UNIVERSITI PUTRA MALAYSIA

IMPROVEMENT OF POWER SWING BLOCKING SCHEME IN DISTANCE PROTECTION RELAY

MOHAMMED SANI YA'U

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By

MOHAMMED SANI YA'U

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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This thesis is dedicated to

my beloved parents

for their love, endless supports and encouragement with love

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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MOHAMMED SANI YA'U

April 2015

Chairman : Ir. Mohammad Lutfi Bin Othman, PhD

Faculty : Engineering

Distance relay is a protective device in electrical power system. It detects faults in transmission system and isolates abnormal or fault conditions by sending a trip signals to the circuit breaker. Power swing is caused by the large disturbances in the power system that if not blocked, could cause wrong operation of the distance relay and can generate wrong or undesired tripping of the transmission line circuit breaker. Due to the characteristics of distance relay that can trip during power swings, a Power Swing Blocking (PSB) unit is developed to prevent unwanted distance relay operation during power swings. The main purpose of the PSB unit is to differentiate between faults and power swings and block distance or other relay elements from operating during a power swing. The problem with the originally available PSB in PSCAD/EMTDC is that it does not follow the exact shape of the operation characteristics of the available quadrilateral distance relay element. The PSB band may get too close to maximum load region, thus making load encroachment possible. This can create false fault or power swing pick up. Power swing blocking must be an immediate decision, immediately before allowing or disallowing the distance relay operations. Thus, PSB band must be attached back-to-back to the characteristic of the distance relay. Otherwise there will be an inaccuracy in measurement of impedance trajectory time interval from outer boundary to the inner boundary of the PSB band. This is the main problem when dealing with the current original PSB element in PSCAD/EMTDC. Therefore an improvement must be made to improve the power swing detection and thus make the quadrilateral distance relay element in the PSCAD/EMTDC to operate more efficiently.This improvement strategy will involve modelling an improved version of the original PSB and also introducing a new phasor comparator PSB scheme. These two techniques shall provide results that can validate the anticipated improvement in power swing detection over the original algorithm inherent in PSCAD/EMTDC. The original PSB problems are addressed in the newly improved FORTRAN and phasor comparator PSB schemes proposed in this research. In the original PSB available in PSCAD, the power swing detection time is close to the distance relay pick up time with a difference of only 0.01 second. This may cause wrong operation of distance relay if the relay picks up earlier and subsequently leading to a tripping of transmission line circuit breaker. However, the

short seperation between the original PSB and the distance relay is addressed using the improved and phasor comparator PSB created in this research. In both cases, power swing detection is improved by 0.04 seconds. That gives sufficient time interval (0.04 seconds) between the PSB detection time and distance relay pick up time thus preventing the distance relay from sending a wrong tripping signal to the circuit breaker. With the modified PSB in the PSCAD/EMTDC, the problems related to the unmatched shapes of the PSB band and the quadrilateral distance relay operation characteristics have been addressed successfully.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

IMPROVEMENT OF POWER SWING BLOCKING SCHEME IN DISTANCE PROTECTION RELAY.

