ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XVII, NR. 2, 2010, ISSN 1453 - 7397

Iuliu Petrica, Adrian Valentin Petrica

Air Compressor Driving with Synchronous Motors at Optimal Parameters

In this paper a method of optimal compensation of the reactive load by the synchronous motors, driving the air compressors, used in mining enterprises is presented, taking into account that in this case, the great majority of the equipment (compressors, pumps) are generally working a constant load.

Keywords: *air compressor, synchronous motor, reactive load*

1. Introduction

The air compressors with piston are working in the industrial enterprises, especially in the mining ones, due to the increase of the need of compressed air. Because the installed power of the air compressors is great in the comparison with the installed power of the enterprises, the problem of optimizing the electrical drive presents a great economical importance.

In the mining enterprises of our country, the piston air compressors are used almost exclusively, driven by synchronous motors of powers, usually, in the range of 100-700 kW.

These motors are fed from distribution stations to which are also connected other consumers, usually great power asynchronous motors, which take a significant quantity of reactive energy. The compensation of this reactive load can be made in advantageous conditions by using the air compressor driving synchronous motors, which, at present, work at a unitary power factor.

2. The method for determining the optimal reactive load distribution among the synchronous motors participating in the compensation

Generally, in a compressor station there are simultaneously working several types of compressors, driven by synchronous motors of different parameters.

The optimal compensation on a certain reactive load Q_c implies a rational repartition of this load among the "n" synchronous motors, participating in the compensation.

As an optimizing criterion, that repartition of the reactive load is established, which gives minimal supplementary active energy losses, P_s, dependent on the producing of reactive energy.

Because the producing of reactive energy by the synchronous motor implies it's over excitation, on establishing the reactive load distribution, the limitations of the stability in service of the motor and its heating must be taken into account.

The calculation method of the optimal distribution of reactive power has at its base the specific increase of the supplementary active power, when producing the reactive energy [2]:

$$\delta = \frac{dP_s}{dQ} \tag{1}$$

For synchronous motors, the supplementary losses, in the case of producing reactive energy, can be calculated with the relation:

$$P_s = Aq^2 + Bq \tag{2}$$

Where:

$$q = \frac{Q}{Q_N} \tag{3}$$

Taking into account the relation (2), for the specific increase of the active power, the expression obtained is:

$$\delta = \frac{2AQ}{Q_N} + \frac{B}{Q_N} = aQ + b \tag{4}$$

The specific active power increase δ depends linearly on the produced reactive power Q.

The calculations effectuated for a concrete situation show that for a large range of motor load variations, the specific increment of the active power maintains itself practically constant, being not dependent on the load of the motor.

It can be easily demonstrated that [2], in the case of reactive load compensation Q_c, with "n" synchronous motors, having the specific active power increments $\delta_i = a_i Q + b_i$, the minimal supplementary active power losses are obtained when the specific increments are the same, i.e.:

$$\delta_1 = \delta_2 = \ldots = \delta_i = \ldots = \delta_n \tag{5}$$

Consequently, taking into account the relations (5) and:

$$Q_1 + Q_2 + \ldots + Q_i + \ldots + Q_n = Q_c \tag{6}$$

The reactive load of each motor results from the relations:

$$Q_1 = \frac{Q_c - \left(\frac{b_1 - b_2}{a_2} + \frac{b_1 - b_3}{a_3} + \ldots + \frac{b_1 - b_n}{a_n} \right)}{1 + \frac{a_1}{a_2} + \frac{a_1}{a_3} + \ldots + \frac{a_1}{a_n}}$$

$$Q_2 = \frac{a_1 Q_1 + b_1 - b_2}{a_2} \tag{7}$$

$$Q_n = \frac{a_1 Q_1 + b_1 - b_n}{a_n}$$

In the situation when the connection of the motor to the bar system is made with a cable of significant length, then the losses in the cable must also be taken into account.

These active power losses are determined with the relation:

$$P_{sc} = \frac{Q^2 R_c}{U_N^2} \tag{8}$$

The specific increment of the active power is obtained from the relation:

$$\delta_c = \frac{2QR_c}{U_N^2} \tag{9}$$

Where R_c is the resistance of the feeding cable. The total specific increment of the active power results from summarizing the relations (4) and (9):

$$\delta_t = \frac{2AQ}{Q_N} + \frac{B}{Q_N} + \frac{2QR_c}{U_N^2} = cQ + b \tag{10}$$

Where:

$$c = 2\left(\frac{A}{Q_N^2} + \frac{R_c}{U_N^2} \right) \tag{11}$$

The relation (7) giving the optimal distribution of the reactive load remain valid in this case too, replacing the "a_i" coefficients by "c_i".

The application of this method in the case of compressor driving synchronous motors presents difficulties in the practice, because, in the majority of the studied cases, difficulties occur at the determination of the data necessary for the calculation.

In such situations the problem can be solved in an experimental way, by determining for each motor, the variation of the stator current I_a, the excitation power P_e and the reactive power Q, with dependency on the excitation current I_e (figure 1).

Because the motors are working at a constant load, there is no problem in obtaining the characteristics, these being determined at this load.

