THREE PORT CONVERTERS FOR RENEWABLE SYSTEM

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Abstract

A three-port converter with three active full bridges, two series-resonant tanks, and a three-winding transformer is proposed. It uses a single power conversion stage with high-frequency link to control power flow between batteries, load, and a renewable source such as fuel cell. The converter has capabilities of bidirectional power flow in the battery and the load port. Use of series-resonance aids in high switching frequency operation with realizable component values when compared to existing three-port converter with only inductors. The converter has high efficiency due to soft-switching operation in all three bridges. Steady-state analysis of the converter is presented to determine the power flow equations, tank currents, and soft-switching region. Dynamic analysis is performed to design a closed-loop controller that will regulate the load-side port voltage and source-side port current. Design procedure for the three-port converter is explained and experimental results of a laboratory prototype are presented.

Keywords- PWM-Pulse width modulation,

I.INTRODUCTION

Future renewable energy systems will need to interface several energy sources such as fuel cells, photovoltaic (PV) array with the load along with battery backup. A three-port converter finds applications in such systems since it has advantages of reduced conversion stages, high-frequency ac-link, multi winding transformer in a single core and centralized control. Some of the applications are in fuel-cell systems, automobiles, and stand-alone self-sufficient residential buildings. A three-port bidirectional converter had been proposed earlier for a fuel-cell and battery system to improve its transient response and also ensure constant power output from fuel-cell source. The circuit uses phase-shift control of three active bridges connected through a three-winding transformer and a network of inductors. To extend the soft-switching operation range in case of port voltage variations, duty-ratio control was added in. Another method to solve port voltage variations is to use a

front-end boost converter, for ultra capacitor applications. To increase the power-handling capacity of the converter, three-phase version of the converter was proposed later. A high-power converter to interface batteries and ultra capacitors to a high voltage dc bus has been demonstrated using half bridges. Since the power flow between ports is inversely proportional to the impedance offered by the leakage inductance and the external inductance, impedance has to be low at high power levels.

To get realizable inductance values equal to or more than the leakage inductance of the transformer, the switching frequency has to be reduced. Hence, the selection of switching frequency is not independent of the value of inductance. A series-resonant converter has more freedom in choosing realizable inductance values and the switching frequency, independent of each other. Such a converter can operate at higher switching frequencies for medium and high-power converters. Other circuit topologies are suggested for a three-port converter such as the current-fed topologies that have more number of magnetic components and fly back converter topologies that are not bidirectional. A constant-frequency phase-controlled parallel-resonant converter was proposed, which uses phase shift between input bridges to control the ac-link bus voltage, and also between input and output bridge to control the output dc voltage. Such high-frequency ac-link systems using resonant converters have been extensively explored for space applications and telecommunications applications.

The Proposed method is a Three-port series resonant converter operating at constant switching frequency and retaining all the advantages of a three - port structure is proposed in this project. The series-resonant three-port converter proposed in this project uses a similar phase shift control but between two different sources. The phase shifts can be both positive and negative, and are extended to all bridges, including the load-side bridge along with bidirectional power flow. In this project, a three-port converter with three active full bridges, two series-resonant tanks, and a three-winding transformer is proposed. It uses a single power conversion stage with high-frequency link to control power flow between batteries, load, and a renewable source such as fuel cell. The converter has capabilities of bidirectional power flow in the battery and the load port. Use of series-resonance aids in high switching frequency operation with realizable component values when compared to existing three-port converter with only inductors. The converter has high efficiency due to soft-switching operation in all three bridges. Steady-state analysis of the converter is presented to determine the power flow equations, tank currents, and soft-switching region. Dynamic analysis is performed to design a closed-loop controller that will regulate the load-side port voltage and source-side port current. In this project, a three-port bidirectional series-resonant converter is proposed with the following features:

1) All ports are bidirectional, including the load port for applications, such as motor loads with regenerative braking.
2) Centralized control of power flow by phase shifting the square wave outputs of the three bridges.
3) Higher switching frequencies with realizable component values when compared to three-port circuits with only inductors.
4) Reduced switching losses due to soft-switching operation.
5) Voltage gain increased by more than two times due to the phase-shifting between input and output bridges as opposed to a diode bridge at the load side.

