Electromagnetic Compatibility and Power-Line Quality

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***Abstract* — The quality of power-line nets is very closely related to electromagnetic compatibility, so several quality parameters need to be evaluated to take this into consideration. Quality parameters are generally measured with the help of analyzer devices. There are standard quantities and parameters - as well as special data relating to the metering of dynamic behavior consumption, or harmonic frequency actions, etc. The basic parameters are analyzed in accordance to the different factors and coefficients of active and reactive processes. Electromagnetic Compatibility Evaluation makes use of results gained from the analysis of power-line quality. The electromagnetic compatibility evaluation results are then more accurate and predictive regarding the actual state and its influence over a distribution network from third-party consumption. This ensures that reliable operations to consumers are maintained and that any negative interaction of the supply network is minimalized.**

Keywords-EMC; power-line quality; consumer net parameters; harmonic frequency; dynamic system

I. INTRODUCTION

Electro-Magnetic Compatibility (further only EMC) is a significant system for the preservation of power-line nets and their operations, for immunity and for the economy of states. Its determination and observance is subject to lawful procurement and standards [1] [10]-[14][16].

The term “power-line quality” is involved in several heterogeneous areas of the distribution network structures connected to appliances that demand energy. The user is closely linked to EMC problems, and the solutions require specific access to low-net frequency (50 Hz and harmonics) and to heavy currents and strong magnetic fields [2][3].

The stability of power-line parameters within tolerance limits is given by legal regulations and standards which provide for electric-power distribution in transmission systems. The energy consumer generally influences issues by connecting to a network - according to the kind and type of arrangement back to a distribution network and next - other neighboring consumers [4].

EMC deals with the ability of each electric or electronic device to work, fault-free, in an electromagnetic field (i.e. electromagnetic susceptibility) and do not generate a disturbance field into its surroundings (i.e. electromagnetic interference).

The problem of EMC is ever-more topical as a consequence of the extensive use of low-current electronic devices on one hand, while, on the other hand, there are ever more numbers of power-semiconductor converters that generate interferential disturbances. These disturbances extend through space and in the ambient environment. The rest of the paper is structured as follows. Section II presents basic power-lines parameters. The following sections address interactions in a power line, periodic voltage fluctuation, voltage asymmetry, harmonics and, finally, power line quality measurement.

II. POWER-LINE NET PARAMETERS

The basic parameters of a power-line network include:

- Supply frequency
- Net voltage
- Supply network voltage difference
- Rapid dynamic voltage changes
- Short-term voltage drops
- Power-line voltage asymmetry
- Harmonic and inter-harmonic voltage
- Short-term or long-term breaks in power supply
- Overvoltage between live conductor and earth

The measured values for each parameter have Root Mean Square (RMS) data, peak data, and given-limit data. The limit data relates to the agreements or contracts between partners. Frequency and voltage parameters are system data based on the distribution system and supply demands. The electrical energy power producers assure these parameters at the production point [5][8].

III. INTERACTIONS IN A POWER-LINE

Electromagnetic Interferences (further only EMI) Sources are generally established by the electrical arrangement (e.g. generators, transformers, changers, switches) or electrical-devices (e.g. sources, LV consumers, automation elements, light sources, etc.). An EMI source can also be a system that produces electrostatic charges. Other specific EMI sources include radio and television transmissions, wireless communications and nets [9].

The coupling between EMI elements is realized by cable as a galvanic structure, or in capacitive or inductive structure environments. A general view of EMI is shown in Figure 1.

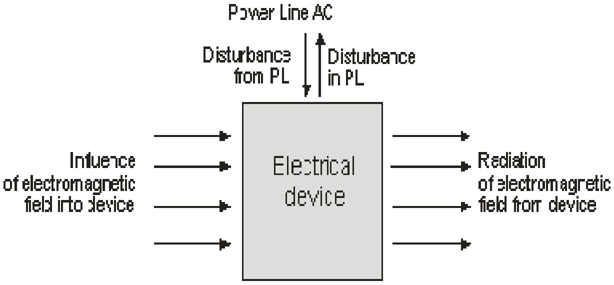

Figure 1. EMI Inter-connection Scheme

The retro-interaction of a connected consumer is always displayed in a real supply network. The current consumption from nets causes voltage change at impedances over time and according to the connection distance. These processes have a stochastic character. A chart showing supply network and consumer connections is shown in Figure 1 [5]-[7].

