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Grid Connected Photovoltaic Power Generation Controller Z-Source Inverter with Single Stage Power Conversion

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ABSTRACT:

A new converter called reconfigurable solar converter (RSC) for photovoltaic (PV)-battery application program, particularly utility-scale PV-battery application.

Photovoltaic (PV) electricity generation is not available and sometimes less available depending on the time of the day and the weather conditions. Photovoltaic electricity output is also highly sensitive to blending, when even a small portion of a cell or module or array is shaded.

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

In the extension concept in order to increase voltage stability and to reduce switching loss introducing a Z-source connected to inverter to increase the stability of voltage and reducing number of switches to reduce the loss by reducing the shoot through problem.

The main concept of the new converter is to use a single-stage three phase grid-tie solar PV converter to perform dc-ac and dc-dc operations. It minimizes the number of conversion stages, thereby improving efficiency by reducing switches and reducing cost, weight, and volume.

Index Terms:

DC-AC Converter, Energy storage, photovoltaic (PV) module.

INTRODUCTION:

Now-a-days renewable energy resources are play an important role in our daily life in that photovoltaic (PV) electricity generation is not available and sometimes less available depending on the time of the day and the weather variations. Solar PV electricity output is also highly sensitive to shading. When even a small portion of a cell, module, or array is shaded, while the remainder is in sunlight, the output falls dramatic.

Therefore, solar PV electricity output significantly changes. 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 systems has been dramatically increased, since, with energy storage, a solar PV 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.

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.

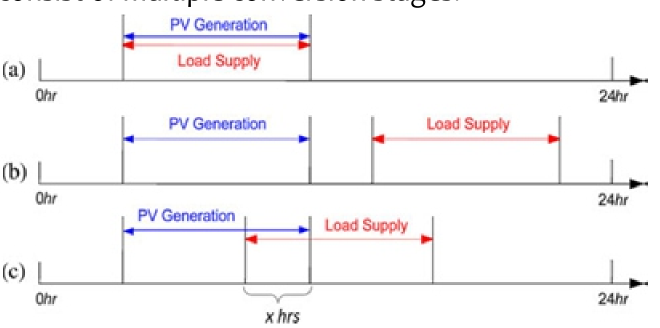

Fig. 1: Different scenarios for PV generation and load supply sequence.

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This paper proposes a novel single-stage solar converter called the reconfigurable solar converter (RSC). Basic concept of the RSC is to use a single power conversion system to perform different operation modes such as PV to grid (dc to ac), PV to grid (ac to dc) for solar PV systems with energy storage device.

The RSC concept arose from the fact that energy storage integration for utility-scale solar PV systems makes sense if there is an enough gap or a minimal overlap between the PV energy storage and release time. Different integration solutions can be compared with regard to the number of power stages, efficiency, storage system flexibility, control complexity, etc. Every integration solution has its advantages and disadvantages.

Reconfigurable solar converter:

The below figure 2 shows the reconfigurable solar converter for a grid connected system. The RSC has some modifications to the conventional three-phase PV inverter configuration. These modifications allow the RSC to include the charging function in the conventional three phase PV inverter conversion.

Assuming that the conventional utility-scale PV inverter system consists of a three-phase voltage source converter and its associated components and the RSC requires additional cables and mechanical switches as shown in Fig. 2. Optional inductors are included if the ac filter inductance is not enough for the charging purpose. And in the extended of this paper is implemented by the Z-source converter for the improvement of the efficiency, for reducing the losses by reducing the shoot through concept occurring as sown in fig.3.

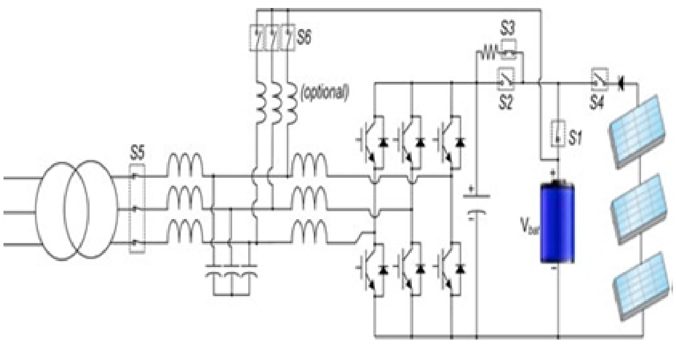

Fig. 2: Schematic of the proposed RSC circuit.

