“I hereby declare that I have read through this report entitle “Islanding Detection Using Passive Reactive Power Imbalance Method” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : ....

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Date : ………………………………..

ISLANDING DETECTION USING PASSIVE REACTIVE POWER IMBALANCE METHOD

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering
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JUNE 2013

I declare that this report entitle “Islanding Detection Using Passive Reactive Power Imbalance Method” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ....

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ACKNOWLEDGEMENT

First and foremost, I would like to thank god for His blessing. Without gods' bless I will not able to complete this research as required. Besides, the help and support from certain groups and individual has encouraged me to finish up this project.

In conjunction, my deepest appreciation to Dr. Gan Chin Kim, my supervisor who had given me endless help, guidance, and support me to make up with the standard as required as an Electrical Engineer student during the final year project. His words and kindness have kept me in orders for me make this project a valuable experience. Even though I have to gone though many difficulties during the process to complete the project, I have successfully finished my project. I also would like to say special thanks to my parent because of their support in term of financial and advice.

Last but not least, thanks to all my friends for giving me support to obtain output of this project and spending their time to share the knowledge and information related to my project. All of the idea and opinion giving by them are very useful and effective to develop and finish this project.

All the knowledge gained at Universiti Teknikal Malaysia Melaka present here in my project report. Finally, I am indebted to all those people who have directly or indirectly helped to make my final year report stint an incredible journey of knowledge and self-improvement.

ABSTRACT

In this era of technology, usage of Micro-Grid at domestic areas has become a new attraction due to its several advantages. The major function of a micro-grid is to ensure a stable operation during the fault at a variety of utility grid disruption. Since the utilization of micro-grid is becoming common, performing in the correct application and operation of micro-grid is important and significant. One of the main challenges in micro-grid operation is islanding detection method. There are several methods that handle the islanding detection that each one of it has its own advantages and disadvantage. This paper presents and investigates the reactive power imbalance method for islanding detection. It is one of the passive methods used. This method was implemented in the case study because of it's simple, effective and low cost operation. However it has the higher non-detection zone (NDZ) and slower response time compare to some active methods. The micro-grid simulation is modelled in MATLAB/Simulink program and the results of the monitoring are discussed as well. As the result, the performance of the Reactive Power Imbalance method for islanding detection state is compared with the simulation model with various load power factor. Finally, the micro-grid model capability with control algorithm is shown in order to meet the load demand.

ABSTRAK

Micro-grid merupakan salah satu sistem penjanaan kuasa yang berupaya untuk beroperasi secara bersendirian supaya menampung beban terdekat. Keupayaan ini boleh diaplikasi apabila sistem penghantaran kuasa mengalami sesar. Terdapat beberapa jenis cara untuk mengesan kes-kes sesaran. Di antaranya adalah kaedah aktif, kaedah pasif, kaedah komunikasi dan sebagainya. Kajian ini dilakukan atas kesan sesaran apabila micro-gid berada dalam keadaan terpinggir dengan menggunakan kaedah pasif. Secara terperinciri, kaedah pasif kuasa reaktif telah dikaji untuk menilai ciri-ciri beban pada factor kuasa yang berbeza. Semakin tinggi nilai faktor kuasa hingga menghampiri uniti, semakin kurang kesan penggunaan mikro-grid pada nilai kuasa aktif, kuasa reaktif, voltan fasa-ke-bumi dan arus fasa-ke-bumi. Dengan pengunnan kaedah pasif kuasa reaktif, masa yang diambil untuk memperbaiki kesan sesaran boleh ditentukan. Bagi mengkaji kaedah ini, simulasi pada MATLAB/Simulink telah berupaya untuk membantu bagi menjayakan kajian malah memudahkan proses pengambilan data pada setiap pembolehubah yang digunakan.

