APPLICATON OF CONTEMPORARY DATA ACQUISITION SYSTEM FOR POWER QUALITY CONTROL ON EXAMPLE OF IRONWORK PLANT NIKSIC

Mirjana Božović, Saša Mujović***

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Abstract: Iron work plant "Niksic" is one of the biggest consumers in Montenegrin electrical transmission system. Presence of an electric arc furnace, known as potential causer of bad power quality, indicates the need for examination parameters related to power quality. Measurements were conducted with three-phase power analyzer (Dranetz PG4400) with its compatible software Dran-View 6.0. The results have been compared with the permitted values defined by the standards. Measurements were conducted during different operating modes.

1. INTRODUCTION

Problems with power quality are very popular today, especially with expansion and development of smart grids. Power quality became the center of events and interests during 70-ties of the last century, with expansion of power electronics converters. They became irreplaceable part of modern computers and industrial production.

Massive use of power electronics converters and negative influence on voltage in energetic system on the one side, and the need for good power quality on the other side, made this issue very important [1]. Besides this category of consumers, there are also non-linear consumers with big consumption, for example an electric arc furnaces. They are additional danger for energetic systems, and their influence will be described in this paper, as well as contemporary data acquisition system for power quality control.

* Spec.Sci Mirjana Božović, Montenegrin electrical transmission system, Moskovska 39, 20000 Podgorica, Montenegro

** doc. Dr Saša Mujović, Faculty of Electrical Engineering, University of Montenegro, Džordža Vašingtona b.b, 20000 Podgorica, Montenegro

2. CURRENT RESEARCHES OF POWER QUALITY IN MONTENEGRO

Power quality in Montenegro is not researched well. According to Grid code-Rules for electrical transmission system operation article 59 which is related to power quality prescribes the following obligation: “The user’s electrical system must be designed and set up in such a way that, while in operation, there are no influences on quality of electricity in the transmission system and third parties, and no interference to information and signal transfer. “ [4]

In Montenegrin electrical transmission system there are three big consumers: Aluminium plant Podgorica, Iron work plant Niksic and Railways of Montenegro. Their operation affects voltage in energetic system, and therefore affects other consumers. Because of that, continuous monitoring and measuring of their influence is necessary. Unfortunately, it was not possible until now, due to lack of equipment. First researches for power quality in Montenegro were conducted in iron work plant Niksic and results and analysis will be presented in this paper.

3. DESCRIPTION OF DATA ACQUISITION SYSTEM

Measurements were conducted during ten days with three-phase power analyzer (Dranetz PG4400) and its compatible software Dran-View 6.0.

The Dranetz-BMI PowerGuide® 4400 is a portable, hand-held, eight-channel power quality meter/monitor. This instrument is designed with a color liquid crystal display (LCD) 1/4 VGA, using touch screen technology. It can monitor, record and display data on four voltage channels and four current channels simultaneously [5]. The 4400 is designed to meet both the IEEE 1159 and IEC 61000-4-30 Class A standards for accuracy and measurement requirements. It can also monitor EN50160 compliance based on the EN (European) Standards. The statistical package called Quality of Supply (QOS) is built into the 4400, with monitoring and setup protocols set to determine voltage measurement compliance required for EN50160 monitoring. European standard EN50160 requires that measurement parameters must be within a specified percentage for 95% of the time.

The Dranetz PG4400 firmware can monitor power quality phenomena for troubleshooting and/or compliance purposes. It can record inrush conditions, carry out long-term statistical studies to establish performance baselines, and perform field-based equipment testing and evaluation for commissioning and maintenance. It supports the use of Compact Flash data cards with at least 32MB storage capacity [5].

The 4400 can be operated from a 50/60 Hz 120/230V AC power source with or without the battery pack installed.

Figure 3.1 shows electrical wiring diagram for Dranetz PG4400 [5].

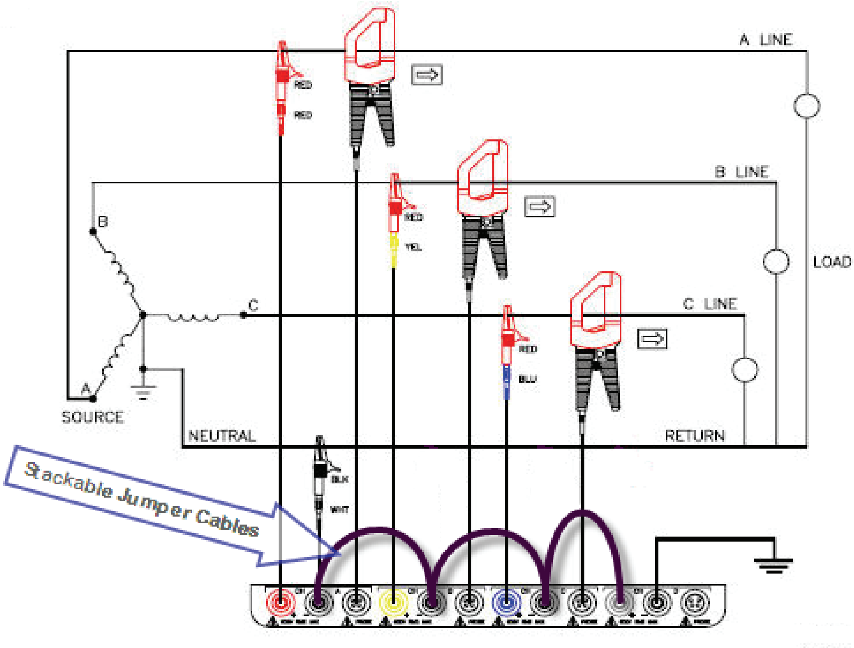

Figure 3.1 Electrical wiring diagram

At starting, Dranetz PG4400 shows next home screen:

