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A SINGLE – STAGE SOLAR POWER CONVERTER FOR PV BATTERY SYSTEM

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ABSTRACT

The main concept of the new converter is to use a Single - stage three phase grid ties - solar PV converter to perform dc/dc and dc/ac operations. This converter solution is appealing for PV-battery applications, because it minimizes the number of conversion stages, improving efficiency and reducing cost, weight and volume.

KEYWORDS: Converter, Energy Storage, Photovoltaic (PV), Solar

INTRODUCTION

Solar photovoltaic (PV) electricity generation is available sometimes higher or lower because it depending on the weather conditions. Solar electricity is also highly sensitive to shading, even small array or portion is shaded the output falls dramatically. Therefore output varies significantly from an energy source standpoint, a stable energy source and an energy source that can be dispatched at the request are desired as a result, energy storage such as batteries and fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV system becomes stable energy source and it can be dispatched at the request. Which results in improving the performance and the value of PV system[1]-[3].

There are different options for integrating energy storage into a utility-scale solar PV system. Specially energy storage can be integrated into the either ac or dc side of the solar PV power conversion system which may be consist of multiple conversion stages[4]-[33]

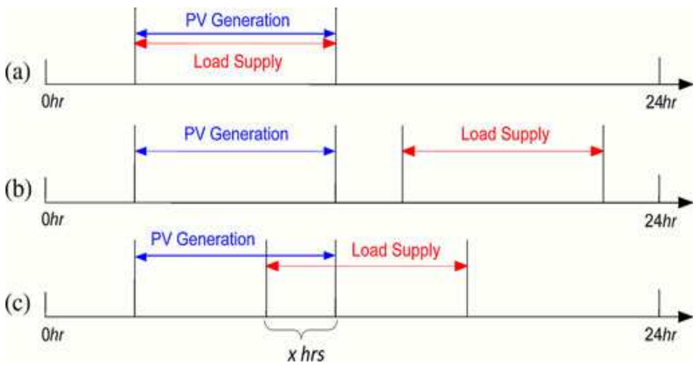


Figure 1

This paper introduce a novel single-stage solar converter called reconfigurable solar converter(RSC). RSC performs different operations modes such as PV to grid(dc to ac), PV to battery (dc to dc), battery to grid(dc to ac), and battery/PV to grid (dc to ac) for solar PV system with energy storage. Figure 1 Shows different scenarios for the

PV generated system. In case a) the PV energy is always delivered to the grid and there is basically no need to energy storage. However, for cases b) and c), the PV energy should first stored in battery and then deliver to grid, and also we can supply from both PV and grid, integration of the battery is highest value and the RSC provide significant benefit over the integration options when t

There is the time gap between generation and power consumption.

Section 1 introduce a RSC circuit, different modes of operations and benefits in section 2 introduce a control of the RSC section 3 verifies the experimental results and performance characteristics. Section 4 conclusions.

