UNIVERSITI PUTRA MALAYSIA

DESIGN OF A NEW SEMICONDUCTOR CIRCUIT BREAKER

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MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

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DEDICATION

This thesis is dedicated to my parents

For their patience and tolerance

During my study.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DESIGN OF A NEW SEMICONDUCTOR CIRCUIT BREAKER

By

MOHD ZIN BIN HASSAN

October 2008

Chairman: Associate Professor Dr. Sinan Mahmood Abdullah, PhD

Faculty: Engineering

The objective of this present work is to design, simulate and testing the new semiconductor circuit breaker. In this thesis, both circuit breakers are built around electronics and semiconductor devices. The designed circuit applies solid state technology to provide relay control and opto coupler device as interface between electronics control circuit and power supply side. The design combines solid-state switching, analog signal output to perform circuit protection and earth leakage circuit breaker.

The simulation has been carried out using the OrCAD simulation software. The real performance of the designed semiconductor circuit breaker has been measured using oscilloscope. The analysis has been carried out on the single phase and three phase loads. The tripping time has been measured during the short circuit test. Waveforms of the

simulations showed that the tripping time is 2 ms on the single phase load and 2 ms on the three phase load. The short circuit test has been carried out showed the tripping is 2 ms on the single phase load and 2 ms on the three phase load. Comparison of the tripping time has been made between the designed semiconductor circuit breaker and conventional circuit breaker which is available on the market. Data sheet of the conventional circuit breaker showed the tripping time is more than 20 ms. Its means that the performance of the tripping time of the semiconductor circuit breaker is much better than the conventional electromechanical circuit breaker.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Master Sains

REKABENTUK INOVATIF PEMUTUS LITAR SEMIKONDUKTOR

Oleh

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Oktober 2008

Pengerusi: **Profesor Madya Dr. Senan Mahmod Abdullah, PhD**

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Objektif tesis ini ialah merekabentuk, melakukan simulasi, membina dan menguji sebuah Pemutus Litar Semikonduktor (SCB). Dalam tesis ini, Pemutus Litar Semikonduktor ini dibina dengan menggunakan peranti elektronik dan semikonduktor. Reka bentuk yang berasaskan applikasi solid state ini menggunakan optocoupler sebagai peranti antara dua muka diantara kawalan elektronik dan bekalan kuasa. Rekabentuk SCB menggabungkan pensuisan semikonduktor, keluaran isyarat analog untuk membentuk pemutus litar bocor kebumi.

Simulasi dilakukan dengan menggunakan perisian simulasi OrCAD. Prestasi sebenar Pemutus Litar Semikonduktor ini diukur dengan menggunakan osiloskop. Analisa dilaksanakan keatas beban sefasa dan beban tiga fasa. Sela masa pemutus diukur semasa ujian litar pintas. Gelombang isyarat simulasi menunjukkan sela masa putus ialah 2

millisaat keatas beban satu fasa. Manakala ujian sebenar menunjukan sela masa putus ialah 2 milisaat bagi beban satu dan tiga fasa. Hamparan data Pemutus Litar Konvensional menunjukkan sela masa putus ialah melebihi 20 millisaat. Ini menunjukkan prestasi Pemutus Litar Semikonduktor (SCB) adalah lebih baik daripada Pemutus Litar Konvensional yang terdapat dipasaran.

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I would also like to thank to my supervisor Asc. Prof. Dr. Sinan Mahmood Abdullah and the members of the supervisory committee Prof Ir. Dr. Norman Mariun for their advice, understanding, support, criticism and co-operation in completing this report.

I certify that an Examination Committee has met on 28 October 2008 to conduct the final examination of Mohd Zin Bin Hassan on his Master of Science thesis entitled "Design of a New Semiconductor Circuit Breaker" in accordance with Universities and University Collages Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHD ZIN BIN HASSAN

Date:

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LIST OF ABBREVIATIONS

A	Ampere
AC	Alternating current
C	Capacitor
DB	Distribution board
DC	Direct current
ELCB	Earth Leakage Circuit Breaker
f	Frequency
Hz	Hertz
HV	High Voltage
LV	Low Voltage
i_{surge}	Surge current
IEC	International Electromechanical Commission
IEEE	Institute of Electrical and Electronic Engineers
IGBT	Insulated Gate Bipolar Transistor
KVA	Kilo volt ampere
LV	Low Voltage
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MV	Medium Voltage
MSB	Main switch board
nsec	Nanosecond (Millimicrosecond)
P	Power
PWM	Pulse Width Modulation
R	Resistance
RCBO	Residual Current Breaker with Overload protection
RCD	Residual Current Device
RMS	Root mean square
SCB	Semiconductor Circuit Breaker
SPN	Single Pole and Neutral
T	Time
T_A	Temperature, ambient
T_j	Junction temperature
TPN	Triple Pole and Neutral
t_d	Pulse delay time
VAC	Voltage alternating current
VDC	Voltage direct current
W	Watt

CHAPTER 1

INTRODUCTION

1.1 Background

The development of earth leakage protection and indicated the very real need for such protection against both shock hazard and fire risk. Only injurious or fatal electrical accidents are reported. It is impossible to determine how many lives have been saved by ELCB's since their first installation three and one half decades ago. It would be frightening to contemplate the consequences of uncontrolled wiring and electricity usage in developing environments that were not provided with such protection devices. It is the Earth Leakage Circuit Breaker which provides not only sensitive earth leakage protection, but also overload and short circuit protection as well as circuit safety disconnect features.

1.2 Problem Statement

This research is to design the new semiconductor circuit breaker and compared to the electromechanical circuit breaker which available in the market. Table 1.1 shows the comparison of tripping time of the circuit breaker available in the market and works of the current thesis.

Table 1.1 Comparison between ELCB available in the market and Current Thesis

Circuit Breaker available in the market.		Current Thesis
Types and make	Tripping time in ms	Current works
CHAC, China GF7 RCD, China CBT China GFIN25, GFIN40, GFIN63, China	0.1 s 0.1 s 0.1 s 0.1> t >60 s	1. Design 2. Simulation 3. Build the hardware 4. Short circuit test 5. Comparing the results.

1.3 Aim and Objectives

The aim of this work is to design a new Semiconductor Circuit Breaker with better speed of tripping time.

The objectives of the thesis are:-

1. To search and gathered varies circuit breaker problems of Circuit Breaker.
2. Compare the advantages and disadvantages of various types of Circuit Breaker.
3. To design a new Circuit Breaker which eliminate the major problems.
4. Simulate the design using the appropriate software.
5. Construct the prototype due to the design.
6. Testing and performance analysis of the designs.

1.4 Thesis Organization

This thesis is organized into five chapters.

Chapter 1 gives an introduction on the purposes of the project including its aim and objectives.

Chapter 2 reviewed of the circuit breaker problems including its effect to electrical power system and sensitive equipments. Several effects and techniques that need to be considered in developing and designing the circuit breaker are also being elaborate and discuss here.

Chapter 3 deals with the circuit breaker design. Different components such as power switching and control switching which related design are also being discussed and selected in order to construct the circuit accordingly.

Chapter 4 presents the results of the measurement and testing profile and some discussions.

Chapter 5 presents the conclusions of the results and suggestions for the future development of the Semiconductor Circuit Breaker.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Earth Leakage Circuit Breaker (ELCB) is mainly prevented electric fire and personal casualty accident caused by personal electric shock or leakage of electrified wire netting. Residual Current Circuit Breakers (RCCB) is similar to ELCB. In mains wiring ELCB is used for the protection, against electrical leakage in the circuit of 50 Hz or 60 Hz. When somebody gets an electric shock or the residual current of the circuit exceeds the fixed value, the ELCB/RCCB can cut off the power. Residual Circuit Breaker's (RCD) are rated by the current differential required to trip them. RCD trips if the difference between line and neutral current exceeds a preset value of 30 mA is common, but 5 mA, 10 mA, 100 mA, 300 mA and 3 A types are available. Trip times are usually specified as less than 30 ms, but delay types (to provide sub circuit discrimination) are available. RCDs are implemented usually in such a way that phase (live) and neutral wires passed through a sensor coil. If currents is equal there is no net magnetic field in the coil. There should be 0 A differential between live and neutral if there is no leakage to ground. If live and neutral currents is unequal due to leaking to earth, a voltage is induced in the coil and activates the circuit breaker. Simplest RCDs have just a toroidal transformer, the L and N fed through the middle, with the secondary feeding a trip solenoid that trip the switching element. Most of the electronics RCD are very sensitive to pulsating DC faults caused by electronics equipment.