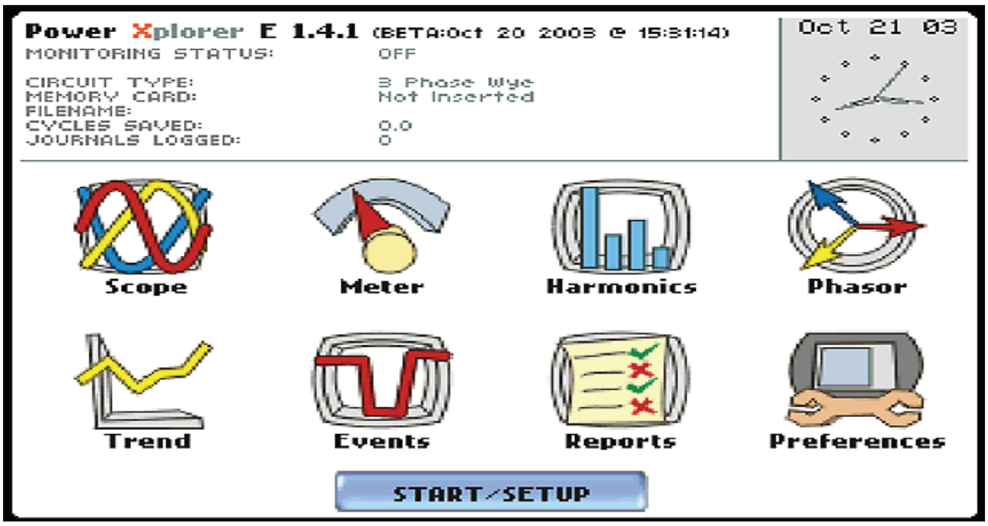

Figure 3.2 Home screen

Home screen (Figure 3.2) is frequently referenced as the starting point for all major functionalities of the Dranetz PG 4400.

Information that appear in the status message area are the monitoring status, circuit configuration, percentage of data card used while monitoring, site/file name, number of event cycles saved, and number of timed intervals saved.

Dranetz PG4400 offers EN50160 analysis. It is a statistical analysis of power quality data based on the EN standard. The statistical package called Quality of Supply (QOS) is built into the 4400, with monitoring and setup protocols set to determine voltage measurement compliance required for EN50160 monitoring [5]. The EN50160-required measurement parameters include Power Frequency, Supply Voltage Variations, Rapid Voltage Changes, Supply Voltage Unbalance, Harmonic Voltage, Interharmonic Voltage, and Mains Signalling. The monitoring site is said to be in compliance if the statistical value over one week for the specified parameters is 95% or greater (Figure 3.3):

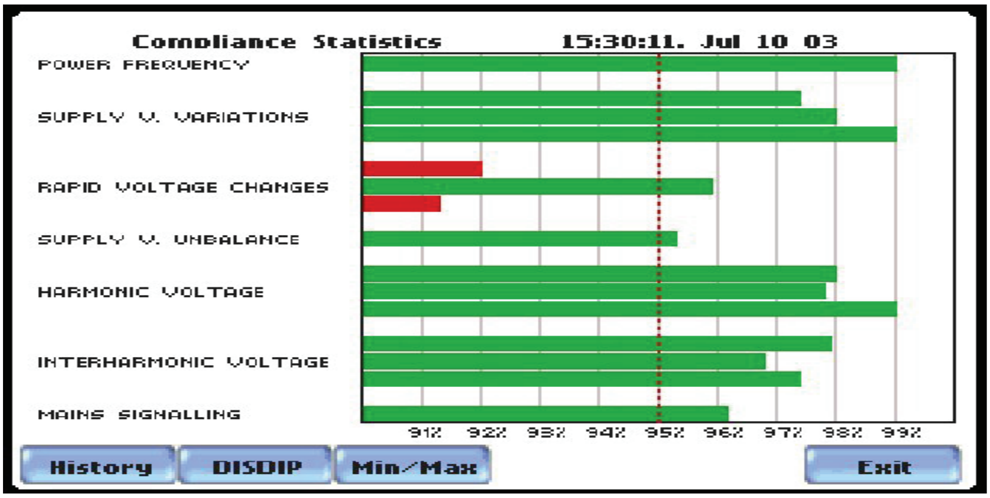

Figure 3.3 EN50160 statistical analysis

4. MEASUREMENTS AND MONITORING OF INFLUENCES OF IRON WORK PLANT NIKSIC

Researching of parameters of power quality was carried out in electrical substation Niksic 110/35 kV on the II bus bar section on 110 kV side of transformer T3. Electric arc furnace is inductive consumer which specially has influences on power quality of energetic system, and power quality of consumers supplied from substation Niksic. Single line diagram TS Niksic is given in Figure 4.1.

