Effects of cryptocurrency mining rig operation on power quality in LV distribution network

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***Abstract*—The paper presents the influence of power supply units of a cryptocurrency mining rig on the power quality in a standard low-voltage network. Measurement and monitoring of the power quality indices of one mining rig with an optimized power of 1000W were performed. For comparison, the results of power quality measurement of a group of desktop computers (PC cluster) from a computer centre are presented. It has been observed that the mining rig had a smaller impact on power quality (harmonics) than the PC cluster, but that they represent a significantly higher and almost constant power demand.**

***Index Terms*—Cryptocurrency mining rig; PC cluster; Power quality; Measurements.**

I. Introduction

Widespread use of computers, computer equipment, various digital electronic and mobile devices, consumer electronics, and household appliances, as well as other nonlinear systems based on energy electronic converters, has led to reports of distorted current waveforms in the network, i.e., occurrences of harmonics [1]. The consequence was a reduction in the power quality and the possibility of the appearance of some negative effects on other interconnected loads (linear), but also on the above-mentioned nonlinear ones. Computers and computer equipment are a special problem due to their frequent concentration in large groups (clusters) [2]. As individual loads, they draw pulse current waveforms from the network with a very high level of distortion, so the total harmonic distortion of this current (THDI) may reach more than 120% [1,2]. However, due to group work in different modes, with different individual parameters (diversity factor), as well as due to the phenomenon of harmonic cancellation and attenuation the THDI of a PC cluster is ranged between 30-40% [2,3]. Furthermore, as their power demand is low in relation to the short-circuit power at the connection point, these values are within the limits stipulated by the international standard IEC 61000-3-4 [1,4].

However, in recent years, the use of cryptocurrencies (Bitcoin, Ethereum, Tether, etc.) is growing, as well as the need to verify their transactions on a public digital ledger (public digital book) known as the blockchain. As this process will also create new cryptocurrency values it is called the Bitcoin, or more generally, the cryptocurrency mining [5]. Unlike individual PCs or their groups (PC clusters) where the power varies during operation, cryptocurrency mining is performed with almost constant power, i.e., with a constant engagement of microprocessor resources. In this case, two problems arise. One is the power demand or efficient operation of the device, i.e., its electricity consumption, and the other is the impact on the power quality in the connected network [6,7]. It should be noted that these devices are of low rated power, so they are connected to a low-voltage single-phase network, i.e., one cryptocurrency mining rig represents a set of 6 graphics cards, which are powered via one or two power supply units. The response to both mentioned problems depends on the quality of the rig, i.e., the optimization of its operation, as well as the construction of the power supply (AC/DC converter with PFC).

There are many papers in the scientific literature that treat the first problem, and a lot of articles and reviews on professional sites (blogs) and journalism are dedicated to that. For the sake of objectivity, only those papers that have been published in the reference scientific literature will be considered here [6-11]. The impact of increasing network losses as a result of the operation of these devices was mainly considered in [6], long-term trends related to changes in the amount of energy per transaction in [8], the cost-effectiveness of mining concerning electricity prices in certain countries and environmental factors in [9], and mining of other cryptocurrencies, beside of Bitcoin in [10]. The issue of the effects on the power quality was less prominent and not researched in more detail. Some results presented in [7] show that such a low interest was a consequence of the higher quality power supply unit applications than in standard PCs, so the recorded current distortion had been less than THDI<10% [7]. However, in the case of larger cryptocurrency mining operations, the distortion of electricity may be more significant, even beyond the standards' permissible limits. This was observed in [11], but more detailed measurements and analyses have not been performed.

This paper aims to present the impact of the cryptocurrency mining rigs, i.e., their power supply units, on the power quality in a low-voltage distribution network and to compare it with the effects of conventional desktop (PC) computers. To enable this, the results of multi-day measurements were used, as well as the appropriate analysis of the measured results in the time and frequency domain.

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 ISBN 978-86-7466-930-3

II. MEASUREMENTS OF POWER QUALITY INDICES

Professional device C.A. 8332 by Chauvin Arnoux [12] was used to measure electricity quality indices, which follow the European standard EN 50160 [1,4]. The measurements were performed over a period of seven days, continuously at the place of connection of the device, i.e., at the busbars of the distribution cabinet in the low voltage network. The power quality indices of a PC cluster placed in the computer centre and a cryptocurrency mining rig were measured. The measured values included the effective value of voltage and current, frequency, power, power factor (PF), flicker, harmonics of voltage and current, and k-factor. However, due to limited space, only the most significant measurement results will be presented here, namely, those related to work efficiency (active P, reactive Q, distortive D, and apparent power S, as well as PF), i.e., electricity consumption (kWh, kVAh), and the impact on the power quality (total harmonic distortion of voltage and current, THDU, THDI).

A. Measurement results for the computer centre

As part of the activities on the subject of master's academic studies "Quality of electricity", measurements of power quality indices are regularly conducted on the internal network of the Faculty of Technical Sciences. For the purposes of this paper, obtained measurement results at the distribution cabinet of the computer centre during November/December 2019 will be used. Fig. 1 shows the measuring point, and Fig. 2 shows the waveform of the voltage and current of the single-phase network. In the line shown, 42 computers are connected, which have different power supply units HP Lite-On PA 1181-7 and Fujitsu D12-250 P1A with powers of 180 W and 250W, respectively. During the measurement, not all of them were turned on, that is, 28 computers were working continuously. The operation of these computers is characterized by high current distortion (Fig. 2), so in addition to active and reactive power, there is also distortion power.

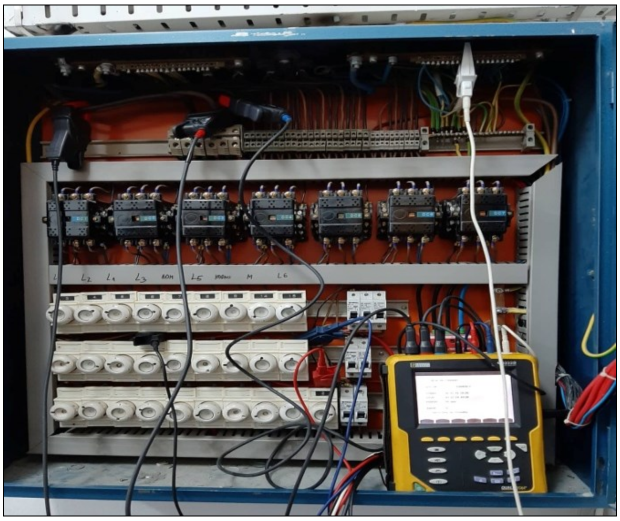

Fig. 1. Photo of measurement location during measurement at the computer centre

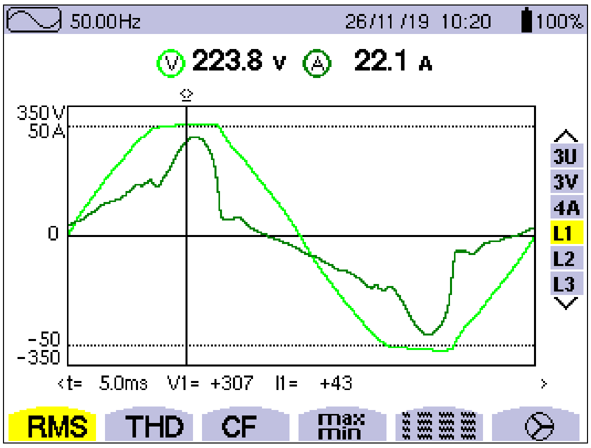

Fig. 2. Voltage and current waveforms of a single phase at the computer centre

Fig. 3 (up) shows the variation of the apparent (S), active (P), and reactive (Q) power, as well as distortion power (D) during a one-week measurement, while Fig. 3 (down) shows their statistical analysis. It can be seen that over 50% of the time computers work in standby (idle) mode, that they are capacitive as the reactive power is Q<0 (this can be also seen from Fig. 2, where the current waveform precedes the voltage one), and that the measured distortion power (D) is negligible. In addition, the measured power factor (PF) presented in Fig.4 indicates significant effects of the PC supply unit capacitance, but also the current harmonic distortion. Fig. 4 shows its variation during the one-week measurement and the statistical analysis. It can be seen that PF was below 0.95 all the time, which indicates a potential problem. In order to better understand all statistical values, Table I gives the most significant results of statistical analysis for all types of power (S, P, Q, and D), as well as for the power factor. It can be seen that power demand is much higher than average power, which shows variation in computers usage.

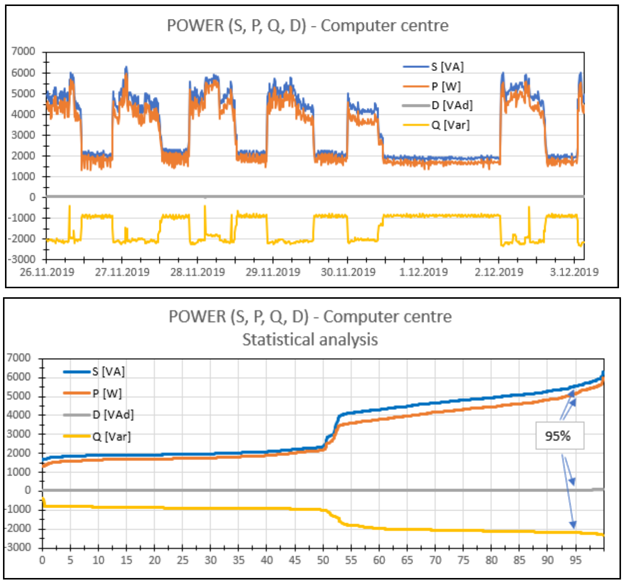

Fig. 3. Variation of the computer centre power demand during one-week measurements: time wave-form (up) and statistical analysis (down)

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TABLE I
STATISTICS FOR POWER (S,P,Q,D) AND POWER FACTOR OF THE COMPUTER CENTRE

Power	Mini-mum	Median (50%)	Average	95% value	Maximum
S [kVA]	1657.3	2348.4	3373.1	5544.1	6290.9
P [kW]	1337.2	2180.7	3029.3	5157.8	5992.5
Q [kVAr]	-381.1	-995.6	-1448.4	-2195.3	-2328.4
D [kVAd]	39.2	50.9	58.6	73.7	75.7
PF	0.79	0,89	0,889	0,936	0,952

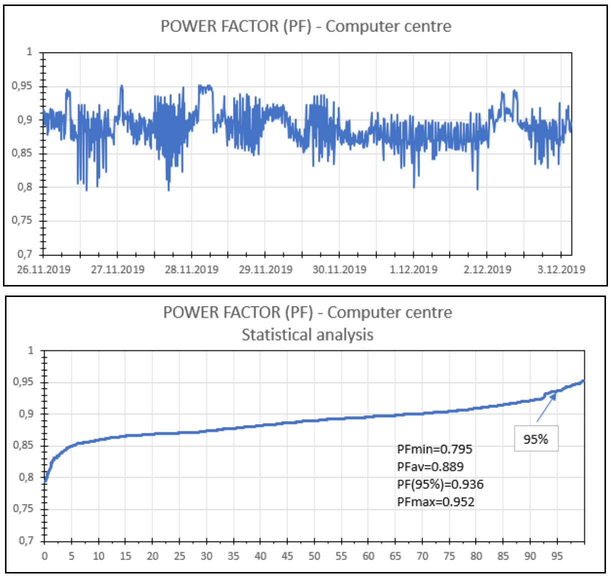

Fig. 4. Variation of the computer centre power factor during one-week measurements: time wave-form (up) and statistical analysis (down)

The observed waveforms of current and voltage (Fig. 2) indicate the existence of harmonic distortion, which is pronounced in the current pulsed waveshape, while in voltage it can be seen as a "flattened top" of the sinusoid. Both distortions are a consequence of the operation of power supply units (in PC and the monitor), which are usually realized as a diode bridge rectifier with a capacitive filtering (for "ironing" of the DC voltage) and additional DC/DC converter (for obtaining different voltage levels). Due to the parallel operation of a large number of computers, the mentioned phenomenon of harmonic cancellation and attenuation is present, so the values of THDI and individual harmonic distortion of the current (HDI) are less than in the case of individual computers. Figs. 5 and 6 show the variation of the THDU (Fig. 5) and THDI (Fig. 6) during one-week measurements. If the results are compared with Fig. 3, it can be seen that the distortions are smaller in the standby ("night" mode) (THDU≈2.2%; THDI≈22%), and that they increase during the working days when the PCs are in active use (THDU≈2.8%; THDI≈45%).

B. *Measurement results of cryptocurrency mining rig*

Cryptocurrency mining uses a dedicated computer assembly (rig) consisting of a power supply unit, mainboard, and graphics cards. Fig. 7 shows an illustrated block diagram of this device. A set of six graphic card units (GCU) were in operation during the measurement, which was powered by two high-quality power supplies: HPE model “ProLiant” DL580 G7 (1200W, Platinum, η=94%) and “Be Quiet!” model Straight Power 11 (650 W, Platinum, η=94%) connected to a single-phase network (230V, 50 Hz). The maximum power of both supplies is 1850W, but they are optimized to work on 1000W. Fig. 8 shows the photo of the treated rig and the location where C.A 8332 was connected.

The main characteristic of the rig´s operation is the constant engagement of the GCU processor, which leads to higher electricity consumption, but also significant thermal losses. For this reason, applied power supply units are of high efficiency (94% -95%), but also with a more complex schematic. They have an additional power factor correction (PFC) unit, which enables close to unity power factor, but also contributes to the significant reduction of harmonic distortion.

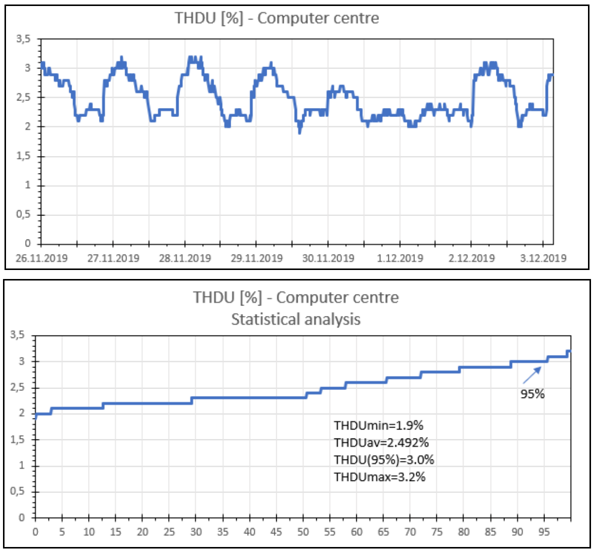

Fig. 5. Variation of the computer centre THDU during one-week measurements: time wave-form (up) and statistical analysis (down)

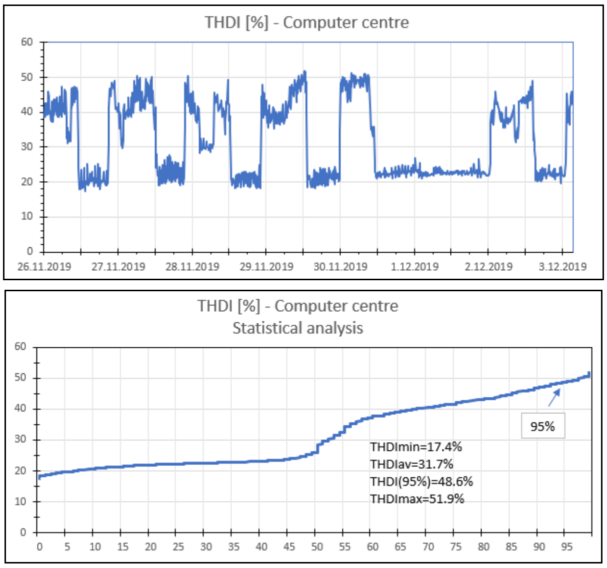

Fig. 6. Variation of the computer centre THDI during one-week measurements: time wave-form (up) and statistical analysis (down)