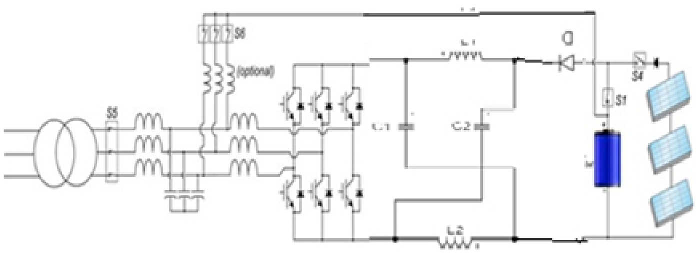

Fig 3: Extension circuit diagram with Z-source converter

Operation Modes of the RSC:

All possible operation modes for the RSC are presented in Fig. 4. In 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 S1 and S6 switches remain open.

In Mode 2, the battery is charged with the PV panels through the dc/dc operation of the converter by closing the S6 switch and opening the S5 switch. In this mode, the MPPT function is performed; therefore, maximum power is generated from PV. There is another mode that both the PV and battery provide the power to the grid by closing the S1 switch. This operation is shown as Mode 3.

In this mode, the dc-link voltage that is the same as the PV voltage is enforced by the battery voltage; therefore, MPPT control is not possible. Mode 4 represents an operation mode that the energy stored in the battery is delivered to the grid. There is another mode, Mode 5 that the battery is charged from the grid. This mode is not shown in Fig. 4.

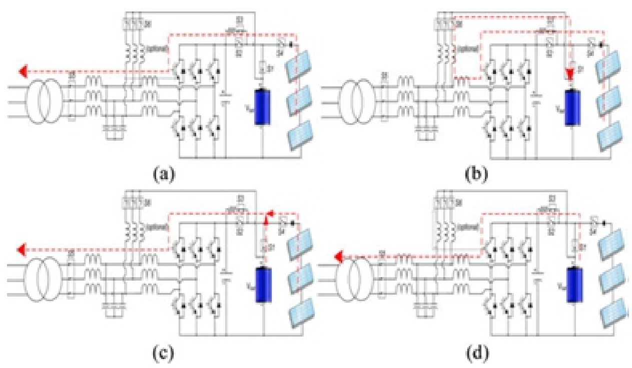

Fig 4: Modes of operation of the RSC

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Benefits of Solar PV Power Plant With the RSC Concept:

The RSC concept provides significant benefits to system planning of utility-scale solar PV power generating stations. The current state of- the-art technology is to integrate the energy storage into the ac side of the solar PV module. The RSC concept allows not only the system owners to possess an expandable asset that helps them to plan and operate the power plant accordingly but also manufacturers to offer a cost-competitive decentralized PV energy storage solution with the RSC.

The technical and financial benefits that the RSC solution is able to provide are more apparent in larger solar PV power plants. Specifically, a large solar PV power plant using the RSCs can be controlled more effectively and its power can be dispatched more economically because of the flexibility of operation.

The developing a detailed operation characteristic of a solar PV power plant with the RSC is beyond the scope of this project. However, different 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.

These two values being results of an optimization problem (such as unit commitment methods) serve as variables to control the solar PV power plant accordingly. In response to the request of the grid operator, different system control schemes can be realized with the RSC-based solar PV power plant as follows:

1) System control 1 for Pgen > Preq;

2) System control 2 for Pgen < Preq;

3) System control 3 for Pgen = Preq;

Z-SOURCE CONVERTER:

Z source network is a one type of DC-DC converter which is used to control the shoot through problem and also used to reduce the harmonics, electromagnetic interference and acts as a Buck-boost converter operation. Z source inverters are recent inverter topologies that can perform both buck and boost functions as a single unit. (Fang Zheng Peng 2003).