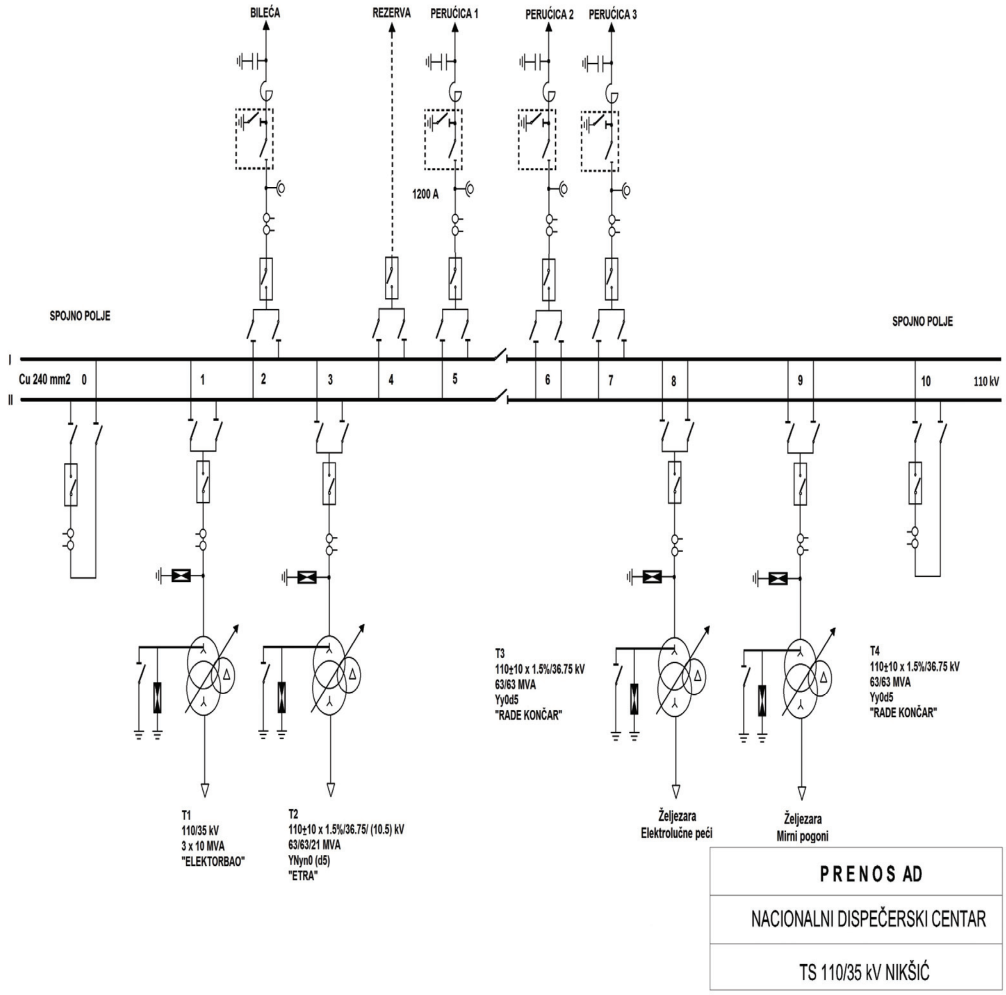

Figure 4.1 Single line diagram TS Niksic

During researching, these data which are important for power quality were measured:

- Active and reactive power
- Power factor
- Apparent power
- Supply voltage
- Voltage unbalance
- Harmonics
- Flickers

4.1 Consumption of active and reactive power, power factor

Operation of an electric arc furnace can be separated in three phases: melting, oxidation and refining [1].

During the first phase, there is a big consumption of active power. In this period charged material is being melted. At the start of melting the arc is erratic and unstable. It is necessary to establish electric arc (because of short circuit, electrode is being connected to the charged material). After that, a path is being created through steady charged material (and once again short circuit is made due to the falling of charged material on electrode) and electric arc is being created. During the falling of charged material on the electrode, transformer is fully loaded. If nominal reactive power of electric arc furnace is denoted with Q_N , then in the period of melting reactive power is changing according to this relation [2]:

$$Q = Q_N (1 \pm 0{,}7) \tag{4.1}$$

In the second phase, during the oxidation, furnace is working with $1/3P_N$ (P_N - nominal power). In the third phase loading is much lower than it is in other two phases.

As an example, 21.04.2013. is chosen as typical day. This date is chosen randomly, because the other days are not much different from this day. Figure 4.2 shows active power of each phase on that day. That figure shows three different operating modes.

During the typical day, electric arc furnace made six operating cycles of melting and, during the other days, up to seven. Operating modes in each day are the same, with similar measurement values.