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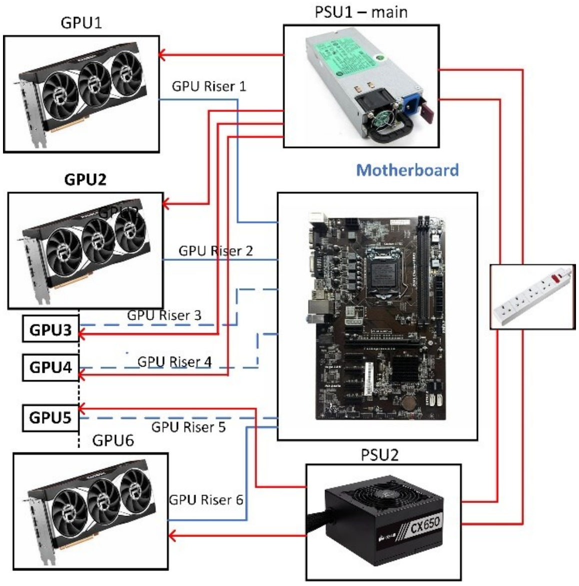

Fig. 7. Block scheme of the cryptocurrency mining rig

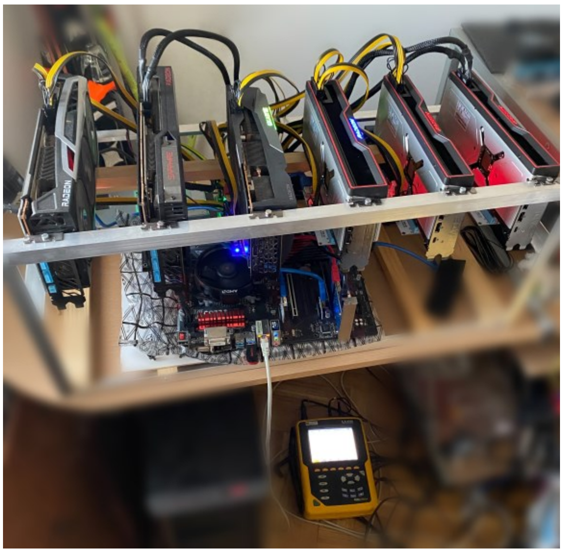

Fig. 8. Photo of measurement location during cryptocurrency mining rig measurement

The measurement results are shown in Figs. 9-14. Fig. 9 shows the waveforms of voltage and current, which are characterized by the flatness of the sinusoidal top and very low current distortion and displacement. Fig. 10 shows the measurement results for different types of power, while Fig. 11 the power factor. It can be seen that there were some short periods with lower power demand, which corresponds to some problems with the Internet and shutting down at the end of the measurement. In order to better understand the statistical values, Table II gives the most significant results of statistical analysis of measured power and power factors for the cryptocurrency mining rig. It can be noticed that the rig works with practically constant power and a close to unity power factor (0.988).

Figs. 12 and 13 show the results of the voltage and current harmonic distortion of the cryptocurrency mining rig. The variation of the THDU during one-week measurements is shown in Fig. 12, while the THDI is in Fig. 13. A low voltage and current distortion can be observed. However, significant increases in current distortion can be observed during the measurement and at the end (Fig.13). These are the periods when there was a significant reduction in processor activity of the GCU i.e., in the mining, when the system operates with lower power (see Fig. 10) and outside the optimal parameters. However, these periods do not significantly affect the overall assessment of current distortion.

