Measurements and Elimination of the Electromagnetic Interference in Industry Environments

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Abstract—**The paper deals with problems and research of the electromagnetic interference of the technology systems with respect to their functionality and reliability for the reconstruction or installation of modern electronics and modern control systems in the existing technologies in industrial areas. It is becoming ever more important to pay attention to problems of the safe operation of the information systems, the data and the signal flow with the lowest error rates of transmission and elimination of the negative influences of various disturbances and interference. The article describes the modern design, simulation and implementation of the measurement methods of electromagnetic interference in a renovated industrial company in the Czech Republic. Based on the evaluation of the measured parameters and waveforms of signals, measures are suggested to eliminate the electromagnetic interference for reliable operation of control systems. Moreover, the implementation of the developed mathematical simulation model for electromagnetic field is explained.**

Index Terms—**Electromagnetic Interference; Interference Elimination; Electromagnetic Compatibility; Signal Analyses; Electromagnetic Simulation.**

I. Introduction

The analysis of electromagnetic compatibility is necessary in cases of implementing modern and technologically complicated control systems for industrial environments, which requires the use of appropriate and proven methods of measurement. The testing in industry is focused on measuring problematic embedded device parameters to protect against interference signals. It also focuses on the identification of interfering signals on the synthesis of technical measures for their suppression. For high quality measurement and analysis of problematic aspects, it is necessary to use modern equipment with measuring technique that allows to measure, analyze, draft and process signals in the frequency domain from 9 kHz to GHz units. Modern methods, procedures and equipment are used for the testing of technological devices. They are precisely defined in relevant standards, but each measurement is considerably variable and specific with regard to the industrial environments and surroundings, where the modern technology of electronics is installed. For this reason, it is necessary to focus on research activities, particularly to problematic areas with the electromagnetic interference. The measurements are performed in the installed heating plant, where a new server room installation is being prepared. There is a large amount of interference from high-voltage and high power pulse signals in the vicinity of the room in concerned. The aim is to perform the measurement analysis and waveform measurements of disturbing signals in the space. A description of an original simulation model of electromagnetic compatibility interference signals in the given area from the measured data is offered [1].

II. Measurement Methodology And Specification

The measurement research is focused on the following measurements:

- Frequency spectrum of interfering signals in the server room
- Induced interference in the electric cable for the server area
- Voltage difference between the grounding pins in the mains power supply and data shielding.

Based on the measured results, certain steps were taken to eliminate the undesirable electromagnetic interference with the operation of the computers in the server room. The measurement was carried out twice. After the first measurement, technical measures were proposed to eliminate the electromagnetic interference. The second measurement was used to verify the elimination of the electromagnetic interference. After the evaluation, the electromagnetic compatibility measurements were necessary to check the performed measures. Further, it has confirmed the need to look at specific spaces with great care and invest in high-performance technical evaluation of the investigated area. The presented measurement is based on the standard of measurement methods of electromagnetic interface CISPR11, but it was reduced for two measuring height only, because of the specific location of the electronic devices. The measuring purpose is to eliminate possible disturbance in a given location of electronic devices only. The realized analyses are described in the following paragraphs [2,3].

A. *Measurement of the interference high frequency spectra*

The measuring points placement for measuring the frequency spectra of interfering signals and analysis of measured data in server room is as shown in Figure 1. In the left room, the measurement was performed in points No.1 to No. 5. In the right part of the room, the measurement was performed in point No. 6 on the area, where it was thought the highest possible undesirable interference, and in point No. 7 - No. 10 which are above ground at a height of 0,5m, where the height at which the new technology to be installed was verified. The measuring antenna was polarized to horizontal and vertical position, because of the maximal power spectra detection for interference analysis at the given frequencies.

