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May 23rd 2014, Kragujevac
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THE IMPACT OF THE MEAN DAILY AIR TEMPERATURE CHANGE ON ELECTRICITY CONSUMPTION

Abstract: *This paper presents the analysis of the impact of weather conditions on the consumption of electricity for the City of Kragujevac in the seven-year period from 2006 to 2012. It points out the mean daily air temperature as the most influential climate (meteorological) parameter, and gives an overview of deviations from the mean values compared to the reference period. Increases and decreases in power consumption depending on the deviations of the mean daily temperature from the normal (average) values are also indicated. In periods of strong and long-lasting cold spells in winter months, there is increased power consumption as a result of heating of residential and office premises. During extremely hot and long summer periods, there is also a tendency of increased electricity consumption because of home air conditioning. In the transitional seasons, especially when the remote heating system is not active, sudden and relatively long periods of cold weather also have a significant influence on the expansion of electricity consumption. A timely and accurate weather forecast can certainly help prevent the electrical power system overload and reduce the risk of possible power system damage.*

Keywords: *Weather conditions,Mean daily air temperature Electricity consumption, Cooling, Heating, Climate change*

1. INTRODUCTION

Increasing demands for energy and dramatic reductions in reserves of energy resources, primarily fossil fuels, make each research on energy consumption significant.

In recent decades, we have witnessed climate changes for which most scientists believe to be of an anthropogenic origin. An enormous consumption of fossil fuels has led to a significant increase in the concentration of greenhouse gases (CO_2, CH_4, NO_2, etc.) which are considered the main cause of the increase in the global average temperature. Climate changes, as well as the growing unpredictability of the weather conditions,cause the growth of uncertainty concerning the estimation of certain types of energy.

The residential sector has significant electricity consumption in most power systems. Changes in electricity consumption in this sector are associated with changes in weather conditions (especially with the change of the average daily air temperature) and they often cause undesirable peaks [1] in the total power consumption within a power system.

Electricity consumption depends on characteristics of the building envelope, quality of the windows and occupant behaviour which further complicates this dependence [2, 3, 4]. Important elements

[4] in the study of the influence of weather parameters on energy consumption include the local position of the object (orientation, slope, solar radiation, wind exposure, presence of vegetation, etc.) and its geographic position (primarily the climate zone of a particular location).

There is a significant number of papers dealing with the studied topic. Valor et al. [5] are examining the connection between the changes of daily air temperatures and the load of the electric power system in Spain. The paper [6] shows the analysis of weather sensitivity of household appliances energy consumption (refrigerators, air conditioners, heating, etc.) in Sydney, Australia. The core temperature was established and it was the starting point from which the additional heating or cooling of residential and office premises began.

The U.S. Energy Information Agency conducted extensive surveys related to the number of possible influencing factors on the electrical energy consumption in the residential sector [8]. The paper [7] studied the effect of changes in air temperature, wind speed and direction, and relative humidity on the energy consumption and it determined how this effect varied in different climate zones. In the papers [7, 8], the impacts of climate factors, object construction properties, socio-cultural and other factors are considered. In the work [9], Lam et al. analyse the impact of seasonal variations in residential and commercial sector electricity consumption in Hong Kong.

The objective of this paper is to present data on the mean temperature and electricity consumption for a seven year period at the City of Kragujevac and then to determine the impact of changes in the mean daily temperature on the power consumption of residential and commercial sector.

2. METHODS

2.1 Location

The city of Kragujevac (44.02 latitude and 20.93 longitude) has an altitude of about 200 meters with a moderate continental climate.

2.2 The obtained data

Temperature measurements were performed at the meteorological station Kragujevac. The variation in the mean daily air temperature for the City of Kragujevac for a five-year period time from 1. January 2006 to 31. December 2012. was recorded.

The mean daily temperature was calculated based on the equation

$$t_{md} = \frac{1}{24}\sum_{i=1}^{24} t_{hi} \qquad (1)$$

where

t_{hi} stands for the measured temperature value for each hour i. The mean daily temperatures were used to calculate the mean monthly temperature as

$$t_{mm} = \frac{1}{n_d}\sum_{i=1}^{n_d} t_{mdi} \qquad (2)$$

where t_{mdi} stands for the mean daily temperature for the i-th day of the month and n_d stands for the number of days in the month (n_d=28, 29, 30 or 31).