For the motors that have an exciter mounted on the shaft, the excitation power is calculated with the relation:

$$P_e = \frac{U_e I_e}{\eta} \tag{12}$$

Where η is the efficiency of the exciter. If the exciter is driven separately, the excitation power is measured at the input of the motor, driving the exciter.

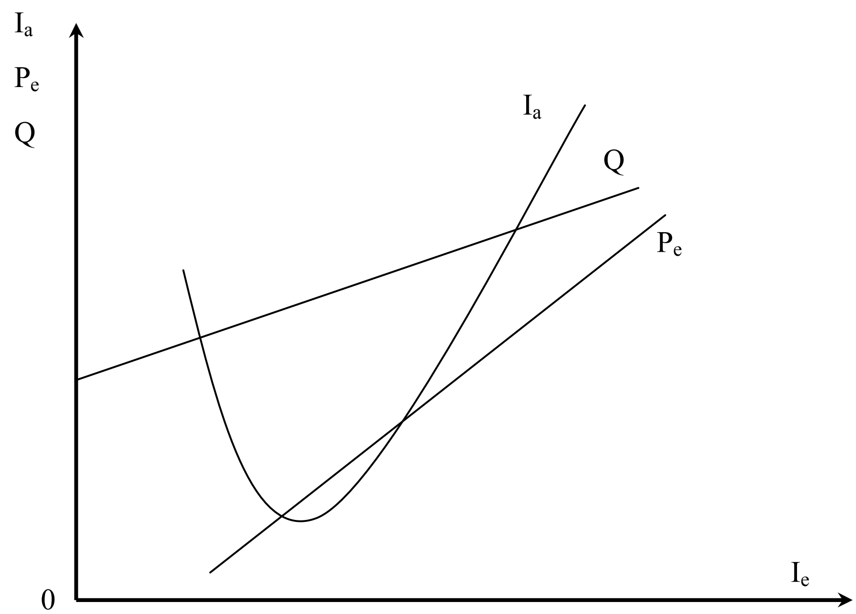

Figure 1. The I_a, P_e, $Q = f(I_e)$ characteristics of the synchronous motor

The specific power increments for each motor are:

$$\delta = \frac{P_a + P_e + P_c - P'_a - P'_e - P'_c}{Q} \tag{13}$$

Where P_a are the losses in the stator windings,

$$P_a = 3 I_a^2 R_a \tag{14}$$

P_c are the losses in the cable that connects the motor to the feeding bar

$$P_c = 3I_a^2 R_c \qquad (15)$$

And P'_a, P'_e, P'_c are the losses in the stator, excitation and cable, if the motor works at cosφ = 1.

For each motor then the δ = f(Q) characteristic is drawn, represented in figure 2. It is to notice, comparing relation (10) to the δ = f(Q) characteristic, that:

$$\delta = tg\psi = \frac{EF}{DF}, \quad b = OD \qquad (16)$$

With the relations (9) and (10), that part of the reactive load of each motor, from the total load Q_c, which is to be compensated, can easily be determined, and from figure 1, results the corresponding excitation current.

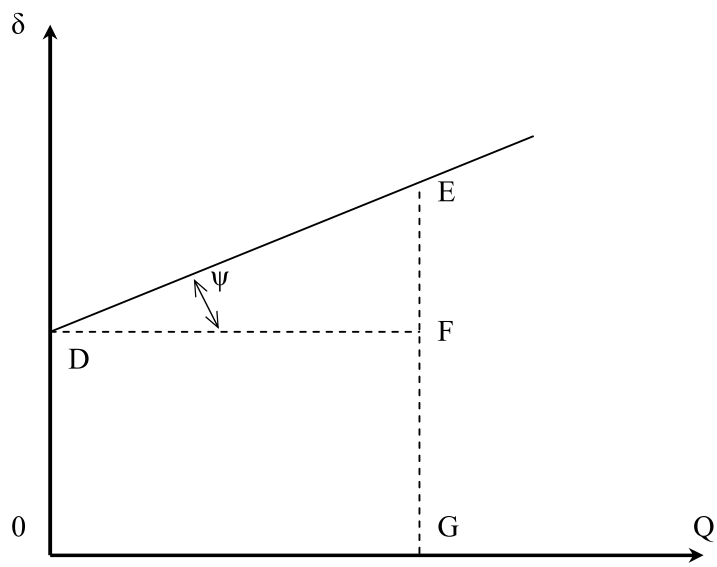

Figure 2. The δ = f(Q) characteristic of the synchronous motor

3. Conclusions

The compensation of the reactive load in the stations to which compressors driving synchronous motors are connected is an entirely justified solution, because of its favorable economical effects.

The presented experimental method is simple, easy to apply and without supplementary investments, on condition that synchronous motors permit excitation overload without exceeding admissible heat.

References

[1] Zărnescu, H., *Utilizarea motorului sincron în acţionări electrice,* Ed. Tehnică, Bucureşti, 1967.
[2] Syromiatnikov, I.A., *Sinchronnije dvigateli,* Gosenergoizdat, Moscow – Leningrad, 1959.

Addresses:

- Prof. Dr. Eng. Iuliu Petrica, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, i.petrica@uem.ro
- Lecturer Dr. Eng. Adrian Petrica, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, a.petrica@uem.ro