Using DISCON dll

# DISCON dll

The bladed-style DLL controller controls the main FAST behavior. Currently (as of 18 Aug. 2017) it consists of the following components:

* Variable speed torque controller
* Collective pitch controller
* Individual pitch controller
* Yaw controller

At this moment the yaw controller cannot be used, since there is a bug in how FAST handles active yaw control from a DISCON dll (<https://github.com/OpenFAST/openfast/issues/25>).

# File description

Short description of all files in the provided Discon\_DLL folder

* CONSTSteps\_MPS.wnd: uniform stepped input wind file. Can be adjusted.
* DISCON.IN: used to pass user-defined parameters to the DISCON dll and avrSWAP
* \Debug
  + CompileRunAndDebug.cmd: compiles the DISCON dll, executes test 18 and copies the debug files to specified debug folder.
  + CompileRunAndPause.cmd: compiles the DISCON dll and executes test 18. After that is pauses so command window output can be read.
  + plotDebugData.m: plots debug data in matlab
  + saveFigs.m: saves all figures that are opened into the most recent debug folder
* \Scripts
  + CompileDISCON.cmd: compiles the DISCON dll
  + plotTest18.m: plots data from the Test18.out file
  + RunTest18.cmd: executes test 18
* \Source
  + DISCON.f90: main controller file
  + Filter.f90: module that contains different filters
  + FunctionToolbox.f90: module that contains different functions
  + IPC.f90: Subroutine that executes Individual Pitch Control

# Manuals

## Compile the DISCON dll with FAST V8

Tested with FAST v8.16.00a and Windows 10 Home

* Download FAST v8 from the NREL <https://nwtc.nrel.gov/FAST8>
* Execute FAST\_v8.16.00a-bjj.exe and extract the zip to C:\FAST preferably
* Download the compiler MinGW from their <http://www.mingw.org/download/installer?>
* Install MinGW to C:\MinGW preferably
* Add FAST and MinGW to your Path: go to Control Panel 🡪 System and Security 🡪 System 🡪 Advanced system settings 🡪 Environment Variables. (In Dutch: Configuratiescherm 🡪 Systeem en beveiliging 🡪 Systeem 🡪 Geavanceerde systeeminstellingen 🡪 Omgevingsvariabelen.) Under system variables double click Path and add the following paths:
  + C:\FAST\bin
  + C:\MinGW\bin
* Make sure to click OK on every opened window and then log off and on or restart the computer
* By typing path in the command window you can check if the paths are correctly added to the list
* Copy the files from the provided DISCON\_DLL directory to their correct location
  + Copy all files in DISCON\_DLL\Scripts to FAST\
  + Copy DISCON.IN to FAST\CertTest
  + Copy CONSTSteps\_MPS.wnd to FAST\CertTest\5MW\_Baseline\Wind
  + Copy all files in DISCON\_DLL\Source to FAST\CertTest\5MW\_Baseline\ServoData\Source. Replace the DISCON.f90 file there.
* In FAST\Compiling in the makefile\_DISCON\_DLLmake sure the following parameters are set:
  + Line 13: BITS = 32
  + Line 20: DLL\_DIR = ../CertTest/5MW\_Baseline/ServoData/Source
  + Line 22: SOURCE\_FILE = FunctionToolbox.f90 Filters.f90 IPC.f90 DISCON.f90
* Rename makefile to makefile\_FAST (or something different) and rename makefile\_DISCON\_DLL to makefile
* By executing CompileDISCON.cmd in FAST\ the DISCON dll is compiled

## Run Test18

Test 18 is a standard test for FAST with an external DISCON dll. Follow these steps to run it:

* In FAST\CertTest\Test18.fst
  + Line 39: set OutFileFmt to 1
* In FAST\CertTest\5MW\_Baseline\NRELOffshrBsline5MW\_Onshore\_ServoDyn.dat, replace the ----BLADED INTERFACE---- section with the contents in ServoDynBladedInterface\_NREL5MW.dat.
* Run the test by executing RunTest18.cmd in FAST\

### Plot results in Matlab

The Matlab script plotTest18.m in FAST\ imports and plots data from Test18. The data is imported in a structure and plots can easily be added when needed.

### Custom uniform stepped wind input

Test18 uses a 60 second wind profile as input. Instead, a uniform stepped wind profile can be used:

* In FAST\CertTest\5MW\_Baseline\NRELOffshrBsline5MW\_InflowWind\_12mps.dat:
  + Line 5: change WindType from 3 to 2
  + Line 16: set Filename to Wind/CONSTSteps\_MPS.wnd
* CONSTSteps\_MPS.wnd (in FAST\CertTest\5MW\_Baseline\Wind) can be modified to get the desired wind profile.
* In FAST\CertTest\Test18.fst:
  + Line 6: set TMax to the required simulation time
* Execute RunTest18.cmd in FAST\

## Enable active yaw control

To enable active yaw control some settings needs to be changed. Note that currently (18 Aug. 2017) active yaw control cannot be used because of a bug in FAST (see the first section for more information):

* In FAST\CertTest\5MW\_Baseline\NRELOffshrBsline5MW\_Onshore\_ServoDyn.dat:
  + Line 52: set YCMode to 5
  + Line 53: set TYCOn to 0
* In FAST\CertTest\5MW\_Baseline\NRELOffshrBsline5MW\_Onshore\_ElastoDyn.dat:
  + Line 16: make sure that YawDOF is set to True

