THE INFLUENCE OF THE REACTIVE POWER AND OF THE DEFORMANT REGIME ON THE QUALITY OD THE ELECTRIC ENERGY OF THE GREAT CONSUMERS

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Abstract - In this paper there are analyzed the specific problems of the great industrial consumers, characterized by the distorted and unbalanced regime and by the power factor under the neutral power factor, there are discussed problems regarding the allocation of the level of disturbances a level of a user group supplied by the same voltage bar of 20 kV. The inadequate usage of the means of limiting the disturbances can generate the overcompensation phenomenon and resonant in the electric network.

These phenomena are found in the current modern users where a large number of receivers are controlled by using the electronic power.

Knowing these phenomena and adopting the inadequate measures have a significant effect on the economic efficiency of the user and on the quality of the electric energy.

Keywords: harmonic distortion, overcompensation, reactive power, allocation disturbances, unbalance.

1. INTRODUCTION

The circulation of the reactive power and the allocation of the level of disturbance to consumers is a very important and generous theme for research.

In the paper there are examined the specific issues of the circulation of the reactive power at a great consumer, with emphasis on the reaction of the batteries with condensers connected on the power bars. By the inadequate usage of the batteries with condensers by users, it can get to the penalization of the consumer for the overcompensation and for the charging of the network with capacitive reactive power.

The overcompensation of reactive power situation is common to large consumers, with unequal consumption in the three phases, being needed, from the design phase, the provision of control for each phase of the battery with condensers.

The distorted regime phenomenon was also studied and examined, but compared with the phenomenon of circulation of reactive power is less known by the final users of electric energy.

In its certain literature, there are reviews on whether to limit the circulation of the deforming regime and on the circulation of the reactive power by using the compensation measures, thus the batteries with condensers and individual filters, from where it resulted the analysis on problems related to the correct harmonic distortion is done simultaneously with the one on the reactive power compensation, specifying that the final user is charged by the distributor only for the issue on the circulation of the reactive power (by not respecting the power factor), not for the pollution of the harmonic network.

Most important is knowing in detail the characteristics of network and user and the strategy of the distributor regarding the quality of the electric energy offered by the consumers connected to the analyzed network.

The analysis and the allocation of the emission levels harmful to individual users must be accompanied by real-time monitoring to track the disruptive consumers in order to analyze the values in the accepted limits stipulated in the electric energy contract.

It is important to specify that the analysis of harmonic distortion problems are corrected simultaneously with those related to the reactive power compensation.

2. THE CIRCULATION OF THE REACTIVE POWER AT A LARGE CONSUMER

Reactive power concept was originally defined for sinusoidal regimes and was attached to this, in the electric network, of the inductive and capacitive elements.

Although reactive power does not develop useful mechanical work, the transfer of reactive power in the electric network causes active losses. In this way there are searched solutions to reduce the circulation of the reactive power in the electric network, being defined the power factor and established the optimum values for this. [1]

However, in practical cases, not - following the reactive power consumption or improper setting of the monitoring of the power factor can lead to a phenomenon of overcompensation, due to the excess production of the capacitive reactive power of the batteries with condensers.

The analysis is based on a real case of a major consumer, where there were conducted theoretical and experimental studies to highlight the specific problems

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that arise in an industrial consumer, characterized by significant changes in active power consumption and therefore an important variation of the power factor.

In fig.1 there is a schematic diagram of the analyzed structure. The reactive power consumption is controlled by the battery with condensers, connected to low voltage suppliers.

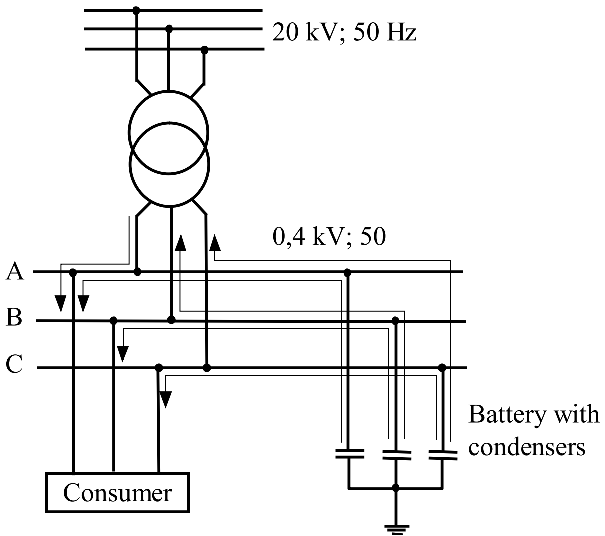

Fig. 1 – The circulation of the reactive power on the three phases of the analyzed consumer.

