ENHANCEMENT OF THE PERFORMANCE OF THE PUBLIC LIGHTING SYSTEMS BY REDUCING ENERGY CONSUMPTION

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Abstract - The project presents a data transmission system in real time using the local public lighting system, with an enhanced application for a medium-small city in Romania. The project contains the standard configuration, the integration in the monitoring system, the value quantification and the calculation and experimental data regarding the efficiency of using this system, together with the effects aimed at reducing the technological consumption generating green house gas .

Key words: energy efficiency, public lighting system

1. INTRODUCTION

In the context of the increasing interest in the enhancement of energetic systems and the reduction of energy consumption, one of the sectors targeted by the Action Plan in the Field of Energetic Efficiency (2007) and by the Ordinance 22/2008 regarding the promotion of measures for increasing energy efficiency in the industrial, public and residential sector is public lighting. [1], [2]

Studies have shown that measures such as the continuous monitoring of energy supply, the replacement of old lighting bodies with new, efficient ones from an energetic point of view, the introduction of lighting flow reduction devices on the main roads in periods with low traffic can save energy.

The continuous monitoring of the power supply is an integrated part of any pro-active management programme. It has the following advantages, among others:

1. It provides information which enables us to determine the load of the existing converters and of backup supplies and allows us to plan future enhancements. The information helps determine whether investments are required in the neighboring areas.

2. It can record the history of the quality of energy which allows the identification of tendencies - such as the increase of the number and magnitude of gaps or increasing the level of harmonics - which can be used for scheduling a preventive maintenance. The elimination of unscheduled disruptions is a great financial benefit, for example, in the case of operations conducted in computing and financial computing centers. These predictable techniques provide the necessary input for achieving a maximum "continuity".

An advanced equipment for analyzing the tension and power rates for each stage according to the applicable laws is necessary in order to monitor the consumption and quality of the electricity generated in the public lighting system [3]

A static energy quality monitoring system must be capable of collecting and storing a large volume of data. This requirement can lead to the loss of a part of the acquired data. This can have two causes:

- the possibility of losing data related to the current events under execution, which prevents the performance of the monitoring process at the fall of the supply tension;
- the possibility of losing the data by filling or over-writing the memory of the analyzer in case of lack of communication.

The possible solutions for solving the issue of loss of data caused by the lack of supply tension are:

- Using uninterruptable supply sources;
- Using devices that detect the power fall of tension, in order to save current data at the dissapearance thereof and to measure the time in which the tension is not supplied.

Permanent communication lines can be used for preventing the loss of data due to over-writing or exhaustion of the internal memory by permanently downloading the data to a central computing device.

3. The decision-making personnel can be immediately alerted if a problem is detected in the energy supply system, using alarms and by sending messages on pagers or PC screens. The immediate notification allows the isolation of problems or the prevention of a chain effect which could put all the equipments at risk.

4. The continuous monitoring provides the necessary data for performing post-breakdown tests of incidents which disturb the supply. This data is necessary in order to establish how and where these events occurred, to understand the way in which they can be avoided in the future and how we can limit their effects.

The data transmission system has an important role in monitoring the energy consumption in real time. Various methods and equipment can be used for the transmission of data, moreover the type of equipment can be enhanced which is possible after a close estimation of the functional advantages and disadvantages and of the price/benefit ratio.

The data transmission support is very important for the accuracy, speed and quality of the transmission, being considered optimal according to the geographical, urbanism and industrialization, security and access factors [4]

SC ICEMENERG SA in collaboration with INCDE ICMET Craiova studied the possibility of enhancing the energetic efficiency of the public lighting system in the city of Bailesti, Dolj county.

2. AN EXPERIMENTAL MODEL OF THE PUBLIC LIGHTING MONITORING SYSTEM

Schematically, the experimental model of the public lighting monitoring system is made up of (fig. 1):

- The data acquisition module
- The data transmission module
- Processing, storage system and operator interface

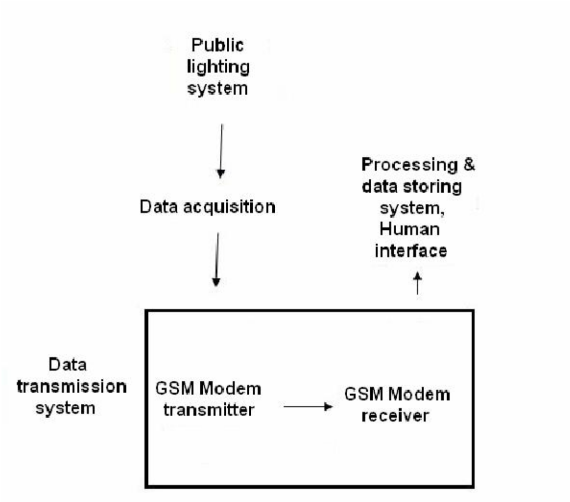

Fig. 1. Experimental model scheme

SC Filiala ECEMENERG SA in collaboration with ICMET Craiova have set up three data transmission models to find the optimal solution for sending the monitored data to the public lighting systems: via ethernet, using optical fiber as support, via GSM and high frequency telephone channels. The results of the experiments indicated the following hierarchy:

From a technical point of view:

1. Data transmission via GSM
2. Data transmission via ethernet, using optical fiber as support
3. Data transmission high frequency telephone channels

From a financial point of view

1. Transmisii de date prin prinethernet, utilizand ca suport fibra optica
2. Transmisii de date prin GSM
3. Transmisii de date canale de telefonie de inalta frecventa

The data transmission via GSM solution was chosen because the solution of data transmission via Ethernet – using optical fiber as support could not be used for the public lighting system in Bailesti (Dolj county), as there is no optical fiber extension provider [5].

Currently, the technique which is most often used in the mobile telephone system for data transmission services is the Global Packet Radio Service (GPRS). This backup data transmission system, according to the current demand, will use one or several access ways on communication lines for mobiles functioning via the transfer of data packets. The access lines will be used by several terminals and from the free access lines even more will be dedicated to GPRS channels, which will highly increase the data transmission speed. A speed of up to 115,2 kbps can be achieved. The GPRS technology is the first step towards integrating the GSM system and the UMTS system (Universal Mobile Telecommunication System).

The GPRS network functions together with the GSM system, completing it with a data package transmission network. The users of this system are virtually permanently connected (the GPRS part of the network). The necessary secondary nodal points are Gateway (access line) GPRS Support Node (GGSN) and Serving GPRS Support Node (SGSN). The SGSN system is responsible for directing all data packages arrived for and sent to all users in the serving domain. Furthermore, it follows the users' movements and secures and directs the access in the system. The various channels have a common access (possibly with contracted access line). The SGSN system is connected to the basic station sub-system (BSS - Base station Subsystem). Hence, the BSS needs a new functional nodal point, the Packet Control Unit.

The entire installation can also be described as two overlaid radio systems which function in parallel, one with transmission through the electrical circuit (traditional GSM), the other one with data packet transmission (GPRS), with a common radio system. The GGSN system is connected on one side to the SGSN system, on the other side it establishes a connection with the other data package transmission stations. The maximum data transmission speed in the system is of 115 kb/s, and the average speed is of approx. 40 kb/s. The GPRS system has the advantage that the provider's invoicing base is the number of bites sent, a measurement unit independent of the time of connection to the virtual network.

The advantages of the data package transmission system:

- At the fixed telephone networks with thread data transmission, the communication channel between the two communication partners has a given width for each direction. Thus, while the partners are connected, the channel between them occupies the capacity of the main station for the entire duration of the conversation, whether the data transmission takes place from both partners, one partner or neither of them.
- In the case of data package transmission networks (e.g. IP), there is no band of a particular width allotted to communication networks. Irrespective of the type of information, this is divided in packages according to the provisions of the protocol; the packages which have a heading include the address of the sending station and of the recipient station and other relevant data regarding the successful

transmission of the respective data. Because the packages sent one after another can reach destination on different paths, it often happens that they do not arrive in the order in which they were sent, hence the recipient must re-arrange them according to the reference number in the heading, thus re-making the initial data transmission operation.

- If the sender does not communicate, does not send packages, does not occupy a bandwidth. This is occupied only if there is an ongoing data transmission, contrasting with the static character of the thread data transmission. In the base situation, the connections have no predefined bandwidth, the data packages can reach their destination through various paths, and moreover the current occupation of the network has a strong impact on the time of delay of the packages. The IP network offers only „best effort" services and does not guarantee that the data packages will reach destination, it only does its best in this respect. In the case of connections of conversations with transmission of data packages with limited resources, the loading of the system will be managed in a different way than in the case of data transmissions. If traffic blockages occur, the connection elements shall remove some packages of data. In the case of data communication, the packages are sent again, and the recipient confirms the arrival thereof (see the TCP protocol). In this case, the flawless data transmission is the most important aspect.

This method cannot be used for data transmissions in real time, because this would delay even more the data transmission. The occurrence of traffic blockages can be prevented by setting up priorities, using more static resources and through a better management of resources. In the case of small data packages, the relative quantity of administrative data stored in the heading increases significantly, which is totally useless from the point of view of overhead data sent.

The mounting presented in figure 2 was used in the laboratory experiments, consisting of:

- Computer no. 1/data source, transmitter programme
- Supply module
- Transmitter module for GSM transmission
- Receiver module for the GSM transmission
- Computer no. 2, Receiver programme
- Coaxial transmission cable, TX and GND signals – RS232
- Coaxial reception cable, RX and GND signals - RS 232

According to the telecommunication standards and to the objectives proposed, tests were made for the two communication terminals in the Orange network, using the agreement frequency and bearers of 1800 MHz, with a data transmission rate of 9600Bps and serial interface RS 232, on the overall transmission – transmitter - receiver – server line.

