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A REVIEW OF DISTRIBUTED POWER ELECTRONICS IN PHOTOVOLTAIC SYSTEMS

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ABSTRACT:

Droop control has commonly been used with distributed generators for relating their terminal parameters with power generation. The generators have also been assumed to have enough capacities for supplying the required power. This is however not always true, especially with renewable sources with no or insufficient storage for cushioning climatic changes. In addition, most droop-controlled literatures have assumed a single dc-ac inverter with its input dc source fixed. Front-end dc-dc converter added to a two-stage photovoltaic (PV) system has therefore usually been ignored. To address these unresolved issues, an improved droop scheme for a two-stage PV system has been developed in the paper. The Proposed scheme uses the STATCOM control structure in both grid-connected and islanded modes, which together with properly tuned synchronizers, and mitigates the harmonics, by providing Reactive power and Load current Subsequently the proposed scheme adapts well with internal PV..

KEYWORDS – *Photovoltaic, dc-ac inverter, harmonics, power generation.*

INTRODUCTION:

A number of new products have come to the market in the field of distributed photovoltaic (PV) power electronics. This category of devices includes DC-DC converters and AC micro-inverters that are designed to either replace or work in concert with traditional central PV inverters. Recent improvements in the efficiency, reliability, and cost of these products have made them viable in many applications, from small residential installations to large commercial PV arrays. The breadth of options and claims among these various products shows that some differentiation exists between these devices. On the other hand, all of these devices share many similar benefits due to their distributed nature. This report intends to highlight the differences and similarities of these technologies and to provide some analysis of their benefits to power production and system economics. In general, the use of power electronics at a per-module or per-PV string basis can reduce the impact of module mismatch and partial shading. A traditional central inverter will have only a few (typically one and rarely two or more) input channels that independently track the maximum power point (MPP) of the PV system. With large utility-scale inverters reaching up to half a megawatt (MW) in size, over 5,000 individual PV panels could potentially operate at one common peak power point. A reduction in the output power of one or more of these PV panels can lead to mismatch in the maximum power point between the various PV modules and strings. Possible causes of MPP mismatch include partial shading, soiling from dust, debris, and bird droppings, and module physical degradation. The impact of partial shading and mismatch can be reduced by increasing the number of independent MPP tracking channels in the PV system. The improvement from distributed MPP tracking depends on the amount of mismatch throughout the system, the size and configuration of the system, and the characteristics of its PV modules, among other factors.

A DC-DC converter is one type of distributed power electronics that can provide such an improvement in system performance. These devices are also sometimes called power optimizers or power boosters. Rather than replacing a traditional central inverter, DC-DC converters work in conjunction with a central inverter, which is still required to convert DC power to AC grid power. However, the distributed electronics on each module or string help to de-couple the maximum power operating point of the individual modules or strings from the overall maximum power point of the system. A DC-DC converter will track the maximum power point of solar module(s) connected to it and either increase (**boost**) or decrease (**buck**) the output voltage to match the optimum voltage requested by the central inverter. Many currently available solar DC-DC converters use a separate enclosure for the power electronics at each panel, typically attached to the PV module frame or rack. Newer proposed versions of this technology involve partnering with PV module manufacturers to integrate the DC-DC electronics directly into the PV panel junction box. This convergence produces a so-called "smart junction box" or "smart panel" that provides some cost and labor savings over separate panel and power electronics. Another type of distributed PV electronics is the AC micro-inverter. While this technology made an appearance a decade ago as an integrated AC module, cost and reliability issues prevented the technology's widespread adoption. The current generation of micro-inverter products appears to be achieving greater market penetration through improved efficiency, reduced cost, increased reliability, and diagnostic capabilities. AC micro-inverters are installed on each PV module, replacing the use of a central inverter. Each PV panel's DC power is converted directly to AC 120 V or 240 V and grid-tied. The output of each PV panel is therefore effective in parallel, which eliminates power losses due to module mismatch. Thus the performance improvements that arise from independently peak-power tracking PV modules can be achieved with micro- inverters as well as with DC-DC converters. An additional benefit to micro-inverters compared with DC-DC devices is the reduction in DC balance of system components, including the central inverter. Also, voltages tend to be lower with micro-inverter systems, which could be a safety benefit for rooftop systems. Figure 1 shows some example topologies for per-panel microelectronics, including DC-DC converters and micro-inverters.

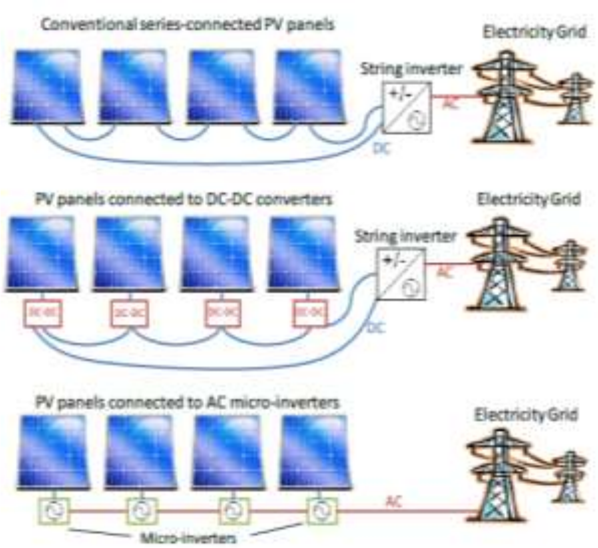

Fig.1: Schematic of conventional single-string PV system (top), DC-DC converter-equipped PV system (middle), and AC micro-inverter-equipped PV system (bottom).

