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A REVIEW: RECONFIGURABLE SOLAR CONVERTER- A SINGLE STAGE PROCESS

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Abstract: ***In this Paper introduced a Converter which is called as Reconfigurable Solar Converter (RSC) for photovoltaic (PV)-battery application, particularly utility-scale PV-battery application. The concept of this new converter is to use a Three-phase single-stage grid-tie solar PV converter to perform dc/ac and dc/dc operations. This converter solution is appealing for PV-battery application. This RSC finds wide application in grid connected solar system since it utilizes single stage conversion rather than multistage conversion, reduced losses, low cost, simple in construction, improved efficiency and reduced volume. Combination of analysis is used to demonstrate the attractive performance characteristics of the proposed RSC. SOLAR photovoltaic electricity generation is not available or sometimes less available depending on the time of the day and the weather conditions. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output is falls dramatically. Therefore, solar PV electricity output significantly varies. Solar PV electricity output is also highly sensitive to shading. 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 the fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV systems has been dramatically increased, since, with energy storage, a solar Photovoltaic system becomes a stable energy source and it can be dispatched at the request, which results in improving the performance and the value of solar PV systems.***

Keywords: RSC Converter, energy storage, photovoltaic (PV), solar system, MPPT.

I. INTRODUCTION

Photovoltaic (PV) generation shows a currently one of the most promising and important sources of renewable green energy. For the purpose of environmental and economic benefits, PV generation system is preferred over other renewable energy sources, since they are clean, inexhaustible and require little maintenance. PV cells are generating electric power by directly converting solar energy to electrical energy. PV panels and arrays, generate DC power that has to be converted to AC at standard power frequency in order to feed the loads. The solar cell V-I characteristic is nonlinear and varies with irradiation and temperature. In general, there is a unique point on the V-P or V-I curve, called the Maximum Power Point (MPP), at which the entire PV system operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Therefore Maximum Power Point Tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP [5] Thus PV systems require interfacing power converters between the PV arrays and the grid. Photovoltaic-generated energy can be delivered to power system networks through grid-connected inverters. One critical issue in PV systems is the probable mismatch between the operating characteristics of the load and the PV array. The system's operating point is at the intersection of the I-V curves of the PV array and load, when a PV array is directly connected to a load.

The Maximum Power Point (MPP) of PV array is not attained most of the time. Thus this problem is overcome by using an MPPT which maintains the PV array's operating point at the MPP. MPP occurrence of in the I-V plane is not known priory; therefore it is calculated using a PV array model and measurements of irradiance and array temperature. Calculating of these measurements is often too expensive and the required parameters for the PV array model are not known adequately. Hence there are several MPPT continuously searches algorithms that have been proposed which uses different characteristics of solar panels and the location of the MPP [3].

MPPT is used to extract the maximum power from the solar PV module and transfer that power to the load. A dc/dc converter (step up or step down) transfer's maximum power from the solar PV module to the load and it acts as an interface between the module and the load. Maximum power is transferred by varying the load impedance as seen by the source and matching it at the peak power of it when the duty cycle is changed. In order to maintain PV array's operating at its MPP, different MPPT techniques are required. Many MPPT techniques are proposed such as, the Perturb and Observe (P&O) method, Incremental Conductance (IC) method, Fuzzy Logic Method etc. the two most popular MPPT techniques.

1) Perturb and Observe (P&O) and

2) Incremental Conductance methods) are studied [2].

There are various choices for integration energy storage into a utility-scale solar PV system. Energy storage can be integrated into the either ac or dc side of the solar PV power conversion systems which may consist of multiple conversion stages [4]. Every integration system has its advantages and disadvantages. Different integration solutions can be compared with regard to the number of power stages, storage system flexibility, efficiency, storage system flexibility, control complexity, etc.

This paper has been introduced in the following manner. The proposed RSC circuit, different mode and system benefits of operation discussed in paper.

II. RECONFIGURABLE SOLAR CONVERTER (RSC)

2.1 Introduction

The schematic of the proposed RSC circuit is presented in Fig.1.