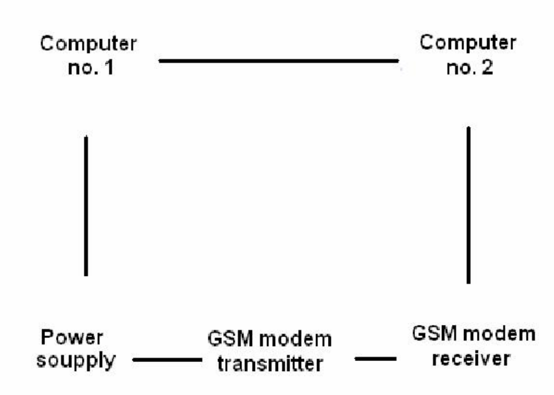

Fig.2. Mounting used for the experimental model of data transmission via GSM

The signal from the output of the first computer (rectangular signal) has an amplitude of 15V (+7,5 ÷ -7,5V). The output signal from the modem and the input signal in the second computer has, according to the type of cable used, an amplitude between 2,2 and 6,5 V (fig. 4.4). This tension is part of the framework of recognition of the serial interface, which needs tensions between -5 and -15 V (logic 1) and between +5 and +15V (logic 0) to detect the existence of a signal. A non-inverting operational amplifier is also used for amplifying the input tension in the second computer.

Duplex connections were set up with band traffic of 1800 MHz and the noise level was determined according the capacity of transmission for occupied bandwidths between 1,4kHz and 7kHz.

The measurement equipments were in the 0,2 class, the maximum error class being of 1% on the entire measurement chain, and the measurement uncertainty was estimated at 1,5%, for a normal distribution and a confidence interval of 95%.

The data obtained are presented in figure 3:

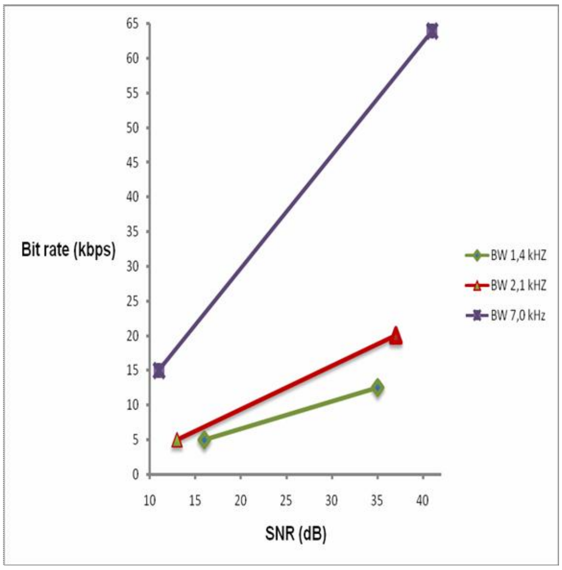

Fig. 3. Data obtained at the data transmission experiments through the GSM modem

Two data files were sent, of different sizes and formats through the experimental mounting with GSM modems. This revealed that the transmission times in the two cases were pretty close.

Even if the RS-232 standard mentions a maximum transmission speed through an interface of (115÷300)kB/s, this speed can be obtained in case of a simple transmission, for a single communication line. In our case the communication is made in both directions. Negotiations, error calculations, re-transmission requests in case of appearance of errors occur, all these increasing the transmission time and generating an average speed of approx. 200 kB/s.

If two GSM modems are interposed, their speed drops and it is, theoretically, lower than the lowest transfer speed in the communication chain – the GSM modem.

The following rows summarizes the measurements made with two types of optical insulation couplings and two types of file, in a simplex-gprs method, on a frequency of 1800MHz:

Type of file	(*.txt)
Size (kB)	3.16
Optical insulation coupling:	600 nm
Speed (kBPS)	64
Distance between modems (km)	0.5
Time (ms)	49.375

Type of file:	(*.txt)
Size (kB)	3.16
Optical insulation coupling:	1300 nm
Speed (kBPS)	62
Distance between modems(km)	1
Time (ms)	50.968

Type of file:	(*.jpg)
Size (kB)	40.6
Optical insulation coupling:	660 nm
Speed (kBPS)	57
Distance between modems (km)	0.5
Time (ms)	712.28

Type of file:	(*.jpg)
Size (kB)	40.6
Optical insulation coupling:	1300 nm
Speed (kBPS)	54
Distance between modems(km)	1
Time (ms)	751.85

The transmission times are pretty close with respect to the insulation coupling and the distance between modems, and the value of the transmission times (including delays) are insignificant compared to the interval between measurements (600 000 ms), of approx. 10^{-4}.

