POWER GRID QUALITY IN METALLURGICAL FACTORY

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Abstract

The article deals with quality power grids in metallurgical industry. Nowadays the power grids are loaded by non-linear loads which cause distortion of voltage and current track. Thanks to this distortion the power grids are overloaded and its efficiency decrease. The expensive adjustments of power grids are necessary. This adjustments increase claims on investments and maintenance. In the article is described developed analytic system that is able detect and measure this distortion. Based on measured values the power grid in the factory can be analyzed and the improvement can be proposed.

Keywords: Metallurgy, power grid, microprocessor, Fourier transform

1. INTRODUCTION

Metallurgical factories have problems with their power grids nowadays. Bad quality and nonlinearity of power grids cause big problems for whole cities around metallurgical factories. Problems in power grids can cause shorter life time of devices, equipment and electrical machines. Sometimes it can destroy the devices. In first phase is necessary exactly measure and identify problems in power grids for providing backgrounds for elimination of sources of these problems.

2. PROBLEM ANALYSIS

There is voltage sinusoidal shape with frequency 50Hz in power grid. Ideally there is only this fundamental frequency. Thanks to nonlinear load like switching power supplies the disturbation appear. These disturbances are caused by higher frequencies. This frequencies are multiple of fundamental 50Hz (e.g. 100Hz, 150Hz,…) and they are called harmonics. Harmonics are added to fundamental. Ideal sinusoid with frequency 50Hz which should be in power grid is shown in **Figure 1**. Measured real sinusoid with disturbances which is in power grid is shown in **Figure 2**. [1,2]

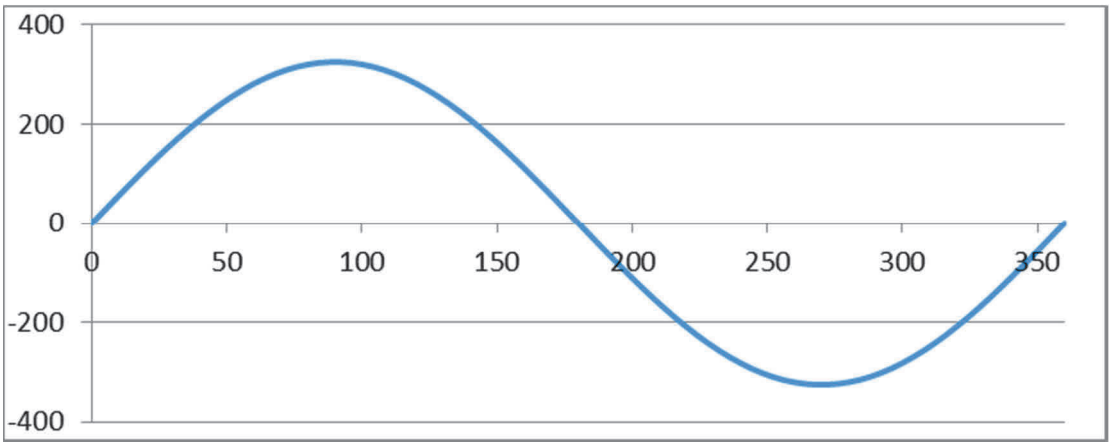

Figure 1 Ideal sinusoid

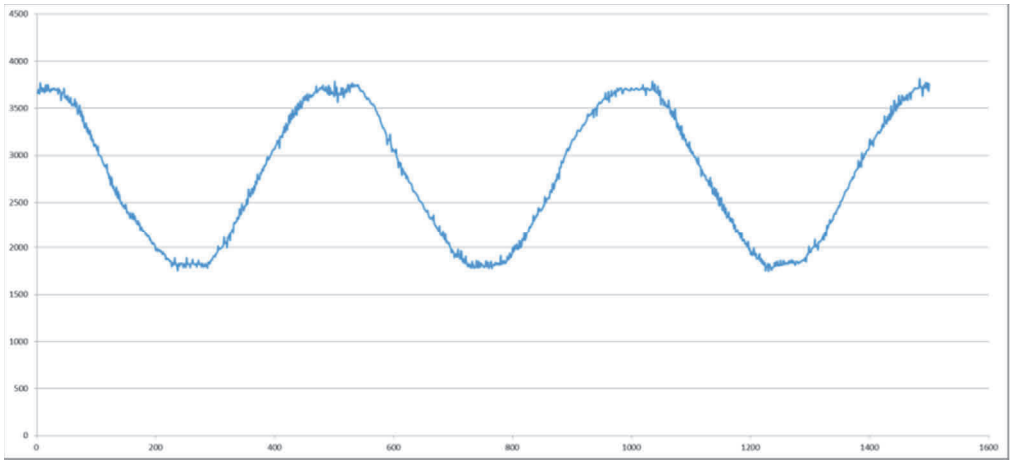

Figure 2 Measured distorted sinusoid

Computing of higher harmonics is defined in theory of Fourier transform. Every harmonic function is the sum of sinuses and cosines with different frequencies and amplitudes. The Fourier transform deal with count of these harmonics and their amplitude. Result of Fourier transform is spectrum of signal. There are individual frequencies on the horizontal axe and amplitudes of these harmonics are on the vertical axe. Fourier transform converts signal from time domain to frequency domain.

Total harmonic distortion shortly THD gives ratio of energies from harmonics and energy from fundamental frequency 50Hz. THD is based on decomposition periodic signal on individual harmonics by Fourier transform. THD is mostly defined as share of individual energies as in equation (1). [3,4]

$$\boldsymbol{THD = \frac{\sum_2^n P_n}{P_1} * 100} \tag{1}$$

where:

P_n - electric power of higher frequencies (W)

P_1 - electric power of fundamental 50Hz (W)

n - count of harmonic frequencies

Harmonic distortion of voltage and current is computed by equations (2) and (3).

$$THD = \frac{\sqrt{\sum_2^n {U_n}^2}}{U_1} * 100 \tag{2}$$

where:

U_n - voltage of harmonic (V)

U_1 - voltage of fundamental 50Hz(V)

$$THD = \frac{\sqrt{\sum_2^n {I_n}^2}}{I_1} * 100 \tag{3}$$

where:

I_n - current of harmonic (A)

I_1 - current of fundamental 50Hz(A)

Power grid quality not only by THD is defined in standart EN 50160. Distorted voltage or current causes very big problems in power grids for several reasons. THD increase temperature of transformers and they have to be over-dimensioned for security reasons. Ability to transfer distorted current of transformers is called K factor. If the transformer is not designed to transfer distorted current it burns. Conductors are overloaded by distorted current so they have to be over-dimensioned too. If the THD is too high it can cause damage or even destruction of electrical appliances. In case of 3 phase power grid the 3rd multiples are added on neutral conductor and high frequency current flow by this neutral conductor. This phenomenon is called triplen harmonics and it appear because 3rd multiples are in phase. The other multiples have phase shift between themselves. If THD appear in power grid it is necessary dimension grid on harmonics components. Sum of transferred power is vector computed by **Figure 3.** [3,4]

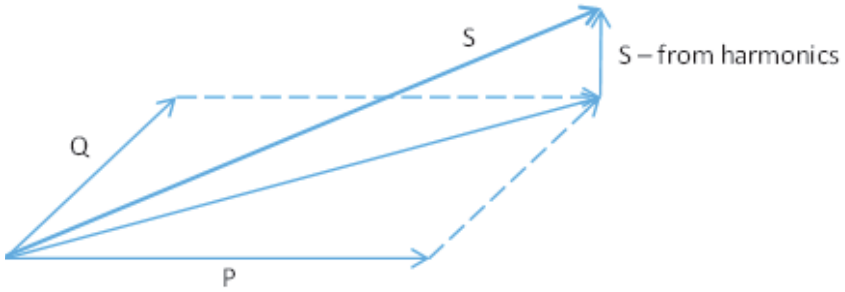

Figure 3 Vector sum of powers

3. SOLUTION

THD measuring is very difficult or even impossible by ordinary measuring tools. Tools for this type measuring have to be very fast and very precise. It causes their very high prices. In this paper was developed measuring system based on 32 bit microprocessor from manufacturer ST Microelectronics. This microprocessor is cheap and efficient for computations discrete Fourier transform and its algorithm. Internal analog - digital converter is able measure waveform in power grid after its adjustment. The microprocessor is able compute and compare individual harmonic components from shape of the waveform by algorithm of discrete Fourier transform. It is possible rate the degree of distortion and quality of power grid in metallurgical factory.

Electrical circuit for signal adjustment is shown in **Figure 4**.

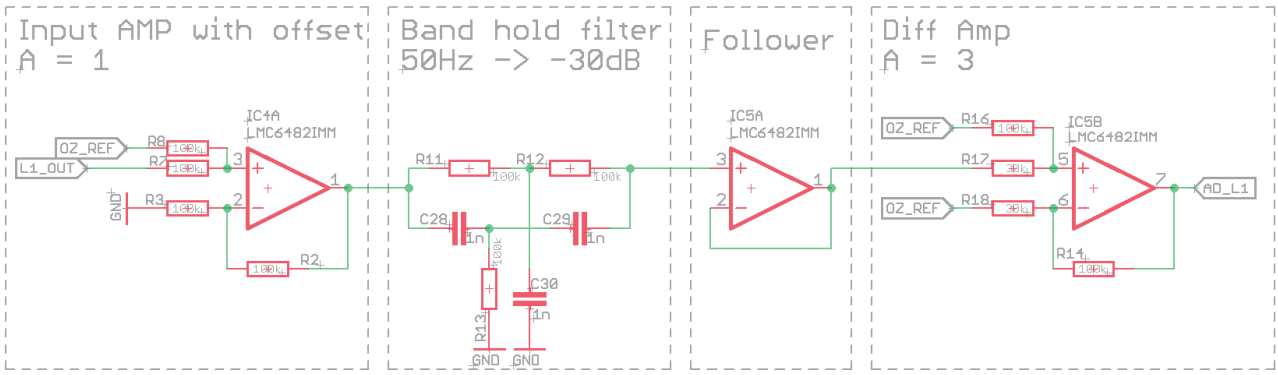

Figure 4 Circuit for signal adjustment

First it is necessary adjust amplitude of sinusoid 230VAC on the measurable size therefore amplitude have to be smaller than reference voltage of AD converter so 3.3V. This is ensured by small transformer which ensures galvanic isolation from power grid too for security reasons.

First part in **Figure 4** make DC offset. Microprocessor cannot measure negative voltage, so if the circuit make offset the whole sinusoid is in positive values. This input amplifier has gain 1 so it don't adjust size of amplitude. Reference voltage for DC offset is created by internal DA converter in microprocessor. It is possible change the offset by software if it is necessary.

Output of input amplifier is connected to the input of filter which suppresses fundamental frequency 50Hz. Possibility of bigger gain of harmonic components which are most important for measuring is ensure by suppressing of fundamental 50Hz.

Signal from this filter is connected to voltage follower. Follower ensure the filter is not influenced or loaded which can change the filter parameters.

The last part of circuit is amplifier with gain 3. Gain higher frequencies which disturb the fundamental 50Hz is ensured by this circuit. The operational amplifiers which are used for this circuit are integrated in microprocessor so this solution minimalize amount of external components.

Sampling frequency of AD converter is set on 25kHz. This frequency is the lowest possible for right measuring as it was tested. For sampling one wave of sinusoid with frequency 50Hz with THD is necessary save 1500 samples. Ratio of individual harmonic components is computed by discrete Fourier transform from saved sampled wave. It is necessary use faster microprocessor for bigger sampling frequency and more samples because of computing time. However the manufacturer of this microprocessor provides faster microprocessors so it is no problem migrate the source code on it.

