EFFECT OF HIGH HARMONICS ON COMPENSATION OF REACTIVE POWER IN ELECTRICAL NETWORKS

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Introduction:

As a result of the industrial development which took place in Syrian Arab Republic, the consumption of reactive power has increased remarkably after modern equipment and new plants have entered the network, of which are: inductive motors - electrical inductive furnaces – thyristor converters – modern lamps (fluorescent lamps – vacuum lamps – led lamps) electronic devices and many other sets.

Upon this, it has become urgently needful to generate reactive power required for the possibility of loading transport lines with more actual power, knowing that the sources of reactive generation are: stations of generating electrical power, transport lines, static and harmonic condensers. Form the economic point, generating reactive in the consumption places or near them so as not to carry reactive power in the lines, especially that high voltage Syrian lines are overloaded. Therefore, it is preferable to generate reactive power by means of condensers owing to their having high and credible economic and technical characteristics. And they do not act passively in stabilizing the network, but the haphazard and unconsidered selection of these condensers will form a great risk to the electrical equipment in the system for high tensions are formed, resulting form high harmonics, knowing that these tensions will increase in a greater form because of these condensers. These effects have begun to appear lately at the industrial plants in the form of the collapse of condenser, installed in factories, which generate reactive power.

We all know that the existence of non-linear loads (thyristor converters, and the haphazard usage of regulators, inverters and electronic devices: televisions, calculators and communication devices) lead to sinusoidal deformation of the current and tension wave which means the existence of harmonics that have not been taken into account.

Due to the presence of condensers, the possibility of and increase occurrence in tensions is always found if it couldn't be prevented at the proper time by means of connecting the suitable percolator. One of the harmonics disadvantages is also the heating of coils in the devices.

The programme of capacity flow has been depended on for finding the optimal solution to the required reactive power and the places of insulation it in the industrial plant whose power factor needs being raised to the required value which is economically and technically defined.

Next, the capacity of required condensers is defined according to this power, and as it is known, the capacity of condensers is calculated from the following relation:

$$C = \frac{Q_c}{U_n^2 \cdot 2\pi f} \cdot 10^3 \qquad (1)$$

Where:

Q_c : (kvar) reactive power required for raising the power factor

V : (volt) phase voltage (between phase and neutral) on both edges of the condenser

C : (farad) condenser power.

It gives inductivity and activity to the inductive motor by the following relations [5].

$$Xa = 0.2 \cdot \frac{U_n^2}{S_n} \quad ,$$
$$\mathrm{Ra} = 0.08 \cdot \frac{\mathrm{U}_\mathrm{n}^2}{S_n} \quad , \qquad (2)$$

As for the network also, inductivity and activity are given according to the following relation:

$$X_s = \frac{U_n^2}{S_k}$$
$$R_s = 0.1 \cdot X_s \qquad (3)$$

As for the loads, they are calculated as follows [5]

$$X_l = \frac{U_n^2 \cdot Q_0}{P_0^2 + Q_0^2}$$
$$R_l = \frac{U_n^2 \cdot P_0}{P_0^2 + Q_0^2} \qquad (4)$$

Where:

Q_0: (kvar): reactive power of the static load, kvar

P_0: (kw): actual power of static load, kw

Generators are represented by reactors over passing X_d'' (of suspensions calculation) and lines are represented by their impedances and transformers by their equivalent circuits[3].

After representation of the network elements completely, a programme has been put on the computer for calculating the equivalent impedance at the suspension point depending on the method of consecutive connection of the network elements[3] (this method depends on building the matrix of equivalent impedances of the network elements which face the inverted matrix of susceptance, but the method inverting the matrix of susceptances reserves a very considerable space in the memory of the computer).

Insufficient power of the system is calculated when the suspension (failure) is three phase with the ground, and it is the most dangerous failure. In this case the failure current[2] is calculated by the following relation:

$$I_{Ki} = \frac{U_{ni}}{Z_{ii}} \qquad (5)$$

U_{ni}: nominal voltage in the failure point

Z_{ii}: equivalent impedance in the failure point is calculated by the said method:

And failure power [6] is calculated by the following relation

$$S_k = \sqrt{3} \cdot U_{ni} \cdot I_{ki} \qquad (6)$$

After calculating the failure power S_k of the network and the nonlinear loads power S_{LOL}, we calculate the rate $\frac{S_k}{S_{LOL}}$

If the nonlinear load is but thyristory converters, then this rate should be greater than 200[5] and in the case of ordinary linear loads the rate should be greater than 100. If the above mentioned two conditions are met, then there is no need for studying the action or effect of connecting the condensers to the said network on the higher harmonics because the effect of this in this case will be weak. And if the above mentioned two conditions are not met, then it would be necessary to study and analyse the form of the withdrawn current wave in the nonlinear load and calculating the high value of graduations current and calculating the equivalent reactances of these harmonics. As it is known, when the network does not contain the capacity loads, these reactances increase form all sides with the harmonics grade according to the following relation:

$$X_k = K \cdot X_k \tag{7}$$

Where:
K : harmonic number
X_k : equivalent reactance of the harmonic.

