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Dynamic Modelling of a 2 MW DFIG Wind Turbine for Converter Issues: Part I

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1. Introduction

The mechanical modelling of a 2 MW DFIG wind turbine is shown. Six cp curves from literature are considered. The gearbox ratio and radius dependence is analysed and a suitable speed control strategy is developed. One matching cp curve, radius and gearbox ratio is chosen. A realistic rotor and generator inertia is computed.

2. Cp-Characteristics

Six different cp characteristics can be seen in Fig. 1. They vary in several aspects (optimal tip speed ratio, maximum,..)

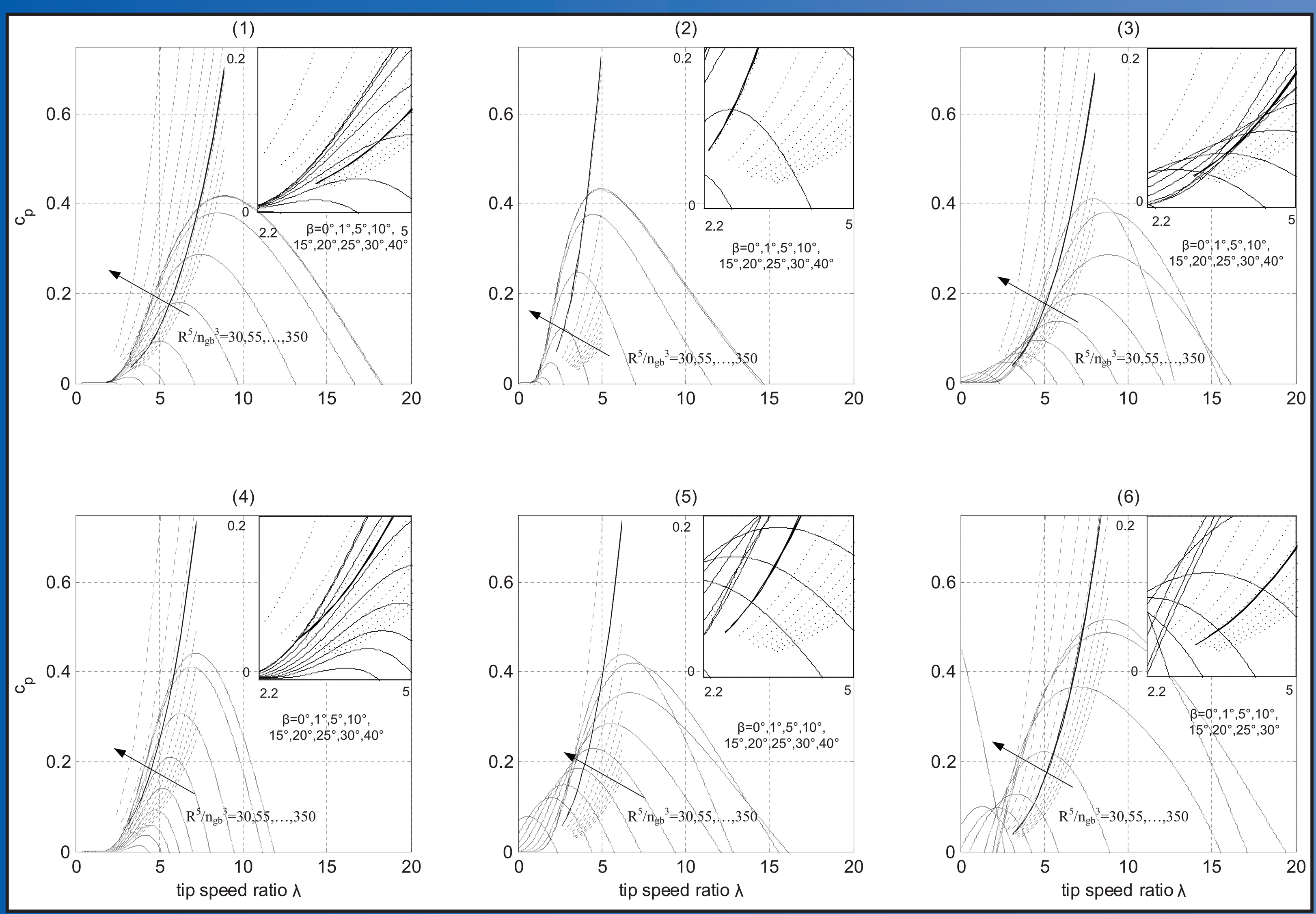


Fig. 1 : Different cp curves (1) MOD-2 turbine Wasynczuk 1981(2) Mitsubishi, 250 kW; 1993, R=15m (3) Arsudis 1989 (4) Ackermann, Variable speed wind turbine (5) Slootweg 2 MW, 2001, R=37.5 (6) GE 1.5, 1.6, 3.6 MW

3. Speed Control Dependence on λ_{opt}

Optimal speed control in partial load: rotational speed increase proportional to wind speed:

$$n_{ref} = \underbrace{\frac{\lambda_{opt} n_{gb}}{2\pi R}}_{\text{const.}} v_{wind}$$

