PERFORMANCE EXPLORATION OF SINGLE PHASE DAB DC-DC CONVERTER UNDER LOAD VARIATION

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Abstract - *This article presents the performance analysis of single phase Dual Active Bridge (DAB) DC-DC converter under load variation. Two of the most important control goals for DAB DC-DC converters are to achieve a high efficiency and a quick dynamic response. This paper concentrated on the quick dynamic response of the DAB. The phase shift pulse width modulation (PWM) is adopted for the control of switches. The proposed configuration is verified in the Matlab Simulink environment. The performance parameter of load voltage and power is presented and analyzed. The projected configuration is presented with and without voltage controller. The proportional and integral (PI) controller is adopted as voltage controller in this paper.*

***Key Words*: DAB, DC-DC converter, Phase shift PWM, Proportional and Integral Controller, IGBT, Dynamic response.**

1. INTRODUCTION

Dual active bridge (DAB) DC-DC converters have many benefits, such as being able to send power in both directions, having a high power density, making zero-voltage switching easy to set up, and being easy to access for cascading and parallelism. As a consequence of this, these converters are utilised in a variety of applications, including distributed generating systems, DC-micro-grid systems, electric car charging systems, energy storage systems, and applications involving power electronic transformers in railway locomotives.

Jan Riedel, et al. [1] investigated using these angles to selectively suppress various dc bus current harmonics over the converter's working range to reduce the size of the DAB dc bus bridge capacitors. Haochen Shi, et al. [2] presented a method for decreasing reactive power while utilising three levels of modulated phase-shift control. Their goal was to improve efficiency in an extensive operation setting. Jianqiang Liu, et al. [3] proposed a power electronic traction transformer (PETT) voltage balancing control approach using dual active bridge (DAB). Wensheng Song et al. [4] suggested a virtual direct power control (VDPC) strategy for DAB dc–dc converters that uses single-phase-shift control in order to deal with the extreme situations. An accurate and general model was presented by Anping Tong et al. [5] to characterise the analytic expressions of the DAB converter while it was under the direction of TPS. On the basis of this, a discussion of the DAB converter's six different operational modes will follow. In order to improve the power quality of the grid, Allan Taylor et al., [6] presented a multiple-phase-shift control that makes it possible to implement a fixed-switching-frequency triple-phase shift (TPS) control at the light load. This control would be used at the light load. The dynamic behaviour of a dual active-bridge (DAB) is discussed in Kazuto Takagi's et al.'s [7] research paper. Jacob A. Mueller et. al., [8] offered a suggestion for generalized average models of dual active bridge (DAB) converters. The use of generalized average modeling necessitates making a compromise between the model's accuracy and its tractability. The authors Nie HOU et. al. [9] proposed a new hybrid control method that they called EPS-DPC. This technique is a combination of EPS-DPC. EPS-DPC control possesses notable characteristics, not only in terms of its efficiency but also of its dynamic performance. A complete optimization control approach was presented by Hou et al. [10] in order to increase the efficiency and dynamic response. Despite the widespread usage of this control method, however, the dynamic performance of the converters still has to be improved. A unique topology for a dc power electronic transformer (DCPET) is proposed by Jiepin Zhang et al. in their paper [11], which is intended for locomotives, ac/dc hybrid grids and dc distribution grids. The work of Shuai Shao and colleagues [12] presents a transformation in which distinct DAB working scenarios (forward/backward, buck/boost) might be comparable to one another. As a result, optimisation of only one scenario (forward/buck) is required to be performed. A unique neutral point clamped as DAB converter with a blocking capacitor was presented by Yang Xuan et al. [13] for use with ESS in dc micro-grids. A blocking capacitor in the primary loop of a conventional NPC DAB converter can match the transformer's primary and secondary winding voltage amplitudes when the voltage ratio is 0.25, 0.5, 0.75, or 1. A piecewise model of the modulation method was created by Amit Kumar Bhattacharjee and colleagues [14], which paves the way for analytical optimization. In addition, the optimization framework incorporates soft-switching conditions, which makes it possible to arrive at a comprehensive solution that lowers switching losses in addition to conduction losses. In conclusion, a hybrid controller that is based on generalized optimization has been suggested as a solution. Alber Filba-Martinez, et al. [15]

