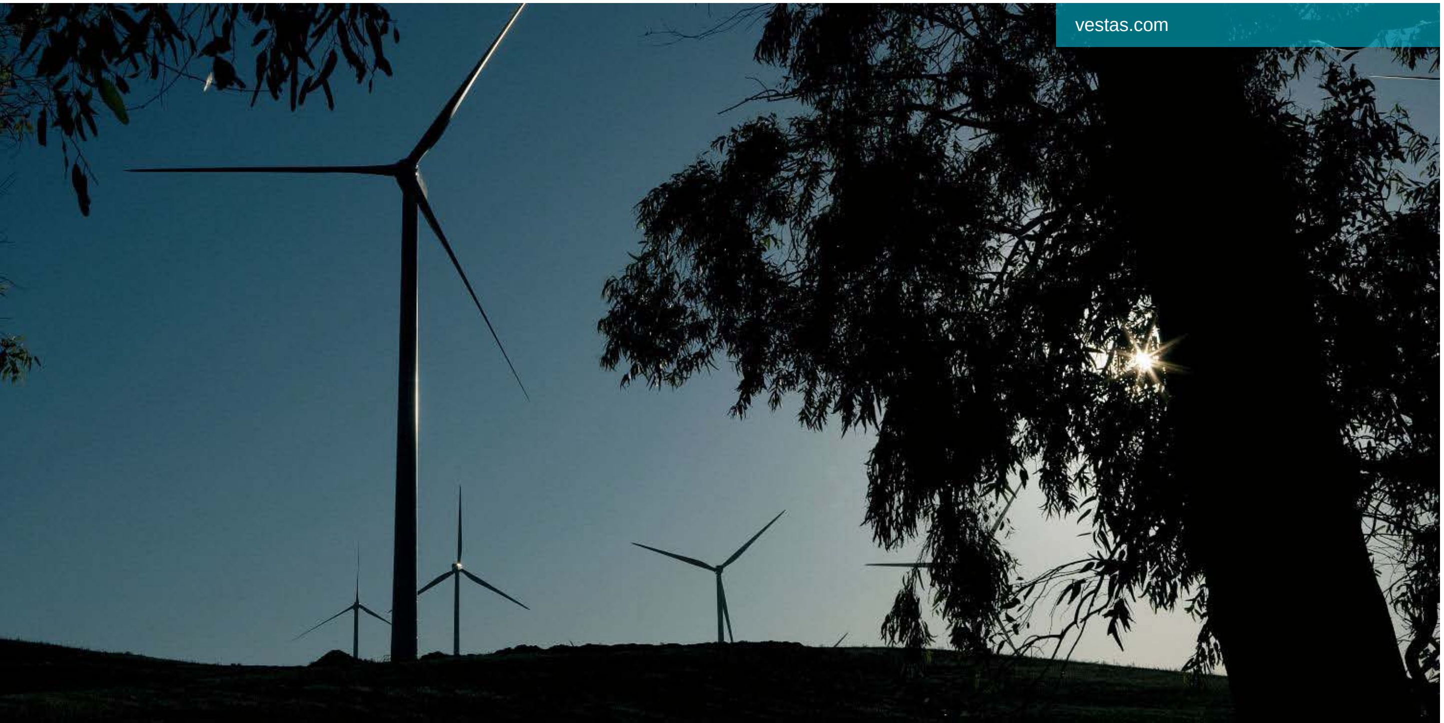
No. 1 in Modern Energy

Fault Current Signatures of DFIG Wind Turbines

Jorge Martinez Garcia



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Agenda

- Introduction
- Vestas DFIG types:
  - VRCC → Single line diagram & control
  - VCS → Single line diagram & control
- Generic VCS short circuit waveforms
- Examples of short circuit waveforms
- Conclusions
- Questions

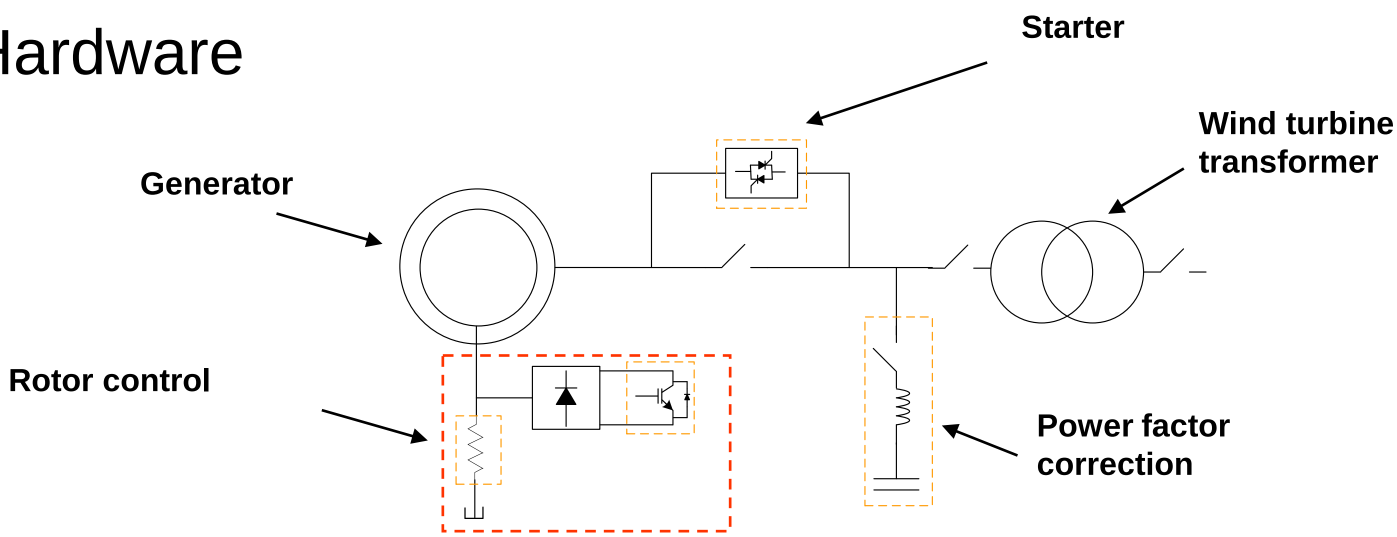
VRCC: Vestas Rotor Converter control **VCS: Vestas Converter System** **DFIG: Double Fed Induction Generator**

Introduction

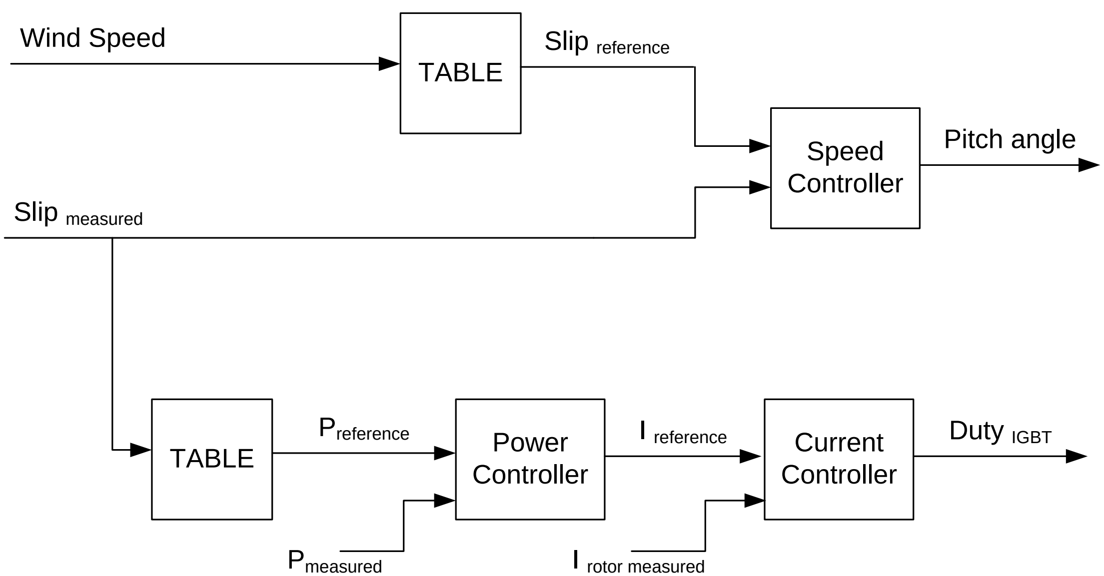
- High increase in the number of wind turbines installed:
  - Wind turbines topology differ from synchronous generators
    - Voltage control
    - Frequency control
    - **Short circuit contribution**
- For a reliable operation of the system the electrical grid should be adapted, at some degree, to the new wind turbines technologies
  - In this case; short circuit contribution from some wind turbine types could differ from synchronous generators

DFIG types: VRCC

- Hardware



- Control



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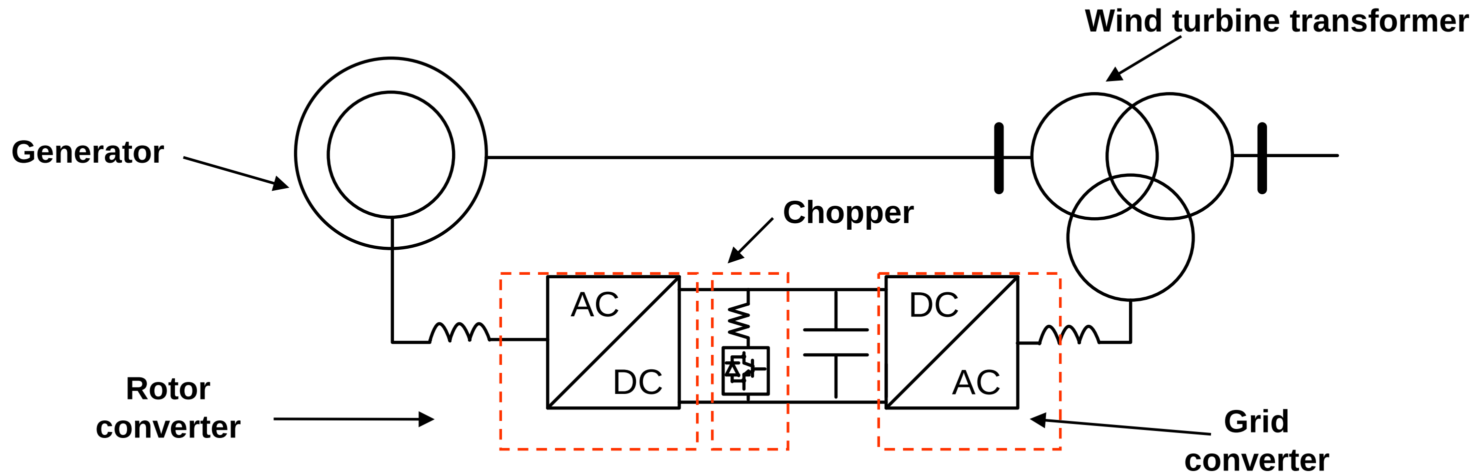
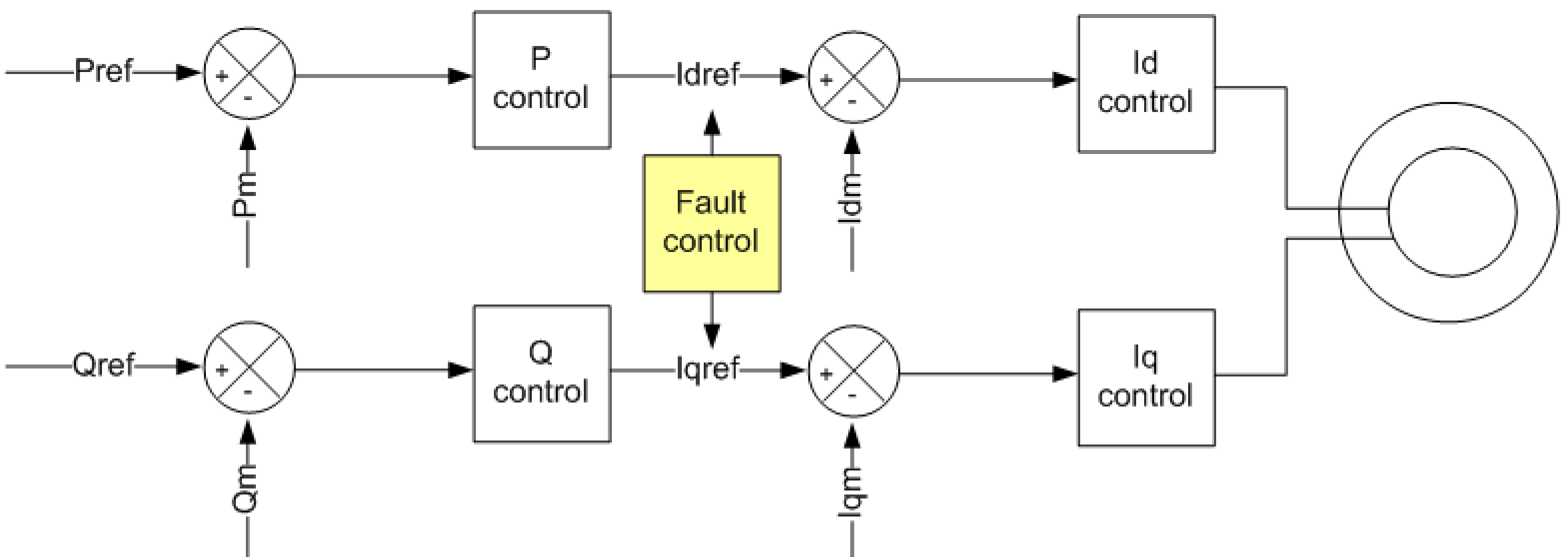
DFIG types: VCS

- Hardware



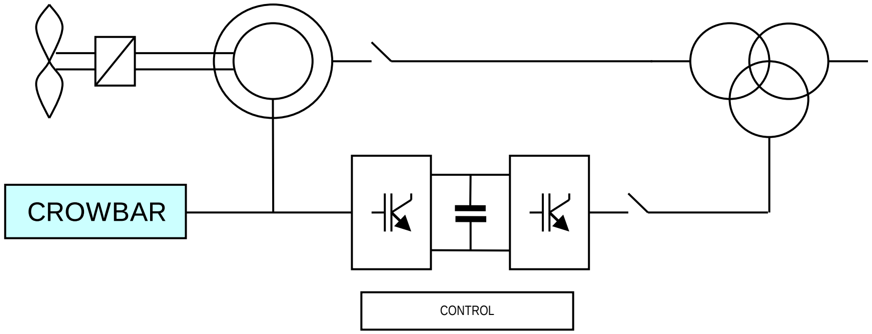
- Control of rotor converter



DFIG: VCS

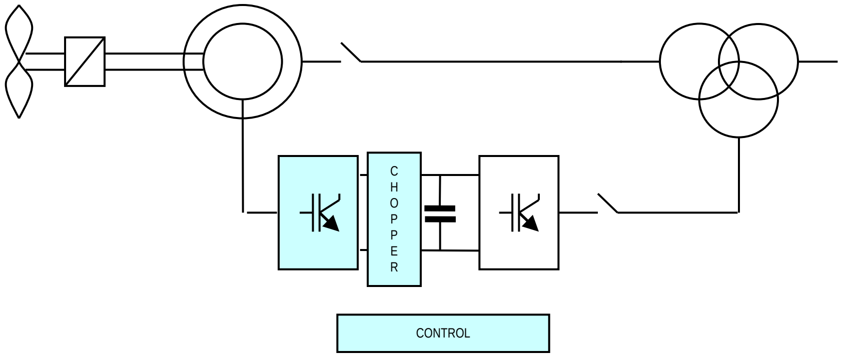
- IN THE PAST:

INSTANTANEOUS DISCONNECTION OF THE DFIG TO PROTECT ELECTRONIC DEVICES



- NOWDAYS:

GRID SUPPORT ⇒
- NO DISCONNECTION Grid Operator Voltage profiles
- REACTIVE CURRENT SUPPORT



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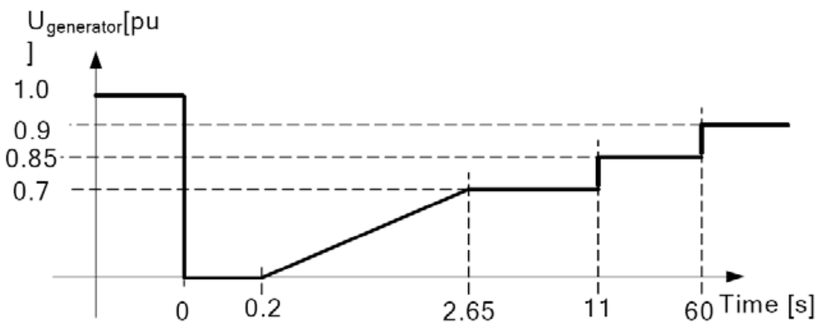
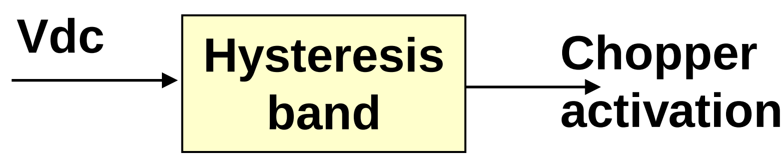
DFIG: VCS

