An Interlinking Converter for Renewable Energy Integration into Hybrid Grids with FC

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***Abstract*— In this works, presents an interlinking structure of converter for sustaining the flexible power as a result of integration of renewable power-based sources into the hybrid grid system. The greatest attribute of the proposed converter has two types ports such as one AC port and two DC ports for maintain the stability. However, the reliable of power quality is difficult to sustain as a result of continuous changes in atmospheric conditions. Hence, in this work, fuel-cell (FC) is utilized to stabilized the changes in hybrid grid system. The system has been designed in the MATLAB/Simulink environment. The simulation results mentioned that the FC-based grid integrated renewable sources system has contributed the finest outcomes for improving the system stability.**

Keywords: Renewable power, hybrid grid system, converter, fuel-cell, stability.

I.INTRODUCTION

To foster sustainable, low-emission development, many countries are establishing ambitious renewable energy targets for their electricity supply. Because solar and wind tend to be more variable and uncertain than conventional sources, meeting these targets will involve changes to power system planning and operations [1]-[3]. Grid integration is the practice of developing efficient ways to deliver variable renewable energy (VRE) to the grid. Good integration methods maximize the cost-effectiveness of incorporating VRE into the power system while maintaining or increasing system stability and reliability [4][5].

In the earlier workmanship research, the spotlight has been put on the power the executives and control of cross breed AC/DC matrices. For occasion, in [6], an outline of half and half microgrids was introduced regarding framework structures, activity modes, power the executives and control. The cross breed microgrid is turning out to be much alluring because of the expansion of current DC loads and RESs with energy stockpiling being coordinated into the framework. In such applications, the interlinking converter is basic (e.g., unwavering quality, reasonability, and steadiness), which empowers incorporating different fuel sources into the matrix. To guarantee the activity, power-sharing methodologies were additionally created for interlinking converters under different situations [6]. In any case, endeavors to create interlinking converters have not been seriously made in the writing, which yet can be a promising intends to upgrade the activity of such crossover energy systems. Unmistakably, the interlinking converter ought to have numerous associations (e.g., DC ports and AC ports).

There are two ways to achieve so: using separated standard DC-DC and DC-AC converters to form a multistage on version system [6]and developing stand-alone multiport configurations [7]–[13].Compared to the former solution, standalone hybrid topologies bring more benefits (e.g., increased reliability, higher power density, and lower system cost due to the reduced number of conversion stages), and they possess more flexibility. For instance, the split-source inverters were introduced in [9] and[10] to enhance the compactness, efficiency, flexible power flow and voltage-boosting, while the leakage current issue was not considered. This is a troublesome challenge when applied in PV systems. To lower leakage currents, transformer less stand-alone converters [12], [13] can be employed, yet lacking bidirectional power flow capability. Additionally, due to adopting of a dual-buck inverter, large AC filter inductors are required, leading to a relatively low power density that contradicts with the benefits of standalone hybrid converters[12]. In all, the state-of-the-art converters have limitations when being used as an interlinking conversion stage in hybrid AC/DC grids. Hence, in this work, fuel-cell (FC) is utilized to stabilized the changes in hybrid grid system. The system has been designed in the MATLAB/Simulink environment. The simulation results mentioned that the FC-based grid integrated renewable sources system has contributed the finest outcomes for improving the system stability.

II. SUGGESTED SYSTEM

A. General Concept

The general concept of the proposed interlinking converter architecture for hybrid grids is shown in Fig. 1. As seen in Fig. 1, the converter has two DC ports and one AC port, where the low-voltage DC (DCL) side can be PV panels, batteries or other RESs, and the high-voltage DC (DCH) side can be connected to a DC grid or loads (also storages). Similarly, the AC side can be an AC load or an AC grid. Notably, all the power conversions in the proposed architecture should be bidirectional for high flexibility. To realize so, the following should be considered: 1) The control switch of the boost converter is replaced by a VSI with its common-mode voltage(CMV) being clamped to achieve the AC output; 2) An active switch, i.e., a synchronous rectifier switch, is adopted for the bidirectional DC-DC conversion, and accordingly, the hybrid converter can achieve boost or buck conversion between the DCL and the DCH sides; 3) A symmetrical impedance network(SIN) is placed at the DCL side, as exemplified in Fig. 1, which is also essential to lower the leakage currents.

