Dorota TYPAŃSKA[1], Adam MAĆKOWIAK[2], Krzysztof SIECZKAREK[2]

Poznan University of Technology (1), Warsaw Institute of Logistics and Warehousing (2)

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The Immunity of the KNX Model to Electromagnetic Pulse Disturbances

***Abstract**. The article presents the test results of the electromagnetic resistance of an intelligent, stationary installation model to pulse interference. The installation model tested was based on the automatic devices of an intelligent building, manufactured by Hager .*

***Streszczenie.** W artykule przedstawiono wyniki badań odporności elektromagnetycznej modelu inteligentnej instalacji stacjonarnej na zaburzenia impulsowe. Badany model instalacji został wykonany w oparciu o automatykę inteligentnego budynku wyprodukowaną przez firmę Hager. (**Odporność modelu KNX na elektromagnetyczne zaburzenia impulsowe**).*

Keywords: Intelligent building, KNX, electromagnetic compatibility, fixed installations.
Słowa kluczowe: budynek inteligentny, KNX, kompatybilność elektromagnetyczna, instalacje stacjonarne

Introduction

Varied electromagnetic disturbances, including pulse disturbances, occurs in low voltage power networks(<1000 V). This disturbance basically comprises voltage and current pulses which overlap with the sinusoidal waveform of voltage or a mains current. It can have the form of single pulses or a beam thereof, appearing accidentally or periodically. A single interfering pulse is generally characterized by a relatively short time of rising and a relatively long time of subsiding. Such signals have a broad-band spectrum. They are different in shape, though most often being close to a exponential waveform or a damped oscillatory waveform [6].

Pulse disturbance results from natural phenomena occurring in nature (atmospheric and cosmic) and the technological activities of people. The atmospheric phenomena that give rise to such disturbance mainly include lightning discharges. Not only when lightning directly strikes the devices of a power network or an industrial line does it cause interference in the circuits of the network, but also it does so when there has been a discharge near such facilities. People's technological activities involve the production of devices that lead to the intentional or unintentional emission of electromagnetic signals. These signals can be conducted to a network via the power circuits of the devices, interfering with other electric elements cooperating with the network. Such pulse interference most often results from the phenomena that accompany switching states in the circuits of the network as well as in the circuits of the electric and electronic devices connected thereto [6].

The article presents the results of the laboratory tests of the KNX installation model exposed to pulse interference.

Laboratory Test Facility

The requirements related to the comfort and flexibility of the managing systems of air-conditioning, lighting and access control are still growing, both for houses and offices complexes. Energy consumption also plays an important role. Greater comfort and safety can be combined with economising on energy only by using an intelligent system controlling and monitoring all the devices. Nonetheless, this approach necessitates laying a large number of conductors from the sensors and working elements to the central controlling and monitoring units. Such an amount of conductors and cables means higher costs of designing and installation work as well as increases the risk a fire, let alone the cost of materials[7].

Fig. 1 KNX system [7]

In order to send controlling data to all the elements managing a building, a system is necessary that does not isolate any devices, ensuring common communication. The KNX bus (fig. 1) is such a system, being independent from the manufacturers of bus devices and applications. Information is sent between the devices by means of a medium (conductor pair, radio waves, powering line or IP/Ethernet) to which the bus devices are connected. The bus devices include sensors and working elements to control the equipment of the building, such as: lighting; blinds/rollers; safety signalling, and monitoring systems; gates for the systems controlling the building, remote control, measurements, audio/video devices, household appliances and the like. All these functions are controlled, monitored and signalled by a unified system, without a central control unit installed [7].

According to the above assumptions, an intelligent installation laboratory model was built. This model was equipped with the following:

- 10-output activating/deactivation actuator,
- lighting intensity level regulator,
- window roller control system.

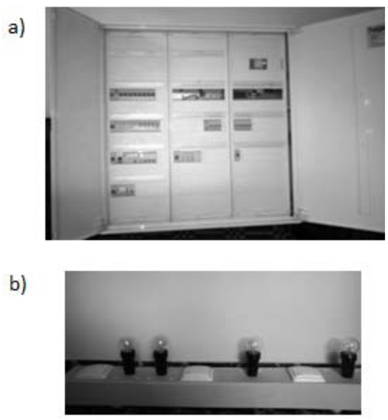

Fig. 2 Laboratory test facility: a) KNX equipment, b) control box

Figure 2a shows the model built and figure 2b shows the control box, which are controlling the operations of particular elements of the model.