A unique feature of Z source inverter is the shoot through state, by which two semiconductor switches of the same phase leg can be turned ON simultaneously. Therefore, no dead time is needed and output distortion is greatly reduced and thus reliability is greatly improved.

Feature is not available in the traditional voltage source and current source inverters. The proposed Z source inverters are mainly applied for loads that demand a high voltage gain such as motor drives and as a power conditioning unit for renewable energy sources like fuel cells, solar, etc to match the input source voltage differences.

The development in Z source inverter topologies provides a consecutive enhancement in voltage gain and output waveforms. A tradeoff between the boosting capability and component count is always a major concern to keep the cost stable.

It is to be noted that increase in the passive components with suitable modifications can improve the performance of these types of inverters.

The topological growth has been in terms of addition or reduction of passive component, inclusion of extra semiconductor switches, alteration or inclusion of dc sources and also changes of modulation schemes etc. Voltage buck inversion ability is also provided for those applications that need low ac voltages.

The Z-source converter employs a unique impedance network to couple the converter main circuit to the power source, thus providing unique features that cannot be obtained in the traditional voltage-source and current-source converters where a capacitor and inductor are used, respectively.

The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter and current-source converter and provides a novel power conversion concept. The Z-source concept can be applied to all AC-to-DC, DC-to-AC, AC-to-AC, DC-to-DC power conversion.

To describe the operating principle and control, this paper focuses on an example: a Z-source inverter for DC-AC power conversion needed in fuel cell applications.

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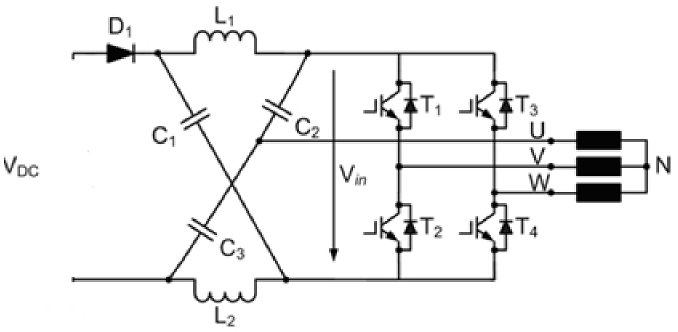

Fig 5: Z-source inverter circuit diagram

Proposed control technique:

The below figure shows the control technique for the proposed Z-source inverter as shown in the proposed converter fig.3. The highest layer of the RSC mode change control is shown in Fig6. This layer consists of fault detection, normal operation mode, fault reset.

The basic fault detection such as detecting overcurrent and overvoltage and fault management like turning off PWM signals are implemented inside the converter control executed in the inner most control loop.

In this way, fast fault detection and protection are possible. In general, shutting down all PWM signals is able to clear the fault. In addition, all relays are forced to be opened.

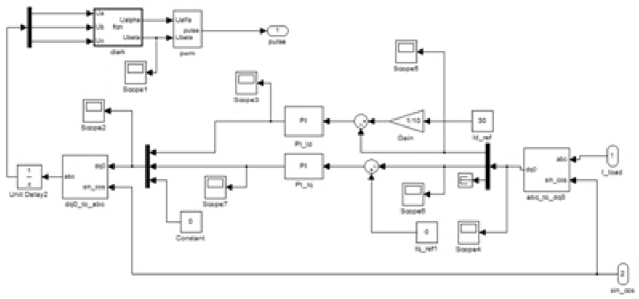

Fig 6: Proposed control technique

Simulation Results:

The below figure shows the simulation diagrams of a proposed converter and the extended converter without Z-source and with Z-source networks as shown in below with their results simultaneously.

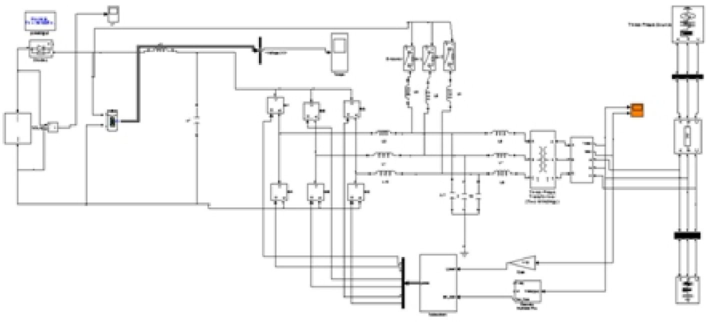

Fig 7: Simulation diagram for a proposed converter without Z-source network.