There is also interest in reducing mismatch losses in larger installations, but perhaps not at the per-panel level. One strategy is to include DC-DC converters at the string level, which can reduce voltage mismatch between parallel strings. A boost converter can also provide a higher constant voltage to the central inverter, thereby reducing resistive losses and optimizing the DC operating point of the inverter. This type of string-level DC-DC equipment can be located inside or in place of a traditional combiner box, leading to the term "smart combiner box." An example of this layout is shown in Figure 2.

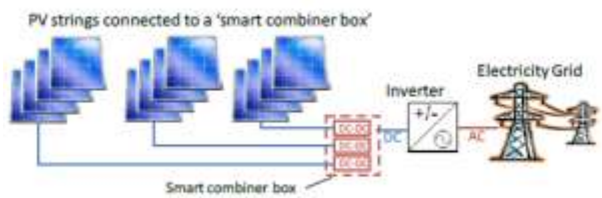

Fig. 2: Schematic of a larger solar installation with multiple strings, each feeding into a "smart combiner box." Maximum power point tracking is provided at the string level.

One aspect of distributed PV electronics that has yet to be addressed is the effect of their long term reliability on the complete PV system. In general, the probability of system failure increases with each component in the system. Understanding the component-level reliability, failure modes, and effect of failure on system availability will be important in assessing the overall value of distributed PV electronics.

Background - Partial Shading and Mismatch Losses:

The impact of shade and mismatch on PV systems has previously been studied, both with and without the use of DC-DC converters or micro-inverters [1-6]. Due to the variety of possible string configurations and module characteristics in PV systems, it is difficult to generalize how mismatch will affect a given system. However, in most PV systems with conventional silicon panels, the presence of shade or mismatch will have a greater than proportional impact on the system's power output. This is due to the serial nature of PV modules in strings, which creates a "Christmas tree effect" in which current reduction in one series-connected module causes mismatch losses in the rest of the string. Because of this potential for greater power losses in mismatched systems (and for hot-spot safety concerns, which are not addressed here), solar module manufacturers typically include one or more bypass diodes in their modules, usually located in the module's junction box. The function of the bypass diode is to allow current to flow past impaired sections of a module that are unable to produce as much current as the rest of the system. To accomplish this, the module section is shorted out by the diode, producing no power of its own. This bypass condition is preferable to allowing the shaded or impaired module to reduce the current of the entire string, thereby lowering production. Since the bypass diode shorts out the partially shaded section, causing its operating voltage to fall to zero, the overall operating voltage of the PV string will be reduced accordingly.

DC-DC Converter Deployment and Topologies:

Several different DC-DC converter device topologies are available for use with individual solar panels, each with different strengths and operating uses. The simplest DC-DC converter uses a single converter stage to either buck (reduce) or boost (increase) the output voltage of a PV panel. In either case, the PV panel output voltage is MPP tracked by the control algorithm in the device. A slightly more advanced DC-DC converter is the buck-boost converter, which uses both buck and boost stages to allow the converter to either increase or decrease the output voltage of a PV panel. The advantages of a buck-boost converter include an increased operating range and the ability to correct for a greater amount of system mismatch. Since the device includes two conversion stages rather than one, the increased flexibility may come at the cost of a slight efficiency reduction as well as possible size and cost increases relative to single-stage devices. In a buck-only DC-DC converter, the output voltage from a shaded panel is decreased, and the output current is increased to match the operating current of the unshaded modules in series with it. Because the current is boosted, there is no mismatch in current between the series-connected modules. There is no longer any need for the shaded module's bypass diodes to begin conducting. Therefore, the panel equipped with the buck DC-DC converter can produce power at a reduced level without needing the bypass diodes to conduct. This type of converter works best in PV systems with limited mismatch, e.g., where shade or mismatch occurs only on a few PV panels. In this case, the buck DC-DC converter is installed only on those PV panels experiencing shade. An increase in annual production results from the partially shaded modules producing some limited amount of power (due to the diffuse component of irradiance that is still present even under shaded conditions) rather than no power at all. The amount of power that can be recovered depends on how diffuse the shade is, but it may account for half or more of the recoverable mismatch loss under certain conditions [5]. A boost-only DC-DC converter operates by taking the input PV voltage (typically at the maximum power voltage of the particular panel) and increasing it. This type of system is typically designed with every PV panel in the system equipped with a boost converter. In some systems, the converter boosts the voltage to a high constant value (~300 Vdc –550 Vdc), and all of the panels are placed in parallel. System mismatch is eliminated here because each panel contributes current proportional to the amount of irradiance it receives. This system will work even with panels facing different directions, or at different tilt angles, because all of the converters are placed in parallel. The high constant-output voltage from the boost converter is chosen to maximize the efficiency of a fixed-input voltage inverter connected to the output.

CONCLUSION:

Some technical and economic aspects related to the Hungarian renewable energy regulations. Five main technical options for PV systems ranging from sizes of 50 kWp to 500 kWp were analyzed related to low- and medium-voltage facilities. In the course of the economic calculations, not only the financial investments needed for the PV systems but also the annual extra yields and the financial expenditures under the current regulations in Hungary were examined in the cases of the HMKE, the Small-scale and the KÁT market environments. The payback periods were between 7–9 years in all the studied related to economic-technical cases. The best IRR, which was 16.5%, belonged to the HMKE alternative, while in the cases governed by the KÁT regulation, this value was 12.2%, because of the higher security needs. It show that each investment alternative can be a good decision from an economic and technical point of view under the Hungarian regulations enforced in 2018.

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