XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6−11, 2009, Lisbon, Portugal

POWER QUALITY MEASUREMENT ANALYSIS OF THE ELECTROSTATIC PRECIPITATOR

Aleksandar Nikolic [1], Ilija Stevanovic [2]

[1] Electrical engineering Institute "Nikola Tesla", Belgrade, Serbia, anikolic@ieent.org
[2] Electrical engineering Institute "Nikola Tesla", Belgrade, Serbia, istevan@ieent.org

Abstract − Power quality measurement analysis of the electrostatic precipitator in thermal power plant under different working conditions is presented in the paper. Control of electrostatic precipitator is realized by digitally controlled antiparallel thyristors. In the first regime (continual) the constant firing angle of thyristor is set in dependence of the reference current. In other regime (intermittent) the ON/OFF period is set. For both control strategies the measurement of the content of higher harmonic of voltage and current is performed. Analysis of the measured results is done according to the methodology based on EU power quality standard EN 50160. The plant under investigation is electrostatic precipitator in the largest thermal power plant "Nikola Tesla A" in Serbia, but the obtained results could be used for any similar power plant.

Keywords: PQ measurements, electrostatic precipitator

1. INTRODUCTION

The combustion of coal for power generation produces fly ash, which must be collected prior to discharge to the atmosphere. Electrostatic precipitators are devices used for collecting of fly ash from smoke gases in power plants that uses coil as a combustion fuel. The precipitator collection efficiency can be expected to exceed 99.5%. Typical plants where electrostatic precipitators are applied are thermal power plants, power station boilers, cement industry, metal industry, etc.

Most existing electrical precipitators are developed with classical continual power supply that provides DC voltage at the end of electrodes. Improvement of this power supply type, that has better purification and overall energy efficiency is obtained by usage of intermittent supply [1].

In this paper the influence of electrostatic precipitator to the power supply is analyzed. Measurements are performed in order to find high-order harmonics (both current and voltage), total harmonic distortion (THD) and power factor. Analysis uses measurement results obtained for two different working conditions of electrical precipitator (intermittent and continual) achieved by different settings of digital control system [2].

Power and control devices of electrostatic precipitator under analysis are developed with semiconductor converter running at 50 Hz. Monophase power supply 380V, 50Hz is connected over disconnector with fuses or compact switch to the antiparalel thyristor combination with phase control. Fig. 1 shows principle connection of the precipitator control system, where Automatic voltage controller is based on the powerful DSP processor.

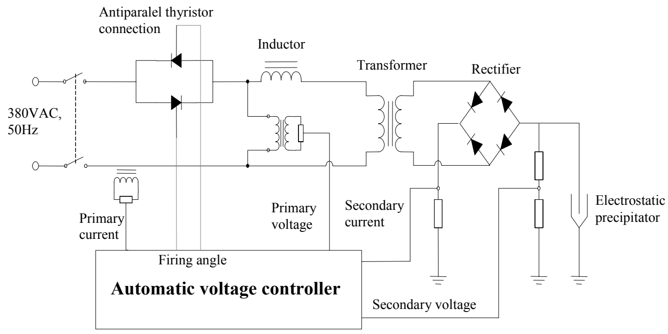

Fig. 1. Block scheme of electrical precipitator control system.

2. MEASUREMENT SYSTEM

Measurement instrument used for measuring of electrical quantities (voltages and currents) and calculation of other quantities (powers, power factor, total harmonic distortion factors, high-order harmonics) according to the standards is power quality analyzer [4]. Instrument employed in this work is power quality analyzer Chauvin Arnoux CA8334 with flexible current sensors for current measuring up to 3000A [5]. The A/D converter resolution is 12-bit, while sampling frequency is 12.8kHz (256 samples at 20ms under 50Hz supply).

2.1 System calibration

To evaluate expected results taken from the field, measurement system was tested in Laboratory with pure sinewave under the same sampling. Calibrating device was RFL model 829M traceable to National standards of Serbia, Certificate No. 1271/16 dated 07.06.2007. Device accuracy of harmonic distortion + RMS noise is 0.1% at 50Hz. Voltage is set to 230V, 50Hz.