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LIST OF SYMBOLS

Vp	–	Phase-to-ground Peak Voltage
Ip	–	Phase-to-ground Peak Current
P	–	Active Power
Q	–	Reactive Power
D	–	Detection Index
D^{th}	--	Detection Index Threshold Value
DG	–	Distributed Generation
RPIM	--	Reactive Power Imbalance Monitoring
IS	--	Islanding Switch
θ	--	Phase angle between DG Voltage and DG Current
ø	--	Phase angle between Load Voltage and Load Current
V_{DG}	--	DG Phase-to-ground Voltage
I_{DG}	--	DG Phase-to-ground Current
Q_{DG}	--	DG Reactive Power
V_{LD}	--	Load Phase-to-ground Voltage
I_{LD}	--	Load Phase-to-ground Current
Z_{LD}	--	Load Impedance
Y_{LD}	--	Load Admittance
I_N	--	Utility Grid Phase-to-ground Peak Current
S_{DG}	--	DG Short Circuit Level

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CHAPTER 1

INTRODUCTION

The main energy provider in Malaysia is Tenaga Nasional Berhad (TNB). It is a private company that is wholly owned by the government in 1990. Besides, there are also two other national energy provider in Sabah and Sarawak such as Sabah Electricity Sendrian Berhad (SESB) and Sarawak Electricity Supply Corporation (SESCO) respectively [1]. Distributed Generation (DG) is a small scale power system that is powered by the renewable energy to support the demand of electricity at local load.

1.1 Problem Statement

Problems occur when the power system happens to have fault during the connection of the Distributed Generation (DG) to support the demand of the electricity at the local load. If the fault is a three-phase line-to-ground fault, the supply from the national grid and DG is grounded. This operation will lead to unintentional islanding for the DG system. The project is to disconnect the utility line to supply power to the local load meanwhile performing an operation to support the local load demand. Once it is disconnected, the DG is in the islanding state because the local load is supplied by the DG. This immediate system is known as micro-grid due to its islanding state that operates as a standalone system. Unintentional islanding is a very hazardous state for the technical workers during installation, as they do not acknowledge that the local load is still supplying by the DG. Besides, the purpose of detecting the islanding mode is to prevent various magnitudes of voltage and frequency being supply the equipment without bothering the demand of the load. This project was to build a simulation circuit and performing a case study during the three-phase line-to-ground fault condition in order to clear the fault condition from affecting the local load.

1.2 Objectives

The three main objectives of analysing the Micro-grid operation are:

i. To detect islanding state of the micro-grid model using MATLAB/Simulink
ii. To detect a three-phase line-to-ground fault at the power system modelling by using MATLAB/Simulink software.
iii. To model and monitor the Passive Reactive Power Imbalance method in MATLAB/Simulink.

1.3 Project Scopes

The scopes of this project are:

i. Detect the islanding state using Passive Reactive Power Imbalance Method.
ii. The Micro-grid system is operated on a three-phase system of 400V and frequency of 50Hz.
iii. The circuit is analysed for a three-phase line-to-ground fault condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Project Background

The prime mover of the national energy providers are mostly non-renewable energy such as coal and gas. Statistically, the usage of natural gas is 62.9%, coal is 26.7% and 10% usage of hydro-electric generation in 2007. 0.4% is a usage of other non-renewable energy such as diesel and oil. Hydro-electric is one of the major renewable energy used as prime mover according to the statistic [2].

The research of renewable energy is being analysed due to its ability to maintain the supply of source continuously. The renewable energies available in Malaysia are solar, wind and hydro but the installation of these sources as a prime mover in a big scale is very expensive. In conjunction to make use of this renewable energy in national grid, it is built in a small scale that supports the local load demand [2]. National grid is also known as utility grid.

2.2 Micro-grid

Micro-grid is cheapest power systems that do not have a transmission line. Micro-grid system is also known as a stand-alone system that has its own generator, transformer and protection system. The generator of a micro-grid system is also known as Distributed Generation (DG). DG is typically includes internal gas turbines, micro-turbines, photovoltaic, fuel cells and many types of renewable energy [3].

At the normal condition, the demand of the load is being shared by the utility grid and DG. Both grids are connected at the Point of Common Coupling (PCC) to share the local load. The one line diagram of the power system mentioned before is illustrated at Figure 2.2.1. When the fault occurs in the transmission line, the micro-grid will tend to support the load demand as a whole automatically. This situation of the micro-grid is known as unintentional islanding mode [3].

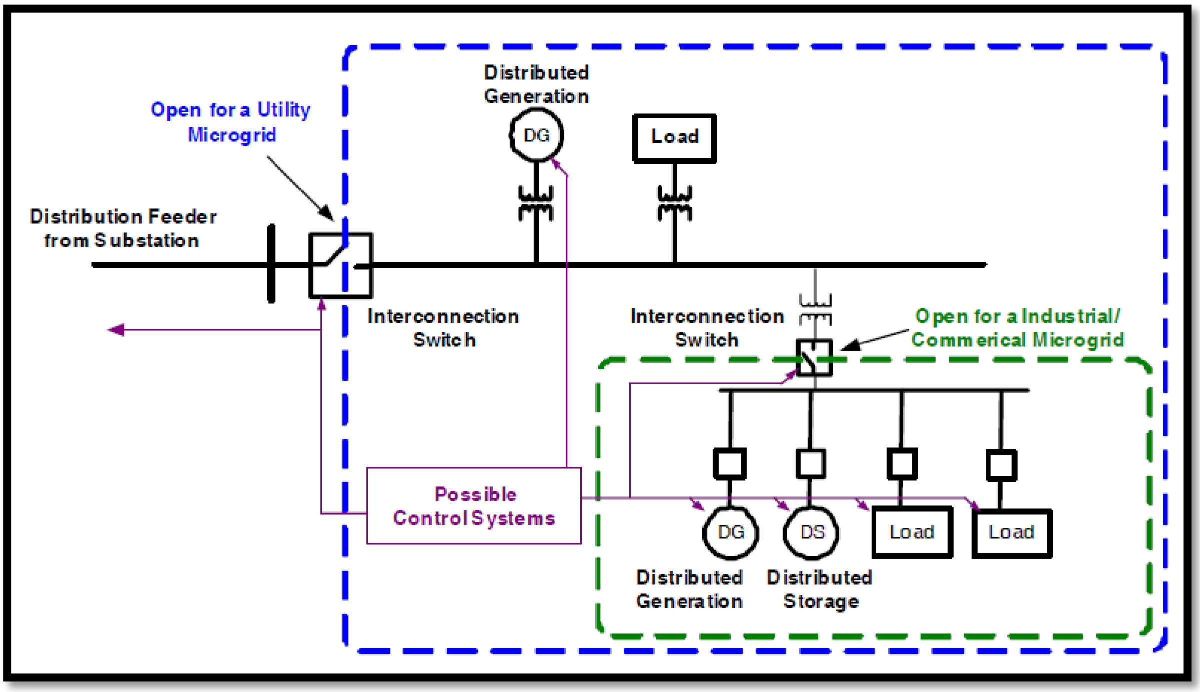

Figure 2.2.1: One line diagram of Micro-grid system [3]

2.3 Islanding State in Micro-Grid

Islanding mode has two types such as intentional and unintentional Islanding. Intentional islanding happens with a planned shutdown of the utility grid during maintenance whereby unintentional islanding mode happens during unplanned shutdown of the utility grid due to occurrence of fault. This occurrence of unintentional islanding mode is unknown because the load is still managing to supply power by the DG [4].

One of the most important issues occur at power system is when the utility grid becomes unavailable. At this point of moment, the micro-grids should be eligible to active its islanding state condition in order to continuously support and meets the local load demand. It is important in terms of safety to let to the utility grid to stay in normal operation and restore the power system.