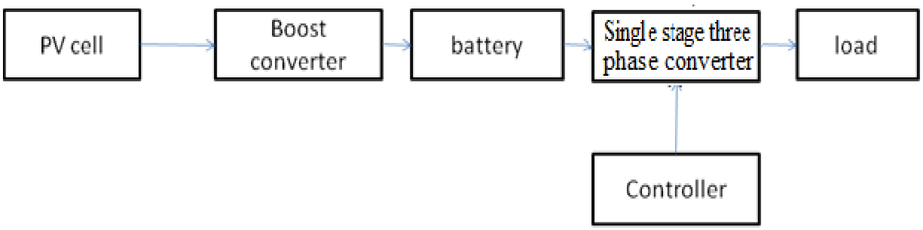


Figure 2: Block Diagram

1. RSC

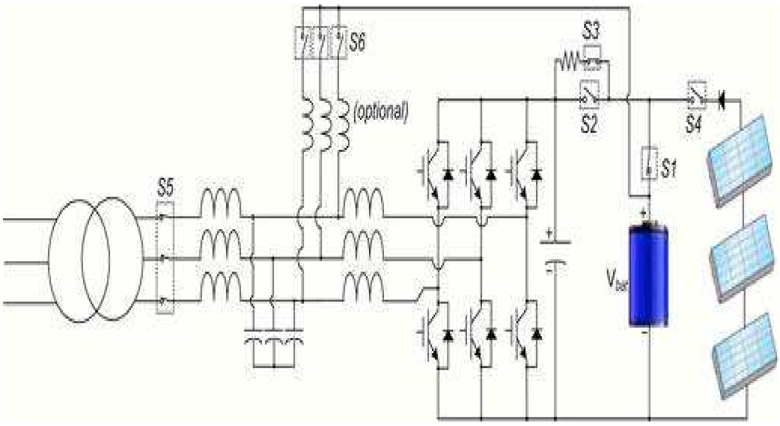


Figure 3: Diagram of the Suggested RSC

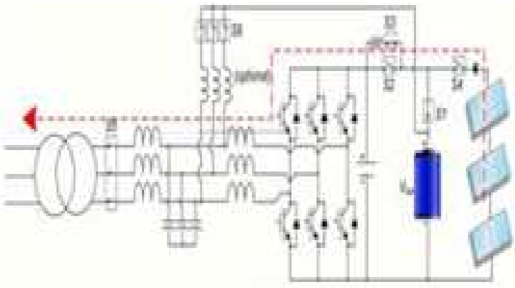
1.1 INTRODUCTION

The proposed RSC shown in figure 3 the RSC has the some modifications to the conventional inverter. These changes let the RSC to involve the charging task in the usual three phase voltage source converter and its related parts, the RSC needs extra cables and mechanical switches as shown in figure 3. Optimal integrators are integrated if the ac filter inductance is not sufficient for charging function.

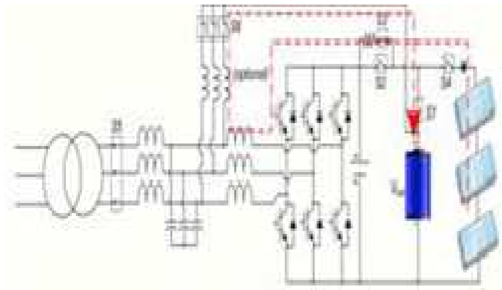
1.2 OPERATION MODES OF RSC

All operation methods are shown in figure 4, in method 1 the PV is directly linked to the grid for dc to ac operation of the converter with prospect of maximum power point tracking (MPPT) monitor S1 and S6 switches are open. In method 2, the battery is charged with solar panels for dc to dc operation by closing S6 and opening the S5 switch in this method MPPT function is achieved. The PV and battery offered power to grid by closing S1. This operation shown in method 3, in this method MPPT is not possible because the Dc link voltage that is similar to the

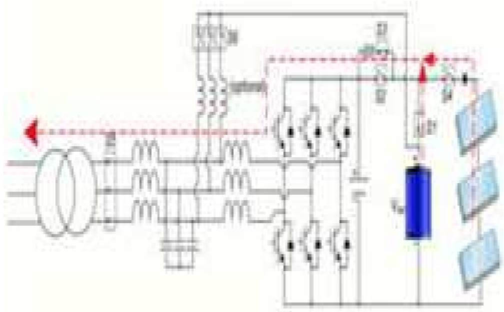
PV voltage that is imposed by the battery voltage, thus the MPPT monitor is not possible. Method 4 represent the energy stored in battery is offered to the grid.



