Control of a Brushless Doubly-Fed Induction Machine

The University Of Chile

Presented by:

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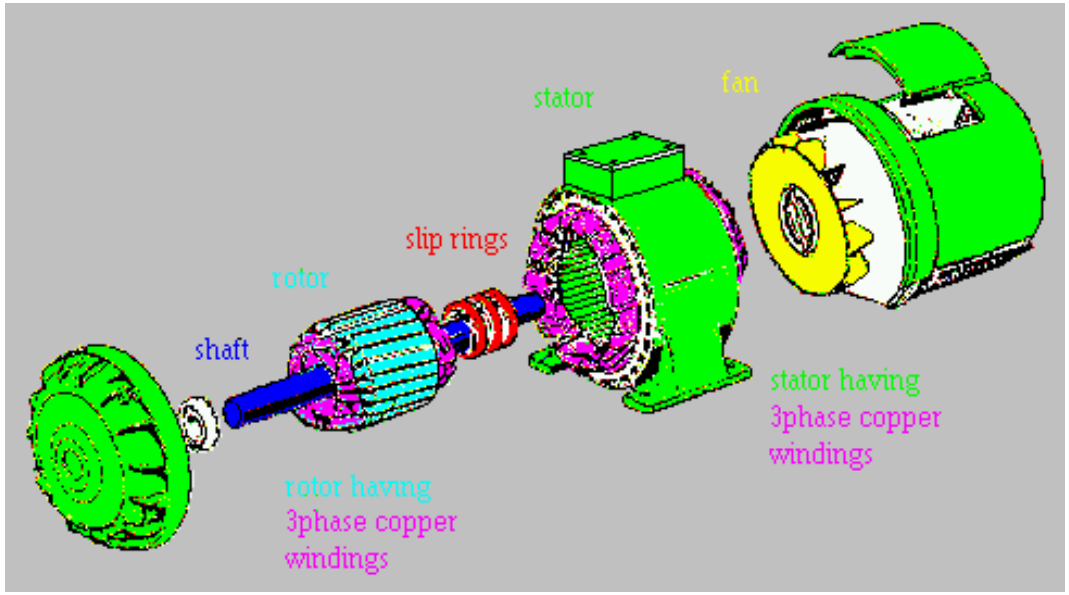
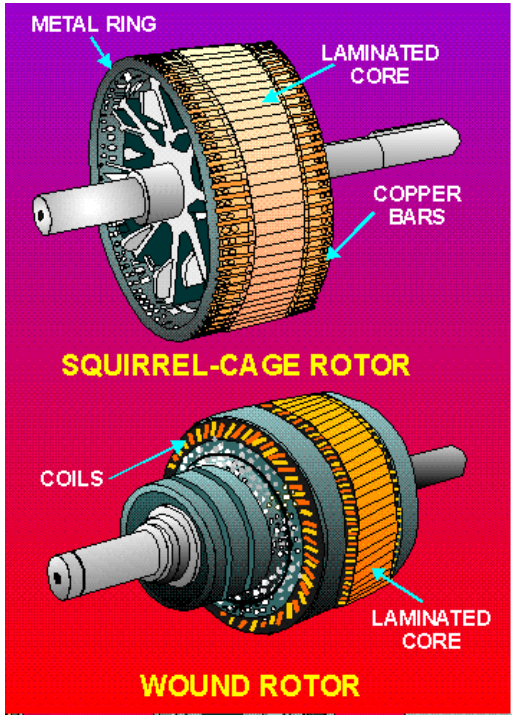
Doubly-Fed Induction Generators

- This machine is widely used in variable speed wind energy applications. Currently this topology occupies close to 50% of the wind energy market.

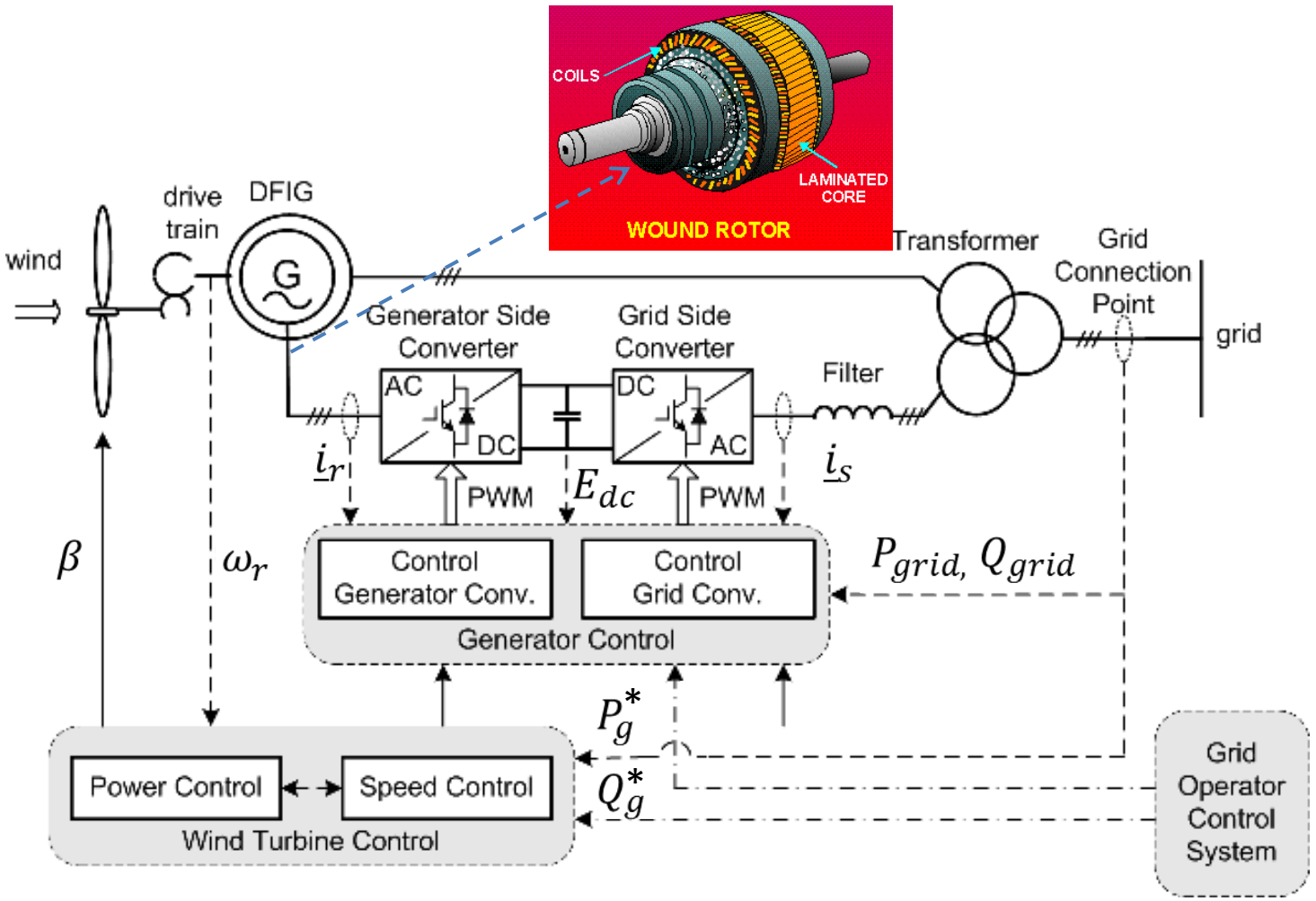




Manufacturer	Reference	NM	Pow. Range (MW)
AAER	A1650-A2000	6	2.0
Acciona	AW	6	1.5 - 3.0
Alstom Power	ECO	4	1.67 - 3.0
Dewind	D8.0 – D9.0	1	2.0
Fuhrlander	FL	6	1.5 - 2.5
Gamesa	G	3	2.0
General Electric	GE Energy	7	1.5 - 2.5 - 2.75
Ghodawat	G	1	1.65
Guangdong Mingyang	MY	2	1.5
Guodian United Power	UP1500 UP2000 UP3000	17	1.5-2.0-3.0
Hyosung	HS	1	2.0
Inox Wind	WT	1	2.0
Mitsubishi	MWT	5	2.4
Nordex	N	9	1.5 - 2.4 - 2.5
Repower	MM	6	2.0 - 2.05
Sinovel	SL	8	3.0
Suzlon	S	2	1.5 - 2.1
Vestas	V80 – V90 V100	7	1.8 – 2.0 – 2.6 – 3.0