In the picture 1 the average values of the mean daily temperature for Kragujevac are shown (for the period from 1961 to 1990) for all of the 365 days of the year. For the use of further analysis,the formula of so called " ideal " curve for the average daily air temperature has been calculated and has the form of:

$$y = 0{,}000000018814x^4 - 0{,}000014585x^3 + \\ + 0{,}0031x^2 - 0{,}0806x + 0{,}4025 \qquad (3)$$

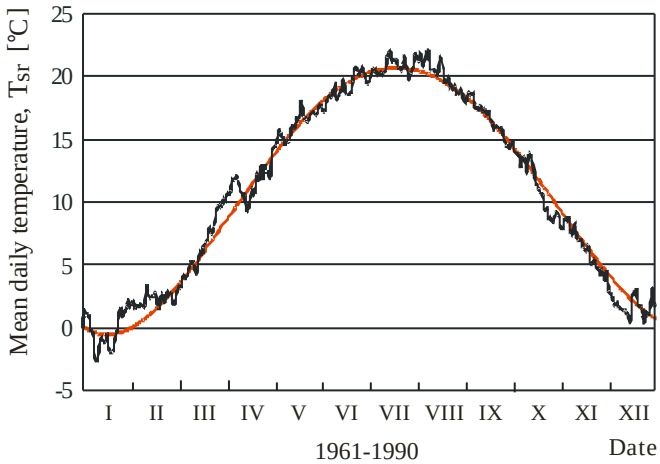

Figure 1 – The mean daily temperatures for the period 1961-1990 for Kragujevac

The data on electricity consumption were taken from the transformer station (TS Kragujevac 2). This transformer station supplies the mainly residential area with no significant industrial plants.

The transformer station TS Kragujevac 2 supplies electrical power to the largest part of the City of Kragujevac (about 200 000 inhabitants). Since this is mainly residential area, the ratio of residential to industrial power consumption is 9 to 1. Out of 105 000 consumers supplied by the TS Kragujevac 2, 98 000 are residential consumers. This transformer station supplies power only to 58 industrial consumers, 57 of which are supplied with medium voltage electricity (10 kV and 35 kV), and one of which is connected to the network of high voltage (110 kV). Public lightning has 692 connections.

It is significant to note that in the area covered by the TS Kragujevac there are about 11 000 gas connections and 27 000 users of the remote controlled heating system.

Therefore, the structure of the electric power system of the TS Kragujevac 2 is such that the impact of the air temperature variations on the power consumed for heating or cooling of residential premises is high.

An important factor with a great influence on the level of power consumption is certainly the price of fuels (gas, coal, fuel oil, wood, electric power). The object of our further investigations will be to determine a more accurate relation between the meteorological (climate) parameters and the electrical power consumption.

3. RESULTS

As a result of the research and the seven-year period of following the daily consumptions on the region covered by TS Kragujevac 2 the average daily power consumptions for each day of the year are gathered.In the picture 2 the diagram of the average daily consumptions is shown as well as so called “ideal” curve for that period.The function of the “ideal” dependence of the daily power consumption on an ordinal number in the year is shown on the diagram.

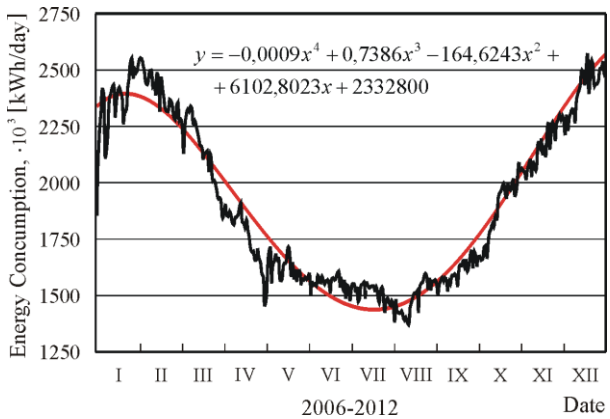

Figure 2 – The daily power consumption on TS Kragujevac 2 during a year

Also, as results of this investigation, diagrams of mean daily temperatures and daily electricity consumptions for the period from 2006. to 2012. are given in Figures 3-9. The gradual increase in the number of customers and in the number of electrical devices that burden the system is not considered.

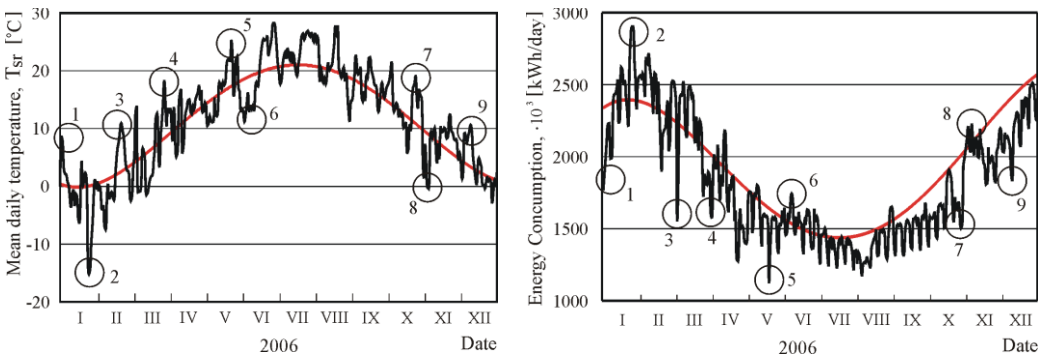

Figure 3 – Mean daily temperature and daily electricity consumption for 2006

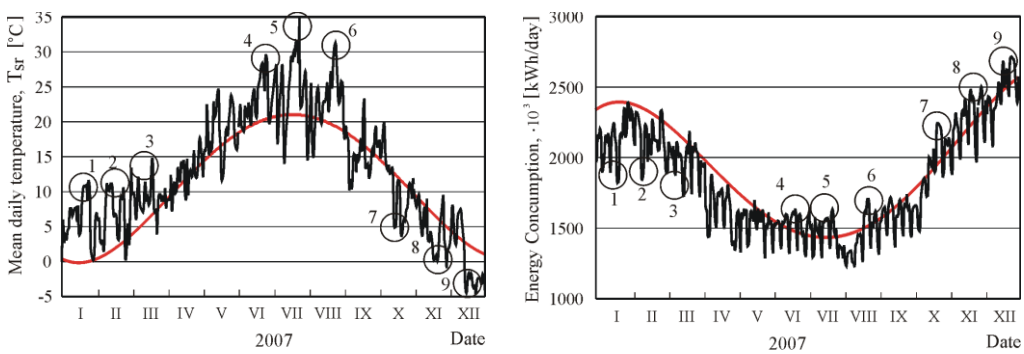

Figure 4 – Mean daily temperature and daily electricity consumption for 2007

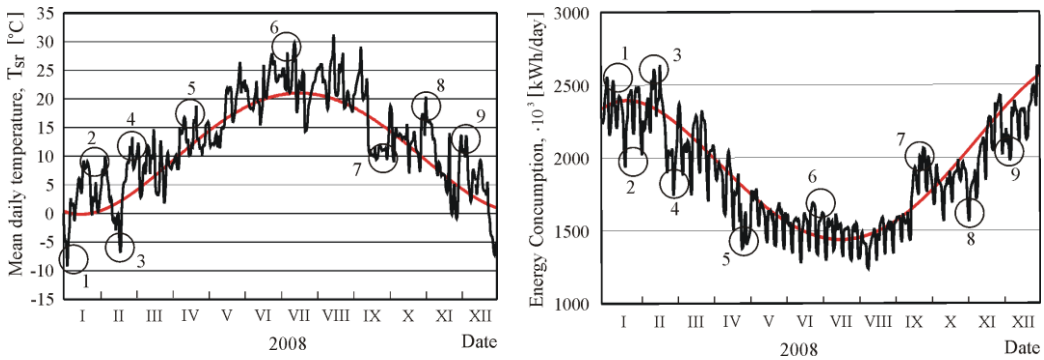

Figure 5 – Mean daily temperature and daily electricity consumption for 2008

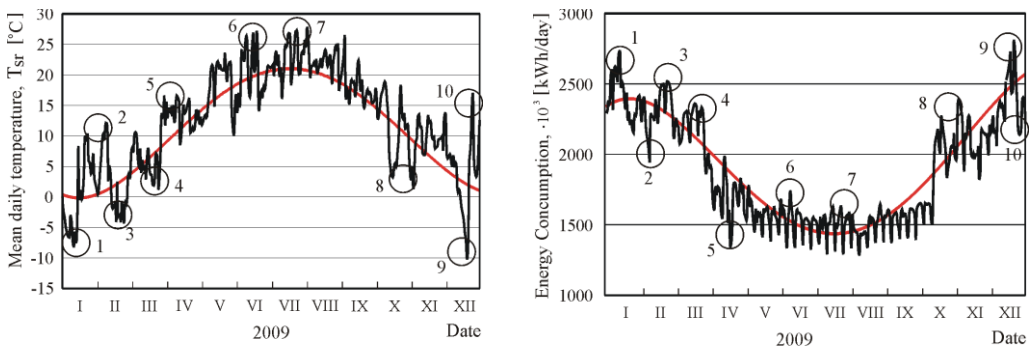

Figure 6 – Mean daily temperature and daily electricity consumption for 2009

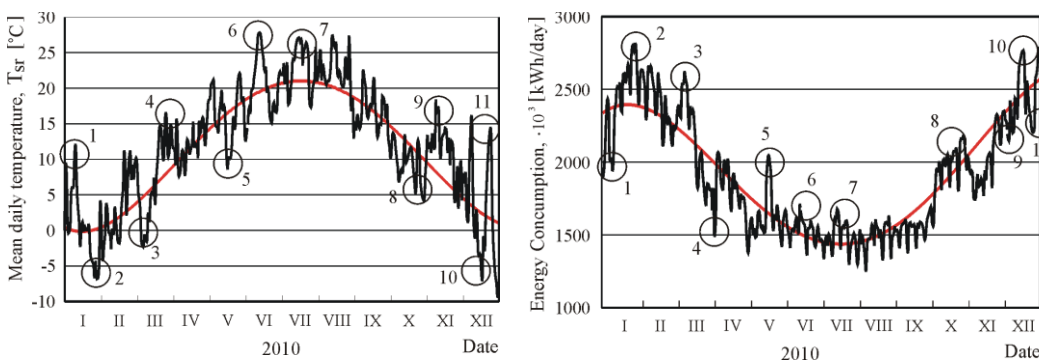

Figure 7 – Mean daily temperature and daily electricity consumption for 2010

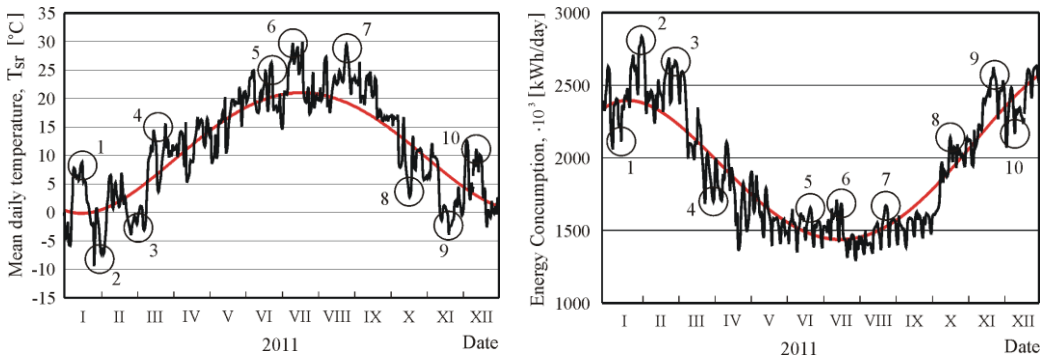

Figure 8 – Mean daily temperature and daily electricity consumption for 2011

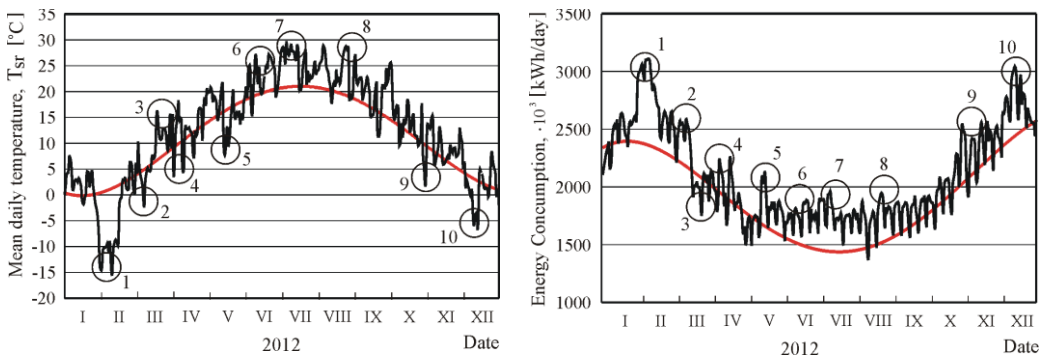

Figure 9 – Mean daily temperature and daily electricity consumption for 2012

4. DISCUSSION

The pictures 3-9 show the obvious congruence of significant changes of the average daily temperature and the changes of power consumption. Peaks in the power consumption (rounded peaks in the diagrams) correspond to the peaks in mean daily temperatures.

In periods of strong cold spells especially in winter months, there is a need for additional heating of residential premises. The amount of electrical power consumed for additional heating depends on a number of factors. Based on the peak intensities in the shown diagrams (Figures 3-9), it can be concluded that the intensity of external temperature variations is a predominant factor