ACTIVE SOLAR SYSTEMS FOR ENERGY EFFICIENT FACADE STRUCTURES

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ABSTRACT

The manner of using solar energy affects the energy performance of the building, as well as the way of shape and materialization or the facility's architecture. Building envelope defines the architectural expression of the building and its relationship to urban and natural environment. Aesthetical expression in the application of active solar systems can be defined according the criteria for evaluating the aesthetic quality by applying the active solar systems, as well as according the concepts of visualization and parameters that determine shape-functional characteristics of active solar systems.

The most important issues while designing photovoltaic systems are: the optimal orientation of the buildings and tilting angle of the photovoltaic modules. In this paper, an analysis is made about the optimal photovoltaic system planned to be installed as an integrated in the structural facade of an existing building in Macedonia. The photovoltaic modules planned to be used are made of hydrogenised amorphous silica (a-Si: H triple). Possibilities that the material offers in respect of the transparency (percent of fullness) are considered in the analysis: opaque photovoltaic module (100% percent of fullness) and semitransparent photovoltaic module (50% percent of fullness). The analysis was conducted using the software PVSYST for calculation and design of the photovoltaic systems, using both methods of preliminary and detailed design. The most optimal photovoltaic system is the system built into the structural facade inclined at an angle of 60. The results of this study showed a maximum contribution of photovoltaic conversion, which also fits with the aesthetic characteristics of a facility. The active solar systems that integrate energy efficient facade structures, contribute to preserving the environment through the use of discretionary (green) energy resources. The usage of the active solar system for energy efficiency of the facade structures lives great development in the developed countries, but they still have not been used in Macedonia.

Keywords: solar energy, photovoltaic systems, structural facade.

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1. INTRODUCTION

Using solar energy has been present in the architecture since the earliest development of the human civilization. The solar energy can be used in the new designed, as well as in the existing buildings. The solar architecture is based on three ways of using solar energy, (Kosoric 2007):

- Passive way of using solar energy
- An active way of using solar energy
- Combined mode (active and passive).

1.1. Aesthetic aspect of buildings envelope during the application of active solar systems

The manner of using solar energy affects the energy performance of the building, the way of shape and materialisation or the architecture of the facility. Building envelope defines the architectural expression of the building and its relationship to urban and natural environment. Aesthetical expression in the application of active solar systems can be defined according (Kosoric 2007):

- Criteria for evaluating the aesthetic quality by the applying the active solar systems
- Concepts of visualization
- Parameters that determine shape-functional characteristics of active solar systems

2. CHARACTERISTICS OF PHOTOVOLTAIC SYSTEMS

Production of electricity from renewable energy sources is becoming more important, and photovoltaic systems can play an important role in it. Unlike the wind energy, biomass and hydropower, the photovoltaic systems extremely well adapt to the buildings.

Despite the fact of many examples which show that photovoltaic systems can be aesthetically neutral or visually attractive architectural element, many BIPV (Building Integrated Photo Voltaic) systems show several architectural qualities. In a good application, photovoltaic systems can improve the character and value of the building. Within the task 7 of the International Energy Agency's (IEA), Photovoltaic Power Systems (PVPS) program, a team of architectural experts studied the necessary requirements that should be satisfied (criteria for innovativity of the design for good quality of the photovoltaic projects) in order to produce a successful photovoltaic integration.

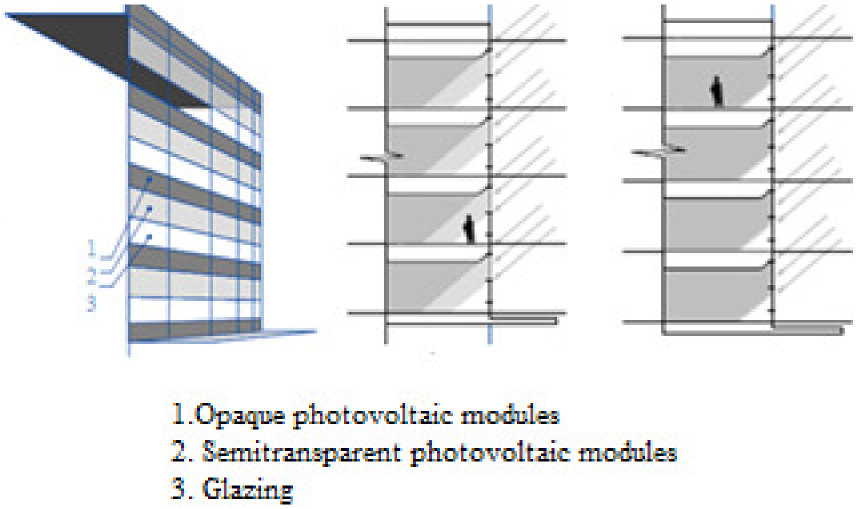
2.1. Functional characteristics of integrated façade photovoltaic systems

Apart from the production of electricity, photovoltaic systems have secondary functions such as:

- function of facade envelope and
- function of glazing or visual comfort.

