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METHODOLOGY OF RUNNING COST ANALYSIS FOR HIGH-EFFICIENCY GAS MICRO-COGENERATION APPLICATION IN OBJECTS with VARYING DEMAND FOR HEAT AND POWER

19.1 INTRODUCTION

Buildings with varying demand for heat and power require delivery of appropriate amount of electricity and heat. This results in the need to deploy and use on a large scale technological solutions for reduction of primary fuel consumption and environmental pollutant emission, while achieving significant savings. One of such solutions is a high-efficiency gas micro-cogeneration of heat and power (MCHP), which can be applied in buildings in combination with other energy sources.

According to the Polish Energy Act, micro-cogeneration is a production in one device of up to 40 kW of electric power and up to 70 kW of thermal energy [1]. In the gas micro-cogeneration, a considerable reduction in energy losses is possible, as compared to separated production of electricity and heat (Fig. 19.1).

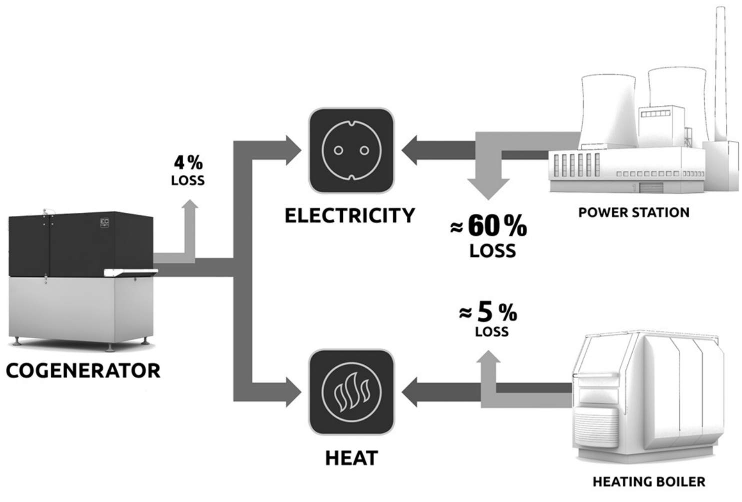

Fig. 19.1 Comparison of energy losses in the combined gas micro-cogeneration of heat and power (MCHP) and in the separated heat and electricity generation

Source: [2]

Capacity ranges and compact size of MCHP units allow for their installation in the existing boiler rooms as well as in specially designed ones. The primary fuel is therefore supplied to the object first, and there converted into heat and electricity. Owing to this, energy is practically produced on site. That also means a dispersed energy production, indicated in the Energy policy principles of the European Union as an essential element of the development structure of energy networks [3, 4, 5]. However, in order to obtain the expected benefits from micro-cogeneration, their appropriate selection is necessary, based on their energy performance. This selection is possible, with the use of the mathematical method presented in this article.

19.2 DATA ANALYSIS WITH THE USE OF LOAD DURATION CURVE

Mathematical statistics deals with methods of inference (estimation and verification of hypotheses) concerning the entire general population, based on examination of randomly-selected part of it, called the sample. In contrast, industry statistics, sometimes referred to as applied, takes up the study of the various spheres of activity such as industrial production, transportation, trade and services. Statistical method description as well as inference are used in both these disciplines. The statistical charts are a tool of analysis and a form of registration of statistical information. Out of the many available chart types for the analysis of the demand of objects for electricity and heat, load duration curve provides especially good results. Measurement at ordinal scale means the arrangement in accordance with the strength or weakness of a feature. This scale is characterized by consistency and transitivity. Assigning a rank to a given measurement establishes its place in the order. The rank itself refers to the order and not to differences between consecutive measurements [6]. The practical reflection of this dependency is load duration curve.

19.3 LOAD DURATION CURVE OF HEAT AND POWER CONSUMPTION

In order to prepare an electric load duration curve of analyzed building annually, it is necessary to obtain information about momentary load demands. For existing objects, it is possible to obtain power readings from the electricity distributor over a period of one year at intervals of 15 minutes [7]. On this basis, it is then possible to draw a load duration curve and find out which demand never falls during the year. From the other hand, for planned properties, it is possible to gather information from total capacity of receivers provided for continuous operation (e.g. pumps, motors, control systems, etc.).

To get the data to draw a heat load duration curve in existing buildings, it is necessary to measure and monitor the medium consumption of heating or fuel. In the case of supplying a building with power from a remote source, it is necessary to register readings of momentary heat input. In the case of the use of fuel to heat the building, for example natural gas, it is necessary to install gas consumption meters on all heat sources or heat meters for heat supply lines. For planned buildings, it is necessary to estimate (for example with a computer simulation) demand of the building for heating, ventilation of the building, production of hot water on site, swimming pool technology, production processes etc.

19.4 PROFILES OF ENERGY CONSUMPTION IN VARIOUS OBJECTS

Figures 19.2-19.6 show sample profiles of the electric power consumption in buildings with different characteristics. The examples show that the power consumption profiles differ depending on the nature of the object. It follows that an appropriate choice of co-generation devices for a particular object without a detailed analysis of such profiles is impossible.

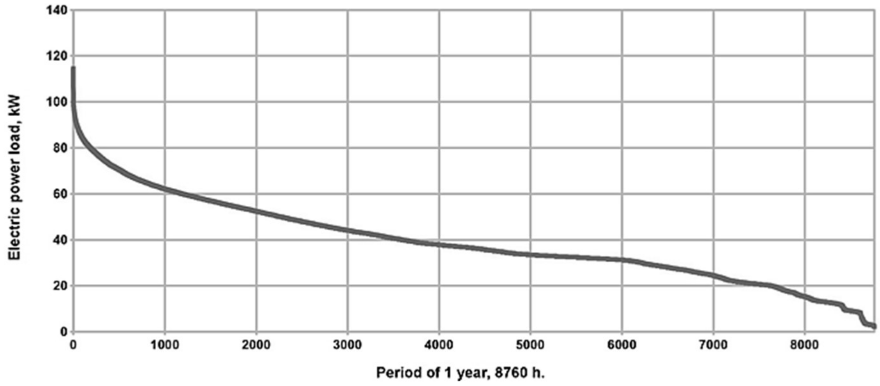

Fig. 19.2 Electric power load duration curve for a school swimming pool

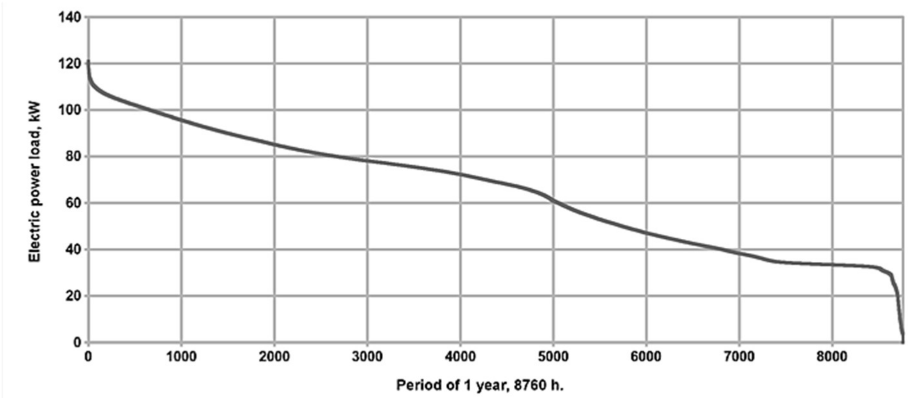

Fig. 19.3 Electric power load duration curve for a municipal swimming pool

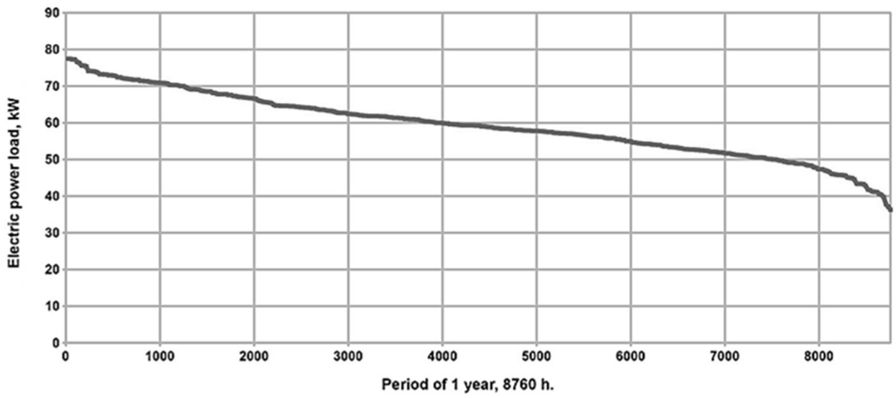

Fig. 19.4 Electric power load duration curve for a spa & wellness center

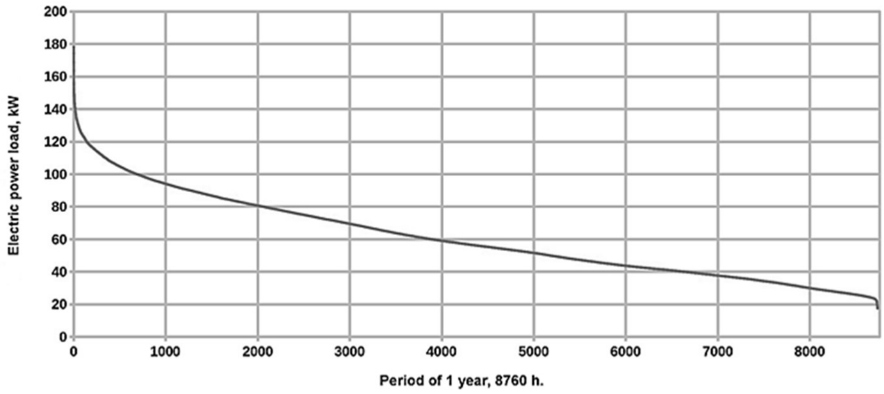

Fig. 19.5 Electric power load duration curve for a hospice

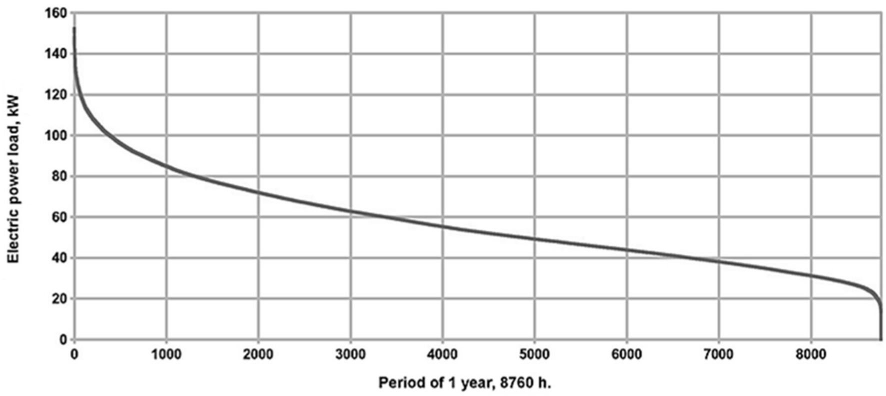

Fig. 19.6 Electric power load duration curve for a hotel

19.5 THE USE OF LOAD PROFILES IN TAILORING OF MICRO-COGENERATION TO THE DEMANDS OF THE OBJECT

Proper selection of co-generator or co-generators output allows their continuous operation up to 24 hours a day throughout the year. This enables significant operational savings and the shortest return on investment periods. It is therefore necessary to select a co-generator with consideration of electrical and thermal power values that occur continuously during the year. The best way to precisely determine such basis is to use load duration curve for heat and electricity.

Figure 19.7 shows the incorrect selection of the co-generation unit – selection for peak power. This means applying the unit of 120 kW of electrical power. Such unit will work in the range of 50-100% of its nominal capacity, which means that co-generator will start when the demand for electric power will be higher than 60 kW. Below this value the co-generator goes into a stand-by mode. In this case, the co-generator unit could work only for about 1250 hours per year. The remaining amount of the electricity should then be purchased from the grid. Basis of electrical power throughout the year for this building is approximately 20 kW. If a micro-cogeneration unit XRGI 20 (it has electrical power modulated in the range from 10 to 20 kW) was selected here, it would work continuously throughout the year – approximately 7760 hours at full power output and then 1000 hours in modulation. If a second micro-cogeneration unit XRGI 20 was installed, it could work 6200 hours per year (Fig. 19.8).

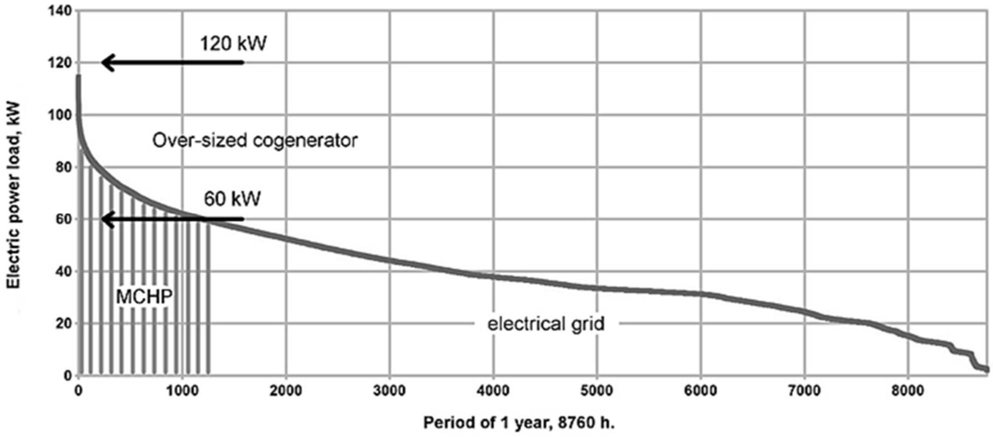

Fig. 19.7 Incorrect selection of co-generation unit with use of peak load for electric power

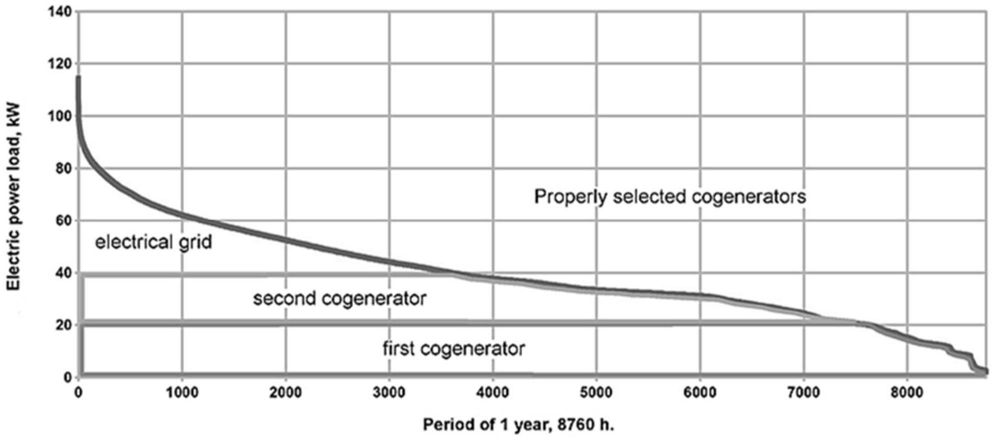

Fig. 19.8 Correct selection of co-generation unit with use of basic load for electric power

Such selection of co-generators allows to avoid the situation in which the system cannot work due to a low consumption of electricity in the building, and provides for the largest number of working hours in a year.

19.6 SUMMARY

High-efficiency gas micro-cogeneration is an efficient technology that allows operational savings in buildings with varying demand for electricity and heat. It is, however, necessary to ensure a proper selection of co-generation units' power to cover demands of a building. This is possible by applying suitable mathematical model using load duration curve for heat and power consumption per year. With such the selection, it is possible to obtain and perpetuate the highest possible operational savings and shortest return times of investments in high-efficiency combined heat and power production technology.

The mathematical model presented hereby is, with correct selection of gas co-generation system output, a practical solution to meet the needs of buildings with different electricity and heat demand profiles, such as e.g. health resorts and spas, swimming pools, hospitals, hotels or manufacturing plants. It ensures high operational savings and obtaining a positive environmental impact by reducing the primary fuel consumption and pollutant emissions.

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METHODOLOGY OF RUNNING COST ANALYSIS FOR HIGH-EFFICIENCY GAS MICRO-COGENERATION APPLICATION IN OBJECTS WITH VARYING DEMAND FOR HEAT AND POWER

Abstract: *Conditions related to high-efficiency gas micro-cogeneration application in buildings with varying demand for heat and power were presented, focusing on joint application of micro-cogeneration and other sources of heat and power in buildings. Such joint application of energy sources is characterized by specific critical parameters on which the most effective use of micro-cogeneration system in objects depends, as well as by the resulting maximal possible reduction of primary fuels and environmental pollutant emission. To ensure achievement of these, designing and application of a proper mathematical model, which has been described in the paper, is required. The model presented therein finds practical application in conducting a proper selection of micro-cogeneration units' capacity for the needs of objects being analyzed, such as health resorts, swimming pools, hospitals, hotels, pensions or manufacturing plants.*

Key words: *Gas mircocogeneration, power and heat demand, load duration curves*

METODYKA ANALIZY KOSZTÓW EKSPLOATACYJNYCH WYSOKOSPRAWNEJ KOGENERACJI GAZOWEJ W OBIEKTACH O RÓŻNYM ZAPOTRZEBOWANIU NA ENERGIĘ ELEKTRYCZNĄ I CIEPŁO

Streszczenie: *W artykule przedstawione zostały uwarunkowania dotyczące zastosowania wysokosprawnej mikrokogeneracji gazowej w obiektach o zróżnicowanym zapotrzebowaniu na energię elektryczną i ciepło, w świetle współłączenia mikrokogeneracji z innymi źródłami zaopatrującymi obiekt w energię elektryczną i ciepło. Układ taki charakteryzuje się pewnymi krytycznymi parametrami, od których zależy jak najefektywniejsze wykorzystanie układu mikro-kogeneracji w obiekcie, i idąca za tym maksymalna możliwa redukcja zużycia paliw pierwotnych i emisji zanieczyszczeń do środowiska. Zapewnienie takich parametrów wymaga opracowania i zastosowania odpowiedniego modelu matematycznego, który został w artykule przedstawiony. Zaprezentowany model matematyczny znajduje praktyczne zastosowanie przy przeprowadzaniu prawidłowego doboru mocy jednostek mikrokogeneracyjnych na potrzeby analizowanych obiektów, takich jak np. uzdrowiska, baseny, szpitale, hotele, pensjonaty, zakłady produkcyjne.*

Słowa kluczowe: *mikrokogeneracja gazowa, zapotrzebowanie na ciepło i energię elektryczną, wykresy uporządkowane*