RCD is classified into few classes: AC, A, B and S. Class AC devices is designed for pure sinusoidal residual currents. Class A device is mainly when the residual current consists of pulsating DC components. Class B is applicable when the residual current is with DC or impulse DC. Class S RCD has a built in time delay. The RCD with 30 mA rating is typical for a single phase 240 V circuit. The RCD with 30 mA residual current sensitivity are generally used for property and person protection. RCDs with a residual sensitivity of 100 mA to 300 mA are recommended for property and equipment protection (particularly where numerous items of equipment are supplied through the protected circuits). RCDs cannot protect people from serious shock which could occur if they contact both live and neutral conductors at the same time (RCDs protect only against live to earth faults). RCDs cannot substitute for care, common sense and regular maintenance. RCDs are no substitute for fuses or circuit breakers (for complete protection both a combination of RCDs and other protection devices are needed) [2]. RCDs are designed to protect both equipment and users from fault currents between the live and earth conductors. They should be used in conjunction with one of the above methods of protection.

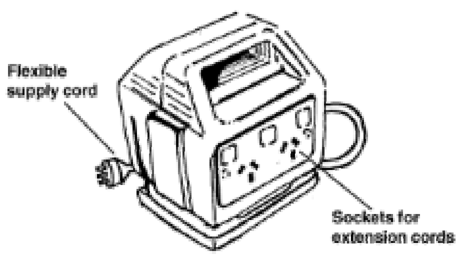
2.2 Types of RCD

There are four types of RCDs;

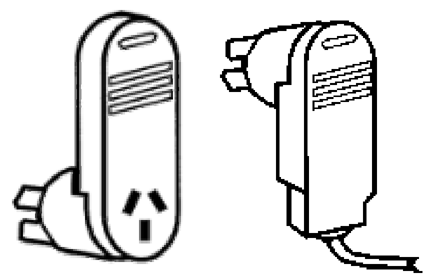
(i) Switchboard mounted power point and plug in (portable).

Switchboard mounted and power point types are referred to as non portable RCDs. Portable RCDs are plugged into a fixed socket. A non-portable RCD installed at the switchboard is the best option in most situations as it protects all the wiring and appliances plugged into the circuit, however, the regulation provides the option of providing non portable RCDs built into fixed sockets [5].

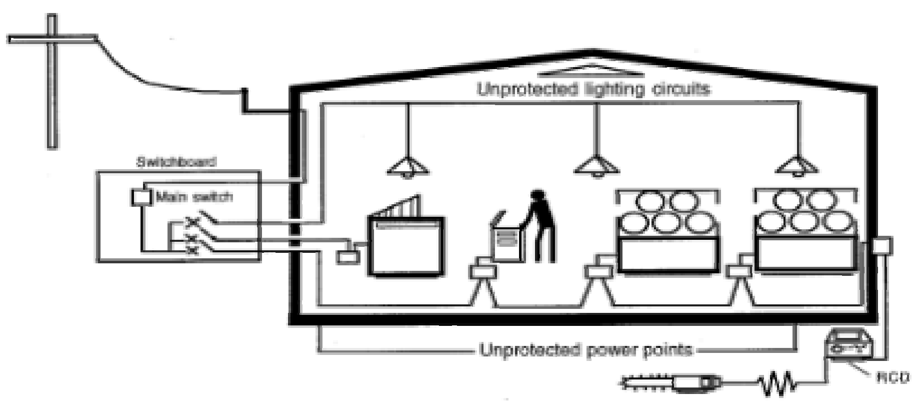
(ii) Switchboard Units - These are non-portable units installed at the switchboard to provide protection of the complete installation, or protection of a selected circuit [1].



(a) Unit suitable for use with extension cords and portable power tools.



(b) Plug adaptor wired to an extension cord



(c) Plugged into External Power Point

Figure 2.1: Portable RCD

(iii) Fixed Socket Units - These are non-portable units consisting of RCD protection inbuilt into a fixed socket outlet to provide protection to equipment plugged into the outlet [1].