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Grid-connected photovoltaic system in Malaysia: A review on voltage issues

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ABSTRACT

Photovoltaic (PV) systems are the most promising renewable energy source in Malaysia due to its abundant solar irradiation. The Malaysian government has launched various renewable energy programs to encourage the use of PV systems. Most of the PV systems are single-phase and the installation is customer driven. Therefore, the growth of PV system in low voltage (LV) distribution network has the potential to raise several technical issues including voltage rise and voltage unbalance. Furthermore, Malaysia is a warm country and geographically surrounded by the sea. The vaporization of the sea water together with the seasonal winds results in a large amount of passing clouds, making this country to be, possibly, the cloudiest region in the world. The solar irradiation is therefore highly scattered and fluctuating. The power output from PV is highly intermittent, hence producing an enormous amount of voltage fluctuations and flickers on the LV distribution networks. All these voltage issues have to be studied experimentally and addressed thoroughly at the early stage before the amount of PV on the network becomes substantial. Therefore, a 7.2 kW grid connected PV system on a radial LV distribution network has been set up to study the voltage issues at the point of common coupling. The power outputs of the PV system are characterised and compared with that of other countries. The probability density of voltage rise and voltage unbalanced factors are derived from the measurement data. Short-term and long-term voltage flicker indexes are calculated to evaluate the severity of the flicker emission. These results are valuable to the policy makers, electricity regulatory body, utility company, customers and PV manufacturers because they can change the policy on the renewable energy and the regulatory framework.

Contents

1. Introduction

Global warming due to the excessive greenhouse gas (GHG) emission has been a concerning issue. Malaysian government is

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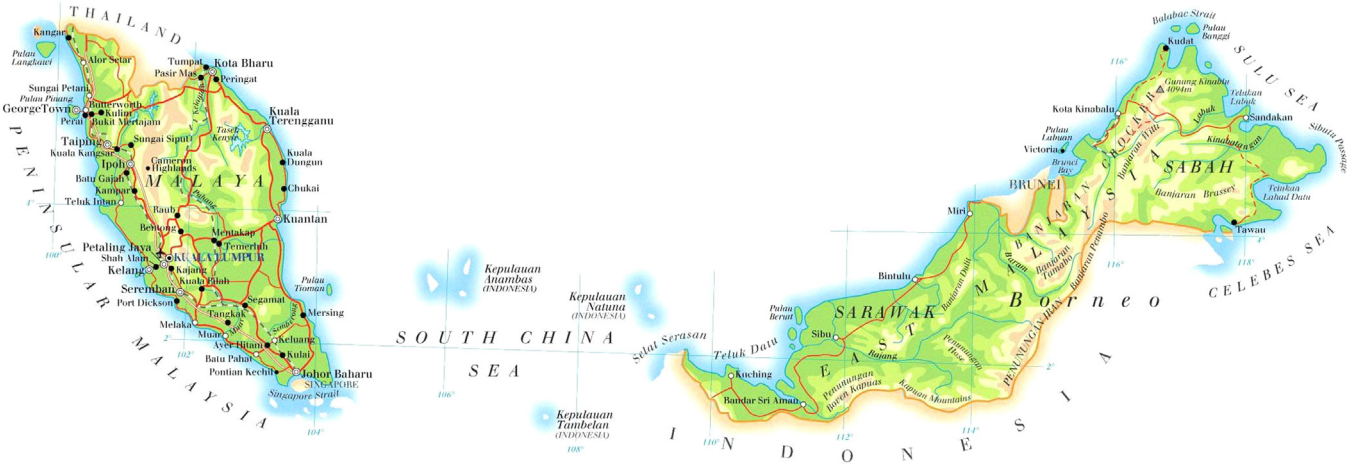

Fig. 1. Map of Malaysia [6].

committed to the reduction of greenhouse gas (GHG) emission by 40% in year 2030 as compared to 2005 level. As a result, the government has launched various programmes to promote renewable energies. Many research papers have been published to discuss the current prospective scenarios for the solar energy development, initiatives and the renewable energy policies in Malaysia.

