

ELECTRICAL POWER QUALITY AND EFFICIENCY DIAGNOSTIC SYSTEM

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Abstract – Today and in the future electrical energy is a significant energy source in all area of life therefore its quality and consumption has more and more importance in practical and also scientific means. Latest standards for power analysing demand high data acquisition rate and strict acquisition rules which can only be achieved with advanced measurement equipments. Using these equipment and “state of the arts” computers we created a complex flexible measurement system for diagnostic electrical power according to IEC standards. We have already used our system at different kind of power networks to characterize quality of the energy and efficiency of its consumption.

Keywords: measurement system, power quality, data acquisition

1. INTRODUCTION

The aim of the research project supported by the Regional University Knowledge Centre of Mechatronics and Logistics Systems at the University of Miskolc was development of a highly reliable system suitable for diagnostics of electrical power network of small and medium enterprises (SMEs) according to EN 50160 and IEC 61000 standards in order to determine efficiency of the energy utilization of the company. Saving the energy resources, minimizing the energy utilization have one of the highest priority in the European Union development directions in the next years, including the EU7 projects focusing also to this area.

Hence our department has made power network measurements for decades in most of all North-East region of Hungary, we had a lot of experiments to build this kind of system. The North-East Hungary is a very special region because of the contaminated electrical caused by the “old-fashioned” metallurgical industry. The quality problems have particular importance in this area especially for the electronics industry, where the technology requires disturbance-free energy source.

2. ELECTRICAL ENERGY

Electrical energy is a significant energy source for industrial and commercial applications. This energy looks like a usual good from one side, as it is produced in a plant and transported to the consumers; but it is a very special

good from the other side as it is produced, transported and utilised at the very same time. As all the goods in general its quality and quantity can be determined, but the quantity is more visible than the quality, therefore in most of cases the consumers don't care about the quality of the electrical energy. Hence the quality has direct effect to the cost, consumers could reduce the electricity bill if electrical energy had better quality and beyond that the poor quality also can cause damages for equipments.

Providing standard quality of electrical energy on the place of utilization is not an easy task, because non-standard energy can not be removed from the network and consumers can also disturb each other operation. The power supplier would like to know how contaminate its power network but the consumers also want to know if they receive the appropriate quality. Examination of the quality and study of the efficiency of energy consumption of company has significant importance.

Standard EN 61000-4-30 and 61000-4-7 define the structure of a full-digital system for electrical energy measurement and set down the measurement methods. These specify more than 18 kHz sample rate on each channel which requires powerful hardware background. Although there are a lot of devices operating according to above-mentioned standards we decided to use a personal computer with a data acquisition board. There are a lot of advantages of the PC based system as opposed to other measuring devices. A PC is always more powerful and flexible, and it can be supplemented with other peripherals according to required functions (e.g. WIFI card to transfer results).

3. MEASUREMENT SYSTEM

3.1. Structure

Our measurement system is included into a standard shielded instrument box which contains voltage and current transducers, power supplies, one motherboard with hard drive and peripherals, one monitor and finally a data acquisition board, acquiring samples with more than 20 kHz which is necessary to meet the requirements of standards EN 61000-4-7. This standard demands the examination of harmonics up to 9 kHz therefore 20 kHz acquisition rate is expedient.

We engineered a flexible system therefore it consists of racks. According to the actual measurement task racks can be swapped. There are different voltage and current racks

and there is one special rack for providing power supply to clamp meters. The number and kind of used racks during measurement are task dependent. Each rack is suitable for measuring one three-phase system. Types of racks:

- Voltage rack with 200V, 500V and 750V measuring ranges
- Voltage rack for clamp meters ($\pm 5V$)
- Current rack with 1,5A and 5A measuring ranges

One mini-ITX motherboard is inside the box. It is small and fast enough to reach its purpose. It fits into the box and it is capable to control measurement and execute on-line calculations during measuring.

We apply PCI 6052 DAQ board which is a multifunctional multiplexed data acquisition board with 16 analogue input and 8 digital input/output ports. Its analogue inputs are used for measuring voltage or current and its digital ports are used to identify racks and learn parameters of racks. Numbers of analogue inputs is enough to be able to measure four three-phase systems in case of we use only one voltage rack and four current racks.

