Application of a power quality analyser to the monitoring of sand preparation processes in foundry plants

K. Smyksy*, R. Wrona, E. Ziółkowski
AGH University of Science and Technology, Faculty of Foundry Engineering, ul. Reymonta 23, 30-059 Krakow, Poland
*Corresponding author. E-mail address: ksmyksy@agh.edu.pl

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Abstract

Process control plays a major role in supervision and identification of states, for example in monitoring of electric circuits power-supplying the foundry machines and devices, such as sand preparation processes, moulding technologies, melting, cleaning and finishing of castings. The monitoring and control equipment includes the power quality analysers. Testing is done using a Japanese analyser KEW 6319 (Kyoritsu) applied to monitoring of the sand preparation process in a foundry plant with low level of mechanization, equipped with the sand preparation unit based on a roller mixer.

Keywords: Power quality, Process control, Sand preparation

1. Introduction

A method of process monitoring and control realised using specialised devices operated via the mains involves the measurements of voltage and current intensity in particular phases, of active, reactive and apparent power demand or the energy consumption. These measurements can be taken with conventional meters and recording devices, both analogue and digital, and with the use of dedicated computer systems [4, 5, 7]. An example of a computer-assisted system is that for recording instantaneous voltage and current levels, used in monitoring of electric machines in foundry engineering, whose operating principles and applications are outlined elsewhere [6, 8]. The system has been developed by the Authors of this paper. Among mobile analysers, the power quality analyser KEW 6310 (Kyoritsu) is well applicable to power measurements. In order to evaluate its adequacy to process control, the authors analyse the sand preparation processes in a small foundry plant with low level of mechanisation, equipped with a sand preparation unit AG-015 based on a roller mixer.

2. Characteristic of a power analyser KEW6310

The power analyser KEW6310 (Kyoritsu) can be used as a recorder of electric parameters in single and three phase systems and in 2-3- or 4-lead installations. The analyser incorporates a circuit that enables the measurements and recording of the following parameters [2, 3]:
- voltage and current intensity in every phase and in the zero lead (RMS value),
- active, reactive and apparent power and the power factor ($\cos\phi$),
active, reactive and apparent power energy,
- phaseangle and frequency,
- harmonic components of voltage and current intensity,
- sudden voltage rise or drops, voltage decay, transients over voltage, inrush current, asymmetry of power-supply.

Available features include flicker measurements and calculations of power demand and capacity of condensers compensating for the uptake of reactive power in induction machines.

Measurements of active, reactive and apparent power energy are available in the time intervals: 1,2,5,10, 15, 20, 30 s and 1,2, 5,10, 15, 20, 30 min.

3. Monitoring the operation of the sand preparation unit AG015

The adequacy of the power analyser is tested on the industrial test run. Utmost care is taken to observe the rules applicable to the power-supply installation. The manufacturing process involves the preparation of sand mix with bentonite in the unit AG015. Major parameters of the sand mix with the moisture content W=5.6% include: compressive strength $R_c=0.095$ MPa, permeability $P_{w}=170 \cdot 10^{-8}$ m$^2$/Pa·s, compactability level $Z=70\%$. Process control requirements include: the pan filling ratio (pan load) and variable moisture content, associated with the amount of added water. Current intensity is measured with clamp sensors 8152 with the measuring range 0-500 A (RMS value).

The mixing process is sequential, involving the following stages: switching on- empty run, operation stage I- sand mix filling and adding water, operation stage II and adding water, so the measurements are taken in the function of process time. Variations of the process parameters are shown in plots of registered voltage and current levels (Fig. 3, 4) in the circuits supplying the mixing unit.

Plots reveal voltage fluctuations and over voltage in particular moments of the sand mixing process. Variations of the active, reactive and apparent power energy at particular stages of the sand mixing process in the mixing unit AG015 are shown in Fig. 5, revealing major oscillations of RMS values in each phase of the mixer’s duty cycle. These oscillations can be attributable to variable loading experienced during one revolution of the mixing unit. One full rotation lasts for about 1.7 s whilst the parameters are recorded every 1 s. During the idle run, the deviations of measurement data from the mean active power 1878 W seem the smallest (standard deviation: 469 W).
It is reasonable to suppose that these oscillations are associated with the state of repair of the driving unit, after a long service life. When the mixer is loaded, deviations from the mean active power value (6061W) tend to increase (standard deviation: 634 W). Apart from increasing the loading acting on the mixer’s drive, the increased deviation levels are probably associated with variable loading of mixer elements per one rotation due to the presence of sand mix. This variability of load experienced within the duty cycle is explained in more detail in the publication [1]. In the subsequent stage measurements are taken of active power uptake by motor in the mixing unit (the roller system) and by the motor in the vertical skip hoist system. Variable parameters influencing the power demand include: the amount of added water and the amount of sand mix in the pan.

Variations of power energy in relation to the amount of dosed water (in the first stage) are shown in Fig. 6. Power measurements are taken in time intervals of 1s.

To better highlight the nature of these variations, the mean values are calculated for the neighbouring measurement points. The scatter of measurement data (explained previously) is smaller around the trend line (the moving average). Variations of the power uptake associated with variations of moisture content in the sand mix follow a different pattern than those registered for rotary and paddle mixers [8, 10], which can be attributable to constructional differences of those machines and the diversity of interactions between the mixer components and the sand mix. Further research and tests in steady state conditions are merited to fully identify all the involved phenomena.

It appears that feeding 3 dm$^3$ of water to the sand mix thus increasing its moisture content by 2% causes the active power uptake to increase by about 800 W (up to the maximal level). Variations of the pan load also lead to increase of the active power uptake (Fig. 7). When a batch I of sand mix (70 kg) is loaded, the average power uptake goes up by 2785 W, when the load is increased (from 70 to 140 kg), the mean active power uptake goes up by 1387 W. Smaller variations of power uptake in the second stage of the process can be explained by the fact that increasing the thickness of the sand mix layer has little effect on roller’s resistance force. Plots in Fig. 7 are graphed using the same procedure as that applied when plotting those in Fig. 6. Furthermore, two maximal values are removed from the set of data: those associated with the peaks revealed in Fig. 5.
4. Conclusions

Power quality analysers are excellent tools for monitoring and control of electric-powered machines used in foundry plants. Measurement and analysis of variations of selected power control parameters (current intensity, active or apparent power demand, voltage fluctuations, or distortions of voltage and current waveform in the selected phase) give us a good insight into the phenomena involved in the manufacturing process.

Applications of power quality analysers used in system monitoring and control are limited by the fact that power measurements are taken exclusively on the supply leads, ahead of the inverter. A recorder of instantaneous voltage and current levels, mentioned previously, does not share this disadvantage. Measurements of instantaneous current and voltage enable a more accurate analysis of complex phenomena occurring during the sand preparation processes in various types of mixers and other devices with electric drive.

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References