Short Circuit Signatures from Wind Turbine Generator Types: I, II, III

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Information contained in the following shall not be construed as an expression of the policies or views of Vestas or as a detailed description of the properties or functioning of wind turbines manufactured by Vestas.

Agenda

- Introduction
- WTG types:
  - I → Single line diagram & control
  - II → Single line diagram & control
  - III → Single line diagram & control: Evolution for LVRT support
- Examples of short circuit waveforms
- Conclusions
- Questions

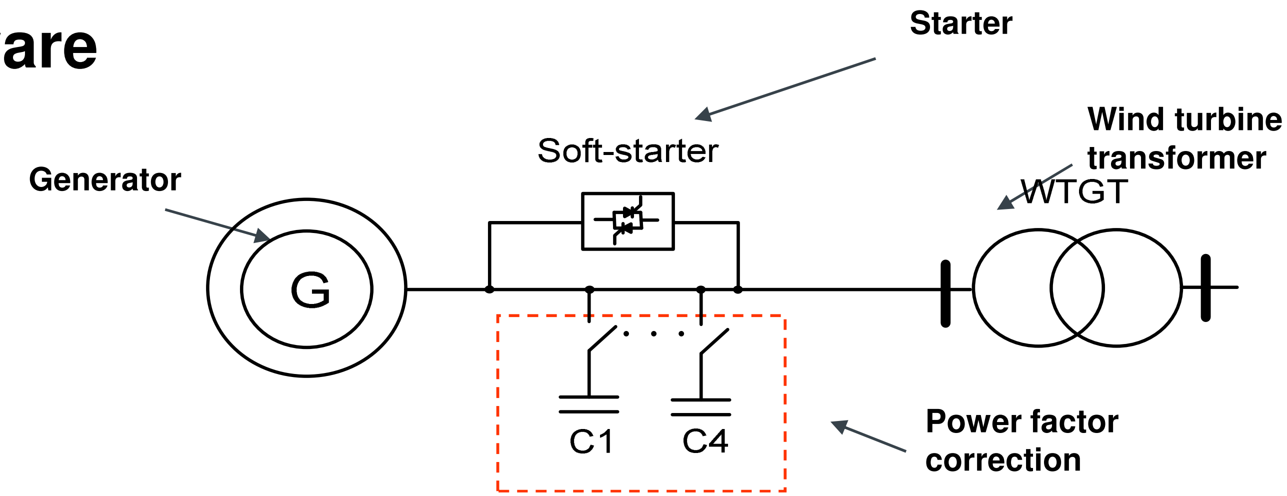
Type; I: Induction Generator   II: Induction Generator with Resistances   III: Double Fed Induction Generator

Introduction

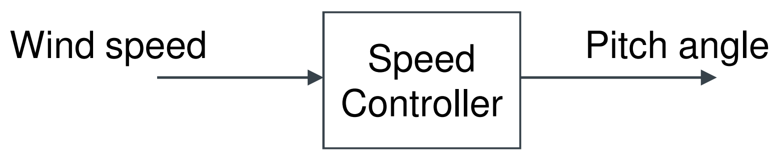
- High increase in the number of wind turbines installed:
  - Wind turbines topology differ from synchronous generators
    - Voltage control
    - Frequency control
    - **Short circuit contribution**
- For a reliable operation of the system the electrical grid should be adapted, at some degree, to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

