Dušan Medveď, Šimon Liška

Concept design of the electrical power quality analyzer using the open-source platform

Abstract: This article deals with the issue of creating a network analyzer of the quality of electric energy using the open-source platform in the form of the Raspberry Pi microcomputer. This paper presents a design of a measurement circuit for recording the AC voltage up to 1500 V and a subsequent analysis of the measured data.

Keywords: power quality analyzer, voltage measurement, Raspberry Pi, power quality, open-source platform

I. INTRODUCTION

Problems with the quality of electric power take a wide range of problems in varying time ranges from ten nanoseconds throughout the time of the stabilized condition or steady state. All of these problems are caused by the different reasons and therefore require different and unique solutions that can be used to improve the quality of electrical power and thus improve the stability of the delivered power and also increase the reliability of devices. Many power quality problems arise from the incompatibility between the power system and the devices connected to the system. It is known that non-linear loads create harmonic currents that can generate resonance in the power supply system. Most problems associated with the quality of electricity therefore can be identified by voltage and current measuring [1].

II. DESIGN OF THE NETWOR ELECTRICITY ANALYSER

At the beginning of the creation of the electricity quality analyzer, it was necessary to determine which electrical quantities would have to be measured and further analyzed. Measured voltage was chosen. From the number of measured voltage samples, it is possible to analyze, calculate various types of energy quality indicators such as voltage waveform, higher harmonic voltage components, short-term voltage changes and even transient phenomena. From graphical dependencies of analyzed samples of measured instantaneous voltage values it is possible to determine the harmonic components of voltage and also the actual value of the frequency of the network.

A. *Selection of essential information*

Electricity measuring devices record large amounts of data. It is therefore necessary to choose the correct and useful valuable data from the measured data. An electrical energy meter device should, after analysis, inform the user about the overvoltage and voltage drop as shown below (Figure 3). The output should also contain information of effective voltage value during the measured section [2].

B. *Choice of open-source platform*

As a next step, it was necessary to select the right type of open-source platform that will handle the entire measurement and process the measured data. Decision was done among the one of the most popular Arduino platforms UNO, MEGA, and Raspberry Pi b+. After the choice, the Raspberry Pi microcomputer was chosen, because it has a choice of operating system and can be used to further extend the measurement properties that the power quality network analyzer can perform.

C. *Design of the measuring circuit*

The problem was how to measure with the Raspberry Pi an alternating voltage within the maximum range of ±1500 V with the highest sampling frequency. The range of values of ±1500 V has been selected because the peak value of short-time overvoltage does not exceed this value. Raspberry Pi is able to detect a direct voltage up to 5 V at its analog input. To achieve this measurement range, it was necessary to reduce the maximum AC voltage from –1 500 V to +1500 V range to a measurable voltage range of 0 V to 5 V, so that Raspberry Pi can measure instantaneous voltage values.

Reducing of the voltage to the desired value was done with a 300:1 voltage divider. At a maximum rated voltage of +1500 V, a current of 1.51 mA would occur on the first circuit (dividing resistors), a load of 2.26 W. Therefore, 5 W resistors were selected. The voltage reduction could also be done by a transformer that would galvanically separate the supply network from the measuring circuit. Galvanic separation is an advantage because the transformer does not transmit electromagnetic noise, and the measuring device can measure more accurately, and the measurement will not be affected. The disadvantage of the transformer is in the necessity to know the frequency range of the transformer, that is, what the maximum frequency value can transformer transfer from the primary side of the circuit to the secondary side. But, when we decreased voltage by the divider, the voltage value was still negative. It was necessary to design a voltage wave shift (offset) that would shift the negative voltage level to positive values in the range from 0 V to 5 V. To shift the voltage level from negative values to positive, an operational amplifier was used that moved the level by 5 V from the negative values to positive.

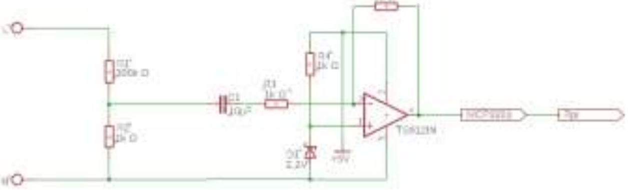

Figure 1 Diagram of the connection of the primary measuring circuit (it was not successful circuit and therefore it was later modified)

Figure 2 shows the voltage from the output of the operational amplifier measured by a laboratory oscilloscope, of a network “ideal” 230 V effective voltage, with maximum values of ±325 V by decreasing and shifting to positive values from 1.67 V to 2.71 V The signal was converted from analogue to digital in shape using the 16-bit AD converter MCP3201 at a sampling rate of 3000 samples per second. The plotted graphical dependence of the measured voltage with Raspberry Pi can be seen in Figure 3, where the number of samples is on the horizontal axis and the vertical axis is the electrical voltage. As one can see, the measured signal in Figure 3 differs greatly from the measured signal of an oscilloscope. Deformation of the voltage wave was caused by considerable noise, which was transmitted through the common neutral point of the network and the measuring circuit.

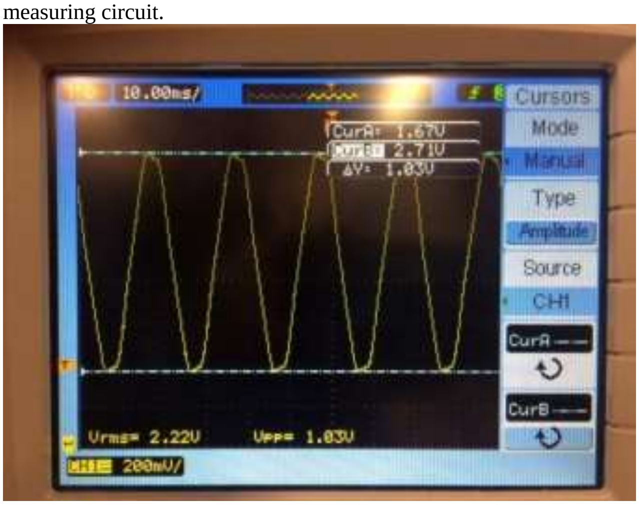

Figure 2 Measured voltage characteristics from the output of the operational amplifier

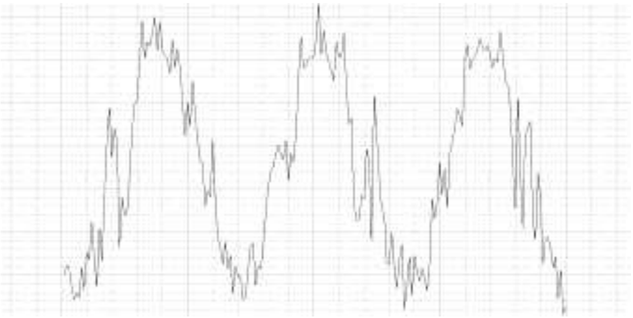

Figure 3 Measured voltage values using Raspberry Pi from the output of the operational amplifier

D. Filtering of the deformed signal

To filter off the noised signal, it was necessary to separate the neutral point of the network or the entire measuring circuit from one another. Figure 4 shows the measured voltage after separating the relevant grounding of the components and the neutral point of the network.

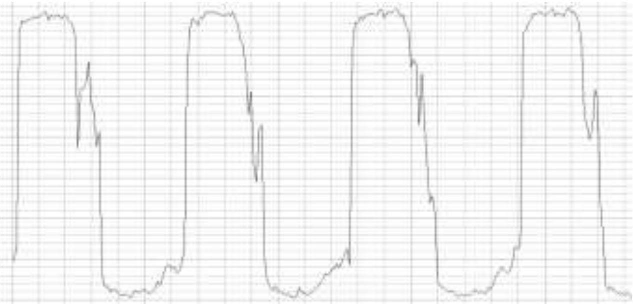

Figure 4 Measured voltage values using Raspberry Pi after separation of common network points

As one can see from Figure 4, the measured signal is more accurate, but not enough, and so that the signal can be processed and analyzed to determine the electrical energy quality parameters.

E. Galvanic separation of the measuring circuit

In order for the network voltage analyzer to correctly read the input analogue values, it was necessary galvanically separate the designed network analyzer from the measured object (socket circuit of an effective voltage value of 230 V ± 10 %). Separation was performed using an insulating amplifier. The final measuring circuit is shown in Figure 5 and connection with real components in Figure 6.

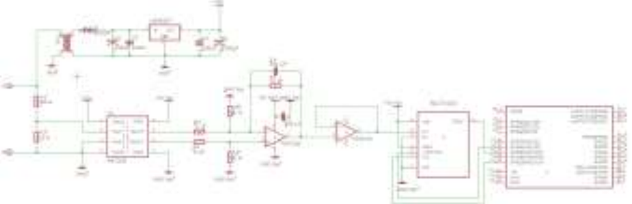

Figure 5 Galvanically separated measuring circuit for measuring the instantaneous voltage

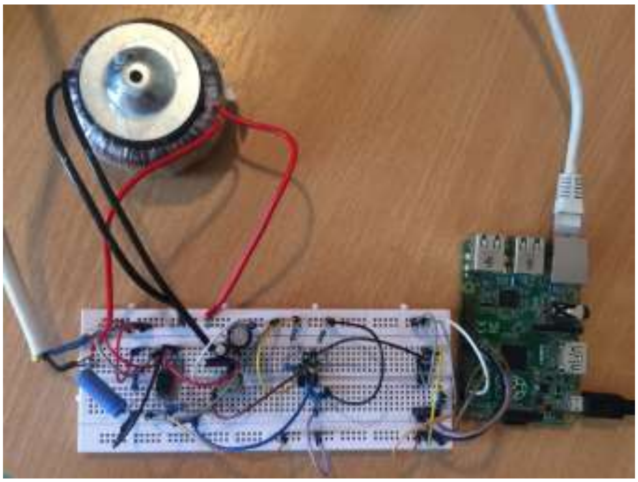

Figure 6 Connecting of the electrical energy quality measurement circuit

Measured and plotted voltage values of a galvanically separated measuring device are shown in Figure 7. The sampling frequency was approximately 13 000 samples per second. The data reading program from the four-wire synchronous serial bus (SPI) was created in the C++ programming language.

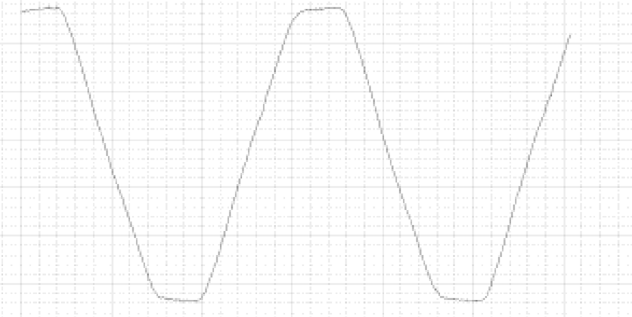

Figure 7 Measured voltage values by galvanically separated measuring circuit

III. EVALUATION OF THE MEASUREMENT OF ELECTRICITY QUALITY PARAMETERS

From the measured instantaneous voltage values, the higher harmonic components of the voltage were analyzed. In this case, Raspberry Pi was created only to capture the measured data, and the next analysis was realized offline (using a desktop computer). Determination of higher harmonic components was realized in MS Excel program, where using the built-in function of Fast Fourier Transform it was possible to determine the higher harmonic components of voltage. The anti-aliasing filter was set to filter higher frequencies from the 25th harmonic voltage component.

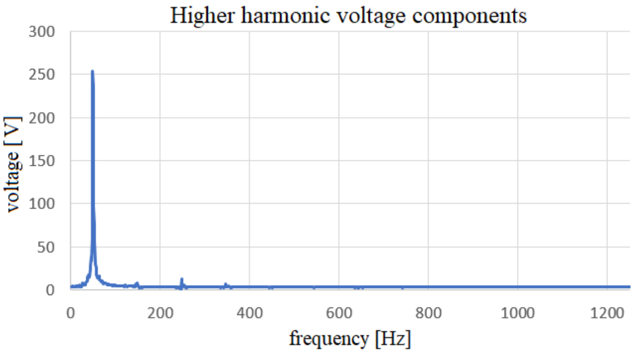

Figure 8 Harmonic and inter-harmonic components of voltage

IV. CONCLUSION

On the basis of the obtained results, it can be stated that the proposed measuring circuit exceeds the minimum normalized data acquisition rates (STN EN 50160). The maximum write speed is 13 000 samples per second. The proposed measurement device has a broad perspective of further extensibility in the direction of autonomous data collection and further processing of the measured data. The next steps of authors will be to enhance the measuring accuracy and adding the on-line processing within the Raspberry Pi.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences under the contract No. VEGA 1/0372/18.

REFERENCES

[1] M. Brúsil, M. Bočkayová, “*Je kvalita elektrickej energie merateľná*”. ZTS Elektronika SKS s.r.o., [online]. [cit.: 7.5.2018]. Available at internete: < http://www.aos.sk/spe/seminare/archiv_1993_2008/www/Clanky/07/ ZTS_SKS_BP07.pdf >

[2] M. McGranaghan, S. Santoso, “*Challenges and Trends in Analyses of Electric Power Quality Measurement Data*”. Hindawi Publishing Corporation. [online]. [cit.: 7.5.2018] Available at < http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.396.5758&rep=rep1&type=pdf >

[3] Š. Liška, “*Využitie open-source platformy v elektroenergetike*” (Utilization of the open-source platform in electrical power engineering). Bachelor thesis. Technical University in Košice, Faculty of Electrical Engineering and Informatics, Department of Electric Power Engineering, 2018.

ADDRESSES OF AUTHORS

Ing. Dušan Medveď, PhD., Technical University in Košice, Department of Electric Power Engineering, Mäsiarska 74, Košice, SK 04210, Slovak Republic, Dusan.Medved@tuke.sk

Bc. Šimon Liška, Technical University in Košice, Department of Electric Power Engineering, Mäsiarska 74, Košice, SK 04210, Slovak Republic, Simon.Liska@student.tuke.sk