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ANTI ISLANDING PROTECTION FOR DISTRIBUTED GENERATION VIA OPEN LOOP VOLTAGE AND CURRENT CONTROL TECHNIQUE

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DEDICATION

This report is dedicated to my father and my mother, who taught me the best kind of knowledge, and they taught me that even the largest task can be accomplished if it is done one step at a time. It is also dedicated to my beloved wife and my dear daughter who stood with me at every moment and endured with me all the difficulties in my study life.

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ABSTRACT

With the advancement of modern technology, Distributed Generation (DG) systems were introduced to strengthen distribution networks and ensure the delivery of electric power with high quality and reliability, as well as to reduce large losses in electrical energy. The DG systems receive great attention and care from researchers and specialists in the field of electrical energy to supply power with high quality. Despite the benefits of DG systems, they confront significant obstacles that have severe consequences for the system, equipment, maintenance employees, and loads. Unintentional islanding is an abnormal event when a component of the distribution system gets electrically disconnected and the loads are supplied with the energy by the DG only. It is one of the most significant issues that have a large impact on the electrical network, especially in the terms of the protection system. Therefore, anti-islanding protection (AIP) is an important part of the islanding prevention system and detection. Many studies have been conducted in the past to determine islanding using a variety of methodologies based on databases. However, these studies faced various limitations during the implementation of these techniques such as a failure in an accurate time of islanding detection, the detection with the presence of faults, and power quality impacts. In this project, the Open Loop Voltage and Current Control (OLVCC AIP) approach is designed and implemented in the Iraqi radial distribution system that consists of the 3- phase 50 HZ 6-bus of 1200 kVA and 20-bus of 31.5 MVA. The accurate time of unintentional islanding is detected using the OLVCC AIP strategy and compared with the reference measurements of normal operating conditions. The effectiveness of the OLVCC AIP approach is observed in various types of faults in the system. Furthermore, MATLAB/Simulink simulation is used in this project. The OLVCC AIP technique performance is validated by comparing it with the voltage index and line current technique. As a result, the proposed technique effectively detected inadvertent islanding in all scenarios in terms of accurate time without any power quality degradation. The proposed approach improved the performance by 52.88% in identifying the islanding.

ABSTRAK

Dengan kemajuan teknologi moden, sistem Penjanaan Teragih (DG) diperkenalkan untuk mengukuhkan rangkaian pengedaran dan memastikan penyampaian kuasa elektrik dengan kualiti dan kebolehpercayaan tinggi, serta mengurangkan kerugian besar dalam tenaga elektrik. Sistem DG mendapat perhatian dan penjagaan yang tinggi daripada penyelidik dan pakar dalam bidang tenaga elektrik untuk membekalkan kuasa dengan kualiti yang tinggi. Walaupun terdapat manfaat sistem DG, mereka menghadapi halangan ketara yang mempunyai akibat yang teruk untuk sistem, peralatan, pekerja penyelenggaraan dan beban. Pepulauan yang tidak disengajakan ialah kejadian tidak normal apabila komponen sistem pengedaran terputus sambungan elektrik dan beban dibekalkan dengan tenaga oleh DG sahaja. Ia adalah salah satu isu paling ketara yang memberi kesan besar kepada rangkaian elektrik, terutamanya dari segi sistem perlindungan. Oleh itu, perlindungan anti-pulau (AIP) adalah bahagian penting dalam sistem pencegahan dan pengesanan pulau. Banyak kajian telah dijalankan pada masa lalu untuk menentukan kepulauan menggunakan pelbagai metodologi berdasarkan pangkalan data. Walau bagaimanapun, kajian ini menghadapi pelbagai batasan semasa pelaksanaan teknik ini seperti kegagalan dalam masa pengesanan pulau yang tepat, pengesanan dengan kehadiran kerosakan, dan kesan kualiti kuasa. Dalam projek ini, pendekatan Voltan dan Kawalan Arus Gelung Terbuka (OLVCC AIP) direka dan dilaksanakan dalam sistem pengedaran jejari Iraq yang terdiri daripada bas 3-fasa 50 HZ 6-bas 1200 kVA dan 20-bas 31.5 MVA. Masa tepat pengembaraan pulau yang tidak disengajakan dikesan menggunakan strategi OLVCC AIP dan dibandingkan dengan ukuran rujukan keadaan operasi biasa. Keberkesanan pendekatan OLVCC AIP diperhatikan dalam pelbagai jenis kerosakan dalam sistem. Tambahan pula, simulasi MATLAB/Simulink digunakan dalam projek ini. Prestasi teknik AIP OLVCC disahkan dengan membandingkannya dengan indeks voltan dan teknik arus talian. Hasilnya, teknik yang dicadangkan berkesan mengesan pulau yang tidak disengajakan dalam semua senario dari segi masa yang tepat tanpa sebarang penurunan kualiti kuasa. Pendekatan yang dicadangkan telah meningkatkan prestasi sebanyak 52.88% dalam mengenal pasti pulau tersebut.

