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The Grid Linked Split-Source Inverter Decoupled Control Scheme

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Abstract: Systems must follow many requirements, such as good efficiency, reduced cost and complexity and, most importantly, improved ability. This is generally achieved before the inversion stage by using the front-end dc-dc booster (BC) converter, leading to a two-step design. In the meanwhile, in terms of reducing the sophistication and volume of the whole system, single-stage power conversion systems that conduct the boosting process during the inversion step have some possible benefits. The split source inverter (SSI) has recently been proposed in[1] as an alternative solution with some interesting features to the commonly used Z-source inverter (ZSI) among many proposed alternatives. Taking into account that the SSI is regulated by a single parameter, i.e. its dc. The modulation index controls the ac and ac sides, and it is of the utmost importance to investigate its grid-connected control function, which has not yet been examined. This paper therefore models the SSI dc side and proposes a modified modulation scheme in accordance with the modulation scheme currently in use. The synchronous reference frame control technique is used to achieve a decoupled SSI control device in grid-connected mode, i.e. the dc and ac sides of the SSI can be controlled separately, which is useful for many applications. The MATLAB / Simulink model is used to test and simulate the applied control scheme, where a reduced scale of 1 kVA grid-connected SSI is designed and simulated for experimental validation purposes. Finally, a constructed infrastructure is placed in order to test and verify the reported research and simulations.
Keywords: Shared Source Inverter (SSI), Z-Source Inverter (ZSI), front-end dc-dc boost converter (BC), Matlab, Simulink

I. INTRODUCTION

The deployment of various renewable energy sources (RESs) to the power grid is gradually increasing, in which the role of power electronics technology in the energy conditioning process used is of vital importance in meeting several requirements[2],[3]. These specifications range from the input side , i.e. the RES, to the output side , i.e. the power grid. For the input side, the management of the RES operating point and the regulation of its output voltage are mandatory issues to be considered due to their reliance on differing climatic conditions[4],[5]. In the meantime, complex control systems are being applied for the output side in order to meet with the quality specifications, e.g. the low harmonic quality of the injected line current[6]. Over the last few years, single-stage power conversion systems have undergone rapid development to replace the traditional two-stage architecture, which includes the front-end dc-dc boost converter (BC) and the VSI output source inverter (VSI)[7],[8]. This evolution has evolved to boost overall machine efficiency in terms of reducing the scale, weight and complexity. Most of these single-stage topologies and their numerous modulation schemes have been examined in[1],[8],[9]. The split-source inverter (SSI) shown in Fig is one of these various single-stage solutions. 1(a) has recently been suggested in[1] as a single-stage dc-ac power converter topology to address certain demerits in other single-stage topologies, such as the discontinuity of the input current and the dc-link voltage.

A. SSI Merits and Demerits

The SSI shall have the following merits:

1) steady DC-connection voltage;
2) constant current input;
3) lower switch voltage loads and higher voltage gain, i.e. lower input DC voltages compared to other comparable topologies;
4) lower passive part count;
5) no requirement for additional active switches relative to the VSI standard;
6) the same standard modulation schemes for simple operation as the VSI;
7) The same swapping state as the VSI.

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In the meantime, SSI suffer from the following demerits:

1) higher current tension of the lower switches;
2) Higher voltage tension and higher output, the Voltage for lower voltage boost, i.e. higher input DC voltage;
3) High-frequency switching of the input diodes.

II. LITERATURE SURVEY

There have been numerous theoretical works on the SSI, such as [10]–[13], in which the authromans [10]–[12] address the three-tier function of SSI using brids of diode-clamped and moving condensers when addressing its one-phase activity in [13]. In the meantime, the grid-connected service control system has not yet been studied. The SSI is modulated with the same eight regular VSI states, unlike ZSI, which uses an additional state, known as the shoot through state, to obtain the boost. This added state provides an extra degree of freedom to control the dc side independently of the one mentioned in [14] – [16] where the traditional two-stage control system is used. It is therefore of utmost importance to explore the feasibility of using the standard synchronous reference mechanism control technology, which is used in many implementations in both stages with the so-called SSI. This paper therefore models the SSI dc side of the device and suggests a modified modulation scheme in combination with a synchronous frame control strategy to achieve a disconnected grid linked SSI control scheme, i.e. the dc and the ac side of the SSI may be independently controlled.