The authors in [1] present an overview of the current perspective for renewable energy development in Malaysia. There are several potential renewable energy sources available in Malaysia, such as solar, biomass, biogas, mini-hydro, and municipal solid waste. The government has introduced a comprehensive policy in implementing renewable energy. The current installed photovoltaic (PV) capacity is approximately 20 MW [2,3]. It is expected that solar energy has the potential to reach more than 6500 MW by 2030. There is approximately 39 MW in biomass and 4.45 MW in biogas under construction as of July 2009. The potential capacity of both biomass and biogas can become 1340 MW and 410 MW, respectively by 2028. The current mini-hydro generation is approximately 30.3 MW and should reach 490 MW by 2020. As for waste power generation, the total capacity is 5.5 MW in August 2009 and can be 360 MW by 2020. With these continuous efforts, Malaysia can be one of the largest producers in renewable and sustainable energy in the world.

The solar energy outlook has been positive and is expected to surpass all other renewable energy sources in Malaysia by year 2050 [4]. This is because Malaysia is a tropical country as shown in Fig. 1 where high solar irradiance is available throughout the year. The Malaysian government has put in efforts to encourage the utilisation of photovoltaic systems especially to the domestic users. The authors of [5] state that Malaysia is likely to be one of the largest solar power producers in the world in the near future. Various research and development on inverters, PV concentrators, solar cells fabrications and characterization have been carried out by many local research institutions. These include research work on grid-connected inverters, development of solar cells and PV concentrator and PV power systems. These research efforts coupled with the government policy on solar energy can stimulate the PV market growth substantially. The Malaysian government has also introduced solar energy programmes such as Suria 1000, Malaysia Building Integrated Photovoltaic (MBIPV) and Feed-In Tariff (FiT) mechanism.

PV systems are expected to grow very rapid on the low voltage distribution networks and hence create several technical issues on the distribution networks. These technical issues can be voltage rise, voltage unbalance, network power losses, reversed power flow and the thermal limits of transformers being exceeded as described in [7–12].The voltage unbalance can be the most serious technical issue because most of the PV systems are single-phase and connected to the low-voltage distribution networks through "fit and inform" principle by customers [7]. However, the majority of the publications present the results based on simulation modelling in Matlab/Simulink or PSCAD. These virtual analyses are not able to consider many other practical factors, such as the passing clouds over the PV panels.

Malaysia is a tropical country geographically surrounded by the seas. The vaporisation of the sea water together with the seasonal winds results in the large amount passing clouds. Fig. 2 shows the global climatology data of the complete clear sky index around the globe. It is shown that Malaysia has no clear sky all year round as compared to any other countries in the world. Under cloudy sky condition, the solar irradiation is highly scattered and fluctuating, hence making the power output of the PV systems to fluctuate substantially [13]. Hence, the intermittent power output from PV tends to generate an enormous amount of voltage fluctuations and flicker to the LV distribution networks.

The technical issues caused by the PV systems in Malaysia become very unique because they are very dynamic instead of steady state. Experimental studies on voltage issues caused by the PV systems are necessary because only experimental data can show the real quality of voltage. All these voltage issues have to be studied and addressed thoroughly at the early stage before the amount of PV systems becomes substantial on the networks. Hence, the objective of this paper is to present the characteristics of voltage quality on the point of common coupling of the distribution networks with photovoltaic systems in Malaysia.

This paper begins with description of an experimental setup consisting of two PV systems, a network emulator and a monitoring system. Section 3 shows the PV power output characteristics. Section 4 presents the characteristics of the voltage rise, voltage unbalance and the voltage flicker on the network. Sections 5 and 6 provide the discussion on the impacts of the technical issues and the need of regulatory frameworks for PV installation.

2. Experimental network set up

To characterize the PV power output and study the voltage quality at the point of common connection (PCC), a laboratory network system consisting of two 3.6 kWp single-phase PV systems, three-phase loads and a monitoring system has been set up as shown in Fig. 3. Table 1 shows the resistance and