WIND TURBINE MODELLING USING DNV GL BLADED

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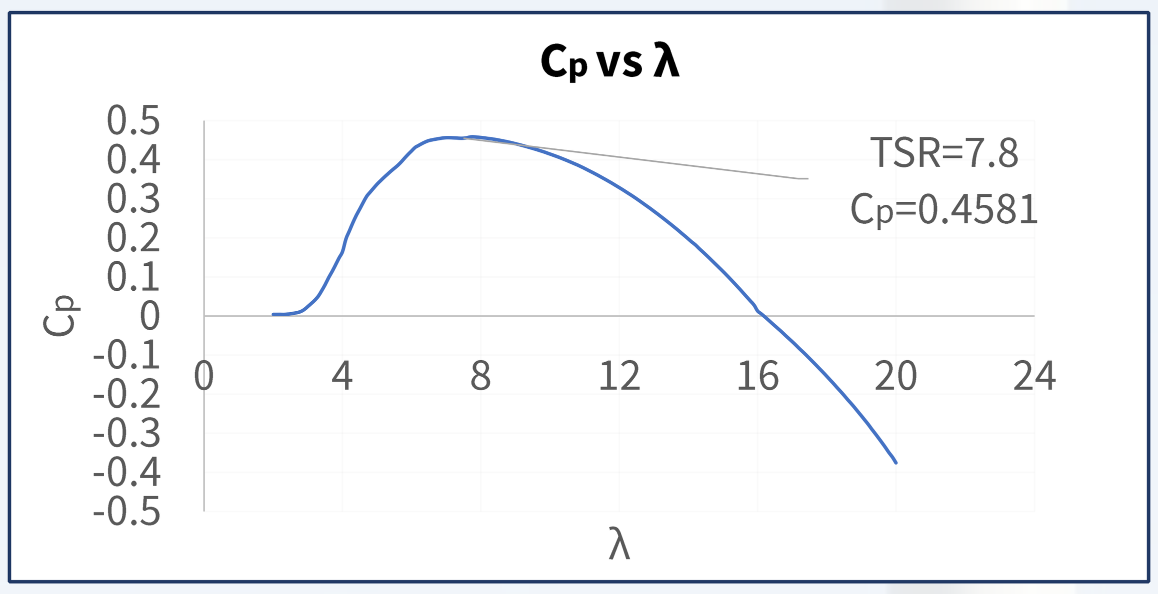
1. INTRODUCTION

The efficiency of wind turbines varies under different conditions based on specific design decisions. Wind energy generation has come a long way from kW to MW-scale generation as a result of advances in technology; however, the need to employ effective strategies to efficiently extract energy remains. Topics under consideration include turbine efficiency at different tip-speed ratios to determine where maximum generation output is achieved and at which tip-speed ratio; gross energy yields achieved during 'ideal' and 'real' operating conditions; pitch-regulated and stall-regulated control features; variable-speed turbine regions of operation and their respective aerodynamic torques and rotor speeds; and effects of changing turbine parameters like gearbox ratio on its performance. Simulations are made using DNV GL Bladed: a software tool developed with a wide array of integrated modelling packages enabling adjustment of parameters like blade aerodynamics, drivetrain, and wind characteristics. Results obtained provide an in-depth understanding of how design is critical in optimizing power generation of **fixed offshore wind turbines** even under adverse environmental conditions.

2. TURBINE PARAMETERS

COMPONENTS	PARAMETERS
Turbine and rotor	Rotor Mass: 33640kg Total hub height: 61.5m Nominal rotor diameter: 80m
Blades	Number of blades: 3 Blade Length: 38.75m Total blade mass: 6547kg
Gearbox	Gearbox ratio: 83.33
Generator	Induction generator
Control strategy	Pitch-regulated, variable-speed control

