THD AND EFFICIENCY STUDY FOR PV GRID-CONNECTED

LAFSAH BT MAT DAUD

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

Faculty of Electrical Engineering
Universiti Malaysia Pahang

JUNE 2012

ABSTRACT

Total harmonic distortion (THD) is a measurement of the harmonic distortion and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. In general, efficiency is a measurable concept, quantitatively determined by the ratio of output to input. The project is all about the experimental study on THD and efficiency for photovoltaic (PV) grid connected. A scale-down less than 1kW system will be developed and established for the study. The impact on THD and efficiency will be assessed to the real network environment by connected three phase motor to Variable Frequency Drives (VFD's) as the load. The experimental will be done by using Power Quality Analyzer (PQA) software and the comparison between before and after connected PV will be conducted. The results of the THD and efficiency for PV grid connected system will be obtained and analyzed under influence of load conditions.

ABSTRAK

Jumlah herotan harmonik (THD) adalah ukuran herotan harmonik dan ditakrifkan sebagai nisbah jumlah kuasa semua komponen harmonik kuasa frekuensi asas. Secara amnya, kecekapan adalah satu konsep yang diukur, yang kuantitnya ditentukan oleh nisbah output kepada input. Tujuan kertas ini adalah kajian eksperimen THD dan kecekapan untuk grid photovoltaic (PV) yang berkaitan. Satu skala-turun kurang daripada 1kW sistem akan dibangunkan dan ditubuhkan untuk kajian. Impak ke atas THD dan kecekapan akan dinilai untuk persekitaran rangkaian sebenar oleh penyambungan tiga fasa motor kepada Pemacu Frekuensi Variabel (VFD) sebagai beban. Eksperimen adalah dengan menggunakan Kualiti Kuasa Analyzer (PQA) dan perbandingan di antara sebelum dan selepas penyambungan PV akan dijalankan. Keputusan THD dan kecekapan bagi sistem grid PV yang berkaitan akan diperolehi dan dianalisis di bawah pengaruh keadaan beban.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
DC	-	Direct Current
AC	-	Alternating Current
THD	-	Total Harmonic Distortion
THDI	-	Total Harmonic Distortion Current
THDV	-	Total Harmonic Distortion Voltage
PCU	-	Power Conditioning Unit
MPPT	-	Maximum Power Point Tracker
ARC	-	Anti-Reflective Coating
PE	-	Power Electronic
PWM	-	Pulse Width Modulation
PCC	-	Point Common Coupling
VFDs	-	Variable Frequency Drives
PQA	-	Power Quality Analyzer

CHAPTER 1

INTRODUCTION

1.1 Overview THD and Efficiency of PV Grid-Connected

Today, the use of Grid-Connected Photovoltaic (PV) systems has been grown to be popular in many parts of the world. More numbers of Grid-Connected PV generators connected to a distribution network through PV inverters can afford to cause harmonic problems. In general, a harmonic problem can be defined as a particular disturbance, which is created by the presence of non-linear components in the electrical system that determines a permanent modification of the voltage and current sinusoidal wave shapes in terms of sinusoidal components at a frequency different from the fundamental. In a grid interconnected photovoltaic power system, the Direct Current (DC) output power of the photovoltaic array should be converted into the Alternating Current (AC) power of the utility power system.

Under this condition, an inverter to convert DC power into AC power is required. A line commutated inverter uses a switching device like a commutating thyristor that can control the timing of turn ON but cannot control the timing of turn OFF by itself. Turn OFF should be performed by reducing circuit current to zero with the assist of supplemental circuit or a source. On the other hand, a self-commutated inverter is characterized in that it uses a switching device that can freely control the ON-state and the OFF-state, such as an IGBT or a MOSFET. A self-commutated inverter can freely control the voltage and the current waveform at the AC side, adjust the power factor, and suppress the harmonic current, and is highly resistant to utility system disturbance.The sum voltage harmonic distortion of the utility grid has been established to influence the harmonic currents of an inverter [1].