The experimental measurements performed on the output terminals of the MT/JT (fig. 2) transformer showed a significant unbalanced loading of the three phases and a poor operation of the reactive power compensation system (the battery with condensers has three phases, with three-phase connection). Thus, A Phase (fig. 2 a)) is charged, with important consume of reactive power. The battery with condensers is set according to the power factor, on A Phase, and ensures a proper functioning of the demanded factor, on this phase.

Phases B and C (Fig. 2 b) and Fig. 2 c)) have a reduced charge (both as active power and reactive power), so that the connection at the battery with condensers leads to the appearance, on these phase, of the phenomenon of overcompensation. In this way, in the network there is transmitted the capacitive reactive power and the consumer is charged for functioning in the capacitive system.

This situation of overcompensation of reactive power is common to large consumers, with consumption inequality in the three phases, being needed, from the design phase, the provision of control systems for each phase of the battery with condensers.

Currently, the consumption inequality in three phases and use of batteries with condensers, operated in three phases and reaching the control signal based on the information from one phase leads to the phenomenon of overcompensation.

The misuse of the battery with condensers leads to the penalty of the user even if the user has compensation installations for the reactive power, hence the fact that mere possession of the equipment of compensation of the reactive power is insufficient, so without their correct use, there is the risk to pay penalties for the neutral power factor deviation to the distribution operator.

From this perspective, the consumer is not entitled to benefit from the local production of the reactive power by reducing the active losses and lack of penalty for the reactive power.

The inadequate management of users connected to phases B and C with insufficient inductive consumers and lack of control on phase of the battery with condensers leads to the overcompensation of the reactive power, so the consumer is charged for entering into the distributor network for capacitive reactive power surplus.

There are basically two important situations encountered in the circulation of large consumers of reactive power:

- the situation when the user is charged for the inductive reactive power introduced in the network (in this situation the consumers don't have battery with condensers), by achieving a power factor less than the neutral one , ie below 0.92;
- the situation where the user has the equipment for the reactive power compensation, appearing here three different cases:
  - the situation where the user pays the capacitive reactive power due to overcompensation (fig. 2);
  - the situation where the user pays penalty for the inductive reactive power, but also for the capacitive reactive power if there is overcompensation;
  - the situation where the user is within the optimum values of the neutral power factor.

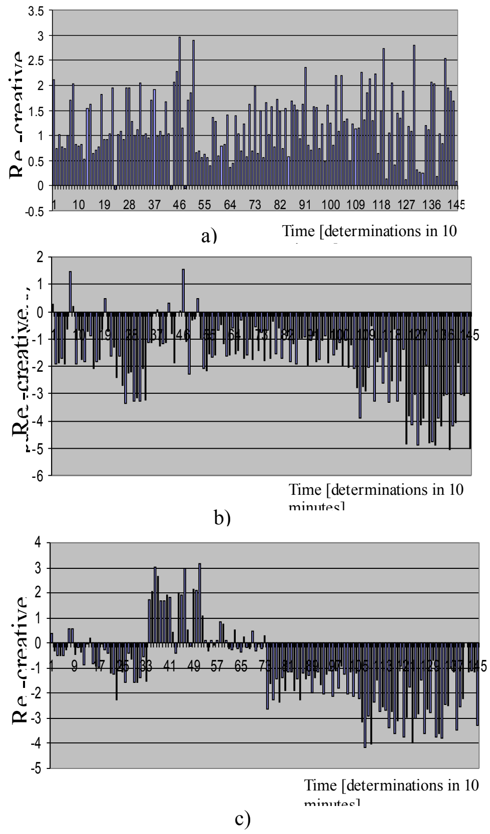

Fig. 2 – Reactive power on the three phases of transformer (low voltage part):

The reactive power circulation in the electric network has a significant influence on the level of tension in the power network nodes, available to consumers connected in the nodes, so that the electricity consumer through its receivers has a very important contribution of reactive power circulation.

3. THE INFLUENCE OF THE DEFORMABLE REGIME ON THE QUALITY OF THE ELECTRIC ENERGY. THE ALLOCATION OF THE DISTURBANCE LEVEL FOR THE GREAT CONSUMER.

