FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 15, No 2, 2017, pp. 145-152
DOI: 10.2298/FUACE160328010S

ANALYSIS OF THE REQUREMENTS FOR INSTALLING PHOTOVOLTAIC SYSTEMS IN ORDER TO ACHIEVE IMPROVED PERFORMANCES: CASE STUDY OF THE CITY OF NIŠ

UDC 728:621.311.243(497.11)

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Abstract. *The use of renewable energies is imperative nowadays. One of the ways to use clean technologies is installation of photovoltaic systems which convert solar energy into electricity, through solar plants. The country's potential for usage of solar energy is determined by the analysis of climatic conditions. The research is conducted on the example of a small-scale solar plant – a pilot project installed in the city of Niš, concerning the analysis of the mounted system and giving the recommendations for their design with the aim of improving efficient energy use. Limitations in the installation of solar plants can occur in the case of an unfavorable position of the building where the installation is planned, and more often, the limitations are related to the investment costs and length of the repayment period of these kinds of technologies. This paper represents a promotion of sustainable electricity supply for our country and it is in correlation with the legal directives of using renewable energies.*

Key words: *renewable energy, photovoltaic systems, climatic conditions, building properties.*

1. INTRODUCTION

The use of renewable energies is a necessity nowadays, because it contributes to the preservation of fossil fuels – non-renewable energy resources (natural gas, coal, oil) and improves the impact on the environment. Sustainable energy supply is also provided, and related to this, the systems for its use have to be developed.

Received March 28, 2016 / Accepted April 20, 2017
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Photovoltaic technology is one of the finest ways to use solar power [1]. The conversion of solar energy into electricity is realized through photovoltaic systems. They consist of photovoltaic modules and balance-of-system (BOS) components [2]. One or several modules constitute the solar panel and they constitute a solar plant with the BOS components. The photovoltaic energy is clean, simple in design and requires very little maintenance [3].

The first solar plant in Serbia was installed in the city of Niš, in the summer of 2011 [4]. It is a rooftop construction, placed on the flat roof of the Faculty of Electronic Engineering and has six photovoltaic panels with the total power of 1200 W. This small-scale solar plant is a pilot project which aims to educate students on the importance of using renewable energies and promote such technology in our country. This type of construction – rooftop construction is very suitable for application because the majority of existing buildings, both residential and public, have flat roofs.

The topic of the paper is the analysis of the requirements for installing photovoltaic systems concerning the country's potential for solar irradiation and includes the recommendations for their design. The recommendations concern the analysis of the relationship between the building's orientation and the solar panel orientation, as well as the disposition of the building in relation to the environment. It was done in order to achieve the highest system efficiency.

2. The Country's Potential for Solar Irradiation

The energy yield of photovoltaic systems depends on a large number of factors. The most important factor is the amount of solar radiation energy which arrives in the plane of the photovoltaic modules, which in turn depends on the local climatic conditions [5]. The intensity of solar radiation varies on different locations [6].

The Republic of Serbia has some of the best solar resources in Europe and solar irradiation is approximately 1400 kWh/m2/yr, which is around 40% higher than the European average. For comparison, the lowest measured values for solar irradiation in Serbia are comparable to the highest values in the leading countries in solar utilization, such as Germany and Austria [7]. The southern part of the country has the highest solar potential, including the cities of Niš, Kuršumlija and Vranje.

Figure 1 and Figure 2 show the direct normal insolation values and the global horizontal irradiation values for the Republic of Serbia [7].

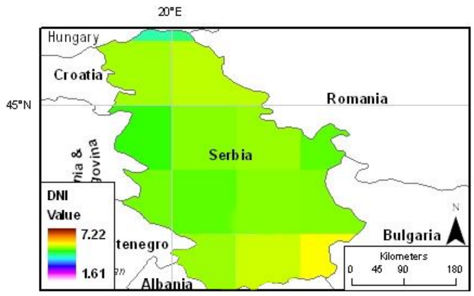

Fig. 1 Serbia solar direct normal insolation

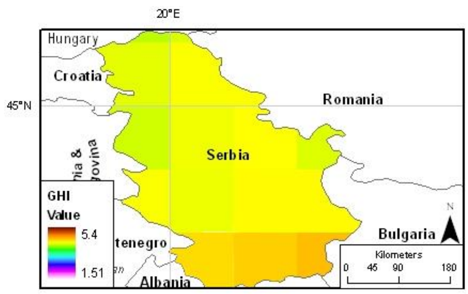

Fig. 2 Serbia solar global horizontal irradiance

The fact that the number of sunny hours is more than 2000 [8], which is higher than the European average, confirms that Serbia has a great potential for the exploitation of solar energy.

3. CHARACTERISTICS OF THE PHOTOVOLTAIC SYSTEMS

The characteristics of the photovoltaic systems are presented through classifications related to operating mode, mounting position and utilization of available solar energy.

3.1. Operating mode

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads. The two principal classifications are:

- Grid-connected or utility-interactive systems and
- Stand-alone systems [9].

