Penetration Issues With Grid Connected Solar Photovoltaic Systems

K. Barkavi

In this article, the recent advances in the grid management of solar photovoltaics (PV) are discussed. Several power quality issues are arising during the solar PV power generation as well as in the distribution networks. The challenges and development related to the renewable power grid and hybrid power management issues are enumerated with the salient methods and techniques to overcome the key power quality challenges and the future scope to overcome the grid penetration issues, especially variation in the intensity of energy sources and demand management.

Index Terms: Solar Photovoltaics, power transmission networks, power quality, reactive power, grid stability.

1. INTRODUCTION

Solar PV (SPV) power generation is not only important but also the proper matching of supply with the demand is vital for optimum use of energy systems. The distribution network always involves PV penetration due to low or surplus power generation. The combination of renewable sources of energy with conventional power generation like a generator or hybrid renewable energy systems (RES) is normally facing the challenges like grid stability, harmonics and voltage fluctuations. Figure 1 shows a typical converter block diagram.

Liu et al. [1] proposed an independent active and reactive power control strategy for large scale grid-connected PV systems (LSGSPV). Nonuniform solar irradiation produces voltage issues during the operation. Output voltage overmodulation was carried out in the cascaded PV system. They successfully demonstrated the proposed techniques on two cascaded 5-kW converters. Various power control issues are tabulated in Table 1.

Table 1. Power control techniques

<table>
<thead>
<tr>
<th>Factors</th>
<th>Techniques</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power schemes control</td>
<td>Active and reactive power control</td>
<td>[1], [5]</td>
</tr>
<tr>
<td>Hybrid systems and integration</td>
<td>Flexi-load management</td>
<td>[2], [7], [17]</td>
</tr>
<tr>
<td>Harmonics</td>
<td>13.3% reduction of harmonic distortion using mathematical modelling.</td>
<td>[3], [18]</td>
</tr>
<tr>
<td>Low voltage mitigation</td>
<td>Low and over voltage mitigation techniques</td>
<td>[4], [10], [12], [14], [18]</td>
</tr>
<tr>
<td>Spatial matching</td>
<td>PV penetration was studied in combination of topographical and topological map data.</td>
<td>[8]</td>
</tr>
<tr>
<td>Frequency stability</td>
<td>Frequency stability improvement is carried out. Storage is important to manage the weak grids.</td>
<td>[9], [11]</td>
</tr>
</tbody>
</table>

Badwawi et al. [2] addressed over the weak grids and drawbacks of storage in the standalone due to the varying power generation of solar and wind hybrid energy systems (SWHES). Major issues of standalone or grid systems are voltage and frequency fluctuation and harmonics. Optimization of SWHES mainly depends on the design of fast response controls. Optimal sizing, power electronics topologies are discussed for stand-alone SWHES. Figure 2 shows schematic of the hybrid energy systems and grid control. Etier et al. [3] studied the harmonic distortion in LSGSPV. The power quality was studied for LSGSPV and electrical grids. Simulink into LabVIEW were used to simulate the effects. They simulated the effects of the solar radiation and the operating temperature of PV modules on the harmonic distortion around 13.3% at a module temperature of 25°C. Pompidakis et al. [4] dealt the overvoltage issues in the PV penetration in the rural distribution networks. They used iterative algorithm. Nine PV consumer connections are considered for the simulation. Control of reactive power is one

2 MATERIALS AND METHODS

The intermittent nature of the RESs requires energy storage or power backup systems. Standalone and grid-connected PV systems involve various operating and networking issues during the operation of the PV power plant. The majority of the solar-based power generation is mainly dependent on the meteorological data. Topographical data mainly involve the selection of control scheme used for the power management of RESs. Especially, a large-scale PV power generation involves a lot of power quality issues with generation side and power grid utilization too. Standalone systems are involving battery storage. However, the large-scale SPV systems are economical in case of using proper grid management.