For comparison, digital power multimeter is used with 0.1% resolution of reading from 3-650AC Volts at 0°-50°C and frequency accuracy of ±0,03Hz. This instrument is reference standard produced by "AVO International", type PMM-1, No. 0305050001 traceable to National standards of Serbia, Certificate No. 3187 dated 18.04.2007.

Measured voltage and THD at reference instrument was 229,83V and 0,01% respectively, while on instrument C.A8334 used for further measurements voltage was 229,8V and THD was 0,0%. In Table 1 high-order odd harmonics up to 25th as per standard EN50160 are given.

Table 1. Measured high-order voltage harmonics on refererence (PMM1) and tested (CA8334) instrument.

Voltage harmonic order	Reference instrument PMM1	Checked instrument CA8334
3	0.09%	0.0%
5	0.04%	0.0%
7	0.02%	0.0%
9	0.02%	0.0%
11	0.00%	0.0%
13	0.00%	0.0%
15	0.00%	0.0%
17	0.00%	0.0%
19	0.00%	0.0%
21	0.00%	0.0%
23	0.00%	0.0%
25	0.00%	0.0%

Other measured data on system under test (PQ analyzer C.A 8334) are given in Table 2.

Table 2. Measured data on PQ analyzer under pure sinewave at 50Hz.

Maximal voltage [V]	242.3
Average voltage [V]	229.8
Minimal voltage [V]	0.0
Peak voltage + [V]	324.6
Peak voltage - [V]	325.3
RMS voltage [V]	229.8
DC voltage [V]	-0.4
THD [%]	0.0
Crest factor (CF)	1.41

2.2 Measurement system configuration

Analyzer is connected in the electrical precipitator plant directly on copper bus bars, behind main power switch in control room, in order to measure overall electrical consumption and analysis of the precipitator influence to the supply network, as shown in Fig. 2.

Fig. 2. Connection of current sensors in the field.

3. RESULTS OF ANALYSIS

Measurements are lasting one hour per working condition (intermittent and continual) and repeated two times for both conditions. The number of measurement points during voltage and current measurement is 256 in the period of 20ms and adjusted interval of results saving to memory is 5s. Fig. 3 and 4 presents electrical precipitator voltage waveform in continual and intermittent working condition, respectively. In both cases voltage spikes due to the thyristor commutation could be observed.

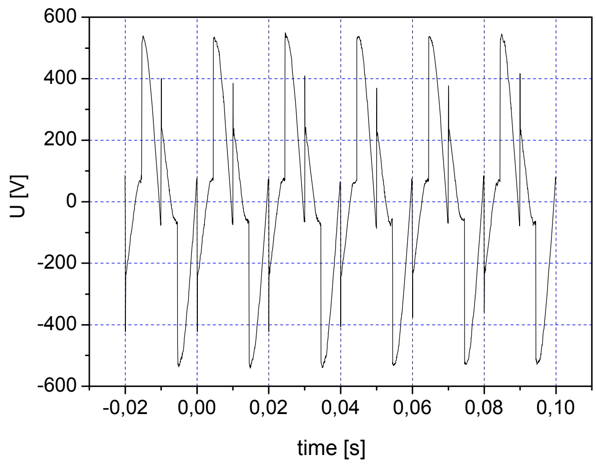

Fig. 3. Precipitator voltage waveform during continual regime.

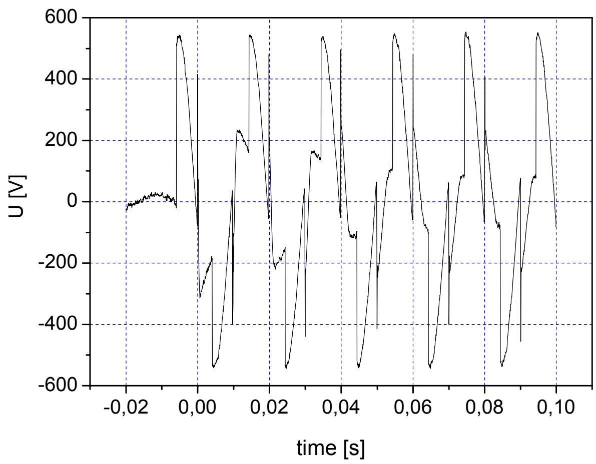

Fig. 4. Precipitator voltage waveform during intermittent regime.