## Setting up a debug archive

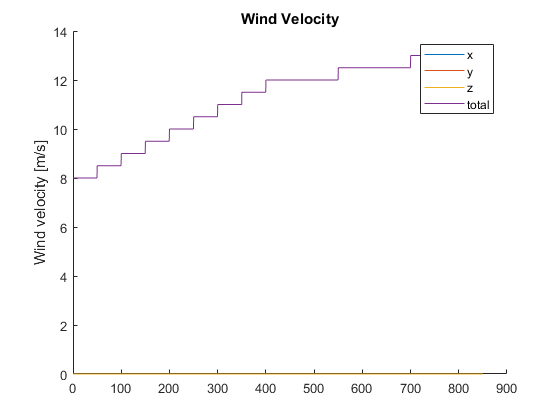
If the DISCON dll is developed further and it gets tested often, a debug archive can be set up. There is support to automatically put test results in a separate folder with a timestamp and plot them if needed:

* Make a new directory for the archive on your computer
* Copy the content of DISCON\_dll\Debug to the archive directory
* In CompileRunAndDebug.cmd:
  + Line 7: set FASTdir to your absolute FAST directory
  + Line 11: set ArchiveDir to your absolute archive directory
* In CompileRunAndPause.cmd:
  + Line 6: set FASTdir to your FAST directory
* In DISCON.f90 in FAST\CertTest\5MW\_Baseline\ServoData\Source:
  + Line 123: set DbgOut to .TRUE.
* Now by executing CompileRunAndDebug.cmd Test 18 is run and the test data is stored in a new folder in the archive directory
* To plot data from a certain test plotDebugData.m can be used. Make sure that data from the correct folder gets plotted. In plotDebugData.m:
  + Line 12: change timeStamp to the name of the folder the debug files are in
* By executing saveFigs.m afterwards, all opened figures get saved in the folder the debug files are located.

# Comparison

In the following pages we will show a side by side comparison of the performance of the discrete controller and a comparable controller made in Simulink. The controller in Simulink runs without using IPC. It can be seen that the discrete controller still needs some tuning.

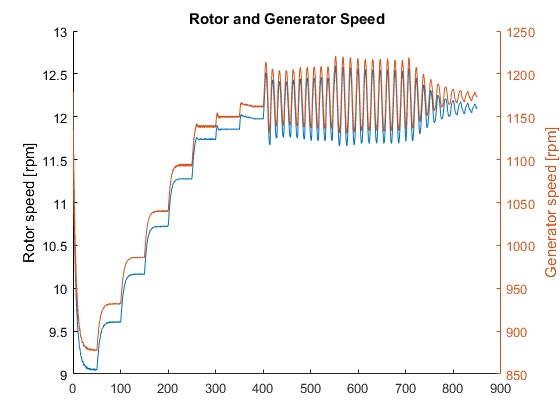
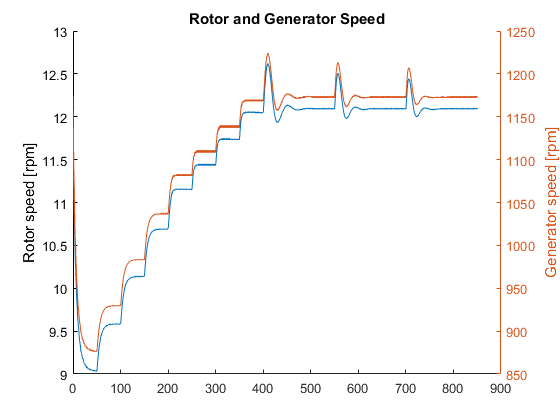
# Wind input



### Rotor and Generator Speed

Top: Simulink

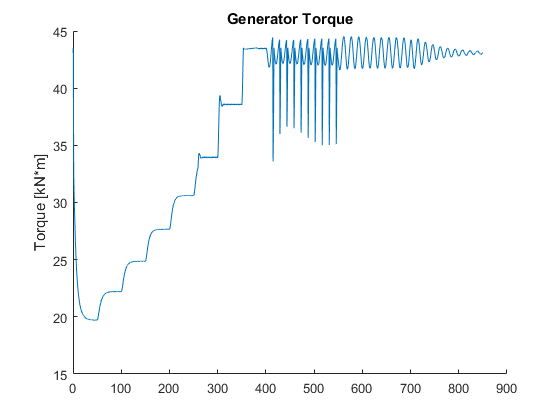
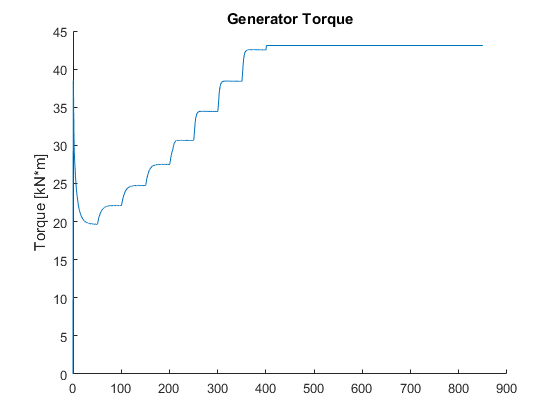
Bottom: DISCON dll



