DOUBLY FED INDUCTION GENERATOR

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INTRODUCTION

- Doubly fed electrical generators are similar to AC electrical generators but have additional features which allow them to run at speeds slightly above or below their natural synchronous speed. This is useful for large variable speed wind turbines because wind speed can change suddenly.

- DFIG Consist two phase windings, one stationary and one rotatry, both separately connected to equipment outside the rotor. Thus the term “Doubly Fed”.

- One winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency. The other winding (traditionally called the field, but here both windings can be outputs) is connected to 3-phase AC power at variable frequency.

- Adjusting the frequency and phase requires an AC to DC to AC converter.

HISTORY

- It was invented by Nikola Tesla in 1888, the rotor winding set of the doubly-fed electric machine is connected to a selection of resistors via multiphase slip rings for starting. However, the slip power was lost in the resistors.
- In Krämer (or Kraemer) drives the rotor was connected to an AC and DC machine fed a DC machine connected to the shaft of the slip ring machine. Thus the slip power was returned as mechanical power and the drive could be controlled by the excitation currents of the DC machines.
- Static frequency converter had a *cycloconverter* connected between the rotor and the AC grid. The cycloconverter can feed power in both directions and thus the machine can be run both sub- and over synchronous speeds.
- Today the frequency changer used in applications up to few tens of megawatts consists of two back to back connected *IGBT* inverters.

DOUBLY FED INDUCTION GENERATOR

- The DFIG is an induction machine with a wound rotor where the rotor and stator are both connected to electrical sources, hence the term ‘doubly-fed’.
- It is a 3 phase induction generator where both the stator and rotor, windings are fed with 3 phase AC signal
- DFIG operates in both sub- and super-synchronous modes with a rotor speed range around the synchronous speed.
- As rotor rotates the magnetic field produced due to t he ac current also rotates at a speed proportional to the frequency of the ac signal applied to the rotor windings.

CONTINUE…

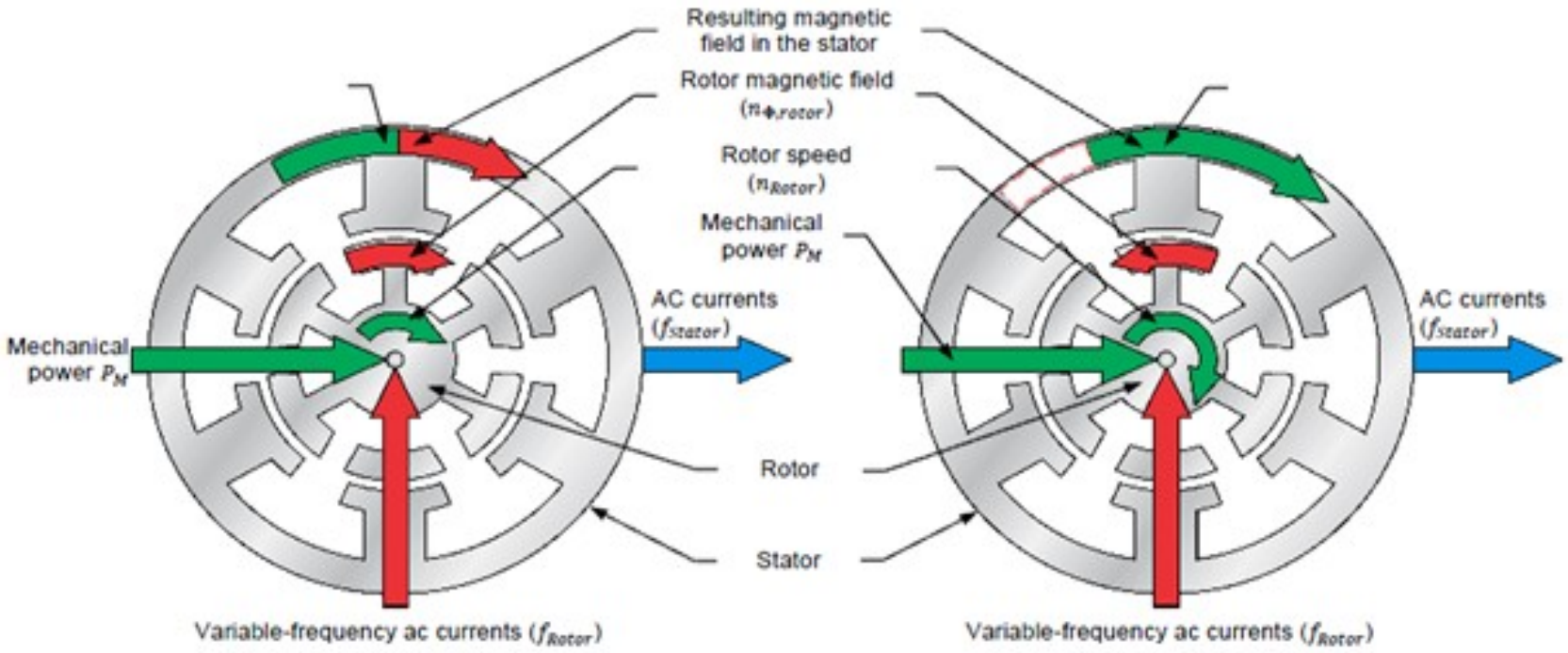
- An AC-DC-AC converter is included in the induction generator rotor circuit. The power electronic converters need only be rated to handle a fraction of the total power – the rotor power typically about 30% nominal generator power. Therefore, the losses in the power electronic converter can be reduced.