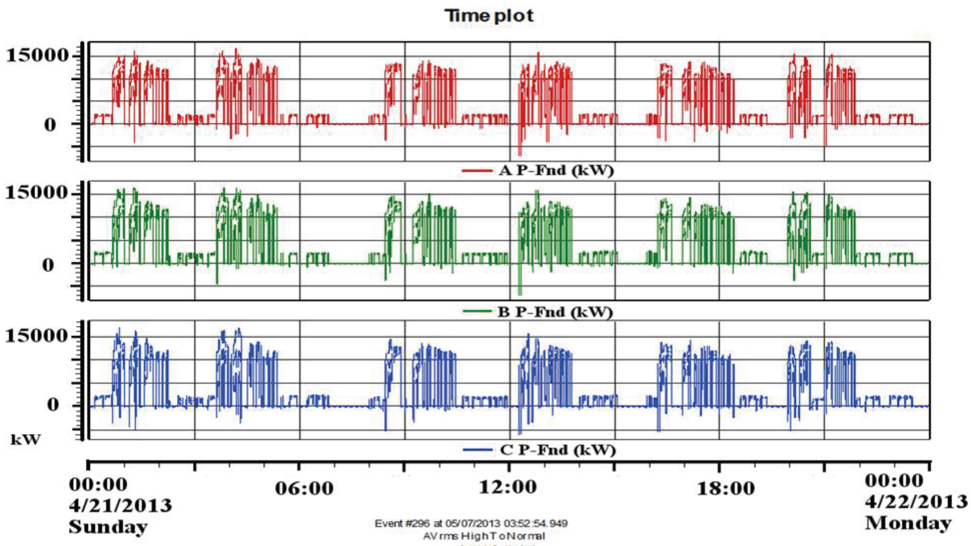

Figure 4.2 Active power during the process of generation

Figure 4.3 presents reactive power on typical day. That shows heavy loading and furnace consumes a large amount of reactive power (the first operating mode), then periods with reduced loading (the second operating mode), and the last mode with light loading.

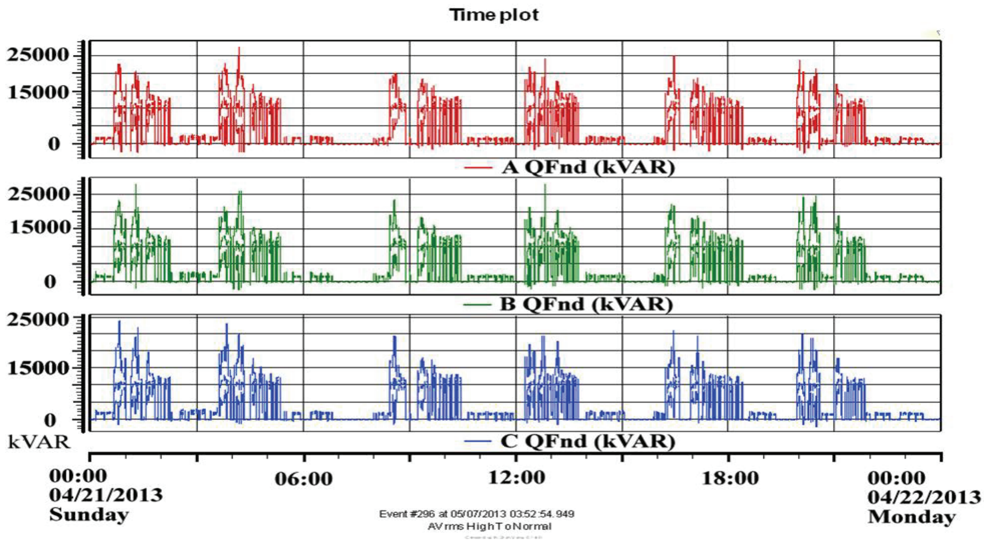

Figure 4.3 – Reactive power during the process of generation

Calculation of maximum/average active/reactive power per minute is given in Table 4.1. Consumption of apparent power and power factor are shown in Table 4.2.

Table 4.1 – Active and reactive power

Mode	*Phase*	*Pmax1min*	*Pavg1min*	*Qmax1min*	*Qavg1min*
I	A	16130	13746	27499	13274
	B	16558	13883	28171	13182
	C	16716	13401	29055	13019
	∑	47513	41030	78585	39089
II	A	2161	2008	2801	2227
	B	2428	2219	2963	2123
	C	2378	2035	2996	2589
	∑	6863	6244	8270	6763
III	A	36	35	/	/
	B	14	13	/	/
	C	20	18	/	/
	∑	69	65	115	69

Pmax1min - maximal active power per minute; **Pavg1min** - average active power per minute; **Qmax1min** - maximal reactive power per minute; **Qavg1min** - average reactive power per minute;

Table 4.2 – Apparent power and power factor

Mode	***Phase***	***Smax1min***		***Savg1min***		***Power factor***
I	A	28425	83502	18931	56727	0,71-0,8
	B	29521		19086		0,7-0,78
	C	30684		18710		0,68-0,78
II	A	3377	10472	2905	9163	0,71-0,75
	B	3627		3178		0,74-0,78
	C	3565		3293		0,72-0,73
III	A	84	239	82	235	/
	B	89		88		/
	C	67		66		/

Smax1min - maximal apparent power per minute; **Savg1min** - maximal apparent power per minute;

Following can be concluded from Table 4.1 and Table 4.2:

a) In operating mode noted with I it is evident that there is a big consumption of active and reactive power. Reactive power gets its maximum value faster than active power (due to short circuits in this period). In this operating mode maximal active power per minute is 47 513 kW, reactive power is 78 585 kVAr and apparent power is 56 727 kVA. Power factor is between $\cos\varphi = 0{,}68$ and $\cos\varphi = 0{,}78$, while consumption of active power is mostly constant in all three phases.

b) In operating mode noted with II active power consumption is mostly constant in all three phases, but that is not the same case with reactive power. Power factor is increasing up to value $\cos\varphi = 0{,}78$.

c) In operating mode noted with III less energy is being consumed.

