PRETRAŽIVANJE / SEARCH
ŠTAMPANJE / PRINT
IZLAZ / EXIT

MEĐUNARODNO REGIONALNO SAVETOVANJE O ELEKTRODISTRIBUTIVNIM MREŽAMA

REGIONAL CONFERENCE AND EXHIBITION ON ELECTRICITY DISTRIBUTION

Crna Gora, Herceg Novi, 5 - 8. oktobar 2004. / ***Montenegro, Herceg Novi, October 5 - 8, 2004***

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POWER QUALITY PROBLEMS IN PLANTS WITH SPOT WELDING MACHINES AND ARC FURNACES, CASE STUDIES

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ABSTRACT

The term “power quality” has been used to describe the variation of the power supply voltage, current, and frequency. The good power quality can be defined as absence of outages and tolerable level(s) of sags, surges, swells, harmonics and flicker at the supply point. Nowadays, power quality problems become very important topic, as they have significant economic effects. Losses in production and cost of reparation caused by disturbances in power line can be quite considerable.

One of the frequent sources of power quality problems is usage of electric energy for metal melting, either for welding, or for casting, or for other purposes. Such processes are accompanied with appearance of voltage sags, flicker, harmonics and other disturbances. The aim of the paper is to give an overview of disturbances produced by spot welding machines and arc furnaces recorded and analyzed by the authors as case studies.

First case is a typical real situation when a small industrial plant with resistance spot welding machines is blamed for power quality problems observed in neighboring private hospital. The measurement results show rapidly load changes, caused by welding machines. This has effects on conditions of power quality parameters in the network. Voltage flicker and harmonics have been particularly traced. Measured values show that flicker level is above recommended limits and can be a cause for power quality problems in nearby hospital. On the other hand, the harmonic values are below IEC or IEEE limits.

Second case explains influence of arc furnaces to surrounding. Measurement of voltage and current characteristics of several electric arc furnaces all over Serbia proves that significant harmonics values can be expected in the nearby distribution network. Results indicate that some harmonics cancellation measures must be undertaken, for example installation of harmonics filters or similar.

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INTRODUCTION

The term "power quality" has been used to describe the variation of the power supply voltage, current, and frequency [1]. The good power quality can be defined as absence of outages and tolerable level(s) of sags, surges, swells, harmonics and flicker at the supply point. Nowadays, power quality problems become very important topic, as they have significant economic effects. Losses in production and cost of reparation caused by disturbances in power line can be quite considerable.

In the past, most of the electronics equipments have been able to operate with relatively wide variations of these parameters. Today, end-user problems related to power quality have steadily increased, due in large part to operation of the existing equipment at the maximum performance point (market demand) and due to ever-increasing use of sensitive microprocessor-controlled loads, which are not so tolerant to these variations. On the other side proliferation static power converters (non-linear loads), which draw a non-sinusoidal current, rapidly increases harmonics levels in the utility network [2]. When the performance of a customer's equipment is considerably affected by a poor power quality, then the customers-utility relations may become quite complex in order to determine the possible patterns of disturbances event and to identify the origins of power system disturbances.

One of the frequent sources of power quality problems is usage of electric energy for metal melting, either for welding, or for casting, or for other purposes. Such processes are accompanied with appearance of voltage sags, flicker, harmonics and other disturbances. The aim of the paper is to give an overview of disturbances produced by spot welding machines and arc furnaces recorded and analyzed by the authors as case studies.

POWER QUALITY DEFINITIONS AND FACTORS

There are numerous indices of power quality, which are used to describe phenomena in voltage and current waveforms [1]. Figure 1 shows some of them that can occur in distribution network. Origins of power system disturbances are often in a customer's electrical system, but many of them arise from normal utility operations. In this paper harmonics, voltage sags and flicker will be presented in more details, as these disturbances are dominant for application of the electric spot welding machines and arc furnaces in industry.

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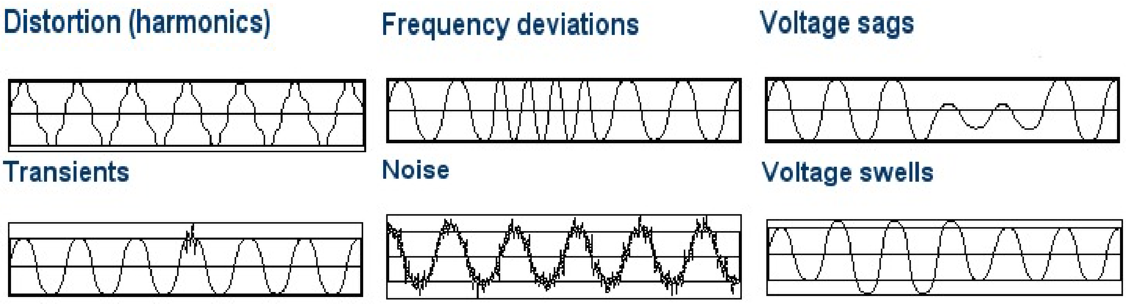

