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Morphological filter applied in a wireless deadbeat control scheme within the context of smart grids

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ABSTRACT

This paper proposes a digital morphological filter to be applied on reference signals for a deadbeat control of a doubly fed induction generator. The signals are wireless-transmitted from a remote operation center and prone to be corrupted by spikes caused by a wireless fading channel. The proposed technique filtering and the control scheme are to be implemented in a microprocessor locally placed at the generator site. The filter acts on the signals at the receiving end of the channel and its outputs serves as clean references to the deadbeat control. In order to evaluate the filter performance, corrupted signals have been generated by means of a simulated channel linking the remote center and the induction generator. The results show the method is efficient in filtering out the spikes without provoking excessive delays.

1. Introduction

In recent times, renewable energy sources have been the recipients of increasing attention from governments and researchers around the world. This interest can be explained by the growing concern about to reduce CO_2 emissions, and also by the searching of economical alternatives for traditional energy sources like petrol or coal. These renewable alternative sources, like solar, tide, or wind energy are usually connected to the power grid both in the transmission and distribution levels. This brings up new technical challenges to monitor and control the energy produced by these sources. Within this context, the development of smart grids (SG) procedures is becoming mandatory for utilities [1].

SGs are modernized electrical power grids. They rely on a much more efficient use of generation, transmission, and distribution infrastructure turning the demand and supply of energy balanced and avoiding contingencies in the system [2,3]. Among the great benefits brought by the advent of SGs technologies, it can be highlighted the arisen of enabling techniques for optimal management of wind power. Recently, advances in wind power technology have greatly improved system integration issues. However, there are still some unsolved challenges for expanding its use. Its employment entails undesirable fluctuations of generated power due to the usual variations of the wind speed, that, if not compensated in real time, can lead to frequency imbalance and disturbance in the stability of the electrical system. Although SGs can minimize this problem through an efficient demand response for load control and dispatch of other generation resources, the use of variable speed aerogenerators and its precise power control system are still necessary.

Among the aerogenerators, the doubly fed induction generator (DFIG) is the most general employed in wind power systems [4], due to its interesting main characteristics as, for instance, the ability to operate at variable speed and the capacity to control the active and reactive power into four quadrants [5,6]. A precise power control of the aerogenerators is essential to maximize the generated power. The advances in wireless communications have made possible implementation of low-cost and multifunctional wireless sensors and communication modules in wind power plants [7] and drive systems [8]. Fig. 1 shows the general scheme of an aerogenerator controlled by a SG operator through a wireless communication channel.

Many modern communication systems are based on wireless transmission [9–11]. It provides benefits such as low cost, high speed links, and easy setup of connections among different devices/appliances. In literature, it is possible to find out

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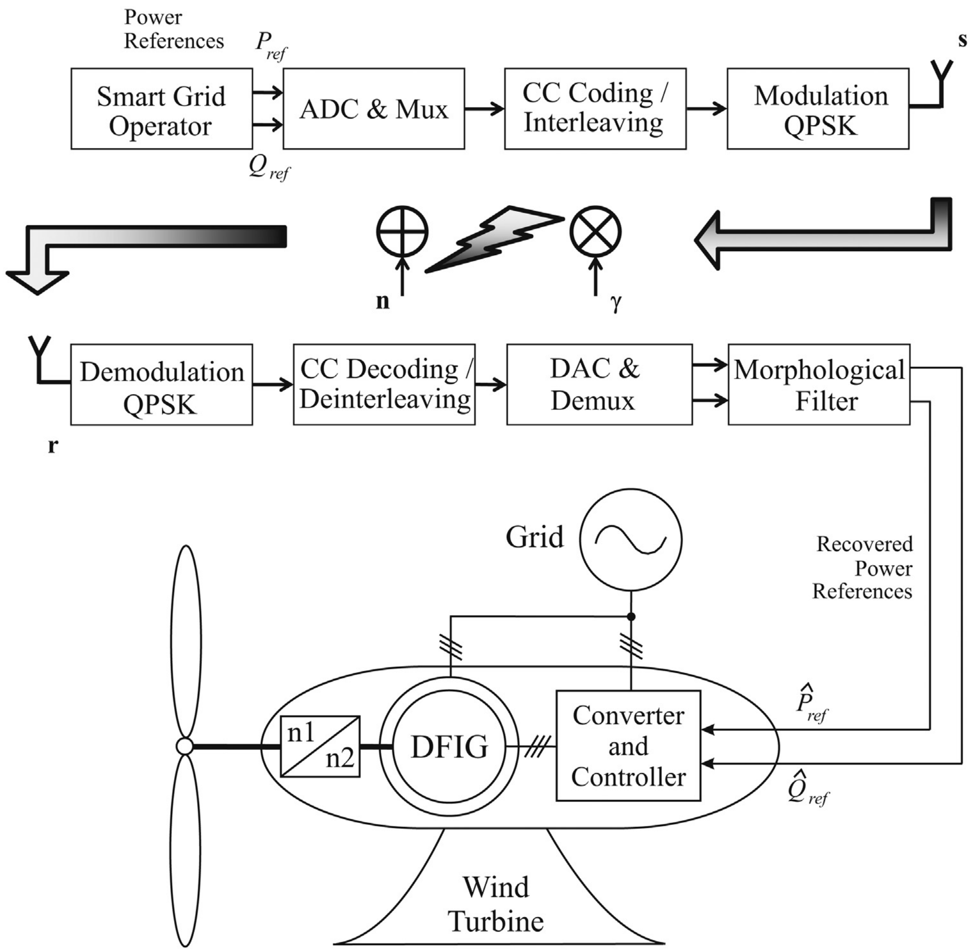

Fig. 1. Wireless system control schematic for an aerogenerator.

few researches referencing the application of wireless technology for renewable energy systems [12,13]. However, wireless transmissions are subject to distortions and errors caused by the propagation channel that can cause severe problems to the controlled and monitored equipments and, thus, to the energy plant as a whole. These signals, due to the destructive effects of the wireless fading channel, still appear corrupted by spikes or impulsive noises even with the employment of forward error correction (FEC) coding scheme [14]. Such problems are more critical from those that usually occurs in telecommunications systems, designed to voice and data transmissions, where small errors can be detected, triggering requests for retransmission (generating delays) or even, in some cases, be ignored without any significant impact to the network.

The most common technique for noise suppression is low-pass filtering with a linear operator [15–17]. Unfortunately, this is not appropriate for suppressing impulsive references. There are alternative linear methods as wavelets algorithms [18,19] and non-linear methods as median filtering [20] or stack filtering [21] that can present better performance. In this paper, it is proposed the application of a morphological algorithm to filter out the spikes corrupting the references signals. This filtering procedure, referred as Feedback Windowed Denoising Morphological Filter (FWDMF), is based on the mathematical morphology theory [22,23], where a non-linear approach can take advantage of *a priori* knowledge of the time domain shape of the analyzed signals and the interferences corrupting them. One of the advantages of mathematical morphology over other approaches is its intrinsically easiness of implementation and computational efficiency as it only deals with sums, subtractions, and extractions of maximum and minimum values.

This paper is organized as follows: the second section briefly describes the fundamental equations for the DIFG and its control strategy. The third section presents the proposed wireless coded system and the wireless fading channel. The fourth section summarily outlines the basics of the morphological theory and its main operators; the fifth one proposes the filter algorithm used in this research. The results and discussions are presented in the sixth section, and the last section concludes the work.

2. Machine model and deadbeat power control

2.1. Machine model

To begin with, let us settle the notation used throughout this section. Thus, the subscripts 1 and 2 refer to physical values from the stator and rotor respectively. The subscript d and q apply to the synchronous axes in which the currents i and voltages v vectors are decomposed. L_1, L_2 and the proper inductances of the stator and rotor windings, while L_m is the mutual inductance. $\vec{v}_{dq}$ is the voltage synchronous vector.

The DFIG power control aims independent stator active P and reactive Q power control by means of the rotor current regulation. For this purpose, P and Q are represented as functions of each rotor current. Considering the stator flux oriented control that decouples