DEVELOPMENT OF FAULT DETECTION SYSTEM FOR THREE--PHASE VOLTAGE SOURCE INVERTER (VSI)

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Bachelor of Electrical Engineering (Industrial Power)

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"I hereby declare that I have read through this report entitle "Development of Fault Detection System for Three-phase Voltage Source Inverter (VSI)" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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DEVELOPMENT OF FAULT DETECTION SYSTEM IN THREE-PHASE VOLTAGE SOURCE INVERTER (VSI)

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

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "*Development of Fault Detection System for Three-phase Voltage Source Inverter (VSI)"* 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 : …….

Name : SA'ADAH BINTI DAUD

Date : …….

To my beloved family

ACKNOWLEDGEMENT

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ABSTRACT

Voltage Source Inverter (VSI) is widely used in larger electronics areas, portable devices and in power generation systems. Lately, this device is highly demand in applications using renewable energy such as Solar Photovoltaic (PV) System and Smart Grid System. As time move on, the development of technologies using renewable energy is needed for future demand since this resource helps in protecting the surrounding. In industry, the performance and effects of the devices are such important factors that must be taken into account in order to ensure the continuity of the applications. Normally, the faults occur on the switching device that is very sensitive. A small electric disturbance may cause destruction at high cost and sudden system failure. The development of fault detection system for Voltage Source Inverter (VSI) is to monitor and detect fault at the early stage. This fault can be detected by the behavior of current waveform. This project aims are to analyze the system based on RMS and average current as the parameters, to develop the system with accurate value measurement and to classify the types of fault occurs. Analysis is conducted in order to identify the fault pattern or behavior by using MATLAB. This analysis will first undergo the circuit design process using Simulink, a tool in MATLAB. The simulation will result in the classification of faults' type. The project designed is focused on applications using three-phase VSI. This system is design using Microsoft Visual Basic 2010 and is known as "VSI Fault Detection System" that can detect and classify only two types of fault which are short-circuit fault and open-circuit fault. The use of NI USB-6009 DAQ Card is to capture signal source or data and interface it with Visual Basic 10.0. The monitor can display the parameters reading and waveform which are RMS current and average current. The type of fault is mention in the system once fault is detected. This system provides precaution and early identification of fault thus reduces high maintenance cost and prevent critical fault from happen.

ABSTRAK

Voltan sumber inverter (VSI) digunakan secara meluas dalam sistem penjanaan kuasa, bidang elektronik dan digunakan untuk peranti mudah alih. Penggunaan peranti ini mendapat permintaan yang luas dalam aplikasi yang menggunakan sumber tenaga yang boleh diperbaharui seperti Sistem Solar Photovoltaic (PV) dan sistem Grid Pintar. Justeru itu, penggunaan sumber yang boleh diperbaharui sangat berguna dalam memenuhi keperluan masa depan disamping dapat melindungi alam sekitar. Keberkesanan dan prestasi sesebuah peranti merupakan salah satu faktor penting untuk memastikan kelancaran sesuatu aplikasi atau sistem. Kebiasaannya, kerosakan berlaku pada suis di dalam litar VSI. Suis-suis yang terdedah kepada gangguan kecil elektrik boleh menyebabkan peranti rosak serta kegagalan sistem beroperasi secara tiba-tiba. Penghasilan sistem pengesan gangguan untuk Voltan sumber inverter (VSI) boleh mengesan dan memantau kerosakan pada peringkat awal. Kerosakan ini dapat dikesan melaui bentuk dan corak gelombang arus. Tujuan projek ini adalah untuk menganalisis sistem berdasarkan arus RMS dan arus purata, untuk menghasilkan sistem yang dapat beroperasi dengan tepat dan untuk mengenalpasti jenis kerosakan yang berlaku. Analisis dijalankan untuk mengenal pasti corak gangguan dengan menggunakan MATLAB. Reka bentuk litar dihasilkan dengan menggunakan Simulink dan jenis kerosakan atau kesalahan dapat dikesan dan dikategorikan melalui proses simulasi. Projek ini direka untuk aplikasi *three-phase VSI*. Sistem ini dihasilkan menggunakan Microsoft Visual Basic 2010 dan dikenali sebagai "VSI Fault Detection System" yang boleh mengesan dan mengelaskan dua jenis kerosakan sahaja iaitu litar pintas atau litar terbuka. NI USB-6009 digunakan sebagai perantara yang dapat merakam isyarat signal dan menterjemahkannya kepada bahasa yang difahami oleh Visual Basic 10. Monitor memaparkan bacaan parameter dan corak gelombang iaitu arus RMS (RMS current) dan arus purata (average current). Jenis-jenis kerosakan VSI akan dipaparkan apabila sistem mengesannya. Sistem ini dapat mengurangkan kos penyelenggaraan yang tinggi dan mencegah kerosakan yang lebih kritikal daripada berlaku.