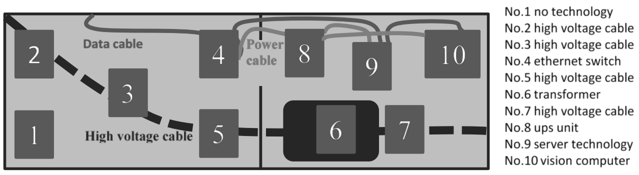


Figure 1: Elementary location for electromagnetic measurement of the interferenc

Measurements were performed for the frequency ranges for the detection of interfering signals, caused by especially induced by interference from the power lines of high voltage transformer:

- Frequency range f = 100 kHz – 30 MHz
- Frequency range f = 30 MHz – 300 MHz
- Frequency range f = 300 MHz – 1 GHz

The battery Spectrum Analyzer R & S FSH-6 is suitable for high-precision measurements in the industry operation (Figure 2). The technical parameters of the spectrum analyzer are as follows: the bandwidth is 100 kHz to 6 GHz, original resolution bandwidth is 100 Hz - 1 MHz, battery power, memory for 100 measurements, easy data transfer to a PC, and the display resolution 320 x 240 pixels.

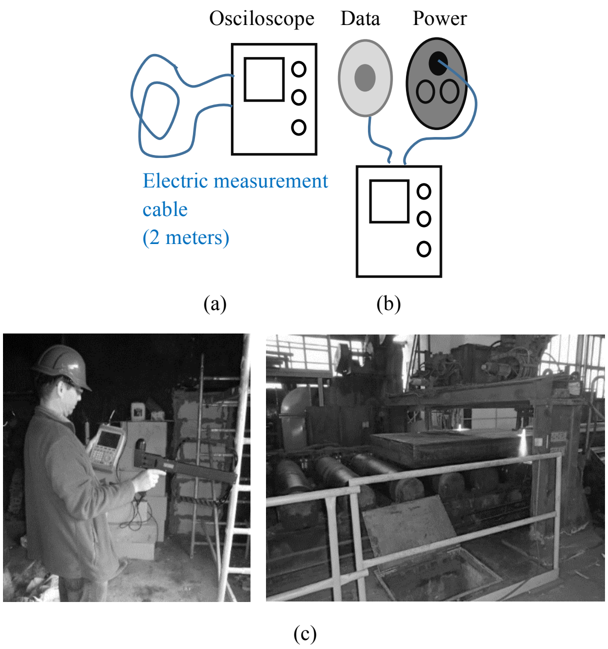


Figure 2: (a) Situation the measurement of interference into electric cable, b) Situation the measurement of voltage difference grounding pins c) The measurement processing examples in future server room and industry area placement

B. *Measurement for analysis of interference into electric cable for the server area*

The measuring points for measuring the induction of the interference into the power cable and analysis of measured data in the server room and industry area can be seen in Figure 1 and 2(a). In the right room, the measurements were taken in points No. 6 and No. 7 and the measuring points No. 8, No. 9, No. 10 at a distance of 0.5 m in view of the subsequent location of innovative technology of the server room. The digital oscilloscope AGILENT DSO7012B is usable for the measurement up f = 100 MHz.

C. *Measurement of voltage difference between the grounding pins of pieces of equipment placed in area*

Measurements were recommended to the properly connections and grounding of all installed electronic components in the server, as shown in Figure 2(b). The conducted analysis is focused on the measurement of the time courses of the interference signals on the grounding pins of different cables in the server room, between the pins and the grounded structures, between the pins and the grounded shielded data cables.

The measurement is conducted by digital oscilloscope AGILENT DSO7012B, the same as the one for the analysis of interference into electric cable for the server area.

