THE UNIVERSITY OF BRITISH COLUMBIA

FOWFSim-Dyn User Manual

UBC Control Engineering Lab (CEL)
October 15, 2021

Contents

1 Introduction

This Matlab code is used to simulate the behavior of a wind farm using the dynamic wake model developed by Ali C. Kheirabadi.[1] With this model, users can observe the motion of the turbines and power outputs for a 5MW wind farm with users specifying the model inputs. This model allows 2 different set of model inputs.

- yaw angle, blade pitch angle and generator torque
- yaw angle, axial induction factor

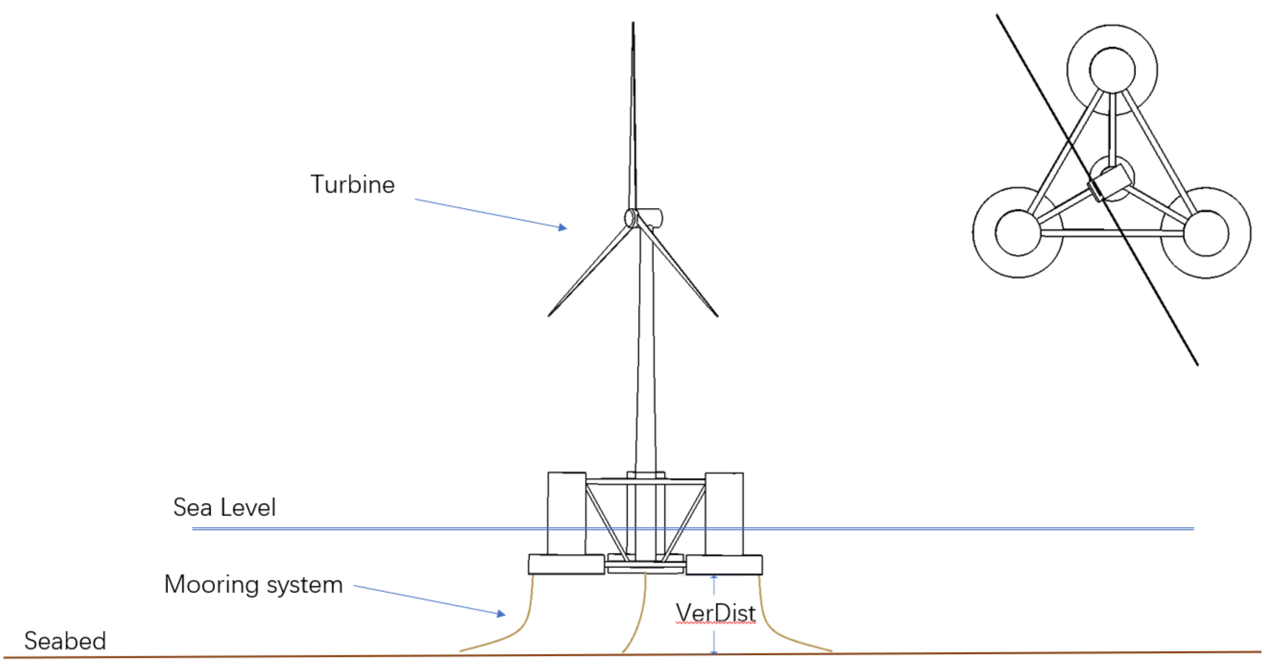

Figure 1: turbine side view

2 Important Files

'MainScript.mat' is the file that users may mainly focus on, it is the place for users to set the inputs and run the simulation.
'Simulink_StateDerivVec.slx' is the Simulink model that process this simulation, some scopes were added in the model in case some users may want to observe the values of some variables. It contains one big functions - 'StateDerivVec', which do the calculations for the model, such as wake effect calculation etc.

