Interleaved LLC Resonant Converter with Hybrid Rectifier and Variable-Frequency Plus Phase-Shift Control for Wide Output Voltage Range Applications

Introduction:

LLC resonant converter is one of the most attractive topologies for its features of excellent soft-switching performance and high-power density. It has been applied in several applications such as server farms, LED drivers, battery chargers, electric vehicles, renewable power systems, etc. Although extensive researches on design, modeling, and control of LLC resonant converters have been carried out by academia and industry departments, LLC resonant converters are still evolving. Tradeoff between conversion efficiency and operation range is still necessary to meet the needs of various applications.

Existing system:

Optimal design methods were proposed to extend the operational voltage range and make full use of the voltage regulation and power conversion capabilities of LLC resonant converters. However, the contradiction between efficiency and voltage range is still inevitable. Burst mode control is employed to improve the conversion efficiency at low output voltage and light load conditions. It is straightforward and effective, but the implementation is complicated.
Meanwhile, low-frequency current and voltage ripples will be introduced by the burst mode operation. Primary-side and secondary-side phase-shift control were proposed to provide another effective control freedom, so as to reduce the switching frequency range of the LLC resonant converter.

Novel voltage regulation method with transformer winding series-parallel auto-regulated principles is proposed for PWM forward and full-bridge converters. This method is a good candidate for PWM converters with wide output voltage range applications. However, the conversion efficiency of these PWM converters is still slightly lower than resonant converters, because the rectifying diodes are hard-switched and have to sustain a high-voltage stress induced by the leakage inductance of the transformer.

Dis-advantages:
- Low conversion efficiency.
- High-voltage stress.

Proposed system:
A novel voltage regulation method for LLC resonant converters through innovative hybrid rectifier and control method is proposed. Variable-frequency plus phase-shift (VFPPS) control is employed to the proposed iLLC resonant converter to regulate the output voltage in a wide output voltage range. Variable frequency control is adopted to regulate the output voltage and the secondary windings are in series when the output voltage is high. Fixed-frequency phase-shift control is adopted to regulate the output voltage by adaptively changing the connection of the two secondary windings when the output voltage is low.
A family of novel interleaved LLC (ILLC) resonant converters is harvested for wide output voltage applications. With the proposed topologies and control, the LLC resonant converters always operate in the $fs \leq fr$ region and the switching frequency range can be narrowed significantly.

The structure of the proposed iLLC resonant converter with a hybrid rectifier, where two LLC resonant switching networks are employed on the primary side and a hybrid rectifier is adopted on the secondary side. The two LLC resonant switching networks are connected in parallel, while the hybrid rectifier on the secondary side is shared by the two secondary windings of the two transformers, $T_1$ and $T_2$. The LLC resonant switching network on the primary side is composed of a switching bridge and an LLC resonant network.

**Advantages:**
- The circulating current and additional conduction losses associated with the magnetizing inductance of the LLC resonant converter is reduced dramatically.
- Output voltage regulation performance.

**Applications:**
- Power conversion applications.
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Block Diagram:

- Dc input
- LLC resonant converter
  - Hybrid rectifier
  - Load
- 12VDC
  - Gate driver circuit
- 5VDC
  - Buffer circuit
  - Microcontroller circuit