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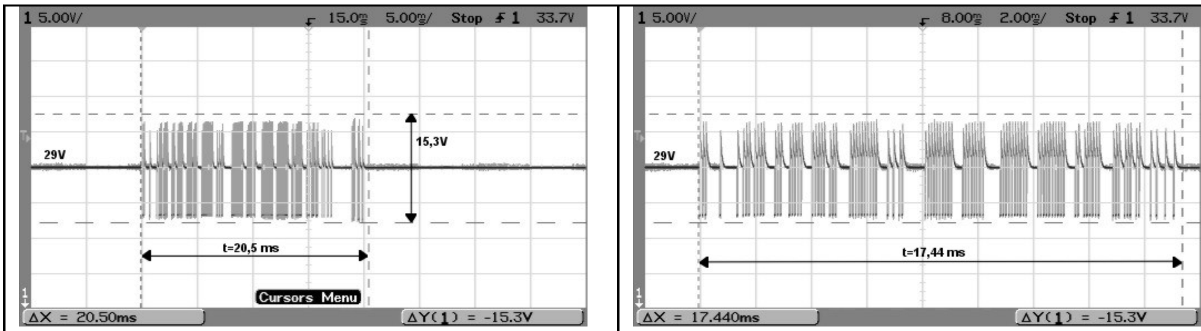
Comparative Analysis of KNX and LonWorks The Intelligent Building Systems in Energy Consumption and Power Quality Monitoring

1. Introduction

This text is a effect and a summary of author's research works, connected with his PhD dissertation and focused on comparison of two the most popular intelligent building systems – KNX and LonWorks. The comparison take into consideration openness, reliability (especially – reliability of communication) and interoperability of these systems. This paper is particularly devoted to possibilities of intelligent building systems using in electrical energy consumption and basic supply parameters measurements, taking into consideration power quality factors and quantities. It is the completion of issues were presenting on the two last KNX Scientific Conferences. The problems connected with electrical power quality was broadly presented in 2004 (MSc. Andrzej Ozadowicz: „Energy Saving and Electrical Power Quality Control in Intelligent Building Systems", Deggendorf 2004) and in 2005 author discussed communication reliability questions in KNX and LonWorks buses (MSc. Andrzej Ozadowicz: „Communication Reliability in the Intelligent Building Systems", Pisa 2005).
All tests and measurements have been realized at special laboratory places, equipped with freely available system devices with basic functions for one room in intelligent building. Additionally there were electrical energy and basic supply parameters meters with KNX and LonWorks interfaces (ABB's meter – DZ 4000 KE and Goosen-Metrawatt's A2000 Multifunctional Power Meter) at the laboratory places.

2. The telegrams in buses - communication reliability

During the research works a lot of real transmission signals in systems' buses have been captured, both for KNX and LonWorks standards. They were talked over and analysed on previous Conference, but some of them have direct influence on further tests and analyses presented in present study, therefore below only short basic conclusions are mentioned.
On the basis of those research works it was stated, that in some cases disturbances in systems' communication buses leads to transmission distortions and even interruptions. It was especially connected with LonWorks standard. These conclusions have been confirmed in the next measurements and tests of data transmission signals form energy meters, with information about consumed energy. When all electrical devices at the laboratory places had been switched on and data signals form energy meters had been generated, there were right transmission and signals only in KNX standard's bus. On the Figure 1 the captured telegram with basic information about actual value of consumed active energy form DZ 4000 KE meter is presented.



a) b)

Figure 1 –KNX telegram: consumed active energy - value; a) telegram with confirmation signal, b) telegram – only useful information (other duration)

This kind of telegram takes 17,5 ms and with confirmation about 20,5 ms. It is about 40% longer than basic telegrams (like switch on/off). DZ 4000 KE meter has ability to send telegrams with information about changes of instantaneous (current) active and reactive power every 8 seconds or after achieving appropriate level of power change (established earlier during device adjusting). This kind of telegram is presented on Figure 2.

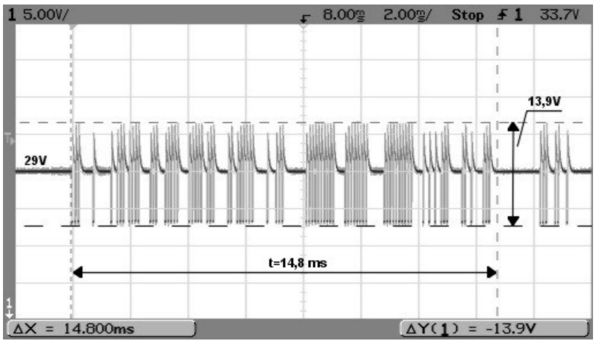


Figure 2 – KNX telegram: instantaneous active power value – DZ 4000 KE meter

This telegram's duration is similar to basic KNX telegrams, because it basis on short bit word (EIS object).