Some commercial DFIGs in the 1MW to 3MW power range

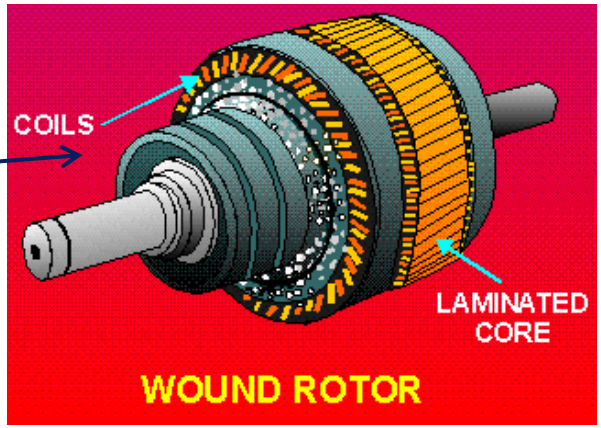
Typical topology for a DFIG



Power converters are usually designed for a nominal power of 30% of that of the doubly-fed machine.

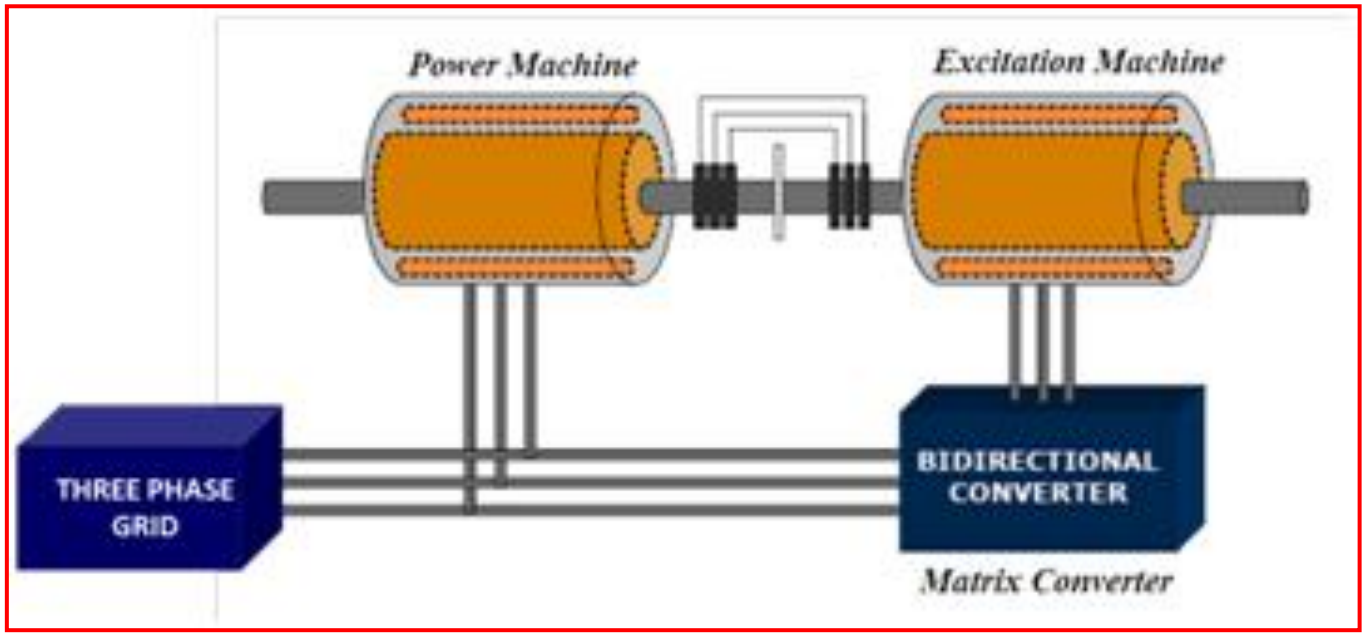
Problems related to the use of Brushes

slip rings



- In most of the applications where robustness is required, the use of brushes has to be avoided.
- For instance in remote areas, where regular maintenance is difficult to achieve.

