Technical White Paper

How to Build a Model of Multi-Phase-Shift With Varying Frequency in PLECS

ABSTRACT

This paper proposes a method for building a control module that has a multi-phase-shift with varying frequency, which is an excellent choice for the simulation and verification of phase-shift control topologies such as DAB or DAB-SRC, and can greatly increase the efficiency of a simulation.

Table of Contents

Trademarks

1 Introduction

Traditional converters have only one type of control method, such as PWM, PFM, or PSM, which control duty cycle, frequency, and phase-shift angle, respectively. Some topologies, such as DAB-SRC, often require a mix of control methods.

Figure 1-1 shows the DAB-SRC topology, and one paper proposes a control scheme with four degrees of freedom[1], that is, a three-phase-shift (TPS) with varying frequency to improve the performance of the converter.

To verify this control logic, you often need to build a simulation model in simulation software, and PLECS is a very simple and fast simulation software. This paper gives an idea of building a control module for this kind of complex control.

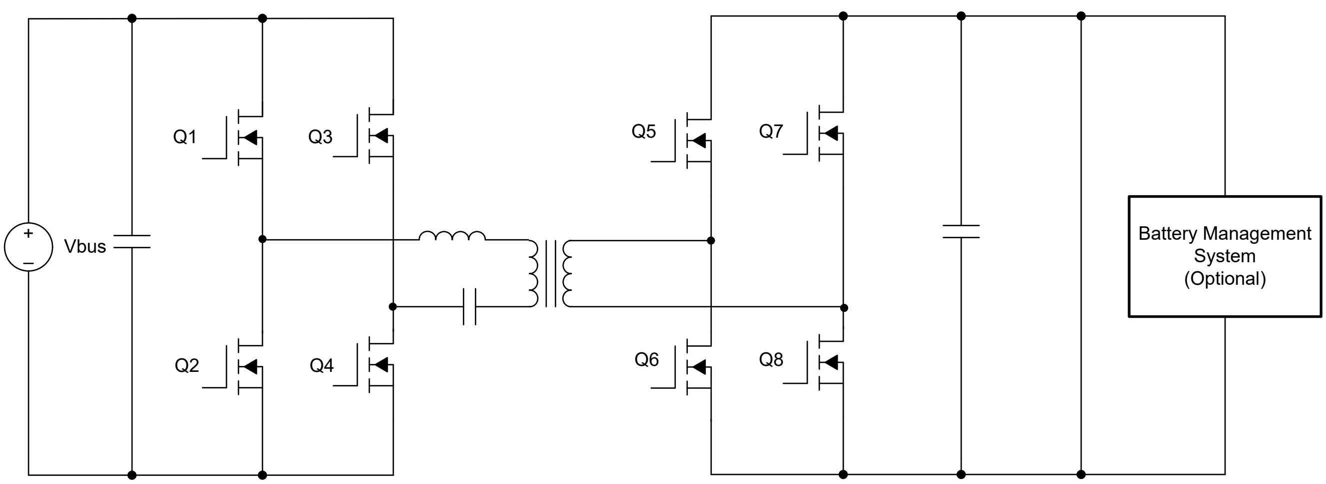

Figure 1-1. Dual Active Bridge Series Resonant Converter

2 Three-Phase-Shift (TPS) With Varying Frequency

The operation principle of conventional TPS control is shown in Figure 2-1, where all switches are operating alternatively at almost 50% duty cycle with necessary dead time. Three phase-shift angles are defined here for bidirectional power regulation.

The inner-bridge phase-shift θ1 is defined as the phase-shift by which the driver signal of Q1 leads that of Q3 in the primary-side bridge. The inner-bridge phase-shift θ2 is defined as the phase-shift by which the driver signal of Q6 leads that of Q8 in the primary-side bridge. Thus, the two high-frequency AC voltages are generated due to the existence of internal phase-shift. The external phase-shift φ is defined as the phase-shift by which the driver signal of Q1 leads that of Q8. The external phase-shift φ can also be defined as the phase-shift by which the positive rising edge of VAB from zero to high level leads that of VCD during one switching period.

When the varying frequency is added with TPS control, each bridge still works at 50% duty cycle, but the switching frequency also changes in real time.

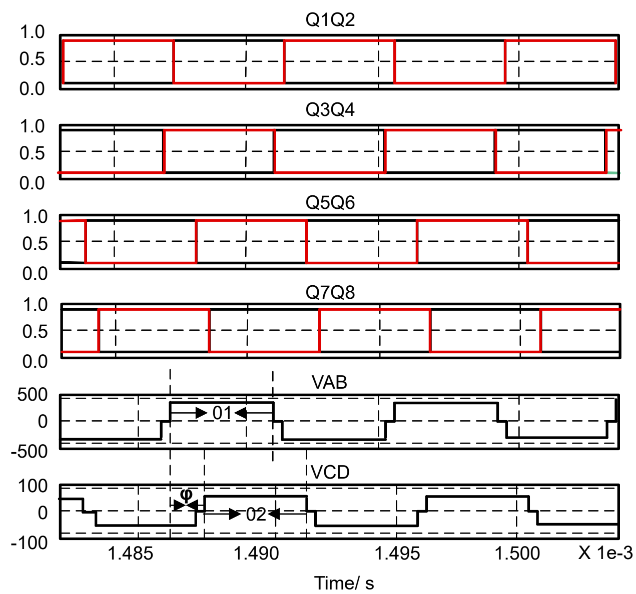

Figure 2-1. Typical Operating Waveforms of the DAB-SRC Under Conventional TPS Control

3 Solution in PLECS

In the demo model of PLECS, there is an SPS-controlled DAB model which has a single-shift module, as shown in Figure 3-1, based on which a multi-phase-shift module can be built.

As shown in Figure 3-2, the module is modified with S1 as the base driver and S3 as the phase-shifted Sita1 on the basis of S1. According to this method, you can obtain the driving signal at different angles of phase-shift on the basis of S1 so that the drive of the multi-phase-shift is no longer a problem, but now the only problem is figuring out how to realize varying frequency while changing the phase-shift angle.

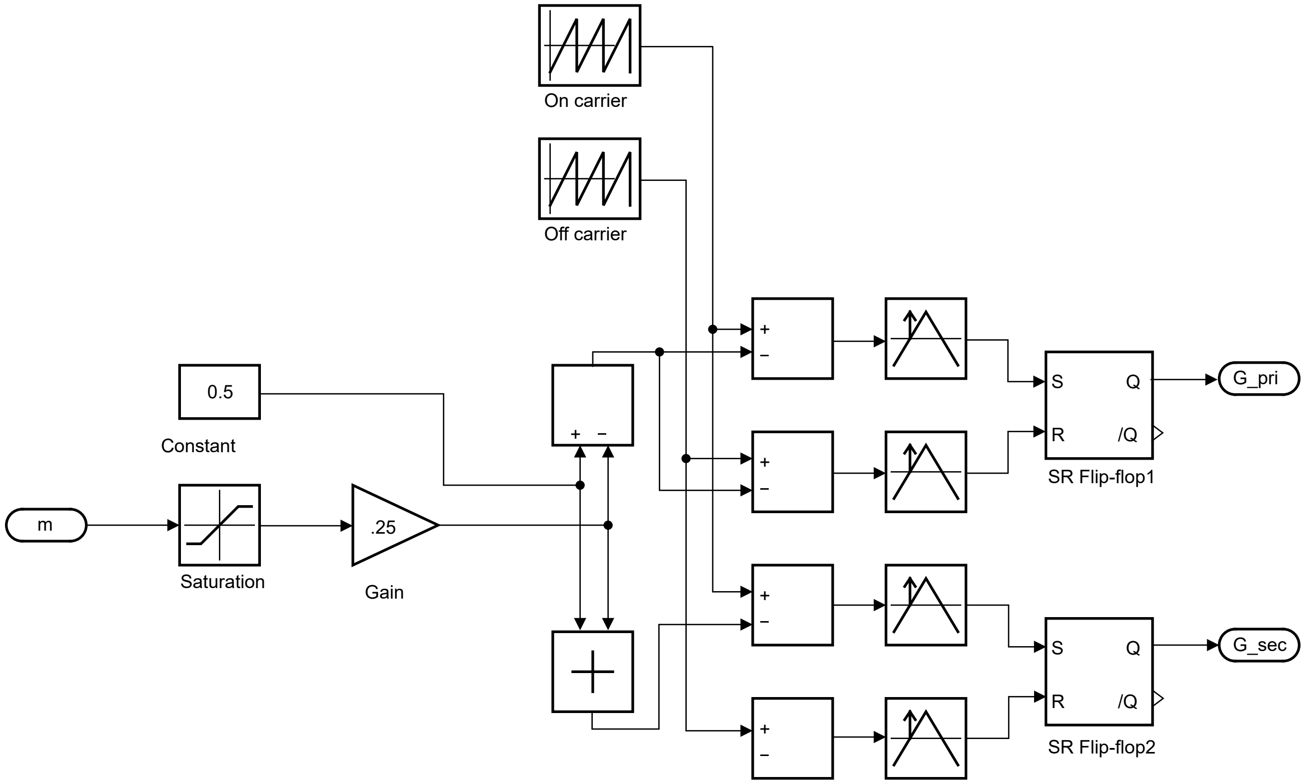

Figure 3-1. Single-Phase-Shift Function Module in Demo Model

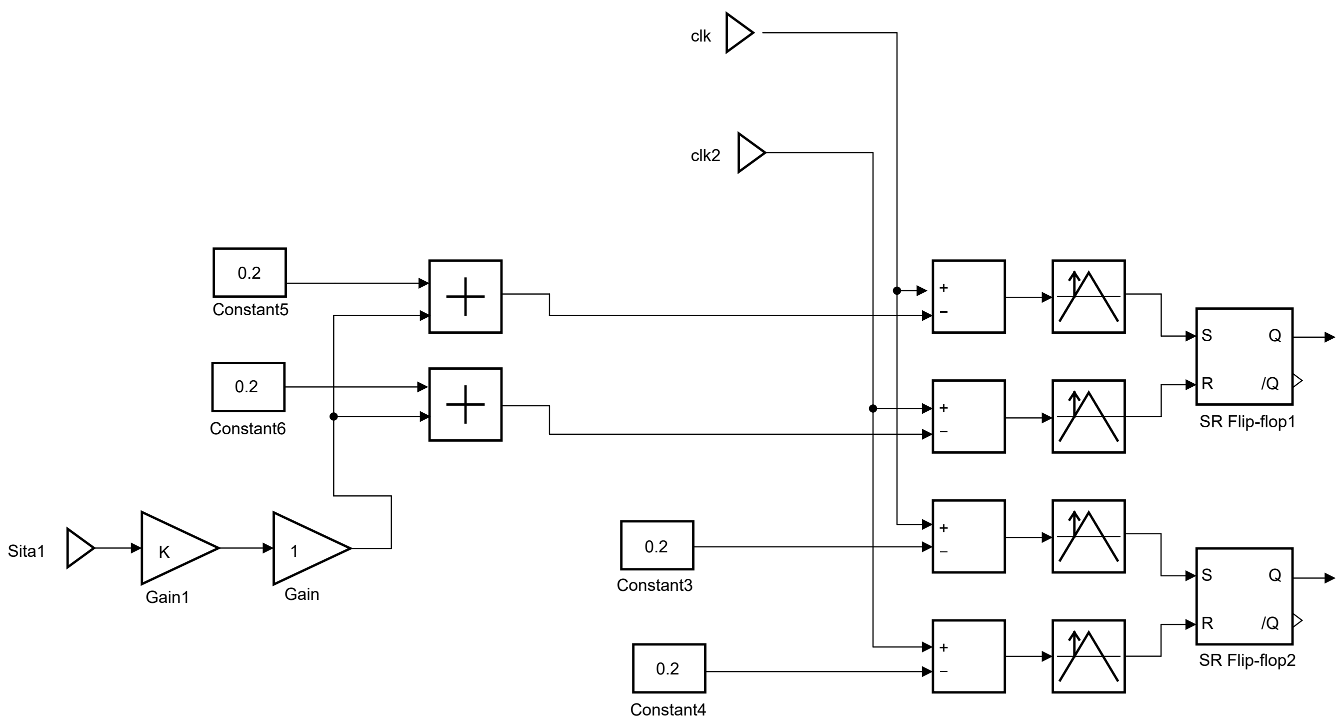

Figure 3-2. Modified Single-Phase-Shift Function Module

As seen from Figure 3-1, there are two carriers (On carrier and Off carrier) used as reference signals, so by changing the frequency of the carriers in real time, you can achieve varying frequency and phase-shift at the same time.

The carriers provided in this demo cannot achieve real-time frequency changes, so you need to find a new way to implement the frequency conversion carriers. Note that the two carriers also have a phase-shift of 1/2 period to make sure the generated duty cycle is 50%, which also increases the difficulty of building the module.

This paper now proposes a way to generate two carriers with varying frequency, while at the same time, the two carriers have a phase-shift of 1/2 period. Simulations built this way are faster than simulations with delays.

As shown in Figure 3-3, the integration (1/s) is used to generate a sawtooth wave, and the external initial condition of the integration is used to generate another sawtooth wave with a 1/2-period phase-shift. The figure also shows the settings for external initial condition and how to connect blocks.