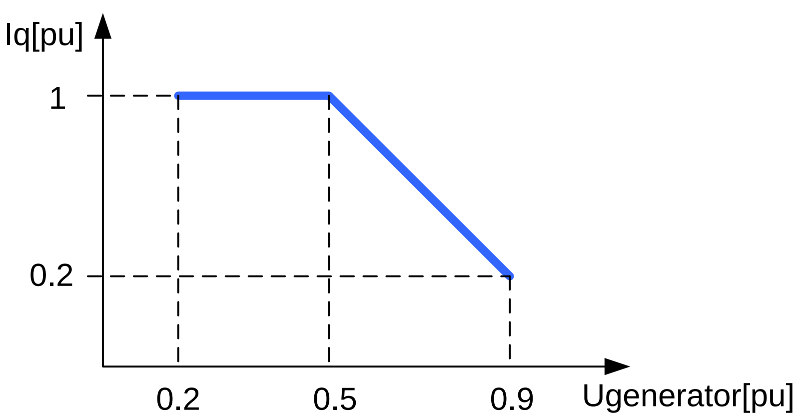
- Control during faults:

GRID SUPPORT ⇒
- NO DISCONNECTION (Chopper control & protection settings)
- REACTIVE CURRENT SUPPORT (current control)

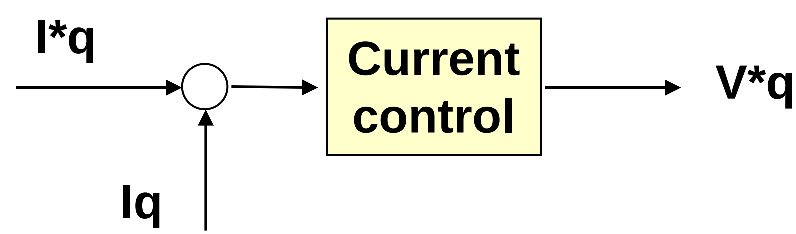


CHOPPER CONTROL:





CURRENT CONTROL:



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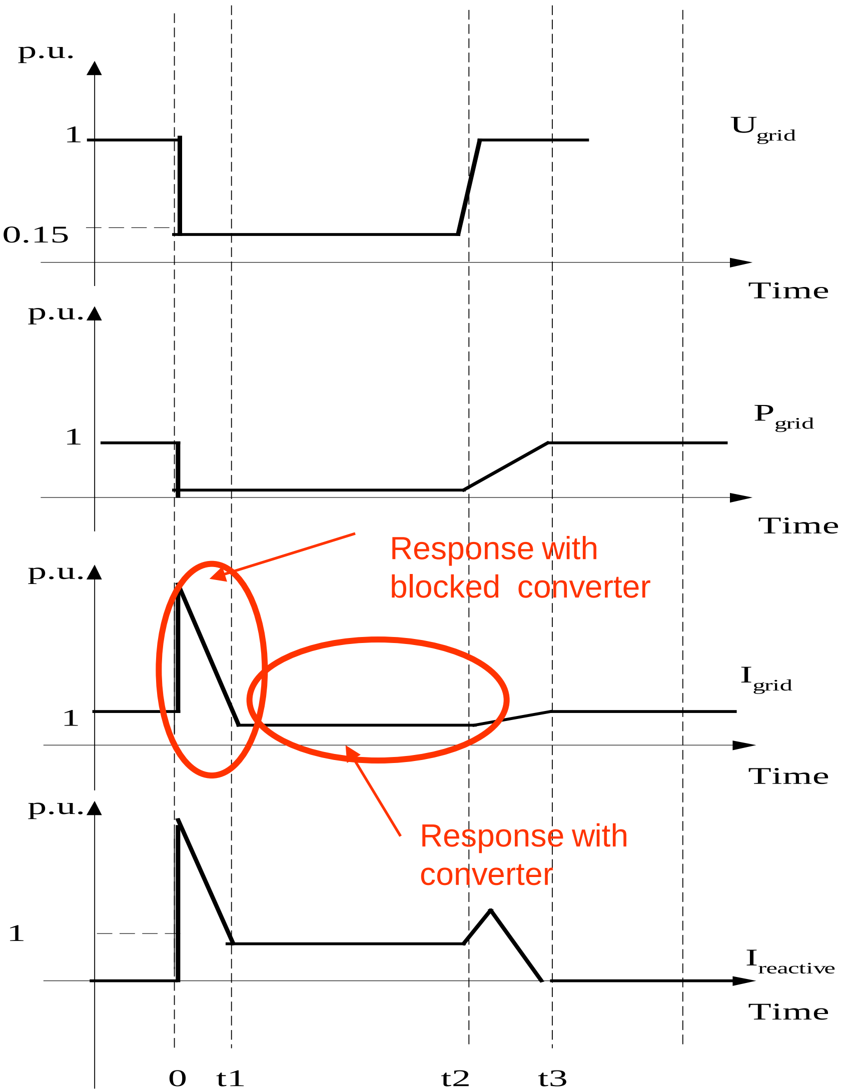
GENERICS ABOUT VCS SHORT CIRCUIT CONTRIBUTION



1. Initial phase, the generator gives a large short circuit current (1 - 5 p.u.).

2. The rotor converter enters current control and starts supporting the grid.

3. During the fault, within the hardware constraints.

4. Turbine speed will increase during the fault. The stored kinetic energy is useful in order to give a fast contribution of active power to the grid when the fault is cleared.