Computed result of discrete Fourier transform by described system is shown in **Figure 5**. Every column is represented by amplitude of specific harmonic component. [5-9]

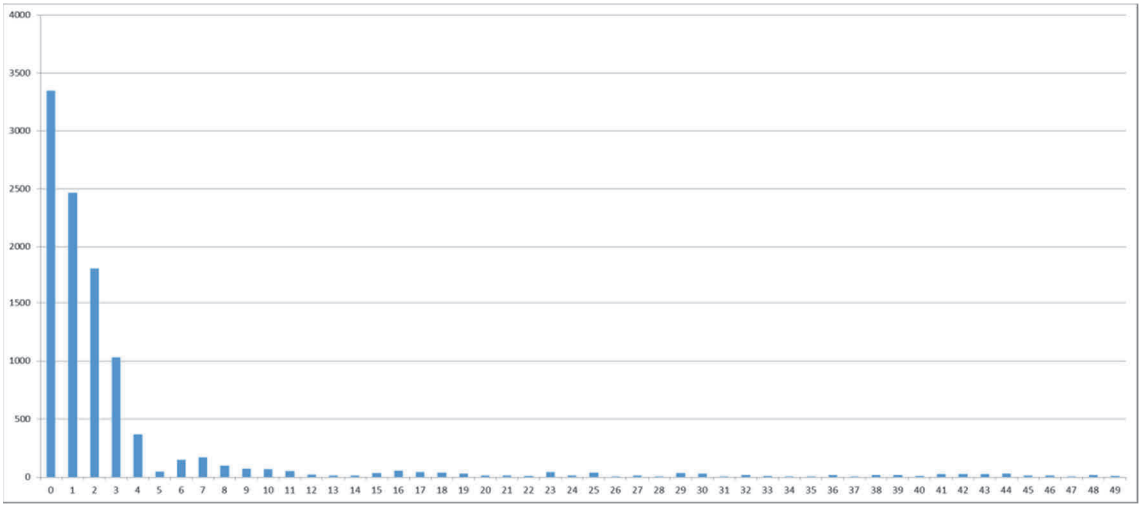

Figure 5 Computed result of measured power grid

4. CONCLUSION

In this paper was described system for measuring of disturbances in power grid in metallurgical factory. System is based on microprocessor which is able measure higher frequencies in power grid. System compute ratio of individual harmonic components which cause disturbances in power grid from measured waveforms. This system was developed on demand from unnamed metallurgical factory near Katowice where first measuring was done. Measuring system is able precisely measure disturbances in power grid and compute frequency of these disturbances. Next step is identification and elimination source of these disturbances.

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REFERENCES

[1] SATPATHI, K., YEAP, YM., UKIL, A., GEDDADA, N. Short-Time Fourier Transform Based Transient Analysis of VSC Interfaced Point-to-Point DC System. *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 2018, vol. 65, iss. 5, pp. 4080-4091.*

[2] COSTA, A., GEORGIDIS, D., NG, TS., SIM, M., An optimization model for power grid fortification to maximize attack immunity. *INTERNATIONAL JOURNAL OF ELECTRICAL POWER & ENERGY SYSTEMS,* 2018, vol. 99, pp. 596-605.

[3] LIU, YK., XU, X. Industry 4.0 and Cloud Manufacturing: A Comparative Analysis. *Journal of manufacturing science and engineering-transactions of the asme*. 2017, vol. 139, no. 034701.

[4] SVEC, P., FRISCHEROVA, L., DAVID, J. Usage of clustering methods for sequence plan optimization in steel production. *METALURGIJA*, 2016, vol. 55, pp. 485-488.

[5] FRISCHEROVA, L., DAVID, J., GARZINOVA, R. Maintenance management of metallurgical processes. In *METAL 2013: 22rd International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2013, pp. 1887-1891

[6] LEE, J., JIN, C., BAGHERI, B. Cyber physical systems for predictive production systems. *Production engineering-research and development.* 2017, vol. 11, pp. 155-165.

[7] KREJCAR, O., FRISCHER, R., Real Time Voltage and Current Phase Shift Analyzer for Power Saving Applications. SENSORS, 2012, vol. 12, iss. 8, pp. 11391-11405.

[8] KOIWA, K., LIU, KZ., TAMURA, J., Analysis and Design of Filters for the Energy Storage System: Optimal Tradeoff Between Frequency Guarantee and Energy Capacity/Power Rating. *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 2018,* vol. 65, iss. 8, pp. 6560-6570.

[9] DAVID, J., POLLAK, M., TUHY, T., PRAZAKOVA, V. Modern communication technologies usage for controlling metallurgical processes. In METAL 2014: 23rd International Conference on Metallurgy and Materials. Ostrava: TANGER, 2014, pp. 1678-1683.