To measure current and voltage and to transfer those into $\pm 5V$ range which is the analogue input range of the DAQ board we use Hall effect voltage (LV-25P) and current (LA-25-NP) transducers inside the racks. The whole system was built round a bus system where through racks get power from the power supplies and computer learns rack's parameters.

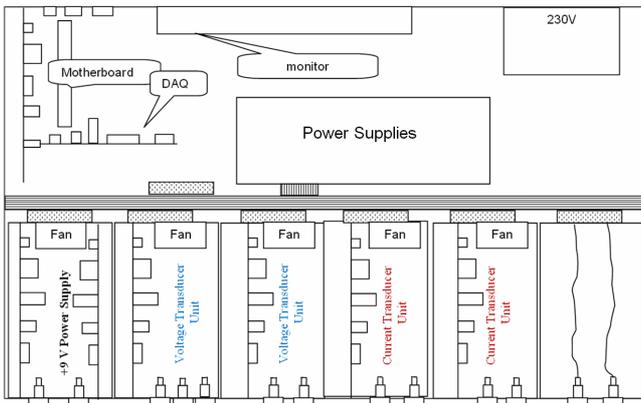


Fig. 1. Arrangement of the measurement box

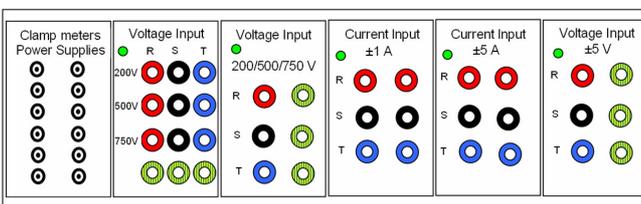


Fig. 2. Front view of the measurement box



Fig. 3. The measurement box

3.2. Software Environment

Our well-designed and implemented application has two different tasks: measuring (control of the measurement process and data storage) and analysis (data processing). Data acquisition can be performed according to standards or according to the actual requirements so it can be different from the standard measuring process. Data processing can run during measuring or at a later time after the measurement. As there is not enough time to calculate all power parameters on-line, measured values are stored on hard drive. On-line calculated parameters depend on our computer's performance. Using today's computers it's not problem to calculate each parameter (RMS, THD, etc.) but other operations suchlike browsing time signals can't go during the measuring process.

Before starting measurement the software identifies the racks which are current and which are voltage racks. Each rack has an EEPROM. It contains the particular multiplier value which is needed to determine the real voltage or current values. This multiplier value is read via digital ports of DAQ board. After identification we can couple current with voltage thereby the application can calculate different power parameters.

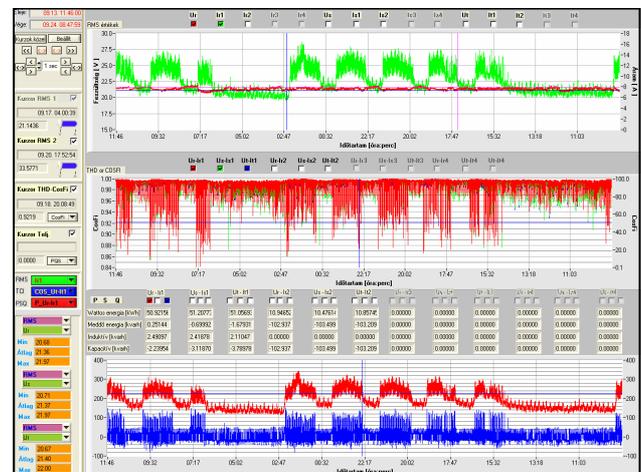


Fig. 4. Display of Software Environment

Maximum, minimum and average values can also be read from the display. Statistic graphs are displayed on Figure 5. Statistical distribution can be created for any values for any time interval. It's easy to compare to distribution of RMS voltage values on the three graphs three-phase system.

