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ZERO ENERGY BALANCE PROPOSAL FOR OFFICE BUILDINGS

BUDYNEK BIUROWY O ZEROWYM BILANSIE ENERGETYCZNYM

Abstract

The paper discusses the issue of prediction of electric energy production using a photovoltaic system which is directly installed at the administrative building. The problem with solar energy, which has been transformed using photovoltaic systems for electricity, is the low capacity to accumulate an excess of produced electricity. This excess of electricity we link within the power grid to send outside the building where the energy was produced to be consumed elsewhere. In this way, we achieve the highest possible utilisation of electricity produced within the boundaries of the building itself. One option is to create opportunities to recharge electric vehicles during working hours, at the time when the production of electricity is the highest but the consumption of electricity is not.

Keywords: photovoltaic system, solar energy, heat pump, synergy

Streszczenie

W artykule przedstawiono analizę przewidywanej produkcji energii elektrycznej z system fotowoltaicznego zainstalowanego bezpośrednio w budynku administracyjnym. Problemem z energią słoneczną, zamienianą przy użyciu systemów fotowoltaicznych w energię elektryczną, jest niska zdolność gromadzenia nadmiaru produkowanej energii elektrycznej. Ten nadmiar energii elektrycznej możemy przy połączeniu z siecią energetyczną wysłać poza granice budynku, w którym energia została wytworzona i zastosować w innym miejscu. W ten sposób możemy najlepiej wykorzystać energię elektryczną wytwarzaną w granicach budynku. Jedną z opcji jest stworzenie możliwości ładowania pojazdów elektrycznych w czasie godzin pracy, kiedy poziom produkcji energii jest najwyższy, a zapotrzebowanie na energię nie jest na wysokim poziomie.

Słowa kluczowe: system fotowoltaiczny, energia słoneczna, pompy ciepła, synergia

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1. Introduction

Renewable energy comes from natural resources that are all around us. It is up to us to discover how we can use these resources to our advantage. Through the right choice and combination of different sources of energy, we can achieve zero energy balance conditions for a building. In this article, we will deal with the synergy of renewable energy sources and how it affects and reduces energy consumption in buildings. Heat pumps and photovoltaics offer the most energy-efficient way to provide heating and cooling in many applications, as they can use the renewable heat sources in our surroundings. The experimental workplace of our Faculty of the “Economic Research Centre for Renewable Energy Sources and Distribution Systems” was founded with the purpose of investigating the possibilities to reduce the energetic costs of buildings tied to economy. The realised project of the Centre creates a real environment for effective implementation research of technologies in laboratory and operative conditions: technologies of co-generative elements, heat pumps, photovoltaic elements, thermal capillaries and technologies in the field of measurement and regulation. The solution is a project with the possibility to repeat this on other similar applications as well as the utilisation of experience and determination of the economical expedience of implementation of researched technologies. In the contemporary phase of the research, we evaluate the operative behaviour of a zero energy balance building, interaction with building constructions and a study of the inner climate parameters and overall results for a central heat supply system.

At the heart of the ZEB concept is the idea that buildings can meet all their energy requirements from low-cost, locally available, non-polluting, renewable sources. At the strictest level, a ZEB generates enough renewable energy on site to equal or exceed its annual energy use. The following concepts and assumptions have been established to help guide the definitions for ZEBs.

2. Research methods of renewable energy sources – photovoltaic system

The existing photovoltaic system, made of monocrystalline photovoltaic panels, from which the measurements were taken, is located on the flat roof of an administrative building in Košice, Slovakia. Monocrystal photovoltaic panels have a rated efficiency of solar energy transformation at a level of around 20%. The system itself consists of 40 photovoltaic panels that are attached to two electric power converters. These converters record the measurement values of the amount of produced electricity at 5-minute intervals. Photovoltaic panels (2×2×10 pc.) are placed in rows on the flat roof of the building, supported by a metal frame structure. The resulting DC power from the photovoltaic panels is transformed into DC voltage with 2 inverters for a single-phase AC voltage and an automatically phased inverter for a single phase AC voltage to two phases of a low voltage distribution grid. Each inverter is equipped with fuses, which automatically disconnect the photovoltaic solar generator from the distribution network when subjected to critical deviations of the monitored parameters from the limits of standard values. The photovoltaic solar system is composed of 40 units of photovoltaic panels. The peak power of one photovoltaic panel is 230 W_p (Fig. 1).



Fig. 1. Installed photovoltaic system

The PVGIS simulation program was used to simulate the photovoltaic system. In order to quantify the amount of energy produced, a mathematical method was developed to calculate the amount of incident solar energy on the Earth's surface for any location and the inclination of solar panels. The measured and simulated values of produced electric energy are set for comparison with the calculated values. This methodology for calculating the amount of electricity produced by the photovoltaic system partly used the measured values for the city of Košice (cloud cover, ambient temperature and direct sun glare).

Produced electric energy comparison

When comparing the all results from different sources (measurement, simulation and calculation) of the produced electricity during the year, there are clear variations in the amount of energy produced each month.

But when we look at the yearly produced electric energy balance of the measured values, we obtain approximately identical results. These results are processed in the following table, where the methodology of calculating the amount of electricity produced for the selected location is more favourable (Table 1).