Fig. 1. Voltage waveforms that typify power quality phenomena

Harmonic distortion

Harmonic distortion describes the continuous or steady state variations in the fundamental frequency. Non-linear loads produce distortion of sinusoidal waveforms when a sinusoidal voltage is applied. Figure 2 shows a current waveform sample recorded during operation of the spot welding machine. The indices related to harmonics are individual (HD_n) and total harmonic distortion (THD). They are defined as:

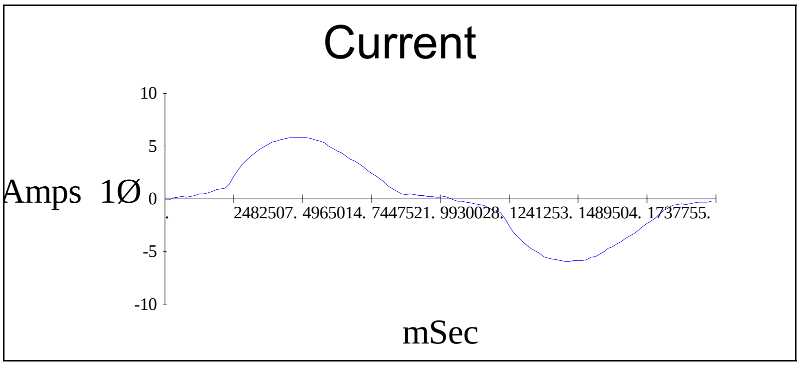

Fig. 2. A record of the spot welding machine current waveform.

$$HDI_n = (I_n / I_1) \cdot 100\,(\%) \qquad HDU_n = (U_n / U_1) \cdot 100\,(\%) \quad , \quad THDI = \sqrt{\sum_{n=2}^{\infty} I_n^2 \Big/ I_1^2} \cdot 100\,(\%) \quad THDU = \sqrt{\sum_{n=2}^{\infty} U_n^2 \Big/ U_1^2} \cdot 100\,(\%) \qquad (1)$$

Voltage sag

Voltage sag (dip) is decrease of the AC voltage RMS value, at the power frequency, of duration from 0.5 cycles (10ms for 50Hz systems) to 2-3 seconds. Voltage sag can be characterized by its magnitude, duration, phase angle jump shift (phase-shift), point on the wave of voltage reduction and restoration, asymmetry of voltage reduction in three phases. The voltage sag is mostly caused by power system faults (short circuits), but it could also be caused by starting of large induction motor, abruptly load changes, transformer energizing [1,3].

Flicker

Flicker can be defined as swift variations of voltage amplitudes occurring at frequencies less than 25Hz. Flicker is caused by large loads, such as arc furnace or electric welders, whose power (active, reactive or both) rapidly changes. Flicker refers to the sensation experienced by the human eye when subjected to changes in the illuminations intensity of a light source caused by voltage fluctuations. Depending on an intensity of voltage sag and a number of fluctuations, the curves for defining flicker levels have been established. It is shown in figure 3. There are two factors that are in use for describing flicker levels: P_{st} - The flicker severity evaluated over a short period - 10 minutes (P_{st} = 1 is the conventional threshold of irritability). P_{lt} - The flicker severity evaluated over a long period (a few hours) using successive P_{st} values. Relation between these two factors is:

$$P_{lt} = \sqrt[3]{\frac{1}{12} \sum_{j=1}^{12} P_{st_j}^3} \qquad (2)$$

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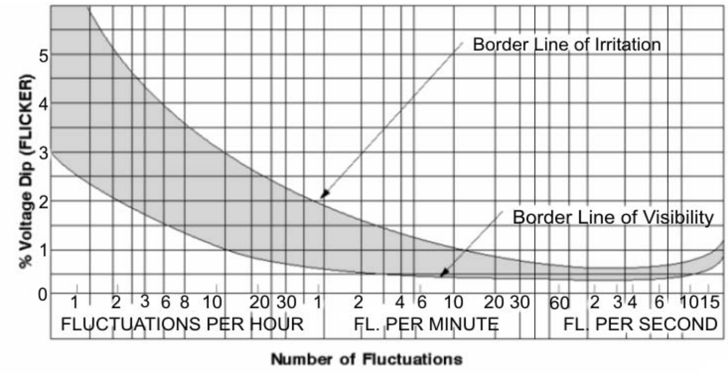

Fig. 3. Flicker limits

OPERATION OF THE SPOT WELDING MACHINES – A CASE STUDY,

The case study is a result of actual power quality disturbances generated by a small industrial plant with spot welding machines. It was initiated by the nearby power supply company customer, a private hospital, which had experienced problems in operation of the sensitive medical equipment and observed light flicker.

