HYDRO AND EOLIC PLANTS

ESF II project of the University of West Bohemia in Pilsen, reg. number: CZ.02.2.69/0.0/0.0/18_056/0013239



EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
Development and Education



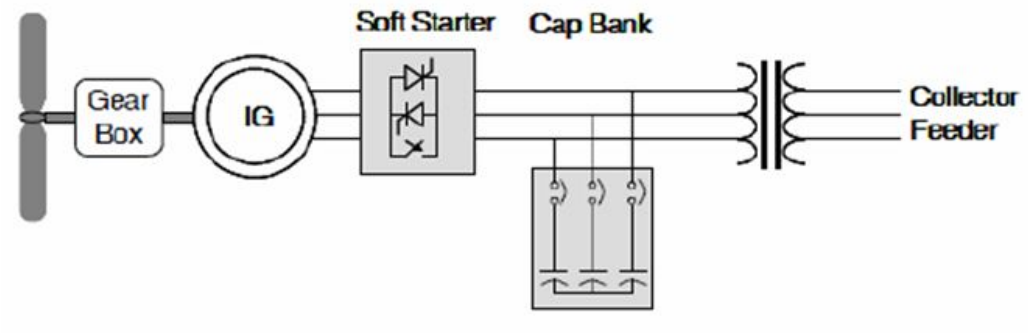
Generators for eolic plants

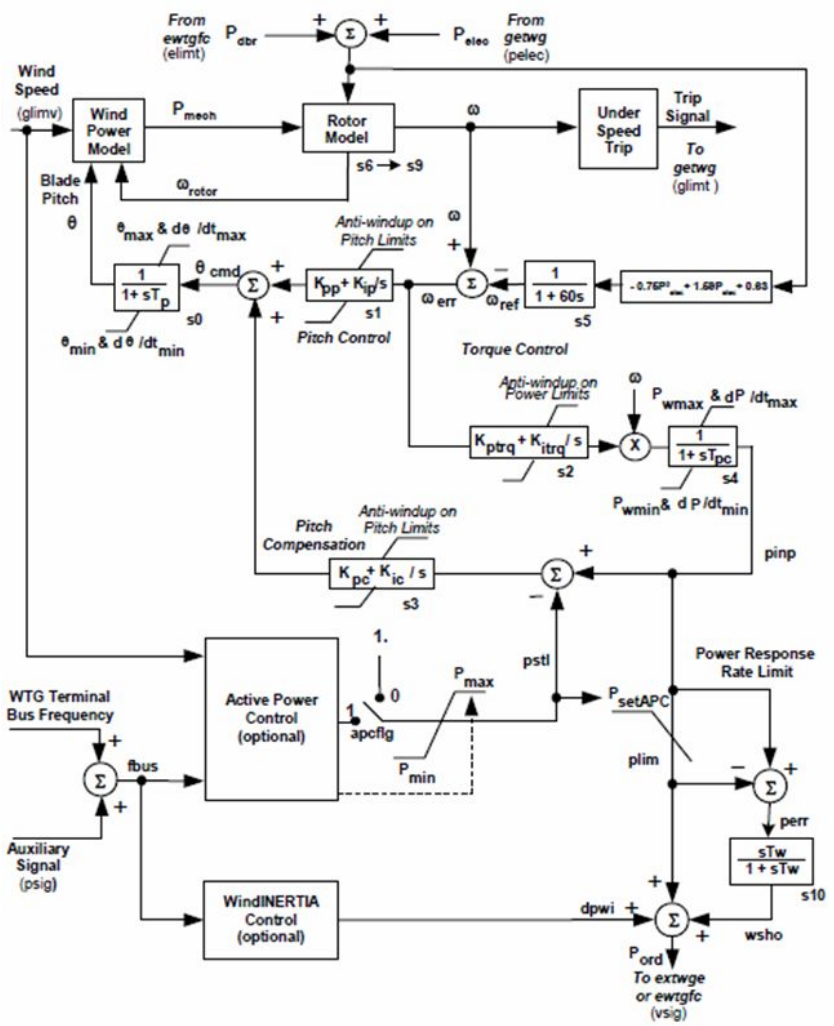
Milan Bělík

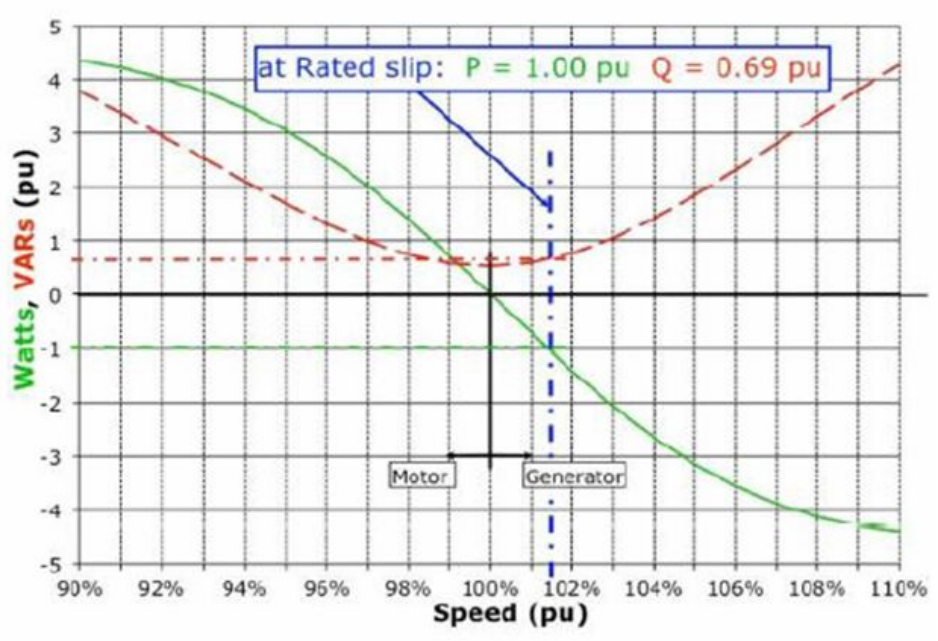
Eolic power plants - generators

- typ 1: squirrel cage generator with gearbox
- typ 2: asynchronous generator with gearbox
- typ 3: asynchronous generator DFIG (DFAG)
- typ 4: synchronous or asynchronous generator with full converter
- typ 5: typ 2 with momentus variator

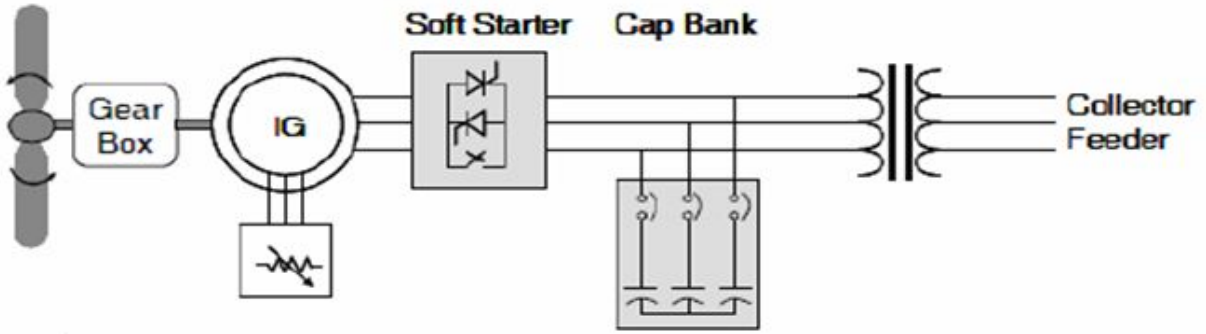
Wind power plant typ 1

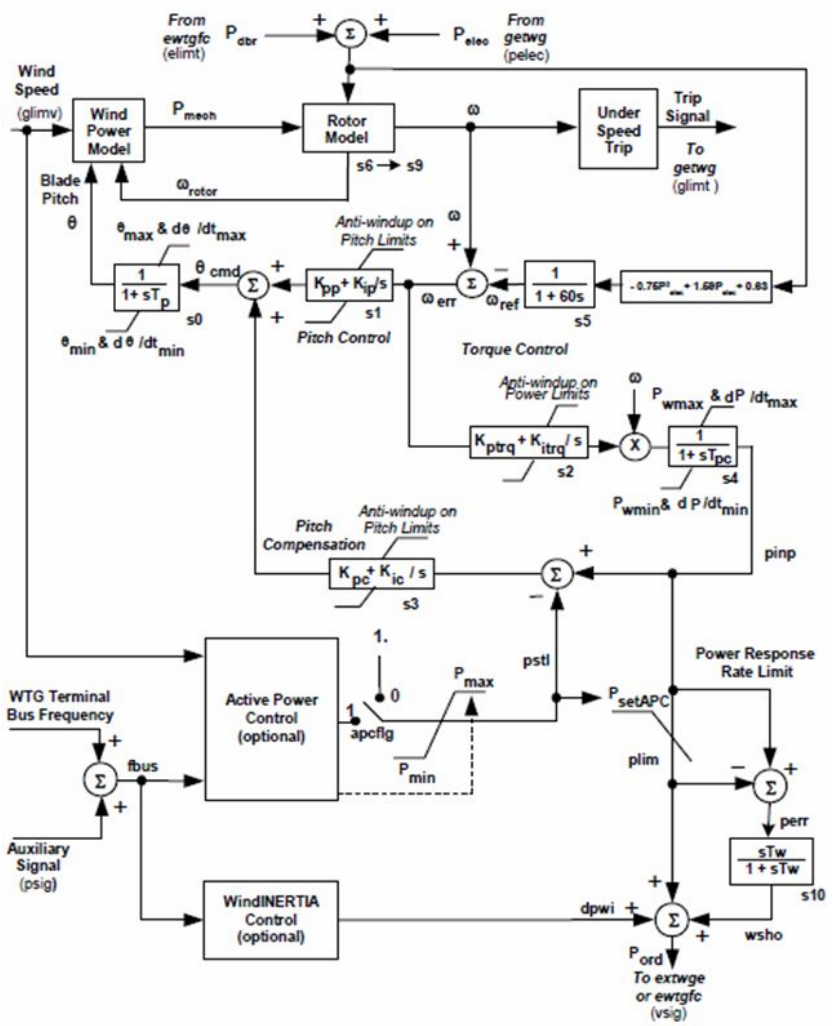


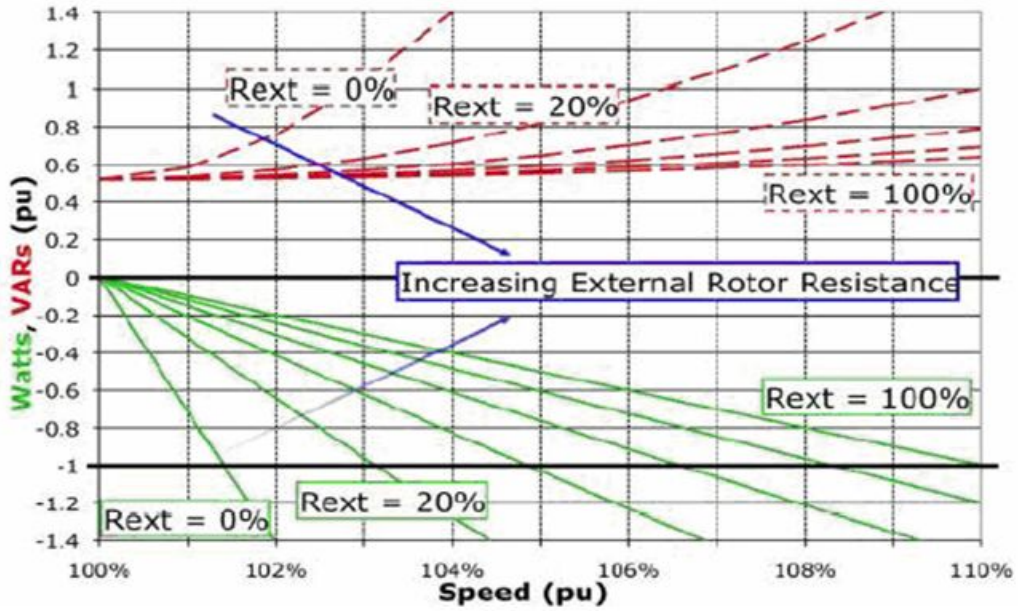

From ewtgfc (elimt)
P dbr
P eleo
From getwg (pelec)
Wind Speed (glimv)
Wind Power Model
P meoh
Rotor Model
ω
Under Speed Trip
Trip Signal
To getwg (glimt)
s6 → s9
ω rotor
Blade Pitch θ
θ max & dθ /dt max
Anti-windup on Pitch Limits
θ cmd
K pp + K ip/s
s1
Pitch Control
ω err
ω ref
1 / (1 + 60s)
s5
- 0.76P² em + 1.68P em + 0.83
1 / (1+ sT p)
s0
θ min & dθ /dt min
Torque Control
Anti-windup on Power Limits
K ptrq + K itrq / s
s2
P wmax & dP /dt max
1 / (1+ sT pc)
s4
P wmin & dP /dt min
Pitch Compensation
Anti-windup on Pitch Limits
K pc + K ic / s
s3
pinp
1.
0
P max
P min
pstl
Power Response Rate Limit
P setAPC
plim
perr
sTw / (1 + sTw)
s10
WTG Terminal Bus Frequency
Active Power Control (optional)
apcflg
fbus
Auxiliary Signal (psig)
WindINERTIA Control (optional)
dpwi
wsho
P ord
To extwge or ewtgfc (vsig)


at Rated slip: P = 1.00 pu Q = 0.69 pu
Watts, VARs (pu)
5
4
3
2
1
0
-1
-2
-3
-4
-5
Motor
Generator
90%
92%
94%
96%
98%
100%
102%
104%
106%
108%
110%
Speed (pu)