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CHAPTER 1

INTRODUCTION

1.1 Research Background / Motivations

Recently, in industrial processes, automation has lead to comprehensive electromechanical systems. The cost of production and operation are high, thus can cause a rise in planned and unplanned standstill. Standstill or breakdown of a single of dozens of drives usually leads to the complete malfunction of the system. Thus, a short standstill times and high utilization over time are required for an economic operation. In case of inevitable maintenance, only short interruption times are allowed and unplanned faults have to be kept minimize [1]. Therefore, it is necessary to assure the safety and continuous operation for application using this equipment since they can improve the productivity [2].

The most common drive in industry is inverters. Inverters are basically used to transfer power from a DC source power to an AC load, such as an AC motor. In power electronics context, the word “inverter” denotes a power conversion circuits that runs from a DC voltage or current source and converts it into AC voltage or current as illustrated in Figure 1.1. Examples of DC voltage source are battery bank, solar photovoltaic cells and an AC voltage supply that undergo rectification into DC.

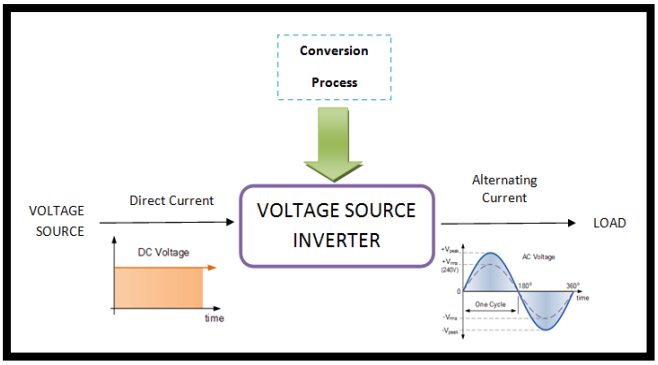

Figure 1.1: Illustration of voltage source inverter

These devices are widely used in power generation systems such as in solar generating systems, electric utility companies that need the conversion of DC power source to AC loads, in power grid and also in High Voltage Direct Current (HVDC) power transmission. They are also widely used in larger electronics systems. Inverter circuits are being applied in industry such as uninterruptable power supply (UPS) unit, electronic frequency charger, and adjustable speed drives (ASD) for ac motors [3]. An example of application using inverters in a grid-connected solar PV system is shown in Figure 1.2 while in HVDC power transmission is shown in Figure 1.3.

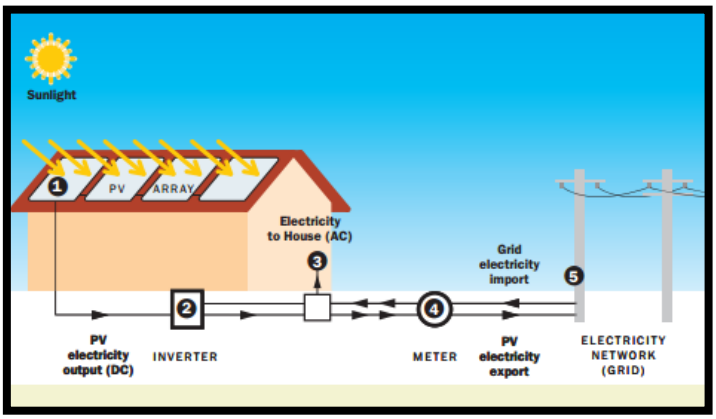

Figure 1.2: A grid-connected solar PV system. [4]

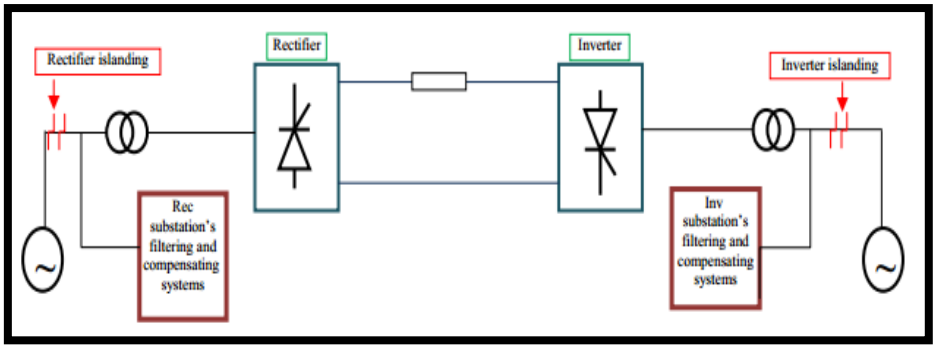

Figure 1.3: A HVDC power transmission. [5]