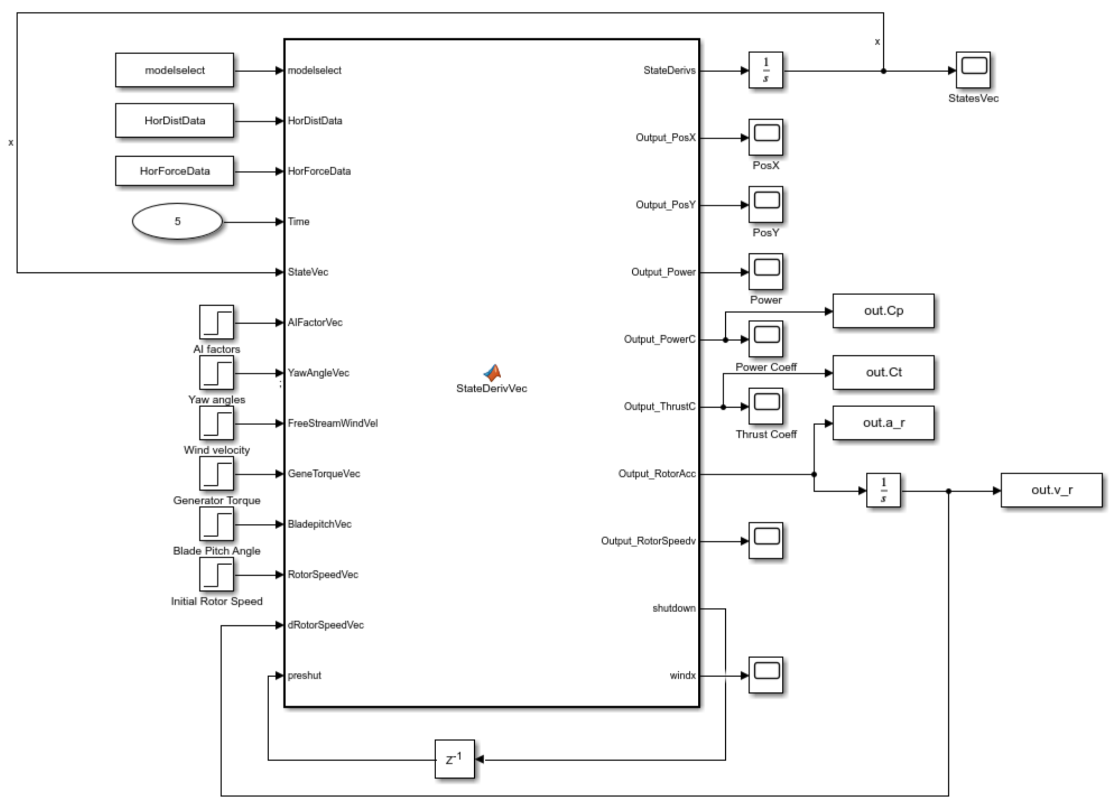

Figure 2: Simulink model

3 Adjustable inputs

This section specifies the inputs that can be adjusted in this code and shows the variable names as they are in the code. There are the main inputs of the model as shown in the figure 1 above, which are the previously-mentioned 2 inputs or 3 inputs and the global wind speed. Also, there are many other variables that can be adjusted depending on users' interest, such as simulation time, turbine dimensions, and wind farm layout etc. In this section, these variables will be explained and the units and sample values would be given for users convenience.
Note that in the Matlab code, some of the variables are defined within Matlab structures, for simplicity, the structure names are shown before the tables.

- Model Selection

  The variable 'modelsection' allow users to select which set of inputs would be used in this code.

  If it is equal to 1, the model will use the 3-input version(Yaw angle, Blade pitch angle and generator torque, and if not, the model will use the 2-input version (Yaw angle, AI factor).

- Model Inputs

  These are the basic inputs of this model.

2input version

Variables in the Code	Explanation	Unit	Sample Value
InitAIFactorVec	AI Factor inputs of the step block in Simulink model[1]	–	1/3
InitYawAngleVec[2]	Yaw angle inputs of the step block in Simulink model	degree	10
Global. MeanWindSpeed	Global wind speed input	m/s	10

[1]It is also possible to change the step inputs to other kinds of inputs, e.g. sinusoidal input.
[2]In the code, it is written as: InitYawAngleVec = [Yaw angle in degrees]$\times\pi/180$,the $\pi/180$ is to transfer degrees to radians.

