# DETECTION OF CROSS-COUNTRY FAULT ON DISTANCE PROTECTION

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# DETECTION OF CROSS-COUNTRY FAULT ON DISTANCE PROTECTION

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*Dedicated to*

My parents and kinfolk's member for their boundless support and encouragement

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# ABSTRACT

Distance relay is one of protection components in transmission line. It is widely used as the main protection that gives a tripping signal to the Circuit Breaker (CB) when the fault occurs in the system. When short circuit faults occur in transmission line, the distance relays provide the protection and trip the CB by disconnecting the faulty portion from the healthy section. The main purpose of this research is to find the detection of Cross-Country Fault (CCF) on Distance Protection (DP). During this CCF condition, the faults are in an abnormal condition. This research is performed on a simple circuit model and IEEE test system with 6 buses, 9 buses and 14 bus systems. By using PSCAD/EMTDC software, the Mho characteristics and Bergeron model type of the transmission lines are modelled and have been simulated to generate the output current and voltage that are used to calculate the reach impedance for protected Zone 1. From the simulation results, it can be observed that the fault voltage and current are almost at the same values with the previous research on the normal fault. It means that the voltage and current will become highly fluctuated during the CCF condition. The result analysis is based on CCF with different locations at the same voltage level and CCF with different locations at different voltage levels. To study the performance of CCF condition, the outputs of all types of fault were considered in this project. It is found that the relays in most of the fault's conditions are operated in the protected zone. Finally, it can be concluded that the effect of CCF on DP are successfully identified.

# ABSTRAK

Geganti jarak adalah salah satu komponen perlindungan dalam talian penghantaran. Ia digunakan secara meluas sebagai perlindungan utama untuk memberi isyarat tersandung kepada Pemutus Litar (CB) apabila berlaku kesalahan di dalam sistem. Apabila kerosakan litar pintas berlaku dalam talian penghantaran, geganti jarak memberi perlindungan dan memutuskan CB dengan mengasingkan bahagian yang rosak daripada bahagian yang baik. Tujuan utama kajian ini adalah untuk mengenal pasti kesan Pintasan Silang Kerosakan (CCF) pada litar Perlindungan Jarak (DP). Semasa dalam keadaan CCF, kerosakan itu berada dalam keadaan yang tidak normal. Tetapi pada hari ini, kebanyakan reka bentuk menara talian penghantaran yang dibina mengandungi paras voltan yang berbeza pada menara yang sama dan kemungkinan keadaan CCF ini berlaku dalam talian penghantaran adalah terlalu tinggi. Kajian ini telah dijalankan ke atas model litar yang sederhana dan ujian sistem IEEE yang mengandungi 6 bas, 9 bas serta 14 bas sistem. Dengan menggunakan perisian PSCAD/EMTDC, ciri-ciri model MHO dan Bergeron dalam talian penghantaran dimodelkan dan telah disimulasi menggunakan perisian ini untuk menjana keluaran arus dan voltan yang perlu digunakan untuk mengira capaian jumlah galangan dalam perlindungan Zon 1. Daripada keputusan simulasi yang diperolehi, dapat diperhatikan bahawa voltan dan arus kerosakan semasa adalah sejajar dengan kajian yang telah dijalankan ke atas silang kerosakan terdahulu. Ini bermakna voltan dan arus meningkat secara mendadak dalam keadaan CCF. Keputusan kajian adalah berdasarkan CCF berlainan lokasi tetapi dalam aras voltan yang sama dan CCF dengan lokasi serta aras voltan yang berbeza. Untuk mengkaji keadaan CCF dengan lebih mendalam, keluaran dari pelbagai jenis kesalahan perlulah diambil berat. Ianya kerana geganti pada keadaan CCF kebanyakannya beroperasi dalam zon kawasan perlindungan. Akhir sekali, dapat disimpulkan bahawa kesan CCF pada DP telah berjaya dikenalpasti.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| DC | - | Direct current |
| DP | - | Distance Protection |
| CCF | - | Cross-Country Fault |
| CAES | - | Compressed air energy storage |
| MW | - | Mega watt |
| GW | - | Giga watt |
| IEEE | - | Institute of Electrical and Electronic Engineering |

## LIST OF APPENDICES

# CHAPTER 1

# Introduction

## 1.1 Research Background

The double line circuit on the same tower are widely used in transmission line system. It may enhance the transmission capacity of each way, other than to reduce the usage of ground and can cost reduction. The lines that share the same portion, their length are or structure are defined as a double circuit transmission lines [1].

