REQUIREMENTS AND CONDITIONS FOR POWER DEMAND AND QUALITY PARAMETERS SYSTEM DEPLOYMENT FOR PUBLIC LIGHTING IN ROMANIA

IACOB A. *, ALEXANDRESCU R. M. *, SALCEANU C. *, IONESCU I. **, RACOVITAN I. **
*Research, development and Testing National Institute for Electrical Engineering (ICMET), Bd. Decebal, no. 118A, Craiova, Romania
** Energy Research and Modernization Institute (ICEMENERG), Bd. Energeticienilor no. 8, Sector 3, Bucuresti, Romania
ramonaalexandrescu@ymail.com

Abstract – The article offers an analysis of required conditions for public lighting management system deployed in a mid-size city in Romania. In order to acquire the optimal solution of technical and economic efficiency it is necessary to establish system requirements, technology availability and a complex analysis of economic efficiency. The subject primarily aims public lighting services and/or administration of each residential area in attempt to set an opinion on the benefits of network monitoring and control of public lighting systems. The deployment of a modular system performance is of major importance to decrease consumption and reduce power losses in lighting networks. This study comes for supporting sustainable development, ensuring environmental conditions and eliminating the effects of pollutants.

Key words: monitoring, public lighting, sustainable development

1. INTRODUCTION

According to various studies, the public lighting energy consumption recorded for a Romanian city rises about 20% of total power demand in that particular city. Europe also concerns more and more for pollution reducing. Actual lighting in Romania is not only a CO_2 emission but a light pollution source, too; this is less considered but of major importance for astronomical observatories.

Therefore, the integration of effective solutions and long-term investments are required for efficient illumination.

Such a wide-spreading project can only be initiated after measurements would have been taken in accordance to the specific situation. Also, further scrutiny is needed for the results obtained after the modernization process. In these conditions and supported by the EU objective on increasing energy efficiency by 20% until 2020, implementing actions have started for a quality parameters' monitoring system on public lighting grid.

Effective range of solutions is quite varied; research teams are dealing with this problem. In the process of choosing the proper solution, the designer must consider a solution that seems to be the most effective for a case is not necessarily the best solution for all cases. For example, integrated telemanagement in a small location pays off very slow; while technology is progressing fast enough for us to consider that new at least as advanced solutions shall cost a lot less by the time the redemption period ends up.

According to our running regulations, monitoring and power quality parameters and indicators determining has to be done using dedicated acquisition and processing equipments and systems. Also, measurement and measured data aggregation procedures and requirements must be considered; during indicators calculation and reporting procedures, covered by international standards and national regulations.

2. WORKING METHODOLOGY

The EN 16001 standard published on September 30-th, 2009 is useful to all organizations in order to set required systems and processes for energy efficiency improvements, reducing costs and greenhouse gas (GHG) emissions.

SR EN 16001:2009 specifies requirements for an energy management system; this is necessary instrumentation for any organization in the process of developing and implementing energy policy and objectives relating to energy aspects.

As recommended, this standard may be used independently or integrated with any other standard related to management (it is similar in structure to ISO 14001 – on environment).

Such system implementation has to consider location's particularities, according to running standards. So, before designing a new lighting system or upgrading the already existing one, an extended documentation on infrastructure is absolutely necessary.

I.S.S.N. 2067-5538

3. STREET LIGHTING NETWORK'S CHARACTERISTICS

Public lighting energy distribution of a mid-size city starts from transformer and distribution stations, assigned on public interest objectives and streets.

Feeding network varies from single-phased (having 220 V, 50 Hz) to three-phased (having 3x400 V, 50 Hz) and even mixed.

The lighting system is controlled with ignition points placed on poles and usually corresponding to MV/LV transformers' stations, feeding both private consumers and street lighting with separate distribution circuits. Ignition points are energized with pulse-separated circuits working on 220 V, 50 Hz, through timer or dusk-to-dawn switch; end-users prefer the timer switch for programming. Switches are either mechanical or electronically. The ignition points for each area are chosen so to reduce distances and pulse signal losses.

