NEW TRENDS IN PHOTOVOLTAIC

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ABSTRACT

The photovoltaic (PV) used in harvesting the solar energy and transferring it to electricity is being continuously improved and still it is an active research topic. This paper deals with the latest information from the field of photovoltaic cells and its efficiency and materials used for their production. It also presents new trends in the inverters used for PV energy systems.

2. INTRODUCTION

The power generated in sustainable energy sources is environmentally friendly, and the sources are not subject to the instability of price and availability that are typical of conventional energy sources such as oil or coal. Advancements in sustainable energy technologies such as in photovoltaic panels are increasing the penetration of distributed generation into the existing energy infrastructure. However, distributed generation units create a new set of technical challenges in modern power systems [1], [2]. There are many ongoing investigations to address these technical challenges. The research focuses mainly in the field of photovoltaic for use of new materials with higher efficiency in converting solar energy into electricity [3], [4], [5], [6]. The progress of development of efficiency goes above 20 % for industrial production. Also the design of inverters used in photovoltaic systems must incorporate adaptive control, and the ability to self-auto-tune, which is necessary to compensate for the various types of sources. This paper presents a short review on the existing materials, technologies and trends in photovoltaic systems and also briefly describes single-stage inverter systems.

3. MATERIALS AND TECHNOLOGIES

To production of photovoltaic cells are used different materials and technologies. The most common and longest used is silicon and its various modifications. In addition to using of semiconductor materials, the photovoltaic phenomenon is also studied in metal oxides and organic materials. The materials of photovoltaic cells are follows [7]:

- monocrystalline silicon,
- polycrystalline silicon,
- hydrogenated silicon,
- gallium arsenide,
- cadmium telluride.

For all the materials used is a fundamental problem in price-performance ratio. For this reason, it is effort to increase cell efficiency, for example better utilization of the solar spectrum with several semiconducting layers one above the other, which are sensitive to different wavelengths and reducing losses, which are identified on the electrical and optical. Optical losses are caused by the portion of solar radiation falling on the semiconductor surface is reflected back into space. To avoid these losses, regulates the cell surface deposition of different antireflective coatings, or finish a smooth and glossy surface so as to reduce its reflectivity. Electrical losses consist of transition generated current through contacts. It is important to those contacts had to a minimum resistance to flow. Since they are in the illuminating part of the cell, they must not obscure the cell [7].

In German joint project [9] was made a comparison of different technologies of solar power generators. It can be seen, that different technologies due to the efficiency of the difference solar cell technologies differs. The highest efficiency has typical GaAs triple junction solar cell comprised of 150 μm rigid substrate [9].

Over 15% efficiencies were demonstrated from 17-cell integrated submodules on these substrates as is shown in [3]. The highest submodule efficiency demonstrated in this study was 15,9%.[3]. On the other hand, efficiency 19.6 % was achieved on 148 cm^2 amorphous/crystalline double heterojunction solar cells. Similar and larger efficiency was achieved for cells in industrial production [4]. The calculations have shown that it is possible to reach an efficiency of around 20% on boron-doped oxygen-contaminated silicon with an industrially feasible cell structure.

Results of the above mentioned boron-diffused front junction are in table 1:

Table 1 – Results of cells with boron-diffused front junction [10]

Rear structure	V_{OC} [mV]	J_{SC} [mA/cm^2]	FF [%]	η [%]
Thermal oxide + locally diffused P-BSF	705	41.1	82.5	23.9
New PassDop layer + laser-fired P-BSF	701	39.8	80.1	22.4
Full-area P-BSF + printed front contacts	654	38.7	80.8	20.5

To improve transformation efficiency, could be used films. From the research made in [11], no significant changes were proved. Efficiency of transformation and efficiency of the panel depends on the particles size used in films. Example of efficiency is shown in the following table:

Table 2 – Characterized parameter of obtained GaAs PV cell measured before and after particle coating [11]

	Without particle coating			With particle coating			
Particle size [nm]	J_{SC} [mA/cm^2]	V_{OC} [V]	η_{ARC} [%]	J_{SC} [mA/cm^2]	V_{OC} [V]	η_{ARC} [%]	$\Delta\eta$ [%]
100	25.15	0.931	17.22	25.91	0.939	18.44	7.08
200	23.66	0.894	15.40	24.92	0.894	16.28	5.71
300	24.76	0.94	16.76	23.03	0.942	16.25	-0.30

As it can be seen from table 2, coating increased its relative efficiency for the diameters of 100 and 200 nm, while 400 nm particles slightly decreased efficiency. One of the possibilities is also use thin-film polycrystalline silicon solar cells with low intra-grain defect density made via laser crystallisation and epitaxial growth. This technology combines the cost benefit of thin-films and the quality potential of crystalline Si technology Efficiency is low, about 5.4 – 8 % [17].

4. INVERTERS

The inverter converts the direct current to alternating current of a given frequency. It must deliver the highest performance. In terms of the optimal action of photovoltaic power plant is necessary to choose the right inverter. The most important factors of selection of the inverter are follows [8]:

- power of photovoltaic power plant,
- shape of the land,
- location of the transformer,
- type of photovoltaic cells.

In terms of selecting an inverter for photovoltaic power plants, inverters can be divided as [8]:

- Decentralized – used mainly for photovoltaic power plants to 1 MW. This is a larger number of smaller inverters that are connected to a string. The number of strings per inverter is smaller and depends on the output of the inverter, as well as the allowable stress.
- Centralized – are mainly used for power with more power than 1MW. It is a central inverter for multiple strings for more power, which is likely more effective. The disadvantage is that the failure of the inverter is lost all power.

