Dual Active Bridge Converter With Solid State Transformer

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ABSTRACT

For the solid-state transformer (SST) application, a three-stage configuration consisting of a PWM rectifier based AC/DC stage, a dual active bridge (DAB) converter based DC/DC stage and a PWM inverter based DC/AC stage offers several advantages. For single-phase SST, the instantaneous input and load power seen by the DC/DC stage varies from zero to twice the load average power at double the line frequency. Traditionally, with phase-shift control, large DAB DC link capacitors are used to handle the instantaneous power variation of the load, with the DAB converter processing only the load average power resulting in better soft-switching range and consequently high efficiency. In this thesis, we have shown the operation for the dual active bridge converter and components. Design and simulation of front end converter is performed with output waveforms. This new kind of power electronics transformer is developed one that can be made self-regulating, coil free, and able to correct power quality problems.

Keyword: - Solid state transformer (SST), *Dual active bridge, high frequency transformer, and AC to AC conversion etc….*

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1. OVERVIEW and OBJECTIVE

The conventional power system includes large, centralized power generators, Electric power is provided to consumers by passive transformers, transmission lines, and substations. The flow of electric power is unidirectional, from generators to consumers. These existing electric power distribution system needs to change. The transformer has been used throughout the twentieth century. Until now, it has consisted of a configuration of iron or steel cores and copper/aluminum coils, with mineral oil serving as both coolant and dielectric medium. Inherent in this type of construction are regulation, significant weight, losses, environmental concerns, and power quality issues. These disadvantages are becoming increasingly important as power quality becomes more of a concern. With the advancement of power electronics circuits and devices, the all solid-state transformer becomes a viable option to replace the conventional copper and-iron based transformer for a better power quality For the 21st century, a new kind of power electronics transformer is developed one that can be made self-regulating, coil free ,and able to correct power quality problems. The solid-state transformer allows add-on intelligence to enhance power quality compatibility between source and load. This new transformer is insensitive to harmonics, prevents harmonics from propagating (in either direction), has zero regulation, prevents load disruptions and faults from affecting the primary system, can supply loads with dc offsets, and does not utilize a liquid dielectric. The purpose is to give the idea about this developing power electronic transformer also known as Solid state transformer.

1.1 Solid State Transformer

SSTs are essentially high switching frequency power electronic converters that have the following functionalities:

- They provide galvanic isolation between the input and the output of the converter.
- They provide active control of power flow in both directions.
- They provide compensation to disturbances in the power grid, such as variations of input voltage, short-term sag or swell.
- They provide ports or interfaces to connect distributed power generators or energy storage devices.

By decoupling the load from the source, the consumers would not see the disturbance at the grid side because the disturbance is compensated by the SSTs. This is the advantage of SSTs for consumers.

At the same time, the power grid would not see the reactive power generated by loads, which is compensated by SSTs. Therefore, the 4 distribution system becomes more efficient and stable. This is the advantage of SSTs for the power grid.

Additionally, SSTs are buffers for renewable power sources, which help reduce the impact of unpredictable and un-schedulable fluctuations of renewable electric power sources on both power grids and loads. This is the advantage of SSTs for renewable power generation.

1.2 Dual Active Bridge

For the DC/DC stage of solid-state transformer (SST), the dual active bridge (DAB) converter is preferred due to its simple structure, high power density, soft-switching feature, the capability of bi-directional power flow and easily implemented phase-shift (PSM) control. The circuit of DAB converter, consists of two voltage sourced full bridge DC-AC inverters that are connected to a high frequency isolation transformer. One huge advantage of DAB is that some parasitic in the circuit are used to achieve desirable properties. The leakage inductance of the high frequency transformer is used as the main energy transfer element and the output capacitance of switching devices is utilized to realize soft-switching operation

A DAB converter is a high-power, high-power-density, and high-efficiency power converter with galvanic isolation. It consists of two H-bridges of active power switching devices and one high-frequency transformer. The high-frequency transformer provides both galvanic isolation and energy storage in its winding leakage inductance. The two H-bridges operate at fixed 50% duty ratio and the phase shift between the two bridges control the amount and direction of power flow. Based-on the configuration of switching devices, there are dc-dc DAB converters and ac-ac DAB converters.

