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Disturbances in Industrial Power Networks

Abstract*. The paper presents some preliminary results of the in-situ measurements of disturbances that were observed in mine underground power network. The purpose of the measurements was to identify potential interfering signals that may occur in such and similar power networks and may be dangerous for electronic equipment powered from, or working in close proximity of such network.*

Streszczenie. *W artykule przedstawiono wstępne wyniki pomiarów in-situ zaburzeń obserwowanych w podziemnej sieci zasilającej kopalni. Celem pomiarów było zidentyfikowanie potencjalnych sygnałów zakłócających pracę innych urządzeń, które mogą wystąpić w takich i podobnych sieciach zasilających i mogą być niebezpieczne dla urządzeń elektronicznych zasilanych z takiej sieci lub pracujących w jej bezpośredniej bliskości* ***(Zakłócenia w przemysłowych sieciach zasilających)****.*

Keywords: power lines, disturbances, industrial environment, mines
Słowa kluczowe: sieci zasilania, zaburzenia, środowisko przemysłowe, kopalnie

Comparison between disturbance and immunity levels

The level of disturbances observed in industrial environments and the required immunity of the devices expected to work in these environments are very often contradictory. Although it is believed that the fulfillment of the requirements according to standards concerning industrial environment (EN 61000-6-2: required levels of immunity and EN 61000-6-4: emission limits) should ensure compatible operation of all devices within a given environment, there are cases when this is not true. In some environments (for example underground mines) the problem of EMC was neglected for many years – there are many old machines that do not comply with standard industrial environment requirements and produce much bigger disturbances. Therefore there is significant risk, that devices introduced in the same environment will not be immune to these disturbances, even if they comply with EN 61000-6-2.

In current practice, many device manufacturers and future users of these devices present the opinion that meeting the aforementioned standard requirements is sufficient "to a peaceful sleep". Well, it is not so!

It should be noted that the device expected to work in the industrial electromagnetic environment is tested in conditions much different from the environmental conditions in the destination of their workplace. In addition, tests are carried out "here and now" (in a short period of time), recording “continuous” disturbances, which in fact are present in the moment of measurements. In addition, one should note that in the real environment, there may be situations of simultaneous incidence of different disturbances, which present different characters, different ways of coupling etc., resulting in complex disturbance environment.

The EN 61000-6-2 [1] and EN 61000-6-4 [2] standards do not require observing the equipment in the long term, while there is a possibility of higher level disturbance appearance over a longer period of time. This particularly applies to immunity testing.

There are also significant problems resulting from the functional safety of devices and people safety in the environment where even rare events resulting from the disturbance (causing incorrect work of the device) may cause disastrous consequences. Occurrence of such situations when there is a possibility of high level disturbances appearance (occurring from time to time) must be related to functional safety and unanticipated consequences in real environment.

These considerations led the IEC to start work on finding new, more stringent requirements for the immunity of equipment working in special industrial environments. As a result, the new standard is being developed, EN 61000-6-7: “Electromagnetic compatibility (EMC) – Generic standards – immunity requirements for safety related systems and for equipment intended to perform safety-related functions (functional safety) in industrial environments”, for testing the immunity of the devices expected to work in the special industrial environments.

In-situ conducted interference - pulse disturbances

Power network is medium in which many electromagnetic events occur, for example switching on/off of high power devices can produce substantial problems and can provoke unwanted (and potentially dangerous) behaviour of equipment connected to the same power network. Most often these unwanted events are high-amplitude pulses of various duration. They can directly interfere with operations of various electronic control devices, or interfere with machine equipment, resulting in undesired reactions, that can even lead to very serious accidents.

Also sudden on/off operations of large inductive loads, which often occur in case of engines operating heavy lifts, turbines etc. can result in large pulses superimposed on the power waveform, with amplitudes exceeding significantly the peak value of nominal voltage in the power network. The fast transients visible on the slopes of voltage waveform are also observed with amplitudes of the order of few tens of Volts. In medium power and high-power networks the switching can result in the series of pulses of very short rise times (several ns), which can provoke substantial danger for microprocessor driven equipment.