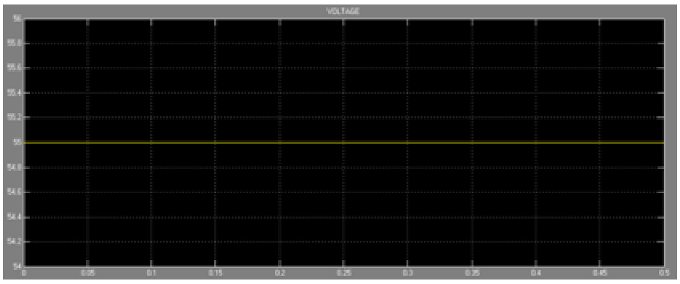

Fig8: Solar input voltage.

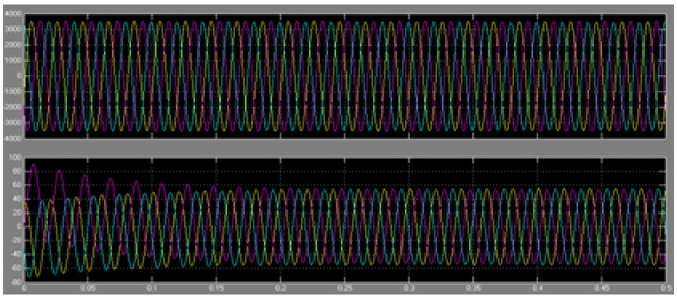

Fig 9: Grid voltage and current.

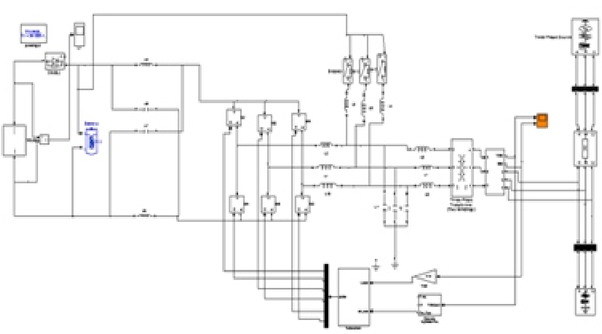

Fig10: Extension simulation of the proposed converter with the Z-source network.

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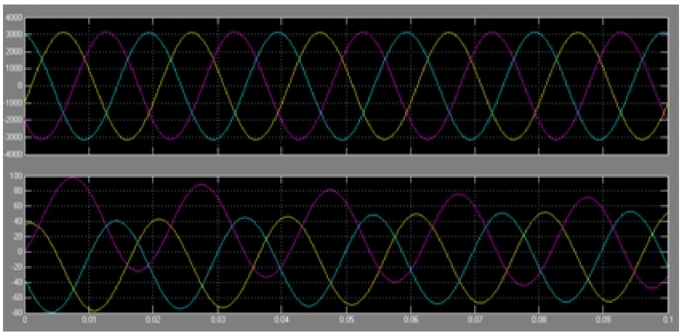

Fig 11: Three phase grid voltage with the Z-source network

CONCLUSION:

In this a new converter called reconfigurable solar converter (RSC) for photovoltaic (PV)-battery application program, particularly utility-scale PV-battery application is used. Photovoltaic (PV) electricity generation is not available and sometimes less available depending on the time of the day and the weather conditions. Photovoltaic electricity output is also highly sensitive to blending, when even a small portion of a cell or module or array is shaded.

The main concept of the new converter is to use a single-stage three phase grid-tie solar PV converter to perform dc-ac and dc-dc operations. In order to increase voltage stability and to reduce switching loss introducing a Z-source connected to inverter to increase the stability of voltage and reducing number of switches to reduce the loss by reducing the shoot through problem. The main concept of the new converter is to use a single-stage three phase grid-tie solar PV converter to perform dc-ac and dc-dc operations. It minimizes the number of conversion stages.

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