2. Block Diagram

Rectifies: *- A single-phase AC/DC rectifier that regulates a high-voltage DC bus and AC voltage when for reactive power compensation is used. It produces low distortion grid current.*

Dual Active Bridge:*- A DC-DC conversion stage with high-frequency transformer for isolation.*

Inverter:-A full: *- Bridge inverter to obtain low-frequency AC from low voltage DC*

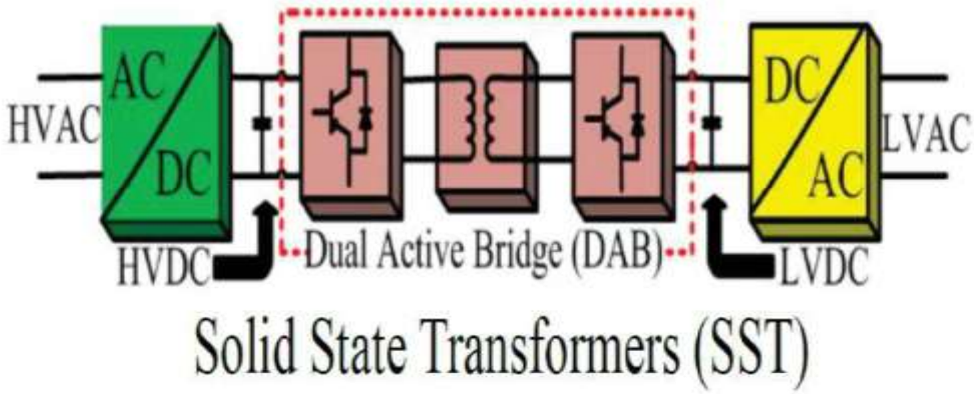

Fig -1 Block diagram

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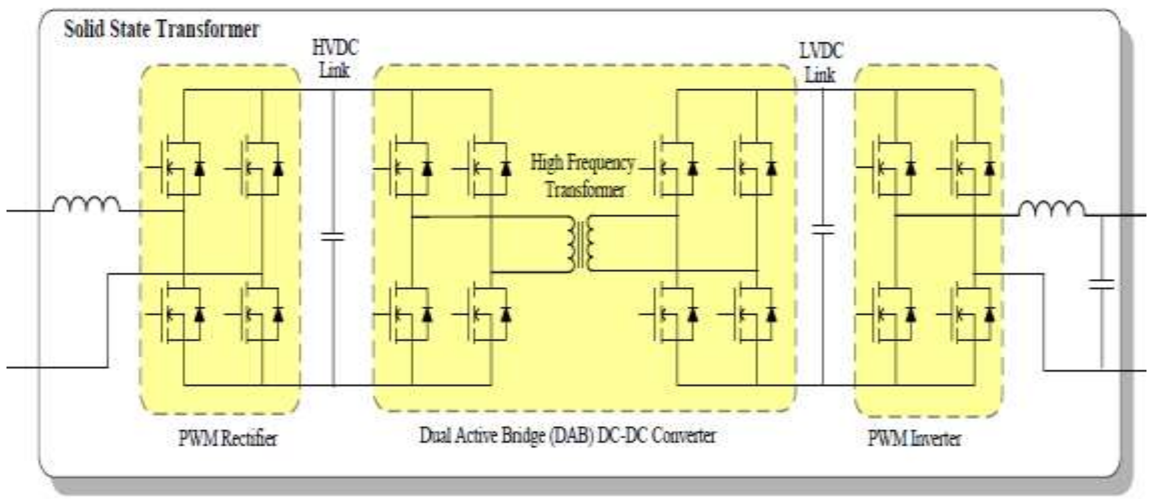

Fig -2: Circuit diagram

2.1 Working

To convert between two different voltage levels, it is necessary to have transformer isolation to fully utilize the silicon switches. Circuit Diagram shows the use of a front-end boost converter for harmonic elimination, a full-bridge inverter for dc to high frequency ac conversion, a high frequency ac transformer for voltage level conversion, a bridge rectifier to convert high frequency ac to dc, and a full-bridge inverter to obtain low-frequency ac. Consider the figure as a building block. The input of the building block is low-frequency high-voltage ac, and the output is a low-voltage ac with the same frequency. The power conversion is equivalent to a step-down transformer except that the power flow is unidirectional. This building block has been adopted as a solid-state transformer module, and the entire system is to connect the input of several modules in series and the output of these modules in parallel. The main purpose of this configuration is to allow a high voltage input that can be tied to distribution voltage level, and to have a low-voltage output that can be used for commercial and residential service. Due to the low efficiency of DAB converter with traditional phase-shift (PSM) control at light load, large DC link capacitors are required in SST handling double line frequency instantaneous power variation to make DAB converter process constant power and consequently obtain high conversion efficiency. However, the large electrolytic capacitors required adversely affect the power density and the reliability of the SST.