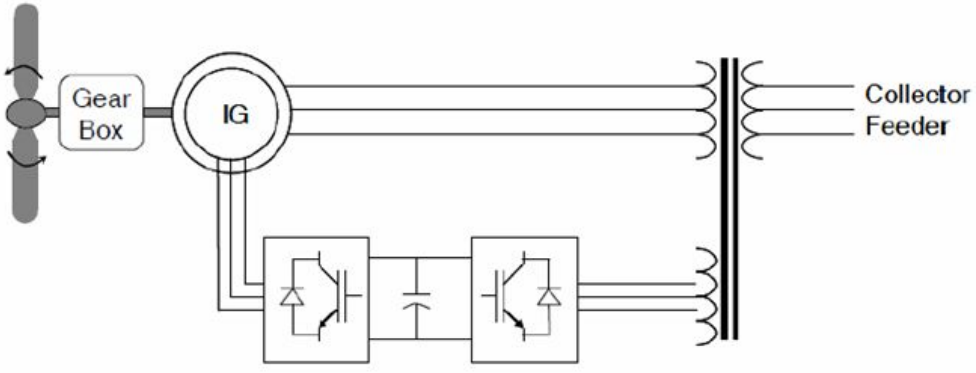
Wind power plant typ 2

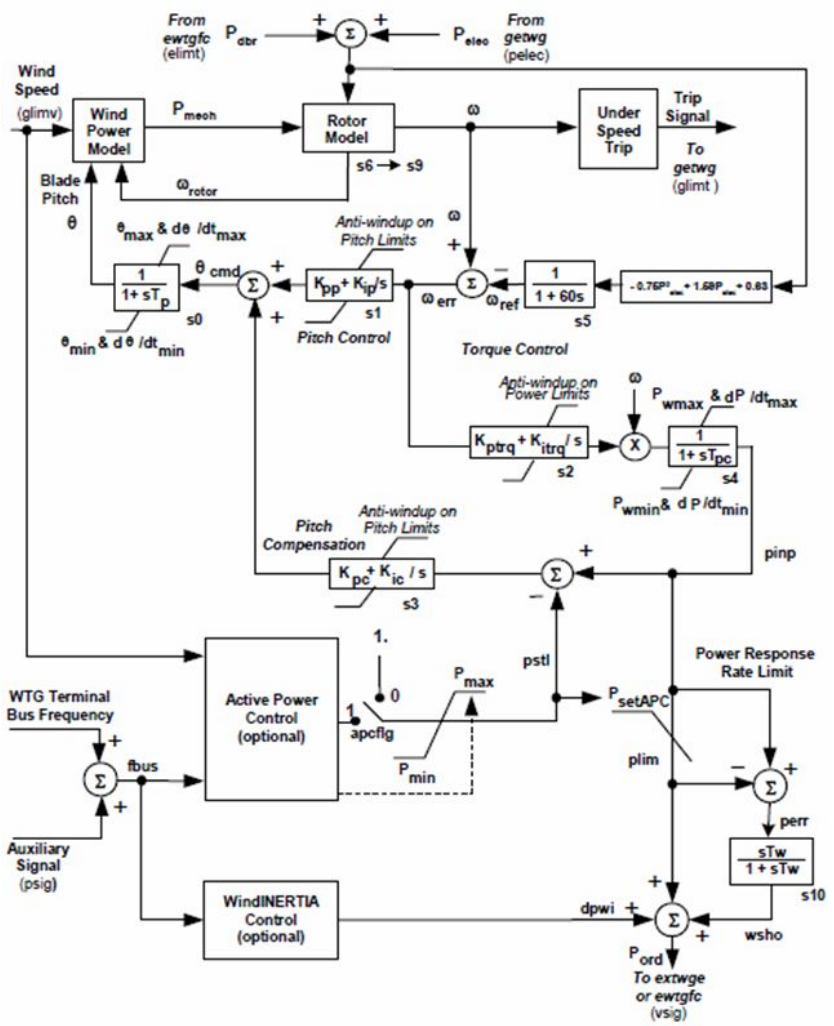


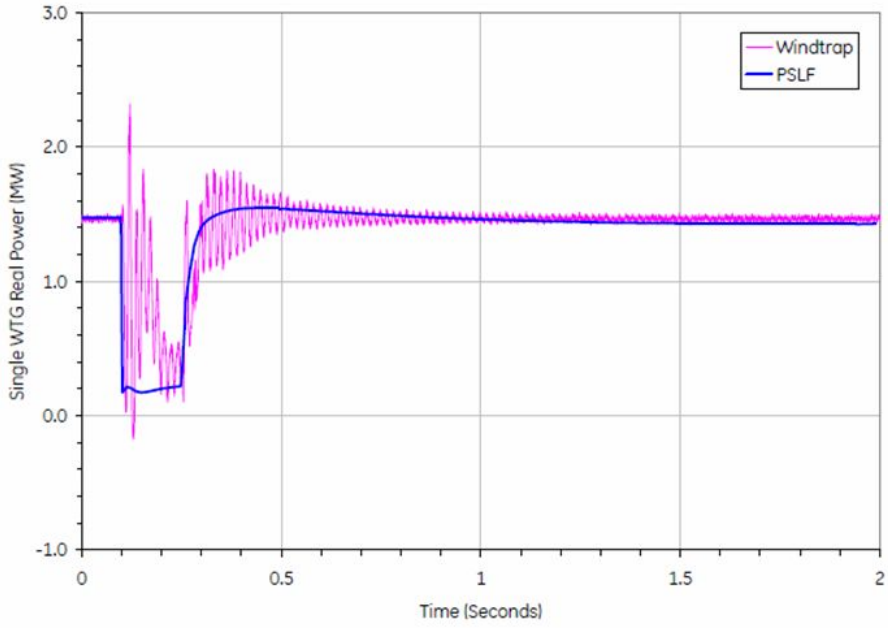

From ewtgfc (elimt)
P dbr
P eleo
From getwg (pelec)
Wind Speed (glimv)
Wind Power Model
P meoh
Rotor Model
ω
Under Speed Trip
Trip Signal
To getwg (glimt)
s6 → s9
ω rotor
Blade Pitch θ
θ max & dθ /dt max
Anti-windup on Pitch Limits
θ cmd
K pp + K ip/s
s1
Pitch Control
ω err
ω ref
1 / (1 + 60s)
s5
- 0.76P² em + 1.68P em + 0.83
1 / (1+ sT p)
s0
θ min & dθ /dt min
Torque Control
Anti-windup on Power Limits
K ptrq + K itrq / s
s2
P wmax & dP /dt max
1 / (1+ sT pc)
s4
P wmin & dP /dt min
Pitch Compensation
Anti-windup on Pitch Limits
K pc + K ic / s
s3
pinp
1.
0
P max
P min
pstl
Power Response Rate Limit
P setAPC
plim
perr
sTw / (1 + sTw)
s10
WTG Terminal Bus Frequency
Active Power Control (optional)
apcflg
fbus
Auxiliary Signal (psig)
WindINERTIA Control (optional)
dpwi
wsho
P ord
To extwge or ewtgfc (vsig)

