EDUCATIONAL PLATFORM USED TO SMART METERING AND METERING OF ELECTRICITY

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The paper presents fundamental problems of the energy metering, as well as some modern trends in the process of measurement and control of electrical quantities, being accessible to those interested in the field approached. In order to demonstrate how an intelligent measurement system works, in the educational platform were installed two single-phase and two three-phase meters, plus a data concentrator that collects data from counters. Data from the concentrator are sent via Ethernet cable to a computer. The meters can be ordered / configured with the specialized software installed on computer.

Keywords: Power Line Carrier (PLC), Radio Frequency (RF), Smart Meters, Smart Meter System, Meter-Bus (M-Bus)

1. Introduction

By 2030, the EU aims to reduce the greenhouse gas emissions by 40% (versus 1990 levels), increase the share of renewable energy at 27% of consumption, and obtain 27% energy efficiency. All EU countries must also get a 50% share of renewable energy in their transport sector till 2050.

By achieving these objectives, the EU can help combat climate change and air pollution, reduce dependency on fossil fuels, and keep energy at affordable prices for consumers and businesses.

In order to meet its targets, the energy strategy by 2020 sets five priorities: making Europe more energy efficient by accelerating investment in efficient buildings, products and transport. It includes the following measures: energy labeling schemes, public building renovation and eco-design for energy products, building a pan-European energy market by constructing the necessary transmission lines, pipelines, LNG terminals, and other infrastructures, protecting consumers' rights and achieving high safety standards in the energy sector. This includes allowing consumers to easily switch energy suppliers, monitor energy consumption and quickly settle complaints, the implementation of the Strategic Energy Technology Plan - the EU strategy to accelerate the development and deployment of low-carbon technologies such as solar energy, smart grids, carbon capture and

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storage, pursuing good relations with the EU's external suppliers of energy and energy transit countries. Through the Energy Community, the EU also works to integrate neighbouring countries into its internal energy market.

At European level, the legislation dealing with smart meters for electricity and natural gas is:

Directive 2004/22/EC of the European Parliament and of the Council of 31 March 2004 of measuring instruments [1],

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency [2],

Task Force for smart grids [3],

M-Bus (Meter-Bus) is a European standard (EN 13757-2 physical and link layer, EN 13757-3 application layer) for the remote reading of gas or electricity meters [4,5],

Open Smart Grid Protocol (OSGP) ETSI TS 103 908 [6].

In accordance with the M/441 standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for electricity meters involving communication protocols that allow interoperability, the following are defined:

F1 remote reading of supplied and consumed energy meters,
F2 bidirectional communication,
F3 measuring/recording interval,
F4 remote management,
F5 home interface, home automation,
F6 portal / Gateway information.

In the context of current technological development, measurements are an indispensable field to technical-scientific activity. Energy transfers as well as information transfers are mainly carried out on the basis of electromagnetic quantities.

The smart meters are connected to the concentrator that collects data from them and sends it through GPRS to the Datacenter. Thus, a bidirectional remote communication flow is automatically accomplished.

The topology of the system is composed of four distinct layers:

Layer 1: Distribution network - Counters installed in the client system are equipped with an M-Bus (Meter - Bus) interface, which allows the connection of up to 4 M-Bus devices, such as gas, water and power meters heat.

Layer 2: MV/LV Substation - There is a data concentrator in the transformer substationș this component is equipped with a narrowband modem and manages and coordinates the assigned devices.

Level 3: Carrier networks - To communicate with the data center, the data concentrator is equipped with a WAN interface that supports multiple transport protocols, such as UHF / VHF, GSM, GPRS, ADSL, and Ethernet.

Layer 4: Data Center - The last level where the data you get is sorted and redirected to the appropriate department.

2. Networked Energy Services (NES)

NES [7] is an intelligent network solution based on software that incorporates smart meters, network connectors, concentrators, and software applications.

Fig. 1. NES components.

