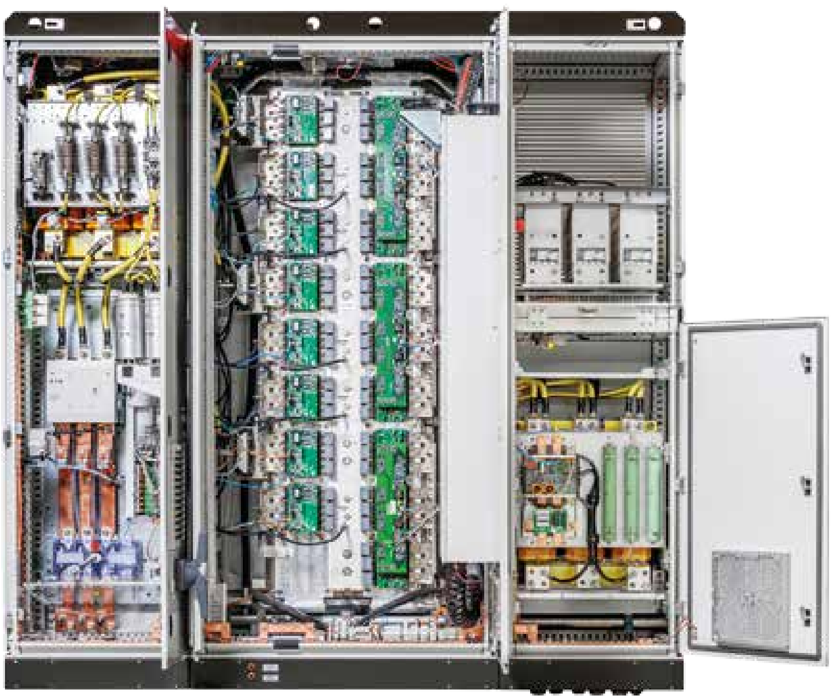
INGETEAM POWER TECHNOLOGY S.A.

Optimal Crowbarless solution for connecting Doubly Fed Induction Generators into weak grids

Wind power penetration into the power generation system has substantially increased during the last twenty years. This fact makes that the power quality and stability of this generation system is becoming increasingly important. For that reason, the grid codes, which establish the requirements that all generation systems must fulfill in order to be allowed to connect to the grid, have been updated in order to guarantee the stability of the grid.

In the recent past, wind turbines were allowed to disconnect from the grid when transients in grid voltage could jeopardize the integrity of their elements, especially the power converter. However, nowadays, due to the large amount of wind power installed in the generation system, this is no longer allowed. With such increase in installed power, the wind industry faces now the challenge of the suitable integration of the wind turbine into the grid, which main issues are the following:

- Large distances between generation and load points:
  In many occasions, the areas with suitable wind resources are not close to those areas where the energy is being consumed. Series and parallel compensation solutions are installed in order to increase the capacity of long transmission lines. These systems can present issues related to Sub-Synchronous Resonances (SSR) and Sub-Synchronous Control Interaction (SSCI), among others.
- Low capacity of the transmission lines:
  These grids are the so-called weak grids. It is defined as a grid which presents a low Short Circuit Ratio (SCR) that in a wind farm is the relation between the short circuit capacity of the grid at the common coupling point of the farm and the rated power capacity of the wind farm.
  Basically, these are grids in which the voltage fluctuates with Active and Reactive power flow.
- Fault Ride Through events:
  These events are usually caused by short circuits produced in the grid. Generation systems must be able to keep connected during these events in order to support the grid stability.

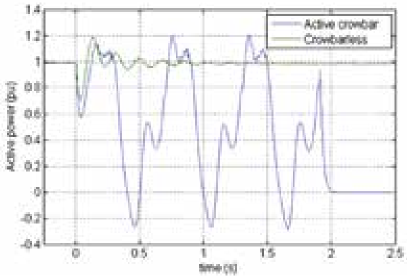


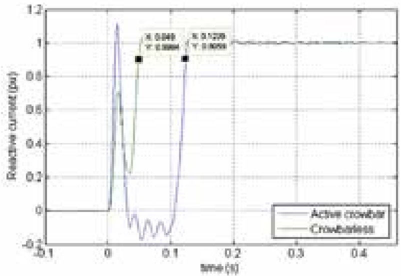
Ingeteam Crowbarless Power Converter

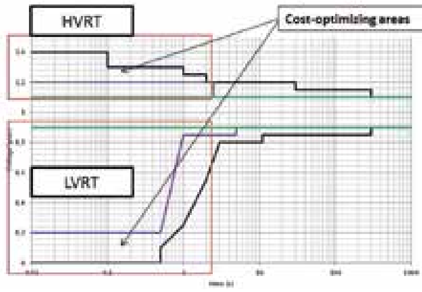
Wind power in India has also experienced a huge growth within the last years, being the installed capacity 22,465MW in 2014, with an average increase of 21% per year according to GWEC report. This increase in generation capacity must be accompanied by a suitable conditioning in the transmission systems. Otherwise, the electric system stability could be compromised. In this regards, due to its rapid growth, the Indian electricity system faces some of the challenges described in terms of grid stability.

The Doubly Fed Induction Generator (DFIG) topology is proven as the most efficient and cost-competitive topology for wind turbines rated up to 3.5MW. That is the reason why it is being currently the most installed topology.

However, its low grid integration capability jeopardizes the use of this type of conversion system, due to its high sensitivity to grid voltage transient, in which high voltages and currents appear in the rotor side of the generator, endangering the power converter connected to it. This is







From left to right: Figure 1. Active power during a SCR change from 5 to 2, with Active crowbar and with Crowbarless system. Figure 2. Current feed-in time for a Crowbarless and Active Crowbar system in a 3ph 20% voltage dip with a 3MW Wind Turbine. Figure 3. Cost optimizing areas for different grid codes requirements.

because the induction generator is directly connected to the grid, so any fluctuation in grid voltage produces a change in the generator flux, which causes high rotor voltages and currents.

The most widely used system to protect the power converter under these events is the so-called active crowbar, a shunt circuit composed by actively controlled switches and dissipation elements which are connected in order to shunt the high currents, avoiding a damage in the converter. This system, however, presents the limitation that while the active crowbar is connected, the power converter is not in operation, the active and reactive power set points cannot be tracked, and therefore the wind turbine is not being controlled.

This Article presents a power converter designed to operate in DFIG topology, which does not include an active Crowbar – Crowbarless solution – but a Modular FRT system instead. Besides, the Modular FRT system is an optimal solution, which means that depending on the grid code to be fulfilled and the electrical characteristics of the system – especially the stator configuration -, the Modular FRT system is selected allowing for a cost-optimal power converter for each wind farm scenario.

The Crowbarless solution presents advantages in the behavior when compared to the active crowbar system solution, especially in issues related to weak grids and FRT events. Besides, these two events may occur together, being a major problem of weak grids. This takes place when a short circuit is produced in the grid and the protection elements upstream the fault trips, isolating different generator systems from the transmission system, thus rapidly changing the SCR in the wind farm (high d(SCR)/dt), making it difficult to control the voltage in the grid and therefore keeping the wind farm generators connected.

Wind power in India has also experienced a huge growth within the last years, being the installed capacity 22,465MW in 2014, with an average increase of 21% per year

Voltage control in wind farms are usually tuned for strong grids, being the control dynamics not suitable for weak grids. The voltage control is not able to keep the grid voltage within the voltage range of the generation systems, as a weak grid presents high ratios of dV/dQ.

In DFIG topologies with converters including any kind of Active Crowbar system, this item is connected when the voltage transients in the grid causes rotor current or/and voltage values out the limit values of the converter. This can lead to instability of the Active and Reactive Power loops, and finally producing a disconnection of the wind turbine.

However, the Crowbarless solution described in this article, together with a suitable selection of grid filter and control loops tuning, is able to keep the control of the wind turbine during these transients, achieving the controllability required in order to operate in weak grids.

In addition, the modularity concept of the FRT system allows for a cost optimization for each application. Next figures show the behavior of the Crowbarless system under different grid events:

Figure 1 shows a comparison in the behavior of the Crowbarless system and the Active Crowbar system during a Short Circuit Ratio change from a value of 5 to a value of 2. It can be seen how the Active Crowbar is repeatedly activated leading to the instability of the system and finally getting tripped. However, the Crowbarless system is able to keep the control of the wind turbine, supporting the grid when required.

Figure 2 shows a comparison of the behavior of the Crowbarless system in a 20 % 3-Phase Voltage Dip with a 3 MW Wind Turbine and rotor peak current of 11 kA in short circuit. The feed-in time of the required amount of reactive current is less than 50ms.

Figure 3 shows different grid codes voltage-time envelope requirements highlighting the cost-optimizing areas for the Modular FRT system modular solution.

Figure 4 shows the Power Converter which includes the Crowbarless modular solution.

This article has introduced the main issues related to wind power integration into the grid, described its implications in DFIG topologies and presented a Crowbarless system for such topologies, suitable in order to fulfil the challenges that the grid integration presents.

The issue related to wind farms connected to weak grids has been analyzed, showing the advantages that this system presents over the most widely used Active Crowbar systems.

Besides, a Modular FRT system modular solution that allows the power converter for a cost-optimization regarding the electrical characteristics of the wind farm and the grid code to be fulfilled has been presented ◂◂