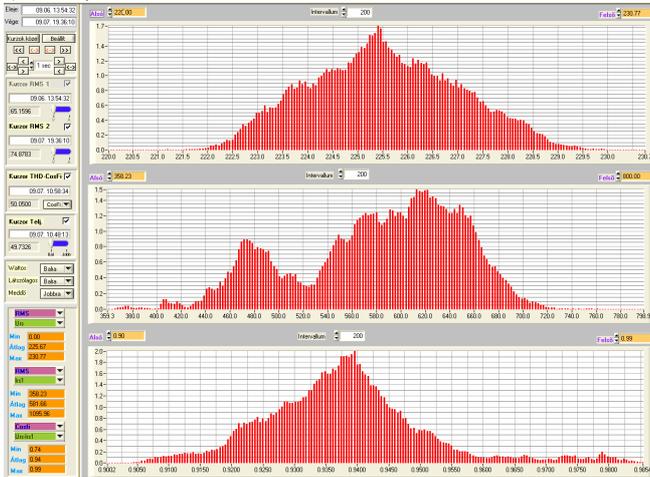


Figure 5. Statistic graphs

The application calculates and displays the following values and changes of these values in time according to IEC 61000-4-30 and IEC 61000-4-7:

- Frequency of the voltages to be measured
- RMS values for all channels (voltages, currents);
- Supply voltage dips and swells
- Voltage interruptions
- Supply voltage unbalance
- Amplitude - frequency spectrum (voltage harmonics and interharmonics) and THD values for all channels;
- $\cos(\phi)$ values for channel-pairs (U - I);
- Apparent, active and reactive power for channel-pairs (U - I);
- Statistical distribution of any properties for any time interval

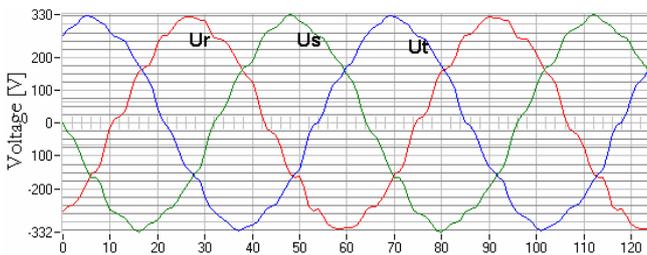


Fig 6. Time signals, disturbances on the electrical network

Time signals shown on Figure 6. can be visualized at any time of any channel since all data is on the computer's hard drive, therefore our measurement system is preferable to other concurrent products, any distortion can be noticed easily.

4. EXPERIMENTS

The release system was tested on electrical power network of nearly 20 companies and one public institution, also suggestions for network changes were provided to them in order to reduce their energy costs. Some experimental results are shown in this chapter.

Total harmonic distortions were in all cases under the standard limits (8%) but some individual harmonics exceeded the limit values for harmonics as you can see on Figure 6. and Table 1.

	U_r	U_s	U_t
1. case	3,70 %	3,85 %	4,80 %
2. case	5,56 %	4,5 %	4,92%
3. case	2,4 %	2,4 %	2,2%
4. case	2,27 %	2,34 %	2,28%
5. case	3,63 %	3,54 %	3,28 %

Table 1. THD values at five companies

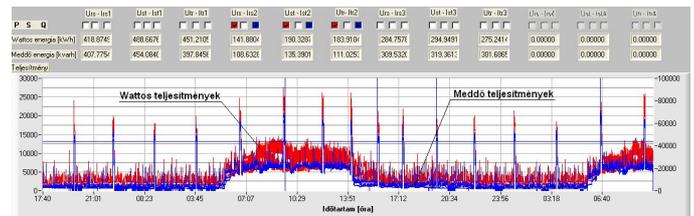


Figure 7. Consumption curves in an office building

The consumption is the one of the most useful part of the evaluation. Figure 7. shows the active and the reactive consumption during measuring. The high amplitude transient values are caused by the air-conditioning devices of the building. The test was performed in September when in Hungary the nights are fairly cold but in the daytime temperature closed to 30°C, nevertheless air conditioning equipment operated according to the diagram with the same frequency in the night as daylight.