In Fig. 5 periods when current is zero could be observed. This is effect of load characteristic and current control. Fig. 6 represent current time diagram while precipitator is in intermittent regime. Besides noticeable short intervals while current goes to zero in every period, after certain number of periods with common current waveform, a much longer periods of 60ms when current is zero appears. This is due to the nature of supply and applied control algorithm.

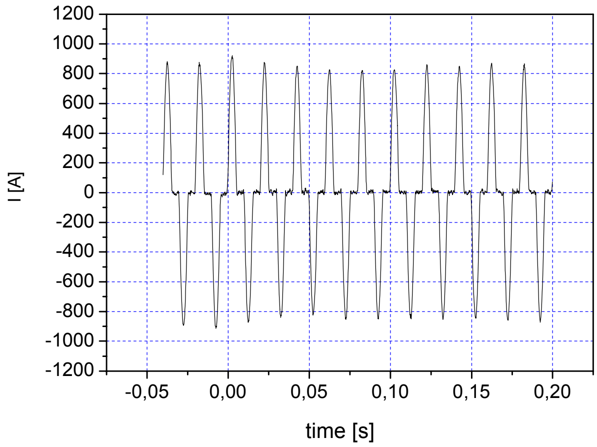

Fig. 5. Current waveform of one precipitator section during continual regime.

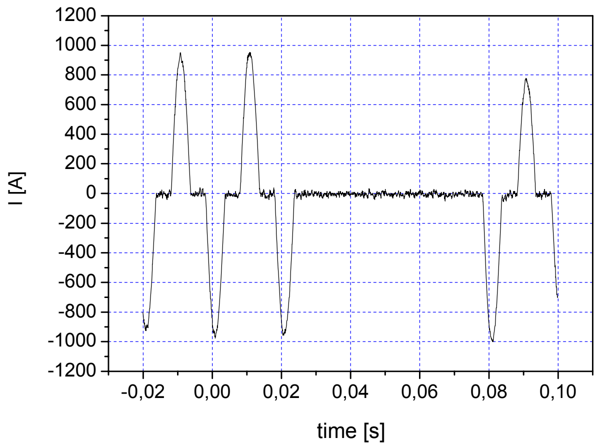

Fig. 6. Current waveform of one precipitator section during intermittent regime.

Further analysis comprises values of current total harmonic distortion THD_I during intermittent and continual control (Fig. 7 and 8 respectively). The similar analysis is performed for voltage total harmonic distortion THD_U (Fig. 9 and 10 respectively). Results for both control regimes are taken under the same working condition of power plant.

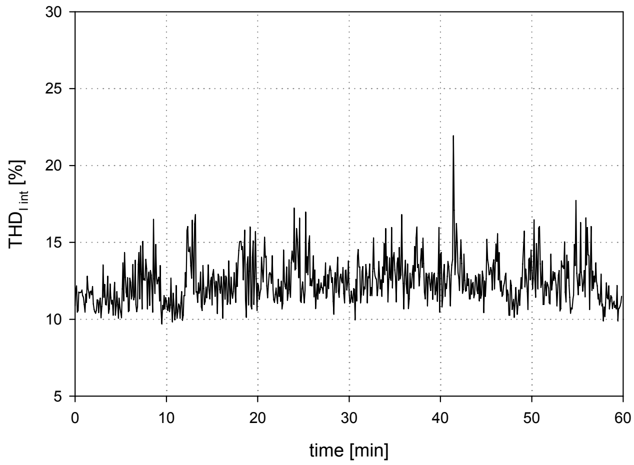

Fig. 7. Current THD factor of the electrostatic precipitator during intermittent regime.