### Generator Torque

Top: Simulink

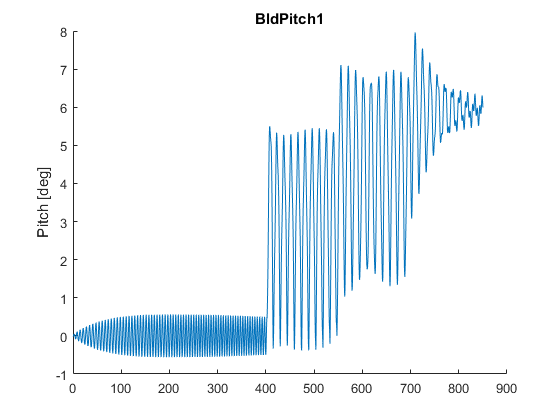
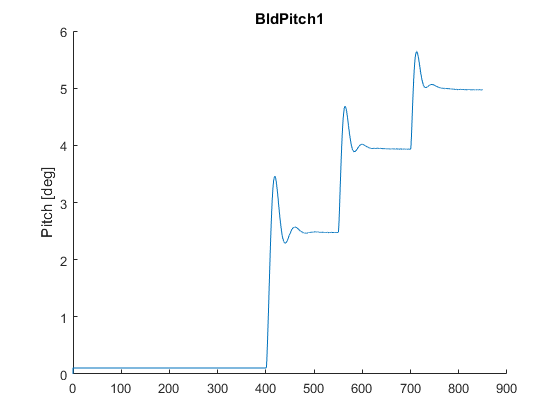
Bottom: DISCON dll



