MEASURING OF THE NETWORK STATIONARY STATE IN THE JAFA FACTORY IN CRVENKA

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INTRODUCTION

Measuring of electric power and energy is always an issue in a distribution network, where the standards metrologic device "there is never enough accuracy and speed" is applied. However certain authors are in favour of less extreme approach – "there should be as much as accuracy and speed as necessary". Based on latter approach, hypotheses is made that it is sufficient to have a standard A/D converter with a double incline, for the construction of a Wattmeter for the meters in the distribution network measuring power and energy respectively. Practically speaking, this means that, in the interval of measuring "the current power" or the effective value of the voltage and current, in a time frame, the form of the voltage and current signal must not change significantly. That is why it is necessary to research the dependence of the middle value of the active power change, the effective value of voltage, effective value of currents and frequency (i.e. the period), in relation to the size of the time frame.

For the reasons listed above, recording was made in the Jaffa factory in Crvenka of the effective value of all three phase currents, all three phase voltages, all three active powers, by phase and frequency, 10 times per second, in continuum of 30 days. To conduct the measuring, a device called VMP was used (this device will be dealt with later on) – utilizing the principle of the stochastic additive A/D converter (1). The measuring and recording was done at the 0.4kV outlet from the power distribution station, from which the factory obtains its electric power supply, and which has only this outlet at the secondary. About 1.8 GB of date was collected, which is considered to be satisfactory sample for the stationary state analyses. This is more so since the factory has a very diverse consumption , with gas being the main energy source.

ORGANISATION OF MEASURING

The instrument VMP 20 (INCELL-Novi Sad), was used for measuring. This instrument displays 4 values : voltage, current, power and power factor. Its supply is 220V, Hz, with 2 input: currents and voltage, both

"floating". The peak in the voltage level is 400V and 5a in the power level. When connected to a computer, assisted by the VMP 20 Ver .4.0 software, it measures and displays on the monitor 6 more values:

- frequency,
- moduo impedances,
- reactive power,
- apparent power,
- active energy,
- reactive energy

Every 2 seconds, the instrument records on the hard disc the basic values that are the characteristic of the user over a period of time:

- real time
- voltage
- current
- active power
- factor of power
- frequency

From the above text, the possible applications of the VMP 20 instrument are as follows:

- expert analyses of mono-phase consumers' consumption.
- expert analyses of the three-phase users' consumption, without the zero lead and with the use of 2 VMP 20 instruments, connected in the Aaron's link.
- expert analyses of three-phase users' consumption, with the zero lead, and with use of 3 VMP 20 instruments.

Figure 1 shows the look of the interface of the VMP 20, Ver 4.0 programme itself.
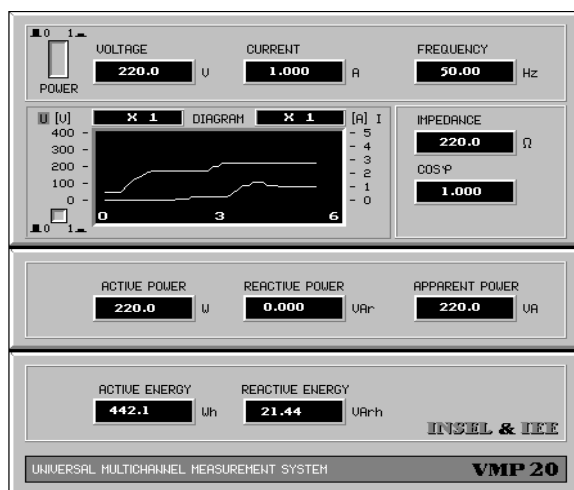

Figure 1-VMP 20 (users interface)

For all the 3 variants of the possible utilization, supporting software is provided. The supporting computer can be any IBM-PC compatible, starting from an XT, to Pentium, on the condition that it has a graphic card of the VGA resolution.

- having in mind that the instrument measures distorted wave forms, it can be used to control the above mentioned parameters of non-linear consumers such as PWM inverters, various tri-storic regulators and other non-liner consumers which are found in regulated electro-motor drives (in steal factories, electric-powered locomotives, electric cars and so on).
- further application is in the quality control of repaired or new transformers, induction motors, dimmers, and so on.
- having in mind the accuracy of the instrument, which is 0.1% of the peak +0.1% of the recorded value, it can be used to control the meters in the electric-distribution network.
- it can be used for drive measurings in large power and energy consumers (it has been tested in power-supply stations of 110kV and 400kV showing an absolute accuracy and confirming the defined performances).
- the instrument can be used for on-line monitoring of all the above mentioned values,

- with a purpose to menage the power and/or energy consumption, i.e. with a purpose of limiting or simply stating some of the above mentioned values.