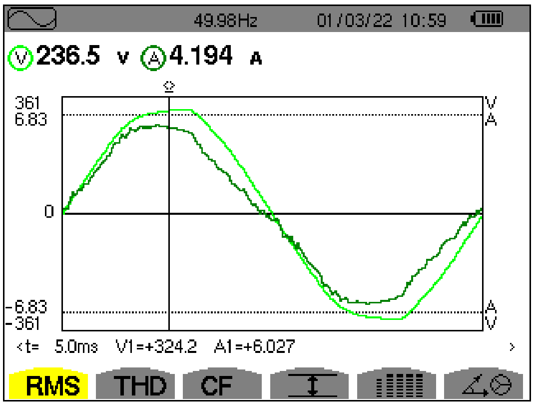

Fig. 9. Voltage and current waveforms of the cryptocurrency mining rig

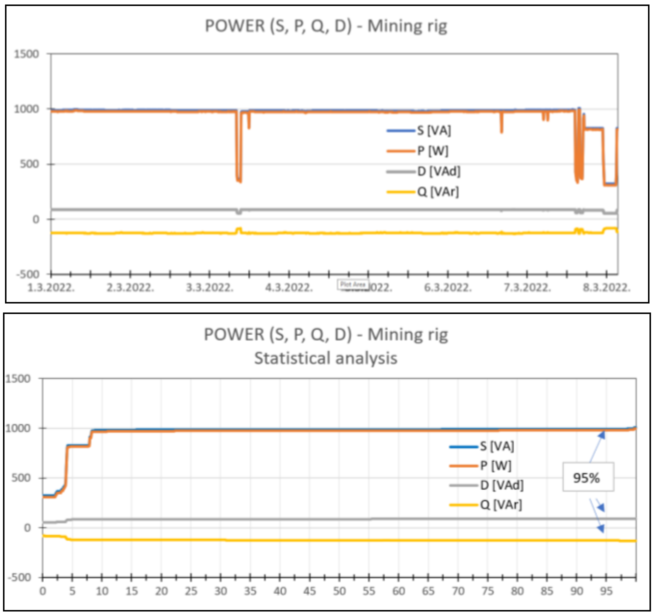

Fig. 10. Variation of the cryptocurrency mining rig power demand during one-week measurement: time wave-form (up) and statistical analysis (down)

III. Discussion

A. Comparison of PC cluster and Mining rig by distortion

Commercial PCs, which are widespread and present in many locations are well-known as current and voltage distortion sources in low voltage distribution networks [1]. If they are clustered, the distortion is much less than if a single one is considered [2]. Yet, the current harmonic distortion limits stipulated by international standards are not surpassed.

Still, the voltage distortion is increased (depending on the power demand of the PC cluster) and may contribute to the appearance of some negative effects at other connected loads. The remaining problems are high and distorted current in the neutral conductor and poor power factor.

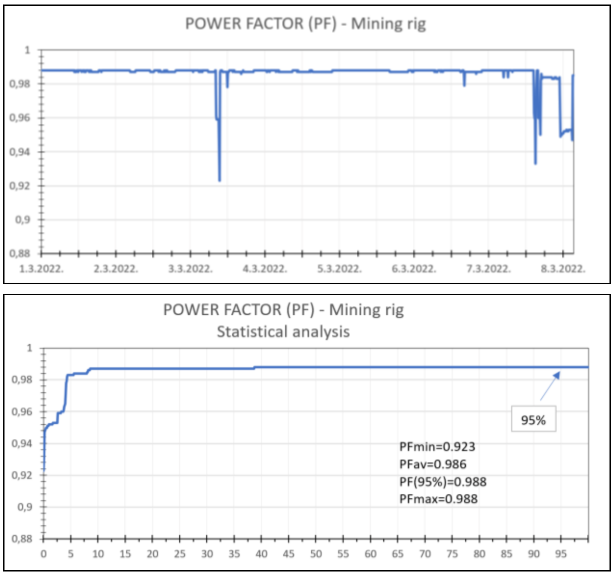

Fig. 11. Variation of the cryptocurrency mining rig power factor during one-week measurements: time wave-form (up) and statistical analysis (down)

TABLE II
STATISTICS OF POWERS (S,P,Q,D) AND POWER FACTOR OF THE CRYPTOCURRENCY MINING RIG

Power	Mini-mum	Median (50%)	Average	95% value	Maximum
S [VA]	323.8	987.8	956.1	992.7	1007.0
P [W]	308.4	975.7	943.9	980.9	994.9
Q [VAr]	-81.3	-125.4	-123.9	-128.6	-1431.3
D [VAd]	53.3	87.8	86.3	88.5	89.6
PF	0.923	0.988	0.986	0.988	0.988