### Blade Pitch

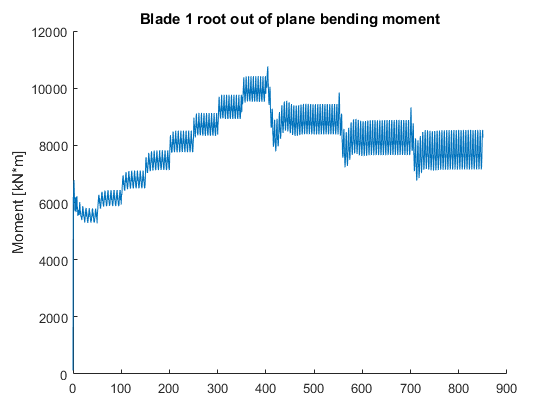
Top: Simulink

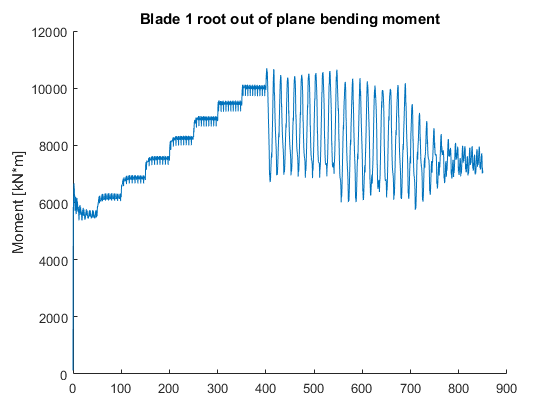
Bottom: DISCON dll



### Blade root out of plane bending moments

Top: Simulink

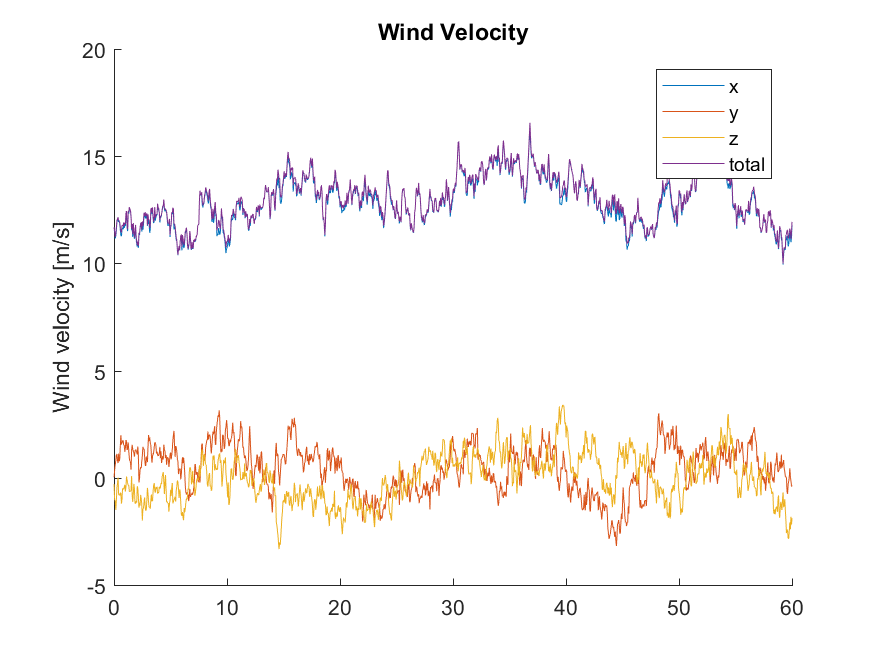
Bottom: DISCON dll



### Wind input

Top: Simulink

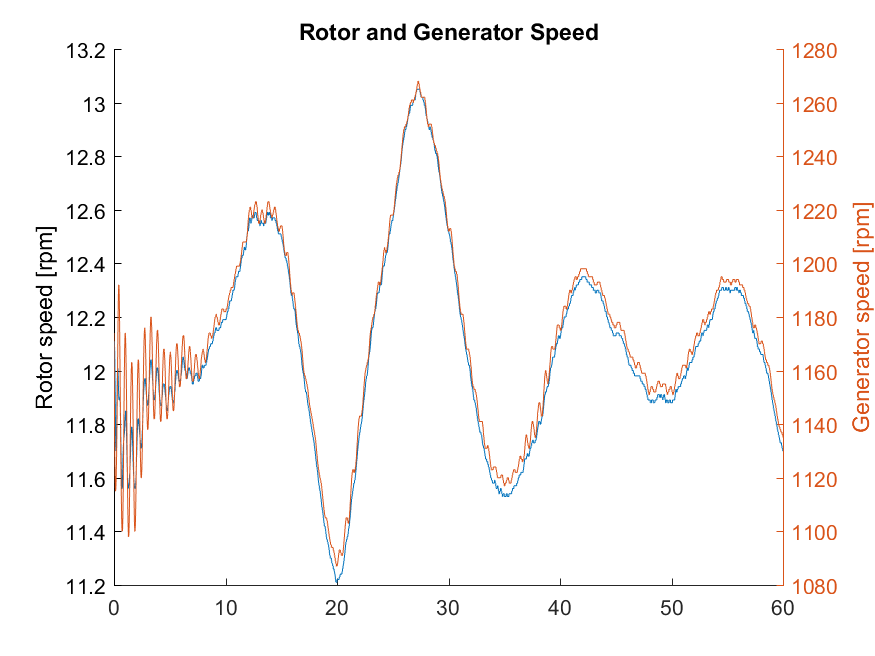
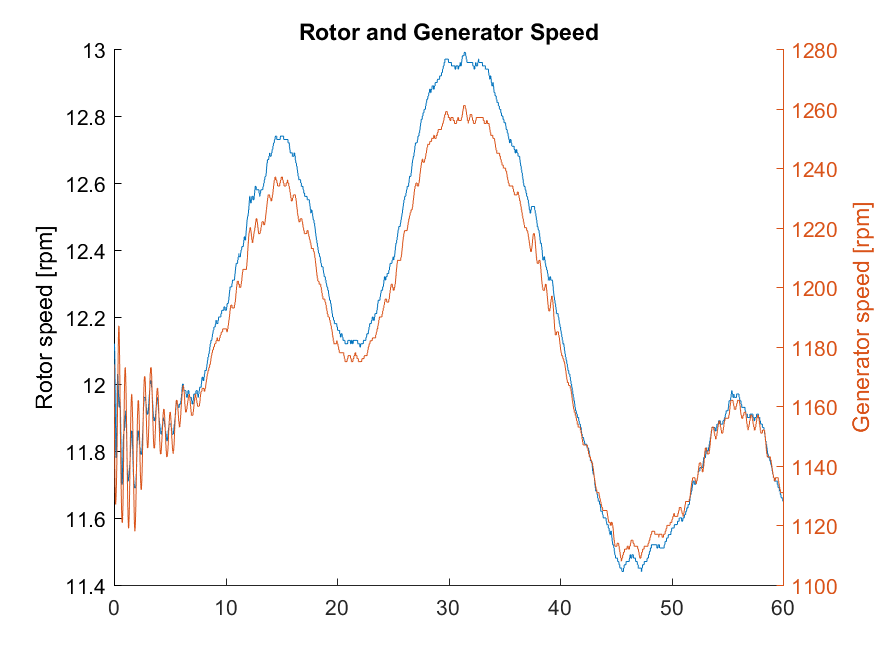
Bottom: DISCON dll



### Rotor and Generator Speed

Top: Simulink

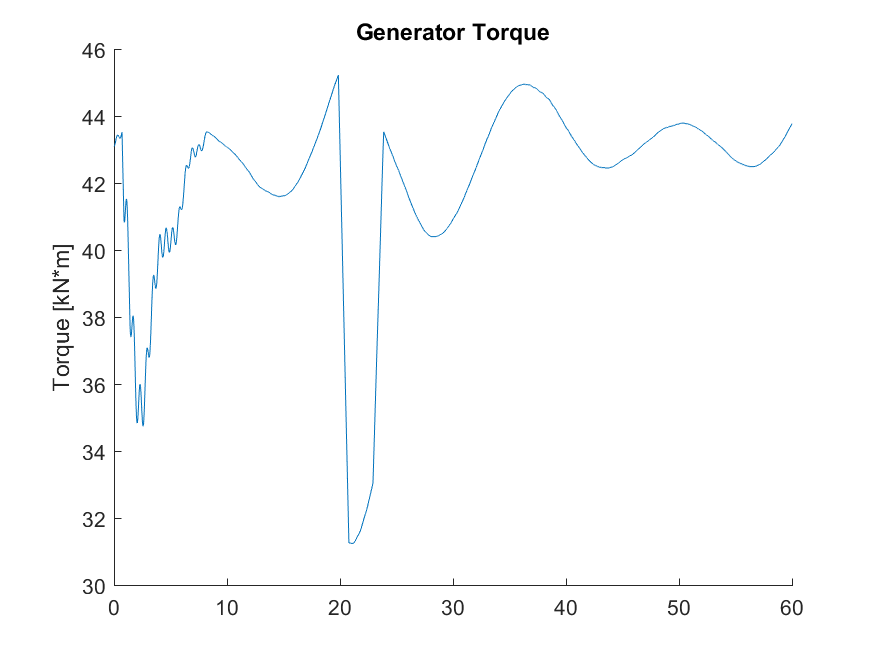
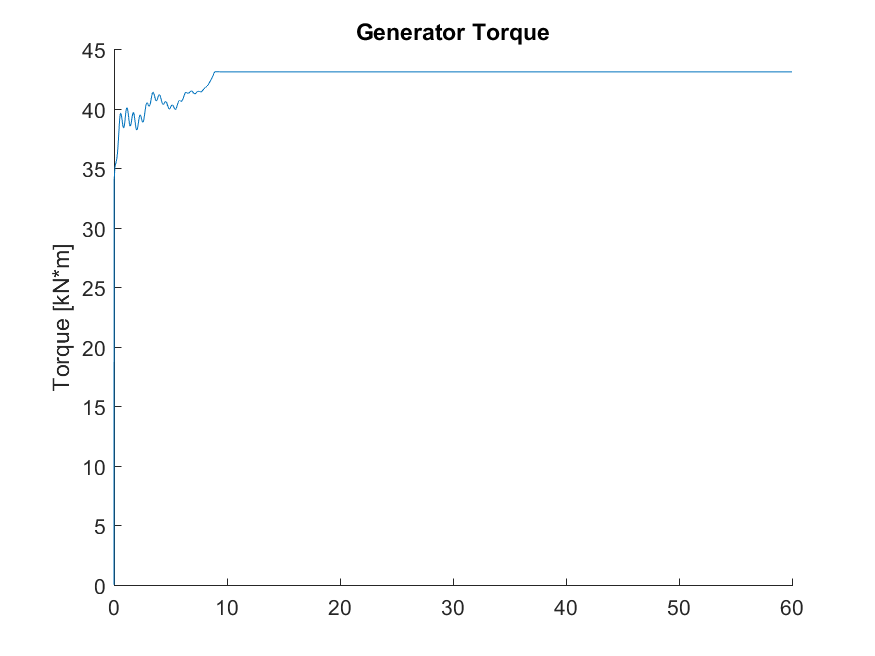
Bottom: DISCON dll



### Generator Torque

Top: Simulink

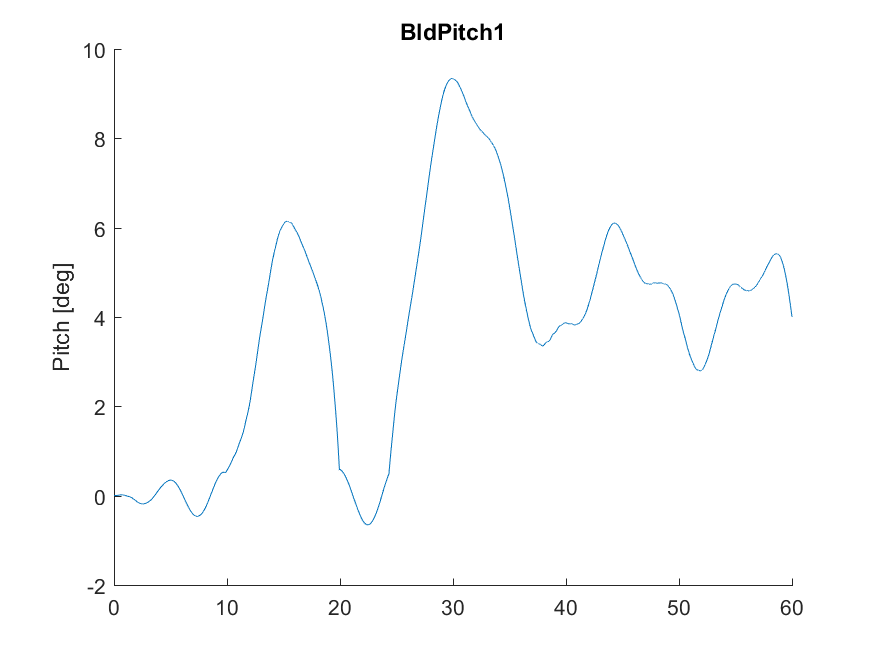
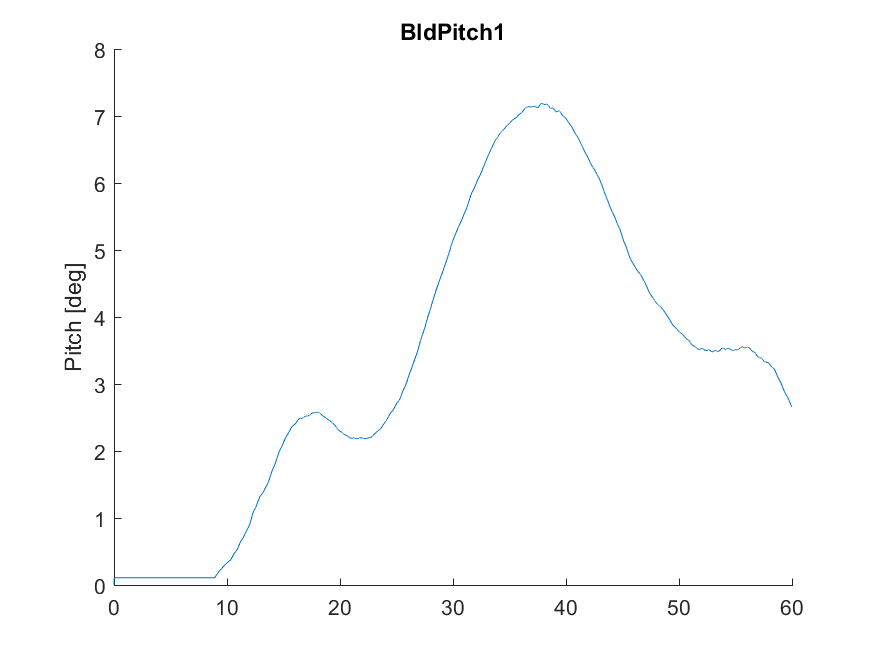
Bottom: DISCON dll



