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Conversion System and Autonomous Converter for the Transformation of Wind Turbines from Fixed Speed to Variable Speed

Fixed Speed Wind Turbine (FSWT) technology was the main workhorse of the wind industry until the appearance of the Variable Speed Wind Turbine (VSWT) technology in the mid-nineties. The first prototype of a VSWT was introduced in Europe in 1995, back then on the recently commissioned wind farm of “El Perdón” (Navarre) with a type C Doubly Fed Induction Generator (DFIG) driven by Ingeteam’s IngeconWind power converter.

As we will see later, FSWT technology lacks critical features required to ensure electrical grid stability, which in combination with the desire to reduce the Cost of Energy (CoE), led to the origin of the VSWT technology and the rapid displacement of the fixed speed topologies over the following years.

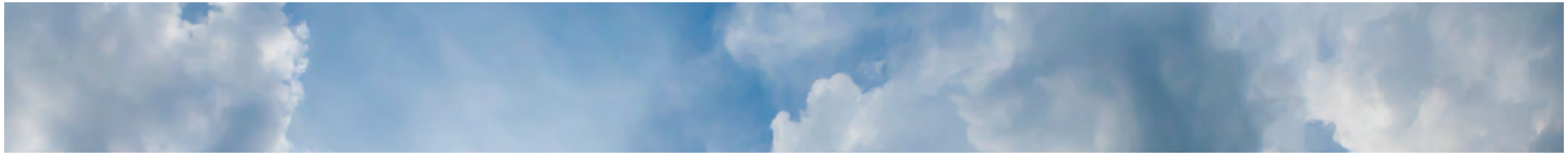
Type A fixed speed generators are characterized by being directly connected to the electrical grid, causing its rotational speed to be load-dependent and almost fixed to grid frequency. Therefore, suffering from high mechanical stress and low power quality (flicker effect and uncontrolled reactive power consumption), as wind’s turbulences are directly transferred through the drive train down to outputted power. Rotor aerodynamic efficiency is also low as optimum Tip Speed Ratio (TSR) can only be achieved for just one wind speed value (partially solved by dual-speed generator technologies).

When comparing both technologies, FSWT and VSWT (**Fig. 1** and **Fig. 2**), it is concluded that the FSWT topology is limited in some features in which the VSWT performs better, such as:

- The VSWT enables the system to obtain the optimum Cp (power coefficient) in a wide range of wind speeds inside the Maximum Power Point Tracking (MPPT) regime (below rated), thus obtaining an increment in the annual energy production (ΔAEP).
- In terms of power quality, the VSWT avoids the flicker effect in the grid side and removes the low frequency harmonics generated by the capacitor banks needed in FSWT topologies for power factor compensation of the generator. Also, it allows for power factor regulation on the grid and enables the system to comply with all grid codes and Fault Ride Through (FRT) events.
- When considering the turbine from a mechanical point of view, the transformation from FSWT to VSWT has an impact in the lifetime of the wind turbine by extending it (Lifetime Extension, LTE), due to the reduction of torque steps in the drive train caused by wind gusts. Similarly, the transients in the start-up of the turbine, the abruptly changing of the generator’s speed, and transients in emergency stops and the ones caused by the electrical grid are drastically reduced, thus also increasing the wind turbine’s lifetime.

Considering these advantages in operation and performance of the VSWT over the FSWT, the transformation of topologies A (**Fig. 3**) and B to either C or D will represent an improvement in certain characteristics of the wind turbine.

The solution here presented consists in an autonomous system of power conversion and control, as described in **Fig. 4**. Such an approach ensures that the modifications to be performed in the FSWT system are minimal, consequently the investment to be relatively low, increasing the Return of Investment (RoI) of the solution.



In order to characterize the improvements related to the transformation of the topology of the wind turbine, INGETEAM is currently involved together with DEWI-UL in a project in which an already installed and in operation type A wind turbine is transformed into a topology type D. Such a project, in an overall view, covers the following stages:

The first step is to obtain the aerolastic simulation model that resembles the FSWT behavior in order to be able to simulate its operation and performance. The plant modelling is defined by certain parameters which are unique for the wind turbine reference under study.

The second step is the characterization through on-site measurements of the needed FSWT characteristics, such as the power curve and mechanical loads. A particular wind turbine already installed on-site is selected for analysis. By characterizing the turbine, the simulation model previously mentioned can be tuned and validated with real application measurements.

Based on this tuned and validated FSWT simulation model, the VSWT solution and simulation model are developed, so that the behavior of the variable speed topology for the wind turbine can be simulated, and improved control strategies can be developed in order to increase its AEP and LTE. Once the correct performance and safe operation of the WT under variable speed are validated against the aerolastic model, the wind turbine topology is transformed on-site through the implementation of the autonomous system of power conversion and control. Once modified, the wind turbine is again characterized by on-site measurements (Fig. 5 and Fig. 6).

By the end of the process, a comparison of topologies by means of on-site measurements for the wind turbine under analysis is performed, together with an analysis based on the simulation models of the various control strategies that optimize the RoI for any given wind turbine.

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