ANALYSIS OF HARMONICS ISSUE IN GRID INTEGRATION SOLAR PHOTOVOLTAIC SYSTEM AND MITIGATION METHOD

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ABSTRACT

Solar photovoltaics system is the most preferable green technology for energy saving especially in Malaysia and the demand of grid connected Photovoltaic system (PV) is increasing continuously to support the needs. Large penetration of harmonics that happened at the point of common coupling (PCC) will affect the overall efficiency and cause power quality issue at the downstream. Total harmonic distortion (THD) is the measurement of harmonic distortion that exist in power system. The acceptable level of THD as referring to the International Electrical and Electronics Engineers (IEEE), IEE 519-2014 has classified voltage harmonics (THDv) based on the voltage range and current harmonics (THDi) based on the range of short circuit current (Isc) over line current (I_L). This report presents harmonics impact to power system due to the installation of solar photovoltaic system. The study involves few analysis techniques to identify the existence of harmonics in the existing power system before and after solar PV integration. Methodology that was approached involved desktop study, actual measurement using power quality analyzer and system modelling and simulation using ETAP software. Measurement was conducted at the PCC of low voltage hybrid PV system which is the integration of solar system with grid supply power system. In this report, the results of harmonics that was measured at PCC prior the integration of solar PV and after the integration of solar PV clearly shows significance difference where harmonics reading of THDi increased to 23.81% from 14.11%. Suitable mitigation method was proposed to control harmonics to below the standard for the purpose of energy optimization. The installation of passive harmonic filter in parallel with non-linear load was found capable to reduce harmonics readings. The capacity of passive harmonics filter was determined from reactance calculation. Based on the results from the improvement technique, it was proven that passive filter could reduce THDi from 23.81% to 7.43%, increased the current from 1206A to 2685A and increase voltage from 415V to 449V. The power factor of the power system has also increase from 0.7 to 0.99. High power factor means power system is run in high efficiency. Maintaining high power factor and efficiency is important to provide a solution for real-time cancellation of harmonic distortions. The implication of the improvement imposed to the system was benefits in terms of energy optimization by eliminate distortion and power quality issue.

ABSTRAK

Sistem fotovoltaik suria adalah teknologi hijau yang paling diutamakan untuk penjimatan tenaga terutamanya di Malaysia dan permintaan sistem fotovoltaik (PV) bersambung grid meningkat secara berterusan untuk menyokong keperluan. Penembusan besar harmonik yang berlaku pada titik gandingan biasa (PCC) akan menjejaskan kecekapan keseluruhan dan menyebabkan isu kualiti kuasa di hiliran. Herotan harmonik total (THD) ialah ukuran herotan harmonik yang wujud dalam sistem kuasa. Tahap THD yang boleh diterima sebagai merujuk kepada *International Electrical and Electronics Engineers* (IEEE), IEE 519-2014 telah mengklasifikasikan voltan harmonik (THDv) berdasarkan julat voltan dan harmonik arus (THDi) berdasarkan julat arus litar pintas (Isc) atas talian arus (I_L). Laporan ini membentangkan kesan harmonik kepada sistem kuasa kerana pemasangan sistem fotovoltaik solar. Kajian ini melibatkan beberapa teknik analisis untuk mengenal pasti kewujudan harmonik dalam sistem kuasa sedia ada sebelum dan selepas integrasi PV solar. Metodologi yang digunakan melibatkan kajian desktop, pengukuran sebenar menggunakan penganalisis kualiti kuasa dan pemodelan sistem dan simulasi menggunakan perisian ETAP. Pengukuran telah dijalankan di PCC sistem PV hibrid voltan rendah yang merupakan penyepaduan sistem solar dengan sistem kuasa bekalan grid. Dalam laporan ini, keputusan harmonik yang diukur di PCC sebelum penyepaduan PV solar dan selepas penyepaduan PV solar jelas menunjukkan perbezaan signifikan di mana bacaan harmonik THDi meningkat kepada 23.81% daripada 14.11%. Kaedah tebatan yang sesuai telah dicadangkan untuk mengawal harmonik di bawah piawai untuk tujuan pengoptimuman tenaga. Pemasangan penapis harmonik pasif selari dengan beban bukan linear didapati mampu mengurangkan bacaan harmonik. Kapasiti penapis harmonik pasif ditentukan daripada pengiraan reaktans. Berdasarkan keputusan daripada teknik penambahbaikan, terbukti bahawa penapis pasif boleh mengurangkan THDi daripada 23.81% kepada 7.43%, meningkatkan arus daripada 1206A kepada 2685A dan meningkatkan voltan daripada 415V kepada 449V. Faktor kuasa sistem kuasa juga telah meningkat daripada 0.7 kepada 0.99. Faktor kuasa tinggi bermakna sistem kuasa dijalankan dalam kecekapan tinggi. Mengekalkan faktor kuasa tinggi dan kecekapan adalah penting untuk menyediakan penyelesaian bagi pembatalan herotan harmonik masa nyata. Implikasi penambahbaikan yang dikenakan kepada sistem adalah berfaedah dari segi pengoptimuman tenaga dengan menghapuskan herotan dan isu kualiti kuasa.