Oleh

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April 2015

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Geganti jarak adalah alat perlindungan dalam sistem kuasa elektrik. Ia mengesan kesalahan dalam sistem penghantaran dan mengasingkan keadaan yang luar biasa atau bersalah dengan menghantar isyarat kepada pemutus litar. Ayunan kuasa berlaku disebabkan oleh gangguan yang besar dalam sistem kuasa yang jika tidak dihalang boleh menyebabkan operasi yang salah oleh geganti jarak dan menghasilkan kesalahan atau tidak diingini pada penyandungan talian penghantaran pemutus litar. Disebabkan ciri-ciri geganti jarak yang boleh tersandung semasa ayunan kuasa, unit penyekat ayunan kuasa dibangunkan untuk mengelakkan yang tidak diingini oleh operasi geganti jarak semasa ayunan kuasa. Tujuan utama unit penyekat ayunan kuasa ialah untuk membezakan kesalahan dari ayunan kuasa dan menyekat unsur geganti jarak dan yang lain dari beroperasi semasa ayunan kuasa. Permasalahan dengan penyekat ayunan kuasa yang asal di dalam PSCAD/EMTDC ialah ia tidak mengikut bentuk ciri pengendalian elemen geganti jarak sisi empat yang sedia ada. Akibatnya ruang penyekat ayunan kuasa boleh terlalu dekat kepada maksimum rantau beban, justeru mungkin membuat pencerobohan beban. Ini boleh menghasilkan kesalahan atau ambilan ayunan kuasa. Ayunan kuasa menyekat mesti perlu menjadi keputusan segera, sebaik sebelum membenarkan atau tidak membenarkan operasi geganti jarak. Oleh itu, ruang penyekat ayunan kuasa hendaklah disertakan kesepadanan dan sekata kepada ciri geganti jarak. Jika tidak akan ada yang tidak tepat dalam pengukuran jarak masa laluan impedans dari sempadan luaran ke sempadan dalaman ruang penyekat ayunan kuasa. Ini adalah masalah utama apabila berurusan dengan unsur penyekat ayunan kuasa yang asal semasa dalam perisian PSCAD / EMTDC. Oleh itu penambahbaikan perlu dibuat untuk meningkatkan pengesanan kuasa ayunan dan dengan itu membuat sisi empat unsur geganti jarak dalam perisian PSCAD/EMTDC untuk beroperasi dengan lebih cekap. Penambahbaikan strategi ini akan melibatkan model versi yang lebih baik daripada penyekat ayunan kuasa yang asal dan juga memperkenalkan skim penyekat ayunan kuasa pembanding fasor. Kedua-dua teknik ini akan memberikan hasil yang boleh mengesahkan pengesanan ayunan kuasa dijangka bertambah baik lebih dari algoritma asal yang terdapat dalam perisian PSCAD / EMTDC. Permasalahan penyekat ayunan kuasa yang asal dialamatkan dalam skim FORTRAN dan penyekat

ayunan kuasa pembanding fasor yang baru lagi bertambah baik telah dicadangkan dalam kajian ini. Dalam penyekat ayunan kuasa yang asal terdapat di perisian PSCAD, masa pengesanan ayunan kuasa terletak berhampiran dengan geganti jarak yang mengambil masa dengan perbezaan hanya 0.01 saat. Ini mungkin menyebabkan operasi yang salah pada geganti jarak jika geganti itu sudah terambil lebih awal dan seterusnya membawa kepada tersandung talian penghantaran pemutus litar. Walau bagaimanapun, pemisahan dekat di antara penyekat ayunan kuasa yang asal dan geganti jarak itu dialamatkan menggunakan penambah baik dan penyekat ayunan kuasa pembanding fasor dihasilkan dalam penyelidikan ini. Dalam kedua-dua kes tersebut, pengesanan ayunan kuasa bertambah baik dengan 0.04 saat. Yang memberi tempoh masa yang mencukupi (0.04 saat) antara pengesanan masa penyekat ayunan kuasa dan masa geganti jarak diambil lalu menghalang geganti jarak dari menghantar isyarat salah tersandung kepada pemutus litar. Dengan penyekat ayunan kuasa termodifikasi di dalam PSCAD/EMTDC di atas, masalah yang berhubung dengan ketidak seragaman bentuk di antara penyekat ayunan kuasa dan ciri kendalian geganti jarak sisi empat telah diselesaikan dengan jayanya.

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I pray may Almighty Allah reward them all abundantly.

