# USING GA TO IMPROVE COORDINATION OF OVERCURRENT RELAYS FOR DISTRIBUTION NETWORK WITH HIGH DG PENETRATION

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# USING GA TO IMPROVE COORDINATION OF OVERCURRENT RELAYS FOR DISTRIBUTION NETWORK WITH HIGH DG PENETRATION

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A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical Power)

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2022

# DEDICATION

This thesis is specially dedicated to ‘‘my beloved mother, father, wife, my son, lecturers, and friends….”

# ACKNOWLEDGEMENT

I want to express my gratitude and appreciation to all those who gave me the possibility to complete this report. A special thanks to my supervisor, IR. DR. Syed Norazizul bin Syed Nasir, who always gave advice and for this patience, motivation and immense knowledge to walk me through the completion of the final project. Deepest thanks and appreciation to my family, friends, and others for their cooperation, encouragement, constructive opinion and full support. Last but not least thanks to all of my friends and everyone, those have been contributed by supporting my work and help myself during the final year project progress.

# ABSTRACT

In recent years, with the increasing penetration of distributed generators (DGs) with large-share capabilities, the efficient coordination of primary and backup overcurrent relay (OCR) schemes has emerged as one of the most challenging tasks in contemporary MV-distribution networks (DN). The main goal is to design a protection scheme to protect the power system where different intermittent sources significantly impact. The performance of the existing protection scheme needs to be analysed to develop a robust power system. In this project, an IEEE 33 bus system is considered for short circuit analysis and protection coordination, relying upon coordination for designing of overcurrent protection scheme to operate the relay efficiently and disconnect the fault section from the healthy network instantly. It also compares the differences between conventional systems and DG-connected radial systems. Moreover, the project examined the coordination scheme based on the Optimization Algorithm. The optimum coordination increases the sensitivity and reliability of the protection system by reducing the operating time of OCRs by using a standard tripping characteristic. Improved optimisation strategies have benefited from a new constraint that considers the maximum Plug Setting Multiplier (PSM) and improves the complementing OCR tripping properties by using optimisation approaches to improve coordination time intervals. The Time Multiplying Setting (TMS) for OCR coordination is optimised using the Genetic Algorithm (GA) in MATLAB coding tools. The ETAP has used the network to test the effectiveness of the proposed new constraint to improve the constrained optimisation technique in grid-connected modes.

# ABSTRAK

Dalam beberapa tahun kebelakangan ini, dengan peningkatan penembusan penjana teragih (DG) dengan keupayaan bahagian besar, penyelarasan yang cekap bagi skim geganti arus lebih (OCR) primer dan sandaran telah muncul sebagai salah satu tugas yang paling mencabar dalam rangkaian pengedaran MV (DN) kontemporari. ). Matlamat utama adalah untuk mereka bentuk skim perlindungan untuk melindungi sistem kuasa di mana sumber terputus-putus berbeza memberi impak yang ketara. Prestasi skim perlindungan sedia ada perlu dianalisis untuk membangunkan sistem kuasa yang teguh. Dalam projek ini, sistem bas IEEE 33 dipertimbangkan untuk analisis litar pintas dan penyelarasan perlindungan, bergantung pada penyelarasan untuk mereka bentuk skim perlindungan arus lebih untuk mengendalikan geganti dengan cekap dan memutuskan sambungan bahagian kerosakan daripada rangkaian yang sihat serta-merta. Ia juga membandingkan perbezaan antara sistem konvensional dan sistem jejari bersambung DG. Selain itu, projek itu mengkaji skim penyelarasan berdasarkan Algoritma Pengoptimuman. Penyelarasan optimum meningkatkan sensitiviti dan kebolehpercayaan sistem perlindungan dengan mengurangkan masa operasi OCR dengan menggunakan ciri tersandung standard. Strategi pengoptimuman yang dipertingkatkan telah mendapat manfaat daripada kekangan baharu yang mempertimbangkan Pengganda Tetapan Palam (PSM) maksimum dan menambah baik sifat tripping OCR yang melengkapi dengan menggunakan pendekatan pengoptimuman untuk meningkatkan selang masa penyelarasan. Tetapan Penggandaan Masa (TMS) untuk penyelarasan OCR dioptimumkan menggunakan Algoritma Genetik (GA) dalam alat pengekodan MATLAB. ETAP telah menggunakan rangkaian untuk menguji keberkesanan kekangan baharu yang dicadangkan untuk menambah baik teknik pengoptimuman terhad dalam mod bersambung grid.

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# LIST OF ABBREVIATIONS

RES - Renewable Energy Sources
PV - Photovoltaic
DG - Distributed Generator
DN - Distribution Networks
CTI - Coordination Time Interval
WTG - Wind Turbine Generator
OF - Objective Function
TMS - Time Multiplier Setting
TDS - Time Dial Settings
GA - Genetic Algorithm
CA - Conventional Approach
PSO - Particle Swarm Optimization
ITC - Inverse Time Current
CTR - Current Transformer Ratio
RSI - Relay Setting Current in amperes
PS - Plug Setting
PSM - Plug Setting Multiplier
ROT - Relay Operating Time in seconds
TCC - Time Current Characteristic
$I_P$ - Pickup Current
N-SC - Non-Standard Characteristics
IEEE - Institute of Electrical and Electronics
IEC - International Electrotechnical Commission

# LIST OF SYMBOLS

A - Constant Relay Characteristics
B - Constant Relay Characteristics
C - Constant Relay Characteristics
$q$ - Binary Digits

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Problem Background

With the increases in the cost of fossil fuels and growing environmental concerns, significant efforts have been made to develop high-quality alternative energy technologies to solve the energy crisis for power system. Recent improvements and innovations in power electronic technology have allowed renewable energy sources (RES) to be grid-connected, with a significantly increased penetration in the network electricity supply. As a result, both academics and businesses have paid high attention to the usage of renewable energy resources across the world [1].

