

# CONTENTS

<b>CHINESE ABSTRACT.....</b>	<b>i</b>
<b>ABSTRACT.....</b>	<b>iii</b>
<b>ACKNOWLEDEMENT.....</b>	<b>v</b>
<b>CONTENTS.....</b>	<b>vi</b>
<b>LIST OF FIGURES.....</b>	<b>viii</b>
<b>LIST OF TABLES .....</b>	<b>xii</b>
<b>I. INTRODUCTION.....</b>	<b>1</b>
1.1 Motivations.....	1
1.2 Literature Survey.....	2
1.3 Contribution of This Dissertation.....	5
1.4 Outline of Contents.....	6
<b>II. REVIEW OF SWITCHING FLOW-GRAPH MODELING</b>	
<b>TECHNIQUE FOR DC CONVERTERS.....</b>	<b>8</b>
2.1 Introduction.....	8
2.2 The Linear Signal Flow-Graph Technique.....	9
2.3 Switching Flow-Graph Modeling Technique for DC Converters....	9
2.4 Examples.....	12
<b>III. THE PROPOSED SWITCHING FLOW-GRAPH</b>	
<b>MODELING TECHNIQUE FOR THREE-PHASE INVERTERS.....</b>	<b>17</b>
3.1 The Concept of Virtual Switch for Inverters.....	17
3.2 The Proposed Switching Flow-Graph for Three-Phase Inverters....	21
3.3 The Corresponding Models Derived from Switching	
Flow-Graph Model.....	24
3.4 Simulation Results.....	27
<b>IV. THE PROPOSED SWITCHING FLOW-GRAPH</b>	
<b>MODELING TECHNIQUE FOR THREE-PHASE RECTIFIERS.....</b>	<b>36</b>
4.1 The Concept of Virtual Switch for Rectifiers.....	36
4.2 The Proposed Switching Flow-Graph for Thee-Phase Rectifiers....	40
4.3 The Corresponding Models Derived from Switching	
Flow-Graph Model.....	42
4.4 Simulation Results.....	46
<b>V. APPLICATION EXAMPLES OF THE PROPOSED</b>	
<b>SWITCHING FLOW-GRAPH MODEL.....</b>	<b>54</b>

5.1	Introduction.....	54
5.2	Application Examples of Inverters.....	
5.2.1	Simulation Examples by Using the Proposed SFG Model	55
5.2.2	Design Examples by Using the Proposed SFG Model.....	60
5.3	Application Examples of Rectifiers.....	66
5.3.1	Simplified SFG Model for Diode-Rectifier Simulation	66
5.3.2	The SFG Model for Three-Phase Rectifiers with Unbalanced Input Sources.....	68
5.3.3	PI-Controller Design for Rectifiers by Using the Proposed SFG Model .....	69
<b>VI.</b>	<b>CONCLUSIONS.....</b>	<b>78</b>
	<b>REFERENCES.....</b>	<b>81</b>
	<b>APPENDIX A.....</b>	<b>A1</b>



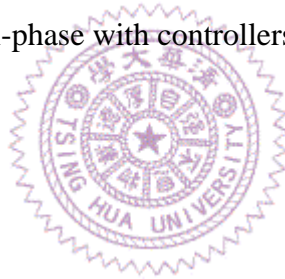
## LIST OF FIGURES

Fig. 2.1	Boost converter: (a) the circuit diagram (b) switch ON, (c) switch OFF. ....	13
Fig. 2.2	(a) The flow-graph of ON-circuit, (b) the flow-graph of OFF-circuit, (c) the switching flow-graph of the boost converters. .	14
Fig. 2.3	(a) The large-signal model, (b) the steady-state model, (c) the small-signal model of the boost converter operated in CCM. ....	15
Fig. 3.1	The circuit configuration of the PWM inverter. ....	17
Fig. 3.2	Equivalent circuit of Fig. 1. ....	21
Fig. 3.3	Switching flow-graph for $j$ phase, $j \in \{A, B, C\}$ (a) when $S_j$ is ON (b) when $S_j$ is OFF (c) combined flow-graph using the switching branch (d) the corresponding virtual switching function. ....	23
Fig. 3.4	The proposed switching flow-graph model for three-phase PWM inverters. ....	24
Fig. 3.5	The large-signal model derived from Fig. 3.4.....	25
Fig. 3.6	The steady state model. ....	26
Fig. 3.7	The small-signal model. ....	27
Fig. 3.8	Simulation results of the output currents with zero blanking time using (a) switching flow-graph model, (b) PSPICE model. ....	29
Fig. 3.9	Simulation results of the output currents with $20\mu s$ blanking time using (a) switching flow-graph model, (b) PSPICE model. ....	30
Fig. 3.10	Dynamic simulation results of the output currents using (a) switching flow-graph model, (b) PSPICE model. ....	31
Fig. 3.11	The large-signal switching flow-graph model considering ON-resistance of active switches. ....	32

