Modeling and Control of Grid-Connected Photovoltaic Power Plant With Fault Ride-Through Capability

According to modern grid codes (GCs), high penetration of photovoltaic power plants (PVPPs) to the utility grid requires a reliable PV generation system by achieving fault ride-through (FRT) requirements. In order to meet these requirements, there are two major issues that should be addressed to keep the inverter connected during grid faults. The two issues are the ac over-current and dc-link over-voltage that may cause disconnection or damage to the grid inverter. In this paper, the control of single-stage PVPP inverters is developed to address these issues and enhance FRT capability. The proposed control scheme introduces the dc brake chopper circuit and current limiter to protect the inverter and ride through the fault smoothly with no perceptible overcompensation. A 1.5 MW PVPP connected into the Malaysian grid and modeled in SIMULINK is utilized to explain the proposed control scheme. The simulation results presented demonstrate the effectiveness of the overall proposed control strategy to ride through different types of faults and to help to ensure the safety of the system equipment.

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1 Introduction

Over the recent years, photovoltaic (PV) energy has become one of the fastest growing renewable energies worldwide in the power sector [1]. This significant increase in the penetration of photovoltaic power plants (PVPPs) to the electric grid is expected to continue developing rapidly in the future [2]. As the penetration of PVPPs to the electricity grid increases, disconnections of these plants during faults are undesirable, as this will lead to the loss of a large amount of PV-generated power, which may cause problems in the stability and operation of the power system. Consequently, many countries have put in efforts to establish elaborate specific technical requirements as a part of their grid codes (GCs) related to the integration of PV farms. The basic GC requirements consist of fault ride-through (FRT), which specifies the range of the grid voltage level under nominal values within which PVPPs have to remain connected to the power grid [3].

Figure 1 shows the general FRT requirements for grid-connected photovoltaic power plants (GCPPPs). The PVPP is required to work continuously in area A, which represents the nominal voltage at the connection point that is the point of common coupling (PCC). However, if the voltage is in area B, the PVPPs have to withstand voltage dip and remain connected to the system for a period of time \(t_0 \rightarrow t_1\); otherwise, they have to be disconnected. In the case that the voltage at the connection point in area C recovers to \(V_1\) within time \(t_2\) after a fault has occurred, it is mandatory for the PVPP to remain under continuous operation without disconnection. The values of \(V_0, V_1, t_1,\) and \(t_2\) differ from the GC to another based on the standards and characteristics of the national grid. An overview study compared the FRT requirements in various international GCs regarding the connection of PVPPs to the utility grid reported in detail in Refs. [3–6].

The main cause of voltage sag is short-circuiting or grid faults. In the literature, some existing analyses and solutions of asymmetrical and ground faults in microgrid distribution systems have been proposed [7,8]. The studies show the effectiveness of the proposed methods to achieve high efficiency and accuracy in fault analysis. Another study analyzing ground faults using a direct building algorithm has been reported. The results demonstrate that the proposed direct building algorithm is accurate and suitable for fault analysis in microgrid distribution systems [9]. On the other hand, fault analysis regarding FRT has not been discussed in these studies.

There are two major problems that must be addressed by PVPPs to achieve the FRT requirements mentioned earlier during and after grid faults [10,11]. The first is the dc-link over-voltage in the dc-side of the PV inverter, as well as the over-current that can occur in the ac side. The second is the control reactive current according to the GC requirements. Most publications recently...