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DISTANCE PROTECTION WITH PENETRATION OF DISTRIBUTED GENERATION INFEED IN TRANSMISSION LINES

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DEDICATION

This report is dedicated to the pure and generous man who made my childhood with his two noble hands after God Almighty, to the soul of my father, may God have mercy on him, to that fragrant rose whose fragrance I can still inhale, to the owner of the giving hand, to my mother's soul, may God have mercy on her. To those who shared my childhood with me and loved me with sincerity and sincerity and cooperated with me to complete this study of mine, to my brothers and sisters, especially my dear sister Suhad Hatem Ahmed, may God bless her with health and wellness. To the one who competes with the relief in gifts and precedes modesty in the virtues, to the one who supported me and took my steps with me and eased the difficulties for me to my dear husband, and my arrival to this success would not have happened without his constant encouragement to me. To my dear children, "my dear son and my dear daughter" seeds of my life and my happiness in life.

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ABSTRACT

The grids changed from passive to active grids with Distributed Generation units (DG) allowing the power flow in either direction. The main objectives of DG units are providing a continuous power supply to the load, providing power where the main grid cannot supply electric power, increasing energy efficiency, improving voltage profile, reducing line losses, reducing the emission of pollutants, improving the system voltage stability, and improving system reliability. However, DG connections give significant influence on the protection coordination. When DGs are connected to the same network, the protection devices will be able to detect and sense the flow of fault currents in different directions. Without DG, the only source of short circuit current was the grid, and protection systems were designed accordingly. The operation of protective devices would be affected by the changes in the fault current level in the power system. The integration of DG into protective equipment could cause reverse power flow, false tripping, loss of protective devices grading, and blinding of protection. In this research, a new distance relay model built using MATLAB Simulink is proposed to compensate the effect of DG integration with the distribution grid. A simple communication-based scheme for accurately calculating the distance to fault in the presence of infeed is proposed. The proposed model is tested by different faults location, different fault arc resistance, and different penetration levels of DG. The proposed protection communication has high accuracy to trip the faults, the fault is cleared by the distance relay in case of distance relay cannot sense the fault, the overcurrent will trip the circuit and the system maintain in operation state, the proposed distance relay is not affected by the infeed in case of the fault present in zone two.

ABSTRAK

Grid berubah daripada grid pasif kepada aktif dengan unit DG membenarkan aliran kuasa ke mana-mana arah. Objektif utama unit DG adalah menyediakan bekalan kuasa berterusan kepada beban, menyediakan kuasa di mana grid utama tidak dapat membekalkan kuasa elektrik, meningkatkan kecekapan tenaga, meningkatkan profil voltan, mengurangkan kehilangan talian, mengurangkan pelepasan bahan pencemar, meningkatkan kestabilan voltan sistem , dan meningkatkan kebolehpercayaan sistem. Walau bagaimanapun, sambungan DG memberi pengaruh yang ketara ke atas penyelarasan perlindungan. Apabila DG disambungkan ke rangkaian yang sama, peranti perlindungan akan dapat mengesan dan merasakan aliran arus kerosakan dalam arah yang berbeza. Tanpa DG, satu-satunya sumber arus litar pintas ialah grid, dan sistem perlindungan direka dengan sewajarnya. Operasi peranti pelindung akan terjejas oleh perubahan dalam tahap arus kerosakan dalam sistem kuasa. Penyepaduan DG ke dalam peralatan perlindungan boleh menyebabkan aliran kuasa terbalik, tersandung palsu, kehilangan penggredan peranti pelindung dan perlindungan yang buta. Dalam penyelidikan ini, model geganti jarak baru yang dibina menggunakan MATLAB Simulink dicadangkan untuk mengimbangi kesan penyepaduan DG dengan grid pengedaran. Skim berasaskan komunikasi mudah untuk mengira jarak ke sesar dengan tepat dengan kehadiran suapan dicadangkan. Model yang dicadangkan diuji oleh lokasi kerosakan yang berbeza, rintangan arka kesalahan yang berbeza, dan tahap penembusan DG yang berbeza. Komunikasi perlindungan yang dicadangkan mempunyai ketepatan yang tinggi untuk menghalang kerosakan, kesalahan itu dibersihkan oleh geganti jarak sekiranya geganti jarak tidak dapat merasakan kesalahan, arus lebih akan mengelirukan litar dan sistem mengekalkan dalam keadaan operasi, geganti jarak yang dicadangkan tidak dipengaruhi oleh suapan sekiranya berlaku kerosakan di zon dua.