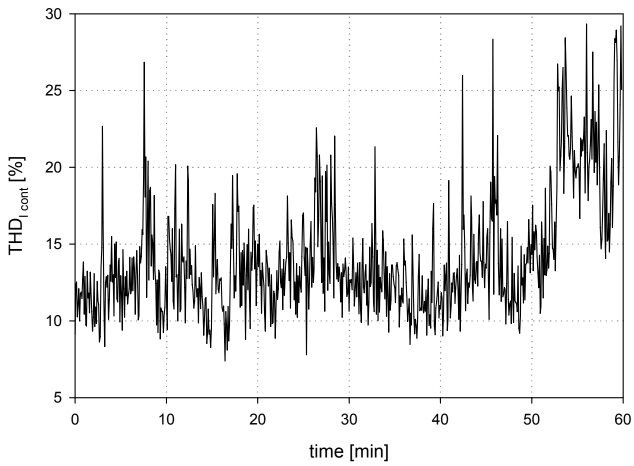

Fig. 8. Current THD factor of the electrostatic precipitator during continual regime.

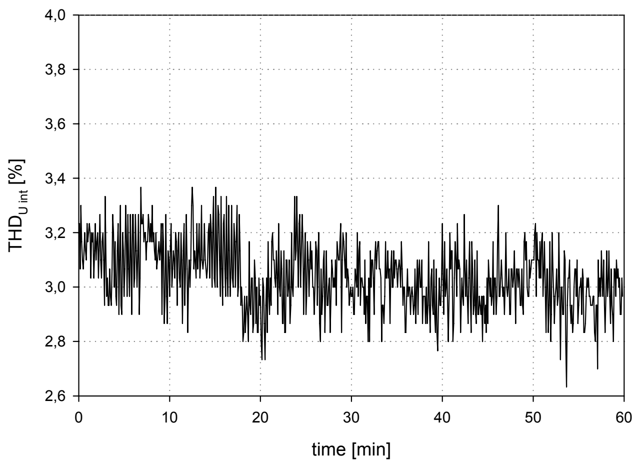

Fig. 9. Voltage THD factor of the electrostatic precipitator during intermittent regime.

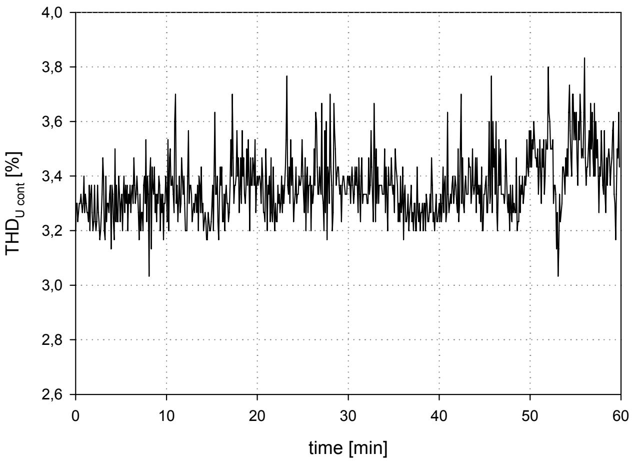

Fig. 10. Voltage THD factor of the electrostatic precipitator during continual regime.

Fig. 11 gives comparison of current high-order harmonics up to 25th order.

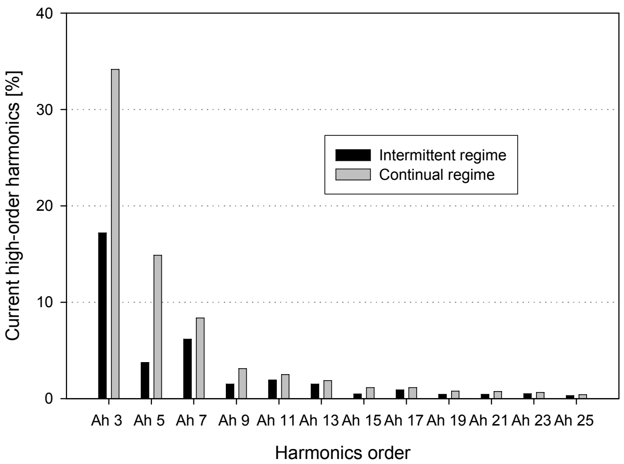

Fig. 11. Comparable values of high-order current harmonics for both precipitator control regimes.

