Using the Antiphase for Elimination the Noise of Electrical Power Equipment

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Abstract. *The aim of this research is to create functional system which eliminates the noise of electrical devices. This system works on active basis, therefore it process parasitic signal itself and use it for elimination of the noise. On the first stage it focuses on elimination of energetic devices with great intensity of noise but with small frequency deviations. The main producers of noise emissions are electrical devices, for example transformers. Nowadays, human health and wellbeing are the priorities connected with every human activity. One of the inseparable factors which have an unfavorable effect on the human organism is the noise around us. Science and research bring new possibilities how to resist these unfavorable impacts. One of the possibilities is the elimination of noise using antiphase.*

Keywords

Antiphase, noise, transformer.

1. Introduction

The aim of this research is to create functional system which eliminates the noise of electrical devices. This system works on an active basis, therefore it process parasitic signal itself and use it for elimination of the noise. On the first stage it focuses on elimination of energetic devices with great intensity of noise but with small frequency deviations.

2. Methods of Elimination the Noise

Methods of elimination can be divided into three basic systems:

- **constructional** - systems heading to basic essence of parasitic sounds for each electrical device. Interventions for eliminate itself relate to construction and development groups and projectors,
- **passive systems -** passive solutions are covered, the rubber dampers and elimination using the building structure. Machine noise can be reduced by consolidating all the proper parts, different coatings, insulation covers,
- **active systems -** active systems are devices capable of eliminating noise, such as using antiphase [1].

3. Antiphase

To understand the system is important to know basic, namely waves alone. Phase of the wave is a dimensionless quantity that determines the relation variable waves, (e.g. displacement noise) at that place and time and to the state variables characteristic waves in temporal and spatial origin. Dependence characteristic of variables determines the shape of "waves" regardless of its dissemination. Phase is a parameter, which depends on the timing characteristic values in a fixed location, which the wave passes, respectively spatial field characteristic values for a fixed moment in time. Antiphase is turning the current signal about 180 ° [4].

The result of the exact antiphase is an absolute deduction of both signals and therefore their complete elimination [2].

3.1. Purpose of Noise Elimination of Power Transformer

The first device tested by elimination of noise will be transformers. Their constant frequency noise is ideal

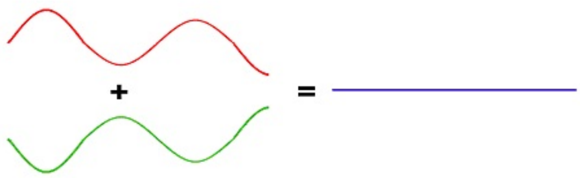

Fig. 1: Generating of antiphase wave.

for sampling and subsequent rotation of the signal to the antiphase. The result would limit the possibility of a majority in the meantime use the anti-noise measures and restriction of noise enclosure of buildings. There would be a possibility for using electrotechnical metallic materials which would increase noise of transformers. But from the other hand, the magnetic properties would be better. The main construction will not be up to a certain point affected by noise-requirements but the efficiency of transformers is increased. Therefore the construction of transformers would be economically profitable.

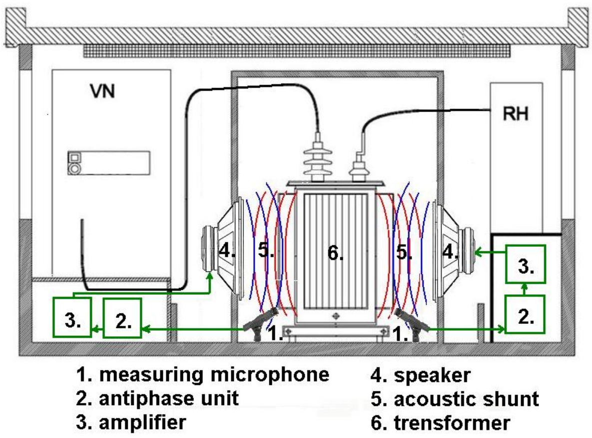

Fig. 2: Elimination of the transformer noise by Antiphase.