The islanding detection methods are shown in Figure 2.3.1 that there are two important categories of islanding detection techniques which are Local and communication methods. Local methods are divided into major group such as passive and active methods. On the other hand, communication methods are divided into two methods such as Power Line Carrier Communication (PLCC) and Supervisory Control and Data Acquisition (SCADA) [5].

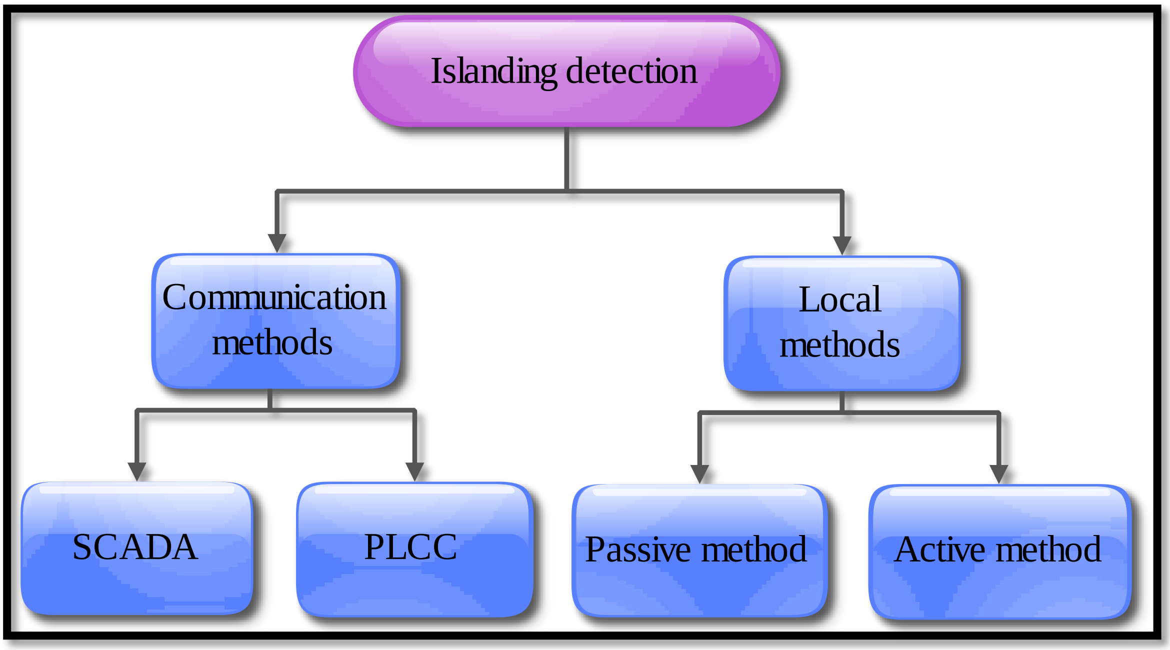

Figure 2.3.1: Islanding Detection Methods [5]

The disadvantages of passive methods are being corrected by the active methods distortion controller or positive feedback to the system. Communication methods are similar to the passive method such as measuring the parameter on both utility and micro-grids but it the measured parameters in communication methods is being send to the control room by wireless, high speed LAN, broadband and mobile. The interfaces of the data transfer are either PLCC or SCADA [5].

There are few advantages of connecting the micro-grid system with the utility grid system at the PCC. A micro-grid system is flexible of locating DG nearer to the load area. It is because DG is a small-scale power system grid and eliminates the transmission line of the power system. On the other hand, due to low voltage supply from the renewable energy is another reason for locating DG nearer to the load.

Micro-grid is a beneficial power system grid because of its capability of improving the reliability of power usage at load. It is a standalone grid that has the ability to support the load demand when failure occurs at the utility grid system. In addition, micro-grid also reduces transmission losses, reduces cost of cables to set up transmission network, reduces the peak demand at national grid system, and defers the investment [6].