To transmit information about instantaneous reactive power level this meter has two types of telegrams presented on Figure 3. First of them is single telegram with long duration, basis on EIS 11 object (32 bit counter; ranges: 0 to 4294967295 or from –2147483648 to +21467483647). To send full information about the reactive power, information about sign is needed (inductive or capacitive power). Therefore the range with signs is used in this situation. Second type of telegram it is actually two individual telegrams: the first with information about instantaneous power value (EIS 10 object – 16 bit counter, range: 0 to 65535 or –32768 to +32767) and the second with sign (EIS 1 object – switching <on/off>, 1 bit). The sign information separation could be used in practise for example to identify alarm situation, when one kind of reactive power is not allowed or desired in supply network. Second of mentioned telegrams could be used also if there are small levels of instantaneous reactive power in the system and particularly if information about sign is not desired.

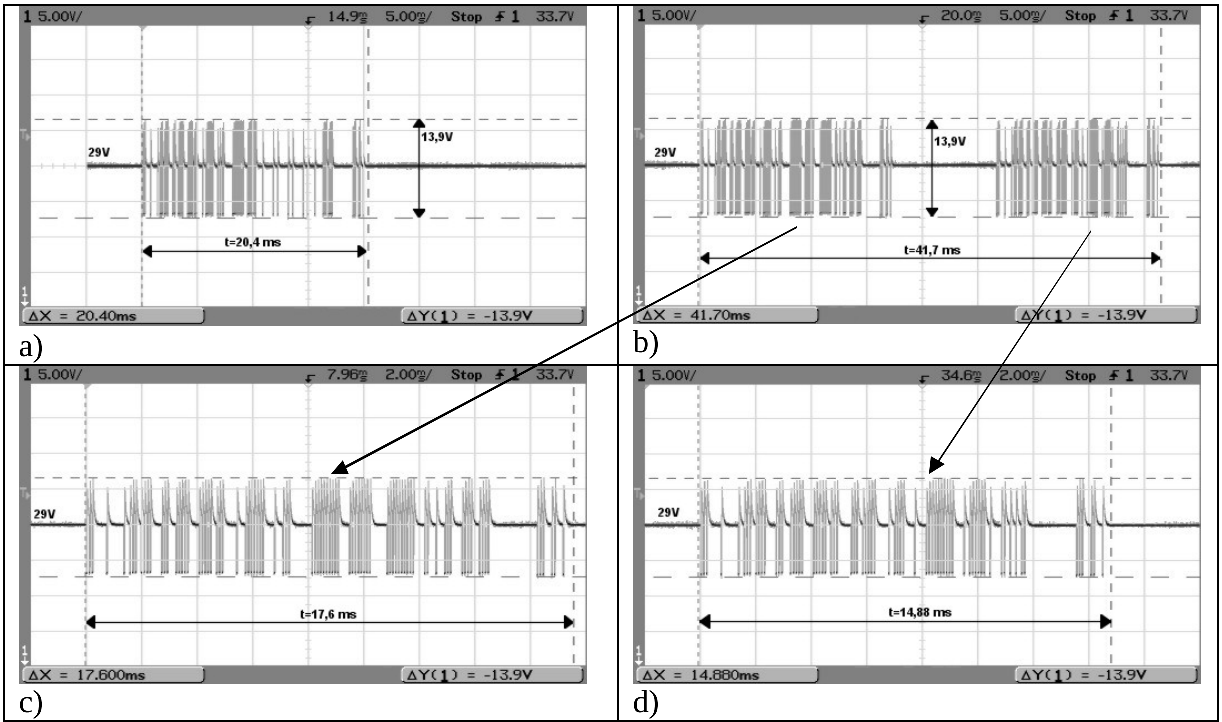


Figure 3 – KNX telegrams: instantaneous reactive power level; a) single telegram (EIS 11), b) two individual telegrams level - sign, c) level telegram (EIS 10), d) sign telegram (EIS 1)

Single telegram (Figure 3 a) duration is similar to telegram with the active energy consumption information about. The second type of telegram with reactive power is connected obviously with longer duration – about 42 ms, both power level and sign information are desired. Note that for both individual telegrams from second type, the confirmation signal is needed. It is proof that they are actually two independent information.

Unfortunately, as it was mentioned earlier, it was not possible to capture similar telegrams for LonWorks standard. Disturbances in the LonWorks bus were significant (they have had high amplitude) and caused transmission interruptions. Sources of these disturbances were: the PC and the servomotor with digital controller, load for meters – they were detailed described on last year Conference. It is important to note that measurements and tests have been realized in specific laboratory circumstances and with the help of concrete instruments. The main reason of problems it was oscilloscope (AGILENT 54624A -100 MHz, 200 MSa/sec, input resistance 1MO) connected to the bus to observe and capture signals. If the oscilloscope had been disconnected, transmission was correct.

3. The intelligent building systems and consumption energy and power quality measurements issue

The electrical energy in power supplies networks in buildings yield to deterioration during transmission and distribution in building. It is effect of the common electromagnetic disturbances. These phenomena bring changes of supply parameters, power quality indicators and features. As the result they are differ form nominal values, in steady states at sinusoidal waves in symmetric poly-phase systems. Low power quality could lead to a lot of negative states in electrical loads (receivers) or sometimes make the work of these devices impossible. These issues were topic of discussion at Conference in 2004. On the Figure 4 there are presented examples of common phenomena in supply networks, connected with power quality.