Public lighting services belonging to several cities were contacted in order to ask about the progress of street lighting upgrading, to perform network and quality parameters measurements, to assess the consumption and design a monitoring system for real application conditions.

Modernization made on street lighting consisted of the following:

- Upgrading to twisted cable network;
- Implementing new switching and control instrumentation into ignition point panels;
- Replacing high pressure mercury lamps with high pressure sodium ones but still equipped with electromagnetic gear.

However, there are no recordings regarding the energy consumption, or quality parameters for power supply of the lighting system before and after modernization takes effect.

4. LAB EXPERIMENTATION – IMPLEMENTING REQUIREMENTS

According to international specifications and the analysis of proposed task, any monitoring system contains 3 levels: electrical measures process acquisition level, monitoring measures analysis level in accordance to power quality (this procedure runs on a remote computer) and the communication between the first two levels.

Monitoring system implementation, as well as its structure is completely determined by a series of requirements which has to be met, in order to decide the appliance of this specific design at the right time and achieving the right results.

One first necessary condition the solution has to comply in order to be considered appropriate is *expandability* – the availability for system upgrades or future changes with minimal effort, both financially and technically. With this condition in mind, we analyzed some offers and made our option on the proposed monitoring system for different applications' configurable power quality analyzer (only input modules may need to be changed). Same acquired data viewing and processing software may be used for all available applications of the chosen device. As for future upgrading, dedicated software allows data management for over 50 different devices, involved in different application types for power system management.

Off-site communication is a determinant factor as well. It is best that the used communication protocols to be widespread in the power systems domain. One robust but stiff communication protocol becomes a limitation in the range of available equipments for the outfit. Besides the communication protocol, other features have an important role in the communication process; these are accepted communication modules, the data transmitter and the transmitting speed. The speed depends on the protocol, communication modules, transmitter and measurement device and computer's communication port. 2 different communication types are better than one in order to prevent communication interruptions due to malfunction of one communication line. Data transmission for suggested monitoring system is possible both with Fiber Optic and GSM modules, so this condition is also accomplished. To overcome cable installation issues and reduce costs, wireless data transfer is introduced.

Computer's h*ardware resources* must correlate to measuring' device specifications for first level tasks fulfilling. These specifications refer to processor's speed, storing volume, available communication ports and even view modes. Software resources matter, too, as there are incompatibilities between dedicated viewing and analyzing software and other software and applications, even operating systems.

Reporting – generating reports is key important to monitoring. There are two options for reporting: automatically generated reports – as alarm options and reports generated on user's demand. Its type should also be configurable, so one can list all measured points and values; all points in alarm, history of equipment ON/OFF commands and status and reason for the command; weekly schedules and holiday program; limits and dead bands. Due to its modularity and allowance for various applications, the power analyzer we opted for cares for any user's possible demand in terms of reporting.

Measurement hardware – current/voltage *measurement transducers* features are established in the power analyzer's technical specifications. This request has determined effect on the right measurement of electrical values. In terms of hardware configuration, it is important to establish the connection type and place the measuring point takes in the network, as a requirement so it does not affect the operation process in any way.

Monitoring points – physical location of the measuring point. From this point of view, it is important to know the optimum number of monitoring points, for the management system's requirements to be met. Their physical location has to consider the street light network's infrastructure. We considered appropriate to place current transformers and voltage measurement in transformer's station, on the outgoing separate public lighting feeding line. Another place to install the monitoring point we considered was the ignition panel; in the network we studied, each ignition points correspond to a transformer's station, so measurements can be performed where is physically more convenient. We decided to install the system within a transformer's station as the ignition panels installed on poles are small and there is no room for our equipment. The advantage of a monitoring system installed over the ignition point lays in an even more organized management structure – as both ignition points and the monitoring system are referred by the public lighting attendance for modernization and maintenance.

