



Cairo University

# **NEW APPROACH FOR ALLOCATING FAULT CURRENT LIMITERS FOR LIMITING SHORT CIRCUIT LEVEL WITH SYSTEM EXPANSION**

By

**HEBA HUSSEIN ABDEL-KHALEK MOHAMMAD**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
In  
Electrical Power and Machines Engineering

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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**Title of Thesis:**

New Approach for Allocating Fault Current Limiters for Limiting Short Circuit Level with System Expansion

**Key Words:**

Short circuit currents, fault current limiters, bus impedance matrix, bus admittance matrix, system expansion and MATLAB.

**Summary:**

System expansion includes addition or replacing one or more system elements such as transmission line, generator plant or units, substation or transformer units and distribution generation.

The objective of this thesis is to analyze and model the power system before and after system additions. The effect of the system changes on the short circuit level is the main target of the thesis. Sensitivity analysis for both system impedance matrix and resulting short circuit currents are the basic keys to appreciate the increase in the short circuit level. The increased short circuit level may increase equipment ratings and causes serious problems.

The present thesis has solved this problem by inserting a fault current limiter FCL accompanied with system upgrading to achieve a considerable saving in the investment of high capacity circuit breakers. The power system has been modeled and sensitivity analysis was utilized to allocate fault current limiter capable for compressing the increased short circuit to a safety level.

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## **Dedication**

*To my beloved father and mother for*

*Their support and encouragement*

*And*

*To my husband and my lovely daughter Noorseen*

# Table of Contents

<b>ACKNOWLEDGMENT.....</b>	<b>i</b>
<b>DEDICATION.....</b>	<b>ii</b>
<b>TABLE OF CONTENTS.....</b>	<b>iii</b>
<b>LIST OF TABLES.....</b>	<b>vi</b>
<b>LIST OF FIGURES.....</b>	<b>vii</b>
<b>NOMENCLATURE.....</b>	<b>ix</b>
<b>ABSTRACT.....</b>	<b>x</b>
<b>CHAPTER 1: INTRODUCTION.....</b>	<b>1</b>
1.1. Introductory Remarks .....	1
1.2. Thesis Objectives.....	1
1.3. Thesis Contribution Outcomes.....	2
1.4. Thesis Organization.....	3
<b>CHAPTER 2: LITERATURE REVIEW ON FAULT CURRENT LIMITERS.....</b>	<b>4</b>
2.1. Introduction.....	4
2.2. What are Fault Current Limiters and Why These are Used in Power Systems?.....	4
2.3. The Role of Fault Current Limiters.....	5
2.4. Types of FCL.....	6
2.5. Reasons and Hazards Due to High Short Circuit Currents.....	6
2.6. Present Status of Dynamic FCL.....	7
2.7. DFCL Effects Considering Different System Configurations.....	7
2.7.1. Case 1: Single transformer.....	7
2.7.2. Case 2: Four transformers.....	8
2.7.3. Case 3: Dynamic FCL on 138 KV bus tie.....	9
2.7.4. Case 4: Distributed generation.....	9
2.7.5. Reduction in Fault contribution from Large motors.....	10
2.8. Applications of Fault Current Limiters.....	10
2.8.1. Fault Current Limiter FCL and High-Temperature Superconductor Fault Current Limiter HTS-FCL Classification.....	11
2.8.2. Insertion of Distributed Generation (DG) in Distribution Systems and Effect on Short Circuit Levels .....	11
2.8.3. Effect of Fault Current Limiter on Problems Arises Due to Inserting Distributed Generation (DG) in Distribution Systems.....	12
2.8.4. Effect of Fault Current Limiter on Distributed Generation Coordinated Relay Protection.....	13

2.8.5. Fault Current Limiting Devices in Distribution Network Extends Lifetime of Power Transformers.....	13
2.8.6. Optimum Fault Current Limiter Placement.....	14
2.8.7. Fault Current Limiter (FCL) for Voltage Sag Mitigation.....	14
2.9. Solutions for Fault Current Level Reduction in Networks with Distributed Generation.....	15
2.9.1. Increase the Breaking/Thermal Capacity of Equipment .....	15
2.9.2. Reduction of the Prospective Short-Circuit Current of the Grid.....	15
2.10. Active Limitation of Short-Circuit Current Levels.....	16
2.11. Limitation Level of Fault Current .....	18
2.12. Effect of Fault Current Limiter Installed in Customer System.....	19
2.12.1. FCL Categorization.....	19
2.12.2. Distribution System Calculation Model.....	19
<b>CHAPTER 3: APPLICATION AND PERFORMANCE OF FAULT CURRENT LIMITERS.....</b>	<b>22</b>
3.1. Definition of Fault Current Limiter .....	22
3.2. The Role of FCL .....	22
3.3. Traditional Ways for Limiting Fault Current currents.....	23
3.4. Method and operation of fault current limiters.....	25
3.4.1 Passive limiters.....	25
3.4.1.1. Types of super conducting fault current limiter (SFCL).....	26
3.4.1.1.1. Superconductive shunt with a resistive bypass element.....	26
3.4.1.1.2. Superconducting shunt with an inductive bypass element.....	27
3.4.1.1.3. Transformer coupled superconducting shunt.....	27
3.4.2. Solid-State limiters.....	28
3.4.3. Hybrid limiters.....	29
3.5 Application of Fault Current Limiters.....	29
3.5.1 Installation of Fault Current Limiters.....	29
3.5.2. System-Device Interactions.....	32
3.4.2.1. Effects of a Fault Current Limiter on System Performance.....	32
3.5.2.1.1 Effects on Protection Schemes.....	32
3.5.2.1.2 Effects on Independent Power Producer Installations.....	32
3.5.2.1.3 Effects on Conventional Switchgear.....	33
3.5.2.1.4 Effects on System Reliability.....	33
3.5.2.2 Effects of the System on a Fault Current Limiter.....	33
3.5.2.2.1 Undesirable Tripping of Fault Current Limiter.....	33
3.5.2.2.2. Ability of Fault Current Limiter to Withstand Short-Circuit Currents.....	33
<b>CHAPTER 4: NETWORK ADMITTANCE AND IMPEDANCE MATRICES .....</b>	<b>35</b>
4.1. Overview.....	34
4.2. Formation of Bus Admittance Matrix.....	34
4.2.1. Node Elimination by Matrix Partitioning.....	38



4.2.2. Kron Reduction Method for Node Elimination .....	38
4.2.3. If Line Charging Capacitors are Included in the System .....	39
4.3. Modification of Bus Impedance Matrix.....	40
4.3.1. Adding a New Bus to the Reference Bus.....	41
4.3.2. Adding a New Bus to an Existing Bus Through an Impedance.....	41
4.3.3. Adding an Impedance from an Existing Bus to the Reference Bus.....	42
4.3.4. Adding an Impedance Between Two Existing Buses.....	42
4.4. Direct Determination of $Z_{bus}$ Matrix .....	43
4.5. Thevenin Impedance And $Z_{bus}$ Matrix.....	46
<b>CHAPTER 5: GENERALIZED APPROACH FOR UPGRADING AND ASSESSMENT</b>	
<b>POWER SYSTEM MODELS.....</b>	<b>50</b>
5.1. Introduction.....	50
5.2. Generalized Approach for Updating System Impedance Matrix.....	50
5.2.1 Case Study: $Z_{bus}$ for the Original System.....	50
5.2.2 Estimating $Z_{bus}$ for the Upgraded System After Adding a New Transmission Line.....	52
5.2.3. Sensitivity Analysis for Bus Impedance Matrix.....	54
5.2.3.1 Calculation of Sensitivity Factors for the Bus Impedance Matrix in Case of Adding Transmission Line.....	54
5.2.4. Estimating $Z_{bus}$ for the Upgraded System When Adding a New Generator.....	56
5.2.4.1. Calculation of Sensitivity Factors for the Bus Impedance Matrix in Case of Adding Generator.....	58
5.3. Building a Relevant Computer Software for Solving the Problem.....	59
5.4. Application of the Developed MATLAB Program for Solving the Problem.....	59
5.4.1. Case A: Adding a Transmission Line.....	60
5.4.2 Case B: Adding a Generator.....	60
5.5. Application to the IEEE 14 Bus System.....	61
5.5.1. Case A: Adding a Transmission Line.....	61
5.5.2. Case B: Adding a Generator.....	66
<b>CHAPTER 6: DETERMINATION OF FAULT CURRENT LIMITER TO SUPPRESS</b>	
<b>SHORT CIRCUIT CURRENT.....</b>	<b>70</b>
6.1. Introduction.....	70
6.2. Fault Current Limiter Required to Suppress Short Circuit Current.....	70
6.2.1. Case 1: Fault Current Limiter Required to Suppress Short Circuit Current When Adding T.L.....	70
6.2.2. Case 2: Fault Current Limiter Required to Suppress Short Circuit Current When Adding a Generator.....	72
<b>CHAPTER 7: DISCUSSION AND CONCLUSION.....</b>	<b>74</b>
<b>REFERENCES.....</b>	<b>75</b>
<b>APPENDIX-A: Computer Software Using MATLAB to Calculate the System</b>	
<b>Impedance Matrix <math>Z_{bus}</math>, Sensitivity Factors of <math>Z_{bus}</math></b>	
<b>and Sensitivity Factors of <math>I_{sc}</math> .....</b>	<b>77</b>
<b>APPENDIX-B: The IEEE 14 Bus System.....</b>	<b>85</b>

