

A new Simpow model DFIG – Doubly-fed Induction Generator

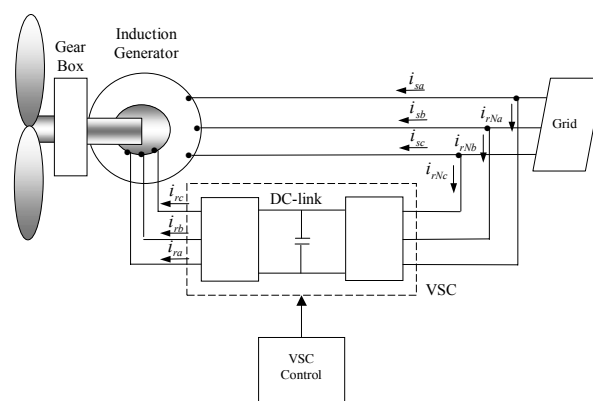
*Developed by Bengt Frankén, STRI
November 17, 2005
Ludvika, Sweden*

Bengt Frankén
2005-11-17

STRI

1

The concept of the Doubly-fed Induction Generator



Bengt Frankén
2005-11-17

STRI

2

Features

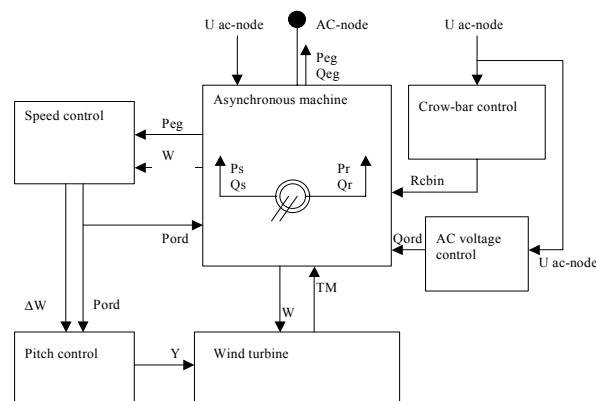
- Aimed for transient studies of wind power, Transta
- 3rd order model including rotor transients
- Single mass model
- Users give DFIG data and wind profile
- Flexibility to exchange any of the models
 - Wind turbine
 - Pitch control model
 - Speed control model
 - Voltage control model
 - Crow-bar protection model
- Step-up transformer outside of the DFIG model

Bernd Frankén
2005-11-17

STRIL

3

Modules



W = rotation speed
 ΔW = rotation speed deviation
 Pord = power order
 Peg = actual power

TM = mechanical torque
 Y = blade angle
 Qord = reactive power order
 Rcbin = crow-bar resistor in/out

Bernd Frankén
2005-11-17

STRIL

4

Data for DFIG model

- Wind turbine data
 - Lengths of the blades
 - Nominal angular speed
 - Efficiency curves (C_p/λ -curve) for the blades and different blade angles
- Generator data
 - S_n , R_s , X_s , X_m , etc.
 - Inertia constant, H , includes the mass of the wind turbine
 - Total Power/Rotor speed-curve given as:

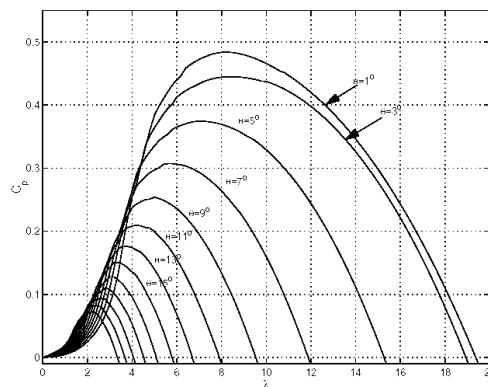
$$W_r = a \cdot P^2 + b \cdot P + c$$

Benedt Frankén
2005-11-17

STRI

5

Efficiency curve (C_p/λ -curve)



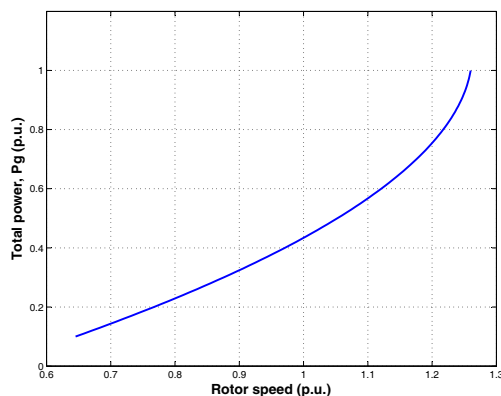
Power Coefficient C_p with blade pitch angle θ (Y at slide #4) as a parameter.