3.2. Measurement and Acoustic Testing

The measurements carried out on four transformers installed at the VSB–Technical University of Ostrava. This is the core three-phase transformers old design. These transformers are not equipped with active cooling - fans that would participate in making some noise. As shown in Fig. 5. Transformer cover is opened and the microphone scans the noise that is reduced to the closest possible distance in order to eliminate environmental influences. For this reason it is also used for the directional microphone. Scanned signal by quality microphone is then sent to quality sound card that it digitizes and this signal is sent to a computer thru USB interface. It works only during the measurement as a digital recording device. The actual records are stored in WAV format, the sampling frequency is 48 kHz resolution and 24 bits quality. This ensures the highest possible quality of recording and thus the quality of the result of subsequent processing of the acquired signal. Fig. 4 shows a simple block diagram of the recording of measuring device, which is the source of the analyzed signals.

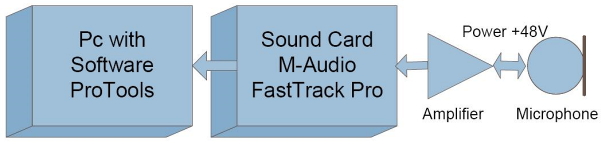

Fig. 3: Block diagram of recording devices for spectral analysis.

For measurements were selected randomly three transformers, which are long-term measurement of noise intensity depending on load. Therefore, the results are taken as in the no-load state and also in loaded state. Subsequent analysis of the transformers seem numbered T615/1 of its parameters are 1000 kVA, 10 kV/400 V, 50 Hz.

In the first case, the transformer worked to 7 % of maximal load, the current flowed through the various stages of the value of 70 A. In this demand can be considered, that transformer worked in the no-load state. The measured noise reached 74,7 dB when the housing is closed and 75,65 dB for open.

The latter was loaded transformer 480 A per phase; it means 48 % load of the total power. Measured noise reached very similar values as the no-load state, 76,8 dB for closed housing and 78,3 dB for open.

1) Spectral Analysis of Transformer T615 in the No-Load State

Figure 4 shows the FFT analysis of captured noise signal transformer T615 in the range 0–1500 Hz. The transformer operates in the no-load state with a large saturation magnetic circuit is expected to be significantly reflected by the frequency 100 Hz causing electromagnetic noise, which also corresponds to twice the fundamental harmonic excitation current $f = 50$ Hz. There are also manifested in the excitation of upper harmonic due to deformation of the excitation current owing to saturation and the shape of the magnetic circuit of the transformer (core with 3 columns, see Fig. 5). The images are then measured upper harmonic on the audio track and basically equivalent to frequencies 200, 300, 400, 500, 600 and 800 Hz. The magnetic flux is closed by air, housing of transformer and other design components and causing the vibration manifesting additional noise [3].

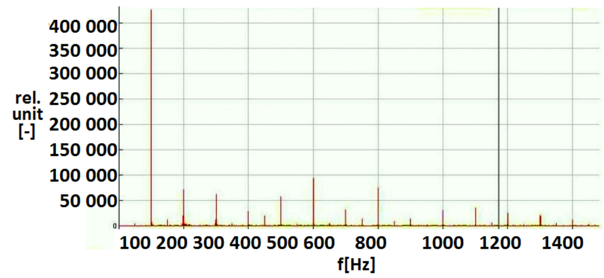

Fig. 4: Spectral analysis of the transformer T615 no-loaded state.

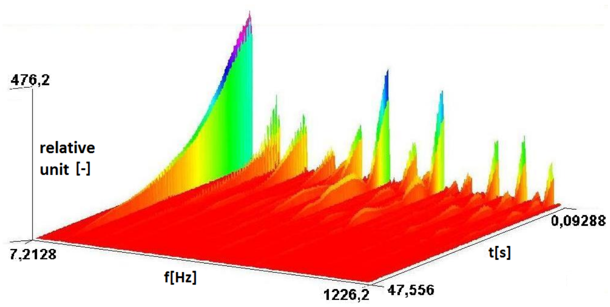

Fig. 5: Spectrogram transformer T615 in the no-loaded state.