D. *Possible disturbing signals from noisy surroundings of electromagnetic measurement*

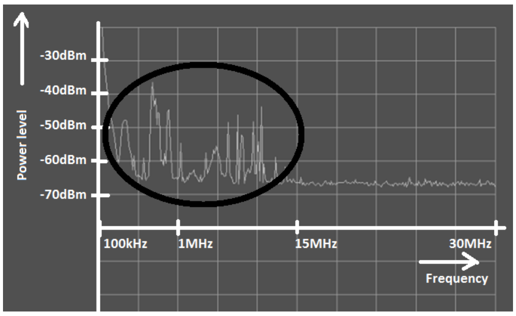
The measurements are based on principles, which are given by the electromagnetic compatibility directive – symbiosis and interrelation signal sources with the measurement of nonstandard states - EMC 2004/108/ES. The description is divided into i) the recognition of EMS - Electromagnetic Susceptibility (device influence generation) and ii) the EMI - Electromagnetic Interference (device influence robustness). The elementary disturbing signals are caused by cables signal propagation by the near field binding (spurious signal – intensity of electric field E, intensity of magnetic field H), by far field emission. The examples of possible generated disturbing signal and reasons of noise are: impulse signal – discharge, switching load, oscillation in signal – switching capacitor, switching wires, harmonic parts in signal – nonlinear load, frequency convertor, resonance, periodic pulses signal – power drives, phase regulator, boost convertor, noise signal – high frequency sources, impulse rectifier, switched signal – switches or fuse, signal decrease – engine start, load connect, short circuit, signal increase – load changes, error [4].

III. Verification and Measured Results

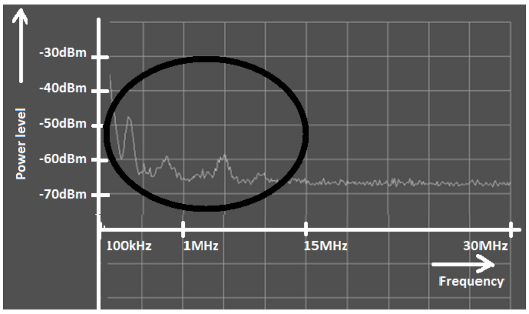
The measurement verification is performed twice: Measurement in actual installation and measurement verification after the recommended modification. The point's placement for measurement of the frequency spectra of interfering signals and analysis of measured data in future server room are the same for both measurements.

A. *Verification and measurement of the interference high frequency spectra*

The obtained measurement results of the high frequency spectra and comparison of these result waveforms are described in this section. The interfering signals, caused by especially induced by interference from the power cables of high voltage transformer were detected in the frequency range of f = 100 kHz - 30 MHz. The transformer was placed 3 meters under 20cm wide concrete floor – measuring point No.6 of Fig.1. Transformer parameters are 22kV/6,3kV with approximately constant spend power 350kVA. High voltage cable was placed 0.5m under concrete floor – measuring points No. 2, 3, 5, 7 as shown in Figure 1.



(a)



(b)

Figure 3: The measurement at No.9 of Figure 1 in the frequency range of f = 100 kHz - 30 MHz
(a) on the floor, P = -35 dBm, P = 3.16×10^{-4} mW,
(b) above the floor d = 0.5 m, P = -48 dBm, P = 1.58×10^{-5} mW

The generated harmonic components of the interference signal were measured directly on the floor - measurement point No. 6, values around PdB = -35 dB, which corresponds to P = 3.16×10^{-4} mW (Figure 3(a)) up to frequency 15 MHz. At a height of d = 0.5 m, there were measured values of interfering signals in the band around PdB = -48 dBm (Figure 3b), which corresponds to P = 1.58×10^{-5} mW (measurement points No. 6, 7). After the realization of recommended modification, especially the implementation of electromagnetic reduction plates on the floor, it was found that there was no significant interfering signals caused by interfering signals from power cables in the frequency range of f = 100 kHz - 30 MHz.

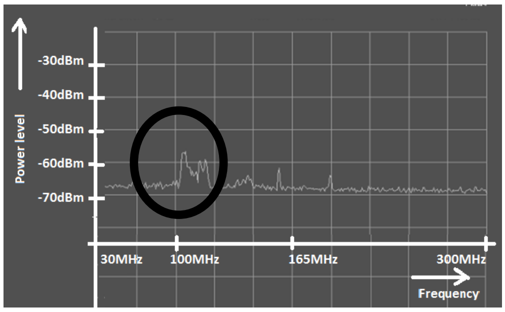
Interfering signals, which are unrelated to interference from the transformer and high voltage cables were detected in the frequency range of f = 30 MHz – 300 MHz. Measured signals were located in the frequency range f = 85-110 MHz, which is radio broadcast band. The measured size of the power harmonic components was more than PdB = -55 dB, which corresponds to P = 3.16×10^{-6} mW. (Figure 4a,b).