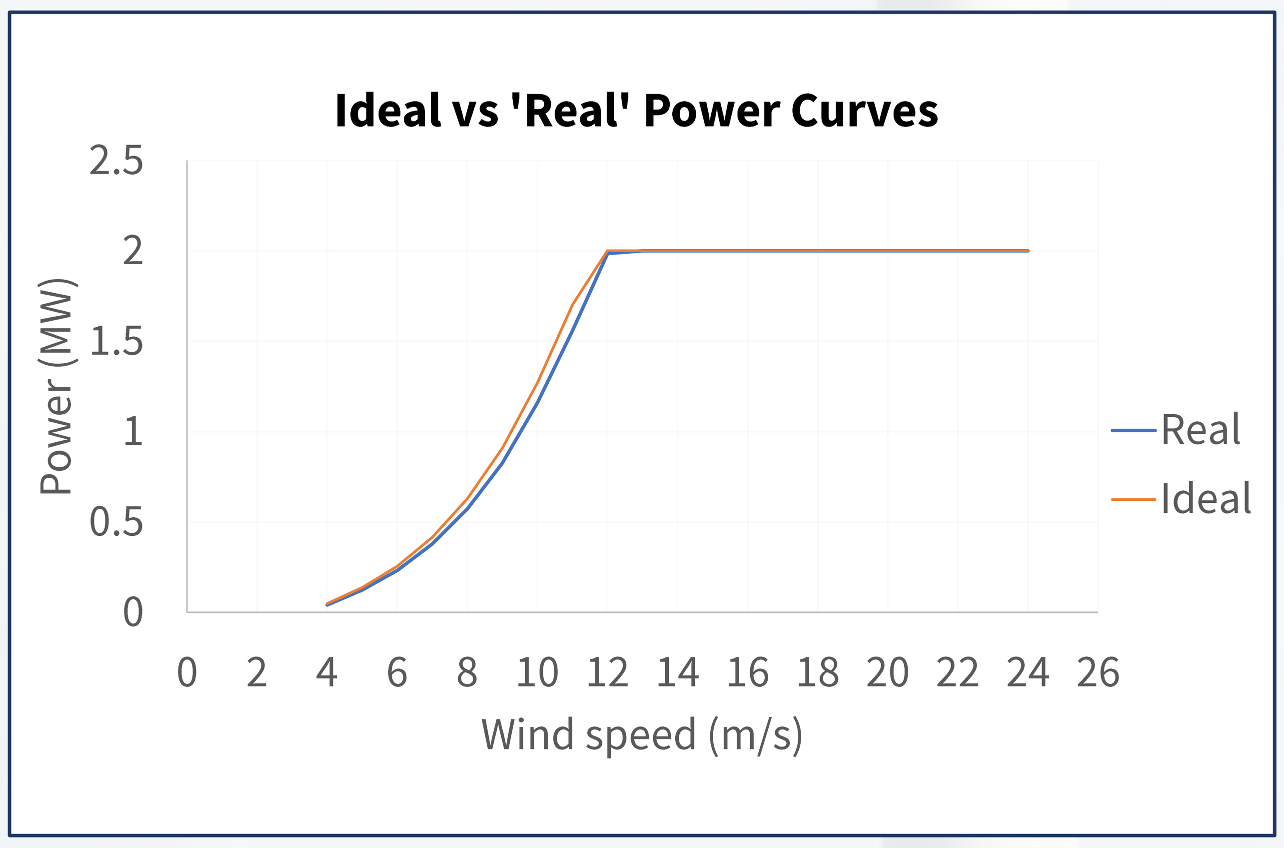
3. POWER COEFFICIENT, Cp, VS TIP-SPEED RATIO (TSR), λ



- A Cp-λ curve is a non-dimensional measure of rotor performance.
- The maximum Cp achieved is 0.4581 and this occurs at the optimum TSR of 7.8.

4. POWER CURVE CONSTRUCTION

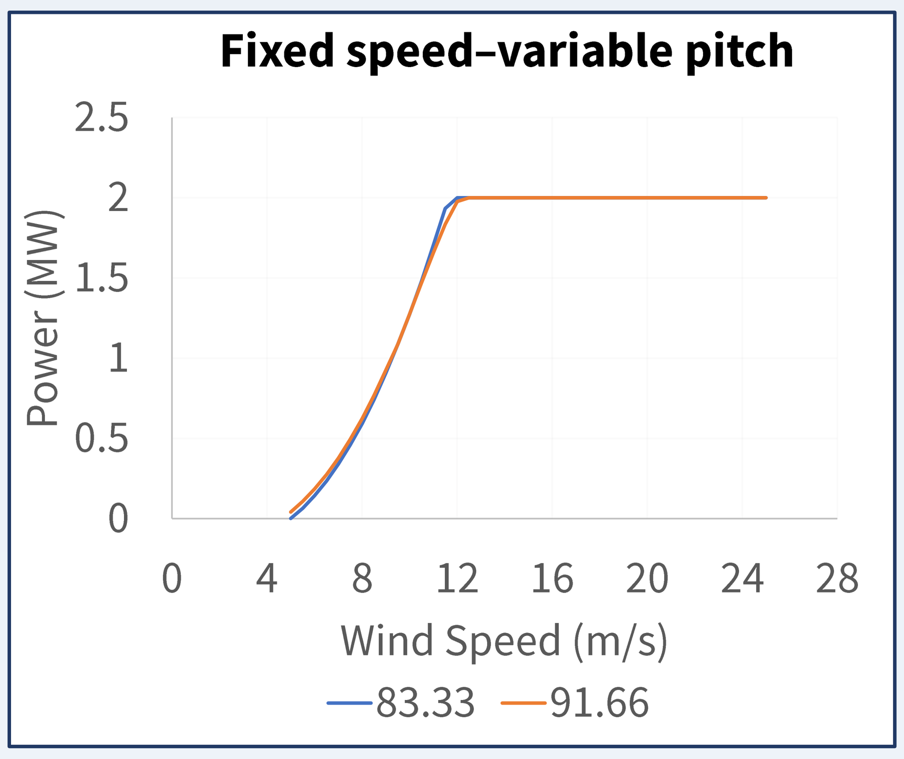
Power curves obtained for variable speed – variable pitch strategy:

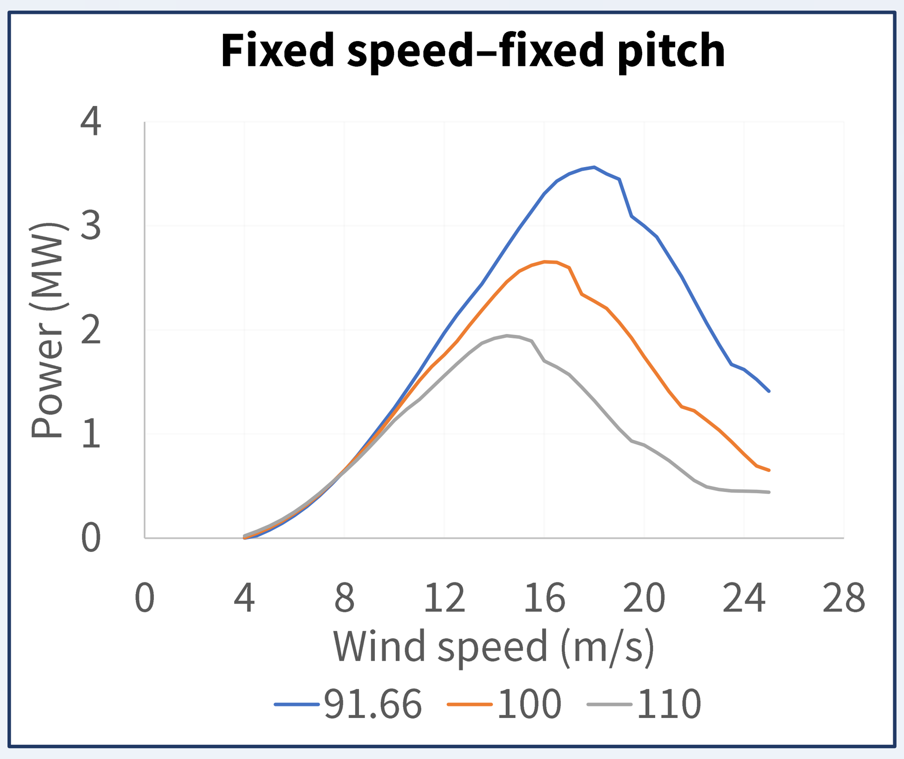


- **Real power curve**: Generated using average values of power output at each wind speed; under real operating conditions energy varies at a specific wind speed.
- **Ideal power curve**: Based on constant generator outputs.
- **Real conditions**: Generation is lower below rated speed and cut-in speed is higher.
- Below rated, pitch is maintained negative and constant and rotor speed varies.
- Above rated, rotor speed is constant and pitch increases reaching positive values.

5. CONTROL STRATEGIES

Changing the control strategy and gearbox ratio, new power curves are obtained:





Fixed speed–fixed pitch operation

i. Maximum power above rated if the gearbox-ratio is not properly selected.
ii. Fall in generation output after reaching maximum power—stall.
iii. Increasing the gearbox ratio decreases rotor speed proportionally.