### Blade Pitch

Top: Simulink

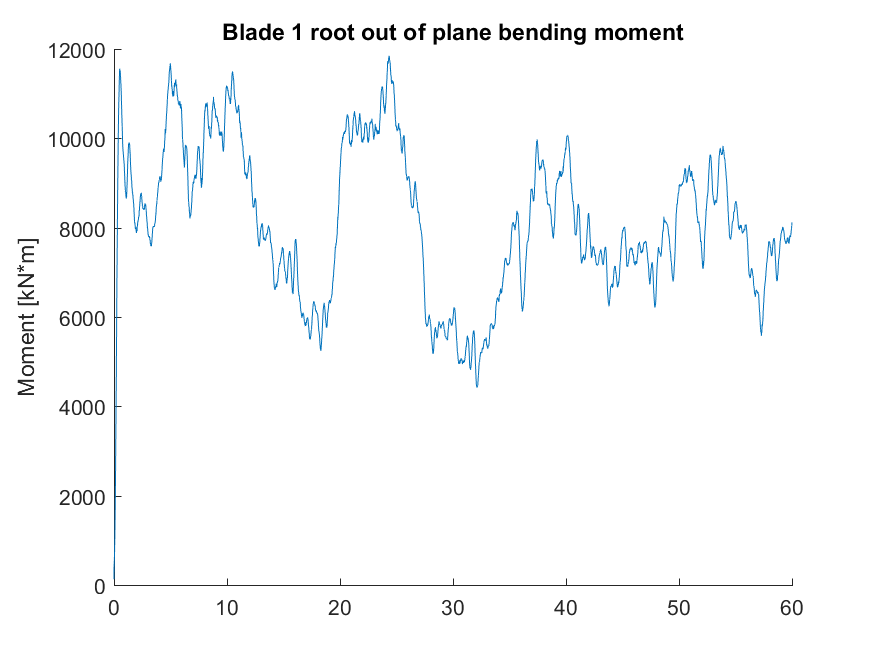
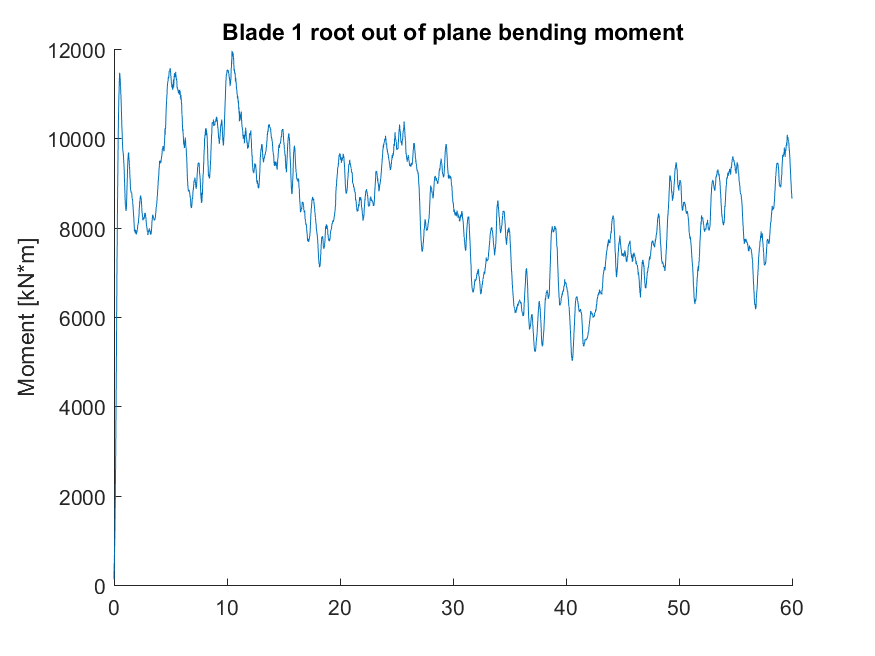
Bottom: DISCON dll