The number of PV Grid-Connected system that connected to the utility grid has no result to the inverter's harmonic currents but it is not the case for load power factor. The ordinary installation pattern of a PV Grid-Connected system consists of a PV array and a grid connected inverter. While the inverter injects power produced from the PV array into the utility grid, there are roughly always some types of loads receiving power from the grid at the same moment. It is usual to ask whether the grid condition and the local loads have influence, if any on the inverter output in addition to the irradiation which directly affects the dc output power of the PV array. In this study, the issues of local loads by taking into consideration the load condition at PCC on the harmonic currents of a grid-connected inverter must be analyzed. An experimentalbefore and after connected PV platform is prepared to measure the Total Harmonic Distortion (THD) and efficiency values on both DC and AC sides.

1.2 Problem Statement

This study has been proposed because of the rapid growth of PV Grid-Connected installation and it is important to explore its effects on THD and efficiency.The total voltage harmonic distortion of the utility grid has been recognized as main factors that can affect the harmonic currents of an inverter. At the same time, the harmonics is majority occurs under influence of load conditions.

1.3 Project Background

The term “harmonics” was originated in the field of acoustics, where it was related to the vibration of a string or an air column at a frequency that is multiple of the base frequency [2]. A harmonic component in an AC power system is defined as a sinusoidal component of a periodic waveform that has a frequency equal to an integer multiple of the fundamental frequency of the system [2]. Harmonics in the voltage or current waveform can then be conceived as completely sinusoidal components of frequencies multiple of the fundamental frequency [2]. PV systems use inverters to get linked to distribution networks that utilize alternative voltage. On the other hand, harmonic currents generated by PV systems may downgrade the quality of the electrical network and change performance of other electrical equipment. In this study, the THD and efficiency of PV Grid-Connected system hasbeenanalyzed under influence of load conditions by varied the frequency.

1.4 Objective

The objectives for this project are stated below:

i. To measure the value of THD and efficiency at PV Grid-Connected.

ii. To obtain and analyzed THD and efficiency under influence of load conditions by varied the frequency.

iii. To compare the experimental of THD and efficiency before and after connected PV.

1.5 Scope of Project

Data has been collected at FKEE laboratory by using Power Quality Analyzer (PQA). The harmonic and efficiency data that already get will be transferred to the computer by using KEWPQAMASTERV203 software. The PV Grid-Connected system configuration has been setup at FKEE laboratory. The setup consist PV array, DC to AC inverter, load and grid system.

1.6 Report Outline

Chapter 1 discuss about the introduction, project background, objective and scope project. Otherwise this chapter discusses more about the application and the goal of THD and efficiency analysis.

Chapter 2 discusses more about the literature review. Besides that the history of PV, PV system works, types of PV, introduction of harmonics, definition of THD, definition of efficiency in PV Grid-Connected and experimental evaluation that related with THD in PV Grid-Connected system also discuss in this chapter.

Chapter 3 focused on methodologies for determine the harmonic and efficiency data. In addition, the flowchart about main procedure PSM 1 and PSM 2 will be discussing more details in this chapter. MATLAB software, Power Quality Analyzer (PQA), block diagram, PV Grid-Connected design using MATLAB, experimental setup of PV Grid-Connected, THD and efficiency formula is also discussed with details in this chapter.

Chapter 4 exposed about the result that displayed and analyzed. This data will be discussing further to get the THD and efficiency study for PV Grid-Connected. The

THD and efficiency will be discussed and analyzed at the grid, PV and motor (load) by varied the frequency and speed by using the Variable Frequency Drives (VFD's).

Chapter 5 is about the conclusions for this study that have been elaborate details.

Chapter 6 is about the recommendation for this study that have been elaborate details.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present about the literature review. Besides that the history of PV, PV system works, types of PV system, introduction of harmonics, definition of THD, definition of efficiency in PV Grid-Connected and experimental evaluation that related with THD in PV Grid-Connected system also discuss in this chapter.