Benedt Frankén
2005-11-17

STRI

6

Total Power/Rotor speed-curve



$$W_r = a \cdot P^2 + b \cdot P + c$$

Benqi Frankén
2005-11-17

STRIL

7

Simulation of Wind Variations

Used data of the 2 MW DFIG

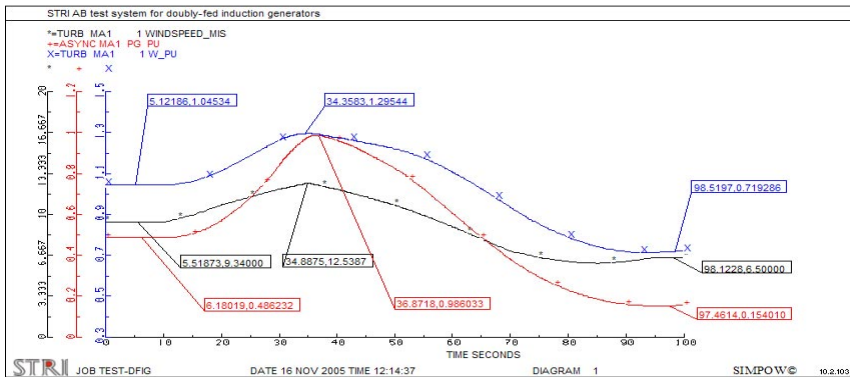
- Wind turbine
 - Blade lengths 36 m
 - Blade weight 10 tonnes
 - Nominal angular speed 1.88 rad/s, i.e., 18 rpm
- Total power/Rotor speed
 - $W_r = a \cdot P^2 + b \cdot P + c$
 - $a = -0.63$
 - $b = 1.40$
 - $c = 0.52$
- Generator (typical)
 - Rated power 2.05 MVA
 - $R_s = 0.01$ pu
 - $R_r = 0.009$ pu
 - $X_s = 0.18$ pu
 - $X_r = 0.07$ pu
 - $X_m = 4.4$
 - $R_2 = 0.03$ pu ($3 \cdot R_s$)
 - $X_2 = 0.25$ pu ($X_s + X_r$)
 - $H = 5.5$ s (based on the heavy wind turbine)

Benqi Frankén
2005-11-17

STRIL

8

Simulation of Wind Variations

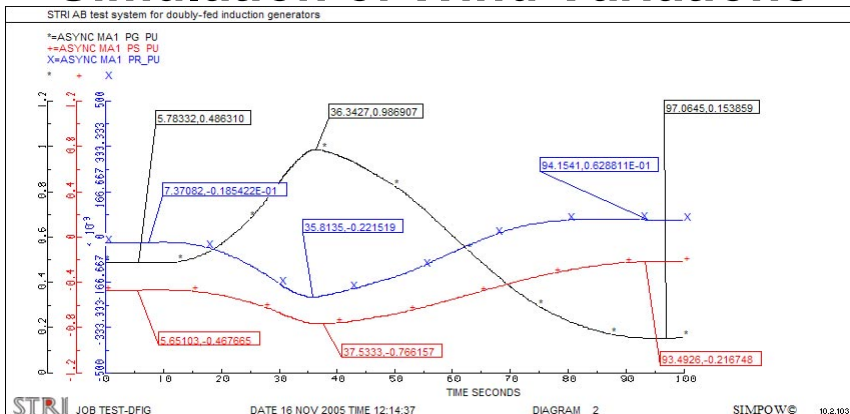


- Wind speed in black – starts at 9.3 m/s, goes up to 12.5 m/s and ends at 6.5 m/s
- Generated power in red – starts at 0.49 pu, goes up to 0.99 pu and ends at 0.15 pu
- Rotation speed in blue – starts at 1.04 pu, goes up to 1.30 pu and ends at 0.72 pu