On the other hand, it also have disadvantages such as high maintenance cost, lesser protection during fault for the load and intermittent grids, and it does not have a consistent of power flow to the load. TABLE I shows the characteristics of various islanding detection methods [7].

Table 2.3.1: Comparisons of islanding detection characteristics [7]

Characteristic	**Local detection method**		**Remote detection method**	
	Active Method	Passive Method	Utility Method	Communication Method
Operations	Injection of disturbance signal at parameters	Monitoring the parameters at PCC	Installing specific equipment at utility	Installing communication equipment
Non Detection Zone (NDZ)	Small	Large	None	None
Response time	Slightly shorter than passive method	Short	Fast	Faster
System cost	Medium	Low	Very high	Extremely high

2.4 Passive Method

From the simple analysis of the characteristic table of each method of Table 2.3.1, passive method is used to monitor the parameters at the PCC. Besides, to set up the system of passive method is cheaper compared to the other methods mentioned in the characteristic table above. Although the passive method is cheap, but it has a large portion of non-detection zone (NDZ) and the response time is much slower than the other three methods such as active method, utility method and communication based method [7].

Passive methods are based on measuring some parameters of the power system at Point of Common Coupling (PCC) and analysis them to detect the islanding. Each parameter has certain range and normal operation. If the measured value is not satisfied with the range the algorithm that is set, the system will detect the islanding condition of the Micro-grid. The measured parameters can be voltage, current, frequency, active power and reactive power [8].

Over/Under Voltage Protection (OVP/UVP) and Over/Under Frequency Protection (OFP/UFP) are the basic passive method that commonly used in islanding detection. It is used by monitoring the voltage and frequency at the PCC. The real and reactive power zones and Non-Detection Zones (NDZ) of OVP/UVP and OFP/UFP is illustrated at Figure 2.4.1 below [9].

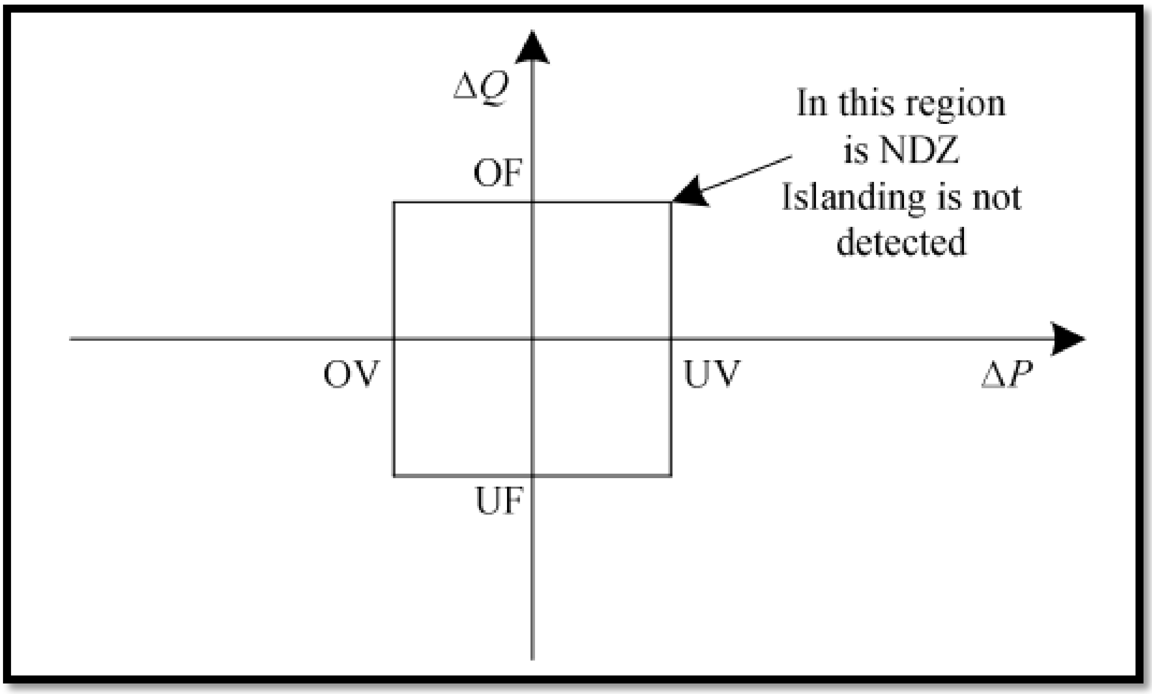

Figure 2.4.1: NDZ of OVP/UVP and OFP/UFP [9]