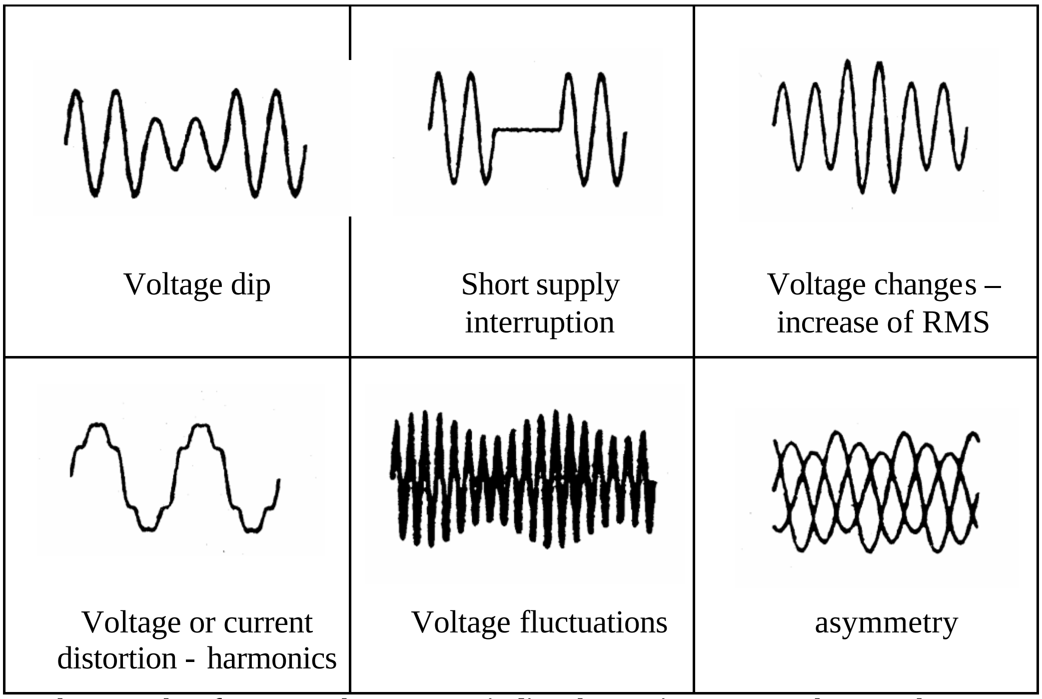


Figure 4 – The examples of common electromagnetic disturbances in power supply networks

Bringing into the market new energy meters and multifunctional power meters with intelligent building systems' interfaces, allow to use them in electrical energy and power quality parameters monitoring and measurements. To make appropriate tests, both mentioned earlier meters, they have been installed in supply line transmitted energy to rooms and lecture halls in building B-1 AGH-UST in Krakow (Electrical Faculty). Chart with connections of the system is presented on Figure 5.

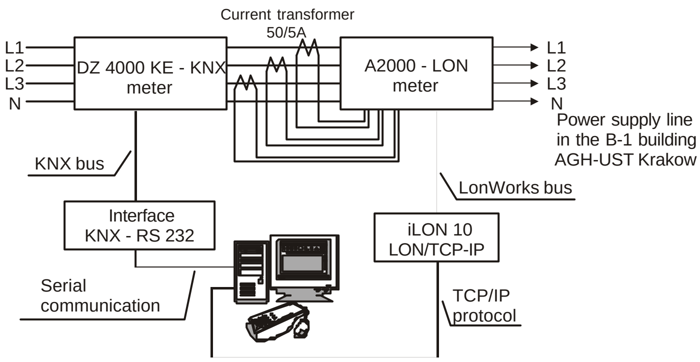


Figure 5 – Supply line in B-1 building – connections chart

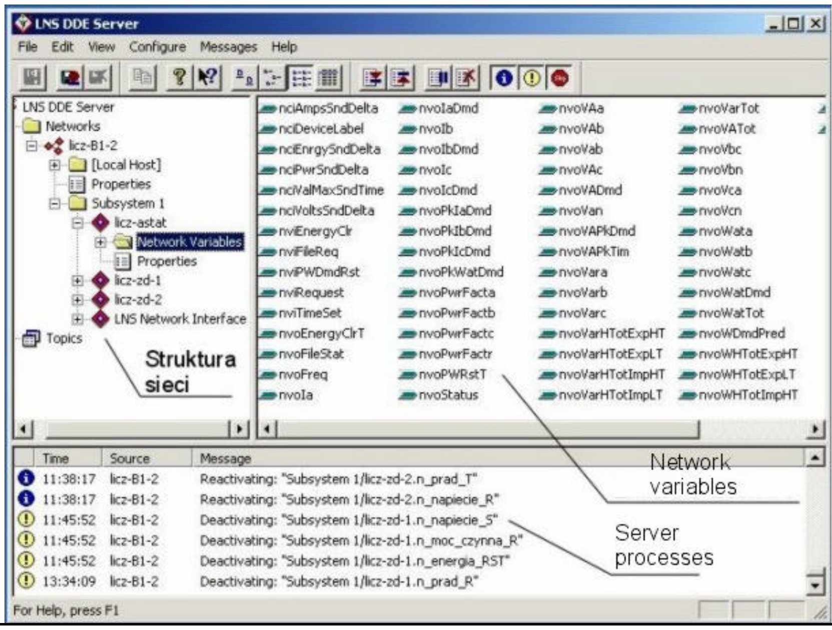
- **<u>Multifunctional power meter A2000 – measurements with LonWorks standard</u>**

Multifunctional power meter A2000 has ability to energy consumption and power levels measurements and additionally observation a lot of power supply network parameters, that are crucial from the preservation of good power quality point of view. These data are transmitted by LonWorks bus as adequately define network variables (components of LonWorks device's interface). For tests and measurements some of them have been selected:

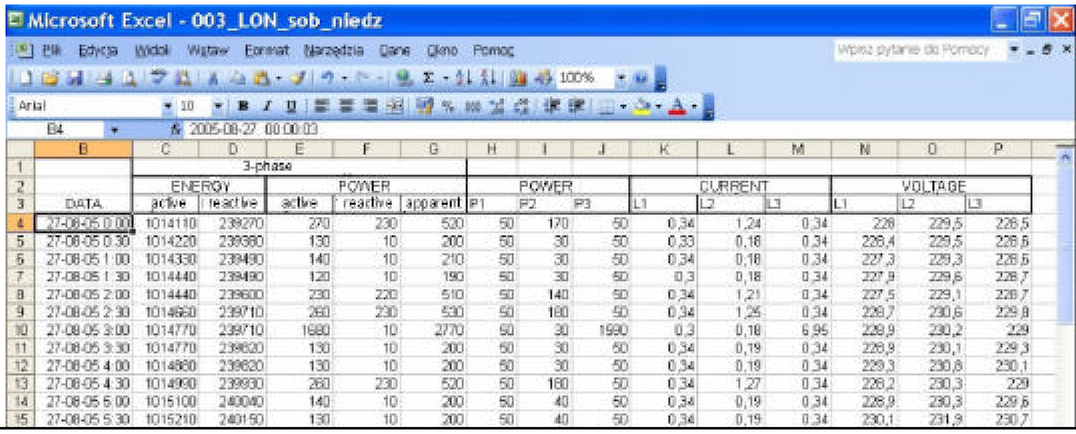
- energy (Wh, VArh) (network variable: SNVT_elec_whr_f)
- power (all types) (network variable: SNVT_power_f)
- voltage (network variable: SNVT_volt_f)
- current (network variable: SNVT_amp_f)

To record and storage data transmitted by LonWorks network, LNS DDE Server package has been used. This package allow to present those data in sheets of common PC application – Microsoft Office Excel. Data are transmitted directly to Excel's sheet, where they are recorded and stored as a file (appropriate macro is needed). The window of LNS DDE Server and fragment of the Excel's sheet with data are presented on Figure 6 a) and b).

a)



b)



DATA	3-phase ENERGY active	3-phase ENERGY reactive	3-phase POWER active	3-phase POWER reactive	3-phase POWER apparent	POWER P1	POWER P2	POWER P3	CURRENT L1	CURRENT L2	CURRENT L3	VOLTAGE L1	VOLTAGE L2	VOLTAGE L3
27-08-05 0:00	1014110	239270	270	230	520	50	170	50	0,34	1,24	0,34	228	229,5	228,5
27-08-05 0:30	1014220	239380	130	10	200	50	30	50	0,33	0,18	0,34	228,4	229,5	228,6
27-08-05 1:00	1014330	239490	140	10	210	50	30	50	0,34	0,18	0,34	227,3	229,3	228,6
27-08-05 1:30	1014440	239490	120	10	190	50	30	50	0,3	0,18	0,34	227,9	229,6	228,7
27-08-05 2:00	1014440	239600	230	220	510	50	140	50	0,34	1,21	0,34	227,5	229,1	228,7
27-08-05 2:30	1014660	239710	260	230	530	50	180	50	0,34	1,25	0,34	228,7	230,6	229,8
27-08-05 3:00	1014770	239710	1680	10	2770	50	30	1590	0,3	0,18	6,95	228,9	230,2	229
27-08-05 3:30	1014770	239820	130	10	200	50	30	50	0,34	0,19	0,34	228,9	230,1	229,3
27-08-05 4:00	1014880	239820	130	10	200	50	30	50	0,34	0,19	0,34	229,3	230,8	230,1
27-08-05 4:30	1014990	239930	260	230	520	50	180	50	0,34	1,27	0,34	228,2	230,3	229
27-08-05 5:00	1015100	240040	140	10	200	50	40	50	0,34	0,19	0,34	228,9	230,3	229,6
27-08-05 5:30	1015210	240150	130	10	200	50	40	50	0,34	0,19	0,34	230,1	231,9	230,7

Figure 6 – Data acquisition in LonWorks system: a) LNS DDE Server, b) Excel package

