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Utilizing Solar Energy in Order to Reduce Energy Loads of Building

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An increased utilization of renewable energy sources in the heat and electricity generation is one of priority tasks of the Slovak Republic to boost the use of domestic energy potential and thus to decrease the Slovakia's dependence on imported fossil fuels. Heat pumps and photovoltaics offer the most energy-efficient way to provide heating and cooling in many applications, as they can use renewable heat sources in our surroundings. The experimental workplace of our Faculty "Economic Research Centre for Renewable Energy Sources and Distribution systems" was founded with the purpose of investigating possibilities to reduce the energetic costs of buildings tied to economy. The realized project of the Centre creates real environment for effective implementation research of technologies in laboratory and operative conditions: technologies of co-generative elements, heat pumps, photovoltaics elements, thermal capillaries, and technologies in field of measurement and regulation. The solution is the project with possibility to repeat it on other similar applications as well as the utilization of experience and determination of economical expedience of researched technologies implementation. In the contemporary phase of the research we evaluate of operative behaviour of the zero-energy balance building, interaction with building constructions and study of inner climate parameters and overall results for central heat supply system.

1. Schematic diagram of the photovoltaic panels and heating/cooling system

Schematic synergy diagram of the photovoltaic system and heating/cooling system with the heat pump in administrative building. Our project analyses a variety of operational and technical variations of energy systems (PV system and heating/cooling system) involved in an individual or integrated production side of the heating, cooling, lighting, hot water and electricity. The individual operational involvement and energy balances, and the parameters of administrative building are scheduled below (Domnit et al., 2012).
Scheme and the PV involvement where is possible, that these energy scenarios are running the administrative building.

- Electricity produced by PV system placed at the building after the transformation of the Sun's energy is delivered to the public electrical grid (Kapalo, 2011).
- The building needs for its operation of the heating and cooling circuit electricity taken from the public electricity grid. This electricity is consumed primarily to power heating and cooling circuits in which are used circulation pumps and heat pump during the heating and cooling season.
- In the case of turning off the heating or cooling circuit, the energy will be consumed solely for the operation of electrical appliances in the building (Figure 1)

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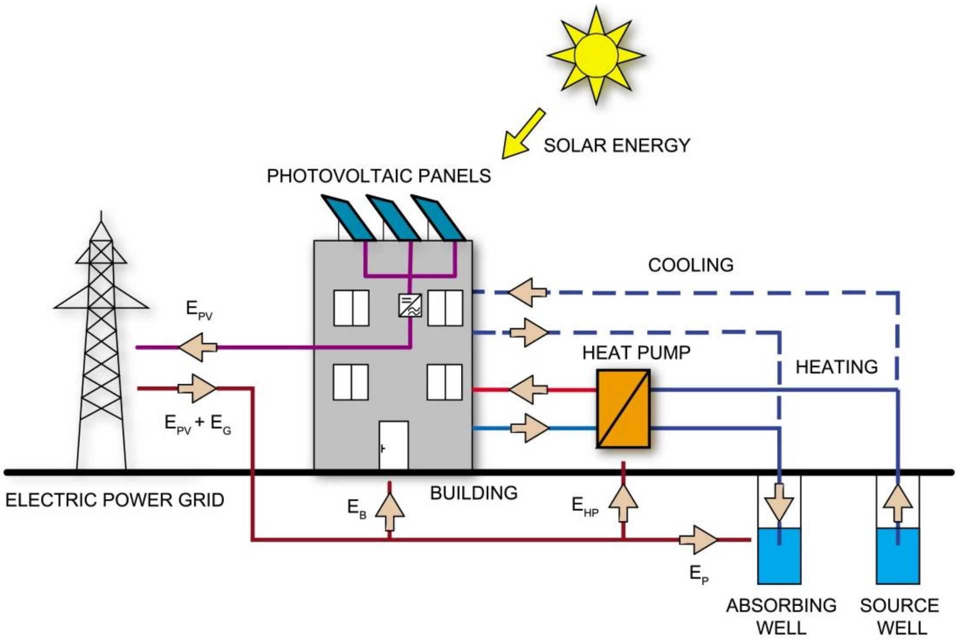

Figure 1: Schematic diagram of PV system, heat pump system and capillary mats

In this chart, the red curve implied electric power need for heating and cooling during the year. Blue curve indicates electric energy demands for building operation during the year including heating and cooling. Orange curve indicates the production of electricity using photovoltaic system throughout the year (Figure 2).