2.5 Reactive Power Imbalance

The reactive power imbalance applying in the passive method is the rate of change of distribution generator (DG) voltage over the rate of change of reactive power at load. The value is known as Detection Index (D) as stated in Figure 2.5.1. To perform the calculation of D, the continuous signal is transform into discrete signal. Similar method is used on the product currently present in the market is the ROCOV relay [10].

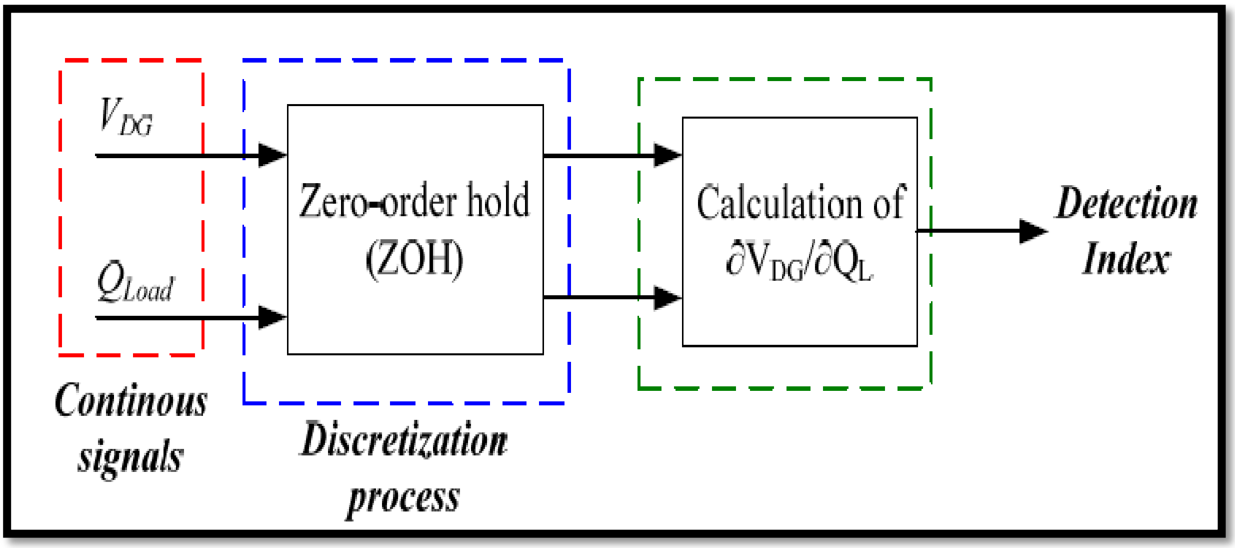

Figure 2.5.1: Discretization and calculation process of D [10]

2.6 IEEE standards on Islanding Detection

According to IEEE 1547 Standard of Interconnecting Distributed Resources with Electric Power Systems, the fault clearing time of the power system should follow the standards given in the Table 2.6.1.

Table 2.6.1: Clearing time standards on IEEE 1547

Voltage range (% of base voltage)	Clearing time(s)
$V < 50$	0.16
$50 \leq V \leq 88$	2.00
$110 \leq V \leq 120$	1.00
$V \geq 120$	0.16

CHAPTER 3

METHODOLOGY

Based on the problem statement explained in Chapter 1, the method that is used to detect the islanding state of the Micro-grid system is passive method. The basic idea of passive method is measuring the parameters of the Distribution Generator (DG) and then comparing it with the parameters' preset value at the utility grid. Many parameters can be analyzed for detection method such as frequency, voltage, active power and etc. In this paper, the parameter that will be analyzing is the reactive power. This method is also known as reactive power imbalance whereby it will detect the islanding state based on voltage value at the DG.