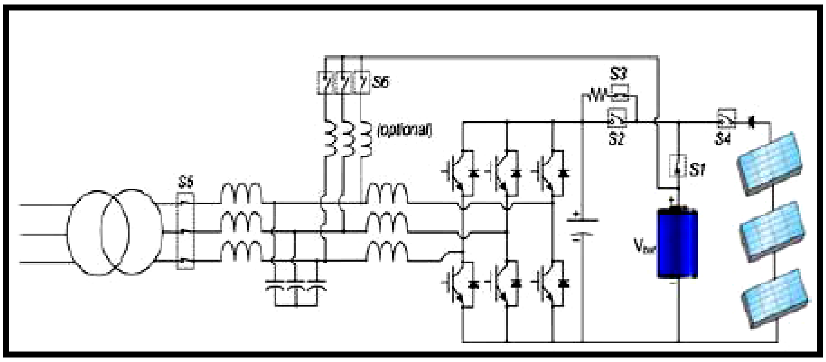

Fig.1 Schematic of the proposed RSC circuit

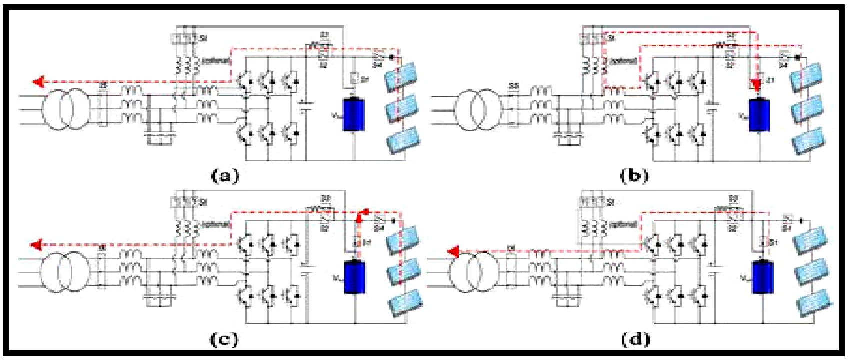

Fig.2 All operation modes of the RSC (a) Mode 1: PV to grid (b) Mode 2: PV to battery (c) Mode 3: PV/battery to grid (d) Mode 4: battery to grid.

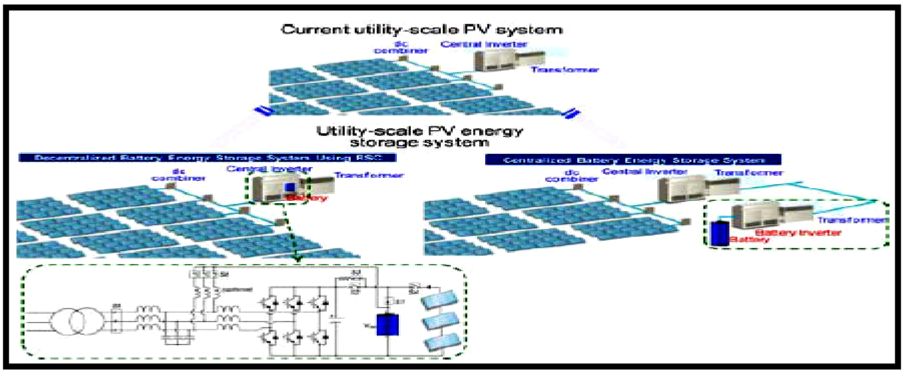

Fig.3 Utility-scale PV-energy storage systems with the RSC and the current state-of-the-art solution

The Reconfigurable Solar Converter has some modifications to the conventional three-phase PV inverter system. RSC include the charging function in the conventional three phase PV inverter system. Consider that the conventional utility-scale PV inverter system consists of a three-phase voltage source converter and its associated components, so the RSC requires additional cables and mechanical switches, as shown in Fig.1.

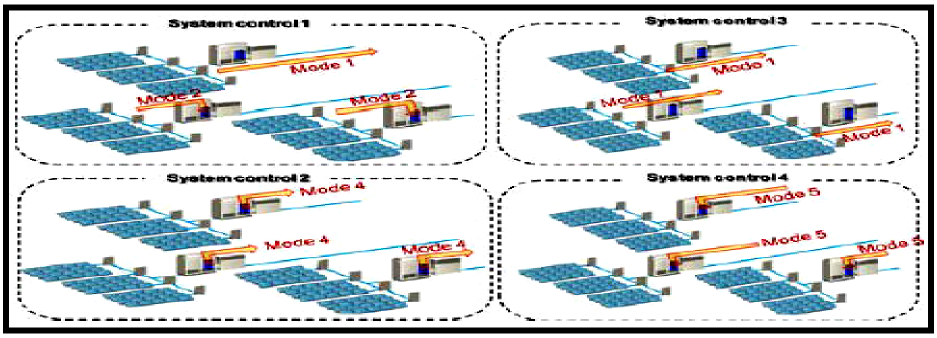

Fig. 4 Example of system operation different modes of a RSC-based solar PV power plant.

2.2 Operation Modes of the RSC

All possible operation modes for the RSC are presented in Fig.2.

In Mode 1: In this mode 1, the PV is directly connected to the grid through a dc/ac operation of the converter with possibility of maximum power point tracking (MPPT) control and the switches $S1$ and $S6$ remain open.

In Mode 2: In this mode 1, the battery is charged with the PV panels through the dc/dc operation of the converter by closing the switch S6 and opening the switch S5. In this mode, the MPPT function is performed; therefore, maximum power is generated from PV.