For example, it is possible to show this in the incidence of disturbing influences from light sources. All sources except light bulbs without regulation react specifically, according to the time behavior of voltage in the network. The process is represented by the following characteristics: the effective value of the voltage; its drift; and changes in the harmonics and inter-harmonics of voltage; etc.

IV. PERIODIC VOLTAGE FLUCTUATION

Periodic Voltage Fluctuation over a longer time-frame is called flicker. It is visible - without measurement, in light sources - displayed as optic reception alterations.

Flicker is induced in appliances by switching on some big power-loading, by starting-up some heavy-duty motors, by some form of variable power-loading, or by dynamic behavior at current consumption levels.

Flicker is also negatively expressed as a magnetic arrangement, when it can shut-off switch elements. Its negative incidence and disturbances are also displayed in the information technology arrangements, or by computation techniques, or measurement and actuator techniques.

V. VOLTAGE ASYMMETRY

Multi-phase systems use an Asymmetry Classification system. Asymmetry means that all three voltage and currents phases have the same amplitude and the phase shift is 120°. This is valid for a system where effective pressure is associated with tension between successive phased tensions. In order to classify asymmetry, there is a need to speculate about the partition of a system into consecutive (d), backward (e) and zero (h) systems.

The main source of asymmetry is the asymmetry of current-loading. There are many appliances that draw heavy power-loads from one or two phases and on the high voltage side (e.g., train traction, electrical ovens). Low-voltage loading is usually single-phase and here, the situation is without guarantee of asymmetry.

VI. HARMONICS

The harmonic frequencies for EMC in a power-line network can be observed up to the fiftieth harmonics scale. Inception of harmonics is an arrangement which distorts the sinusoidal wave. Devices - such as frequency converters rectifiers and units that transact phase-angle control of sinus traces induce a very strong rise in harmonics and have a very strong influence that is possible to follow for the third harmonics scale (150 Hz), the fifth (250 Hz) scale, and the seventh harmonic scale (350 Hz) [5][6][8]-[11].

A description of the real process of harmonics scales: x(τ) is possible with the help of the Fourier Function:

$$x(\tau)=a_0+\sum_{1}^{n}\left[a_k.\cos(k.\overline{w}.\tau)+b_k.\sin(k.\overline{w}.\tau)\right] \qquad (1)$$

where,

$$\overline{w}=\frac{2\pi}{T}=2\pi f\,, \qquad (2)$$

$$a_0=\int_{-T/2}^{+T/2}x(\tau).d\tau=\frac{1}{2\pi}\int_{-\pi}^{\pi}w.\tau.d(w.\tau) \qquad (3)$$

$$a_k=\frac{1}{\pi}\int_{-\pi}^{\pi}x(w.\tau).\cos(k.w.\tau).d(w.\tau) \qquad (4)$$

$$b_k=\frac{1}{\pi}\int_{-\pi}^{\pi}x(w.\tau).\sin(k.w.\tau).d(w.\tau) \qquad (5)$$

The total harmonic content is assessed in accordance with the Total Harmonic Disturbance (THD) parameter - it is a total distortion of the harmonics or of a total harmonic factor. Its formula is given by:

$$THD_1=\frac{\sqrt{\sum_{2}^{n}I_k^2}}{I_1} \qquad (6)$$

Voltage spikes and related disturbances are negative and have backward effects on the power-line network from the harmonics. Different processes are the source of harmonics and at the connection point of devices. The harmonic currents flow from a nonlinear arrangement to the networks and change the impedance of the network.

VII. POWER-LINE QUALITY MEASUREMENT

A demo-measurement was performed using a FLUKE 437 device [12].

The wiring of the device for a three-phase system is shown in Figure 2. It is possible to parameterize this to various kinds of networks (e.g.TN S, TN C).

Measurement is performed using an embedded micro-computer system, programmed for the automatic metering of concrete functions.

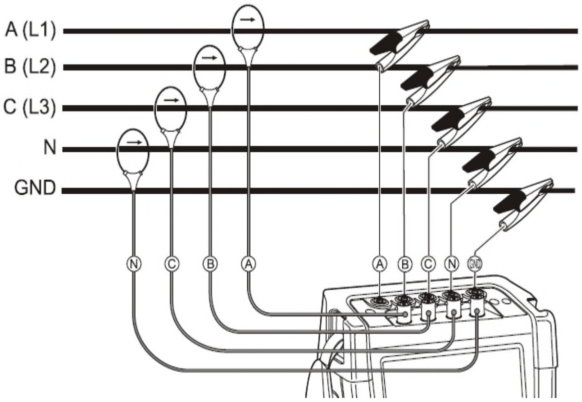

Figure 2. Scheme of connection on a three-phase network

The basic metering is transformed using algorithms for the parameters mentioned below:

- The measurement time-window (Tw) is 10/12 cycles in accord with the frequency - (i.e. 50/60 Hz), IEC 61000-4-30
- It uses 5 samples per 10 cycles
- The sampling of metering using a Fluke 437 device is 100 kHz (10 mm), and is derived from the frequency of sinusoids.
- The accuracy of measurements is for voltage of 0.1% from V_{nom} for a near entrance; for a current of 0.5% out of the read values
- The resolution is 0.01V; for flows within an i430flex TF cable is 1x 1A; for 10x greater sensitivity, it is 0.1A
- A 16-bit ADC on 8 channels is employed
- The frequency accuracy and resolution is 90.001 cps
- Effective Voltage: $Urms = \sqrt{\frac{1}{T_w}\sum_{n=0}^{T_w} u_n^2}$

  (7)
- Effective Current: $Irms = \sqrt{\frac{1}{T_w}\sum_{n=0}^{T_w} i_n^2}$ (8)
- Effective Power (W):

$$P_x = \frac{1}{N}\sum_{n=K}^{K+N} u_x(n).i_x(n) \quad (9)$$

- Basic Effective Power of Phases (W) :

$$P_{1X} = U_{1x}.I_{1x}.\cos(\varphi u_{1x} - \varphi i_{1x}) \quad (10)$$

- Apparent Power (S):

$$S_X = U_x.I_x, \quad (11)$$

- Reactive Power (only basic) (Q):

$$Q_{1X} = U_{1x}.I_{1x}.\sin(\varphi u_{1x} - \varphi i_{1x}) \quad (12).$$

A. *Examples of Measurements on Devices*

The model measurements were performed for selected appliances – namely, for a small Voltcraft 2256, 60VA power supply; for an IR radiator like a typical ohmic appliance, and for an ETATOOL 930W impacted drilling machine as an inductance appliance.

B. *Measurement Results*

The results of sample measurements are presented in Figure 3, here below. As a demonstration, it shows metering of U – voltage; I – current; and f – frequency, for an IR radiator:

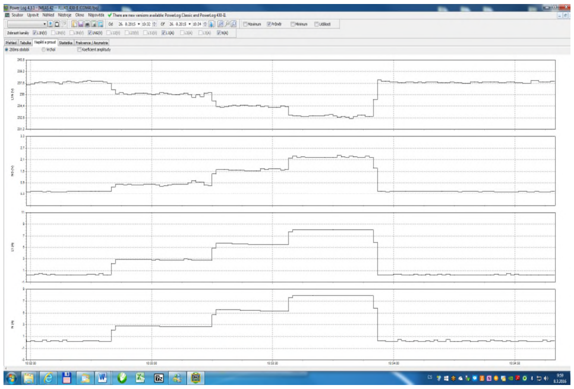

Figure 3. Graphs of MEAS42 Measurements

Another demonstration shown in Figure 4, is the measurement falls and over-swings for a drilling machine:

