



Ain Shams University
Faculty of Engineering
Electrical Power and Machines Department

Directional Overcurrent Relays Protection Schemes in Microgrids

A thesis submitted to the Faculty of Engineering, Ain Shams University in
partial fulfillment of the requirements for the Degree of Doctor of
Philosophy in Electrical and Machines Engineering

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STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirement for the Ph.D. degree in Electrical Engineering. The included work in this thesis has been carried out by the author at the Electrical Power and Machine department, Ain-Shams University. No part of this thesis has been submitted for a degree or a qualification at other universities or institutes.

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Thanks to ALLAH who gives us the power and hope to succeed.

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ABSTRACT

The high reliable operation of an electrical system network depends on the proper coordination of its protective relays that protect this system. The improper outage of any part in the protected electrical systems will affect its reliable operation. Definitely, each portion in the protected zones has primary protection and backup protection for providing a high level of security.

Protection devices should be coordinated such that: primary protection will provide the first defense to clear the faulty section, and if it fails the backup protection should operate after a predefined coordination time interval to isolate the defective part without influencing the rest of the system.

Designing directional overcurrent relays (DOCRs) protection schemes mandatory needs the important following data: Three-phase short circuit currents from the short circuit analysis, load flow analysis, relay pairs identification, and the current transformer ratio (CTR). In this thesis work, the load flow and short circuit analysis are obtained using ETAP software, the relay pairs are identified using a LINKNET algorithm.

This thesis presents a solution to the problem of coordinating the (DOCRs) in Microgrids. The significant implementation of Microgrids challenged the protection engineers especially in designing protection microgrid schemes. This challenge comes from the bi-directional fault current variation and the dynamic behavior of these grids.

A proper solution is presented for solving the coordination problem of directional overcurrent relays (DOCRs) in microgrids based on two different methods. The first method is based on the meta-heuristic techniques, such as Genetic Algorithm (GA), Moth-flame optimizer (MFO), and the Coyote Optimization Algorithm (COA), with a new objective function to solve the problem of local minima because the coordination problem has an excessive number of unknowns' variables. The second method is an analytical iterative method that is presented for the first time and it is a promising solution for the coordination problem.

The proposed methods had been validated on the IEEE 8-bus System and 15-bus system Microgrid.

Abstract

The proposed Microgrid is assumed to be operated in grid-connected mode and implemented with synchronous distributed generators that will cause high-level fault current during the fault occurrence.

MATLAB 2018b environment is used to simulate the proposed methods and algorithms to obtain the optimal settings for the coordinated (DOCRs) in Microgrids.

Keywords: Directional overcurrent relays coordination, Microgrids, protection schemes, Artificial intelligent, analytical techniques.

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List of Symbols

CT_i	Current Transformer Of i^{th} Relay
CTI	Coordination Time Interval
$dt_{pen}(i)$	CTI Penalty For i^{th} Relay
dt	Coordination Time Interval Symbol in MATLAB M-File
$if_{3ph}(i)$	Three Phase Fault Current Of i^{th} Relay
$I_{f,min,i}$	Minimum Fault Current Of i^{th} Relay
$I_{pi,min}$	Minimum Pick-Up Current Of i^{th} Relay
$I_{pi,max}$	Maximum Pick-Up Current Of i^{th} Relay
$I_{rated,i}$	Nominal Current Flow In i^{th} Relay
K, α, L	Overcurrent Relay Characteristic Equation Parameter
n_{pairs}	Number of Relay Pairs
OLF	Overload Factor
PS	Plug Setting
$PS_{i,min}$	Minimum Plug Setting Of i^{th} Relay
$PS_{i,max}$	Maximum Plug Setting Of i^{th} Relay
pen_{TMS}	Summation Of TMS Penalties for All Relays
pen_{dt}	Summation of CTI Penalties for All Relays
$T_{op}(i)$	Operating Time of The Of i^{th} Primary Relay
T_p	Primary Relay Operating Time
T_b	Backup Relay Operating Time
TMS	Time Multiplier Setting
$TMS_{i,min}$	Minimum Time Multiplier Setting Of i^{th} Relay
$TMS_{i,max}$	Maximum Time Multiplier Setting Of i^{th} Relay
TMS_{pen}	TMS Penalty For i^{th} Reay
λ	Normalizing Factor