These components meet the needs for intelligent metering, Advanced Metering Infrastructure (AMI) systems and markets [8, 9] from the perspective of the network, not just the meter. Unlike the RF solution, which uses a card-integrated card as an add-on, the NES system uses the power grid cables, and upgrades the existing metering system into a smart grid. This allows the system to provide the smart grid with information about the quality of electricity and the efficiency of its delivery.

3. Educational Platform used for the measurement and control of electrical energy

The originality of the paper consists in developing of an on line educational platform. Therefore, the students and those interested in the domain of energy measurement can study the hardware and software configuration of intelligent controls.

3.1. Hardware structure of the platform

In order to demonstrate how an intelligent electricity metering and metering system works, an educational platform (Fig. 2) was built and it consists in two single-phase and two three-phase electric meters supplied by S & T.

Fig. 2. Hardware structure of the experimental platform.

Single-phase meters are MTR1000 type and three-phase ones are MTR3000 or MTR3500 respectively. In addition, the platform contains a DCN 1000 concentrator that collects data from counters.

MTR 1000 meters are based on NES proven Power Line (PL). Like the full range of NES smart meters, the MTR 1000 integrates into power line-based communication network.

The MTR 1000 counters provide power quality analysis: sag and swell, number of peak power incidents, short-circuit current number, long interruptions number, duration and time of the last 10 long-wave currents, maximum and minimum frequency, loss phase, total harmonic distortion.

The MTR 3000 meter is a direct-mounted, three-phase, electronic consumer meter with switch and built-in PLC based.

The MTR 3500 is a semi-direct three-phase electronic balance meter designed for general measure in the transformer substations.

In Fig. 3 is a simplified scheme of connections made to the experimental platform.

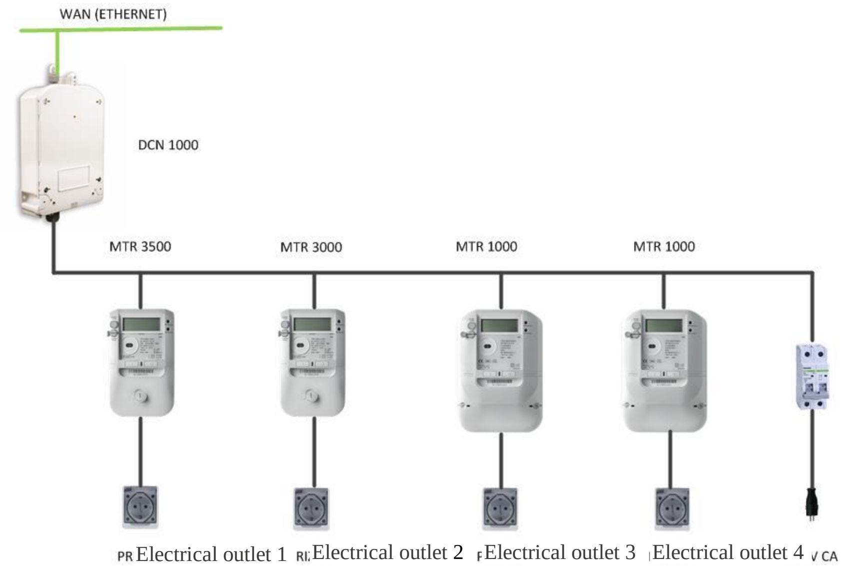

Fig.3. Simplified scheme of experiment platform connections.

Intelligent NES meters [10, 11] create a reliable and robust distribution network so non-technical losses can be detected. Unauthorized, recorded and communicated changes can be detected even during a power outage. They offer the ability to upload 16 channel profile data. By activating a proactive position, it can be reduced the average intervention times, reducing operating costs.

Heightened demand for power availability, distributed generation, and greater efficiency create need for more consumption and power quality measurements. To meet this need, NES provides smart meters delivering 4x16 channels of profile data loading. Each of these can be configured independently for interval, size, and collection settings. Now you can have a dedicated data set for monitoring and up to three additional data sets for collecting power quality metrics like voltage, current, total harmonic distortion (THD) [12]. It is possible to store these data locally (in the counter), or to extract measurements whenever it is needed (daily, weekly or monthly).