The team of National Institute of Telecommunications, EMC Laboratory in Wroclaw conducted a series of power quality measurements in one of copper mines, both on and underground [4]. Measurements were done with power quality analyzer connected, for different periods of time, to power line connections of different mine machines (for example lifts or conveyor belt engines). Particular attention was paid to the on/off operation incidents and what phenomena connected with these operations can be recorded in terms of power quality.

Fig. 1 shows voltage changes in power line cables of ventilator engine of high effectiveness. Presented is max hold diagram of 40 sample measurements performed in 200 ms intervals. The amplitude of fast changes (in time period of about 100 μs) of voltage waveform exceeds 800 V.

The other phenomena typical for industrial power networks are strong distortions of power waveforms, and consequently the occurrence of harmonic distortions, see Fig. 2. Such disturbances are caused particularly by

nonlinear equipment, such as for instance thyristor converters, often used in the lift machine circuits. The associated disturbances can particularly be seen in the lower frequency ranges.

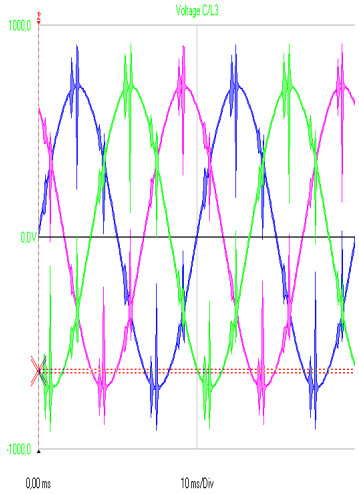

Fig. 1. Voltage changes in power line cables.

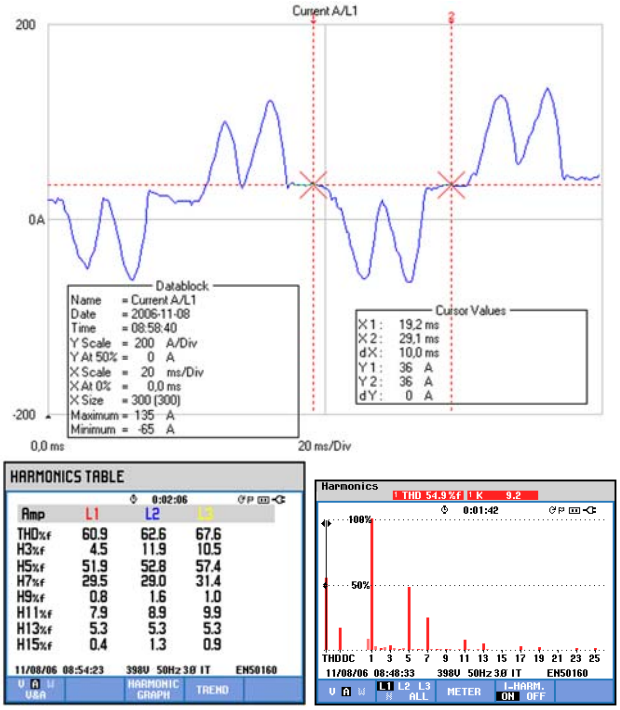

Fig.2. Example of current waveform measurement for one of the phase lines of power inverters (1450 rotations/minute) and harmonic distortions. Symbols shown are according to standard EN 61000-4-30

During the tests in underground mines, the team of National Institute of Telecommunications collects information about the electromagnetic environment in the real operating conditions of the mining plant. These measurements are not performed on separated plants or mines for experimental studies, these tests have been done during copper exploitation in real life active mine. The most relevant research concerning the disturbances in electromagnetic environment in the mine turned out to be conducted disturbances - it is the result of the fact that, in most mines, power network is of the "soft" type to which devices, that generate significant transient conditions, are connected.

