sequence as follows:

$$\underline{k}_s^- = \frac{\underline{Y}^-}{\underline{Y}^+}, \qquad (3)$$

d). The complex zero asymmetry factor is obtained through the reported complex values of the zero sequence and positive sequence, according to the next relation:

$$\underline{k}_s^0 = \frac{\underline{Y}^0}{\underline{Y}^+}, \qquad (4)$$

In some countries, the asymmetry level is characterized through the maximum variation of the phase voltage reported to the medium value of the three phases, related to this medium value. In this case, for the phase voltage system U_A, U_B, U_C, a medium value U_{med} and variations δ_A, δ_B, δ_C are calculated:

$$\begin{aligned} U_{med} &= \frac{U_A + U_B + U_C}{3} \\ \delta_A &= \frac{U_A - U_{med}}{U_{med}} \\ \delta_B &= \frac{U_B - U_{med}}{U_{med}} \qquad (5) \\ \delta_C &= \frac{U_C - U_{med}}{U_{med}} \end{aligned}$$

2. LIMIT VALUES OF ASYMMETRIC STATE INDICATORS

The compatibility levels for low frequency perturbations below 10 kHz, are differentiated in CEI recommendations for the next three classes of the electromagnetic medium:

- first class, represented by the low voltage insulated network, including the perturbations sensitive equipments;
- second class, including the connections points in high voltage, placed in industrial environment and public networks;
- third class, which is referred to the connection points in low voltage and medium voltage, from industrial area.

The standards about asymmetrical state is referred to the negative sequence and zero sequence components from voltage system, through the negative asymmetry limited values indication and, rarely, for the voltage asymmetry or zero asymmetry coefficient (factors).

Conformal with the CEI standards, the following limit values for the negative asymmetry coefficient are recommended, in accordance with the electro-magnetic state classes, as follows:

k_{sMax}^- = 2% for devices from 1st and 2nd class;

k_{sMax}^- = 3% for devices from 3rd class.

In Romania, the maximum limit values of the negative asymmetry coefficients, for voltage systems are:

- 2% for low voltage and medium voltage networks and, also, in the connection node of a electrical traction substation;
- 1% for high voltage networks.

The standard proposal, in concordance with the international requirements, establishes the necessity of statistical analysis for the voltage asymmetry and framing in 2% limit of total asymmetry coefficient, in case of 95% from observing period, which is considered, in generally, one week.

In case of the three-phased network supplying of receivers like induction coreless furnaces a Steinmetz symmetrization installation is used structured from a symmetization inductance, the single-phased load, compensated through the capacitor battery and the capacitor symmetrization battery, coupled in a triangle connection.

3. STEINMETZ CONNECTION

The Steinmetz symmetrizing scheme, presented in Figure 1, is used to the mains connection of the industrial frequency coreless induction furnaces.

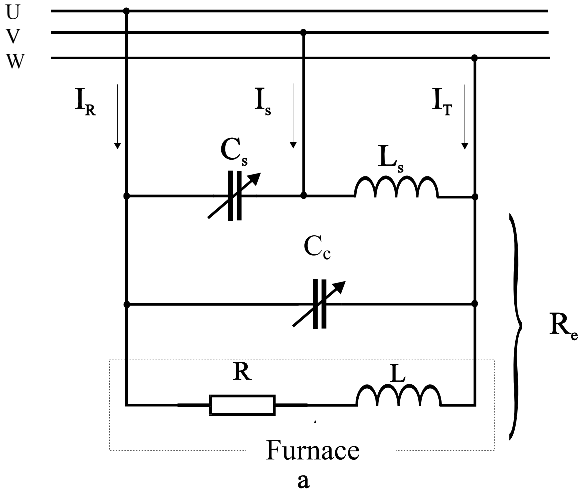

Figure 1. The Steinmetz symmetrizing circuit

The induction furnace, having R and X as electrical parameters (the power factor is usually included in the interval 0.05 – 0.25), is provided with the compensating capacitor battery C_c, composed of a fix step and a number of commutable steps; these steps are controlled according to the reactive power of the load. The Steinmetz symmetrizing circuit includes the reactor L_s and the capacitor C_s both being step-like adjustable.

The analytical study of this circuit is realized in [1], in the assumption of a perfect accord between the load parameters and the reactive components of the Steinmetz circuit. The pursuit of the compensating-symmetrizing process is made now with classical measuring instruments, that are insufficient for an accurate estimation of the symmetry and the control is made at operators will. The analysis done in [2, 3] emphasizes the possibility of the compensating-symmetrizing process control based on the dissymmetry coefficient minimization.

4. CALCULUS ALGORITHM

The final purpose is represented by the minimizing of negative asymmetry coefficient, his values being in accordance with the CEI standards.

This thing can be made using the mathematical calculus, starting from the initial parameters R_0 and X_0 of induction coreless furnace.

For our final aim it was developed a testing algorithm which follows the next calculus ways:

1. R_0 and X_0 – knows → is determined C_c → is determined X_{ls} and X_{cs} → is determined I_d, I_I, I_h → is determined $\mathbf{k_{id}}$;
2. R_0 and X_0 – knows → is determined C_c → is determined X_{ls} and X_{cs} → is determined R_e, X_e → is determined $\mathbf{k_{id}}$.

The R_0 and X_0 initial parameters have been obtained from measures in case of a real furnace, obtaining results passing the calculus algorithm and being compared with the effective measurements results.

Table 1

X_{ls} [Ω]	X_{cs} [Ω]	R_e [Ω]	X_e [Ω]	I_1 [A]	I_2 [A]	I_3 [A]	I_d [A]	I_I [A]	k_{id}
1.51	1.4462	0.882	-0.075	155.78	138.04	158.08	150.393	12.429	**0.0826**
2.285	0.9433	0.769	-0.125	212.22	204.24	187.32	201.007	14.545	**0.0723**
2.285	0.699	0.568	-0.196	292.02	284.6	299.42	291.955	8.556	**0.0293**
1.51	0.619	0.428	-0.078	323.52	388.64	343.58	350.776	39.288	**0.112**
1.51	3.097	0.36	0.21	131.92	494.31	477.59	343.534	212.757	**0.619**

Table 2

Nr. crt.	R_0 [mΩ]	X_0 [mΩ]	C_0 [mF]	C_c [mF]	X_c [Ω]	R_e [Ω]	X_e [Ω]	X_{ls} [Ω]	X_{cs} [Ω]	k_{id}
1	77	250	11.63	11.941	0.2667	0.882	-0.075	1.51	1.4462	**0.083**
2	67	220	13.24	13.897	0.2291	0.769	-0.125	2.285	0.9433	**0.073**
3	63	190	15.103	15.853	0.1892	0.568	-0.196	2.285	0.699	**0.03**
4	17	85	36.17	37.347	0.0852	0.428	-0.078	1.51	0.619	**0.112**
5	11	72	43.37	39.325	0.0809	0.36	0.21	1.51	3.097	**0.62**

As we can observed from each table, the negative asymmetry coefficient has approached or equal values. These aspects validate the developed calculus algorithm.

5. CONCLUSIONS

Using the MathCAD software, the equations system written in complex has been solved in order to determine the positive sequence and negative sequence currents components and the aim function, given by the negative asymmetry coefficient.

Identical results were obtained through the both determination versions, that is validating the established adjustment algorithm.

Using the complex calculus formula for the line currents, the voltage value is not influencing the aim function values.

6. REFERENCES

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