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POWER AND DECORATIVE SOLAR FAÇADES

The work presents an analysis of the possibility of obtaining electric energy from a PV façade, both in the case of standard fitting – tilted at the angle of 90° and directed towards the south, and for a wall fitted at the angle of 75° also directed towards the south. In order to determine the energy gains expected in the second case, a computer simulation confirming the assumptions was executed.

1. INTRODUCTION

Photovoltaic modules have been used in construction as long as since the seventies of the past century. Initially, they constituted a separate element placed on the roof; later, they became popular as a roofing addition; now, they are more and more often integrated with the building - BIPV (Building Integrated Photovoltaics) [1, 2, 3, 4, 5, 6, 7, 8, 9, 10].

The most efficient type of photovoltaics to be used in this type of solutions is thin-film photovoltaic cells. The cells used in construction are manufactured in the form of flexible materials (TFPV roof membranes), as well as in the form of rigid materials (BIPV roof tiles and façades). It is also possible to use BIPV modules as window modules (transparent) [2, 3].

Their fitting and maintenance is not difficult. It is also possible for such an installation to cooperate with the power supply network.

At the current stage of development of this technology, an additional visual effect can be achieved apart from the functional values. Façade modules can, thus, play two roles: of an esthetic element and of a power generator. Companies which manufacture façade modules provide a full range of color options.

Both in the case of wall PV modules as well as in the case of roof modules, it is possible to change their positioning which makes it possible to adjust them to the angle of sunlight. Sometimes they cooperate with heliostats.

2. FAÇADE MODULES – VISUAL ASPECT

Apart from their functional characteristics and provision of energy, PV modules must also play an architectural and decorative role. This is achieved through providing

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them in the appropriate color range dependent on the type of the cells used, the protective housing, its texture, the frame, foil lamination, the angle of sunlight.

In practice, cells made of crystalline silicon are used most often. As a result, the colors of façade modules are not very varied. Monocrystalline materials (m-Si) are navy-blue or black and polycrystalline cells (p-Si) are manufactured in different shades of blue.

Modules installed on the south-west façade and on the south façade come from different manufacturers, but they are manufactured solely as silicon modules – mono- and polycrystalline and amorphous [8]. They are not situated directly on the façade but on supporting structures, parallel to the wall.

Figure 1 presents a photovoltaic façade installation placed on the Environmental Engineering Faculty building of Warsaw University of Technology.

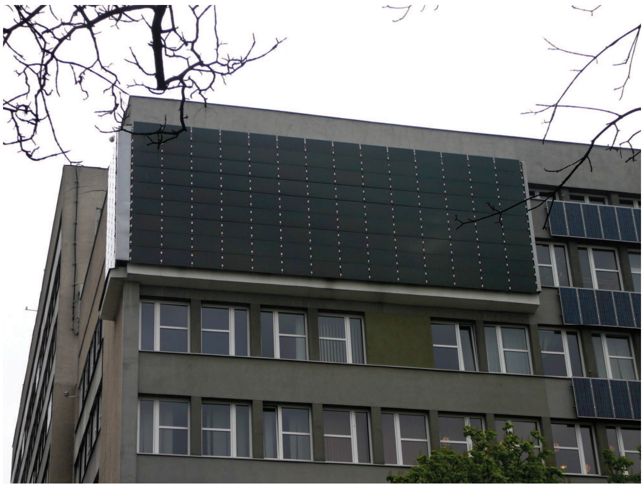

Fig. 1. PV façade installation on the Environmental Engineering Faculty building of Warsaw University of Technology (photo: Grażyna Frydrychowicz-Jastrzębska)

The color scheme of the installation described is standard, framed modules of the glass-foil type with dark blue (gradually changing into black) crystalline cells on a white background; it does not utilize the current technology options.

In the last several years, the technology has been developed, making it possible to improve the esthetic values of the cells mounted on building façades. The Fraunhofer, Schüco, SUNWAYS companies are leaders with respect to new solutions offered in a broad range of colors. Colored cells manufactured by those companies are characterized by relatively high efficiency.

