UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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IMPACT OF DISTRIBUTED GENERATION ON POWER SYSTEM PROTECTION

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IMPACT OF DISTRIBUTED GENERATION ON POWER SYSTEM PROTECTION

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A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

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DECLARATION

I declare that this dissertation entitles "Impact of Distributed Generation on Power System Protection" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :…..……..……………………..

Name: : Dawood Saleem Ahmed

Date: :.....………………………… ....

APPROVAL

I hereby declare that I have read this report and in my opinion this dissertation is sufficient in terms of scope and quality for the award of Master in Electrical Engineering.

Signature :…………:……………. ....

Supervisor Name : Dr. Hidayat Bin Zainuddin

Date: :……………………………….. ....

DEDICATION

This dissertation work is dedicated to my wife, and my big family; you are good examples and you have taught me to work hard for the things that I aspire to achieve.

ABSTRACT

This dissertation describes a simulation study of the impact of distributed generation (DG) interconnection to an existing distribution system of an Iraq system. The increase load demand in many countries pushes the electrical company to use DG technology to meet their load. From the literature review, it was found in spite of many positive effects of DG such as reduce the power losses and reduce voltage drop; the parallel operation of DG with an existing distribution system has many technical problems. One of the most significant issues of parallel operation is the change of fault level and suitability of existing protection system that indeed needs to be maintained within acceptable limits as defined in the international standards. Therefore, this dissertation is performed to investigate the impact of DG based synchronous generator driven by diesel engine on both the fault level and protection system. A small part of the distribution system in Baghdad capital-Iraq which the DG is currently interconnected at 11kV bus has been chosen and modeled using DIgSILENT PowerFactory version 15. The impacts of DG installation at three different locations, i.e. two possible locations which are 33kV and 132kV buses as well as the actual location have been investigated. The dissertation basically includes two investigations which are; examine the change in the fault level without the presence of DG and with DG interconnection at three interconnection locations by executing three-phase fault at each bus of the network as well as investigate the suitability of protection devices through performing single-line-to-ground and three-phase faults at 33kV and 11kV feeders within the distribution system. The results show that after an extensive simulation study, the increase in short circuit level is noticeable at the buses where the DG is interconnected and the protection performance of unidirectional overcurrent relay suffer from blinding and sympathetic tripping as well as the under reach of distance relay, therefore, a series remedy is needed for safety purposes and to reliability of the system.