DESCRIPTION OF THE DATA-PROCESSING PROGRAM

In the realization of the data-processing program obtained from VMP 20, Turbo Pascal was used – the Windows 98 version. The processing process itself consisted of three parts.

The first part was related to the processing in the sense of finding out middle values within the set time intervals of monitoring. The middle value of the signal in a time frame is taken in order to eliminate the noise that is generated by the measuring instrument itself. The suggested time intervals for measuring are the intervals of:
- 0.5 seconds
- 1 second
- 1.5 seconds
- 2 seconds

The data necessary for the processing is stored in data banks VMP_XXXX.DAT, where XXXX stands for the four-digit number. The first processing data bank started with the number 1000. The data bank itself is a text-type one – its look is shown in the table below:

```
13: 0:28:43 229.5 227.3 228.8 0.39 0.28 0.59  76.8  76.8 121.4 3044
13: 0:28:54 229.5 227.3 228.8 0.37 0.28 0.59  75.0  78.6 121.4 3044
13: 0:28:65 229.1 227.3 228.8 0.37 0.28 0.59  75.0  76.8 121.4 3044
13: 0:28:76 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 121.4 3044
13: 0:28:81 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 123.2 3044
13: 0:28:92 229.4 227.3 228.7 0.39 0.28 0.59  76.7  76.7 121.4 3045
13: 0:29: 3 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 121.4 3044
13: 0:29:14 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 121.4 3044
13: 0:29:25 229.5 227.3 228.8 0.37 0.28 0.59  75.0  76.8 121.4 3044
13: 0:29:31 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 121.4 3044
13: 0:29:42 229.5 227.7 228.8 0.39 0.28 0.59  75.0  78.6 121.4 3044
13: 0:29:53 229.1 227.3 228.8 0.39 0.28 0.59  75.0  76.8 123.2 3044
13: 0:29:64 229.5 227.3 228.8 0.39 0.28 0.59  75.0  78.6 121.4 3044
13: 0:29:75 229.1 227.7 228.8 0.37 0.28 0.59  75.0  76.8 121.4 3044
13: 0:29:85 229.1 227.3 228.8 0.37 0.28 0.59  75.0  78.6 121.4 3044
```
TABLE 1 – the look of one part of the data bank VMP_XXXX.DAT

The first eleven characters are reserved for the time when the device measured the voltage, the current and the power of all the three phases, as well as the frequency.

After the time of signal selection, there are three values of the voltage (first, second and third phase), then three values of the current (first, second and third phase) and then the three values of the power (first, second and third phase) – finally, at the very end, there is the value of the frequency at the given moment of time.

This structure is common for all the data banks. It is necessary to process the data banks that have been recorded over a ten-day period – this form of processing contained precisely one thousand data banks. Each of the data banks had about 900 lines, and each line had 10 pieces of information relevant for the processing. Based on this, it is evident that there is a total of some 90,000,000 pieces of data to be processed, for each individual time frame. On this occasion, namely, it was necessary to perform four rounds of processing 90,000,000 pieces of data. Fortunately, owing to a relatively fast processor, the processing took no more than 15 minutes.

Following the above mentioned processed output, the obtained result of processing was in the form of four data banks of the textual type, containing data or, more precisely, the differences between the two middle values of every two adjacent time frames.

The number of the newly-obtained varied, depending on the size of the time frame, and it was between 4,499,990 and 17,999,990.