2.2 History of PV

In the late 1950s the first conventional photovoltaic cells were created, and during the 1960s were mainly used to supply electrical power for earth-orbiting satellites [3]. In the 1970s, improvements in industrialized, performance and excellence of PV modules helped to decrease costs and opened up a number of opportunities for powering distant terrestrial applications, including battery charging for navigational aids, signals, telecommunications equipment and other critical, low power needs [3]. Photovoltaic became a popular power source for consumer electronic devices, including calculators, watches, radios, lanterns and other small battery charging applications in the 1980s.

Subsequent the energy crises of the 1970s, significant efforts also began to build up PV power systems for residential and commercial uses both for stand-alone, remote power as well as for utility-connected applications. Throughout the similar period, international applications for PV systems to power rural health clinics, refrigeration, water pumping, telecommunications, and off-grid households increased dramatically, and remain a major portion of the present world market for PV products [3]. Nowadays, the industry's manufacture of PV modules is growing at approximately 25 percent annually, and major programs in the U.S, Japan and Europe are rapidly accelerating the accomplishment of PV systems on buildings and interconnection to utility networks [3].

2.3 Types of PV System

Photovoltaic power systems are normally classified according to their useful and operational requirements, component configurations, and how the equipment is connected to other power sources and electrical loads [3]. Two principles for classifications are grid-connected or utility-interactive systems and stand-alone systems. Photovoltaic systems can be designed to give DC and/or AC power service, can function interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems [3].

The first one type is Grid-Connected (Utility-Interactive) PV Systems. Grid-Connected or Utility-Interactive PV systems are designed to function in parallel with and interconnected with the electric utility grid [3]. The main component in grid-connected PV systems is the inverter, or power conditioning unit (PCU) [3]. The PCU converts the DC power produced by the PV array into AC power dependable with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized [3].

Figure 2.1 illustrates that when the PV system output is greater than the on-site load demand, this allows the AC power produced by the PV system to either supply on-site electrical loads, or to back feed the grid. At nighttime and throughout other periods when the electrical loads are larger than the PV system output, the equilibrium of power necessary by the loads is received from the electric utility This safety characteristic is required in all Grid-Connected PV systems, and ensures that the PV system will not carry on to operate and feed back onto the utility grid when the grid is downward for service or repair [3].

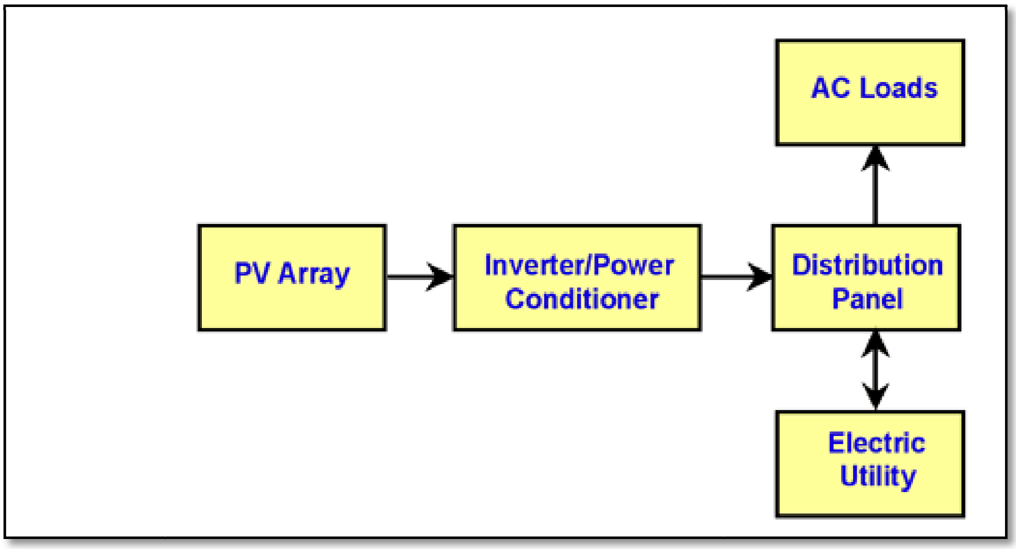

Figure 2.1 Diagram of Grid-Connected Photovoltaic system [3]

Since there is no electrical energy storage (batteries) in direct-coupled systems, the load only operates during sunlight hours, making these designs suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar