Time-Variant Online Auto-Tuned PI Controller Using PSO Algorithm for High Accuracy Dual Active Bridge DC-DC Converter

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Abstract— **The proliferation of clean energy and environmentally friendly transportation has contributed to the development of electric vehicles (EVs) including the EV DC charger system. A dual active bridge (DAB) is a DC-DC converter that has the required features for an EV DC charger. A proportional-integral (PI) controller is a common method in power electronics applications, including DAB. However, the manual tuning of PI parameters using Ziegler-Nichols (ZN) needs a lengthy time and the tuning values are practical and well-functioning at the tuning point only. Moreover, the fixed gains in offline tuning cannot fully control the system output as needed and do not guarantee the robustness of the system. This paper proposes a time-variant online auto-tuned PI controller using a particle swarm optimization (PSO) algorithm for the 200 kW DAB system. The DAB performance with the proposed controller is evaluated in terms of steady-state error, *ess* and dynamic performance under various reference voltages at different loads and load step changes. Comparative analysis between the proposed method and manual tuning performance are presented. A hardware-in-the-loop (HIL) experimental circuit is built to validate the simulation results. The DAB with the proposed method produces 64% higher accuracy and 40% faster response compared to manual tuning. tuning.**

Keywords—time-variant online tuning, particle swarm optimization, dual active bridge, accuracy, dynamic performance

I. Introduction

Nowadays, global warming has become a serious issue due to the risen of energy consumption from fossil fuels. The phenomenon causes an environmental problem, and air pollution can affect a population's health. Thus, the concern on development of electric vehicles (EV) and smart grid headed for green energy has become increased in recent years [1]. Most EV productions are embarking toward connected technologies vehicle-to-grid (V2G), vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) [2], [3]. The plug-in electric vehicle (PEV) is one of the intelligent product of V2G technology that allowing the energy exchange between the EV and the power grid or energy strorage system (ESS) [4]. The smart EV charger stations are required to support the growth of PEV applications [5].

The EV charger system is categorized to AC charger and DC charger for on-board and off-board chargers, respectively. The on-board EV charger uses low power while off-board charger has the high power features [6]. This paper focusing on the DC-DC converter part that consisting in EV DC charger system. Inline to the requirement of fast charging, bidirectional power flow and isolation part in EV charger system, a dual active bridge (DAB) DC-DC converter become most popular converter that promising the aforementioned features [7]–[8] .

DAB converter was proposed in early 1990s [9] is consisting of two full bridges converter through high frequency transformer as shown in Fig. 1. The symmetric structure of the DAB allowing the bidirectional power flow which forward direction is from primary bridge to secondary bridge and vice versa for the reverse direction[10]. Besides, the DAB guarantee high efficiency, high power density and have simple control strategy [11][12]. The phase-shift modulation is used to determine the direction and magnitude of the power flow in DAB. There are four common types of phase-shift modulation, which single phase-shift (SPS), extended phase-shift (EPS), dual phase-shift (DPS) and triple phase-shift (TPS) [13]. The major difference of those above-mentioned phase-shift modulations are the number of control variables that are referring to the phase-shift angle, ϕ. The SPS is the simplest modulation where it only needs one ϕ to be controlled, while EPS and DPS has two control variables, and TPS has three control variables.

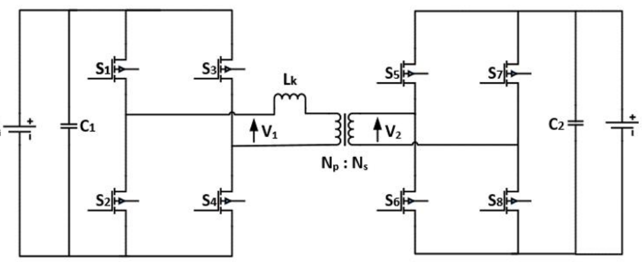

Fig. 1. Schematic circuit of DAB converter

The optimization methods with different objectives to achieve minimum power backflow, minimum current stress and high efficiency have been proposed in the DAB system, where the online and offline optimization using Lagrange Multiplier method (LMM)[14], global optima condition[15],