Photovoltaic inverter can contain either a voltage or current control [8].

A simple way to increase the output voltage of sustainable energy sources is to connect a number of them in series and use a conventional voltage source inverter. However, this series configuration has some drawbacks, such as low reliability and low efficiency [15].

1.1. Circuit topologies for a three-phase system

In Figure 1(a), a step-up transformer is utilized at line frequency to boost the voltage after the inverter. However, this solution has several disadvantages, such as loud acoustic noise, huge size and relatively high cost. Furthermore, the transformer should be designed for a relatively wide range of power which leads to a low system efficiency. In Figure 1(b), a two-stage circuit topology is used in which a dc-dc converter and an inverter are cascaded. In the first stage, the dc-dc converter boosts and regulates the dc-bus voltage, and in the second stage, the inverter converts the dc voltage into an ac voltage. This topology, in comparison with the topology displayed in Figure 1(a), requires two individual control systems and uses one more solid-state switch, as well as an electrolytic capacitor bank at the dc-bus. This will result in a lower reliability and efficiency, as well as a more complicated control scheme [12]. Although the multi-level inverters are effective, the added complexity of the circuit, and the additional components, reduce both the overall efficiency and reliability of the system, and may raise the overall cost of the power electronic interface.

Another option is the z-source inverter. The z-source inverter has the capability of boosting and inverting the dc voltage in a single-stage, with fewer solid-state switches in comparison with multi-level inverters and the above-mentioned two-stage topologies depicted in Figure 1(a) and Figure 1(b), respectively. As can be seen in Figure 1(c) [13], the z-source inverter is a combination of a voltage source inverter and a current source inverter. The z-source inverter contains relatively high input current ripples, which may result in high stresses on the dc-link inductors and capacitors [13]. The application of this topology was reported by [14] as a grid-tie single-stage inverter for distributed generation systems, specifically for residential photovoltaic systems. The current source inverter topology in conjunction with an appropriate control scheme can form a single-stage boost-inverter that can be used for sustainable energy conversion systems. The current source inverter (CSI) has a dc-link inductor and ac capacitors, as one can observe in Figure 1(d).

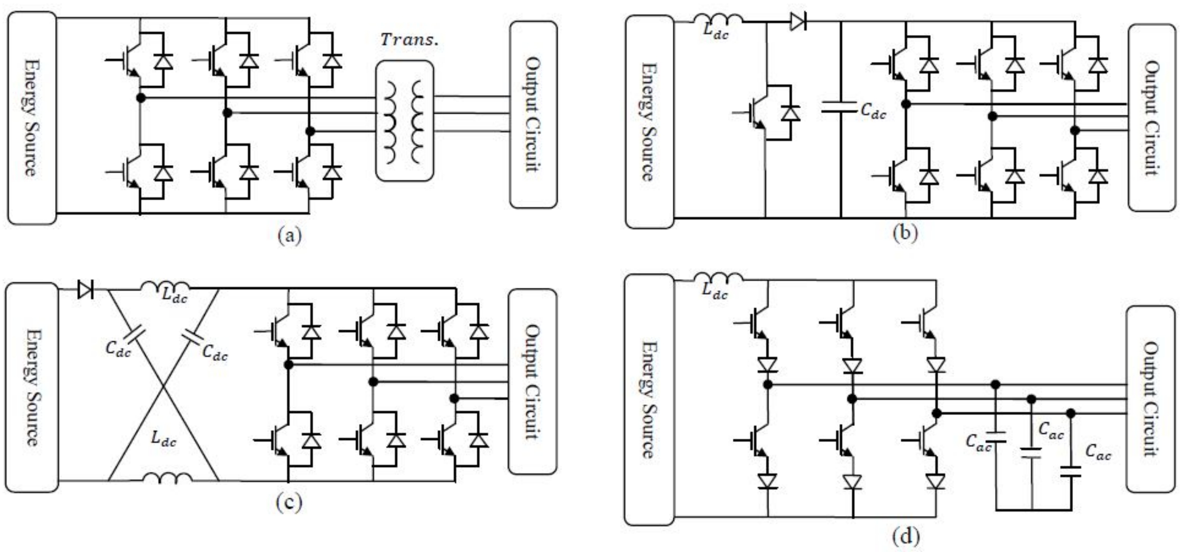

Figure 1 – Four three-phase options for connecting sustainable energy sources (fuel cells and PVs) to the grid or loads: (a) VSI cascaded by Transformer, (b) Boost dc-dc converter cascaded by VSI, (c) Single-stage z-source inverter, and (d) Single-stage CSI. [15]

5. CONCLUSION

In this paper, a short review on the existing materials, technologies and trends in photovoltaic systems has been performed. Photovoltaic has become a worldwide one of the fastest growing direction relative to the annual increase in installed capacity. Production of electricity from photovoltaic power plant will grow annually by 30%. The using of new materials and research of new types of cells go towards new and high efficient materials. The highest priority for all is to use the most efficient materials for conversion of sun energy to electric energy. 3rd generation of photovoltaic cells and improved (more than 20 % efficiency) photovoltaic cells help us to convert the energy more efficient. On the other hands it is necessary to focus also on interconnection of large sources into small grids.

In the paper are also mentioned pros and cons of three-phase inverter systems. The efficiency, reliability, and ease of control methods are the most important challenges for such systems.

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