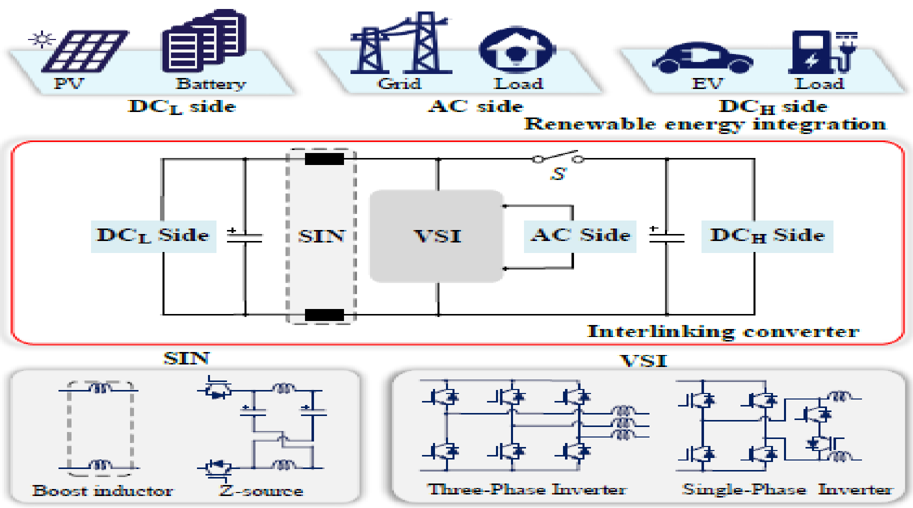

Fig. 1. General concept of the proposed interlinking converter architecture, where S represents an active switch, allowing the bidirectional power flow.

In such an architecture, the CMV will be clamped to be half of the DCL voltage by the symmetrically arranged impedance and the VSI. To demonstrate the CMV clamping, the proposed interlinking converter architecture with a single-phase inverter is exemplified as shown in Fig. 2.

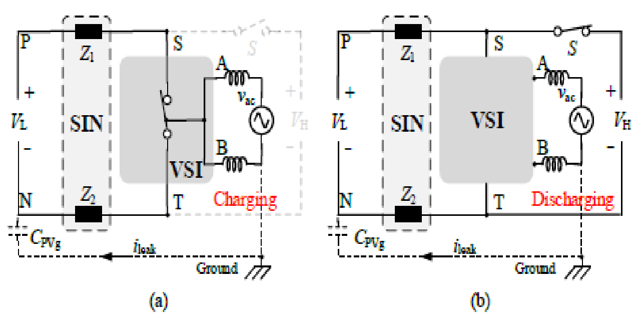

Fig. 2. Operational states of the proposed interlinking converter architecture with a single-phase inverter: (a) charging state and (b) discharging state, whereZ1 and Z2 are the equivalent impedances of the SIN (Z1 = Z2), P and N are the positive and negative terminals of the DCL side, S and T are the positive and negative input terminals of the VSI, A and B are the output terminals of the VSI, VL, VH and vAC are the DCL voltage, the DCH voltage and the AC voltage, CPVg and ileak are the PV parasitic capacitor and the leakage current.

As observed in Fig. 2, there are two modes, i.e., the charging and discharging states of the SIN, which are defined as follows:(1) During the charging period, the VSI operates in shoot though(ST) mode and the active switch S is OFF, as depicted in Fig. 2(a). Accordingly, the terminal voltages are vAN=vBN= VL=2, and the CMV vcm [12] is calculated as

$$v_{\text{cm}} = \frac{v_{\text{AN}} + v_{\text{BN}}}{2} = \frac{V_{\text{L}}}{2}$$