### Blade root out of plane bending moments

Top: Simulink

Bottom: DISCON dll



# avrSWAP

For the sake of convenience, the content of the avrSWAP records can be seen here. See also Bladed User Manual Version 4.2 from Garrad Hassan & Partners Ltd, appendix A.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Record** | **Data** | **Data** |  | **See** |  |
| **number** | **flow8** | **type9 Description** | | **note(s** | **Units** |
|  |  |  |  | **)** |  |
| 1 | in | I | See Section A.2 |  | - |
| 2 | in | R | Current time |  | s |
| 3 | in | R | Communication interval |  | s |
| 4 | in | R | Blade 1 pitch angle |  | rad |
| 5 | in | R | Below-rated pitch angle set-point | 1 | rad |
| 6 | in | R | Minimum pitch angle | 1 | rad |
| 7 | in | R | Maximum pitch angle | 1 | rad |
| 8 | in | R | Minimum pitch rate (most negative value allowed) |  | rad/s |
| 9 | in | R | Maximum pitch rate |  | rad/s |
| 10 | in | I | 0 = pitch position actuator, 1 = pitch rate actuator |  | - |
| 11 | in | R | Current demanded pitch angle |  | rad |
| 12 | in | R | Current demanded pitch rate |  | rad/s |
| 13 | in | R | Demanded power | 2 | W |
| 14 | in | R | Measured shaft power | 3 | W |
| 15 | in | R | Measured electrical power output |  | W |
| 16 | in | R | Optimal mode gain | 3,5 | Nm/(rad/s)2 |
| 17 | in | R | Minimum generator speed | 3 | rad/s |
| 18 | in | R | Optimal mode maximum speed | 3 | rad/s |
| 19 | in | R | Demanded generator speed above rated | 1,3 | rad/s |
| 20 | in | R | Measured generator speed |  | rad/s |
| 21 | in | R | Measured rotor speed |  | rad/s |
| 22 | in | R | Demanded generator torque above rated | 3 | Nm |
| 23 | in | R | Measured generator torque | 3 | Nm |
| 24 | in | R | Measured yaw error | 4 | rad |
| 25 | in | I | Start of below-rated torque-speed look-up table =R | 3,5 | Record no. |
| 26 | in | I | No. of points in torque-speed look-up table =N | 3,5 | - |
| 27 | in | R | Hub wind speed | 4 | m/s |
| 28 | in | I | Pitch control: 0 = collective, 1 = individual |  | - |
| 29 | in | I | Yaw control: 0 = yaw rate control, 1 = yaw torque control |  | - |
| 30-32 | in | R | Blade 1-3 root out of plane bending moment | 18 | Nm |
| 33 | in | R | Blade 2 pitch angle |  | rad |
| 34 | in | R | Blade 3 pitch angle |  | rad |
| 35 | both | I | Generator contactor | 10 | - |
| 36 | both | I | Shaft brake status: 0=off, 1=Brake 1 on | 19 | - |
| 37 | in | R | Nacelle angle from North |  | rad |
| 38-40 | out |  | Reserved |  |  |
| 41 | out | R | Demanded yaw actuator torque | 13,21 | Nm |
| 42 | out | R | Demanded blade 1 individual pitch position or rate | 12,14 | rad or rad/s |
| 43 | out | R | Demanded blade 2 individual pitch position or rate | 12,14 | rad or rad/s |
| 44 | out | R | Demanded blade 3 individual pitch position or rate | 12,14 | rad or rad/s |
| 45 | out | R | Demanded pitch angle (Collective pitch) | 12 | rad |
| 46 | out | R | Demanded pitch rate (Collective pitch) | 12 | rad/s |
| 47 | out | R | Demanded generator torque |  | Nm |
| 48 | out | R | Demanded nacelle yaw rate | 13,21 | rad/s |
| 49 | out | I | Message length OR -M0 | 15 | - |
| 49 | in | I | Maximum no. of characters allowed in the “MESSAGE” | 6 | - |
| 50 | in | I | No. of characters in the “INFILE” argument | 6 | - |

....continued overleaf....



|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Record** | **Data** | **Data** |  | **See** |  |
| **number** | **flow8** | **type9 Description** | | **note(s** | **Units** |
|  |  |  |  | **)** |  |
| 51 | in | I | No. of characters in the “OUTNAME” argument | 6 | - |
| 52 | in | I | DLL interface version number (reserved for future use) | 6 | - |
| 53 | in | R | Tower top fore-aft acceleration |  | m/s2 |
| 54 | in | R | Tower top side to side acceleration |  | m/s2 |
| 55 | out | I | Pitch override | 16 | - |
| 56 | out | I | Torque override | 16 | - |
| 57-59 | out |  | Reserved |  |  |
| 60 | in | R | Rotor azimuth angle |  | rad |
| 61 | in | I | No. of blades |  | - |
| 62 | in | I | Max. number of values which can be returned for logging | 7 | - |
| 63 | in | I | Record number for start of logging output | 7 | - |
| 64 | in | I | Max. no. of characters which can be returned in | 7 | - |
|  |  |  | “OUTNAME” |  |  |
| 65 | out | I | Number of variables returned for logging | 17 | - |
| 66-68 | in | R | Reserved |  |  |
| 69-71 | in | R | Blade 1-3 root in plane bending moment | 18 | Nm |
| 72 | out | R | Generator start-up resistance |  | ohm/phase |
| 73 | in | R | Rotating hub My (GL co-ords) | 18 | Nm |
| 74 | in | R | Rotating hub Mz (GL co-ords) | 18 | Nm |
| 75 | in | R | Fixed hub My (GL co-ords) | 18 | Nm |
| 76 | in | R | Fixed hub Mz (GL co-ords) | 18 | Nm |
| 77 | in | R | Yaw bearing My (GL co-ords) | 18 | Nm |
| 78 | in | R | Yaw bearing Mz (GL co-ords) | 18 | Nm |
| 79 | out | I | Request for loads | 18 | - |
| 80 | out | I | 1 = Variable slip current demand at position 81 | 11 | - |
| 81 | both | R | Variable slip current demand | 11 | A |
| 82 | in | R | Nacelle roll acceleration | 18 | rad/s2 |
| 83 | in | R | Nacelle nodding acceleration | 18 | rad/s2 |
| 84 | in | R | Nacelle yaw acceleration | 18 | rad/s2 |
| 85-89 |  |  | Reserved |  |  |
| 90 | in | R | Real time simulation time step |  | s |
| 91 | in | R | Real rime simulation time step multiplier |  | - |
| 92 | out | R | Mean wind speed increment | 20 | m/s |
| 93 | out | R | Turbulence intensity increment | 20 | % |
| 94 | out | R | Wind direction increment | 20 | rad |
| 95-96 |  |  | Reserved |  |  |
| 97 | in | I | Safety system number that has been activated |  | - |
| 98 | out | I | Safety system number to activate |  | - |
| 99 | in | I | Reserved |  |  |
| 100 | in | I | Reserved |  |  |
| 101 | in | R | Reserved |  |  |
| 102 | out | I | Yaw control flag | 21 | - |
| 103 | out | R | Yaw stiffness if record 102 = 1 or 3 | 21 | - |
| 104 | out | R | Yaw damping if record 102 = 2 or 3 | 21 | - |
| 105 | in | R | Reserved |  |  |
| 106 | in | R | Reserved |  |  |
| 107 | out | R | Brake torque demand | 19, 22 | Nm |

....continued overleaf....