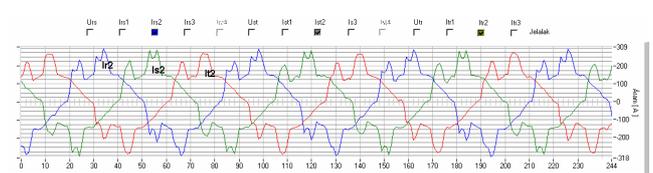


Figure 8. Time signals of three-phase currents. In some cases identification of voltage-current signal-pairs caused serious problem

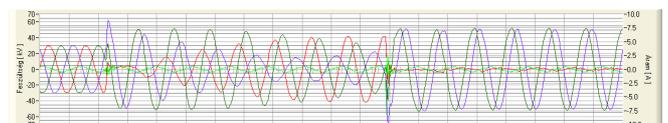


Figure 9. Record in a wind power-station where the voltages of generator suffered a serious disturbance

To evaluate efficiency of consumption the power factor needs to be examined. Although companies are punished when the power factor is low even so $\cos(\varphi)$ values in some cases were unacceptable. On the figure 10 statistics of power factors in two different companies are shown and average values of five companies are on table 2.

	1. case	2. case	3. case	4. case	5. case
$\cos(\varphi)$	0,77	0,94	0,97	0,98	0,8

Table 2. $\cos(\varphi)$ values at five companies

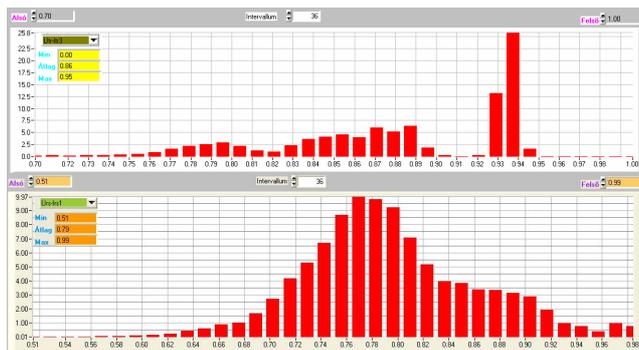


Figure 10. Statistics of the power factors in two different workshops

5. FUTURE DEVELOPMENT

We continue the research and development of the whole system and we have several ideas for increasing its usefulness and efficiency:

- Remote control, remote data processing.
- Increasing speed of evaluation using artificial intelligent methods.
- Increasing speed of calculations by using FPGA DAQ board.

It is expedient if the measurement system can be reached via internet. In this stage we have not got any information on the operation of our test system which is usually situated more hundreds of kilometres from our institution and runs 10-20-30 days continuously. If any problem occurs during the test we can't do anything and the test must be repeated, wasting time and cost. If our system could send status reports and/or emergency signals, it would highly increase the reliability of the system. Controlling it via internet would also provide possibility of receiving some already available data, characteristic parameters providing remote in-process system diagnostics. WIFI or GPRS technologies are considered since it's not sure that wire network is installed on the field.

The more complex part of the development is the artificial data-mining. As we know from the practice, the evaluation can take very long time. More thousands of data has to be investigated which is a very tiring and long process for a person or a team. Using artificial intelligent methods for evaluation the efficiency of evaluation can be appreciably increased. If the application could find known patterns in time signals the source of the distortion can be discovered easily.

Recently we purchased NI-7833R FPGA board. This card could be increase greatly the calculation capacity of the system therefore we are making plans how we could implant this device in our measurement equipment and which calculations need to be executed on PFGA.

6. CONCLUSIONS

The complex diagnostic equipment presented in the paper is used for diagnostic power networks in North-East region of Hungary. It provides simple and reliable definition of disturbances polluting electrical energy and analysing efficiency of its consumption.

Earlier we have built our measurement system from many parts which were connected into system by many cables therefore the installation process was long and complicated. Now thanks to the flexible rack system and complex measuring box the installation is much shorter and easier. Using our own developed software we can measure according to different rules not only with standards regulation so we make the measurement depending on the actual task.

ACKNOWLEDGMENTS

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