So designed experiment was quite unique because the equipment under test was devised as complex installation model, not only single module.

The Immunity of the KNX Model to Electromagnetic Pulse Disturbances According to the Polish Law

By the term of electromagnetic immunity to pulse disturbance is meant the immunity to the following:
- pulse magnetic field (PN-EN 61000-4-9 [1]),
- electrostatic discharges (PN EN 61000-4-2 [2]),
- electrical fast transient/burst (PN EN 61000-4-4 [3]),
- surge (PN EN 61000-4-5 [4]),
- Voltage dips, short interruptions and voltage variations (PN EN 61000-4-11 [5]).

The following chapter shows the test setups and the results of immunity of the test model to pulsed disturbances. According to the Standards the Performance, the equipment under test was classified on the following criteria:

a) normal performance within limits specified by the manufacturer, requestor or purchaser;

b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator's intervention;

c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;

d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

Testing the Immunity to a Pulse Magnetic Field

Pulse magnetic fields are generated by lightning striking buildings and other metal structures, including overhead masts, earth conductors and networks, and as a result of transient states caused by short-circuits in the electric systems of medium and high voltage [1].

The test is carried out mainly in relation to electronic equipment intended to be installed in electric power plants and central remote control units[1].

The measurement stand consists of the following elements [1]: ground plain (reference), equipment tested, measurement generator, induction coil, terminal assembly, decoupling filter.

Table 1 presents recommended test levels [1].

Table 1 Test levels[1]

Level	Magnetic pulse field intensity [A/m]
1	n.a. 2)
2	n.a. 2)
3	100
4	300
5	1000
x1)	special
1. The "x" test level is not specified . This level may by defined by the technical requirements of a product. 2. n.a. – not applicable.	

The immunity of the KNX model to a pulse magnetic field was tested in accordance with the above recommendations of the standard [1]. Figure 3 shows the test stand.

Twenty pulses were sent trough the aerial at 5s time intervals between single pulses of a magnetic pulse intensity of 1000 A/m. The model tested was resistant to the disturbance (table 2).

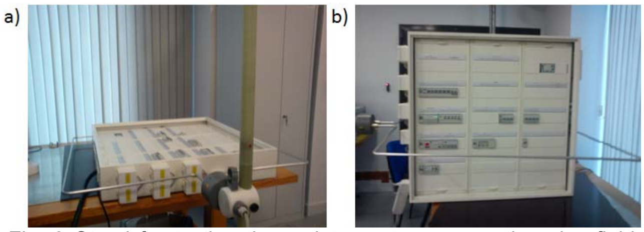

Fig. 3 Stand for testing the resistance to a magnetic pulse field, where: a) horizontally positioned device tested, b) vertically positioned device tested

Table 2 Test results of the immunity of the model to a pulse magnetic field

Field strength [A/m]	Position of the coil	Performance criterion
1000	horizontal, position in half height of the loop antenna	a
1000	vertical, position in half height of the loop antenna	a

Testing the Immunity to Electrostatic Discharges (ESD)

Devices, systems, sub-systems and periphery devices may be affected by static electricity discharges due to environmental and installation conditions, such as low relative air humidity, the use of low conductivity lining (made of artificial fibres), vinyl clothing and the like, ones that can occur in all locations defined by the standards applying to electric and electronic equipment [2].

There are two ESD test methods, one based on a contact discharge and the other on an air discharge. A contact discharge is a recommended method. Test voltages for each method are given in table 3. With an air discharge, the test should be carried out for all the test levels of table 3, from the lowest level to the required level inclusive. In the case of a contact discharge, the test should be carried out only for the required test level [2].

Table 3 Test levels[2]

Contact discharge		Air discharge	
Level	Test voltage [kV]	Level	Test voltage [kV]
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
xa	Special	xa	Special
a "x" is any higher, lower or intermediate level; this level should be specified by the relevant technical specification of the device.			

The ESD test stand comprises[2]: ESD generator, return discharge conductors, discharge resistors 470kΩ, reference ground plain, devices tested, all connections forming a discharge path.

Figure 4 shows the stand for testing the KNX model.