In Poland, photovoltaic modules integrated with the building are produced by Solar Future Energy.

Figure 2 presents examples of cells offered in different colors from the marble group (a) and (b).

a) b) c)

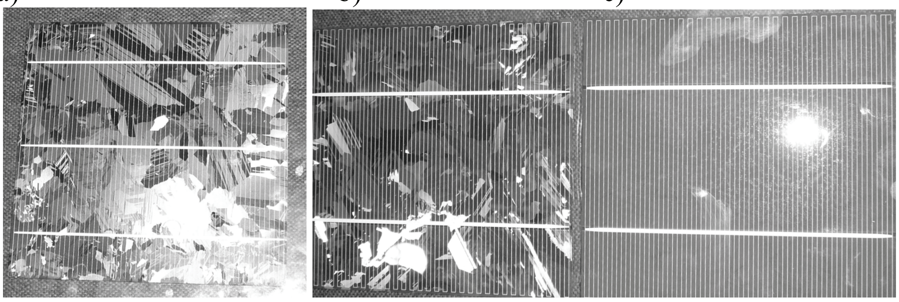

Fig. 2. Colored façade photovoltaic cells: marble (a and b) classic (c)
(photo: Grażyna Frydrychowicz-Jastrzębska)

The LOFTM SOLAR company from Taiwan manufactures C-Cell cells in a broad range of colors, 5 options for monocrystalline silicon cells, 10 options for polycrystalline cells, and mixed color solutions. The efficiency of those cells exceeds 15 %.

The offer of Solar Development includes façade modules in different colors (12 options).

An interesting solution is offered by the Fraunhofer company. The efficiency of the cells manufactured by the company reaches up to 16 % [1]. Figure 3 presents a photovoltaic module manufactured by the Fraunhofer company. Cells with varying colors and efficiency levels are widely used in architecture [5].

Fig. 3. Fraunhofer ISE 60 cm x 100 cm module
(photo: by courtesy of Katarzyna Anna Białecka Fraunhofer)

In practice, it is possible to use modules with the total area of 2000 mm x 4000 mm, both as window elements as well as façade elements (different transparency levels) [5].

3. FAÇADE MODULES – FUNCTIONAL ASPECT

The most frequently mentioned functional features of BIPV are: direct energy consumption without the need to transmit it (loss reduction), optional cooperation with the power network, no need to buy the land for the installation, reduction of construction material consumption, no need to install a monitoring system and fencing, the possibility for the installation to cooperate with a green building lighting system.

Figure 4 presents the possibilities of placing photovoltaic modules on the roof and on the façade of a building, considering only the functional aspect of their operation. As it is clear, the most effective positioning of the collectors as far as the power efficiency criterion is concerned, is placing them on a tilted roof and on the façade facing south. Measurable benefits can also be made from covering a flat roof with the modules [2, 3].

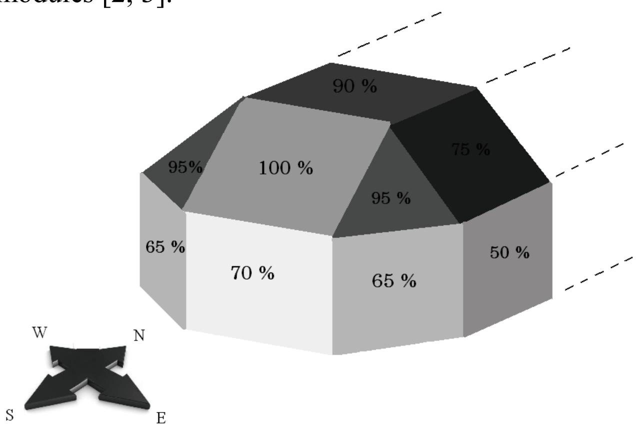

Fig. 4. The possibilities of positioning BIPV photovoltaic modules
Authors' own work on the basis of [4]

In the case of the façade installation presented on Figure 1, the modules are not placed directly on the façade but on supporting constructions parallel to the wall. In other solutions, photovoltaic wall modules can also change their inclination angle so as to adjust their positioning to the angle of the sun.