Values of power factor from Table 4.2 are calculated in specific way. They don't include negative values of power factor (they appear as the results of furnace's generating reactive power, it can be noticed in Figure 4.4).

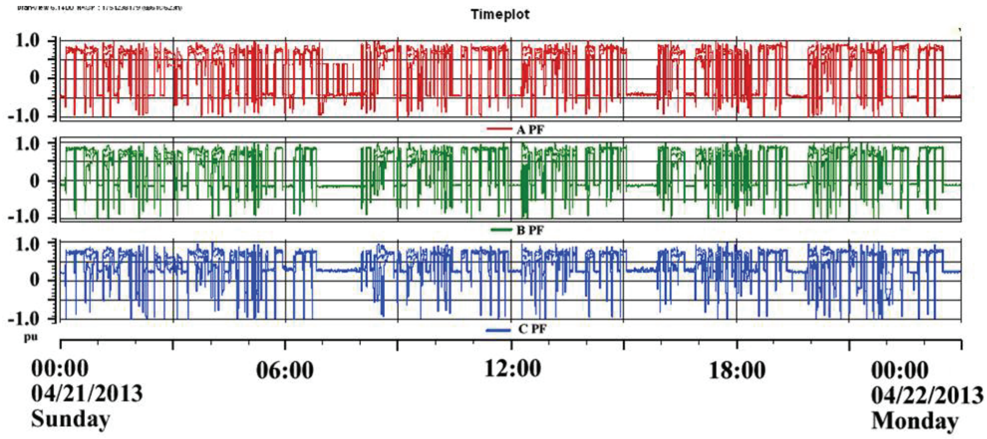

Figure 4.4 – Power factor during the typical day

4.2 Supply voltage

Figure 4.5 shows values of average voltage per minute for three phases during ten days of conducting measurements. The non-uniform peaks in voltage indicate erratic behavior of arc.

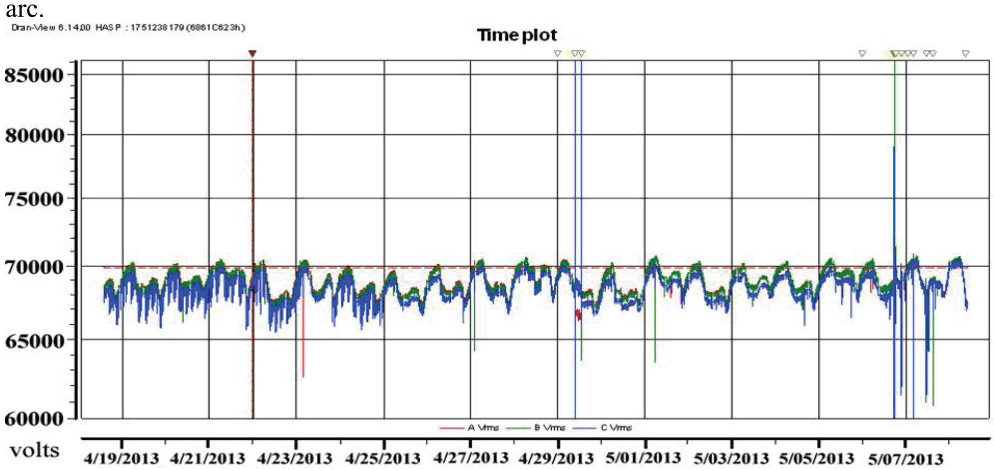

Figure 4.5 Voltage as a function of time

Average value of voltage per phase A on 21.04.2013. was 69 312,55 V (109,1 Un), phase B had voltage 69 237,1 V (109 Un) and phase C 68 842,1 V (108,4 Un). This represents that voltage on phase C is lower than other two phases during each day for approximately 0,68% Ua and 0,57% Ub. High values of voltage during conducting measurements are consequence of the position and operation of hydro power plant „Perucica". That power plant influenced on better voltage circumstances in the system. Voltage for each phase is in defined limits.

Figure 4.6 shows one event from 29.04.2013. in 12:55 AM, when there was overvoltage because of atmospheric discharges. These values of voltage had been registered:

Phase A: $u_a = 79611 \cong 1{,}25 u_n$

Phase B: $u_b = 95837 \cong 1{,}51 u_n$

Phase C: $u_C = 129971 \cong 2{,}05 u_n$

The highest value of voltage was in phase C, and disturbance lasted about 80 ms.

