OVERCURRENT RELAY SETTING BY USING ADAPTIVE TECHNIQUE

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To my beloved family and specially my dears father, mother and sister

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ABSTRACT

As cost-effective protection relays, Overcurrent (OC) relays are used as the main protection equipment in distribution grids and backup protection for distance relays in transmission and sub-transmission lines. Basically, two parameters are considered as OC relays settings: pickup currents ($I_{pick\ up}$) and Time Setting Multiplier (TSM). Hence, the objective in the coordination problem of OC relays is to determine $I_{pick\ up}$ and TSM of each relay. These methods can be classified into two different approaches: Off-line and On-line coordination approaches. By analyzing all faults, abnormal operating conditions, and system contingencies as well-known as Off-line coordination techniques, several methods have been developed to solve coordination problem of OC relays. However, the response of relays would not be satisfactory in a condition which has not been included the analysis earlier. Meaning that, required short circuit currents due to any fault that occurred in grid cannot be adjusted to the coordination problem of OC relays. Therefore, the risk of occurring mal-operation or miss-coordination becomes high. In order to achieve a robust protection scheme, the OC relays settings must be updated regarding to any change which results into new topology of the grid. In this thesis, a reliable protection scheme is achieved by implementing the proposed adaptive protection algorithm. For this purpose, the idea of employing the Thevenin equivalent circuit is utilized to check the power grid operation for any change continuously. By applying the proposed technique, the accurate settings of overcurrent relays in distribution network are determined. As a result, the proposed adaptive protection algorithm can avoid the unnecessary blackouts in distribution network and provide reliable and sensitive protection scheme.

ABSTRAK

Untuk perlindungan geganti yang efekttif, geganti arus lebihan (OC) digunakan sebagai alat perlindungan utama dalam grid agihan dan perlindungan sokongan untuk geganti jarak dalam penghantaran dan sub-talian penghantaran. Pada dasarnya, dua parameter yang dianggap sebagai tetapan geganti arus lebihan iaitu : Arus Ambilan (PS) dan Masa Tetapan Pengganda (TSM). Oleh itu, objektif dalam masalah penyelarasan daripada geganti arus lebihan ialah untuk menentukan Masa Tetapan Pengganda bagi setiap geganti. Kaedah-kaedah ini boleh diklasifikasikan pada dua pendekatan yang berbeza iaitu: Penyelarasan talian tertutup dan talian terbuka. Dengan menganalisa semua kerosakan, keadaan operasi yang tidak normal, dan sistem luar jangkaan yang dikenali sebagai teknik penyelarasan talian tertutup, beberapa kaedah telah dicapai bagi menyelesaikan masalah penyelarasan geganti arus lebihan. Walaubagaimanapun, keadaan tindak balas geganti kurang memuaskn, dimana analisa kerosakan tidak dimasukkan lebih awal. Ini bermakna arus litar pintas diperlukan kerana kerosakan yang berlaku dalam grid tidak dapat diselaraskan dengan masalah penyelarasan geganti arus lebihan (OC). Oleh itu, risiko untuk berlakunya ‘mal-operasi’ atau ‘miss-penyelarasan’ menjadi tinggi. Untuk mencapai satu skim perlindungan teguh, tetapan geganti arus lebihan mestilah dikemaskini berdasarkan sebarang perubahan kepada keputusan baru topologi grid. Dalam tesis ini, skim perlindungan yang boleh dipercayai dicapai dengan melaksanakan algoritma perlindungan penyesuaian yang telah dicadangkan. Bagi tujuan ini, idea bagi menggunakan Litar Setara Thevenin digunakan untuk menyemak operasi kuasa grid bagi apa-apa perubahan secara berterusan. Dengan menggunakan teknik yang dicadangkan, tetapan tepat geganti arus lebihan dalam rangkaian agihan ditentukan. Hasilnya, algoritma perlindungan penyesuaian yang dicadangkan boleh mengelakkan kerosakan dalam pengedaran rangkaian dan menyediakan skim perlindungan yang boleh dipercayai dan sensitif.

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LIST OF ABREVIATIONS

OC	-	Overcurrent
TSM	-	Time Setting Multiplier
PS	-	Plug Setting
LP	-	Linear Programming
MINLP	-	Mixed Integer Non-Linear Programming
SCADA	-	Supervisory Control and Data Acquisition
HV	-	High Voltage
IDMT	-	Inverse Define Minimum Time
DT	-	Define Time
NLP	-	Non-Linear Programming
IBFS	-	Initial Basic Feasible Solution
GA	-	Genetic Algorithm
POS	-	Particle Swarm Optimization
CGA	-	Continuous Genetic Algorithm
OF	-	Objective Function
NM	-	Nelder-Mean
DUT	-	Dominant Utilization Topology
ILP	-	Interval Linear Programming
DG	-	Distributed Generation
LV	-	Low Voltage
CIT	-	Coordination Time Interval

CHAPTER 1

INTRODUCTION

1.1 Overview

In the presence of increasing industrial developments and consequently growing energy consumption, importance of accessing to reliable electricity widely has been attention [1]. In addition to reliability, it is compulsory to generate sufficient amount of electric power to transmit on a continuous basis where systems efficiency depends on continuous electricity accessing [2]. To achieve this, protection system associated with the power system must be able to identify and compensate any effects or fails in the system which leads to long term blackouts [3]. Otherwise, more delays required to restore the system to its normal operating in case of blackout or damage to equipments which is costly. Furthermore, utilization of the suitable protective equipment is fundamentally important in terms of safety and minimizing damages on the electrical devices. To achieve this, protective relays such as overcurrent relays must promptly clear any fault with disconnecting as few components as possible.