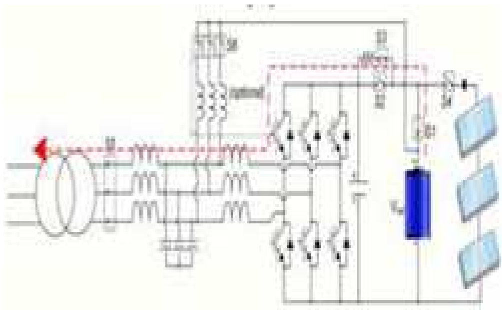
a) PV to Grid



b) PV to Battery



c) PV/Battery to Grid



d) Battery to Grid

Figure 4: All Operation Methods of RSC

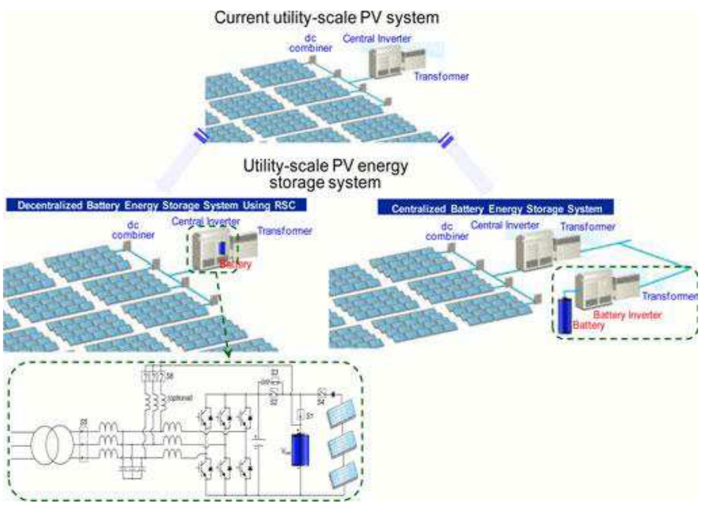


Figure 5: Utility-Scale PV- Energy Storage Systems with the RSC and the Current State of the Art Solution

1.3 SYSTEM GAINS OF PV POWER PLANT WITH THE RSC METHOD 1

The RSC method 1 offers major gains to system planning of utility –scale solar PV power plants. The current state of the art technology is to combine the energy storage into the ac side of solar PV systems. An example of viable energy storage solutions is the ABB issued energy storage (DES) solution is that is a complete package up to 4MW, which is linked to the grids directly with its communication means, can be used as a mean for peak shifting in solar PV power plants [33].

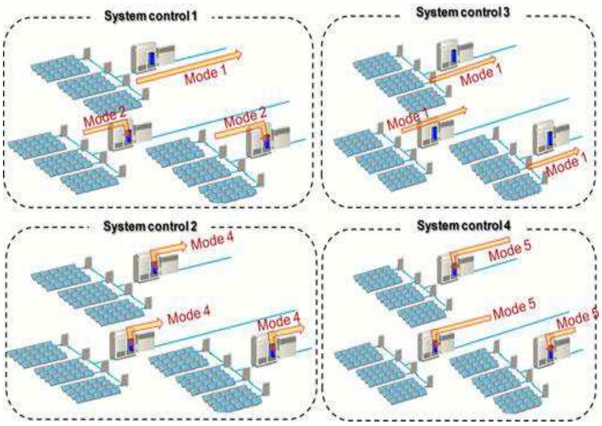


Figure 6: Example of Different System Operation Methods of a RSC Based Solar Power Plants

The RSC method 1 permits not only the system owners to have an flexible ability that assist them to arrange and run the power plant correspondingly although manufacturers to preset a cost –aggressive dispersed PV energy storage solution with the RSC and the current state of art tools the technical and financial gains that the RSC solutions is able to offer are more apparent in larger solar PV power plant using the RSCs can be monitor more economically since of the flexible operation Developing a full operation characteristics of a Solar PV power plant with the RSC is further than the scope of this project. But, different system monitor s as shown in figure 6 can be suggested based on the requested power from the grid operator p required and available generated power from the plant p generation these two values being results of an optimization problem (such as a unit commitment method Serve as variables to monitor the solar PV power plant accordingly. In other words, in response to the request of the Grid operator, different system monitor plans can be realized with the RSC –based solar PV power plant as follows:

- System monitor 1 for p gen > p req;
- System monitor 2 for p gen < p req;
- System monitor 3 for p gen = p req;
- System monitors 4 charges from the grid (operation method 5).

2 RSC MONITORS

2.1 Monitor of the RSC in the dc/ac Operation Methods (Method 1, 3, 4, 5)

The dc/ac operation of the RSC is used for delivering power from PV to grid, battery to grid, PV and battery to grid, and grid to battery. The RSC performs the MPPT algorithm to deliver maximum power from the PV to the grid. Like the usual PV inverter control, the RSC control is implemented in the synchronous reference frame. The synchronous reference frame proportional integral current monitor is employed. In a reference frame rotating synchronously with the fundamental excitation, the fundamental excitation signals are transformed into dc signals. As a result, the current regulator forming the inner most loop of the monitor system is able to regulate ac currents over a wide frequency range with high bandwidth and zero steady state error. For the pulse width modulation (PWM)scheme, the usual space vector PWM scheme is used. Figure 7 presents the overall monitor block diagram of the RSC in the dc/ac operation. For the dc/ac operation with the battery, the RSC monitor should be matched with the battery management system (BMS), which is not shown in figure 7.

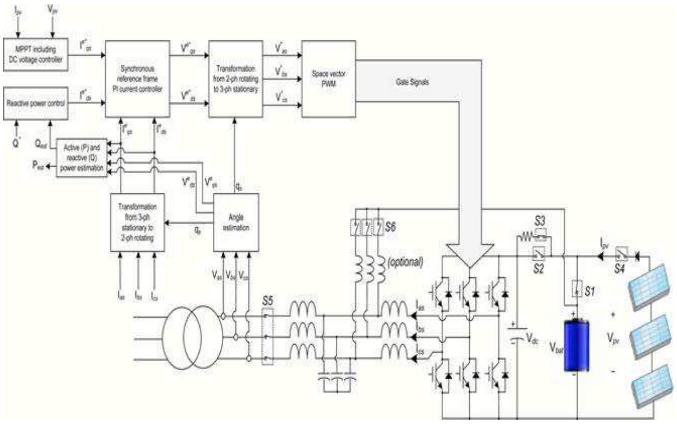


Figure 7: Overall Control Block Diagram of the RSC in the dc/ac Operation

2.2 Monitor of the RSC in the dc/dc Operation Method (Method 2)

The dc/dc operation of the RSC is also used for delivering the maximum power from the PV to the battery. The RSC in the dc/dc operation is a boost converter that monitors the current flowing into the battery. In this research, Li-ion battery has been selected for the PV battery system. Li-on batteries need a stable current, stable voltage type of charging algorithm. In other words, a Li-ion battery should be charged at a set current level until it achieves its final voltage. At the last voltage, the charging process should switches over to the stable voltage method, and offer the current essential to posses the battery at this final voltage thus the dc/dc converter performing charging process must be able of offering stable monitor for maintaining either current or voltage at a stable value, depending on the state of the battery. Typically, a few percent capacity losses happen by not performing stable voltage charging. But, it is not uncommon only to use stable current charging to simply the charging monitor and process. The latter has been used to charge the battery. Thus, from the monitor point of view, it is just sufficient to monitor only the inductor current. Like the dc/ac operation, the RSC performs the MPPT algorithm to convey maximum power from the battery in the dc/dc operation Figure 8 shows the overall monitor block diagram of the RSC in the dc/dc operation. In this method, the RSC monitor should be managed with the BMS, which is not shown