The popular mode concept of the modulating signals in this decoupling control device is used to govern the dc side, thereby allowing for a greater degree of freedom from two control parameters, such as the two-staged architecture. The research and study of the control system with various single-stage topologies in the grid-connected operating mode is growing considerably for different applications. The authors addressed the operation of the quasi-Z-source inverting three-phase inverters (qZSIs) in grid-connected photovoltaic systems, while the authors implemented a qZSI energy storage system without any external circuitry in the [18]–[20] mode, taking advantage of many passive elements without restricting the versatility of the control system. In the other hand, the controller architecture was discussed[21] for the grid-connected ZSI in order to increase the distribution system's power efficiency. In addition, the use of qZSI as an interconnector in a standard ac-dc hybrid micro grid was investigated [22], in which its power was investigated using the full boost method. Consequently, such an inquiry with the SSI was required to define the use of it in grid-connected mode and to lay down compulsory design steps to achieve this goal and also to stress the limitations associated with this process.

III.BLOCK DIAGRAM

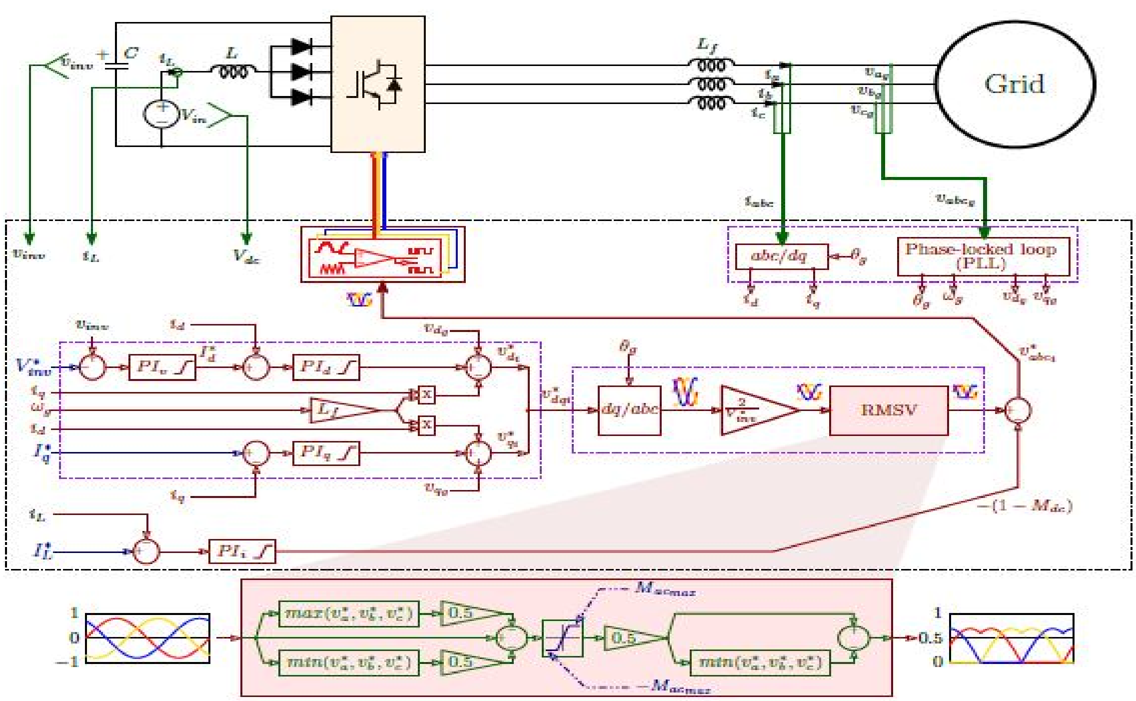

Fig. Block Diagram

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This section develops and studies the study of the integrated control scheme, which is used with the SSI in the grid-connected mode of operation. The key aim, as discussed before, is to explore the possibilities of using the same synchronous reference frame control strategy used in the two-stage design in which the dc-link voltage is regulated by the controller of the output current, while the input current or input voltage is regulated by the BC's duty cycle. This section therefore begins first by explaining the adopted adjustment to the SSI modulation system, which is proposed to add two control parameters by which the SSI ac and dc sides, like all single-stage topologies, can be independently controlled under such limitations.

A. Regulated MSV Modulation Scheme

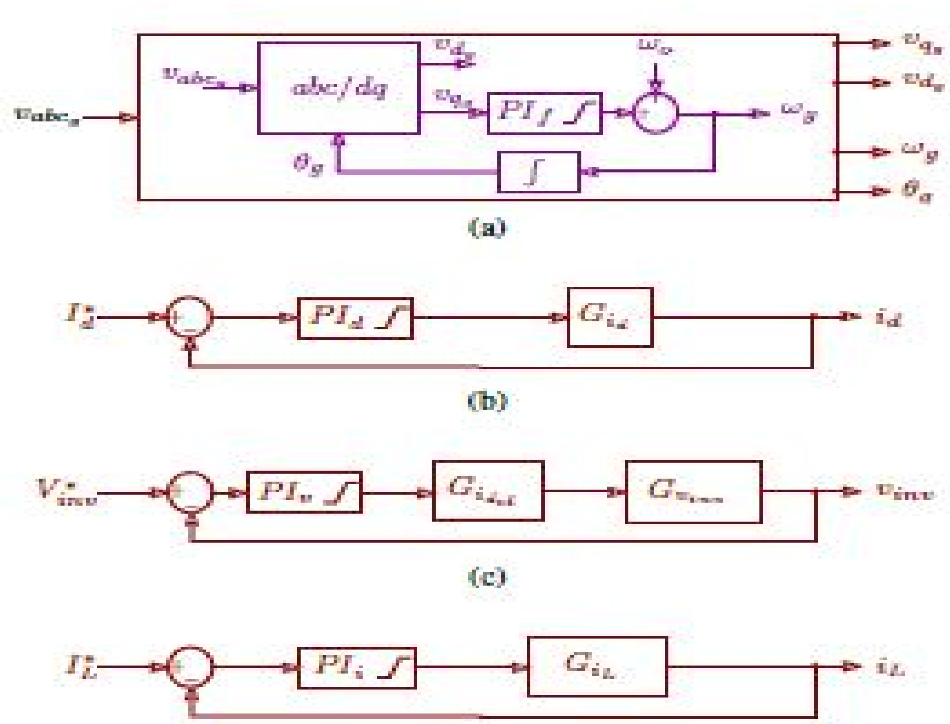

Fig. Block diagrams of the different control loops. (a) phase locked loop (PLL), where !o is the nominal angular frequency; (b) output current control loop considering the d component, where the q one is equivalent to it; (c) dc-link voltage control loop; (d) input current control loop.

B. SSI Decoupled Control Scheme

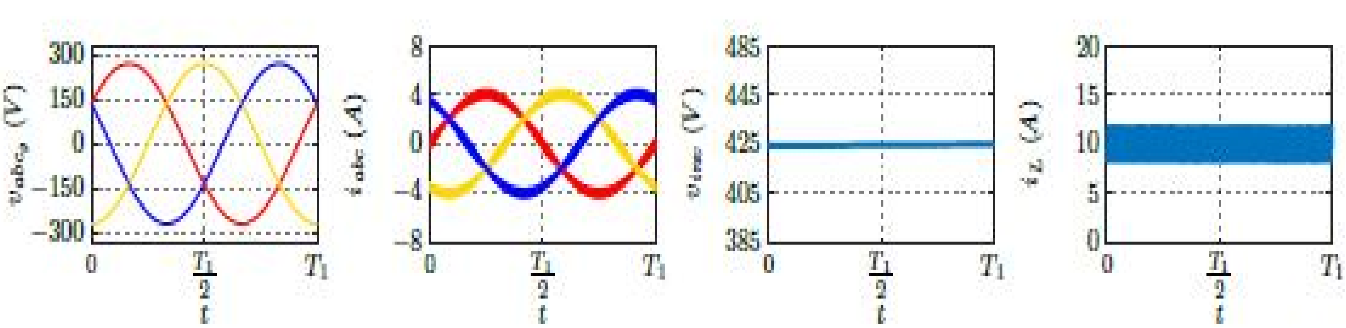

Fig. Grid-connected SSI simulation results at steady-state for one fundamental cycle

IV. PROTOTYPE SETUP

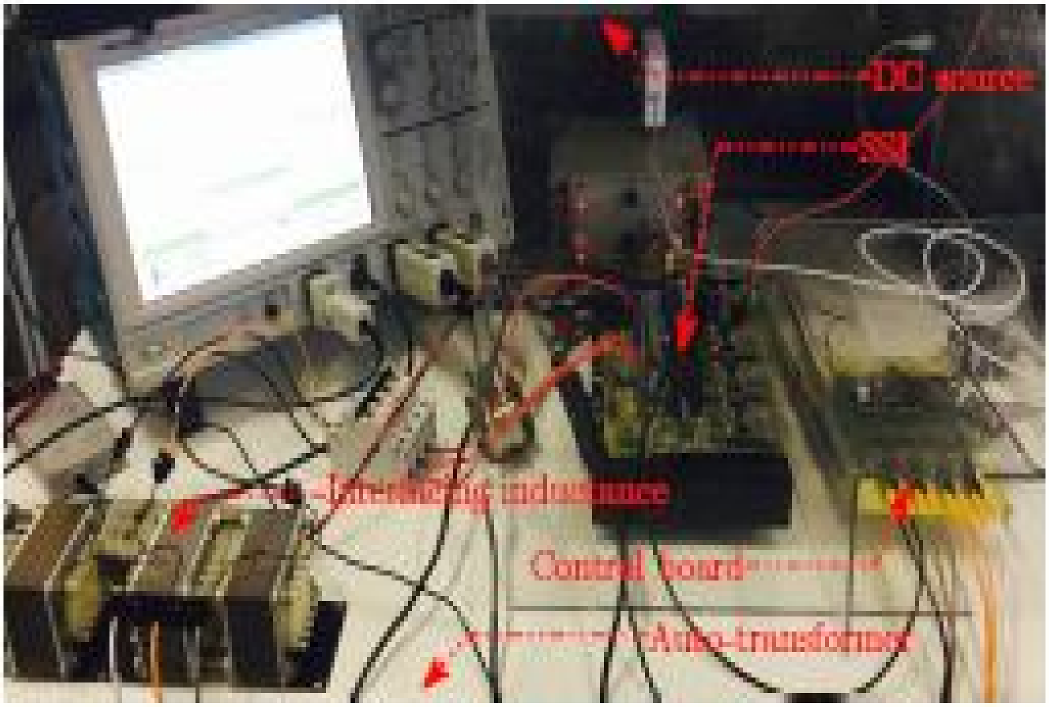

Fig. Grid-connected SSI experimental prototype.

V. CONCLUSION

This paper discussed the split-source inverter (SSI) closed-loop control in grid-connected operating mode, where a decoupled control mechanism was added to separately control the SSI dc and ac sides, which is useful for many applications. A combination of the proposed controlled modified space vector (RMSV) modulation scheme and the widely used synchronous reference frame control technique is the basis of this control scheme. First, the SSI dc side has been modelled and then the control system implemented is addressed. Using the MATLAB / Simulink model, this paper checked the implemented control scheme, considering various transients, and then checked the simulation results using a reduced 1 kVA experimental prototype size. The machine is correctly controlled and a completely decoupled regulation of both the input dc current and the output ac current has been obtained, as seen in the simulation and the experimental results.

