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Dual Active Bridge Converter for SST using Single Phase Shift Control Technique

[1]Syed Rehanuddin, [2]Prof. Seema. N. Kharat, [3]Prof. K. Chandra Obula Reddy
[1]Mtech Electrical Power System, [2]Assistant Professor, [3]HOD & Prof, Department of Electrical Engineering
[1]Electrical Power System,
[1]M.S.S College of Engineering, Jalna, India

Abstract : As we know solid state transformer is very popular device nowadays to its highly advantages and applications in this project we have analyze the solid state transformer and dual active bridge converter and combining both the circuit to achieve the required results. SST has many advantage over normal transformer like very less losses, less weight, high switching frequency. It's a multistage transformer consists of converters/inverters. The main component of the project is Rectifier, inverter and dual active bridge for getting required output. SST doesn't provide the stable output on its own but with the help of control technique that can be reached, it's one of the reason dual active bridge plays an important role. DAB gives constant power, high efficiency does not require much components. The propose MATLAB Simulink consists of semiconductor switches that connected across the transformer with high frequency the proposed system has been analyzed in MATLAB System.

***Index Terms* – Solid State Transformer (SST), Dual Active Bridge (DAB), Single Phase Shift (SPS).**

I. INTRODUCTION

The Power Distribution System which are being used nowadays are not effective. the construction of the existing transformer which contains iron or steel cores and coils with dielectric medium have major losses and much more weight and quality concerns due to above mention disadvantage its necessary to improve the quality of power with the advance technology/Circuit which can replace the conventional power system having large and concentrated power generators and provide powers through passive transformers, due to these solid state transformer has become a very good option to replace the old method. SST has many advantages like its coil free, Self-Regulating, enhance Power Quality with add-on circuitry and Control techniques. The purpose of this paper is the give the Solid state transformer Stable output by using the dual active bridge converter using SPS control Strategy.

1.1 Solid State Transformer: Solid State Transformer is a replacement of conventional system to meet the requirement of smart grid. SST usually contains a high frequency transformer with AC-AC converter or DC-DC Converter. In addition to perform the same function as regular transformer it can limits current. Voltage regulation and improve power factors which establish the connection Different DC or AC equipment's. SST can operate and functional on high frequency and high voltage due to which it's very high reliable and efficient. Based on the converters used for designing the SST can be classified further.

1.2 Dual Active Bridge Converter: Dual active bridge is bidirectional DC/DC converter consists of two DC/AC bridge converters and a high frequency transformer. The reason HF Transformer is used because it can provides the different voltage levels, So that step up or step down voltage can be gains through DAB based on the power system usage. HF transformer reduces the core saturation due to that distortion of voltage and current are eliminated and low weight and cost are the main characteristics of DAB converter.

The Power Circuit of Dual active bridge converters is shown in below Figure.

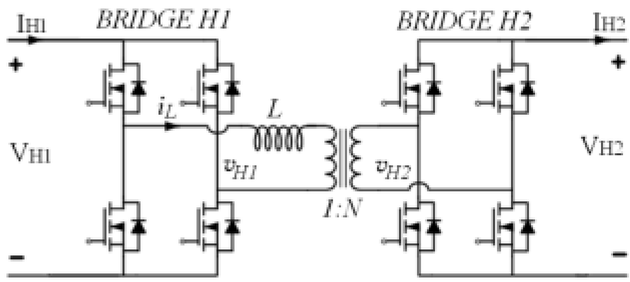

Fig. 1.1: Power circuit of DAB

The inductor L in the Fig 1.1 plays an important role in power flow control by the transformer leakage inductance, and controls the flow of iL current between two sides of the dual active bridge converter which is equal to controlling the flow of power on both side. The Bridges H1 and H2 generate square wave voltages vH1 and vH2 and helps in regulating the direction of the current iL by phase shifting.

As mention above, the power depends on the value of inductor L and which can be defined as below

P = (nVH1VH2/2π ^2fsL) Ø (π - |Ø|)

Where:

- n=1/N Ratio of High Frequency
- VH1 and VH2 are DAB voltages on the both sides
- fs is Switching frequency for both H1 and H2 bridges
- L is the inductance of the inductor
- ϕ is Phase angle between the voltages of DAB

1.3 Single Phase Shift Control: Worth noting that the transmission power characterization for a DAB converter changes with the type of modulation strategies (single, extended or dual phase shift controls). The single-phase-shift control is the most widely used control method for DAB converters and it has been also considered in this project for both the full bridges H1 and H2.

