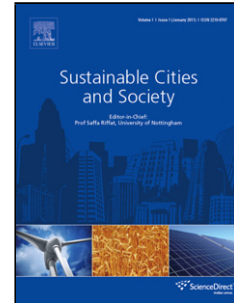


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# Impact of Large PV and Wind Power Plants on Voltage and Frequency Stability of Jordan's National Grid

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## Highlights

- Grid capacity should be considered when renewable sources are integrated to grid.
- Penetration levels of renewable sources affect static and dynamic voltage stability.
- Frequency stability is affected by PV and type 4 wind generators.
- VAR compensation devices improve voltage stability of systems with renewable sources.
- Frequency emulators can help in improving frequency stability.

**Abstract**—The impact of integrating large photo voltaic (PV) and wind power (WP) renewable energy plants (REPs) to the national grid of Jordan is presented. The capacity of the national grid to integrate REPs and upgrading of the transmission grid to increase the grid capacity is examined through computer simulations using load flow analysis. Congestion management based on line flow capacity constraints has also been carried out. It was found that the maximum penetration levels of the REPs should not increase beyond 10% of the Jordan's annual peak demand. However, accommodation of penetration levels to up to 1600 MW of REPs by 2020 is proposed by network upgrading. The effect of increasing the penetration levels of REPs, during normal conditions, on voltage and frequency stability has been analyzed. The maximum power generation of the REP that can be connected to the grid at a proposed location before voltage collapse occurs has been determined. It was found that by introducing voltage and reactive power support, the maximum power generation of REPs can be doubled. Frequency stability analysis shows that frequency stability of the grid can be maintained even when the penetration level of the REPs reaches up to 40% of the total generation. Furthermore, stability analysis has confirmed the importance of interconnection with neighboring power systems. All simulation studies have been implemented using the professional DIGSILENT software package.

**Keywords**—Renewable energy; Photovoltaic; Wind; Voltage stability; Frequency stability; Grid capacity

## 1. Introduction

In line with the global technological advances in exploiting renewable energy resources, the Ministry of Energy and Mineral Resources (MEMR) of Jordan is keen to facilitate the integration of electricity generation using solar and wind energy to the national grid. This is very significant as it will reduce the reliance on imported energy and create economical feasible alternatives to reduce the total energy bill without any adverse effects on the energy efficiency or the local community (MMER, 2015). However, as compared to the conventional steam and gas turbine plants, the REP, either wind or solar, have different technical characteristics. Therefore, connecting high levels of intermittent REP creates additional challenges to maintain the stability of electrical transmission systems, either during normal operation or in the event of

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