Doubly Fed Induction Generator

By Adhithya

What is a DFIG?

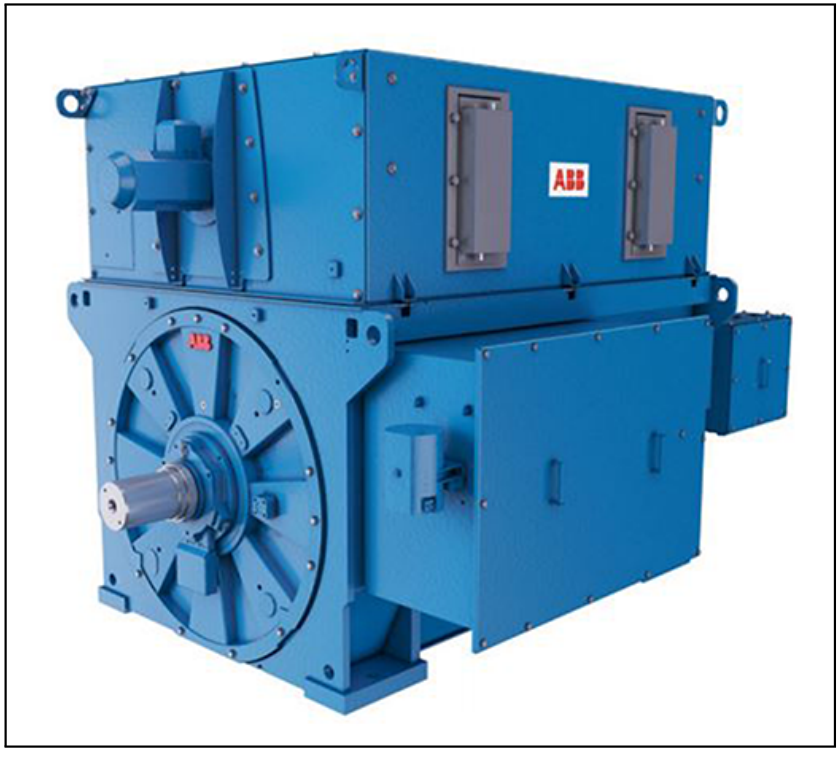
Figure: Commercially available DFIG.
Courtesy of ABB

- It has two sets of $3\,\phi$ *windings*: on both **stator** and **rotor**.
- Suited for **variable speed** common which is common with wind turbines.

Technical Specification

	Technical specifications
Standard	IEC60034, IEC61400
Power	up to 6MW
Shaft heights	500, 560, 630
Number of poles	4-6
Voltages	up to 12kV
Frequency	50Hz or 60Hz
Ambient	-30 up to 50 °C
Cooling	Air to air, Air to water, Open air cooled
Protection	up to IP54
Enclosure material	Welded steel
Bearings	Antifriction

Figure: Nameplate details.



Antifriction bearing

Figure: Image Courtesy of cedengineering.com

Stator

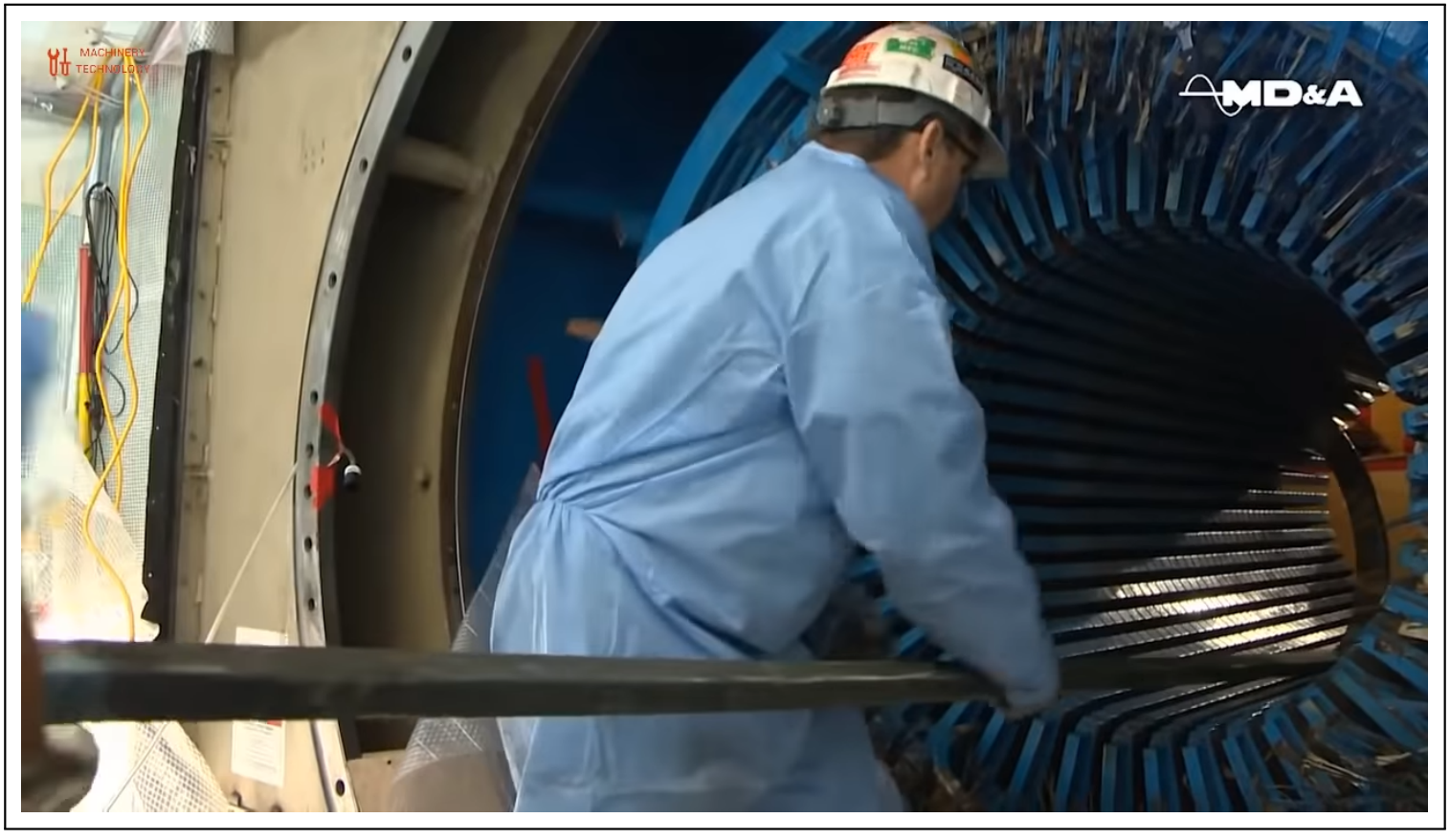


Figure: Typical large 3ϕ *stator*.

