MEASURING AND EVALUATING ENERGY CONSUMPTION IN STREET LIGHTING NETWORKS

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Abstrakt
Smart metering and smart grid are incoming technologies that provide new opportunities in various fields. In connection with the issue of evaluation of the energy aspects of public lighting networks opens up the possibility of evaluating and measuring consumption. Based on the obtained values would be possible to determine energy consumption of lighting systems. This obtained value could serve as a basis for comparing the relevant networks and thus the optimality assessment of lighting designs. Currently, the measure placed in the switchboard of public lighting. If we have considered sections parametramim same lighting, it is necessary to obtain more value from the measured or determined to assess the consumption of time. Proposal of such methods is still under construction but the basic methods have already been outlined.

Keywords: *energy aspects, public lighting networks, smart metering, smart*

1 INTRODUCTION

Currently is assessed of energy consumption most new products. In order to use technology more effectively and reduce CO2 emissions in the construction industry since 2008 certified newly built and renovated buildings. Preparation methods and determining the limits of different classes, depending on conditions in individual countries, lasted several years. The aim is to fulfill the obligations of the Kyoto Protocol, which committed the EU.
Before short period the EU was create mandate to assess the energy consumption of public lighting systems. It is one of the best ways to evaluate the effectiveness of proposed solutions and to meet Kyoto Protocol commitments. The evaluation methodology was created in the working group CEN TC 169/226 JWG. The aim is not only define the evaluation process but also to verify the measurement of energy consumption in the sections under consideration.

2 MEASUREMENT METHODS OF ELECTRICITY CONSUMPTION

Accurate calculation of energy consumption in public lighting would be very complicated. Therefore, the verification of the calculated values should be compared with measured values. There are two possible ways of measuring the consumption:
• long-term measuring - captures the time interval changes in the network
• short-term measuring - captures only immediate consumption of the network.

These measurements can be used with distribution power supply voltage or power supply with precise sinusoidal voltage of 230 V. When we used precise voltage then is eliminated by overvoltage or undervoltage effects, as well as voltage distortion. If is used the network voltage supply and we want to determine consumption in nominal terms, they should be used the correction factors taking into account the deviation from the sinusoidal voltage, as in this case is influenced by the luminous flux.
Measuring the actual energy consumption in public lighting network does not reflect the use of the management system. If we propose to measure the power that would take into account the control system to be used long-term metering.

Long-term measurements take into account:
• voltage regulator - dimming due operating with reduced communication, sunrise and sunset time or at reduced performance due to reducing network power
• variable time of switching street lighting – control during the day varies depending on the day and on the part of year
• passive consumption of the network - particularly the control system.