Generally, when consumers are affected by power quality problems, they have several possible solutions: to contact utility, to contact the equipment manufacturer, to engage a consulting companies specialized for providing solutions related to power quality problems, or to solve their problems by themselves [4].

In this case an expert opinion was asked. Since the hospital is placed close to the plant and the patterns of occurrence of disturbances were in relations with working schedule of the plant, investigation of the power quality parameters at supply input of a plant has been undertaken.

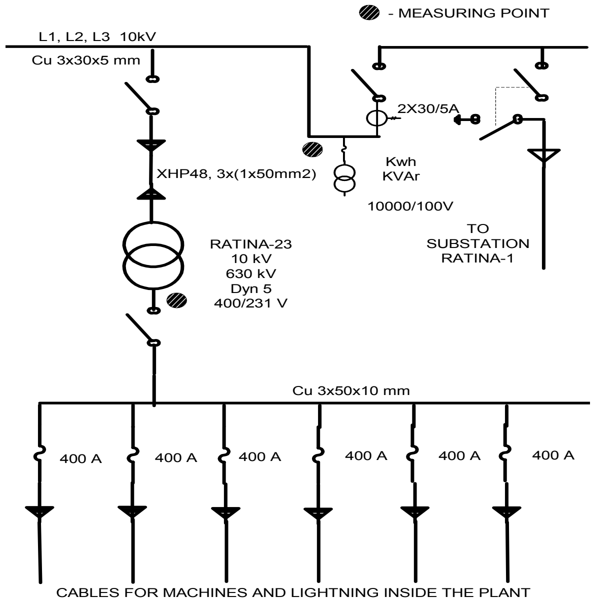

Fig. 4. Power connections of substations

Both, private hospital and plant, were connected to the same 10kV power grid, with they own 10/0.4kV transformers. Plant was fed from a substation “Ratina-23” while hospital was connected to a substation “Ratina-1”. Distance between those two substations is about 170 meters. The detailed schematic of the power connections is given on figure 4.

Plant produces two basic products, iron nets for armoring concrete and iron bulk, both used at building site. There are several AC induction motors with rating powers about: 37kW, 12.5kW, 18 kW. These motors drive machines that are used to prepare untilled wire to a certain diameter and length, which will be welded later. There are two resistance spot welding machines, whose operation principle is shown in figure 5.

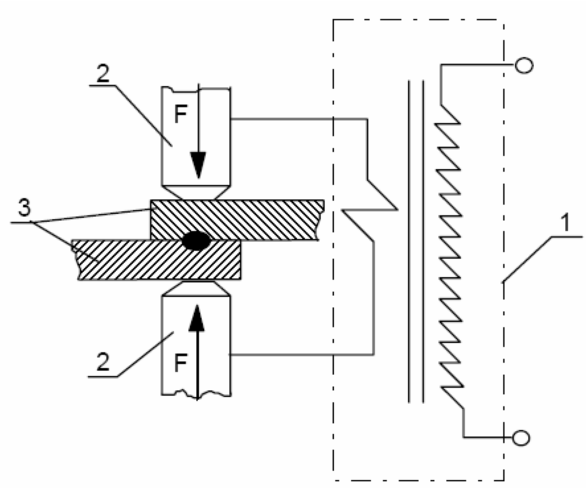

Fig. 5. Resistance spot welding machine

Machine consists of a transformer (1), whose secondary windings are connected to two non-consumable electrodes (2), and wires (3) that will be welded are in between. Voltage on secondary side of a transformer is usually about 10 V, while the current can have very high values (kA) depending on wires diameter.

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One machine is used for producing iron wire bulk, while the other is used for production of iron nets. The size of the net can vary depending on a number of used iron rods. It consists of twelve transformers, which enable simultaneous resistance spot welding of a different number of wire rods. Connection of these machines to the power supply is shown on figure 6.

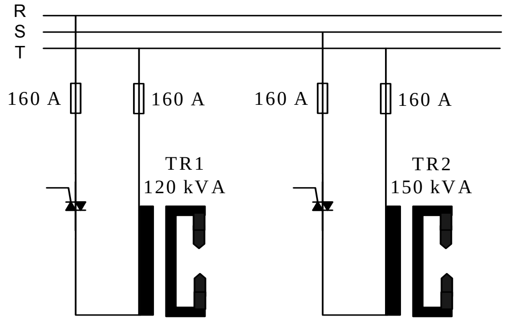

Fig. 6. Connection principle

THE MEASURING SYSTEM AND RESULTS

The measurement was performed by commercially available computer based measuring instrument, which measures voltage and current harmonics and flicker in all three phases with averaging intervals on choice, 1 sec, 1 min, 10 min and 15 minutes. For the analysis of harmonics the six measuring channels of the system are sampled with a frequency of 5.6 kHz (112 samples per network period with PLL operation). Analogue/digital conversion is done using six parallel-arranged A/D-converters with a resolution of 16 bits. The measuring data recording and analysis is done each second, on a 160 ms data block (8 periods) using Blackmann-Harris-Window.