Table 4 shows a comparison of the test results of the immunity of the KNX model to static electricity discharges. With a value of ± 8kV, there was spark-over to the apparatus. However, it did not interfere with operation of the devices, hence it follows that the model tested was resistant to electrostatic discharges.

Fig. 4 Testing the immunity of the KNX model to electrostatic discharges

Table 4 Test results of the immunity to electrostatic discharges

Discharge voltage level [kV]	Discharge type	Performance criterion
±4	Contact, to the casing	a
±8	Contact, to the casing	a
±4	Air, to the working elements	a
±8	Air, to the working elements	a

Testing the Immunity to Electrical Fast Transient/Burst

A test using repeated, rapid transient states involves the use of series containing a number of rapid transient states coupled with the connections of power, control , signals, and the earthing of electric and electronic devices. This test is distinguished by a large amplitude, a short rise time, a high frequency of repeating, and a small energy of the transient states [3].

The test is aimed at proving the resistance of electric and electronic devices when exposed to transient interference that appears during transient connection states (disconnecting induction loads, the effect of relay contact being disconnected, etc.) [3].

Table 5 Test levels[3]

Test voltage of the open circuit and the frequency of repeating pulses				
Level	Power supply and PE connection		Signal I/O, data and control connection	
	Peak voltage [kV]	Repeating frequency [kHz]	Peak voltage [kV]	Repeating frequency [kHz]
1	0.5	5 or 100	0.25	5 or 100
2	1	5 or 100	0.5	5 or 100
3	2	5 or 100	1	5 or 100
4	4	5 or 100	2	5 or 100
x[a]	Special	Special	Special	Special
Conventionally, a repeating frequency of 5 kHz is used, but 100 kHz is closer to a real situation. Selection committees determine frequencies appropriate for particular products or types of products..				
[a] The "x" test level is not specified. It should be defined in the technical specification.				

Table 5 presents test levels recommended for testing the immunity to the series of fast transient states. This test applies to the tested device connections of the power supply, earthing, signals and control.

The test stand comprises the following equipment [3]: reference ground plain, coupling device, decoupling assembly, device tested, test generator.

Table 6 Test results of the resistance to the series of rapid transient states

Port	Voltage [kV]	Frequency [kHz]	Performance criterion
$230V_{AC}$	±1	5	a

Table 6 presents a comparison of the test results of the immunity of the KNX model to the series of fast electric transient states. Lacking signal ports, the installation had only the power supply connection, hence there was only one test. When disturbance was conducted, the model operated properly.

Testing the Immunity to Surges

The tests of the immunity of a device or installation to surges are classified in two groups[4]:

a) surges caused by transient connection states in the power system:

- connection interference in the main power supply system, such ones as occur during connecting condenser batteries;
- interference caused by minor local connections or load changes in the power switching network;
- interference caused by resonance circuits connected to such connection elements as thyristors;
- system interference, such as short-circuits and arc discharges to the installation earthing system.

b) surges caused by transient lightning states:

- direct strokes of lighting in the outer, causing large currents which generate voltages as a result of the resistance of the earth or the impedance of the outer circuit;
- an indirect stroke of lightning which induce voltages/currents in the conductors outside and/or inside the building.
- atmospheric discharge current flowing through the earth as a result of nearby direct ground discharges coupled with common earthing paths of the installation earth system.

Table 7 presents recommended test levels for surge voltages.

Table 7 Test levels[4]

Level	Open circuit voltage ± 10% [kV]
1	0.5
2	1.0
3	2.0
4	4.0
x	Special
The "x" level can be any higher, lower or intermediate level.	

The measurement stand comprises[4]: device tested, auxiliary equipment, when necessary, coupling and decoupling assemblies, generator, reference ground.

Table 8 Test results of the resistance to surge interference

Voltage level [kV]	Coupling	Performance criterion
1	L-N	a

When the device was exposed, no serious interference was found with its operation (table 8). The model tested complied with the requirements of the standard [4].

Testing the Immunity to Voltage dips, short interruptions and voltage variations

Electric and electronic devices can be exposed to voltage dips, short voltage interruptions and voltage variations in the power network. Voltage dips and short interruptions are caused by the disturbance in the network, above all by short-circuits in the installations or sudden and large load changes. In special cases, at least two consecutive dips or interruptions can occur. Voltage variations are caused by continuously changing loads connected to the network[5].

