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A virtual synchronous machine control scheme for wind turbines

L. Lu[a] and N. A. Cutululis[a]

Virtual synchronous machine (VSM) control is one category of control schemes applied to converters, which enables converters to perform with similar characteristics as synchronous generators (SGs) by using SGs' models in the control schemes.

Research has been carried out to apply VSM control on wind turbines (WTs). Qing-Chang Zhong *et al*. implemented their VSM control on type-4 WTs, which is based on a fifth-order round rotor SG model without rotor damper windings and with no saturation effects in the iron core. This model includes all the good and bad properties of an SG. For instance, undesirable phenomena, such as loss of stability due to underexcitation as well as oscillations around synchronous frequency, could occur[1]. Yiwei Ma *et al*. implemented their VSM control on type-4 WTs, which not only includes the transient dynamics of stator windings in the electrical part of an SG model, but also includes models of automatic generation control (AGC), governor and turbine in the mechanical part[2]. Both of them are trying to emulate SGs' properties as much as possible.

However, considering the big differences between a converter and an SG in structures and characteristics, it is feasible only to emulate the desirable properties of an SG rather than include the undesirable ones together, which is also more favourable for system stability and power quality. Meanwhile, as a converter does not have those stator and rotor windings in reality, there is no need to add them virtually to make control schemes complicated. In this way, advantages of converter control, like fast control speed, are kept. Therefore, the goal of this paper is to develop a type of VSM control, which has qualified frequency and voltage control capabilities while with simplified control schemes.

The proposed VSM control scheme in this paper is mainly based on the classical model of an SG, which is used extensively in stability studies. This model offers considerable computational simplicity; it allows the transient electrical performance of the machine to be represented by a simple voltage source of fixed magnitude behind an effective reactance[3]. The simplification of the control scheme mainly lies in the electrical equations of the SG model, for which only an exciter is emulated. The state-space representation of a single type-4 WT connected to an infinite bus is derived and block diagrams are given (shown in Figure 1 below). Simulations in MATLAB Simulink validate the feasibility of this control scheme. Furthermore, its performance in frequency and voltage control is compared with another control scheme (shown in Figure 2 below), which includes the field circuit apart from the swing equation and exciter.

The main novelty and contribution of this paper is to propose a simple but qualified VSM control scheme for type-4 WTs, which keeps the fast control of a converter while at the same time avoids the undesirable characteristics of an SG, like its complexity, electromagnetic relationships between flux linkages and electromotive forces, etc. This simplicity makes it easier for present WTs to adopt. Furthermore, a detailed state-space representation of the VSM control scheme is given for better understanding.

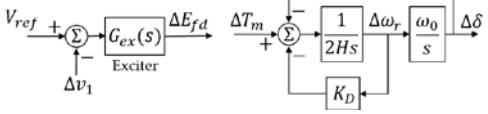

Figure 1 Classical model with exciter

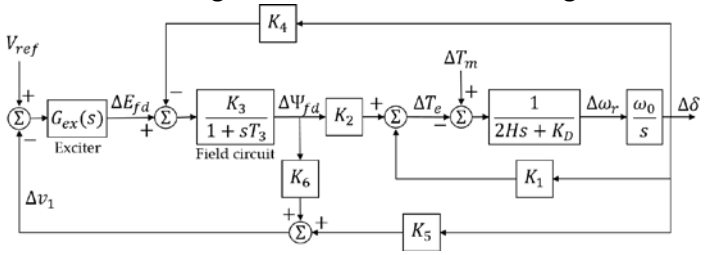

Figure 2 Classical model with field circuit and exciter

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[a] Dep. Wind Energy, Technical University of Denmark, Frederiksborgvej 399, 4000 Roskilde, Denmark

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