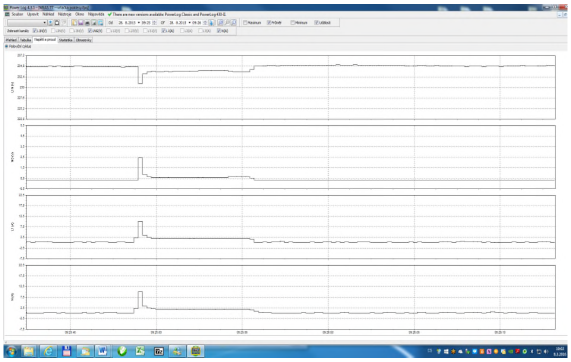

Figure 4. Graphs of MEAS44 Measurements

The measurement of harmonics is depicted in Figure 5 and Figure 6 for voltage, and subsequently - for the THD coefficient:

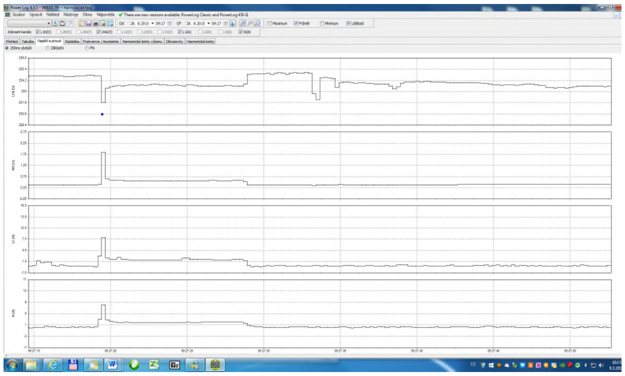

Figure 5. Liner Graphs of MEAS79 Measurements

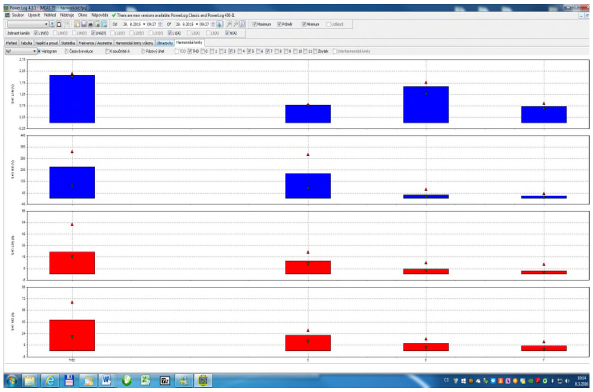

Figure 6. Column Graphs of MEAS79 Measurements

The measurement of asymmetry and impacts on voltage and current is shown in Figure 7:

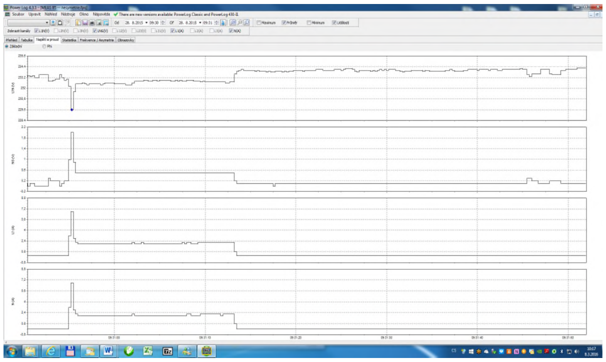

Figure 7. Graphs of MEAS85 Measurements

VIII. CONCLUSION

This contribution shows the significance and impacts of connections with power-line quality. It presents all the problems that it solves – i.e. common main problems like for instance – the generation of harmonics, and the impacts of fast changes – i.e. "flicker" and "voltage asymmetry". It also goes on to show examples of the measurement of power-line quality by the help of modern devices - for three sample appliances. At the same time, there is an accent on the structure relating to electromagnetic compatibility questions.

REFERENCES

[1] R. C. Dugan, Mark McGranaghan, Surya Santoso, H. Wayne Beaty, Electrical Power Systems Quality. McGraw-Hill, 2003.

[2] A. Baggini, Handbook of Power Quality. Wiley, 2008

[3] A. Kusko, T. Marc, Power Quality in Electrical Systems. McGraw Hill, 2007.

[4] Rules of operation of distribution systems. Quality of voltage in distribution system, ways of its detection and evaluation. (Pravidla provozování distribučních soustav. Kvalita napětí v distribuční soustavě, způsoby jejího zjišťování a hodnocení.). Prague – ERU, 2011. PPDS.

[5] A. Dán, P.Santarius, Quality of supplied energy in nets of low voltage (Kvalita dodávané energie v sítích nízkého napětí). Ostrava – VSB-TU a Hungarian Copper Promotion Centre.

[6] P.Mindl, Problems of EMC in operation of electric arrangement and instruments of low voltage (Problémy EMC v provozu elektrických zařízení a přístrojů nízkého napětí). Prag – CVUT, 2001

[7] P. Marek, Measurement and analyse of quality of power-line nets. (Měření a analýza kvality napájecí sítě). BRNO-VUT, 2013

[8] W. Langguth, Quality of electric energy – guide. Grounding and EMC. Principles of electromagnetic compatibility (EMC) (Kvalita elektrické energie – Průvodce. Uzemnění a EMC. Základy elektromagnetické kompatibility (EMC)). Leuven-Hungarian Copper Promotion Centre. Translate Ostrava-VSB-TU, 2006

[9] J. Driesen, T. CraenenBroeck, Quality of electric power – guide. Interference voltage. Introduction to the asymmetrically (Kvalita elektrické energie – Průvodce. Rušivé napětí. Úvod do nesymetrie). Leuven-Hungarian Copper Promotion Centre . Překlad Ostrava-VŠB-TU, 2005

[10] V. Hašpl, Higher harmonics and its incidence on power-line net (Vyšší harmonické a jejich působení na síť). Elektro 6/2008, pp. 32-33

[11] ČSN IEC 1000-2-1 (33 3431) Electromagnetic compatibility (EMC). Part of 2: Environment. Chaptert of 1: Description of environment - electromagnetic environment of low - frequency conducted by disturbance and signals in public distribution power-line nets. (Elektromagnetická kompatibilita (EMC). Část 2: Prostředí. Díl 1: Popis prostředí - elektromagnetické prostředí pro nízkofrekvenční vedené rušení a signály ve veřejných rozvodných sítích.). Czech Office for standards, metrology and Testing, Prague, 1993

[12] ČSN IEC 1000-2-2 (33 3431) Electromagnetic compatibility (EMC). Part 2: Environment. Chapter 2: Compatibility levels of low-frequency disturbing conducted by disturbance and signals in public distribution power-line nets. (Elektromagnetická kompatibilita (EMC). Část 2: Prostředí. Díl 2: Kompatibilní úrovně pro nízkofrekvenční rušení šířené vedením a signály v rozvodných sítích nízkého napětí). Czech Office for standards, metrology and Testing, Prag, 1995.

[13] ČSN EN 61000-2-4 (33 3432) Electromagnetic compatibility (EMC). Part of 2: Environment. Chapter of 4: Compatibity levels of low-frequency disturbing conducted into industrial fabrics. (Elektromagnetická kompatibilita (EMC) - Část 2: Prostředí - Oddíl 4: Kompatibilní úrovně pro nízkofrekvenční rušení šířené vedením v průmyslových závodech). Czech Office for standards, metrology and Testing, Prag, 2003.

[14] ČSN EN 61000-4-11:1996(33 3432) Electromagnetic compatibility (EMC). Part of 4: Environment. Chapter of 11: .Short - period of drops of voltage, short interrupts and slow voltage change - examination immunity. (Elektromagnetická kompatibilita (EMC) - Část 4: Zkušební a měřicí techniky - Oddíl 11: Krátkodobé poklesy napětí, krátká přerušení a pomalé změny napětí - Zkoušky odolnosti.). Czech Office for standards, metrology and Testing, Prag, 2005.

[15] Fluke Corporation. Three - phase analyzer of quality of electric energy (Třífázový analyzátor kvality elektrické energie.) Fluke 437-II. User guide. 2012.

[16] IEEE Standard 519 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems section 10.5 Flicker