

Critical Conduction Mode Control for Coupled Inductor Based Totem-pole PFC

Recently, the totem-pole PFC rectifier has seen renewed popularity with the help of the high voltage Gallium-Nitride (GaN) high-electron-mobility transistor (HEMT). The HEMT has a better figure-of-merit, especially its smaller reverse-recovery effect as compared to that of the Si MOSFET. The critical conduction mode (CRM) operation in the GaN-based totem-pole PFC provides soft switching operation at a higher switching frequency. It results in better switching loss and smaller passive components compared to continuous- conduction mode (CCM) with hard-switching operation. To reduce the inductor size, increase power density, and maintain a high efficiency, CRM operation should be applied to the GaN based totem-pole PFC.

The coupled inductor in CRM based totem-pole PFC has characteristics of different dynamic inductance depending on the input voltage. In 400 V DC link voltage range, negative coupling with a high coupling coefficient provides lower switching frequency range, which results in lower switching loss. Furthermore, the DC flux cancellation in the negative coupling inductor also provides smaller core loss.

Extended on-time of SR devices are required to fully achieve soft-switching operation. Fig. 1 shows valley switching voltage for a negative coupled inductor. Valley switching voltage is the voltage across the main switches when the main switch is turned on without extended SR on-time. So the extended SR on-time is required when the valley switching voltage is not equal to 0. Compared to non-coupled inductor valley voltage, extended SR on-time is required even though the input voltage is lower than half of the output voltage.

Fig. 2 shows the state-plane during the resonant period for main switches. The red line shows resonant state-plane when no SR extended on-time is applied with hard switching. On the other hand, the blue line shows the resonant state-plane with extended SR on-time. A higher negative current with extended SR on-time helps fully discharge the output capacitor of main switches. Therefore, the proposed CRM control for coupled inductor provides fully soft-switching operation in full line cycle, which results in better efficiency and reliability in the GaN devices.

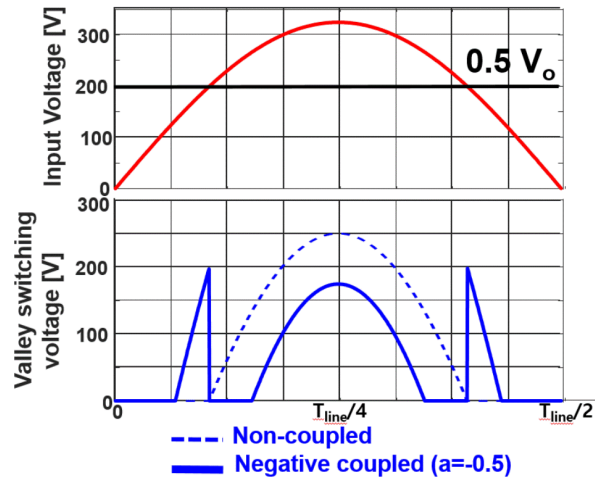


Fig. 1. Valley switching voltage with coupled inductor

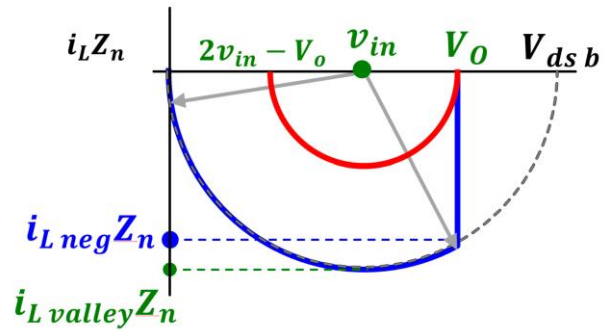


Fig. 2. State-plane during the resonant period for CRM converter