The measurement of conducted interference in LV industrial power network can only be performed using RF current probe. The use of Artificial Mains Network (typical for laboratory measurements of conducted interference) is impossible for industrial plant (with work currents of several hundreds of Amps with the voltages of 500/1000 Volts, for some industries even higher). There are no AMNs commercially available that can be used in such conditions. Furthermore, in most cases it is impossible to insert the AMN into the power line of a working mine or at least it causes great difficulty. Therefore it is another reason for current probe usage – the simplicity of measuring set-up and ease of use in real world industrial plant environment; there is no need to break the power line, which is necessary in case of AMN. The alternative could be the use of voltage probes, but it can also be difficult in real world industrial plant applications, because of the impossibility of definitive description of reference ground plane in in-situ conditions (especially in mine tunnels) and usually the mains cords are isolated, so there is a problem of how to connect the probe tip to the tested line.

APD measurements of conducted disturbances

Because of disturbance characteristics that can appear in industrial plants power networks, it is justified and worth to use APD (Amplitude Probability Distribution) measurements. As of today, the APD is usually recommended to be used for frequencies above 1 GHz, for wideband digital systems measurements [3]. However, it is worth to draw attention to the fact that nowadays digital systems appear also quite often at the frequencies below 1 GHz, for example BPLC systems in frequency band below 30 MHz. These systems are often used to control big machines or as industrial plants telecommunication systems.

APD can be very useful for disturbance characteristics description in cases, when those disturbances are random and short in time. In those cases one can, in realistic amount of time, evaluate parameters of the disturbances and compare them with current limits, set for measurements with a quasi-peak detector.

APD measurement technique is basically the evaluation of the probability of disturbance level being higher than allowed limit (for radiated or conducted emissions). The measurements are performed after determining the most critical frequency for the evaluated situation.

It is worth mentioning, that long time data gathering using APD allows to determine given disturbance occurrence percentage and its strength (level). Tests of this type are especially important for disturbance connected risks evaluation when safety is concerned.

Measurements in real industrial environment – mine power network

Presented below are some real world measurement results of conducted disturbances measured in real industrial power network. The figures show the electromagnetic disturbances in power networks in relation to current standards. Such relation shows how important it is to provide adequate protection against disturbances of devices in unique environments such as underground mines.

On figures 3 and 4 some real world measurements of conducted emissions in mine power lines are presented in comparison with existing limits for disturbances in industrial environments. As can be seen on those figures, those limits are significantly exceeded, therefore a simple conclusion that there is a need for further tests and analysis of disturbances occurring in those environments. One can ask the question if the immunity requirements are enough to give required protection for equipment introduced to such special environments, especially in case of equipment connected with safety (for example gas sensors and meters).

As it was mentioned before, the moments of on/off operations of high power machines in industrial environment can produce big currents in power lines (see figures 5 and 6). Those currents can present some serious interference for

other equipment connected to the same power network. The biggest threat can exist for signal lines as well as control and safety equipment.

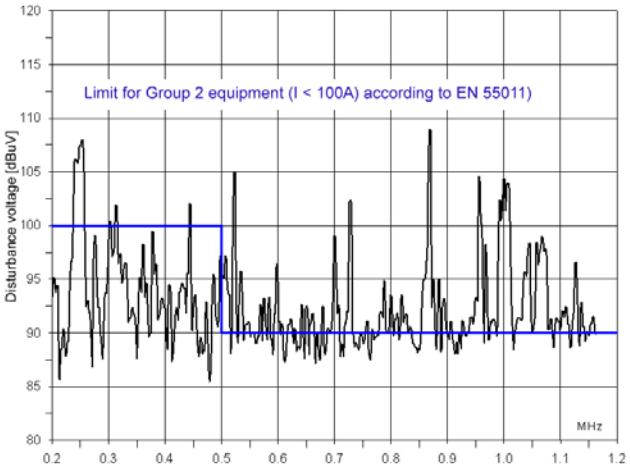

Fig.3. Comparison of some real world disturbances with existing limits. Measured in underground conveyor control room in a working copper mine.

