Application of Boost Inverter For Grid Connected Fuel Cell Based Power Generation

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ABSTRACT

The boost inverter architecture is used as a building block in this research to create a single phase grid connected fuel cell (FC) system with low cost and compactness. In addition, to support the FC's sluggish dynamics, the proposed system includes battery-based energy storage and a dc-dc bidirectional converter. The voltage mode of the single phase boost converter is maintained, but the low frequency current ripple is regulated by the current mode. The battery provides the low frequency current ripple, which mitigates the impacts of such ripple pulled straight from the FC. This technology, however, may work in either a grid-connected or independent mode. In grid linked mode, the boost inverter can regulate the active (P) and reactive (Q) powers using a second order generalised integrator algorithm that offers rapid signal conditioning for single phase circuits. At the grid side, we may lower Total Harmonic Distortion (THD). In addition, we have a backup storage device to accommodate the sluggish dynamics of the FC sources that are all integrated into one system. To confirm the performance of the proposed system, a design model and guidelines, simulation, and experimental findings from a laboratory prototype are available.

Keywords- Boost Inverter, Fuel Cell, and Grid Connected Inverter, Power Conditioning System (PCS), PQ Control

I. INTRODUCTION

Solar photovoltaic and fuel cell (FC) energy producing systems must be conditioned for both dc and ac loads. The whole system comprises of power electronics energy conversion technologies and, depending on the desired applications, may also include energy storage. Despite the fact that the FC system requires an additional energy storage unit in order to achieve a high-quality power supply. An inversion stage is required when such systems are used to power ac loads or are integrated with the energy grid. Low-power FCs have a low and variable output voltage that varies with load current. According to the current-voltage characteristics of a 72 cell proton exchange membrane FC (PEMFC) power module, the voltage fluctuates between 39 and 69V depending on the output current level. Furthermore, due to the operation of components like as pumps, heat exchangers, and fuel processing machines, hydrogen and oxidant cannot respond to load current changes instantly. To generate ac power, a two-stage FC power conditioning system has been widely investigated. Due to its cascaded power conversion levels, the two-stage FC power conditioning system has drawbacks such as being big, expensive, and generally inadequate. A topology that is suited for ac loads and is powered by dc sources capable of boosting and inverting the voltage at the same time has been suggested to alleviate these limitations. This topology's double loop control method has also been recommended for improved performance even under transient settings. A boost inverter-based single-stage FC system has been proposed. The single stage system can reduce the complications that the two-stage FC power conditioning system can cause. Overall efficiency dealing with single level and typical two level systems has been raised by roughly 10% across the range of the power rating, according to this article. This study shows how a freestanding FC system with a boost inverter and a bidirectional backup storage unit can sustain the sluggish dynamics of the FC while also eliminating the ripple that reduces the FC's lifetime and efficiency. Despite the fact that the performance and operational characteristics of such a system for grid applications are a significant step forward, they have yet to be published in the technical literature. The primary goal of this work is to propose and publish complete experimental findings for a grid-connected single phase FC system with only one energy conversion step. In particular, the proposed system, which is based on a boost inverter with a backup energy storage unit, addresses the previously described difficulties, such as the FC's low and changeable output voltage, sluggish dynamics, and current harmonics on the FC side. The single energy conversion stage combines boosting and inversion operations, resulting in excellent power conversion efficiency, reduced converter size, and cheap cost.

II. PROPOSED SYSTEM

2.1 Proposed FC Energy System

2.1.1 Description of the FC System

Figure 1 shows the block diagram of the suggested grid-connected FC system. It also depicts the power flow between each component. Two power converters, such as a boost inverter and a bidirectional backup unit, make up this system. The FC and backup units, which are both connected to the same unregulated dc bus, provide the boost inverter.

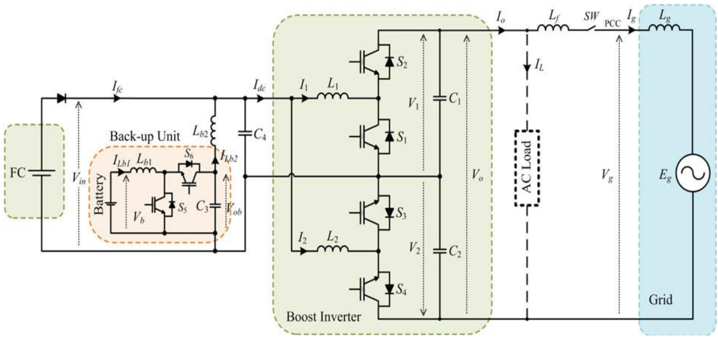

Fig.1.General Structure of the Suggested Grid-Connected FC System

Through an inductor, the output side is connected to the load and grid. To support the FC power production, the system includes a current mode controlled bidirectional converter with battery energy storage and a voltage controlled boost inverter. The FC system should be able to respond dynamically to changing input voltage while keeping a consistent power output. Voltage and current bandwidth should be disclosed by the FC stack's makers. The system also generates active (P) and reactive (Q) power control in grid linked mode. The employment of a grid compatible frequency and voltage droops are key aspects of the PQ maintenance in inductive integrated voltage sources.

