THE INFLUENCE OF ELECTRIC TRANSFORMERS' SPECIFIC PARAMETERS MODIFICATION ON POWER DISTRIBUTIONS AND ON TECHNOLOGICAL APPROPRIATE CONSUMPTION (TAC) WITHIN THE ENERGETIC SYSTEM

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Abstract: The paper deals with a comparative analysis – using DINIS(E) programming environment – of the way electric transformers' specific variables (Iron losses, the parameters of the equivalent scheme, the level of primary power supply, etc.) influences power distributions, active and reactive, from a well-defined contour within the energetic system. Also, the paper deals with the way interconnection of a great number of transformation units, with different functional characteristics may influence the level of losses within the global system – result as a consequence of multiple connections – level ultimately emphasised by the technological appropriate consumption (TAC).

Keywords: electric transformers, electric power supply networks

1. INTRODUCTION

The energetic system is a very complex system. That is why is very hard to perform an analysis of its behavior, even in symmetrical operating conditions. Moreover, the complexity of this system is due to both the complexity of its component subsystems (as independent entities) and the multitude of interconnections between them. One of the remarkable complex interconnected systems analysis solutions is showed by [Dimo, 1979], in the so-called nodal analysis (nodes method REI). Another complex interconnected systems analysis method has been given previously by Gabriel Kron [Happ, 1975] under the name of diakoptics. The fundamentals of both methods is practically based on a modern philosophical idea of analysis of complex systems, which are non-linear systems, in the true sense of the word, using fractals analysis, the two scientists were remarkable forerunners in promoting this modern idea. It is remarkable that both methods (that of Gabriel Kron, from 1940-1950 and that of Paul Dimo, from 1970-1980) deal with the same fundamental idea: cutting of the complex network (Kron), respectively, cutting of the great interconnected system (Dimo), down to a network/system which is to comprise, as a piece of hologram, the properties of the whole. The analysis is consequently performed on this fractal pattern (common expression, used today in fractal theory), and the results obtained can be extended to the whole network/system. We have applied a similar idea to analyze the behavior of the energetic system, using the DINIS (E) software. The method we have applied is a consequence of software performance to deliver the topological image of the interconnected system. This way, we have applied the partitioning method (diakoptics) to the big system, submitted to analysis, and the result was of a contour comprising a relevant number of interconnected subsystems [transformers (19), lines (24), and charges (18)], allowing us to shape the seed body/subsystem.

Since the transformers represent, practically, the most complex subsystems from the contour to be analyzed, our study has been based on the way subsystem's specific parameters variation may influence power distribution within the contour (and,

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by extension to the big system, as a whole). Such an analysis has been eased thorough two classes of parameters available for the transformers within the contour: the first class dealt with the design parameters and the second with the parameters found based on the algorithm we have suggested in previous step of the project and which had as starting point the tests carried out by the manufacturer at transformers' delivery.

2. POWER DISTRIBUTION – WITHIN THE CONTOUR ANALIZED – UNDER MODIFICATION CONDITIONS OF TRANSFORMERS' SPECIFIC VARIABLES

2.1. Power distribution - within the contour analyzed - under modification of losses in the ferromagnetic core. Influence of above on TAC

In order to check the influence of parameters from the branch side of the equivalent scheme in "T" (used to simulate transformers) from the contour submitted to analysis upon power distribution, two situations have been taken into account:

- the transformers do not have losses in the ferromagnetic core (in which case the conductance corresponding to these losses and furthermore the active component of no-load current are both insignificant);
- the transformers do have losses in the ferromagnetic core (equal with those specified by the manufacturer at the no-load testing of each transformer).

In the last situation, the model resistance and the corresponding conductance are measured, based on core losses.

In the first situation, above presented, the Iron losses of each transformer are not significant (compared to rated apparent power), so, by extension, for each unit considered separately and for all interconnected transformers within the contour these losses are considered insignificant. Although, taking into account the systemic vision (and Bertalanffy's definition to the systems, according to which "a complex system, comprising several subsystems always has new qualities, additional to those of component subsystems"), this extension is not quite accurate, to be able to visualize exactly the effect of these slight variations in an interconnected complex system we have chosen as reference this first situation. The simulation tests have shown the following:

- in the case of considering the ferromagnetic core losses as insignificant (of transformers within the contour analyzed) the losses of reactive power from the branch side of the network become, also, insignificant. In this case, the power factor within the contour canalized is around the value imposed, which is 0.92;
- in the case of taking into account the ferromagnetic core losses (and of the entire branch side of transformers' equivalent scheme), the reactive power consumption highly increases, which proves that equilibrium has been broken and main appearance of the magnetization reactant's character (useful). As a consequence of increaser's in the reactive power, additionally demanded by the transformers' cores, the power factor decreases (from the value 0.92 down to values of 0.85-0.86).

The values obtained for the powers dealt with within the contour submitted to analysis - for all cases of comparative analysis carried out in this paper – are shown, synthetically in the table 1, positioned at the end of the paper.
The influences due to losses in transformers' cores are also shown on TAC level (see fig. 1).

2.2. Power distribution - within the analyzed contour – in the case of equivalent scheme parameters modification. Influence on TAC

This time, it has been performed a comparative analysis between real transformers, with losses in the ferromagnetic core for two types of parameters:

- transformers' design parameters, one one hand;
- parameters resulted as a consequence of the tests carried out by the manufacturer at transformers' delivery to the customer.

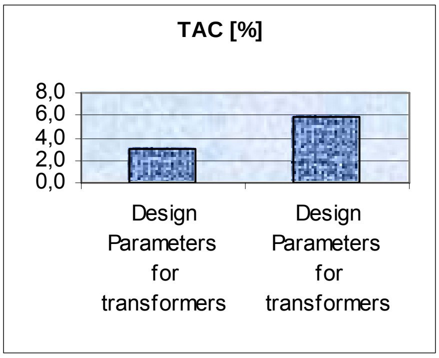

Fig. 1. Influences of transformers' ferromagnetic core losses on TAC

Power distributions – obtained in these cases – have revealed a major influence of the transformers within the contour on energy quality dealt with in the energetic system. The parameters obtained – based on tests – were completely different compared to the designed parameters (20-30% higher, due to some additional losses components hard to evaluate during designing process, as there are no accurate analytical expressions to calculate them). These parameters cause highly increasing in both active and reactive kind of losses, leading to global worsening of power factor within the system, to all component subsystems' efficiency decrease, to an increase of voltage dropping on the transportation and distribution, and, ultimately, to a shorting in service life of the whole system. Of course, this phenomenon of increase of losses level is also reflected in TAC increase (see figure 2).

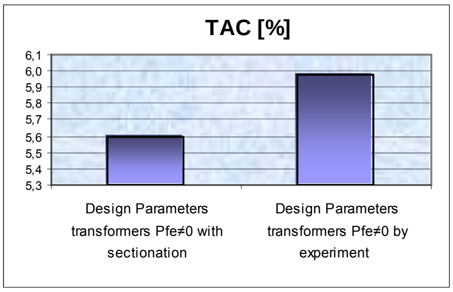

Fig. 2. Influence of transformers' parameters on TAC

2.3 Power distribution – within the analyzed contour – in the case of voltage supply modification. Influence on TAC

In order to find simple and practical methods to diminish losses within the analyzed contour (and by extension, in the whole energetic system), and of TAC, we have simulated an increase in voltage level, in transformers' primary from 6 kV to 6.6 kV. This method has been used both for transformers' design parameters and for testing parameters. Figures 3 and 4 show the results of comparative analysis, on TAC's level for the two categories of transformers considered within the contour analyzed, in the case of plotting modification from the values corresponding to 6 kV to that of 6.6 kV of voltage.

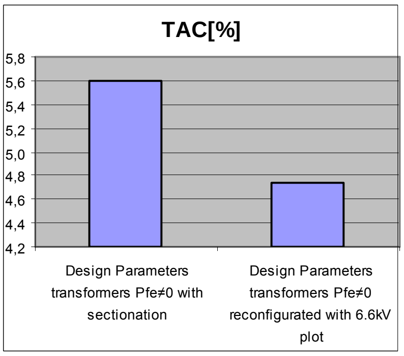

Fig. 3. Influence of supply voltage on TAC

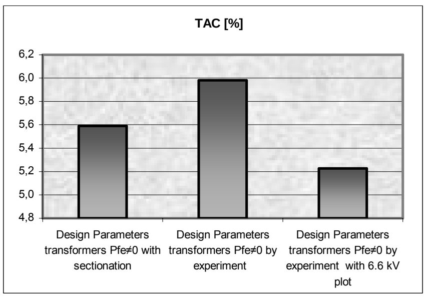

Fig. 4. Global influence (parameters + supply voltage) and supply voltage influence - in the situation of real transformers – on TAC

Of course, the magnetic flux is proportional with terminals' voltage square, a high level of supply voltage leads to an easier magnetization of interconnected transformers' cores, without an additional increase in the reactive component of no-load current, and furthermore, with lower reactive power consumption. Meanwhile, it also results a decrease of active kind of losses (on transportation and distribution lines, but also in the fluxes of losses inside the transformers). Thus, it results higher quality values for the energy dealt with within the analyzed contour (higher power factor, lower voltage dropping levels on transportation line, etc.).

2.4. Power distribution - within the contour analyzed - in the case of connection in parallel of transformers from different generations. Influence on TAC

The energetic system is having a continuous growth. Meanwhile, the sector is submitted, periodically, to a process of modernization. That's why, at a certain moment in time, the energetic system, but also for any contour considered, may comprise transformers from different generations. This is the case of the specific contour analyzed in this paper, where 4 (four) out of 19 (nineteen) interconnected transformers are relatively new, as they have been produced and mounted in the system after 1990. We have studied the power distribution, replacing new transformers' parameters with the values obtained by the manufacturer on testing stand. Definitely, the new transformers have lower losses in the ferromagnetic core than the old ones, due to use of new manufacturing technologies and materials (electro technical steel sheets, 0.3 mm thick, cold rolled, with oriented crystals instead of hot rolled, non-oriented crystals, 0.35 mm thick sheets). Also, the new transformers, using new technologies have new geometric sizes (smaller than the old ones), and consequently new values of resistance and reactance in the series side of the equivalent "T" scheme (generally, lower than the old ones') and, of course, lower values of Joule losses. Consequently, within the contour analyzed, by interconnection from different generations transformers a new equilibrium would appear so as to allow an energy distribution to a higher quality level (reflected by a significant diminish of active and reactive power losses, a significant improvement of power factor, efficiency, etc.). These advantages would also be reflected on TAC, by reducing it, as shown in figure 5.

Since the percent of new transformers within the contour considered is relatively small, both in number and installed load (4 new transformers out of 19, respectively 1.3 MVA out of 40 MVA) a significant reduction of TAC does not show. A significant reduction is obtained, as always in practice, by using combined methods, as shown in the comparative analysis presented in the previous paragraphs (see figure 4).

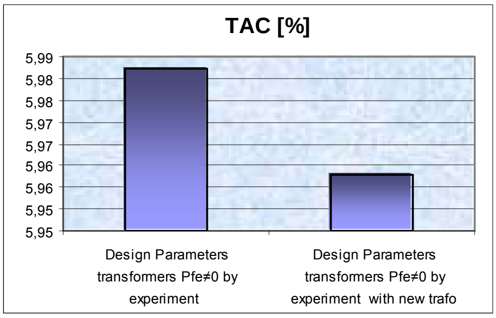

Fig. 5. Influence of using different generations transformers on TAC

2.5. Power distribution, within the contour analyzed, in the case of branch connection of transformers from different generations to the modification of supply voltage level. Influence on TAC

It has been considered a permanent modification of primary transformers' plots to 6.6 kV, including the contour comprising different generations transformers. Power distribution that resulted in this case is synthetically shown in table 1, and the comparative analysis, upon TAC is shown in figure 6. It is worth to mention that for comparison reasons, figure 6 shows the values of TAC obtained to the variation of transformers' specific parameters within the contour analyzed, precisely to point out the fundamental idea of using combined methods in order to raise quality level of energy dealt with within the energetic system.