developed a solution to operate MLI converters. The solution was presented. The inherent imbalance of the voltages across the dc-link capacitors is the primary problem with these types of converters. This problem prevents the converter from functioning correctly and from being utilized to its full potential. M. A. Awal, along with other researchers, [16] suggested a method for balancing the capacitor voltage. A triple phase shift modulation (TPS) with an optimization technique that tries to maximize the efficiency of the dual active bridge converter was proposed by Simone Pistollato, et al. [17]. In smart dc power systems, such a converter is frequently utilised to link renewable or energy storage systems. This is because loss minimization via TPS is essential in these types of systems, particularly in light-load conditions. An enhanced model-based phase-shift control (MPSC) technique was proposed by Wenguang Zhao et al. [18]. Without having to make any adjustments to the controller parameters while they are being used online, the improved MPSC method. The construction of the controller's parameters is straightforward, and the same model parameter has the same level of sensitivity as MPSC. Simulations and experiments have shown that it is useful and effective, proving its veracity. A deadbeat current controller was presented by Shusheng Wei et al. [19] for an isolated bidirectional DAB. A refined technique to single phase shift modulation is utilized by the controller in its operation. This is accomplished by utilizing the pulse width as an additional control variable in addition to the phase shift ratio, which is the only control variable utilised by the standard single phase shift modulation. Kisu Kim et al. [20] suggested a split-capacitor dual active-bridge (DAB) converter. SC stands for split capacitor. To decrease the dc-bias current in dual-active-bridge (DAB) converters, Qinglei Bu et al. [21] introduced a unique transient phase shift control (TPSC), which is universal for multiple phase shift control schemes. To begin, the dc-bias current models are constructed under a variety of distinct transient circumstances. An optimized hybrid modulation system was proposed by Lucas Mondardo Cnico and colleagues [22]. This scheme was developed to minimize the total power losses of a 3-DAB converter when subjected to load and voltage changes. After reviewing literature survey, the single phase Full Bridge DAB is considered in this paper along with PS PWM due to its simplicity and easy to implement. The PI [23]-[28] controller is adopted in voltage control loop to control the voltage, current and power by controlling the duty cycle.

This paper is organized as four sections. The first section is the introduction and literature survey. The principles of DAB are presented in section II. The performance parameters using simulation analysis is discussed in section III. Finally, the conclusion is presented in section IV.

2. Dual Active Bridge DC-DC converter

The DAB consists of eight semiconductor devices, a high frequency transformer, an energy transfer inductor, and dc-link capacitors. It is a regulated, bidirectional, high-power dc-dc converter. Together, these components make up the dual active bridge. A more easy representation of the converter can be made by imagining it as a standard full-bridge that has been fitted with a regulated rectifier. The symmetry of this converter's primary and secondary bridges makes it possible to control the passage of electricity in either direction. It was chosen for the application involving the smart green power node for this purpose. Each full-bridge consists of two totem-poled switching devices energized by complementary square-wave pulses. These pulses constitute the driving force behind the operation of the full-bridge. These complementary pulses are what power the devices being discussed here. The term "switching frequency" refers to the rate at which these complementary devices switch on and off. This frequency is used by the converter. IGBT components have been increasingly prevalent in the production of high voltage switching converters during the past few years. These devices have been used to produce these converters despite not having an inherent body diode and having a bigger equivalent output capacitance than the devices that have been used previously.

Fig. 1 is a diagram that illustrates the DAB architecture. In this diagram, the letter 'n' represents the turns ratio of the transformer, v1 represents the output voltage of bridge 1, and v2 represents the output voltage of bridge 2. When combined, the two full-bridge circuits that make up the converter are connected to one another via an isolated transformer and an extra inductor denoted by the letter Ls. The entire bridge on the left, which is labelled as bridge 1, is connected to a high-voltage DC bus, whilst the bridge on the right, which is labeled as bridge 2, is connected to an energy storage device. Both bridges are shown in the figure below. The converter is said to be operating in the "forward mode" when it is moving power from the DC bus into the energy storage device. When functioning in the reverse mode, electricity is transferred from the energy storage system to the DC bus. This occurs when the system is in operation. As a consequence of this, power drawn from the battery will be depleted.