2.1.2 Boost Inverter

The boost inverters are made up of two bidirectional boost converters that are linked together in series. With a variable duty cycle, each boost converter creates a dc bias with predicted ac output voltage, resulting in a unipolar voltage larger than the FC voltage. Every converter output, as well as the combined outputs, are described in detail. The most ideal technique to maintain individual boost converters covering a wide range of operating points is to use a double loop control strategy for boost inverter control, as shown in this work. This control technique is based on an averaged continuous time model of the boost architecture, and it has various benefits when dealing with nonlinear loads, abrupt load variations, and transient short circuit circumstances, which the sliding mode control cannot handle. The inverter uses this control method to maintain a steady working condition by restricting the inductor current. The inverter achieves a very dependable functioning as a result of its capacity to keep the system under control even in these scenarios. The boost inverter's reference voltage is created by the PQ control algorithm's ability to sustain active and reactive power. Using proportional resonant (PR) controllers, the voltages between C1 and C2 are maintained to track the voltage references. The PR controller, as compared to the standard proportional integral (PI) controller, has the capacity to minimise the PI controller's disadvantages, such as the inability to follow a sinusoidal reference with zero steady state error and weak disturbance cancelling capabilities. PR controllers sustain currents via L1 and L2 to achieve stable operation under unique situations such as nonlinear loads and transients. The boost inverter's control design schematic is shown in Fig.2. With the dc bias, Vdc, the output voltage reference is split to provide two distinct output voltage references for the two boost converters. By multiplying the input voltage Vin by half of the peak output magnitude, the dc bias may be produced.

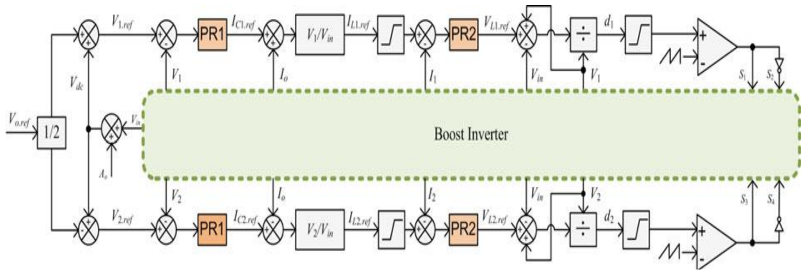

Fig.2. Boost Inverter Control Block Diagram

2.1.3 Backup Energy Storage Unit

The backup energy storage unit's operations are split into two categories. The backup unit is designed to support the FC's sluggish dynamics, and in order to safeguard the FC system, it creates the low frequency ac current that is required for boost inverter operation. The low frequency ripple current generated by the batteries has an influence on their lifetime, however it is better to be stressed by such low frequency ripple current between the most costly FC components and the comparatively inexpensive battery components. A current mode controlled bidirectional converter and a battery serve as the energy storage unit in the backup unit. When a 1 kW load is added from a no-load state, the backup unit immediately produces 1 kW of power from the battery and delivers it to the load. When the load is unexpectedly unplugged, the undesired power from the FC can be recovered and stored in the battery, improving the energy system's overall effectiveness.

2.1.4 Control of the Grid-Connected Boost Inverter

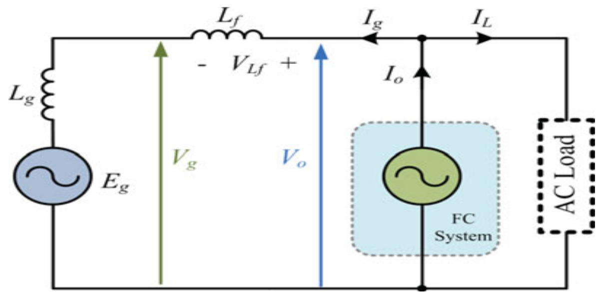

Fig.3. Equivalent Circuit of the Grid-Connected FC System

Figure 3 shows the grid integrated FC system's equivalent circuit, which includes two ac sources (Vg and Vo), an a.c inductor Lf between the two ac supply, and the load. The grid voltage is Vg, while the boost inverter output response voltage (containing the FC and backup unit) is Vo. The phase locked loop and the orthogonal system generator are shown in

Fig 4 as part of the PQ control method. Using the droop control approach, the inverter voltage reference is created to regulate the active and reactive power.