K. Barkavi, Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai, India. E-mail: kbankavi@gmail.com
Yang et al. [5] focussed on the integration issues of PV penetration. The power control of such decentralized and vulnerable grids is important to obtain higher efficiency and reliability. A flexible power controller is proposed for commercial PV inverters. Mosayebian et al. [6] discussed hourly operation management of microgrid (MG) at stochastic conditions. Linear programming is used to reduce the computational time. They have demonstrated on SWHES. Archana and Vidhyapriya [7] proposed synchronous reference frame unified power flow controller (SRF-UPFC) for grid-connected SWHES. D-q theory is used to generate control signals for shunt and series converters. This is useful to mitigate voltage sag/swell, reactive power compensation and harmonic reduction.

Sob o et al. [8] used time series analysis to predict the hourly PV power penetration with the electricity generation with electricity demand. The combination of topographical and topological map data is used in the analysis. Energy storage is used in the large SPV systems to counteract the weak grids. Vitale [9] studied the frequency stability improvement in weak grids using advanced storage with power converters. Storage has been serving better with dynamic grid support for SWHES. Hilton et al. [10] compared small batteries to a single larger feeder connected battery (FCB). FCB responds to the power flows and capable of reducing the voltage issues. Gupta et al. [11] studied the power quality issues of 100 kW GCSPV using MATLAB/Simulink software. They studied the voltage and current issues at different load conditions. The voltage regulation mitigation techniques in distribution system discussed by Chaudhary and Rizwan [12]. The impacts of high PV penetration into distribution systems are mainly dependent on the current and voltage profiles. The stability and security of the power grid are important aspects of the modern integration of PV plants [13]. The intensive grid code regulations are to be prepared with the PV manufacturers and developers to meet the recent trends in renewable power generation. Figure 3 related the voltage issues in the SPV and feeder as per the NREL report (2008). Popavath and Kaliannan [14] proposed a method for the severe power quality problems using custom power devices with reactive power supply. Low voltage ride through suggests the injection of real and reactive power supports grid voltage during abnormal grid conditions. Tafti et al. [15] proposed a flexible power point tracking (FPPT) to provide the upper limit for the voltage in grid-connected systems. An adaptive FPPT control scheme was investigated on a 30kW grid-connected single-phase PV system. They demonstrated the fast and accurate control during the abnormal conditions. Resource assessment and techno-economic analysis of a SWGCSPV for different locations in Saudi Arabia was carried out by Alharithi et al. [16]. The simulation results are applicable for the similar meteorological and environmental conditions. Sarkar et al. [17] showed the voltage quality issue occurs not only due to the considerable penetration of PV but also due to the connected load and X/R ratio of the feeder. Figure 4 consolidates the various power quality control techniques.

Elkholy [18] carried out statistical analysis of each harmonic,
power factor and total harmonic distortion. Different loading conditions are tested. The characters of current harmonics and voltage harmonics are studied. High current total harmonic distortion observed when the power levels below its rated value. Methods to balance the photovoltaic systems under non-uniform solar radiation and improvement of thermo-electrical performance of PV through different cooling methods presented [19, 20]. Different optimization methods of solar and wind hybrid systems are discussed to improve the overall system productivity [21]. Barkavi et al. [22] demonstrated a grid integrated solar micro inverter using space vector modulation technique. Simulation studies showed the various control techniques for the standalone and grid-connected PV power plants. Few are unique to the respective applications. However, the authors addressed the region-specific PV plant issues and provided the mitigation techniques.

4 CONCLUSION

The various penetration issues related to grid connected SPV systems are discussed. Standalone and grid connected HRES possesses different current and voltage issues which have to be controlled effectively during the low and overload conditions. Supply and demand mismatch lead to damage to the grids. A flexi-load operation is one of the potential options to harness the solar energy effectively.

- The selection of proper control strategy is vital to operate the plant with the maximum power output and stable grid at ease and quickly.
- Design of a suitable dynamic control scheme is required to mitigate the power quality issues of a large scale grid connected RESs.
- More generalized control techniques perform poorly in other regions. Several power control techniques are applicable to the region-based on the meteorological data.

Most of the control schemes are used to perform under severe load conditions. A technique which possesses a fast response, measurement accuracy and management of power quality issues are the need of the hour to effectively utilize the renewable energy systems.

REFERENCES