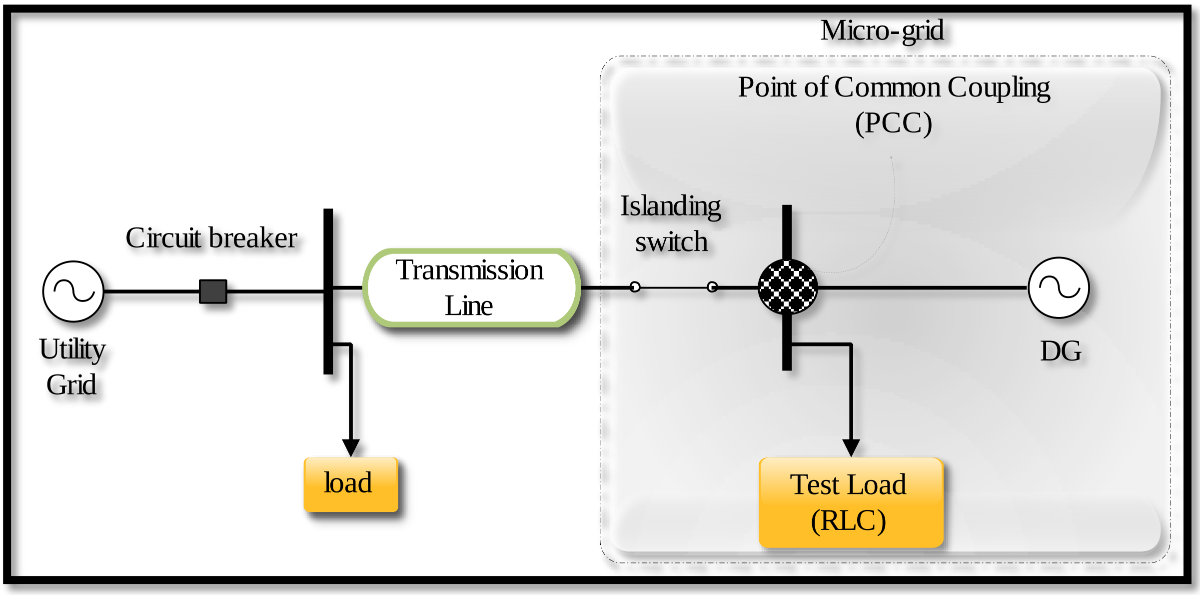

Figure 3.1.1: Micro-grid modelling diagram

The modelling diagram of the Micro-grid circuit is shown in Figure 3.1.1. This figure illustrates the connection of DG and the Utility grid at the Point of Common Coupling (PCC). The test load is a RLC load. Islanding switch is the main part to disconnect the transmission line during a faulty condition. Once the islanding switch is open, automatically the micro-grid is in the islanding state because the test load is fully supported by DG.

3.1 Procedure

The procedure begins by measuring the three-phase voltage (V), and three-phase current (I) at the Utility grid, Load and DG. Then the value of Active power (P)and reactive power (Q) at load and DG is calculated. The signals of V, I, P and Q is then converted to discrete by using the Zero-Order Hold (ZOH) filter. The calculation of Detection index (D) is performed after the conversion process. D is calculated as D= $\frac{\partial V_D}{\partial Q_L}$ [8], will be explained in section 3.3, Calculation.