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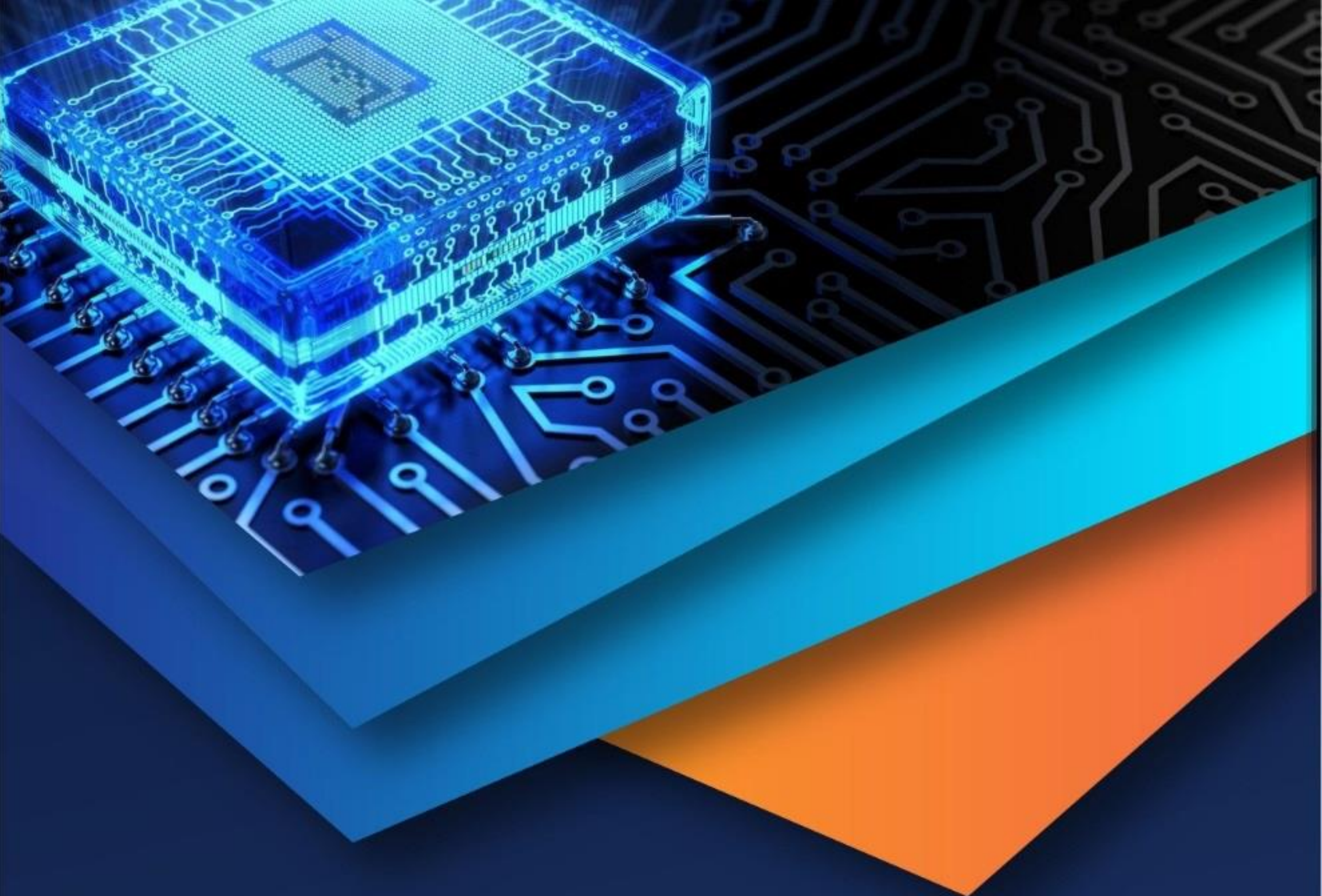

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