Sustainability and profitability of photo voltaic systems as effective renewable resources application

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Abstract. Solar panel functionality, design, accessibility on the world market, their costs and maintenance are considered in this manuscript. Those are all crucial issues that will determine the following use of solar panels in the future. Solar panels are very important and innovative step to smart cities and environment. There is a constant improvement of those devices and their appearance. At the moment, they are a very powerful tool which represents the strength of renewable resources. Through this manuscript, also the benefits of its application, economic and technical aspects are analyzed and discussed.

Introduction

Sustainability through renewable resources application is on the agenda of most countries, regions [1], organizations, and particularly cities [2]. New methodological approach are developed with the goal to justify its feasibility [3]. Solar panels are seen as an effective eco-building tool in the power utility management while protecting green environment. They are mostly integrated in the residential buildings as in buildings with different purposes, as well as in rural areas [4]. The functioning of the solar panels is based on light conversion into electricity. One of the obstacles of this function, is low efficiency of the energy conversion, thus there must be large areas for sufficient insulation. Not less important are financial aspects of solar panels installation, initial costs, costs of maintenance, discount rate interest, investigation linked with insulation hours, location of the residential area, and design of solar panel. Solar panel industry advances each day and it is unstoppable on the market. It is becoming one of the inevitable equipment for modern technologies and for gaining more or less free energy [5]. The need for alternative sources of energy occurred for several reasons:

- the inability of current primary sources to meet the demand for energy due to the constant increase of energy consumption at a global level,
- an increase in electricity prices due to the conflict between production and consumption,
- energy obtained by burning fossil and nuclear fuels leaves growing ecological consequences,
- constant and increased exploitation of non-renewable energy sources will come to the same vanishing reserves.

The above reasons have resulted in the increasing awareness that new energy sources are essential in order to avoid dependence on non-renewable energy resources and their negative impact on the environment [6]. Therefore, to meet the energy needs of the population in recent times, use of renewable energy sources, especially solar energy, is dramaticly increasing [7].

Renewable energy sources include: water energy (hydro), wind energy, solar energy, biomass, geothermal energy, tidal energy (energy of tides, waves, natural currents) [8-10]. Solar radiation, in addition to direct radiation, is responsible for the constant renewal of wind energy, ocean currents, waves, and water flows. Solar energy arrives to Earth in the form of light and heat. It's free and anywhere available source of energy, which in one hour sends as much energy as the entire population

of the Earth spends annually. Solar energy is sufficient to produce annually an average of 1700 kWh/m^2 of electricity [11]. Solar energy is most commonly used in the following two ways:

- Solar collectors - systems that convert solar energy into thermal energy of water (or other fluids)
- Photovoltaic systems - directly convert solar energy into electricity on the principle of photovoltaic effect.

Long before the PV systems have become a reliable source of electricity in the systems connected to the electricity grid ("on grid"), they were used as an isolated "off-grid" systems for power supply in remote areas where the network was unavailable. Secondly, in cases of more power photovoltaic systems, they are used as additional sources whose energy is injecting in the electric power grid in order to transport to the users ("on grid" systems) .

Solar-cell configuration

Solar cells are little, minor units that accumulate solar energy and convert into electrical energy. When photons of light fall on the cell, they transfer their energy to the charge carriers. In the core of PV cell, there is a p-n junction, which consists of two semiconducting silicones (two layers) (Fig.1) [12]. The p-n junction functions as a certain circuit. This circuit generates an electric field. The electric field over a junction triggers in circuit an electric flow. Energy conversion efficiency can be improved by using appropriate materials for the coverage of the p-n junction. For instance one of the appropriate materials for gaining efficiency is antireflection coating and the other is textured surface. These materials enhance the spectral sensitivity of the silicon photodiode and absorb more sunlight rays. Solar cells could be composed of various semi-conducting materials [13]. One of the negative characteristics for solar energy conversion efficiency is its dependence of solar cell temperature. Changing of solar cell temperature could produce the gaps in transmission of a current. There is another constant, which is described as the fill-factor *ff*. It is defined as ratio of the maximum power (P max) and initial power (P 1).