I certify that a Thesis Examination Committee has met on 21 April 2015 to conduct the final examination of Mohammed Sani Ya'u on his thesis entitled "Improvement of Power Swing Blocking Scheme in Distance Protection Relay" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

A-B-G	Phase A, B to ground
A-B-C-G	Phase A, B, C to ground
A-C-G	Phase A, C to ground
A-G	Phase A to ground
A-B	Phase A to B
A-C	Phase A to C
A-B-C	Phase A to B to C
B-G	Phase B to ground
B-C-G	Phase B, C to ground
B-C	Phase B to C
C-G	Phase C to ground
CT	Current Transformer
CCVT	Capacitor Coupled Voltage Transformer
CB	Circuit Breaker
EMTDC	Electromagnetic Transient including DC
FORTRAN	Formula Translation
FFT	Fast Fourier Transform
IEEE	Institute of Electrical and Electronic Engineers
Inm	Negative sequence current
PSCAD	Power System CAD
PSB	Power Swing Blocking
Ra	Resistive component
Xa	Reactive component
Z	Trajectory impedance
21	Device number for distance relay
68	Device number for power swing blocking

CHAPTER 1

INTRODUCTION

1.1 Overview

The technological era of today makes use of large amount of energy to generate electrical power to the consumers. The main objective of power system is to provide energy for human use in a way that is practically secure, reliable and in an economic manner. For the production of energy, the fundamental processes are; the generation, transmission, and distribution (1945; Wang and Mcdonald, 1994). Since the said process involved some of the complex largest systems for production of electrical energy, therefore, a solid electrical power system protection scheme must be provided for every power system (Karegar and Mohamedi, 2009).

Among the commonly used protecting devices for the protection system in transmission line is distance relay (Gérin-Lajoie, 2009; Phadke, 1979; Pradhan and Routray, 2005). This type of device meets the requirement of reliability and speed needed to protect extensively used power system on networks. Power swing incident occur when there are disruptions in power system that if its not block may prompt an undesired operation of the distance protection relay which could generate incorrect tripping of the transmission line circuit breaker. These disturbances in the system creates oscillations in the generator rotor angles which would subsequently result in extreme oscillations in the power flow. These variations in power flow can cause undesirable relay operation which can disturb the power system and cause power blackouts or major outages. In this research, a novel algorithm is proposed that will block the undesired maloperation of the distance protection relay during a power swing incidents. The system model is developed using Power system CAD (PSCAD/EMTDC) supported with FORTRAN porgramming language. The algorithm used and other simulation results that are obtained will be explained in details at the later sections of this thesis.

1.1.1 Distance Relay in Power System

Distance relay is a protective device in electrical power system. It detects faults in transmission system and isolates abnormal or fault conditions by sending trip signals to the circuit breaker (S. Brahma, 2006; S. M. Brahma, 2007; Schweitzer Iii and Roberts, 1993). The main advantage of using a distance relay is that its zone of protection depends on the impedance of the protected line that is constant virtually independent of the magnitude of the voltage and current (Gers and Holmes, 2004). Relay is defined by the IEEE as “an electric device that is design to interrupt input conditions in a prescribed manner, and after specified conditions are met, to respond to cause contact operation or similar abrupt changes in association electric control circuits” (Jay and Goetz, 1988).

Distance relays are widely used for the protection of transmission lines. It operate when there is a fault in a transmission line by giving a signal to the circuit breaker to trip and isolate the line from the rest of the network. Distance protection is a non-unit type of protection and has the ability to discriminate between faults occuring in different parts of the system, depending on the impedance measure (Gers and Holmes, 2004). Distance relays are classified depending on their characteristics in the R-X plane, the number of incoming signals and the method used to compare the incoming signals. The most common types compare the magnitude or phase of the two incoming signals in order to obtain the operation characteristics, which are straight or circular lines drawn in the R-X plane.

1.1.2 Power Swing

Power swing oscillation which is sometimes called power swing can occur if there is a power system fault, or when switching operations are carried out which involves the connection or disconnection of large quantities of load. Basically, power swing is caused by the large disturbances in the power system as a result, if it is not blocked it could cause wrong operation of the distance relay and can generate wrong or undesired tripping of the transmission line circuit breaker (Esmaeilian *et al.*, 2011).

