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Considerations regarding PV systems

Ciprian Vlad[1,*], Cristian Victor Lungu[1]

[1] *“Dunarea de Jos” University of Galati, Faculty of Automation, Computers, Electrical and Electronics Engineering, Department of Automation and Electrical Engineering, 800008 Galati, Romania*

[*] *Corresponding author: ciprian.vlad@ugal.ro*

Abstract
The integration of renewable power supplies in urban areas and their integration in everyday life is the new trend for the latest research. By using renewable power supplies combined with the latest improvements regarding energy efficiency can help reduce energy consumption, greenhouse gas effect and toxic emissions. This paper presents the latest research in PV systems integration within cities. Urban areas have an unexplored potential for decentralized power production. PV systems are affordable and require minimal maintenance, thus making them suitable for such applications.

Keywords: micro power systems, photovoltaic power, PV fabrication, renewable power supplies.

1. INTRODUCTION

Solar cells provide the most benign approach to the world’s energy crisis. Photovoltaics are regarded favourably as a long-term option for sustainable energy supply, aiding at least to partly reduce emissions [1].

At the end of 2019 the European Green Deal was published, this is the most important action towards obtaining climate neutrality. During the COVID-19 crisis, the EU presented, as a response, in July 2020, the European Recovery Fund. The European Commission proposal of September 2020, that proposed 55% emission reduction in 2030, together with the European Parliament proposal that followed soon after, had changed the level of greenhouse gas reduction ambitions. Energy system modelling shows that achieving the updated targets will require large quantities of renewables deployed at an unprecedented pace. Over the past 10 years solar PV has achieved the technological and market maturity to spearhead EU efforts to reach the energy and climate targets [2].

2. GENERAL OVERVIEW

Photovoltaic panels (usually abbreviated PV) are a renewable source of energy that functions by enabling the direct conversion of solar radiation into electric current [3].

The broad categories of technologies used for photovoltaic panels are classified as follows: 1st, 2nd and 3rd generation technology. Crystalline silicon cells represent the 1st generation; cadmium telluride cells are part of the 2nd generation (and other thin film technologies). Third generation includes technologies that have not been commercialised on a large scale yet. Thus, the classification is as follows[4]:

- 1st generation Crystalline Silicon (c-Si), monocrystalline are very efficient, but expensive, highest purity silicon, sophisticated manufacturing process, multicrystalline or polycrystalline, solar cells cut from multifaceted silicon crystals, most common type used, cheaper than monocrystalline;

- 2nd generation, thin film are one or more thin layers of photovoltaic material on surface, e.g. glass, stainless steel or plastic, these are amorphous silicon, non-crystalline form of silicon, uses less scarce materials; cadmium telluride (CdTe), semi-conductor compound formed of cadmium and tellurium, cost-effective but not as efficient as crystalline silicon, these panels have a high toxicity of cadmium; copper-indium-gallium-selenide (CIS or CIGS), it's a newer technology, highest efficiencies of thin film technologies, higher manufacturing costs because of the complexity of the process;
- 3rd generation Concentrator photovoltaics (CPV) and emerging technologies. CPV utilises lenses to focus sunlight on to solar cells. The cells are made from very small amounts of highly efficient, but expensive, semi-conducting PV material. CPV cells can be based on silicon or III-V compounds usually gallium arsenide (GaA); Dye-sensitised solar cells are lower-cost and release electrons from, titanium dioxide covered in a light-absorbing pigment; Organic solar cells are composed of biodegradable materials such as organic polymers or small organic molecules; while lower in cost they can present a risk of material degradation and instability; last, hybrid cells involve the combination of current technologies on the market and the combination of organic and inorganic semiconductors [1], [3], [4], [5].

A comparison between photovoltaic technologies is presented in Table 1. The parameters are efficiency, cost, generation in diffuse lighting conditions and the analysis consists of ratings rather than numbers due to a large number of producers and integrators of these technologies. [6]

Table 1. Comparison of PV technologies [6]

Nr.	Property	Monocrystalline	Multi / Polycrystalline	Thin Film (CdTe, CIGS, Amorphous crystalline)
1	Efficiency	Highest	Moderate	Lowest
2	Cost	Highest	Moderate	Lowest
3	Generation in diffuse light	Average	Average	Better

As the distribution of solar irradiation is different for varied geographical latitudes and the intensity of the light determines the amount of electrical power each cell generates, the power of a photovoltaic system will vary depending on the geographical location [3].

The key components of PV systems are the modules which are placed in an array to form the PV panel, these devices can operate in outdoor conditions. PV modules can be manufactured using different materials as it was previously explained, according to [4] and by different fabrication technologies. According to [7] the main criteria for a successful placement on the market of particular PV technologies is the cost of electricity produced by the photovoltaic systems [7].

The PV system is made of photovoltaic modules and other BOS (balance of system) components [7], [8].

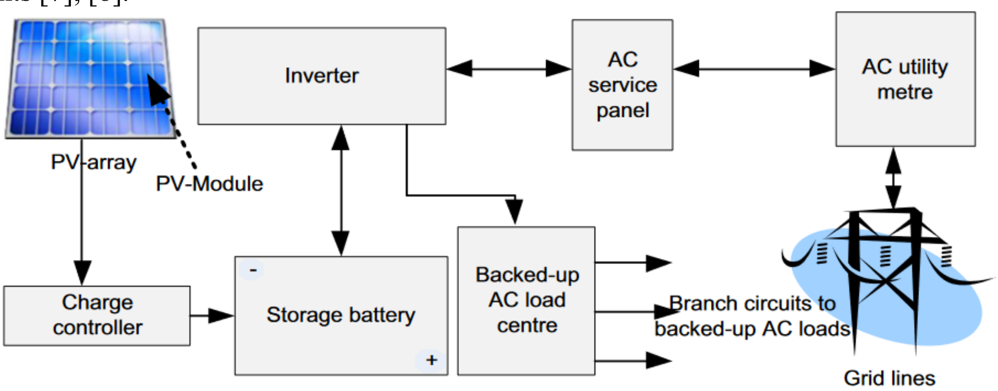

Fig. 1. A simplified schematic of the PV system [8]

As module efficiency increases, the cost of BOSs decreases, and thus the cost of modules increases. The efficiency of the modules is important for optimizing the cost of the PV system [7].

The price of the PV systems is corelated with the efficiency and technologies. Another important parameter dedicated to PV systems is the Levelized Cost of Energy (LCOE), that consider the operating costs, and the total energy produced during the system service life [7].

3. NEW DEVELOPMENTS IN FOTOVOLTAIC RESEARCH

The following subchapters present some of the latest developments in photovoltaic panels technologies.

A. Perovskites technology for solar cells

According to [9], [10], [11], a new technology of solar cells consists of perovskite solar cells, they are rated as the most efficient of all solar cell families due to their low-cost synthesis and enhanced power conversion efficiency (PCE) [9].

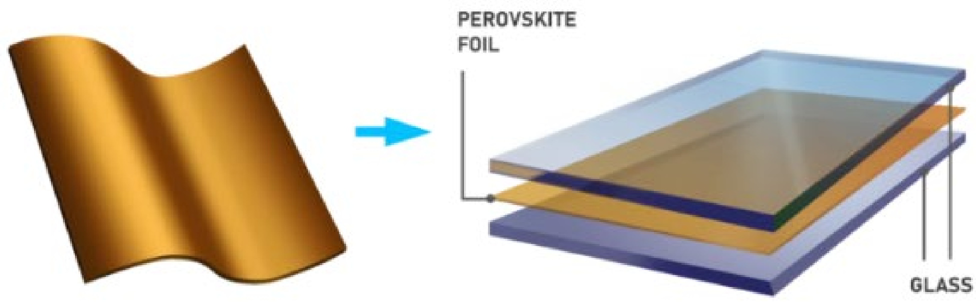

Fig. 2. Structure of the perovskite solar cell [10]

According to [11] the power conversion efficiency (PCE) of the perovskite solar cells (PSCs) has achieved 25.7 %.

Perovskite technology can be easily applied to windows, thus a thin and lightweight photovoltaic layer can be placed between two sheets of glass and mounted on a building as presented in Figure 3.

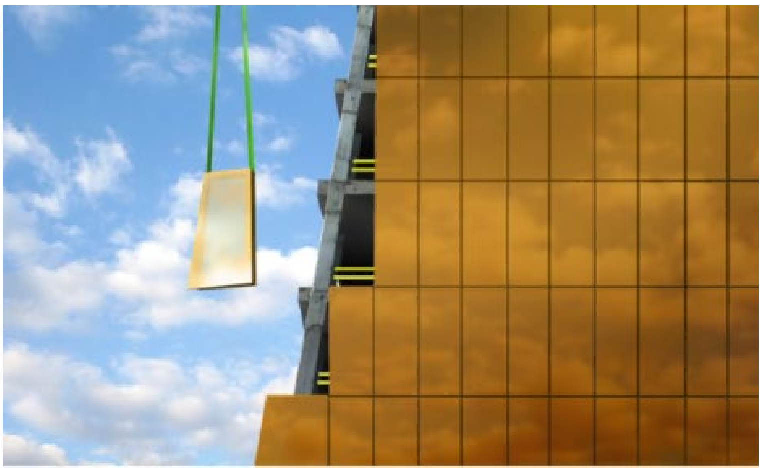

Fig. 3. Power-generating windows made with perovskite solar cells [12]

The remarkable optoelectronic capabilities of perovskite structures enable the achievement of astonishingly high-power conversion efficiencies on the laboratory scale. However, a critical bottleneck of perovskite solar cells is their sensitivity to the surrounding humid environment affecting drastically their long-term stability [13].