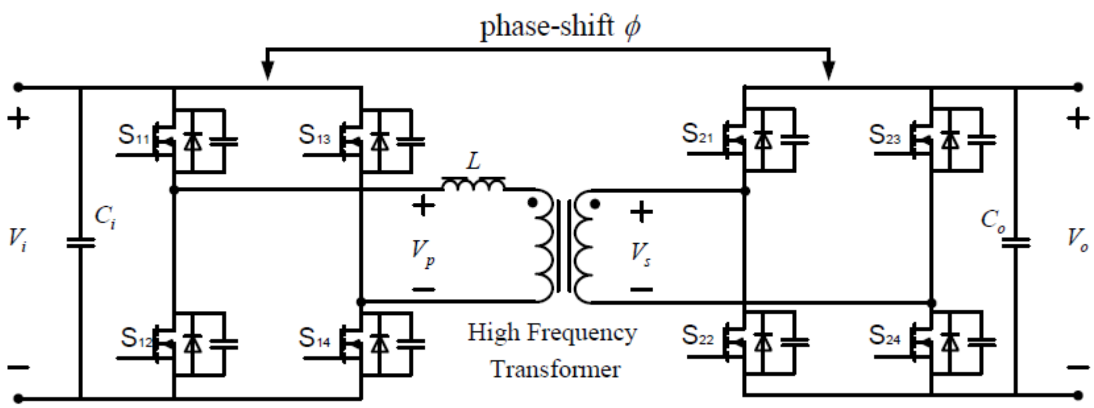

Fig -3: Circuit diagram of DAB

To simplify the analysis, the primary-referred simplified equivalent circuit of DAB converter is shown in Fig. It is assumed that: 1) all resistance is negligible; 2) transformer magnetizing inductance is neglected; 3) transformer winding capacitance is neglected. The transformer is replaced by the equivalent leakage inductance. The outputs of primary and secondary side full bridge DC-AC inverters are square waveforms with a constant duty ratio of 50%, which are generated by operating all switches with 50% duty ratio and turning on/off the diagonal switches in the same bridge at the same time. The phase-shift between primary and secondary bridges is, as analyzed below, which determines the amount of power transferred from leading bridge to lagging bridge.

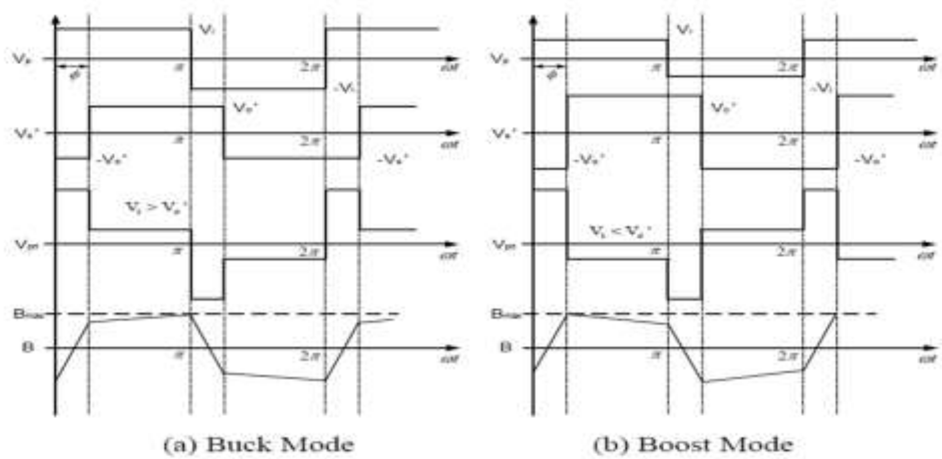

Fig -4: Output of DAB

The SST with DC-link capacitor includes three stages. First stage is an AC/DC converter which is utilized to shape the input current, to correct the input power factor, and to regulate the voltage of primary DC bus. Second stage is an isolation stage which provides the galvanic isolation between the primary and secondary side. In the isolation stage, the DC voltage is converted to a medium-frequency square wave voltage, coupled to the secondary of the MF transformer and is rectified to form the DC link voltage. The output stage is a voltage source inverter which produces the desired AC waveforms.

2.2 Simulation of Front End Converter

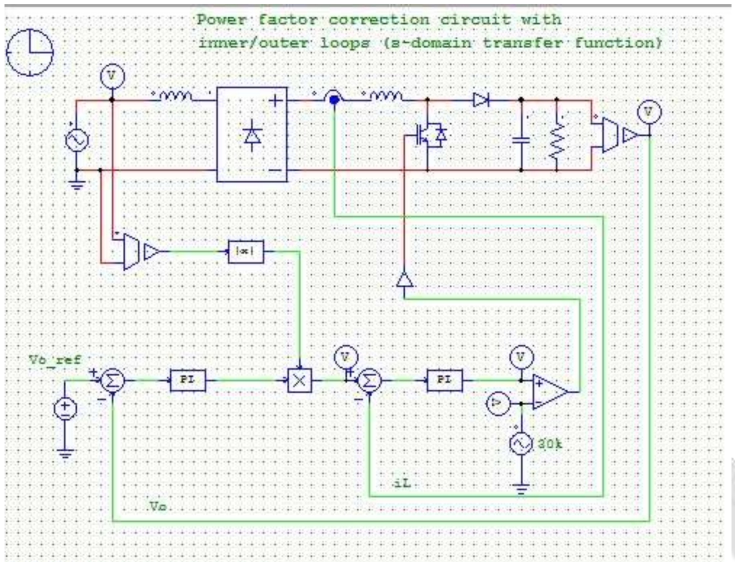

Fig -5(Font-10, Bold): Circuit Diagram of front End Converter (Font-10)

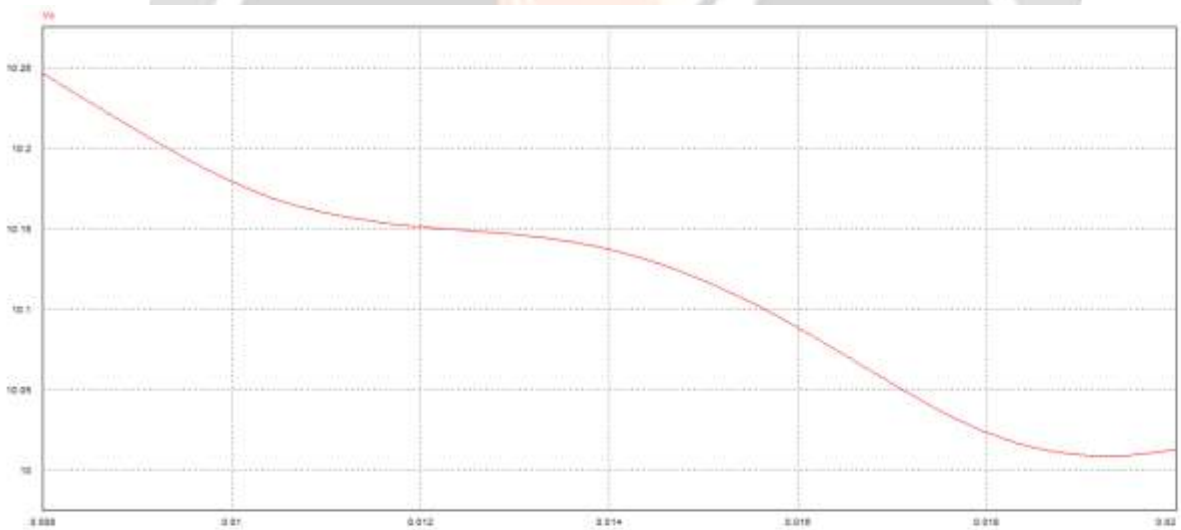

Fig -6: Output of front End Converter

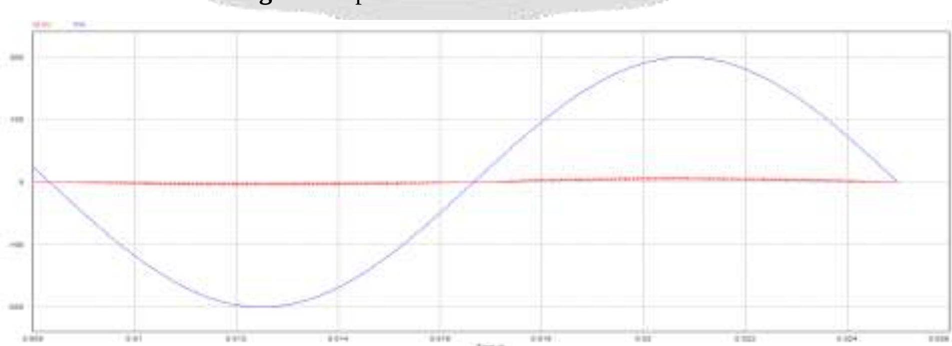

Fig -7: Output of front End Converter

2.3 Components

- N-channel MOSFET-9530
- P-channel MOSFET-540
- Opto-coupler MCT2E
- Transformer (230V to 12V,0.25A)
- Transformer (230V to 12V,1A)
- Diode IN4007
- Diode IN5438
- IN 4728a zener diode
- Voltage Regulator IC 7805, 7812, & 7815
- Capacitor 4700 micro F, 50V
- Capacitor 470 micro F, 25V
- Arduino Mega Controller
- IR 2110 Driver IC
- Single strand wires, PCB board
- Resistors- 1K,10 ohm, 22 ohm
- IGBT G20N60
- High frequency Transformer (20000Hz)