3-input version

Variables in the Code	Explanation	Unit	Sample Value
InitGeneTorqueVec[3]	generator torque inputs of the step block in Simulink model	Nm	27000
InitBladePitch	Blade pitch angle inputs of the step block in Simulink model	degree	0
InitYawAngleVec	Yaw angle inputs of the step block in Simulink model	degree	10
Global. MeanWindSpeed	Global wind speed input	m/s	10
InitRotorSpeedVec	Initial rotor speed inputs of the step block in Simulink model to get the rotor start rotating	rad/s	1

- Simulation
  This is the basic simulation setup where user can set the sample time and total simulation time.

Variables in the Code	Explanation	Unit	Sample Value
SampleTime	sample time of the simulink model	sec	1
timeEnd	total simulation time	sec	1200

- Wind Farm Layout
  These variables represent the 2D layout of the wind farm with user specifying the number and spacing of turbines on X and Y directions. The following figure 3 shows a 2D illustration of a 2x2 wind farm.

Structure name: 'Farm'

Variables in the Code	Explanation	Unit	Sample Value
NumTurbX	Number of turbines along X axis	–	2
NumTurbY	Number of turbines along Y axis	–	2
SpacingX	Distance between turbines along X axis	m	7*Global.TurbDia[4]
SpacingY	Distance between turbines along Y axis	m	4*Global.TurbDia

[3] It is also possible to change the step inputs to other kinds of inputs, e.g. sinusoidal input.

[3] This can also be simply defind as numbers e.g. Farm.SpacingX = 630;

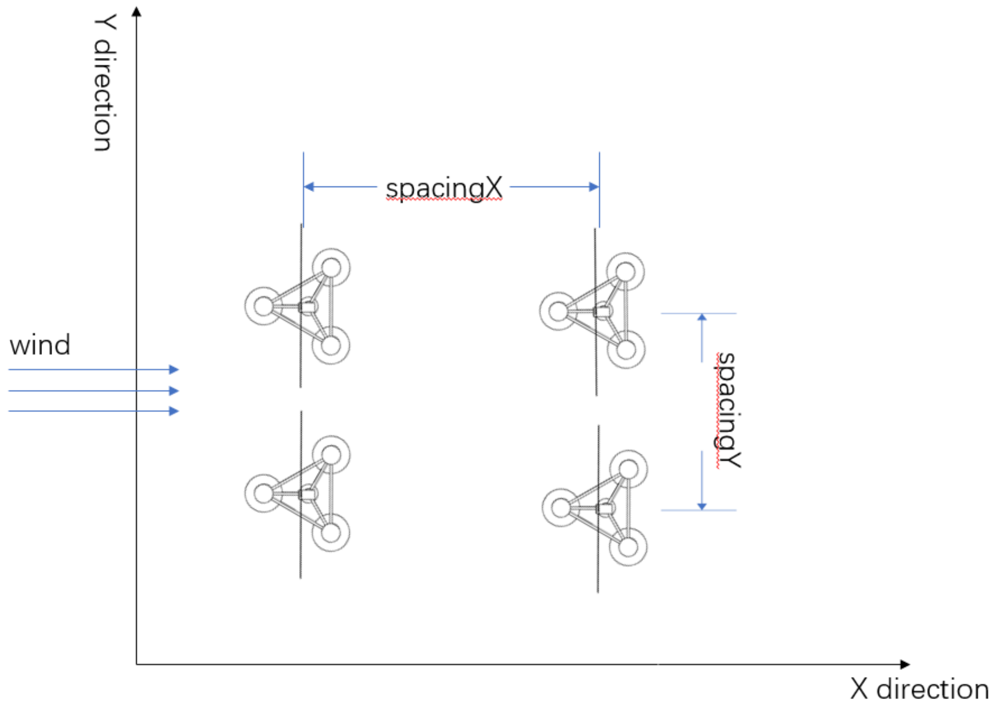

Figure 3: 2D model illustration of a 2x2 case

- Wake Model Settings
  These variables specifies the wake model's Gaussian distribution profile standard distribution and (diametrical) spatial wake expansion constant.

Structure name: Global.

Variables in the Code	Explanation	Unit	Sample Value
WakeExpConst	(Diametrical) Spatial wake expansion constant	–	0.08
GaussStd_Slope	Slope of Gaussian profile	–	0.025
GaussStd_Inter	Intersection of Gaussian profile[5]	–	0.396

- External property
  These are simple variables specifying some basic constants used in this model.

Structure name: Global.

Variables in the Code	Explanation	Unit	Sample Value
AirDensity	Air Density	kg/m^3	1.225
WaterDensity	Water Density	kg/m^3	1028
Global.GravAccel	Gravitational acceleration	m/s^2	9.81

[4] With the sample values of slope and intersection, the Gaussian profile standard deviation is set to be σ=0.025$\hat{x}$+0.396 m

- Turbine dimensions
  These variables are regarding the basic turbine settings.

Variables in the Code	Explanation	Unit	Sample Value
Turb(TurbNum). Mass	Turbine mass	kg	1.4×10^7
Global.TurbDia	Turbine rotor diameter	m	126

- Platform hydrodynamic properties[2]
  These variables specify the dimensions of the platform and hydrodynamic constants. The following figure 4 shows a 2D illsutration of these variables and figure 5 is a 3D figure created from Solidworks.

Structure name: Turb(TurbNum).

Variables in the Code	Explanation	Unit	Sample Value
TopCylDragCoeff	Drag coefficients of three top cylinder portions	–	0.61
BottCylDragCoeff	Drag coefficients of three bottom cylinder portions	–	0.68
MidCylDragCoeff	Drag coefficient of middle cylinder	–	0.56
TopCylDia	Diameters of three top cylinder portions	m	12
BottCylDia	Diameters of three bottom cylinder portions	m	24
MidCylDia	Diameter of middle cylinder	m	6.5
TopCylLength	Submerged lengths of three top cylinder portions	m	14
BottCylLength	Submerged lengths of three bottom cylinder portions	m	6
MidCylLength	Submerged length of middle cylinder	m	20
AddedMassCoeff	Added mass coefficients of any cylinder	–	0.63