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LIST OF ABBREVIATIONS

AC	-	Alternate Current
DC	-	Direct Current
FiT	-	Feed in Tariff
GITA	-	Green Incentives Tax Allowance
GITE	-	Green Incentives Tax Exemption.
LSS	-	Large Scale Solar
LV	-	Low Voltage
MD	-	Maximum Demand
MDC	-	Malaysian Distribution Code
MPPT	-	Maximum Power Point Tracking
MV	-	Medium Voltage
NEDA	-	New Enhancement Dispatch Agreement
NEM	-	Net Energy Metering
PC	-	Personal Computer
PCC	-	Point of Common Coupling
PERC	-	Passivated Emitter & Rear Cell
PF	-	Power Factor
PPU	-	Pencawang Pembahagi Utama
PSS	-	Power System Study
PV	-	Photovoltaic
PWM	-	Pulse Width Modulation
RE	-	Renewable Energy
SMPS	-	Switch-Mode Power Supply
SPD	-	Surge Protecting Device
THD	-	Total Harmonic Distortion
TNB	-	Tenaga Nasional Berhad
VSD	-	Variable Frequency Drive

LIST OF SYMBOLS

A	-	Ampere
I	-	Current
V	-	Voltage,Volt
W	-	Watt

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Renewable energy (RE) sources for electricity supply is much depending on the type of scheme provided in each country. In Malaysia, the connection is possible to be done in few methods, NEM (Net Energy Metering), FiT (Feed in Tariff), LSS (Large Scale Solar), NEDA (New Enhancement Dispatch Agreement) and SELCO (Self Consumption). The benefits of using renewable energy for electricity supply is of course to reduce utility cost while be fond with government incentive for renewable energy. Currently, there are two types of government incentives provided for renewable energy scheme which are GITA (Green Incentives Tax Allowance) and GITE (Green Incentives Tax Exemption). Solar PV has dominant RE market in Malaysia as until 2016, 64% from total RE generated was contributed from solar source. Figure 1.0 shows the capacity of RE installation in Malaysia from year 2012-2016.

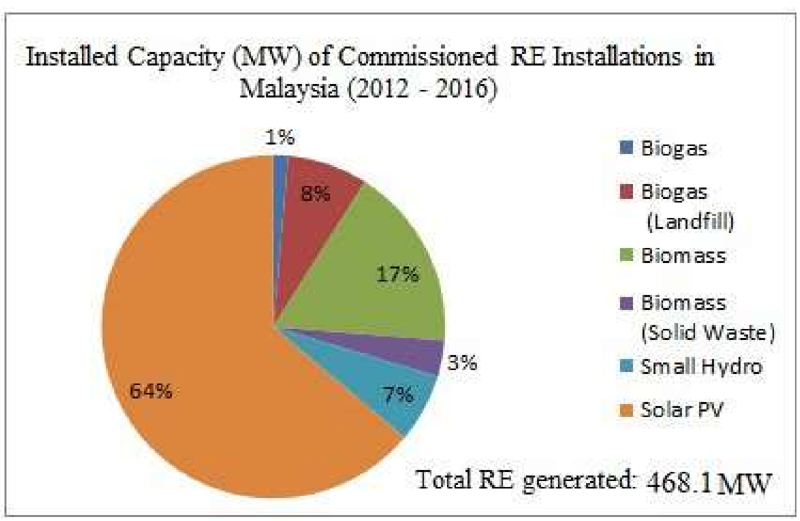

Figure 1.0 Capacity of RE in Malaysia

The integration of renewable energy from solar source to the existing grid system is possible in two ways which are the MV (medium voltage) or LV (low voltage) penetration. One of the concerning issue with grid interconnection system is the power quality. The increasing penetration rate of RE source in the power systems is raising technical problems such as voltage regulation, network protection coordination, loss of mains detection, and RE source operation following disturbances on the distribution network which is the general problem of RE source, Nicolae, Golovanov et al.

Prior to the proceeding of power system study (PSS) and solar system design, it is much important to check on the fault level of the substation. This is to ensure that the power system is able to absorp the disturbances due to power quality issue at the point of common coupling (PCC). Referring to the Tenaga Nasional Berhad (TNB) Technical Guidebook on Grid-Interconnection of Photovoltaic Power Generation System to LV and MV Networks, among the power quality issue that will cause the disturbance are voltage fluctuation, harmonics, low power factor, flicker and voltage unbalance. Therefore, solar system design shall meet the requirement of Malaysian Distribution Code (MDC) and TNB Technical Guidebook on Grid-Interconnection of Photovoltaic Power Generation System to LV and MV Networks.