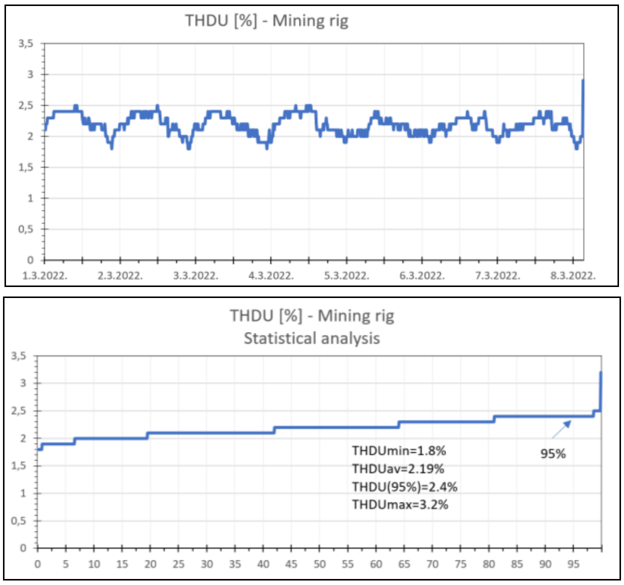

Fig. 12. Variation of the cryptocurrency mining rig THDU during one-week measurements: time wave-form (up) and statistical analysis (down)

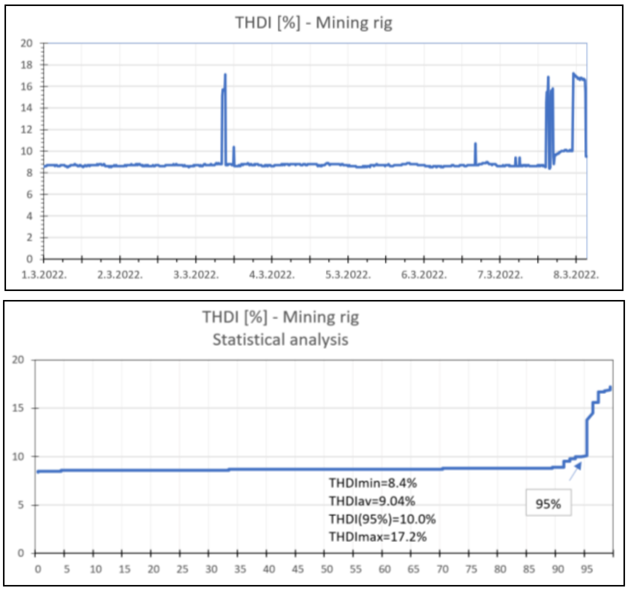

Fig. 13. Variation of the cryptocurrency mining rig THDI during one-week measurements: time wave-form (up) and statistical analysis (down)

In the case of the connection of the cryptocurrency mining rig to the low voltage distribution network the measured harmonic distortion factors and power factor are good and in accordance with international standards. It shows that the power supply units of the rig are carefully selected to enable optimum operation.

Table III shows a comparison of main power quality indicators recorded during measurements of the PC cluster and the cryptocurrency mining rig. It can be seen that the cryptocurrency mining rig has superior performance. Such a conclusion is not a surprise as the power supply units of the mining rig are of much higher quality than the ones of the PC in the cluster.

TABLE III
COMPARISON OF DISTORTION FACTORS AND POWER FACTORS OF THE PC CLUSTER AND THE MINING RIG

	THDU (95%)	THDU (Max.)	THDI (95%)	THDI (Max)	PF 95%	PF (Max)
PC cluster	3.0%	3.2%	48.6%	51.9%	0,936	0,952
Mining rig	2.4%	3.2%	10.0%	17.3%	0.988	0.988

B. Comparison of PC cluster and Mining rig by power and electricity consumption

The PC cluster and the cryptocurrency mining rig comparison by power demand and electricity consumption is more interesting. The measurement results show that the power demand of the cryptocurrency mining rig is much higher. Moreover, it is constant over time, so the low-voltage distribution network may see it as a high (~1000W) load of a resistive nature (like some heater).

