Chapter 13
Stability Analysis of Grid-Connected Photovoltaic Systems

M. A. Mahmud
The University of New South Wales at Australian Defence Force Academy, Australia

M. Jahangir Hossain
The University of Queensland, Australia

H. R. Pota
The University of New South Wales at Australian Defence Force Academy, Australia

ABSTRACT

This chapter presents an overview Photovoltaic (PV) power generation and integration of PV systems with power grid. This chapter also presents a Feedback Linearizing Current Controller (FBLCC) to synchronize the PV system with the grid. This controller is designed based on the feedback linearization technique. The reference current for the controller is generated from the Maximum Power Point Tracker (MPPT). The stability of a single-phase grid connected PV system is analyzed through the Lyapunov function. To do these things, a suitable mathematical model of grid-connected PV system is also presented in this chapter. The performance of the designed controller is tested on a single-phase grid-connected PV system.

INTRODUCTION

Demand for electricity is increasing day by day. The increased demand for electricity has outstripped that for other forms of energy. Renewable energy, which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, is the best choice as alternative sources of energy.

According to the Global Status Report 2007, about 18.4% of global final energy consumption came from renewable energy sources in 2006, with 13% coming from traditional biomass, which is mainly used for heating, 3% from hydroelectricity and rest 2.4% accounted from new renewable energy sources (small hydro, modern biomass, wind, solar, geothermal, and bio fuels). The annual growth rate of wind energy is about 30% (Kroldrup, 2010), with a worldwide installed capacity of 157,900 Megawatts (MW) in 2009 as

it is widely used in Europe, Asia and US. Global status Report 2009 shows that at the end of 2009, cumulative global Photovoltaic (PV) installations surpassed 21,000 MW as PV power stations are popular in Germany and Spain. Even Australian government and other developed countries set their target to generate 20% of their total energy supply from renewable energy by 2020.

PV system such as solar cell is the most promising energy sources in the recent years. PV installations are increasing day by the due to their small size and environment friendly operation. PV installations are suitable for large-scale (grid-connected) as well as small off-grid (stand-alone) applications, sometimes in rural and remote areas, where energy is often crucial in human development. Small off-grid application requires battery bank to store energy whereas in large-scale applications, battery bank is not essential. The target of grid-connected photovoltaic system is to transfer maximum power into the grid with unity power factor.

PV generation entirely depends on the atmospheric condition. If the weather sunny, the PV generation is more but if the weather is cloudy, PV generation is less. Moreover, the intensity of sunlight is not same throughout the sunny weather, which causes the variation of PV generation. Due to this variation, PV system will not properly synchronize with the grid, which causes serious problems related to the stability of the system. This chapter will address these issues.

BACKGROUND

Power systems are designed to operate in a top-down fashion which means power is generated from generating station, then transmitted through the transmission network, and finally distributed to the consumers through distribution system. But the recent trends of power system engineers are to operate the systems within their stability limits as well as put some new generation within the distribution network. The inclusion of gen-

erators within the distribution level is known as distributed generation. However, PV generation has also reaching consequences in transmission and distribution networks. As the conventional generators are not environment friend, the power industries are now trying to introduce some alternative sources of energy from which solar energy, i.e., PV generation is the best choice.

The operation of PV systems depends on several factors such as environmental, technical, commercial social and political. As our target is to present an elaborate overview of technical factor, some technical concerns are listed below (Rikos, et al., 2008):

- saturation of the existing network and reduction of security margins;
- geographical and ecological constraints;
- stability and security problems;
- continuous demand growth;
- need for investment to sustain the development in the power demand;
- privatization, deregulation and competitive environment of the electricity market;
- emergence of new rational technologies with ecological advantages, which can be combined with heat generation.

The output power of PV cell changes due to the environmental factors such as temperature and light intensity. When cloud passes through the PV cell, the PV generation is disturbed, i.e., output power of PV cell changes. To match these changes, an MPPT is essential. There are extensive literatures on MPPT in (Chung, et al., 2003; Rodriguez & Amaratunga, 2007; Esram, et al., 2006). Though there are lot of methods for MPPT, Perturbation and Observation (PO) and incremental conductance methods are most familiar as they can track power all time. In PO method, the derivative of power (dp) and the derivative of voltage (dv) need to be measured to determine the movement of operating point. If the ratio of dp and dv is positive the reference

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