- DFIG is widely used in wind turbines along with induction or permanent magnet synchronous generators network through power electronics converters.

- DFIG is currently the system of choice for multi-MW wind turbines.

- As a result a constantly rotating magnetic flux passes through the stator windings, which cause induction of ac current in the stator winding, depend upon the rotor speed and frequency of current fed to rotor.

WORKING PRINCIPLE



CONTINUE….

- In this case, mechanical power at the machine shaft is converted into electrical power supplied to the ac power network via both the stator and rotor windings. Furthermore, the machine operates like a synchronous generator whose synchronous speed can be varied by adjusting the frequency of the ac currents fed into the rotor windings.
- The rotating magnetic field passing through the generator stator windings not only rotates due to the rotation of the generator rotor .
- In a doubly-fed induction generator, both the rotation speed of the rotor and the frequency of the ac currents fed into the rotor windings determine the speed of the rotating magnetic field passing through the stator windings.
- when the magnetic field at the rotor rotates in the same direction as the generator rotor, the rotor speed and the speed of the rotor magnetic field add up.

WIND TURBINE

CONTINUE

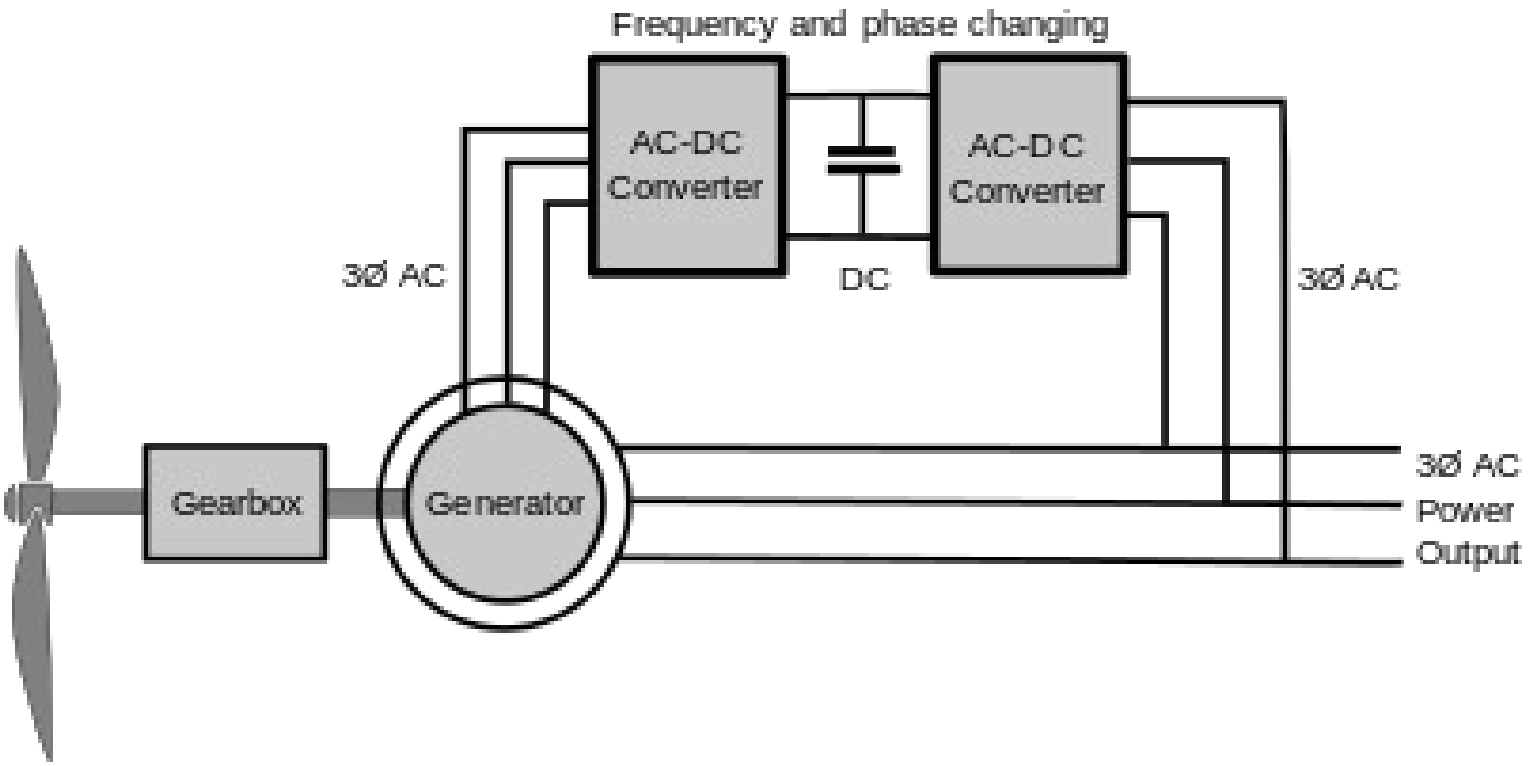
- Most doubly-fed induction generators in industry today are used to generate electrical power in large wind turbines. This is primarily due to the many advantages doubly-fed induction generators offer over other types of generators in applications where the mechanical power provided by the prime mover driving the generator varies greatly .

- Large-size wind turbines are basically divided into two types which determine the behavior of the wind turbine during wind speed variations: fixed-speed wind turbines and variable-speed wind turbines.

- In fixed-speed wind turbines, three phase asynchronous generators are generally used. Because the generator output is tied directly to the grid the rotation speed of the generator is fixed and so is the rotation speed of the wind turbine rotor. Any fluctuation in wind speed naturally causes the mechanical power at the wind turbine rotor to vary and, because the rotation speed is fixed, this causes the torque at the wind turbine rotor to vary accordingly.

CONTINUE…

- In variable-speed wind turbines, the rotation speed of the wind turbine rotor is allowed to vary as the wind speed varies. This precludes the use of asynchronous generators in such wind turbines as the rotation speed of the generator is quasi-constant when its output is tied directly to the grid.