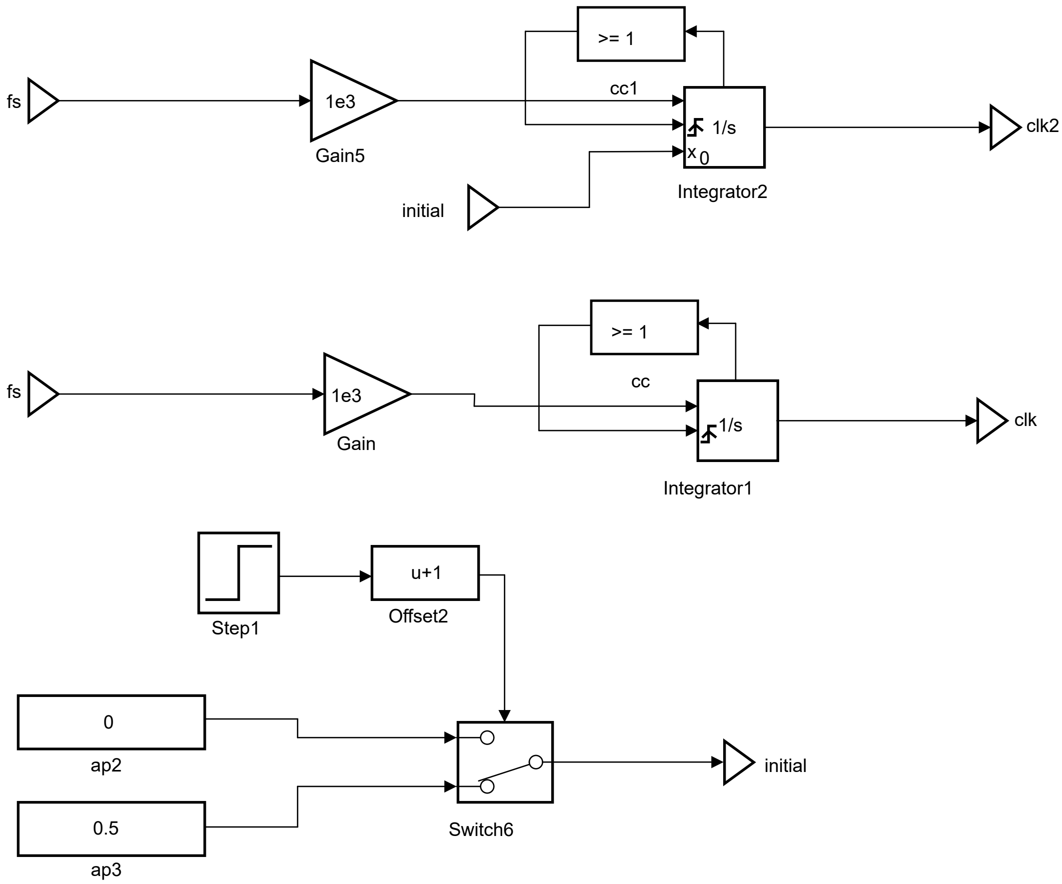

Figure 3-3. Schematic Diagram of the Implementation of a Variable Frequency Sawtooth Wave

Figure 3-4 shows the switching frequency varies from 300kHz to 100kHz for the clk and clk2 waveforms with no problems.

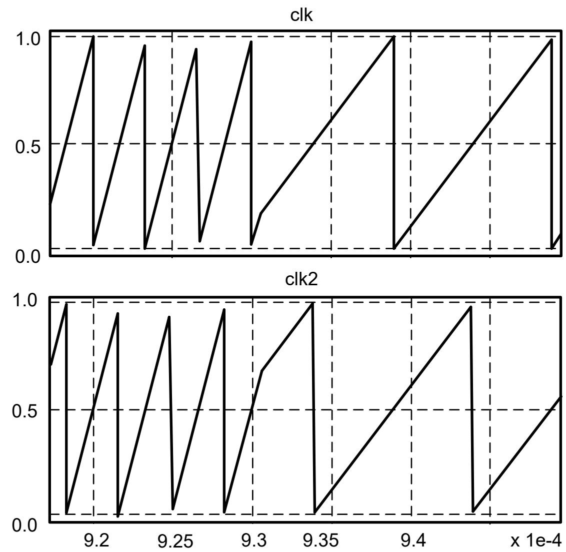

Figure 3-4. Detailed Waveforms When Changing Switching Frequency

4 Conclusion

In this paper, a method for building a multi-phase-shift with varying frequency control module is proposed, which is an excellent choice for the simulation and verification of phase-shift control topologies such as DAB or DAB-SRC, and can greatly increase the efficiency of a simulation.

5 References

1. M. Yaqoob, K. H. Loo, and Y. M. Lai, "A four-degrees-of-freedom modulation strategy for dual-active-bridge series-resonant converter designed for total loss minimization," *IEEE Trans. Power Electron.*, vol. 34, no. 2, pp. 1065_1081, Feb. 2019.