Design of High Power Wide Gain Range CLLC Converter

For applications that have high power and wide gain range, such as EV chargers, energy storage, PV, and railway auxiliary power supplies, the converter usually consists of two stages: A PFC/Inverter and an isolated dc-dc stage, as shown in Fig. 1. For such applications, the dc voltage, V_{dc}, could have a varying range of 2:1.

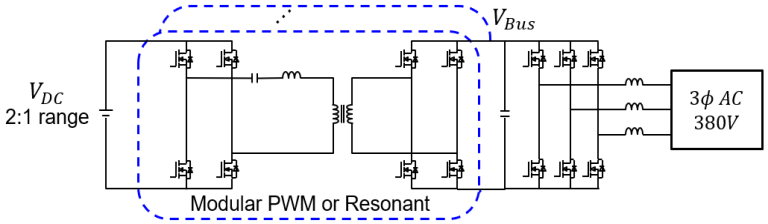

Fig. 1. Two-stage structure: Isolated dc-dc and PFC/Inverter

Conventionally, phase shift PWM converters are used for the dc-dc stage. However, considering its limited ZVS operating range, the efficiency and power density are also limited. From the switching loss point of view, resonant converters have huge advantages due to their ZVS capability and low current turnoff, especially when wide bandgap (WBG) devices are used. However, a resonant converter, e.g. CLLC, is not suitable for wide gain range applications with the conventional frequency modulation. Thus, multiple control strategies are combined to solve the problem. In general, a flexible dc link voltage is selected to release the required gain range for the dc-dc stage. Then depending on V_{dc}, the CLLC converter will operate in one of three operation modes: Boost mode when V_{dc} is low, PWM mode when V_{dc} is high, and DCX mode when V_{dc} is in the middle. Besides the reduced gain requirement for the dc-dc stage, another benefit of the flexible V_{bus} is that the CLLC converter could always achieve high efficiency in the DCX mode, where a nominal voltage range will be located by properly selecting the turns ratio n for each application. Fig. 2 shows the dc-dc stage topology and key waveforms of three-mode operations.

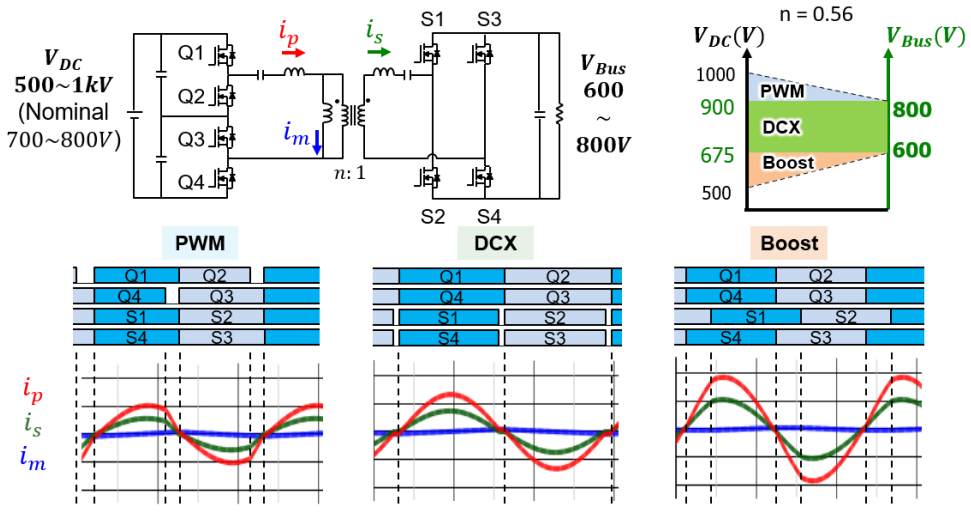

Fig. 2. Circuit topology and simulated waveforms of three-mode operations

Operating principles of the three modes, as well as an optimized design procedure are introduced in detail, and a 30kW prototype is built for demonstration, achieving a peak efficiency of 99%.