Small-Signal Modeling of Multiphase V2 Constant On-Time Control with Phase Overlapping

Multiphase V2 constant on-time control (COT) based on the pulse distribution method is increasingly used in voltage regulators for CPUs and GPUs because of its good light-load efficiency, fast transient response, and simple structure. This control technique becomes unstable when the output capacitor time constant is less than half of the fixed on-time of each phase. For low duty cycle applications, an external ramp is sufficient to stabilize the system. However, external ramp and current ramp (known as hybrid ramp) are used together to stabilize the system for wide duty cycle applications. When the duty cycle of an N-phase V2 COT controlled buck exceeds 1/N, the output voltage exhibits variable on-time and off-time modulation from a small-signal perspective. Hence, single-phase V2 COT control models cannot be extended to these multiphase V2 COT control architectures in the phase overlapping regions (or when D > 1/N), as shown in Fig. 1.

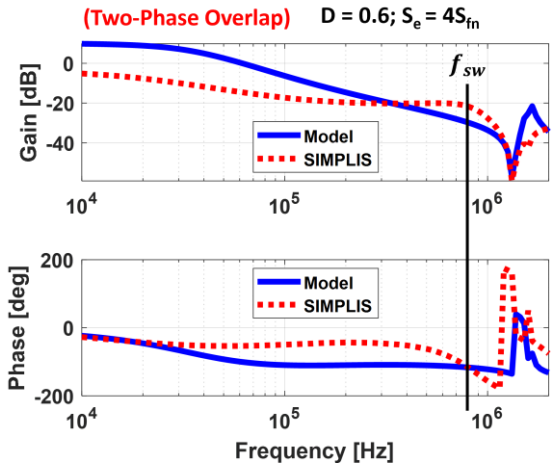

Fig. 1. Issue in extending the single-phase V2 COT model to multiphase V2 COT model using the slope equivalence concept between the single-phase inductor and multiphase buck total current.

To address this issue, this work presents a general small-signal model of multiphase V2 COT control architectures for the whole duty cycle range based on the describing function (DF) method. The total current modulation law with multiphase V2 COT control remains the same as current-mode COT control. Using the modulation law and performing Fourier analysis on the perturbed waveforms, the control describing function was derived. The derived model is found to be accurate up to half the total current steady-state frequency, as shown in Fig. 2. The proposed models were further verified using experimental results from a 12-phase V2 COT controlled buck platform.

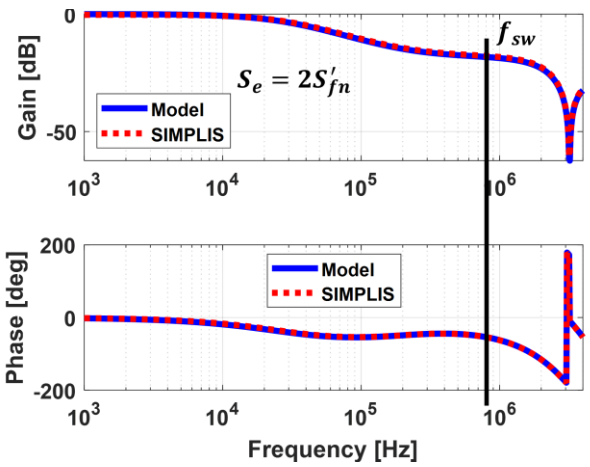

Fig. 2. Verification of the control-to-output response of multiphase V2 COT control in two-phase overlapping region using proposed model