Photovoltaic systems can operate interconnected with or independent of the utility grid, and can be connected to other energy sources and energy storage systems.

The small-scale solar plant installed on the rooftop of the Faculty of Electronic Engineering is a grid-connected photovoltaic system with six photovoltaic panels and the total power of 1.2 kW.

3.2. Mounting position

By mounting position, photovoltaic systems can be:

- Free-standing and
- Building integrated systems.

Free-standing photovoltaic systems are structures supported on steel framing, i.e. their own structure. They can be placed on the ground or attached to rooftops and building structures. Ground mounted systems need additional space and the constructions can be large, because they have their own foundations (Fig. 3 [10]). They are characterized by an easy access. However, rooftop constructions do not need additional space, which is suitable for densely built urban areas and places where ground construction cannot be installed. If the systems are small scale, there is no need for additional supporting structures. That is the case of the solar plant in the city of Niš (Fig. 4 [4]), because the additional weight of the photovoltaic system is only around 120kg plus weight of construction for panels installation [11]. For the rooftop constructions, the details of fixation of photovoltaic systems on existing roofs should be taken into consideration. For the systems which are not fixed on existing constructions, but only placed, a particular problem is related to wind resistance and stability.

Fig. 3 An example of a ground mounted system

Fig. 4 Rooftop construction – solar plant in the city of Niš

Building integrated photovoltaic (BIPV) system implies displacing conventional building materials by the materials which provide fully integrated electricity generation, while also serving as part of the weather protective building envelope. It can serve as a shading device for a window, a semi-transparent glass facade, a building exterior cladding panel, a skylight, parapet unit or roofing system, etc. [12]. Figure 5 [13] shows an example of building integrated photovoltaic system. Such systems allow architects to design the whole building, instead of fitting the rooftop structure.

Fig. 5 An example of a building integrated photovoltaic system

3.3. Utilization of available solar energy

Utilization of available solar energy is related to the amount of solar energy which can be obtained for a given area of photovoltaic modules. Whether the utilization of solar energy is complete depends on the construction of solar panels, i.e. whether the system is:

- Fixed or
- Tracking [14].

Firstly, it is important to define two angles in photovoltaic module position. One angle is the horizontal orientation in which the modules face straight up towards the zenith. The other is the inclination angle in which the modules are tilted with respect to the ground at an angle equal to the site latitude [14].

Fixed systems have both angles fixed. Tracking systems may have fixed horizontal orientation and the movable inclination angle in the case of 2-axis tracking systems, and both movable angles for 3-axis tracking systems. The greatest amount of solar energy is obtained when the sun's rays fall perpendicularly to the module surface. It is known that the angle of the sun's rays changes during the seasons, so the tracking systems have better utilization of solar energy, because they can obtain the greatest amount of solar energy at any time by adjusting the angle perpendicularly to the sun's rays.

For example, for the city of Niš, the optimal panel inclination angles during the year are shown in Figure 6 [11].

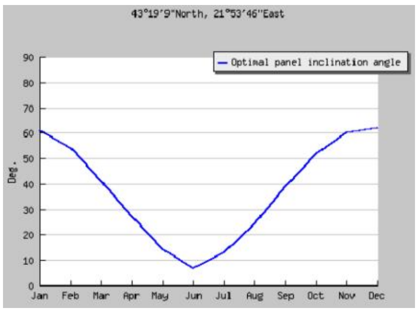

Fig. 6 The optimal panel inclination angles during the year for the city of Niš

Photovoltaic modules are typically installed on structures by using a fixed module orientation dependent on the site characteristics. It is much easier to install a fixed photovoltaic system than the tracking system, and the investment costs are lower. The advantage of the tracking systems in which photovoltaic modules are pointed at the sun is achieving the overall capture of solar energy by a given area of modules by 30 – 50% when compared to modules with a fixed tilt [14].

The solar plant in the city of Niš is a fixed system in which the panels have the south orientation in the horizontal plane and the inclination angle of 33° (Fig. 7 and Fig. 8) [4].

Fig. 7 Fixed photovoltaic system

Fig. 8 South orientation of panels

4. Building Position

The position of the panels in relation to the position of the building is discussed in the case of installation of the photovoltaic system as a rooftop construction. In this regard, the position of the building is analyzed as:

- Absolute (building orientation) and
- Relative (the position of a building in relation to other buildings and the environment) [15].

4.1. Utilization of available solar energy

In the northern hemisphere, the most favorable building orientation is south, because the greatest amount of natural light comes from the south. However, the orientation was not the primary condition of building design and construction in the past. This is important for the analysis because the south orientation is also the most favorable orientation for the photovoltaic panels in the horizontal plane, concerning northern hemisphere.

The design and installation of the system should be fitted into the building's architecture and into the environment. The solar plant on the rooftop of the Faculty of Electronic Engineering in Nis is a small scale solar plant, with six photovoltaic panels, and its size does not affect the environment.

Figure 9 [11] shows the basis of a flat roof of the Faculty of Electronic Engineering and the disposition of the panels with south orientation.

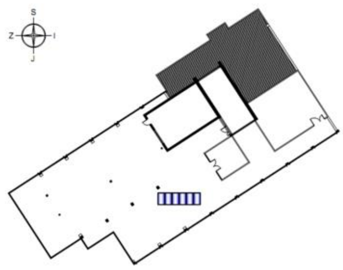

Fig. 9 Building orientation and panel disposition

4.2. The position of a building in relation to the environment

The position of a building, on which the construction of photovoltaic system is planned, in relation to the environment, is very important, because the appearance of shadows from adjacent buildings or trees would reduce the efficiency of the system.

On the example of the faculty building, whose flat roof the photovoltaic system is installed on, it can be seen that the building is free-standing and the environment does not affect the appearance of shadows on the roof (Fig. 10 [11]).

Fig. 10 Site plan of the Faculty of Electronic Engineering, Niš

5. Limitations

Limitations related to the installation of photovoltaic systems refer to spatial impossibility or unfavorable position to install the system on a particular location or on a building. They also refer to investment costs.

Solar photovoltaic systems are generally characterized by a high fixed cost and low operational cost, unlike conventional generation sources which have substantially high operational costs that cannot be ignored in the investment planning programs [16]. The most commonly used and the simplest way to estimate economical characteristics of a photovoltaic system is the payback period. The payback period can be appropriately defined as the time needed for the cumulative revenue earned to equal the total initial investments. It is an important indicator for the life-cycle analysis of photovoltaic systems [17].

The example of justifiability of financial investment is the data for the mini solar power plant "Domit" in Leskovac [18]. In 2012, the investor company constructed the first solar plant in the south of Serbia, with the power of 30kW, which is connected to the distribution system of the Serbian electric power company, for which the subvention tariff is guaranteed by the state for 12 years since commission, at a price of 20.66 of Eurocents per 1 kWh. The total annual income is around 7,500 Euro [19]. Regarding that, the value of the investment is around 45,000 Euro, and it is clear that the investment is returned after six years [20].

On the example of the pilot project of the solar plant in the city of Niš, with the total power of 1,2 kW, the payback period is calculated to be 8 years, based on the country tax incentives and rebates for solar energy [4].

6. CONCLUSION

Solar energy is a clean, renewable way to provide electricity. By using photovoltaic technologies through solar plants, solar energy is converted into electricity. Recommendations for the design are given in order to achieve improved performances.

Concerning the country's potential for solar irradiation, it has been concluded that the Republic of Serbia has some of the best solar resource in Europe. A grid-connected and free-standing photovoltaic system installed as a rooftop construction in the city of Nis was analyzed with regard to the requirements for the design. The advantage of such systems is that they can be installed on existing buildings, while building integrated photovoltaic systems have to be pre-planned in the building designs. However, building integrated photovoltaic systems are more efficient because the envelope of the building has a dual function: weather protection and electricity generation.

Fixed photovoltaic panels are easier to install and they are more economical in comparison to the tracking systems which have better performances in collecting the solar energy.

The orientation and disposition of the building, on which the installation of the photovoltaic system is planned, have an influence on setting the panels. In terms of architectural design, it is necessary to fit new construction into the existing environment, as well as to provide the best conditions for solar energy collection. The small scale solar plant in Niš does not affect the building's architecture by the position of the panels on the rooftop, and the environment also does not affect the operation of the solar plant.

The greatest efficiency of the system is provided by the fulfillment of the requirements for design and construction of the photovoltaic systems.

The economic factor for installing the photovoltaic system is very important at the present. The use of technologies for a sustainable electricity supply is in correlation with the legal directives of using renewable energies in our country. For this reason, the reduction in the cost of photovoltaic technology installation and the reduction of the payback period are expected in the near future.

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ANALIZA USLOVA ZA POSTAVLJANJE FOTONAPONSKIH SISTEMA U CILJU POSTIZANJA UNAPREĐENIH PERFORMANSI: STUDIJA SLUČAJA GRADA NIŠA

Korišćenje obnovljivih izvora energije je imperativ u današnje vreme. Jedan od načina primene čistih tehnologija je instalacija fotonaponskih sistema koji konvertuju sunčevu energiju u električnu, preko solarnih elektrana. Analizom klimatskih uslova je utvrđen potencijal zemlje za upotrebu solarne energije. Na primeru solarne elektrane malog kapaciteta - pilot projekta izvedenog u gradu Nišu, sprovedeno je istraživanje koje se odnosi na analizu postavljenog sistema uz davanje preporuka za njihovo projektovanje u cilju povećanja energetske efikasnosti. Ograničenja koja se javljaju u vezi sa instalacijom fotonaponskih sistema su nepovoljan položaj objekta na kome je planirana izgradnja, a mnogo češće se odnose na investicione troškove i period otplate ovakvih vrsta tehnologija. Rad predstavlja promociju održivog snabdevanja električnom energijom za našu zemlju, što je u korelaciji sa zakonskim direktivama korišćenja obnovljivih izvora energije.

Ključne reči: *obnovljivi izvori energije, fotonaponski sistemi, klimatski uslovi, karakteristike zgrade.*