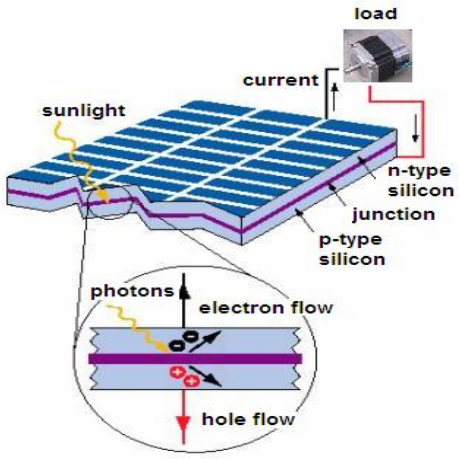

Figure 1. A schematic view of a PV cell core layers

According to the red curve in the Figure 2 [14], as in p-n junction emerges constant current I and as voltage raises, power P=V*I raises linearly with voltage. Obviously from Fig.2 current I is constant up to some value of voltage (V_{opt}) /in this case 16V. In range of V(0,16v) p-n junction operates as a constant current source. As reaching a critical point of a voltage (V_{opt}),

the power reaches the maximal value P_{opt}. When the voltage is over a critical point V_{opt}, and keeps raising over the limit, the current will fall sharply and consequently the power falls.

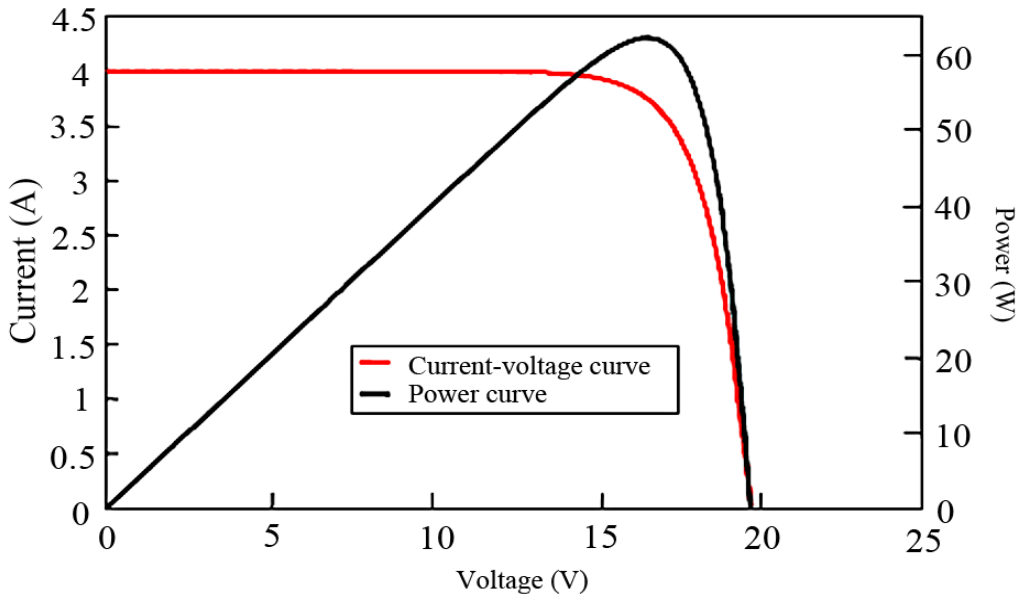

Figure 2. Typical I-V and P-V characteristics when the temperature changes: crystal silicon module with the variation of the power

Electricity transformation efficiency of solar cells is very low and reaches about 14%. The efficiency should be improved with different strategies and methods. One of the methods is Maximum Power Point Tracking (MPPT). This method is supposed to adjust the changing temperature of a cell to the working conditions and to balance with the voltage value of an array of solar cells, trying to maintain V_{opt}, i.e. P_{opt}. This method also manipulates with radiant intensity adjusting angle of solar panels. The intention is to find optimal factors (leading to P_{opt}) that can make benefits from using solar modules and panels. The conclusion is that must exist the balance in solar spectrum and that the cumulative voltage should never be over a critical point.

Innovative application of solar panels

Photovoltaic solar systems become more and more incorporated in national energy strategies and energy plans all over the world. Japanese Ministry for economy, trade and industry (METI), plans to install photovoltaic solar systems of 5 GW power up to 2020.year. Until 2030. year it is predicted that the power of these systems will be 82,8 GW [15]. Numerous organizations, like EPIA and Greenpeace association predict that the most expanded use until 2020, will have solar „on-grid systems", of whom 80 % will be integrated in residential area.