Voltage Dips and Short Interruptions

The transition between the rated voltage of the device U_T and the changed voltage is on a spike basis and may start and end at any phase angle of the power voltage. The test levels used are as follows: (U_T in %): 0%, 40%, 70% and 80%[5].

Table 9 presents the test levels and durations times recommended for voltage dips, and Table 10 shows the test levels and duration times for short interruptions[5].

Table 9 Recommended test level and duration times of voltage dips [5]

Class	Test level and duration times of voltage sags for a frequency of 50/60 Hz				
Class 1	On a case by case basis, according to the requirements for the devices				
Class 2	0% during ½ period	0% during 1 period	70% during 25/30* periods		
Class 3	0% during ½ period	0% during 1 period	40% during 10/12* periods	70% during 25/30* periods	80% during 250/300* periods
* 25/30 periods mean 25 periods for the tests at a frequency of 50 Hz, and 30 periods for the tests at a frequency of 60 Hz					

Table 10 Recommended test level and duration times of short interruptions [5]

Class	Test level and duration times of short interruptions for a frequency of 50/60 Hz
Class 1	On a case by case basis, according to the requirements for the devices
Class 2	0% during 250/300* periods
Class 3	0% during 250/300* periods
* 250/300 periods mean 250 periods for the tests at a frequency of 50 Hz, and 300 periods for the tests at a frequency of 60 Hz	

The levels and duration times should be specified by a standard on selection. A test level of 0% corresponds to a complete power voltage failure. In practice, a test level of 0% to 20% of the rated voltage may be treated as a complete failure [5].

Voltage Variations

When the immunity to voltage changes is tested, a particular transient state is taken into consideration between the rated voltage U_T and the measured voltage[5].

Table 11 Waveform of short power voltage variations [5]

Voltage test level	Voltage dropping time	Dropped voltage time	Voltage rising time (50/60 Hz)
70%	Abrupt	1 period	25/30* periods
* 25/30 periods mean 25 periods for the tests at a frequency of 50 Hz, and 30 periods for the tests at a frequency of 60 Hz			

Table 11 presents the recommended duration times of voltage sags and the time when the dropped voltage should remain the same. The rate of the change should be constant, though voltage can change on a spike basis. Spikes should occur when crossing zero and should not be larger than 10% U_T. Spikes below 1% U_T are treated as a constant change in voltage[5].

Table 12 Test results of the immunity to voltage dips

Class	Test level	Voltage [V]	Dips duration time	Performance criterion
Class 2	0%	0	½ period	b
Class 2	0%	0	1 period	b
Class 2	70%	161	25 periods	b

Table 13 Test results of the immunity to short interruptions

Class	Test level	Dips duration time	Performance criterion
Class 2	0%	250 periods	b

Table 14 Test results of the immunity to short voltage changes

Voltage test level	Voltage dropping time	Dropped voltage time	Voltage rising time	Performance criterion
70%	Abrupt	1 period	25 periods	b

Tables 12, 13, 14 present the test results of the resistance of the KNX model to voltage dips, short voltage interruptions and voltage variations.

Summary

This article presents the test results of the immunity to electromagnetic pulse interference. Tests were carried out to check the behavior of the installation model equipped with intelligent electronic systems, sensitive to electromagnetic disturbances. This was an introduction to the tests of the electromagnetic compatibility of fixed installations, ones fitted in facilities.

The tests conducted showed that the model was immune to pulse disturbances. As was proven by the immunity to a pulse magnetic field, electrostatic discharges, the series of abrupt transient states and surges, the model fell within category a, operating normally within limits specified by the manufacturer, principal or purchaser; only when tested for the immunity to voltage dips, short interruptions and voltage variations did it come under category b, momentarily failing to perform its function properly or deteriorating in performance, and yet overcoming such interference when it ceased, reverting to normal operation without the intervention of the operator.

Authors: *Dorota Typańska, Poznan University of Technology, Piotrowo 3A, 60-965 Poznań, dorota.typanska@put.poznan.pl,*
Adam Maćkowiak, Institute of Logistics and Warehousing, *Estkowskiego 6, 61-755 Poznań,adam.mackowiak@ilim.poznan.pl,*
Krzysztof Sieczkarek, Institute of Logistics and Warehousing, *Estkowskiego 6, 61-755 Poznań, krzysztof.sieczkarek@ilim.poznan.pl*

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