In Mode3: In this mode 3, there is another mode that both the PV and battery provide the power to the grid by closing the switch S1. This operation is shown as Mode 3. In this mode 3, the dc-link voltage that is the same as the PV voltage is enforced by the battery voltage; therefore, MPPT control is not possible.

In Mode 4: In this mode 4, represents an operation mode that the energy stored in the battery is delivered to the grid.

In Mode5: There is another mode, Mode 5 that the battery is charged from the grid. This mode is not shown in Fig.2.

2.3 System Benefits of Solar PV Power Plant with the RSC Concept

The RSC provides various benefits to system planning of utility-scale solar PV power plants. In Fig.3 shows examples of the PV energy storage solutions with the RSC and the current state-of-the-art technology. The benefits of the RSC solution is able to provide are more apparent in larger solar PV power plants. Specifically, using the RSCs a large solar PV power plant can be controlled more effectively and its power can be dispatched more economically because of the flexibility of operation. However, various system controls as shown in Fig.4 can be proposed based on the requested power from the grid operator Preq and available generated power form the plant Pgen. RSC-based solar PV power plants are as follows:

1) System control 1 for Pgen>Preq;

2) System control 2 for Pgen<Preq;

3) System control 3 for Pgen = Preq;

4) System control 4 for charging from the grid (Operation Mode 5).

III. RSC CONTROL

The RSC Control in 4 different ways in briefly-

1. Control of the RSC in the DC/AC Operation Modes (Modes 1, 3, 4, and 5)
2. Control of the RSC in the DC/DC Operation Mode (Mode 2)
3. Design Considerations and Modifications to the
4. Conventional Three-Phase PV Converter Mode Change Control

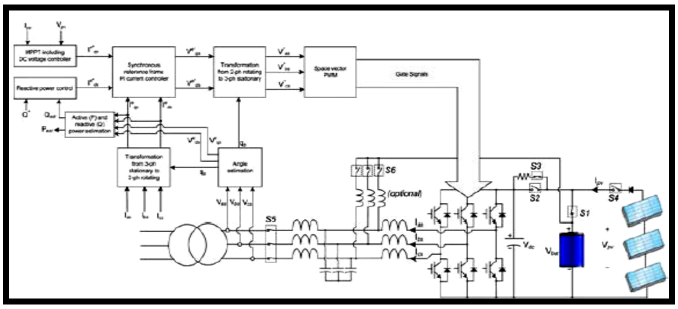

Fig.5 Overall control block diagram of the RSC in the dc/ac operation.

The RSC dc/ac operation is used for delivering power from PV to grid in mode 1, battery to grid in mode 3, PV and battery to grid in mode 4, and grid to battery in mode 5. The overall control block diagram of the RSC in dc/ac operation is shown in Fig.6.

The RSC dc/dc operation is used for delivering the maximum power from the PV to the battery in mode2. The overall control block diagram of the RSC in dc/dc operation is shown in Fig.6.

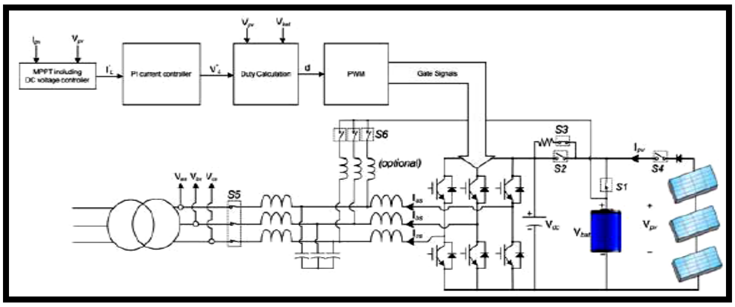

Fig.6 Overall control block diagram of the RSC in the dc/dc operation.

3.1 PV array Characteristics

For a good solar cell, the series resistance (Rs), should be very small and the shunt (parallel) resistance (Rp), should be very large. For commercial solar cells (Rp) is much greater than the forward resistance of a diode. The I-V curve is shown in Fig.7. The curve has three important parameters namely open circuit voltage (Voc), short circuit current (Isc) and maximum power point (MPP). In this model single diode equivalent circuit is considered. The I-V characteristic of the photovoltaic device depends on the internal characteristics of the device and on external influences such as irradiation level and the temperature.

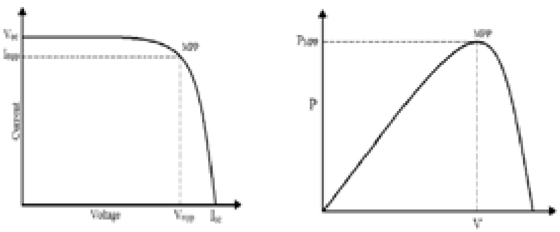

Fig.7 I-V and P-V characteristics of PV cell

IV. MPPT ALGORITHMS

4.1 Perturb and Observe (P&O) Algorithm

A slight perturbation is introduced in this following algorithm. The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same direction. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the steady state is reached. The perturbation size is kept very small in order to keep the power variation small [3]. The algorithm can be easily understood by the following flow chart which is shown in Fig.8.