As presented in Fig. 2(b), the SIN is discharging, the VSI operates in the DC-AC conversion mode, and S is in ON-state. Due to the CMV (denoted as vcm VSI) being already clamped by the adopted VSI vcmVSI= (vAT+vBT)=2 = VH=2. Considering the terminal voltage vAN= vAT{VZ2, vBN= vBT{VZ2, the resultant CMV of the proposed converter can be obtained as

$$v_{\text{cm}} = \frac{v_{\text{AN}} + v_{\text{BN}}}{2} = \frac{(v_{\text{AT}} - V_{\text{Z2}}) + (v_{\text{BT}} - V_{\text{Z2}})}{2} = \frac{V_{\text{H}} - (V_{\text{Z1}} + V_{\text{Z2}})}{2} = \frac{V_{\text{L}}}{2}$$

where VZ1 and VZ2 are the SIN voltages, i.e., VZ1 = VZ2.It can be observed from Eqs. (1) and (2) that the proposed interlinking conversion architecture can maintain a constant CMV due to the employment of the SIN and the VSI with its CMV being clamped. Thus, the proposed interlinking converter is suitable for PV applications. It is worth noting that the leakage current suppression can only be achieved at the DCL side. Additional isolation equipment can be considered at the DCH side according to application requirements (e.g.,in a DC grid).

B. Operational Flexibility

As shown in Fig. 1, the adoption of the synchronous rectifier switch enables the bidirectional power flow between the DC ports. Furthermore, the VSI can also achieve reactive power injection with a dedicated modulation method, where the power factor can be adjusted between [-1, 1]. In all, the proposed hybrid converter has high flexibility and controllability for RES integration into hybrid grids. As shown in Fig. 3, the flexibility is reflected by the possible operation modes, which include: the power feed-in mode (Mode I), the power feedback mode (Mode II), and the power factor mode (Mode III):

(1) In Mode I, the DCL side is a source (e.g., PV panels) to provide power to the DCH side, the AC side or both. In this case, the converter achieves the boost DC-DC conversion and DC-AC conversion from the DCL side to the DCH and the AC sides, respectively. Additionally, in this mode, both the DC Land the DCH/AC sides can feed power into the AC/DCH side.

(2) In Mode II, there are three operation cases. Firstly, the power from the AC side is fed back to the DCL and DC H sides (i.e., the two DC ports are loads), where the converter operates in the active rectification for the DCH side and the buck DC-DC conversion for the DCL side from the AC side. Secondly, the power feed-back mode is the case where only the DCL side is working as a load (e.g., charging batteries). That is, both the DCH and AC sides are providing power. Thirdly, both the DCL and the AC sides are acting as loads, where the DCH side should perform the buck DC-DC and the DC-AC conversions, respectively.

(3) In Mode III, whatever power flow modes between the DCL and DCH sides are, the power factor at the AC side should be controlled flexibly to enable grid-connected applications. The proposed converter architecture can achieve

so when the modulation method for the DC-AC conversion has reactive power injection capability, as indicated in Fig. 3.

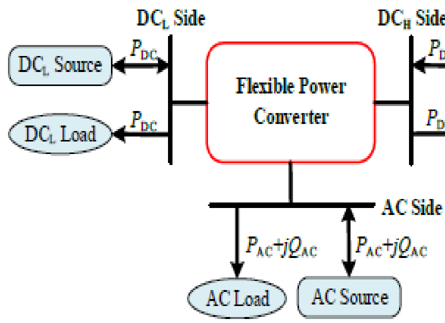

Fig. 3. Possible operation modes of the proposed interlinking conversion architecture, where PAC and QAC represent the corresponding active power and reactive power at the AC port.

When applied in a hybrid AC/DC grid (i.e., the AC and DCH ports are connected to grids), the overall system operation ca be enhanced to a large extent. For instance, when the AC grid requires support (e.g., to tackle the frequency stability), the active power from the input DCL side can be regulated, while the DCH grid can also provide support by feeding power to the AC port. Similarly, if the DC side has stability issues under faults (e.g., under voltage issues), the AC grid can be operated in the rectification mode to help the DC grid withstand the fault. In all, the proposed power conversion architecture can be a flexible and promising solution to the integrating of RESs into hybrid AC/DC grids.

C. Topology and Modulation Example

A modulation strategy for the proposed architecture is further demonstrated on an exemplified converter using a highly efficient and reliable inverter concept (HERIC) inverter as the VSI and a symmetrical inductor network as the SIN, which
is shown in Fig. 4.

