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Photovoltaic penetration issues and impacts in distribution network – A review

M. Karimi [a], H. Mokhlis [a,b,*], K. Naidu [a], S. Uddin [c], A.H.A. Bakar [b]

[a] Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] University of Malaya Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D UM, University of Malaya, 59990 Kuala Lumpur, Malaysia
[c] School of Information Technology & Electrical Engineering, The University of Queensland, Australia

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ABSTRACT

The solar energy generation has grown significantly in the past years. The importance of PV penetration in power system as a major element of renewable energy source has seen it being widely used on a global scale. Despite its promising success, PV penetration presents various issues and its impact on the distribution system has to address for seamless integration in the power system. In this paper, a comprehensive overview on important issues affecting the distribution system as a result of PV penetration is presented. Pertinent issues such as voltage fluctuation, voltage rise, voltage balance, and harmonics and their effect on the system are discussed in details. The islanding issues, which are of critical importance to the stability and integrity of the system, are also thoroughly reviewed. Details on different islanding techniques – remote and local techniques and their advantage and disadvantages are shown. Therefore, this paper can provide useful information and serve as a reference for researchers and utility engineers on issues to be considered with regards to PV penetration.

Contents

* Corresponding author at: Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 7967 5238.
E-mail addresses: mazaher@um.edu.my, karimimazi@gmail.com (M. Karimi).

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1. Introduction

Utilization of green energy resources has grown in the past decade, annually. The aims of Renewable Energy Sources (RESs) are to provide a technically and economically improvised integration of RESs in power system networks and at the same time to reduce the need for support the increasing demand in future and reduce CO_2 emission. Although, these new technologies are free from pollution, however, the integration of RESs in power system network will cause some issues. For instance, some types of RESs such as Photovoltaic (PV) and wind generation can cause oscillation in the power system's voltage and frequency. This is due to the intermittent nature of these types of RESs. Hence, intermittent sources, especially PVs, create new challenges in the electric power system. Integration of PVs in electric power system further leads to different issues for electrical engineer such as power quality, power imbalance between generation and load demand, voltage and frequency variation [1–3].

In recent years, PV technology has been developed quickly and made this technology viable even for small scale power generation in distribution system. Solar PV capacity for grid-connected system around the world was 10 GW in 2007, 16 GW in 2008, 24 GW in 2009 and 40 GW in 2010 [4]. The solar PV market has been steadily growing and the growth curve from 1995 to 2012 can be seen in Fig. 1.

In terms of globally installed capacity, PV is the third most important renewable energy source after hydro and wind power [5]. For instance in European Union (EU), PV represents about 37% from all new capacity of energy sources installed in 2012. Therefore, typical studies are carried out to investigate possible adverse impacts on the power quality, protection coordination and operation of distribution feeders. These investigations also examine the interactions of distribution equipment such as on load tap changers and status of capacitor banks [6]. Therefore, increasing penetration of PV in distribution level applies more stress on the utility voltage regulation devices and can even cause them to malfunction.

In this regard, the technical issues of utility power system on the grid side and the PV side need to be considered for safe operation of PV and to maintain reliability of the grid. This article which considers PV integration issues in distribution system will help utility companies with these new types of renewable sources. In addition, it will help researchers and utility engineers to reduce the limitation related to PV interconnection.

2. PV installed capacity and generation scale

Renewable energy installation in recent years has seen further growth. This has hugely contributed to the awareness on the importance of renewable energy and government policies in revising energy priorities to ensure adoption and significant growth of renewable energy. The cost of renewable energy has also dramatically declined over the years, thus making them competitive compared to non-renewable energy sources such as fossil powered power. The bar chart in Fig. 2 shows the total power generation capacity in Giga Watt (GW) for renewable energy resources on a global scale [7].