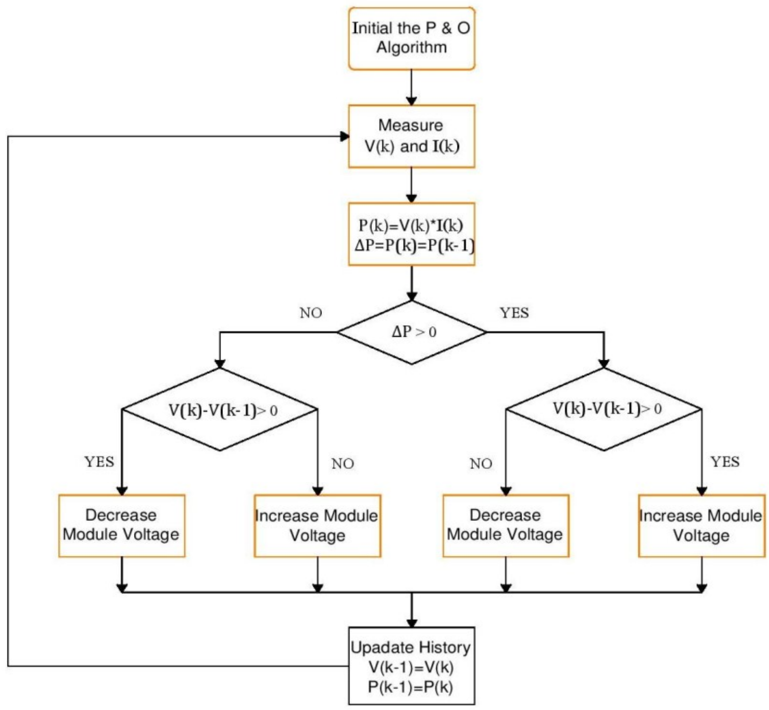

Fig.8 Perturb and Observe Algorithm

4.2 Incremental Conductance (IC) Algorithm

In this Incremental Conductance (IC) method overcomes the disadvantage of the perturb and observe method in tracking the peak power under fast varying atmospheric condition [2]. The disadvantage of this algorithm is that it is more complex when compared to Perturb & Observe methods. The algorithm can be easily understood by the following flow chart which is shown in Fig.9.

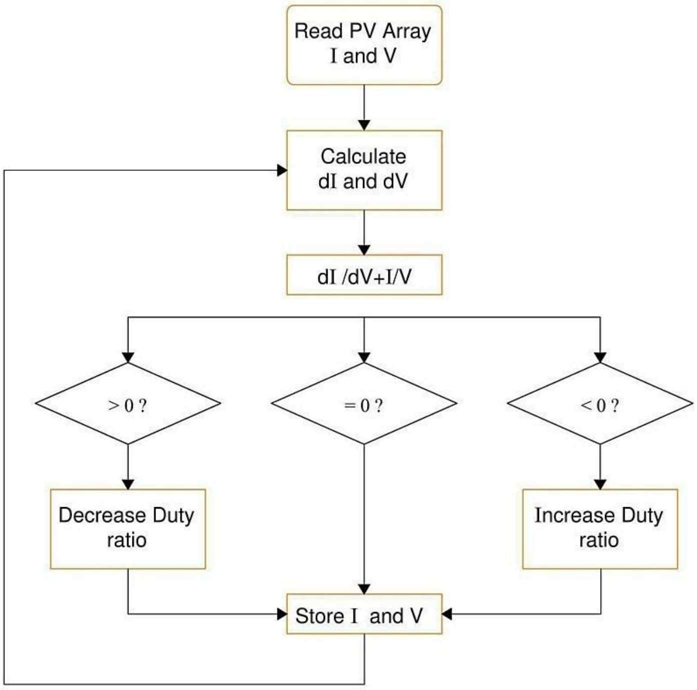

Fig.9 Incremental Conductance Algorithms

CONCLUSION

In this paper introduced a new converter called RSC for PV-battery application, particularly utility-scale PV-battery application. The basic concept of this RSC is to use a single power conversion system to perform different operation 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 systems with energy storage. The solution requires minimal complexity and modifications to the conventional three-phase solar PV converters for PV-battery systems. This model is used for the maximum power point tracking algorithms. It is proved that Incremental conductance method has better performance than P&O algorithm. These proposed algorithms improve the dynamics and steady state performance of the photovoltaic system as well as it improves the efficiency of the dc-dc converter system.

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