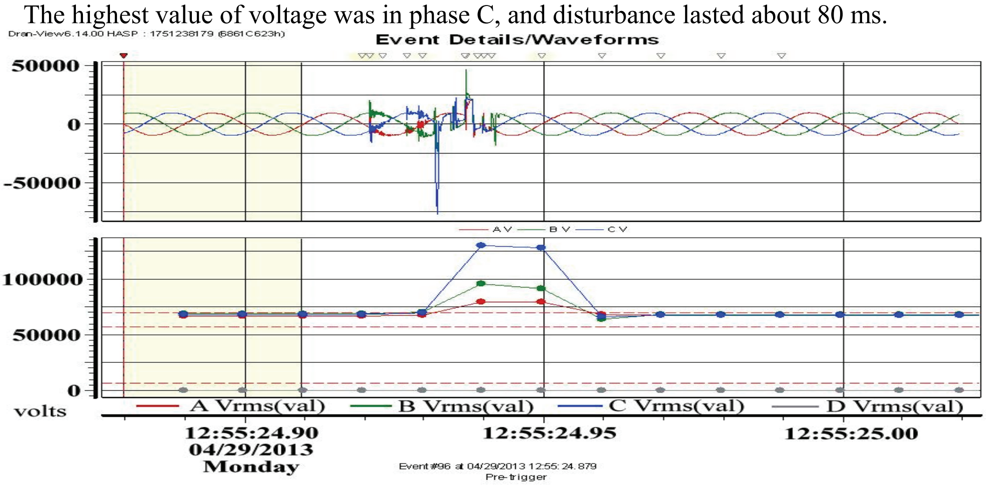

Figure 4.6 – Transient overvoltage 29.04.2013. at 12:55 AM

Measuring equipment recorded failure on bus bar section II on 06.05.2013., when voltage per phase B was about 35 % Un [3[.

On 23.08.2013. we registered complaint by consumers which have been supplied from substation Niksic, because of low voltage. That happened in period when HPP "Perucica" was not in operation.

That fact shows that additional measurements needed to be conducted, in period when HPP "Perucica" is not in operation or it has reduced power generation.

4.3 Voltage unbalance

According to international standard EN 50160, for 95% of time during one week, 10 minutes root mean square value of negative sequence component of the supply voltage should be greater than 0 and not exceeding 2 % of value positive sequence component. Grid code-rules for Montenegrin electrical transmission system defines that in normal operating condition as it is described in IEC 61000-333---13, maximum value for supply voltage unbalance shall not exceed 2% [4].

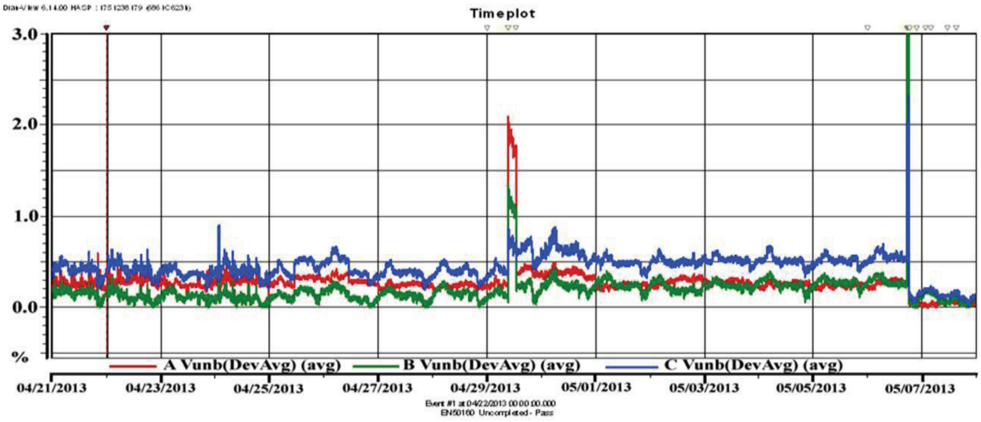

Figure 4.7 Voltage unbalance in iron work plant Niksic

Figure 4.7 shows voltage unbalance for three phases during ten days. Voltage imbalance per phase C is much bigger then imbalance per other two phases. That is obvious, because phases have unequal load. Voltage unbalance is under 1%.

If we take a look at Figure 4.8 which shows voltage unbalance during the selected day, we can have the same conclusion as for Figure 4.7. During the failure on 06.05.2013. and occurrence of overvoltage on 29.04.2013., limit for voltage imbalance is exceeded, what is expected.