In this project, a three-port series resonant converter is introduced to interface renewable energy sources and the load, along with energy storage. It was proven by analysis and experimental results that power flow between ports can be controlled by series resonance and phase-shifting the square wave outputs of the three active bridges. The converter has bidirectional power flow and soft-switching operation capabilities in all ports. Dynamic model and controller design is presented for centralized control of the three-port converter. A design procedure with normalized variables, which can be used for various power and port voltage levels, is presented.

In new proposed method

- Changing the phase shift inverter as PWM inverter
- Elimination of series resonance.
- Designing hardware for motor load instead of resistive load.

Advantage due to above changes

1. Harmonic reduction
2. Soft switching
3. Transformer size has been reduced.

II. PROPOSED SYSTEM

DC to DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. Every electronic system is designed to operate from a supply voltage, which is usually assumed to be constant. A voltage regulator provides this constant DC output voltage and contains circuitry that continuously holds the output voltage at the design value regardless of changes in load current or input voltage, assuming that the load current and input voltage are within the specified operating range for that regulator. In portable systems, the input voltage is often a battery, a DC voltage. DC to DC converter type regulators take such DC input voltage and produce the required output voltage which could be higher or lower than the input battery voltage. DC-to-DC converters are the power supply that output a fixed voltage efficiently, converting the input voltage. It accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. They are also used to provide noise isolation, power bus regulation, etc.

One technique that has demonstrated promise in obtaining improved system performance is soft switching. Soft switching converters constrain the switching of power devices to time intervals when the voltage across the device or the current through it is nearly zero. This significantly reduces the device switching losses and hence allows higher switching frequencies and wider control bandwidths, while simultaneously lowering *dv/dt* and electromagnetic interference (EMI) problems.

Soft switching can be achieved by two methods:

- Zero voltage switching (ZVS)
- Zero current switching (ZCS)

The use of soft switching in dc/dc converters and induction heating for industrial applications is fairly common and widespread. Soft switching in dc/dc converters is fairly simple to realize, because at any given operating point, power flow is unidirectional, the switching frequency is fixed, and modulation is at zero frequency, i.e. dc. The task of realizing soft switching in dc/ac inverters is considerably more complex. This is primarily because unlike most dc/dc converters, inverters require bi-directional power flow between the dc bus and the ac output, and typically have two distinct operating frequencies, one associated with modulation and the other with the fundamental output frequency. Further, soft switching operation is required over a much wider range of load conditions.

Soft switching inverters are generally classified into two distinct categories: resonant link and resonant pole inverters. Resonant link inverters tend to use one set of resonant components per inverter, and achieve low loss switching of all its power semiconductors using a common zero voltage (or current) crossing point. Known configurations include the passively clamped and actively clamped resonant dc link inverters, and various forms of quasi-resonant dc link inverters. Resonant pole inverters, on the other hand, tend to use one set of reactive L-C components per inverter phase. Known forms include the basic resonant pole inverter, the auxiliary resonant commutated pole inverter and various forms of resonant snubber circuits. While soft switching circuits can be of both the zero voltage or zero current switching types, and often include both types, this paper will focus on configurations which realize a voltage source inverter function and primarily use zero voltage switching of the main devices.

III. ADVANTAGES OF SOFT SWITCHING

Advances in soft switching converters have set new benchmarks in performance and cost in power converter technology, and have shown promise in overcoming the limitations of conventional hard switching technology. The use of zero voltage switching with IGBT power devices demonstrates of some aggressive benchmarks when compared with conventional technology.

These include:

- 100% power device utilization
- Low EMI which meet Mil-specs
- Enhanced robustness.
- High power densities
- High switching frequencies
- High efficiencies.

The following are some of the main advantages of soft switching:

- Improved Device Utilization.
- dv/dt with Soft Switching.
- EMI with Soft Switching.

