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A Review of the Low-Voltage Ride-Through Capability of Wind Power Generators

Yi-Liang Hu[a], Yuan-Kang Wu[a]*, Chiu-Kuo Chen[b], Chih-Hua Wang[c], Wei-Tai Chen[c] and Liang-Il Cho[c]

[a]National Chung Cheng University, No. 168 University Road, Min-Hsiung, Chiayi, 62102, Taiwan
[b]Bureau of Standards, Metrology and Inspection,BSMI
[c]Taiwan Electric Research & Testing Center,TERTEC

Abstract

With the increasing wind power penetration, the dynamic behavior of modern power systems changes. Wind turbine generators (WTGs) should provide the ancillary services to enhance the transient stability of the power system. Currently, the installed WTGs are required to equip with the low-voltage ride-through (LVRT) capability based on the grid codes; that is, the WTGs should stay connected to the grid during short-term voltage drops. This paper reviews control stategies of the WTGs for providing the LVRT capability. First, the extra devices for limitating the transient current and voltage in WTGs are introduced. Then, the control techniques for the reactive power support without any additional components are reviewed. This investigation provides useful information to wind turbine manufacturers and grid operators.

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Keywords: Wind turbine generator; Low-voltage ride-through; Reactive power support.

1. Introduction

The increasing share of the wind power generation gradually changes the dynamic characteristics of modern power systems. To maintain the transient stability of a power system, the installed wind turbine (WT) must provide the ancillary services. Currently, the grid codes in most countries require that the large-scale wind power plants must

* Corresponding author. Tel.: 886-939500016
E-mail address: allenwu@ccu.edu.tw

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stay connected to the grid for a short period during the voltage dip [1-6]. This is the so-called LVRT capability of WTs. If the WTs are tripped off immediately after voltage sag, the grid voltage will drop further. Also, the system frequency will drop due to power imbalance. Then, the power system may be blackout due to a cascade of failures of generators. To prevent the system blackouts, the WTs must be equipped with the LVRT capability. The typical requirements for the LVRT capability of WTs in the grid codes are shown in Fig. 1. As shown in Fig. 1(a), the WTs must keep connection to the grid if the system voltage and fault duration remain in the shadow area. Because the voltage drop of the WT terminal causes both over-current in the windings and over-voltage in the DC-link, the additional protection devices should be installed. Moreover, WTs must deliver the reactive current during the voltage dips to maintain the grid voltage. This voltage control must be activated within 20ms after the voltage sag is detected. The required amount of the reactive current relies on the voltage dip, as indicated in Fig. 1(b). The reactive current output of a WT should be within the shadow area. After the fault is cleared, WTs must continue to deliver the active power immediately with the gradient of at least 20% of the rated power per second. In section 2, the protection devices for the fulfillment of the LVRT requirement are investigated. The strategies for controlling reactive current are reviewed in section 3.

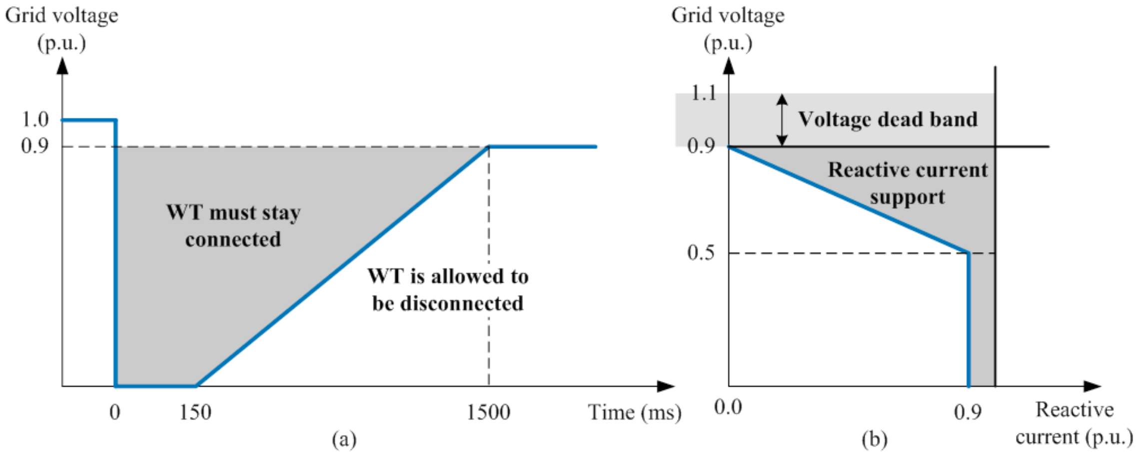

Fig. 1. The grid code requirements that consist of (a) ride-through curve and (b) support curve of reactive current.

2. Protection devices for LVRT

The doubly-fed induction generator (DFIG) is sensitive to the change of the grid voltage because the stator of DFIG is connected directly to the grid. Through the magnetic coupling, the sudden change of the stator voltage may cause the over-current and over-voltage in the rotor circuit. To avoid the damage of the power converter, the extra protection schemes must be implemented. The existing two types of protection schemes for DFIGs are to utilize crowbar and demagnetization. In the crowbar protection scheme [7-9], the additional crowbar resistors are connected to the rotor circuit to damp the rotor current. However, the main drawback of this scheme is that the rotor-side converter (RSC) is disabled to protect the semiconductors. The DFIG operates as the conventional induction generator and temporarily loses the controllability of the active and reactive power. The grid voltage drops deeply because the DFIG absorbs reactive power from the grid during the grid faults. In the demagnetization scheme [10-13], the strategies for controlling the RSC are designed to cancel out the oscillation of the stator flux. The robustness of these algorithms strongly depends on the selection of the control parameters and the estimation of the system parameters. Thus, the major drawback of this scheme is that these algorithms are too complicated to be implemented in industrial applications.

If the stator voltage of the DFIG can be kept at the pre-fault value during the faults, the crowbar or demagnetization protection is unnecessary. Therefore, the dynamic voltage restorer (DVR) was proposed to compensate the voltage drop [14-16]. The DVR is composed of the voltage source converters (VSCs), LC filters and coupling transformers. During a normal condition, the transformers are bypassed by the switches. Once the fault is