Type I

Hardware

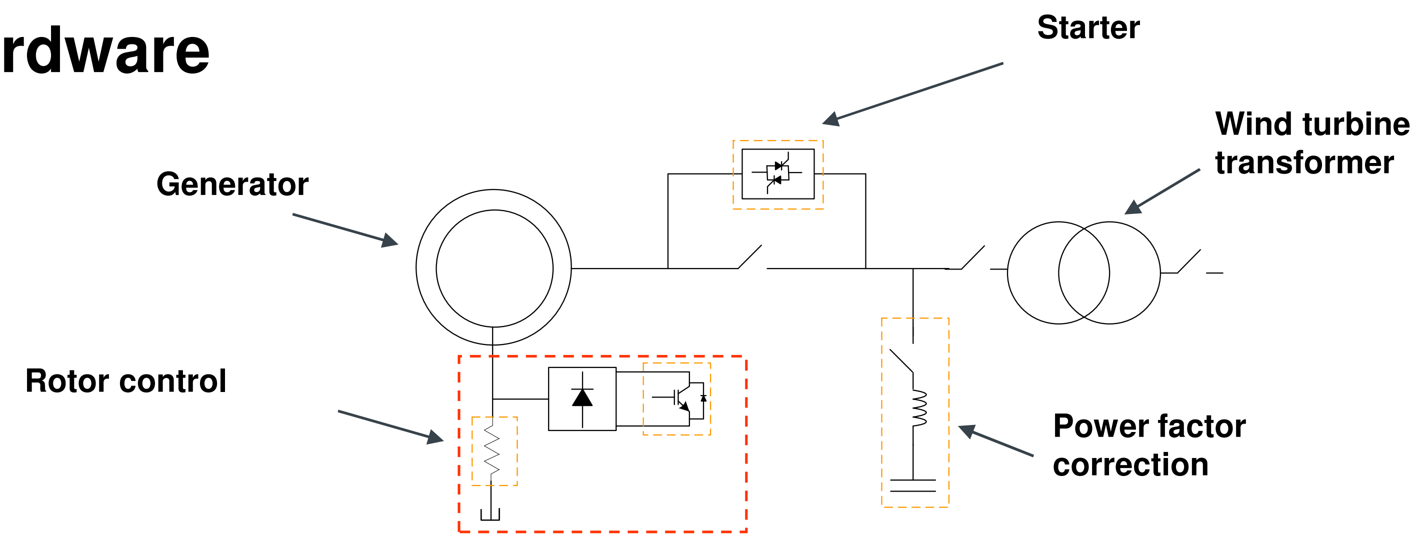


Control

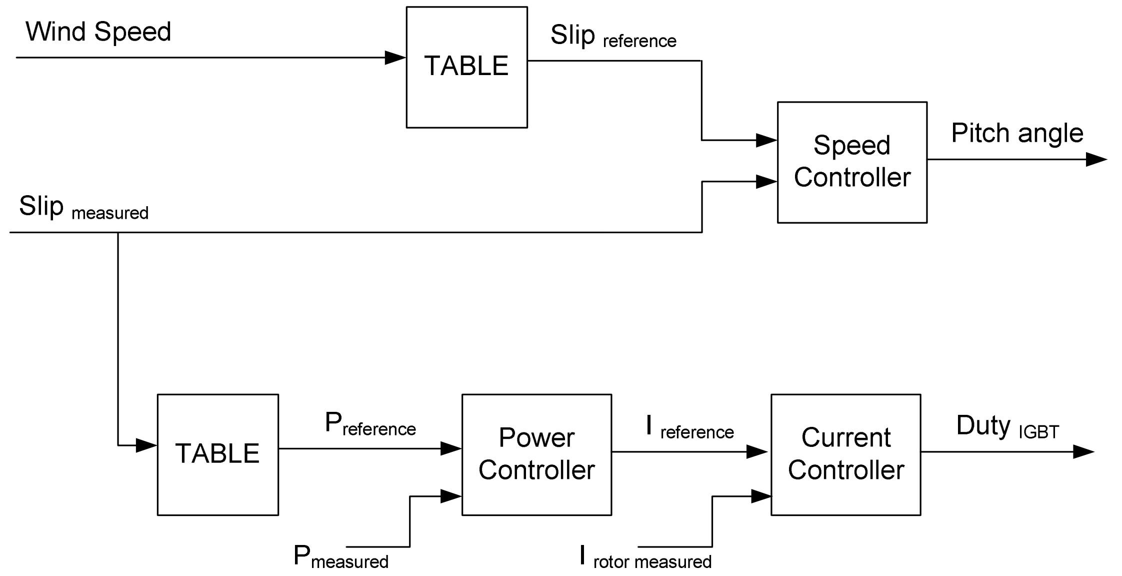


Type II

Hardware

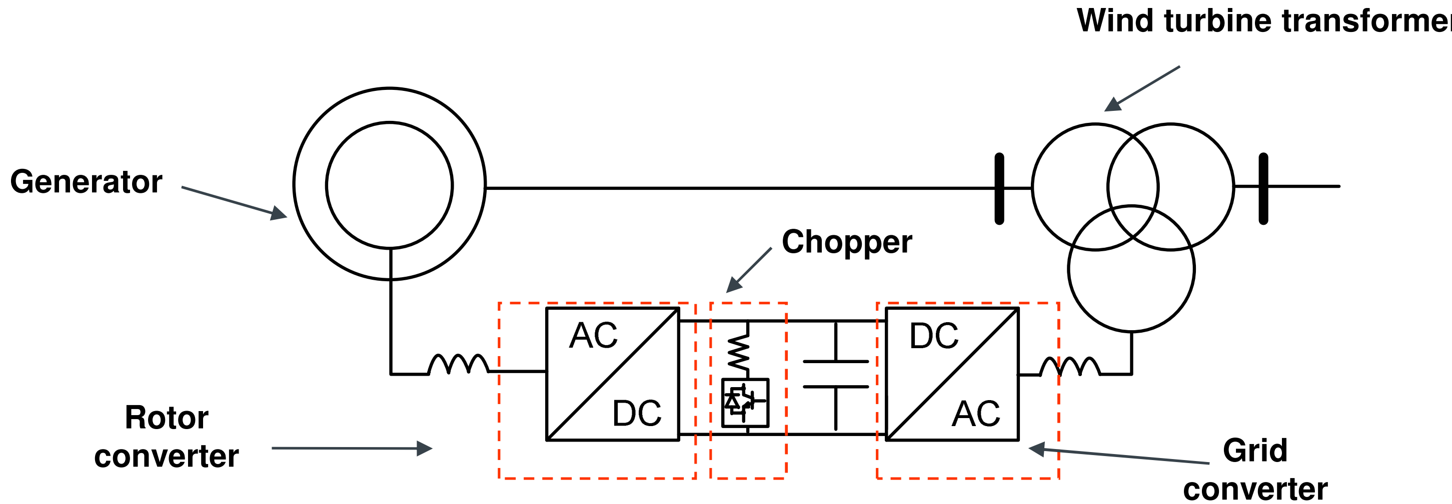


Control

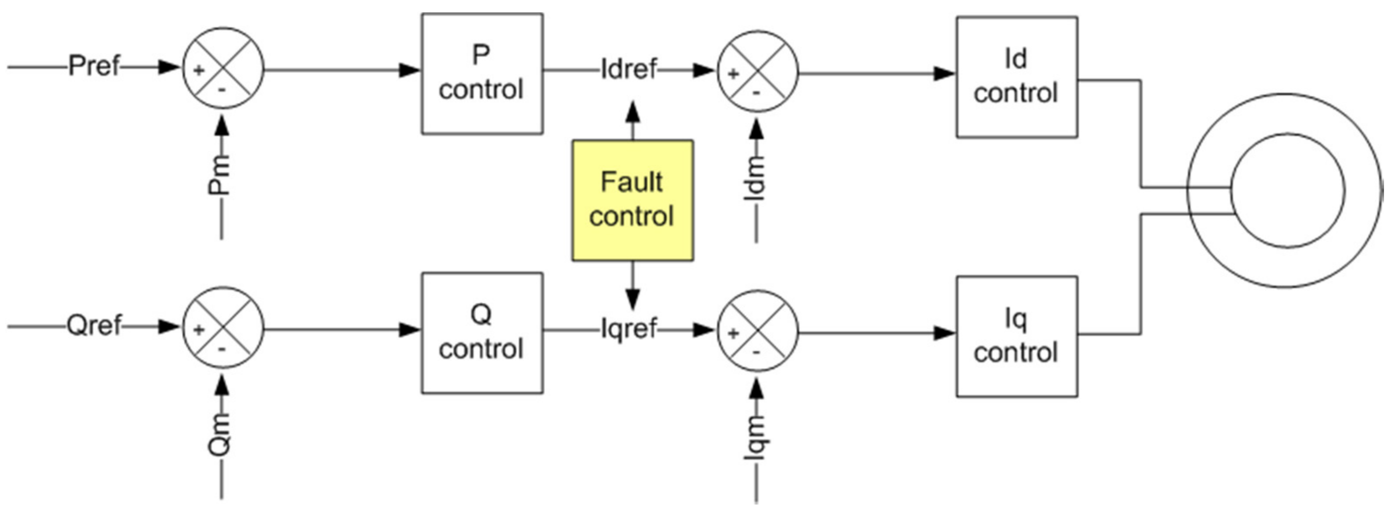


Type III

Hardware



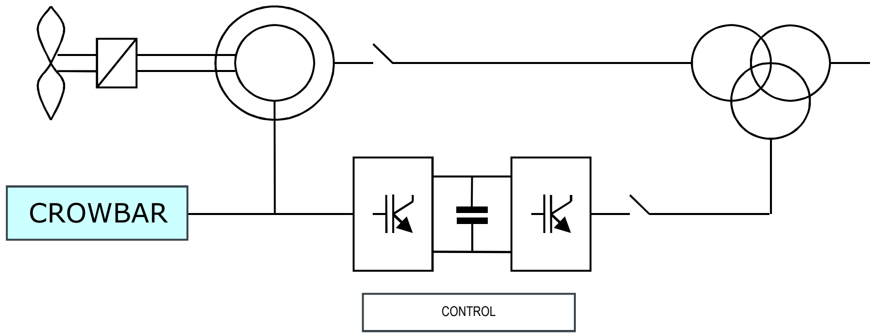
Control of rotor converter