In the single-phase-shift control, the diagonal switching pairs are turned on simultaneously with a duty cycle of 50% (ignoring the small dead time) and with 180 degrees phase shift between two legs so to provide a nearly square wave voltage across transformer terminals.

Single phase shift is one of the popular control strategy for DABS. SPS maintains the power flow and voltage on the both sides of HF Transformer. SPS control provides many advantages like - inertia is less, high dynamic, soft-switching control and ease to access etc. when the voltage amplitude of both the side of SST is unbalanced due to large circulating current then there is the increment in resultant RMS and maximum current that increase the power losses and reduce its efficiency. SPS Control technique removes the above mentioned problem.

II. LITERATURE SURVEY:

For doing this project many previous studies and assignment were referred. In this project we have used Dual active bridge converter with SST and single phase shift technique for controlling the voltage and power flow. SPS control provides many advantages like soft witching control and less inertia. The dual active bridge converter first introduced in 1991 and since then it has become very popular in DC-DC conversion application for power flow and zero voltage switching capability. The design and control of the DAB converter is well explained in this paper, as one of the classical control methods. The single phase shift control is applied due to its simplicity.

As increase in power demand globally and reduction in fossil fuels have encourages the usage of renewable energy sources in grid application. accordingly increased in power sources and loads as well as the necessity for active power flow control passive transformer does not have much advantages over when applied in smart grid hence solid state transformer were introduced for the potential solution, solid state transformer were first introduced in 1970

III. SYSTEM DEVELOPMENT:

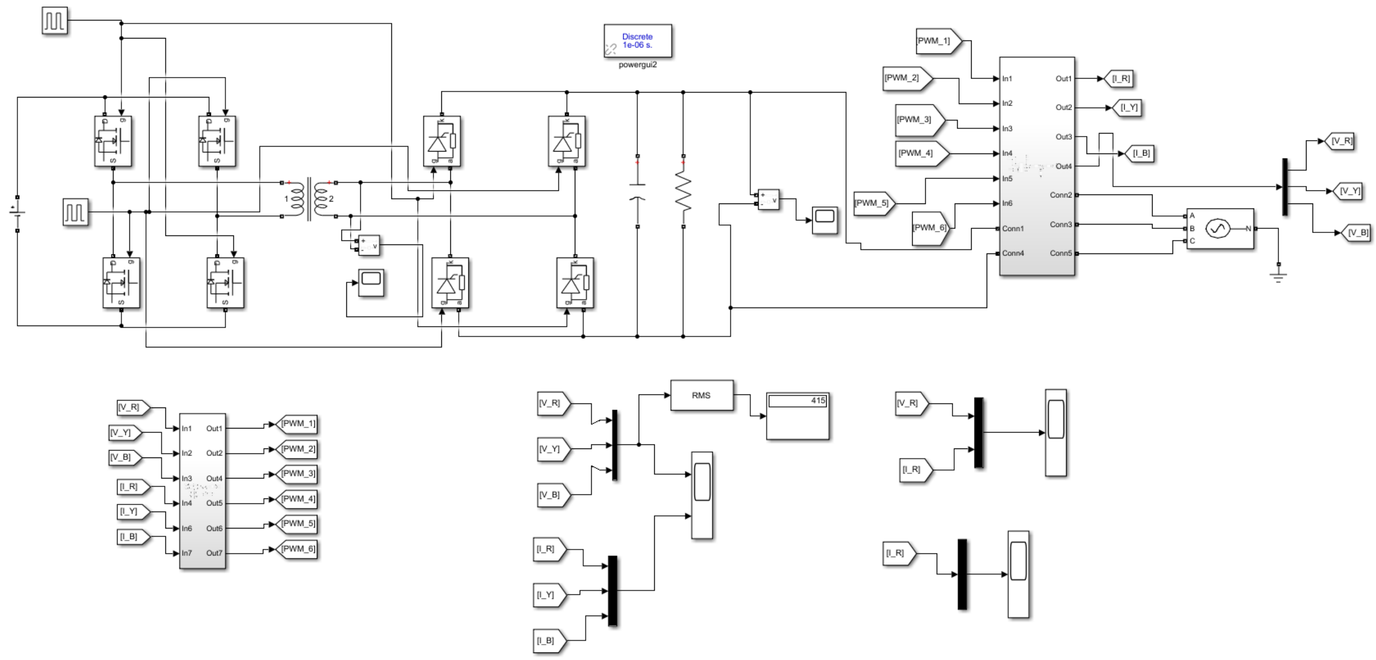

Fig 3.1: MATLAB Simulation of Whole System

The Figure 3.1 shows the complete simulation diagram of the system in MATLAB. It can be divided into following blocks:

1. Solid State Transformer
2. Dual Active Bridge Converter

1. Solid State Transformer:

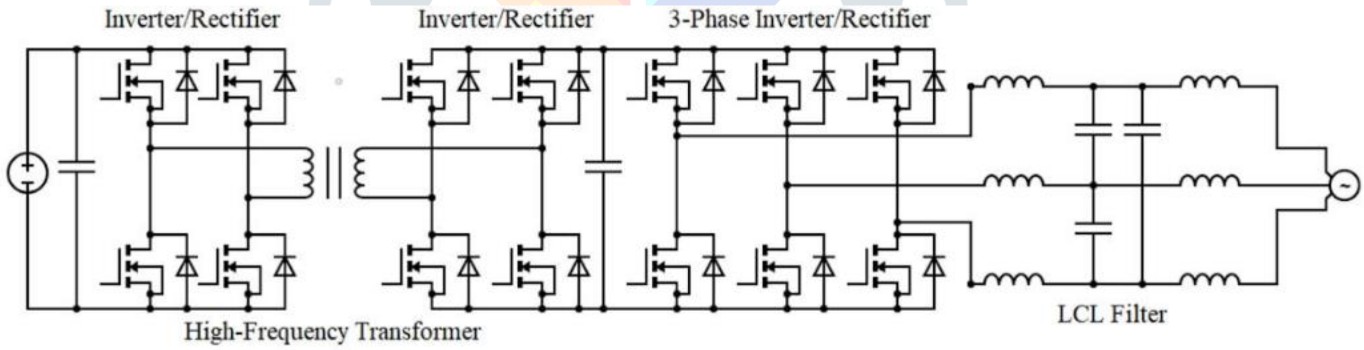

Fig 3.2: Topology of Solid state transformer

The architecture of SST can be classified based on the power conversion stages which was proposed by lothar Heinemann et al. Below figure presents a topology of the design of solid state transformer made up with power switching converters to replace the bulky transformers which helps by providing power flow control and reduces overall size.

SSTs are characterized by three main features: Connection to at least one medium voltage or High voltage port (either AC or DC), Medium frequency isolation stages, Controllability over input and/or output electrical parameters. SSTs have quickly evolved and numerous topologies have been proposed and named as SSTs. However, only topologies which satisfy these three key features are considered as an SST and are included in this Paper.

Solid state transformer is a high frequency power electronic converters with following functions as below:

- SST provide electric isolation between the converters input and output
- SST has quick control on the flow of power in both direction
- SST have interfaces that can be connected to distributed power generators or storage devices
- SST counterbalances disturbances/variations of voltage or short term sag or swell

When the load is decoupled from the source, Power grid would not see the reactive power generated by loads and the from consumer side, consumer would not see the disturbances from the grid side as the disturbances are compensated by SST, this is the advantage for consumer when SST is used. Therefore the distribution system becomes more stable and efficient. This is the advantage of SST for power grid.

Additionally, for renewable power sources, the impact of unpredictable or unscheduled fluctuations of electric power from both power grid and loads can be reduced with the help of solid state transformer. This is the advantage of SSTs for renewable power generation.

2. Dual Active Bridge Converter:

DAB converter topology consists of two active H-bridges and one HF transformer. When input voltage changes through phase shift modulation output voltage can be regulated. Power is transferred from one Bridge to other i.e. leading bridge to lagging bridge. A DAB converter is high power, high power density and high efficiency power converter.

A DAB converter consists of two switching bridges and one high-frequency transformer. Each switching bridge is made up of four high-frequency active controllable switching devices (MOSFETs or IGBTs) in an H-bridge connection. Such connection is similar to the one used in full-bridge dc-dc converters. However, instead of using uncontrollable switching devices (such as diodes) bridge in the other side of transformer, DAB converters use two active bridges formed by active controllable devices. This is why the name “Dual Active Bridge” is given to this kind of converters.