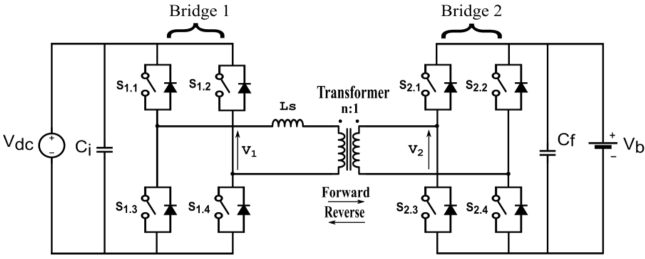

Fig -1: Schematic diagram of Full Bridge DAB

It is feasible to direct the flow of electricity over the dual active bridge by altering the phase of the pulses that are produced by one bridge in reference to the other. The control mechanism known as phase shift modulation, or more commonly abbreviated as PS, reroutes power between two dc buses in such a way that the leading bridge gives power to the trailing bridge. This is accomplished by shifting the phase of the modulation signal. Since the power may be modified using a fundamental PI-based controller, the Phase-Shift (PS) modulation is the method that can be put into practice with the least amount of effort and in the shortest amount of time. The switching circuit is built in such a way, as can be seen in Figures 2 and 3, that it generates a high-frequency square-wave voltage with a duty cycle of fifty percent at each of the bridge terminals. This can be seen because the switching circuit is made in such a way.

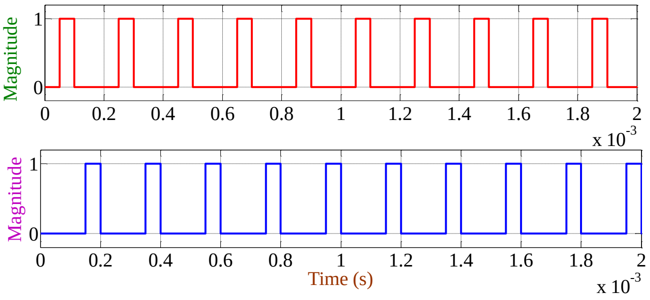

Fig -2: Duty cycle for Bridge-1

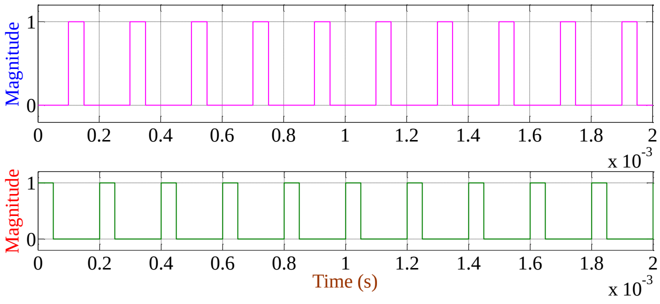

Fig -3: Duty cycle for Bridge-2

The modulation technique known as phase-shift modulation is likely the easiest one to implement for twin active bridge converters. The degrees of freedom are reduced to ϕ as a result of the adoption of D1=0.5 and D2=0.5.

3. SIMULATION RESULT ANALYSIS

The proposed configuration is analyzed in two cases. The projected work is presented without using voltage controller in case1. In case 2, the voltage controller is added and presented its impact on the output results. The simulation specifications are listed in Table-1.

Table -1: Specifications

Parameter	Value
Input Voltage	230 V
Load Resistance	46.3Ω, 40Ω
Capacitor	3300μF
Transformer	1:1, 230 V, 50Hz
Inductor	0.5mH

3.1 Without voltage controller

In this section, performance results of projected configuration are without voltage controller is presented.

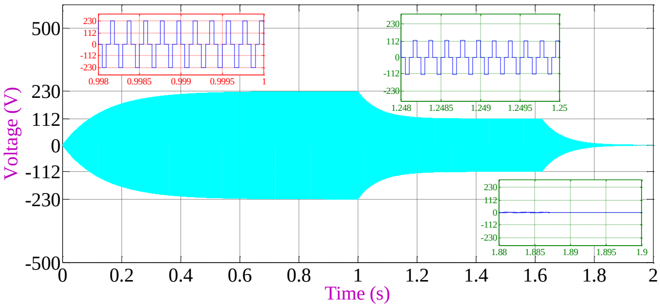

Fig -4: Transformer voltage under load variation

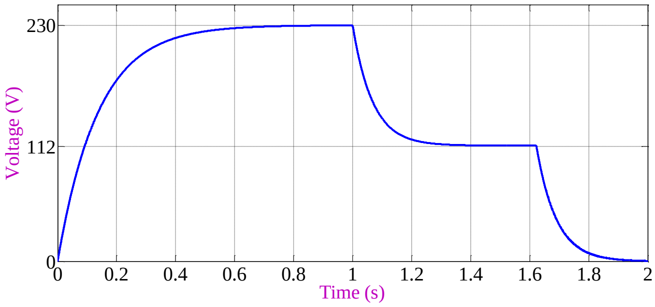

Fig -5: Output voltage under load variation

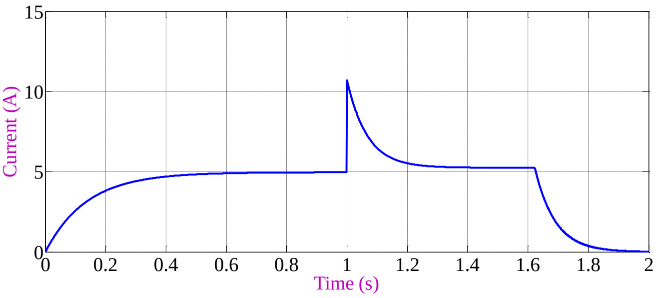

Fig -6: Output current under load variation

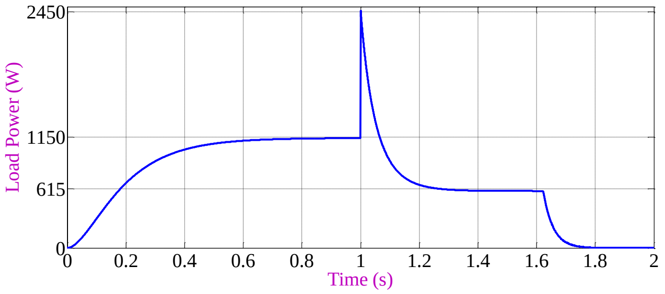

Fig -7: Output power under load variation

Using uncontrolled voltage loop is creating the distortion of outputs in dynamic condition. In this scenario, the resistive load of 46.3Ω is connected from t=0 sec to t=1 sec and another resistive load of 40Ω is connected from t=1 sec to t=2sec. The corresponding results are depicted in Fig. 4, Fig.5, Fig.6 and Fig.7. From Fig.4, it is observed that the transformer secondary voltage is 230 V from 0 sec to 1 sec and it is reduced to 112 at t=1sec. The transformer voltage further reduced and reached to zero at t=2sec due to unavailability of voltage controller. Similarly, the load voltage, current and power is also reached zero as depicted in Fig.5, Fig.6 and Fig.7. Hence, it is required to adopt voltage controller to stabilize all these effects.

3.2 With voltage controller

In this section, performance results of projected configuration are with voltage controller is presented and analyzed.