## List of Tables

Table 3.1.: Past methods considered to decrease short circuit currents and their drawbacks .....	24
Table 5.1.: Ranking diagonal elements of $Z_{bus,new}$ according to the effect of adding a T. L. between bus 5 and bus.....	65
Table 5.2.: Ranking diagonal elements of $Z_{bus,new}$ according to the effect of adding generator at bus 14.....	69
Table 6.1.: Values of $Z_{FCL}$ for different reduction ratios in short circuit current when a T.L is added between buses 5 and 9.....	71
Table 6.2.: Values of $Z_{FCL}$ for different reduction ratios in short circuit current when a generator T.L is added between buses 5 and 9.....	72
Table B-1: The IEEE 14 Bus System Line Data.....	86
Tables B-2 and B-3: Generators Data.....	87

# List of Figures

Figure 2.1.: Example of a Simple Power Network.....	5
Figure 2.2.: Single Transformer Configuration of case 1 .....	8
Figure 2.3.: Four Transformers Configuration of case 2.....	8
Figure 2.4.: Configuration of case 3: DFCL on 138 KV bus tie for bi-directional current limit.....	9
Figure 2.5.: Configuration of case 4: Local Generation in parallel with Utility.....	9
Figure 2.6.: Configuration of case 4: Reduction in Fault contribution from Large motors.....	10
Figure 2.7.: Model of Fault Current Limiters.....	14
Figure 2.8.: Radial Feeder Configuration of electric power systems .....	17
Figure 2.9.: Matrix Structure with Unchangeable Relay Scheme.....	18
Figure 2.10.: Calculation model for a distribution system .....	20
Figure 2.11.: The variations in the values of R (resistance) and L (inductance) with time measured from the instant of short circuit occurrence .....	20
Figure 2.12.: The limiting ratio or the %age decrease in fault current from its original value for different values of $R_{FCL}$ and $X_{FCL}$ .....	21
Figure 3.1.: Simple circuits to clarify the effect of the FCL in suppressing the short circuit current .....	22
Figure 3.2.: Inductor/capacitor tuning fault current limiter .....	23
Figure 3.3.: Silver-sand fuses in the circuit for fault current limiting .....	24
Figure 3.4.: simple circuit representations at which the inductor is used to limit fault current .....	25
Figure 3.5.: Application of SFCL to limit the fault current (resistive shunt type).....	26
Figure 3.6.: Application of SFCL to limit the fault current (inductive shunt type).....	27
Figure 3.7.: Coupled Transformer in shunt with superconducting material.....	27
Figure 3.8.: Resonant type solid state limiter.....	28
Figure 3.9.: Triggered vacuum switch based hybrid limiter.....	29
Figure 3.10.: Installation of a fault current limiter in a bus tie/coupling.....	30
Figure 3.11.: Installation of fault current limiters in incoming feeders.....	31
Figure 3.12.: Installation of fault current limiters in outgoing feeders.....	31
Figure 3.13.: Preferred locations for installing fault current Limiters.....	32
Figure 4.1.: Voltage source with a source impedance and its Norton equivalent .....	35
Figure 4.2.: Single-line diagram of a simple power network.....	35
Figure 4.3.: Impedance diagram of the power network of Figure 4.2.....	36
Figure 4.4.: Admittance diagram concluded from of the impedance diagram .....	36
Figure 4.5.: Considering charging capacitors in the admittance diagram of the power system Fig. 4.2.....	40
Figure 4.6.: A new bus is added to the reference bus.....	41
Figure 4.7.: Adding A new bus to an existing bus through an impedance .....	41
Figure 4.8.: Impedance $Z_b$ is inserted between two existing buses .....	42
Figure 4.9.: Network of step-2.....	44
Figure 4.10.: Network of step-3.....	44
Figure 4.11.: Network of step-4.....	45
Figure 4.12.: Network of step-5.....	45
Figure 4.13.: Network of step-6.....	46

Figure 4.14.: Two-bus power system.....	46
Figure 4.15.: Thevenin equivalent between buses k and j.....	59
Figure 5.1.: The one-line diagram of the original power system.....	51
Figure 5.2.: The admittance diagram of figure 5.1.....	51
Figure 5.3: The admittance diagram of the upgraded system by adding a transmission line.....	52
Figure 5.4.: System upgrade model when adding a transmission line Between buses 3 and 4.....	53
Figure 5.5.: The admittance diagram of the upgraded system by adding a generator...	56
Figure 5.6.: System upgrade model when adding a generator at bus k.....	57
Figure 5.7.: The IEEE 14 Bus Test System in case of adding a transmission line between bus 5 and bus 9.....	62
Figure 5.8.: The IEEE 14 Bus Test System in case of adding a generator at bus 14....	66
Figure B-1.: The IEEE 14 Bus System.....	85