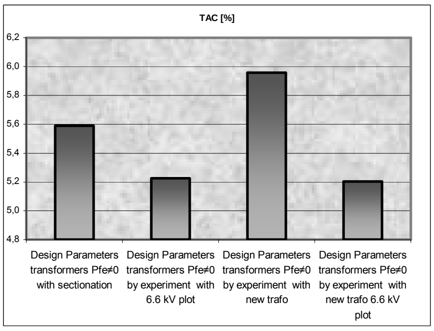

Fig. 6. Global influences of variation of parameters + a combination of transformers from different generations + supply voltage variation on TAC; a combination of transformers from different generations + supply voltage variation on TAC; supply voltage in case of using the combination of transformers from different generations on TAC

Also, it is worth mentioning the following:

- all power distributions have been obtained for radial networks;
- only the symmetrical operating conditions have been considered for analysis;
- for each configuration analyzed (of the particular contour chosen) the static and dynamic stability have been checked.

As a result of the analysis, specific conclusions have been drawn in order to explain the phenomena produced within the contour in each situation; based on these conclusions extensions have been made so as to be able to suggest implementation in the near future of certain practical solutions within the energetic system.

3. RESULTS OBTAINED. COMMENTS

The comparative analysis carried out in the paper has pointed out especially important aspects regarding the influence of transformers' specific parameters variation on TAC (as an ultimate indicator of various disturbances within the energetic system). The reference for the comparative analysis have been considered the transformers with design parameters, with losses in the ferromagnetic core, supplied with a nominal primary voltage of 6 kV, (except the case of influence of ferromagnetic core losses) (column 4 of the variants analyzed in the table 1). The conclusions are as follows:

- in the case of using transformers with losses in the ferromagnetic core different from zero (column 2 in table 1), TAC is practically double compared to the case of using transformers without core losses (see figure 1); the effective increase is 97.63% compared to the reference chosen;
- due to certain higher values of the parameters obtained from testing compared to those designed there is an increase with 7.02% of TAC within the contour analyzed (column 7 compared with 4 in the table 1), feature also shown in figure 2;
- the increase of voltage in transformers' primary leads to a decrease with 15.18% of TAC for the design values of parameters (column 6 compared with column 4 in the table 1); this feature is also shown in figure 3. A decrease of TAC (with 6.5% compared to the reference chosen), in the same conditions also shows up in the case of interconnection of transformers with parameters resulted from the tests performed by the manufacturer (column 8 compared with 4 in the table 1), feature shown in figure 4. For real transformers (with parameters measured as result of tests), this decrease - obtained though primary voltage modification - is significant (column 8 compared with 7 in the table 1), feature shown in figure 4, stressing an important idea to be used when dealing with energetic systems and which consist in replacing the present distribution transformers with 6 kV primary voltage values with transformers with higher voltage values (i.e. , 20 kV);
- in case of using new transformers within the contour analyzed (only 4 out of 19), TAC is increasing with 6.58% compared to reference

value (column 9 compared with 4 in the table 1), value which is lower, however, than the one found in the case of using only old generation transformers (7.02% respectively) (column 9 compared with 7 in the table 1); the latter situation is shown in figure 5;

- If for the new network (comprising 4 new transformers) the primary voltage is increased to 6.6 kV (column 10 in the table 1), the TAC is decreasing compared with the reference situation (6.91% compared with column 4 in the table 1). But TAC values are also lower than in the case of using only old generation transformers, at the same voltage level (column 8 in the table 1), features shown in figure 6.

4. GENERAL CONCLUSIONS. SUGGESTIONS

As a result of the comparative analysis carried out in the paper, we can draw certain conclusions, especially important and which can be put into practice in order to improve the operation of the contour analyzed, and the whole energetic system (in accordance with the philosophical ideas upon which this analysis is based on).

- Re-configuration of the existent network by studying, as a preliminary if the dynamic stability of the system is not modified (its capacity to deal successfully with extreme situations, such as injury);
- Re-assignation of loads on transformers within the contour analyzed, as in all the cases – shown in the comparative analysis -the powerful transformers considered (of 1000 kVA) have been 15-20% overloaded;
- Replacement of distribution transformers, type 6 kV/0.4 kV, with transformers type 20 kV/0.4 kV, both for reasons economy of reactive power consumption and diminish line voltage dropping.
- Use of condenser batteries in the nodes where a higher consumption of reactive power is reported in order to improve power factor within the contour analyzed;
- On line watching of energetic consumptions within the contour analyzed a dynamic change of voltage level – in transformers' primary – demanded by the dynamic modification of power level requested by the loads connected in the secondary.

A precise analysis on static and dynamic operation stability of the energetic system is to be performed, for each solution to be implemented.

5. BIBLIOGRAPHY

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Table 1

Nr crt	Study Case	Variances utilized for comparative analyze									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		Design Parameters for transformers $P_{fe}=0$	Design Parameters for transformers $P_{fe}\neq0$	Design Parameters transformers $P_{fe}\neq0$ without sectionation	Design Parameters transformers $P_{fe}\neq0$ with sectionation	Design Parameters transformers $P_{fe}\neq0$ reconfigurated	Design Parameters transformers $P_{fe}\neq0$ reconfigurated with 6.6kV plot	Design Parameters transformers $P_{fe}\neq0$ by experiment	Design Parameters transformers $P_{fe}\neq0$ by experiment with 6.6 kV plot	Design Parameters transformers $P_{fe}\neq0$ by experiment with new trafo	Design Parameters transformers $P_{fe}\neq0$ by experiment with new trafo 6.6 kV plot
1	Power supplied - [kW]	4277	4424	4262	4342	4262	4246	4540	4387	4509	4365
2	Total point load - [kW]	3923	3923	3923	3923	3923	3923	3923	3923	3923	3923
3	Total dist.load - [kW]	0	0	0	0	0	0	0	0	0	0
4	Total loss - [kW]	353.6	500.9	338.5	418.7	338.5	322.4	617.2	463.9	585.6	441.9
5	Line loss - [kW]	237.9	295.7	179.2	255.6	179.1	173.7	307.7	224.8	304.2	222.9
6	TF shunt loss - [kW]	0	38.3	39.9	39.3	39.9	40.2	38.5	39.8	38.3	39.5
7	TF shunt kvar - [kVAR]	0	2344.2	2373.4	2364.8	2373.4	2292.4	2305.2	2137.2	2296.5	2126.6
8	TF series loss - [kW]	115.7	167	119.5	123.8	119.5	108.5	271	199.3	243.1	179.5
	Total Power supplied - [KWh]	12831000	13272000	12786000	13026000	12786000	12738000	13620000	13161000	13527000	13095000
	TAC - Line Analized [%]	2.87	3.50	2.24	3.10	2.23	2.18	3.55	2.71	3.54	2.70
	S/SN	0.19	0.20	0.19	0.19	0.19	0.19	0.20	0.19	0.20	0.19
	Power loss on Trafo - [KWh]	6647.28	316665.47	326021.82	321730.48	326017.53	327743.58	325543.37	330446.88	321932.83	326748.26
	TAC TRAFO [%]	0.05	2.33	2.49	2.41	2.49	2.51	2.33	2.45	2.32	2.43
	Time utilization	1590	1590	1591	1590	1590	1590	1590	1590	1591	1591
	Power on line W_l	12824352.72	12955334.53	12459978.18	12704269.52	12459982.47	12410256.42	13294456.63	12830553.12	13205067.17	12768251.74
	Power loss on Line - [KWh]	378261.00	470163.00	285107.20	406404.00	284769.00	276183.00	489243.00	357432.00	483982.20	354633.90
	S	4752.22	4915.56	4735.56	4824.44	4735.56	4717.78	5044.44	4874.44	5010.00	4850.00
	Total TAC (KWh)	384908.28	786828.47	611129.02	728134.48	610786.53	603926.58	814786.37	687878.88	805915.03	681382.16
	%	2.9998	5.9285	4.7797	5.5899	4.7770	4.7411	5.9823	5.2266	5.9578	5.2034
	Error [%]		97.63	-14.49		-14.54	-15.18	7.02	-6.50	6.58	-6.91

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