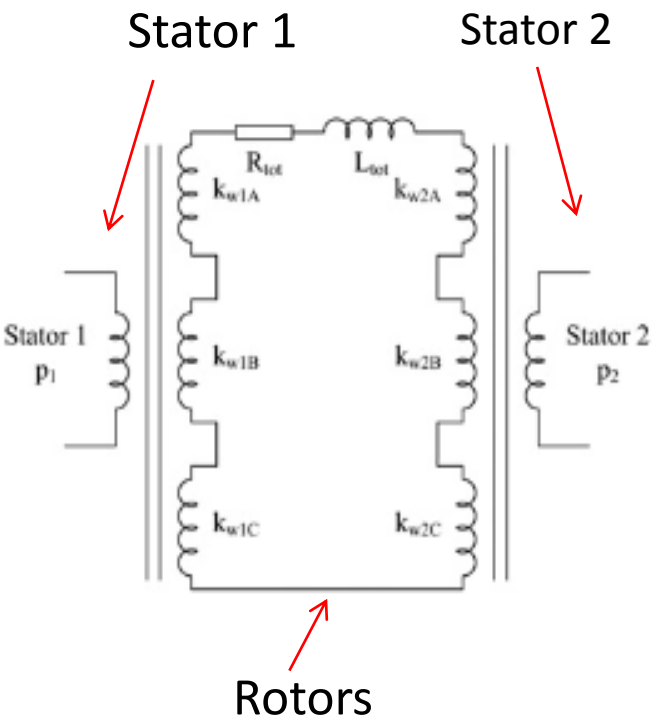
Proposed Brushless Topology

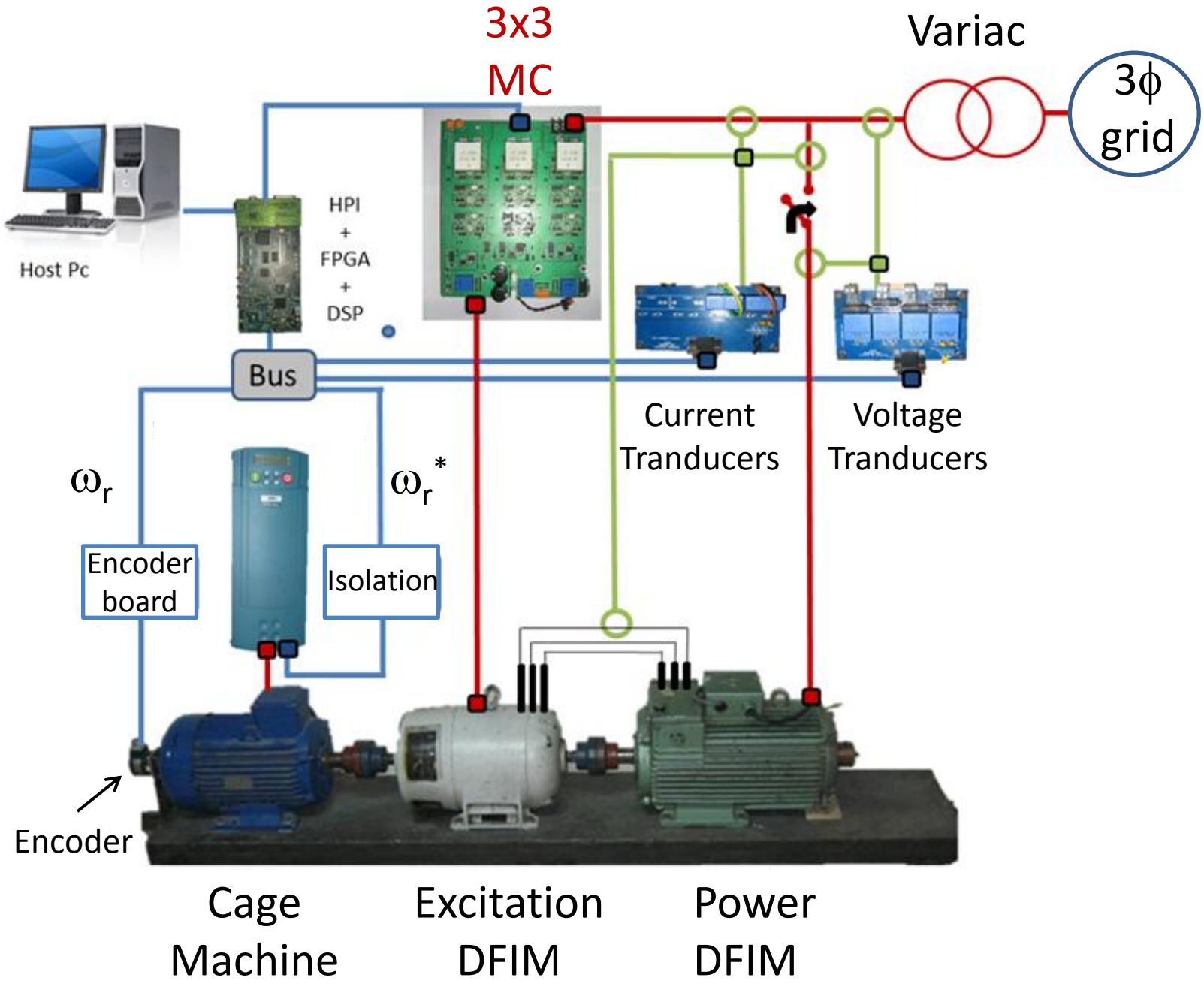


- This is just a representation.
- Two DFIGs in the same shaft (“cascaded” implementation). The signals induced in the rotor of the first machine are used to excite the power machine.

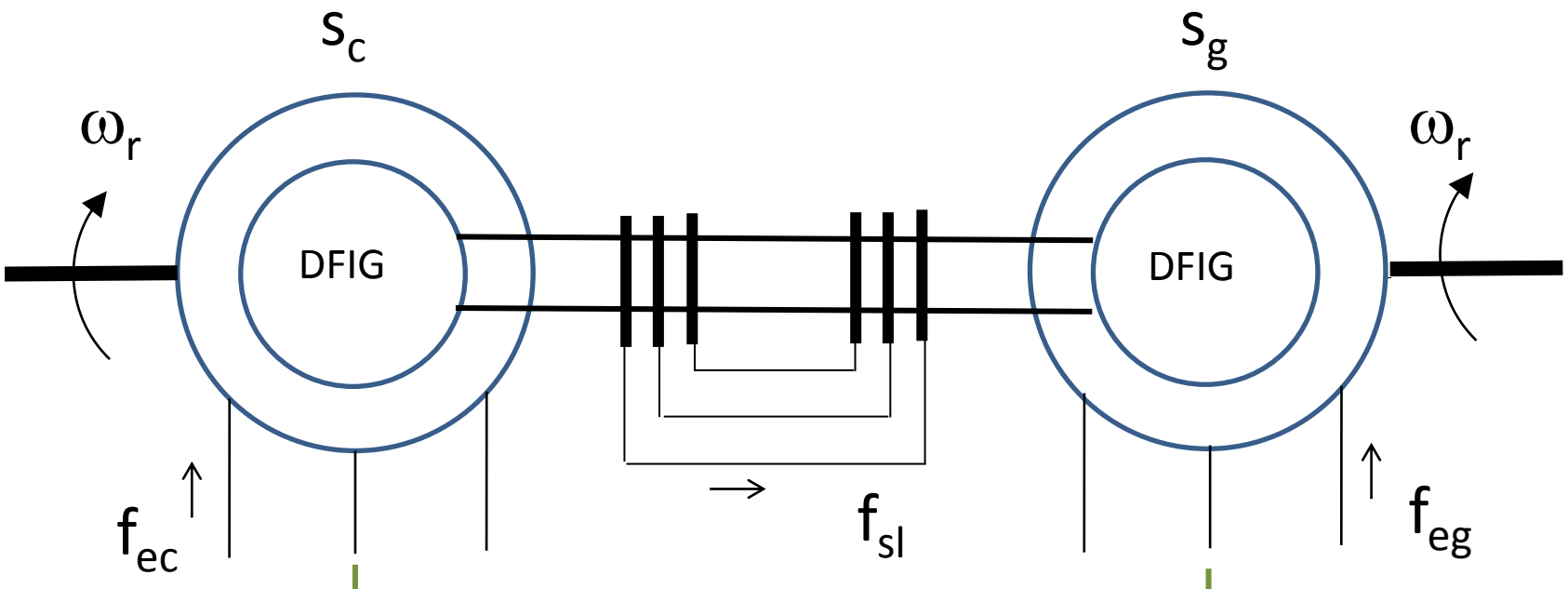
Proposed Brushless Topology

- The Brushless DFIG (BDFIG) could be also implemented using two (3ϕ each one) stator windings.
- Mathematically the BDFIG implemented using two cascaded machines is similar.




3x3
MC
Variac
3ϕ
grid
Host Pc
HPI
+
FPGA
+
DSP
Bus
Current
Tranducers
Voltage
Tranducers
ω_r
ω_r^*
Encoder
board
Isolation
Encoder
Cage
Machine
Excitation
DFIM
Power
DFIM