5. RESULTS

Analyzing the proper solution based on the above specified requirements, we concluded to a class A stationary power quality analyzer – modular system for maximum flexibility.

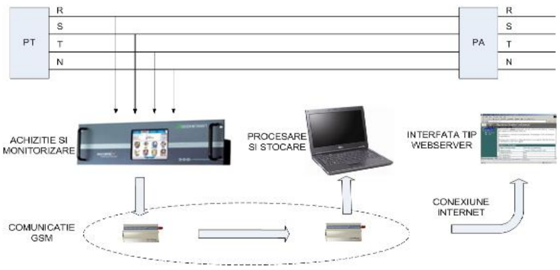


Fig. 1. Monitoring system using MAVOSYS10

The system consists of a rack with 4 slots; two slots are filled with voltage and current modules, and two slots remain open for further application development. Encore Series Software allows for the analyzer to be used in a wide variety of electrical systems and a wide range of configurations. It has a users' web-browser password protected interface and a wide range of functions. Encore Series Software is suitable for data acquisition and storage:

- User interface is simple, based on a web application,
- Software allows management of more than 50 analyzers;
- Quality analysis for consumption, energy and network processes.

So, expandability is met both as for MAVOSYS upgrading possibilities and for the entire system expanding at city level.

Power quality analyzer, MAVOSYS 10 has multiple-choice for acquired data transmission from the process. It comes with serial communication ports (RS232, RS485), Ethernet, GSM / GPRS.

The off-site communication requirement is accomplished and even overcame. For data transmission system design model two GSM modems and 2 communication terminals (with self-diagnosis status signaling) were used; 2 communication cards were also acquired for data transmitter.

Keeping in mind the hardware resources requirement, data acquired are stored on a notebook with high storage volume, at least one USB to RS 232 serial adapter and good visualization performance. Software generated reports ca be printed with a color printer if the user chooses so.

Current measurement is taken with cable crossing current transformers having different transforming ratios; the 100/5 A ratio fitted our application. As for voltage measurement, there is no need for transformers.

Due to its installing place, the monitoring system needs insurance against possible voltage drops, over voltages, rapid voltage changes, etc. with a dedicated UPS. UPS has two jobs here that are to ensure and maintain connection between controller and remote power network, for process recorded data.

Reporting options are plenty with MAVOSYS 10. There are 9 different types of available reports regarding the aspects needed to be highlighted. These are:

- DataNode summary,
- Quality of supply compliance,
- Voltage quality,
- Energy and demand,
- Event summary,
- Top 10 events,
- Event statistics,
- Waveform distortions,
- InfoNode summary.

For each report type, a few choices are also available; a specific device (from the 50 possible connected devices) may be selected for reporting or you can obtain information from all devices centralized in one report, time and date interval are to be selected and a heading may be completed if additional criteria are needed for identification.

With these various options MAVOSYS 10 may offer reports for periodically power quality statistics for one or more measuring points, energy consumption for bills' supervising, statistics on power quality before and after an event or system upgrading.

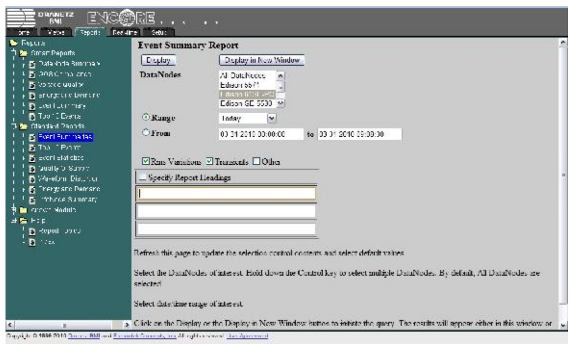


Fig. 2. Reporting options for monitoring system using MAVOSYS10

Technically, the system's performances refer to online monitoring process and reporting for power quality parameters.

Benefits due to monitoring systems implementation refer to the following:

Online monitoring and data transmision from the analyzer to the supervisory post assures predictive management developed with statistical data on long-term evolution. The data are to be centralized and stored in a data-base, then used in modernization studies, projects, energy efficiency and audit, comparison to recorded data after moderinzations processes take effect.

Controlled energy consumption indirectly involves CO_2 emission and GHG reduction, which is of great importance for the environment.

Monitoring requirements for public lighting systems, determined on experimental model took in the lab and considering lighting grid specifications refer to two aspects:

- Control:
  - Manual or automated start/stop for public lighting for the entire city, or only for few segments;
  - Self-dependent luminous flux dimming applications for specific segments where traffic conditions allow it.
- Monitoring:
  - Periodical complete reports over power quality of supply;
  - Daily situations on malfunctioning lighting bulbs;
  - Predictions on life-span for lighting bulbs' elements; based on this information, time frequency can be set, along with the approximate number of purchased devices;
  - Monitoring the lifetime of each device that helps the user to exploit the product warranty.

6. EVALUATION

Financially, the monitoring system costs are as follows:

- Monitoring system's costs, having only one measuring point is about 48000 RON, that is 11500 EUR;
- Estimated value for equipments used to monitor the whole street lighting, having 11 measurement points reaches to 430000 RON, that is 102000 EUR.

Our first solution reaches high prices comparing to benefits obtained with appropriate implementation. The damping time is considerable, so the investment is not feasible any longer.

Having said that, it is time to consider replacing the power analyzer with a less advanced one and one remote transmitting option; keeping though the possibility to transfer recordings locally, through cable connection. In lab experiments, we used also a lower class power analyzer; this was MAVOLOG 10 analyzing accordance with our requirements. New analyzer option has good capabilities for recordings storing and it is equipped with a UPS module able to maintain supply for up to 10 hours for one data logger. The result is in a more accessible configuration, fulfilling though with the monitoring application's requirements. Its software can only support 10 more analyzers, which might be a problem, as our application refers to an 11 ignition points town. In this case, a larger structure should consider more than one centralizing stations.

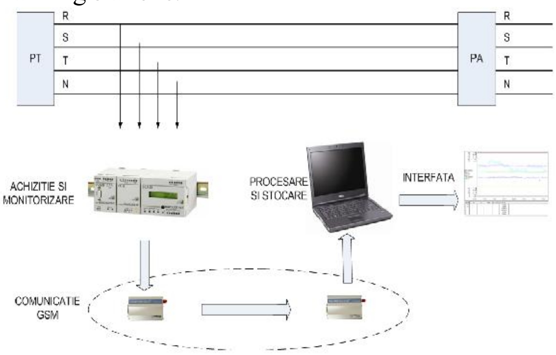
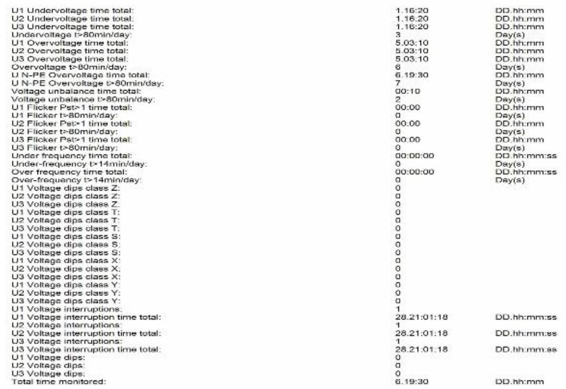


Fig. 3. Monitoring system using MAVOLOG10

For the off-site communication requirement, one communication line option stands on; that is GSM communication with one RS 232 serial port for external modem connection. The RS 232 port can also be used to local data transfer. We can admit the off-site communication is accomplished.

Hardware resources are easier to take into consideration this time as METRAwin software for MAVOLOG 10 is less "exigent" when it comes to hardware limitations. An RS 232 port is necessary. There are no software limitations, as well.

There are some disadvantages of MAVOLOG 10 network analyzer, and one is with reporting options. Therefore, the end-user cannot configure its visualization mode. Only two report options are available and only on demand. The visualization modes for these reports are listed below, in figures 4 and 5. No waveform reporting is available.



U1 Undervoltage time total:	1.16:20	DD.hh:mm
U2 Undervoltage time total:	1.16:20	DD.hh:mm
U3 Undervoltage time total:	1.16:20	DD.hh:mm
Undervoltage t>80min/day:	3	Day(s)
U1 Overvoltage time total:	5.03:10	DD.hh:mm
U2 Overvoltage time total:	5.03:10	DD.hh:mm
U3 Overvoltage time total:	5.03:10	DD.hh:mm
Overvoltage t>80min/day:	6	Day(s)
U N-PE Overvoltage time total:	6.19:30	DD.hh:mm
U N-PE Overvoltage t>80min/day:	7	Day(s)
Voltage unbalance time total:	00:10	DD.hh:mm
Voltage unbalance t>80min/day:	2	Day(s)
U1 Flicker Pst>1 time total:	00:00	DD.hh:mm
U1 Flicker t>80min/day:	0	Day(s)
U2 Flicker Pst>1 time total:	00:00	DD.hh:mm
U2 Flicker t>80min/day:	0	Day(s)
U3 Flicker Pst>1 time total:	00:00	DD.hh:mm
U3 Flicker t>80min/day:	0	Day(s)
Under frequency time total:	00:00:00	DD.hh:mm:ss
Under-frequency t>14min/day:	0	Day(s)
Over frequency time total:	00:00:00	DD.hh:mm:ss
Over-frequency t>14min/day:	0	Day(s)
U1 Voltage dips class Z:	0	
U2 Voltage dips class Z:	0	
U3 Voltage dips class Z:	0	
U1 Voltage dips class T:	0	
U2 Voltage dips class T:	0	
U3 Voltage dips class T:	0	
U1 Voltage dips class S:	0	
U2 Voltage dips class S:	0	
U3 Voltage dips class S:	0	
U1 Voltage dips class X:	0	
U2 Voltage dips class X:	0	
U3 Voltage dips class X:	0	
U1 Voltage dips class Y:	0	
U2 Voltage dips class Y:	0	
U3 Voltage dips class Y:	0	
U1 Voltage interruptions:	1	
U1 Voltage interruption time total:	28.21:01:18	DD.hh:mm:ss
U2 Voltage interruptions:	1	
U2 Voltage interruption time total:	28.21:01:18	DD.hh:mm:ss
U3 Voltage interruptions:	1	
U3 Voltage interruption time total:	28.21:01:18	DD.hh:mm:ss
U1 Voltage dips:	0	
U2 Voltage dips:	0	
U3 Voltage dips:	0	
Total time monitored:	6.19:30	DD.hh:mm

Fig. 4. Monitoring system reporting generated with MAVOLOG 10

Still, information offered is sufficient for keeping an eye on public lighting consumptions and quality of supply.

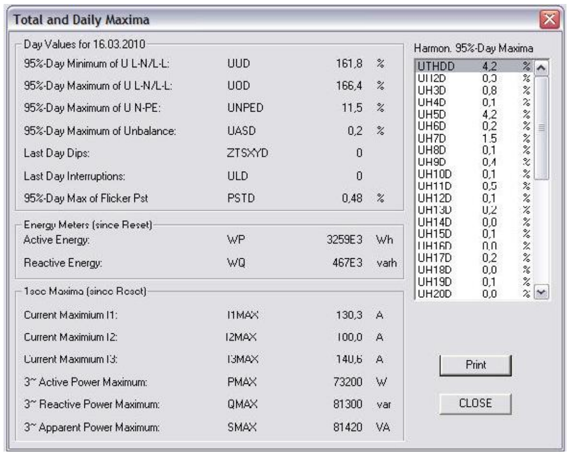


Fig. 5. Total and daily monitoring system reporting generated with MAVOLOG 10

Financially, the monitoring system including MAVOLOG 10 network analyzer is:

- Monitoring system's costs for one measurement point and the controller's post are about: 21200 RON, that is 5000 EUR;
- Estimated value for one controlling post and 11 measuring points (meaning the entire street lighting

in our studied town), reaches to 158200 RON that is 37500 EUR.