A particularly innovative solution was introduced in 2012 by the Schüco ProSolTF company. The façades are covered with special thin-film cells (8 mm), based on the solution of the tandem type, in this particular case – amorphous and microcrystalline silicon. The efficiency of the new BIPV modules is higher in comparison to the existing modules by 30 %. Special black coating provides a visual effect, and, what is most important, their dual-purpose character makes it possible to produce electric energy and provide thermal insulation at the same time. The most extensive discussion of the problem is presented in [6].

Such dual-purpose modules are to be used on the façade of the Oławska Gallery. They will also use the energy of diffuse radiation. The Gallery is also planned to be self-sufficient in energy (although connected with the power network). Large glazing requires the use of cells with a high level of transparency.

Unfortunately, the higher the transparency, the lower the efficiency. There are more and more solutions that make it possible to cover window panes with solar cells. "Window" cells based on a foil made of nanoparticles of titanium dioxide and pigment were constructed in Great Britain and in the USA. A disadvantage of the new solution is lower transparency and, thus, they are usually fitted on staircase windows or skylights.

Transparent foil pasted on the window panes and equipped with photovoltaic modules was developed in EnSol AS in Norway. The structure of the material is also based on nanoparticles. It is estimated that the efficiency of a photovoltaic cell constructed in this way can reach 20%. Commercial version of the technology created by EnSol should be available on the market in 2016 [10]. Figure 5 presents a summary of polycrystalline silicon cells manufactured by SUNWAYS with respect to their color and maximum efficiency values achieved [6].

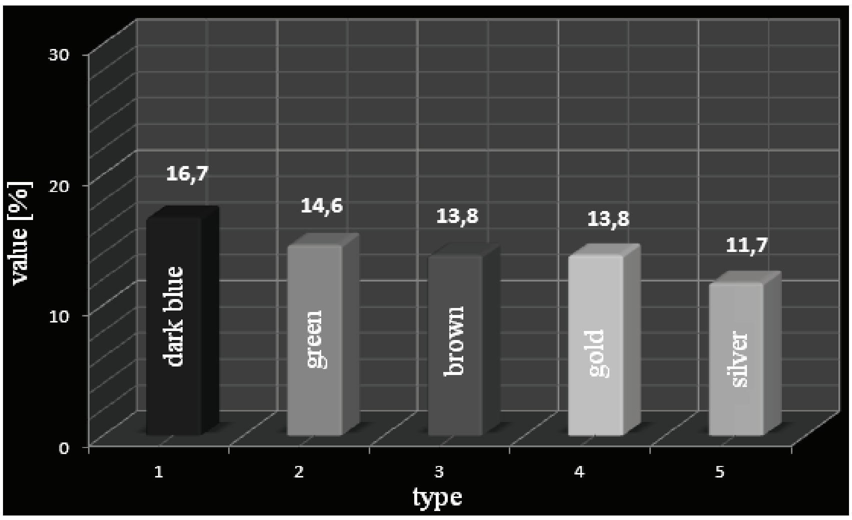

Fig. 5. The efficiency of colored silicon cells manufactured by SUNWAYS

As it is clear, colored cells are characterized by considerably high efficiency values for a widely used solution.

4. ENERGY GAIN SIMULATION FOR AN INCLINED BIPV FAÇADE

In certain solutions, photovoltaic wall modules fitted on supporting structures parallel to the wall (vertically to the surface) can be slightly inclined, for example at the angle of 75-85°, which provides their adjustment, at least partially, to the angle of the sun.

Considering higher efficiency values of solar collectors tilted in relation to the skyline in comparison to collectors positioned vertically, the option of increasing the energy gain through constructing a façade tilted at the angle of 75° in relation to the skyline was investigated. An example of such a building is presented on Figure 6. A computer simulation for the PV façade installation placed on the wall of the building tilted at the angles of 75° and 90° was executed. In both cases, the modules faced south. The nominal power of the installation was 2,8 kWp; the installation was constructed of polycrystalline cells.