Data collected during measurements allow to assess how much electrical energy is used in different time durations, what are demands for power at selected moments and what are levels and values of basic supply network parameters, if some of loads are connected or disconnected to it. For the sake of easy interpretation huge data collections, graphical presentation – graphs have been chosen. Those graphs are presented at the next part of text, where they are compared with similar graphs drawn for KNX standard (on the basis of data from DZ 4000 KE meter).
Unfortunately due to all network variables for single node in LonWorks network have been used by meter's manufacturer (max number of variables is 64) to transmit data and parameters directly connected with currents, voltages, energy and power, there are not enough network variables to transmit data with current THD factor value and amplitudes of selected current or

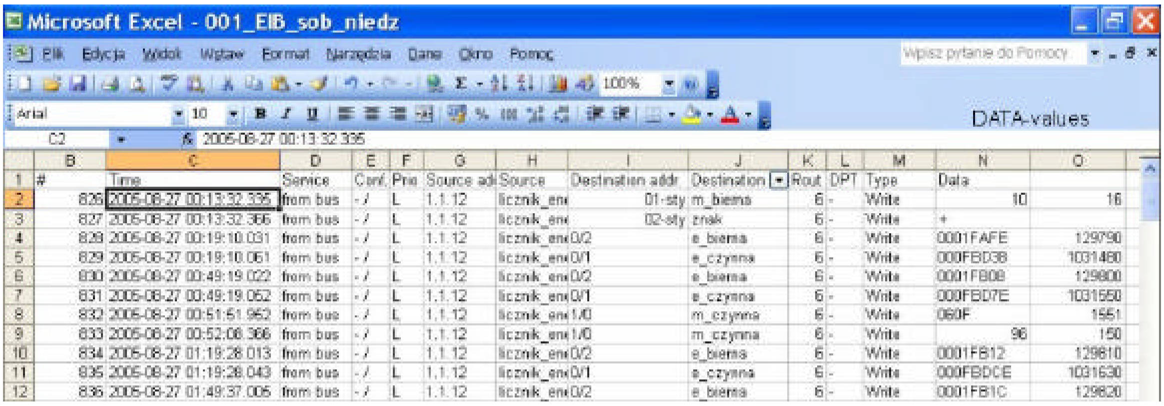
voltage harmonics, although they are measured by meter A2000. This kind of information is only available to observe and record by serial port RS 232 and could be graphically presented as varied graphs (line, bar) with proprietary software for this meter - METRAwin 10/A2000 package.

- **DZ 4000 KE meter – measurements with KNX standard**

DZ 4000 KE meter has similar as A2000 abilities to energy consumption measure in power supply line, current voltages and currents in individual phases, power factor, frequency and current instantaneous power levels (active and reactive power). Some of these values could be transmitted as KNX's telegrams by system's bus and then used by other nodes or data acquisition systems (for example: visualisation, HMI etc.). Used EIS objects are as follow:

- Active and reactive energy – EIS 11 – 32 bit counter
- Instantaneous active and reactive power – EIS 10 – 16 bit counter
- Instantaneous active and reactive power with sign – EIS 11 – 32 bit counter
- Request meter reading – EIS 1 – 1 bit
- Type (sign) of instantaneous power – EIS 1 – 1 bit. It is used with EIS 10 together (instantaneous power absolute value)

To record and storage KNX data, the tool Group Monitor form ETS3 package cooperated with Microsoft Excel have been used. The telegrams recorded in Group Monitor had been saved as data (text) files and then they have been processed in Excel package. It is worth to note that values (for example energy consumption data) are recorded as hexadecimal, therefore the first and basic operation in Excel is conversion of them to decimal form. The fragment of the window with Excel's data sheet is presented on Figure 7.



	#	Time	Service	Conf.	Prio	Source ad	Source	Destination addr	Destination	Rout	DPT	Type	Data	
2	826	2006-08-27 00:13:32.335	from bus	- /	L	1.1.12	licznik_en	01-sty	m_bierna	6	-	Write	10	16
3	827	2006-08-27 00:13:32.366	from bus	- /	L	1.1.12	licznik_en	02-sty	znak	6	-	Write	+	
4	828	2006-08-27 00:19:10.031	from bus	- /	L	1.1.12	licznik_en	0/2	e_bierna	6	-	Write	0001FAFE	129790
5	829	2006-08-27 00:19:10.061	from bus	- /	L	1.1.12	licznik_en	0/1	e_czynna	6	-	Write	000FBD38	1031480
6	830	2006-08-27 00:49:19.022	from bus	- /	L	1.1.12	licznik_en	0/2	e_bierna	6	-	Write	0001FB08	129800
7	831	2006-08-27 00:49:19.052	from bus	- /	L	1.1.12	licznik_en	0/1	e_czynna	6	-	Write	000FBD7E	1031550
8	832	2006-08-27 00:51:51.952	from bus	- /	L	1.1.12	licznik_en	1/0	m_czynna	6	-	Write	060F	1551
9	833	2006-08-27 00:52:08.366	from bus	- /	L	1.1.12	licznik_en	1/0	m_czynna	6	-	Write	96	150
10	834	2006-08-27 01:19:28.013	from bus	- /	L	1.1.12	licznik_en	0/2	e_bierna	6	-	Write	0001FB12	129810
11	835	2006-08-27 01:19:28.043	from bus	- /	L	1.1.12	licznik_en	0/1	e_czynna	6	-	Write	000FBDCE	1031630
12	836	2006-08-27 01:49:37.006	from bus	- /	L	1.1.12	licznik_en	0/2	e_bierna	6	-	Write	0001FB1C	129820

