Faculty of Electrical Engineering

MODELLING AND PROTECTION OF A 14 BUS POWER SYSTEM USING POWER FACTORY DigSILENT SOFTWARE

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DECLARATION

I declare this dissertation entitled “Modelling and Protection of a 14-Bus Power System Using Power Factory DigSILENT" is the result of my own research except as cited in the reference. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ……………..............................

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Date : ……………..............................

APPROVAL

I hereby declare that I have read this dissertation and in my opinion, this dissertation is sufficient in terms of scope and quality as a partial fulfillment of Master of Electrical Engineering (Industrial Power).

Signature	: ……………..............................
Supervisor Name	: Prof. Dr. Marizan Bin Sulaiman
Date	: ……………..............................

DEDICATION

Almighty Allah who blessed me with a lot of graces.

I dedicated this dissertation to my beloved parents, Malik Jalil Kreem and Seham Ali who give me a strong and gentle soul who taught me to trust in Allah and believe in hard work.

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ABSTRACT

This dissertation presents a method for protection coordination of Midwest United States IEEE 14 bus system for distribution and transmission line in close operation mode. For validation, modeling and simulation grid have been done using Power Factory DigSILENT software. Historically Electric distribution power systems are designed as pure radial networks and protection system network using overcurrent relay which have gradually evolved into close loop or meshed networks meanwhile transmission system designed as a close or meshed system and protected by distance relay. Close loop and meshed networks are becoming more preferred options which offer greater improvement in power quality and system reliability. However Mal operation had been occur in coordination power system using directional overcurrent relay.as a result, this study present an improved method on coordination of close loop distribution system using General Coordination Close Loop method (GCCL) by directional over current relay. This is done through dividing the system to many paths and input the load and short circuit data of each path to MATLAB program code, producing relay coordination as the output. Then the result is then applied to DigSILENT modeling relays to simulate fault scenario to check tripping time in main and backup protection system. This study also involved on adding the synchronous condensers to the grid. The current injected by synchronous condenser may change the fault level both in magnitude and direction, which result in a loss of selectivity. The impact of synchronous condenser on short circuit levels and protection grading has been simulated and analyzed. Besides that, the simulation has been done to coordinate transmission line protection using distance relay. The results shows the effectiveness of source impedance and infeed of multi-transmission line on the second and third zone for distance relays in terms of tripping time. Also system behavior has been observed after implementing fault scenario scheme for the above mentioned contingencies events, and the result shows success in the coordination system protection within acceptable limits and regain of power system protection.

ABSTRAK

Disertasi ini membentangkan tentang kaedah penyelarasan perlindungan bagi sistem 14 bas Midwest Amerika Syarikat IEEE untuk pengedaran dan talian penghantaran kuasa dalam mod operasi tertutup. Sabagai pengesahan, pemodelan dan simulasi grid telah dilaksanakan menggunakan perisian Power Factory DigSILENT. Mengikut sejarah, sistem pengedaran kuasa elektrik telah direka bentuk sebagai rangkaian radial tulen dan rangkaian sistem perlindungan menggunakan relay muatan arus berlebihan yang kemuadian beransur dan berkembang menjadi gelung tertutup atau rangkaian berangkai manakala sistem penghantaran pula direka sebagai sistem tertutup atau berangakai yang dilindungi oleh relay jarak jauh. Gelung tertutup dan rangkaian berangkai kian menjadi pilihan yang menawarkan peningkatan yang lebih baik dalam kualiti kuasa dan kebolehpercayaan sistem. Walau bagaimanapun, operasi Mal didapati sedang berlaku dalam sistem penyelarasan kuasa yang menggunakan relay muatan arus berlebihan., sabagai hasil, kajian ini membentangkan satu kaedah yang lebih baik dalam penyelarasan sistem pengedaran gelung tertutup dengan menggunakan kaedah Koordinasi Umum Gelung Tertutup (GCCL) dengan arah melalui relay muatan arus berlebihan. Hal ini dilakukan dengan membahagikan sistem kepade beberapa laluan dan beban dan data litar pintas bagi setiap laluan akan di input ke kod program MATLAB justeru, menghasilkan koordinasi relay sebagai output. Kemudian, keputusan yang diperoleh kemudiannya digunakan untuk relay pemodelan DigSILENT untuk mensimulasi senario kesalahan untuk memeriksa masa pemutusan litar dalam sistem perlindungan utama dan pelindungan sandaran. Kajian ini juga melibatkan penambahan kondenser selari ke grid. Arus yang disuntik oleh kondenser selari boleh mengubah tahap kerosakan dalam kedua-dua magnitud dan arah justeru, mengakibatkan kehilangan selektiviti. Kesan kondensor selari pada tahap litar pintas dan penggredan perlindungan telah disimulasikan dan dianalisis. Selain itu, simulasi telah dilakukan untuk mengkoordinasikan perlindungan talian penghantaran menggunakan relay jarak jauh. Keputusan menunjukkan keberkesanan sumber impedans dan sumber dari pelbagai garisan transmisi pada zon kedua dan ketiga untuk relay jarak dari segi masa pemutusan litar. Tingkah laku sistem juga telah diperhatikan selepas mengimplimentasikan senario kerosakan untuk peristiwa-peristiwa luar jangkaan yang dinyatakan di atas, dan keputusan menunjukkan kejayaan perlindungan sistem koordinasi adalah dalam batas yang boleh diterima dalam perlindungan sistem kuasa.

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LIST OF ABBREVIATIONS

Abbreviation	**Specification**
AC	Alternative Current
CT	Current Transformer
DC	Direct current
DG	Distribution generation
GEN	Generator
IEEE	Institute of Electrical and Electronic Engineers
IDMT	Inverse Definite Minimum Time
I_P	Pickup Current
OC	Overcurrent Relay
TR	Transformer
TMS	Time Multiplier Setting
T	Operating Time
DTT	Direct Transfer Tripping
DOCR	Directional Overcurrent Relay
PS	Plug Setting

CTI	Coordination Time Interval
PSM	Plug Setting Multiplier
T_{ch}	Time Characteristic for Overcurrent Curve
T_{op}	Time Trip Operation
MV	Medium Voltage
T_{TFR}	Time Trip First Relay
TCT	Total Clearing Time
UTeM	University Teknkal Malaysia Melaka

LIST OF SYMBOLS

Symbol	Specification
Z	Impedance
R	Relay
%	Percent
L	Line
Δ	Delta Transformer Configuration
Y	Wye Transformer Configuration

CHAPTER 1

INTRODUCTION

1.1 Background

Modern civilization makes use of large amount of energy to generate goods and services. From the industrial plants, the providers of public services to the society, all of them need the energy to satisfy and create the well-being of modern society. One of the most important forms of energy is electric power system that provides energy for human use in a secure, reliable and economic manner. Electric power systems are made up of facilities and equipment that generate, transmit and distribute electrical energy. Also, Electric power systems are one of the largest and most complex systems man has ever built. Power systems need an auxiliary system that must take corrective actions on the occurrence of a fault. This auxiliary system is known as a protection system.

Protection systems are sets of equipment, schemes, and policies dedicated to detecting faults in the protected elements of the power systems, to disconnect the faulted element and to reestablish the service, if it was the case. Protection is always a serious concern in the industrial environment. The action of the relays and protective devices play an important role in running the industries in healthy and safe condition. Because power systems operate in different operating states, different fault scenarios may occur. Protection systems must be provided with different schemes and equipment to detect and to react to each and every one of these fault scenarios, from the most simple to the most complex and compelling.

One of the most important equipment employed in the protection of power systems is protective relays. This is one of the most flexible, economical and well-known devices that provide reliable, fast and inexpensive protection. Protection relay is defined by the IEEE as “an electric device that is designed to interpret input conditions in a prescribed manner, and; after specified conditions are met, to respond to cause contact operation or similar abrupt changes in associated electric control circuits” (IEEE standards Coordinating Committee 21 2014). Protective relays have provided protection since the beginning of the electric industry, and have encountered great transformations with time as power systems have grown in size and complexity (Tjahjono, Priyadi, et al. 2016). Overcurrent relay is a sensing relay, which operates when the current increases beyond the operating value of the relay. Depending upon the time of operation, overcurrent relays may be categorized as instantaneous over current relay, inverse time overcurrent relay, definite time overcurrent relay, inverse definite time overcurrent relay, very inverse overcurrent relay and extremely inverse overcurrent relay. An impedance relay is a voltage controlled overcurrent relay. The relay measures impedance up to the point of fault and gives tripping command to the circuit breaker if the impedance is less than the relay setting Z.