The existing platform meters offer options that allow additional auxiliary counters (gas, water, heat) to be introduced into the system via a profile-compatible interface. Counters are safely connected to ZigBee (RF) radio or LonWorks® PL, M-bus, Multipurpose Expansion Port (MEP), or Open Smart Grid Protocol devices. They can be integrated into the Home Area Network (HAN) to energy management systems or other expanded services.

The DCN 1000 is a low-voltage assembly concentrator in the Smart Metering with PLC interface.

The Distributed Control Node (DCN) 1000 Series is a data concentrator that manages smart meters and other devices on a low-voltage power supply. It provides the communication infrastructure between network devices and power outlets by effectively coordinating bidirectional data sharing on the device. It detects and reports problematic conditions, such as power outages and faults of connected devices. They communicate with system software through an IP-based utility.

The DCN 1000 constantly provides accurate data on power consumption and quality. The DCN 1000 provides end-to-end data encryption for network security to protect the privacy of consumers through additional multiprocessing authentication needed to counteract cyber-attacks. The DCN 1000 can be installed at any point in the low voltage power line network, including the distribution transformer, located additionally behind an IEC meter or an ANSI counter.

The design allows you to choose the installation point with the lowest cost on the network or where the power of the WAN signal is the best.

3.2. Software structure of the educational platform

NES System Software makes integration of new and existing applications with IT standards fast and easy. The software used to configure the optimal performance of the educational platform is:

NES Provisioning Tool,
NES Element Manager (Real-time system status and various statistics, graphs, incident reporting),
NES Diagnostic Tool (Viewing Communication Settings, Incidents and Programming Command Counters),
VMware Player 12 (Virtual Machine),
SQL Server 2012 (Connection to the database),
Server Manager (Server Configuration/Management).

The data on the concentrator is transmitted via Ethernet cable to the computer. The VMware Player 12 software is installed on the computer, which is compatible with software on the counters that can control/configure the counters.

The GPRS-WAN connectivity is set to connect the GPRS data center to the Data Center server. When establishing a GPRS network, WAN requirements are applied:

the WAN system must be capable of delivering TCP/IP packets between the AMI system (located in the data center) and the data concentrator at a rate of 9600 bps or higher,
the WAN system must support static IP addresses for the AMI System server (the data concentrator may have a static or dynamic IP address),

the WAN system must accept the two-way routing message (from AMI system concentrator and AMI system to data concentrator),

the AMI system and data concentrator use the following communication ports:

- ❖ Port 80 to contact AMI for emergency events;
- ❖ Port 65432 - The AMI system uses the port to contact the data concentrator;
- ❖ Passive port 21 and FTP (ports 65401 - 65420) - AMI uses passive FTP to transfer files between the AMI (FTP client) and data concentrator (FTP server) system.

to ensure the security of data communications, SIM cards must support encryption of data over the Internet.

The NES Meter 3.2 software (fig. 4) is used to program the meters, which allows:

Calendar Setup – TOU Schedules,

Day Schedules,

Non-recurring dates - Non-recurring dates lists,

Recurring dates - Recurring dates lists.

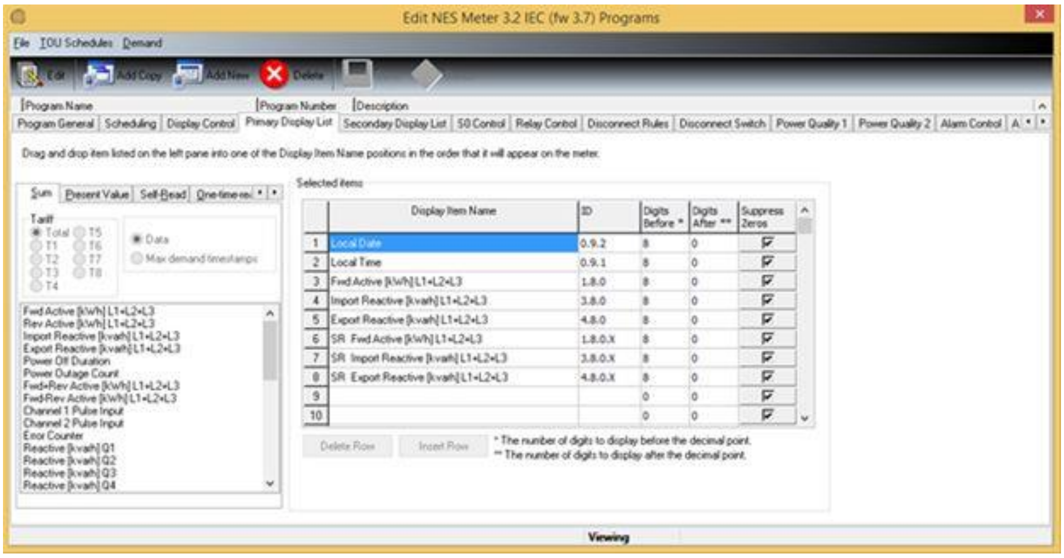

Fig.4. Primary Display Configuration Window.

In the programming session, it is possible to configure the meters:

single phase and three phase tariffs,

display control, S0 control, relay control,

disconnect rules, disconnect switch,

power quality 1, power quality 2,

alarm control, alarm configuration,

display the charging profile,

event log,

pulse/digital inputs,

network communications, measurements.

4. Testing the educational platform

The testing of the educational platform consists in verifying the functionality of the electricity metering and metering system. A first check was performed on each display test counter. Then proceed to the next step, namely to check the consumption recording on them (fig.5).

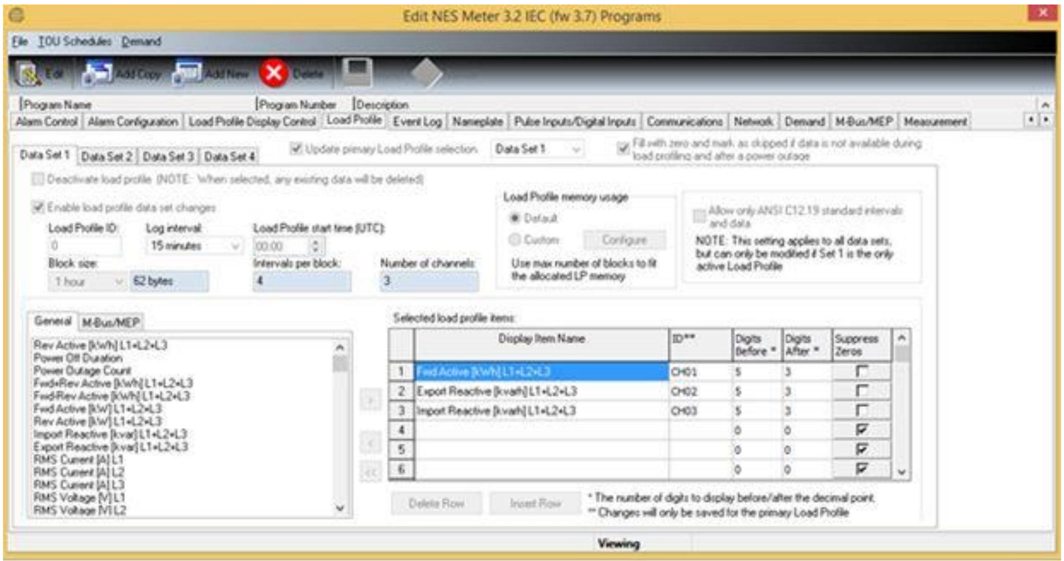

Fig.5. Testing consumption recording.

Following the recording of electricity consumption in time, the smart meter can display the user's load curve. It takes over the information about the energy supplied and presents it to the user in a detailed form. This information is useful for differentiated hourly charging of electricity. The user, knowing when energy is more expensive and looking at his own consumption graph, will be aware of the costs he is doing, and will look for ways to reduce energy consumption during peak periods.

Another function of smart meters is to separate the total consumption of a home on electrical devices. Thus, the consumer may have graphs on the consumption of a particular electrical device over a given period. This feature reduces electricity consumption. Other functions of the smart meters would be: remote transmission of energy to the supplier, presentation of the approved customer tariff, automatic shutdown of electricity supply in case of anomalies detection or bad-payers and inform the provider when disruptions occur in the power supply.

The tests were performed on the start-up and then communication between the experimental platform and the computer (Fig.6).

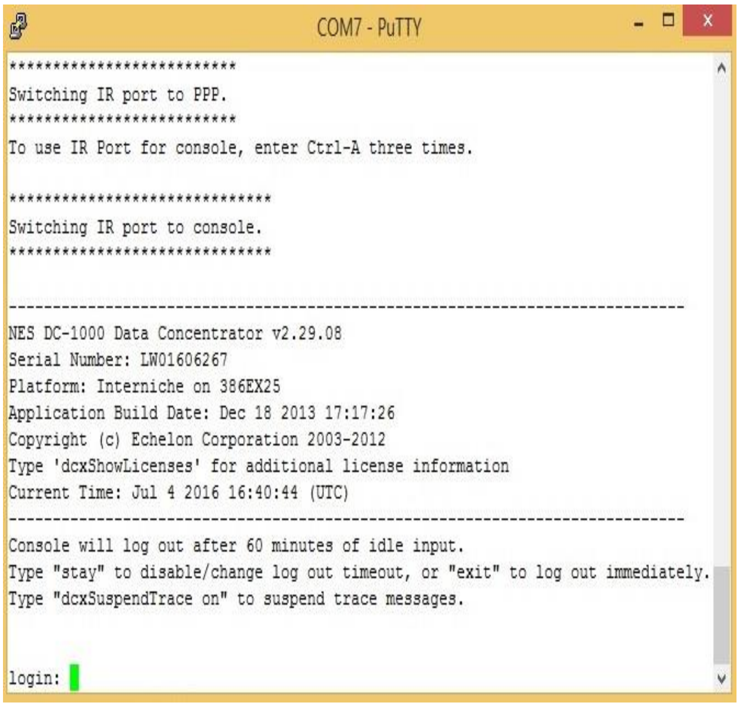

Fig.6. Testing the operation of the communication.

The educational platform allows users to gain insight into how to build and configure an intelligent measurement system. With this, you can study the main components (smart meters) and their role in the system.

A first stage is to simulate energy consumption and take the measurement results to the computer. The meters can be connected to the computer via a USB cable or local network cable with an RJ45 connector.

The control system used by the counters is the Head End System (HES). The platform uses this metering company's hardware and software to exchange data flow across the network.

The platform has four AC outlets where the user can connect a load after the platform is switched on. Then the meters enter a TEST state and the load is measured. With the connected task, users can see real-time instantaneous energy consumption in W, hourly consumption in kWh, Ampere current, network frequency in Hz, current flow and eventual defects. With the dedicated software applications listed above, charges can be changed remotely (meter communication must be set to GPRS) and load curves observed.

The second stage consists in verifying the platform functionality through dedicated software (NES Provisioning Tool, NES Element Manager, NES Diagnostic Tool, VMware Player 12, SQL Server 2012, Server Manager).

In the event of defects, the NES Element Manager application provides users with the exact location of the incident and event logs until the defect occurs. Platform users can control the meter and stop it.

The diagnose of communication with the learning platform is done through the NES Diagnostic Tool software (fig. 7).

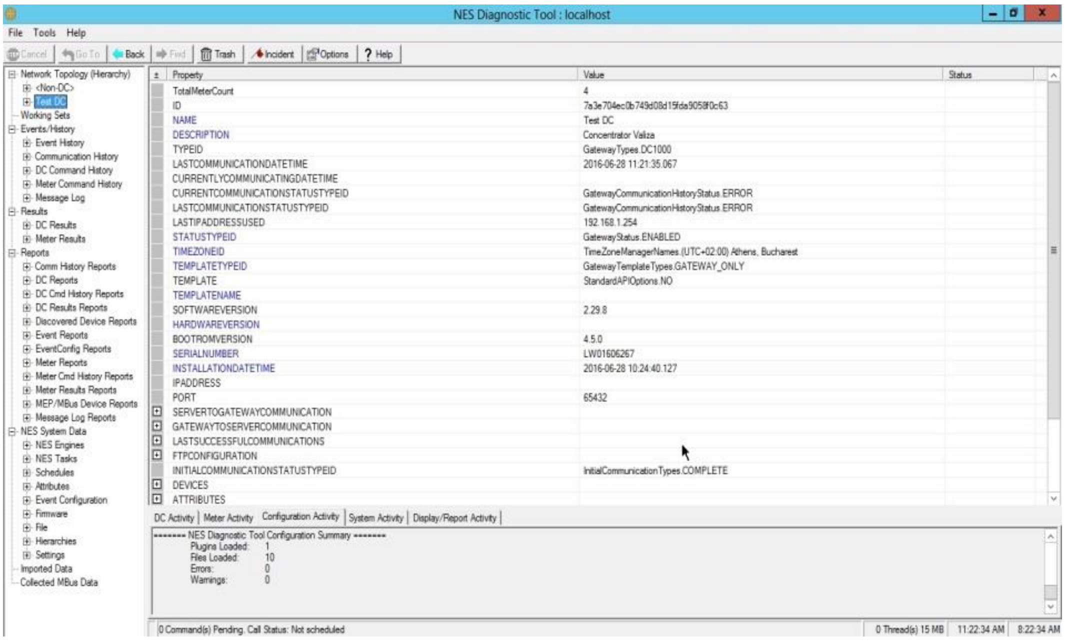

Fig.7. Diagnosing the educational platform.

The platform offers users the ability to view the following:

accuracy of measurement,
on demand remote tariff changing,
firmware updates,
reporting.

Using the virtual machine created with the VMware Player 12 utility on which the software configuration and data management software suites have been installed, the following steps will be performed:

manage firmware updates, remotely configure the meter, over the air (OTA) modify the tariff, and acquire data through the NES Element Manager application;
log events on counters and firmware updates through the NES Diagnostic Tool.

The full-featured database is accessible through this platform by connecting to the test server and opening the SQL Server 2012 application.

The educational platform helps to understand the optimal configuration of smart meters.

5. Conclusions

Even if technological advances are more and more common in industry, many people do not know the notion of smart meter alias intelligent counter. This paper aims to familiarize students with this notion and also how data on these counters can help save energy, money and improve safety. Presenting these valuable data to customers in a concise, easy-to-understand way can help save energy. With the involvement of customers, these data can be the key to building a smart grid that allows for a behavioral response to demand, dynamic pricing, and more.

A clear path for hiring customers in intelligent meter data is to present this information effectively. Thus, in addition to the functions of the meters presented in the paper, web portals can be made to provide customers with as much useful information as possible about their use. The standardization of data formats allows the creation of portals in which they can easily integrate with data obtained from smart meters.

Smart meters have the following advantage:

a) *vs. clients*

customer awareness and energy saving,
accurate reading and billing,
pricing and flexibility,
better conditions for protected consumers,
better comparison of service offerings,
increased competition among traders,
Smart homes could be made by connecting other devices to the smart meter.

b) *vs. distributors*

improves control and monitoring of the network,
reducing fabrication costs through full automation production process,
easier recognition of network failures, repair identification,
better quality control,
smart grid network control systems,
preconditions for smart grids.

c) *vs. suppliers and dealers*

optimizing spending by changing tops,
reducing balancing energy through better forecasting,
new services for special requirements,
more attractive image,
data accessible to authorized users.

Increasing energy consumption has forced many states to optimize energy monitoring systems. Thus, Sweden on July 1, 2009 reached 100% use of smart meters [15]. From 2016, Japan began deploying large metering infrastructures and is expected to be completed by 2024 [16]. In 2019, Finland will be the first data center to display the information received from smart meters [17]. The year 2025 is the maximum term for the development of smart cities based on smart metering in India [18]. The above are just a few examples that lead us to the conclusion that an intelligent metering educational platform is a study opportunity for students and beyond. However, a cyber-attack on a smart meter coordination center can allow a hacker to throw a whole city in the dark with a simple click.

R E F E R E N C E S

1. http://www.lne.eu/publications_en/directives/04-22e.pdf
2. http://www.buildup.eu/sites/default/files/Energy%20Efficiency%20Directive%202012-27-EU%20en.pdf
3. https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force
4. https://ec.europa.eu/eip/ageing/standards/ict-and-communication/data/en-13757_en
5. T. Matt, M. Schappacher, A. Sikora, "Development of a Web-Based Monitoring Device for the Wired Metering Bus (M-Bus) as Defined in EN13757-3", ICSGCE 2015, 20-23 Oct., Offenburg, Germany pages: 187 - 194.
6. K. Kursawe, C. Peters, "Structural Weaknesses in the Open Smart Grid Protocol", ARES 2015, 24-27 Aug., Toulouse, France, pag. 1-10.
7. S. Horsmanheimo, J. Eskelinen, H. Kokkoniemi-Tarkkanen, "NES - Network Expert System for Heterogeneous Networks", ICT 2010, 4-7 April, Doha, Qatar , pag. 680-685.
8. Shengjie Xu, Yi Qian, and Rose Qingyang Hu, "A Study on Communication Network Reliability for Advanced Metering Infrastructure in Smart Grid", DASC/PiCom/DataCom/CyberSciTech 2017, 6-10 Nov., Orlando, FL, USA, pag. 127-132.
9. L.C. Lipan, Analysis of smart solution in modern efficiency distribution systems for buidings, Scientific Bulletin, University POLITEHNICA Bucharest, Series C: Electrical Engineering, vol. 78, iss. 3, 2016.
10. J. Zheng, D.W, Gao, L. Lin "Smart Meters in Smart Grid: An Overview", GreenTech 2013, 4-5 April,, Denver, CO, USA, pages. 58-64.
11. E. Zaharovitz, Modern instruments for electricity measurement under present situation, Scientific Bulletin, University POLITEHNICA Bucharest, Series C: Electrical Engineering, vol. 76, iss. 4, 2014.
12. E. Cazacu, M. C. Petrescu, V. Ioniţă and L. Petrescu, "Nonsinusoidal load current effect on the electrical and thermal operating parameters of oil filled power distribution transformers," 2018 18th International Conference on Harmonics and Quality of Power (ICHQP), Ljubljana, Slovenia, 2018, pp. 1-6
13. NES SmartMetering System_2009_eng.
14. NES Patagonia Security Whitepaper_NG Platform_2014_eng.
15. Mannikoff; H. Nilsson, "Sweden – reaching 100 % 'smart meters' July 1, 2009", IEEE Power & Energy Society General Meeting 26-30 July, Calgary, AB, Canada, pages. 1-4.
16. Y. Tsukamoto T. Inoue, S. Kurosawa, "Smart Metering Infrastructure in Japan", APSCOM 2015, 8-12 Nov., Hong Kong, China, pages. 1-5.

    A. Mutanen. H. Niska, P. Jarventausta, "Mining smart meter data – Case Finland", CIRED Workshop 2016, 14-15 June, Helsinki, Finland, pages. 1-5.

17. S. Patel, U. Kumar, P. Kumar, "Role of Smart Meters in Smart City Development in India", ICPEICES-2016, 4-6 July, Delhi, India, pages. 1-5.