German Government intends to enhance the partition of alternative sources from 13% currently, to 27% in 2020. At the moment, in Germany there are more than 400 000 photovoltaic solar systems, although under the law were allowed just 100 000 PV solar systems. Despite of very overcast and rainy weather, and small amount of insulation hours (1500h/year), Germans invest a lot in the use of solar energy [16]. All these statistical data show the accessibility and popularity of PV solar mechanisms and their sale on the world market.

Germany is a world leader in giving incentives for producing electricity from solar panel mechanisms.

Facade and roof PV solar systems became a popular replacement for classical building materials. They are used as front and top glass coverage and layers. They also participate in a transmission of a solar energy and as insulators. They are significant for a physics of a building.

There is an interesting application of solar cells in the framework of modern technology, that is still under investigation. It is so called Dynamic Shading Window System, which is developed by researchers in a multidisciplinary research firm Materiallab. This technology relates to an integrated, solar concentrating semitransparent plastic modules that are located in the space between two glasses. In each module are integrated glass lenses that follow the movement of the sun. This system uses the most superior solar cells that absorb light more efficiently compared to other technologies of solar cells.

There are different configurations of solar-cell mechanisms. The focus of the illumination is achieved through various lenses, mirrors and plates. The complex configuration of solar panel system, so called Power-Tower uses digitally controlled lenses as a mirror for concentrating the amount of rays on the central tower. Tower is further linked to the water heater or a heat pump.

There are certain factors which influence on application and performance of PV systems and they are sorted as a relevant criteria:

- technical-building aspect; location of a building;
- thermal performance of a building unit; esthetic and architectural aspects;
- installation, manner of use and maintenance of PV system; profitability of PV system;
- materials and compatibility in terms of environmental protection

Figure 3. Solar bridge in London and solar-roof and facade 24 m² in Germany [17]

Economic aspects of solar panel installation and their maintenance

The prices of photovoltaic systems have fallen sharply in the period between 1991 and 2000 when their prices fell by more than 3 times. Expenses of the works have also declined in recent years due to the increase of this market and standardizing the product. The price of installing a PV system depends on the kind of system, its size and technology applied. According to some statistics for maintenance of PV systems, for the solar systems of 5 kW, assumed quantity of maintenance hours is 8 hours per year. For solar systems with the power of

5-100 kW the needed quantity of maintenance is 16 hours per year and for solar systems with power beyond 100kW, this quantity of maintenance is 24 hours per year.

The initial investment costs are the costs of preparation and project management as well as the cost of the works. The initial investment costs (Eq. 1) can be broken down into two components:

$$\mathbf{I_o = I_{of} + I_{oc}.} \quad (1)$$

$\mathbf{I_{of}}$ - one-time expenses at the beginning of the project
$\mathbf{I_{oc}}$ - costs that are reusable and repeated throughout the project

Other dynamic criteria for the project installation of solar system are:

- net current value; rate of savings; discount rate of return;
- dynamic payback period; internal rate of return;

