Accumulation elements and their possibilities of use for accumulation of energy from photovoltaic systems

Pavel Chrobak and Martin Zalesak

***Abstract*—**The paper deals with accumulative materials with high the specific heat capacity. Such materials allow to accumulate energy from photovoltaic panels in thermally accumulation devices both in the form of heat or cold. Due to the increasing demands to reduce energy intensity building are important substances that have a high specific heat capacity. Special position in this have thermally accumulation panels (PCP), which appeared on the market recently and are capable of accumulating large amounts of power compared to other commonly used substances. The efficiency of energy production and use of photovoltaic panels is affected by many factors and it climatic conditions, energy storage properties and more. In the paper are presented and evaluated the usability of balance in any particular case, based on real meteorological data for the winter season

***Keywords*—**Accumulation, heat loss, photovoltaic, solar radiation, temperature, invertor.

I. Introduction

NOWADAYS, great emphasis is placed on reducing the environmental burden associated with human activities. For this reason, in 2010 the European Union introduced a directive on the environmental performance of buildings. A substantial part of the total energy consumption in the European Union creates of building and it 40% and the share of CO2 emissions is about 36% which is a considerable ecological impact on the environment. One of the ways to reduce the energy requirements of buildings is the use of appropriate accumulation materials in combination with renewable energy sources [1]. The alone renewable energy sources such as wind or solar radiation cannot cover the consumption of buildings evenly over the whole year. Therefore, the produced electrical energy to be stored for periods when there is a shortage.

We in this paper will focus on the possibilities of obtaining energy from photovoltaic panels and particularly its storage in thermal storage devices for heating buildings in winter. For this purpose we use a variety of substances that have specific storage characteristics, such as water, oil and materials used for the accumulation of heat or cold thermal processes associated with phase change material.

II. Physical principle of photovoltaic conversion

Before more than 150 years ago by Alexander Edmond Becquerel discovered principle technology for the direct conversion of sunlight into electricity by using the photoelectric effect on large semiconductor photodiodes (photovoltaic cells). The individual photodiodes are called photovoltaic cells and are usually attached to larger units (photovoltaic panels).

The simplest photodiodes consists of two semiconductors with a different type of electrical conductivity. In one of the layers of material of the type N predominate negatively charged electrons, while in the second layer of material P predominate "holes" which are essentially blanks which readily accept electrons. At the point where these two layers meet with a P - N junction where there is a pair of electrons with holes, thereby creating an electric field that prevents other electrons move from the N - layer to the P – layer [2]. Normally, the electrons in the semiconductor material are firmly bonded to the atoms of the crystal grid and the material is then nonconductive. By adding a very small amount of an element with a greater number of valence electrons to the crystal creates a region of conductivity of the type N, in which free electrons exist and they can create electrical charge. Conversely an impurity element with a reduced number of valence electrons creates a region with conductivity of the P type, in which the crystal grid range “hole are as” without electrons. If the semiconductor material capture of a photon of sufficient energy, it results in creation of an one electron-hole pair [3]. If the circuit is closed, the wearer's hub starts to move in opposite directions to the negative electrode. A positive hole is shown in Figure 1.

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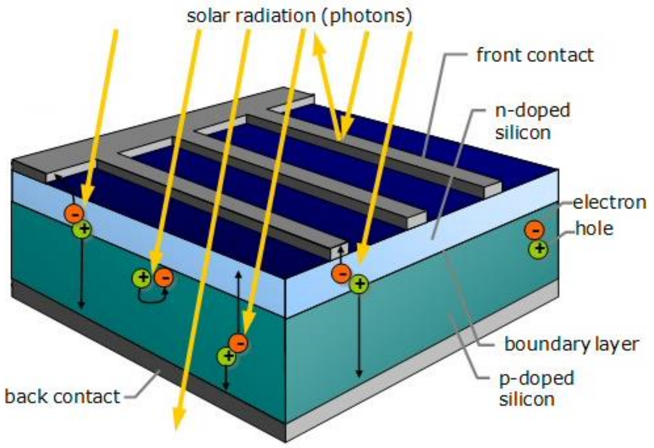

Fig. 1 the structure of the photovoltaic cell [2]

Photovoltaic cells can be divided accordingly to the type of photovoltaic cells on monocrystalline, polycrystalline and amorphous. The various types of photovoltaic cells differ from each other mainly efficiency and amount of silicon.