B. Flexible organic solar cells

An organic solar cell is composed of two distinct layers of polymeric components of plastic and similar flexible materials which have similar properties of being semiconductor in nature (see figure 4). Organic solar cells (OSCs) have made significant development in recent years, with improvements in terms of both power conversion efficiency (PCE) and flexibility. [14], [15]

In order to meet some of these challenges of inorganic component-based solar cells, organic solar cells (OSC) have been presented by a section of the scientific community as a preferred alternative. OSC utilizes organic matter in order to generate electrons for power generation, unlike silicon in inorganic-based systems. [15]

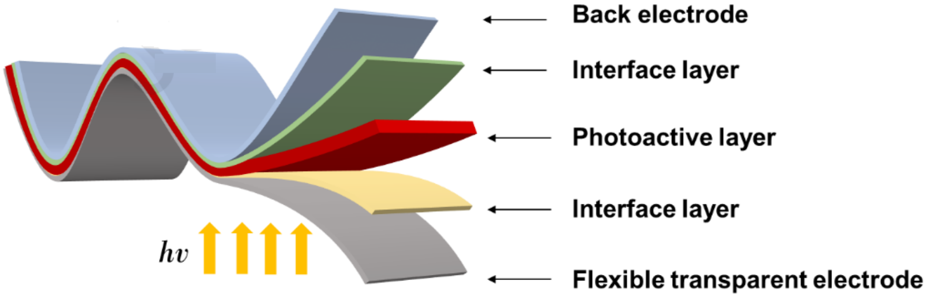

Fig. 4. Structure of the flexible organic solar cell [16]

Organic solar cells are also known as photovoltaic cells. In an organic solar cell battery, the battery is charged automatically by solar energy. This system of power generation has some inherent disadvantages as the requirement of solar energy makes it dependent on solar radiation. There is also the issue of materials used to fabricate the organic solar cell which is of considerable low efficiency. Hence, as it stands today, wind and other forms of alternative energy-based systems perform better compared to solar energy but solar cells generate 20% more energy compared to wind energy. This is due to the fact that since the electrons in photovoltaic cells move from one place to other the energy is generated thereby charging the battery. Due to reasons of sustainability and its potential to contribute to the reduction of greenhouse emission, there is considerable interest in the development of organic solar cells [15].

4. CONCLUSIONS

Installing PV systems correctly done, provides added value to a property but improperly done, it can be disastrous. There are several parameters to be considered, firstly, if the location is suitable for installing PV systems regarding lighting, size of roof top and / or other locations even ground mounting is an option, the orientation of the site, the ideal orientation is facing south to use most of the sun energy also installation size, and shading. All these issues must be addressed together with the weight of the solar panel.

Every PV system is comprised of 4 basic components: grid, solar panels, loads and solar inverter; the power required by the load is provided by solar panels, grid or both combined. There are 5 scenarios for this system:

- When solar generation is equal to the load request, solar power only is used, while grid is available but not used;
- Solar power generation is less than the load request, in this case all solar power will be consumed by loads and grid connection completes the power required;

- If solar power generation is larger than the load request, the generated solar power is used to fulfill the load request and the rest is exported to the grid;
- In case the solar power generation is 0, this may occur during night or foggy times, the grid alone supplies the power load requirements;
- In the absence of the grid, solar power systems shut down, this is done for maintenance staff safety.

Main issue for solar energy is the fact that it’s uneven on the planet and also inconsistent, a total reliance implies an effort to get sun in shady spots, also photovoltaic system provide energy during peak hours of sun light, thus effective storage is required and the efficiency for most commercial systems is 20-30%, this is not a big issue due to the long exploiting period and minimal maintenance required and most important of all, the materials used for making the photovoltaic panels are not biodegradable or eco-friendly.

In figure 5, an example of the multiple application domains for the photovoltaic panels is shown.

Fig. 5. Examples of microelectronics applications for photovoltaic panels [17], [18], [19]

Flexibility plays a major role in these applications and the market for small electronics devices and integration for power generation is continually growing.

Larger scale applications are presented in Figure 6. Using photovoltaic panels to cover electrical load requirements indoors, powering a parking lot which is very useful with the emerger of electric vehicles (EV) or powering an EV directly.

Fig. 6. Examples of larger scale applications for photovoltaic panels [20], [21], [22], [23]

According to [6] new developments are currently being researched to provide alternatives for classic silicone panels and to reach every market available such as small electronic devices that are now part of everyday life and to ensure cheap manufacturing for these products. Cell technology is constantly evolving and becoming cheaper, easier to use, and it finds new application domains.

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