The developments in relaying technology have not solved definitively all the protection issues. Therefore, substantial investigations and researches on protection and protective relaying continue (McLaren et al. 2001), specifically on setting and adjustment of relays and interrelation of protective relays with a different component of the power system, especially control elements. Relay coordination is used to achieve proper fault identification and fault clearance sequence. The coordination studies are performed to ensure safety operation of the system . In relay protection, coordination services examine the coordination between the protective devices with the help of Time Current Characteristics (TCC) from the lower stream to the upper stream and the short-circuit values at the particular feeder. These short circuit values are calculated from power system studies. The values calculated will be used for determination of the relay and protective device settings to ensure proper and safe operation of the system. Nowadays simulation makes it easier for all fault types to be simulated.

Power system study and analyses are important parts of power system engineering. For the last few years, electrical engineers have been focusing on the power system studies using software tools. The role of modeling and simulation has been widely recognized throughout the history of power engineering education since the computers that are capable of performing the complex simulations became available (Celli et al. 2012). A number of efforts has been made in this direction. Recent advances in engineering sciences have brought a revolution in the field of electrical engineering after the development of powerful computer based software.

In this work simulation had been done using DigSILENT Power Factory. It is one of the most sufficient for developed modeling and simulation tools aimed at better understanding the design concept and related applications for protective system, as well as substation communication and automation solutions are presented (Pradhan et al. 2016). In this study, all the result of protection relay response and short circuit calculations have been evaluated using DigSILENT simulation.

Transmission system protection coordination using distance relay to protect transmission line. A careful selection of the relay reach settings and tripping times for the various zones of measurement enables the correct coordination between distance relays in a power system, as this study coordination zone depends on Tenaga Nasional Berhad (TNB)(Zin et al. 2012). The time-distance plotted by VisPlottz option provided by DigSILENT.

Historically, electric distribution power systems were designed as pure radial networks, which have gradually evolved into a close loop or meshed networks. Radial operations have been applied for years in order to protect medium voltage distribution networks and their greatest benefit is their simplicity. However, with a much greater focus on the improvement in power quality, system reliability and environmental problems, close loop and meshed networks are becoming the preferred options(Huang & Chen 2009).

A lot of distribution systems were designed to have closed loop structure, however, operate in open loop mode to avoid problems such as the challenges in coordination protection relays in close loop mode. When a fault occurs it needs to separate a large scale of distribution line to isolate the fault area. Moreover, the power failure of distribution line will result in DGs shutdown for DGs that are integrated into the utility grid using a distribution system (Mashau & Kibaara 2011).

Increasing number of electrical companies have started to adopt close and mashed loop structure in a distribution system that would decrease the outage range to improve the power supply reliability and guarantee normal operation in DGs in a cause of a fault. However, the close loop operating will bring some other issues. The protection system for the grid that designed as close loop structure operating in an open loop mode was built using directional over current relay, some of the possible solutions to protect the distribution system by using distance relay (Olatoke & Darwish 2013).

The proposed solution in this study is by using an existing relay (directional overcurrent relay) to protect the close loop distribution system. This study evaluating and coordination protection power system for 14 bus IEEE power system. Distribution system for 14 bus from bus 6 to bus 14 is considered as close loop distribution system.

The coordination result for relays in close loop distribution system is evaluated using MATLAB algorithm. Input data is the short circuit current from DigSILENT simulation, the output will be the result for setting distribution relays in close loop system.

As the generation mix evolves to a higher penetration of renewables and less traditional thermal generation, there are places in the power grid where stability becomes a challenge. It is one that can be enhanced by an unexpected technology which is a synchronous condenser. Adding synchronous condensers can help with reactive power needs, increase short-circuit strength and thus system inertia and assure better dynamic voltage recovery. The current injected by synchronous condenser changes the fault level both in magnitude and direction, which thereby result in a loss of selectivity.

1.2 Motivation for Research

The motivation for this research:

i. Coordination system protection of close loop distribution system using directional overcurrent relays in order to avoid power system operate in open loop condition.
ii. Impact of the synchronous condenser on the protection system girding in term of short circuit current.
iii. Coordination system protection of transmission line using distance relay in order to avoid under reach due to multi source and multi-feed to the fault from the different