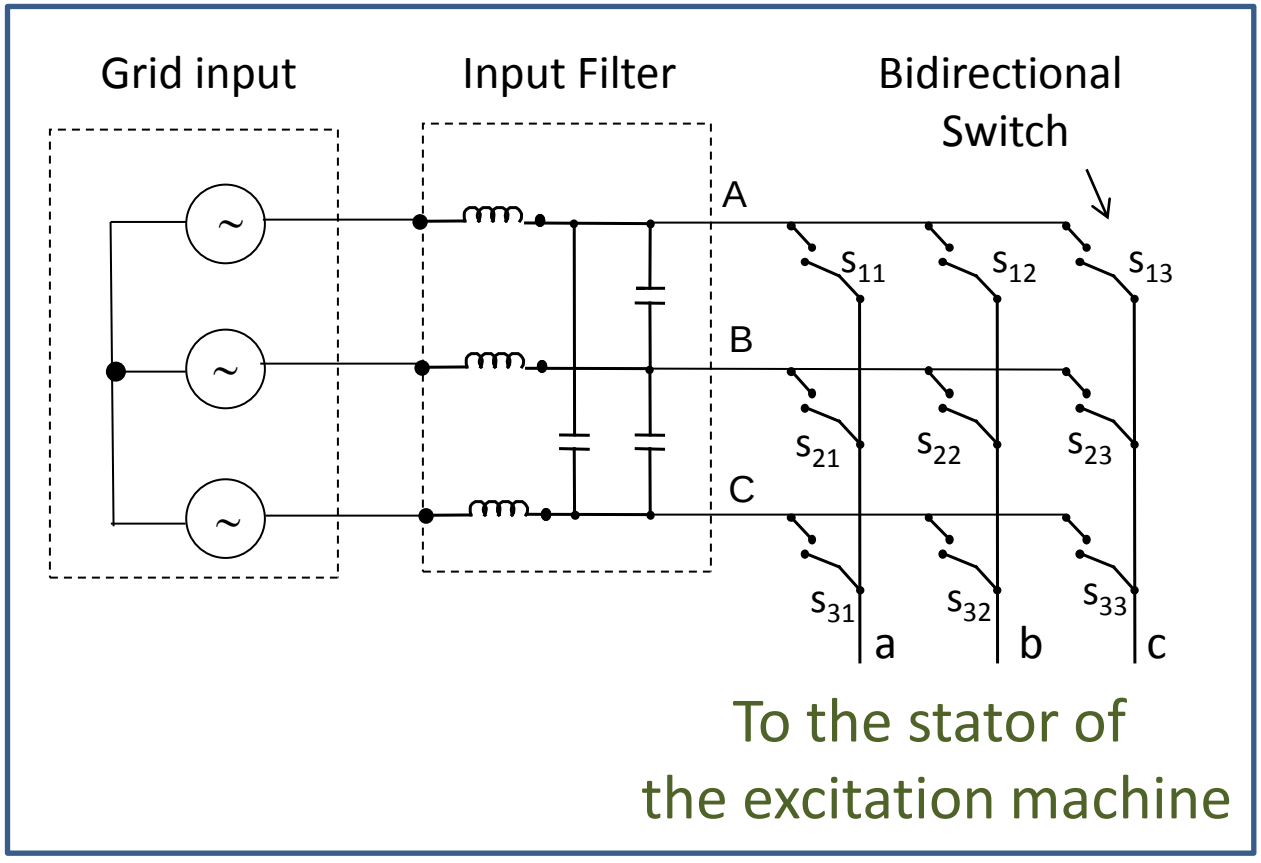
Proposed Brushless Topology



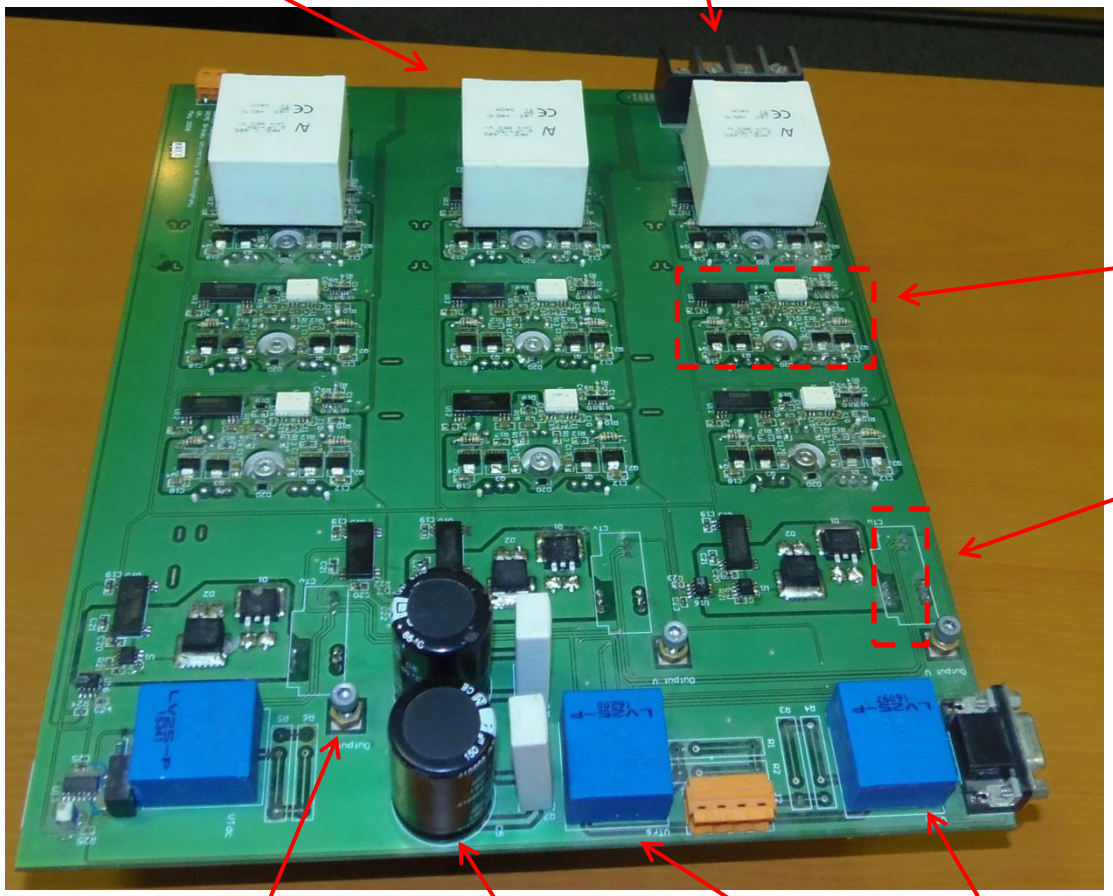
To Matrix Converter

To Grid

Power Converter used in this applications

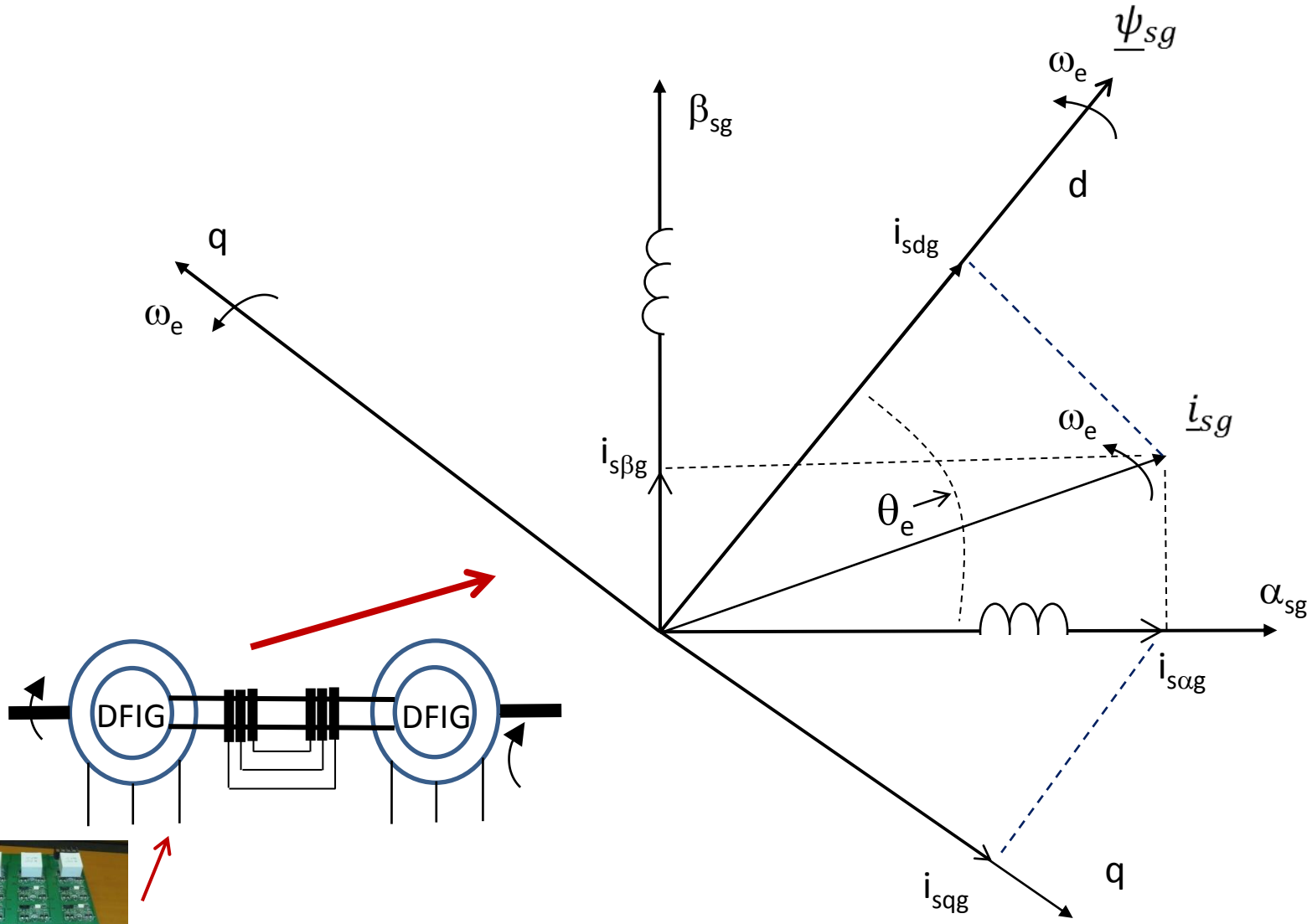


Power Converter used in this applications



Designed in the University of Nottingham

Vector Control System