Once the value of D is obtained, it is then compared with the threshold value of D^{th}. The D^{th} is set as one. If the amplitude of D is larger than the D^{th}, then number of counter, N will increase by one and will repeat the process until the total counter, N^{th} is met by the counter system. The value of N^{th} is set according to how fast was the detection time is needed. The lesser of N^{th}, the faster the system will tend to perform islanding state of micro-grid. If N^{th} is set as five, the islanding switch will trip the connection of utility grid from the local load at the fifth counter. At this point, the local load is connected to the micro-grid as in an islanding state.

If the value of D is lesser than one, the counter will not operate. At this point, there will be a feedback loop to repeat the initial procedure of measuring the parameter. Every counter the system will repeat the parameter measuring process until the counter reaches N^{th}.

During islanding state the local load is supplied with the same amount of reactive and active power that does not affect the load. The transition time of the power system from the non-islanding state to islanding state is dependent on the N^{th} value of the counter. According to IEEE 1547 standard the reconnection time of the local load to the supply should be within 0.16 second [11]. The simulation of the micro-grid is done over the MATLAB/ Simulink software.

3.2 Flow Chart

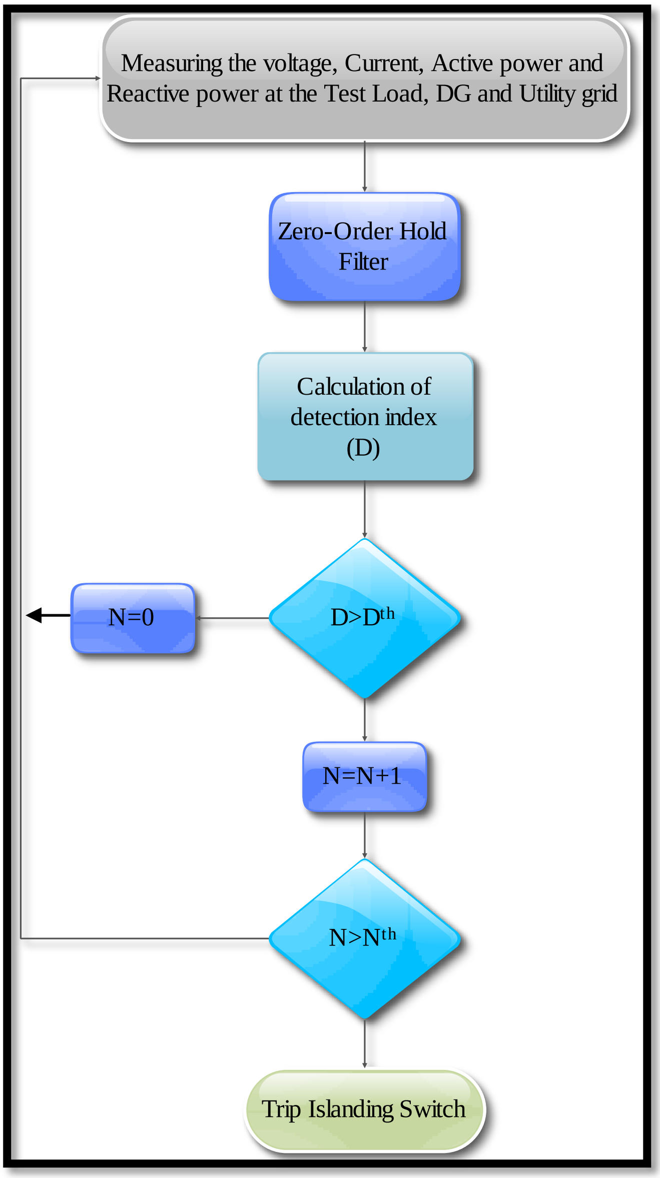

Figure 3.2.1: Reactive Power Imbalance Algorithm

The procedure explained in sub-topic 3.1 is illustrated in a flow chart in Figure 3.2.1. The output of the flow chart is the status of the islanding switch either open or close. Open status meaning that the utility grid is disconnected from the PCC meanwhile close status of the islanding switch meaning that the load is still supported by the Utility grid.