Based on this situation, there are about 120 kinds of faults occurred in double circuit lines, due to the existence of the cross-country fault (CCF) [1,2]. It is very complicated to calculate and analyze the fault that occurred in double circuit lines and very important to study the characteristics of cross-country fault first.

The fault that is involving different phase and occurring at two different locations in power system can be defined as a cross country fault [1-3]. In this case, the differential protection must trip only for fault that occurs in protected zone, but sometimes it may not trip the internal faults or trip the external faults incorrectly.

These faults often occur at a worst possible time and locations. Sometimes, it will occur with maximum amount of current and cause big damages. Electric utilities often face the problem due to fault that always occur in transmission lines. Sometimes, these faults often cause the maximum amount of inconvenience and occur at the worst possible time to the customer utility.

In order to protect the components in transmission lines from damages, distance protection relays are used and operated within a certain distance. The distance protection is a non-unit system of protection which offers considerable economic and technical advantages.

The protected circuit located along the distance protection relays also is a comparatively simple to apply and can be fast in operation. In transmission system, the distance protection works by utilizing the fact that the measured impedance from a point directly in proportional to the distance. The location and operating systems can be measured by comparing it with the setting impedance.

## 1.2 Problem Statement

Parallel transmission lines have been extensively utilized in modern power systems to enhance the reliability and security for the transmission of electrical energy. The challenging problems in the power system protection are when the parallel lines in different possible configurations are combined with the effect of the mutual coupling. The main sources of the problem are when the possibility of the occurrence of CCF and the mutual coupling are occurs in transmission line.

From the previous research, most of the research is conducting in normal fault condition. The research for CCF are rarely conducted especially

the research in distance protection transmission line system area. This research proposed the effect of CCF in transmission line and the result of the analysis will be compared with the analysis of the basic fault. The performance and the behaviour of the fault in the distance protection during CCF condition are also being considered.

## 1.3 Objectives of The Research

The main objective of the proposed research is to identify the effect of cross-country fault on distance protection. To achieve the objective, sub-objectives are as follows:

a) To study and understand the cross-country fault condition

   The current and voltage fluctuate very high during the CCF condition. The distance protection will detect the abnormal condition and the output value will be calculated in order to detect the CCF condition.

b) To simulate cross-country fault using PSCAD/EMTDC

   This software is a standard simulation for the study of the electrical behaviour. By using this software, the value of the current and voltage detected can easily be calculated in order to detect the CCF on distance protection.

c) To find and analyze the effect of cross-country fault on distance protection

   After modeling the system using software, the result will be analyzed and recorded. When the CCF occurs in transmission line, the distance protection will detect the abnormal fault and the breaker will automatically trip. From that, the value will be calculated and the distance protection will detect the fault either it occurs inside or

outside the protection zone. Then, the result will be compared with the previous normal fault condition.

## 1.4 Scope of Research

The scope of this research can be divided into two parts. Firstly, the different types of faults that occur at transmission are simulated. There are about 120 kinds of faults occurred in double circuit lines due to the existence of the cross-country fault [1,4,7]. These faults may occur at the worst possible time and can cause the maximum amount of inconvenience to the customer utility.

The next stage is to find the function for distance relaying protection if there are faults that occur at double circuit transmission lines. In order to protect the components from damages caused from faults, the distance protection relays have used and operated within a certain distance. Distance protection relays also is a comparatively simple to apply and can be fast in operation for faults located along most of the protected circuit.

In this research, the PSCAD/EMTDC software has been used for analytical simulations. The analysis of this research consists of IEEE buses transmission line power system including 6-bus, 9-bus and also 14-bus system. Using this software, the analysis has been done by simple model that represent the real system.

## 1.5 Contributions of Research

As mentioned earlier under the research background, the double circuit line on the same tower are widely used in transmission line system. The possiblity of faults occured between lines is very high. This is called as cross-country faults, which is a fault that occur at tower involving the different location of faults or in different type of voltage levels. Most of the previous research are based on the normal fault condition that occurs in transmission line. This research has been be carried out because:

a) Analysis on detection of cross-country fault on distance relays
b) The compariosns between fault and cross-country fault being analyzed and the detection of the CCF being simulated

This study should be carried out due to previous studies focused on five types of fault that occur in a location on same tower and voltage; which is single line to ground, double line to ground, three phase to ground, double line fault and three line fault.

