Design, Application and Comparison of Passive Filters for Three-Phase Grid-Connected Renewable Energy Systems

Mojgan Hojabri[1], Mehrdad Hojabri[2]

[1]Faculty of Electrical and Electronics Engineering, University Malaysia Pahang, 26600 Pekan, Malaysia, Mojganhojabri@ump.edu.my

[2]Electrical Department, Science and Research Branch, Islamic Azad University, Kermanshah, Iran, Mehrdad.hojabri.66@gmail.com

ABSTRACT

Second and third-order passive filters (LC and LCL) are interesting filters to use for grid-connected PWM inverters. Because of the stability problems of these filters around resonance frequency, series and damping resistor can be add to an LCL filter. However, the resistor value has impact on the filter respond, voltage and current harmonic distortion and filter power loss. In this paper, the mathematic characteristics of LC, LCL filter, series and parallel damping LCL filters will be described with their design to apply in 3-phase PV grid-connected inverter. And, simulations have down to validate the theoretical analysis of the filters on filter performance, power quality and filter power loss for 3-phase grid-connected renewable energy system application.

Keywords: Passive Filters, LCL Filters, Filter Power Loss, Harmonic Distortion, Renewable Energy Systems.

INTRODUCTION

Filters are main parts of a renewable energy system. First- order passive filters are L type which are generally use for controlling grid-connected inverter. The main disadvantage of this type of filters is their big size. Another type of the passive filters is LC filters (second-order). Because of the big size of the inductor, the size of this filter is large. Moreover, time delay and resonance frequency are another drawbacks of LC filters. Compared with a first-order and second-order filters, a third-order LCL filter has lower coast and smaller size in applications above several kilowatts. However, resonance frequency is still as a problem of these filters.

To repress the resonances of an LCL filter, active damping [1]–[2] or passive damping [3]–[5] can be used. The price of active filter is high due to the additional cost of the sensors and control system. Because of the low cost and simple circuit in a stiff grid application, a passive damping strategy is more preferred. A simple damped LCL filter is an LCL filter with series or parallel resistor with capacitor. By adding a resistor to the filter circuit, the power loss will increase. So, finding the optimum resistor value to decrease the peak resonance of LCL filter is very important.

Therefore, in this paper characteristics of LC, LCL filter, series and parallel damping LCL filters will be discussed. Since maintaining a good power quality is important for the reliable operation of the system and loads [6], these filters will be applied to a three-phase PV system. Then, the inverter output will be filtered in order to obtain low voltage and current distortion. And also, the filter impacts on grid current will discussed.

PRINCIPLE OF PASSIVE FILTERS

First, grid-connected converters are the interface to connect renewable energy sources to the power system. To reduce the harmonics injected by the converters a high value of input inductance should be used. However, L filter design is easy but in application above several kilowatts it becomes expensive because of using large filter reactor. Moreover, the system dynamic response becomes poor.

A. LC FILTER

The filter consists of an inductance in series with the inverter and a capacitance in parallel with the grid (Figure-1). By using this parallel capacitance, the inductance can be reduced, thus reducing costs and losses compare with L filter. By using a large capacitance, other problems such as high inrush currents and high capacitance current at the fundamental frequency or dependence of the filter on the grid impedance for overall harmonic attenuation will appear [7].

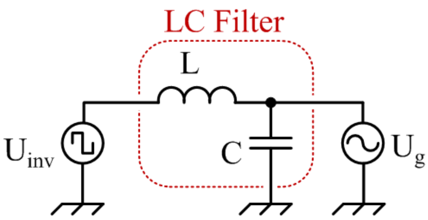

Figure-1. Grid-connected LC filter.

The LC filter transfer function of grid side voltage and inverter input voltage in grid-connected mode of operation is given by (1). The bode plot is presented in Figure-2.

$$G(s) = \frac{U_g}{U_{inv}} = \frac{1}{S^2 LC + 1} \quad (1)$$