Flicker measurement was performed separately. The sampling frequency for flicker measurement was 400Hz, with averaging interval 1 or 10 minutes. The measurement accuracy was 0.1% for the instrument alone, not taking into account the accuracy of the instrument transformers for connection (already available in the power system). Instrument also has implemented an oscilloscope measurement mode to observe and register voltage and current waveforms.

The measurement results are presented in the figures 7-12.

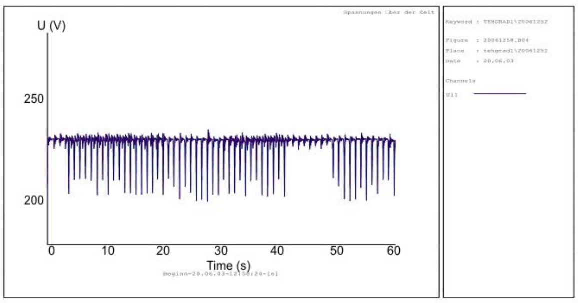

Fig. 7. Flicker at 0.4kV level (phase R)

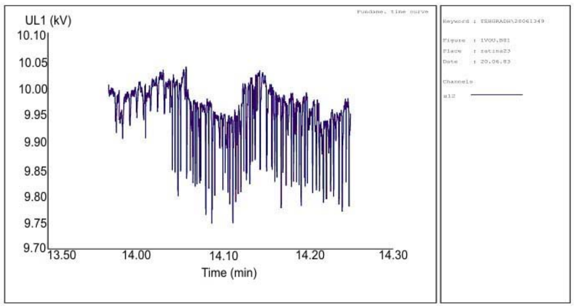

Fig. 10. Flicker at 10kV level (phase 1)

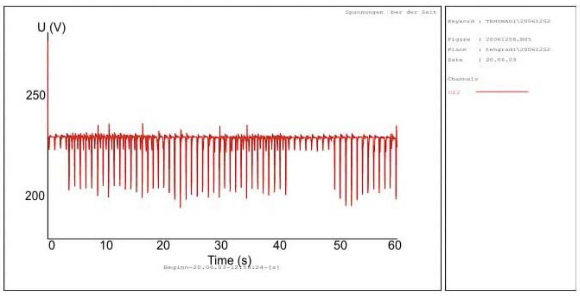

Fig. 8. Flicker at 0.4kV level (phase S)

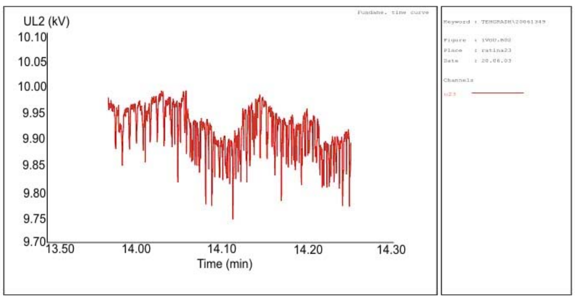

Fig. 11. Flicker at 10kV level (phase 2)

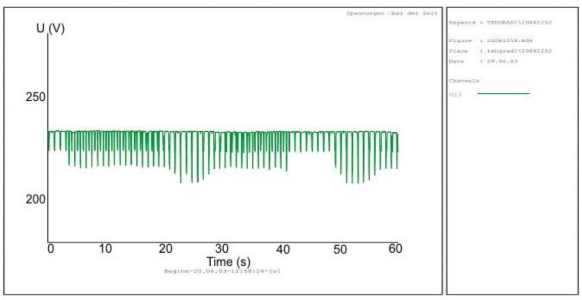

Fig. 9. Flicker at 0.4kV level (phase T)

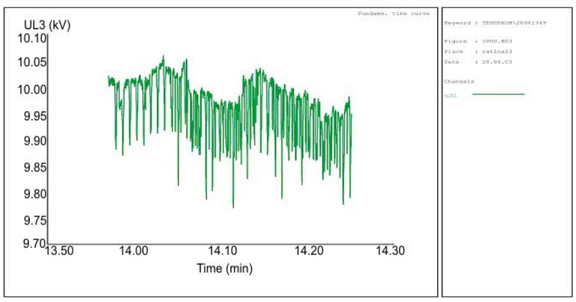

Fig. 12. Flicker at 10kV level (phase 3)

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Figures 7 – 9 show voltage dips at 0.4kV level in all three phases measured during welding process of 60 seconds. It is noticeable that voltage dip level is varying depending on which machine is operating. Smaller voltage dips are result of a work of iron bulk machine, while the iron nets machine produce bigger voltage dips at 0.4kV level. As machines have periodical operation cycles, these dips are turned into flicker disturbances of various levels. Figures 10 – 12 show voltage variations measured during 30 minutes measurement, on the primary side of a transformer at 10kV feeder. There are also large variations in RMS value of voltage at 10kV level caused by welding machines in the plant.