Obtaining the quality level of electric energy at the bars of the consumers supply requires that the electricity distributors to monitor the quality indicators and to determine, for each consumer, the limit of disturbance that can generate, so that the disturbances caused by all consumers to be below the permissible limit in terms of electric energy quality (values determined by performance standards of the electric energy distributor).

Based on the admitted values for the level of disturbance in the supply bars, the electric energy distributor must allocate to each of its consumers a disturbance level, so that adding them can ensure the admitted values. [1]

Under the current standard the allocation of the level of disturbance is made in relation to the power contracted by each consumer connected to the same supply bar.

The classification of the consumers in the allocated quotas provides the premises to achieve a high quality standard in supply bars. Currently, the allocation calculations are made for disturbances in the form of harmonic distortion, for voltage fluctuations (flicker effect) and for fluctuations such as unballance.

The evaluation of the emission limits for harmonics disturbances form, determined by consumer comprising nonlinear receivers is done in three stages, dependent particularly from the disturbing source characteristics.

If a task does not meet the criteria in stage 1, there will be made the evaluation in the stage 2 for the specific characteristics of the harmonic producing equipment at the same time with the absorption capacity (auto - compensation) of the network. The allocated level of interference is inferred from the levels of planning and it is divided between users according to their power (individual) reported to the total available power network. Assigning the levels of individual industrial users in MT it is necessary to take into account the level of disturbance resulting from higher voltage networks. [2]

If a task does not meet any criteria in stage 2, stage 3 is to accept higher emission levels with exceptionally and temporarily title. (fig. 3). In the following there are considered the problems that appear in the stage 2 in the assessment of the consumers connected to MT network and the allocation of disturbance quota. To highlight the methods proposed in this technical note for the evaluation of the harmonic emission limits allocated in stage 2, it is considered an example for a MT network with a nominal voltage of 20 kV (fig. 4).

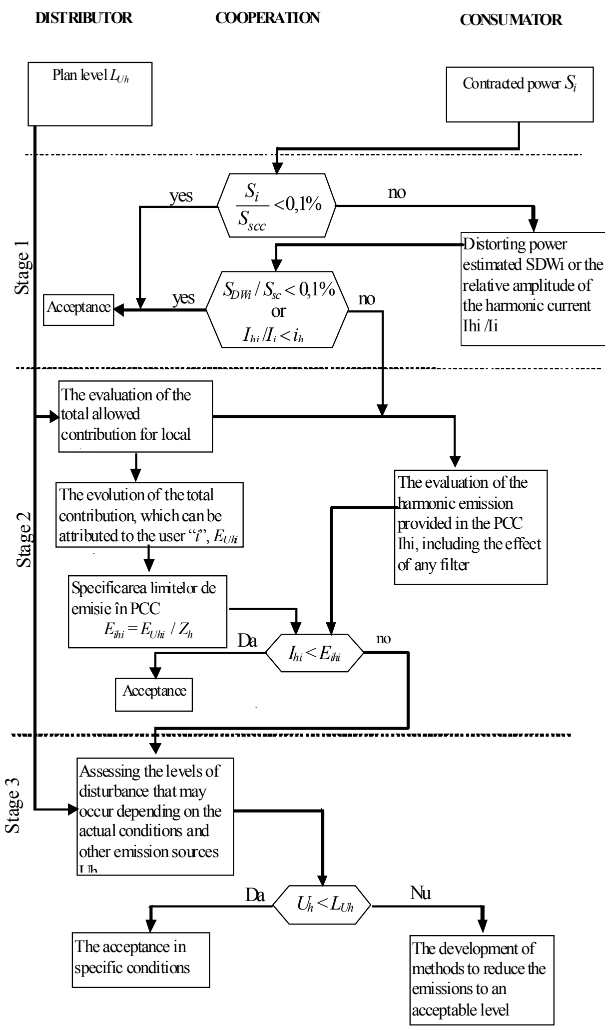

Fig. 3 Polluant emissions assessment algorithm

3.1 CASE STUDY ON THE ALLOCATION OF THE LEVEL OF PERTURBANCE CALCULATED FOR THE HARMONIC OF LEVEL 5.

The network includes six airlines with nominal voltage of 20 kV, supplied by a 110/20 kV transformer, with nominal power of 40 MVA, each line having the length of 5 km, 5 km, 7 km , 10 km, 15 km, 17 km (fig. 4) .

The apparent power of the transformers which are positioned on the average voltage is 500 kVA, 600 kVA, 800kVA, 1200kVA, 1600kVA, 500kVA.