ABSTRAK

Disertasi ini menerangkan tentang kajian simulasi kesan sambungan Penjana Teragih (PT) kepada system pengagihan yang sedia ada dalam sistem Iraq. Peningkatan permintaan beban di banyak negara memaksa syarikat elektrik menggunakan teknologi PT untuk memenuhi beban mereka. Daripada kajian literatur, didapati walaupun banyak kesan positif PT seperti mengurangkan kehilangan kuasa dan mengurangkan kejatuhan voltan operasi selari PT dengan sistem pengagihan yang sedia ada mempunyai banyak masalah teknikal. Salah satu isu yang paling penting ialah perubahan aras kerosakan dan kesesuaian sistem perlindungan sedia ada yang sememangnya perlu dikekalkan dalam had yang boleh diterima seperti yang ditakrifkan dalam piawaian antarabangsa. Oleh itu, kajian ini dijalankan untuk menyiasat kesan penjana segerak PT berasaskan enjin diesel terhadap aras kerosakan dan sistem perlindungan. Sebahagian kecil daripada sistem pengagihan di Bandar Baghdad, Iraq yang mana PT disambungkan di bas 11kV telah dipilih dan dimodelkan menggunakan DIgSILENT PowerFactory Versi 15. Kesan pemasangan DG di tiga lokasi berbeza iaitu dua lokasi kemungkinan, di bas 33kV dan 132 kV serta lokasi sebenar telah disiasat. Disertasi pada dasarnya menyentuh dua kes utama iaitu; memeriksa perubahan dalam aras kerosakan tanpa kehadiran PT dan dengan sambungan DG di tiga lokasi sambungan melalui pelaksanaan kerosakan tiga fasa pada setiap bas rangkaian serta menyiasat kesesuaian peranti perlindungan dengan melakukan kerosakan talian tunggal ke bumi dan kerosakan tiga fasa pada penyuap 33 kV dan 11kV dalam sistem pengagihan. Keputusan kajian simulasi menunjukkan peningkatan yang banyak pada aras litar pintas adalah ketara pada bas disambungkan dengan PT dan prestasi perlindungan bagi geganti arus lebih satu arah mengalami masalah terpelantik kabur dan simpatetik serta di bawah jangkauan geganti jarak. Oleh itu, penyelesaian yang serius diperlukan untuk tujuan keselamatan dan untuk meningkatkan kebolehpercayaan sistem.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation	Specification
AC	Alternative Current
ACSR	Aluminum Conductor Steel Reinforce
AAAC	All-Aluminum-Alloy Conductor
CT	Current Transformer
CHP	Combined Heat and Power
DC	Direct Current
DG	Distributed Generation
DR	Distribution Resource
DN	Distribution Network
DSG	Distributed Synchronous Generator
EPS	Electric Power System
FC	Fuel Cell
FCL	Fault Current Limiter
GEN	Generator
IEEE	Institute of Electrical and Electronics Engineers
IDMT	Inverse Definite Minimum Time
I_p	Pickup Current
LV	Low Voltage
LTC	Load Tap Changer

mmf	Magneto Motive Force
OC	Overcurrent Relay
OHL	Overhead Line
ONAN/ONAF	Oil Cooling/Forced Air Cooling
PCC	Point of Common Coupling
p.u.	Per Unit
PV	Photovoltaic Cells (Solar Cell)
RCS	Remote Control System
SFCL	Superconductor Fault Current Limiter
TR	Transformer
TDS	Time Dial Setting
T	Operating Time
VT	Voltage Transformer
XLPE	Cross-Linked Polyethylene
UTeM	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

Symbol	Specification
ρ	Air Density
U	Wind Speed
C_P	Power Coefficient of Rotor (Aerodynamic)
Z	Impedance
R	Relay
Δ	Delta Transformer Configuration
Y	Wye Transformer Configuration
RMS	Electromechanical Transient
EMT	Electromagnetic Transient

CHAPTER 1

INTRODUCTION

1.1 Background

The first and simplest form of power generator in Iraq was developed in 1917 in the form of diesel-driven direct current (DC) generators, operating in the city of Baghdad. The generator, however, only served a small number of consumers. Following the success, other Iraqi cities began installing diesel stations and their distribution networks, such as the city of Kirkuk and Basrah in 1918, the city of Mousal in 1921, and the city of Ramadi in 1927.

In present, Iraq has around eight steam generation plants, 20 gas-powered facilities, and six main hydroelectric plants with expected capacity of 11,120 MW though some are being repaired. Among the power supplies, 40 percent is thermal, 22 percent is hydropower and 38 percent is gas-powered. The major problem faced by the power grid and electricity industry in Iraq is the shortage in a generation. This is mainly due to aging power plants, plus the lack of proper routine of overhaul maintenance. In addition, the political and economic circumstances in Iraq during the past 20 to 30 years make it difficult to install new generators. Generally, shortage in power generation, rapid rise in demand and consumption, and degradation of system components (due to aging and other reasons) all lead to long hours of load shedding and operation beyond standard limits (Hassan and Moghavvemi, n.d.; Reda et al., 2006).

One potential solution for these problems is the installation of small-size diesel generating units (defined here as distributed generating (DG) units). In reality, due the fact that load concentration in major cities and chaotic situation which hinder the construction of remote power stations with adequate transmission facilities, the addition of these DG units has to be in the already established stations, with condition if they are geographically possible due to shortage of space.