Upon the harmonic current and the equivalent reactance of the harmonic, the harmonic tension is calculated according to the following relation:

$$U_k = X_k \cdot I_k \tag{8}$$

Then, the rate of harmonic voltage K is calculated with respect to the nominal voltage of the first harmonic[1] according to the following relation:

$$P_{ku} = \frac{U_k}{U_{1N}} \tag{9}$$

After calculating these rates (proportions) for the sake of all the studied harmonics[1] the sum of voltage is given by the following relation:

$$U = U_{1n} \cdot \sqrt{\sum_{k=1}^{F} P_{ku}^2} \tag{10}$$

Where: F : a greater harmonized number.

When the system contains a capacity load, the equivalent reactance increases in some harmonics as a result of connecting the equivalent reactance XC of the condensers to the system. And if the equivalent reactance of the system before connecting the condenser is Z_k then the equivalent reactance after connecting the condensers Z'_k.

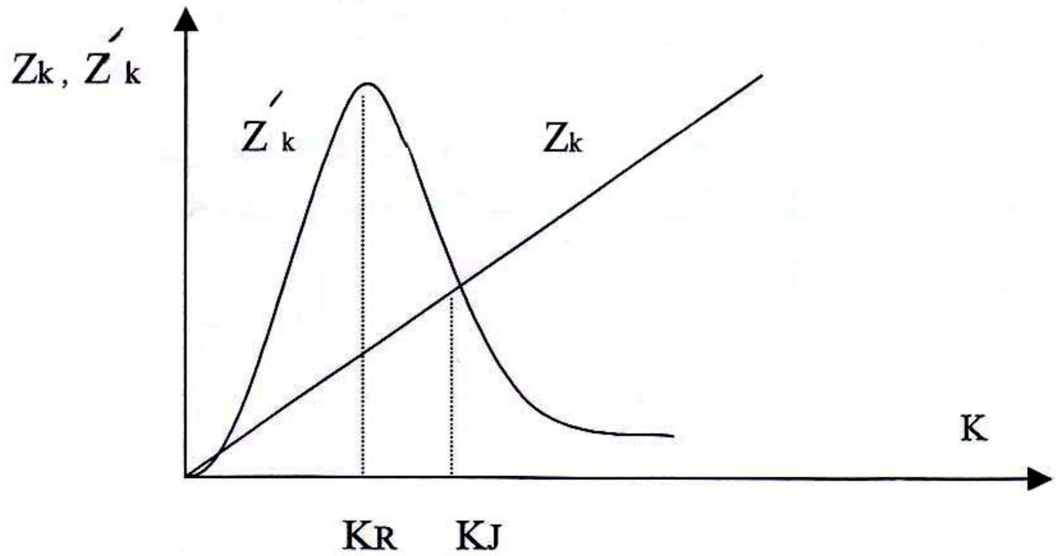

Fig. 1

Figure (1) illustrates the change of the impedance value by the indication of the harmonics value. We notice from the figure that the reactance increases considerably in the harmonic KR, and this leads to the increase of the harmonic voltage K and consequently to the increase of the voltage sum greatly where it forms a risk to the devices insulation and their collapse. Upon this, suitable percolators must be placed to absorb the adjacent harmonics from KR.

For the purpose of illustrating the practical possibility of this study, we have applied it to a given (specific) plant containing the following loads:

- inductive motors with power 2440 K.V.A
- Ohmic loads 775 K.W
- inductive loads 1000 K.VAR
- direct current loads fed by thyristory converters 2×1455 K.W
- nominal voltage of the plant 20 K.V
- connecting a set of condensers with power (knowing that condensers connection in this case may be risky) 2030 K.VAR

By applying the previous study of this plant and by making use of the two relations (5,6), we find that the short circuit power is: $SK = 91 \quad M.V.A$

At the beginning the following relation should be verified first:

$$\frac{S_k}{S_{LOL}} = \frac{91 \cdot 10^6}{2 \cdot 1455 \cdot 10^3} = 31.27$$

As this value is smaller than 200, therefore, we must study the effect of condensers connection of the increase of higher harmonics value and finding the harmonic in which is found the greatest voltage value, and upon this, the form of the current wave feeding the thyristory converter has been drawn by means of an advanced signal drawing instrument containing a memory for keeping the given quantities figure (2), and the shown curve illustrates the deformation of the sinusoid of the current wave feeding the thyristory. This deformation results from the accumulation of different harmonics.