III. THERMAL ACCUMULATION MATERIALS

For thermal energy storage are used based on physical principles of heat accumulative material, the phase change storage material, desorption of moisture from the porous materials in the range of hygroscopic sorption of moisture and dehydration crystal chemically pure substances [5]. According recovered physic-chemical principle can still be divided into thermal energy storage of several types and a sensible heat accumulation, accumulation of latent heat, absorption of water vapor and other physico-chemical processes. Currently most used for storing thermal energy, water, which has all of the commonly used materials highest specific heat capacity of 4180 J / (kg K). Further still uses a lesser extent aggregates having a higher operating temperature range but a lower heat capacity and 800 - 1000 J / (kg K). A drawback of these commonly used accumulation materials is particularly complicated construction and the demands on the heat accumulator space. The aforementioned deficiencies are largely eliminated based materials Phase Change Materials (PCM) materials or phase change of the working substance is shown in Figure 2.Description of the system

System described in this chapter is applied in the laboratory of environmental engineering at the FAI UTB in Zlin. The system consists of 9 photovoltaic panels with a total area of 11.25 square meters. The panels used, are of the type of polycrystalline photovoltaic cells. The producer of these panels has declared an energy efficiency of 15% (for angle of the panels surface inclined from the horizontal one of 45 ° with the southeast azimuth of the normal direction to the panel surface).Installed panels are shown in Figure 2.

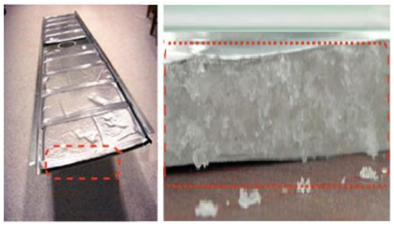

Fig. 2 phase change materials [4]

PCM materials are used primarily for storage of latent heat and can be water, paraffin, salt hydrates. These substances are able to absorb, retain and release large amounts of heat or cold in a relatively small temperature change. This is a change such as physical state from solid to liquid. The heat that is accumulated is called latent heat. The panels are in the form of plates which are a mixture of ethylene and molecular paraffin wax closed. These boards are easily modifiable shape (easy divisibility sharp instrument) and can be easily installed on walls, bearing walls and ceilings, under plasterboard etc. These features can be used not only for storage of latent heat, but also for Sensible heat storage [6, 7].

IV. DESCRIPTION OF THE SYSTEM

System described in this chapter is applied in the laboratory of environmental engineering at the FAI UTB in Zlin. The system consists of 9 photovoltaic panels with a total area of 11.25 square meters, inverter, accumulation panels and thermocouples.

The panels used, are of the type of polycrystalline photovoltaic cells. The producer of these panels has declared an energy efficiency of 15% (for angle of the panels surface inclined from the horizontal one of 45 ° with the southeast azimuth of the normal direction to the panel surface). Installed panels are shown in Figure 3.

Fig. 3 photovoltaic panels

Surface reaches 750 Wm-2, the electric power produced by the panels should be P = 1265 W, based on the declared efficiency by the producer. The output DC voltage of the panels is converted by the AC voltage inverter in one phase AC current with the 230 V AC. This inverter also displays information about the amount of energy produced by the various operating states of the system (fault, instantaneous power, voltage, total produced energy by the system, etc.) [8, 9].

Fig. 4 inverter Sunny Boy

Figure 4 shows the inverter Sunny Boy 1700 with defined efficiency by the European standards ηeuro =91.8%. This value has been measured under varying climatic conditions where maximum efficiency were reached ηmax = 93.5% with the optimal measuring conditions (stable temperature conditions, nominal DC voltage and medium values of AC power). The rest of the converted energy is lost by the electrical conversion in the form of heat [8], [9].

The penultimate section of the system consists of two panels with a total storage area of 4.8 square meters that are placed in Laboratory of Environmental Engineering. The panels are 12 plates forming a mixture of paraffin wax and 60% copolymer of 40% ethylene. Between the layers of wax plates are always placed 3 Heizfolien a total power of 3600 W. Specific heat capacity of the material comes in a range of operating temperatures averaged 11,000 J / (kg K). For heating and cooling options includes panel and tube heat exchanger. The panels are coated polished galvanized sheet.

The last part of the system consists of 6 pieces of thermoelectric cells with a total output of 550 watts, which allow (through the transmission medium of water) to cool the accumulation panels in the summer months.