IV. SOFT-COMMUTATING METHOD FOR AN ISOLATED BOOST CONVERTER

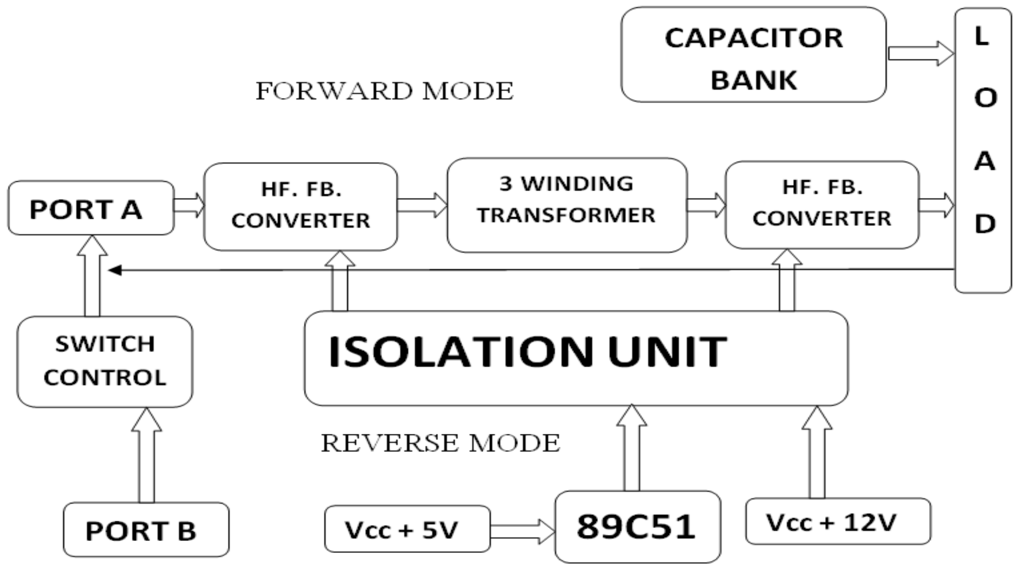
High power isolated bi-directional dc/dc converter have become key components in alternative energy systems. In contrast to an isolated buck converter, driving a transformer with a current-fed inverter in an isolated boost converter will lead to a high voltage spike across the current-fed inverter switches because of the leakage inductance of the transformer.

A dual active full bridge dc/dc converter was proposed for high power bi-directional application. It employs two voltage-fed inverters to drive each side of the transformer, eliminating the current-fed inverter. Both voltage-fed inverters operate at soft-switching condition. A dual active half –bridge soft-switching bi-directional dc/dc converter was proposed with reduced power component counts.

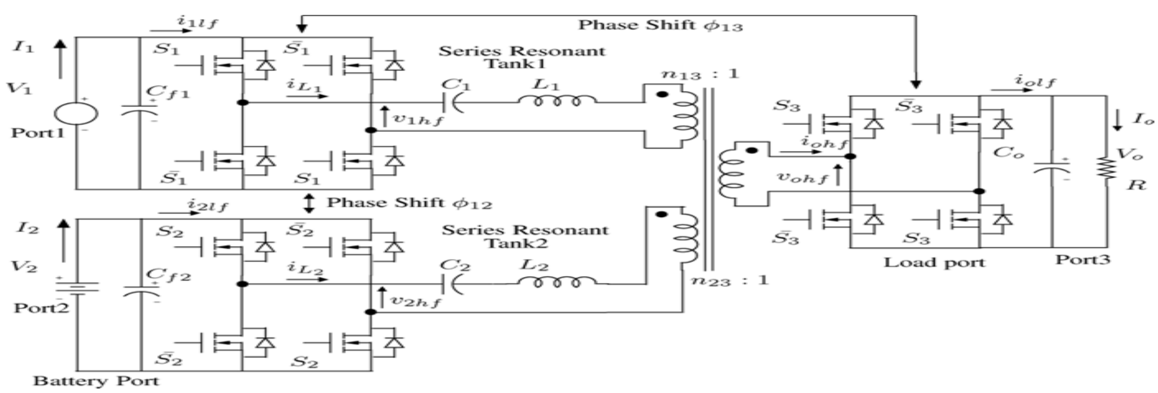
It has voltage-fed inverter at high voltage side and current fed inverter at low voltage side. Both converters utilize the leakage inductance of the transformer as the energy-transferring element, driving energy to flow both ways in one switching cycle. Since the leakage inductance of the transformer is a key parameter in resonant transition type converter design and has to be well controlled, manufacturability will be an issue in mass production. In addition, while soft switching is achieved in resonant transition type isolated bi-directional dc/dc converters, high circulating conduction losses often offset the efficiency gained by soft-switching.