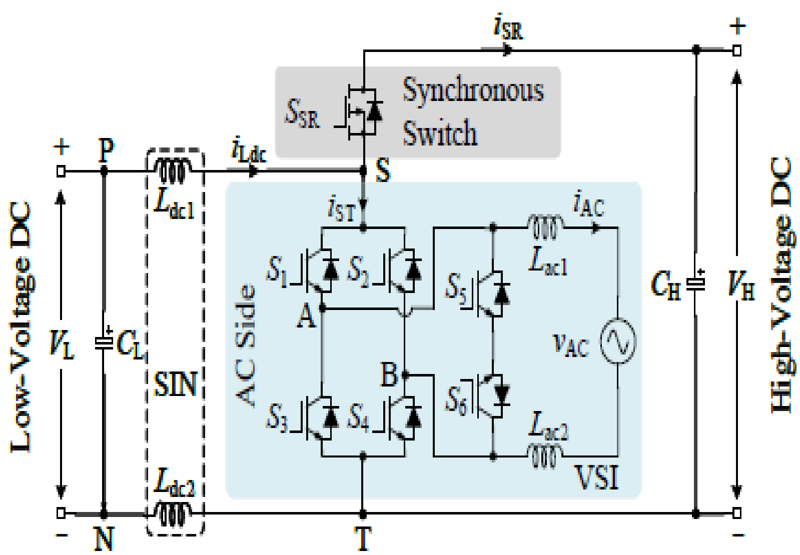

Fig. 4. An example of the proposed interlinking conversion architecture using a symmetrical boost inductor network and an HERIC, where SSR is the synchronous rectifier switch, the boost inductors are Ldc1, Ldc2, (i.e.,Ldc1 = Ldc2),

CL and CH are the DC capacitors, idc, iST and iSR are the DC inductor current, the VSI input current and the synchronous rectifier switch current, iAC is the current of the L-type filter (i.e., including Lac1 and Lac2,Lac1 = Lac2), and its positive direction is from the VSI to the AC grid.

III. FUEL-CELL (FC)

Fuel cell makes use of chemical reaction to generate electricity. It is possible to generate electricity with minimum pollution by making use of Fuel cell as it makes use of hydrogen and oxygen to ultimately generate electricity and a harmless byproduct, water. Fuel cells provide efficient and clean energy using this energy conversion and thus regarded as renewable energy resources. In general, chemical reaction takes place inside the fuel cell and it makes use of two electrodes, an anode and cathode respectively and an electrolyte between them for the reaction to take place. Hydrogen is the basic fuel for the reaction to take place but it also makes use of oxygen and a catalyst to speed up the reaction. As fuel cells are static in nature because of their quiet operation without noise or vibration and its simple modular construction makes them highly efficient. Thus fuel cell provides a cleaner, much efficient and flexible source of energy. A fuel cell consists of following components: Anode, cathode and an electrolyte between them. The operation of fuel-cell is demonstrated in Figure 5.

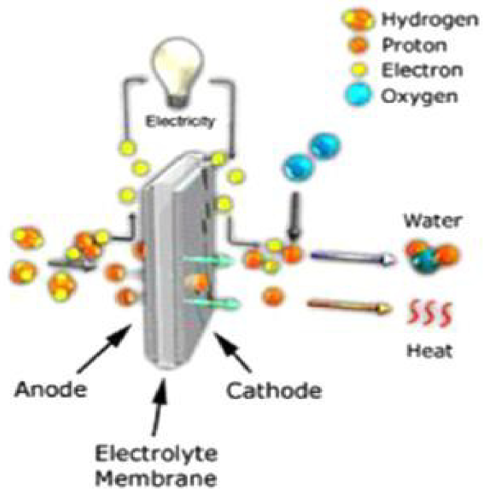

Figure 5 Fuel cell operation

The chemical reaction on which this occurs is as follows:

$H2 = 2H+ + 2e-$

The hydrogen ions travel through the acidic electrolyte and the electrons travel to the cathode end to complete the circuit. At cathode end, the electrons and hydrogen ions react with oxygen which is supplied to the tank through external pipeline to form water.

$O2 + 2H+ + 2e- = H2O$

The total reaction of fuel cell is shown below which gives out water, electric work and heat as output:

$H2O + O2 = H2O + Wele + Qheat$

The by-products; heat and water are continuously removed so as to continuously maintain the isothermal operation for generation of electricity. Therefore, water and heat needs to be managed efficiently for effective operation of fuel cells.