Signals, which are unrelated to interference from the transformer and high voltage lines were detected in the frequency range of f = 300 MHz – 1 GHz. The measured signals were located in the frequency range f = 550 MHz and f = 900 MHz, which is only broadcasting television signal band and mobile phones. The measured size of the power harmonic components was more than PdB = -55 dB, which corresponds to P = 3.16×10^{-6} mW. (Figure 5(a) and (b)).

B. Verification and measurement of the interference high frequency spectra

Measurements were focused on measuring the time courses of induced by interference into the cable in the measured sever area. The measured signals were located in the f = 50 Hz of the interference harmonic signal with maximal amplitude W_{max} = 3.74 V and maximal RMS W_{RMS} = 2.6 V. (Figure 6(a)).

After the realization of recommended modification, especially the implementation of electromagnetic reduction plates on the floor, there were reducing signals caused by signals from power cables and transformer at frequency f = 50 Hz with maximal amplitude W_{max} = 0.72 V and RMS W_{RMS} = 0.45 V. (Figure 6(b)).



(a)

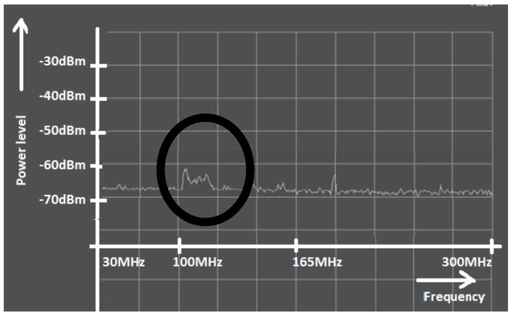
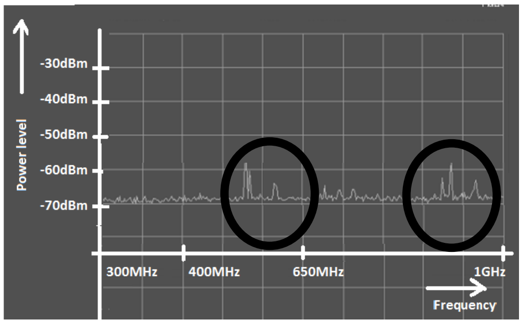
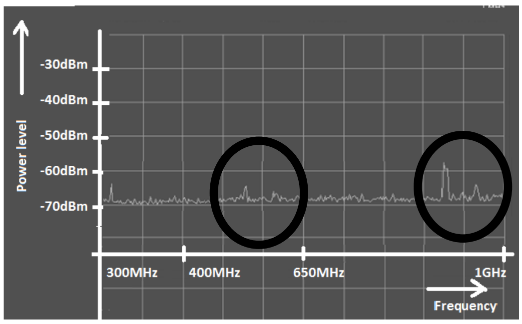


Figure 4: The measurement at No.9 of Figure 1 in the frequency range of f = 30 MHz – 300 MHz
(a) on the floor, P_{db} = -55 dBm, P = 3.16×10^{-6} mW,
(b) above the floor = 0.5 m, P_{db} = -55 dBm, P = 3.16×10^{-6} mW

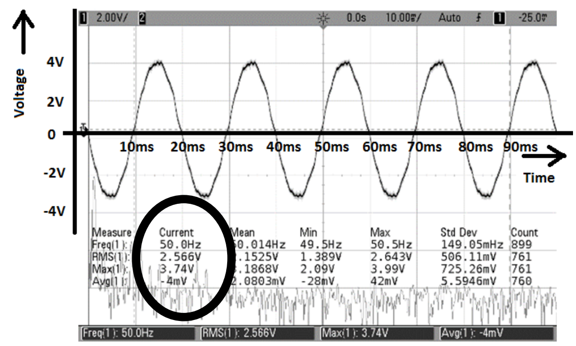


(a)

