Dynamic Control and Performance of Dual Active Bridge Converter based Particle Swarm Optimization

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Abstract

This paper presents analysis of the dynamic response of the isolated bidirectional dual active bridge (DAB) DC-DC converter using particle swarm optimization (PSO) algorithm. On the basis, the fast dynamic response is one of the main control objective for DAB system to ensure the system able to have fast time recovery and adapt with various control environment. A 200 kW DAB system with single-phase shift (SPS) modulation is tested for direct and indirect online tuning phase-shift angle, ϕ using PSO algorithm. In direct tuning, the optimal ϕ is directly tuning using PSO. While in indirect tuning method, the optimal values of PI parameters are functioning to well-tuned the desired ϕ in the DAB system, where both values of K_P and K_I have been optimized using the PSO algorithm. The DAB performance with both proposed methods is evaluated in terms of dynamic response for load step changes under various reference voltages. Comparative analysis between direct and indirect methods are carried out using hardware in-the-loop (HIL) experimental. The DAB with indirect online tuning produces 11.50ms faster response compared to the direct online tuning method.

1 Introduction

Recently the world energy crisis has become serious problem due to the depletion of fossil fuels causing from the risen consumption of the resources. Since the air pollution also becoming the big concerned from the fossil fuels usage, the renewable energy such as wind and solar energy has got the high attention in recent years [1]. The significant concern for efficient and sustainable energy has led to the development of intermediate energy storage system such as smart grid and electric vehicles.

The bidirectional DC-DC converter is essential as power conversion stage in aforementioned applications [2]. With bidirectional power flow, high efficiency and high power density features, dual active bridge (DAB) is one of the DC-DC converters that attracts many researchers and have been widely used in many applications [3].

The DAB has two full bridges, where primary side and secondary side of bridge were galvanic isolated through a high frequency transformer as portrayed in Fig. 1. The phase-shift angle, ϕ is the controlled variable in DAB that control the magnitude and direction of power flow. A positive value of ϕ indicates the forward direction which is the power flow from primary part to secondary part and the reverse direction is denoted by negative value of ϕ. The single phase-shift (SPS) modulation is one type of the phase-shift modulation that was commonly used in DAB, where it required to control only one ϕ [4].

The Lagrange multiplier method, genetic algorithm (GA), mathematical programming methods and Ant Colony Optimization (ACO) are the optimization methods that have been proposed in DAB application to generate the optimal ϕ [5][6][7]. The use of particle swarm optimization (PSO) for offline tuning have been applied in [5] where this algorithm benefits include a reduction in computational burden, quick convergence and ease of implementation Nevertheless, since the lookup table is necessary to implement the offline methods, it is not always viable [8] especially when there are disruptions in the DAB system. Therefore, the online tuning based on PSO algorithm is proposed in this paper to overcome the drawbacks of the offline tuning and provides a potential high robustness system.

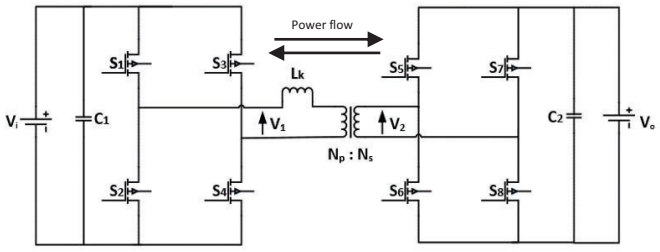

Figure 1 Schematic circuit of DAB converter

The linear controller cannot adequately guarantee system stability and control performance in the nonlinear system due to its various dynamic performances [9]. Therefore, optimization algorithms are increasingly being used as controllers in place of a linear controller in overcoming such been used in a variety of applications, including PV applications [10]. This direct control strategy can nonetheless