The type of the power quality issue that will be analyse in this study is harmonics distortion of voltage and current at the PCC. The standard of Total Harmonic Distortion (THD) that is accepted by MDC is 5% at rated inverter output at PCC. International standard for harmonics THD is tabulated in IEC 61727-2003 Table 1. This project will be carried out in a Test Facility Centre in Senai, Johor where solar panel system size of 425kWac will be installed.

1.2 Problem Statement

Harmonic distortion is a major issue to solar system. The effect of harmonics disturbances will limit power supply from solar system to distribution line. Besides, it may downgrade the quality of power supply and alter the performance of electrical equipment. David G Infield reported on a study of several inverters linked to the grid from a comprehensive power quality perspective. The measurements were generated into low-voltage (LV) network by taking individual single-phase inverters under a specific limit of effective conditions and for several converters' similarity tied at the same point on the grid, Abdullah, Thamar et al.

The inverter is the cause of problems that affect the stability of the power system because it is a switching device served to adjust the frequency of the AC power as needed. At the same time, it can cause harmonics which result in waveform distortion and affect electronic devices that receive power, Sindhuja, Rathinam et al. Photovoltaic systems are inverter-based type of electricity generators where the conversion will allow solar power to be distributed into electrical installation.

Industrial equipment that is used at the downstream in example lighting ballast, variable frequency drive (VFD) and personal computer (PC) contributes to non-linear load that will produce harmonics and will be injected to the distribution system. The condition will harm power transmission at PCC where harmonics current injection can further transfer to harmonic voltage distortion and cause the voltage drop. The greater the current harmonics, the greater harmonic voltage distortion.

1.3 Objectives of the study

The objectives of the study are;

i) To measure harmonic distortion at PCC using power quality analyser.
ii) To model and simulate the system for non-renewable source and renewable source power system.
iii) To propose suitable mitigation technique to eliminate harmonics issue for system improvement in terms of efficiency and power factor.

1.4 Scopes of the study

The study involves few stages of continuous monitoring and measurement. The scope of work is as below;

i) Stage 1 : Desktop measurement from existing data. Examining existing and historical data that related to harmonics issue.

ii) Stage 2 : Actual measurement to be taken at the PCC grid power injection. The duration the measurement is eight days.

iii) Stage 3 : Simulation using software to identify harmonics at PCC with solar PV power injection and mitigation method

At the end of Stage 3, a full set of harmonics study report based on above sequence shall be delivered together with mitigation plan proposal.

1.5 Limitations of study

There is some limitation occurred on the study. The most difficult situation is the restriction movement order embarked by the Government of Malaysia due to Covid-19 disease. Due to the limited movement allowed, solar panel project that is planned to start on July 2021 need to be extended to October 2021. Therefore, the measurement for solar system is only be able to be taken on the earliest January 2022. The other critical issue is the data that was not properly keep and was lost. Thus, the desktop study will be conducted with the available data.

The study was made to identify the impact of harmonics issue to the existing power system. The study was not conducted to analyse other type of power quality issue and the investigation was made to solar photovoltaic power system, the data is not applicable for other type of renewable energy such as wind.

1.6 Significance of the Study

The study is important and shall be prioritized for the company prior the installation of solar PV to ensure solar system penetration to the distribution line is at the maximum and highest efficiency. Besides, the installation of solar PV does not decrease power quality at the building distribution side that may interrupt daily operation. Harmonics distortion will cause operation interruption and losses to the plant where it could be major. In the worst case, the operation may disrupt for days or weeks due to equipment failure. Instability power supply will turn the solar project payback period to an extension as the solar power supply cannot be fully utilized in maximum capacity.

Clean and consistent power supply is required for plant full operation as the demand for power supply is increasing year by year due to the expansion. Same goes to the utilization of electronics equipment in the plant where more electronics test will be conducted due to higher production demand and the increasing of non-linear load is expected.

Therefore, without proper mitigation plan to resolve the issue, the installation of solar power system will cause harmonics to be more serious.

1.7 Report Outline

The report of the study contains of five chapters. Chapter 1 discusses on the introduction of the study where the subtitle includes the background, problem statement, objective, scopes, significance of the study and the limitation. Chapter 2 consist of the literature review on the solar photovoltaic system and the design, solar power generation and distribution, harmonics distortion and standard of acceptance. Complete methodology of the study and research process will be briefly discussed in Chapter 3. The type of equipment and software that will be used for the measurement will be detailed. Chapter 4 further discusses on the results, findings, analysis and the proposal on the mitigation plan. Finally, Chapter 5 provides the conclusion and recommendation.

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