Dual active bridge consists of three main components:

- Inverter: Bridge inverter which will convert low voltage DC to low frequency AC
- Dual Active Bridge: A high frequency transformer with DC/DC conversion stage
- Rectifier: AC/DC rectifier which will regulated HV DC and AC voltage when grid power compensation is used

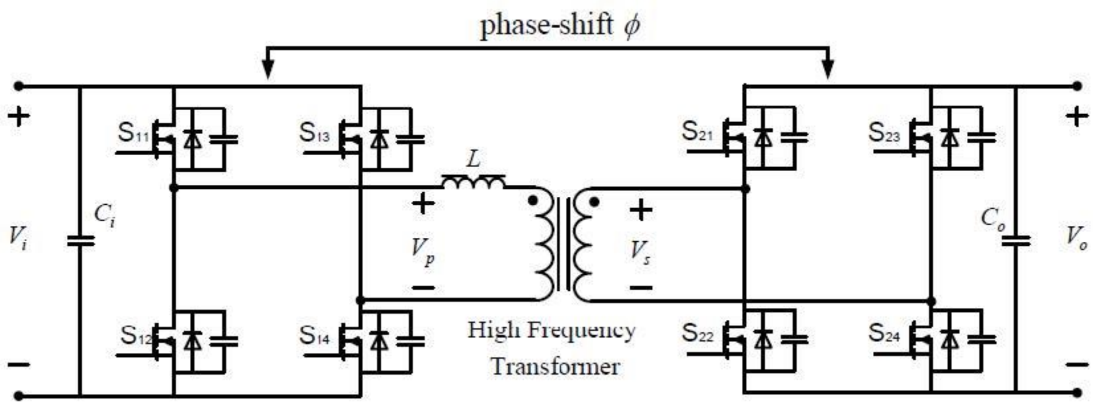

Fig 3.3: Circuit diagram of DAB

It is necessary to have transformer isolation in order to convert two different voltage levels. Circuit diagram shows the use of front end boost converter to eliminate the harmonics, a full bridge inverter to convert DC to HF frequency and a high frequency transformer for conversion of voltage level. Consider the Figure as a block where the input given is low frequency high voltage ac, and the output is low voltage ac with same frequency. The power flow is unidirectional and conversion of power is equivalent to a step down transformer. The block module is adapted as a solid state transformer module. A high voltage input that can be tied to distribution voltage level and to have a low voltage output for commercial and residential usage is the main purpose of this configuration.

IV. MATLAB RESULTS AND DISCUSSION:

As we know solid state transformer is very popular device nowadays to its highly advantages and applications in this project we have analyze the solid state transformer and dual active bridge converter and combining both the circuit to achieve the required results. SST has many advantage over normal transformer like very less losses, less weight, high switching frequency. It’s a multistage transformer consists of converters/inverters. The main component of the project is Rectifier, inverter and dual active bridge for getting required output.

SST doesn't provide the stable output on its own but with the help of control technique that can be reached, it's one of the reason dual active bridge plays an important role. DAB gives constant power, high efficiency does not require much components. The propose MATLAB Simulink consists of semiconductor switches that connected across the transformer with high frequency the proposed system has been analyzed in MATLAB System.

In gird connected energy system there are power system problems like frequency fluctuations, harmonics, less efficient and shocks, etc. Solid state transformer which is power electronics based transformer can provide the solution for these issue which consists of power electronic converters. In order to solve the power quality problems, a solid-state transformer has been developed which uses a novel hybrid switch system without cooling equipment with negligible loss consumption. SST operation ensures an integral exchange of electrical energy between the primary and auxiliary supplies without interruption of the power supply for both basic and critical loads.

Solid state transformer provides an easy solution for consumer when high demand of power is required. Extra highlights of SST include High Frequency, Low Voltage, Strong Voltage Regulation, Reactive Power Compensation, Harmonic Distortion Protection of Non-Linear Loads and Unbalanced Load for HV and MV System, Due to which protection can be provided for HV system voltage drop, etc.