# Nomenclature

$V_s$ : Supply voltage  
 $Z_s$ : Supply load  
FCL: Fault current limiter  
 $F_{max}$ : Excessive electromagnetic stresses  
VD: Voltage drop  
E: Arc energy  
HTS-FCL High-Temperature Superconductor Fault Current Limiter  
IPP: Interconnection panel point  
GPI: global performance index  
 $Z_{source}$ : Source impedance  
DFCL: Dynamic Fault current limiter  
DG: Distribution generation  
TCFCLR: Thyristor Controlled Fault Current Limiting Reactor  
CB: Circuit breaker  
 $Z_T$ : The transformer short circuit impedance  
 $X_{FCL}$ : Impedance of fault current limiter  
 $S_{FCL}$ : Power rating of FCL  
 $Z_{fault}$ : Fault impedance  
SFCL: Superconductor current limiter  
GTO: gate turn off  
TVS: Triggered Vacuum Switch  
 $Y_{bus}$ : Bus admittance matrix  
 $Z_{bus}$ : The bus impedance matrix  
 $Y_{chij}$ : Shunt admittance between the line i and j  
 $Z_{orig}$ : The bus impedance matrix of the original system  
 $Z_{new}$ : The bus impedance matrix of the upgraded system

# Abstract

Considerable increase of electrical power consumption requires power system expansion. Subsequent reinforcement for the system and the interconnection of more distributed generations is a must to accommodate with the increased demand. As a result, short-circuit currents flowing in the network will increase and in some cases may exceed the ratings of existing circuit breakers (CB) and may damage system equipment. Besides, the short circuit currents may generate higher mechanical forces that can overcome the safety of the power system elements.

The present thesis has an important role in the field of power system expansion planning and operation. The power system has been modeled and analyzed for operation and expansion planning. The effect of the system changes on the short circuit level is calculated and appreciated through sensitivity analysis. The proper solution to compress the increased short circuit level accompanied to system expansion is introduced through suitable allocation of the fault current limiter in the system.

The present thesis has solved this problem by inserting a fault current limiter FCL accompanied with system upgrading to achieve a considerable saving in the investment of high capacity circuit breakers. The site of the FCL is determined from sensitivity analysis for both system impedance matrix and resulting short circuit currents. While the size of the FCL is determined from the required compression of short circuit level assigned by the designer engineer.

Computer software is built utilizing MATLAB simulation to model and appreciate system operation. The introduced approach was applied for the IEEE 14 bus system and encouraging results have been obtained.

# **Chapter 1 : Introduction**

## **1.1 Introductory Remarks:**

Considerable increase of electrical power consumption requires power system expansion. Subsequent reinforcement for the system and the interconnection of more distributed generations is a must to accommodate increased demand. As a result, short-circuit currents flowing in the network will increase and in some cases may exceed the ratings of existing circuit breakers (CB) and may damage system equipment. Besides, the short circuit currents may generate higher mechanical forces that can overcome the safety of the power system elements.

The previous mentioned dangers, thrusts the problem for finding some suitable means to limit short circuit currents. It was found that, the increased short circuit currents can be suppressed, effectively, by inserting fault current limiters in the power system. Then, the circuit breakers installed in the system which having lower breaking capacities can be utilized without replacement which is cost minimization.

Handling this problem, primary, requires modeling the power system before and after inserting system expansion, through the bus impedance matrices. Besides, sensitivity analysis is carried out to appreciate the effect of the resulting changes in the system impedance matrix elements - after system expansion - through calculating and ranking their sensitivity factors. This represents the main and necessary step towards assigning the fault current limiter allocation. The value of the proposed fault current limiter is determined considering the required suppression in the short circuit current. While its location is selected to moderate the effect of the added component on the short circuit level utilizing sensitivity analysis.

It is thought that the present thesis plays an active role in system operation and security. Besides, the utilization of the proposed approach enables electric power sector decision makers to best utilize the system components and achieving an economic impact through controlling short circuit level that severely affect life time of the most system components. The beauty and easiness of the introduced method is to deduce directly the more affected locations from the upgraded impedance matrix and its sensitivity analysis. Neither complex mathematical treating nor trial and error estimation are required.

## **1.2 Thesis Objective**

The present thesis has an important role in the field of power system expansion planning and operation. Consequent expansion of the system is a must due to the sequential increase in system demand and changes superimposed on system topology and configuration. System expansion includes addition or replacing one or more system elements such as transmission line, generator plant or units, substation or transformer units and distribution generation. The objective of this thesis is to analyze and model the power system before and after system additions. Traditional and introduced