Keeping this evaluation in mind and considering previous costs evaluation for the more advanced monitoring system (including MAVOSYS 10 power analyzer), we appreciate a cost reduction of up to 6500 EUR per one experimental monitoring system (containing one measurement point, one controller post and communication system) and a significant 64500 EUR cost reduction for town's entire street lighting.

No matter the chosen analyzer, applying useful measures indicated with the power quality analysis generates a few significant advantages considering the following:

- Cost reduction for energy bills;
- CO_2 emission and GHG reduction;
- Maintenance costs' reduction;
- Significant increase of lifespan for luminaries;
- Visual comfort increasing.

As we have experienced in our application, no monitoring system configuration is generally valid. When a management system has to be designed and implemented for a specific application, the designer has to work on the structure mentioned before and a list of requirements certainly helps him to establish some directions to follow.

CONCLUSIONS

One big argument for public lighting management is the comfort extent along with increasing traffic safety obtained from one tightly controlled and monitored system. It is already well - known that specialists have elaborated many studies to determine the social impact of nighttime lighting.

It is essential that a study of monitoring system implementation in a city is done with the competence of a neutral organization; it is of major importance to remove traders' temptations to sell equipment in any form.

Romania adopted the SR EN 16001:2009 standard, not long ago; this standard specifies requirements for establishing, implementing, maintaining and improving an energy management system. It is applied for continuous improving in terms of energy use in a sustainable and more efficient manner. EN 16001:2009 standard elaboration and adoption contribute to continuous improving process stimulation and, further away, to efficient energy use. This matter encourages monitoring implementation and consumption analysis plans in any organization.

According to standard specifications, one efficient monitoring system precedes in practice the following tasks:

- The possibility of taking decisions to improve energy efficiency;
- Annual continuous consumption improvement and energy performance improvement;
- One more elaborate analysis for areas with good potential for energy savings.

Power quality monitoring is usually necessary for reacting to problems, and to identify possible solutions. Continuous and permanent power monitoring has emerged as an integral part of overall system performance assessment. The greatest benefit of continuous power monitoring is that it puts users in a proactive position by increasing their knowledge and giving them the tools to increase system reliability. Still, in practice, the decision for taking the right solution has to

REFERENCES

[1] Ministerul Economiei, Comerțului şi Mediului de Afaceri „First National Energy Efficiency Action Plan 2007-2010", 2007.

[2] The European parliament „DIRECTIVE 2006/32/EC on energy end-use efficiency and energy service", 2006

[3] EN 50160 "Voltage characteristics of electricity supplied by public distribution systems", CENELEC Standard, July 1995

[4] CEI 61000-4-30 - Electromagnetic Compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods.

[5] SR EN 16001:2009 - Sisteme de management al energiei. Cerințe şi ghid de utilizare

[6] Ghid practic pentru Sistemele de management energietic – "Energy Management Systems – A Practial Guide", PECI, oct. 1997

[7] ICMET Craiova, ICEMENERG Bucuresti "Echipamente pentru monitorizarea consumului de energie electrică în industrie şi iluminatul public", contract Sectorial 16, etapa 1/noiembrie 2008

[8] ICMET Craiova, ICEMENERG Bucuresti "Echipamente pentru monitorizarea consumului de energie electrică în industrie şi iluminatul public", contract Sectorial 16, etapa 2/noiembrie 2009.