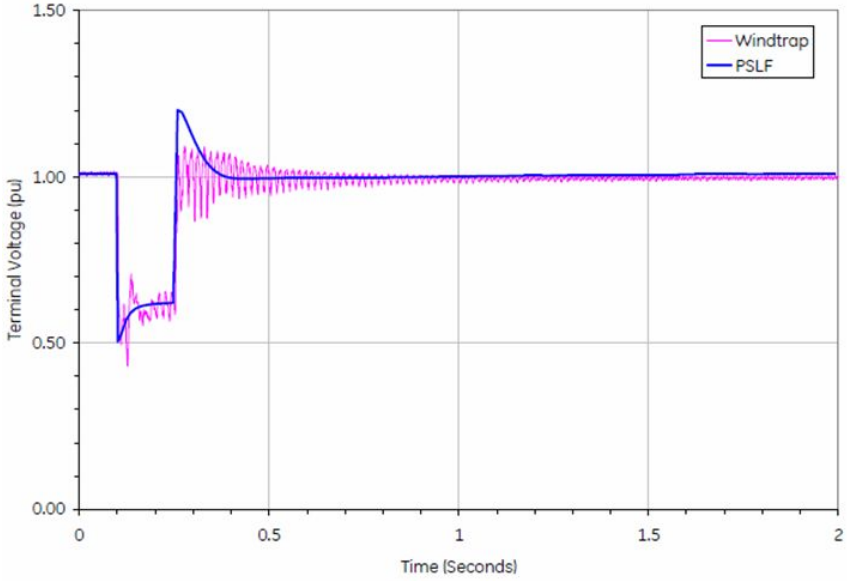

Rext = 0%
Rext = 20%
Rext = 100%
Increasing External Rotor Resistance
Rext = 100%
Rext = 20%
Rext = 0%
Watts, VARs (pu)
Speed (pu)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
100%
102%
104%
106%
108%
110%

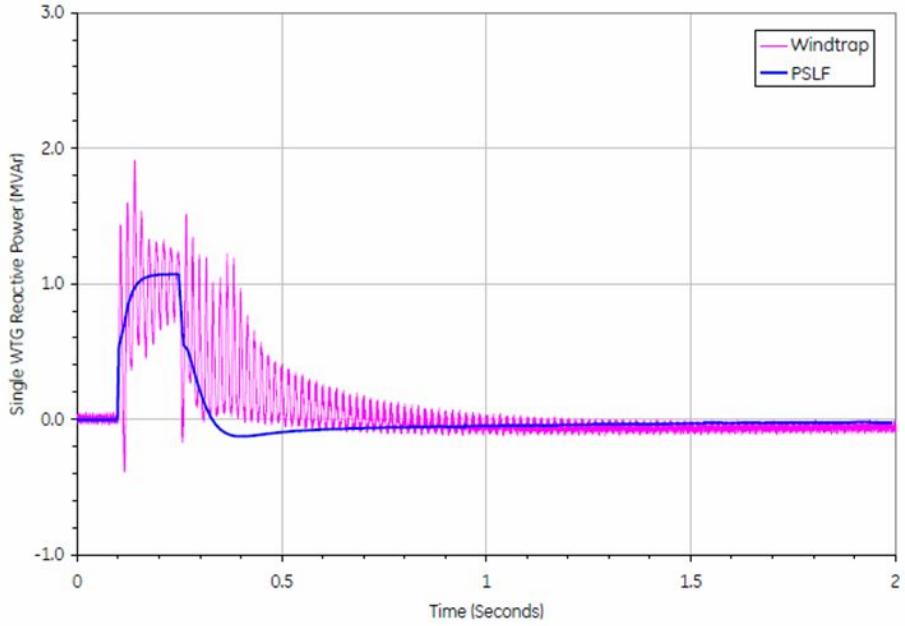
Wind power plant typ 3



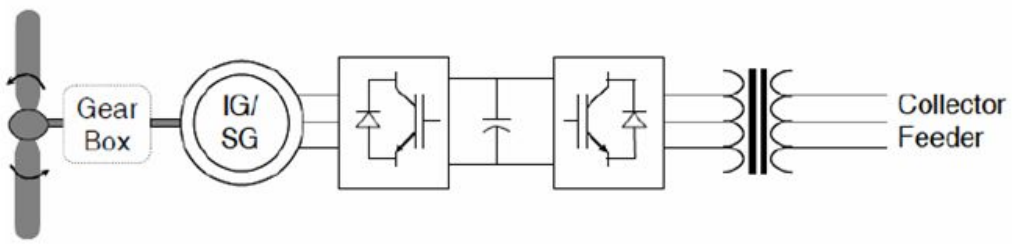

From ewtgfc (elimt)
P dbr
P eleo
From getwg (pelec)
Wind Speed (glimv)
Wind Power Model
P meoh
Rotor Model
ω
Under Speed Trip
Trip Signal
To getwg (glimt)
s6 → s9
ω rotor
Blade Pitch θ
θ max & dθ /dt max
Anti-windup on Pitch Limits
θ cmd
K pp + K ip/s
s1
Pitch Control
ω err
ω ref
1 / (1 + 60s)
s5
- 0.76P² em + 1.68P em + 0.83
1 / (1+ sT p)
s0
θ min & dθ /dt min
Torque Control
Anti-windup on Power Limits
K ptrq + K itrq / s
s2
P wmax & dP /dt max
1 / (1+ sT pc)
s4
P wmin & dP /dt min
Pitch Compensation
Anti-windup on Pitch Limits
K pc + K ic / s
s3
pinp
1.
0
P max
P min
pstl
Power Response Rate Limit
P setAPC
plim
perr
sTw / (1 + sTw)
s10
WTG Terminal Bus Frequency
Active Power Control (optional)
apcflg
fbus
Auxiliary Signal (psig)
WindINERTIA Control (optional)
dpwi
wsho
P ord
To extwge or ewtgfc (vsig)

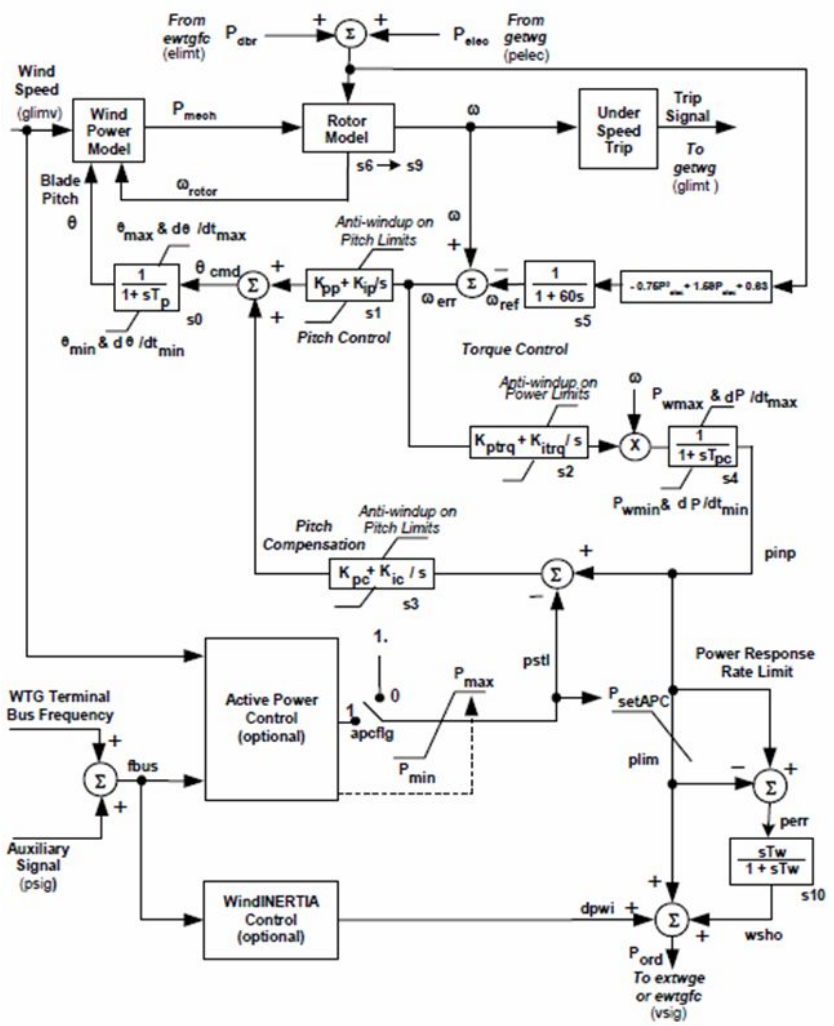

Windtrap
PSLF
Single WTG Real Power (MW)
3.0
2.0
1.0
0.0
-1.0
0
0.5
1
1.5
2
Time (Seconds)