Evolution of type III according to Grid codes: LVRT requirements

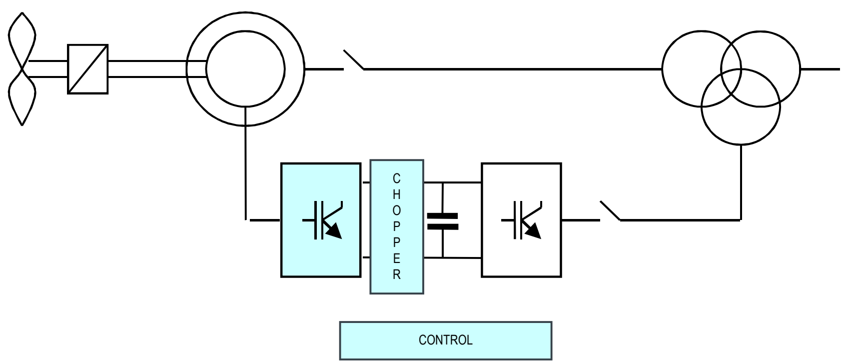
- IN THE PAST:

  INSTANTANEOUS DISCONNECTION OF THE DFIG TO PROTECT ELECTRONIC DEVICES



- NOWDAYS:

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

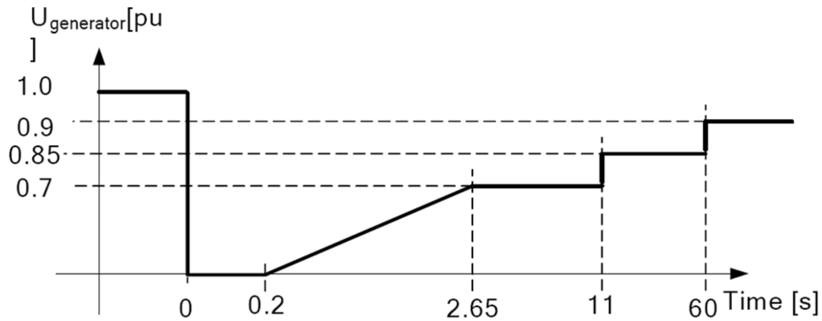


Wind. It means the world to us.™

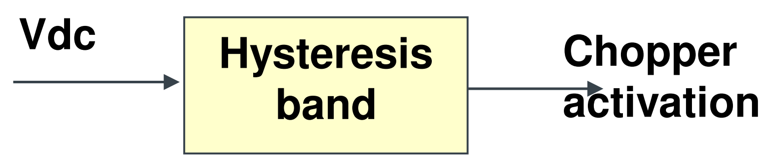
Type III: Control during faults

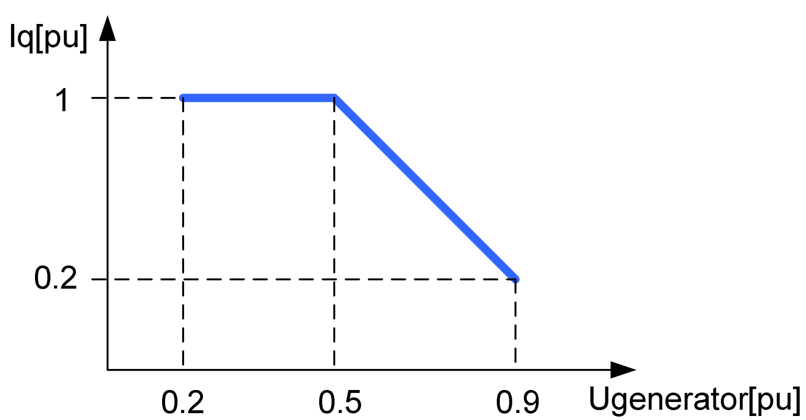
- Control during faults:

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

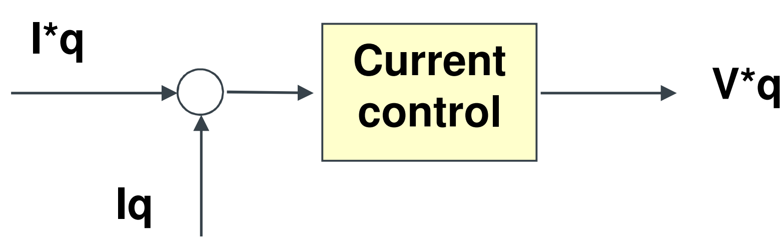


CHOPPER CONTROL:

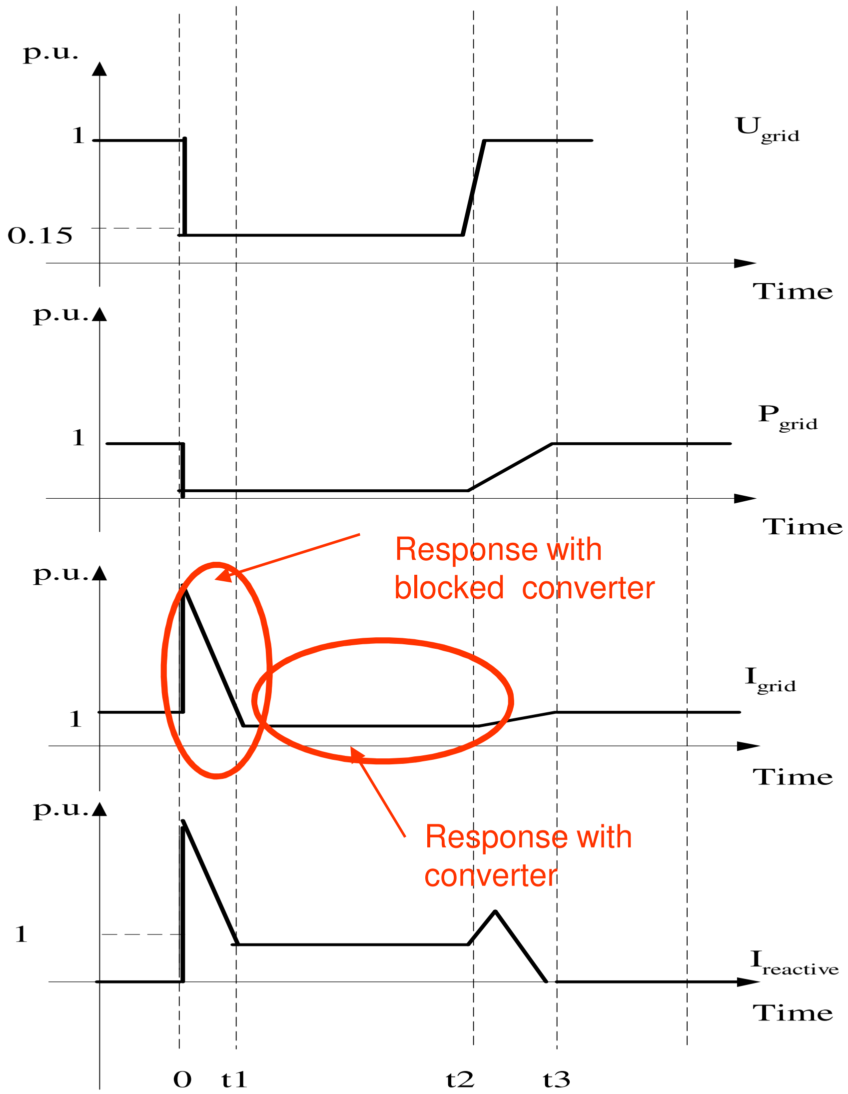




CURRENT CONTROL:



Generic Short Circuit Contribution of WTG Type III



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. 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.

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

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

Protection distance Algorithm 16 s/cycle full cycle cosine filter, Schweitzer Engineering Laboratories, Inc
(used in the next figures to extract fundamental components)

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:

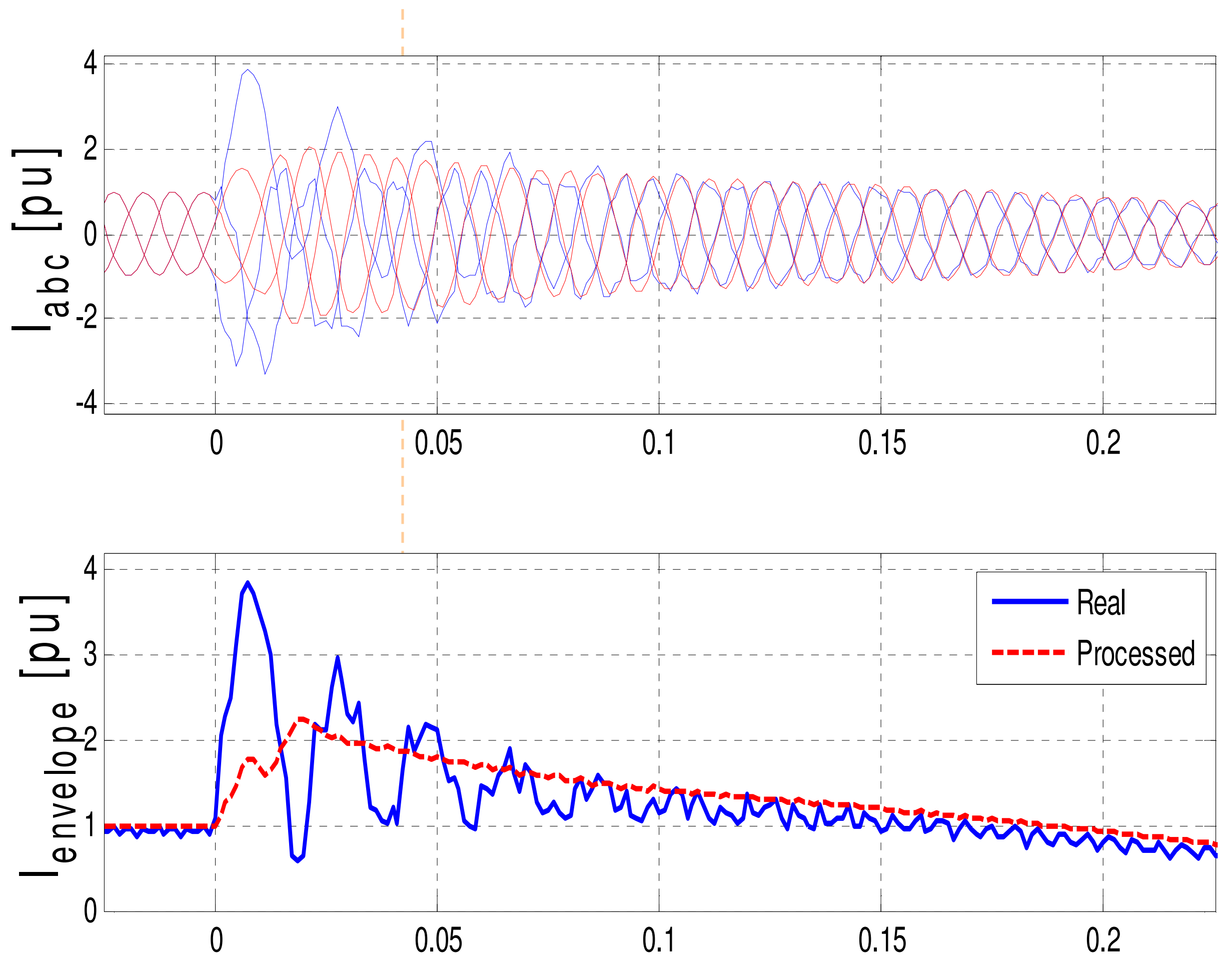
- N = 15
- n = 0, 1, 2, ….N
- smpl = sequence of samples 0, 1, 2, 3,……….
- spc = number of samples per cycle (16)
- $I_{smpl+spc-n}$ = Current samples
- $IX_{smpl+spc}$ = Filter output
- Io = filter derived current phasor

Type I short circuit waveforms

Remaining voltage = 25%. **SYMMETRYCAL FAULTS (200ms- 100% RATED POWER)**

Currents:

recorded (blue)
processed (red).



Current envelopes:

recorded (blue)
processed (red).

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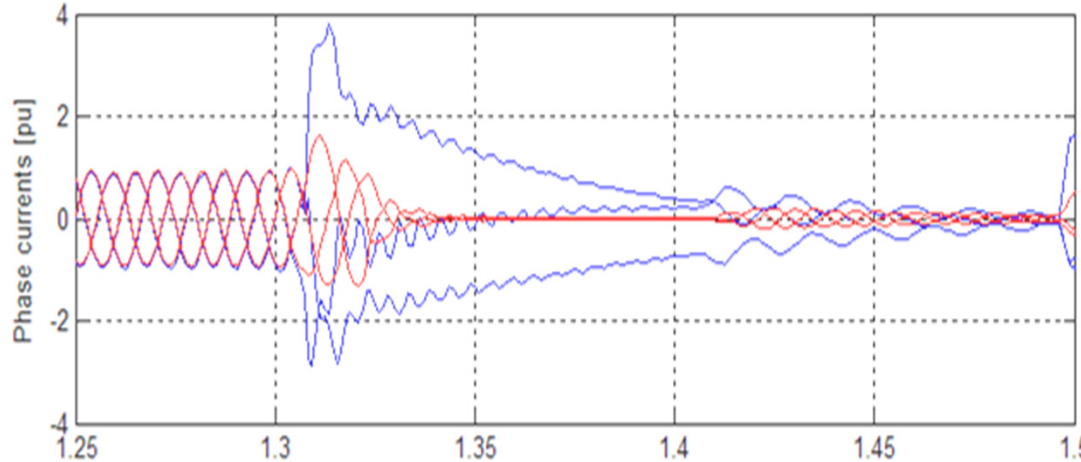
Type II short circuit waveforms

Remaining voltage = 0%, **SYMMETRYCAL FAULT (200ms- 100% RATED POWER)**

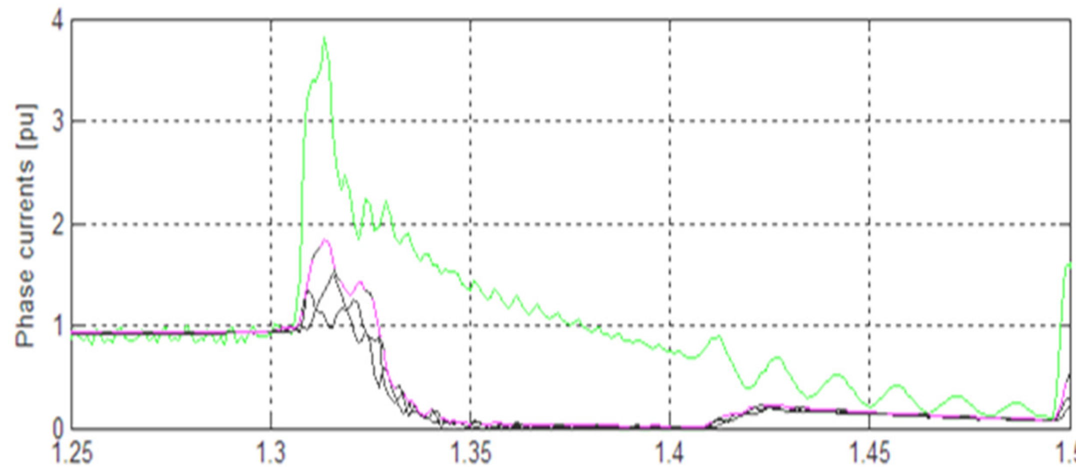
Currents:

recorded (blue)
processed (red).



Current envelopes:

recorded (green)
processed (black, magenta).



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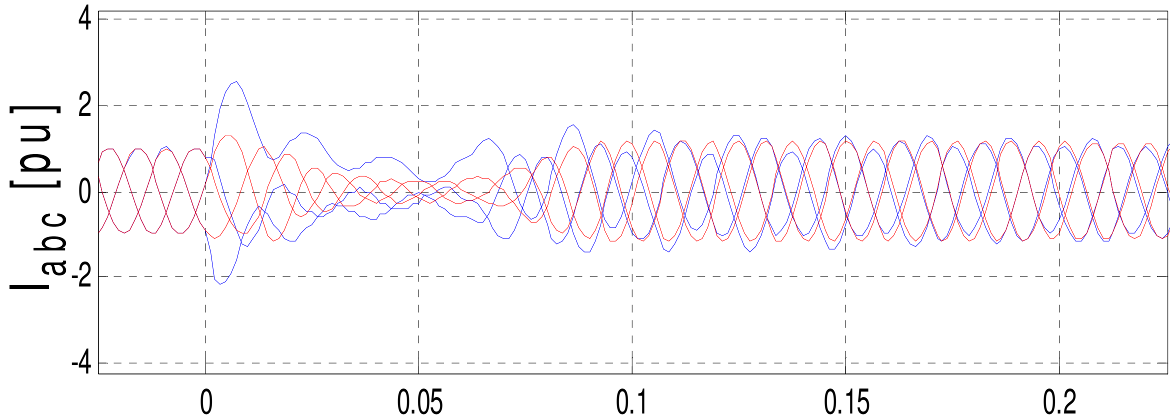
Type III short circuit waveforms

Remaining voltage = 25%. **SYMMETRYCAL FAULTS (200ms- 100% RATED POWER)**

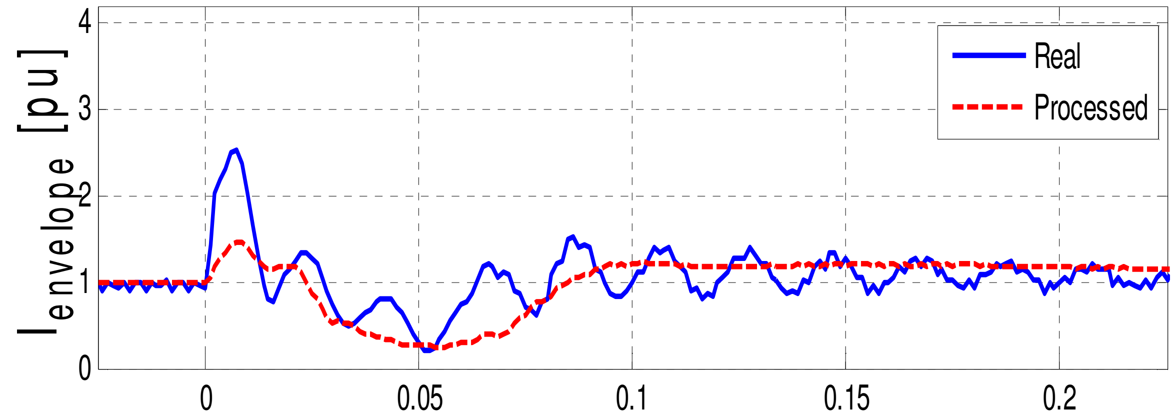
Currents:

recorded (blue)
processed (red).



Current envelopes:

recorded (blue)
processed (red).



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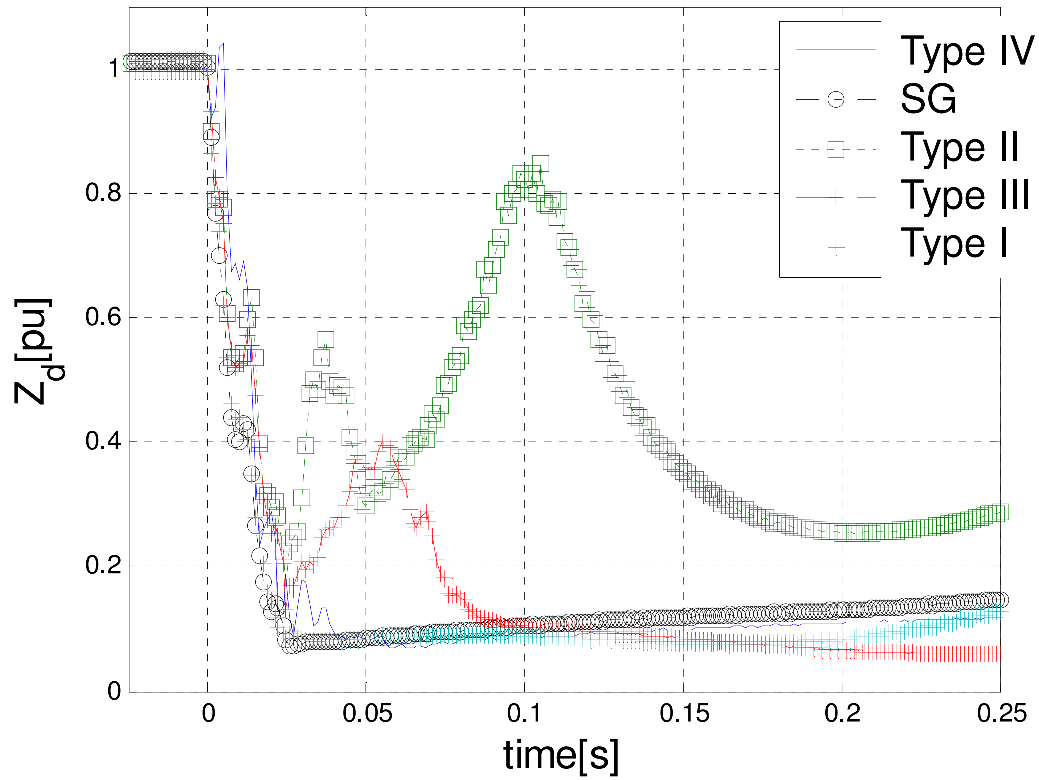
Impedance to the fault according to the generator type when using typical distance protections algorithms.

By using 16 s/cycle full cycle cosine filter and data of faults with remaining voltage 25%



	Type I	Type III	Type II	Type IV	SG
I_{peak} [pu]	*3.9*	*2.5*	*2.5*	*1.4*	*4.2*
I_{peak} relative to SG [pu]	*0.93*	*0.61*	*0.61*	*0.33*	*1.00*

SG: Synchronous Generator

[ref] IEEE Power & Energy Society. "*Short Circuit Signatures from Different Wind Turbine Generator Types*".

Conclusions:

- **Type II and Type III short circuit response quite different from Synchronous generators during severe faults :**

  Lower AC component
  Lower Peak value

  •Affection to the relays setting when using fundamental component extraction: Relays at stations, could not have an optimal operation in distinguish protective zones

•Type I "close*" short circuit response to traditional SGs

(*) no excitation system

Thank you for your attention