

# Reductions in electricity losses in the distribution power system in case of the mass use of compact fluorescent lamps

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## ABSTRACT

The paper presents a method for the evaluation of the reductions in the technical and non-technical distribution losses in case of the mass use of compact fluorescent lamps (CFLs) in buildings in Serbia. The evaluation was based on an assumption that the two most used incandescent lamps in each of the 25–50% of the total number of dwellings in Serbia will be replaced with adequate CFLs, and that the same total number of lamps will be replaced in residential and non-residential sectors. A general methodology for the hourly estimation of the distribution loss reduction in case of reduced electricity consumption, based on the statistical processing of available data and on an integral (macroscopic) approach, is presented and used in the calculations. Such a methodology is appropriate because the electricity cost rate in the region changes on an hourly basis, being highest during hours when peaks of both the power demand and the decrease of distribution power losses occur. The paper illustrates that considerable reductions in both the technical and non-technical losses in the Serbian distribution power system can be achieved by applying energy efficient light sources.

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## 1. Introduction

Distribution power systems in the developing countries, such as Serbia, are characterised by high losses, both technical and non-technical [1–3]. The technical losses result from transits of active and reactive energy through the distribution network, while the non-technical losses are caused by errors in the process of metering, reading, accounting and invoicing, as well as by non-realized payments for the energy consumed by some customers [1]. It was emphasised in Ref. [4] that, besides economic consequences, electric power losses cause a dissipation of heat which increases the temperature of the distribution power system components and can result in insulation failure. Considering the facts that the economic gain, as well as life span and reliability of the system, increase when power losses decrease, different techniques for power loss minimization, such as automation of the distribution system reconfiguration [4–8], proper design and planning of the distribution system [9,10] and demand side management [1,2,11,12], have become the subjects of intensive research.

One way to reduce losses in the distribution system is to reduce electricity consumption, especially in hours when peak loads occur. This reduction can be attained by replacing energy inefficient electrical appliances with energy efficient ones. The largest possibility

for percentage energy savings (about 75%) is offered by compact fluorescent lamps (CFLs), intended to replace energy inefficient incandescent lamps [13–20].

Since power utilities have the largest benefits from the mass use of CFLs, both economic and environmental, the Serbian Power Utility was interested in conducting CFL promotion programs, and therefore engaged our working group to determine all technical, economic and environmental impacts of the mass use of CFLs in Serbia [21]. It was shown in Ref. [13] that, in order to precisely calculate the cost-effectiveness of such promotion programs, decrease of electricity consumption has to be calculated for each hour, because the electricity cost rate in the region changes on an hourly basis, being highest when peaks in the daily diagrams of both the power demand and coincidence factor for lighting occur. It is also essential to distinguish the net reductions in electricity consumption from the reductions in transmission and distribution losses, because they have different economic effects on the power system. However, to the best knowledge of the authors, none of the existing studies adequately discuss the implications of the distribution loss reductions on the cost-effectiveness of CFL promotion programs (it was roughly taken into account in Ref. [11] through avoidable maintenance and operating costs of the power system, and in Ref. [17] through transmission and distribution costs). The main objective of this paper is to present the implications of the mass use of CFLs on the reductions in the distribution losses, and hence on the total reductions of power injected into the distribution network, on an hourly basis. A general methodology for the hourly estimation of

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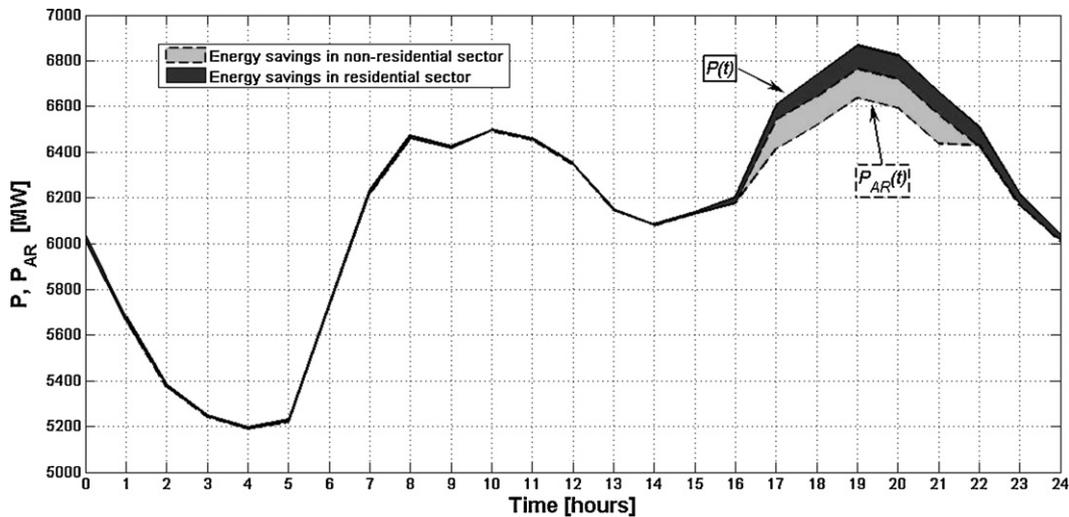


Fig. 1. Comparison of  $P(t)$  and  $P_{AR}(t)$  for the analysed case.

the distribution loss reductions in case of reduced electricity consumption, based on the statistical processing of available data, is presented and used in calculations related to the Serbian Power Utility, as a case study.

## 2. Reductions in net electricity consumption and power demand in case of the mass use of compact fluorescent lamps in buildings in Serbia

The research was based on the assumption that the two most used incandescent lamps in dwellings (one of 100 W in the living room and one of 60 W in a hall) will be replaced with adequate CFLs, and that the same total number of lamps will be replaced in residential and non-residential buildings (only 100 W lamps are supposed to be replaced in the latter case). It was shown in Ref. [15] that the adequate replacements for incandescent lamps of 60 W and 100 W represent CFLs of 15 W and 23 W, respectively. It was considered that the described replacements would be made in 25%, 30%, 35%, 40%, 45% and 50% of the total number of dwellings in Serbia, which approximately equals  $N_D = 2,500,000$ .

Evaluation of the net reductions in electricity consumption and power demand is the basic step for the determination of all relevant impacts of the mass use of CFLs in Serbia. A general method for such an evaluation is presented in Ref. [13]. The daily diagrams of the total electrical power demand in Serbia ( $P(t)$ ) for days with the maximum and minimum yearly peak loads are compared with the corresponding daily diagrams ( $P_{AR}(t)$ ) which took into account the planned lamp replacement and the coincidence factors for the observed lamps (the one related to the residential sector is obtained by on-site monitoring of 344 dwellings). As an illustration, the comparison of  $P(t)$  and  $P_{AR}(t)$ , with the separation of reductions in electricity consumption in the residential (upper area) and non-residential sector (lower area), for 09.02.2005, representing the day with the maximum yearly peak load, and for the replacement rate of 50%, is presented in Fig. 1.

The results of the calculations of the decrease of electricity consumption ( $\Delta W$ ) and the peak load ( $\Delta P_{max}$ ) for the analysed case and for all of the considered replacement rates, conducted using the algorithm presented in Ref. [13], are presented in Table 1.

It should be noted again that Table 1 contains the net values, i.e. the real values are higher due to the reductions in power and electricity losses occurring in the transmission and distribution parts of the power system. These net values of the reduction in electricity consumption cannot be considered to be the direct economic bene-

fit for power utilities, because they represent electricity which will not be sold to the domestic consumers. This electricity might be exported or it will reduce import of electricity. The possible economic gain for power utilities in this case depends on electricity cost rates in the country and in the region. The economic effect can be either positive or negative because both electricity cost rates, in the country and in the region, change on an hourly basis. On the other hand, the decrease of losses in the transmission and distribution parts of the power system, either technical or non-technical, represents an obvious economic gain for power utilities.

## 3. Characteristics of the Serbian Power Distribution System

The Serbian Power Distribution System Operators (SPDSO) purchase electricity almost exclusively from the Serbian Power Utility, receive it through the network of the Serbian Transmission System Operator and sell it to the final consumers. According to [22], in 2005 the SPDSO bought 29261 GWh of available electricity, and billed and realized payments for 5677 GWh delivered to consumers on high and middle voltage levels and 19364 GWh delivered to those on the low voltage level (households participated with 74.4% in electricity consumption on the low voltage level). The difference between the electricity of 29261 GWh and the total electricity of 25041 GWh for which the payments were realized represents the total distribution loss which amounted to 4220 GWh, or 14.42% of the energy delivered to the distribution network. Energy balances of the SPDSO, realized in years 2004–2006, estimated for 2007 and planned for 2008, are presented in Table 2 [22–27].

The total distribution losses, presented in Table 2, represent the sum of technical and non-technical losses. It is estimated that the technical losses represent 60% of the total distribution losses in Serbia [22]. These losses, as identified in Ref. [1], are caused by:

1. resistance of contacts and conductors, where 'Joule' losses occur,
2. transformer plate magnetization, where 'iron' losses occur,

Table 1

Reductions in electricity consumption and the maximum power demand for the analysed case of the mass use of CFLs in Serbia [13].

Rate of replacement	25%	30%	35%	40%	45%	50%
$\Delta W$ [GWh/year]	209.8	251.8	293.8	335.7	377.7	419.7
$\Delta P_{max}$ [MW]	115.2	138.2	161.3	184.3	207.3	230.4

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