IV. SIMULATION OUTCOMES

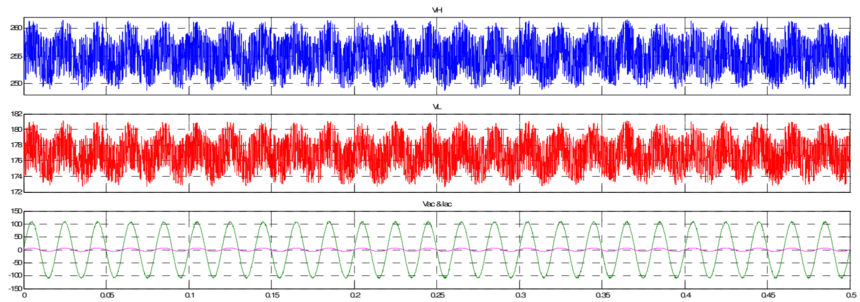

Fig. 6. Performance of the proposed interlinking converter with an PID based HERIC as the VSI operating in Mode I.

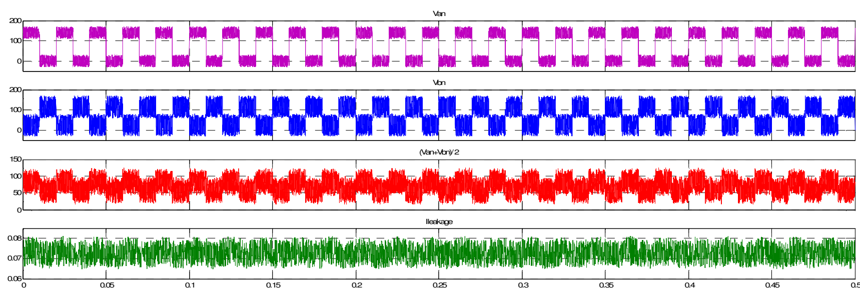

Fig. 7. Performance of the proposed converter with PID, where vAN and vBN are the voltage of the terminals A and B to N in Fig. 4, respectively, and vcm and ileak are the CMV and the leakage current.

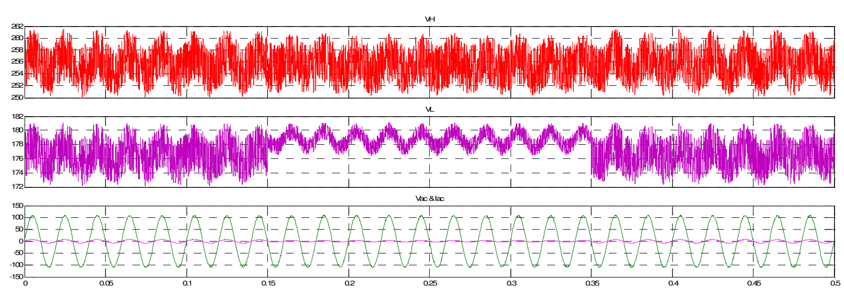

Fig. 8. Performance of the proposed interlinking converter with PID under load step changes at the AC side in Mode

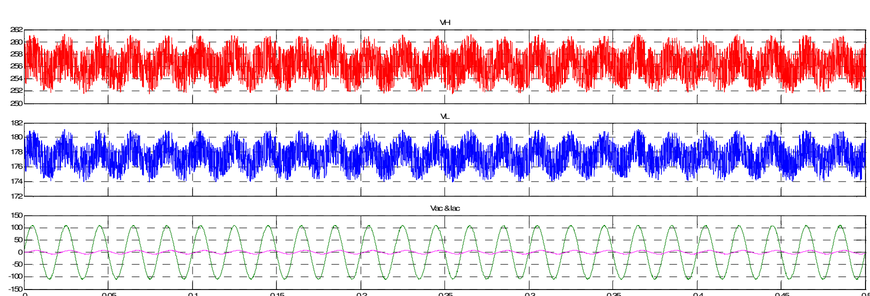

Fig. 9. Performance of the proposed interlinking converter with PID operating in Mode III, where iAC is lagging vAC

V. Conclusion

In this study, an interlinking type converter is utilized to ensure the grid stability for incorporating the various renewable sources. The suggested control structure is designed with various new power devices in boost converter for an active switch in VSI converter. The privileges of interlinking converter can be rendered the reliable power, good efficiency, reduce the leakage current, and sustain the flexible power. Moreover, fuel-cell is implemented in the proposed system for overcoming the difficulties in the grid system at different nonlinearities. As per the simulation outcomes, the proposed FC-based system enhances the grid stability while integration of high penetration of renewable sources.

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