中文摘要

於電力電子領域中，三相切換式轉換器是一種應用甚為廣泛的電路架構。 但由於其電路架構中具有非線性之開關元件與三相間相互耦合之原因，使得三相切換式轉換器的建模非常困難與複雜。 因此本論文主要目的即在針對三相切換式轉換器提出一簡便的圖像式建模工具，即“開關訊號流程圖法”。 此方法之特點是可將線性訊號流程圖理論應用於具多切換開關之電路，並建立其模型，方便研究其電路之非線性動態特性。

本論文所提開關訊號流程圖法主要貢獻之一即此方法可靈活的應用於直流轉換器或三相切換式轉換器，並同時可獲得其大訊號模型，小訊號模型與穩態模型。此模型可同時清楚的描述出電路參數之因果關係， 提供設計者在設計控制器時，方便做系統性的觀察。本論文之另一貢獻為提出一虛擬開關及虛擬切換函數之概念，並將其與應用於三相切換式轉換器之建模過程。 其優點包括:

(a) 藉由定義虛擬開關及其虛擬切換函數，可成功的解決其三相切換式轉換器，包括三相全橋整流器與三相全橋反流器在建模過程時，交流電壓極性變換所造成的建模困境。

(b) 此概念之應用可非常容易將主動開關之盲時效應及導通電阻之考量納入模型， 使其更具實用價值。

(c) 當完成虛擬開關及其虛擬切換函數之定義後， 三相切換式轉換器之六個主動開關及六個二極體，可以輕易地整合在一起並簡化為三個虛擬開關。 根據此包含三個虛擬開關之等效電路，全橋電路之每一相開關訊號流程圖近乎可以解耦合，使得相與相間建模複雜度降至最低。

(d) 在建模過程中，只需要三個子電路與三個虛擬切換函數，因此即可非常容易地完成三相切換式轉換器之開關訊號流程圖。

(e) 在簡單的建模過程中，其相對之大訊號模型，小訊號模型與穩態模型也非常容易直接由前述開關訊號流程圖輕易得之。

(f) 只需藉由簡單的邏輯運算將原有的開關控制訊號與電流方向做整合，即可獲得虛擬切換函數，而二極體之切換函數也可同時獲得。

除此之外，本論文所提建模法之另一優點為應用此開關訊號流程圖法所建立之模型， 可非常容易用 MATLAB/SIMULINK 來模擬並印證此模型之實用性; 同時，在相同的模擬條件下， 建立於 MATLAB/SIMULINK 軟體環境下之開關訊號流程圖模型，大約只需 PSPICE 模擬軟體十分之一的模擬耗時。此一特性可以很有效的提升與系統設計結合之整合性，也大幅降低一般切換式系統之模擬耗時。

本論文所提之開關訊號流程圖法除可應用於直流轉換器與三相切換式轉換器之外，也可適於應用在其它各種多開關電路， 例如二極體濾波器、柔式切換開關電路、並聯多階反流器等。

ABSTRACT

Three-phase switching converters are broadly used in high power electrical systems. However, because of the nonlinear operation of switching components and the coupling between the three phases, the modeling work of a three-phase switching converter is very difficult. Therefore, a graphic modeling tool, namely switching flow-graph (SFG) modeling technique, for three-phase switching converters is proposed in this dissertation. This technique extends the familiar linear signal flow-graph theory to model the nonlinear switching circuits and greatly simplifies the analysis of nonlinear dynamics of the multi-switch circuits.

One of the major contributions of this dissertation is that the proposed SFG technique can be applied to model the three-phase switching converters. The large-signal, steady-state and small-signal models of the switching converters can easily be developed simultaneously. At the same time, the proposed SFG model is able to provide the cause-effect phenomena of the switching converters, which is helpful to the controller design and system analysis. Another major contribution of this dissertation is proposing the concept of the virtual switch and virtual switching function which are very powerful for modeling multi-switch converter systems and possess the following merits:

(a) By defining the virtual switch and virtual switching function, the difficulties of modeling the three-phase switching converters which include three-phase full-bridge inverters and three-phase full-bridge rectifiers can be obviated successfully.

(b) Based on the concept, the effect of ON-resistance and blanking-time of the active switches can easily be taken into account. It is very valuable for actual application.

(c) As the virtual switch and virtual switching function are defined, the six active switches and six diodes of the three-phase switching converters can easily be integrated and simplified to three virtual switches. According to the equivalent

circuit with the virtual switches, the switching flow-graph of each phase is almost decoupled. Therefore, the complexity of the modeling work between phase and phase is automatically diminished.

(d) Only three virtual switches and three virtual switching functions are required during the modeling process. The switching flow-graph for three-phase switching converters can be developed very easily.

(e) The corresponding large-signal, steady-state and small-signal models can be obtained straightforward from the simple switching flow-graph.

(f) The virtual switching function can be obtained easily by using the logical operators to combine the switching functions of active switches and the judgment of current directions. Simultaneously, the switching function of the diode can also be found.

Moreover, the proposed SFG model can be implemented easily with MATLAB/SIMULINK facilely to carry out the time-domain simulation. The simulation results generated from the proposed SFG model are well confirmed with that generated from PSPICE. The computer execution time required by using the proposed SFG model is only about one tenth of that required by PSPICE under the same simulation conditions. It is more computationally efficient for system-level simulation as compared with the PSPICE model. In fact, the proposed SFG technique can also be applied to model various converters such as DCM DC-DC converters, three-phase diode-rectifiers, soft-switching circuit and parallel VSI, etc.