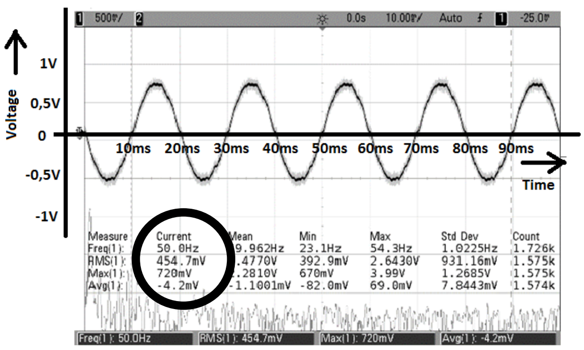


(b)

Figure 5: The measurement at No.9 of Figure 1 in the frequency range of f = 300 MHz – 1 GHz
(a) on the floor, Pdb = -55 dBm, P = 3.16×10^{-6} mW,
(b) above the floor d = 0.5 m, P_{db} = -55 dBm, P = 3.16×10^{-6} mW



(a)



(b)

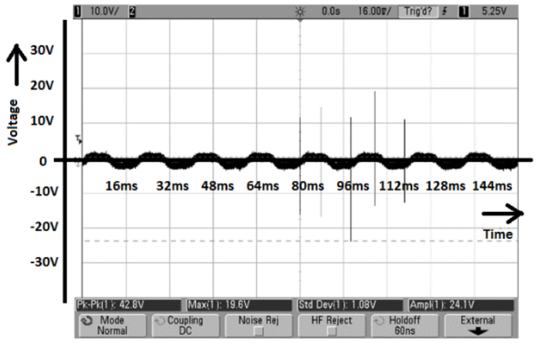
Figure 6: The measured signal in the time domain - frequency f = 50 Hz
(a) on the floor, maximal W_{RMS} = 2,6 V, maximal W_{MAX} = 3,74 V
(b) above the floor d = 0.5 m maximal W_{RMS} = 0,45V, maximal W_{MAX} = 0,72V

C. Verification and measurement of voltage difference between the grounding pins of devices

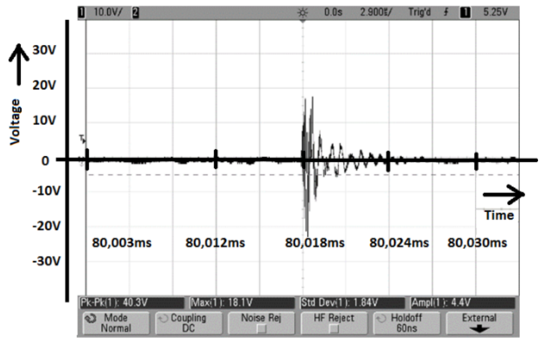
Measurements were focused on measuring the time courses of the interference signals on the grounding pins of different wires in the server room, between the pins and the grounded structures, between the pins and grounded shielded data cables.

It can be observed that the interference backswings of voltage in values up to $W_{PEAK-PEAK}$ = 80V peak - peak (Figure 7). The measured interfering signals in the shape of pulses were at unevenly decomposed in time. It can be deduced the high voltage transformer or the high voltage distribution systems were in operation under the server room.

It was recommended for a properly connections and grounding of all components in the server, emplace the servers at least half a meter above ground level, the power supply of the computer equipment (servers) exclusively via UPS (uninterruptible power supply), which include overvoltage and EMC filters that will have to be located immediately near the server. Furthermore, it is necessary to perform mutual separation and minimizes parallel data lines, galvanic separation of the data and the network part, to spatially locate servers far away as possible from the interference sources (from high voltage transformer); galvanic isolation and higher resistance to interference can be applied to the use of the specific industrial computer, which is deployed for industrial use and contains the components to eliminate the external interference of the electronic system [5,6].



(a)



(b)

Figure 7: The measured signal in the time domain with pulse disturbance signal up to $W_{PEAK-PEAK}$ = 80 V
(a) Voltage signal in time domain,
(b) zoom of pulse disturbance in measured voltage signal in time domain

After the realization of the recommended modification. It was found that there is no significant interfering signals between the grounding caused by interfering signals from the power supply.