## 1.6 Thesis Outline

This thesis is divided into five chapters. Every chapter has its own strength. For the first chapter, the introduction of the research is covered. Its including the objectives of the research and also the contributions for the research. The second chapter will discuss the entire subject that contributed in this research as stated in the literature review. From this chapter, the teoritical regarding the research will be discussed. The previous research is also being discussed in detail. The third chapter is about the methodology of the research that covers the software used for the simulation and its related library tools that has been used in the simulation. The purposed of choosing this software

is also being discussed and the model that has been used during the simulation is also being clarified in this chapter.

Chapter 4 will discuss on the result and discussion of this research. During the simulation, the output result will be compared with the normal fault and the previous works output. The results is based on the IEEE test system which consist of 6-bus, 9-bus and 14-bus test systems. All the results will be recorded in this chapter. Chapter five will conclude all the information regarding to this project. The recommendation for the future development and study are also being discussed in this final chapter.

## REFERENCES


[1] R. Burgess and A. Ahfock, *Minimising the Risk of Cross-Country Faults in Systems Using Arc Suppression Coils*, Hadi Saadat, Power System Analysis (2nd ed.), Milwaukee School of Engineering: McGraw Hill, 2004

[2] Colin Bayliss and Brian Hardy, *Transmission and Distribution Electrical Engineering* (4th ed), The Boulevard Oxford: Newnes, 2012

[3] J. Duncan Glover, Mulukutla S. Sarma and Thomas J. Overbye, *Power System Analysis and Design* (5th ed.), Stamford: Cengage Learning, 2011

[4] P. M. Anderson, *Power System Protection* (1st ed.), A. John Wiley & Sons Inc Publication, 1999

[5] S. Sivanagaraju and S. Satyanarayana, *Electrical Power Transmission and Distribution* (1st ed.), India: Dorling Kindersley (India) Pvt. Ltd, 2009

[6] Arun Phadke, *Power System Protection: The Electrical Power Engineering Handbook* (1st ed.), Boca Raton, CRC Press LLC, 2001

[7] U. A. Bakshi and M. V. Bakshi, *Elements of Power System* (1st ed.), India: Technical Publication Pune, 2008

[8] Peter Rush, Network Protection and Automation Guide (3rd ed.), France, Copyright AREVA T&D, 2002

[9] Yashasvi B, Vidushi K and Ramesh P, Simulation of Mho Cahracteristics for Transmission Line Protection Using PSCAD, *International Journal of Research in Engineering & Applied Sciences*, Volume:2 (Issue: 2), February 2012pp: 540-550

[10] Akanksha P, Karishma G and Ramesh P, Modeling of Impedance relay using PSCAD/EMTDC, *International Journal of Research in Engineering & Applied Sciences*, Volume:2 (Issue: 2), February 2012, pp. 551-560

[11] N. A. Omar. A. A. M. Zin, A. M. Yusof and S. P. A. Karim, Effect of 132kV Cross-Country Fault on Distance Protection, *Modelling Symposium (AMS), 2012 Sixth Asia*, 29-31 May 2012, Bali, 2012, pp: 167-172

[12] Harikrishna M, Performance of Quadrilateral Relay on EHV Transmisson Line Protection During Various Faults, *ACEEE International Journal on Control System and Instrumentation*, Volume:1 (Issue: 1) , July 2010, pp. 1-6

[13] Manohar Singh, Dr. B.K Panigrahi and Dr. R.P Maheshwari. Transmission Line Fault Detection and Classification, *Emerging Trends in Electrical and Computer Technology (ICETECT), International Conference*, 23-24 March 2011, Tamil Nadu, 2011, pp 15-22

[14] Apostolov, A. Tholomier, D. Sambasivan, S. Richards, Protection of Double Circuit Transmission Lines, *Protective Relay Engineers, 60th Annual Conference*, 27-29 March 2007, College Station, TX, 2012, pp: 85 - 101

[15] Pairoj Kajoijilert sakul, Santi Asawasripongtorn, Peerayot Sanposh, Jittiwut Suwatthikul and Hideaki Fujita, Modeling and Simulation of 500kV Transmission Network for Neumerical Fault Calculation, Detection, Using PSCAD/EMTDC, *Power and Energy Engineering Conference (APPEEC), Asia-Pacific*, 25-28 March 2011, Wuhan, pp 1-4

[16] A. H. Osman and O. P. Malik, Transmission Line Distance Protection Based on Wavelet Transform, *Power Delivery, IEEE Transactions*, Volume:19 (Issue: 2), 2004, pp: 515-523

[17] R. Burgess and A. Ah fock, Minimising the Risk of Cross-Country Faults in Systems Using Arc Suppression Coils, *Generation, Transmission & Distribution, IET*, Volume:5 (Issue: 7, 2011), pp: 703-711

[18] M. Sanaye Pasand and H. Khorashadi Zadeh, Transmission Line Fault Detection and Phase Selection Using ANN, *International Conference on Power System Transient IPST*, December 2003 New Orleans, 2003, pp: 1-6

[19] Anamika Jain, A. S. Thoke and R. N. Patel, Fault Classification of Double Circuit Transmission Line Using Artificial Neural Network, *International Journal of Electrical and Computer Engineering*, Volume 3 (Issue: 16) , 2008, pp: 1029-1034

[20] Huang Yong, Chen Minyou and Zhai Jinqin, High impedance Fault Identification Method of the Distribution Network Based on Discrete Wavelet Transformation, *Electrical and Control Engineering (ICECE), International Conference*, 16-18 Sept. 2011, Yichang, pp: 2262 – 2265

[21] Z.Y.Xu, W.Li, T.S.Bi, G.Xu and Q.X. Yang, First Zone Distance Relaying Algorithm of Parallel Transmission Lines for Cross-Country Nonearthed Faults, *Power Delivery, IEEE Transactions*, Volume:26 (Issue: 4), 2011, pp 2486 – 2494

[22] Anamika Jain, A.S. Thoke, R.N. Patel and Ebha Koley, Inter circuit and Cross-Country Fault Detection and Classification using Artificial Neural Network, *India Conference (INDICON), Annual IEEE*, 17-19 Dec. 2010, Kolkata, pp: 1-4

[23] Xiangning Lin, Hanli Weng and Isin Wang, Identification of CCF of Power Transformer for Fast Unblocking of Differential Protection, *Power Delivery, IEEE Transactions*, Volume:24 (Issue: 3) , July 2009, pp: 1079-1086

[24] Fermando H. Magnago and Ali Abur, Fault Location Using Wavelet, *IEEE Transaction on Power Delivery*, Volume:13 (Issue: 4), Oct 1998, pp; 1475 – 1480

[25] Jeo-Air Jiang, Ching-Shan Chen and Chin-Wen Liu, A New Protection Technique for Fault Detection Direction Discrimination, Classification and Location in Transmission Lines, *IEEE Transactions on Power Delivery*, Volume:18 (Issue: 1), January 2003, pp; 34 – 42

[26] Anamika Jain, V. S. Kale and A. S. Thoke, Application of ArtificialNeural Networks to Transmission Lines Faulty Phase Selection and Fault Distance Protection, *Proceedings of the IASTED International Conference Energy and Power System*, Mac 29 – 31 2006, Chiang Mai Thailand, , pp: 262 – 267

[27] Naylor and J. H. *Power System Protection: Principles and Components-Fault Calculation* (3rd ed.), The Institution of Engineering and Technology, 1997

[28] Krzysztof Solak and WaldemarRebizant, Analysis of Differential Protection Response for Cross-Country Faults in Transmission Lines, *Proceedings of The International Symposium on Modern Electric Power Systems (MEPS)*, 20 – 22 September 2010, Wroclaw, pp: 1 – 4

[29] A. Apostolov, D. Tholomier, S. Sambasivan and S. Richard, Protection of Double Circuit Transmission Lines, *Protective Relay Engineers, 60th Annual Conference*, 27-29 March 2007, College Station, TX, pp: 85 – 101

[30] S.M. El Safty, H.A. Ashar, H.El Dessouki and M.El Sawaf, On-line Fault Detection of Transmission Line using Artificial Neural Network, *Power System Technology, PowerCon 2004 International Conference,* 21-24 Nov. 2004, pp: 1629-1632

[31] Voima Sampo, Using Distence Protection in Smart Grid Environment, *IEEE PES Innovative Smart Grid Technology Conference,* 12-15 October 2014, Istanbul, Turkey, pp: 1-6

[32] Asli Demirguc-Kunt and Enrica Detragiache, *Cross-Country Empirical Studies, National Institute Economic Review* (1 st ed.), World bank Policy Research Working Paper, September 2005

[33] J. R. Dunki-Jacobs, The Arcing Ground-Fault Phenomenon, *Industry Application, IEEE Transactions,* Volume:1A-22 (Issue: 6) , November 1986, pp: 1156-1161

[34] Olimpo Anaya-Lara and E. Acha, Modeling and Analysis of Custom Power Systems by PSCAD/EMTDC, *Power Delivery, IEEE Transactions*, Volume:17 (Issue: 1), Januari 2002, pp: 266-272

[35] Pasculescu Dragos, Romanescu Andrei, Pasculescu Vlad, Tatar Adina, Fotau Ion and Vajai Gheorghe, Presentation and Simulation of a Modern Distance Protection From the National Energy System, *Environment and Electrical Engineering (EEEIC),* 8-11 May 2011, Rome, pp: 1 – 4

[36] Bogdan Kasztenny, Jeff Mazereeuw and Bruce Campbell, Phase Selection for Single –Pole Tripping: Weak Infeed Conditions and Cross-Country Faults, Annual Western Protective Relay Conference, 24–26 October 2000, Markham, Ontario, pp: 1-19

[37] H. B. Elrefaie and A. I. Megahed, Fault Identification of Double Circuit Lines, *Developments in Power System Protection, Seventh International Conference on (IEE),*9-12 April 2001, Amsterdam, pp. 287-290

[38] J. G. Andrichak and G. E. Alexander, Distance Relays Fundamentals (1st ed.), Canada, GE Power Management Publication, 2002

[39] A.M. Gole, O.B. Nayak, T.S. Sidhu and M.S. Sachdev, A Graphical Electromagnetic Simulation Laboratory for Power System Engineering Programs, *Power Systems, IEEE Transactions*, Volume:11 (Issue: 2), May 1996, pp: 599-606

[40] Levine and Ross, Determinants of Economic Growth: A Cross-Country Empirical Study, *Journal of Comparative Economics, Elsevier,* Volume 26 (Issues: 4), December 1998, pp: 822-824

[41] M. Saini, A.A. Mohd Zin, M.W. Mustafa, A.R. Sultan, Fault Analysis Using PSCAD/EMTDC for 150 kV South Sulawesi Transmission System, *IEEE Symposium on Industrial Electronics and Applications (ISIEA2012),* 23-26 September 2012, Bandung, pp: 146-146

[42] Bhavesh, Bhalja and R. P. Maheshwari, Trends in Adaptive Distance Protection of Multi-Terminal and Double Circuit Lines, *International Journal in Electrical Power Components Systems*, Volume:34 (Issue: 2), Jun 2006, pp: 603 – 617

[43] Bhavesh, Bhalja and R. P. Maheshwari, Protection of Double Circuit Lines using Wavelet Transform, *IE Journal-EL,* Volume:87 (Issue: 2), September 2006, pp; 67 – 70

[44] R. Cimadevilla, Improvements in the Operation of a Distance Relay During Resistive Fault, *67th Protective Relay Engineers Annual Conference*, March 31 2014-April 3 2014, College Station Tx, pp: 132-185

[45] Bak C.L, Distance Protection of Cross-Bonded Transmission Cable System, *IET International Conference on Development in Power System Protection (DPSP 2014),* March 31 2014-April 3 2014, Copenhagen, pp: 1-6

[46] Bhavesh, Bhalja and R. P. Maheshwari, Philosophy of Protection for Multi-terminal and Double Circuit Lines, *Conference on Computer Applications in Electrical Engineering*, September 28 – October 1 2005, Recent Advances, Roorkee, India, pp: 582 – 588

[47] Sandro Gianny Aquiles Perez, *Modelling Relays for Power System Protection Studies*, Doctor of Philosophy, University of Saskatchewan, Canada, July 2006

[48] Suresh Maturu and U. Jayachandra Shenoy, Performance Issues of Distance Relays for Shunt FACTS Compensated Transmission Lines, *International Conference on* Power System Technology (POWERCON), 24-28 Oct. 2010, Hangzhou, pp: 1 - 6

[49] Dharshana Muthumuni, "Introduction to PSCAD/EMTDC and Application", Getting Started and Basic Features, Manitoba HVDC Research Centre, Canada, 2000

[50] Craig Muller, User's Guide on The Use of PSCAD, Canada, Manitoba HVDC Research Centre, September 2005

[51] Manitoba HVDC Research Centre, PSCAD/EMTDC: Electromagnetic Transient Program Including DC Systems, 1994