with a great influence on the quantity of additionally consumed electrical power. In the table 1 the numerous regularities of consumption peaks caused by the change of the average daily temperature are shown by season (note: the division of months by season on the basis of climate criterion.)The largest consistency of the consumption changes during winter months (December,January and February) is noticed.

Table 1 - The regularity of power consumption peaks by season

	Winter	Spring	Summer	Autmn	Σ
2006	**4**	**2**	**1**	**2**	**9**
2007	**3**	**1**	**3**	**2**	**9**
2008	**5**	**1**	**1**	**2**	**9**
2009	**5**	**2**	**2**	**1**	**10**
2010	**4**	**3**	**2**	**2**	**11**
2011	**3**	**2**	**3**	**2**	**10**
2012	**2**	**4**	**3**	**1**	**10**
Σ	**26**	**15**	**15**	**12**	**68**
%	**38,25**	**22,05**	**22,05**	**17,65**	**100**

The length of strong cold spells or the length of warm spells in winter months also influences the electric power consumption. Other factors that have an influence on the intensity of power consumption peaks include usage of fuels, periods of major religious and state holidays, prices of fuels, construction characteristics of the buildings etc.

Due to obvious climate changes, periods of extremely hot weather in summer have become both more frequent and longer. During these periods, air conditioners are intensively used for cooling of residential premises; therefore, electrical power consumption is significantly increased.

In transient periods (autumn and spring) when the remote controlled heating system is not in function, there is an increased risk of overloading the electric power system.

Geographic location and the climate zone affect the overall dependence of electric power consumption on different weather conditions.

It is observed that there are high peaks in power consumption associated with high (summer) and low (winter) temperature peaks.

There are also some variations in power consumption for minor changes in the air temperature, but they could hardly endanger the operation of the electric power system.

5. CONCLUSION

It is obvious that there is a strong relationship between changes in the external temperature and energy consumption in the residential and commercial sector. Based on the diagrams of power consumption for a five-year period (2006-2012) for the City of Kragujevac, it can be concluded that there is high electricity consumption in the residential and commercial sector as a response to extreme changes in the mean daily air temperature.

Lower air temperatures (in winter) present a greater danger to operation of the electric power system because the system is already heavily loaded in winter. A timely and accurate weather forecast followed by an appropriate response from both those in control of the power system and the consumers can certainly contribute to energy savings and prevent power system damage with serious consequences.

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