Active-clamp type isolated boost dc/dc converters achieve soft switching while minimizing the circulation current and achieve relatively high efficiency power conversion. However, an active snubber, which consist an active switch and a capacitor, has to switch at twice the switching frequency and at the full power of the main dc/dc converter. The burden of high current stress and associated thermal issues of the active switch and the capacitor add limitations to active-clamped snubber methods in bi-directional high power applications. Active commutating is a method that presets the current in leakage inductance to the boost inductor current before the commutation event occurs. However in both active commutating methods, the switches at voltage-fed side inverter are hard switching.

This paper proposes a “soft-commutating” method for an isolated boost full bridge converter in high power bi-directional application. In addition, zero voltage switching (zvs) is also achieved for all switches at the voltage-fed side inverter in boost mode operation.



1.1 Block Diagram of three-port series-resonant converter



1.2 Circuit diagram of Three-Port Series-Resonant Converter

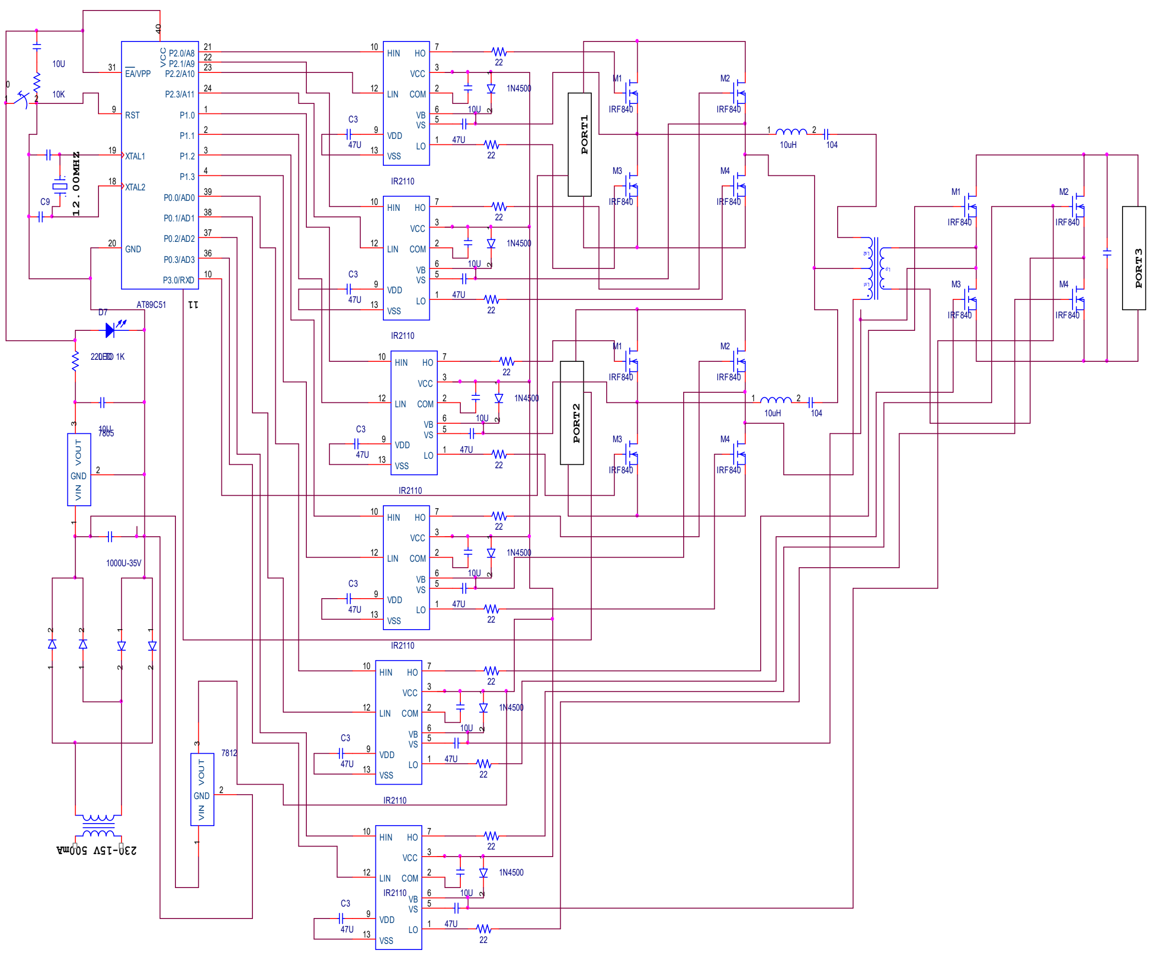
V. FEATURES OF THREE-PORT SERIES-RESONANT CONVERTER