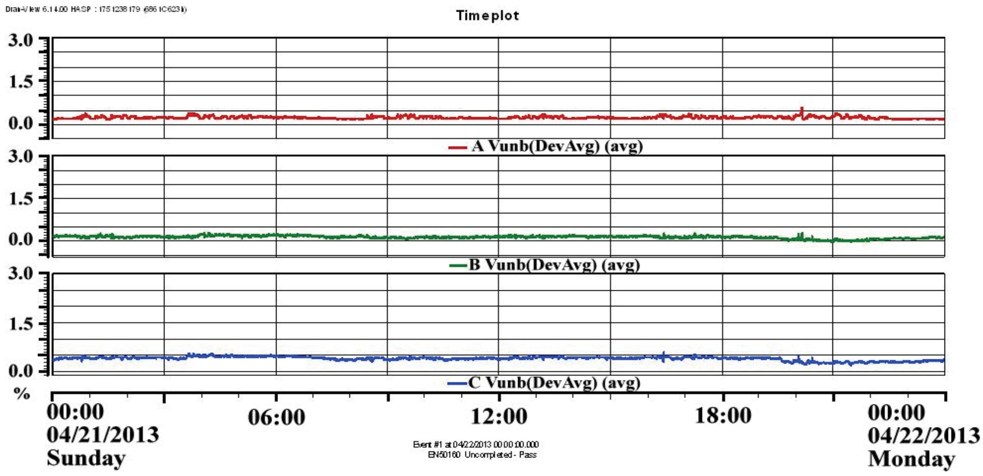

Figure 4.8 Voltage unbalance for each phase on selected day

4.4 Harmonics

One of important parameter in power quality are harmonics. High levels of power system harmonics can create voltage distortion and power quality problems. Figure 4.9 shows voltage harmonics until 30th one.

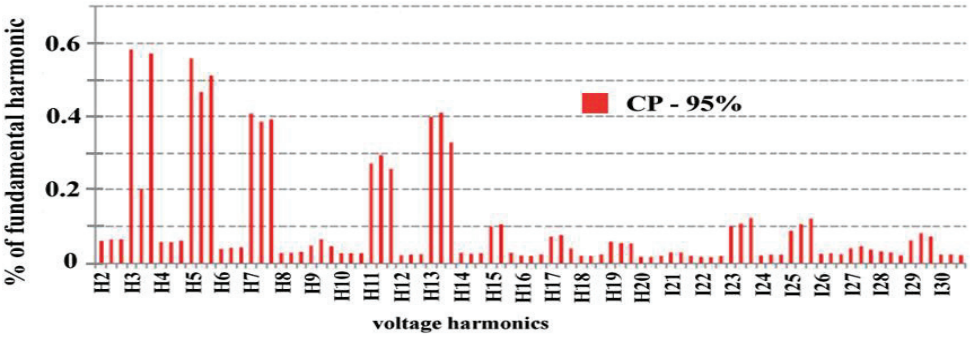

Figure 4.9 – Voltage harmonics on 110kV side on busbar section II in substation Niksic 110/35 kV [3]

During transients total harmonic voltage distortion (THDv) is higher than power quality standards, due to atmospheric discharges, manipulation and in periods when substation Niksic was de-energized.

Phase B has lower values of THDv than the other two phases, and it is shown in Figure 4.10.

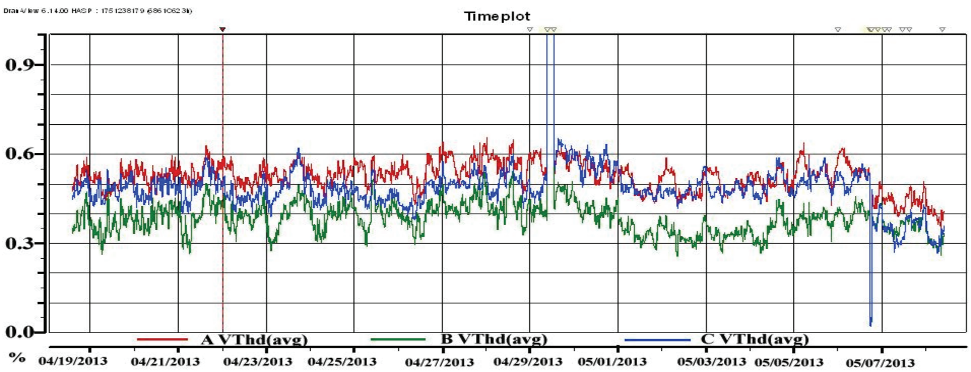

Figure 4.10 – Average values of voltage harmonics during ten days for phase A, B and C

Harmonics from 30th to 50th have values lower than 0,1% of fundamental fundamental voltage harmonic and they are under the limits for each phase. [3]

International standard EN 50160 defines that in one week during the measurement, 95% values of THDv should not exceed 3%. According to this, THDv in ironwork plant is within limits specified by IEEE (Table 4.3).

Table 4.3 Average values of THDv [3]

Average Value	0.7912	0.5855	0.7353
CP 95%	0.8698	0.684	0.862
phase	**A**	**B**	**C**

4.5 Flickers

According to IEC standards, flickers can be described with two parameters: short term flicker severity index (Pst, Figure 3.10) and long term perception (Plt, Figure 3.11). Standard EN50160 defines limit only for Plt index for 95% of time during one week of measuring:

$$P_{lt} \leq 1 \tag{4.2}$$

It has been determined that values of P_{st} and P_{lt} index rise along with furnace operating cycle.