The amount of renewable power capacity for the three main renewable energy resources – hydro, solar and wind are analyzed. The Concentrating Solar thermal Power (CSP) and solar hot water capacity are also considered as entities for solar PV energy. It can be clearly observed that the hydropower constitutes as major percentage of renewable energy resource. This is due to the constant availability and huge capacity of hydro power in many different parts of the world. Solar PV and wind power, which are intermittent in nature, have limited availability based on their geographical location. In 2013, the total installed capacity of hydropower is 1000 MW, solar PV and wind power are at 783 MW and 318 MW, respectively [8].

Another important observation that can be viewed is that the total generation capacity in 2013 has decreased in comparison to 2012. This is in correlation to the global investment level in renewable energy resources. Fig. 3 shows the global investment (billion USD) in renewable energy by region from 2004 till 2014.

Majority of the regions in 2013 have experienced a drop in total investment in comparison to 2012. The decline in investment is mainly attributed to shifts on uncertainties in renewable energy policy as well as reduction on technology costs. Despite the decrease in investment, the ratio of installed capacity for solar PV in 2013 with respect to 2012 is at 22.85%. This ratio is greater than hydropower and wind which are at 16.22% and 14.89% respectively.

The global installed capacity of renewable energy has reached 480 GW, while the contribution of EU-27 was 210 GW. Global installed capacity of wind has reached to 318 GW in 2013 due to great installation capacity by China and Canada. Europe's installed

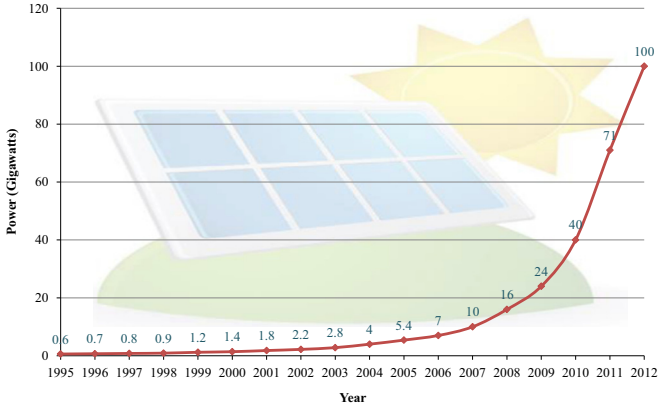

Fig. 1. Generation power of PV market around the world.

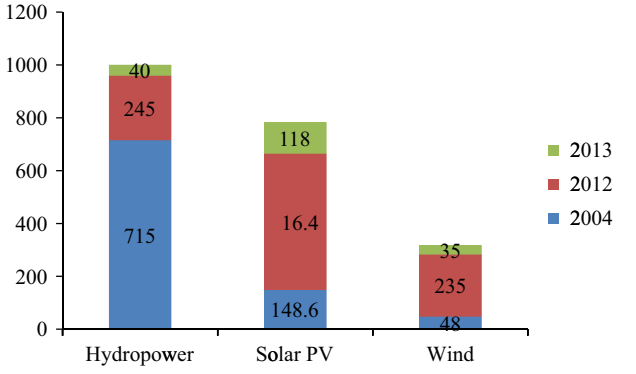

Fig. 2. Renewable energy power capacity in GW.

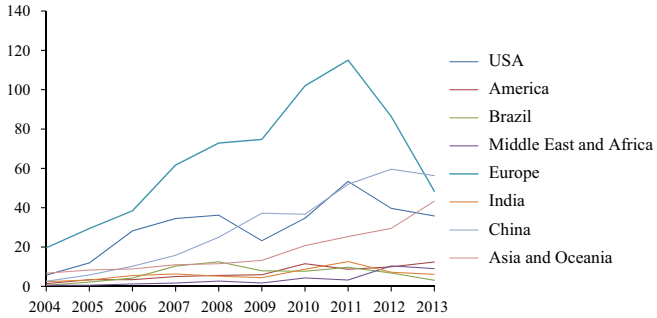

Fig. 3. Global investment in renewable energy by region (billion USD).