n_{gb}- gearbox ratio ; R- rotor radius ; λ_{opt} - optimal tip speed ratio

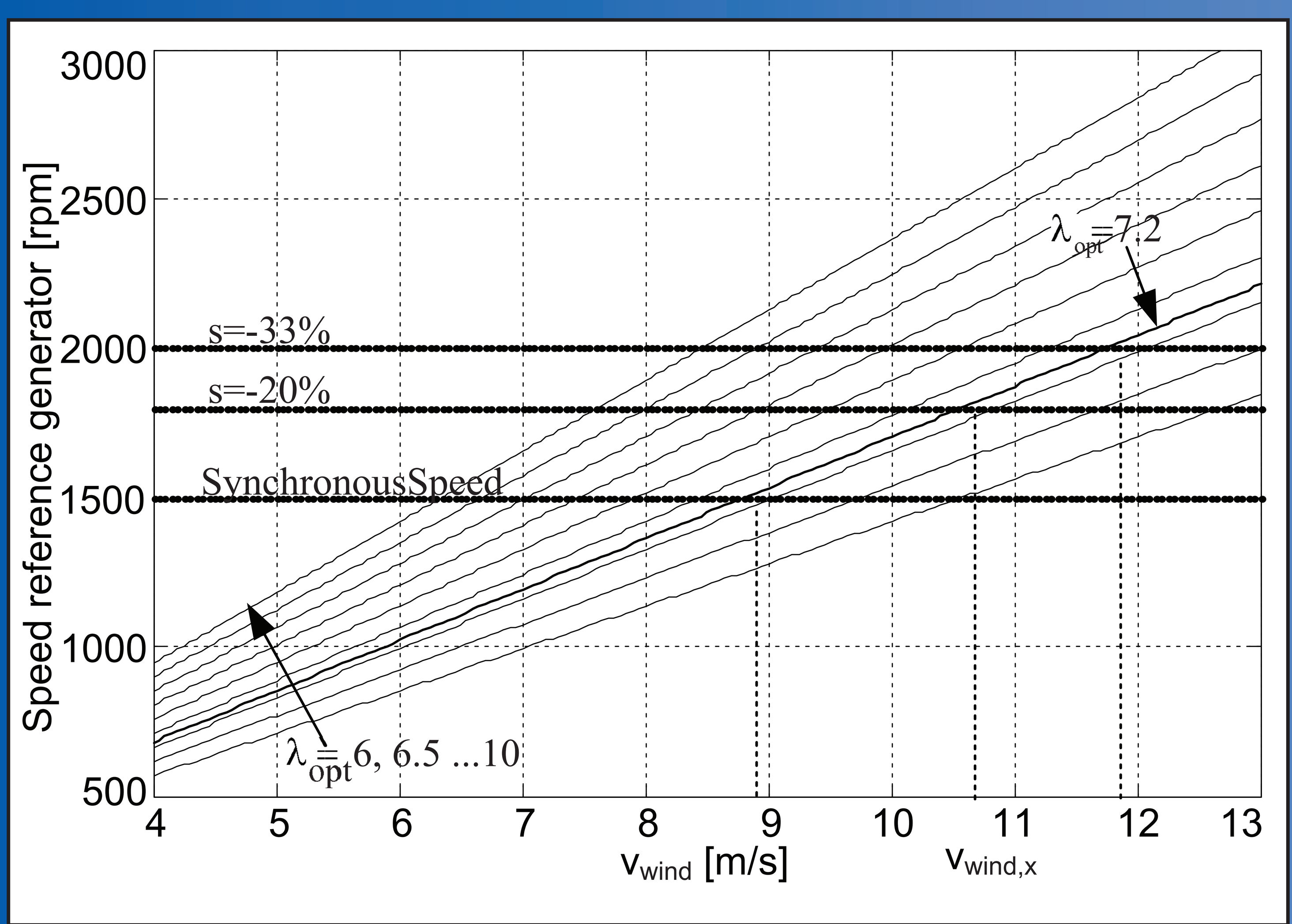


Fig. 2. R=40m, gearbox ratio=100 assumed. At a specific wind speed, the rotational speed reaches its maximum.

4. Pitch Control Dependence on Gearbox Ratio and Radius

Assuming a constant slip of -20% in full load, the following equation holds for cp

$$c_p = \frac{P_N n_{gb}^3}{0.5\rho\pi\varpi_{1800}^3 R^5}\lambda_{max}^3$$

Starting with optimal tip speed ratio, this relation is plotted in Fig. 1, for different R^5/n_{gb}^3 ratios (30,55,... , 350). It can be seen, that only specific curves match one cp characteristic. Characteristic 1 is found to be suitable with $R^5/n_{gb}^3 = 171$. The corresponding pitch angle reference is shown in Fig. 3. The gearbox ratio is set to 95, R=43 m.

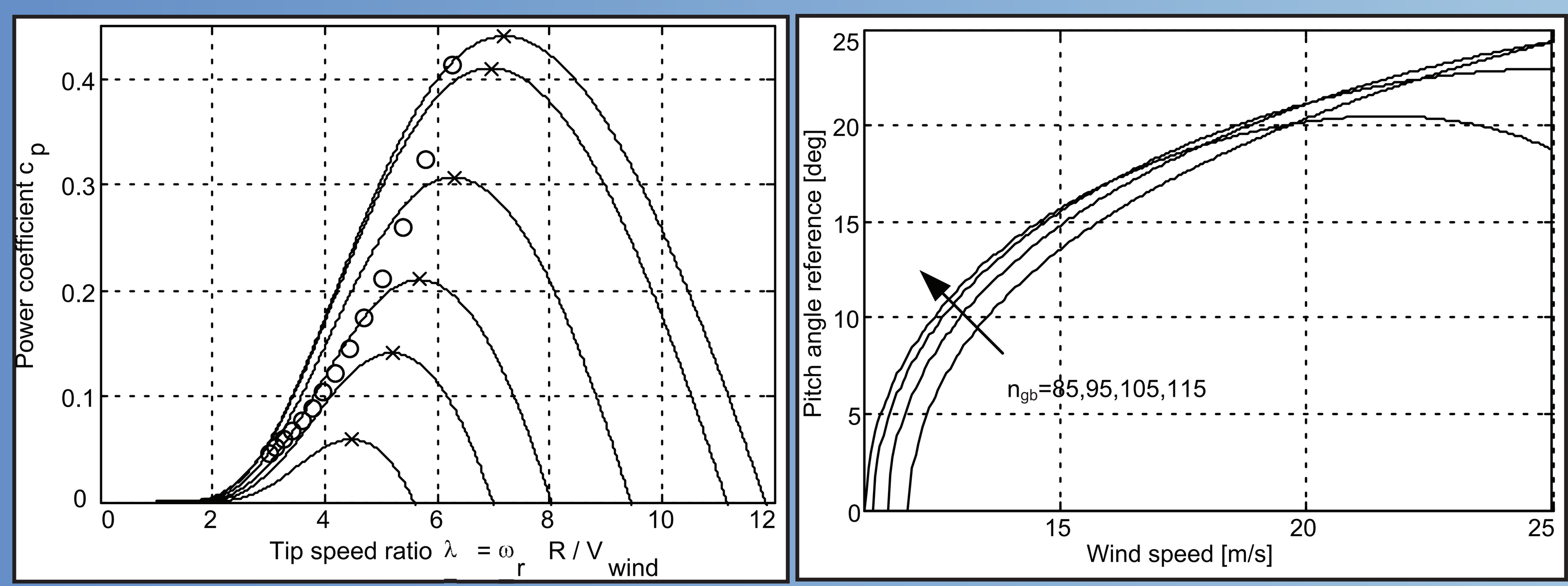


Fig. 3.Left: Steady state operatin points in full load Right: pitch angle reference in full load for conf. 1 with different gearbox ratios

5. Rotor Inertia

The following rotor inertia constants are found in literature:

	GE (50 Hz) 1.5MW…1.6MW …3.6MW	Ackermann 2 MW	1	2	3	4	5	6	7	8	9
H_r [s]	**5.29…4.96…5.74**	**4.5**	**3.7**	**4.35**	**5.07**	**5.76**	**4.38**	**4.45**	**4.57**	**4.6**	3.63
J_r [*M*kgm²]	3.93 (1.5 MW)	**6.41**	6.06	7.12	8.3	9.43	5.62	6.37	10.3	7.6	**5.9**
J_r^0 [kgm²]	645.6 (1.5 MW)	729.31	600	705	729	933	710	721	740	745	590
R [m]	~38.5 (1.5 MW)	not available	39	42.3	44	40.5	35.5	40	44	45	37.5
n_{gb}	78 [19]	93.75	100.5	100.5	100.5	100.5	89	94	118	101	100

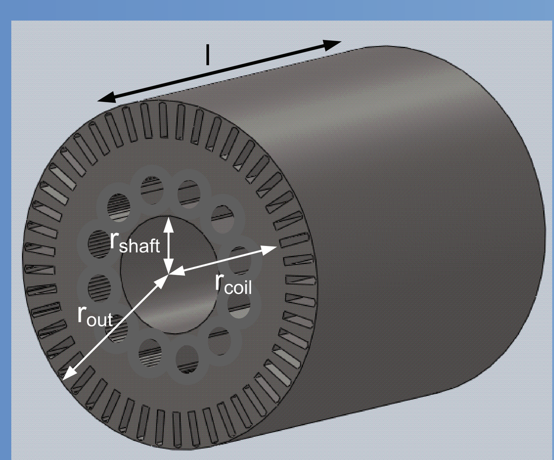
Tab. I. 1 Gamesa G80 2 Gamesa G87 3 Gamesa 90 4 Gamesa 83 5 Bonus 2MW 6 DeWind D80 7 Suzlon 2MW 8 MADE AE90 9 [16]

The time constant relation to the inertia is:

$$H_r = \frac{E_{kin,base}}{P_{base}} = \frac{0.5 J_r \omega_{base,r}^2}{P_{base}}, \quad \omega_{base,r} = \frac{2\pi f_{line}}{p \cdot n_{gb}}$$

The rotor inertia is set to 700 kgm².

6. Generator Inertia



The generator rotor inertia is computed with CAD software and a typical model of a 2 MW DFIG rotor. The copper coils are modelled as a hollow cylinder. The result is: $J_g = J_{g,stack} + J_{,coil} = 85.66\text{kgm}^2$

Fig. 4. CAD model of rotor

7. Conclusion

- Dynamic mechanical model of a 2 MW DFIG wind turbine
- From six cp characteristics only one is found to be suitable
- Speed control and pitch angle reference is developed.
- Realistic rotor and generator inertia is found.
- A future publication will address the modelling of the electrical part of the wind turbine.

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