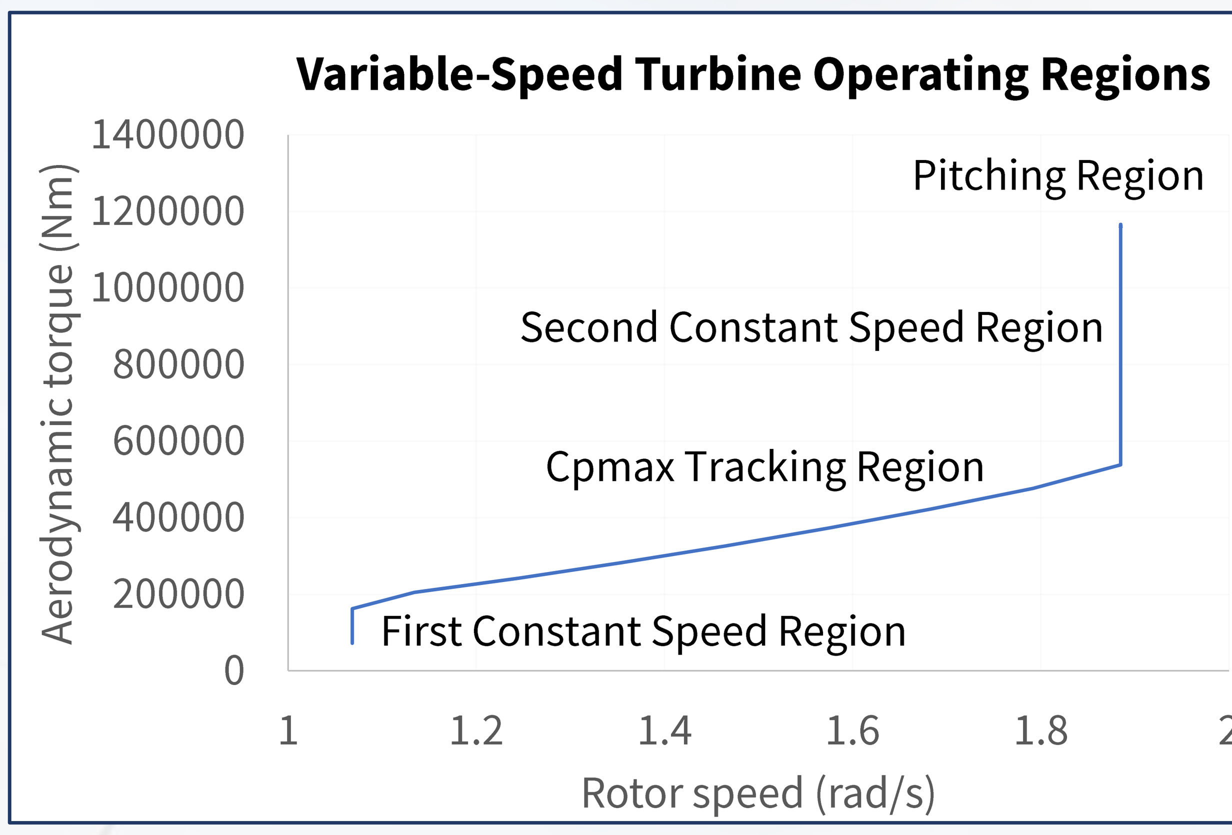
Fixed speed–variable pitch operation

i. Similar output to variable speed-variable pitch.
ii. Less power generation, starts later and has a higher cut-in speed.

Annual energy yield

- Variable speed-variable pitch → 6999 MWh
- Fixed speed-variable pitch → 6764 MWh
- Fixed speed-fixed pitch → 6079 MWh

6. OPERATING STRATEGY



Keep the turbine work at its optimum condition. Four different regions of the graph:

- **1st constant speed:** Torque increases within the cut-in speed; the rotor speed has to be constant, achieved by maintaining the pitch angle at a negative value.
- **Cpmax tracking:** Rotor speed increases with increasing wind speed below rated. Pitch angle is fixed at a particular value for maximum energy production.
- **2nd constant speed:** Torque increases in order to maintain constant power output. The pitch angle adapts to a positive value to avoid the incident angle.
- **Pitching:** Higher value of rated wind speed, a 90-degree pitch angle, and blades in pitch-to-feather mode. Reduce the wind load on the blades to avoid system failure.

7. CONCLUSIONS

- Although information obtained is focused on modelling of fixed offshore wind turbines, by implementing proper control, this knowledge can be duly applied for floating offshore wind turbines which experience more environmental forces and effects.
- The power coefficient, C_p, of a 3-bladed turbine can reach a value as high as 0.48 which is achievable at a tip-speed ratio of about 7.5. This C_{pmax} is practical since it is lower than the maximum achievable Betz limit—approximately 0.59. This discrepancy occurs due to imperfect blade design and operational losses (drag, tip).
- Stall regulation, although simple, causes unpredictable power variations and damage due to mechanical stresses from vibrations after stall. Therefore, blades of a turbine to be used for stall regulated-fixed speed operation must be robust.
- Fixed-speed control has complexities since its overall performance is dependent on a single rotational speed. If the design speed is low, the turbine reaches peak power, which has a low value, at a low wind speed. At higher wind speeds than peak, the turbine will undergo stalled operation which is quite inefficient. Hence, gearbox ratio and pitch angle are regulated based on wind speed distribution at the site to increase the power output.
- Fixed-speed turbines have been the preferred choice for many years due to their simplicity, but they have disadvantages like the need for support structures for safety above rated wind speed due to high thrust forces. Variable-speed control promises a greater advantage compared to other strategies in achieving a higher annual energy yield.

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