Measurement of short-term flicker severity P_{st} is shown on figures 13 and 14. It can be seen that P_{st} values, caused by work of welding machines, are much higher than 1. For 0.4kV level P_{st} have value between 6 and 11, while at 10kV level P_{st} is lower and in the range between 1.5 and 4. Patterns of occurrence of these voltage variations correspond to time interval of welding process in plant.

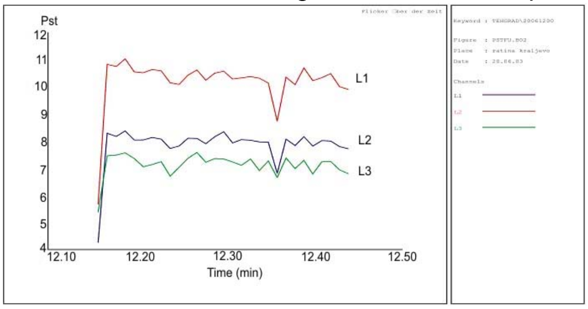

Fig. 13. Flicker P_{st} values at 0.4kV

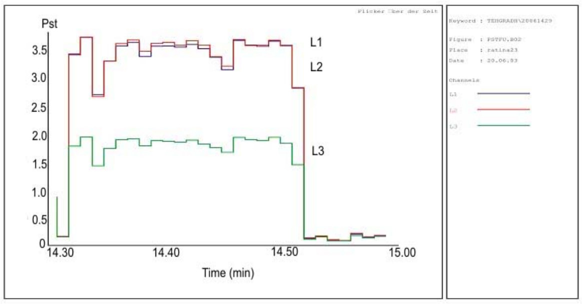

Fig. 14. Flicker P_{st} values at 10kV

Figures 15 and 16 illustrate results of voltage harmonics measurement at 10 kV level on the primary side of transformer and statistical representation of the measurement results. Voltage harmonics are below limits recommended by IEEE standard ($THDU_{lim}$=5%, HDU_n=3%) [5].

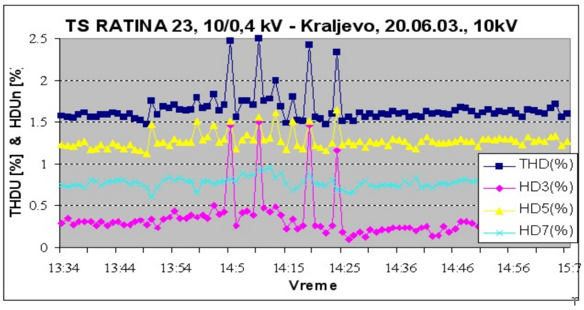

Fig. 15. Voltage harmonics at 10kV (L1)

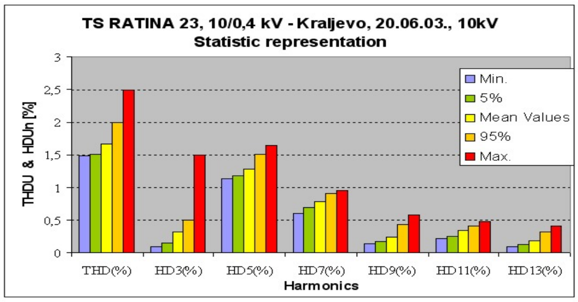

Fig. 16. Voltage harmonic – statistic presentation

DISCUSSION OF MEASURMENT RESULTS

From the short time measurement performed during one day, we can see that there are certain problems with power quality in the plant. Flicker P_{st} values provide evidence that plant with resistance spot welding machines produce a flicker in the voltage. P_{st} values are much above the limiting value P_{st} = 1, especially on 0.4kV level, inside plant, where P_{st} is in range between 6 and 11, while on the primary side of a transformer P_{st} have values between 1.5 and 4. These can effect other consumers a can be a source of power quality problems in nearby hospital. Voltage harmonics measurements show that harmonics values are bellow their limits and that plant does not pollute network with voltage harmonics.