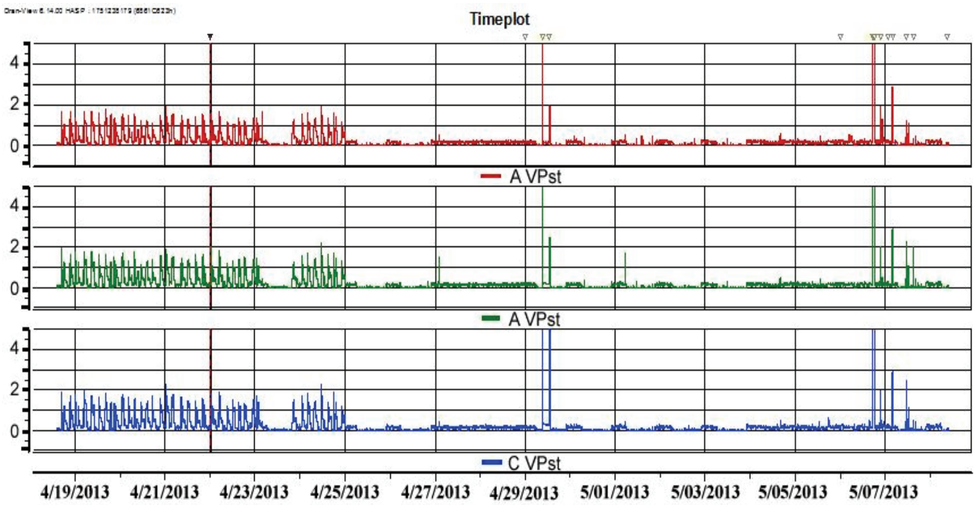

Figure 4.11 – Pst index during furnace operation

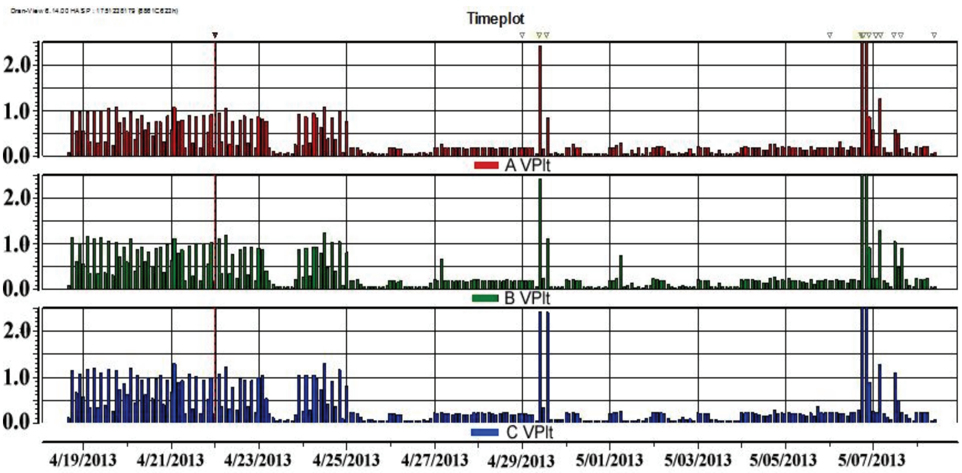

Figure 4.12 – Plt index during furnace operation

Figures 4.11 and 4.12 shows that Pst and Plt have values higher than 1 at the beginning of heat cycle when arc strikes, melting starts and the voltage flickers are evident.

But during ten days, average values of Pst index per phase A, B, C are: 0,38; 0,41 and 0,43 respectively. Average values of Plt index pre phase A, B, C are: 0,54; 0,58 and 0,60 respectively [3]. These values are in limits according to IEC standards, but temporary values in 95% of samples are above limits.

5. CONCLUSION

Operation of an electric arc furnace has influences on the power quality.

System operator CGES conducted measurements of electric power quality in iron work plant Niksic during ten days and found problems related to:

- consumption of reactive power
- power factor
- voltage and transients in voltage (spikes)
- voltage unbalance
- harmonics
- flickers

The measurements of power quality are carried out on 110 kV side.

Measurements were conducted with three-phase power analyzer (Dranetz PG4400) with its compatible software Dran-View 6.0. The results have been compared with the permitted values defined by the standards. Measurements were conducted during different operating modes.

Dranetz PG4400 offers EN50160 analysis. It is a statistical analysis of power quality data based on the EN standard. In this analysis, green bars indicate compliance, red bars indicate not compliant, black bars indicates incomplete period. The statistical package called Quality of Supply (QOS) is built into the 4400.

Testing confirms that is necessary to build-in filters. In that case, flicker level would be in acceptable limits. It is also the fastest way to solve this problem. Flickers can also be reduced by increasing power of short circuit. It is necessary to put compensation devices, and that will also have effects on power factor. Appearance of transient overvoltages can affect sensitive devices. Surge arrester should be installed on 110 kV side.

Additional measurements are planned during repair and maintenance, or during reduced power generation in HPP "Perucica". In these measurements HPP "Perucica" made a better voltage circumstances in the system.

Continuous monitoring and measuring are necessary for this consumer and that is the only way to have a proper insight into its influences on power quality.

REFERENCES

[1] V. Katić, "Kvalitet električne energije – viši harmonici", Novi Sad, 2002.
[2] www.etf.unsa.ba
[3] Elektroenergetski koordinacioni centar, Crnogorski elektroprenosni sistem, „Uticaj rada elektrolučne peći u „Željezari" Nikšić na kvalitet električne energije - Preliminarno ispitivanje", Podgorica, maj 2013.:
[4] Crnogorski elektroprenosni sistem, „Pravila za funkcionisanje prenosnog sistema električne energije", Podgorica, oktobar 2011.
[5] Dran-View 6.0, „User's guide", DRANETZ – BMI