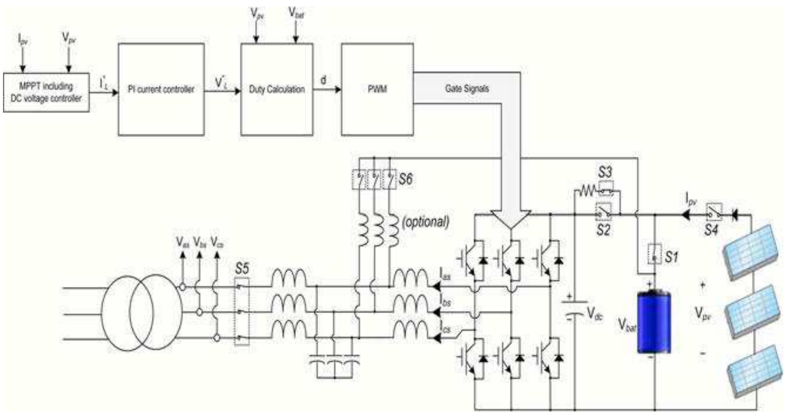


Figure 8: Overall Control Block Diagram of dc/dc Operation

2.3 Strategy Issues and Changes to the Usual Three Phase PV Converter

One of the most important condition of the project is that a new converter for PV battery system must consist least difficulty and changes to the usual three phase solar PV converter system. Thus, it is essential to explore how a three phase dc/ac converter works as a dc/dc converter and what changes should be made. It is wide spread to use a LCL filter for a high power three phase PV converter and the RSC in the dc /dc operation is probable to use the inductors already existing in the LCL filter There are chiefly two types of inductors, coupled three phase inductor and three single phase inductors that can be used in the RSC circuit. Using all three phase of the coupled three phase inductors in the dc/dc operation affects a major drop in the inductance value due to inductor core saturation. The reduction in inductance value needs inserting additional inductors for the dc/dc operation which has been marked as “optional” in figure 2 to shunt extra inductors, only one phase can do the dc/dc operation. But when only one phase, for example phase B, is used for the dc/dc operation with only either upper or lower insulated –gate bipolar transistor (IGBT) are turned OFF as balancing switching, the flowing current occurs in phase A and C through filter capacitor, the coupled inductor, and switches ensuing in radically high current ripple in phase B current.

To stop the flowing current in the dc/dc operation, the following two solutions are suggested; 1) all unemployed Upper and lower IGBT must be turned OFF; 2) the coupled inductor is exchanged by three phase inductors.

Whares the primary solution with a coupled inductor is straight forward, using three single –phase inductors makes it possible to use all three phase legs for the dc/dc operation:

- Synchronous operations;
- Interleaving operation;

In the primary solution, all three phase legs can work synchronously with their own current control. In this task, the battery can be charged with a higher current compared to the case with one-phase dc/dc operation. This leads to faster charging time due to higher charging current capability. But, each phase operates with higher current ripples. Higher ripples current flowing into the battery and capacitor can have negative results on the lifetime of the battery and capacitor.

To beat the aforementioned problem associated with the synchronous operation, phase B and C can be moved by applying a phase offset for the interleaving operation using three phase legs, phase B and C are moved by 120 and 240 respectively. The inductor current control in interleaving operation needs a different inductor current sampling scheme, as shown in figure 8. Generally, for digitally control of a dc /dc converter, the inductor current is tested at either the beginning or centre point of PWM to confine the average current that is unbound fro switching noises. For two phases interleaving that two phases are 180 apart, there is change the sampling scheme, since the average inductor currents for both phases can be attained with the usual sampling scheme.

But, for three –phase interleaving, a changed sampling scheme is needed to compute the average currents for all three phases B and C must be moved by 120 and 240, respectively, may entail that computation needed inductor.

CONCLUSIONS

A passive MPPT technique, to be utilized mostly in large grid connected PV plants, has been introduced and discussed; it is essentially based on the energy storage capabilities of batteries that are proposed to be put in parallel to a proper number of PV subs –fields, so as to be used in a distributed manner. If well designed in their location, in their nominal voltage value and in their capacity, batteries can naturally catch the MPP of each PV sub-field, also compensating for critical unbalanced solar irradiation conditions.

Furthermore, the presence of an energy storage system can make more attractive grid-connected PV plant, due twosome important additional capabilities not common of currently conceived grid- current control for each phase should be done asynchronously. Using the interleaving operation reduces the ripples on the charging current flowing into the battery. Thus, the filter capacitance value can be decreased considerably.

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