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
GIZA,EGYPT
2016

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

Under the Supervision of

Prof. Dr. Hussain Magdy Zein El-Din

Professor of Electrical Power and Machines
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

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

Approved by the Examining Committee

_____

Prof. Dr. Hussain Magdy Zein El-Din Thesis Main Advisor

_____

Prof. Dr. Ahdab Mohammad Kamel Al-Morshedy, Internal Examiner

_____

Prof. Dr. Ebtisam Mostafa Mohammad Saied, External Examiner

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

Engineer's Name:	Heba Hussein Abdel-Khalek Mohammad
Date of Birth:	11/11/1987
Nationality:	Egyptian
E-mail:	hebahussein624@yahoo.com
Phone:	01092455594 - 0482598412
Address:	Arab El-Raml, Quesna, El-Menoufia Governorate
Registration Date:	01/10/2010
Awarding Date:	
Degree:	MASTER OF SCIENCE
Department:	ELECTRICAL POWER AND MACHINES
Supervisors:	Prof. Dr. Hussain Magdy Zein El-Din

Examiners:

Prof. Dr. Hussain Magdy Zein El-Din (Thesis main advisor)

Prof. Dr. Ahdab Mohammad Kamel Al-Morshedy (Internal examiner)

Prof. Dr. Ebtisam Mostafa Mohammad Saied (External examiner)

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.

Acknowledgments

First and foremost, I would like to thank Allah, the Almighty, for nothing is possible without His will. (My success is not but through Allah. Upon him I have relied, and to Him I return). [Quran 11:88]

I am grateful to the invaluable assistance and guidance of my advisor Prof. Dr. Hussain Magdy Zein El-Din his professionalism and vast technical knowledge has always been a source of encouragement for me. You have been an outstanding and a caring advisor.

Dedication

To my beloved father and mother for

Their support and encouragement

And

To my husband and my lovely daughter Noorseen

Table of Contents

List of Tables

List of Figures

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