Apart from solar panels, inverters also play role in transmitting power from batteries and fuel cells. Grid-tied inverters are used in solar electricity system. These inverters have the ability to feed back energy into the utility grid since it produces alternating current with the amplitude and frequency as the energy provided by the utility distribution network. Thus, these help during blackout since they can be shut off. Therefore, inverters play a big role in order to achieve or to make a system to be possibly operated. As time move on, the development of technologies using renewable energy is needed for future generation to fulfill their demand as well as to protect the environment and make it greener. So the inverters are important device and their efficiency must be taken into account.

Inverters are divided into two types which are Current Source Inverter (CSI) and Voltage Source Inverter (VSI). For Voltage Source Inverter (VSI), a DC voltage source is converted to be fed to AC voltage load. Usually, the fault occurs at the switching device of the circuit. There are several types of fault may appear in VSI namely DC link capacitor short-circuit fault, Open-circuit fault, and short-circuit fault [6]. When these faults occur, the associated system need to be stopped for a maintenance schedule. The main idea and information about the waveform behavior of these faults are one of the important key for protection and tolerant control for this equipment. This behavior must be analyzed in order to detect the type of fault occur on the switching device.

This project presents the design and development of fault detection system to detect and measure faults occur in Voltage Source Inverter (VSI) at the early stage. The system can also differentiate between two types of faults that are open-circuit fault and short-circuit fault.

The parameter will be measured are current in RMS value and average value. The data will be recorded and stored efficiently thus, the fault of VSI can be monitored.

1.2 Problem Statements

Most of power electronic devices such as Voltage Source Inverter (VSI) run in an environment requiring rapid speed variation, frequent starting or stopping and constant overloading. This circuit is subject to many failures such as constant abuse of voltage overswings and the surge of over-current. Even though the devices come with protection such as snubber circuits, switching devices are thermally fragile and physically small.

In Voltage Source Inverter (VSI), the faults normally occur on the switching device that is very sensitive. Even a small electric disturbance can lead to the exceeding of thermal rating resulting in rapid destruction. In case of expensive, high power systems, safety critical system and multi-converter integrated automation systems, the presence of faults will result in sudden system failure.

The occurrence of fault such as open-circuit fault and short-circuit fault will affect the efficiency of a system or application. Prevention should be taken first to avoid much worst damage. Thus, to prevent damages at a high cost, the fault occurrence must be monitored earlier. The faults can be detected by the behavior of current waveform. Analysis must be done to ease in identifying and classifying the types of fault occurs at the switches.

1.3 Objectives

The objectives of the proposed project are:

1. To analyze VSI fault detection system based on average current and RMS current using MATLAB Simulink.

2. To develop VSI fault detection system that will provide accurate value for the measurement parameters that is the average value and RMS value of current in each phase of the system using Visual Basic 2010.
3. To classify types of fault occur in VSI whether it is open-circuit or short-circuit faults.

1.4 Scopes

The scopes of this project are:

1. This project detects and classify fault in three-phase VSI whether it is open-circuit fault or short-circuit fault.
2. This system utilizes the Microsoft Visual Basic 2010 software to display the waveform behavior as well as measurement parameters and NI USB-6009 Data Acquisition Card (DAQ card) to capture source signal and interface it with Visual Basic 2010 software.
3. This project detects the occurrence of fault by the average and RMS current value.
4. The system designed display the RMS and average value of current.
5. The current signal used is not more than 50Ampere.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principles

2.1.1 Voltage Source Inverter (VSI)

Inverters are designed to provide either single-phase or three-phase output. Usually, three-phase ac is required in larger industrial applications. Inverter is also classified into two that is offline and online inverter. An inverter is called offline inverter or autonomous inverter if it is the only source of the load ac line. If an inverter is a part of the common power supply line, it is known as a line-fed inverter or online inverter. Voltage source inverter (VSI) and current source inverter (CSI) are distinguished in accordance with the circuit arrangement classification.

A Voltage source inverter (VSI) or voltage stiff inverter is the most commonly used type of inverter which forms voltage with properties. The properties are magnitude, frequency and phase. This inverter comes with low internal impedance. Basically, VSI has a capacitor of high capacity connected across the supply source that keeps input voltage to be constant. The switches of VSI are constructed on the base of the full controlled devices such as transistors, GTO thyristor or MCT. If bidirectional current is required, the freewheeling diodes are connected across the switches [7].