- All ports are bidirectional, including the load port for applications, such as motor loads with regenerative braking.
- Centralized control of power flow by phase shifting the square wave outputs of the three bridges.
- Higher switching frequencies with realizable component values when compared to three-port circuits with only inductors.
- Reduced switching losses due to soft-switching operation.
- Voltage gain increased by more than two times due to the phase-shifting between input and output bridges as opposed to a diode bridge at the load side.

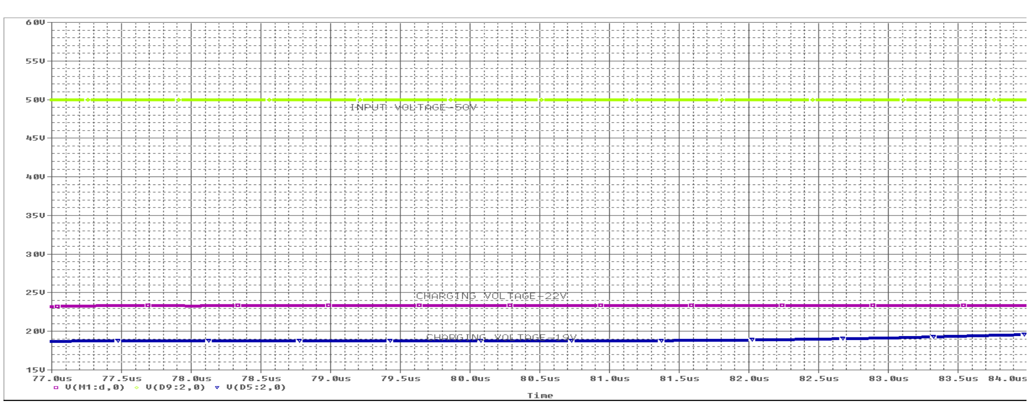
VI. ADVANTAGES OF THREE-PORT CONVERTER

- Reduced conversion stages.
- High-frequency ac-link.
- Multi winding transformer in a single core.
- Centralized control.