Short circuit voltage u =15 % ; Ssc = 1900 kVA .

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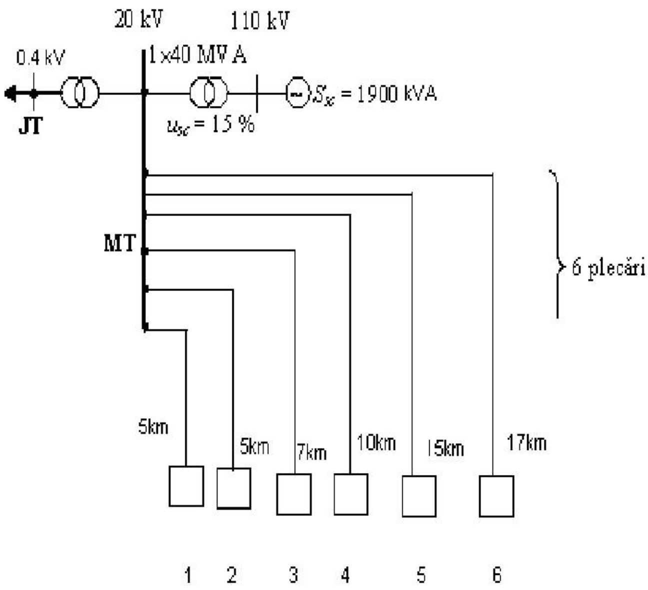

Fig 4. The distribution network with six lines and one task per each line.

For this configuration of fig. 4, we have achieved in MATLAB 7.1 programming environment, the program for allocation of the level of disturbance to six lines (on the level of medium voltage - 20 kV) with a load on each line.

This case it was analyzed and calculated the values for the most common harmonic allocated to consumers, the 5 level harmonic, at a medium voltage line.

Monitoring the consumers, harmonic disturbance source is made on the electric power curve.

The accepted limit for harmonic emission of voltage can be transformed into the harmonic power emission limit by dividing the harmonic impedance in PCC of each user [4]

$$E_{Ihi} = \frac{E_{Uhi}}{Z_h} \tag{1}$$

Commonly, the emission limit EIhi is indicated as a percentage of the corresponding load current contracted by the user *i*

$$E_{Ihi} = \frac{E_{Uhi}[\%] \cdot 1000 \cdot U_N^2}{Z_h \cdot S_i} \tag{2}$$

where U_N is the nominal voltage of the network, in kV, and the contracted power S_i is introduced in kVA.

In the Table 1 there were calculated (using the calculation program in Matlab 7.1) the individual emission limits for harmonic currents of level 5, in three cases (% - of the user load current Ii).

The calculations for each of the six nodes on each line, where there are disruptive tasks, lead to the data shown in Table 1.

The determination of the emission limits may be done in three different cases:

- in the first case there is considered directly the generally accepted level of disturbance as a harmonic of the MT network; the process can be applied especially for the 20 kV stations where that are radial connected individual consumers (consumers of low voltage are not connected via a transformer 20 / 0.4 kV and there are not connected lines that supply more consumers);
- in the second case, there is considered explicitly the presence of JT loads, the process can be applied in particular when the 20 kV bars are connected only by individual consumers and by a source for consumers of low voltage by using a transformer of 20/0,4 kV);
- in the third proposed case there are considered long MT networks (network with over 10 km long cables and / or airlines over 5 km inorder to take into consideration the possibility to limit excessive users connected to the end of the line; the procedure can generally be applied when the connection lines of 20 kV supply more consumers.

3.1.1 EMISSION LIMITS DETERMINATION USING THE SECOND METHOD OF APPROACH

In the second approach, for case 2, there is explicitly considered the contribution of harmful sources connected in the low voltage network, and the accepted global value $G_{h\ MT+JT}$ of the contributions determined by the disturbing sources from MT şi JT network, it considers the S_{MT} power connected in MT network, the S_{JT} power connected in JT network and coincidence factor F_{MJ} between the disturbing loads from MT and JT (generally F_{MJ} = 0,5) results from the relationship: [4]

$$G_{h\,MT} = \sqrt[\alpha]{\frac{S_{MT}}{S_{MT} + S_{JT} \cdot F_{MJ}}} \cdot \left[L_{h\,MT}^{\alpha} - (T_{h\,IM} \cdot L_{h\,IT})^{\alpha}\right] \tag{4}$$