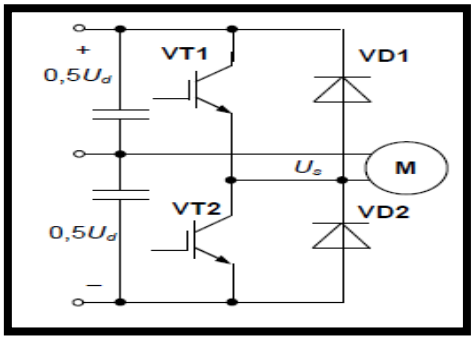

Figure 2.1: Half-bridge Single-phase VSI [7]

Figure 2.1 represent a half-bride midpoint configuration of the single-phase VSI. Usually the role of switches VT1 and VT2 are played by BJTs, IGBTs, MOSFETs, GTO thyristors or force-commutational SCRs. VT1 and VT2 will arrange the DC source with the common terminal to supply the load, M. During the positive half cycle, switch VT1 is turned on which gives the positive supply. On the other hand, during the negative cycle, switch VT2 is turned on and giving negative supply. If VT1 and VT2 are turned on at the same time, both switches will operate and short the DC supply. Freewheeling diode in the circuit that is VD1 and VD2 feed the reactive energy of the load back to supply. The feedback diodes will start conducting when the current and voltage are of opposite polarities [7].

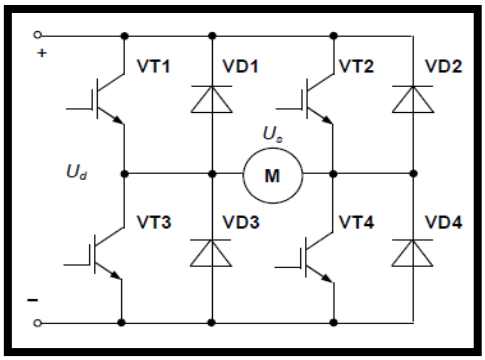

Figure 2.2: Single-phase Full-bridge VSI [7]

Figure 2.2 shows the full-bride configuration of single-phase VSI. Each of its legs includes a pair of transistors with anti-parallel discharge circuits of reverse current built on the freewheeling diodes [7]. Each feedback diodes provide an alternate path for the inductive

current, which continues to flow when its switch is turned off. The feedback diodes will return the generated power back to the supply whereas the switches carry the reactive voltage.

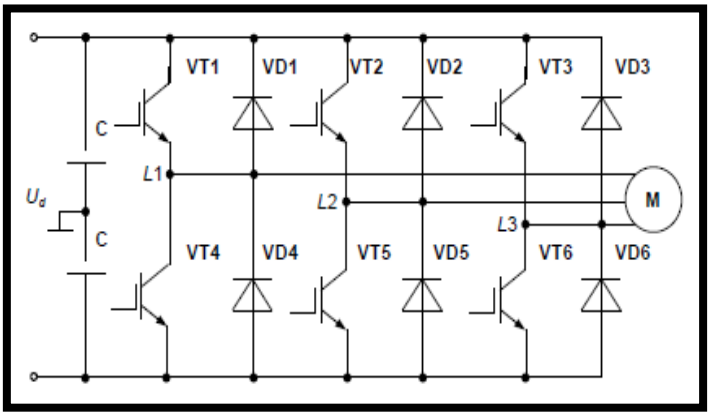

Figure 2.3: Three-phase VSI [7]

A three-phase VSI consists of three equal legs as shown in Figure 2.3. Each leg is for each phase. The output of each leg is depending on the dc supply load and the switching status while the output voltage is independent of the load current magnitude. An example of switching sequence for Figure 2.3 is VT1-VT6-VT2-VT4-VT3-VT5-VT1-VT6…[7] Theoretically, only one switch for each pair will be in closed position, while the other pair will be open. The switching scheme and its voltage output are summarized in Table 2.1.

Table 2.1: Switching scheme of three-phase inverter

VT1	VT2	VT3	VL1	VL2	VL3
0	0	0	0	0	0
0	0	1	0	-Vdc	+Vdc
0	1	0	-Vdc	+Vdc	0
0	1	1	-Vdc	0	-Vdc
1	0	0	+Vdc	0	-Vdc
1	0	1	+Vdc	-Vdc	0
1	1	0	0	+Vdc	-Vdc
1	1	1	0	0	0