1.1.3 Power Swing Blocking

Due to the characteristics of distance relay that can trip during power swings, a Power Swing Blocking (PSB) unit is developed to prevent unwanted distance relay operation during power swings. The main purpose of the PSB function is to differentiate between faults and power swings and block distance or other relay elements from operating during a power swing (Dubey and Samantaray, 2013; Khan and Yan, 2008; Lin *et al.*, 2008).

1.2 Problem Statement

The characteristic of the original power swing blocking element available in PSCAD/EMTDC does not match with the operational characteristics of the available quadrilateral distance relay for the remote zone 3 and reverse zone 4 used in transmission line protection. The problem of the available power swing blocking in PSCAD/EMTDC is that the PSB band coordinates setting do not match with the actual quadrilateral distance relay characteristic. The problem with this are:

i. The PSB band may get too close to maximum load region, thus making load encroachment possible. This can create false fault or power swing pick up.
ii. PSB must be an immediate decision, immediately before allowing or disallowing the distance relay operations. Thus, PSB band must be attached back-to-back to the characteristic of the distance relay.

Otherwise there will be an inaccuracy in measurement of impedance trajectory time interval from outer boundary to the inner boundary of the PSB band. This is the main problem when dealing with the original PSB element in PSCAD/EMTDC. Therefore an improvement must be made to improve the power swing detection and thus make the quadrilateral distance relay element in the PSCAD/EMTDC to operate more efficiently.

1.3 Objective of the Research

The objective of this research are:

- To improve the power swing blocking scheme for the quadrilateral distance protection relay available in PSCAD/EMTDC so that its power swing detection characteristics match with the actual operational characteristic of the quadrilateral distance relay and thus making detection of power swing more efficient.
- This improvement strategy will involve modelling an improved version of the original PSB detection and also introduce a novel phasor comparator PSB technique. These two techniques shall provide results that can validate the anticipated improvement in power swing detection over the original algorithm inherent in PSCAD/EMTDC.

1.4 Scopes of the Research

In order to realize the hypothesization of the power swing blocking in protective relay operations, the following scope of works shall be carried out.

- Modelling and simulating a double-sourced parallel transmission line system as practiced by TNB and recommended by CIGRE using PSCAD/EMTDC.
- Modelling and simulating a quadrilateral distance protection relay in PSCAD/EMTDC with presence of available power swing blocking element.
- Develop and improve the version of power swing blocking scheme by using FORTRAN programming language in PSCAD/EMTDC by carrying out the following techniques:
    - I. Rewrite the FORTRAN source code to correct the deficiency in the original source code.
    - II. Develop an entirely new algorithm based on the concept of phasor comparator.
- Validate the improvement in the power swing detection by comparing both the rewritten FORTRAN source code and the novel phasor comparator with the original PSB.

1.5 Thesis Organization

This thesis is organized in five chapters. The first chapter is an introduction of the thesis that describes the basic background of the distance relay, power swing, power swing blocking and their relationship with distance protection relay. The importance of the power system will be discussed in this chapter by viewing the current trend of protection and problem involved in electrical power protection system. The problem statement, objectives and scope of this research is explained in this chapter.

Chapter 2 of this thesis will discuss about the previous works that has been done by other researchers on the related field. The overview of the research, fundamentals of distance relay operations as well as the summary of the results that was obtained will be discussed in this chapter.

Chapter 3 will be the methodology of the thesis to describe the flow of the research. The software used to design and model the transmission line, distance relay and power swing blocking schemes used in this research will be introduced in this chapter.

The results and discussions will be discussed in chapter 4. The characteristic of power swing blocking scheme and the result of the simulation will also be shown in this chapter. A comparison between the original, improved and phasor comparator power swing blocking will also be discussed.

A brief summary of the research conducted such as important conclusions and recommendation will be shown in chapter 5. The last part will be a list of references and appendices.

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