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Reductions in electricity consumption and power demand in case of the mass use of compact fluorescent lamps

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ABSTRACT

The paper presents a general methodology for the evaluation of the reduction in electricity consumption and its market value, as well as the reduction of the peak power demand in case of the mass use of compact fluorescent lamps (CFLs), illustrated on the Serbian power system. The evaluation was based on the assumption that the two most used incandescent lamps in each of 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. The daily diagrams of the total electrical power demand in Serbia for days with the maximum and minimum yearly peak loads are presented and compared with the corresponding daily diagrams which took into account the planned lamp replacement and the coincidence factors (CFs) for the observed lamps, which in case of the residential sector are obtained by on-site monitoring of 344 dwellings. It was shown that, in order to precisely calculate the cost-effectiveness of the planned action, decrease of electricity consumption has to be calculated for each hour, because the electricity cost rate (ECR) usually changes on an hourly basis.

1. Introduction

The highest reductions in electricity consumption, by applying energy efficient technologies, can be achieved in the residential (possible reduction up to 27%) and commercial sector (possible reduction up to 30%) [1]. The major part of these reductions can be attained by replacing energy inefficient incandescent lamps with energy efficient light sources such as compact fluorescent lamps (CFLs). Energy savings can further be increased during the summer period due to lower cooling requirements in buildings where energy efficient lighting is used [2]. Since in many countries electricity is predominantly produced by coal-fired power plants, the electricity savings caused by the mass use of CFLs are followed by lower emission of mercury and greenhouse gases. It should also be emphasized that there are the following two disadvantages of the CFL use from the energy and environmental aspects:

– conventional CFLs generate a high content of higher current harmonics, which results in voltage distortion [3] and higher losses in the distribution network, and
– CFLs contain mercury, which is why special attention should be devoted to their organized and safe disposal.

Experience from all over the world shows that the mass use of CFLs in residential, commercial and public buildings results in a significant decrease of both electricity consumption and daily peaks of power demand in national power systems [4,5]. In addition, energy losses in power transmission and distribution networks decrease, import of electrical energy could be reduced (or export increased), investments in new generation, transmission and distribution capacities could be postponed, lifetime of power system equipment increases, environmental pollution decreases, etc. [4–10]. It is obvious that the largest benefits from the mass use of CFLs, both economic and environmental, go to power utilities and states. Hence, power utilities and competent ministries throughout the world support CFL promotion programs. However, cost-effectiveness of such programs has to be calculated prior to the action, in order to provide successful investment.

The Serbian Power Utility was interested in conducting such programs, and therefore engaged our working group to determine all technical, economic and environmental impacts of the mass use of CFLs in Serbia [11]. During the research the following influencing factors of the cost-effectiveness of such programs were distinguished: electricity cost rates (ECRs) in the observed country and its region, composition of the national power system, daily diagrams of power demand and participation of lighting, environmental and tax policies in the observed country, and prices of CFLs and incandescent lamps. However, the majority of researchers who had

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Nomenclature

CFL	compact fluorescent lamp
CF	coincidence factor
$CF_R(t)$	CF daily diagrams for the considered lamps in residential buildings
$CF_{NR}(t)$	CF daily diagrams for lamps that are planned to be replaced in non-residential buildings
N_D	total number of dwellings in Serbia
R_R	rate of lamp replacement
$P_I(t)$	daily diagram of electrical power demand that only includes the replaced incandescent lamps
P_{IR}	power of the replaced incandescent lamps in a dwelling
P_{INR}	power of the replaced incandescent lamps in the non-residential sector, reduced to a dwelling
$P_C(t)$	daily diagram of electrical power demand which only includes CFLs used in the described replacement
P_{CR}	power of the CFLs used in the described replacement in a dwelling
P_{CNR}	power of the CFLs used in the described replacement in the non-residential sector, reduced to a dwelling
$P(t)$	daily diagrams of the electrical power demand in Serbia
$P_{AR}(t)$	daily diagrams of the electrical power demand in Serbia after the described lamp replacement
ΔW	total reduction in electricity consumption for a period of one year
RMV	regional market value of the saved electricity in a period of one year
$ECR(t)$	hourly electricity cost rate in the observed region
ΔP_{max}	absolute decrease of the peak load
δP_{MAX}	relative decrease of the peak load

similar tasks only took the reduction in electricity consumption into account [5,6,12]. Their analyses were based on the total duration of activity of artificial lighting in buildings per day, and not on the time-of-use patterns. In Ref. [13] decrease of the peak load was also taken into consideration. However, the reduction in power demand was not analysed throughout a day. Refs. [14,15] included time-of-use patterns for indoor lighting, created by data collected from end-users and power utilities through questionnaires and

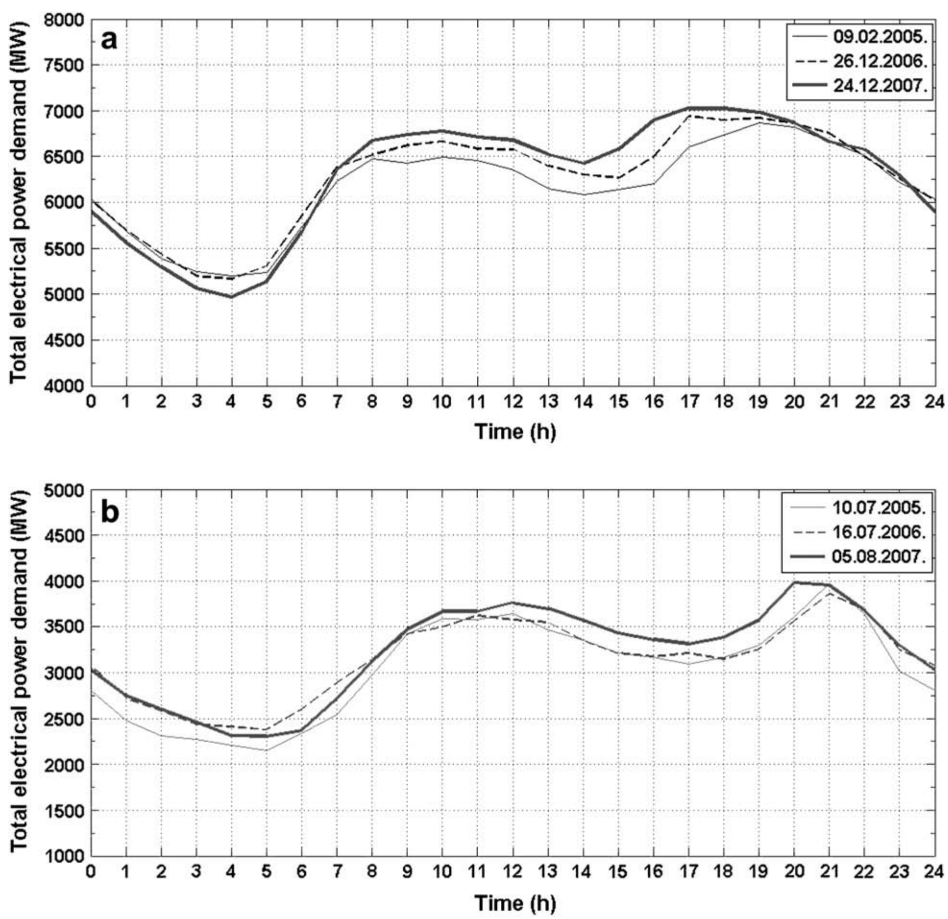

Fig. 1. Daily diagrams of the total electrical power demand in Serbia for the years 2005–2007, related to the days with the maximum (a) and minimum (b) yearly peak loads.