STATIC AND DYNAMIC IMPACTS OF EMERGENCY GENERATOR IN POWER DISTRIBUTION SYSTEMS

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ABSTRACT

Nowadays, most of the people in this world cannot live without electricity especially to the patient at the hospital. Emergency power system is to improve power quality in delivering the electrical power to the customers. The utility company is responsible to locate emergency power system such as emergency generator. This project will presents the impacts of static and dynamic of emergency generator when it has been allocated in distribution systems. Static means the load flow and fault analysis while dynamic is transient stability analysis. 4-bus test system and 9-bus test system will be analyzed using PSCAD and MATLAB programs. The data of two test system are obtained from MATPOWER. The synchronous machine with exciter and governor model used as emergency generator. Critical loads are connected with the emergency generator. From the result, load flow was varied after an emergency generator placement. The real power is increase while reactive power is decrease during the switching caused by circuit breaker. It has a fault current when fault occurred in the system. Fault is setting in duration of 0.2s at 1.0s of time. Circuit breaker is opened to interrupt the circuit and isolate the fault in the system and close back after the fault is cleared. An emergency generator is supplied the voltage to critical load during the fault event. When fault occurred, it only gives the impacts to the line and the bus during the fault. Load angle of generator is experience to transient stability. Before fault occurs, it is in steady-state condition. Transient stability conditions occur after fault is clear then become in stability condition. For the conclusion, transient stability is not affected in distributing electricity to the customer. By placing an emergency generator, it has no problem in order to distribute energy to the load either in normal condition or abnormal condition.

ABSTRAK

Pada masa kini, ramai yang tidak dapat hidup tanpa tenaga elektrik terutamanya para pesakit di hospital. Sistem kuasa kecemasan juga adalah untuk memperbaiki kualiti kuasa dalam penghantaran kuasa elektrik kepada pengguna. Syarikat utiliti bertanggungjawab untuk meletakkan sistem kuasa kecemasan seperti penjana. Projek ini akan membentangkan kesan statik dan dinamik penjana kecemasan apabila ia diletakkan di dalam sistem distribusi. Statik adalah analisa arus beban dan kerosakan manakala dinamik pula adalah analisa kestabilan sementara. System ujian 4-bas dan system ujian 9-bas akan dianalisa dengan menggunakan program PSCAD dan MATLAB. Data sistem ujian diperolehi daripada MATPOWER. Model mesin segerak bersama perangsang dan pengawal digunakan sebagai penjana kecemasan. Beban kritikal dihubungkan dengan penjana kecemasan. Daripada keputusan yang diperolehi, arus beban telah berubah selepas dipasangkan penjana kecemasan. Kuasa nyata bertambah manakala kuasa reaktif berkurang semasa pertukaran yang disebabkan oleh pemutus litar. Adanya arus kerosakan apabila berlaku kerosakan di dalam sistem. Kerosakan telah disetkan dalam tempoh 0.2 saat pada 1.0 saat. Pemutus litar telah dibuka untuk mengganggu litar dan mengasingkan kerosakan daripada sistem dan menutup balik selepas tiada lagi kerosakan. Penjana kecemasan telah membekalkan voltan kepada beban kritikal semasa kerosakan berlaku. Apabila kerosakan berlaku, ia hanya memberi kesan kepada baris dan bas semasa kerosakan. Sudut beban pada penjana mengalami kestabilan sementara. Sebelum kerosakan berlaku, ia berada pada keadaan mantap. Selepas kerosakan tiada, keadaan kestabilan sementara berlaku dan sehingga ia menjadi keadaan yang stabil. Sebagai kesimpulannya, kestabilan sementara tidak memberi kesan dalam pengagihan elektrik kepada pengguna. Dengan meletakkan penjana kecemasan, ianya tiada masalah dalam mengagihkan tenaga kepada beban samada dalam keadaan normal mahupun tidak normal.

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LIST OF SYMBOLS

P	-	Real power
Q	-	Reactive power
S	-	Apparent power
V_{line}	-	Line voltage
V_{base}	-	Base voltage
$V_{line-line}$	-	Line-to-line voltage
V_{phase}	-	Phase voltage
Z_{base}	-	Base impedance
Z_{act}	-	Actual value of impedance
Z	-	Line impedance
X_L	-	Line inductance
L	-	Inductance
C	-	Capacitance
X_c	-	Line charging
C_{shunt}	-	Shunt capacitance
I_{phase}	-	Phase current
$I_{line-line}$	-	Line-to-line current
ω	-	Angular frequency
Π	-	pi
f	-	frequency
b	-	Susceptible line charging

LIST OF ABBREVIATION

PV	-	Generator bus
PQ	-	Load bus
RMS	-	Root-mean-square
DC	-	Direct current

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CHAPTER 1

INTRODUCTION

1.1 Overview of the project

This project is to study the static and dynamic impacts of emergency generator placement in power distribution system in order to improve the delivery electricity to consumer. Emergency power system are very important for lighting, control power, transportation, mechanical system, heating, refrigeration, production, space conditioning, fire protection, data processing, life support, communication systems and also signal systems. This project used generator as an emergency power systems. Other types of emergency power systems are battery charger and UPS that are used by customers. All this types of backup power are for protection to the power systems.

The commercial and industrial facilities as well as hospitals, high schools, colleges, jails and public safety facilities are already equipped with emergency power generation units. These units which run on diesel fuel that is already installed and is used in case of a service. The generators also require fuel onsite for their operation when running the generators more often, so they need for more onsite diesel fuel. It has been proposed that these emergency generating units also be put in operation to supply power during times of peak demand. Electrical power systems are susceptible to emergencies that can lead to the interruption of service to customers. This is also to avoid the damaged of equipments and to reduce the power quality crisis to customers and also to utilities.

Emergency generators come in a variety of types and have varying amounts of kilowatt (kW or 1000 watt) capacity. The average commercial grade generator will produce anywhere from 150kW to 800 kW. This is the standard range for generators installed in commercial buildings to support emergency equipment, such as lighting or elevators. For smaller buildings or those who only need generation for emergency lighting there are smaller generators available ranging from 50 to 150 kW. There also have the environmental quality issues when used the generators. They are produce noise and release large amounts of particle waste into the air. Other complications may also arise such as health and safety issues may offer challenges.

Although many industries using the emergency generator as a backup power systems, they should also to study and consider about the static and dynamic impacts of emergency generator placement such as load flow, fault current and transient stability in power distribution systems. This project required to perform some analysis by using two software's which MATPOWER3.2 and PSCAD to analyze two test case which 4-bus and 9-bus test systems.

1.2 Literature Review

For this project, I make some literature review before I start my project. This is very important to me for more understanding about this project. In 1997, Gordon S. Johnson had made his research about the integrity of emergency systems. In his paper, he was discussed about the emergency system performance. The performance of an emergency system under adverse conditions needs to be anticipated. Designers often apply circuit protection in the same as they would do with a utility source. It appears that performance under emergency power conditions is frequently not investigated. Generators have sub transient reactance of 10 to 25 percent, limiting bolted fault current to four to ten times rating. A molded case circuit breaker with an instantaneous trip set for eight to twelve times its rating will not function as short circuit protection when used as a main line breaker for a generator supply. Under short circuit the voltage of a generator that does not have excitation support will simply collapse without tripping the circuit breaker. Even if the breaker is rated at half the generator rating the breaker is not likely to trip. That main line breaker is not our principal concern [12].

In 1990 IEEE research paper was discuss about a new development in emergency power for small to mid sized CPE telephone systems. The specifications for wide variety of small generators from several manufacturers were evaluated. The sizes of generator ranged from 1kw to 10kw. It became very obvious that the smaller sizes did not have the peak current capabilities to power the loads. The loads are estimated to be 1kva of telephone or computer, 500 watts of emergency lighting and one small emergency air-conditioner at 1kva. The smallest size of generator that would power this load with a 20% margin was a 4kw generator. This size unit was selected for testing. The various types and brands of generators were tested for voltage regulation, frequency, wave shape and spurious electrical noise. The worst case unit provided frequency stability of ±5%, voltage +15% - 50% and 5volts to 100volts peak of high frequency transients [14].

In the previous research in 1993 was discuss about reliability analysis of electric supply including standby generators and uninterruptible power supply system. The objective of a standby and emergency system is to enhance the reliability of electric supply. Therefore its choice depends on the outage frequency and duration of utility supply and reliability and affordability requirements. In general, provision of higher reliability means increase in the cost of acquisition. This cost needs to be balanced with the cost of interruption to the customer. Therefore, for proper selection, methods of reliability calculation and of reliability worth are both important [15].

In 2008, El-werfelli, M.; Brooks, J.; Dunn, R. was made research about an optimized defense plan for a power system. On their paper, a Genetic Algorithm is applied to find the minimum amount of load shedding, following severe faults, at various frequency thresholds that are able to secure the network, or even enhance the dynamic performance. Also, another Genetic Algorithm is applied to obtain an optimal islanding scheme to geographically restrict the extent of the fault. Practically, defense plans are designed to act against incidents which are not covered at the system planning stage. There are many methods that can be used to prevent system collapse immediately following an incident. These include generator tripping, fast valving, load shedding excitation controls and system islanding. Of these, load shedding, generator tripping and system islanding are considered to be the most effective control actions. However, generator tripping is often associated with conservative networks. These defense schemes are based on the fact that, in extreme situations, it is better to shed some loads, or parts of the network, rather than to lose the whole network [16].

1.3 Objective

The objective of this project is to investigate the static and dynamic impacts of emergency generator placement in distribution systems. This is included to identify the impacts of power losses, fault current and transient stability in order to allocate the emergency generator in the system. To achieve this objective, the project is carried out by using the two test system which is 4-bus test system and 9-bus test system.

1.4 Scope of project

The scope of this project is focusing on the load flow and transient stability analysis by using the data from MATPOWER for 4-bus test system and 9-bus test systems. All this data is use to run load flow in MATLAB and model a single line diagram in PSCAD to get the load flow result.

1.4.1 Transient stability

In recent years, power systems have been operated under more stressed conditions and close to their stability limits. Due to recent blackouts, power system security has become a major concern. Under these circumstances, an important problem that is frequently considered for secure operation is the severity of transient stability. We will study on transient stability using two test systems. The influence of switching from utility to emergency condition will be investigated in transient stability analysis.

Transient stability is the ability of the power system to maintain in stability after large, major and sudden disturbances that are occurrence of faults, sudden load changes, loss of generating unit and line switching. Stability studies are conducted at planning level when new generating and transmitting facilities are developed. When emergency generators in the power system are start to running and to generate the electricity, the power system become stable are possible. There need time to become stability. Before it becomes stable, there are transient stability between steady state stability and stability. What is going to be analyzed in this project is transient stability.

1.4.2 Load Flow

The load flow study also known as power flow study which is an important tool involving numerical analysis applied to a power system. Unlike traditional circuit analysis, a power flow study usually uses simplified notation such as a one-line diagram and per-unit system, and focuses on various forms of AC power such as reactive, real, and apparent power rather than voltage and current. It analyses the power systems in normal steady-state operation. The great importance of power flow or load flow studies is in the planning the future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power flow study is the magnitude and phase angle of the voltage at each bus and the real and reactive power flowing in each line [13].

1.5 Problem statements

From this project, there are three problem statements. First is the importance of the emergency generator placement in power distribution systems. Emergency generator is very important because to prevent customers from disconnecting of electricity. Without electricity, the completion of the daily task becomes impossible. So it is important to hospital, commercial buildings and manufacturing industry because they might be have a problem such as health issues and economic loss when the grid utility was break-down or have any faults. The emergency generator is connected with the critical load and generate power when normal utility out of service. For example in hospitals, there are required for safety and insurance reasons to have emergency generation back up for use with important electrical equipment such as computer systems and life-support. Often most hospitals have more than one generator, one for their offices and another for emergency equipment.

Second, we need to choose the correct size of generator to place in the distribution system depends on the load capacity which will be used. If we used the larger capacity of loads, we need to use the larger capacity of generator to avoid the generator become damage. For an example, the generator can supply only 30% of total power if a single-phase load is connected. Some hospitals, depending on their size, may have three or four generators. So we need to make some calculation before install the emergency generator for the critical load.

The third problem is the impacts of emergency generator installations to the distribution systems. The impacts that we need to study in this project is the power losses, fault current and transient stability that appeared in the distribution system when the generator is start-up and during the generator is running.

1.6 Report Outline

This report includes six chapters. The first chapter is an introduction which is an overview of the project, literature review, objectives, scope of the project that will discuss about transient stability and load flow and problem statements. In chapter two states the detail explanation about the project which include introduction, static and dynamic impacts, emergency generator, power distribution system, transfer switch, circuit breaker and summary of the chapter. In the chapter three, the modeling of the project, MATPOWER3.2 and PSCAD/EMTDC tools and also the test system that will be analyzed are discussed. The results and discussions will be covered on chapter four which include the load flow analysis, faults analysis and transient stability analysis. This chapter will show the result of the graph from the PSCAD that has to be discussed after we do the simulation of the test systems. The comparisons of two results are using the table. The conclusion and recommendation of this project is in the last chapter.

CHAPTER 2

STATIC AND DYNAMIC IMPACTS OF EMERGENCY GENERATOR IN POWER DISTRIBUTION SYSTEMS

2.1 Introduction

This project will study about the static and dynamic impact. The static in this project means the load flow and dynamic is the transient stability. A load flow study calculates the real power and reactive power flows in a power system. A model of the real system is made using a computer power system simulation program such as PSCAD. The results show how the electrical system will perform in emergency operating conditions. The load flow study is necessary as the first step before move to the transient stability study.

2.2 Static and Dynamic Impacts

2.2.1 Static Impact

We will gain the static impact result after doing the load flow and fault analysis. The load flow analysis is concerned with describing the operating state to an entire power system. Typically, the amount of power generated and consumed by the customers is at different locations. The load flow analysis will determine the unknown quantities by a given such known quantities such as voltage magnitude and voltage angle. From these quantities, the flowing of power can be determines. The load flow in power system was produced a power losses between from bus injection into bus injection. Generators are represented in power system to generate the power. Fault studies are an important part of power system analysis. There are various types of fault which can be divided into three-phase balanced faults and unbalanced faults. The various types of faults are single line-to-ground fault, line-to-line fault and double line-to-ground fault. The magnitude of the fault currents depends on the internal impedance of the generators plus the impedance of intervening circuit.

2.2.2 Dynamic Impact

Dynamic impact in this project is a transient stability. Transient stability study is usually performed on commercial or industrial power systems with large amounts of local generation. This type of study is essential when adding or upgrading generators within a facility. Stability is defined as the ability of a power system to experience a sudden change in generation, load or system characteristics without a loss of synchronism. Dynamic stability studies examine long-term effects of various disturbances. They are effective for large and extensive systems where heavily loaded machines exist. In such cases, a disturbance may initiate very low-frequency oscillations between and among machines, which can be amplified over a relatively long period of time, ultimately resulting in a partial or complete outage. Dynamic stability studies can establish load shedding schemes and evaluate the effects of motor starting conditions.

Whenever a load is applied to or removed from a generator set, the engine speed, voltage, and frequency will experience a transient condition or a temporary change from its steady-state condition. When the emergency loads are removed, the engine speed increases momentarily, causing system overshoot before returning to its steady-state condition. The time required for the generator set to return to its normal steady-state speed is called recovery time.

2.3 Emergency Generator

The emergency power system does not instantaneously become available upon the loss of the normal power supply source. It takes some time to get the emergency generator system started. Starting requirements will vary depending on the application. Emergency generator sets can typically start to accept loads when they reach approximately 90% to 95% of rated frequency, at which point the breaker closure is initiated. Emergency generators will operate with the engine governor set for isochronous control for load frequency control, which maintains the engine-generator at a constant speed with no governor droop, while not synchronized to the electrical power system.

The order of emergency generator units' startup and shutdown is also important. If the same generator unit is always started first, it will accumulate hours and maintenance expenses at a higher rate than the remaining units. To make the operating hours among the units more uniform, the first unit to start can be designated as the first unit to shut down as the emergency loads are restored to normal power supply source. The emergency generator control system can monitor the remaining emergency load and generator capacity and control the unloading of the generator units for a smooth shutdown sequence. An emergency power system with paralleling capability has tremendous advantages.

The parallel capability allows for closed transition transfer, provides the ability to load test the emergency generator system without using load banks, and provides electrical peak shaving or demand management capability. To operate in parallel, the system voltage, frequency, and phase angle must be within prescribed limits. In other words, the generator units must be at the same speed and frequency, operate with the same frequency directional rotation, and produce almost exact sine waves. When paralleling sources, fault current contributions from parallel sources and protective relay protection requirements should be considered in the system design.

2.4 Power Distribution Systems

In the early days of electricity distribution, direct current (DC) generators were connected to loads at the same voltage. The generation, transmission and loads had to be of the same voltage because there was no way of changing DC voltage levels, other than inefficient motor-generator sets. Low DC voltages were used on the order of 100 volts since that was a practical voltage for incandescent lamps, which were the primary electrical load. Low voltage also required less insulation for safe distribution within buildings.

Distribution networks are typically of two types which are the radial and interconnected. A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical of long rural lines with isolated load areas. An interconnected network is generally found in more urban areas and will have multiple connections to other points of supply. These points of connection are normally open but allow various configurations by the operating utility by closing and opening switches. The benefit of the interconnected model is that in the event of a fault or required maintenance a small area of network can be isolated and the remainder kept on supply.

Within these networks there may be a mix of overhead line construction utilizing traditional utility poles and wires and, increasingly, underground construction with cables and indoor or cabinet substations. However, underground distribution is significantly more expensive than overhead construction. In part to reduce this cost,