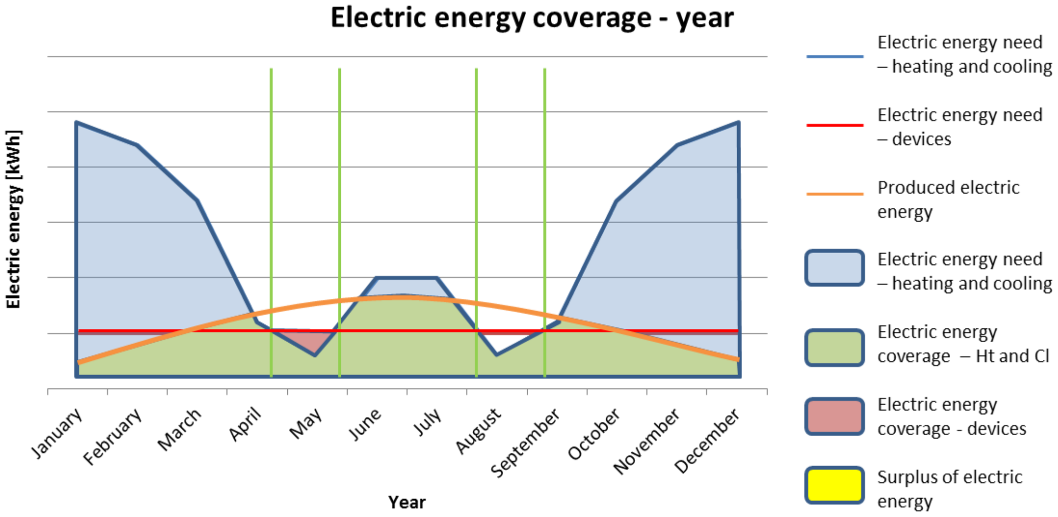

Figure 2: Electric power needs for heating, cooling, electricity and produced electricity by PV system during the year

2. Photovoltaic system and heat pump proposals

For the office building is proposed photovoltaic system with direct connection to the grid. This system involvement is the most used connection of photovoltaic systems. Wide application of this photovoltaic system is in places with sufficient coverage of electric distribution network. The system does not require accumulation battery as electric energy going directly into the electricity grid. Such involvement is calculated to have financial return of the system. Heat pump is a device which can use the heat of air, water or ground. These devices operate on an electrically driven vapour-compression cycle (Pérez et al., 2011).

In the selection of a natural source for heat pump it is especially considered its availability, quality, yield and temperature. If the temperature of the source or pollution exceed acceptable values for specific heat pump can be used standalone hot water circuit, but it is necessary to calculate the temperature of the auxiliary working medium (water, brine) will be about 5 °C lower than the natural polluted source. The best source for heat pump is ground water. This is because it has relatively constant and high temperatures (12 °C), usually is not chemically contaminated. The disadvantage is its small amount. The most commonly is used water from wells.

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

Heating and cooling system incorporates a separate electricity meter. The electricity meter records consumption of electric energy source as well as circulation pumps in the building. Area includes heating source heat pump (HP), submersible pump (P1), and circulation pumps (P2-P5). Source cooling circuit includes a submersible pump (P1) and circulation pump source (P2 – P5) (Figure 2.). During the heating season is the biggest consumer of electricity in the system is heat pump. During the cooling period water from the source well is used for cooling, thus we are not producing cold in the building and in this case the heat pump is decommissioned. On the other side we are also measuring consumption of electricity in the heating system (Figure 3).

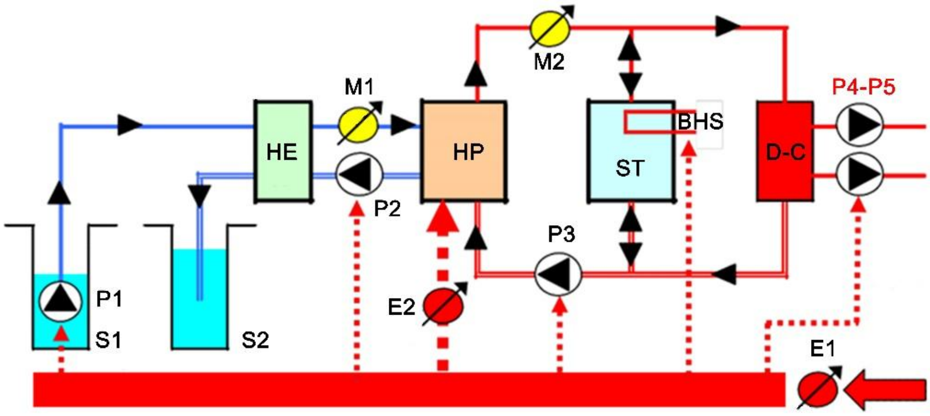

Figure 3: Depicted scheme of the connection of a heat pump water/water and electricity consumption

where:

- HE – heat exchanger;
- HP – heat pump water/water, 0 °C/35 °C COP 3.8; heat performance 95.3 kW;
- M1-2 – heat meter;
- E1-2 – electricity meter;
- ST – storage tank of heat;
- 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 cold office building

1. Heat:
   - Energy loss during the heating season: 1,000 GJ
   - Requirement for maximum output power supply: 125 kW
2. Cold:
   - Energy loss during the summer: 330 GJ
   - Requirement for maximum output power supply: 50 kW

4. Research methods of renewable energy sources – photovoltaic system

Photovoltaic system, on which the measurements take place from December 2009, is located on a flat roof building in Košice. The system itself consists of 40 photovoltaic panels that are attached to two electric power converters. These converters recorded at 5 min intervals the amount of electricity produced.
As a simulation program is used PVGYS (2014). In calculating the amount of electricity was developed methodology to calculate the amount of incident solar energy on Earth's surface for any location and inclination of solar panels. There is prepared methodology for calculating the amount of electricity produced by photovoltaic system, which is partly uses the measured values for the city of Kosice (cloud cover, ambient temperature, direct sun glare).
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 it is more favourable the methodology of calculating the amount of electricity produced for the selected location (Table 1).

Table 1: Comparison of measured data

Data collection methods	electric energy [kWh/y]	variation [%]
Measurement	8,752.505	-
Simulation	8,920.000	1.88
Calculation	8,840.974	1.00

5. Proposal of photovoltaic system at the administrative building

Photovoltaic panels are placed in rows on the flat roof of the building in the metal framework structure. The resulting DC power from photovoltaic panels is transformed into DC voltage with inverters for single-phase AC voltage and automatically phased inverter for single phase AC voltage to two phases of low voltage distribution grid. Each inverter is equipped with security protection, which in case of deviations of monitored parameters from the limits of standard values automatically disconnects the photovoltaic solar generator from the distribution network. Photovoltaic solar system is composed of 365 pieces of photovoltaic panels. The peak power of one photovoltaic panel is 230 Wp (Figure 4).
When using a calculation model of the amount of produced electrical energy transformed from solar energy using photovoltaic system were examined different tilt angles of photovoltaic panels (Huld et al., 2010). At different slopes of photovoltaic panels we receive a different amount of generated electricity. When comparing these results we have achieved the most favourable inclination of 37 ° tilt of solar panels, when production reaches maximum power (Figure 5) (Tauš et al., 2009).

Figure 4: Proposal of photovoltaic system

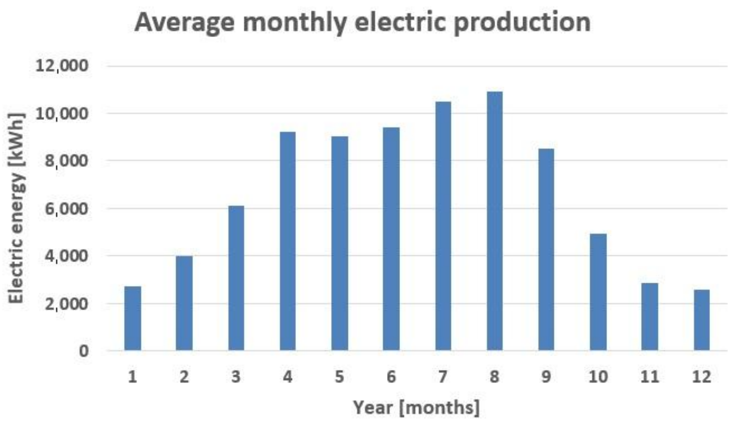

Figure 5: Average monthly production of electric energy

6. Conclusion

The electric energy demand for the administrative building during the heating season is 65 MWh/y and during the cooling season is 19.4 MWh/y. Overall electric energy demand to drive the heat pump and other circulation pump in the system is about 84.5 MWh/y. Calculated amount of electricity produced by photovoltaic system is 81.1 MWh. According to annual energy balance of heating and cooling system, we can say that the energy demand will cover 96 % with electric energy that will be produced with the proposed photovoltaic system. If the parameters of photovoltaic panels will increase in the future, there is possibility to say that whole system during the year will be fully covered with electric energy that is produced through the photovoltaic system. On the other side we should say, that we need to cover additional energy demands for lightning and also for electric equipments in the offices. This could be possible, if the peak power of one photovoltaic panel will be around 300 Wp. After these system modifications we will be able to say that evaluated administrative building will be building with zero-energy balance, which mean that administrative building will be completely self-sustaining. It is effective if we could cover the energy consumption on the base of yearly energy balance (Table 2).

Table 2: Comparison of measured data

Month	Produced electricity	Consumed electricity	Electricity deficit	Electricity excess	Electricity cover
January	2,738.478	13,041	10,302.522	-	21 %
February	4,019.468	15,391	11,371.532	-	26 %
March	6,150.312	7,690	1,539.688	-	80 %
April	9,268.765	5,098	-	4,170.765	182 %
May	9,046.633	2,478	-	6,568.633	365 %
June	9,403.427	4,649	-	4,754.427	202 %
July	1,0491.05	5,073	-	5,418.050	207 %
August	1,0949.68	4,692	-	6,257.680	233 %
September	8,591.682	2,529	-	6,062.682	340 %
October	4,964.713	3,937	-	1,027.713	126 %
November	2,886.080	7,486	4,599.920	-	39 %
December	2,586.539	12,438	9,851.461	-	21 %
Overall	81,096.827	84,502	37,665.123	34,259.950	96 %

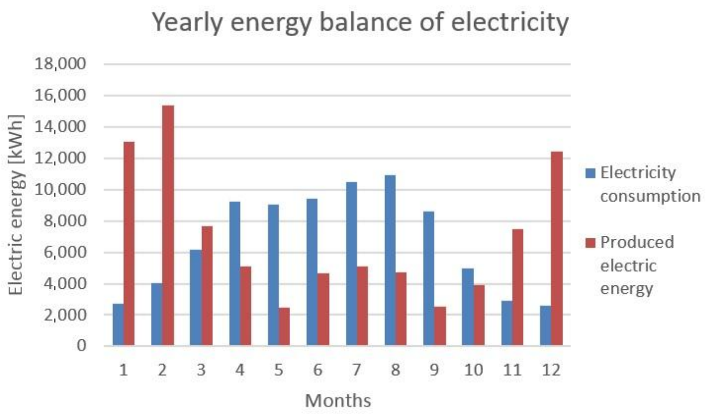

Figure 6: Average monthly production of electric energy

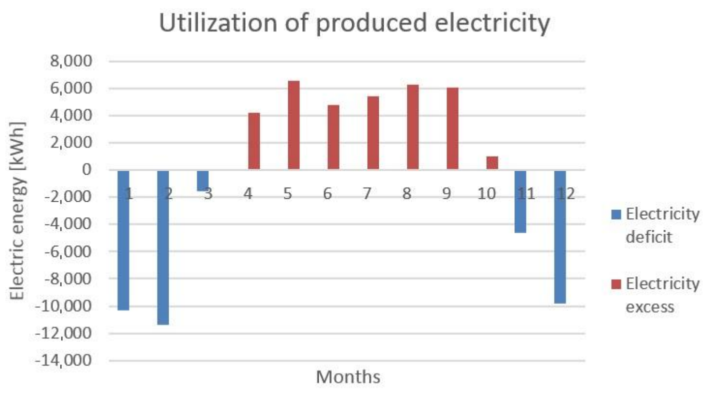

Figure 7: Average monthly production of electric energy

Acknowledgements

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