2.1.1. Function of facade envelope

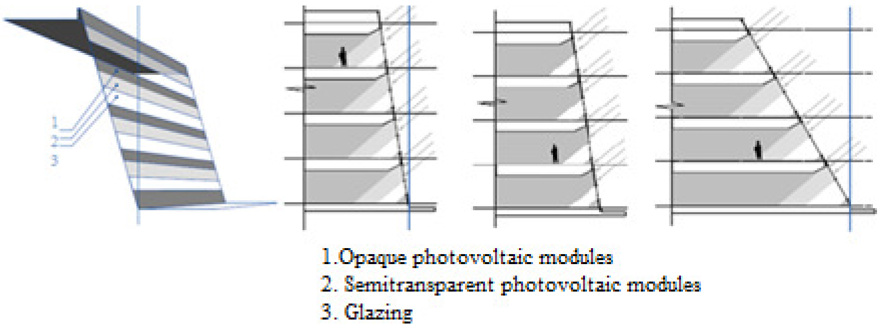
Photovoltaic systems used for facade envelope can be placed over the facade parapets or above the whole walls, on the lintels (Figure 1). Because these are parts of the facade where there should not be any light transmission, different types of non-transparent photovoltaic modules can be applied.



a) b) c)

Figure 1: Facade wall with integrated opaque and semitransparent photovoltaic modules

Integration of photovoltaic modules in the frames of the inclined facade wall gives the possibility of photovoltaic system with high efficiency. The opaque modules can be integrated on the opaque parts under different inclinations (Figure 2).



a) b) c) d)

Figure 2 - a) Inclined facade wall with integrated opaque and semitransparent photovoltaic modules b) Section through the facade wall with slope 60° with integrated opaque and semitransparent photovoltaic modules c) Section through the facade wall with slope 80° with integrated opaque and semitransparent photovoltaic modules d) Section through the facade wall with inclination 80° with integrated opaque photovoltaic modules (Farrington 1993)

2.1.2. Function of glazing

Semitransparent photovoltaic modules are used in a function of glazing (Figure 3). Different types of semitransparent photovoltaic modules can be used in materialization of the transparent parts in vertical facade walls, due to the specific requirements for heat transfer. Semitransparent photovoltaic modules can be used in materialization of transparent parts in inclined facades also. Application of semitransparent modules is represented in the Figures 2a, 2b and 2d.

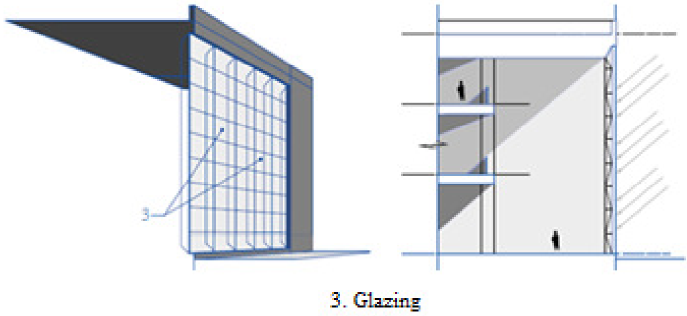


Figure 3: Layout and section of a structural facade with integrated semitransparent photovoltaic modules, (Farrington 1993)

2.2. Aesthetical characteristics of integrated photovoltaic systems

Architects are not faced with the question of whether to include photovoltaic systems in their designs and what will be the physical, mechanical, electrical, financial and organizational conditions of the building only, but they are primarily concerned with the issue of how to integrate photovoltaic systems from an aesthetic point.

3. CALCULATION METHODS FOR PHOTOVOLTAIC SYSTEMS

3.1. PVSYST – General data

There are many software packages for calculation and design of the photovoltaic systems. PVSYST is used in this paper. When applying the abovementioned software, one can use two methods (User Guide 1994), as follows:

- method of preliminary design
- method of detailed design

3.2. Applied materials

Taking into account the functional-shaping and aesthetic characteristics of the photovoltaic modules used in the building envelopes the possibilities provided by the photovoltaic modules integrated in-isolating glass will be considered in the structural walls. In this case, hydrogenated amorphous silicon (*a-Si: H tripple*) is applied, integrated in the isolating glass, (User's Guide 1994). The type of the *a-Si*: H tripple module which has a power of 42 Wp/m^2.