3. APPLICATION – MEASURES OF ENHANCING THE PUBLIC LIGHTING SYSTEM IN THE CITY OF BAILESTI

The electrical parameters of the street lighting system of the city of Bailesti were measured in four transformation stations corresponding to 4 lighting points in order to implement the optimal solution at a real scale.

Enhancement calculations were made based on the mathematical modelling of the network, materialized in proposals of enhancing the public lighting system, being limited to, from the point of view of the investment:

- The replacement of the Hg lamps with high pressure Na lamps (replacement of 3 Hg lamps of 250 W with Na lamps at HP of 150 W and 3 Hg lamps of 125 W with Na lamps at HP of 70 W, fitted with electronic ballast and controller).
- The replacement of the electromagnetic ballasts with electronic ballasts and controlers (replacement of 88 electromagnetic ballasts with electronic ballasts and controllers for lamps of 150W with NA at HP, replacement of 278 electromagnetic ballasts with electronic ballasts and controllers for the 70 W lamps with Na at HP)

The investment amounts to approx. 190 thousand lei, the energy saved by reducing the consumption of active and reactive energy, but also by the losses in cables and converters, of approx. 32 thousand lei; according to this valuation, the period of recovery of the investment is of 6 years.

We specify that we have considered other important advantages of this optimization:

- Increasing the available power of supply converters
- The operational safety by removing the effects of harmonics, $THD_I < 7\%$
- Insuring the energy quality
- Increasing the life-span of all the devices of the system
- Reducing the maintenance costs

The valuation of the measured lighting points was conducted, measured before and after the implementation of the enhancement measures proposed.

The state of the consumption rates measures and the valuation of the improvement rate for a transformation point are presented in the following paragraphs:

Air transformation point: PTA2
State: Initial
Type of network: Three-phase x400 V, 50 Hz
Type of lighting lamps:
3x250W with Hg,
55x70W with NA-HP with electromagnetic ballast and igniter,
Stage-level loading:
I_1= 14 A
I_2 = 14 A
I_3 = 12 A
I_{med}=13,3 A
Level of the average harmonic distortion:
THD_U=3,4%
THD_I=22%
Power factor: 0.66
Three-phase average average active power:
6147 W
Three-phase average reactive power:
6615 VAR

Air transformation point: PTA2
State: Post-optimization
Type of network: Three-phase x400 V, 50 Hz
Type of lighting lamps:
3x150W with NA-HP,

73x70W with NA-HP with electronic ballast and controler,
Stage-level loading:

I_1= 7 A
I_2 = 7 A
I_3 = 6 A
I_{med}=6,67 A

Level of the average harmonic distortion:

THD_U=2,5%
THD_I=7%

Power factor: 0.99

Three-phase average average active power: 4305 W

Three-phase average reactive power: 613 VAR

For the entire application, the improvements obtained after implementing the changes revealed by the optimization calculations, as well as after the quantification of the efforts and advantages are presented below:

Calculation of the energy saving:

Activity energy saving: 8339 Wx10h/dayx365days=30437 kW/year

Saving with the payment of active energy: 30437 kW/an x 0,49lei/kWh=14914lei/year

Reactive energy saved in one year: 26947 var x10h/day x 365 days= 98357 kvar/year

Saving with the payment of re-active energy: 98357 kvar/year x 0,049lei/kvarh=4819lei/year

Total saving with the payment of electricity=19733 lei/year

Calculation of the investment :

3 lamps/150W x 31lei=93 lei
3 lamps/70W x 22lei=66 lei
88 balasts/150W x 218 lei=19184 lei
284 balasts/70W x 160 lei= 45440lei
369 controlers x 200 lei= 79200lei
Total investment= 118390lei

CONCLUSIONS

4.1. The optimization of the public lighting plans and installations saved a high amount of energy which, if expressed in money, reported to the investment efforts, determine a recovery period of approx. 6 years, only with direct expenses.

4.2. The data transmission is a major component of the process of monitoring the efficiency of the public lighting activity; this enables decision-making interventions centralized in real time and the optimization of the operation of the systems in the limits set.

4.3. The most economical solution in terms of the quality/cost ratio is the data transmission via GPRS, with bilateral GSM points, type subscriber, with query on request or with sequential transmission protocol.

4.4. The system used allows the real time transmission of analogical data with a speed of approx. 64kBps and of digital data with a speed of 200kBps, the unweighted noise level according to the transmission capacity on occupied bandwidths between 1,4kHz and 7kHz of max. 25dB; with weighting systems mounted on communication terminals, the S/N ratio can be reduced to 10 – 12 dB.

4.5. The high amount of energy saved through the implementation of the system increases the degree of energetic efficiency of the optimized installation, with positive impact on green house gas emissions.

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