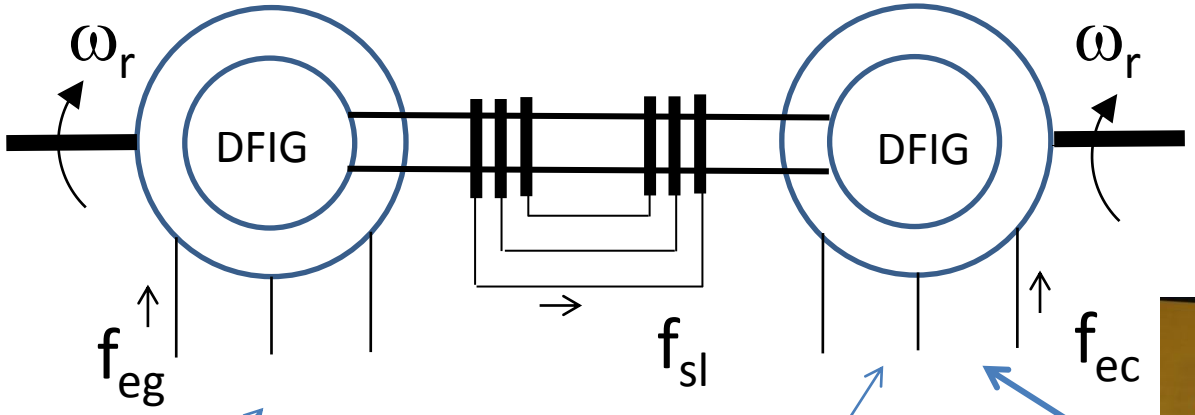


Control system

Power machine currents

Excitation machine currents

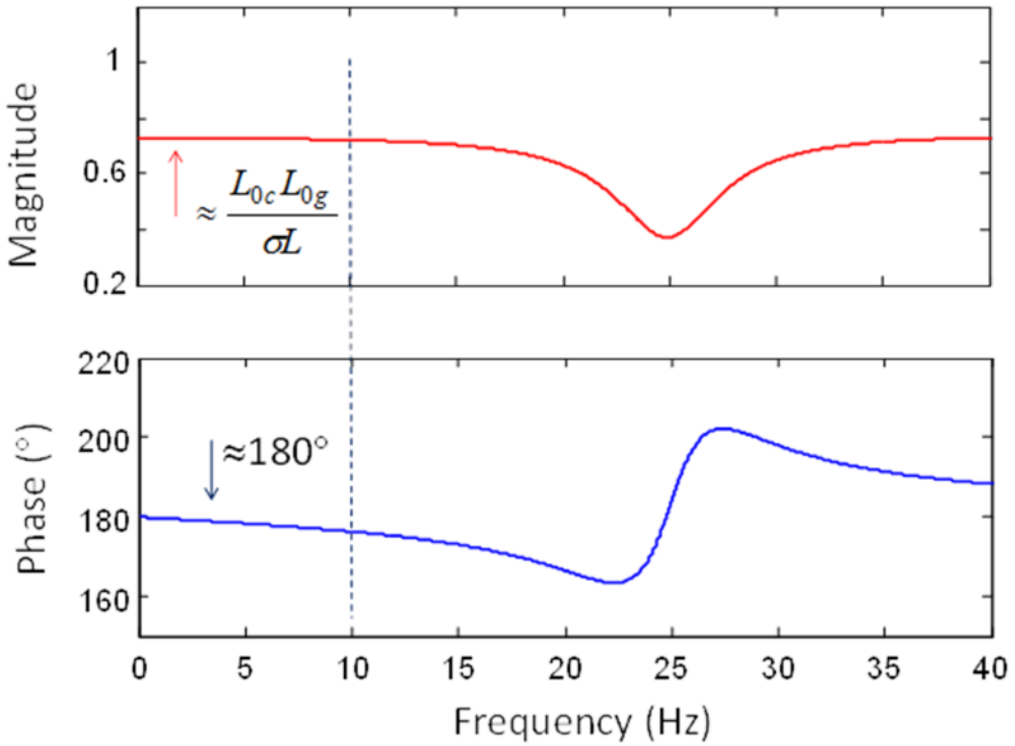
$$\begin{bmatrix} \Delta i_{sgd} \\ \Delta i_{sgq} \end{bmatrix} = \begin{bmatrix} G_d(s) & -G_q(s) \\ G_q(s) & G_d(s) \end{bmatrix} \begin{bmatrix} \Delta i_{scd} \\ \Delta i_{scq} \end{bmatrix}$$



Power machine currents

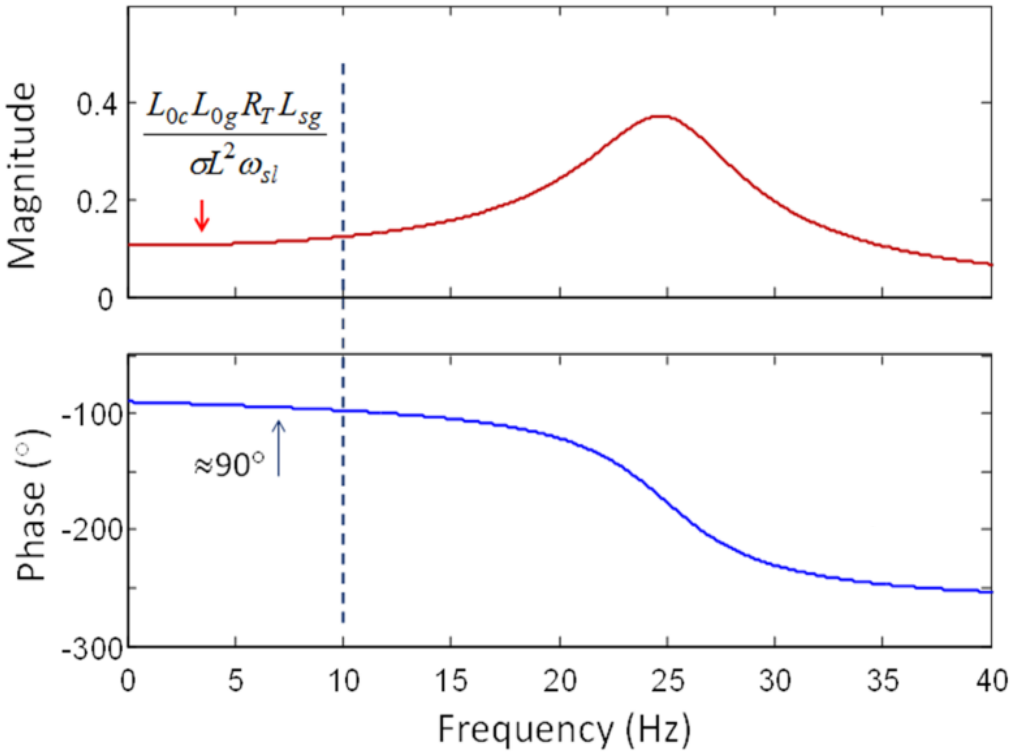
Excitation machine currents

Relationship between the currents in the excitation and power machines



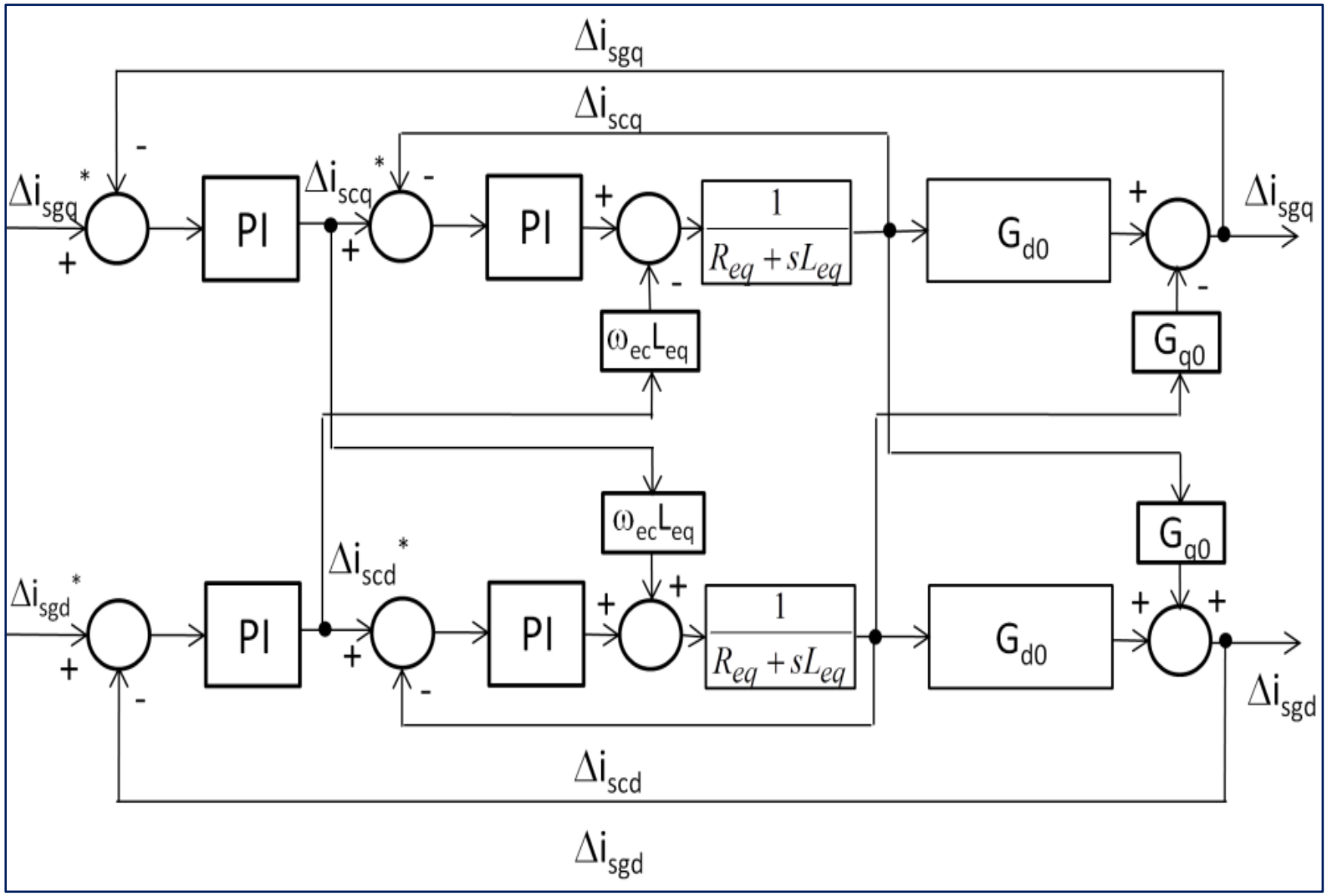
$G_d(\omega)$

Relationship between the currents in the excitation and power machines



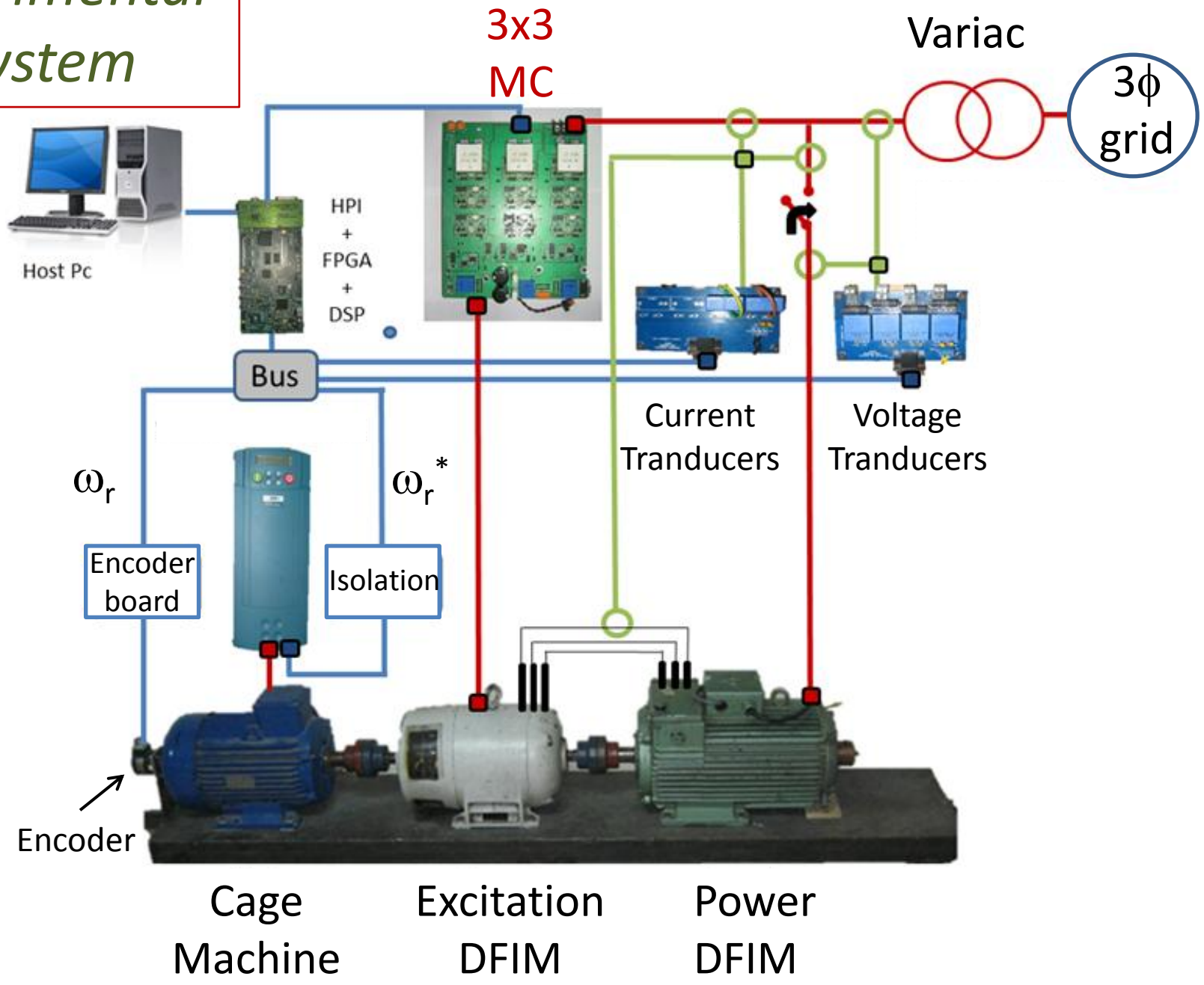
$G_q(\omega)$

Control Loops

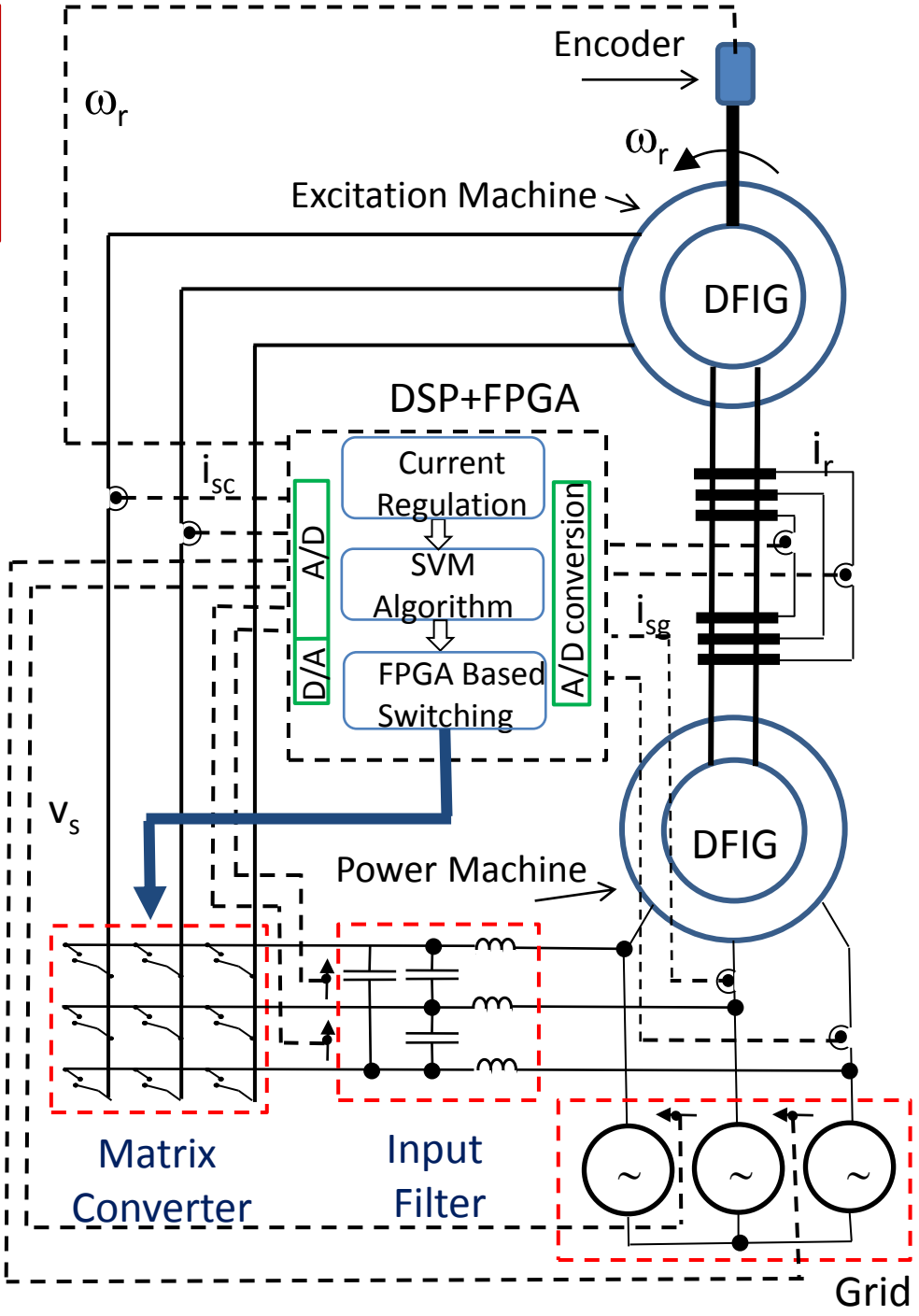


Nested control loops. The outer loop is regulating the currents of the power machine. The inner control loop is regulating the currents of the excitation machine.

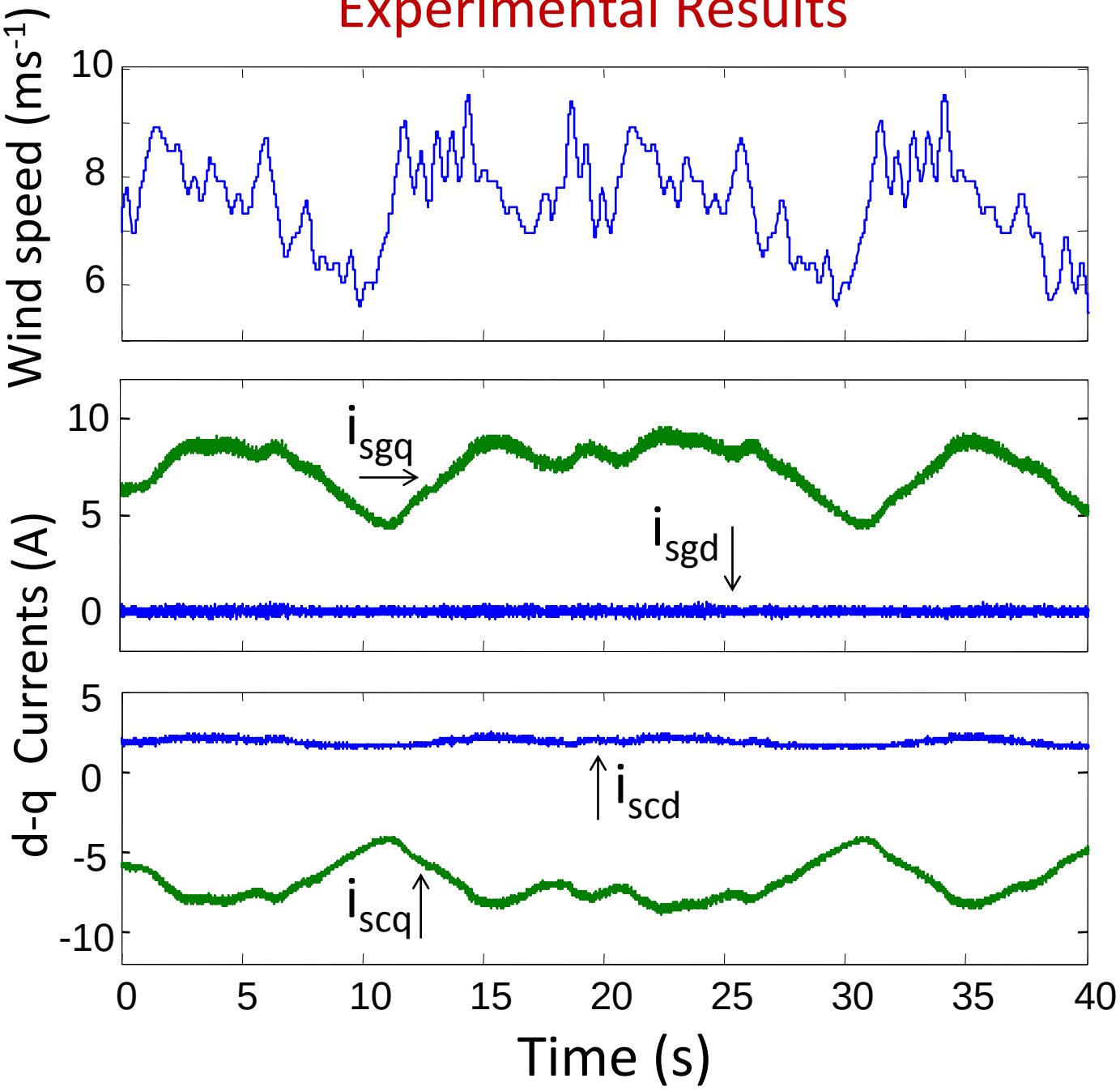
Experimental System



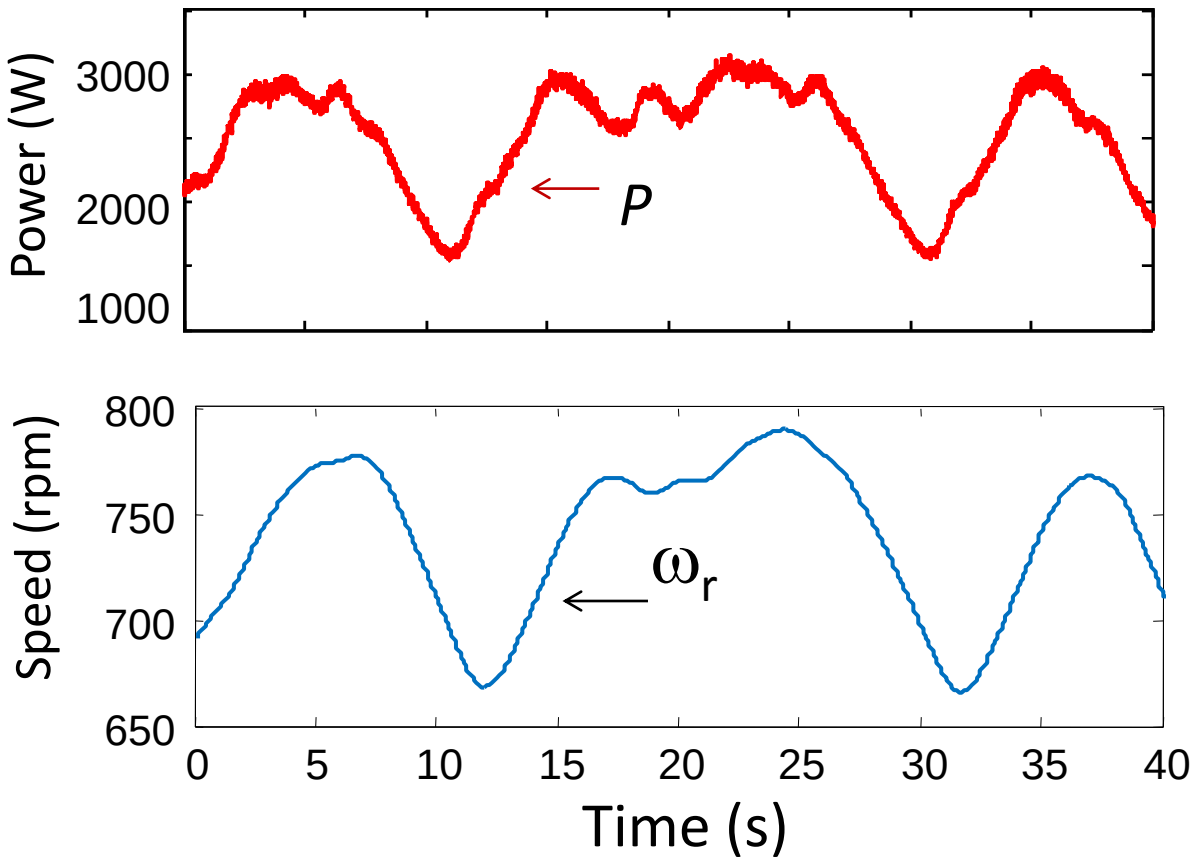
Experimental System



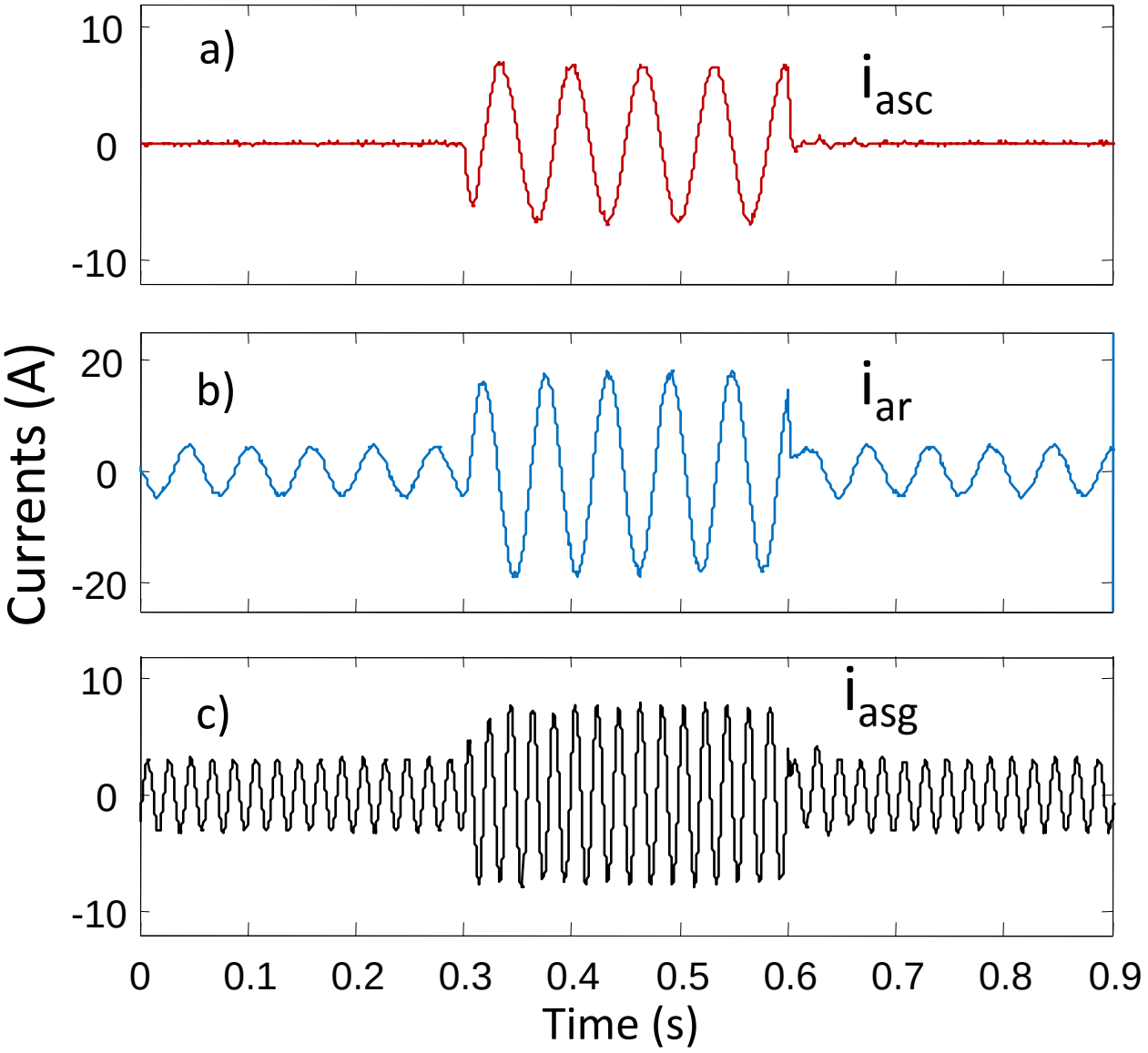
Experimental Results



Experimental Results



Experimental Results



Conclusions

- The BDFIG is an alternative to the conventional Doubly-Fed Generator in remote sites where maintenance is not simple to achieve.
- The simplified model proposed here can be used to design the control system. The simplifications arise from the fact that wind energy systems have slow dynamic due to the relatively large blade inertia.
- Experimental results have been obtained which confirm the performance of the proposed methodology.

Any question?