Fig. 14 (up) shows a comparison of a PC cluster and the cryptocurrency mining rig's active power demand. The power demand of the PC cluster is downsized to the one comparable with the cryptocurrency mining rig (~1000 W). Fig.14 (down)

 ISBN 978-86-7466-930-3

shows the same comparison, but regarding the electricity consumption. It can be seen that the power demand of the cryptocurrency mining rig was in some periods much higher, while in others similar to the PC cluster. Regarding electricity, the consumption was much higher (almost twice).

C. *Effects on voltage distortion (THDU)*

Considering the above observations, it is rational to assume that the operation of the PC cluster, as well as the cryptocurrency mining rig, may have some effects on the low-voltage distribution network voltage harmonics. From Fig.5 it can be seen that there is a high difference between the voltage harmonic levels during the night (PCs are in idle mode) and during the day. It can be estimated that the PC cluster operation increase voltage harmonics from $THDU_{night}$=2.3% to $THDU_{day(95\%)}$=3.0%, i.e., for 30%, up to $THDU_{day(max)}$=3.2%, i.e., for almost 40%.

In the case of the cryptocurrency mining rig, there are no differences between night and day, so it is difficult to estimate the rig´s effect on voltage harmonics. Still, from Figs.10 and 14, it can be noticed some periods with low power operation (when the mining process has been ended and the rig had continued operation in an idle mode), i.e., with a reduced effect on voltage harmonics. Therefore, observing corresponding Fig.12 it can be estimated that the cryptocurrency mining rig operation increase voltage harmonics from $THDU_{min}$=1.8% to $THDU_{day(95\%)}$=2.4%, i.e., for around 33%, up to $THDU_{day(max)}$=3.2%, i.e., 78%!

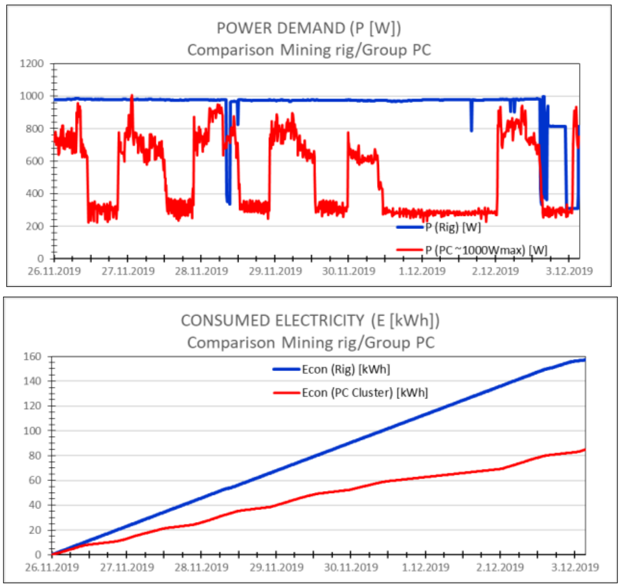

Fig.14. Comparison of the cryptocurrency mining rig and a PC cluster of the same size: of power demand (up) and consumed electricity (down)

IV. Conclusion

The paper presents research results of the cryptocurrency mining rig's effects on the power quality at the low-voltage distribution network. The most important power quality indices obtained during one-week measurements are recorded and discussed. For comparison, similar research has been worked out for a PC cluster.

The research results show that cryptocurrency mining rig has higher power demand and electricity consumption than the similar-sized PC cluster. The power factor is much better (close to unity) than the PC cluster has (below 0.95). It has a lower effect on current distortion (THDI), while the effects on voltage distortion (THDU) are similar to the PC cluster ones.

However, the THDU of the cryptocurrency mining rig might increase significantly if more rigs are connected at the same bus and endangered power (voltage) quality for other loads. Further research will be focused on this problem.

Acknowledgement

This work was supported by the Republic of Serbia, Ministry of Education, Science, and Technological Development, through the Integrated and Interdisciplinary Research project entitled “Innovative Scientific and Artistic Research from the Faculty of Technical Sciences Activity Domain” under Grant No. 451-03-68/2022-14/200156.

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