V. METHODOLOGY VALIDATION PARAMETERS

In order to exploit the latent heat panels for heating Laboratory Techniques environment in winter, we need to know the heat loss of the room, the energy manufactured by the photovoltaic panels and the average heating power accumulation panels. The heat loss of the room is determined by the relationship (1) [10]:

$$\dot{Q} = f \cdot U \cdot (\Delta\Theta) \qquad (1)$$

where $\dot{Q}$ is heat loss of the room [W],

f correction factor,

U transmission heat loss coefficient [W/(m^2.K)],

A area [m^2],

$\Delta\Theta$ temperature difference [°C].

The actual amount of electricity produced by photovoltaic panels calculation based on data obtained from the sensor solar radiation (solarimetru), which is oriented in the direction of photovoltaic panels. This sensor records the total amount of solar radiation incident on the photovoltaic panels. From this value we calculate the real efficiency of a photovoltaic system according to the relationship (2) [10]:

$$\eta = \frac{P_m}{P_{rad}} = \frac{P_m}{E \cdot A_C} \qquad (2)$$

where P_m is performance of a photovoltaic panel [W],

P_{rad} tower of the incident radiation [W],

E total intensity of solar radiation[W/m^2],

A_c surface of the photovoltaic cell [m^2].

Based on the efficiency of photovoltaic panels and the total amount of solar radiation incident on panels about the quantity of electricity that we are able to produce power for heat storage panels. The last step is to determine the heating output of the heat accumulation modules according to the relation (3) [10]:

$$\dot{Q} = \dot{q} \cdot A = h \cdot \Delta\Theta \cdot A \qquad (3)$$

where $\dot{Q}$ is heating power panels [W],

$\dot{q}$ heat flow density [W/m^2],

A Area panels [m^2],

$\Delta\Theta$ temperature difference [°C],

h coefficient of heat transfer [W/m^2.K].

VI. MEASUREMENT

In the observed winter from October to March during the years 2013-2014 were recorded using weather station outdoor climatic conditions. The following Table 1 shows the average outdoor temperature in different months, the intensity of solar radiation and the amount of electricity produced by photovoltaic panels.

Table 1: Measurement values

Year 2013-2014			
Months	Average outdoor temperature [°C]	Average global solar radiation [W/m^2]	Energy made by PV [kWh]
October	11.17	99.12	142.372
November	5.81	39.33	52.815
December	2.4	28.62	40.033
January	2.03	31.96	41.135
February	4.46	74.24	104.283
March	8.27	138.27	180.903
Year 2014-2015			
October	11.23	81.21	111.236
November	8.17	38.51	71.63
December	2.38	29.36	57.38
January	1.62	26.35	61.22
February	0.6	73.52	78.994
March	4.95	114.81	150.101

Further, based on the construction and technical parameters calculated heat loss room temperature and heating capacity storage panels see in table 2.

Table 2: Parameters premises and accumulation panels

Premises		Accumulation panels	
Wall dimensions[m]	8,6x7,3 x3,1	Panel dimensions [m]	2x2,4
Dimensions of windows 2 [m]	4x1,9	Working temperature min. [°C]	25
External reference temperature [°C]	-15	Working temperature max. [°C]	35
Internal reference temperature [°C]	22	Consumption of heating foil [W]	3600
Heat loss wall [W]	1338,5	Heating power [W]	157,4
Heat loss window [W]	764,7		
Total heat loss [W]	2103,2		

All these values are summarized in the database. Based on the monthly heat loss room was created chart heating panel as shown in Figure 5.

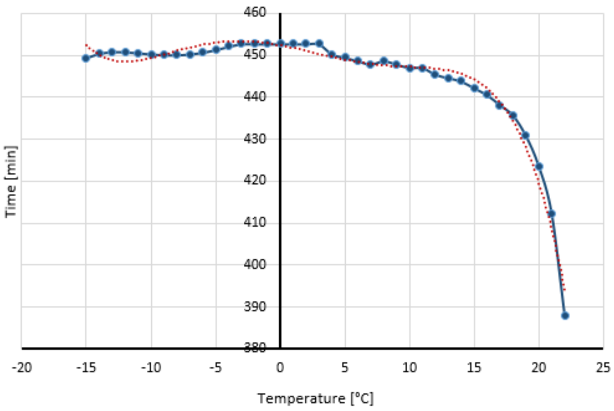

Fig. 5 the course of the heat accumulation panel

From this graph was subsequently modeled equation storage heating panel, which was subsequently verified on an experimental equipment located in a laboratory techniques environment (4):

$$y = -0{,}00003 \cdot x^5 + 0{,}0002 \cdot x^4 + 0{,}0074 \cdot x^3 - 0{,}0591 \cdot x^2 - 0{,}5742 \cdot x + 452{,}4 \quad (4)$$

The measured values were then recalculated so that potential performance storage and photovoltaic panels correspond to real values. The results showed that the required minimum surface storage panels should be increased from the original 4.8 m2 to about 64 m2 and the area of photovoltaic panels from the original 11.25 m2 to 150 m2. The following figure 6 shows the production and consumption of electricity in January 2014.

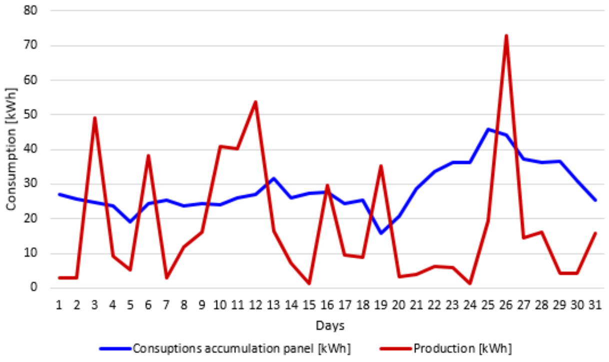

Fig. 6 production and consumption of electricity each day

From the figure it follows that in twenty three days in the month of January electricity consumption exceeds production, but in some days in the month again electricity production exceeds consumption considerably. This unfavorable state electricity production is particularly affected by adverse weather conditions that occurred in this month. In particular, the frequent occurrence of fog in combination with dense clouds, which greatly affect the production of electricity in cloudy days. On some days, the months of January moreover lay on the surface of photovoltaic panels, thin snow cover. After deduction of the differences of production and consumption of electricity is based, that only 13 days of January electricity production is insufficient. Overall, however, the production of electrical energy in the winter season as in 2013 and 2014 significantly exceeds consumption, as shown in the following figures 7 and 8.

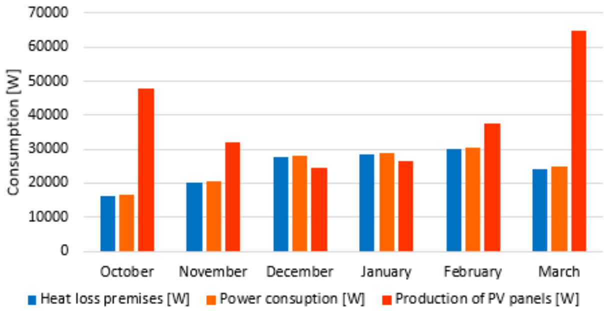

Fig. 7 comparison of production and consumption of electricity for heating in year 2013 – 2014

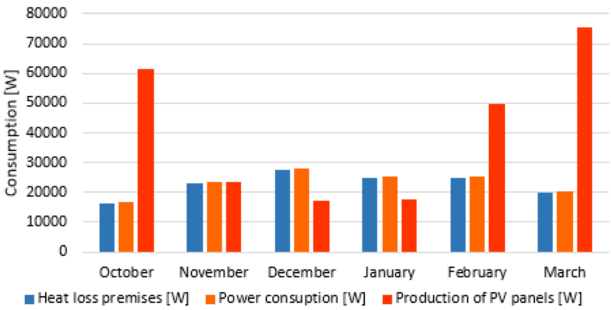

Fig. 8 comparison of production and consumption of electricity for heating in year 2014 – 2015

Based on the measured values of electricity production in the wintertime years 2013-2014 shows that photovoltaic panels are applicable for supplying accumulation panels. However, due to irregular supply of electricity by photovoltaic panels, which is influenced by climatic conditions is a necessary part of the energy back up. Such a backup can be realized using the battery system, which is not completely suited to all environments, because the storage battery has its own specifics and some extra batteries lose capacity over time. A much better solution is to sell surplus electricity into the public grid and consequently its repurchase at a time when the generation of electricity by photovoltaic panels insufficient.

VII. CONCLUSION

In this paper were presented thermal accumulation materials (PCM) and their options use in combination with photovoltaic panels. On the data obtained from measurements in winter periods 2013 and 2014 it was found that one can use the heat accumulation panels (PCM) for storing electrical energy in the form of heat and this subsequently used for heating the room. Accumulation materials based on PCM having nearly three times the storage capacity compared to commonly used materials such as water, oil, etc. This can significantly increase energy autonomy objects without major reconstruction work. More research will be, under what conditions would have given the latent heat panels used for room cooling in summer.

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