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LIST OF ABBREVIATIONS

DG	-	Distribution generation
DR	-	Distance relay
CT	-	Current transformer
V_f	-	Pre fault voltage at fault point
Z_0	-	Zero sequence impedance
Z_1	-	Positive sequence impedance
Z_2	-	Negative sequence impedance
V_0	-	Zero sequence voltage
V_1	-	Positive sequence voltage
V_2	-	Negative sequence voltage
I_0	-	Zero sequence current
I_1	-	Positive sequence current
I_2	-	Negative sequence current
Ko	-	Compensation factor
Z1	-	Zone one
Z2	-	Zone two
Z3	-	Zone three
Z_F	-	Fault impedance
I_{AS}	-	Current phase A
V_{AS}	-	Voltage phase A
V_{DR}	-	Voltages at that measure in from the distance relay
Z_{DR}	-	Impedance by the distance relay
K	-	Infeed ratio
I set	-	Setting current
TMS	-	Time Multiplier Setting
I_f	-	Fault current
Rf	-	Fault resistance

LIST OF SYMBOLS

β	-	Angle of the fault impedance

CHAPTER 1

INTRODUCTION

1.1 Overview

Although the penetration of the distribution generation (DGs) has several advantages such as increasing the reliability, security, improving the voltage profile of the power system reduce the system losses, the protection of such systems still dominates as main challenges in their operating [1]. Another benefit of using the DG in the power system is to reduce the capital investment in the high voltage transmission lines because the generators are installed close to load center, this shows the chance of faults in the high voltage transmission lines is also reduced as possible, but it increased in the distribution side.

The typical operation of a power distribution system is that it will continue to operate under a steady-state and with no faults. A fault in a system is a type of failure that can affect the flow of electricity. There are two types of faults in a power system: open circuit and short circuit. The majority of the fault studies in a power system are related to the second type, which is a short circuit. This type of circuit can be divided into two types, namely unsymmetrical and symmetrical. According to system experience, about 70% of line faults are single-phase to ground faults, while about 5% are three-phase symmetrical. [2].

Fault occurrences cause the system to depart the normal state, therefore, causing voltage, current and frequency changes until the fault separation by protecting devices. Fault current waveform and behaviour changes throughout the first few cycles. Symmetrical components are well established mathematical tools for use in the unbalanced fault current analysis [2].

DG face many challenges related to their reliability and quality of service continuity. The power distribution system is subjected to faults which causes operational failures because of the expansion of power grids, which increases the risk of faults. A protection system's goal is to decrease the impact of faults by quickly isolating the detect and isolate the faulty lines. the protection system should be secure and reliable to reduce the damage as possible. The nature of location-oriented failures in power distribution systems necessitates that protection systems be enhanced by faults [3].

Several protection devices can be used to protect the distribution systems such as overcurrent relays, Earth fault relays, etc. In some cases, when the security and reliability are taking in the considerations, the distance relay are used for improving the performance of protection system. The main function of the distance relay is to protect high voltage transmission systems during all short circuit types. Due to the various defects in the conventional distance protection, it can cause maloperation. “Infeed effect”, is one main challenge in which the impedance seen by the relay is more than the actual between the fault point and relay location in the substation. Another important issue is the coordination between the distance relay and the other relays (overcurrent, earth fault and line differential relays).

An incorrect tripping sequence could arise from a scheme failure, leading the system to fail and causing harm to customers. The fault-clearing operation may take longer than expected due to minor configuration difficulties. Because of its capacity to notice problems in a specific area, unit protection, such as pilot wire and current differential relays, is usually utilised as the primary protection. Backup protection is provided by nonunit devices such as distance and overcurrent relays, which detect time-coordinated in-zone and out-zone failures [4,5].

Miscoordination is a regular event caused by an unexplained fault, which is more prevalent when a new source is brought into the distribution system. The DG is a typical cause of system miscoordination since it offers so-called bidirectional power flow into the system. The goal of this study is to address so-called miscoordination in protection system considering the distance protection relay sensitivity breakdown due to DG insertion.

1.2 Problem Statement

The main important objective of the protection system is to detect and isolate the faults as quickly as possible to minimize the faulty area in power system with continuity of the power supplied to healthy area and reduce the impact on the stability limits. The protection system can be considered as control system to monitor the power system equipment and take the necessary action when it senses any abnormal conditions. Circuit breakers are used to open circuits to minimize current flow, while protection relays are devices used to trip the circuit breakers [6].

Protection relays need to maintain coordination order for clearing the faults; however, the insertion of DG may change the relays sensitivity and hence may disturb coordination harmony. Several methods are used to isolate the faulty line upon the existence of faults in such a way that the feeder towards that line is stopped. Overcurrent relay is tripping off the feeder from the entire downstream zone upon if current is consumed in larger amounts. This increases the span of power interruption from the consumer's point of view. Auto-reclosers are used to switch off the feeder for a particular time and then to return the feeder since most of the faults are temporary [7]. The technique of a recloser cannot be stand if the fault is permanent. Distance protection relays are used to target a particular zone where the feeder for this limited zone is tripped off.

Insertions of DG influence the sensitivity of the distance relay and destroy the coordination order. In distribution systems the ratio of R/X is higher than the transmission system, then the losses is more, and the voltage drop is also high, thus led to specific errors in the distance protection relay will be resulted. In addition, the errors of the distance relay increased at the distribution side because of the short length of the transmission feeders.

Distance relays suffer from the effect of the infeed power and fault resistance that can cause incorrect reading of current and voltage due to DG injection power. At the end the problem of using distance relays in distribution systems is the coordination between the different types of protection relays for proper fault detection and isolation. In this work, implementing the distance relay in the distribution system in present of DG is studied, discussed, and simulated by using MATLAB-Simulink program to overcome the problems associated with distance relay with DGs.

1.3 Research Scope

1. The single distribution generation is integrated into the distribution network.
2. The location of distribution generation is assumed to be optimal at the distribution level.
3. This project only focuses on single phase to ground fault.

1.4 Research Objectives

This study aimed to address the problems of protection system fails due to uncertain DG penetration; the following objectives are made to perform the study.

1. To investigate the effect of various DG penetration levels on the distance relay coordination.
2. To implement an appropriate communication scheme for relays coordination and mitigate the impact of DG penetration.
3. To evaluate the performance of communication scheme protection relay coordination by comparing with previous communication scheme.

REFERENCES

[1] Lin Hengwei, Liu Chengxi, Guerrero Josep M., Quintero and Juan Carlos Vasquez” Distance Protection for Microgrids in Distribution System” the 41th Annual Conference of IEEE Industrial Electronics Society, IECON 2015.

[2] John J. Grainger and William D. Stevenson JR.," Power System Analusis ", International Edition, McGraw-Hill Series in Electrical and Computer Engineering, book, 1994.

[3] Yu Chen, Minghao Wen, Zhen Wang, Xianggen Yin, “A novel instantaneous value based incremental quantities distance protection for AC transmission lines”, International Journal of Electrical Power & Energy Systems, Volume 135, 2022

[4] Junchao Zheng, Peng Li, Kai Xu, Xiangping Kong, Chenqing Wang, Jinjiao Lin, Chi Zhang, A distance protection scheme for HVDC transmission lines based on the Steady-state parameter model, International Journal of Electrical Power & Energy Systems, Volume 136, 2022

[5] F.M. Aboshady, Modified distance protection for transmission line with hexagonal phase-shifting transformer, International Journal of Electrical Power & Energy Systems, Volume 134, 2022

[6] Dr. Rashid H. Al-Rubayi and Ammar Abbas Majeed,” Protection Coordination with Distributed Generation in Electrical System of Iraqi Distribution Grid” Eng. &Tech.Journal, Vol.34,Part (A), No.6,2016.

[7] P. I. Santos e Abreu and A. Gomes Martins,” Assessment of the Behavior of Protection Systems in Radial Networks with Distributed Generation” conference paper, IEEE, 2016.

[8] K. Pandakov, C. M. Adrah, Z. Liu, H. Kr. Høidalen, Ø. Kure,” Hardware-in-the-loop testing of imped ance protection with compensation of fault impedance and DG infeed current” IET, The Journal of Engineering, 2018.

[9] A.M. Tsimtsios, V.C. Nikolaidis,” Application of distance protection in mixed overhead-underground distribution feeders with distribution generation” IET, The Journal of Engineering, 2018.

[10] Lin Hengwei, Liu Chengxi, Guerrero Josep M., Quintero and Juan Carlos Vasquez” Distance Protection for Microgrids in Distribution System” the 41th Annual Conference of IEEE Industrial Electronics Society, IECON 2015.

[11] Shuchismita Biswas and Virgilio Centeno,” A Communication based Infeed Correction Method for Distance Protection in Distribution Systems” conference paper, IEEE, 2017.

[12] Vassilis C. Nikolaidis, M. Tsimtsios and Anastasia S. Safigianni” Investigating Particularities of Infeed and Fault Resistance Effect on Distance Relays Protecting Radial Distribution Feeders with DG” IEEE ACCESS, 2017

[13] V. C. Nikolaidis, C. Arsenopoulos, A. S. Safigianni and Costas D. Vournas” A Distance Based Protection Scheme for Distribution Systems with Distributed Generators” conference paper, IEEE, 2016.

[14] Jing Ma, Jinlong Li, and Zengping Wang” An Adaptive Distance Protection Scheme for Distribution System with Distributed Generation” IEEE, 2010.

[15] Adrianti, Edwindiansyah Asharry, Muhammad Nasir” A Distribution Line Protection Scheme for Network with Distributed Generation” Jurnal Nasional Teknik Elektro, 2021.

[16] Fahd Hariri and Mariesa Crow” New Infeed Correction Methods for Distance Protection in Distribution Systems” Energies Journal, MDPI, 2021.

[17] Jianfang Li, Xiaohui Song and Jing Ma,” A Novel Adaptive Distance Protection Principle for Distribution System with Distributed Generators” International Power, Electronics and Materials Engineering Conference (IPEMEC 2015),2015.

[18] Saad M. Saad, Naser El Naily, Faisal A. Mohamed” Investigating The Effect of DG Infeed on The Effective Cover of Distance Protection Scheme in Mixed-MV Distribution Network” nt. Journal of Renewable Energy Development (IJRED), 2018.

[19] Naser El Naily, Saad. M. Saad, Reda. E. Elsayed, Safaa. A. Aomura, and Faisal A. Mohamed” Planning & Application of Distance Relays coordination For IEC Microgrid Considering Intermediate In-Feed Factor” The 9th International Renewable Energy Congress (IREC 2018), 2018.

[20] S.P.S. Matos, M.C. Vargas, L.G.V. Fracalossi, L.F. Encarnação, O.E. Batista, Protection philosophy for distribution grids with high penetration of distributed generation, Electric Power Systems Research, Volume 196, 2021

[21] Haifeng Li, Chengjiang Deng, Zhenggang Zhang, Yuansheng Liang, Gang Wang, An adaptive fault-component-based current differential protection scheme for distribution networks with inverter-based distributed generators, International Journal of Electrical Power & Energy Systems, Volume 128, 2021.

[22] Seyed Fariborz Zarei, Saeed Khankalantary, Protection of active distribution networks with conventional and inverter-based distributed generators, International Journal of Electrical Power & Energy Systems, Volume 129, 2021.

[23] P.H.A. Barra, D.V. Coury, R.A.S. Fernandes, A survey on adaptive protection of microgrids and distribution systems with distributed generators, Renewable and Sustainable Energy Reviews, Volume 118, 2020.

[24] Ndamulelo Mararakanye, Bernard Bekker, Renewable energy integration impacts within the context of generator type, penetration level and grid characteristics, Renewable and Sustainable Energy Reviews, Volume 108, 2019.

[25] David Martin, Pankaj Sharma Amy Sinclair and Dale Finney" Distance Protection in Distribution Systems: How It Assists With Integrating Distributed Resources" IEEE, 65th Annual Conference for Protective Relay Engineers, 2012.

[26] Kamphol Tuitemwong, Suttichai Premrudeepreechacharn, Expert system for protection coordination of distribution system with distributed generators, International Journal of Electrical Power & Energy Systems, Volume 33, Issue 3, 2011.

[27] Debadatta Amaresh Gadanayak, Protection algorithms of microgrids with inverter interfaced distributed generation units—A review, Electric Power Systems Research, Volume 192, 2021

[28] Gurpreet Kaur, Anupama Prakash, K. Uma Rao, A critical review of Microgrid adaptive protection techniques with distributed generation, Renewable Energy Focus, Volume 39, 2021

[29] Ji-Soo Kim, Gyu-Jung Cho, Jin-Sol Song, Jae-Yun Shin, Dong-Hyun Kim and Chul-Hwan Kim" Development of Protection Method for Power System

interconnected with Distributed Generation using Distance Relay" J Electr Eng Technol.2018.

[30] https://www.electricaleasy.com/2018/02/radial-parallel-ring-main-interconneted-distribution.html, by Kiran Daware Power Distribution, Power System, "Electrical Easy".

[31] Amir Ghorbani, Majid Sanaye-Pasand, Hasan Mehrjerdi" Accelerated distance protection for transmission lines based on accurate fault location" Electric Power Systems Research, 2021.

[32] Cormac Brady," Investigations of relay protection systems in MV networks with large in-feed of distributed generation" Master thesis, Institute of Energy Technology, Denmark.

[33] Electrical 4 U "Over-current Relay Working Principle Types" 2020, Website: https://www.electrical4u.com/over-current-relay-working-principle-types/

[34] Melake Kuflom, Peter Crossley, Mark Osborne," Impact of 'intermediate' sources on distance protection of transmission lines" The 14th International Conference on Developments in Power System Protection (DPSP 2018).

[35] Shuchismita Biswas, Virgilio Centeno,"A Communication based Infeed Correction Method for Distance Protection in Distribution Systems" Conference Paper · September 2017 DOI: 10.1109/NAPS.2017.8107226.