Figure 7 – The Excel package window with KNX standard data

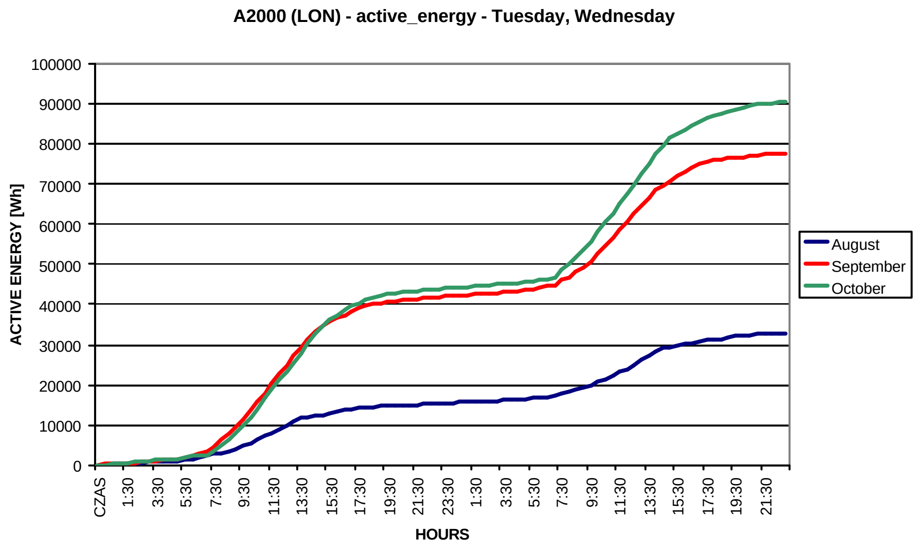
The collected data, after adequately process, have been used to create graphs to fast and simple interpretation. These graphs are presented at the next part of the paper.

Unfortunately, although DZ 4000 KE meter has ability to measure basic parameters of power quality (phase voltages, phase currents, frequency, power factors etc.), no one of them is available as communication object, telegram for system's bus. They are only available for user directly on LCD display on meter's casing. They are not available by any other popular communication standard (RS 232, RS 485, USB).

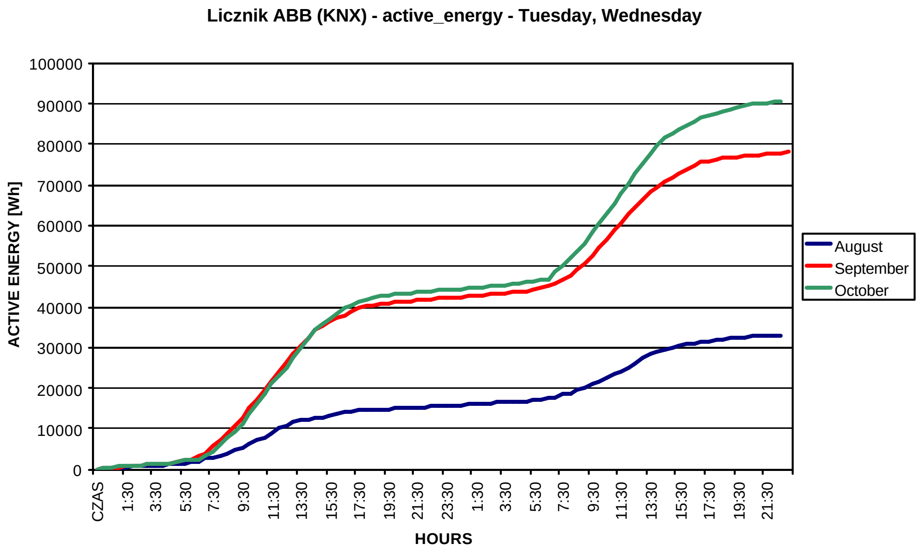
From the author's point of view to enhance meter's functionality and its better adaptation to current market demands (power quality is more and more popular among engineers and individual consumers), it is very important to equip it with for example USB connection port and make available additional data (for example: voltage and current harmonics, voltage and current RMSs, frequency etc.) by this serial port and system bus (EIS objects).

4. The analysis of selected data from energy meters

As it was mentioned above the data colleted during measurements for both standards have been used to create some graphs. The data had been collected during 3 months period in 2005 – August, September and October. Four days have been selected for each month – Tuesday, Wednesday and Saturday, Sunday. It is worth to note, that each of the months is specific from energetic point of view. August is holiday period for the universities, so low energy consumption is characteristic for it. October however is the first month of academic year and this is connected with radical growth in energy consumption (more loads are connected to the supply network). September is transitory period between those two months.
On the Figure 8 there are basic, energy consumption graphs, adequately for A2000 and DZ 4000 KE meters.



a)



b)

Figure 8 – The energy consumption graphs

More usable to asses power quality in supply network are graphs created basis of data from multifunctional power meter A2000 (LonWorks standard). For example there are current level of instantaneous power (active, reactive and apparent) graphs on the Figure 9 and voltage RMS changes for individual phases graphs on the Figure 10.