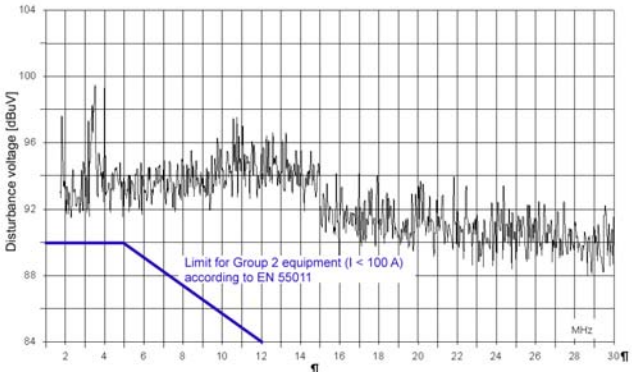

Fig.4. Comparison of some real world disturbances with existing limits. Measured in underground conveyor control room in a working copper mine.

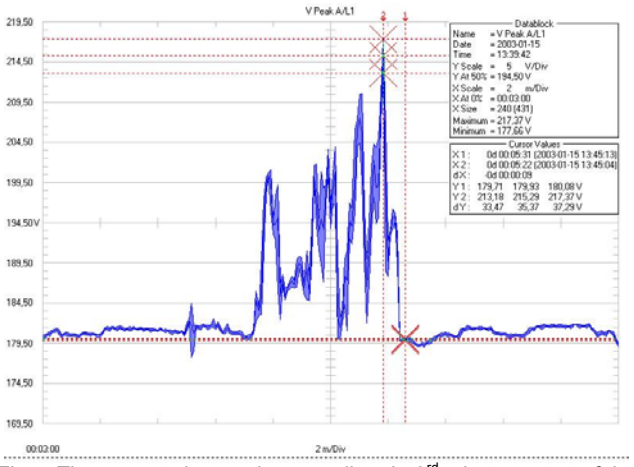

Fig.5. The current changer in power line. In 3rd minute – start of the transportation engine

In existing mines it is also common to arrange different line (power, control and signal) parallel and there is some serious crosstalk between lines. The result of this can be the occurrence in one line of disturbances whose source is in a different line – when disturbances from power line occur in signal or control line they can potentially present significant danger, especially when some safety equipment is connected to these lines (for example gas sensors or meters).

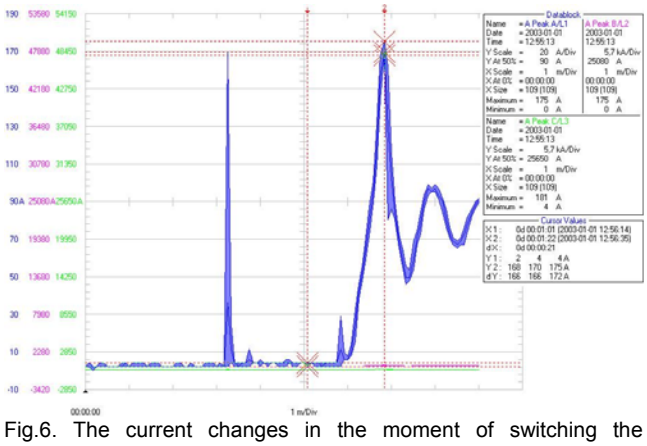

Fig.6. The current changes in the moment of switching the conveyor on, power network analyzer probe connected before inverter.

Conclusion

The description of electromagnetic events given in this paper does not form the complete characterization of all phenomena. Its objective is to draw attention to some disturbing events, observed in the real world, that should be taken into account when evaluating their potential impact on the equipment working in underground mines. Further works are needed to describe some special industrial electromagnetic environments such as the one of underground mines. In 2010 the scientific consortium was formed by AGH University of Science and Technology, Institute of Innovative Technologies EMAG, National Institute of Telecommunications, Institute of Power Systems Automation Ltd. The purpose of this consortium is to prepare such a description for the electromagnetic environment in mines.

REFERENCES

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