NEW PV SYSTEM CONCEPT – INDUCTIVE POWER TRANSFER FOR PV MODULES

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ABSTRACT: The proposed new PV system concept is based on several AC modules that are connected in series using inductive power transfer. These modules include a cell matrix that is connected to a module integrated DC/AC inverter. The high frequency AC current flows through the primary side planar coil generating a magnetic flux. Outside of the PV module, there is a clamp including ferromagnetic material for the magnetic circuit that caries the magnetic flux to the secondary winding. The magnetic flux induces an AC current in the secondary winding, which is formed by the common cable. An AC/AC converter is placed at the end of the PV module strings to generate the 50 Hz and to connect the PV power plant to the electricity grid. This new PV system concept is a fundamentally new approach of the electricity transmission in the field of PV system technology. It is not restricted to the replacement or optimisation of an individual system component, but it requires the continuing development of the PV module construction and the contactless connection technology to the common cable. The proposed inductive power transfer per each PV module opens up a complete new field for the PV system technology.
Keywords: PV system, inductive power transfer, AC modules, module integration,

1 INTRODUCTION

In 2016, the PV system related costs amounted to 1200 $/kWp for commercial applications and system sizes of 1 MW according to the NREL benchmark report. In that case, the soft costs are disregarded including the land acquisition, sales tax, overhead, net profit, etc. The cost share for the PV modules is 51% whereby half of that falls to the share of the cell production. The inverter cost amount to 11%. The costs for structural and electrical balance of system (BOS) are 14% and 12%, respectively. The labour costs including the necessary equipment for the installations correspond to 12% [1].

The levelized cost of electricity depends not exclusively on the initial costs. There are other factors such as lifetime of PV system components as well as maintenance cost due to system component defects. The IEA PVPS task 13 analysed frequently occurring PV module and system defects. In the first year after commissioning, the main defects represent potential induced degradation, connector failures, junction box defects or defective bypass diodes [2].

The proposed new PV system concept affects three quarter of the present PV system in terms of costs with potential cost reductions regarding BOS, installation and maintenance. Additionally, it should eliminate common system component failure.

2 NEW PV SYSTEM CONCEPT

The goal is to develop a new PV system that uses an integrated inductive power transfer (IPT) technology for the power feed-in between the cell matrix and the string wiring. The DC current produced by solar cell matrix is converted into high frequency AC current within the laminated area of the PV module. The output of this inverter is connected to a planar coil that generates a magnetic flux.

A connection element (magnetic clamp in Figure 2) has to be developed that includes the magnetic coupling between the primary winding formed by the planar coil and secondary winding formed by the common cable. The clamp contains the magnetic circuit based on high frequency magnetic material. Optionally, this clamp could serve as module retainer by attaching it to the module in an interlocking and force-fitting manner. The magnetic flux generated by the planar coil is transported over a magnetic circuit and it induces a small voltage in the high voltage common cable (the number of turns of the primary side is greater than the number of turns of the secondary side). The high voltage can be achieved by connecting multiple modules to the common cable, in similar manner. A high frequency power cable will be used. At the end of a module string, there is an AC/AC converter because the used transmission frequency within the string is higher than 50 Hz.

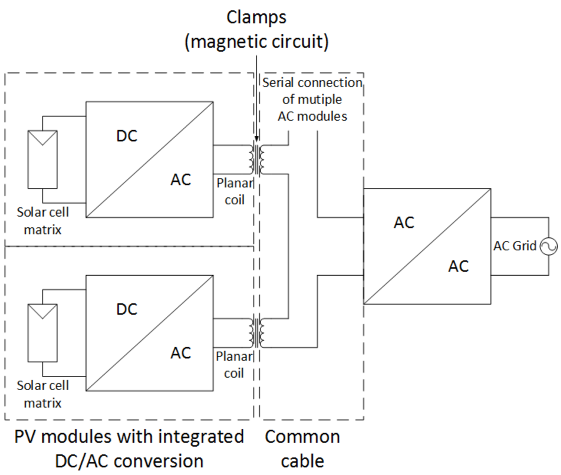

Figure 1: The electronic schematic represents the new PV system concept based on several AC modules that are connected in series using IPT.

A control and communication system has to be developed that synchronises all AC PV modules and allows an upscaling of the PV power plant (>100 kWp).

The whole system can be described as a high frequency transformer based grid-connected inverter where the high frequency AC stage is inside the PV module. Figure 1 shows the electrical schematic of the proposed new PV system concept and Figure 2 and 3 illustrates its mechanical setup.

In a first step, a DC/AC/DC system will be developed where the common cable carries DC current. This provides a functional prototype at an early stage without the need for the complex synchronization and communication system.

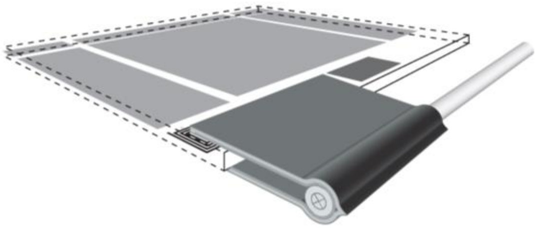

Figure 2: The 3D drawing [3] shows a small section of the new PV module with the solar cells (light grey), the electronics (dark grey) and the planar coil integrated in the laminated module packaging. Outside the PV module, the magnetic clamp needs to be positioned exactly above the planar coil. The common cable is wound around the clamp building the secondary winding. The system is not restricted to only one winding as shown in this drawing.