OPERATION OF THE ARC FURNACES

Electric arc furnaces are well known harmonics and light flicker sources and therefore they have significant effects on distribution network power quality [1,6,7]. The reason for that is non-liner voltage-current characteristic of electric arc and also occasional operation in short-circuit regime due to nature of the melting process in the arc furnaces. High oscillations of the input currents producing both mechanical and thermal strains, results also in additional fundamental and harmonics voltage drop on both furnace’s and distribution transformer reactance. To avoid such effect arc furnaces are often connected to point of common coupling (PCC) of higher short circuit power i.e. of higher voltage level. Still in some cases this is not economical or practically possible. In such cases, operation of the arc furnaces produces harmonics and flicker problems for other consumers [8].

Operation of the arc furnaces will be presented through results of measurements in several case studies. Four large arc furnaces in different regions of Serbia are taken into consideration:

1. Electric arc furnace of company “Livnica” in Kikinda
2. Electric arc furnace of company “Cer” in Čačak
3. Electric arc furnace of company “Mačkatica” in Surdulica and
4. Electric arc furnace of company “Sartid” (now ”US Still”) in Smederevo

The operation of these arc furnaces have been monitored with current and voltage harmonic measurement system over a period of one week. Some of these results have been presented in [1,8] and they will not be repeated here. Therefore, the aggregate results of voltage and current harmonics are presented in Figs.17-20. Two main values are shown for each case:

1. Maximum recorded level of current and voltage total and individual harmonic distortions (THDI & THDU and HDI & HDU, respectively).
2. 95% recorded values of current and voltage total and individual harmonic distortions.

All recorded voltage harmonics values are compared with voltage harmonic limits presented in two main standards – IEC 61000-2-4, for the class 2 consumers and IEEE Standard 519, while all recorded current harmonics values are compared with current harmonic limits from IEC 61000-3-4, Stage 2 standard and IEEE Standard 519.

Fig. 17 shows results of maximum values of voltage harmonics. The dotted lines are limits from the above mentioned standards, while solid line connects voltage harmonics values averaged over all measurements. It can be observed that the most of the harmonic values are below limits. The averaged value is also below limits, although for the THDU and HDU3 it is at the IEEE limits value.

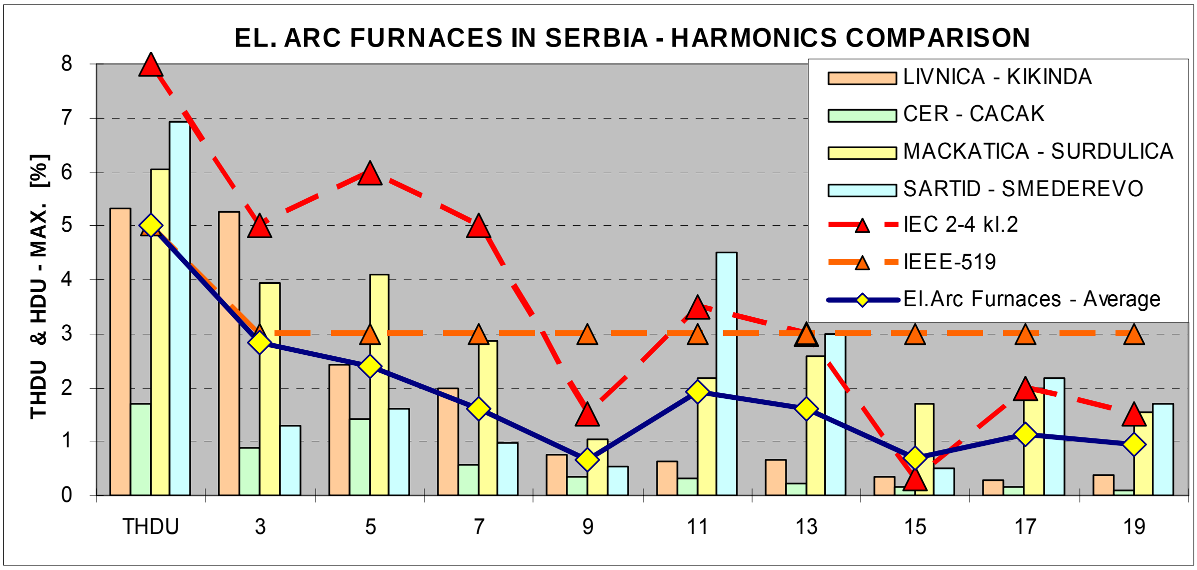

Fig. 17. Maximum values of recorded arc furnace’s voltage harmonics.

On the other hand, if results of the maximum recorded current harmonics are considered, it can be seen from Fig.18 that low order harmonics are above limits (THDI, HDI3, HDI5), while higher harmonics are below limits. It indicates that some harmonics cancellation measures must be undertaken, for example installation of harmonics filters or similar.