Table 1

Comparison of measured data

Data collection methods	electric energy [kWh/year]	variation [%]
Measurement	8752.505	–
Simulation	8920.000	1.88
Calculation	8840.974	1.00

3. Research methods of renewable energy sources – progressive indoor environmental system

The heating and cooling system incorporates a separate electricity meter. The electricity meter records the consumption of the electric energy source as well as the circulation pumps in the building. The area includes the heating source heat pump (HP), submersible pump (P1) and circulation pumps (P2-P5). The source cooling circuit includes a submersible pump (P1) and circulation pump source (P2 – P5) (Fig. 2). During the heating season, the largest consumer of electricity in the system is the heat pump. During the cooling period, water from the source well is used for cooling; thus, we are not producing cooling in the building, and in this case, the heat pump is decommissioned. On the other hand, we are also measuring the consumption of electricity in the heating system (Fig. 2).

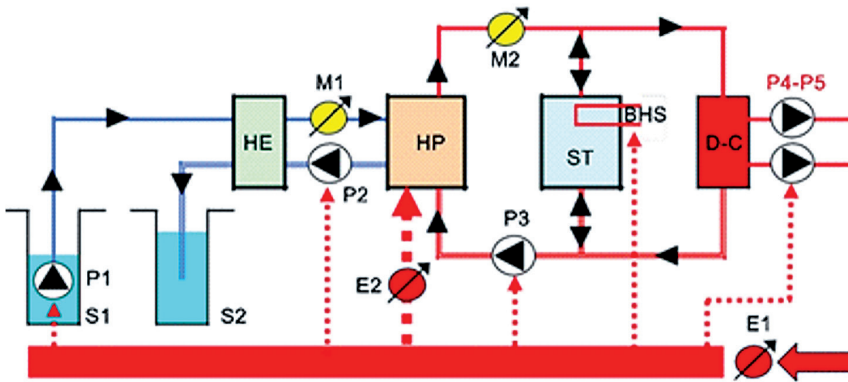


Fig. 2. Depicted scheme of the connection of water/water heat pump and electricity consumption

where:

- HE – heat exchanger
- HP –water/water heat pump, 0°C/35°C COP 3.8; heat performance 95.3 kW
- M1-2 – heat meter
- E1-2 – electricity meter
- ST – heating storage tank
- BHS - bivalent/backup heat
- S1-2 – source/suction well
- P1 – submersible pump
- P2-3 – circulation pumps – engine room
- P4-5 – circulation pumps – building
- D-C – distributor-collector

Requirements for supply of heat and cooling to the office building

1. Heat:

- Energy loss during the heating season: 1,000 GJ
- Requirement for maximum output power supply: 125 kW

2. Cooling:

- Energy loss during the summer: 330 GJ
- Requirement for maximum output power supply: 50 kW

Energy performance and technological annual energy input of energy source wells

Energy potential of the water source was measured via a hydrological test. Given the nature of the ground and the building above it, the test of a part of the sedimentation showed that the ground motion is not detected until the yield point of the water source at 7 l/s. A test for 7 days × 24 hours showed that suction wells are capable of such absorption of a volume of continuously pumped water. For the purposes of supply of heat, it is then possible to determine the energy performance of the wells as follows:

- Coverage of water source: 7 l/s
- Water temperature: 14°C
- Two heat pumps connected in series
- The temperature difference for each heat pump: 4°C
- The number of heating days: 204
- Days of cooling: 153
- Temperature difference: 4°C

Proposal of a photovoltaic system in the evaluated administrative building

One part of the photovoltaic system will be placed in rows on the flat roof of the building on a metal framework structure, and the other part of the photovoltaic system will be placed on the inclined metal structure on the south side of the administrative building. This design increases the number of installed photovoltaic panels and also fills in the blank and unused space of the office building. The resulting DC power from photovoltaic panels is transformed into DC voltage with inverters for single-phase AC voltage and an automatically phased inverter for single phase AC voltage to two phases of a low voltage distribution grid. Each inverter is equipped with security protection, which in the case of deviations of the monitored parameters from the limits of standard values automatically disconnects the photovoltaic solar generator from the distribution network. The photovoltaic solar system will be composed of 365 photovoltaic panels. The peak power of one photovoltaic panel will be 230 Wp. Depending on the weather conditions for Slovakia, the entire photovoltaic system is inclined at an angle of 35° (Fig. 3).

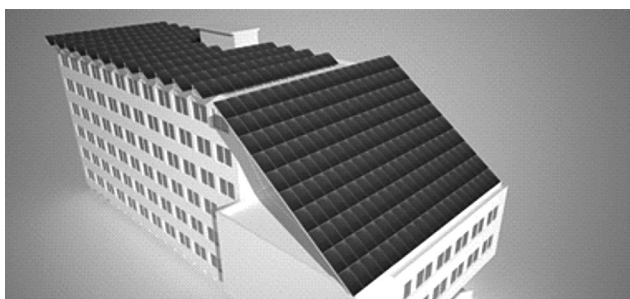


Fig. 3. Photovoltaic system proposal and design

4. Conclusions

The electric energy demand for the administrative building during the heating season is 65 MWh per year, and during the cooling season, it is 19.4 MWh per year. Overall electric energy demand to drive the heat pump and other circulation pumps in the system is about 84.4 MWh per year. The calculated amount of electricity produced by photovoltaic system is 80.7 MWh. According to the annual energy balance of the heating and cooling system, we can say that energy demand will be 96% covered by the electric energy produced with the proposed photovoltaic system. If the parameters of photovoltaic panels increase in the future, there is the possibility to say that the entire system during the year will be fully covered by the electric energy that is produced through the photovoltaic system. On the other hand we should say that we need to cover additional energy demands for lighting as well as for electric equipment in the offices. This could be possible if the peak power of one photovoltaic panel is around 300 Wp. After these system modifications, we will be able to say that the evaluated administrative building will be a building with a zero-energy balance, which mean that the administrative building will be completely self-sustaining. This is effective if we could cover the energy consumption on the basis of the yearly energy balance.

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