Rotor

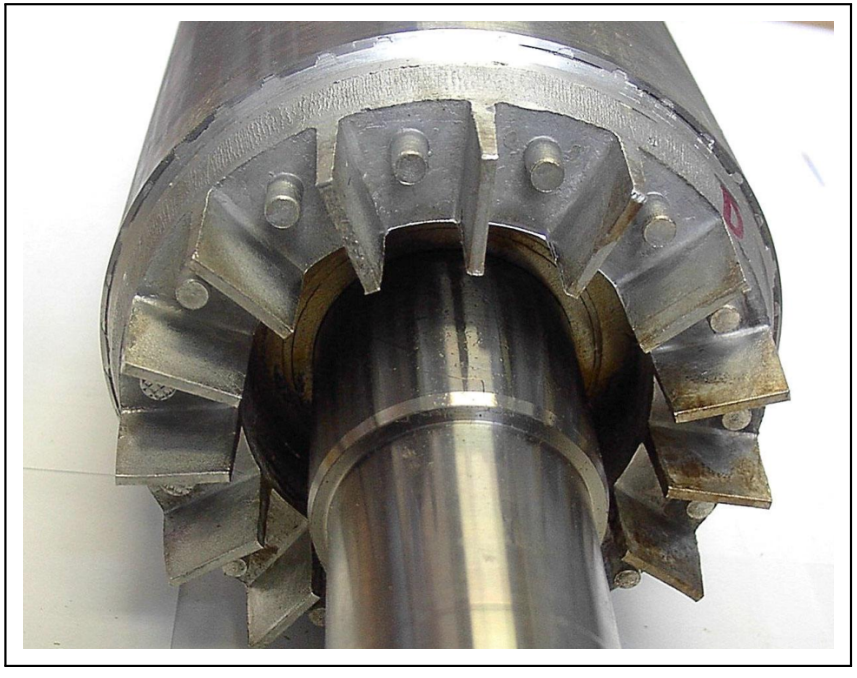


Figure: Squirrel Cage

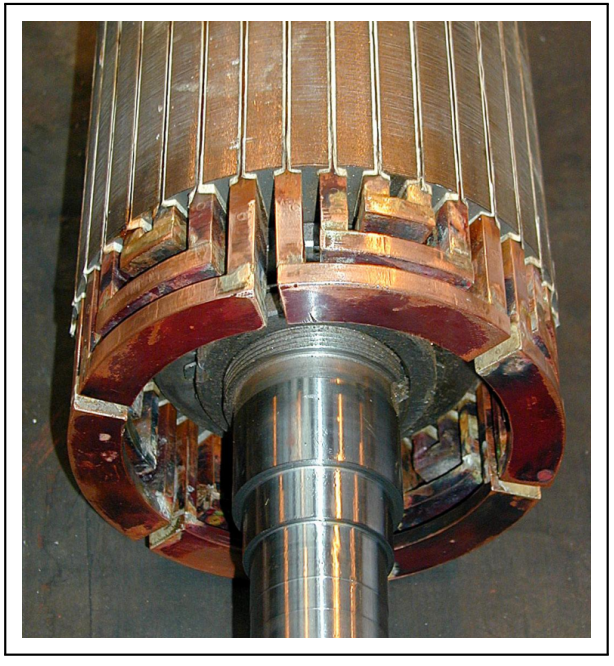


Figure: Wound Rotor

Rotor

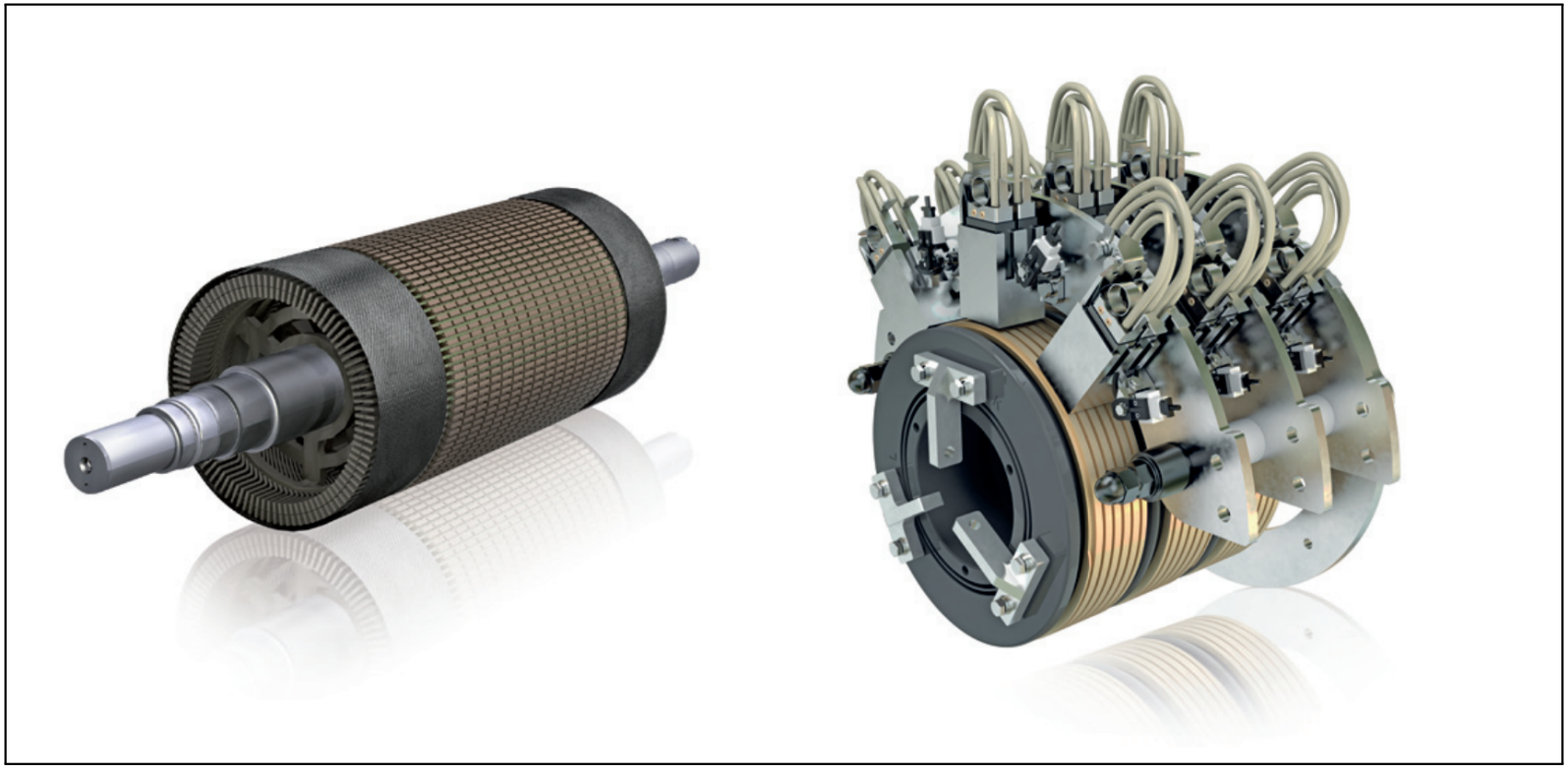


Figure: Image courtesy of ABB

Rotor details

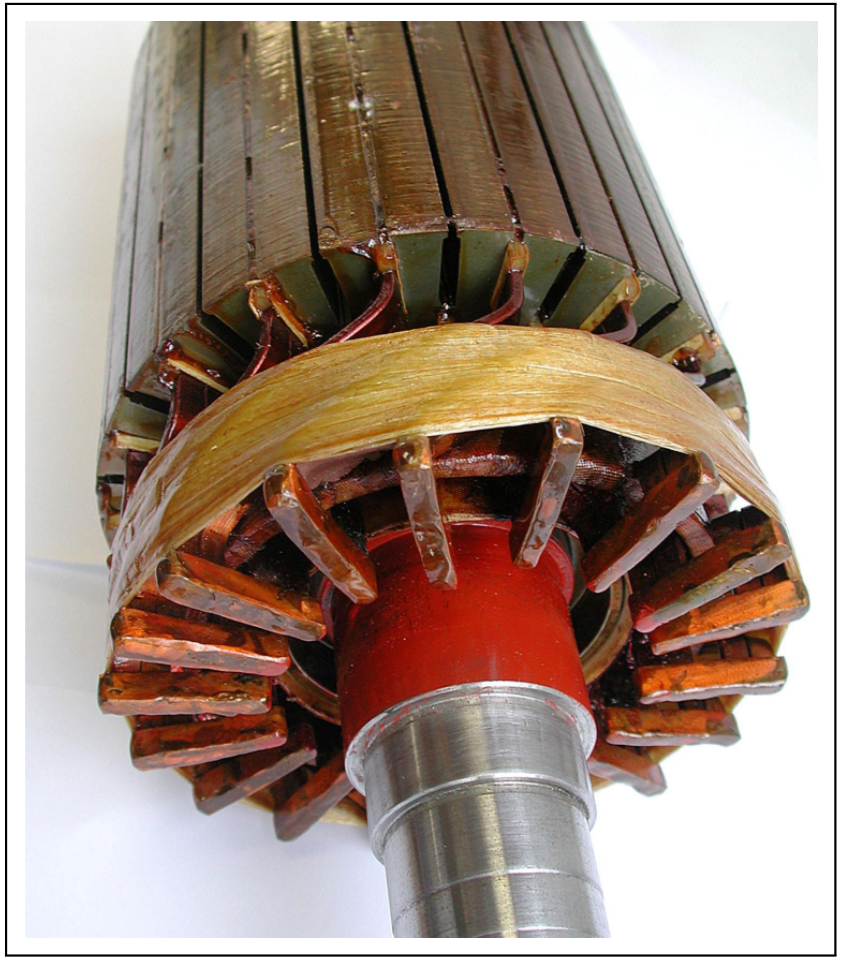


Figure: DFIG Rotor.

- Rotor have high turns $(2\times \ to\, 3\times)$ that of stator.
- Consequently, the rotor will have higher voltages and lower currents

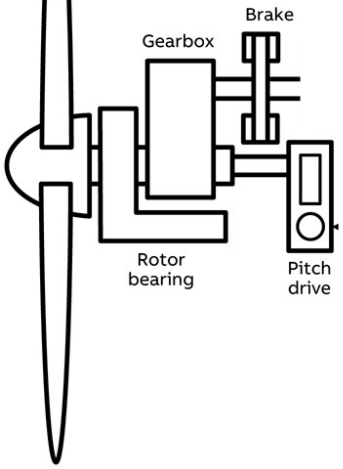


Figure: Prime Mover and it's auxiliaries.

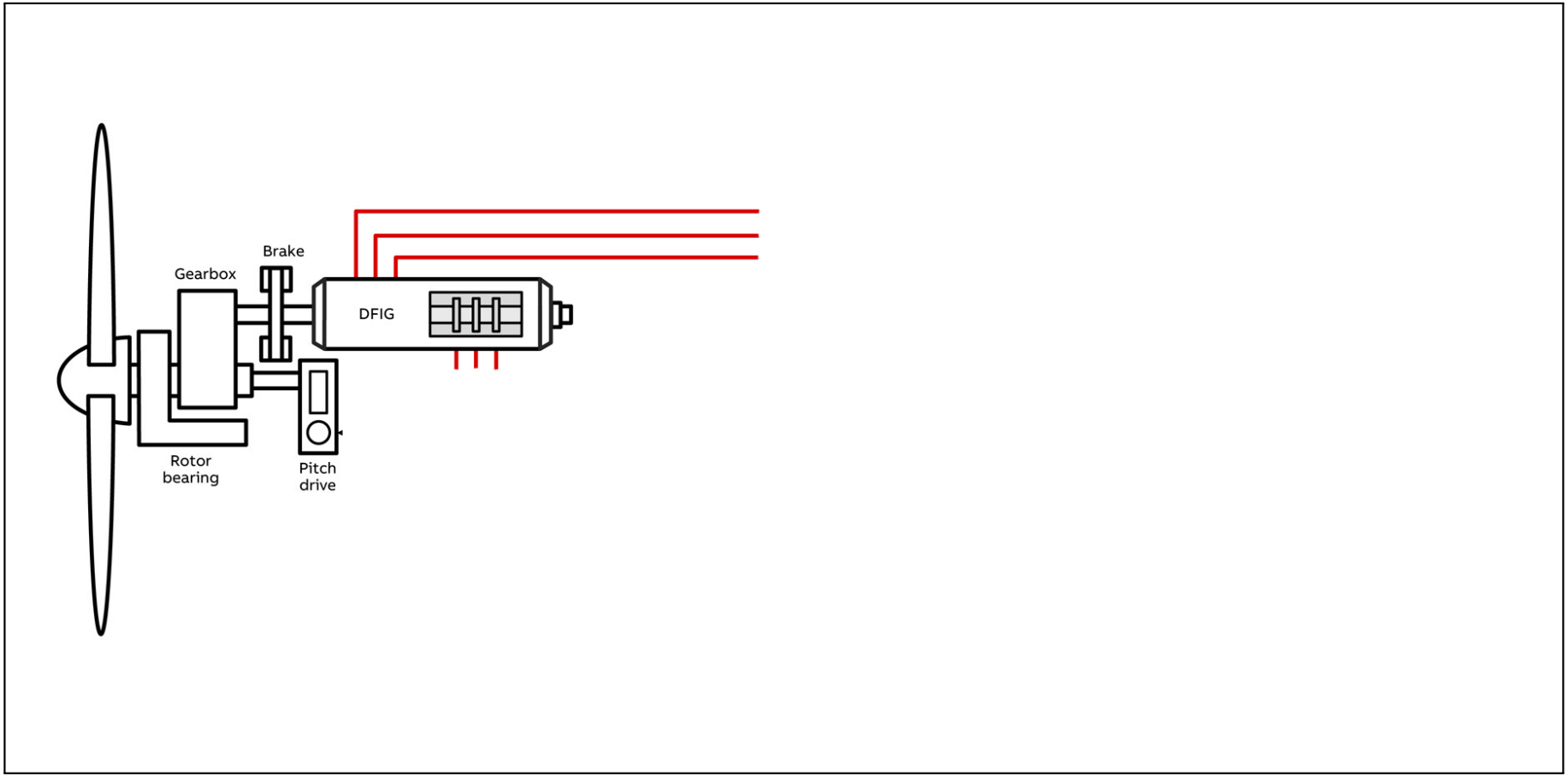


Figure: Generator

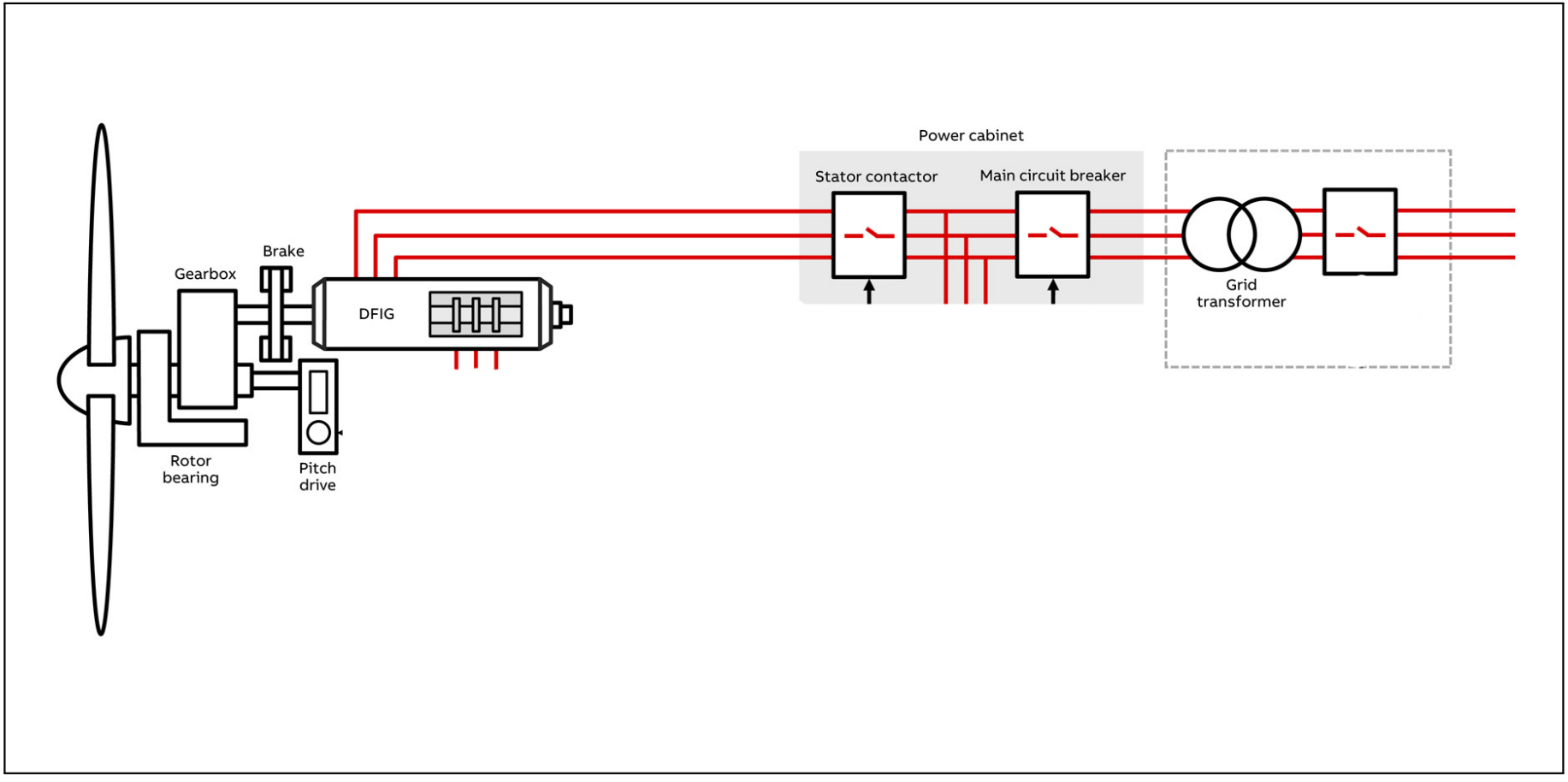


Figure: Stator Connections

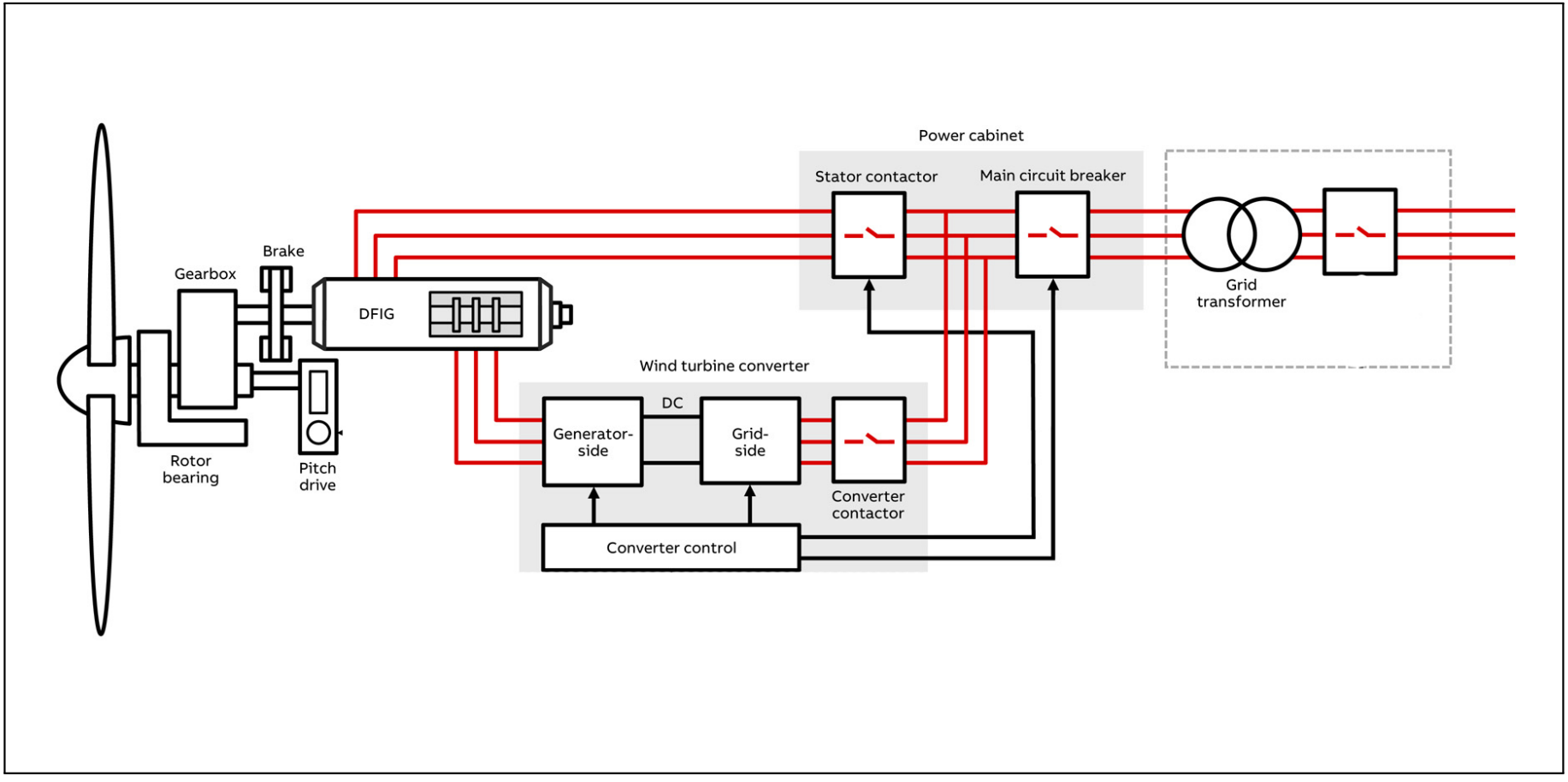


Figure: Rotor Connections and control

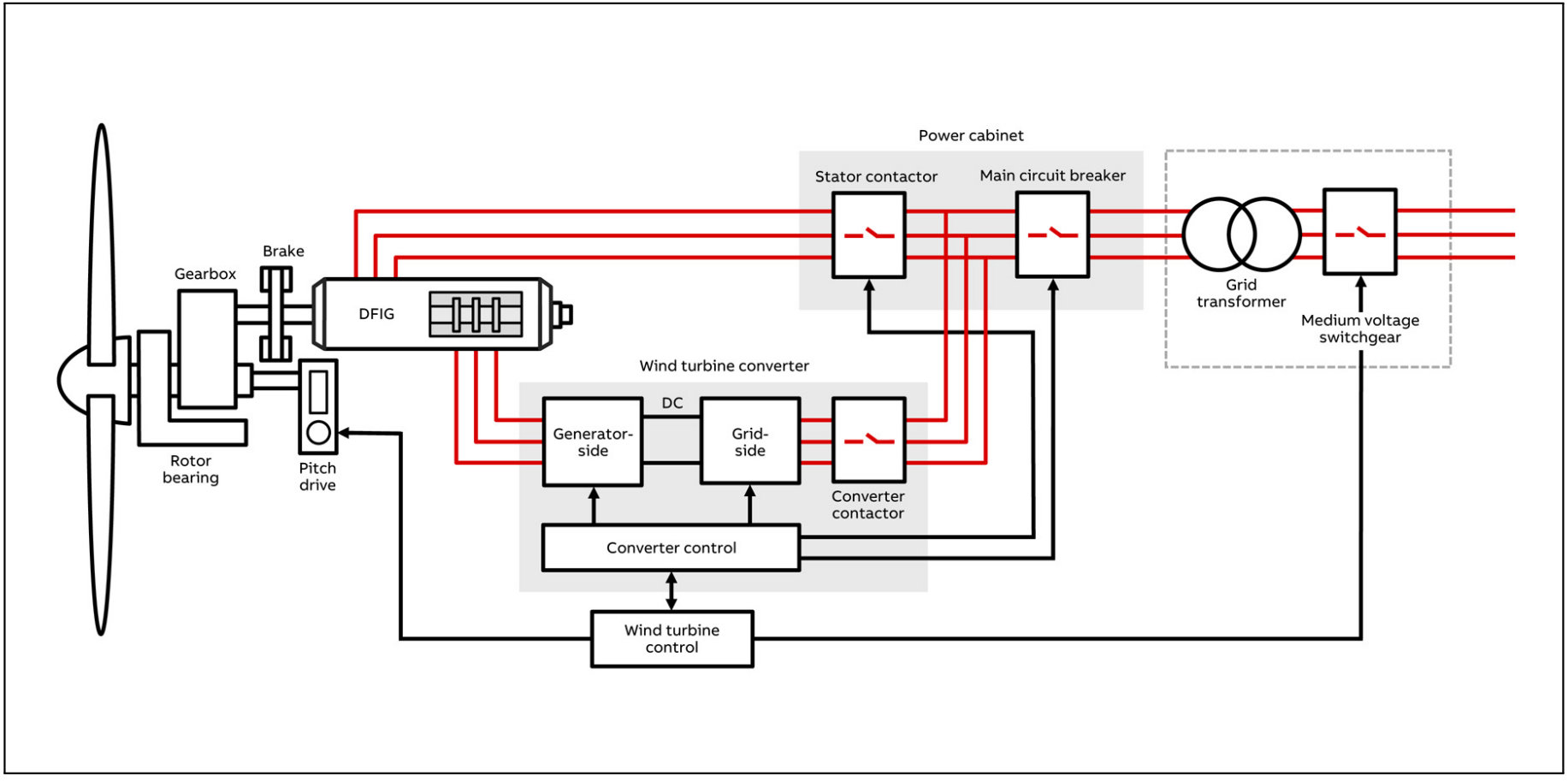


Figure: DFIG system as a Whole.

Working

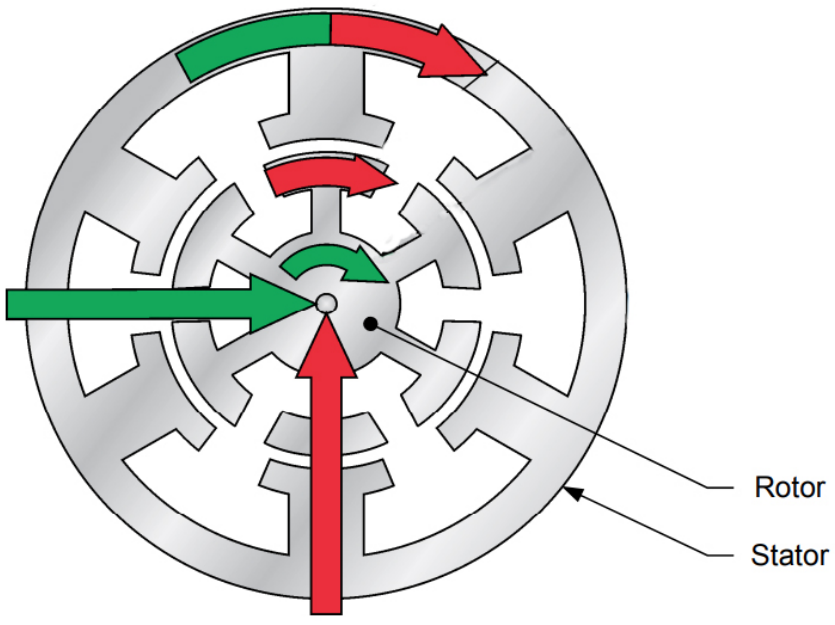


Figure: Stator and Rotor of DFIG

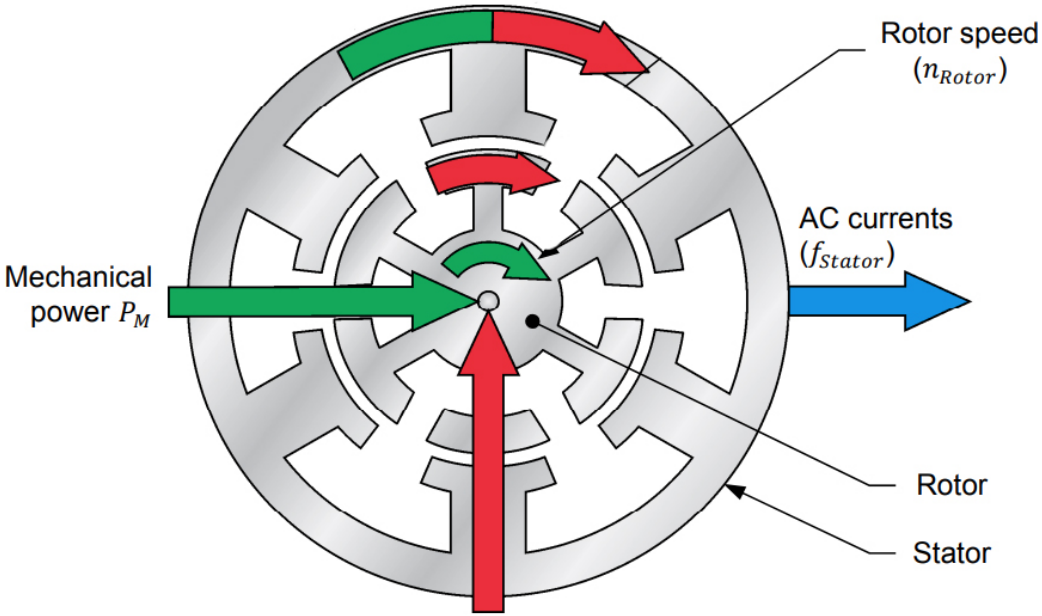


Figure: Mechanical power imparted into rotor, which induces AC voltage with frequency f_{stator}