3. Simulation of DAB (Dual active bridge)

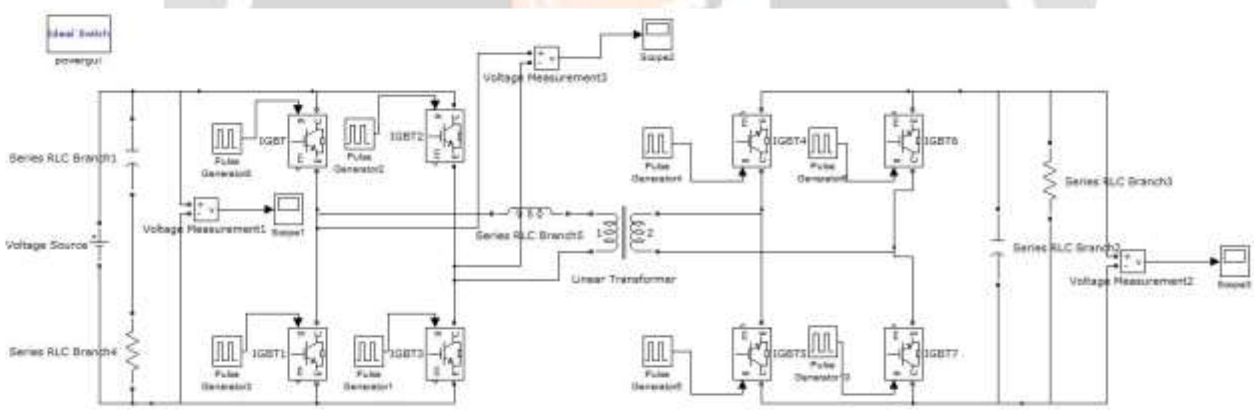

Fig -8: Circuit Diagram of DAB

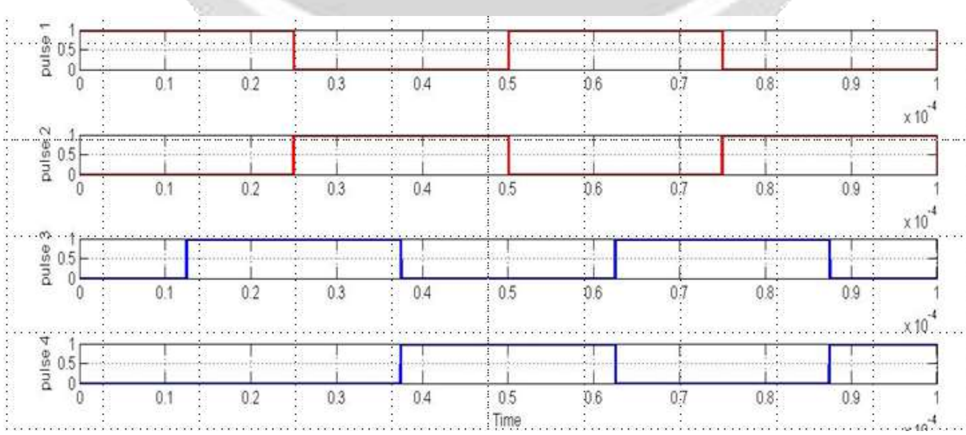

Fig -9: Gate pulse of DAB

3.1 Advantages

- Protects load from power supply disturbances
- Voltage Harmonics and sag compensations
- Protects power systems from the load disturbances
- Load transients and harmonic regulations
- Unity input power factor under reactive load
- Sinusoidal input current for non-linear loads
- Protection against output short circuit
- Operates on distributed voltage level
- Integrates energy storage

4. CONCLUSIONS

In this work, a novel dual active bridge converter is presented for solid state transformer application. A high frequency transformer is used to minimize the bulk of passive components. Four quadrant switch cells and phase shift modulation ensure that energy can flow in both directions. A design case study is given. Simulation result for front end converter is given.

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