As cost-effective protective relays, overcurrent relays (OC) have been employed in distribution system. Usually, these relays are the main protection devices in distribution grids and backups for distance relays in transmission and sub-transmission lines [4]. Basically, two parameters are considered as OC relays settings: pickup currents ($I_{pick-up}$) and Time Setting Multiplier (TSM). Hence, the objective in the coordination problem of OC relays is to determine $I_{pick-up}$ and TSM of each relay [5]. In order to prevent any mal-operation or miss-coordination, overcurrent relays must adjust with accurate values of pick up current and time dial setting.

1.2 Problem Background

Several methods that have been developed to solve coordination problem of OC relays can be classified into two different approaches: Off-line and On-line coordination approaches. Traditionally, conventional approaches have been applied to solve coordination problem of OC relays [10-16]. Since these approaches encountered with problems for complex and interconnected networks, optimization techniques introduced to overcome the mentioned problems [17-18]. These optimization techniques can be divided into linear and non-linear techniques. In linear techniques, pickup currents assumed to be known. Thus, the Linear Programming (LP) is employed only to minimize operating time [19-22]. Since, overcurrent relays coordination problem is a Mixed Integer Non- Linear Programming (MINLP), LP techniques have limitations in term of low number of restrictions. This leads to introduce non-linear technique or intelligence based optimization methods. Considering the nonlinearity effects and integer variables in problem formulation are the major benefits of the intelligent based optimization methods [23-24]. Genetic algorithm (GA) and Particle Swarm Optimization (PSO) have been presented as two powerful tools in order to solve this complex optimization problem [25-34].

However the optimization techniques presented reliable performance in order to solve coordination problem, these protection techniques are in relation to the concept of pre-determinism which involves analysis of all faults, abnormal operating conditions, and system contingencies. In protection scheme based on pre-determinism concept, the response of relays would not be satisfactory in a condition which has not been included the analysis earlier [4-9]. Meaning that, required short circuit currents due to any fault that occurred in grid cannot be adjusted to the coordination problem of OC relays**.** Therefore, the risk of occurring mal-operation or miss-coordination becomes high.

In order to achieve a robust protection scheme, overcurrent relays must be adjusted by new settings. For this purpose, microprocessor based relays have been employed in order to introduce adaptive protection scheme [35-37]. In this manner, a Supervisory Control and Data Acquisition (SCADA) system checked the system for any alterations continuously. As mentioned above, in protection scheme based on pre-determinism concept, the response of relays would not be satisfactory due to uncertainties. Although, the proposed centralized adaptive protection approaches have been provided good solution for this problem, the coordination process depends on the monitoring performance of SCADA system.

In this thesis, a reliable protection scheme is achieved by implementing the proposed adaptive protection algorithm. According to the proposed algorithm, new setting for the overcurrent relays can be obtained regarding to any change in topology of the grid. The method is an On-line technique and based on the Thevenin equivalent circuit of the grid that seen from each bus. This provides a monitoring capability which removes any dependency on SCADA system performance. In this thesis, proper settings of overcurrent relays that adjusted in a High Voltage (HV) substation are determined by employing proposed adaptive protection algorithm.

1.3 Objective of Study

The objectives of this study are as follow.

1. To obtain the Thevenin equivalent circuit parameters for the test system
2. To determine the required short circuit currents for accurate setting of overcurrent relays in HV substation by applying obtained Thevenin equivalent circuit parameters.
3. To propose new accurate setting of overcurrent relays in HV substation due to any changes in grid topology (add/remove equipment).

1.4 Scope of Study

To achieve the research objectives, the following scopes will be covered:

1. Thevenin equivalent circuit is derived only for one bus.
2. IEEE 14-bus system is considered as case study.
3. MATLAB and POWERWORLD software are employed in this study.
4. Only HV substation relays are considered for finding accurate setting.
5. Changes in grid topology such as add new equipments or take out of use of equipments are considered

1.5 Research Significant

The main significant in this work is to propose accurate settings for OC relays in order to solve coordination problem regarding to any change in grid topology.

1.6 Thesis Outline

This thesis is prepared in five chapters as follow.

Chapter 1: Describe on the problem background and statement, objectives, scopes and significances of the study.

Chapter 2: Reviews some related works done by previous investigators on conventional and optimization methods to solve the coordination problem of OC relays.

Chapter 3: Specifies the research process employed in this thesis.

Chapter 4: First, the Thevenin equivalent circuit impedances are obtained for test system under different operating conditions. Then, required short circuit current levels are calculated by applying different values of the Thevenin impedances regarding to each operating condition. Finally, the accurate settings of each OC relays in test radial distribution network are determined according to the different values of short circuit current levels.

Chapter 5: Presents conclusion and future work.

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