The look of the data bank containing the results of the first processing round is given in the table below:

```
0.0050 0.0800 0.0150 0.0020 0.0000 0.0010 0.0850 0.2650 0.1800 0.0500
0.0200 0.0000 0.0400 0.0025 0.0000 0.0010 0.0900 0.0900 0.0000 0.0000
0.1150 0.0000 0.0050 0.0000 0.0000 0.0000 0.0900 0.0000 0.0000 0.0000
0.2500 0.2950 0.0150 0.0020 0.0000 0.0000 0.0000 0.1750 0.0000 0.0500
0.1050 0.1250 0.1700 0.0015 0.0000 0.0000 0.2700 0.1750 0.0000 0.3500
0.0200 0.0200 0.2200 0.0020 0.0000 0.0000 0.0900 0.0900 0.0000 0.7000
0.0200 0.0200 0.0200 0.0000 0.0000 0.0005 0.1800 0.0900 0.0000 0.0000
0.0000 0.0200 0.0200 0.0045 0.0000 0.0055 0.2700 0.2700 2.5150 0.1000
0.0000 0.0200 0.0000 0.0035 0.0000 0.0040 0.0900 0.2700 1.1750 0.0500
0.0450 0.0200 0.1000 0.0035 0.0000 0.0000 0.0900 0.0000 0.0900 0.0000
0.0050 0.0000 0.0400 0.0055 0.0000 0.0000 0.4500 0.0000 0.0900 0.2500
0.2400 0.0200 0.0800 0.0010 0.0000 0.0275 0.0000 0.0000 6.5450 0.3500
0.0950 0.0200 0.0600 0.0025 0.0000 0.0025 0.1800 0.0000 0.6850 0.2500
```
TABLE 2 – the look of output data bank of the first processing round.

- the first column contains the differences between all middle values of the first phase voltage in two adjacent time frames.
- The second column is related to the differences in middle values of the second-phase voltage, whereas the third column refers to the differences in middle values of the third phase.
- In columns four, five and six, there are differences of the current middle values form the first, second and third phase.
- In columns seven, eight and nine, we have differences in power values of the first, second and third phase.
- In the final, tenth column, there are differences in middle values of the power in the first, second and third phase.

By obtaining all four output data banks, the first part of data processing was completed.

The second part of the program refers to the processing of data obtained in its first part. More precisely, the second part deals with the distribution of the differences. The intervals of differences themselves are taken in accordance with the observed value. There are fifteen such intervals. The frequency, voltage and power have the same intervals, while different intervals were taken for the current, because the intervals taken for the frequency, voltage and power are too rough for current.

The distribution is done in accordance with the following intervals:

for current:	for voltages, powers and frequency:
1. from 0 to 0.0005	1. from 0 to 0.1
2. from 0.0005 to 0.001	2. from 0.1 to 0.2
3. from 0.001 to 0.0015	3. from 0.2 to 0.3
4. from 0.0015 to 0.002	4. from 0.3 to 0.4
5. from 0.002 to 0.003	5. from 0.4 to 0.5
6. from 0.003 to 0.004	6. from 0.5 to 1
7. from 0.004 to 0.005	7. from 1 to 2
8. from 0.005 to 0.01	8. from 2 to 4
9. from 0.01 to 0.02	9. from 4 to 6
10. from 0.02 to 0.05	10. from 6 to 10
11. from 0.05 to 0.1	11. from 10 to 15
12. from 0.1 to 0.5	12. from 15 to 20
13. from 0.5 to 1	13. from 20 to 25
14. from 1 to 3	14. from 25 to 30
15. from 3 to max.	15. from 30 to max.

The results are stored in textual data banks, according to the time frame used in the processing. It has been noticed that, although the frequency has a very fine behaviour, there are difference values larger than 30, which is practically impossible. Through a more detailed analysis, it was discovered that the two values are probably the mistakes coming from the instrument itself so, after a consultation, it was decided not to take these into account and to continue the analyses without them.

After two more processing rounds, contained in a single program, another program was written, which produced an even more precise result. This program had a task to calculate the middle value of the change in a given signal. The middle value of the change in the signal was calculated in the following way:

$$SVP(a) = \sum_{i=1}^{15} \frac{\Delta_i \cdot n_i}{ub}$$

$$\Delta_i = \frac{\min vrednost \, int + \max vrednost \, int}{2}$$

(1)

where:
- *min value int, max. value int.*: minimum value of interval, maximum value of interval.
- n is the number of differences in the observed interval.
- ub is the total number of data pieces (for a time frame of 1 second it is 899999)
- a is the observed signal

The values were calculated for all types of signals and for each phase. As a result of this processing, four textual data banks are obtained, one for each of the time frames. In the data banks, there are ten values, each of which showing the middle value of the change of each signal separately. With a distribution like this, it was easy to establish how the signals change. For the aesthetic purposes, as well as for the purposes of clarity, the data

was additionally processed, using Microsoft ® Office 2000/ EXCEL. This data will be shown in the following parts of the work.

DISPLAY OF DATA

The results whose follows was obtained with usage of Microsoft® EXCEL-u. The next figures are for window of 0,5s wide.
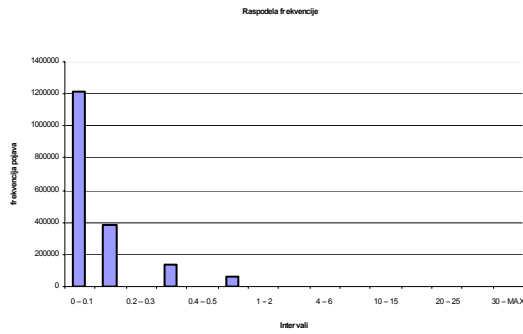

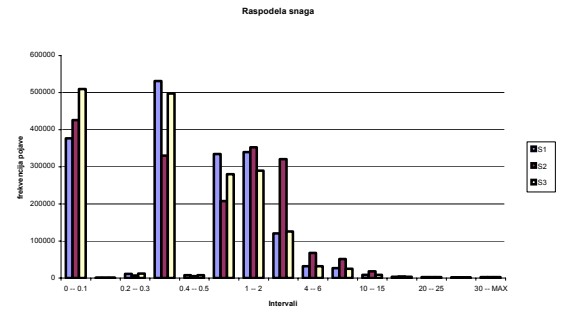Figure 2- Display of difference distribution of frequency over intervals

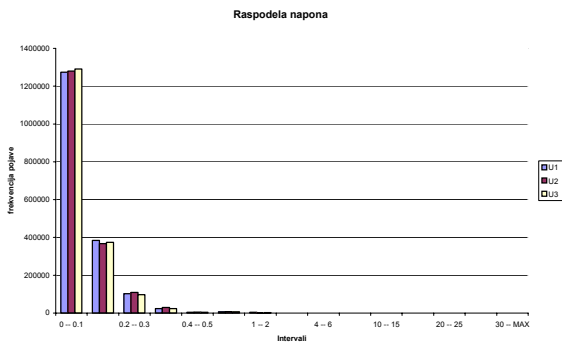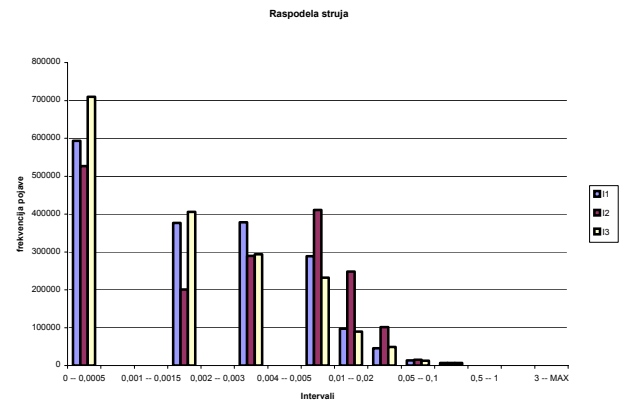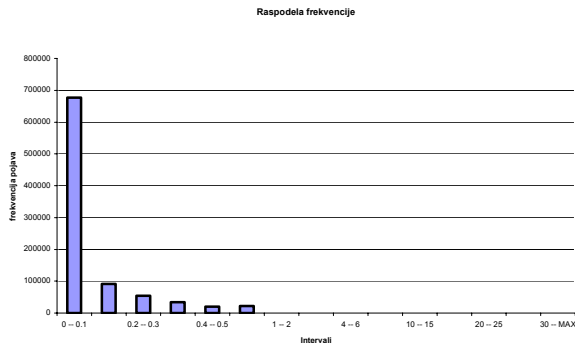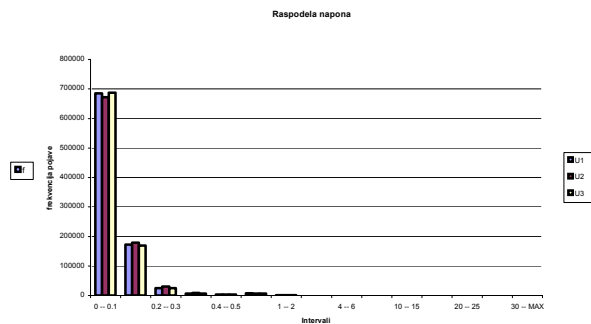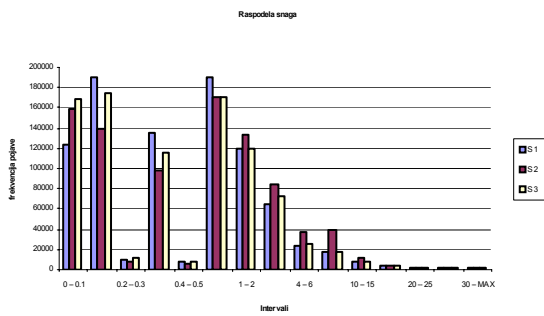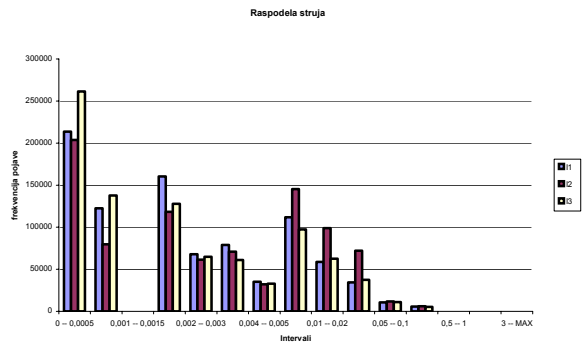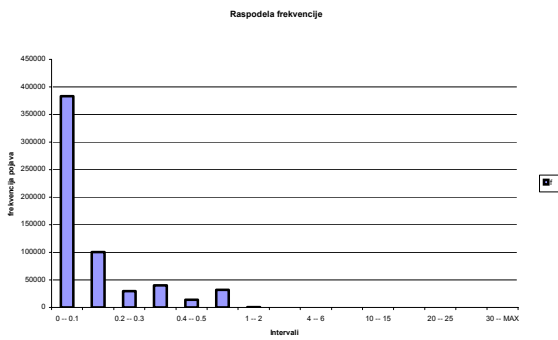Figure 4-Display of difference distribution of power over intervals

