Comp3402 Wind Turbine Control (ctd)

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Purpose	(i) To learn about Wind Turbine control strategies for Regions 1-4 with a focus on Region 2 and Region 3. (ii) To conduct a series of **investigations** and subject the observations to analysis.
Files Required	Unreal4 resources and Octave scripts.
ILO Contribution	LO 4
Send to Me	nix
Homework	Read chapter 4

Investigations

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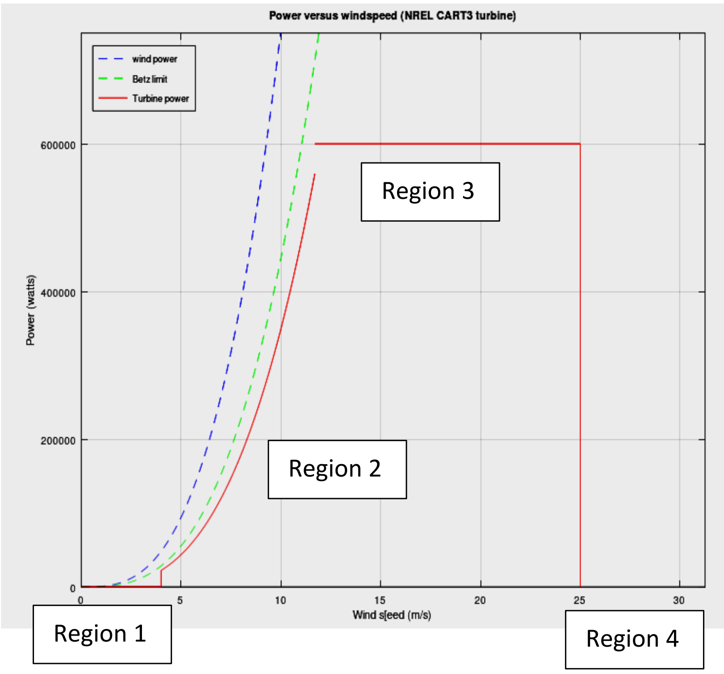
1 Parameters for the NREL-CART3 600kW turbine

Below are the parameters for this wind turbine, defined in Unreal and also Octave. On the left is the power curve showing the four regions, the energy in the wind and the Betz limit. These curves are all proportional to wind-speed cubed, i.e. v^3.

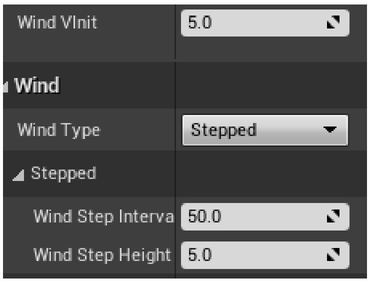


R	Rotor radius	20m
ρ	Air density	1.2 kg/m^3
J	Inertia	613,301
λ_{opt}	Optimal tip speed ratio	6.6
$C_{p,max}$	Maximum power coefficient	0.4633
ω_{rated}	rated angular velocity	3.9521
v_{cutIn}	Cut-in wind speed	4 m/s
v_{cutOut}	Cut-out wind speed	25m/s
v_{Rated}	Rated wind speed	11.7 m/s

Important Stuff

1. In Region II, the turbine should move to operate at the optimal tip-speed ratio λ_{opt} which will give the maximum power coefficient $C_{p,max}$ so it extracts the maximum power *at any wind speed* in this region.

2 Investigating the Region-II Controller



(a) Set the wind type as shown here so that the wind speed is stepped from 5 m/s to 10 m/s in Region II. Run the simulation and stop *just before the time is 100 secs*, then you will get one step.

(b) Run the Octave script **WT** to get the plots.

Let's consider the omega-time plot following the step in wind speed at 50 secs. You should see a 'rising response' where the Region II controller adjusts the rotation speed omega to extract the maximum power for this wind speed.

Remember the control law in this region which tells us how rotation speed is adjusted with time, in the time interval Δt the rotation speed is changed by

$$\Delta\omega = \frac{1}{J}\left(\tau_{wind} - \tau_{gen}\right)\Delta t$$

which depends on the difference in the forward torque from the turbine and the backward torque from the generator.