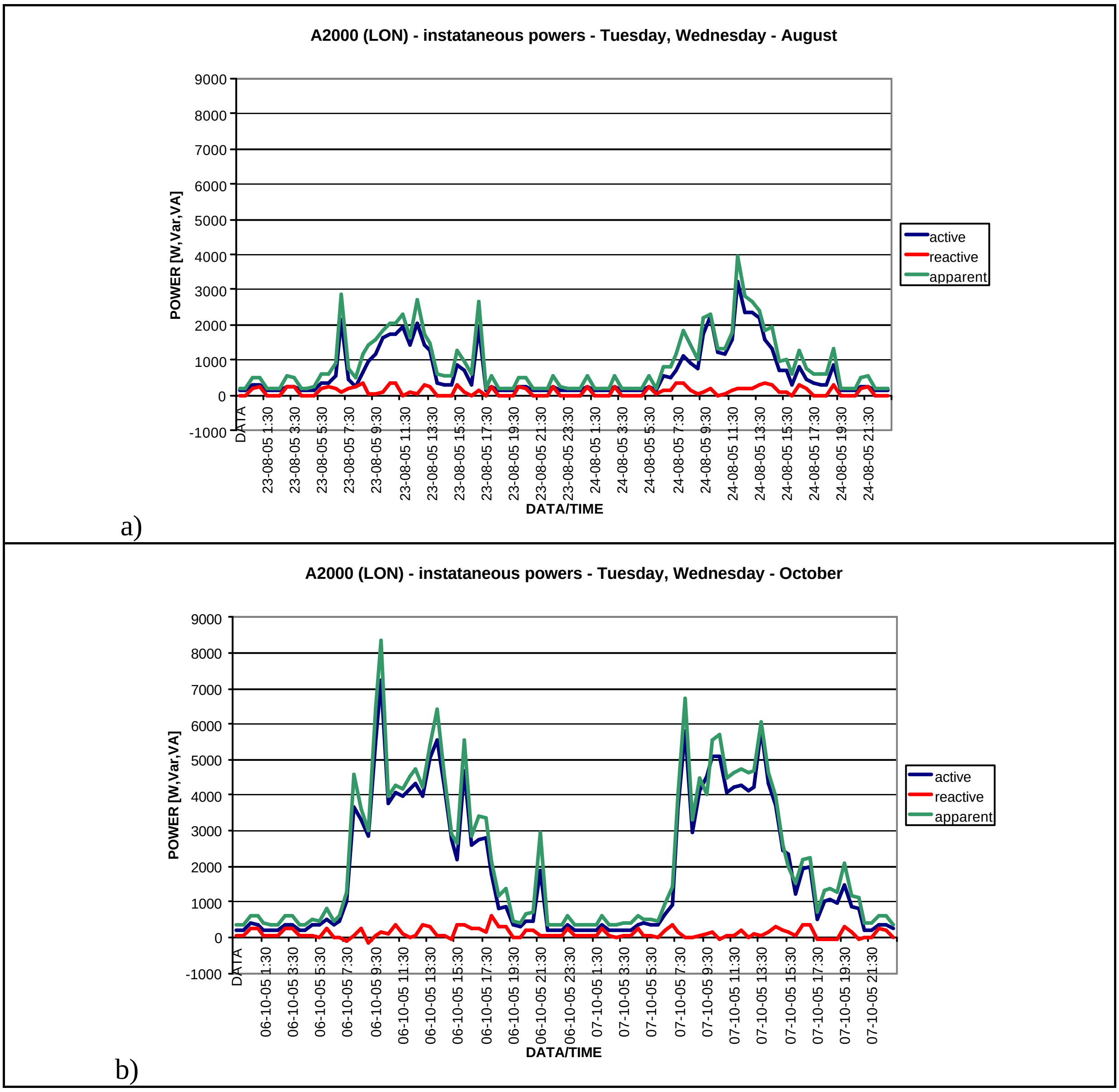


Figure 9 – The current level of instantaneous power (active, reactive, apparent) graphs

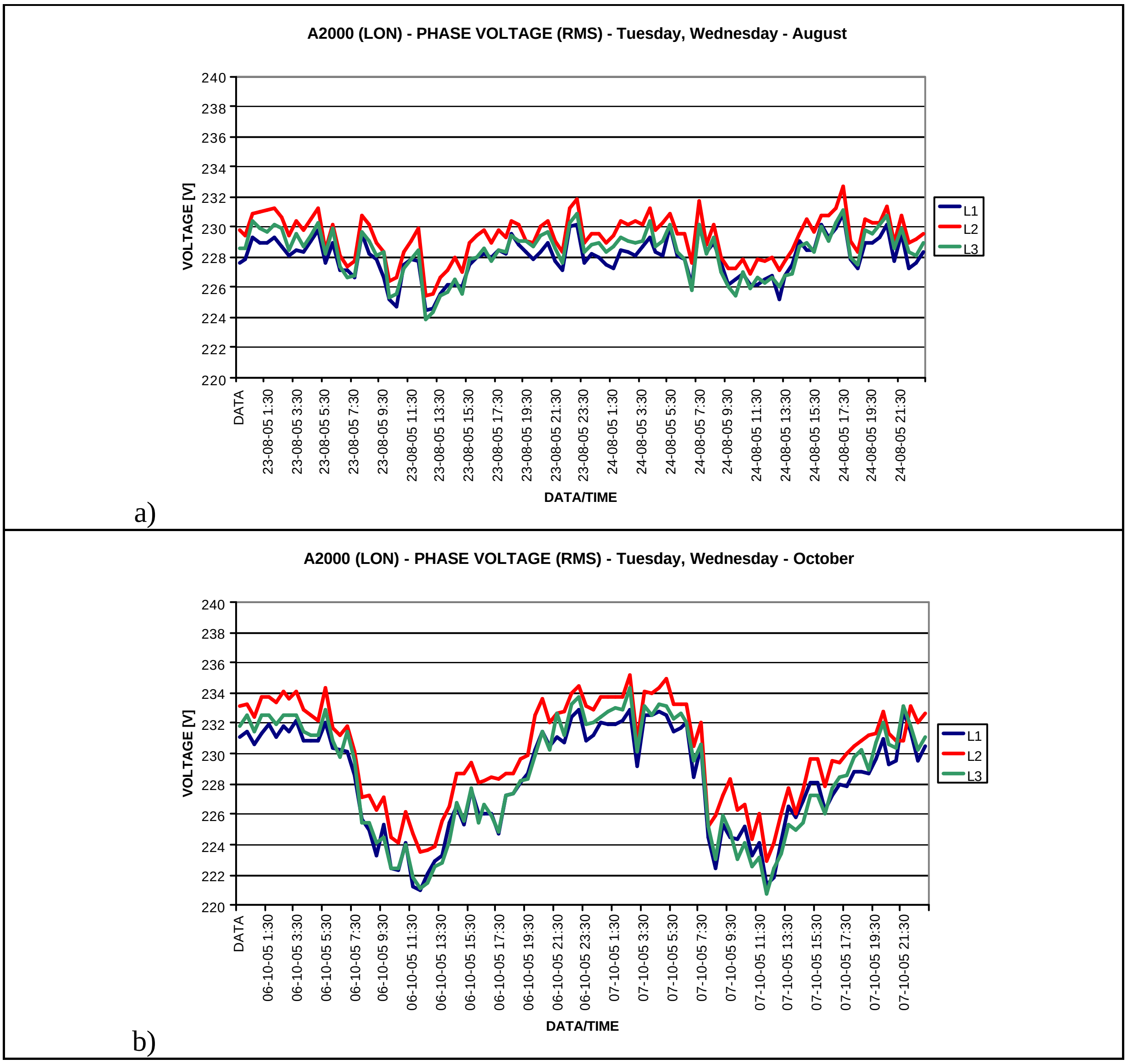


Figure 10 – The voltage RMS changes for individual phases graphs

After analysis of these graphs it is possible to say that intelligent building systems can be used for monitoring and asses of basic power supply network parameters and power quality (in the limited range of course). From graphs on Figure 10 it could be read what is the range of voltage RMS value changes, how it depends on selected period and number of connected to the supply network loads. This information in some justified cases could be base for claims with energy provider, concerned preservation proper power quality in supply network. Thanks to that monitoring it is possible to actually asses current supply line loading by information about instantaneous power and energy consumption (even for individual phases). The telegrams with energy consumption information can be used in accounting with energy provider, as well. Since data are available in digital form, it is also possible to record and storage them and then it could be used to prepare specialist analysis, reports or to determine trends in parameters and factors behaviour.

5. Summary

The power industry is one of essential, if not the most essential trade of the national and world economy. Particular issue is ensuring of continuous providing of energy for all consumers, especially from industry and public sectors. Therefore more and more significant is possibility to realize monitoring and measurements energy consumption, power and selected power quality factors in real time. Information and graphs collected in this paper show current capabilities of the intelligent building systems' devices in this field. Both compared standards have large potential but basis on tests, research works and current market offers analysis, not only in Poland, it is possible to say that at the moment the victory's palm is held by LonWorks standard (though it is not satisfactory state yet). Manufacturers and vendors of devices equipped with LonWorks interface offer larger number of available parameters (as network variables SNVT), features and functions. It is important and needed to make an appeal to other manufacturers and research and development centres, particularly used KNX standard: please, respond to current market demands and design new devices, maters with abilities to measure broader range of power supply networks' parameters and to make them available as KNX telegrams.

This kind of intelligent building systems applications have chance to significant development in the future, particularly in prospect of more often connections with local networks in buildings, with Ethernet networks in plants and with the global network Internet. Thanks to these connections measured energy consumption, power quality factors and parameters could be analysed in remote places, located practically all over the world.

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