Fig. 3.12	Waveforms of $F_{S_{AP}}$ , $F_{S_{AN}}$ , $F_{D_{AP}}$ , $F_{D_{AN}}$ , $F_A$ and $v_{AN}$ for (a) $i_A > 0$ (b) $i_A < 0$ . ....	33
Fig. 3.13	The steady state current waveforms of A-phase (a) simulation result (b) experimental result [43]. (horizontal 20ms/div, vertical 2A/div) .....	35
Fig. 4.1	The circuit configuration of the PWM rectifier. ....	37
Fig. 4.2	Equivalent circuit of Fig. 4.1 .....	39
Fig. 4.3	The corresponding virtual switching function. ....	39
Fig. 4.4	The proposed switching flow-graph model for three-phase PWM rectifier. ....	40
Fig. 4.5	The large-signal model derived from Fig. 4.4. ....	41
Fig. 4.6	The large-signal switching flow-graph model considering ON-resistance of active switches. ....	41
Fig. 4.7	The large-signal model of the three-phase rectifier based on d-q coordinate. ....	43
Fig. 4.8	The steady state model based on d-q coordinate. ....	44
Fig. 4.9	(a) The small-signal expression for two variables multiplied together, (b) The small-signal model based on d-q coordinate. ....	44
Fig. 4.10	The Simulation results of the output voltage using (a) proposed SFG model, (b) PSPICE model. ....	48
Fig. 4.11	The Simulation results of the AC current and voltage for A-phase using (a) proposed SFG model, (b) PSPICE model. ....	48
Fig. 4.12	Waveforms of $F_{S_{AP}}$ , $F_{S_{AN}}$ , $F_{D_{AP}}$ , $F_{D_{AN}}$ , and $F_A$ for (a) $i_A > 0$ (b) $i_A < 0$ . ....	49
Fig. 4.13	The Simulation results of the output voltage using (a) proposed SFG model, (b) PSPICE model. ....	50

Fig. 4.14	The Simulation results of the AC current and voltage of A-phase using (a) proposed SFG model, (b) PSPICE model.....	50
Fig. 4.15	(a) The diagram of the experiment, (b) the prototype of the experiment.....	52
Fig. 4.16	(a) The simulation waveforms, (b) the experimental waveforms of the phase voltage and current for A-phase without controllers.....	53
Fig. 5.1	The simulation structure of the proposed SFG model connecting with the functional blocks of PSB. ....	55
Fig. 5.2	The simulation waveforms of stators currents ( $A$ ), mechanical rotor speed ( $rad/s$ ) and electromagnetic torque ( $N.m$ ). ....	56
Fig. 5.3	The simulation model of the SMPMSM implemented with MATLAB/SIMULINK. ....	59
Fig. 5.4	The simulation model of the SMPMSM with the proposed SFG model. ....	59
Fig. 5.5	The simulation waveforms of torque and rotor speed.	60
Fig. 5.6	The control structure of the SMPMSM.....	60
Fig. 5.7	The small-signal model represented in frequency domain.....	61
Fig. 5.8	The A-phase current controllers implemented with MATLAB/SIMULINK.....	63
Fig. 5.9	The simulation model of the motor system with the proposed SFG model .....	64
Fig. 5.10	The simulation waveforms of the stators currents $i_d$ , $i_q$ , torque and rotor speed for $f_s = 1kHz$ .....	65
Fig. 5.11	The simulation waveforms of the stators currents $i_d$ , $i_q$ , torque and rotor speed for $f_s = 10kHz$ .....	65
Fig. 5.12	The circuit configuration of the full-bridge diode rectifier.....	66
Fig. 5.13	The Simulation results of the output voltage using (a) proposed SFG model, (b) PSPICE model.....	67

Fig. 5.14	The Simulation results of the AC current and voltage of A-phase using (a) proposed SFG model, (b) PSPICE model.....	67
Fig. 5.15	The large-signal model for three-phase rectifiers with unbalance input sources	68
Fig. 5.16	The control structure for the three-phase rectifier.....	70
Fig. 5.17	The small-signal SFG model for finding out the transfer functions of $\frac{\hat{v}_{DC}(s)}{\hat{i}_d(s)}$ and $\frac{\hat{v}_{DC}(s)}{\hat{i}_q(s)}$ .....	69
Fig. 5.18	Fig. 5.21 The small-signal SFG model for finding out the transfer functions of $\frac{\hat{i}_d(s)}{\hat{d}_d(s)}$ , $\frac{\hat{i}_d(s)}{\hat{d}_q(s)}$ , $\frac{\hat{i}_q(s)}{\hat{d}_d(s)}$ and $\frac{\hat{i}_q(s)}{\hat{d}_q(s)}$ .....	72
Fig. 5.19	The simulation model created with MATLAB/SIMULINK.....	75
Fig. 5.20	The simulation results of (a) the output voltage, (b) the AC current and voltage of A-phase with controllers.....	76



## LIST OF TABLES

Table 3.1	Six qualified switching states .....	18
Table 4.1	Six qualified switching states .....	36