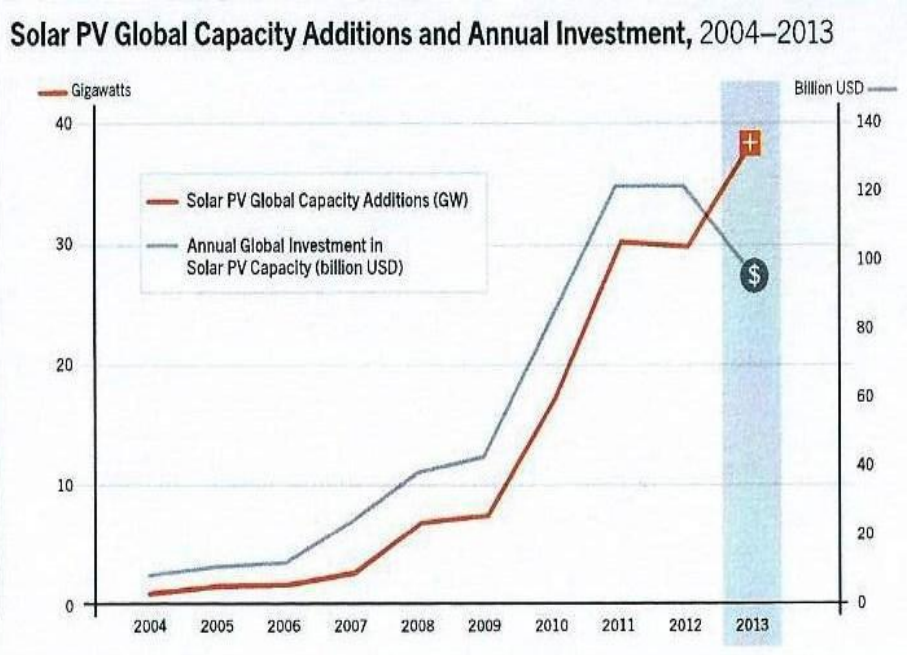

Figure 4. Globally new-installed PV systems until 2013: investment -22%, additions +32% [18]

A comparative analysis of cost-effectiveness - an example

An example of the cost of installing solar collectors for domestic hot water - for household with 4 members of the family:

- on average, it takes about two solar collectors (about 4 m2) and boiler capacity of about 200 liters. Price system for heating domestic hot water using solar energy from 1500 to 2000 €, depending on the quality;
- installing systems to heat water four-member household would annually save about 2,800 kWh to 3,600 kWh of electricity. The value of these savings is approximately 120 € per year. In addition, any increase in the price of electricity would affect the reduction of the period for return on investment.

According to the results of the European Association "Interat", the price of heating water for household using flat solar connectors - in areas where there are more than 1,600 hours of sunshine a year, today is 1: 1 - compared to other heating systems water. In the case of the construction of the basic solar system - installations for the heating of domestic hot water with two solar collectors and water tank (battery heat - boiler) volume of 200 liters can save around 70% or more of annual electricity consumption for heating water. Smaller prices for heating relates to cheaper solar panels and installations. Bigger prices relates to the more expensive systems with more complex installations with heat exchangers, system of forced circulation of fluids and automatic regulation of operation.

By today's electricity prices the value of invested capital (investments) would be returned for about 10 to 12 years. However, it is unlikely that the price of electricity in the coming years will not grow, and therefore really pay off time will not be longer than five years. Some of the analyzes related to the assessment of the increase in electricity prices point to the likelihood that the pay off period will be even shorter - from three to five years. Most of the certified system has a service life of 25 to 30 years, and after the expiration of ten years from the installing, the solar system will free to heat water for 15 to 20 years. The only charge for his work is negligible maintenance and supply pumps, whose power is, depending on the manufacturer and the system range, from 40 W to 65 W. The entire system, therefore, will not use more electricity than a regular light bulb.

If every household in Serbia (2.5 million households) would have only one unit of solar collector (with collector area of 2 m^2) for heating hot water - on an annual basis will be saved amount of energy equivalent to the heat energy obtained by burning about 500,000 tons of oil, or about 5 kWh energy. For a service life of 30 to 50 years - it would be about 15 to 25 million tons of oil. If that amount of oil put into the rail tanker - it annually would be the rail tanker composition about 500 km long.

Conclusion

In recent years, the human population has become aware that it is necessary to find new sources of energy because of the constant utilization of primary energy sources resulted in the disappearance of the same, as well as irreparable environmental pollution. The increase in CO_2 emissions leading to global warming, i.e. climate change The solution was found in renewable energy sources, especially solar energy which is subject of this paper..

Solar, clean renewable energy falls to Earth every day for free, regardless of any human activity. In addition, every day the sun sends a lot of more energy than we can use. Solar energy the Earth receives in a day would provide the world's total energy needs for a period of 30 years at the current rate of consumption. This dramatically illustrates the potential of solar energy, but a number of factors - technological, economic and others prevent us to take advantage of this potential.

Widespread application of renewable energy sources is the the reality of most developed countries in Europe and the world. Not only because renewable sources are environmentallymore preferable vs fossil fuels, but also because they are domestic energy sources increasing the employment rate. It can be said that the profitability of solar cells and their scale of application depends not only on sunshine, but also from incentive state compensation, and in particular of the level of market price of electricity.

End-of-use recycling technologies are under development. Facilities can operate with little maintenance or intervention after initial setup. Solar electric generation is economically competitive where grid connection or fuel transport is difficult, costly or impossible. Examples include satellites, island communities, remote locations and ocean vessels. Once the initial capital cost of building a solar power plant has been spent, operating costs are low when compared to existing power technologies.

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