



**DESIGN OF POWER ELECTRONIC
INVERTER FOR ACTIVE POWER
REDISTRIBUTION IN AN UNBALANCED
THREE PHASE SYSTEM**

M. T.K.De Silva

(PG/EE/22/99)

thesis submitted to the Faculty of Engineering, University of Moratuwa

in partial fulfillment of the requirement for the degree of

Master of Engineering

In

Electrical Engineering

Under the supervision of

Dr. J.P.Karunadasa

Faculty of Engineering

University of Moratuwa

2004

80500



Abstract

This project presents a scheme to balance the active power consumed by unbalanced loads in three-phase four wire system.

Power systems are generally unbalanced due to asymmetry of the load applied and different time operations by consumers. Unbalanced operating conditions cause lot of problems to the power system.

There are schemes for power balancing in three phase three wire systems, but this project illustrates power balancing in three-phase four wire systems.

It can be shown that a power electronic converter based on the generalized instantaneous power theory, can redistribute active power among phases. The generalized instantaneous power theory can be used in both three-wire and four-wire three-phase systems.

Power electronic circuit takes power from the phase that delivers low power and feeds to the phase that delivers high power. Therefore load as viewed by the power source becomes balanced without negative and zero sequence components although unbalanced power is still supplied to the load.

The load current and the voltage are measured continuously and the instantaneous power is calculated. Reference current wave for the hysteresis current controller is calculated using the-control strategy. Power electronic inverter is controlled by hysteresis current controller and it redistributes the active power in the phases. There are no external power sources used and the inverter is driven by a capacitor. Therefore power source supplies balanced power to an unbalanced source.

The simulation studies of the project is done by MatLab software and results show that the source current becomes balanced after connecting to the power electronic



converter The rating of the power electronic converter is decided on the basis of the phase unbalance rather than the rated load power.

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and behalf, it contains no material previously published or written by another person nor material, which to substantial extent, has been accepted for the award of any other academic qualification of an university or institute of higher learning except where acknowledgement is made in the text.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

M.T.K. De Silva

M.T.K.De Silva
February 2004

UOM Verified Signature

Dr. J.P.Karunadasa
Project Supervisor
February 2004

Acknowledgements

First of all, thanks to Dr. J.P. Karunadasa for his guidance and advice throughout my research as the supervisor.

I am also grateful to all the staff led by Prof J.R. Lucas of the Department of Electrical Engineering, University of Moratuwa for their help with this research.

My special thanks also go to all the previous researchers who contributed to the development of knowledge in this area of concern which immensely help me throughout this research work..

Last, but by no means least, a special mention for my daughter, Nethmi and my husband Muditha who have provided the love and support required for such a work as this to be completed.

Thank you to everyone for all the help, support and encouragement.



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Contents

	<i>Page</i>
<i>Acknowledgement</i>	ii
<i>Abstract</i>	iii
CHAPTER 1	
INTRODUCTION	1
CHAPTER 2	
ACTIVE POWER UNBALANCE	3
CHAPTER 3	
<i>LITERATURE REVIEW</i>	6
3.1 Phase Power Balancing of a Diesel Generator Using a Bi-Directional PWM Inverter	6
3.2 Instantaneous Reactive Power Compensators Comprising Switching Devices without Energy Storage Components	9
3.3 Generalized Instantaneous Power Theory for Three-Phase Power Systems & Reactive Power Compensation	13
CHAPTER 4	
PRINCIPLE OF SOLUTION	17
4.1 Principle Description	17
4.2 Symmetrical Components of Current Waveforms	20
CHAPTER 5	
MEHODOLOGY	22
5.1 Circuit Diagram	22
5.2 Three-Phase PWM Current Controlled Voltage Source Inverter	24
5.3 Hysteresis current controller	26

5.4 Control Strategy	29
CHAPTER 6	
OBSERVATION & RESULTS	32
CHAPTER 7	
CONCLUSION	37
REFERENCES	38
ANNEX 1	
Static, Thyristor Controlled Shunt Compensator	39
ANNEX 2	
A Review of Active Filters for Power Quality Improvements	40
ANNEX 3	
4.1 Mat Lab - Math Works Product Family	42
4.2 Mat Lab - Model & Simulate Power System	44



University of Moratuwa, Sri Lanka.
 Electronic Theses & Dissertations
www.lib.mrt.ac.lk



Table of Figures

Page

1. Figure 2.1 Voltage and Current waveforms of Balanced Resistive Load	3
2. Figure 2.2 Three-phase Load Currents in Balanced Case	4
3. Figure 2.3 Instantaneous Active Power in Balanced Condition	4
4. Figure 2.4 Three-phase Load Currents in Unbalanced Case	5
5. Figure 2.5 Instantaneous Active Power in Unbalanced Condition	5
6. Figure 3.1 Single Line Diagram of the System	6
7. Figure 3.2 Inverter Unit of Each Phase	7
8. Figure 3.3 Phasor diagram: Inverter mode	8
9. Figure 3.4 Phasor diagram: Rectifier mode	8
10. Figure 3.5 $\alpha - \beta$ coordination transformation	9
11. Figure 3.6 Instantaneous Space Vectors	10
12. Figure 3.7 Reactive Power Compensator System	11
13. Figure 3.8 Control Circuit	11
14. Figure 3.10 Three phase Coordination	13
15. Figure 3.11 System Configuration of Instantaneous Reactive Power Compensation	15
16. Figure 4.1 Power Redistribution in an Unbalanced Three-phase Four-wire System	17
17. Figure 5.1 Schematics of Power Redistribution System	22
18. Figure 5.2 Circuit Diagram	23
19. Figure 5.3 Three-Phase PWM Current Controlled Voltage Source Inverter	25
20. Figure 5.4 Hysteresis current controller	27
21. Figure 5.5 Hysteresis current controller	28
22. Figure 5.6 Reference current wave generation control strategy	31
23. Figure 6.1 Instantaneous Voltage and Current Waveforms	33
24. Figure 6.2 Unbalanced Load Current Waveforms	33
25. Figure 6.3 Instantaneous Active power	34
26. Figure 6.4 Reference Current Waveforms	34
27. Figure 6.5 Hysteresis Current Controller Output Waveforms	35
28. Figure 6.6 Capacitor Charging & Discharging Waveform	35

29. Figure 6.8 Inverter Current Waveforms

36

30. Figure 6.9 Source Balanced Current Waveforms

36



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk