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SIMULATING THE EFFECTS OF GRID-CONNECTED PV SYSTEM IN A RESIDENTIAL AREA USING OPENDSS

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SIMULATING THE EFFECTS OF GRID-CONNECTED PV SYSTEM IN A RESIDENTIAL AREA USING OPENDSS

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A report submitted in partial fulfillment of the requirements for the degree

of Bachelor of Electrical Engineering (Industrial Power)

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I declare that this report entitle "*Simulating the Effects of Grid-Connected PV System in a Residential Area Using OpenDSS*" 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 : ……

Date : ……

To my beloved father, mother, family, lecturers and friends for their loving, understanding, care and support.

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ABSTRACT

The impact of high PV penetration into the grid, particularly at the distribution side has been extensively studied. However, most of the available research focuses on North American style systems. This project aims to investigate the effect of high PV penetration in a European-based distribution network, which is the electricity supply system Malaysia is based on. The scope for this work is limited to a residential distribution network. The modelling is done using OpenDSS. The network model used is the IEEE European Low Voltage Test Feeder which consists of 55 loads that represent a generic housing area. Each load point is then equipped with a 4 kW PV system that denotes the typical size of a PV system installation for one house. Next, PV output variability is represented by two sample days of actual irradiance variability obtained from PVSG Lab, FKE UTeM; one for clear day and another for a high variability day. The aspects analyzed were voltage unbalance, voltage rise and reverse power flow. One significant finding of this project is that voltage rise exceeds the standard of 1.05 pu during noon, when voltage at the load side is higher than the transformer secondary side. Besides that, the high variability irradiance has more impact than clear sky irradiance during reverse power flow as the fluctuation of high variability irradiance is fluctuate more often compared to clear sky irradiance.

ABSTRAK

Kesan penembusan sistem PV yang tinggi ke grid, terutamanya di bahagian pengagihan telah dikaji dengan meluas. Namun, kebanyakan hasil penyelidikan tertumpu kepada sistem Amerika Utara. Projek ini menyasarkan untuk menyiasat kesan penembusan PV yang tinggi dalam rangkaian pengagihan berasaskan Eropah, yang merupakan asas kepada sistem bekalan elektrik di Malaysia. Skop bagi kajian ini dihadkan kepada rangkaian pengagihan perumahan. Untuk mencapai objektif, model telah dibuat menggunakan OpenDSS. Model rangkaian yang digunakan adalah *IEEE European Low Voltage Test Feeder* yang terdiri daripada 55 beban yang mewakili satu kawasan perumahan yang umum. Setiap satu titik beban kemudiannya dipasang dengan sistem 4 kW PV yang mewakili saiz lazim untuk pemasangan sistem PV bagi sebuah rumah. Keluaran PV yang berubah-ubah diwakili oleh dua sampel hari sebenar di mana nilai keamatan cahaya diperoleh daripada PVSG Lab, FKE UTeM; satu untuk hari cerah dan satu lagi untuk hari yang mempunyai variasi tinggi. Aspek yang dianalisa adalah ketidakseimbangan voltan, kenaikan voltan dan aliran kuasa balikan. Satu perolehan signifikan daripada projek ini adalah kenaikan voltan melebihi piawaian 1.05 pu sewaktu tengahari, apabila voltan di bahagian beban lebih tinggi daripada voltan di bahagian sekunder pengubah. Selain itu, keamatan cahaya dengan variasi tinggi mempunyai kesan yang lebih besar berbanding dengan keamatan cerah kerana naik turun keamatan cahaya yang lebih kerap.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia is a country that is blessed with ample amount of sunlight throughout the year. The government, in their commitment to diversify the fuel resource to include renewable energy began to encourage the use of solar system among Malaysians. Solar radiation can be used to generate electricity for free as it supplies by nature and is continuous. The use of solar radiation does not bring any harm to the earth as it generate clean green energy since there is no dangerous greenhouse gas emissions produced from the process of converting the sunlight to electricity energy. Besides that, solar system is very unique because it does not need large-scale installation, requires low maintenance and does not necessitate continuous supervision. Furthermore, solar system is suitable to be installed at the urban and residential area as it generates electricity quietly. Solar system does not use any equipment that produces noise compare to other renewable energy where they use turbine which produce noise.

One of the attractive renewable energy that uses sunlight for electrical generation technologies that have been widely implemented today is photovoltaic (PV) [1]. Photovoltaic (PV) is the direct conversion of light into electricity. Photovoltaic module which is a number of solar cell electricity connected and mounted in frame is designed to supply electricity at certain voltage. Current that is produce is directly dependent on amount of light strikes the module. Several connections of PV panels can supply enough power for household, huge electric utility or industrial applications and hundreds of PV panels can be interconnected to form a single, large PV system. Photovoltaic has three common configurations which is grid connected system, stand alone system with storage and stand alone system with directly connected loads [2]. Among the three common configurations, grid-connected PV system is

the lowest cost and the lowest maintenance type of residential solar electric system [3]. Grid-connected PV system is also known as “grid-tied” or “on-grid” solar system. This is because PV panels are connected to the local mains electricity grid.

Urban or residential areas that are using grid-connected PV system to supply power to their electrical appliances can use electricity power from PV solar panel or from normal mains electrical grid. During daylight hours, grid-connected PV system users can use their own electrical energy generated from their PV panels to supply their electrical appliances. But, during the night time, on cloudy time and rainy days where the generation of electricity from their panel drops or is unavailable, grid-connected PV system users get supply from the normal mains electrical grid. Electricity flows back-and-forth to and from the mains grid depend on sunlight conditions and the actual electrical demand at that time. Besides that, the main advantage that it can bring to the users is it can reduce the electricity bills [4].

PV power system can sometimes produce more electrical power than is actually needed by the users, especially during the afternoon when the penetration of sunlight on modules of PV is high and the load demand for residential area is low. The extra electrical power is either stored on batteries or most grid-connected PV system send the extra electrical power to the normal mains electrical grid. When grid connected PV system send the extra generated electrical power to the normal mains electrical grid, it can sometime give bad impact to the networks. High fluctuation of PV power with fast weather conditions does disturb the network voltage stability. Researchers in [5] prove that voltage stability issue does exist in distribution network for residential customers due to high penetrations of photovoltaic (PV). Therefore, this issue is necessary to investigate on the Malaysian distribution network.

1.2 Motivation

Since the issue on voltage instability at the distribution level does occur when the penetration of PV power is high, this issue motivates to study the effect of high PV penetration on a residential distribution network. This project can benefit local utility company, Tenaga Nasional Berhad (TNB) in accommodating higher PV penetration to the Malaysian distribution grid since the maximum penetrations of PV power that can feed to our grid without affecting the grid stability can be known. The significance of research is to study the impact or effects of different penetration of power distributed from grid-connected PV system on the Malaysia residential area distribution networks. In this project, the distribution network will simulate using Open Distribution System Simulator (OpenDSS).

1.3 Problem Statement

Researchers from other countries have proved that high PV power penetration do give negative impact on network stability. However, in Malaysia, photovoltaic (PV) power penetration on the distribution network is still low. Therefore, we do not know how high the maximum penetrations of PV power that can feed to our grid without affecting the grid stability. An investigation needs to be conducted so that we know the maximum PV power penetration level that is allowed to be fed to the grid so that the grid stability can be maintained. It is good to avoid the worst case scenario from happening as grid stability will cause serious concerns for the government and utility company.

1.4 Objectives

The objectives of this project are listed as follows:

1. To simulate a small-scale residential distribution network.
2. To simulate distributed photovoltaic (PV) power in small scale distribution network.
3. To evaluate the impact of distributed photovoltaic (PV) power penetration to the distribution network.