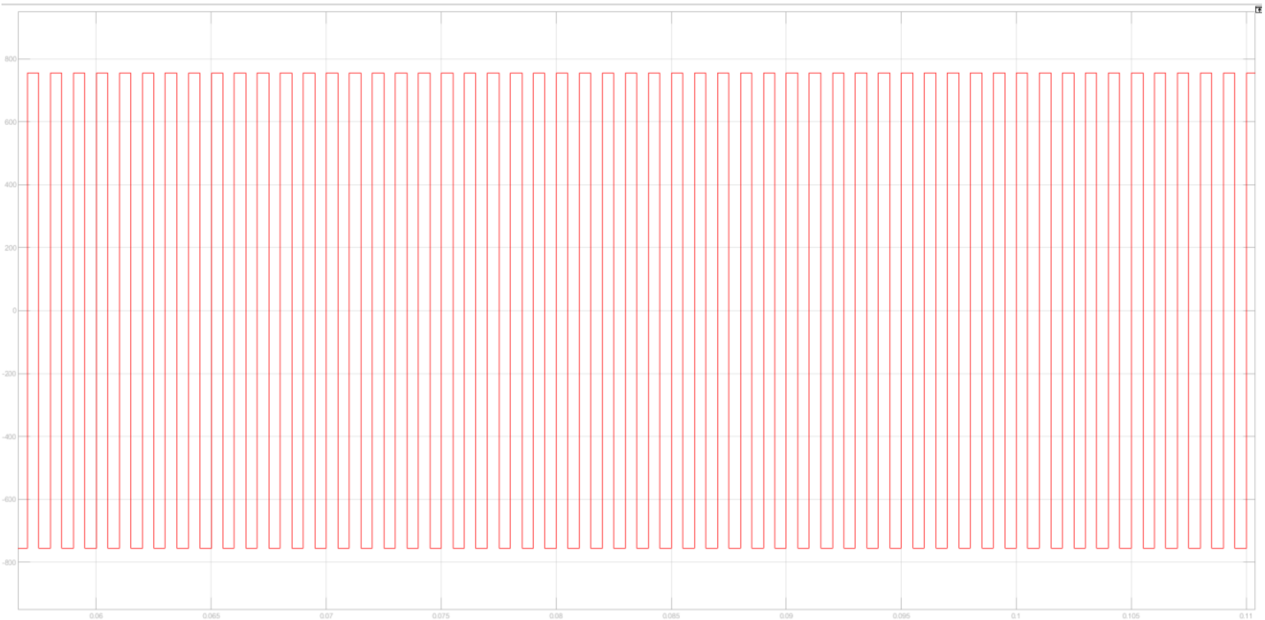

Fig 4.1: Voltage of primary side of SST

The output waveform of both side of transformer in DAB is shown in Figures 4.1 that are improved by the SPS control technique. The desired improved result of DC load voltage has been shown in Figure 4.2.

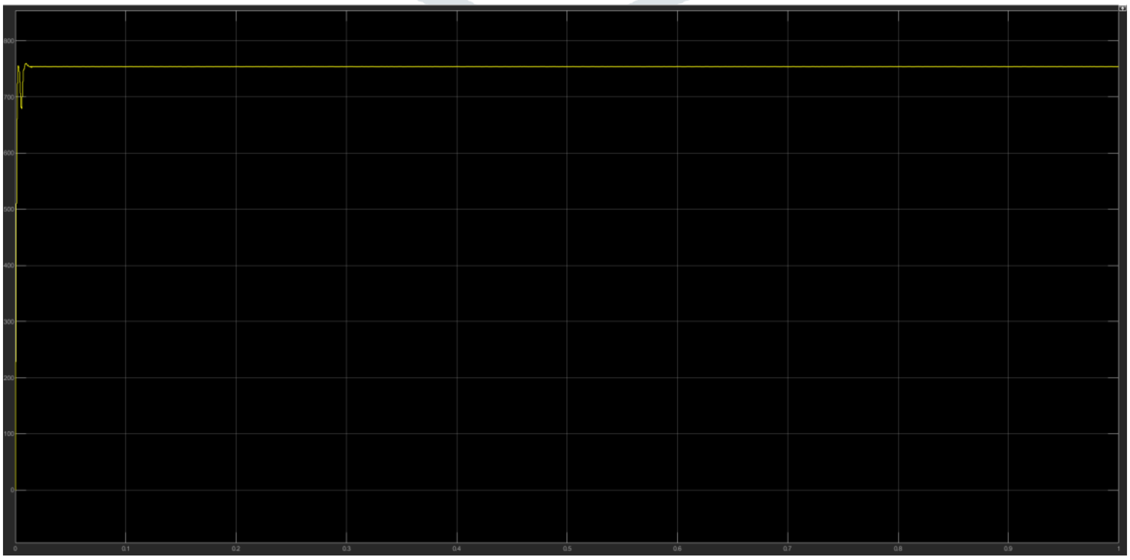

Fig 4.2: Desired Voltage of secondary side of DAB converter

The output waveform of voltage and current at the HV side of SST is shown in figure 4.3. As per the output results, Voltage of the primary side is not pure sinusoidal and current is distorted. Which is Similar to the secondary side of solid state transformer.