5. As the voltages return to normal condition, the generator will reduce reactive current injection.

6. After voltage recovery normal power control is re-enabled and the power is ramped back in a controlled way.

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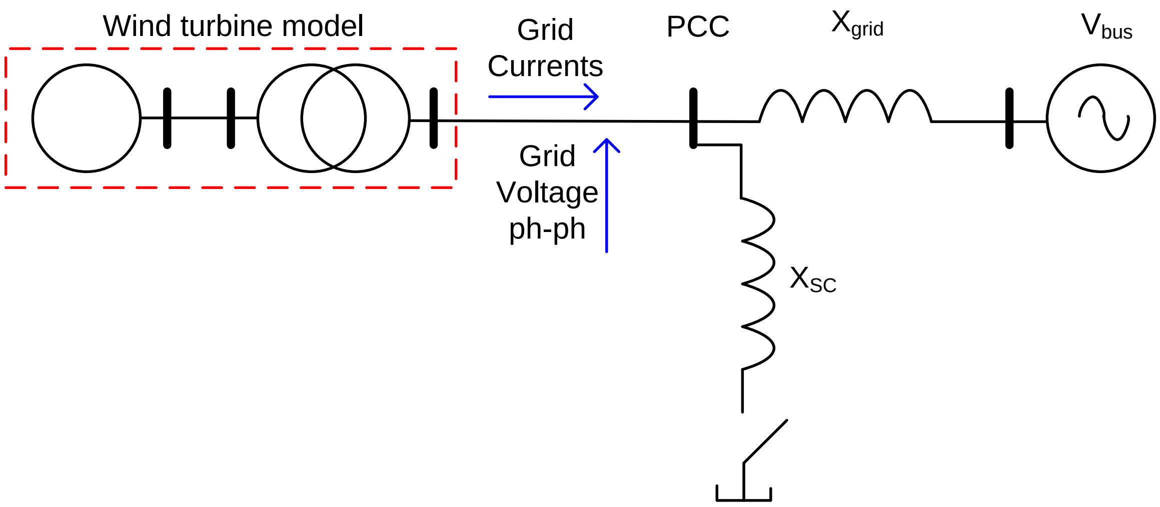
DFIG short circuit

- ***Short-circuit*** **simulation set up*. VCS 2MW***



<u>Test Cases (Remaining Voltage at PCC)</u>

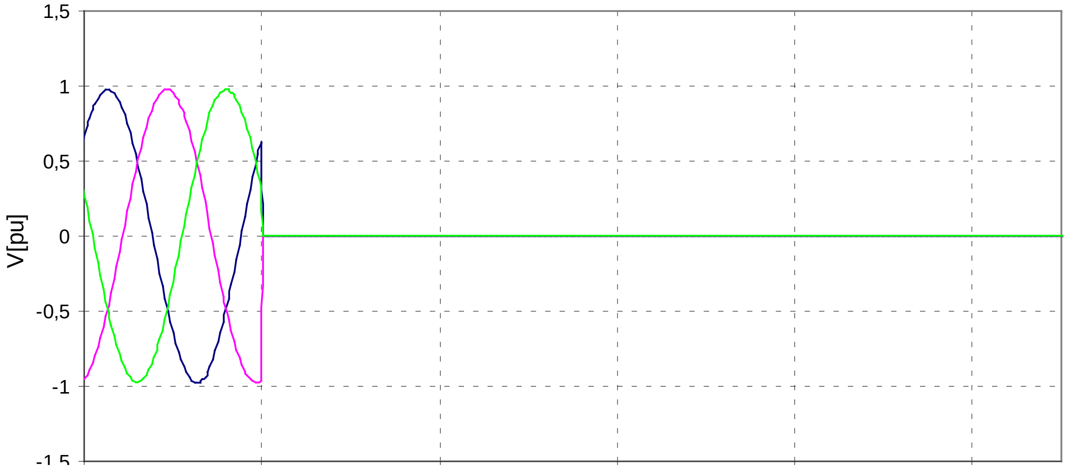
0%

25%

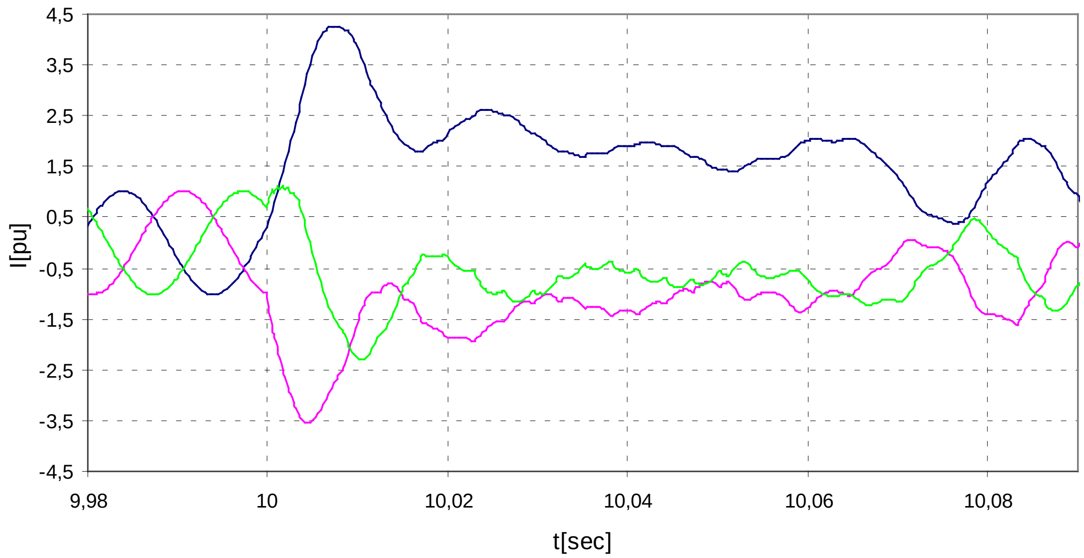
DFIG short circuit

- ***Short-circuit test waveforms. VCS 2MW, remaining voltage = 0%.***
  SYMMETRYCAL FAULTS (200ms- 100% RATED POWER)

Line-line voltage at MV transformer terminals



Currents in medium voltage side of turbine transformer.



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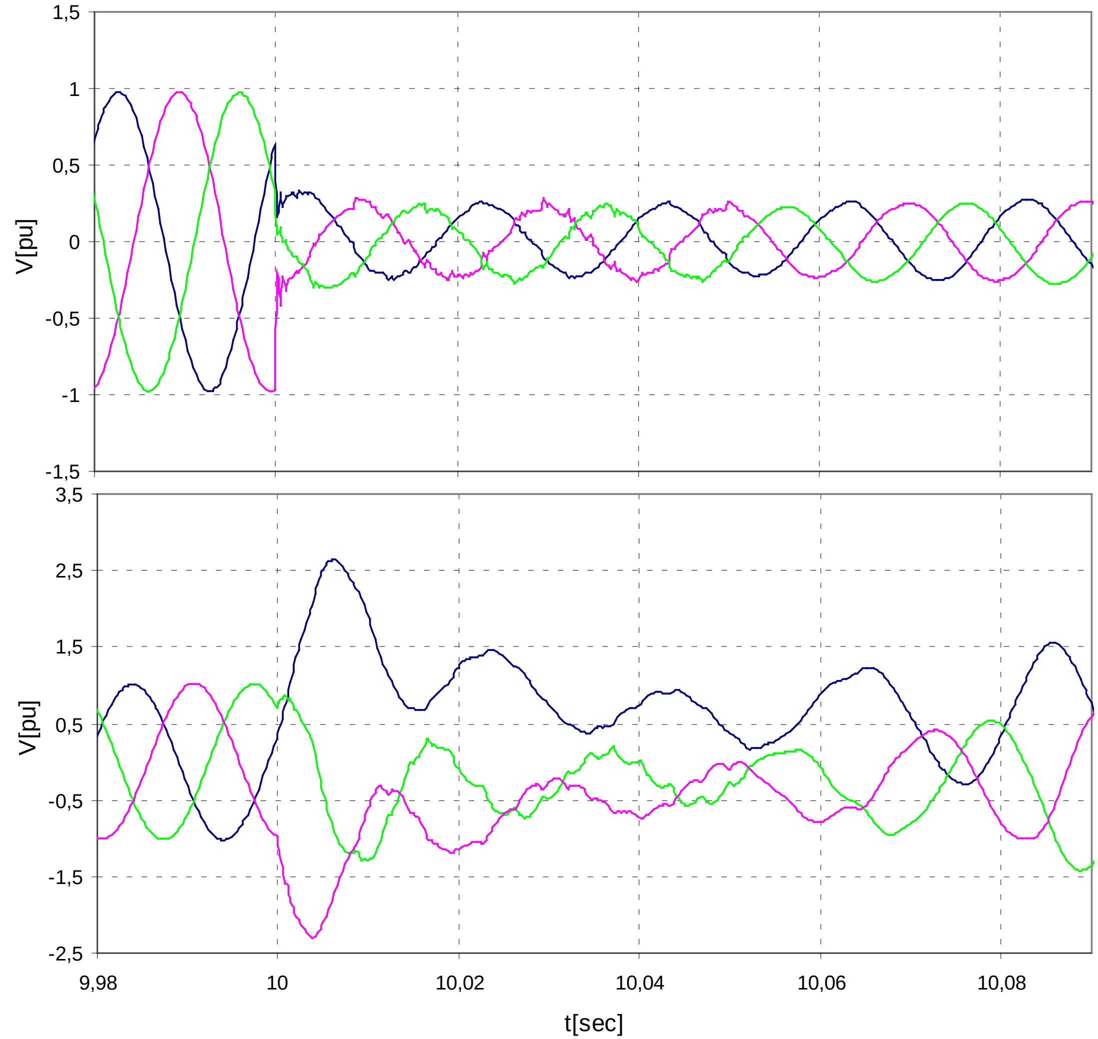
DFIG short circuit response

- ***Short-circuit test waveforms. VCS 2MW, remaining voltage = 25%.***

SYMMETRYCAL FAULTS (200ms- 100% RATED POWER)

Line-line voltage at MV transformer terminals

Currents in medium voltage side of turbine transformer.



Algorithm use in the next figures:
16 s/cycle full cycle cosine filter

The filter coefficients $$CFC_n = \cos\left[\frac{2\pi}{16}\cdot n\right] \quad (1)$$

The Cosine filter $$IX_{smpl+spc} = \frac{2}{N+1}\sum_{n=0}^{N} I_{smpl+spc-n} CFC_n \quad (2)$$

The phasor magnitude $$|Io|_{smpl+spc} = \sqrt{\left(IX_{smpl+spc}\right)^2 + \left(IX_{smpl+spc-\frac{spc}{4}}\right)^2} \quad (3)$$

The phasor output $$Io_{smpl+spc} = IX_{smpl+spc} + j\cdot IX_{smpl+spc-\frac{spc}{4}} \quad (4)$$

where:

N	=	15
n	=	0, 1, 2, ….N
smpl	=	sequence of samples 0, 1, 2, 3,………
spc	=	number of samples per cycle (16)
$I_{smpl+spc-n}$	=	Current samples
$IX_{smpl+spc}$	=	Filter output
Io	=	filter derived current phasor

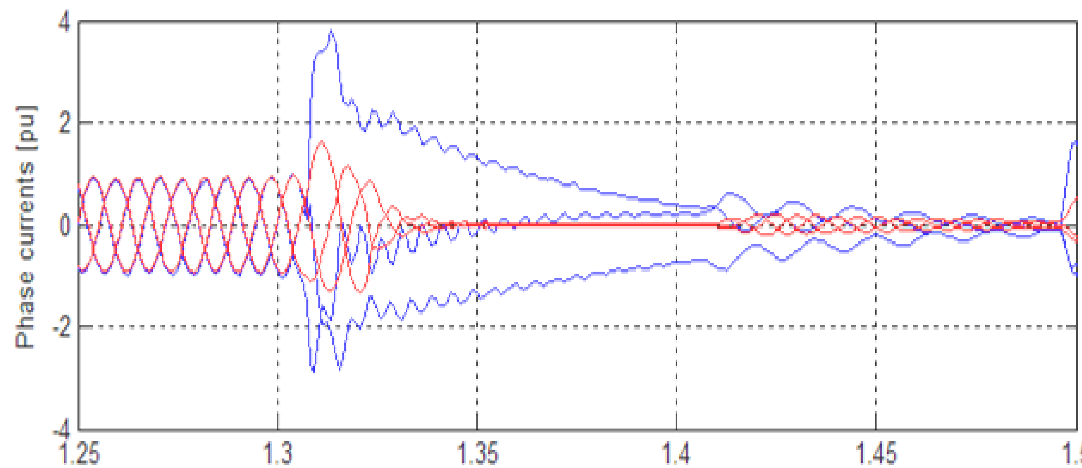
paper by: Stanley E. Zocholl and Gabriel Benmouyal, Schweitzer Engineering Laboratories, Inc.

Analysis of current following fundamental extraction

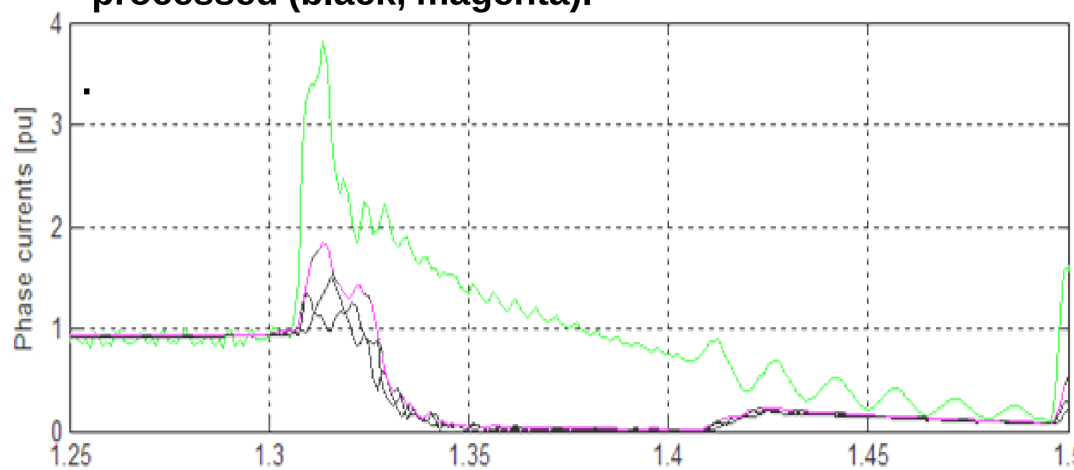
- ***Short-circuit test waveforms. VRCC 1.8MW, remaining voltage = 0%.***

SYMMETRYCAL FAULTS (200ms- 100% RATED POWER)

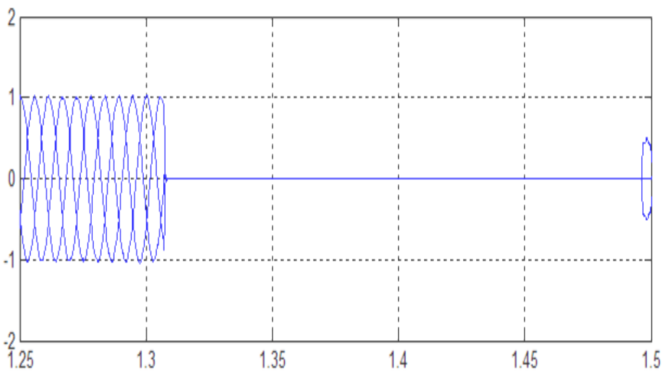
phase currents as recorded (blue) processed (red).



phase current envelope as recorded (green) processed (black, magenta).



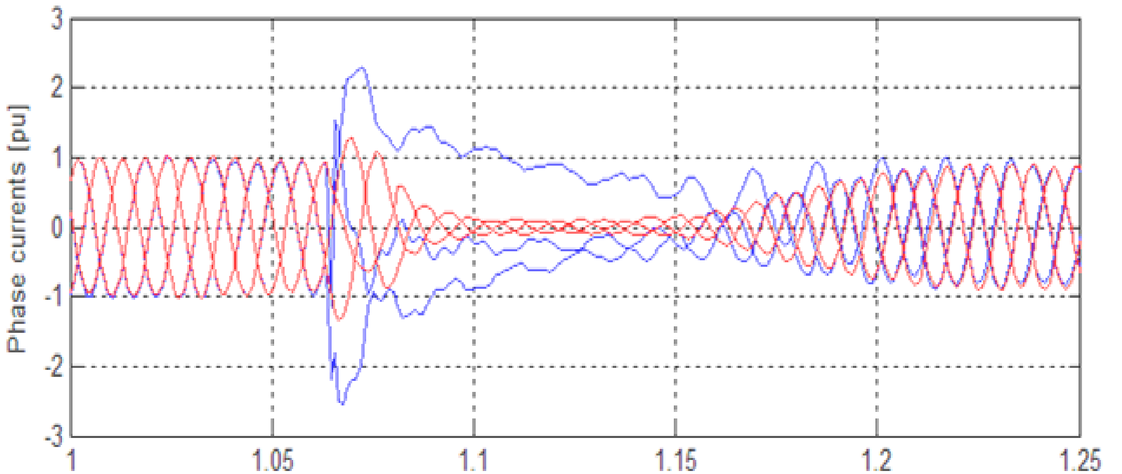
Turbine voltages, phase-ground.



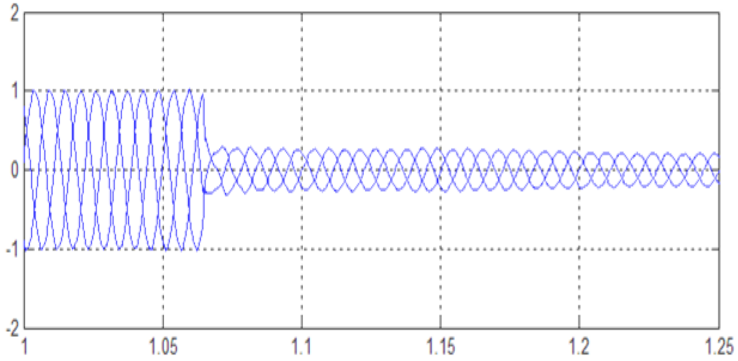
Analysis of current following fundamental extraction

- ***Short-circuit test waveforms. VRCC 1.8MW, remaining voltage = 25%.***
  SYMMETRYCAL FAULTS (300ms- 100% RATED POWER)

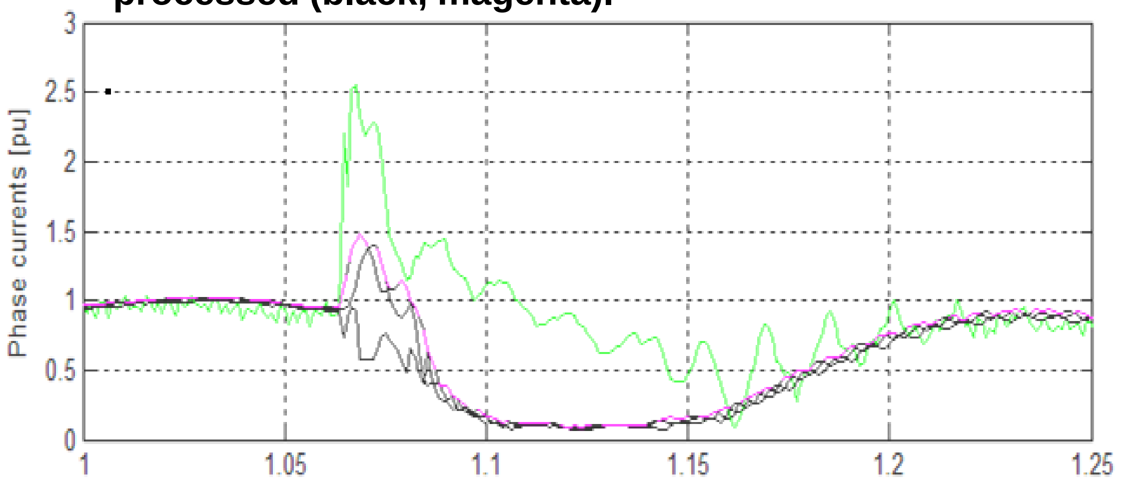
phase currents as recorded (blue) processed (red).



Turbine voltages, phase-ground.

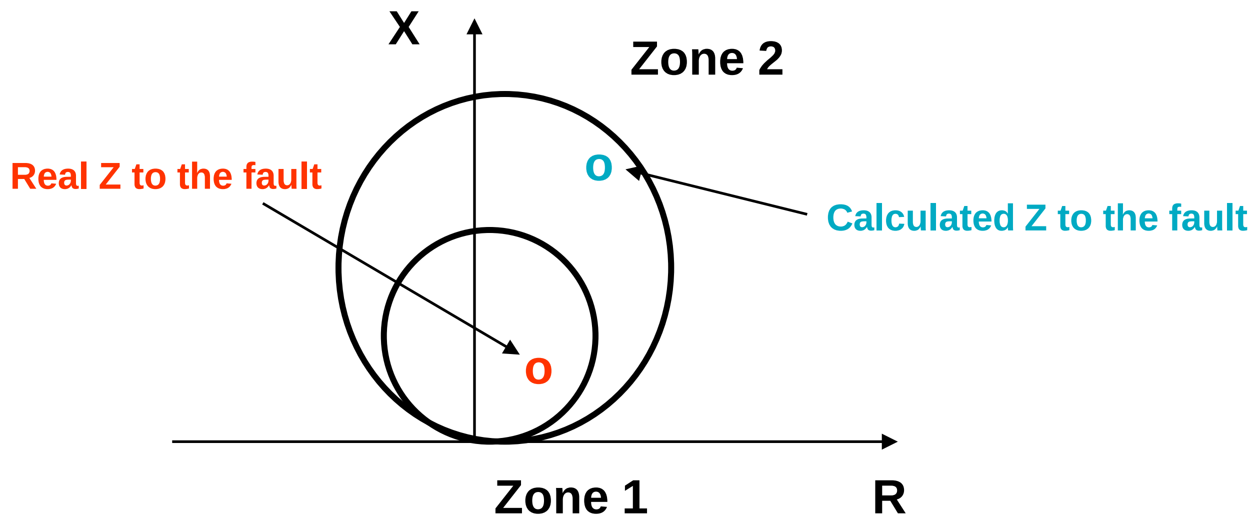


phase current envelope as recorded (green) processed (black, magenta).



Affection to the relays setting when using fundamental component extraction

Example distance relay characteristic:



- **Lower fundamental current will lead to higher Z**

- **Relays at stations, could not have an optimal operation in distinguish protective zones**

- **DFIG Wind power plants with dedicated line connection: overcurrent relaying line protection**

Conclusions:

- DFIG short circuit response quite different from Synchronous generators

- Low AC component exhibit during faults

- Affection to the relays setting when using fundamental component extraction

- No zero crossing for several cycles

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