(c) When the wind speed increases suddenly, which of the two torques starts to increase? Therefore is $\Delta\omega$ positive or negative? Confirm you answer by looking at the omega-time graph

(d) Now, when the two torques are equal, what is the value of $\Delta\omega$? At what time on the omega plot can you find this value of $\Delta\omega$?

Also remember that the controller adjusts τ_{gen} so that the rotation speed (omega) changes to make the TSR its optimal value.

(e) Let's take a look at the tip speed ratio and how this changes as the wind speed increases. Remember the expression for tip speed ratio is (TSR)

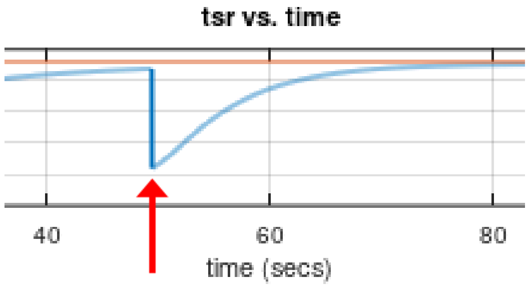
$$\lambda = \frac{\omega R}{v}$$

So, let's calculate the TSR ***just before*** the step in wind speed. We can do this in Octave. You will need to get the value of ω (**omega**) from the Octave plot, I got 1.61, so in Octave type the following to calculate the TSR

R = 20
omega = 1.61
v = 5
tsr = (omega*R)/v

Hopefully this should give you something close to the optimal value 6.6.

Now look at the TSR graph near the step in windspeed; the TSR drops and then recovers.



(g) First let's measure the drop from the curve. I got something around 3.2.

(h) Now let's try to understand why it drops. You can see this from the expression

$$\lambda = \frac{\omega R}{v}$$

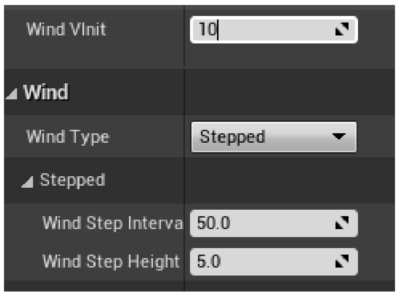
Think, which of the variables in the expression has changed because of the step in wind speed?

Use this changed value in the above expression for TSR and check it agrees with your measurement in (g).

(i) Now the expression for the turbine torque has TSR-cubed in the denominator (check book chapter) so what happens to the size of the *turbine* torque? Looking at the expression in (d) for $\Delta\omega$ the change in omega, how must the *generator* torque change to make $\Delta\omega = 0$?

(j) Now grab a class-mate and try to explain in Simple English what the Region-2 controller is doing. You may refer to the class lecture notes and the Book Chapter. This would be great preparation for your position paper.

3 The Region II to Region III Transition.



(a) Set the wind type as shown here so that the wind speed is stepped from 10 m/s to 15 m/s so crossing from Region II to Region III. Run the simulation and stop *just before the time is 100 secs*, then you will get one step.

(b) Run the Octave script **WT** to get the plots. You will see a bit of Region II which you understand, followed by transition to Region III

(c) At what time do the blades' pitch (β, beta) start to increase? This is not the same time as the wind step increase. Let's see why. Remember the Region III pitch control law is

$$\frac{d\beta}{dt} = -K_p(\omega_{rated} - \omega)$$

in other words, it responds to the turbine rotation speed ω and not to wind speed directly. If ω increases (as the turbine responds to increasing wind speed (Region II Controller) then what sign is the right hand side of the above expression, when ω becomes greater than ω_{rated}? So what happens to the pitch angle β?

(d) Look again at the beta plot when it start to rise, and the blades pitch. Why does this take time? Why does beta not change instantaneously?

(e) Now have a conversation with a class-mate about the Region III controller. Perhaps you could start your discussions with the power-time graph? Understanding this will help your position paper.