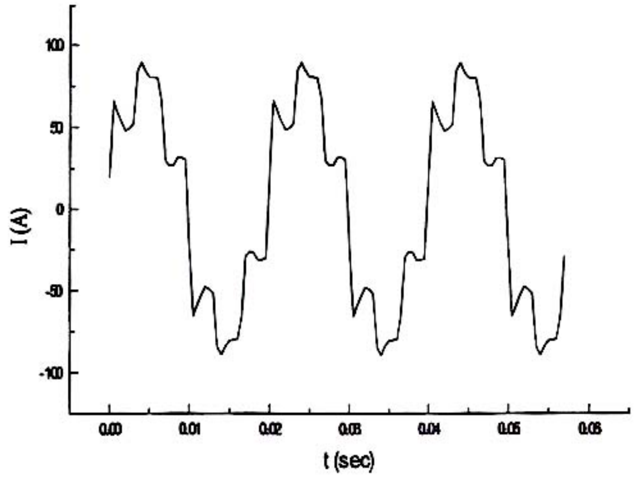

Fig. 2

By means of a computerized programme and depending n the principle of diffusing Vorieh's series, the previous wave shape has been analysed and then finding the current values of the following harmonics:

$$15 = 17.4 \ , \ 17 = 14.2 \ \text{A} \ , \ \text{I}11 = 4.8 \ \text{A} \ , \ \text{I}17 = 3.1 \ \text{A} \ ,$$
$$\text{I}19 = 2.5 \ \text{A} \ , \ 123 = 1.0 \ \text{A} \ , \ 125 = 0.7 \ \text{A}$$

And the equivalent impedance of the previous harmonics has been found in the two cases before and after connecting the condensers and the voltages values of these harmonics by making use of the relation (8), and the following table summarizes the results that have been reached.

Table 1

K	Z_k	U_k		Z'_k	U'_k	
		V	%		V	%
5	19.4	337.8	2.9	38.1	663.0	5.7
7	27.1	384.8	3.3	650.0	923.0	80
11	42.6	259.9	2.2	30.7	187.3	1.6
13	50.4	241.9	2.0	22.2	106.6	0.9
17	69.9	216.9	1.8	14.0	43.4	0.4
19	73.6	184.0	1.6	12.0	30.6	0.3
23	89.1	89.1	0.7	9.5	9.5	0.08
25	96.8	67.8	0.6	8.0	6.0	0.05

From the table we deduce that the seventh harmonic voltage on the loads terminals has risen from 384.8 V before connecting the condensers to 923 V after connecting the condensers. Thus the voltage sum on the loads terminals on the basis of the relation (10) by making use of the given quantities of table (1) before connecting the condensers, this voltage sum is:

$$U = 1.0 \cdot 20000 = 20000 \quad \text{V}$$

After connecting the condensers we find:

$$U = 1.28 \cdot 20000 = 25640 \quad \text{V}$$

And consequently, the rate of voltage rise after connecting the condensers is: 28%.

This constitutes a great risk for the mounted (installed) devices, and the condensers can't be connected in this case where the companies manufacturing condensers do not allow the rise of the voltage over (more than) 20% except for very limited minutes during the day.

Deduction:

1- Non-usage of condensers haphazardly, particularly in the factories with nonlinear loads.

2- Studying the harmonics in the network and defining the harmonic in which the phenomenon of voltage increase is formed on connecting the required condensers for raising the power factor.

3- Designing the percolator, required and suitable, for absorbing the dangerous harmonics which form on connecting these condensers.

4- Protection from momentary currents resulting from the condensers connection.

5- Designing the percolator (filter) required and suitable for absorbing the dangerous harmonics which exist (form) on connecting these condensers.

6- Protection from the momentary currents resulting from connecting condensers.

7- Application of industrial security on (when) installing condensers.

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SURFACE ROUGHNESS AT ABRASIVE JET MACHINING

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One of the characteristics of the surfaces obtained as result of applying a certain machining process is the surface roughness. Even nowadays there are many parameters used to define the surface roughness, on the mechanical drawings especially the surface roughness parameter Ra is inscribed. The size of the surface roughness can be modified by various machining methods; one of these machining methods is the surface abrasive jet machining, which is based on the effects generated at the contact of the abrasive particles transported and directed to the workpiece surface by means of a compressed air jet. The results of the applying the abrasive jet machining can be influenced by the machining conditions; the paper presents some experimental results obtained at the study of the influence exerted by the average dimensions of the abrasive particles, by the distance between the nozzle and the flat surface of the test piece and by the angle of inclination between the abrasive jet and the flat surface of the test piece on the size of the surface roughness parameter Ra. The main conclusion was that for the considered experimental conditions, only the distance between the nozzle and the flat surface of the test piece exerts a significant influence on the surface parameter Ra.