However, the maximum harmonic values are not reliable indicator of harmonics existence, as it can be a single case over a long period of time. Therefore, 95% value is considered more appropriate - it represent the level, which is not surpassed during 95% of monitoring time. These values are represented in Fig. 19 and 20 for the voltage and current harmonics, respectively. Now all voltage harmonics are below but very close to the limits, while current harmonics have high levels, especially low order harmonics. The above conclusion of necessity of introducing some of the harmonic mitigation techniques is valid and is verified.

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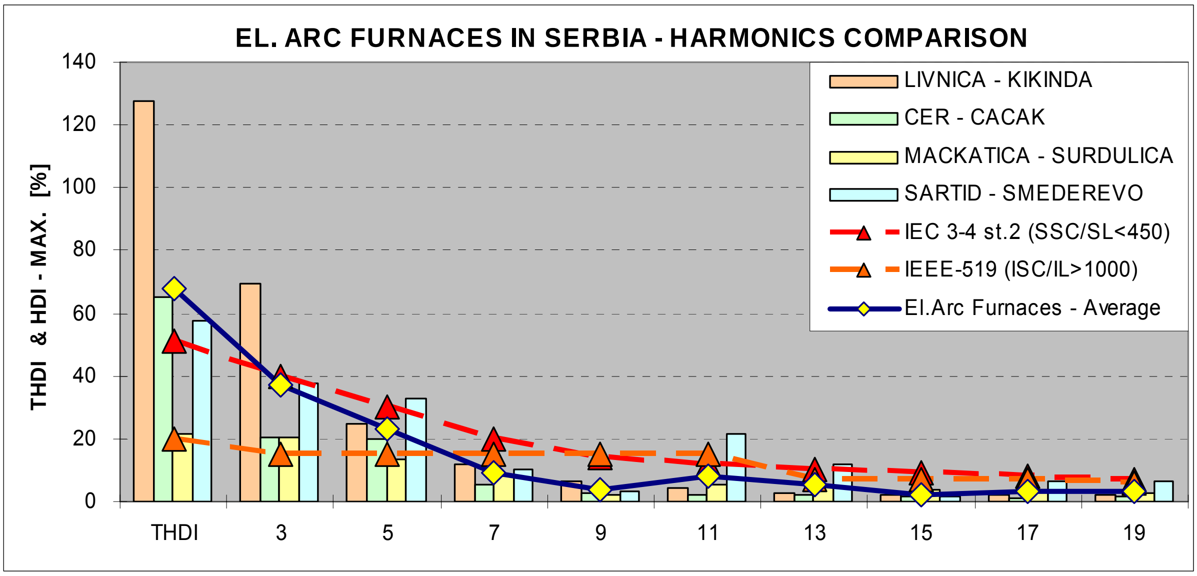

Fig. 18. Maximum values of recorded arc furnace's current harmonics.

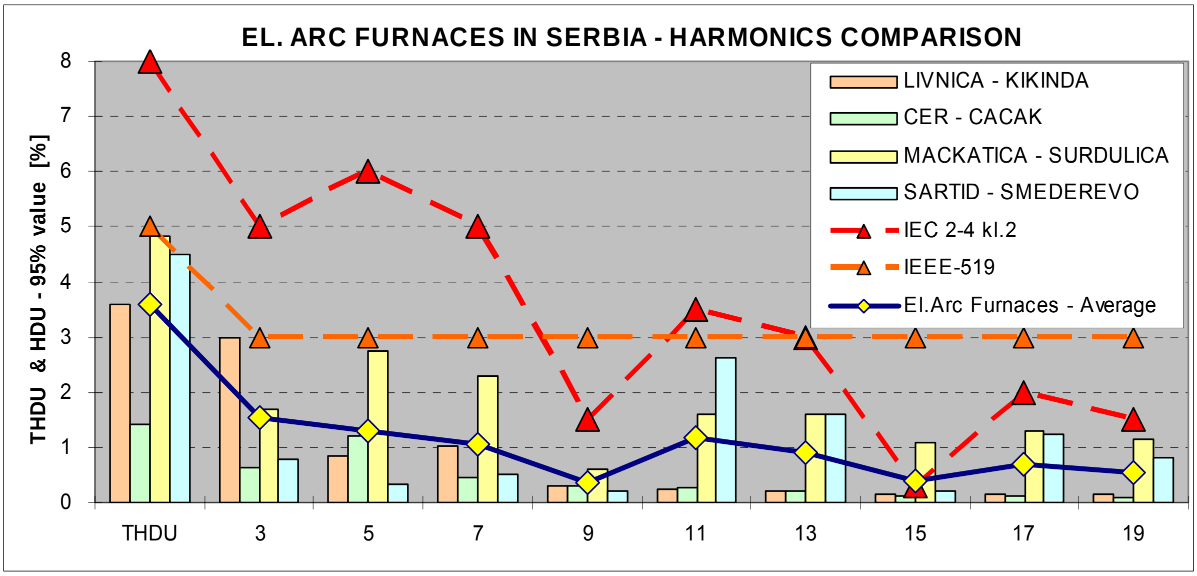

Fig. 19. 95% values of recorded arc furnace's voltage harmonics.