2) Spectral Analysis of Transformer T615 in the Loaded State

Whole system is spectrally "clear" after loading the transformer and carrier frequency noise remains 100 Hz. There is a core to de-saturate the load transformer and thus also to mention upper harmonic. This state war confirmed by spectral analysis of the transformer in loaded state, see Fig. 8.

The size of the transformer noise depends on the magnetic flux; it depends on the voltage and then idle current. The noise of the transformer is strongly associated with the magnetization process. Saturation of the transformer core idling is higher and is given to the design, construction and the type metal. As can be seen from the performed measurements are an essential component of the noise frequency element 200 Hz. This frequency band is due to the magnetostriction effect of sheets, which will be most pronounced in the area of maximum permeability. This point is illustrated in Fig. 11 (this figure shows teoretical current look) and Fig. 12 (figure shows the current look on oscilloscope). Upper harmonics respect exponential load transformer, which is tied to the decline in core saturation. The decay rate of component noise 200 Hz is given by current course, this is why the more meaningful representation of frequency 200 Hz, which is an even-numbered multiple of the fundamental power frequency of 50 Hz. Even-numbered multiples of the fundamental frequency are given to the nature of magnetic induction [3].

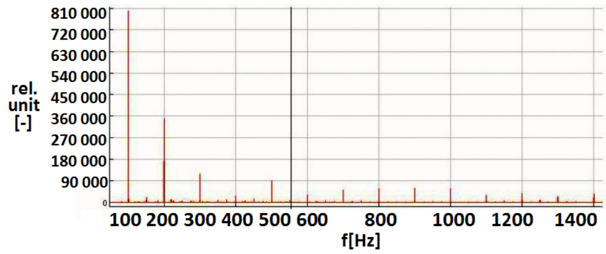

Fig. 6: Spectral analysis of the loaded transformer T615.

The sound spectrogram of a loaded transformer (Fig. 7) is clearly the focus of specific noise frequencies.

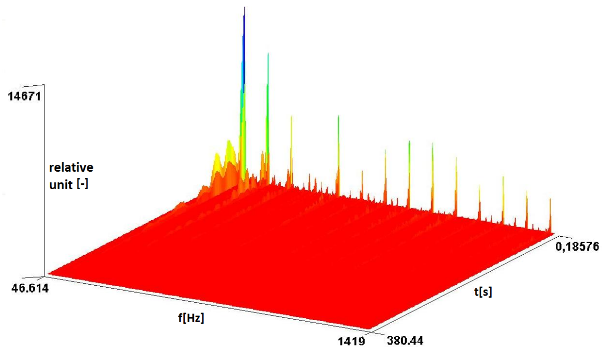

Fig. 7: Spectrogram loaded transformer T615.

Fig. 8 is clearly evident that frequency of the network is not exactly 50 Hz, but there are subtle differences, which must be account in the system to eliminate noise using antiphase. Here, the CPB (Constant Percentage Bandwidth) analysis was used to accurately determine the value of the columns.

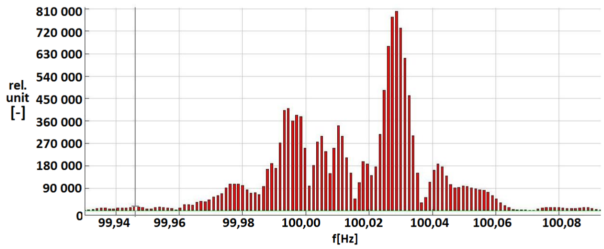

Fig. 8: Focus spectral analysis of the loaded transformer T615 to the frequency of 100 Hz.

It is clear from these measurements, that entire system to eliminate noise using antiphase transformer id designed entirely to eliminate the noise around 100 Hz. This applies to the measurement of transformers; in the case of transformers using active cooling would be difficult to analyze the situation of the fan noise [5], [6].