Renewable energy sources-based distributed generators DG are becoming more prevalent, posing a severe threat to the operation of the power system. Protection and coordination consider one of the common problems of distribution networks with DG penetration [2]. Fuses, recloser, and overcurrent protection provide a trip signal that separates the faulty part from the healthy part of the system. When the overcurrent relay OCR surpasses a specific value, the relay activates with negative consequences for relays and protection systems such as false tripping and coordination loss between primary and backup relays. The number of protection required is determined by the position and the amount of Photovoltaic PV penetration [3]. Protection mechanisms should function adequately in both utility grid linked and island modes of operation. DG power production varies from zero to maximum output with standard solar irradiation. As a result, these operating conditions cause changing fault current levels and reduce voltage and current protection performance.

Traditional power systems are designed to have a distribution system with electricity flowing in one direction, from the transmission network through the distribution grid and eventually to the customers [4]. Now a day, the main challenges stem from distributed generator (DG) production output's heavy reliance on variable weather conditions that shift rapidly. These include reversed power flow, voltage increase, network stability, and protection. In terms of the system protection, the integration of DG might result in the redistribution of fault currents in feeder circuits. During faults, redistribution may result in a greater current magnitude on the feeder, which in some cases exceeds the rating of fuses, breakers, and so on. Changes in fault current and direction may also result in a loss of protection coordination between protection devices [5].

## 1.2 Problem Statement

The overcurrent relays observe the current flow from the source to the load. They are coordinated so that the downstream relays have to discover the fault first and disconnect a feasible minor section of a line upon fault clearance. The relays' coordination is maintained by employing time grading. Nowadays, the majority of distribution networks (DN) utilize DG as a backup generator to support the main generator, particularly when the load in that region is high. Because of the availability of DG in the distribution network, the power system operation in that region must be changed. Many studies do not pay close attention to the limitations of standard inverse time-current characteristics in the commercial OCR installed in the DN, which have a significant impact on the coordination time and the total operating time interval of the network [6]. Numerical relays integrated in modern DN protection systems are not compatible with optimization approaches, causing nuisance tripping and non-selectivity in the grid protection schemes. However, the technological challenges imposed by the significant penetration of distributed generators into modern distribution networks generate a new difficulty that does not consider the boundaries of standard inverse time-current characteristics in the industrial OCRs linked to the distributed network. Additionally, it directly influences the overall amount of operating time and the time interval required for coordination (CTI). Furthermore, the incompatibility of conventional techniques with the tripping characteristics incorporated in numerical relays will lead to nuisance tripping and non-selectivity in the operation of distributed network protection systems.

## 1.3 Objectives of the Study

The purpose of this project is to explore the effects of the DG on the protection system of medium voltage distribution networks (e.g., relay operation, setting, and coordination) and to provide solutions to the difficulties. The following are the main objectives of the project:

(a) To investigate severity of DG affects overcurrent protection coordination and fault current levels in a MV distribution system.

(b) To examine the power system's parameters such as current flow, voltage, and power, in order to coordinate overcurrent relays in a radial distribution system with and without DG penetration.

(c) To formulate overcurrent relay coordination in a radial distribution system with the correct settings with and without DG.

## 1.4 Scope of the Study

The project examines the effects of DG such as solar PV and wind turbine generator (WTG) on a distribution network's overcurrent protection coordination.

(a) ETAP is simulated distribution networks IEEE33 bus to determine the performance of the overcurrent protection system.

(b) Simulations and investigations are conducted without using of DG. Following that, the DG model is connected to the system. The performance of the overcurrent protection is checked once more by using ETAP simulation software.

(c) The project examines the influence of distribution generator such as PV and wind generator on the protective system's performance.

(d) The computation optimization techniques (Genetic Algorithm) are implemented to mitigate the relay operation time.

(e) The radial distribution system has been selected, with balancing fault type being tested across the system, followed by a simulation to determine the proper coordination for overcurrent relays in the system.

(f) The investigation is limited to a 12.6 kV medium-voltage network.

## 1.5 Research Significant

The main significance of this project is to propose accurate settings for OC relays in order to solve coordination problems regarding any change in grid topology and to minimize the negative effect of the DG penetration power system on the protection relay coordination. This research is also contributed to check a new way to set the OC protection relays.

## 1.6 Project Outline

This project is prepared in five chapters as follows: Chapter 1 describes the background and problem statement, objectives, scopes, and significances of the study. Chapter 2 discusses and reviews some related works of previous studies. Chapter 3 describes the methodology used to achieve the project's main objectives. Mathematical formulation analysis and genetic algorithm are used. Chapter 4 presents the final results based on the implementation of the proposed coordination method. All implementation cases are proposed to analyze the capability of the proposed method to achieve the research objectives. Chapter 5 presents the project conclusion.

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