DG such as diesel engine can be easily directly installed in synchronous generator compared with conventional power generation. Therefore, many countries are interested in accommodating and extending DG in their distribution networks. Cost of the transmission line and distribution network construction is rising; however, the cost of DG technologies is descending. This makes it more economical to increase loads from DG to distribution feeders compared to expanding the transmission line and distribution facility (Willis and Scott, 2000). DG at distribution level has positive impacts on the system voltage profile and substations capacity. However, the extent of such benefits depends greatly on the DG size and location. Heavily loaded systems need more than one DG to rectify the voltage profile and to achieve other DG promised benefits (AlHajri and El-Hawary, 2007).

By integrating DG into the utility power grid, the line upgrades could be postponed, then there exists the possibility of a greater efficiency of the power delivery. The Power flow should be reduced, thus, minimizing losses. Particularly, the heavily loaded feeders or the transmission corridors could be relieved. This is also potential as opportunity for improving power quality, allowing the consumers and utility equipment to be more durable (To et al., 2007). However, DGs have significant impacts on electric utility power delivery systems. With higher levels of DG penetration, greater impacts are expected on both the transmission and distribution systems. DG basically will induce many protection issues to the distribution system during an event of a fault, for example, blinding and sympathetic, overcurrent relay and under-reach of distance relay (Sharkh et al., 2014). These impacts on protection system are mainly due to DG contribution to the fault current which are not considered in the planning stages. Furthermore, the presence of such DG causes the change of fault level and consequently on the previously mentioned protection problems.

1.2 Motivation for Research

To achieve the desired support from DG to the grid either by small part or most of the load, this means a large number of DG generators have to be embedded in the distributed network. However, large capacity installation of DG will induce severe power system problems. In the case of DG in Iraq, there have been registered problems of protection system without apparent reason. The worst case was a major fire in both DG system and the distribution substation, in addition to fatality to lives of employees who worked in the field of electrical network maintenance (Mozina, 2001). Therefore, the existing protection system should be more effective or work well to avoid such problems. For these reasons, this study will focus on investigating the impact of the DG on short circuit levels, which certainly will affect the protection system performance. However, to ensure successful large scale penetration of DG generators in existing distribution network, it is necessary to examine and understand the nature of these problems. Thus, researches need to be conducted to develop approaches for successful integration of DG generators in existing network.

The influence of DG based synchronous generator driven by diesel engine on protection coordination includes blinding, sympathetic of overcurrent, reduction in reach of distance relay and fault withstand capacity of devices, which have not been investigated in detail for medium voltage networks.

1.3 Problem Statement

Nowadays, global power electricity demand is growing at a tremendous rate. The main concern of any electrical utility is to generate adequate electricity to meet consumer demand. One potential solution is by installing DGs, which are small-scale generators interconnected to the power distribution system such as diesel generator system.

As traditional distribution systems have been designed to operate radially, the main issue will be the power flow by the new interconnected generation to existing power distribution system. In radial systems, the power flows from the upper terminal voltage down to customer site. Therefore, the protection system is easy to handle as long as the fault current only flows in one direction (Jenkins et al., 2008). However the presence of DG based diesel generator system in distribution system will change the fault level and consequently lead to protection system problems, such as blinding and sympathetic of overcurrent relay and under reach of distance relay. Thus, more complex protection investigation is necessary to overcome the appearing problems in a radial system.

To improvise the new configuration, distribution system design regarding DG technology, sizing and location must be taken into account these affect the short circuit levels and the protection chains strength.

1.4 Objective of Research

The objectives of this project are:

- To analyze the short circuit levels of the distribution system connected with DG based synchronous generators at different location of different voltage levels.
- To evaluate the performance and suitability of existing protection devices (overcurrent and distance relay in terms of blinding, sympathetic and under reach) against changing in short circuit levels.