3.3. Construction of Antiphase Eliminator Model

After choosing power transformer device and after subsequent acoustic measurement and spectral analysis the first prototype of device which eliminated its noise using antiphase could have been realized. After spectral analysis of transformers noise it was concluded that this device will be constructed to eliminate the strongest frequency component which is frequency 100 Hz. As the test could not take place on the transformer itself due to safety reasons, the special measurement workplace simulating the actual noise of the transformer must have been created. The base comprise of two stands with identical speakers attached. One of these simulates the noise of transformer and the second stand produces antiphase which causes acoustic short. There are different types of schematic connections applied on the stands and acoustic efficiency, consumption of the system and other quantities are tested.

1) Schematic Proposal of Prototype

On the first stage the simple system which would verify functionality of all basic components was proposed. It is a system which works with computer simulation only. This simulation sends 100 Hz frequency signal to one linear amplifier. This is the main frequency of transformer noise emissions. Amplifier intensify signal to the speaker to 78 dB which is actual transformer noise intensity. Computer sends the identical signal 100 Hz from the second channel, but this one is turned 180 degrees. This signal is again increased by linear amplifier and it is sent to second, opposite speaker.

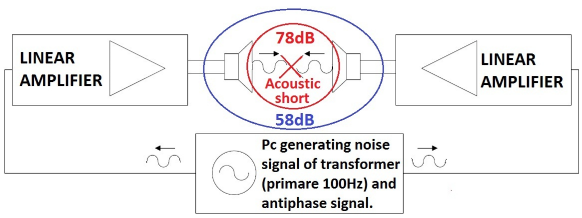

Fig. 9: Block diagram of the prototype Antiphase eliminator.

On the second stage the system is supplied with designed microphone which receives noise emissions. These noise emissions are again produced by the right part of circuit that is supplied with a computer which in this phase transmits the actual transformer noise record to amplifier. The amplifier intensity of the signal to the speaker is 78 dB - this is measured value of transformer acoustic emissions. So the right part of circuit simulates the actual transformer. The left part of circuit starts with microphone designed by us, and it receives transformer sound closely. Received acoustic signal is sent to SQN unit which is an analog device turning microphone phase in actual time so it works as phase control. In this unit we can also partly adjust frequency extent. In our case any intervention is unwanted - apart from turning the phase. Turned signal goes to linear amplifier which intensify signal to the speaker system to performance we need. If the specific distance of speaker systems is kept, there is an acoustic short and therefore unwanted acoustic emissions are eliminated.

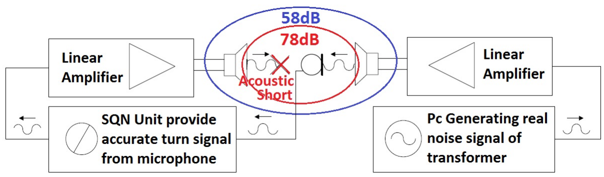

Fig. 10: Block diagram of the prototype Antiphase eliminator.

At this stage, the device is designed that the turning the phase is realized by analog devices as it is faster than signal digitization so far. Signal digitization would be of higher quality, but it would mean delays when sampling and turning the signal. That is why the analog way is chosen. So, SQN unit is a device which contains microphone preamplifier and analog input that receives a signal from the microphone. On the input of this channel the turning of phase can be easily switched and turned signal is sent from analog output of SQN unit to the input of amplifier. The amplifier intensity and intensity signal to speaker which sends 5-phase wave against the parasitic noise.

2) Prototype Construction

The proposal of schemes showed how the model was designed so now the construction itself can be introduced. The model required a great amount of wood construction material, the specific approach was chosen. The whole construction is made of wood waste, it is assumed that after a series of tests and measurements it will not be used in operation and antiphase eliminator will be professionally constructed again - based on the same model. The chosen method is more economic and environmental friendly. The construction itself consists of two identical stands which are equipped with identical speaker systems. The eliminator stand is different only in one point - in has free space for sound level meter above speakers. This space should provide passing the parasitic signal behind the eliminator construction. Whole construction is precisely anti-resonant reinforced so the tests are not disturbed by losing components while long-term high acoustic pressure works.

The present model is based on the scheme 1 see Fig. 9, it is a connection testing the system in simplified

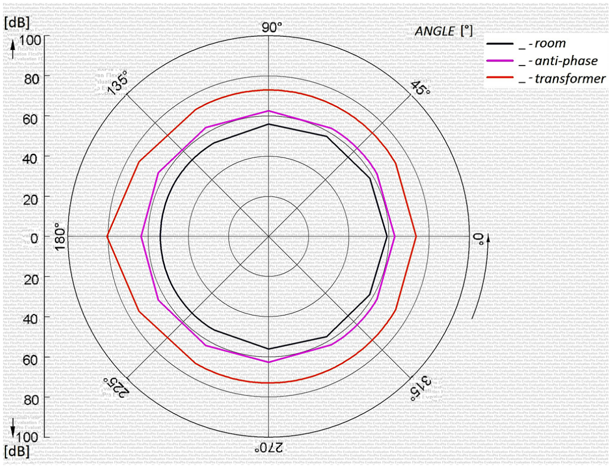

Fig. 11: Photo-documentation of construction prototype Antiphase eliminator.

frequency zone and only in simulating computer mode. The product of British company Carlsbro PA1670 was used as a terminal amplifier. Also, special computer audiocard M-audio FasTrack Pro is used in the system. The other integral components are software?s ProTools and Sequoia. These programs provide sound records and turning the signals to antiphase. Program SiaSmartLive 5 is software doing actual measuring of acoustic quantity and proceeds FFT and CPB analysis in actual time which allows watching current spectrographs. The whole physical construction is shown in Fig. 12. The model is ready to start with tests and measurements, and if these tests are successful and if model works in these conditions, the second stage will start - connection according to scheme - see Fig. 10 and another series to tests and measurements will follow.

4. Results of Antiphase Eliminator Model

The polar graph compares all three situations, noise of the room (blue), noise of the transformer (orange) and noise during elimination by antiphase (violet).

The main result of this research is the elimination the noise of transformer about 17 dB. Based on the results achieved by the model of Antiphase Eliminator we started to construct a prototype that could be tested on a real transformer.

5. Construction of Prototype of Antiphase Eliminator

Compared to the original intention, the construction is different as the elimination is carried out only from

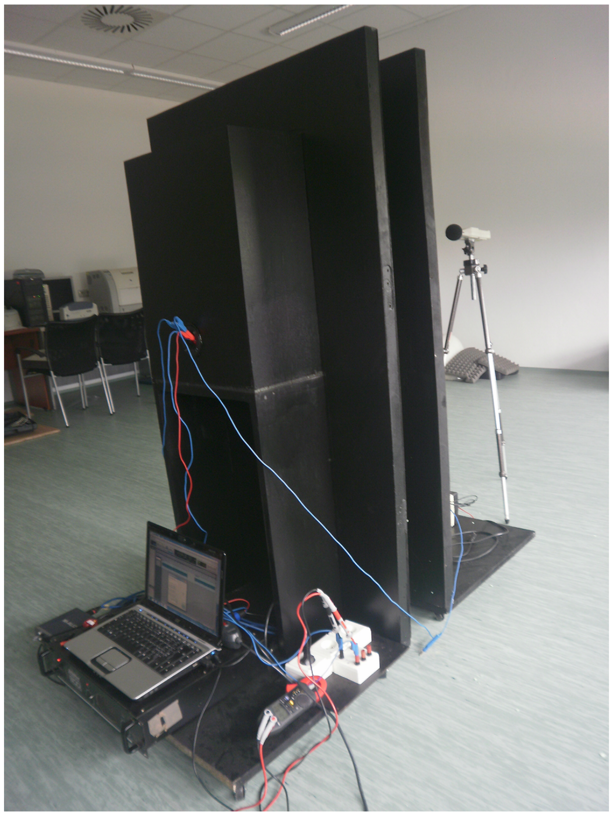

Fig. 12: Model Antiphase eliminator for measuring the intensity of noise.

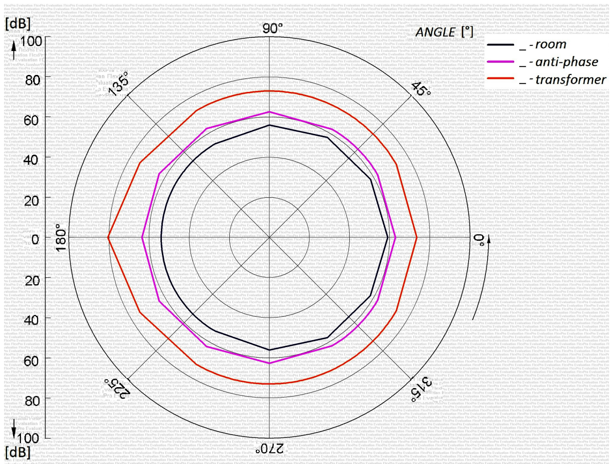

Fig. 13: Polar graph comparing the results.

one side. The reason is a complexity of acoustic wave spreading. We know from the measuring on the model that a production of feedback in the system is a serious problem. The effect of two speakers against each other would cause serious problems with this phenomenon. The whole system will be one-side after the function verification.

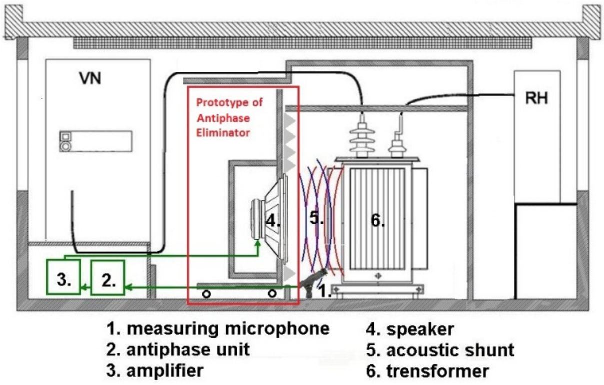

Fig. 14: Elimination of the transformer noise by Antiphase.

6. Connection of Prototype

During the tests of Antiphase Eliminator, several kinds of connection were tried experimentally. The motivation was to confirm function of Antiphase Eliminator in practice. All types of connection were combined and subsequently measured.

In Fig. 15, you can see the final connection of Antiphase Eliminator prototype. The final connection is created by two circuits. One of them is only for measuring (upper) and the second makes antiphase wave.

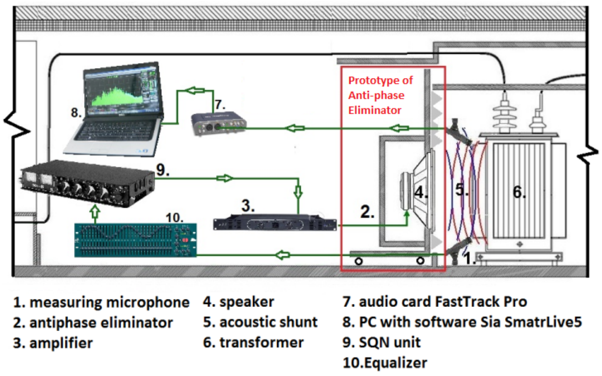

Fig. 15: Polar graph comparing the results.

7. Results Obtained by Eliminator

During all connections and measurements, a spectral analysis of transformer noise was continuously performed both in regular operation and in the elimination.

From the graphs of spectral analysis of transformer noise both during elimination and without the elimination, it is clear that the elimination was successful also in a real transformer. Frequency 101 Hz was suppressed by 13,1 dB and also the remaining frequencies ranged below −60 dB.

The graph in Fig. 16 presents the spectral analysis of noise transformer T616; it is clearly evident that the carrier frequency 101 Hz stands apparently above the rest of the spectrum. Also, the multiples of this frequency of 200, 300 and 500 Hz are evident.

All these frequencies exceed level −50 dB.

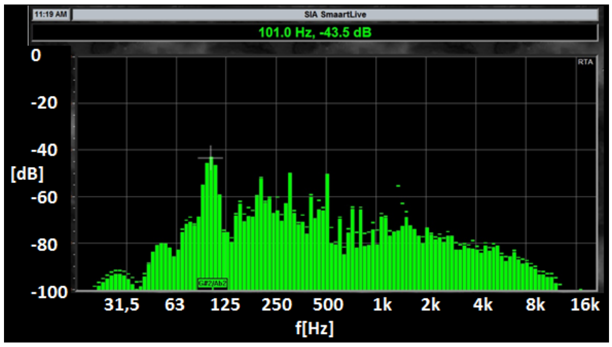

Fig. 16: Spectral analysis of the noise of transformer T616.

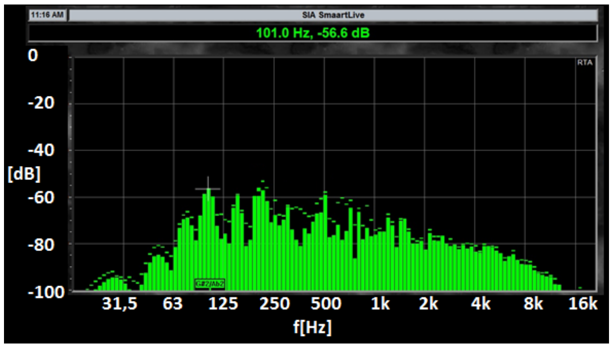

Fig. 17: Spectral analysis of the noise of transformer T616 during elimination.

8. Conclusion

If the certain physical conditions are kept, the system after improvement could be applied to any electrical equipment. This process is depended on a speed of sampling and ability to apply the right antiphase wave. There could be also influence of frequency heterogeneity of parasitic noise. The ambition of the project is to use this application for an elimination of noise various electrical equipment.

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References

[1] CHMELIK, K. and J. POSPISILIK. *Elektricke stroje v energetice.* Ostrava: Vysoka skola banska–Technicka univerzita Ostrava, Fakulta elektrotechniky a informatiky, 2003. ISBN 80-248-0314-3.

[2] HAMATA, V. *Hluk elektrickych stroju.* Praha: Academia, 1987.

[3] TOMLINSON, H. *Anti-noise* [online]. 2009. Avaiable at: `http://www.mefeedia.com/-Anti-noisebyTomlinsonHolman`.

[4] Standard CSN 01 1601, CSN EN ISO 266, *Acoustics. Frequencies for measuring.*

[5] Standard CSN EN ISO 3740, *Acoustics - Determination of sound power levels of noise.*

[6] MISAK, S. *Technicka Diagnostika.* Ostrava: Vysoka skola banska–Technicka univertita Ostrava, Fakulta elektrotechniky a informatiky, 2007.

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Stanislav MISAK was born in 1978 in Slavicin, Czech Republic. He received his associate professor in 2009 in Electrical power engineering from department Electrical Power Engineering, VSB–Technical university of Ostrava, Czech Republic. He was in 2011 nominated for the top 100 researchers of the World, awarded the national patent and other intellectual property patent protections. In 2012 was appointed of a delegate from the Czech Republic to the European Union Commission for the strategic management of renewable energy sources: Sherpa - European Community Steering Group for the SET-Plan, Wind and Solar Energy, GRID Systems. He has been successful in obtaining a number of research contracts and grants from industries and Federal government agencies for projects related to these areas. He is currently engaged with his team in implementing the SmartGrid technologies based on bio-inspired methods and prediction models in distributions and transmission systems.