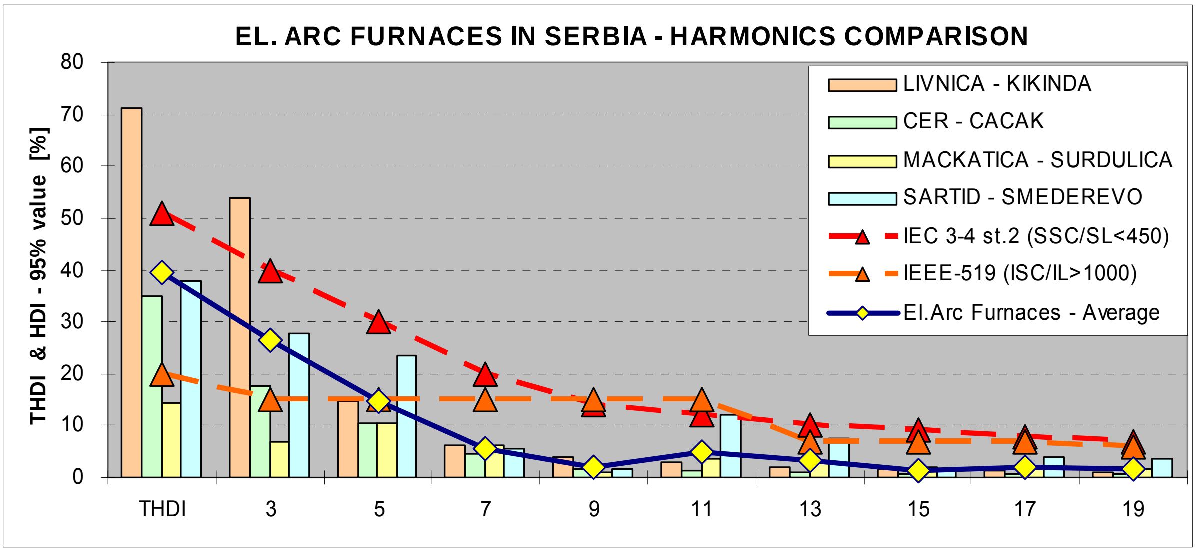

Fig. 20. 95% values of recorded arc furnace's current harmonics.

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CONCLUSION

The above-presented paper has focused on a few characteristics of power line disturbances – flicker and harmonics.

First case is a typical real situation when a small industrial plant with resistance spot welding machines is blamed for power quality problems observed in neighboring private hospital. The measurement results show rapidly load changes, caused by welding machines. This has effects on conditions of power quality parameters in the network. Therefore, voltage flicker and harmonics have been particularly traced. The periodic changes of the line voltage RMS values, i.e. occurrences of a flicker, have been noticed. Further, distortion in the voltage waveforms - the harmonics, has been also marked. Measured values show that flicker level is above recommended limits and can be a cause for power quality problems in nearby hospital. On the other hand, the harmonic values are below IEC or IEEE limits.

Second case explains influence of arc furnaces to surrounding. Measurement of voltage and current characteristics of several electric arc furnaces all over Serbia proves that significant harmonics values can be expected in the nearby distribution network. Results indicate that some harmonics cancellation measures must be undertaken, for example installation of harmonics filters or similar.

LIST OF REFERENCES

1. Katić V, 2002, “Electric power quality - harmonics”, Edition: Technical Sciences – Monographs, No.6, University of Novi Sad – Faculty of Technical Sciences, Novi Sad (in Serbian).
2. Price K, 1993, “Practices for Solving End- User Power Quality Problems”, IEEE Transactions on Industry Applications, Vol.29, No.6, pp.1164-1169.
3. Milanović J, 2003, “Voltage Sags, Causes, Consequences & Assessment”, Lecture notes for Power Quality short course, UMIST.
4. Koval D, 1990, “Power System Disturbance Patterns”, IEEE Transactions on Industry Applications, Vol.26, No.3, pp.556-562.
5. IEEE Std. 519-1992, 1993, “IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems”, IEEE Press, New York.
6. Heydt G, 1991, “Electric Power Quality“, Stars in Circle Publications, West LaFayette.
7. Brajović V, 1990, ″Thermo-electrical equipment and stations″, Engineering Faculty, Čačak (in Serbian).
8. Brajović D, Katić V, Popović S, 2002, “Electric arc furnaces as harmonics sources – measurement results analysis”, 3rd Yugoslav Conference on Electric Power Distribution Networks - JUKO-CIRED, Vrnjačka Banja, Vol.1, Paper No.R-2.01, pp.95-101 (in Serbian).

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