Figure 3-Display of difference distribution of voltage over intervals

Figure 5-Display of difference distribution of current over intervals

The next four figures represent distribution of measurement quantities: frequency, voltage, power and current for time windows of 1s wide.

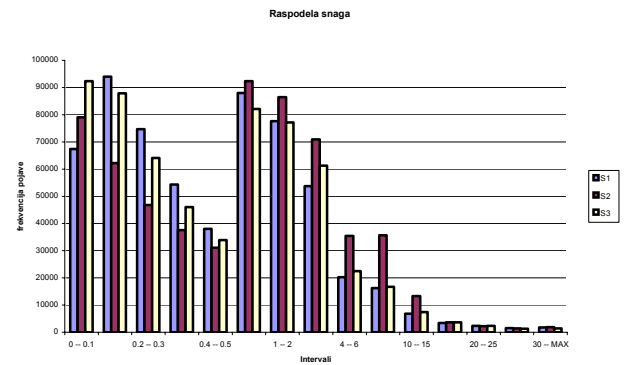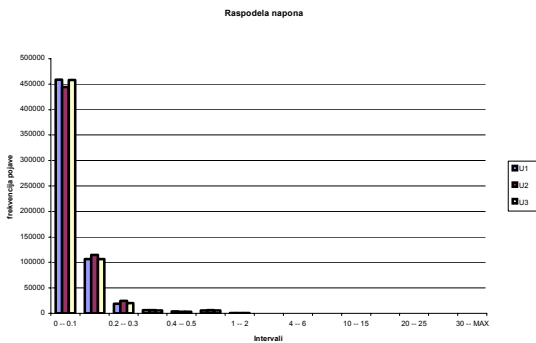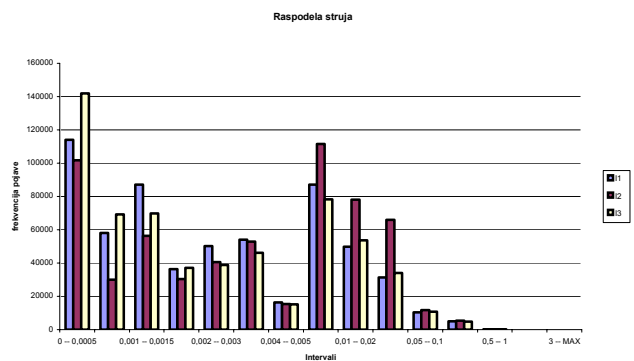Figure 6- Display of difference distribution of frequency over intervals

