A Review of Low Voltage Ride-Through Techniques for Photovoltaic Generation Systems

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***Abstract*—The rapid development of photovoltaic (PV) generation systems has made the low voltage ride-through (LVRT) techniques, which is stepping forward fast, more and more important. This paper presents a review of LVRT techniques for PV generation systems, which mainly focuses on the critical techniques of fault detection and grid synchronization, current control and dc-link voltage control under various voltage dip operation conditions and overall solutions for a large-scale PV station with detailed illustration. Besides, the development trends of low voltage ride-through techniques for PV generation systems are discussed as well.**

I. Introduction

Nowadays, developing grid-friendly converters, aiming at performances improvement during normal and grid fault operation conditions, is a significant trend all over the world, especially in the area of renewable energy interfacing conversion. For instance, following the requests of low voltage ride-through (LVRT) in wind turbine generations, the LVRT requirements of PV generation system have been proposed and are updating in plenty of countries as the increase in capacity and penetration level of PV generation systems. The general LVRT requirements of PV generation systems focus on keeping inverters connected to the grid without generating overcurrent and meanwhile offering reactive power support to help the grid recovery during various fault conditions. The LVRT requirements are well accepted and widely spread in virtue of its benefits in voltage recovery [1, 2] and frequency stability, ignoring the impacts on transient stability of high-penetration grid [3].

Although LVRT regulation is generally accepted, the specific requirements and standards vary from country to country. As shown in Fig. 1, for example, the differences of limit curves for the voltage, beyond which the converters are required to connect to the grid, are obvious. Concretely speaking, comparing to the Denmark standards, Germany (E.ON) standard [4] and Chinese standard GB/T 19964-2012 [5] force grid-tied inverters to remain connected to the grid even the voltage drops to zero for 150ms while other countries permit them to protect themselves from grid in such severe fault condition. And the reactive power support requirements, such as the ratio of reactive power to voltage drop depth, maximum required reactive power, are different from country to country, as shown in Fig. 2. Besides these basic requirements, the detailed rules, such as reference voltages, recovery gradient, response time and so on, are different either. E.ON standard, for example, takes the lowest values of three line-to-line grid voltages as reference voltage while Chinese standard chooses line-to-line voltage or phase voltages as reference voltage in different fault conditions.

Ignoring the detailed differences among these standards, the basic requirements and the kernel are easy to be concluded precisely – optimal supports for grid stability and rapid responses in both LVRT entry and exit process. However, all these efforts are proposed based on the benefits to grid rather than concerning about grid-tied inverters themselves, resulting in a plenty of problems and challenges in terms of inverter design, test procedures and operational process. The most significant challenge, for example, is that grid-tied inverters may suffer from severe voltage disturbances but should remain stable, avoid over-current and adjust output current to fulfill reactive power requirement.

Moreover, although the LVRT techniques of wind power

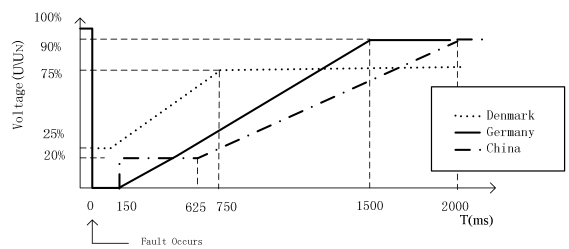

Fig. 1. Limit curve for grid voltage of different countries.

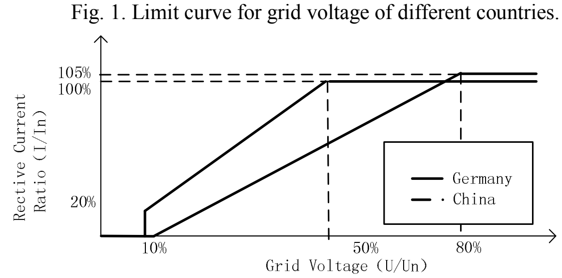

Fig. 2. The principle for voltage support.

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