Bernd Franke
2005-11-17

STRI

Simulation of Wind Variations

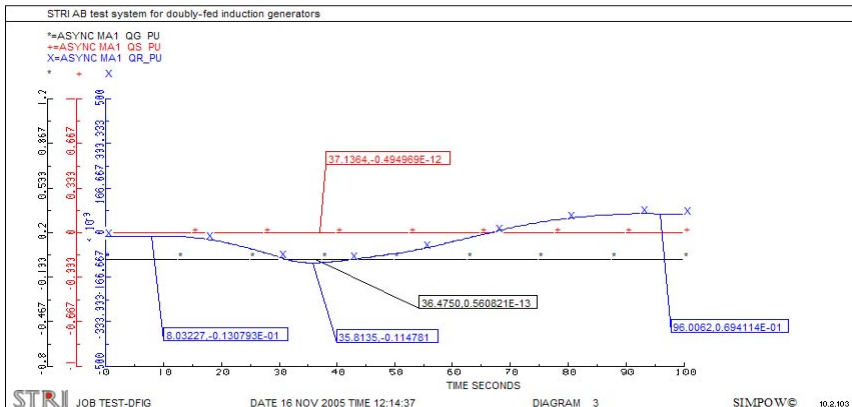


- Generated power in black – starts at 0.49 pu, goes up to 0.99 pu and ends at 0.15 pu
- Stator real power in red – starts at -0.47 pu and varies between -0.77 pu and -0.22 pu
- Rotor real power in blue – starts at -0.02 pu and varies between -0.22 pu and +0.06 pu

Bernd Franke
2005-11-17

STRI

Simulation of Wind Variations

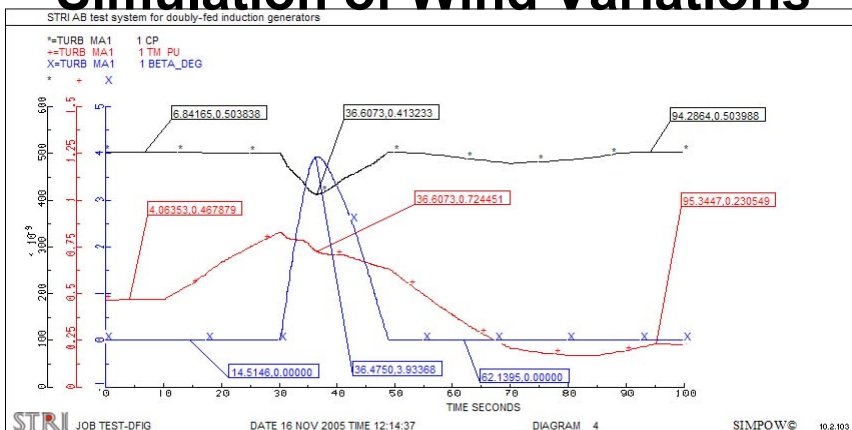


- Consumed Mvar in black – 0.0 pu as unity power factor control in rotor circuit
- Stator Mvar in red equal to consumed Mvar i.e. 0.0 pu
- Rotor Mvar in blue – starts with 0.01 pu and varies between -0.11 pu and +0.07 pu

Bernd Franken
2005-11-17



Simulation of Wind Variations



- Efficiency Cp in black – 0.5 pu as optimum and decrease to 0.41 pu at active pitch
- Mech. torque in red – starts at 0.47 pu and is reduced at active pitch
- Blade angle in blue – starts with 0 deg and increase to 4 deg at active pitch

Bernd Franken
2005-11-17



References

- Andreas Petersson, *Analysis, Modeling and Control of Doubly-fed Induction Generators for Wind Turbines*, Ph.D. thesis, Chalmers University of Technology, Sweden, 2005.
- Florent Maupas, *Impact of Voltage Control Equipment on the Network Integration of Large Offshore Wind Farms Interconnected with HVAC*, Master thesis X-ETS/EES-0424, Department of Electrical Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, December, 2004.
- Vladislav Akhmatov, *Analysis of Dynamic Behaviour of Electric Power Systems with Large Amount of Wind Power*, Ph.D. thesis, Technical University of Denmark, Lyngby, Denmark, April, 2003.
- Francesco Sulla, *Modeling of Asynchronous Machines in Simpow*, ABB TR H 03-168, Master thesis, ABB Utilities, Västerås, Sweden. Also available as B-EES-0301, Department of Electrical Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, March, 2003.

Bengt Franke
2005-11-17

STR I

13

STR I

Bengt Franke
2005-11-17

STR I

14