Transient Mitigation in Switching Capacitor Banks Using Solid-State Devices

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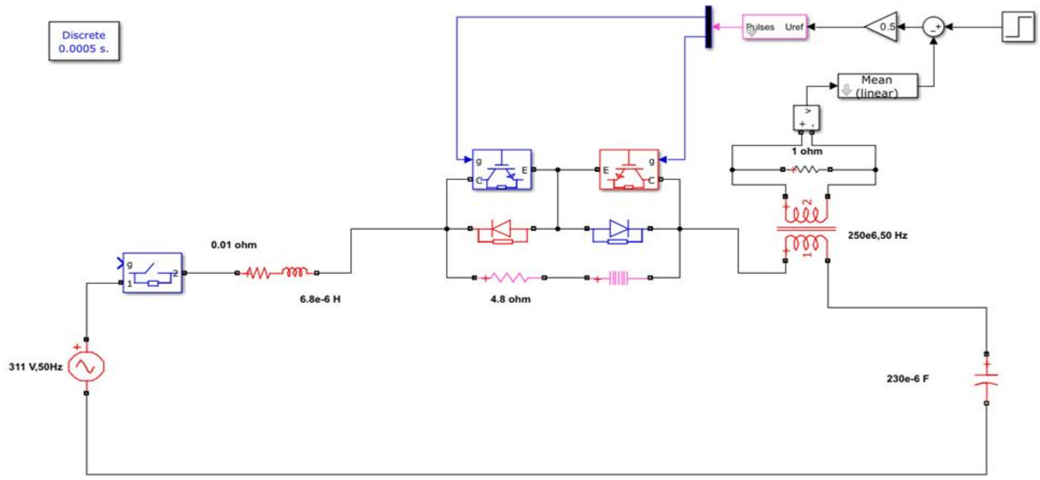
Abstract

Conventional capacitor bank switching frequently produces voltage and current transients that may disrupt operation, accelerate component degradation, and reduce system stability. This study investigates transient mitigation using solid-state switching devices, specifically insulated gate bipolar transistors (IGBTs) controlled by zero-crossing and pulse width modulation (PWM). Numerical simulations were performed in MATrix LABoratory (MATLAB)/Simulink by varying snubber parameters (Rs–Cs), PWM duty cycle, switching instant, and filter configuration. Results indicate that solid-state switching significantly lowers the magnitude of current and voltage surges compared to conventional mechanical switching. Parametric evaluation of the R–L circuit identifies R = 0.01 Ω as an optimal value, balancing initial inrush current limitation with sufficient damping. Furthermore, the configuration of Rs = 12 Ω, Cs = 33 nF, and a duty cycle of 15% demonstrates superior performance by reducing peak current by over 50%, suppressing peak voltage, and minimizing oscillations. These improvements alleviate device stress, enhance stability, and extend equipment lifetime. Compared to manual switching, the IGBT–PWM scheme achieves lower I_{peak}, V_{CE} peak, and switching losses while maintaining conduction efficiency. The findings highlight solid-state switching as a promising and practical solution for designing reliable, efficient, and power-system-friendly capacitor bank switching systems.

Table of Contents



Innovative Description: Transient mitigation in switching capacitor banks using solid-state devices.