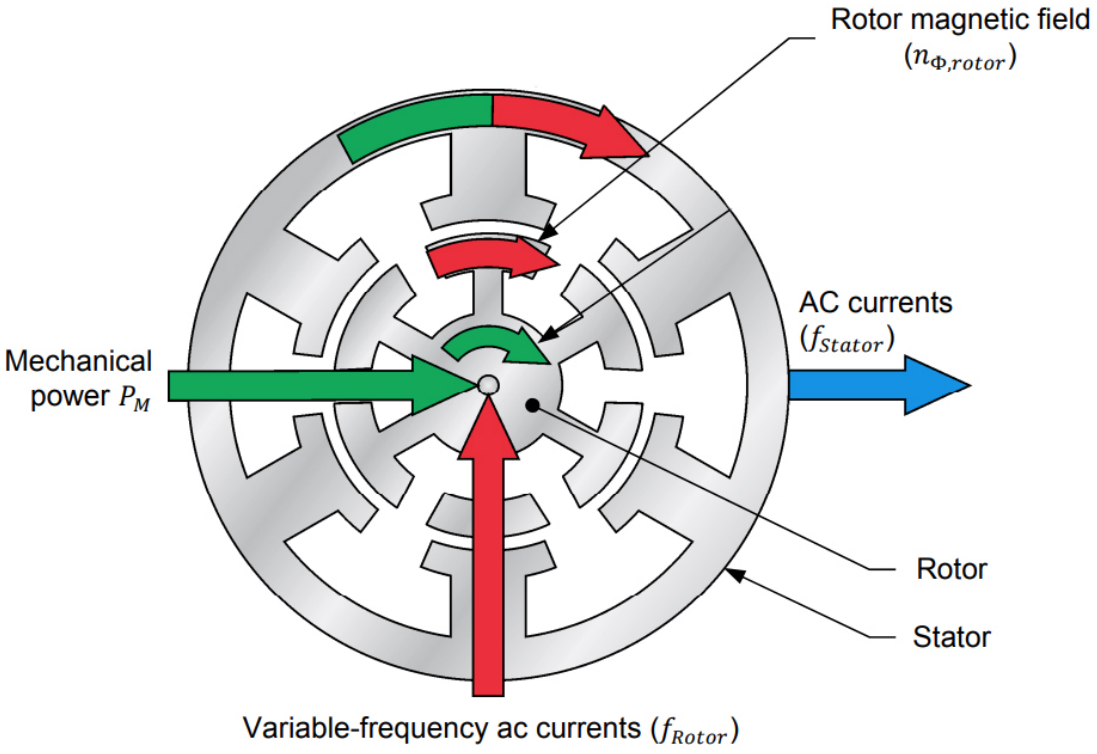


Figure: Rotor's AC current frequency determines the speed of Rotor's magnetic field.

Animation time

- DFIG principle with Magnetic field animation
- DFIG Operation

"A picture is worth a thousand words, unless it's an animation, then it's priceless." 😂

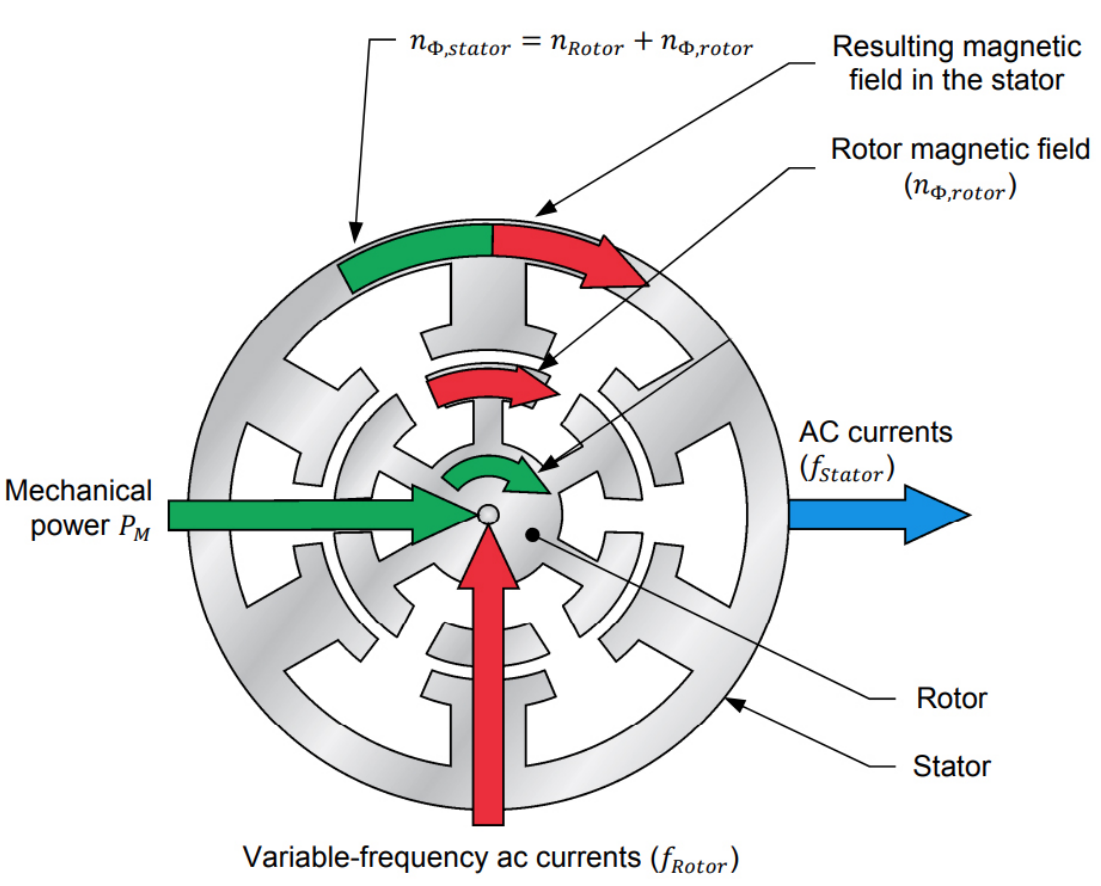


Figure: Stator R.M.F. = Rotor's Mech. Speed + Rotor R.M.F. Speed

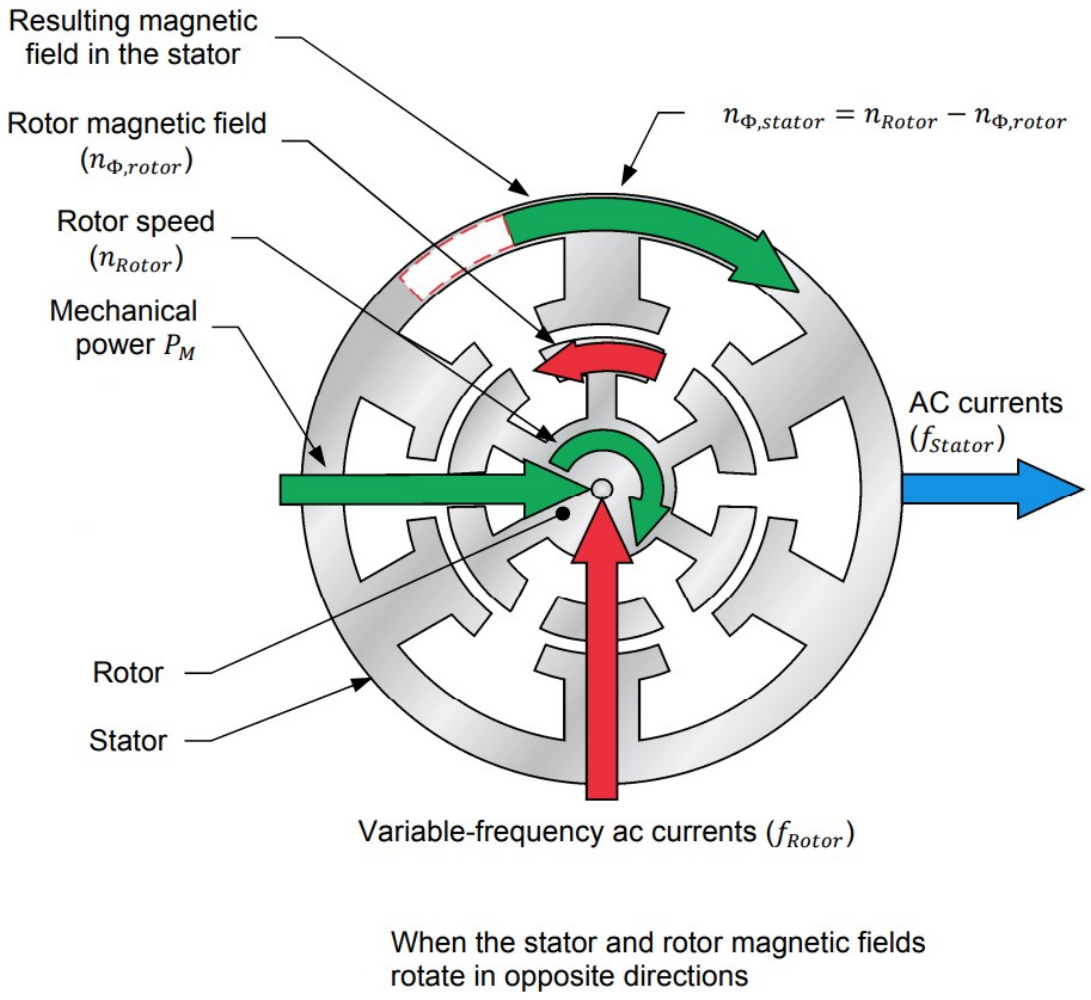


Figure: Stator R.M.F. = Rotor's Mech. Speed + (- R.M.F. Speed)

Doubly-fed Induction Generator Empirical data

Speed (r/min)	Mechanical Power (W)	Stator Active Power (W)	Stator Reactive Power (var)	Rotor Frequency (Hz)
1470	230.6	264.5	4.49	11
1500	235.4	267.0	4.55	10
1530	240.1	264.7	-1.03	9
1559	244.5	264.7	5.53	8
1800	282.4	265.8	9.78	0
1919	300.8	264.4	2.25	-4
1950	305.7	265.1	-2.95	-5
1980	310.5	265.5	0.57	-6
2009	315.1	267.0	0.43	-7
2040	319.9	267.0	0.91	-8
2069	324.6	266.8	-1.19	-9
2099	328.7	267.3	-3.22	-10

Table: Table of Doubly-fed Induction Generator Results. from: Reference 1

Machine data:

- Poles $= 4$
- Grid frequency $= 60\,Hz$

Key Points

- A *DFIG* functions as a *variable-speed synchronous generator*, it can be adjusted by modifying the rotor frequency (f_{rotor}).
- During periods of **low wind speeds**, the rotor frequency is increased, to match the synchronous grid frequency.
- Conversely, during **high wind speeds**, the rotor frequency is increased, but the direction of $Rotor_{R.M.F.}$ is reversed to counterbalance the high speed, matching the synchronous grid frequency.

Operational Range

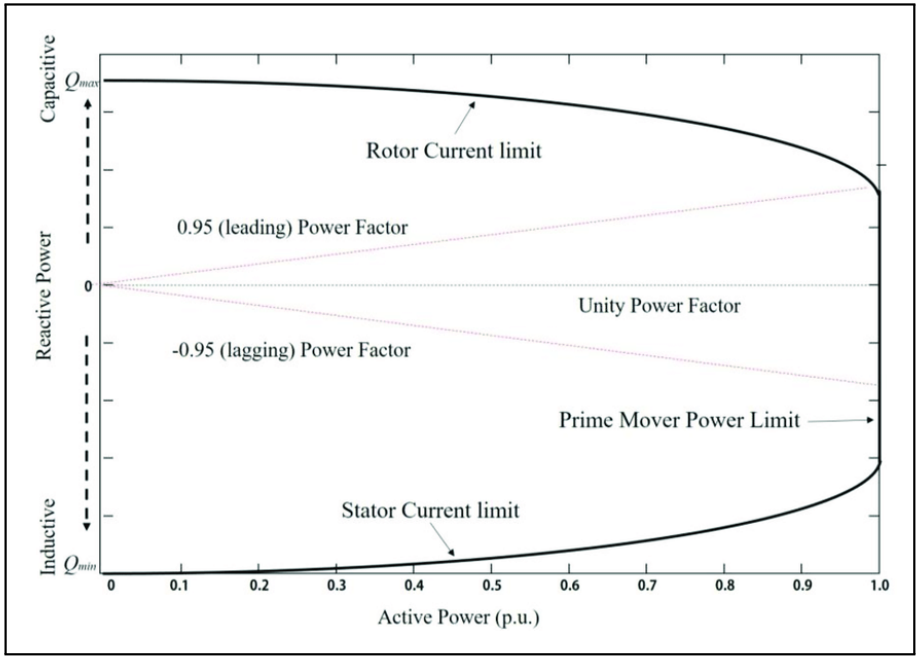


Figure: Capability curve of DFIG

- It allows variation of $\pm 30\%$ synchronous speed.
- Limits due to armature and field heating.

Control principle

- The control principle used is either the
  - Two-axis current vector control
  - or Direct Torque Control D.T.C.
- D.T.C. proved to be stable high reactive currents are required from generator.