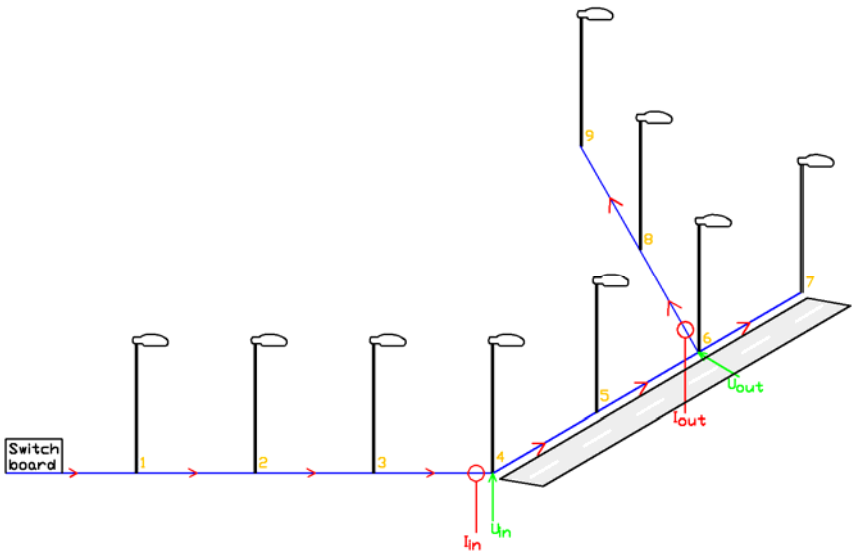

Fig.1 Example of energy consumption measuring for the selected section

Long-term measuring of power consumption

For such a measure would be appropriate to use devices that allow data logged. With these measurements it is possible to assess the quality of network design and in terms of impact on the electrical distribution network and thus a possible increase in network operating costs in the future, it is to the distribution companies to pass costs associated with the generation of harmonics to the customer. To measure the long-term estimated the correct design of network management, it would be best that lasted one year. Long-term measurements can be:
• the selected segment - consumption will be based only on the selected segment,
• the distributor - consumption will be based on all the segments supplied by the distributor. Such measurements are nowadays installed for better monitoring of network traffic, so in this case as not to increase the cost of measuring features.

Short-term measuring of power consumption

It is easier and allows quantification of energy consumption at specified time. Measurement of the instantaneous power consumption allows energy to convert the measured values to light intensity for the selected period. In this method of measuring power is measured by the absolute value of the power entering and exiting performance. Final consumption is defined as the difference of these values . An example of measurements in the network is shown in Figure 1.

3 INPUT POWER IN SECTION

Input power undistorted waves

Calculation of undistorted input power is possible only in network with luminaires with harmonic filter.

$$\overline{S} = \overline{U}_{f1}.\overline{I}^{*}_{f1} + \overline{U}_{f2}.\overline{I}^{*}_{f2} + \overline{U}_{f3}.\overline{I}^{*}_{f3} \qquad [VA] \tag{1}$$

$$P = \mathrm{Re}\{\overline{S}\} = U_{f1}.I_{f1}.\cos(\varphi_1) + U_{f2}.I_{f2}.\cos(\varphi_2) + U_{f3}.I_{f3}.\cos(\varphi_3) = P_1 + P_2 + P_3 \qquad [W] \tag{2}$$

$$Q = \mathrm{Im}\{\overline{S}\} = U_{f1}.I_{f1}.\sin(\varphi_1) + U_{f2}.I_{f2}.\sin(\varphi_2) + U_{f3}.I_{f3}.\sin(\varphi_3) = Q_1 + Q_2 + Q_3 \qquad [VAr] \tag{3}$$

$$S = \left|\overline{S}\right| = \sqrt{P^2 + Q^2} \qquad [VA] \tag{4}$$

where U_{f1}, U_{f2}, U_{f3} - phase voltage,

$\varphi_1, \varphi_2, \varphi_3$ - phase of voltage,

P - active power ,

Q - reactive power,

S - apparent power.

Input power deformed waves

The described method of calculating the power lights in the network can be used in network with the lamp connected between phase and neutral but also if the lamps are connected interphase. If the lights have a special power supply with harmonic filter, for example, variable switching power supply, so they are always fed with a distorted voltage. The power supply voltage appears deformed in the calculation of the deformation performance.

$$P_1 = U_{0_{f1}}.I_{0_{f1}} + \sum_{h=1}^{n} U_{h_{f1}}.I_{h_{f1}}.\cos(\varphi_{h_{f1}}) \qquad [W] \tag{5}$$

$$P_2 = U_{0_{f2}}.I_{0_{f2}} + \sum_{h=1}^{n} U_{h_{f2}}.I_{h_{f2}}.\cos(\varphi_{h_{f2}}) \qquad [W] \tag{6}$$

$$P_3 = U_{0_{f3}}.I_{0_{f3}} + \sum_{h=1}^{n} U_{h_{f3}}.I_{h_{f3}}.\cos(\varphi_{h_{f3}}) \qquad [W] \tag{7}$$

where P_1, P_2, P_3 - input power,

$U_{0_{f1}}, U_{0_{f2}}, U_{0_{f3}}$ - DC voltage,

$I_{0_{f1}}, I_{0_{f2}}, I_{0_{f3}}$ - DC current,

$U_{h_{f1}}, U_{h_{f2}}, U_{h_{f3}}$ - harmonics of voltage,

$I_{h_{f1}}, I_{h_{f2}}, I_{h_{f3}}$ - harmonics of current.