High-order voltage harmonics are besides comparison of two control regimes compared with maximal permissible values provided by European power quality standard EN50160.

In Table 3 could be noticed that high-order harmonics are lower than permissible values whatever strategy is applied for control of the precipitator.

Table 3. Measured high-order voltage harmonics in comparison to the limits defined by EN50160 standard.

Harmonic order	Standard EN50160	Intermittent regime	Continual regime
3	5	1.97	2.70
5	6	1.43	2.00
7	5	1.37	1.47
9	1.5	0.53	0.70
11	3.5	1.13	1.23
13	3	0.77	0.90
15	0.5	0.30	0.33
17	2	1.13	1.17
19	1.5	0.60	0.70
21	0.5	0.43	0.45
23	1.5	0.90	1.00
25	1.5	0.57	0.63

Average power factor in all three phases for both regimes is shown in Fig. 12. It could be observed that power factor disturbances are lower in the case of intermittent regime (minimal and maximum values are 0.71 and 0.75 respectively). During continual regime these oscillations are higher due to the breakdown voltage at the electrodes (minimal value is 0.62 and maximum is 0.77).

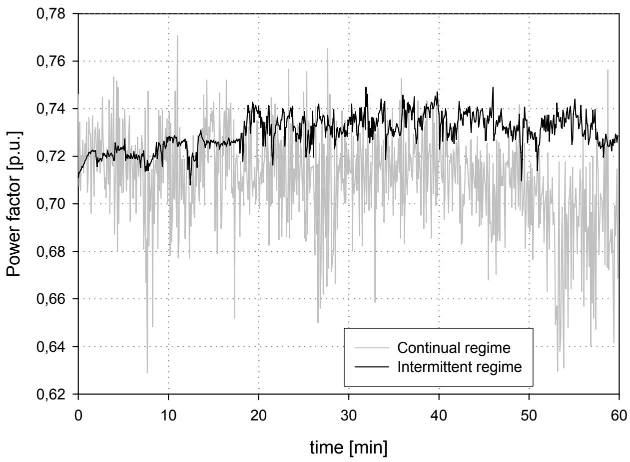

Fig. 12. Power factor for both control regimes.

At the end, comparison of power consumed during both regimes is given in Fig. 13.

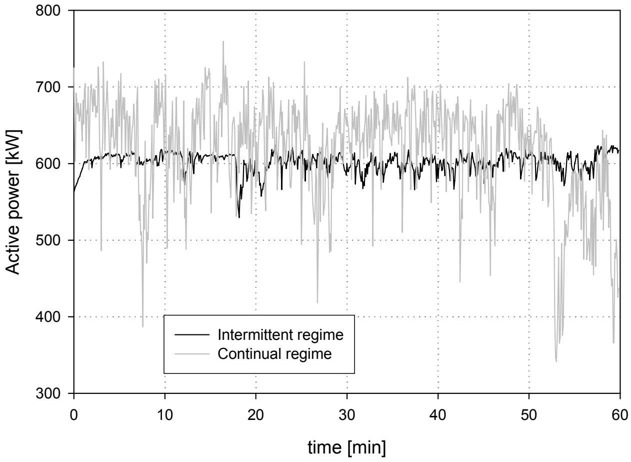

Fig. 13. Active power consumed during both control regimes.

Measurements in both regimes are performed under the same power plant working conditions. In the intermittent regime a significant power savings are achieved, since the average power was 600kW, while the average power in continual regime was 650kW. Also, during continual regime an abrupt power changes could be seen. These changes are due to the frequent occurrence of breakdown voltage and in several intervals goes to 100kW.

4. CONCLUSIONS

Results of power quality measurement analysis are presented in the paper with the aim to compare two different control strategies of electrical precipitator and their influence on overall power quality and energy efficiency.

Proposed measurement methodology based on EU power quality standard EN 50160 demonstrate advantages of one control strategy (intermittent) over another (continual). During the same power plant working conditions measurement results shows better energy efficiency of intermittent control strategy (about 8%) and lower high-order harmonic values (especially current) up to 25%.

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