CONTINUE…

- The power electronics devices used in doubly-fed induction generators, on the other hand, need only to process a fraction of the generator output power, i.e., the power that is supplied to or from the generator rotor windings, which is typically about 30% of the generator rated power. Consequently, the power electronics devices in variable-speed wind turbines using doubly-fed induction generators typically need only to be about 30% of the size . This reduces the cost of the power electronics devices, as well as the power losses in these devices

MODELLING OF DFIG

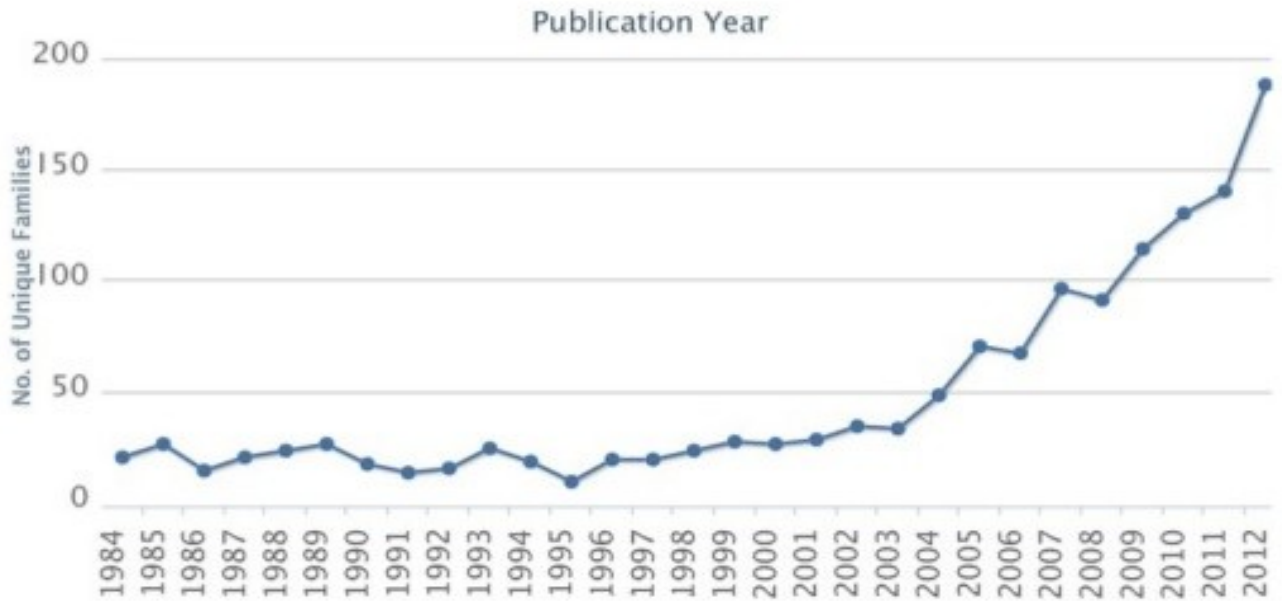
- The doubly fed induction generator has been used for years for variables speed drives.
- Using vector control technique the bidirectional converter assures energy generation at nominal grid frequency and nominal grid voltage independently of the rotor speed.
- To compensate for the difference between the speed of the rotor and the synchronous speed with the slip control
- The main characterstics may be summarized as follows:

➢ Limited operating speed range (-30% to +20%).
➢ Small scale power electronic converter.
➢ Complete control of active power and reactive power exchanged with the grid.
➢ Need for slip rings.
➢ Need for gearbox.

PUBLICATION TREND

Publication Trend

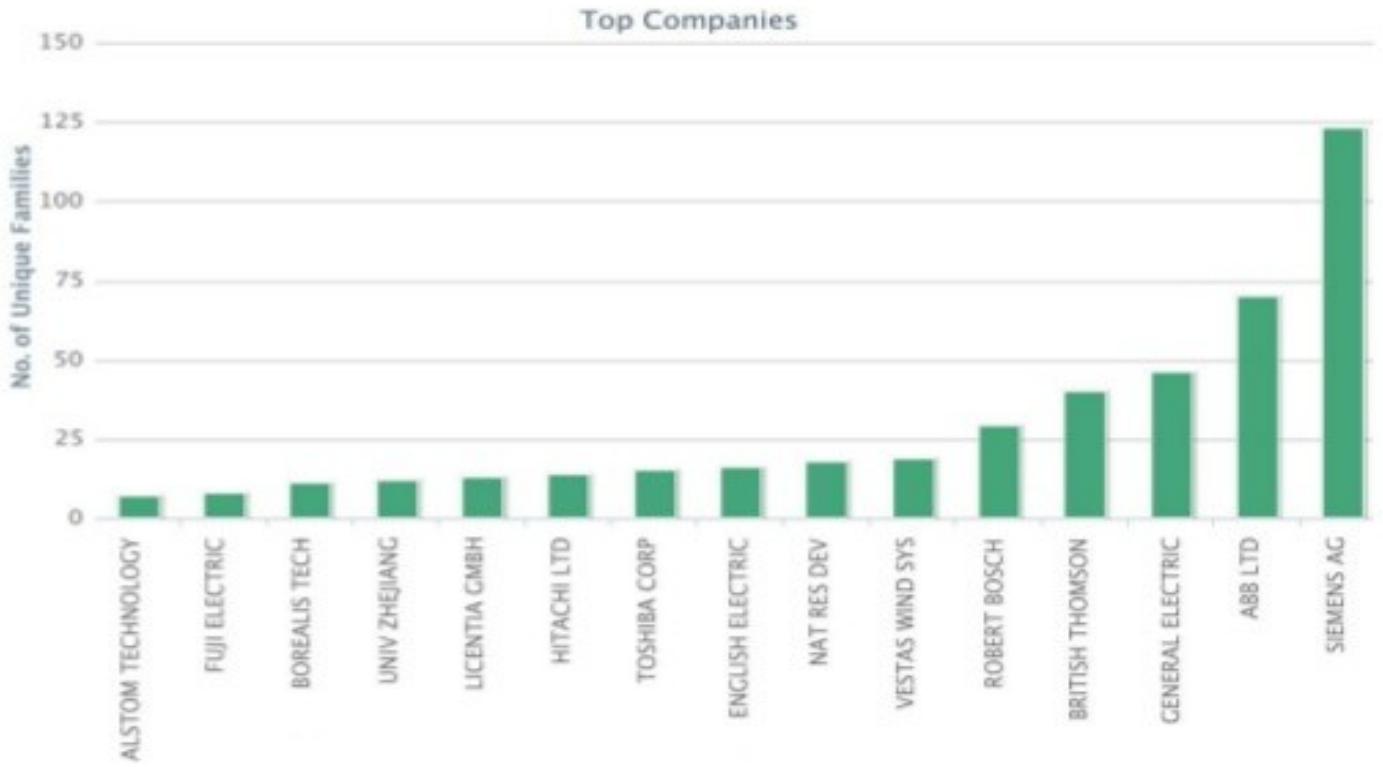
- Chart shows the publication trend for Doubly Fed Induction Generator (DFIG) in the last 30 years
- Number of publications have been increasing steadily with a steep rise in 2012



TOP COMPANIES

Top Companies

- The chart shows top 15 companies ranked by number of unique families
- Siemens is at the top followed by ABB Ltd and General Electric