3 INNOVATION

In recent decades, the focus of public research funding was almost on the optimisation of solar cell efficiency itself and less on another important part, the BOS Components. The reason for this was that the solar cells had the major cost share. In today's PV power pants, the cost share of the crystalline silicon solar cells are roughly one quarter of the total system costs. The rest is divided into module production, installation and balance of system components such as subconstruction, inverter, cabling, installation material and planning [1]. The new PV system concept represents a new solution approach, which affects system components that account for three quarters of today's total system. With the described system in chapter 2, several advantages arise with the goal to reduce initial system costs as well as operating and maintenance costs for large PV power plants (>100 kWp).

Due to the galvanic isolation, there will be no potential induced degradation. Additionally, it allows using even higher system voltages, which is reached by connecting more AC modules in series with lower voltages than state-of-the-art PV modules. The voltage increase will reduce the amount of copper needed for the cabling. The installation costs are going to decrease because there are no electrical connectors. This saves time on wiring and eliminates weather-related connector failures, which are listed as frequently occurring system failures in the IEA PVPS task 13 [2]. Less expertise for electrical connection is needed on-site because the installation of the magnetic clamp is a purely mechanical connection. The IPT technology allows the disconnection under load. This leads to a reduction in the maintenance costs and yield losses because it is not necessary to shut down a whole string. Furthermore, it increases the fire protection and the safety of people (no electric arcs). The new topology has a DC/AC inverter integrated in the AC modules allowing the implementation of an individual MPP tracker. This results in a reduction of module mismatch as well as shading losses. Additionally, the new AC modules have no junction box increasing the reliability of the PV system.

This new solution approach for PV systems is designed for applications in large ground-mounted, rooftop or facade PV power plants. The main reason is that a certain amount of AC modules is needed to reach the higher voltage level and that the potential in labour costs reduction and the benefit of industrial prefabrication are greater for large systems.

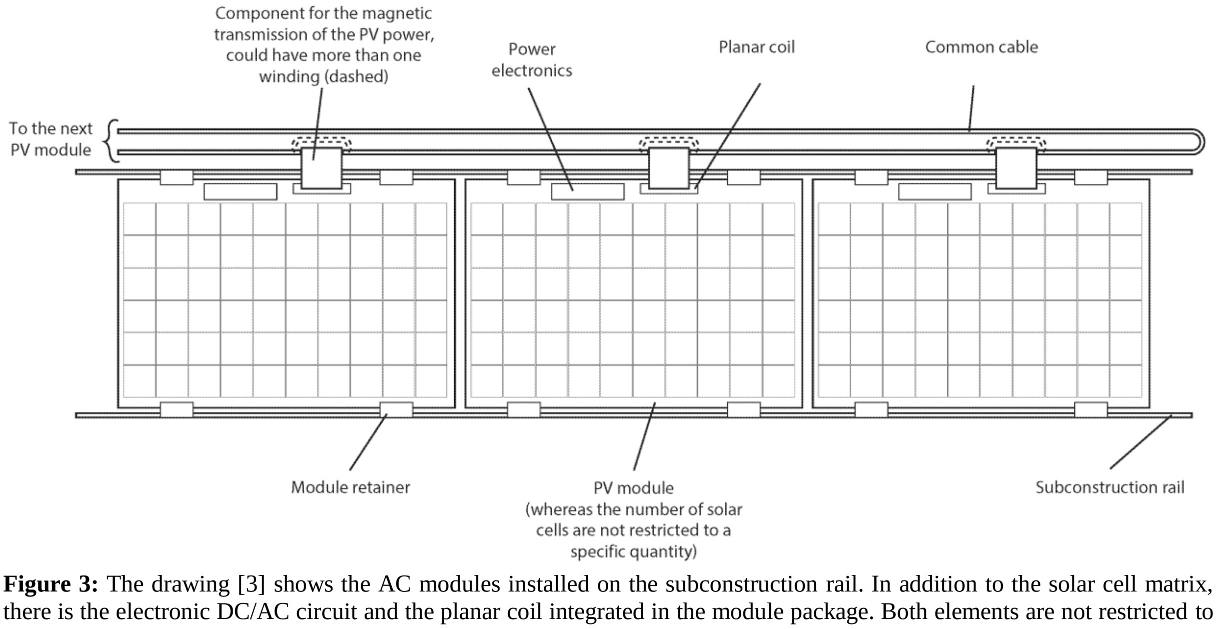

Figure 3: The drawing [3] shows the AC modules installed on the subconstruction rail. In addition to the solar cell matrix, there is the electronic DC/AC circuit and the planar coil integrated in the module package. Both elements are not restricted to be positioned on the long edge of the module. The common cable is wound around each magnetic clamp connecting all modules in series. The voltage on the secondary winding is smaller than the DC voltage of all serial connected solar cells inside the module. This allows adding more AC modules in the PV string compared to a state-of-the-art PV system.

4 CONCLUSION AND OUTLOOK

The new PV system concept is a fundamentally new approach of the electricity transmission in PV power plants. The main idea is not limited to an individual optimisation or exchange of components, but focuses on the further development of the design of the PV modules and the balance of system components including the optimally matched contactless connection technology.

The first task includes the design and development of DC/AC conversion circuit whereas the second task contains the design of the magnetic clamp based on experiments and finite element simulations. Therefore, the optimal system specifications have to be determined including system frequency, module thickness to integrate the electronics, input voltage (serial or parallel cells), input current (cell size), single module output voltage, total system voltage, magnetic material, number of primary and secondary winding, etc.

The goal within the next year is to demonstrate the technical feasibility of the new PV system technology using appropriate switching technology and material combination. In the coming years, this should enable launching a new product that allows a cost-effective installation with minimum maintenance effort.

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