Figure 7-Display of difference distribution of voltage over intervals

Figure 8-Display of difference distribution of power over intervals

Figure 9-Display of difference distribution of current over intervals

The next four figures represent distribution of measurement quantities: frequency, voltage, power and current for time windows of 1,5s wide.

Figure 10-Display of difference distribution of frequency over intervals

Figure 12-Display of difference distribution of power over intervals

Figure 11-Display of difference distribution of voltage over intervals

Figure 13-Display of difference distribution of current over intervals

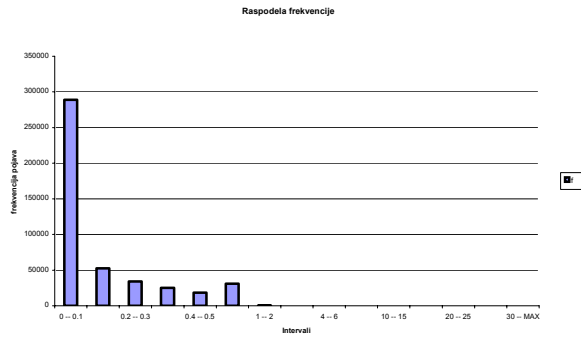The next four figures represent results for time windows of 2s wide.

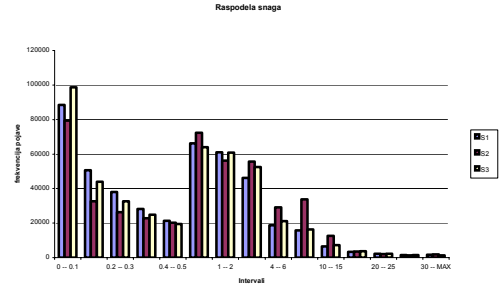Figure 14-Display of difference distribution of frequency over intervals

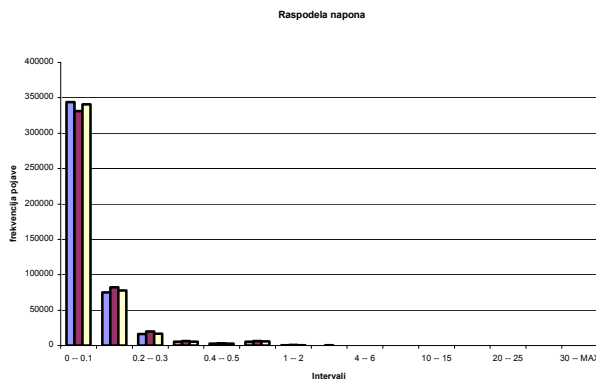Figure 16-Display of difference distribution of power over intervals

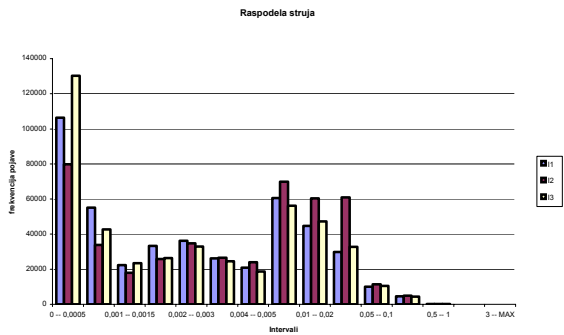Figure 15-Display of difference distribution of voltage over intervals

Figure 17-Display of difference distribution of current over intervals

In the followed text we will display results obtained by usage of equations for calculating of the middle value of the change.
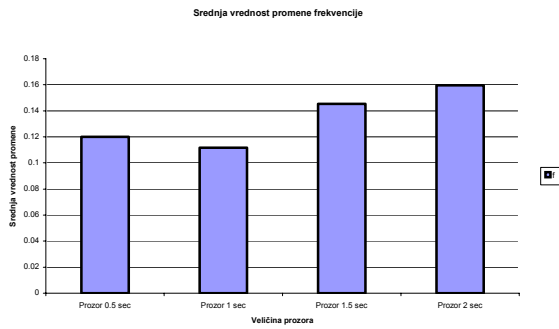