2.1.5 Design Guidelines

The parameters were used to develop the power components of the recommended system. The maximum inductor ripple current is determined to be 5% of the maximum inductor current. When V1 is highest and V2 is lowest. The specified values for L1 and L2 are 650 and 700 H, respectively, for the minimal inductance.

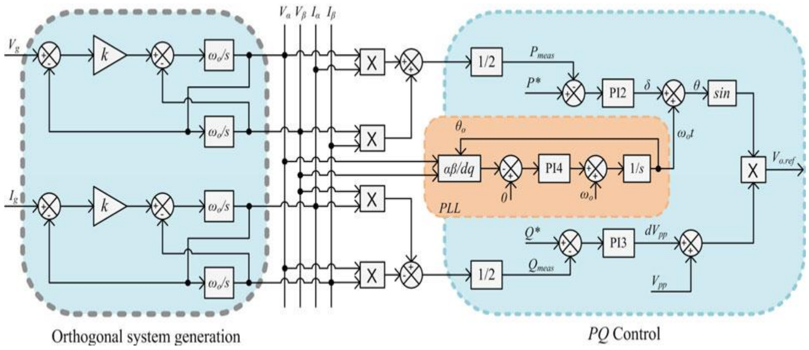

Fig.4 Block Diagram of the PQ Control Algorithm for Boost-Inverter Output Voltage Reference Generation

During transient situations, the backup unit should provide the load with all of the power it requires. In this situation, the boost inverter's maximum inductor current should show in the inductor Lb2. As a result, the maximum inductance of Lb2 may be determined. The battery's capacity should be designed to compensate for the FC's sluggish dynamics and startup time. For energy, two generic 12V lead acid batteries are introduced to address the demand for quick dynamics and a low-cost solution. To evaluate battery capacity, the FC startup time should be used as a worst-case scenario. The low and high voltages of the battery are illustrated. To know the minimum voltage per cells, the low voltage of the battery is separated by the number of cells.

III. SIMULATION AND EXPERIMENTAL RESULTS

To approve its overall performance, the proposed FC system has been discussed, constructed, simulated, and tested experimentally. The system's ac output voltage was chosen to verify the analytical results. The system's ac response voltage was set at 220V, while the dc input voltage was changed between 43 and 69 V. The boost inverter and backup unit actions are shown in the simulation results. When full load is desired from the no load operating point, the total power is generated by the backup unit to the load. Then the power absorbed from the battery starts decreasing moderately allowing gentle step up to deliver power which should increase up to meet the demand load power. The backup unit protects the FC from potential damage by mitigating the ripple current due to the operation called boost operation. A passive filter placed between the FC and the boost inverter can integrate the FC's high frequency output response ripple current. It is described how active and reactive power restraints work. The suggested system's experimental efficiency is around 93 percent at peak point and 83 percent at rated output power. Therefore the suggested FC system achieves an improved total efficiency when compared with a traditional two-level FC system. The single phase grid linked FC system that has been proposed has been developed. A dc power source is employed in this research to create dc output between 43 and 69V, the same voltage range as a 72 cell PEMFC. Three insulated gate bipolar transistor (IGBT) modules are utilised to produce the boost inverter for two modules and the backup unit for one module in the power electronics stack. The DSP controller unit was chosen for its cheap cost, embedded floating point unit, high speed, on-chip analogue to digital converter, and high performance pulse width modulation unit.

IV. CONCLUSION

This article recommends a single phase single power stage grid linked FC system based on boost inverter topology with a backup battery-based energy storage unit. The simulation response and a few laboratory tests confirm the suggested FC system's operation characteristics. In conclusion, the proposed FC system offers a number of appealing properties, including a single high-efficiency power conversion level, a simplified topology, cheap cost, and the ability to operate in both independent and grid-integrated modes. Furthermore, a PQ control method based on SOGI can sustain active and reactive powers in single phase FC systems in grid linked mode, providing quick signal conditioning for single phase systems. At the grid side, we may lower Total Harmonic Distortion (THD). We also have a backup storage device to handle the sluggish dynamics of the PV and FC sources, which are combined into a single system. Even though it should be noted that if the grid voltage includes a harmonic component, the boost inverter's voltage mode control may result in a distorted grid current.

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