Vector control of DFIG

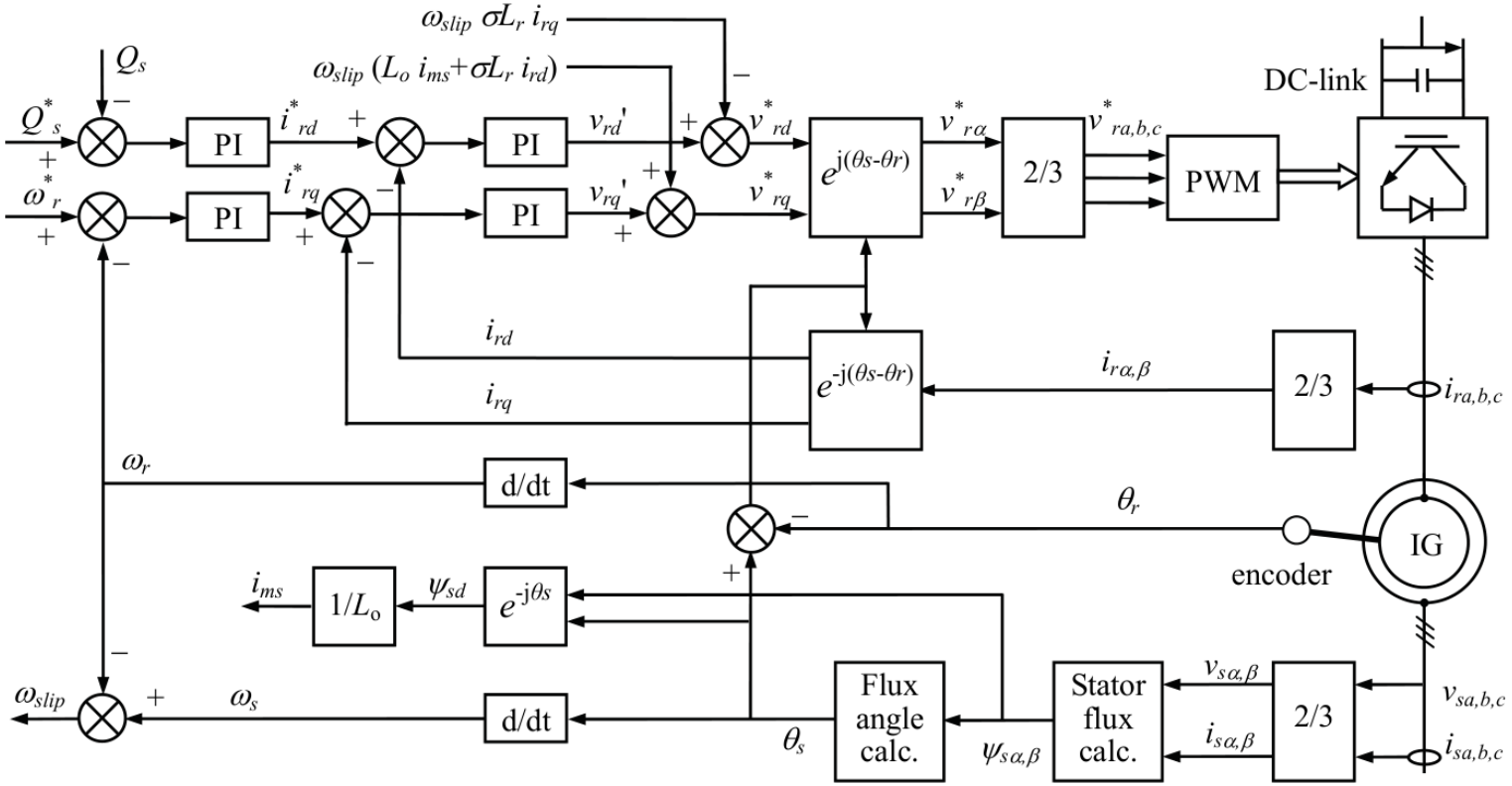


Fig. 11. Vector control structure for rotor-side converter.

Direct torque control of DFIG

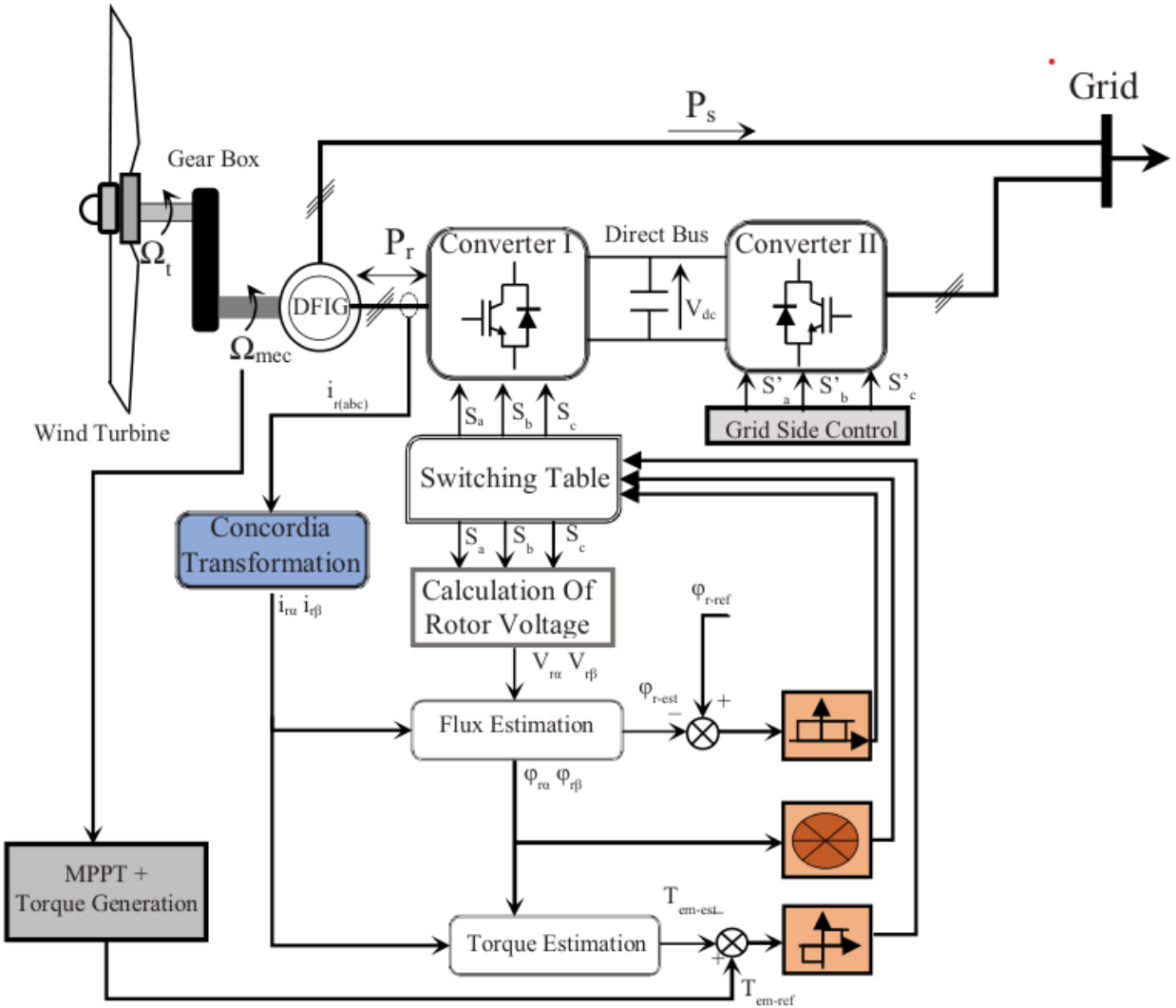


Fig.2. DTC Control applied to DFIG connected to the grid.

Merits and Demerits of DFIGs

Merits

- Easy on the **gearbox**. (Reduced mechanical stress due to power system).
- Better fault ride-through capability. Whereas synchronous generator will **slip** when V_{stator} falls below a threshold.

Merits and Demerits of DFIGs

Merits

- Easy on the **gearbox**. (Reduced mechanical stress due to power system).
- Better fault ride-through capability. Whereas synchronous generator will **slip** when V_{stator} falls below a threshold.
- Smaller converter size (only about 30% of the rated power).
- Ability to support grid voltage and frequency regulation.

Demerits

- Complex power conversion circuitry.
- Slip ring and brush maintenance.

References 📖

This presentation would not have been possible without the invaluable following:

1. A **wonderful practical** introduction to DFIG from labvolt.festo.com
2. Peng DFIGs principle with **beautiful** animations
3. DFIG Wikipedia-Wikiwand
4. ABB.com DFIGs
5. Evan Knapp video on DIFG
6. My website - explore.airgapflux.in (Additional resources on the subject)

Tools used

1. Latex Beamer source code for this presentation can be found here: GitHub DFIG seminar Adhithya.
2. Adobe Photoshop was used to edit some of the images.
3. Overleaf.com, which was used for preparing this presentation.
4. Special thanks to LaTeX Beamer tools and the authors of the Singapore theme, whose contributions greatly improved the quality of this presentation.

"Education is the journey that transforms curiosity into knowledge and passion into expertise."

Thank you for your time

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