IV. Simulation Model of Disturbance Interference Signal Propagation From Measured Results

The simulation model of disturbance interference signal propagation is implemented from the measured results, which are settable in the original developed application. Mathematical approximation of noise signal intensity is realized by Maxwell equation and quadrature propagation compute to a given area.

$$\Delta\vec{E} - \mu \cdot \epsilon \cdot \frac{\partial^2 \vec{E}}{\partial t^2} - \mu \cdot \sigma \cdot \frac{\partial \vec{E}}{\partial t} = 0 \qquad (1)$$

It is possible to compute the intensity of electric field intensity E, magnetic field intensity H by the given permeability, conductivity and permittivity.

The measured power signal P (dBm) is possible to recalculate on units mW or by given impedance Z_0 = 50Ω of antenna to voltage V, where P_0 is equivalent of 1 mW.

$$P(\text{dBm}) = 10 \cdot \log \frac{P(\text{mW})}{P_0(\text{mW})} \Rightarrow U = \sqrt{Z_0(\Omega) \cdot P(\text{W})} \qquad (2)$$

There is an implemented simplified homogeneous electromagnetic field without incidence of boundaries effects designed by the base of Equation (1). The simulation model of the electromagnetic field was based on numerical calculation of Finite Element Method by differential equation solution. Boundary conditions were simplified to constant permittivity, tangent part of electric field intensity, E in boundary area, given the approximate potential value from own measuring in boundaries network nodes close to floor in distance 50 centimeters, magnetic field intensity, H in nodes was computed as minimal residuum by the least squares method. Approximation function of simulated nodes network has a linear form [7]. It is possible to measure data typesetting in the developed application as RMS value WRMS, maximal amplitude value WMAX, power value, P, effective value, W_{ef}. The setting data pixel resolution was realized for the difference in the possibility of view of separate layer in the area.

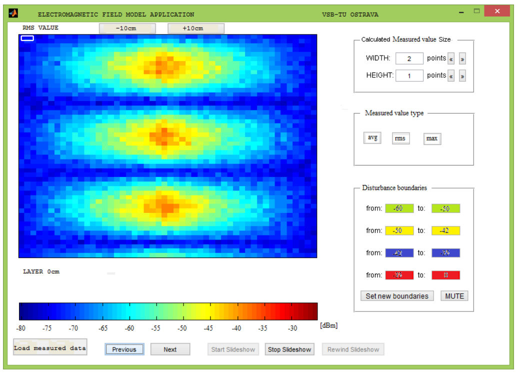


Figure 8: Original application of electromagnetic field simulation model from measured data (setting-power level P[dBm])

The setting of disturbance boundaries gives very important instruments for an autonomous detection of dangerous signal values. This developed application presents easy and powerful way for helpful estimative simulation conception (Figure 8).

V. Conclusion

The paper described a brief synopsis of research, focusing on measurement, simulation and elimination of the electromagnetic interference in the industrial areas, which is conducted under the grant together with an industrial company. The development of the measurement procedure and verification, through comprehensive analyses, was in the specific industrial environment, considered as very important in the design and implementation of the electronic system, and later for its verification through correct operations. The paper briefly presented the initial measurements and proposed certain measures to eliminate undesirable interference with its results comparison. The implementation of the original simulation model was described with the comparisoan of measurements. The implementation of the recommended measurements to prevent the failure rate and instability of the innovative technology in industrial environment was also described. Results of the realized measurements of frequency spectrum of interfering signals in the server room, induced interference in the electric cable for the server area, voltage difference between the grounding pins in the mains power supply and data shielding were presented as well. The main signal noise problem was detected from the induced disturbance voltage pulses between the grounding pins of devices moreover 80V. This shape of pulses are too intensive from the high voltage transformer or the high voltage distribution systems, which are in operation under the server room. This study also reported a successful minimal disturbing measurement after the implementation of overvoltage and EMC filters, mutual separation, minimizing of parallel data lines, galvanic separation of the data and the network part, server location far away as possible from interference sources, galvanic isolation and higher resistance to interference.

Acknowledgments

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