The total active power is calculated:

$$P = \sum_{f=1}^{3} \left(U_{0_f}.I_{0_f} + \sum_{h=1}^{n} U_{h_f}.I_{h_f}.\cos(\varphi_{h_f}) \right) \qquad [W] \tag{8}$$

The total reactive power is calculated:

$$Q = \sum_{f=1}^{3} \sum_{h=1}^{n} U_{h_f}.I_{h_f}.\sin(\varphi_{h_f}) \qquad [VAr] \tag{9}$$

The total deformed power is calculated as the sum of the deformed powers in the individual phases. Taking the deformation performance of the vector difference between apparent power and the amount of active and reactive power:

$$D = \sum_{f=1}^{3} \sqrt{\sum_{j=0}^{n} \sum_{k=0}^{n} \left[U_{j_f}^2.I_{k_f}^2 - U_{j_f}.I_{j_f}.U_{k_f}.I_{k_f}.\cos(\varphi_{j_f} - \varphi_{k_f}) \right]} \qquad [va] \tag{10}$$

where U_{j_f}, U_{k_f} - voltage harmonics, where *j* a *k* describe harmonics and *f* describes phase,

U_{k_f} - harmocnics of voltage, where *k* describe harmonics and *f* describes phase,

I_{j_f} - harmonics of current, where *k* describe harmonics and *f* describes phase.

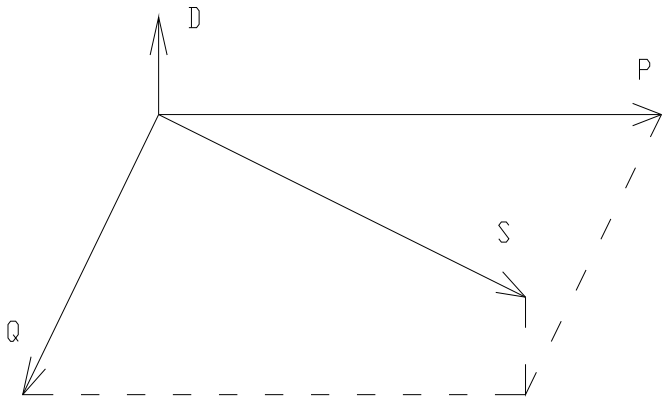

Fig.2 Vector diagram of power

Apparent power of deformed wave:

$$S = \sqrt{P^2 + Q^2 + D^2} \qquad [VA] \tag{11}$$

This way can measure and calculate the apparent power in grid. If the attempt to measure the power consumption in a selected section of the network in Fig. 1, consumption is calculated as the difference between input and output power:

$$\overline{S} = \overline{S}_{in} - \overline{S}_{out} \qquad [VA] \tag{12}$$

where $\overline{S}_{in}$ - input apparent power

$\overline{S}_{out}$ - output apparent power.

In all cases, if selected segment, which is located in part of the network (not at the end of the network), all power values can be calculated as the difference of incoming (In) and outgoing (Out). Calculating only of undistorted waves has resulted in neglect of the deformation performance, depending on what type of light source on the network may cause an error in the calculation of the order of tens of percent. In particular, the switching power supply powered and lamps with induction ballast are a big performance impact deformation. To quantify the costs associated with the operation should be considered and the costs associated with capacity reserved power. This value is reflected in the financial aspects of network operation.

4 CONCLUSION

Measures results should be the value of the energy consumption of the network. On the basis of measurements and calculations should be fixed ranges of individual classes of energy intensity. The exact definition is SLEEC stage to a working group of CEN. The aim is that it was a value to uniquely compare solutions proposed network of public lighting, which the operators are forced to use effective technologies. Ultimately, should drop energy consumption and therefore the CO2 produced.
Method of calculation and measurement should evaluate:
• efficiency of converting electricity to light - is expressed as power density in units of lm / W,
• control consumption - consumption of network management features such as timer, communication devices, etc..,
• consumption of the regulator - the regulator control circuit consumption or losses in the controller,
• passive consumption - consumption during the day when the light is turned off.

ACKNOWLEDGEMENTS

This paper was supported by the agency VEGA MŠVVaŠ SR under Grant No. 1/1100/12 ´Smart grid as part of power distribution networks - new measurement methods and consumption control methods´.

This paper was supported by the agency KEGA MŠVVaŠ under Grant No. 018STU-4/2012 ´Support of education in the field of power engineering in secondary and primary schools´.

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