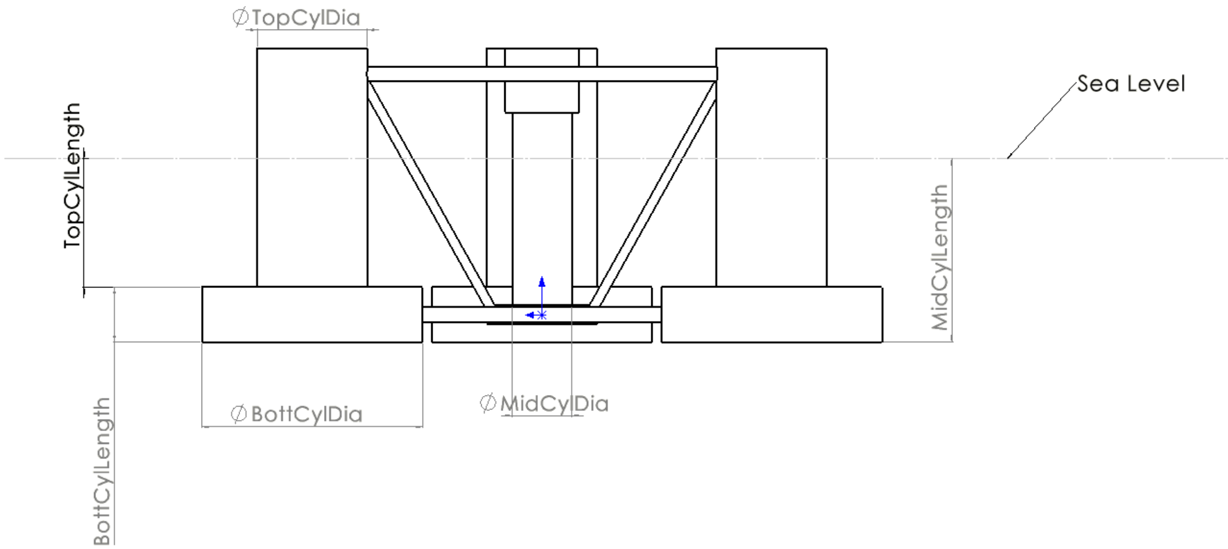

Figure 4: side view of the platform

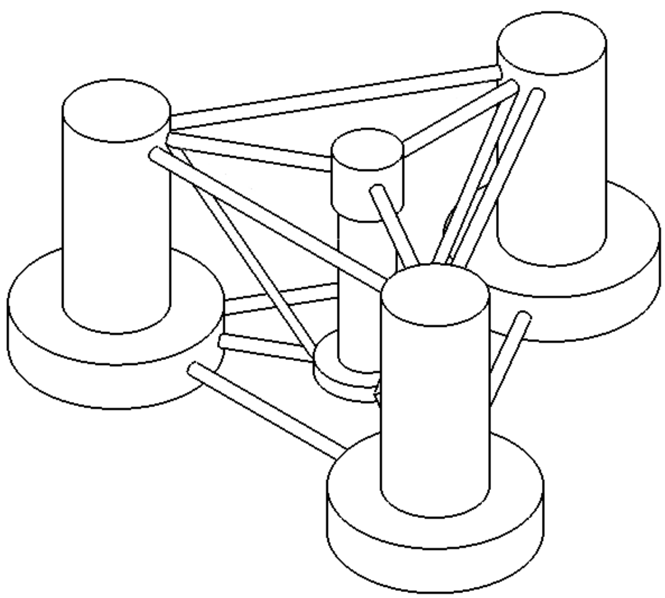

Figure 5: 3D model of the platform

- Mooring system properties
  These variables are used to specify the mooring system setup, such as anchor distance and mooring cable length.

Structure name: Turb(TurbNum).

Variables in the Code	Explanation	Unit	Sample Value
AnchDistRelG	Relative distance from turbine center to Anchors[6]	m	837.6
FLDistRelG	Relative distance from turbine center to fairleads [7]	m	40.87
VerDist	Fairlead distance above seabed	m	186
CableLength	Mooring cable length	m	935
CableDia	Mooring cable diameter	m	0.0766
CableNetDensity	Cable mass per unit length in water	kg/m	108.63
CableStiff	Cable tension per unit strain	N	753.6×10^6
SeabedFricCoeff	Coefficient of static friction between cable and seabed	$-$	1

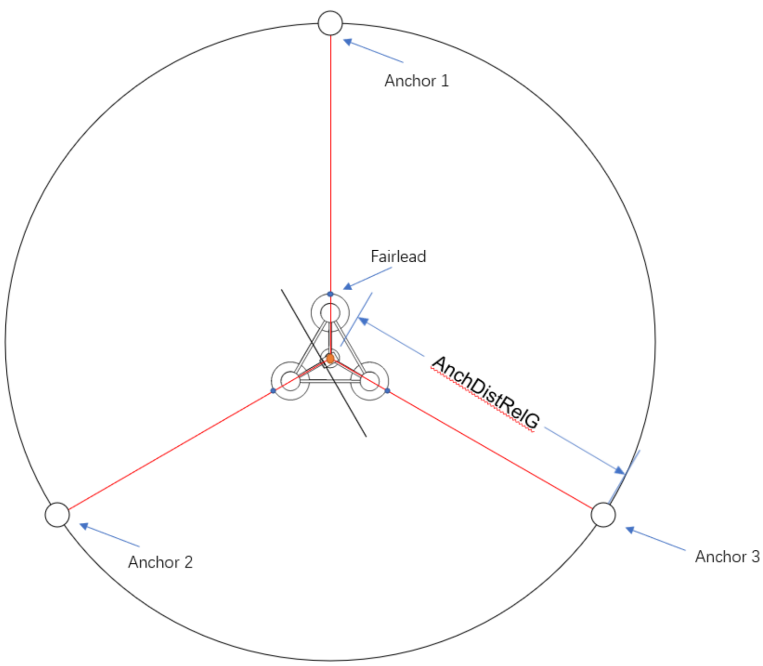

Figure 6: Anchor and failead position illustration

[5]As shown in figure 6, Anchors are located at angles of 60, 180, and 300 degrees along a circle of this radius surrounding the neutral positions of their respective turbines. The locations would be calculated in the code with trigonometric functions of 60, 180, 300 degrees. Note: figure 6 may not be perfectly to the scale.

[6]Similar to Anchor positions, the fairlead locations are calculated in the same way.

- Initial Conditions
  These variables are used to set the initial turbine positions, initial turbine velocities and initial wake effect states. The default setting of these variables are zero matrices (zeros(2,Farm.NumTurb)). The size of the matrices would need to adjusted with respect to the number of turbines in the farm.