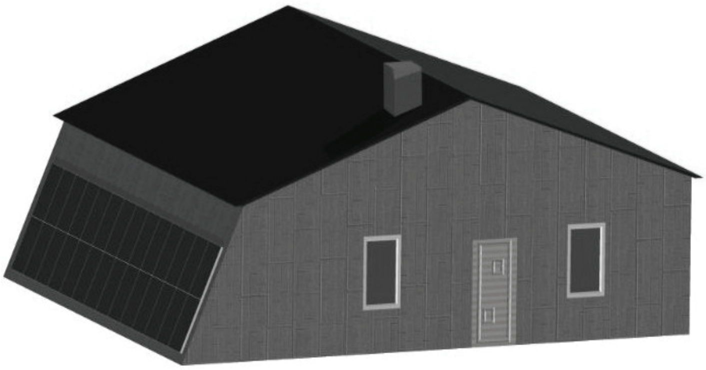

Fig. 6. An example of a building with a PV façade installation mounted at the tilt angle of 75° and facing south

Figure 7 presents the energy gain for the PV façade installation mounted at the angle of 75°. In the case analyzed, the gain achieved in the period of one year for the tilted installation located in Poznań exceeds the values obtained for a vertical wall by 20 %. Thus, a slight tilt of the wall which can be easily implemented both with respect to the construction as well as the visual design of the building can bring considerable benefits. Figure 7 presents the energy gain that can be achieved in the period of one year for a building façade installation with the tilt angle of 75° in comparison to a standard vertical façade.

Table 1 presents a summary of daily and monthly energy gain values.

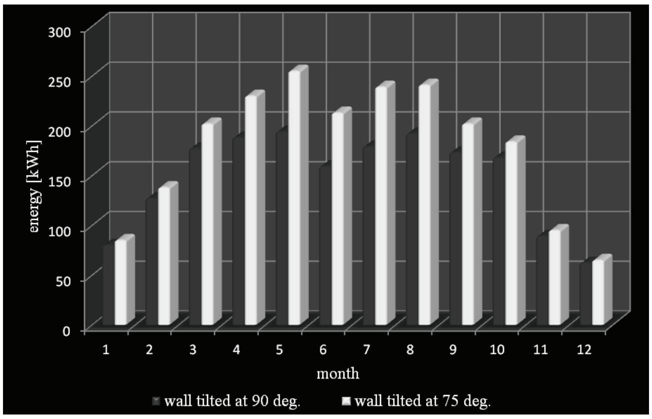

Fig. 7. The energy gain that can be achieved in the period of one year for a building façade installation with the tilt angle of 75° in comparison to a standard vertical installation

Table 1. Monthly energy gain and average daily energy gain obtained by using a PV façade installation tilted at the angle of 75° in comparison to a standard vertical installation

Gain / Month	Monthly energy gain [kWh]	Monthly energy gain [%]	Average daily gain [kWh]
January	5	6,3	0,2
February	11	8,7	0,4
March	25	14,1	0,8
April	42	22,3	1,4
May	61	31,4	2,0
June	54	34	1,8
July	60	33,5	1,9
August	49	25,5	1,6
September	29	16,8	1,0
October	17	10,2	0,5
November	6	6,7	0,2
December	3	4,8	0,1

5. CONCLUSIONS

On the basis of the analyses and the computer simulation performed, it was concluded that:

1. Using the tilted architectural object façade proposed by the authors makes it possible to achieve measurable energy gains.
2. For the analyzed location of the city of Poznań with the geographical coordinates of 52°24'59" N, 16°57'59" E, with the assumption that the power of

the façade installation used is 2,8 kWp, the gains achieved for a façade facing south and tilted at the angle of 75° in particular months are presented in table 1.

3. The annual energy gain for the tilt angle of 75° exceeds 20 %, which amounts to the value of 362 kWh in the case of the installation analyzed (Fig.7).
4. The highest energy gains resulting from the change in the positioning of the installation can be obtained between April and August.
5. A visualization of the object with a tilted solar wall (Fig. 6) confirms the fact that the esthetic value of the building is not compromised.

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