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Economic and Exploitation Aspects of Reactive Power Compensation Consumed by Laboratory Roller Mixer

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Abstract

Results of measurements of selected electrical parameters in supply system of laboratory roller mixer (IODi AGH type) during its operation are presented. Basing on the analysis of measured electric parameters and energy consumption the compensation capacitors system was chosen. The effect of improving the power factor cosφ (and also tgφ) has achieved. After capacitors installation in supply system of the mixer drive the measurements of electric parameters and analysis of harmonic of voltage and current were realised. The results were compared with the limit values from electromagnetic compatibility (EMC) standard PN-EN61000-3-2. The economic and operational effects of reactive power compensation in supply system of the mixer have been highlighted.

Keywords: Laboratory roller mixer operation, Reactive power compensation, Eeconomic analysis of compensation

1. Introduction

Laboratory roller mixer is a foundry device used for various kind of moulding sand preparing. Then the moulding sand is usually used for making some samples for evaluating of technological properties of moulding sand.

The scheme of mixer is presented in Fig. 1. As a drive of the mixer the three-phase induction motor is used. The active power of the motor is 1 kW. The measurement of instantaneous values of phase voltages and currents in supply system has been realised with using a special registration system. The operation of this systems has been described in detail in publication [1, 2]. The measurements results are elaborated using special calculation algorithm. It allows determination such parameters as RMS values of phase voltage and currents, RMS values of active, reactive and apparent power as well as power factor – cosφ and tgφ. Additionally the harmonic analysis of voltages and currents has been done.

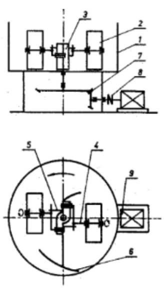

Fig. 1. Scheme of IODi AGH roller mixer (Simpson type): 1 - mixer pan, 2 - roller, 3 - head, 4 - the axes of rollers mounted on the rockers, 5 - supports for establishing the heights of the rollers suspension, 6 - paddle, 7 - gear, 8 - clutch, 9 - electric drive

2. Measurements and registration results of selected energy parameters

In Fig. 2 the view of window of registration system service program with instantaneous values of phase voltages and currents in chosen time period of stable operation of the roller mixer has been shown.

Fig. 3 presents diagrams of time runs of active, reactive and apparent power as well as cosφ and tgφ values calculated on the base of measured instantaneous values of voltages and currents.

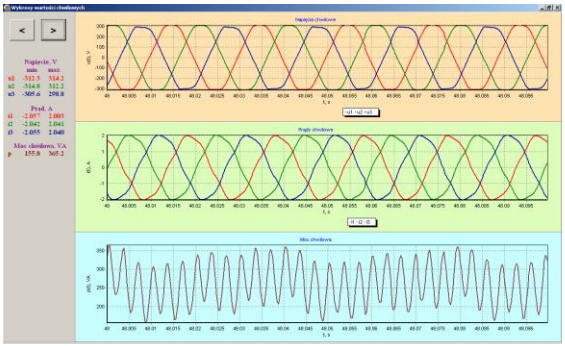

Fig. 2. View of window of registration program with time run of instantaneous values of voltages (u), currents (i) and power (p) for stable operation of investigated mixer

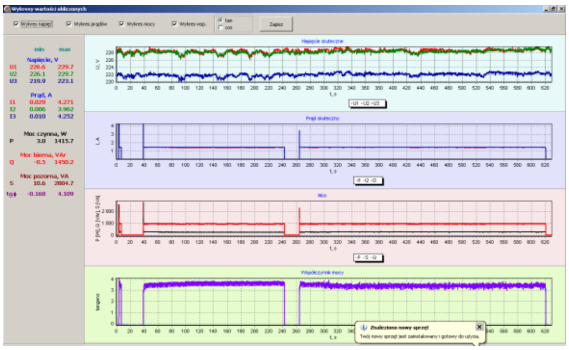

Fig. 3. Graphs of calculated effective values of voltages (U) and currents (I) as well as individual power components (P,Q,S) and factor tgφ

Analysis of the data from graphs (Fig. 3) leads to conclusion that the value of reactive power consumption by the mixer drive is significant. The value of tgφ is in range of 3.0-3.8 which corresponds to the value of power factor cosφ in range 0.25-0.3. Such values of these coefficients differ significantly from the limit values (tgφ=0.0÷0.4 and corresponding values of cosφ=0.93÷1.00) specified in the agreements or tariffs of electricity distributors (e.g. [8]).

Oversized reactive power consumption (in this case the induction power) is connected with additional fee defined by the formula [8]:

$$O_b = k \cdot C_{rk} \cdot \left(\sqrt{\frac{1 + tg^2\varphi}{1 + tg^2\varphi_0}} - 1 \right) \cdot A \qquad (1)$$

where:

O_b - charge of excess reactive power, expressed in PLN,

k - conversion factor, it equals:

- 0,50 for consumers connected to the highest voltage distribution networks (110 kV),
- 1,00 for consumers connected to the medium voltage distribution networks (15 kV), 3,00 for consumers connected to the low- voltage distribution networks;

C_{rk} - the price of electricity, expressed in PLN/MWh or PLN/kWh,

$tg\varphi$ - coefficient connected with reactive power consumption,

$tg\varphi_0$ - contractual coefficient, typically equal 0.4,

A - 24-hour consumed active energy or for time zone with control reactive power consumption, MWh or kWh.

For mean value of tgφ=3.5 which is representative for steady operation of tested mixer (under assumption that consumer is connected to low voltage network) the above formula takes the form:

$$O_b = 3 \cdot C_{rk} \cdot \left(\sqrt{\frac{1 + 3{,}5^2}{1 + 0{,}4^2}} - 1 \right) \cdot A \approx 9{,}14 \cdot C_{rk} \cdot A \qquad (2)$$

In compensated supply system for tgφ from range 0.0-0.4 the additional fee O_b=0. In the case of tested mixer operation the additional fee increases 9 times variable component of charge of electricity consumption. Obviously the total cost of electricity consumption still depends on values of fixed and variable rate for distribution and constant rate of sales and other factors identified in the tariffs of the distribution and sale of electricity.

In order to lower the factor tgφ in the supply system of the mixer the compensate capacitors were chosen and the series of measurements and calculations were performed analogous to the case without compensation system. In Fig. 4 some measurements of instantaneous values of voltages, currents and power for the stable operation time period of roller mixer with compensation system are presented. Fig. 5 shows the changes of effective (RMS) values of voltages, currents and power components as well as the factor tgφ.

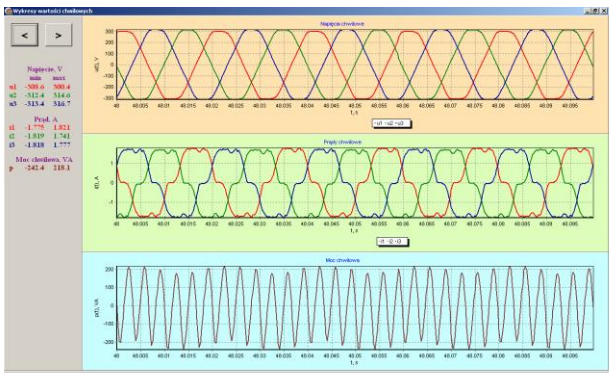

Fig. 4. Graphs of instantaneous values of voltages, currents and power for the stable operation time period of roller mixer with compensation system

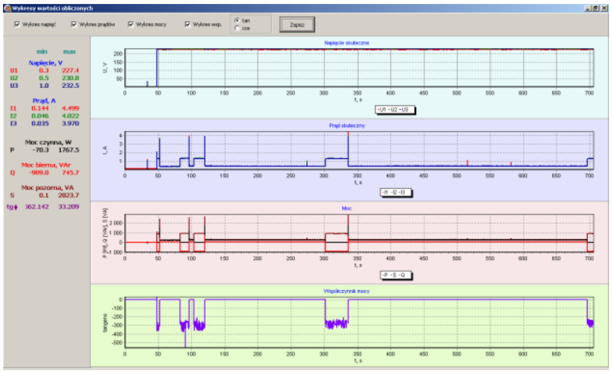

Fig. 5. Graphs of changes of effective values of voltages, currents, power and tgφ for the stable operation time period of roller mixer with compensation system

Value of tgφ for supply unit of mixer drive with compensation system is about 0.1 which corresponds to the power factor value cosφ 0.995. It means near "ideal" compensation without the need of payment for oversized reactive energy consumption.

3. Harmonic analysis of voltages and currents

The shape of currents from Fig. 4 is far from sinusoidal shape. In order to determine the level of current distortion the harmonic analysis of voltages and currents time run using FFT algorithm was performed. Such analysis was done for two cases without and with reactive power compensation system in supply unit of mixer drive. The results of calculation are presented in Fig. 6 for voltages and Fig.7 for currents. Calculated value of THD_u is 3.71% and it is not exceed the limit values 8% from standard PN-EN 50160 [5-7]. This applies to both supply system: with and without compensation.

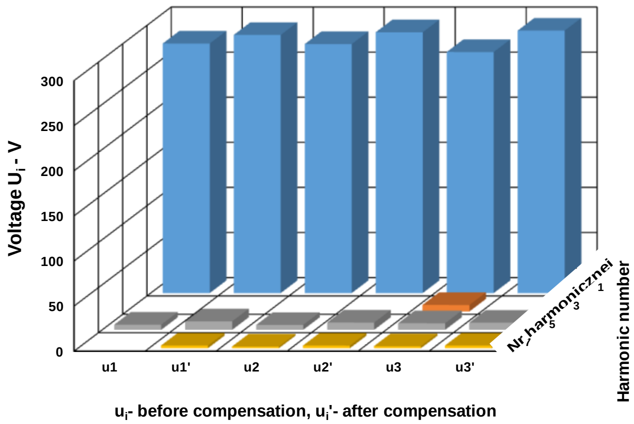

Fig. 6. Voltage harmonics in power supply of mixer drive before and after compensation

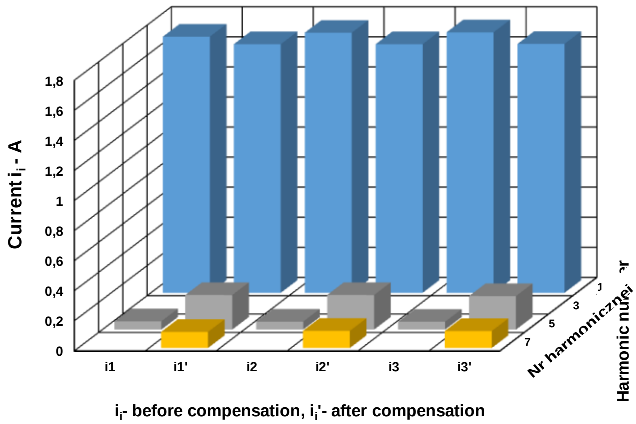

Fig. 7. Current harmonic in power supply of mixer drive before and after compensation

Analysis of current values (Fig. 7) shows that application of compensation system has led to fivefold increase of current of the 5^{th} harmonic and the presence of the 7^{th} harmonic is visible (it is not visible before compensation). Comparison of harmonic component of currents can be done with using the standard PN-EN 61000-3-2 [5]. This standard defines acceptable values of harmonic components of currents under assumption that maximum value of phase current is not exceed 16 A (in network of low and medium voltage). Due to this standard the tested mixer is A class receiver and acceptable value for: the 3^{th} harmonic is 2.3 A, the 5^{th} harmonic is 1.1 A and for the 7^{th} is 0.77 A [5]. This standards has also specifies the limit values of other odd and even harmonics from the second one to the 40^{th} harmonic. Direct comparison of harmonic values (Fig. 7) with normed limit values leads to the conclusion that the harmonic amplitudes in the compensated supply system of mixer drive is acceptable. It means that there is no need of application of expensive filtration system for higher harmonics in compensation system.

4. The exploitation importance of introduction of reactive power compensation

The using of capacitors banks for power factor correction in presented example shows that in the greater scale of above described solution the positive economic effect can be achieved. It should also draw attention to the exploitation benefits such as reduced values of currents or decreasing of voltage drops in the supply lines. These basic benefits have improved the quality of supply network operation i.e. parameters of voltage in industrial plant where the compensation system of reactive power were introduced.

In modern production lines with control systems it is an important advantage. Because such control systems need the stable and exactly specified parameters of supply voltage. The use of reactive power compensation using the capacitor banks requires further analysis of the parameters of capacitors operation in the existing industrial conditions.

The example of necessity of such approach is presented harmonic analysis of currents. A wider review of this problematics can be found in [7].

5. Summing up

Machines and devices with electric drive used in foundry industry very often have not got a compensation system of reactive power. Such an example is the roller mixer described above. For this machine the value of power factor cosφ is in the range 0.25–0.35. So low value of power factor has economic importance, because induces the additional fee for electricity. It has also negative exploitation aspect due to induction character of load of the supply network and next deterioration of quality of supplied electric energy.

The proper choice of compensation capacitors banks allows to obtain such value of power factor cosφ (for the purposes of settlement of accounts tgφ) for which there is no additional fee. At the same time the carried out harmonic analysis of voltages and currents in compensated supply system of mixer drive has proved that there is no need of introduction of additional filtration system for higher harmonic components. In the case of operation of this mixer it is possible decreasing of electricity charge with relatively small investment costs (costs of several capacitors). The quality of electric energy in local network practically will not be impaired.

Acknowledgments

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