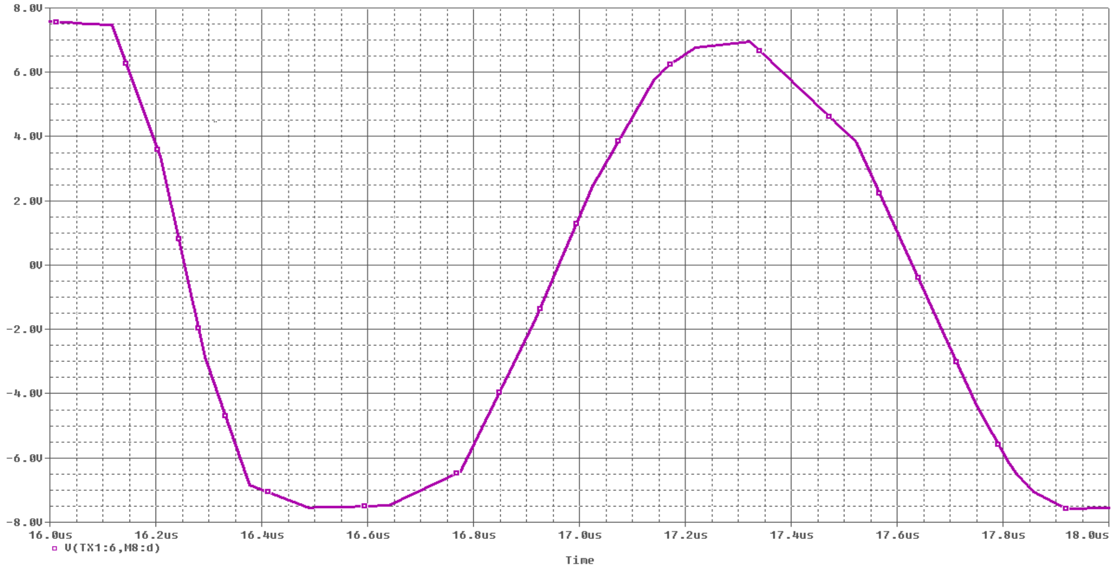
VII. HARDWARE CIRCUIT DIAGRAM



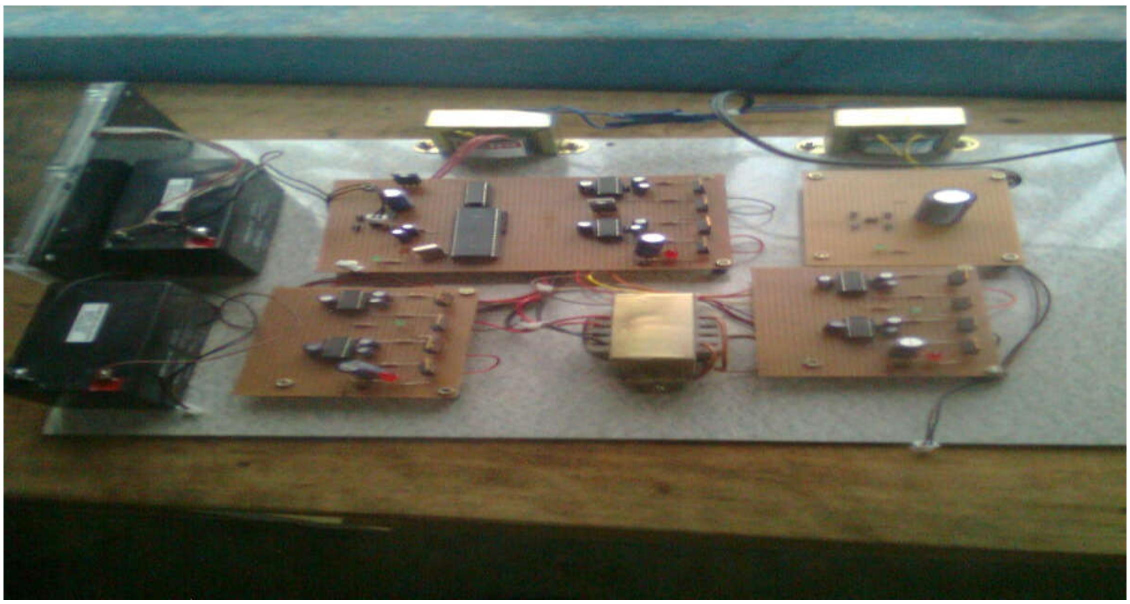
1.3 Hardware Circuit of three port converter



1.4 Input Waveform across the series resonant tank



1.5 Output Waveform across the series resonant tank



1.6 Photograph of Hardware Prototype Model

VIII. CONCLUSION

This paper deals with the implementation of simulation for bidirectional dc-dc converter, which allows transfer of power flow between the two dc sources in either direction. This converter can reverse the direction of flow of current, and thereby power, while maintaining the voltage polarity unchanged. Simulation of charging and discharging mode of bidirectional dc power supply was done successfully and waveforms are obtained. This bidirectional power flow is achieved by using same power components hence will minimize the hardware.

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