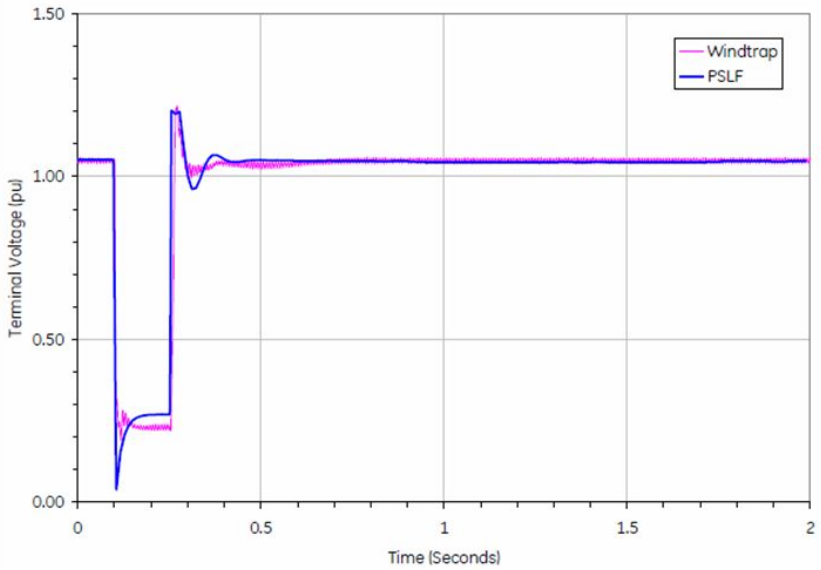

1.50
1.00
0.50
0.00
Terminal Voltage (pu)
0
0.5
1
1.5
2
Time (Seconds)
Windtrap
PSLF

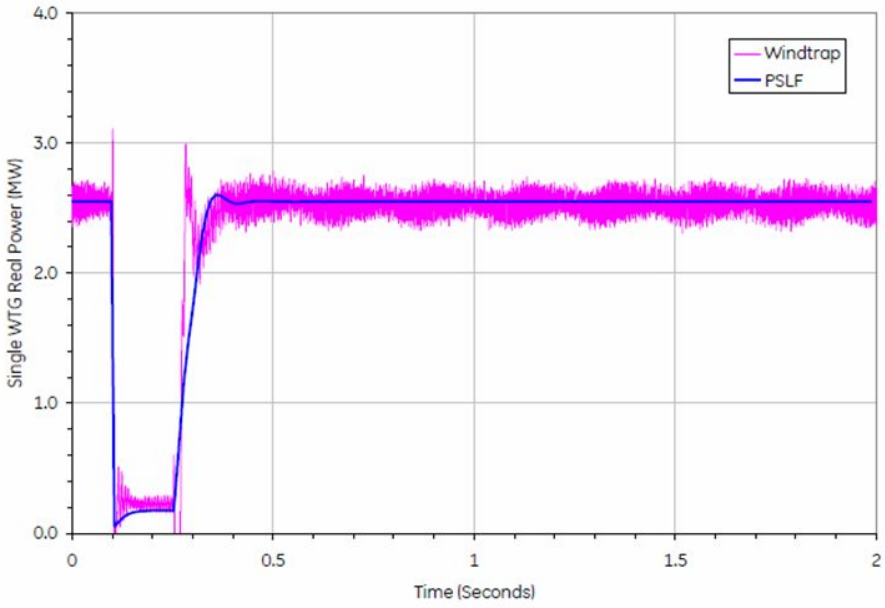

Windtrap
PSLF
Single WTG Reactive Power (MVAr)
3.0
2.0
1.0
0.0
-1.0
0
0.5
1
1.5
2
Time (Seconds)

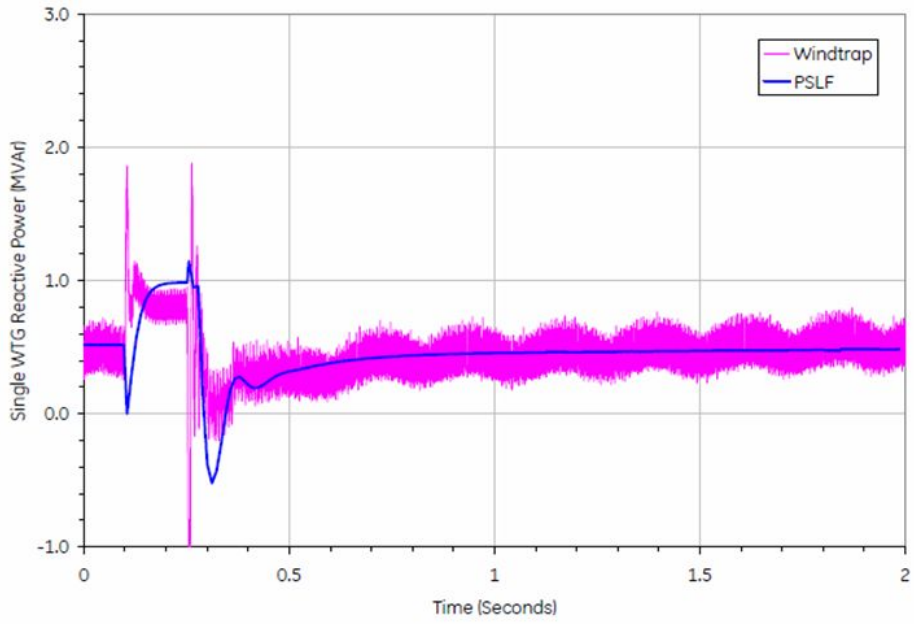
Wind power plant typ 4

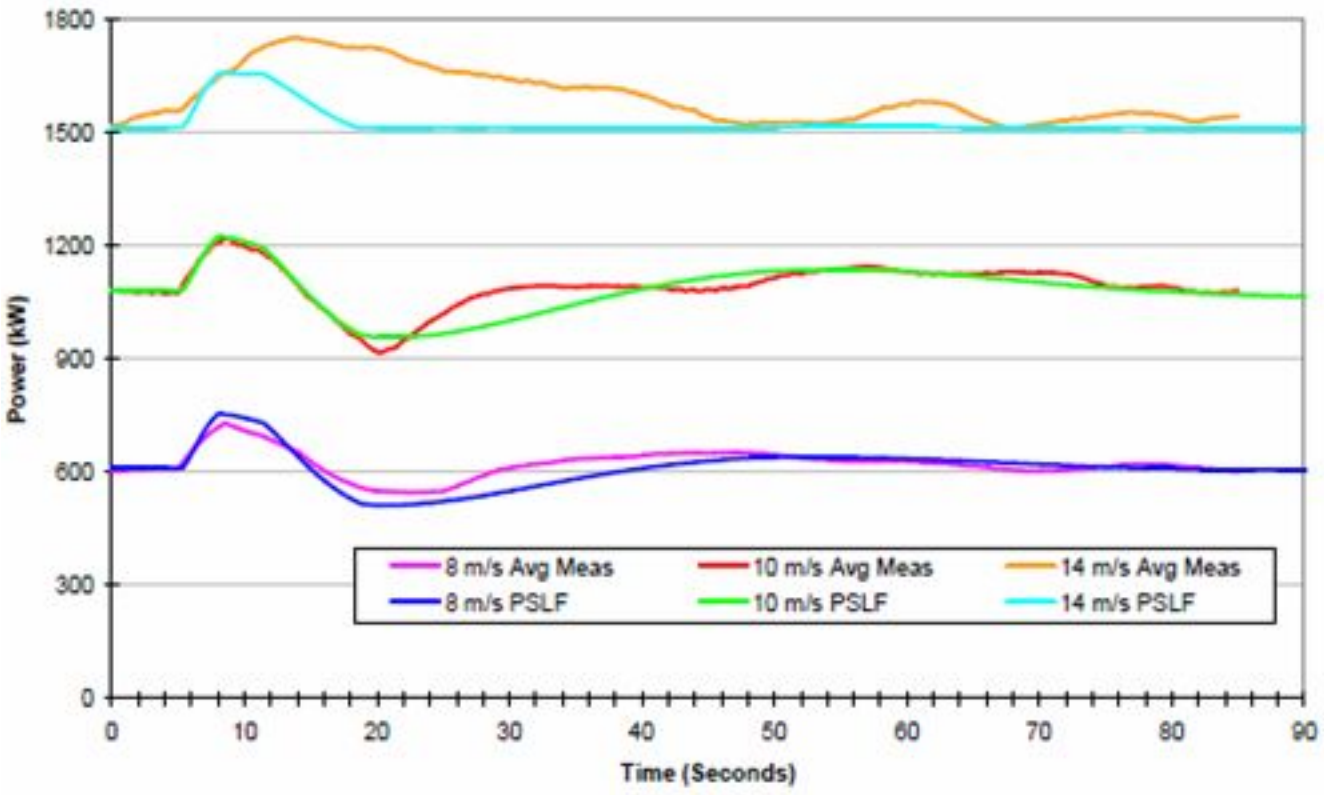



From ewtgfc (elimt)
P dbr
P eleo
From getwg (pelec)
Wind Speed (glimv)
Wind Power Model
P meoh
Rotor Model
ω
Under Speed Trip
Trip Signal
To getwg (glimt)
s6 → s9
ω rotor
Blade Pitch θ
θ max & dθ /dt max
Anti-windup on Pitch Limits
θ cmd
K pp + K ip/s
s1
Pitch Control
ω err
ω ref
1 / (1 + 60s)
s5
- 0.76P² em + 1.68P em + 0.83
1 / (1+ sT p)
s0
θ min & dθ /dt min
Torque Control
Anti-windup on Power Limits
K ptrq + K itrq / s
s2
P wmax & dP /dt max
1 / (1+ sT pc)
s4
P wmin & dP /dt min
Pitch Compensation
Anti-windup on Pitch Limits
K pc + K ic / s
s3
pinp
1.
0
P max
P min
pstl
Power Response Rate Limit
P setAPC
plim
perr
sTw / (1 + sTw)
s10
WTG Terminal Bus Frequency
Active Power Control (optional)
apcflg
fbus
Auxiliary Signal (psig)
WindINERTIA Control (optional)
dpwi
wsho
P ord
To extwge or ewtgfc (vsig)


1.50
1.00
0.50
0.00
Terminal Voltage (pu)
0
0.5
1
1.5
2
Time (Seconds)
Windtrap
PSLF


Windtrap
PSLF
Single WTG Real Power (MW)
4.0
3.0
2.0
1.0
0.0
0
0.5
1
1.5
2
Time (Seconds)


3.0
2.0
1.0
0.0
-1.0
0
0.5
1
1.5
2
Single WTG Reactive Power (MVAr)
Time (Seconds)
Windtrap
PSLF


1800
1500
1200
900
600
300
0
Power (kW)
0
10
20
30
40
50
60
70
80
90
Time (Seconds)
8 m/s Avg Meas
10 m/s Avg Meas
14 m/s Avg Meas
8 m/s PSLF
10 m/s PSLF
14 m/s PSLF