For the analyzed example, if it is considered $L_{5\ IT}$ = 2 % şi $L_{5\ MT}$ = 5 % it results

$$G_{5\,MT} = \sqrt[1,4]{\frac{18}{18 + 26 \cdot 0,5}} \cdot \left[5^{1,4} - (1 \cdot 2)^{1,4}\right] = 2,7\% \tag{5}$$

where $L_{h\ MT}$ is the planned level of disturbance unde the harmonic form of h level, in the network MT, $L_{h\ IT}$ – planned level of disturbance unde the harmonic form of h level, in the network of IT, $T_{h\ IM}$ – transfer factor of disturbance in the form of harmonic of level h of the high-voltage network in medium voltage network (it can be considered $T_{h\,IM}$ = 1).

The assessment of individual limits of the loads connected to the MT is done according to the number of individual Si loads in total SMT load connected to the medium voltage network and to the simultaneity factor of the disturbing FMT source connected to the MT network

$$E_{UhiMT} = G_{hMT} \cdot \sqrt[\alpha]{\frac{S_i}{S_{MT} \cdot F_{MT}}} \qquad (6)$$

The values E_{UhiMT} largely depend on the FMT non-simultaneity factor, size that must be known for a specific network analysis.

To highlight the importance of the correct choice of this size, there are considered two extreme values F_{MT} = 0,4 şi F_{MT} = 1.

For the two values it results E_{UhiMT} = 0,4 % (for F_{MT} = 0,4) and E_{UhiMT} = 0,2 % (for F_{MT} = 1).

Consumer	*Harmonic*	*Disturbance allowence [A] Mod 1 E_{I5i}*	*Disturbance allowence level in percentage (%) Caz 1*
1	5	0.726	5.0199
2	5	0.8253	4.7651
3	5	0.8431	3.6506
4	5	0.8993	2.5961
5	5	0.8268	1.7900
6	5	0.3273	2.2676

Consumer	*Harmonic*	*Disturbance allowence[A] Mod II E_{I5i}*	*Disturbance allowence level in percentage(%) Caz II E_{I5i}*
1	5	1.3942	9.6594
2	5	1.5881	9.1691
3	5	1.6223	7.0246
4	5	1.7305	4.9955
5	5	1.5909	3.4445
6	5	0.6298	4.3635

Consumer	*Harmonic*	*Disturbance allowence [A] ModIII E_{I5i}*	*Disturbance allowence level in percentage (%) ModIII E_{I5i}*
1	5	2.9742	2.9210
2	5	2.9742	2.9210
3	5	2.9293	2.9210
4	5	2.8463	2.9210
5	5	2.7149	2.9210
6	5	2.6626	2.9210

CONCLUSIONS

The usage of batteries with condensers for reactive power compensation, in the electrical networks with uneven loading on the stage and affected by distortions of electric current shall consider the harmonic resonance phenomena occurrence and overcompensation.

The usage of batteries with condensers automatically controlled based on information from a single phase, in real power networks is not recommended.

One of the most effective ways to limit the disturbances in the form of harmonic is the allocation for disruptive consumers and then monitoring them to fit into the allocated limits.

REFERENCES

[1]. Golovanov N., Iordanescu I , et al. – Instalaţii electroenergetice şi elemente de audit industrial (Electro Energetic Installations and Industrial Audit Elements) – N'ERGO Publishing House, Bucharest, 2008.

[2]. Golovanov N, Postolache P, Toader C -Consumatori de energie electrica (Electric Energy Consumers). AGIR Publishing House, Bucharest, 2009.

[3]. *** Voltage characteristics of electricity supplied by public distribution systems, EN 50160/2009.

[4]. *** Electromagnetic compatibility (EMC) – Part 3: Limits – Section 6: Assessment of emission limits for distorting loads in MV and HV power systems – Basic EMC Publication – IEC 61000–3–6/2005.

[5]. Golovanov. N., Postolache P. , Toader C. – Eficienţă şi calitatea energiei electrice (Electric Energy Efficiency and Quality) - Agir Publishing House, Bucharest,2007.

[6]. Arie, A., Negus, C., Golovanov, C., Golovanov, N. – Poluarea cu armonici a sistemelor electroenergetice funcţionând în regim permanent simetric. Editura Academiei Române, Bucureşti, 1994.

[7]. Hafner, J. – On the reduction of harmonics in power systems – a new hybrid power filter approach, Berlin, 1999.

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