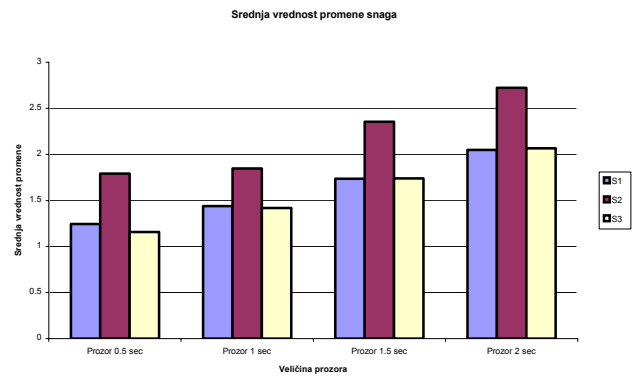Figure 18-Display of the middle value of the frequency change

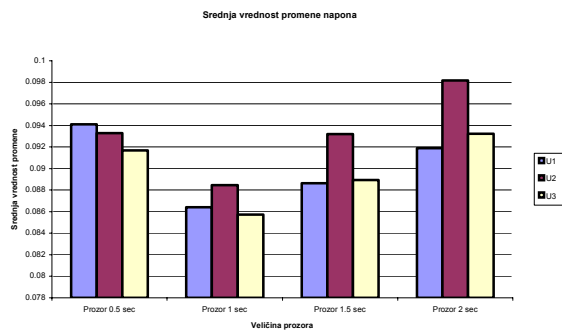Figure 20-Display of the middle value of the power change

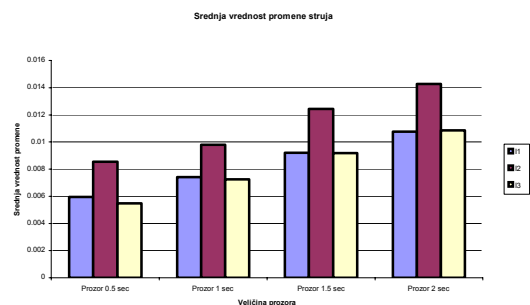Figure 19-Display of the middle value of the voltage change

Figure 21-Display of the middle value of the current change

The following table shows the results obtained by the use of the SVP program – the program used for processing the data obtained by scribbling the program for processing data banks made by VMP 20 recording.

middle values of change	frame 0.5sec	frame 1 sec	frame 1.5sec	frame 2 sec
U1	0,09411	0,08641	0,08864	0,09189
U2	0,09329	0,08844	0,0932	0,09815
U3	0,09168	0,08572	0,08894	0,09321
I1	0,00594	0,0074	0,00921	0,01075
I2	0,00855	0,00979	0,01244	0,01428
I3	0,00547	0,00725	0,00918	0,01085
S1	1,24522	1,43976	1,7338	2,04721
S2	1,78921	1,84713	2,35287	2,72248
S3	1,15754	1,41933	1,73909	2,06345
f	0,12011	0,11158	0,14525	0,1595

TABLE 3-middle values of the change of value in voltage, current power and frequency

Based on what is exposed above, a detailed analysis was done for time frames of 0.5 sec, 1 sec, 1.5 and 2 sec. the middle value of the signal change for the recording interval of 10 days and in the 2-second time frame, the 0.005% frequency, 0.038% voltage, 0.7% power and 1% current was evaluated as a very encouraging result. In shorter time frames the values are lower, but then, the problem of conducting a slow AD converter measuring is much more complex, or practically insolvable.

CONCLUSION

The conducted analysis of the results obtained by measuring in the JAFA factory in Crvenka confirms the hypothesis of the sufficiently large stationary state of the observed EES, which opens possibilities to use slow but highly precise AD converters with double incline, in the realization of the digital measuring system.

REFERENCES

[1]. V. V.Vujicic, S.S.Milovancev, M.D.Pesaljevic, D.V.Pejic, and I.Z.Zupunski, **Low-frequency stochastic true RMS instrument**, *IEEE Trans. on Instrum. and Measur.*, vol. 48, pp. 467-470, April 1999.