3.3. Application of a preliminary design - description of the experiment

Preliminary project will be done through a structural facade with integrated photovoltaic modules. The place that is planned for installation of the photovoltaic modules is determined by the aesthetic and the shaping characteristics of the building.

4. DEFINITION AND DIVISION OF TYPE A-STRUCTURAL FAÇADE

For integration of the photovoltaic modules in a vertical structural facade (type A), several variants can be defined (sub-types A1, A2, A3), which differ among themselves according to the inclination angle: 60°, 80°90°. Within this division, each sub-type will be considered through two categories of transparent material, such as:

- A1. Vertical structural facade - angle 90°:
  A1/1- opaque photovoltaic module
  A1/2- semitransparent photovoltaic module
- A2. Inclined structural facade - angle 80°
  A2/1- opaque photovoltaic module
  A2/2- semitransparent photovoltaic module
- A3. Inclined structural facade - angle 60°
  A3/1- opaque photovoltaic module
  A3/2- semitransparent photovoltaic module

5. DATA ANALYSIS AND RESULTS

5.1. Daily energy consumption

The preliminary design method gives a possibility for calculation of the total electricity needs for the requirements of the users.

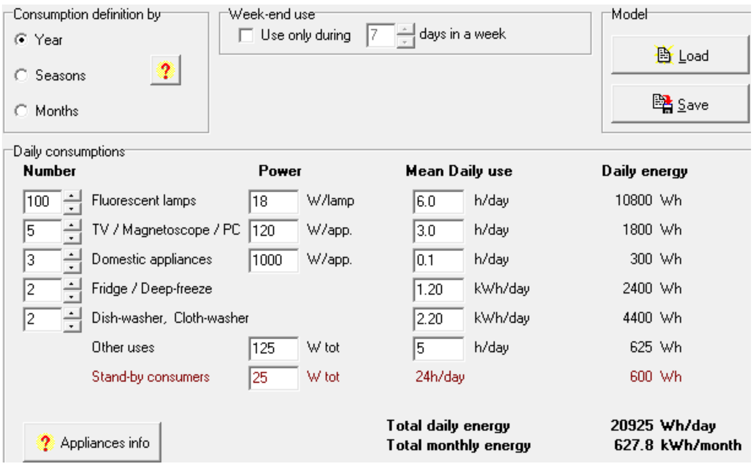


Figure 4: Daily consumption of electricity during a year, PVSYST

The main consumers of electricity in the residential and business building are shown in Figure 4, for which the preliminary design has been performed. The values are calculated for the period of use of seven days a week during the year.

5.2. Results for application of type A

The total annual production of electricity while installing integrated photovoltaic systems in the structural facade (type A) is obtained by summing the results of the individual orientations of the specified type. The total electricity produced will be different for each sub-type (A1, A2, A3). Values A1/1 and A1/2; A2/1 and A2/2, as well as A3/1 and A3/2 are summed, because the opaque and the semitransparent modules are planned to be used simultaneously over the parapets and over the lintels. The values are presented in Table 1.

Table 1 - Total annual electricity production of type A1, A2, A3

Orientation	**A1 (A1/1+A1/2)**(MWh)	**A2 (A2/1+A2/2)**(MWh)	**A3 (A3/1+A3/2)**(MWh)
East	3.50	3.89	4.59
Southeast	0.31	0.34	0.42
South	0.38	0.41	0.55
Southwest	0.31	0.34	0.42
West	1.65	1.83	2.16
Total:	**6.15**	**6.81**	**8.14**

