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# Generalized Method for an Appropriate Choice of the Number of Pole Pairs Combinations of the Brushless Doubly-Fed Machines

**Kenmoe Fankem Eric Duckler**

*Dept. of Physics, University of Ngaoundere, Cameroon*

*Correspondence to: Hanshith K, Department of Technology, Shivaji University, Kolhapur 416004, India, Tel 9594649029; E-mail: kharadepa@yahoo.co.in

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## Editorial note

There is increased worldwide wind power generation, a large percentage of which is grid connected. The doubly fed induction generator DFIG wind energy conversion system WECS has many merits and, as a result, large numbers have been installed to date. The DFIG WECS operation, under both steady state and fault conditions, is of great interest since it impacts on grid performance. This review paper presents a condensed look at the various applied solutions to the challenges of the DFIG WECS including maximum power point tracking, common mode voltages, subsynchronous resonance, losses, modulation, power quality, and faults both internal and from the grid. It also looks at approaches used to meet the increasingly stringent grid codes requirements for the DFIG WECS to not only ride through faults but also provide voltage support. These are aspects of the DFIG WECS that are critical for system operators and prospective investors and can also serve as an introduction for new entrants into this area of study.

Nowadays, the most popular use of Doubly-Fed Induction Machines DFIMs concerns Wind Power Applications. They have been preferred over the conventional squirrel-cage induction machines because those latter used as Adjustable Speed Drives ASDs, are fully-fed machines. Indeed, all their power passes through a power converter. This has implications on the size and the total cost of the system. Doubly-fed induction machines in contrary to SCIM can operate with a converter of lower rating than its full kVA, thus offering a relative inexpensive and compact solution.

The drawback of this machine is the presence of slip-rings and brush-gear arrangement that makes it subject to frequent maintenance that can be the potential cause of sparking. These factors have been an impediment towards the wide-scale use of the DFIMs in offshore wind turbines and other various drives application

To overcome this drawback, the Brushless Doubly-fed Machine BDFM has been proposed in the litterature as an altenative to DFIM. The BDFM offers a reliable solution without compromising the advantages of the DFIM. In other words, the machine still requires a power converter of the similar rating as a DFIM, albeit freed from slip-ring and brush configuration.

## Advances

This has been gained thanks to the stator flux oriented control. Nevertheless, beyond the effect of heating, the robustness of such control strategy is affected by saturation especially the main magnetic one. Accounting for the effect of the magnetizing branch saturation in steady-state stability analysis, considering the case of a voltage-controlled DFM and the case of a current-controlled one, represents the aim of the study. To this end, a numerical procedure based on a combination of the eigenvalue and the fixed point methods has been developed. It has been found that, in both cases, accounting for saturation yields a stabilization effect which is more or less significant depending on the rotor supply parameters.

The maximum value of the rotor voltage will increase with the size of a voltage dip. This means that it is necessary to design the inverter so it can handle a desired value of a voltage dip. For the investigated systems the maximum rotor voltage and current, due to a voltage dip, can be reduced if the doubly-fed induction machine is magnetized from the stator circuit instead of the rotor circuit. Further, it has been found that the choice of current control method is of greater importance if the bandwidth of the current control loop is low.

The response of the doubly-fed induction machine to grid disturbances, is a subject rarely treated in the literature. One exception is Kelber in . Kelber concluded that it is necessary to actively damp the flux oscillations either with a flux differentiation compensation or use an extra inverter in the star point of the stator winding. However, Kelber has mainly focused on the "quality" of the damping and how fast a grid disturbance is damped out for different types of flux dampers. But, how the magnitude of the currents in the rotor circuit depends on aspects such as the bandwidth of the current control loop and the size of the grid disturbances was not presented. The magnitude of the rotor current due to a grid disturbance is of importance since the magnitude must not exceed the rated value of the inverter. If the magnitude of the rotor current reaches the rated value, a "crow-bar" must short-circuit the rotor circuit in order to protect the inverter.

## Properties

The gain in energy for a DFIG system compared to fixed-speed system, variable-speed IG system, and the PMSG system, for different average wind speeds, as a function of the rotor-speed range, is presented. The average efficiency, with an average wind speed of 6.8 m/s, for the permanent-magnet synchronous generator is taken from . The inverter losses of the permanent-magnet synchronous generator system are assumed similar to the stator-fed induction generator system. It can be seen in the figure that the gain in energy increases with the rotor-speed range, even though the inverter losses of the DFIG system increases with the rotor-speed range. One reason for this is that if the rotor-speed range increases, the DFIG can operate at optimal tip speed ratio, λ, for lower and lower wind speeds. If the rotor-speed range is set ideally, i.e., it is possible to run at optimal tip-speed ratio in the whole variablespeed area, the DFIG system produces approximately the same amount of energy as the fixed-speed system. Further, it can be seen that there is a possibility to gain a few percentage units in energy efficiency compared to a variable-speed IG system. In comparison to a direct-driven PMSG system there might be a slight gain in the energy depending on the average wind speed.

The DFIG WECS, like any other renewable energy extraction system, seeks to maximize the extracted power by maximizing the system efficiency in a bid to shorten the installation cost return period. A shorter cost return period makes the project more appealing and competitive when viewed against the conventional energy sources.

This is critical considering that the maximum power extractable is limited by the strength of the renewable source which in most cases may additionally be varying. MPPT for WECS seeks to run the generator at an optimal speed relative to the wind speed as experienced by the turbine rotors.