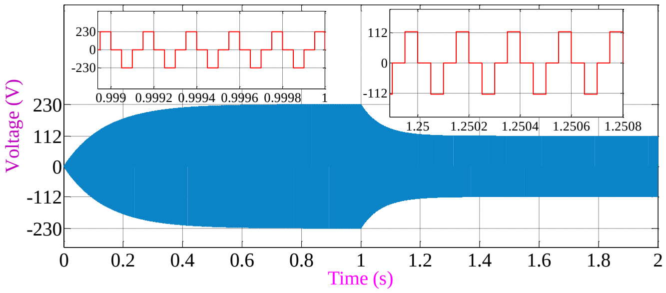

Fig -8: Transformer voltage under load variation

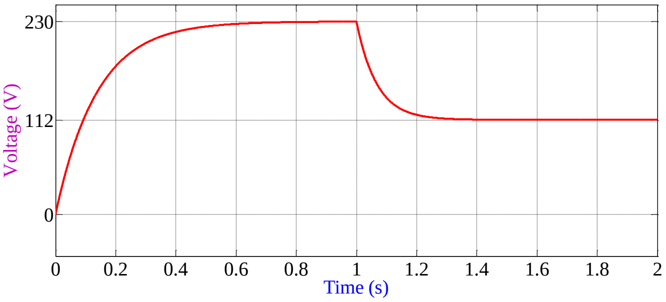

Fig -9: Output voltage under load variation

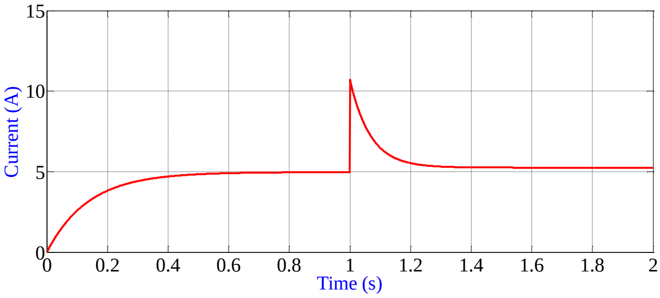

Fig -10: Output current under load variation

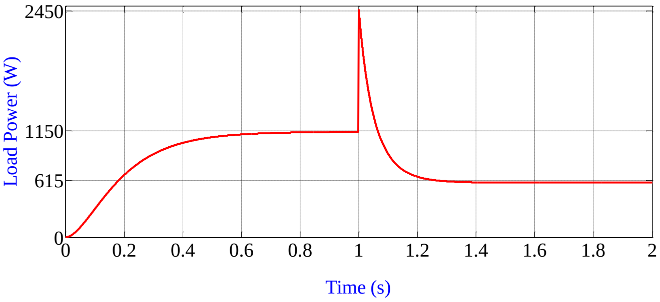

Fig -11: Output power under load variation

Using controlled voltage loop, the corresponding results are depicted in Fig. 8, Fig.9, Fig.10 and Fig.11. From Fig.8, it is observed that the transformer secondary voltage is 230 V from 0 sec to 1 sec and it is reduced to 112 at t=1sec. The transformer voltage of 112V is maintained constant after t=1sec also due to impact of voltage controller. Similarly, the load voltage, current and power is also controlled after t=1 sec as depicted in Fig.9, Fig.10 and Fig.11. Hence, it is proved that the voltage controller is effectively performed for this case.

The comparative performance analysis is illustrated in Fig.12, Fig.13 and Fig.14. From all these figures, it is observed that the voltage controller is effectively performed in dynamic conditions.

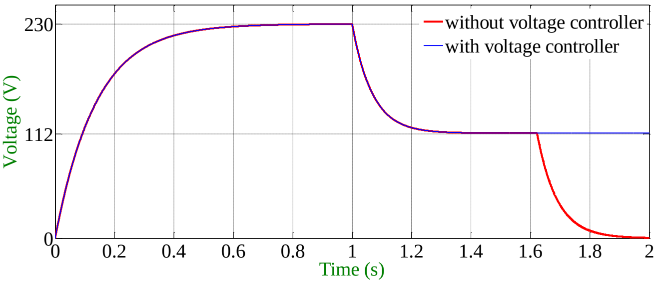

Fig -12: Output voltage under load variation

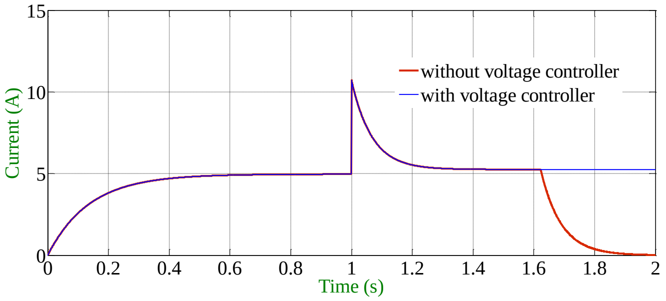

Fig -13: Output current under load variation

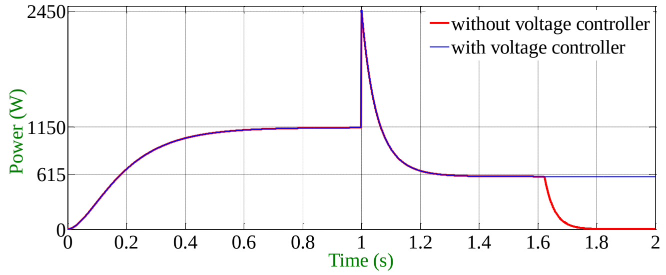

Fig -14: Output power under load variation

4. CONCLUSIONS

The principle of single phase DAB is presented. The concept of phase shift pulse width modulation scheme is described. The proposed configuration is analyzed in two cases including with and without voltage controller. The importance of voltage controller is described in the results section. The projected configuration is suffers for the output parameters such as load voltage, load current and load power. These parameters are reaching zero during load variation. The above said problem is nullified using PI controller which is adopted in voltage controller block. The PI is controller is effectively controlled the parameters of load voltage, load current and load power.

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