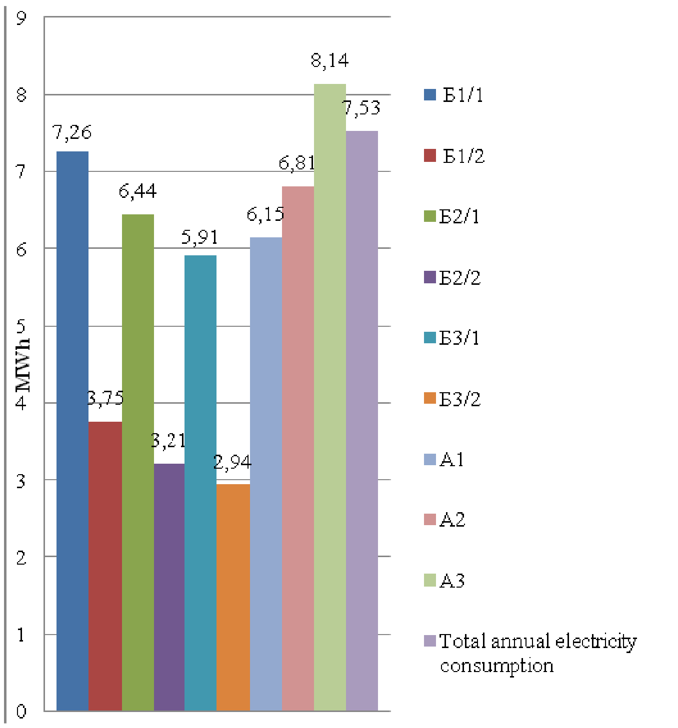


Figure 5: Comparison of the calculated values of total electricity production with a total annual electricity consumption.

Figure 5 shows all the values of generated electricity, for all sub-types compared with the annual electricity required.

Applying photovoltaic module of same material (a-Si: H / a-SiGe: H / a-SiGe: H-triple-junction) over the same area inclined at different angles, the same values of the investment, but different values of annual production are obtained. Type A3 is selected, which meets the basic requirements of the electricity consumers and also fulfils the shaping and aesthetic characteristics of the building, (Goxha 2012).

6. CONCLUSIONS

6.1. Short evaluation

This paper studies the analysis of the optimal photovoltaic system, planned to be installed in the structural facade in a building in Gostivar, Republic of Macedonia. This system is considered as a photovoltaic system integrated into the structural facade (type A).

The photovoltaic modules planned to be used are made of hydrogenized amorphous silica (a- Si:H tripple). Possibilities that the material offers in respect of the transparency (percent of fullness) are considered in the analysis: opaque photovoltaic module (100% percent of fullness) and semitransparent photovoltaic module (50% percent of fullness).

The necessary data are provided using the sophisticated software *PVSYST*. For Gostivar, the data is as follows:

- latitude: 41°48′
- longitude : 20°54′
- elevation: 526 m

The optimal solutions for all types (A1, A2, A3) and sub-types (A1/1, A1/2, A2/1, A2/2, A3/1, A3/2) are obtained using the method of preliminary design. Summation of the results is performed through few steps:

- Each orientation is considered separately, and total annual production per each orientation is obtained.
- Total production of electricity for the whole building of type A is determined.
- The obtained values of the total production of electricity are compared to the total annual consumption (diagram 1)
- The most optimal and the most appropriate solution is adopted.

The most appropriate designed optimal photovoltaic system is the one comprised of photovoltaic modules that are integrated on the inclined structural facade, under an angle of 60°. These photovoltaic modules are arranged in two bands, i.e.: the opaque part of the parapet wall is covered by non-transparent modules, while the part on the lintels is covered by semitransparent modules. In this way, the aesthetical criteria, as well as the customers’ needs are fulfilled.

The annual necessary consumption of electricity for the whole building is 7530 kWh. This value is completely compensated by production of the electricity with photovoltaic system, and by the total produced quantity of 8140 kWh during one year. In other words, the produced energy in the building is 1,85 kWh/hour, while consumed is 1.3 kWh/ hour electricity. The rest of the electrical energy, about 0.55 kWh/hour or 2376 kWh/annually, is a surplus of electricity, i.e. a part which is repurchased by the local distributive companies. When the payment of the investment is considered, it should be mentioned that World Bank has a great part in the investments, almost 70% of the total investment is on them.

6.2. Conclusions and recommendations

The above mentioned facts lead to a unique conclusion that the collaboration between the architects and the civil engineers should be closely connected, in order to achieve the final results:

- Active solar systems aesthetically integrated in an energy efficient structural facades
- Optimally designed system that enables maximum contribution
- Quality in-built modules and additional equipment that provide durability of the system
- Economical profitability, including the Government's projects in collaboration with the World Bank, projects of the distributive companies and their interest in payment of the surplus of the produced electricity.
- Great contribution to the environmental protection with a usage of the infinitive (green) resources of energy.

The usage of the active solar system for energy efficiency of the facade structures lives great development in the developed countries, but they still have not been used in Macedonia, (Popovska et al. 2009).

Hopefully, the conscience and the interest of the architects in active solar systems will rouse, and with a common collaboration of the companies and all other key factors, the necessary conditions for their application will be provide in Macedonia soon.

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