

**Advanced Fault Ride-Through Control of DFIG based Wind Turbines
including Grid Connection via VSC-HVDC**

**Der Fakultät für Ingenieurwissenschaften der
Abteilung Elektrotechnik und Informationstechnik
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von

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Christian Feltes

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Hamburg, in February 2012

Christian Feltes

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Nomenclature

Notation

$y(t)$	Time dependent quantity
\underline{y}	Complex quantity
\underline{y}^*	Complex conjugated quantity
\underline{y}^z	Space vector
\mathbf{y}	Vector
\mathbf{Y}	Matrix
\bar{y}	DC component
\tilde{y}	Oscillatory component
\hat{y}	Magnitude of oscillatory component
$f(t)$	Function in time domain
$F(s)$	Function in Laplace domain
$L\{f(t)\}$	Laplace transformation of function $f(t)$
$G(s)$	Transfer function
$\mathbf{g}(s)$	Vector of transfer functions

Symbols

P	Active power in [W]
ρ	Air density in [kg/m^3]
A	Area in [m^2]
c_p	Power coefficient in [p.u.]
λ	Tip speed ratio in [p.u.]
β	Pitch angle in [$^\circ$]
v	Speed in [m/s]
Ω	Angular frequency in [rad/s]
R	Rotor in [m]
c	Coefficient
ω	Angular frequency in [p.u.]
t	Time in [p.u.]

t'	Time in [s]
t	Torque in [p.u.]
H	Inertia time constant in [p.u.]
J	Inertia constant in [kg · m ²]
p	Number of pole pairs
k_{sh}	Shaft stiffness constant in [p.u./rad]
d_{sh}	Shaft damping constant in [p.u.]
θ	Mechanical angle in [p.u.]
v	Instantaneous voltage in [p.u.]
i	Instantaneous current in [p.u.]
ψ	Instantaneous flux in [p.u.]
r	Resistance in [p.u.]
l	Inductance in [p.u.]
σ	Leakage coefficient in [p.u.]
x	Reactance in [p.u.]
z	Impedance in [p.u.]
s_G	Generator slip
s	Complex frequency in [p.u.]
δ	Damping coefficient in [p.u.]
τ	Time constant in [p.u.]
k	Gain factor in [p.u.]
k_1	Tuning factor of SCDF and MFDF in [p.u.]
\mathbf{K}_{MFDF}	MFDF filter matrix [p.u.]
φ	Phase angle in [rad]
\underline{k}_V	Complex coupling factor considering stator voltage in [p.u.]
\underline{x}'	Complex transient reactance in [p.u.]
\underline{s}	Complex power in [p.u.]

Subscripts

W	Wind rotor quantity
wind	Wind quantity

R	Rotor quantity of generator
comb	Combined quantity
0	Synchronous quantity, initial value
r	Rated quantity
S	Stator quantity of generator
M	Main quantity of generator
σ	Leakage quantity
a,b,c	Phase quantities
1,2,0	Symmetrical components
d,q	Components of space vector in rotating reference frame
α,β	Components of space vector in stationary reference frame
W	Reference tracking function
Z	Disturbance response function
G	Grid quantity
y	General placeholder for voltage, current or flux
f	Filter quantity
meas	Measured quantity
d	Dead time
i	Running index
sum	Sum
PT1	PT1-filter quantity
F	Filtered quantity
FC	Filtered and error-compensated quantity
p	Proportional
I	Integral
ref	Reference value
FF	Feedforward term
V	Voltage term
I	Current term
max	Maximum value used for controller limitations
fund	Fundamental frequency component
prio	Component with assigned priority
Σ	Sum
initial	Initial value

stat	Stationary component
p	Peak value
CH	Chopper quantity
CB	Crowbar quantity
P	Active component
Q	Reactive component

Superscripts

\angle	Arbitrary Coordinate system
$\angle 0$	Stationary reference frame
$\angle v_{G1}$	Reference frame aligned to positive sequence grid voltage
$\angle v_{S1}$	Reference frame aligned to positive sequence stator voltage
$\angle \omega_s$	Coordinate system rotating with stator frequency
$\angle -\omega_s$	Coordinate system rotating with negative stator frequency
*	Conjugated complex quantity

Abbreviations

AC	Alternating current
DC	Direct current
WT	Wind turbine
WF	Wind farm
HV	High voltage
MV	Medium voltage
LV	Low voltage
DFIG	Doubly-fed induction generator
FSCG	Full size converter generator
FSIG	Fixed speed induction generator
PMSG	Permanent magnet synchronous generator
SRIG	Slip ring induction generator
EESG	Electrically excited synchronous generator
VSC	Voltage source converter
HVDC	High voltage direct current
EMT	Electro-magnetic transient

RMS	Root mean square
FOM	Full order model
ROM	Reduced order model
LSC	Line-side converter
MSC	Machine-side converter
BSF	Band stop filter
DT	Dead time function
PT1	First order delay
SCDF	Symmetrical component decomposition filter
MFDF	Multi-frequency decomposition filter
FRT	Fault ride-through
LVRT	Low voltage ride through
HVRT	High voltage ride through
MPPT	Maximum power point tracking
PCC	Point of common coupling
FACTS	Flexible AC transmission system
STATCOM	Static synchronous compensator
IGBT	Insulated gate bipolar transistor
GTO	Gate turn-off thyristor
NPC	Neutral point clamped
FC	Flying capacitor
PWM	Pulse width modulation
DSP	Digital signal processor
PLL	Phase locked loop
SEC	Sending end converter
REC	Receiving end converter