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LIST OF ABBREVIATIONS

DEG	-	Distributed Energy Resources
DG	-	Distributed Generation
IEEE STD	-	Institute of Electrical and Electronic Engineers Standard
AIP	-	Anti Islanding Protection
MV	-	Medium Voltage
LV	-	Low Voltage
PCC	-	Point of Common Coupling
NDZ	-	Non Detection Zone
PLCC	-	Power Line Carrier Communications
THD	-	Total Harmonic Distortion
CIDI	-	Current Islanding Detection Indicator
FTV	-	First Criterion Values
STV	-	Second Criterion Values
VSC	-	Voltage Source Control
LFBD	-	Locking Frequency Band Detection
SVS	-	Sandia voltage shift
UV	-	Under Voltage
OV	-	Over Voltage
UF	-	Under Frequency
OF	-	Over Frequency
ROCOF	-	Rate of Change of Frequency
OVP	-	Over Voltage Protection
UVP	-	Under Voltage Protection
GMS	-	Gaussian Modulated Signal
UTM	-	University Technology Malaysia
OLVCC	-	Open Loop Voltage and Current Control
BCC	-	Bus of Common Coupling
SLG	-	Single Line to Ground
DLG	-	Double Line to Ground

LIST OF SYMBOLS

f	-	Resonant Frequency
Q_f	-	Power Quality Factor
V	-	Voltage
R	-	Resistance
L	-	Inductance
C	-	Capacitance
P_{load}	-	Load Real Power
Q_{load}	-	Load Reactive Power
V_a	-	Phase A voltage
V_b	-	Phase B voltage
V_c	-	Phase C voltage

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CHAPTER 1

INTRODUCTION

1.1 Background of project

Electrical power systems are major energy supply and delivery systems in real-time and at acceptable voltages without any problem in the supply. Electrical power is the main source of people's daily lives. Electric power systems are developed in proportion to the increase in demand as a result of the expansion of important facilities such as commercial, industrial, and domestic activities, and other activities that require electrical current to perform their tasks. The development of power systems has resulted in an expansion of their different sizes and types. The essential components of an electric power system are generation, transmission, and distribution systems, as shown in Figure 1.1. Generators produce the energy required by demand. The system begins with a generation process that produces electric energy in the power station using many different energy sources. Then in the transmission system, high voltage power lines efficiently transfer the electrical power to consumer sites over long distances with high efficiency. Finally, substations convert this high-voltage electric power into a low-voltage that is transmitted across distribution power lines to residential, industrial, and commercial consumption.

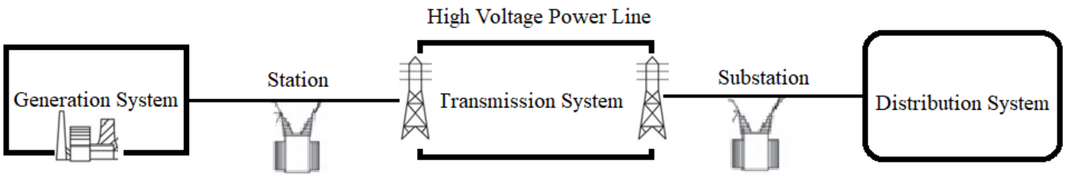

Figure 1.1 The Essential Components of An Electric Power System

The great demand for electric energy, especially at the beginning of the last century, led to an increase in the burden on power plants that use fossil fuel derivatives such as oil, gas, coal, etc. This, in turn, affects the sustainability of these resources in generating electric power to meet the needs of consumers. In addition, there are other challenges related to the patterns of existing electrical power systems and their sustainability in the medium and long term, which relate to the quality and stability of electrical power. In the era of the rapid development of modern technology, which contributed to relieving the burden on electric power stations, the Distribution Generation (DG) system was introduced in order to support electrical networks, especially distribution networks, to deliver electricity to consumers (commercial, industrial, and domestic) reliably, economically, and high quality. Therefore, the generation distribution system has been of great importance in the field of research, which aims to link it with distribution networks to be close to the loads. DGs are an integral part of energy systems as their inclusion aims to reduce environmental pollution from the use of fossil fuel derivatives, improve system resilience, reduce energy losses, meet load requirements and increase system efficiency from an economic and technical perspective [1].

A DG unit is an electrical generator that generates alternating current and operates in parallel with the utility distribution system to provide power to the load. For DG operations, there are two sorts of generators: inverter-based and rotating machines. One of the important factors to consider in connecting DGs with the utilized network is to require a coordinated and sustained generating of power between all the units in a grid as well as their location. Moreover, when connecting and operating the DGs systems with the distribution networks, all measures must be taken to protect the electrical network and its vehicles, as well as the load in the event of any problem in the network, whether it is from the distribution network or from the DGs [2]. Concerns have arisen about distribution network protection due to the fact that fast-growing DG units and cause a host of technical problems, such as islanding, Unsynchronized reclosing, system security, maloperation of protection facilities, reliability and stability, and voltage regulation. The protection systems for the electric power system are important and necessary when linking the DG systems with the distribution networks in order to avoid risks to the electrical network, as well as which lead to material damage to the basic components of the network, as well as to consumers of all kinds.

Islanding is one of the main problems faced by the network, which has an important negative effect on the network such as the distribution stations as well as the loads. According to IEEE STD 1547-2008 [3], Islanding can be defined as an abnormal event of the network when a component of the distribution system gets electrically disconnected from the power system's reset but is still supplied by the DG linked to it as shown in Figure 1.2. Normally, the distribution network lacks active power generation sources, and it is left without power when the fault in the upstream of the transmission line occurs. The DG, on the other hand, will continue to supply power to the utility system and the load. Islanding can be identified as intentional or unintentional islanding [4]. During a catastrophic utility outage, intentional islanding occurs when a DG source sustains to supply electricity to local loads. Unintentional DG islanding occurs when a section of a power distribution system is isolated from the primary supply source (distribution substation) but is still powered by the DGs. The risks that an islanded operation provides to distribution utility staff, customers, and substations. Because the power quality parameters (voltage and frequency) in the isolated system may not be within acceptable limits, the power system equipment may be destroyed as a result of insufficient protection and poor power quality. As a result, research into islanding detecting technologies is both necessary and valuable.

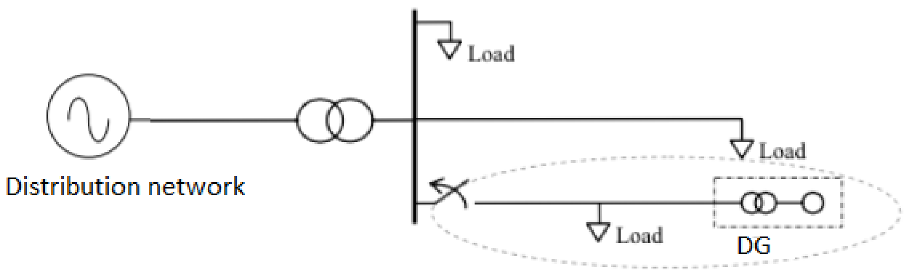

Figure 1.2 Islanding situation

The most important issue that is the voltage and frequency parameters of the main electricity delivered in the distribution line must be followed by grid-interactive inverters. To maintain proper communication with the utility supply as well as for protection, DG systems should be integrated with a real-time monitoring equipment.

Islanding detection in the power system is a primary protection for the power system and a big challenge, especially in the distribution system because it protects the system, electricity workers, and the loads or customers as well as the cost, time, and effort. The fundamental reason for anti-islanding is that there's a danger that deviation to the voltage and frequency of the generator can harm systems in the islanded section. The risk of electric shock to maintenance workers is more increased as they do not know that islanding occurs outside in their service section [5]. The system if not coupled with high-grade equipment, can potentially lead to the area becoming dynamic overload zone or overcurrent which means the transient overcurrent run through the array to cause problems. This could result in damages to certain equipment as well as those that are sensitive [6]. In the event of islanding, the DG system must be disconnected from the network and the loads immediately because it may cause significant damage to the network equipment as a result of the flow of transient currents through the DG system and thus lead to damage to the circuit breakers and the main protection equipment [6]. In this project, the anti-islanding protection (OLVCC AIP) approach using open-loop voltage and current control is presented to detect the accurate time of islanding in the system without impact on the power quality of the network in order to overcome unintentional islanding and protect the whole system and maintenance workers. The OLVCC AIP technique has several processes based on synchronous parameters and measurement of the voltage at the bus of common coupling and the deviation of the frequency during islanding when any unintentional islanding cause may occur.

1.2 Problem Statement

Changing the source of power through the presence of DG units could have an impact on the efficiency and power loss of the system. Unfortunately, as mentioned before, Islanding phenomena can be occurred intentionally or inadvertently [3]. The safety, liability, and quality of provided power are high on the priority list in utility systems. The distribution networks connected with the DG systems may encounter unnatural conditions which are when one or more main network feeders are separated through cycle circuit breakers that feed the loads. This condition leads to unfavorable operating conditions that cause major problems in the network equipment and the safety of workers in the field of electricity and maintenance in addition that damage the loads connected to the network due to unintentional islanding. Therefore, great importance must be given to secure this system and provide adequate protection for it to ensure the sustainability and security of electrical energy as well as the safety of the workers. The islanding detection or anti-islanding protection technique is regarded as an important research topic because it offers consumers even the substations numerous benefits as well as protection.

There are several strategies of data-based methods to analyze and determine unintentional islanding in the power system: those that depend on voltages, frequencies, harmonics, impedances of the network, and the active and reactive power through several algorithms that have been developed recently. Several attempts in several studies and works have been done using different techniques depending on these data-bases. Although there are certain methods that have their own strength and efficiency as compared to others, they have different methods and limitations that come to light when performing those techniques new the different cases. Some approaches, for example, are a failure in identifying an accurate time of islanding detection, the detection with the presence of faults, power quality impacts and cost in implementing.

Thus, anti-islanding protection is the main topic to reach satisfactory results in the work since it saves a lot of things like cost, effort, and time to achieve goals. Thus, there is still a need to use improved technologies or implement the strategies through different strategies to reach accurate results. Furthermore, there is a need to develop and validate the studies and researches for islanding detection. In this project, the optimum Open Loop Voltage and Current Control (OLVCC) AIP technique is chosen in order to identify unintentional islanding in the distribution system with DG unit without any impact on the power quality of the system.

1.3 Objectives

The aim of this project is to identify the accurate unintentional islanding in order to protect the whole power system, electricity workers, loads, as well as the DG unit. In order to achieve this aim, there some list of objectives are prepared, which are:

i. To design the Open Loop Voltage and Current Control (OLVCC AIP) technique in order to implement it in the power system.

ii. To determine the accurate time of unintentional islanding using the proposed technique and compare the results with the reference measurements of the normal operating condition of the power system.

iii. To observe the effectiveness of the proposed technique in the various types of faults in the power system.

iv. To validate the performance of the OLVCC AIP technique by comparing it with the Voltage Index and Line Current technique.

1.4 Project Scope

This project includes an extensive study for islanding determination by using the AIP technique in order to protect the whole system as well as the electrical workers. The following are the areas in this project:

i. The power system of 6-bus and 20-bus of the Iraqi distribution power system has been used and tested through the OLVCC AIP technique.

ii. Select the optimal technical parameter for islanding detection including (utility system, MV/LV transformer, Power of RLC loads, and DG unit).

iii. Simulation using MATLAB/SIMULINK software has been used to analyze and validate the accuracy performance of the OLVCC AIP technique.

1.5 Project Outline

This project includes five chapters. Chapter 1 covers the introduction, involving the background of the project, problem statement, objectives, and also the scope of the study.

Chapter 2 illustrates and discusses an overview of the background of islanding phenomena in power systems especially in the distribution network with the distributed generator units, the types of islanding, and the techniques of anti-islanding. Besides, the literature review of the anti islanding methods of related previous studies involves a comprehensive explanation of the advantages and disadvantages of each approach, as well as the principle of operation to comprehend the project case. Finally, this chapter critically reviews the previous works in the researches of islanding detection methods.

Chapter 3 discusses the methodology of the whole project. A detailed procedure of project works is described and depicted in a flowchart. It also discusses the test system and the data used in this project to reach accurate results. The economically efficient and reliable method used in this project to achieve the objectives is the OLVCC AIP. Besides, the frameworks of the OLVCC technique operation and its implementation through this project are also explained in this chapter.

Chapter 4 includes the results of this project and their discussion. Many different scenarios are simulated and implemented in the 3- phase 6-bus and 20-bus radial distribution systems in order to obtain accurate results, analyze them, and be reinforced by illustrative figures for the results.

Chapter 5 overviews project management, which includes a project schedule in Gantt Chart format.

Chapter 6 covers the project's completion, as well as some ideas and recommendations for future research based on the project's findings.

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