  1. InitTurbPosMat Unit: m
  2. InitTurbVelMat Unit: m/s

4 Outputs

There 2 types of outputs from this code.
First, it would output a figure showing the X,Y Positions and mechanical power outputs with respect to the time.

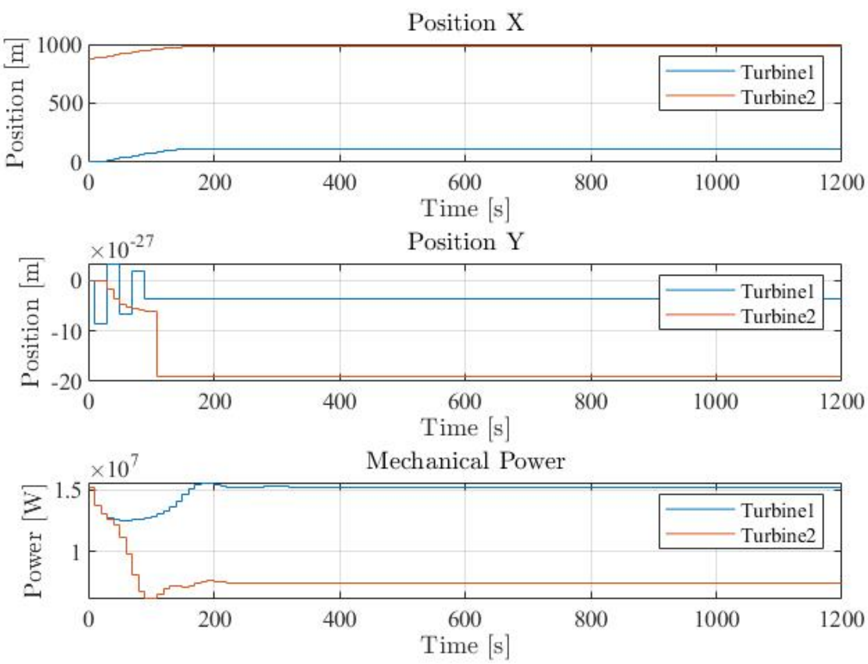

Figure 7: 2x1 wind farm example

Also, the code would output the incoming wind speed and turbine velocities as 'windX.mat', 'velX.mat' and 'velY.mat' as well as in the scopes inside the Simulink model.
Note that since we assume wind direction is X direction, only windX is important for the wind speed. The numbering of the output plots follows is first number along the Y axis and then number along X axis, the following figure 8 shows the numbering of a 2x2 case.

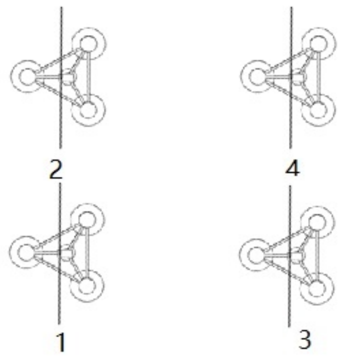

Figure 8: 2x2 numbering example

5 Limitations

- Floating platform heave, yaw, pitch, and roll are neglected in this model.
- The mooring line tensions are calculated based on steady-state analysis, which might cause inaccuracy in predicting tubine loads.
- FOWFSim-Dyn does not capture wake centerline deflection caused by rotor rotation.
- In this model,the free stream wind velocity is assumed to be uniform throughout.
- As shown in the input section, the model is based on that the a rectangle-shaped turbine layout, with wind blowing from +X direction.
- Also, the middle cylinder is assumed to have the same diameter along itself, while from NREL's data the diameter is slightly different at the top and bottom of the middle cylinder.

References

[1] Ali C. Kheirabadi and Ryozo Nagamune. "A low-fidelity dynamic wind farm model for simulating time-varying wind conditions and floating platform motion". In: *Ocean Engineering* 234 (2021), p. 109313. ISSN: 0029-8018. DOI: `https://doi.org/10.1016/j.oceaneng.2021.109313`. URL: `https://www.sciencedirect.com/science/article/pii/S0029801821007290`.

[2] A. Robertson et al. "Definition of the Semisubmersible Floating System for Phase II of OC4". In: (Sept. 2014). DOI: `10.2172/1155123`. URL: `https://www.osti.gov/biblio/1155123`.