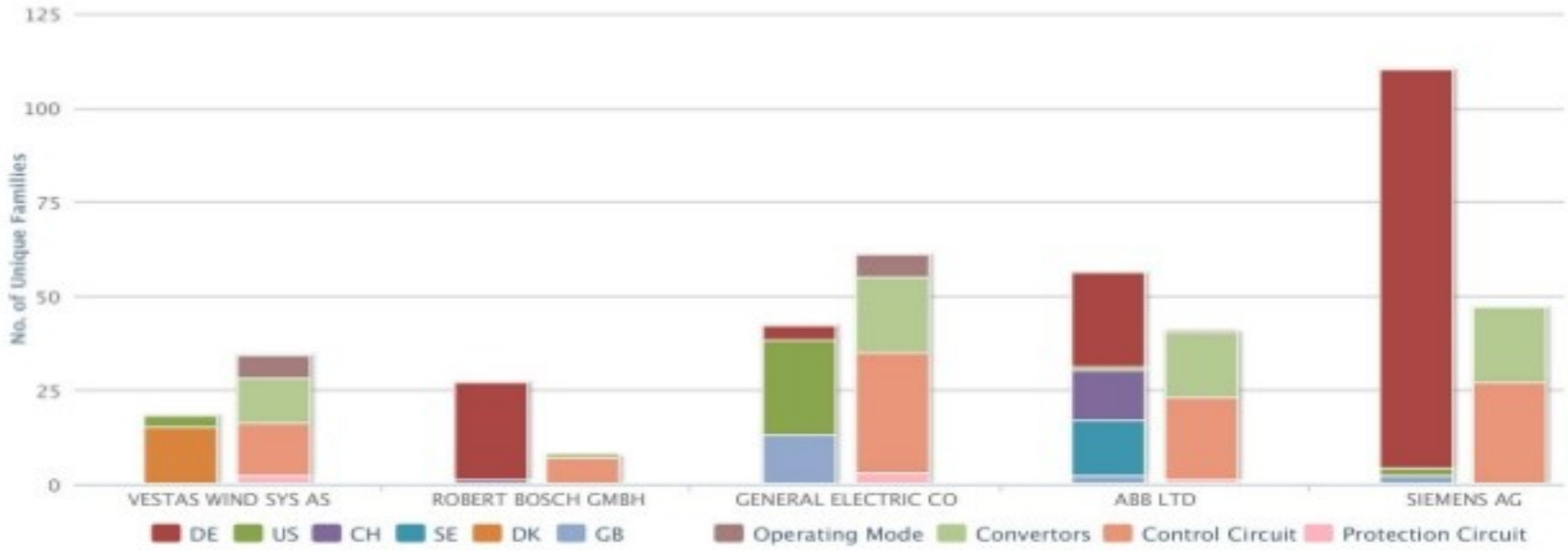


RESEARCH BEING DONE

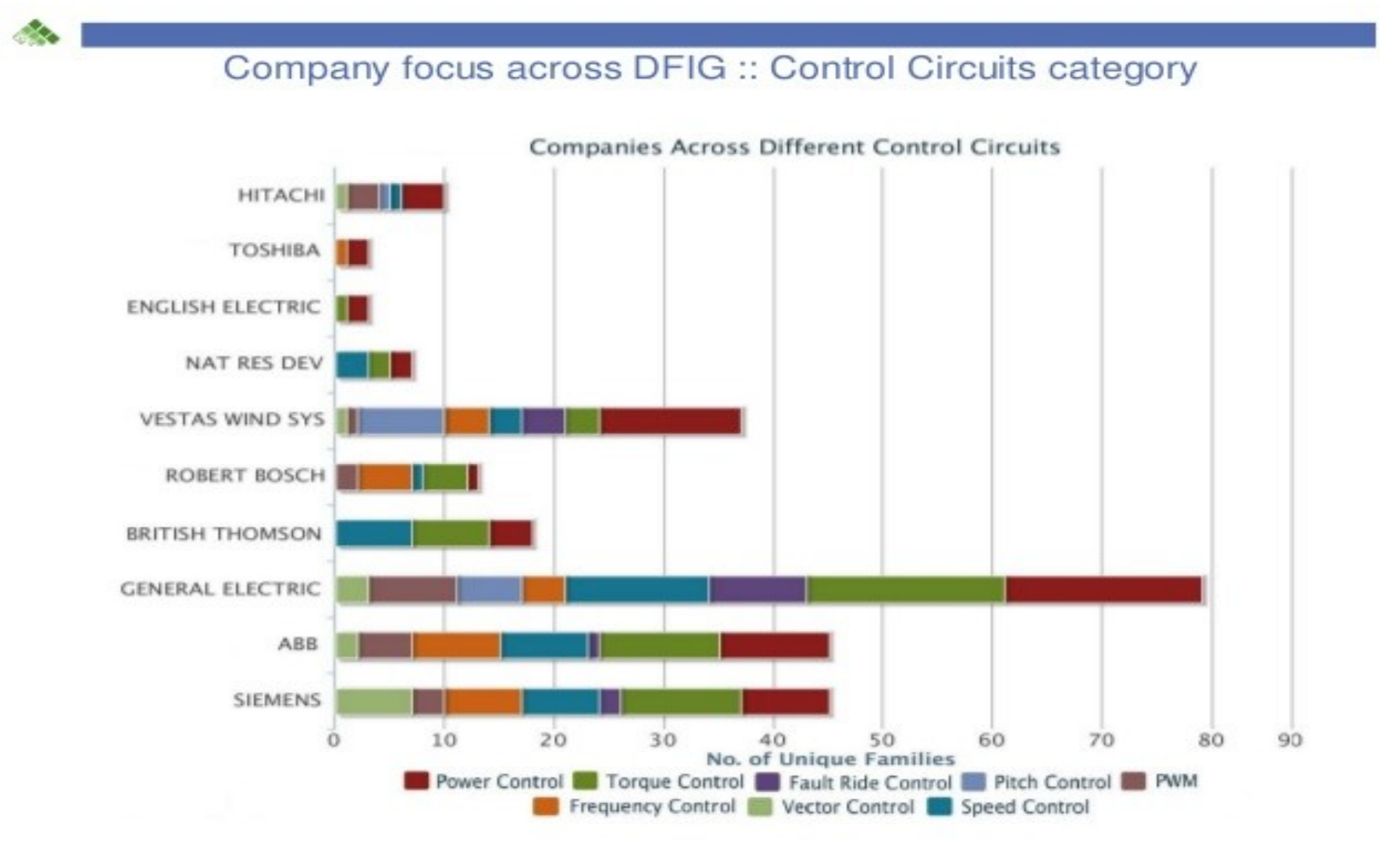
RESEARCH AREAS

Where are researching teams of key companies located and which are the key research areas ?

- The chart shows leading companies across priority countries and various research areas. (The left stack is for priority country and the right is for research area.)
- Although each company has only one main priority country for its filings, records from ABB are spread across multiple priority countries.



COMPANY FOCUS ACROSS DFIG



ADVANTAGES

- Sub synchronous and super synchronous operation is possible.
- Possible speed regulation for optimal utilization of energy (typically +20 to -25%).
- Significantly reduced power rating and cost of the converter.
- Low losses, which assures a high overall efficiency and on outstanding availability due to the compact design with a minimal no. of components.
- Fast dynamic response due to static devices.

DISADVANTAGES

- Slip rings wear and tear, maintenance.
- Complex control of entire unit.
- Direct connection to the grid is difficult.
- Output voltage is dependent upon rotor speed and stator.

CONCLUSION

- The DFIG system costs more than fixed-speed induction generators without converters. However, the performance and controllability are excellent in comparison with fixed speed induction generator systems; they capture more wind energy, they exhibit a higher reliability gear system, and high-quality power supplied to the grid. It saves investment on full-rated power converters, and soft-starter or reactive power compensation devices. In the case of a weak grid, where the voltage may fluctuate, the DFIG may be ordered to produce or absorb an amount of reactive power to or from the grid, with the purpose of voltage control. Also because of its ability to control reactive power and to decouple active and reactive power control by independently controlling the rotor excitation current, DFIG is preferred in wind power generation

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THANK
YOU!