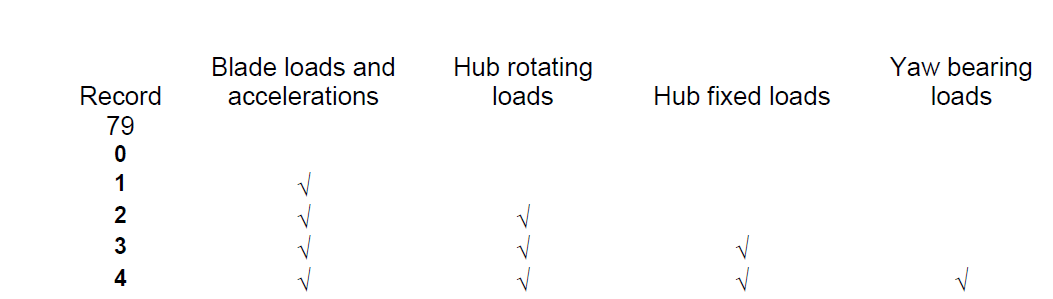


|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 108 | out | R | Yaw brake torque demand |  | Nm |
| 109 | in | R | Shaft torque (= hub Mx for clockwise rotor) | 18 | Nm |
| 110 | in | R | Hub Fixed Fx | 18 | N |
| 111 | in | R | Hub Fixed Fy | 18 | N |
| 112 | in | R | Hub Fixed Fz | 18 | N |
| 113 | in | R | Network voltage disturbance factor |  | - |
| 114 | in | R | Network frequency disturbance factor |  | - |
| 115-116 |  |  | Reserved |  |  |
| 117 | in | I | Controller state | 23 | - |
| 118 | in | R | Settling time (time to start writing output) |  | s |
| 119 |  |  | Reserved |  |  |
| 120-129 | both | R | User-defined variables 1 to 10 | 24 |  |
| 130-142 |  |  | Reserved |  |  |
| 143 | in | R | Teeter angle |  | rad |
| 144 | in | R | Teeter velocity |  | rad/s |
| 145-160 |  |  | Reserved |  |  |
| 161 | in | I | Controller failure flag |  | - |
| R | in | R | First generator speed in look-up table | 3,5 | rad/s |
| R+1 | in | R | First generator torque in look-up table | 3,5 | Nm |
| R+2 | in | R | Second generator speed in look-up table | 3,5 | rad/s |
| R+3 | in | R | Second generator torque in look-up table | 3,5 | Nm |
| ... |  | ... | ... etc., until ... |  | ... |
| R+2N-2 | in | R | Last generator speed in look-up table | 3,5 | rad/s |
| R+2N-1 | in | R | Last generator torque in look-up table | 3,5 | Nm |
| M0 | out | I | Message length, only if record 49 < 0 | 15 |  |
| M1 - Mn | out | C | Message text, 4 characters per record | 15 | - |
| L1 onwards | out | R | Variables returned for logging output | 17 | SI |

Notes:

1. Pitch regulated case only.
2. Not for variable speed pitch regulated case.
3. Variable speed case only.
4. Based on free wind at hub position - no modelling of actual nacelle anemometer or wind vane.
5. If the look-up table option is selected for the optimal mode below rated control, then record 16 is zero, record 25 contains the record number (R) of the start of the look-up table, and record 26 contains the number of points in the table (N).
6. DLL case only: see Sections [5.9.2](#page64) and A.3.
7. DLL case only: see Section A.5.
8. in = data supplied by simulation, which may be used but not changed by the external controller.  
   out = data supplied by the external controller to the simulation.  
   both = data which is written by the simulation but which may be changed by the external controller.
9. Record type for EXE case. I = integer, R = real (floating point), C = character. In the DLL case, all records are actually passed as 4-byte real (floating point) numbers.
10. 0 = off, 1 = main (high speed) or variable speed generator, 2 = low speed generator.
11. Only used with the variable slip generator electrical model. Set record 80 to 1 if using record 81 to send a rotor current demand. If record 80 is 0 (default), then the torque demand (record 47) will be used to control the generator.
12. See record 28.
13. See record 29.
14. Depending on record 10.
15. EXE case only: see Section A.3.
16. See Section A.4.
17. DLL case only; see Section A.5.
18. Record 79 is used to request additional measured loads and accelerations to be provided by the simulation:





1. For shaft brake 1; to apply additional brakes, this is a binary flag: specify a value of

where Bi = 1 if the brake with index number i is applied, otherwise 0. The brake index numbers are as follows:

|  |  |
| --- | --- |
| Index number | Brake description |
| **1** | **Shaft brake 1** |
| **2** | **Shaft brake 2** |
| **3** | **Generator brake** |
| **4** | **Shaft brake 3** |
| **5** | **Brake torque set in record 107** |

1. For the Real Time Test facility, it is useful for the user to be able to change the wind conditions manually during a simulation from code in the external controller. Bladed will increase the mean wind speed, turbulence intensity (of all components) and wind direction by the value set in the respective field.
2. Yaw control flag in record 102 (affects the flexible yaw model only):

0: Default (record 48 sets the yaw rate demand).

1: As 0 but change the linear yaw stiffness according to record 103 (no effect on hydraulic accumulator model).

2: As 0 but change the yaw damping according to record 104.

3: As 1 but also change the yaw damping according to record 104.

4: Use record 41 (yaw torque demand) to override the yaw spring and damper.

1. Brake torque demand used for brake index 5 (see note 19).
2. Controller state flag is set by the Bladed internal controller as follows:

0: Power production

1: Parked

2: Idling

3: Start-up

4: Normal stop

5: Emergency stop

1. May be used to share information between user-defined DLLs for different turbine components.