Fig 4.3: current of SST

The voltage is stepped down but it is also not pure sinusoidal that is shown in figure 4.4. After connecting the DC-link capacitor, ripples have been seen in output DC It is due to the unbalancing of DAB. After applying the SPS control technique in DAB the output results of SST are improved that can be seen from results. There is a pulse of secondary H-bridge have 50% phase shift from primary H-bridge

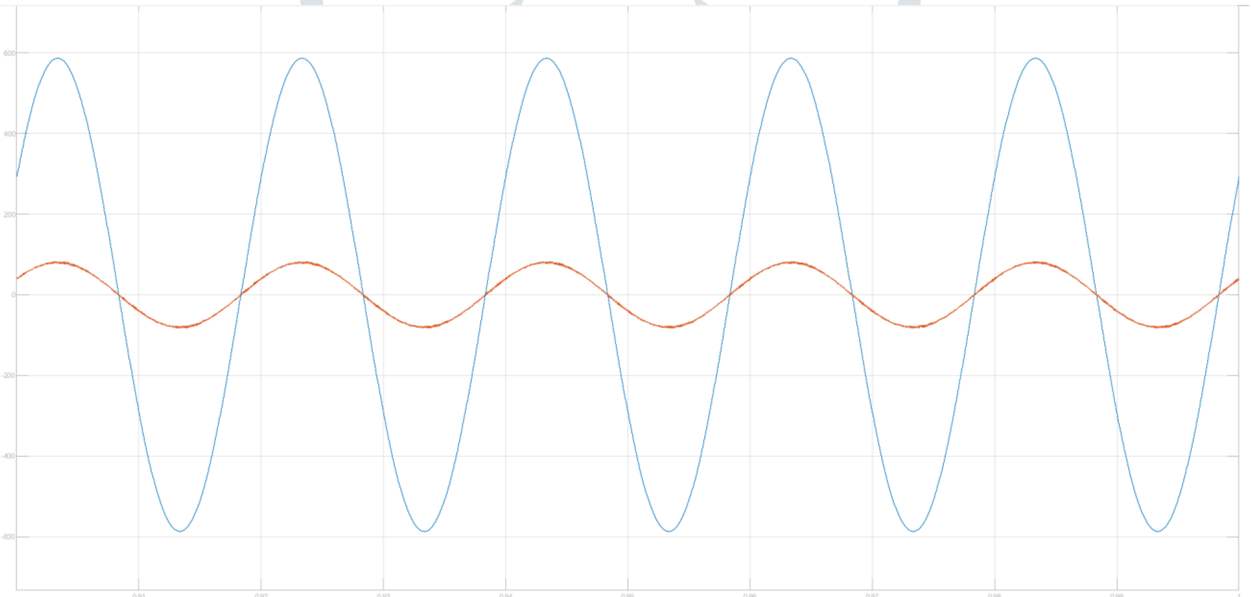

Fig 4.4: Output voltage and current waveforms when the DAB is connected to a full-bridge inverter

Fig 4.4 shows the output voltage and current waveforms when the DAB is connected to a full-bridge inverter and a resistive-inductive (R-L) load.

Advantages:

- Protection for output short circuit
- Protection from power supply disturbances for loads
- Protection from load disturbances for power system
- Harmonics regulations
- Power factor unity for reactive loads
- Operates when distributed
- Transient load
- Input is sinusoidal for nonlinear loads

V. CONCLUSION:

Solid state transformer alone cannot provide the required constant output, but with the help of control techniques it can be achieved. To eliminate this problem we have used dual active bridge DC-DC converter which is based on Single phase shift technique. This paper present the Dual active bridge for solid state transformer with SPS control technique. DAB converter with Control techniques plays an important role as it provides constant output by eliminating the large Dc capacitor, it also provides the higher efficiency and reduces the usage of passive components. In this paper Eight MOSFET are used which are connected across the high frequency transformer i.e. Solid state transformer for controlling the operation. from the simulation result it has been evident the SPS control in DAB improved the steady state performances, and enables the System to provides the desired voltage on the both side of transformer

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