1.5 Scope

The scopes of this project are to investigate the impact or effects of PV power penetration by grid-connected PV systems on residential area at distribution level. A model of small scale residential distribution system will be built and simulated using Open Distribution System Simulator (OpenDSS). OpenDSS is an open-source distribution system simulator which is used specifically to simulate the distribution system. The model of small scale residential distribution will be build follows the standard of European low voltage bus network so that the simulation results are correct and can be applied to the real situation. Besides that, OpenDSS software will be used to generate the penetration of PV power. Lastly, this project analysis only on voltage characteristics effects when there is grid-connected PV systems in a residential area distribution network using OpenDSS software.

1.6 Expected Project Outcome

At the end of the project, the small scale residential distribution network of European low voltage bus network is expected successfully built and simulated using OpenDSS software. Besides that, it is expected that the distributed photovoltaic (PV) power in small scale distribution network is simulated by using OpenDSS software. Furthermore, at the end of the project the impact on voltage characteristics and current of distributed photovoltaic (PV) power penetrates at the distribution network is expected to be evaluated.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principles

Based on problem statement, objective and scope in Chapter 1, a study on the theory and basic principles is done in order to fully understand the project. The necessary theories that related to photovoltaic (PV) effects on grid which are voltage unbalanced, reverse power flow, voltage rise or issues, protection coordination and lastly, flicker and harmonics are included in this sub-topic of Chapter 2. Besides that, details information on Open Distribution Simulator System (OpenDSS) software, OpenDSS architecture model and comparison between European and North American distribution network are stated in this sub-topic of Chapter 2.

2.1.1 Voltage Unbalance

Voltage unbalance happens when voltage magnitude of each phase of three phase network is dissimilar or the phase angle between two phases of the three phase network is different [6]. As an example, when there is high penetration of PV power at phase-A compared to phase-B and phase-C, voltage will be higher at phase-A than other phases. As the voltage magnitude is not the same at each of the phases, the voltage is unbalanced and overvoltage is occur at phase-A. The case of the example is occurred when the installation of integrated PV to the grid is not controlled at each phases. This scenario is supported by [7] and [8] where in the investigation, the researchers found that the uncontrolled installation of integration PV on grid on each phases at distribution network does make the grid became

unbalanced. This situation creates uneven voltage rise as PV penetration on each of the phases is distribute unequally. Therefore, voltages are unbalanced in the network and disrupt the stability of the grid.

In small region, PV power swing fast followed the fast changing of weather conditions and cloud movement, as a result uneven voltage rise at the distribution level creates even worst condition on grid stability. According to [9] the unbalanced voltage at the phases can be reducing by distribute PV power in each of the phases equally. When same researcher in [7] extended investigation on voltage stability problem at residential area in [5], found that voltage instability occurred at 40% PV power penetration at distribution level. Throughout the investigation, a PV inverter reactive power support scheme is developed to solve the voltage stability problem instead of installing extra devices to solve the problem. Before, in [7] reactive power is not considered as the reactive power will increase the voltage variation in the investigation.

In the research [5] reactive power is included in the analysis as the voltage variation need to be increase so that voltage stability can be achieve. Researcher in [1] also found that 40% is the highest PV penetration that is allowed to penetrate on grid when penetrate the PV on unbalanced network at distribution level. The analysis is conducted in mathematical form on unbalanced voltage variation by using voltage variation sensitivity matrix and observed approximate linearity. Researchers in [5] and [7] both using the different methods in investigate the voltage characteristics, but found the same maximum level of PV penetration that is allowed to distribute among the consumer.

The level penetration of PV power that is found by the researchers can be used in this project to find out what are the effects on Malaysia distribution network. Furthermore, [5] suggested that the location of install the source storage of PV should be at the downstream feeder because according to the investigation, voltage instability problem can also be solve by properly choosing the right location of storage. This action can reduce voltage drop along the distribution line. The suitable types of load to install the right quantity of integrated PV on grid in analyze the unbalanced voltage is better in dynamic load rather than static load.