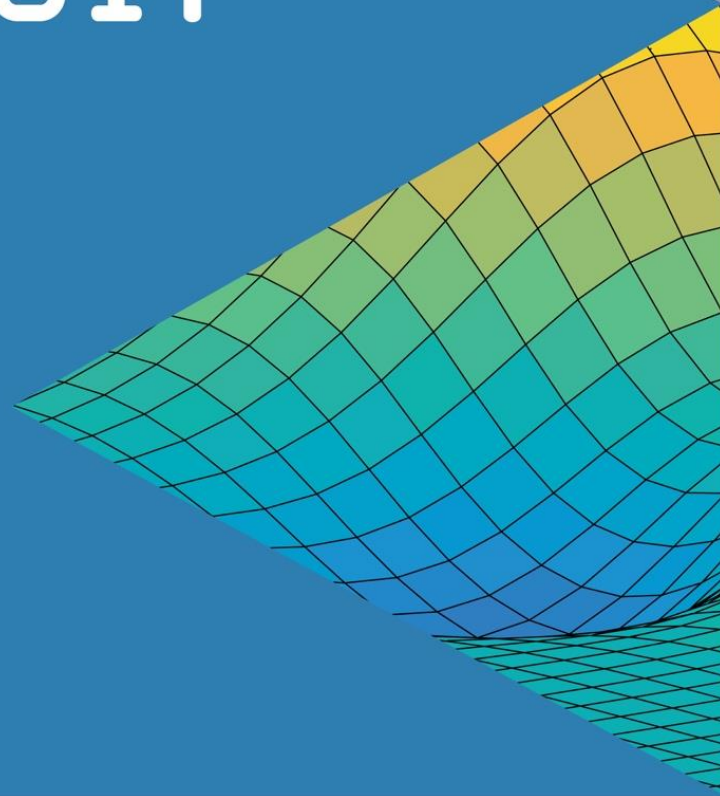


MATLAB EXPO 2017

Testing Simulink Models

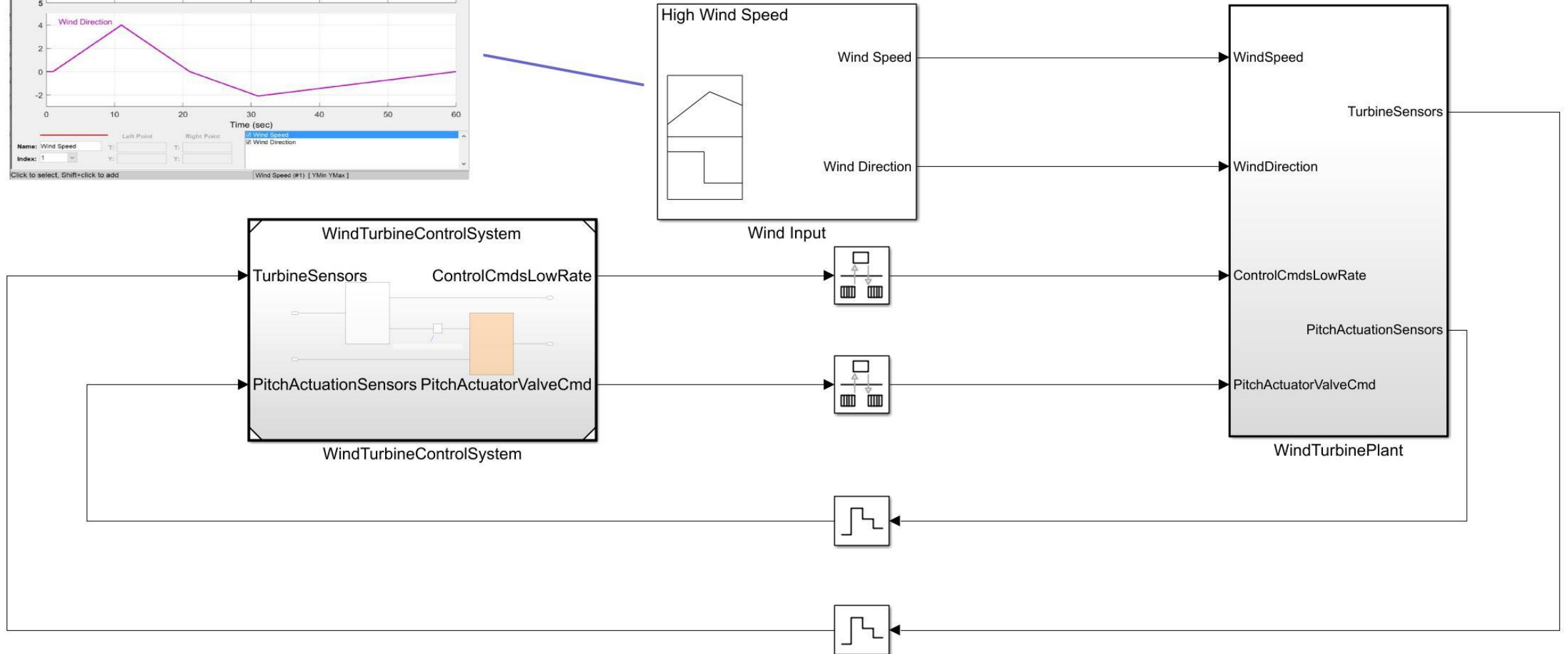
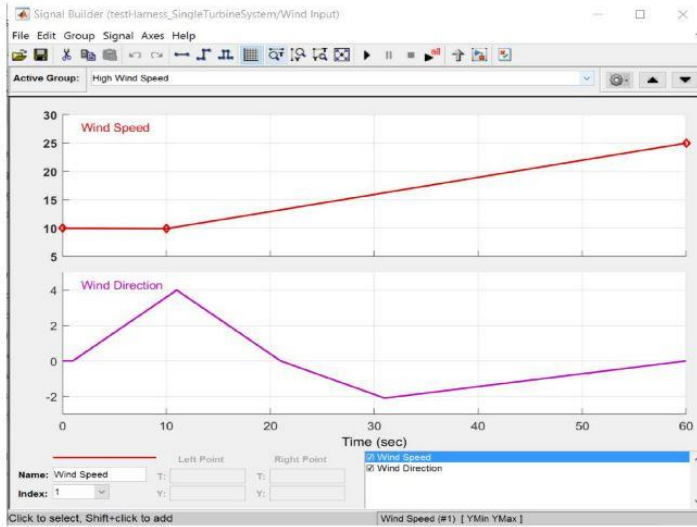
Fraser Macmillen



Test Infrastructure

- Model set-up desired parameters, variants, operating point, etc.
e.g. test start up script
- Model stimulus desired inputs driving the model
e.g. signal builder block, .xlsx, test sequence
- Views of behaviour signal traces, read-outs, animations, etc.
e.g. scopes, simulation data inspector
- Verification of behaviour desired behaviour is checked
e.g. verification blocks, post-simulation scripts

Wind Turbine



Common challenges:

- **Problem:** cannot do anything unless a particular script is run first
Solution: use project startup, data dictionaries, models always “ready to go”
- **Problem:** model is tied to particular means of stimulus (from file, signal builder, etc)
Solution: use test harnesses + variants
- **Problem:** changes to the design and test mixed together
Solution: save test infrastructure externally to your design; separate source control
- **Problem:** one person’s system is another person’s component
Solution: model referencing, suitable interfaces
- **Problem:** performance degraded by infrastructure not needed for “my test”
Solution: multiple harnesses / variants

Simulink Test

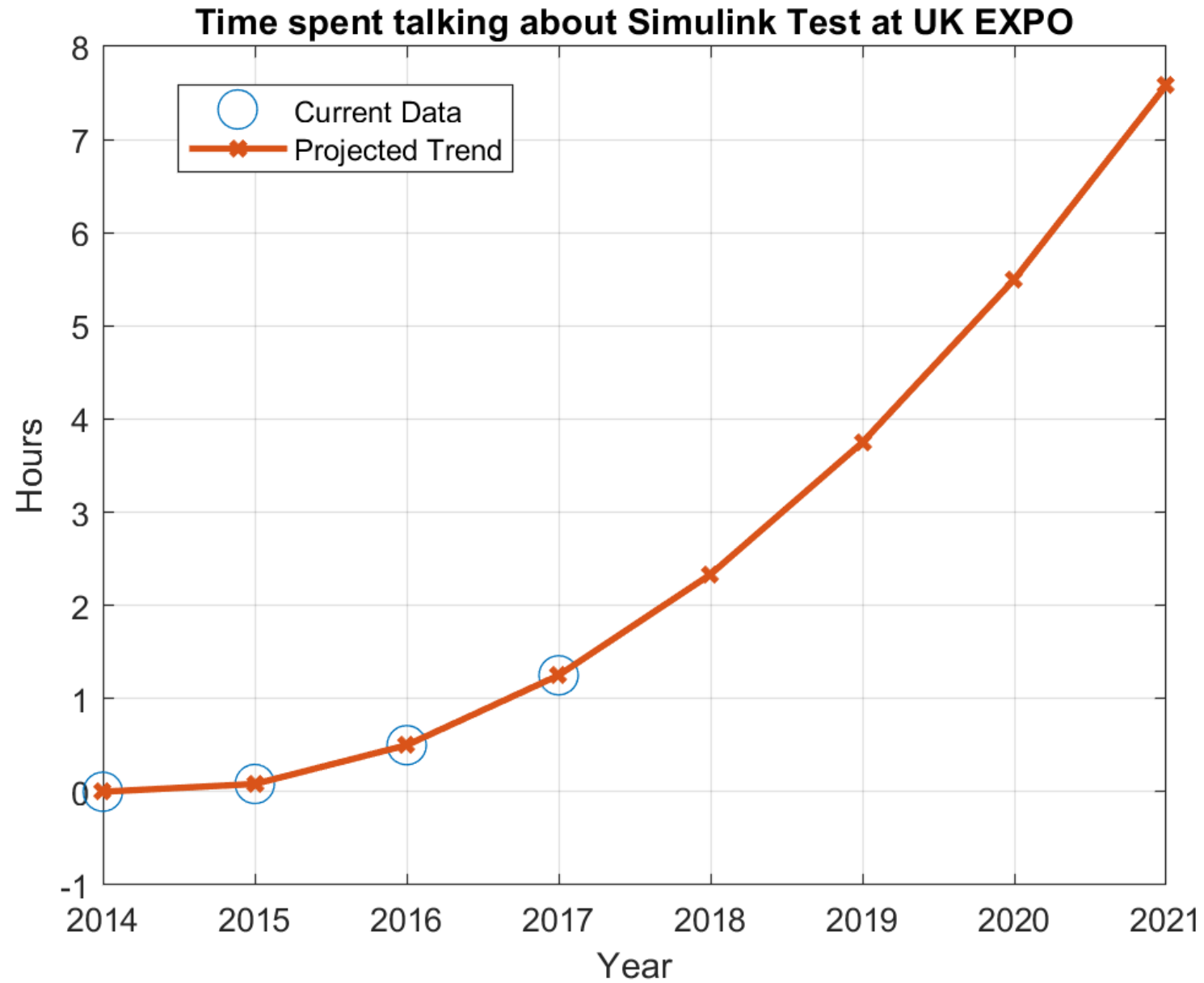
Why Simulink Test?

Saves you time:

- Creating / managing test infrastructure
- generating & (re)-running multiple tests
- reporting results
- a common test environment –
everyone doing things in a consistent manner

Gives you capability:

- new ways of authoring test scenarios
- easy integration with other tools
(Requirements, Coverage, Test Generation, MATLAB Unit Test, Continuous Integration)



Simulink Test Overview

1. Test Harnesses

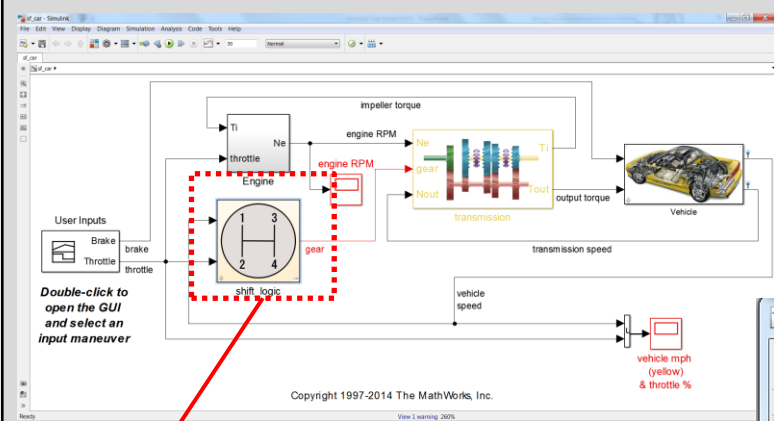
- Synchronized, simulatable test environment

2. Test Stimulus Integration

- Inputs and assessments based on logical, temporal conditions

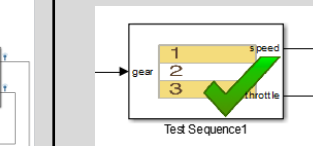
3. Test Manager

- Author, execute, manage test cases
- Review, export, report



Main Model

Component under test



DoubleSTDriven/Test Sequence1 - Test Sequence Editor

High Wind Speed

Wind Speed

Wind Direction

Wind Input

ConstantWindNoYaw

Wind Speed

Wind Direction

Excel

Test Manager

Slow Accel

Report Generated by Test Manager

Title: LandingGearControl-Regression Tests

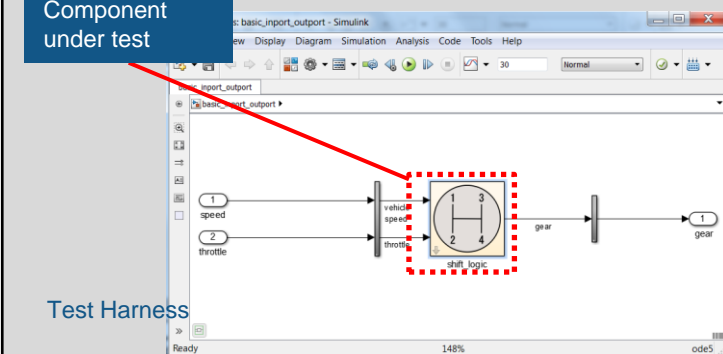
Author: Jessica Johnson

Date: 20-Feb-2015 18:28:22

Test Environment

Platform: PCWIN64

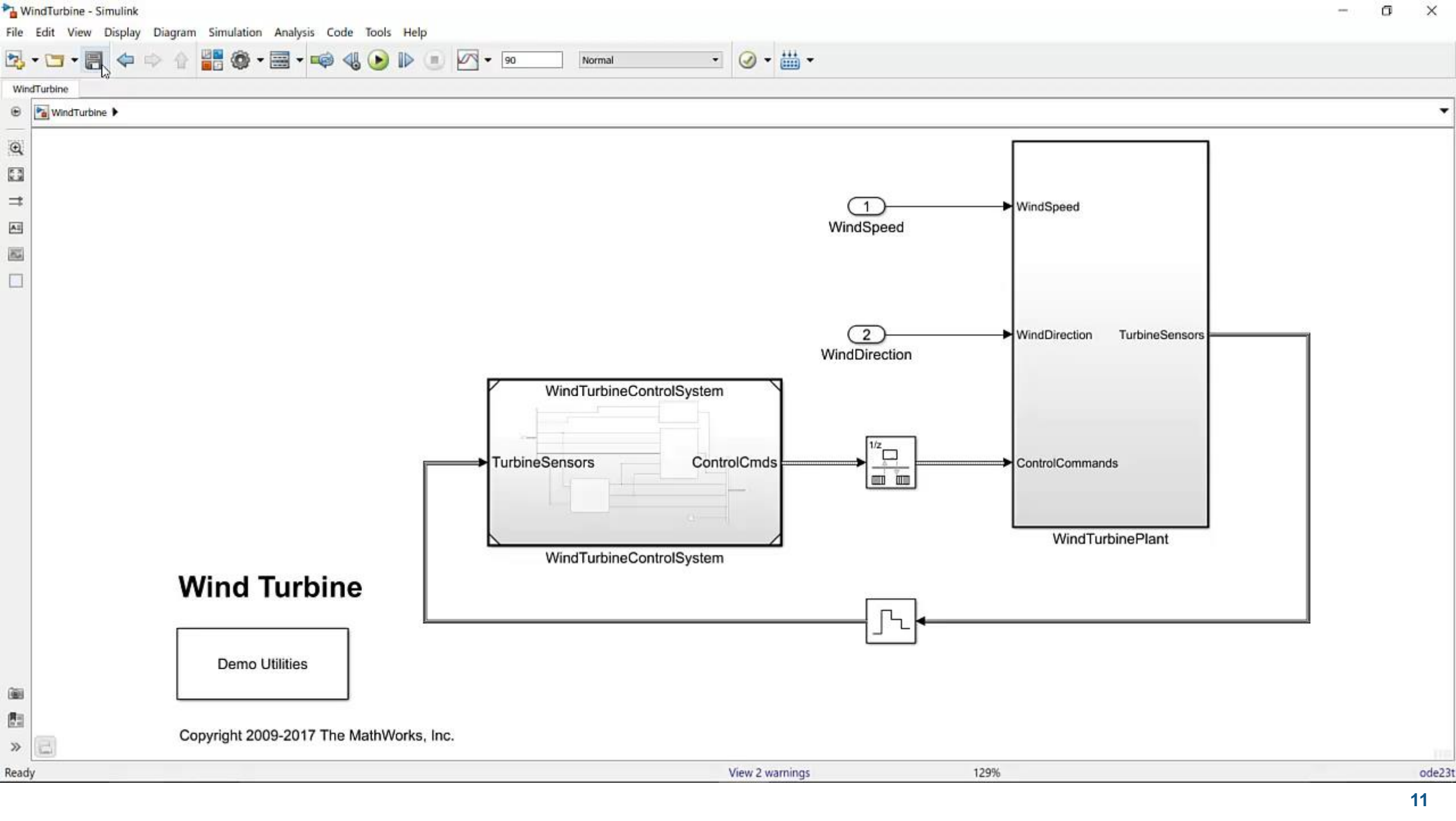
MATLAB: (R2015a)



Agenda

- Creating Test Harnesses
- Creating Test Cases
- Testing against Requirements
- Reporting
- Coverage analysis
- Multi-release regression testing
- Continuous integration

Test Harnesses

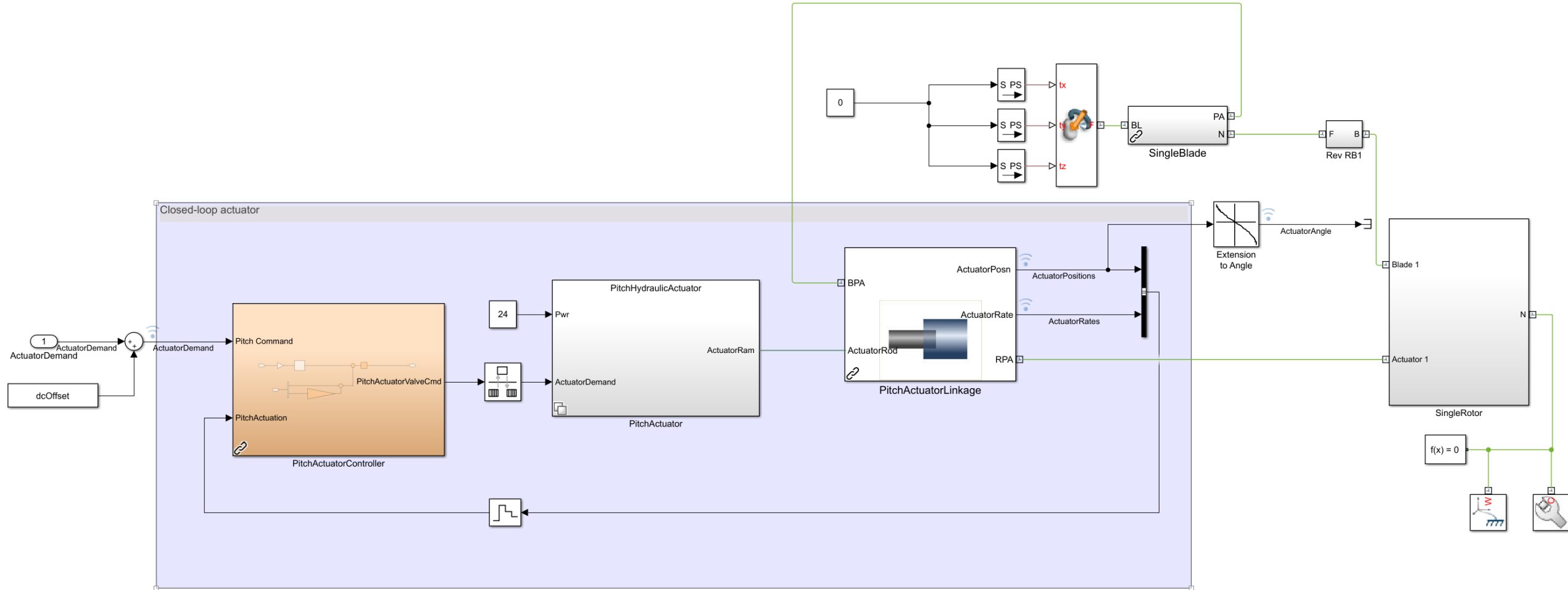


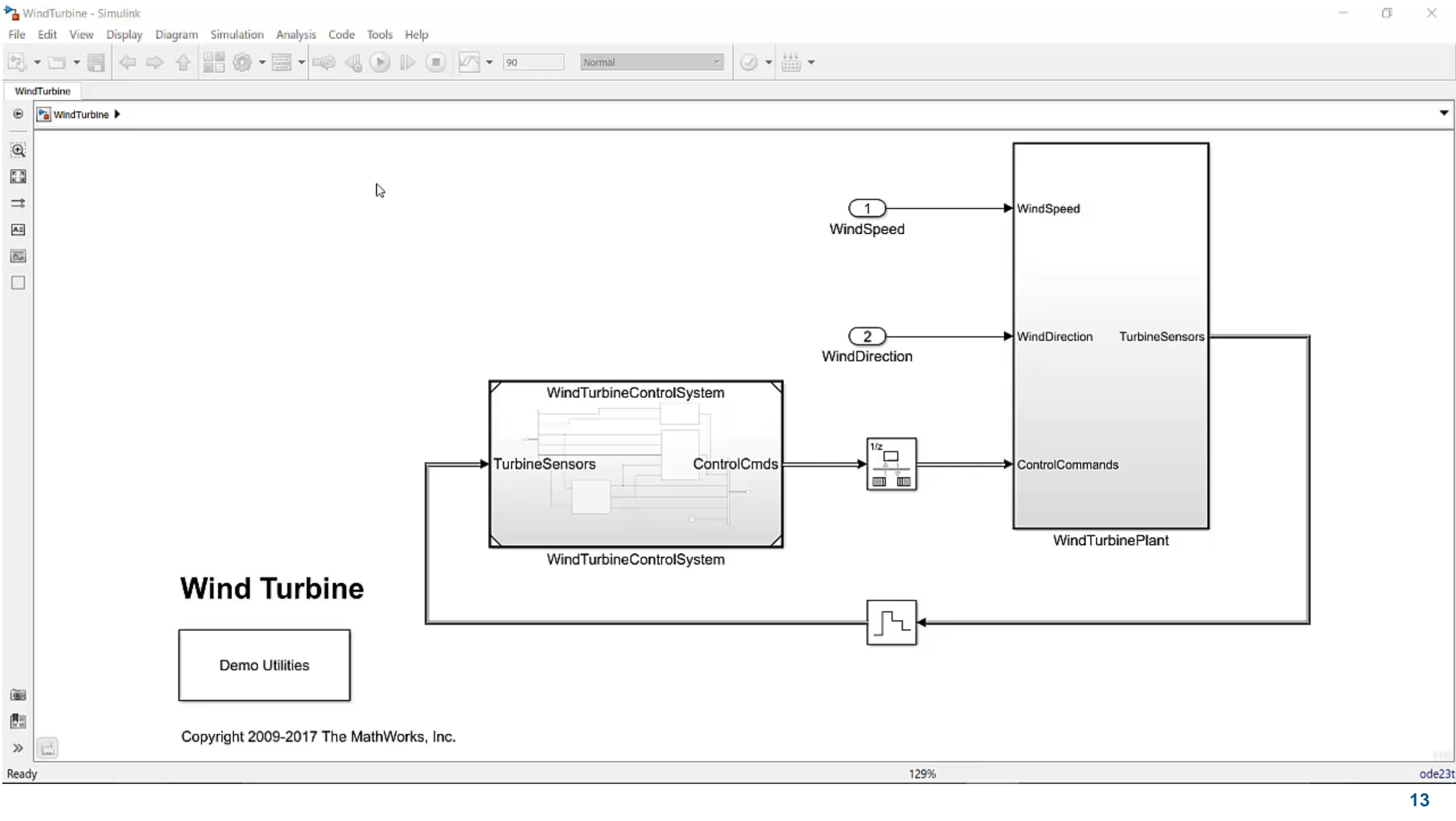
Wind Turbine

Demo Utilities

Copyright 2009-2017 The MathWorks, Inc.

What if you already have a harness model....





Common questions...

Do I need a separate harness for each test?

Test Harness Release Highlights

R2017a:

- Test harness import
- Create harnesses for components with physical (Simscape) connections
- More control over synchronisation

R2017b:

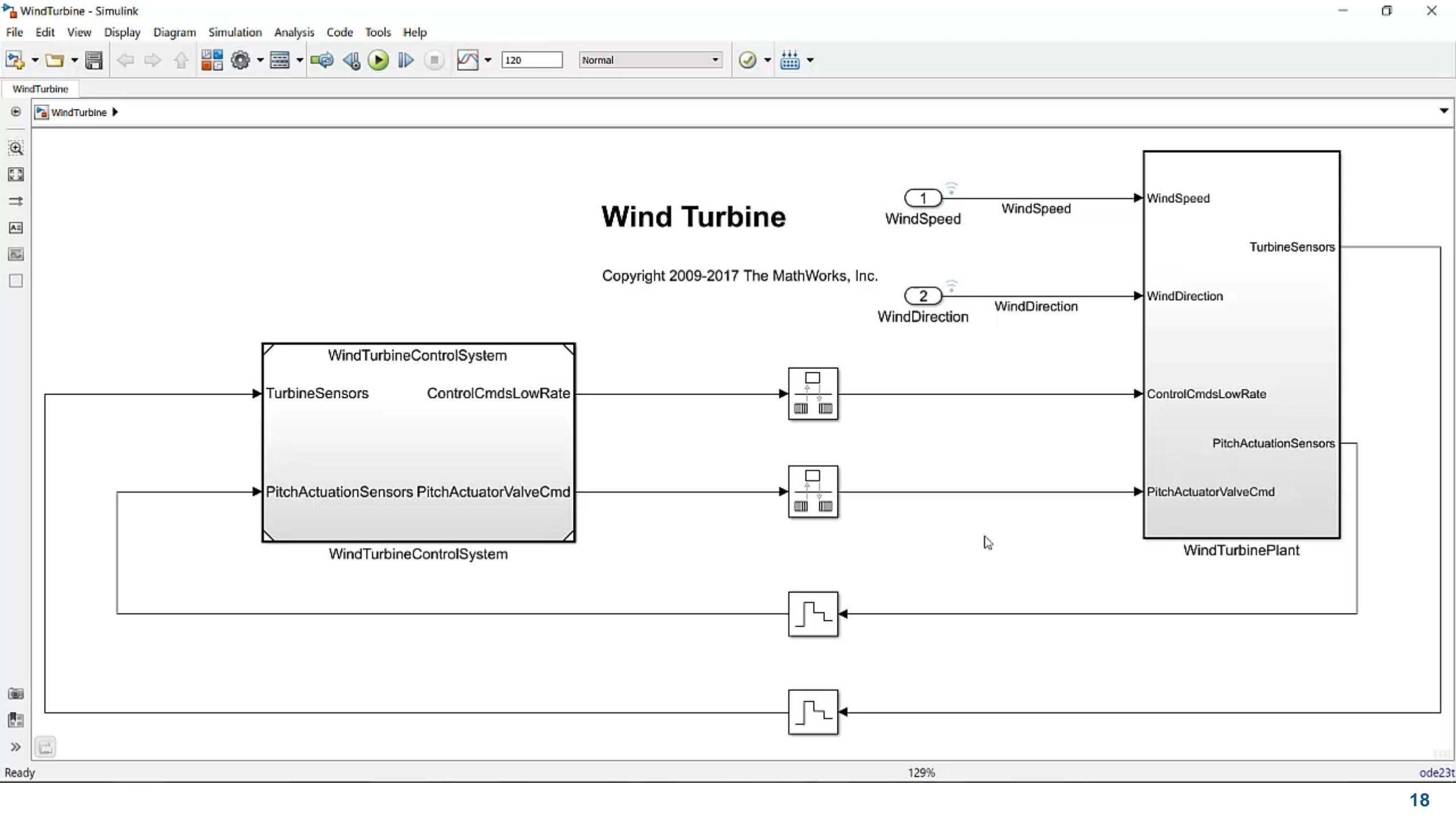
- Harness create/re-build callbacks
- Model comparison prior to synchronisation

Test Cases

&

Test Stimuli

Create a test case using the original signal builder

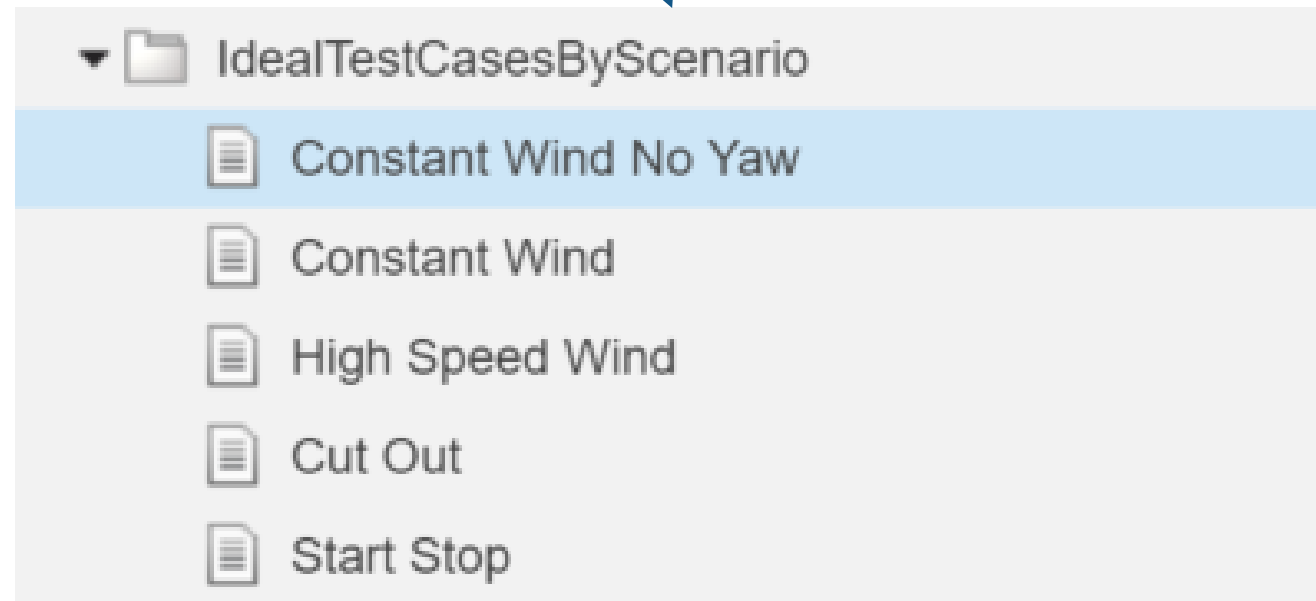
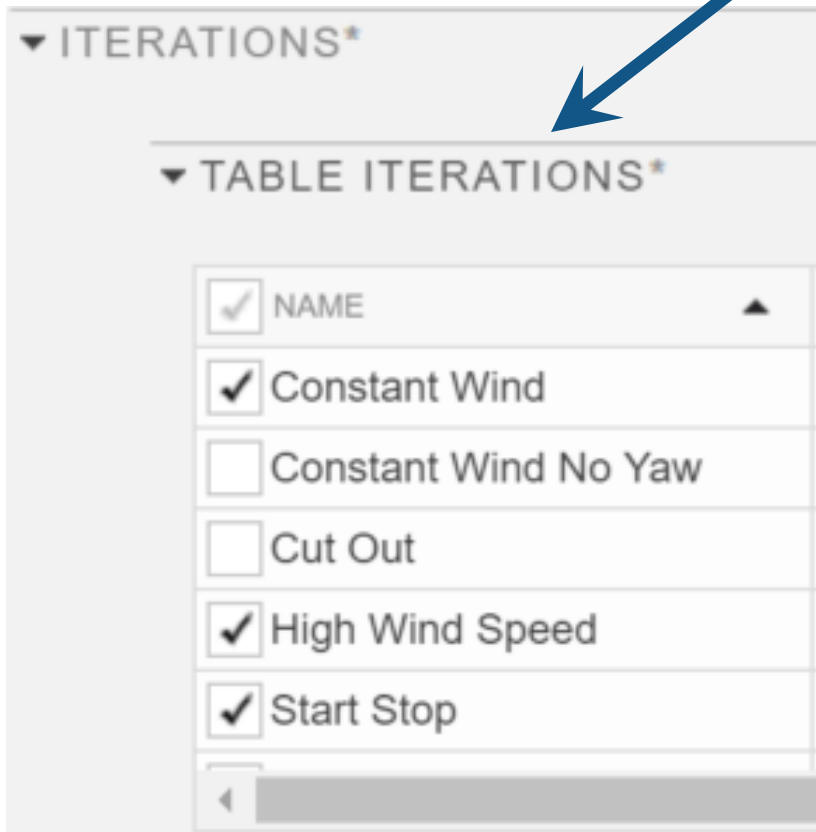


What have we done so far....

- Created and imported test harnesses
- Created a test case for running multiple simulations (iterations) with different scenarios

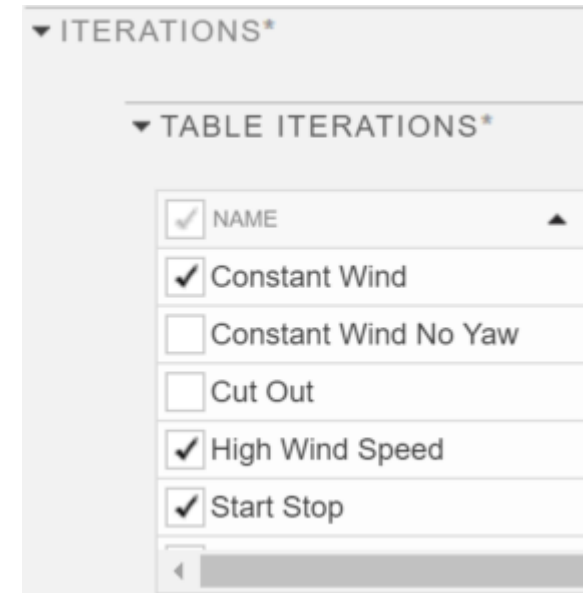
Common questions...

When should I use iterations vs multiple test cases?



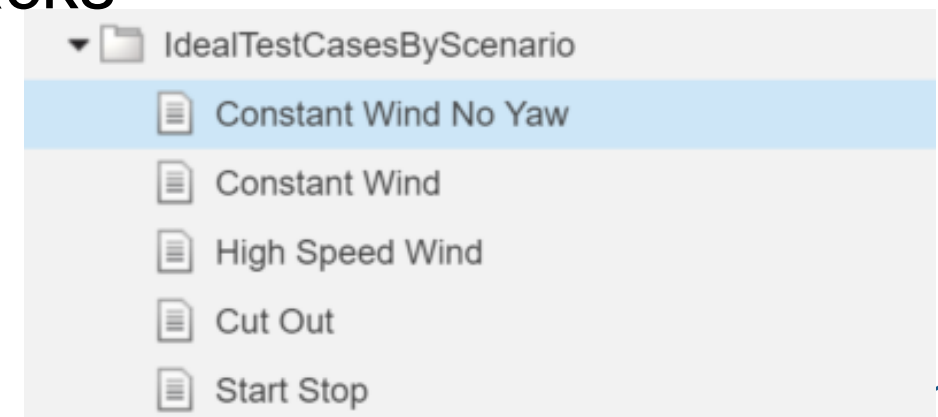
Use iterations if:

- Same model/harness & test type
- Same set-up (callbacks)
- Usually run together
- Relate to same requirements(s)
- Can use fast-restart



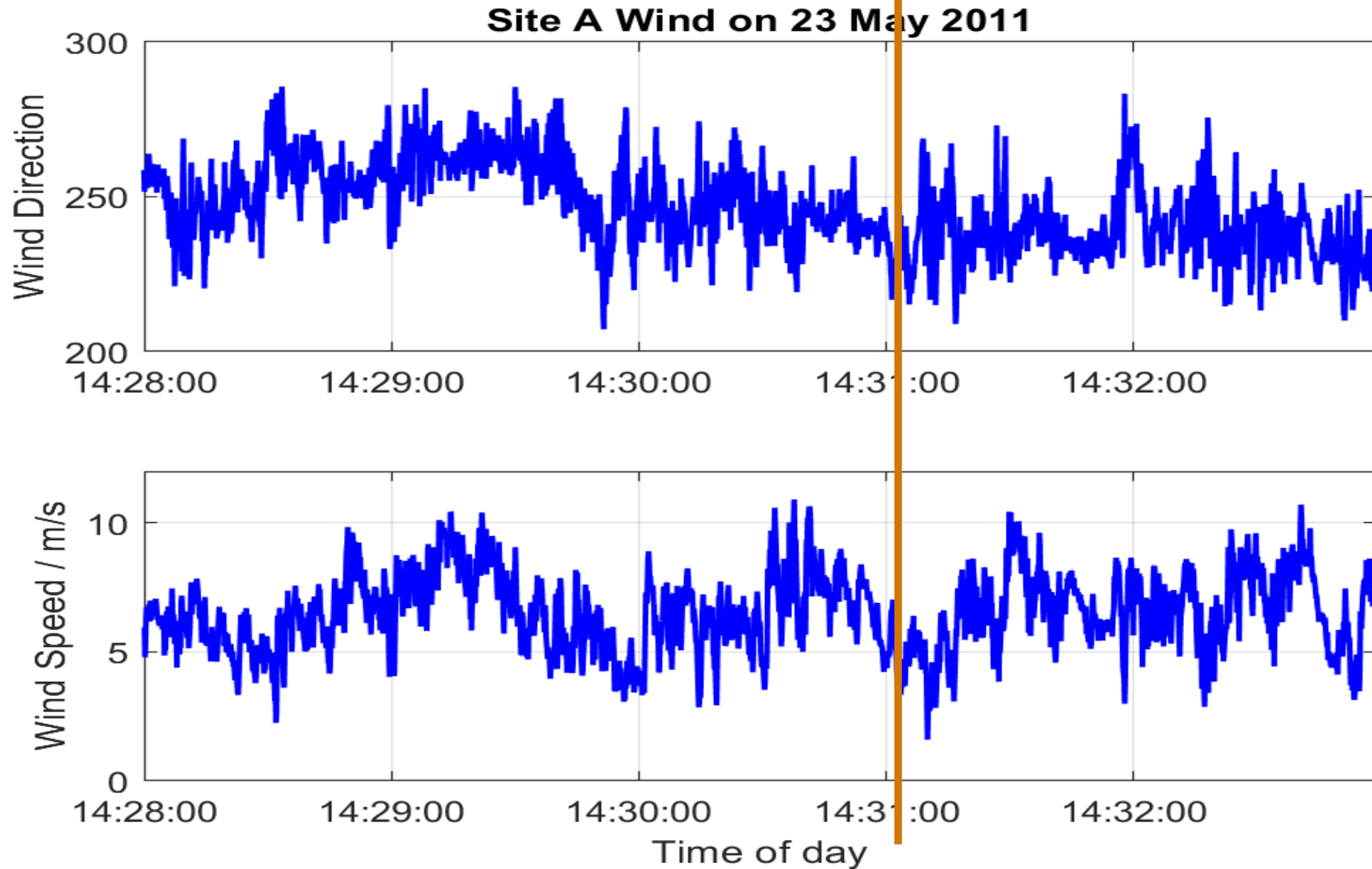
Use separate test cases if:

- Need independent configuration control
- Different model/harness/test type or callbacks
- Relate to distinct requirements
- Distinct control of coverage



Create a test case using real-world recorded data

My data



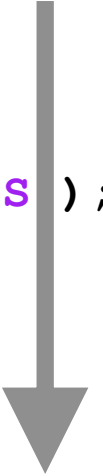
Importing time-stamped data from Excel or text files

```

% pre-process .xlsx file
% get import options
importOptions = detectImportOptions('SiteWindDataRecorded.xlsx')
% set sheet
importOptions.Sheet = '2011_05_23';
% tell it that Time is in a date-time format
importOptions = setvartype(importOptions, 'Time', 'datetime');
importOptions = setvaropts(importOptions, 'Time', 'DatetimeFormat', 'HH:mm:ss.SSS');
% read data in
T = readtable('SiteWindDataRecorded.xlsx', importOptions);
% convert to timetable
TT = table2timetable(T);
% re-sample to 1sec intervals
TTT = retime(TT, 'secondly', 'nearest');

```

Time	WindSpeed	WindDirection
00:00:00.175	14.59	214.9
00:00:00.306	14.47	212.3
00:00:00.437	16.1	208.5
00:00:00.568	17.94	209.4
00:00:00.700	17.53	210.9
00:00:00.831	16.93	219.6
00:00:00.962	15.25	218.2
00:00:01.093	12.73	220.1
00:00:01.224	13.71	212.2
00:00:01.355	11.89	218.6
00:00:01.486	15.94	212.2
00:00:01.617	16.51	208.1
00:00:01.748	17.11	211.8



Time	WindSpeed	WindDirection
0	14.59	214.9
1	15.25	218.2
2	16.46	212.2
3	16.08	207.3

Test Browser Results and Artifacts

Filter tests by name or tags, e.g. tags: test

- tests_ForEXPO
 - IdealTestCases
 - OriginalTest
 - RealWorldScenarios

PROPERTY	VALUE
Name	OriginalTest
Type	Simulation Test
Model	WindTurbine
Harness Name	testHarness_SingleTurbin...
Simulation Mode	[Model Settings]
Location	C:\macmill\Demos\Genera...
Enabled	<input checked="" type="checkbox"/>
Record coverage for syste...	<input type="checkbox"/>

IdealTestCases x Start Page x OriginalTest x Visualize x

OriginalTest Enabled

tests_ForEXPO » IdealTestCases » OriginalTest

Simulation Test

Select releases for simulation: Current

- TAGS
- DESCRIPTION
- SYSTEM UNDER TEST* ?
- PARAMETER OVERRIDES* ?
- INPUTS ?
- ITERATIONS* ?
- CUSTOM CRITERIA ?

What have we done so far....

- Created and imported test harnesses
- Created a test case for multiple simulations (iterations)
- Created a test case importing real-world data from Excel using root import mapping

Testing Against Requirements (Verification)

Good quality textural requirements....

#	Property	Description
1	Correct	Requirement has no errors and is not an error
2	Compliant	with one or more documented upper level requirements (operational, customer needs, etc)
3	Complete	Each requirement covers all aspects of the requirement's intent.
4	Consistent	Is not in conflict with any other requirement. Is consistent with the environment
5	Validated	Ensures the requirement will lead to the right design, i.e. reflects fully, correctly and objectively system objectives, scope, operational use, etc
6	Achievable	Can be implemented in a cost-effective manner that considers cost and schedule constraints
7	Unambiguous	The requirement has only one possible interpretation. Questions are: Could the requirement be read different ways by different people? What are the different interpretations of the requirement?
8	Verifiable	Expected performance or functionality expressed in a manner that allows verification to be objective, preferably as a result of an observable, ideally measurable, effect
9	Singular	Use a unique "shall" in each textual requirement to express a single design Demand (unique intent).
10	Positive	Negative requirements are very difficult, if not impossible, to verify. Negative requirement may be used only for safety requirements
11	Adequate	Each requirement is expressed as a problem statement i.e. it defines what is needed, not a solution, except if a particular implementation is a constraint to be resolved by design and test

This model had requirements such as...

9. Pitch Controller Requirements



Track angle within	0.2 degree
Rotor speed	Wthin 10% of nominal
Rise Time	3 seconds
Settling Time	5 seconds

These are ambiguous, incomplete, and not clearly verifiable

Hopefully a bit better is...

REQ001: when in power generation mode the rotor speed shall be maintained within $\pm 10\%$ of the [RotorNominalSpeed]

Definition: [RotorNominalSpeed] shall be calculated for a given turbine design to correspond to the rated generator speed converted to rotor speed based upon gearing implementation to requirements [ref. TBD].

Rationale: control average power, shed aerodynamic load

Verification: by system level simulation

REQ002: under inertial load only (zero aerodynamic load) the rise time of the blade pitch angle to a $\pm 10^\circ$ step change in pitch angle demand shall be less than 3 seconds

Definition: rise time shall be measured as the time elapsed from initiation of the step to 90% of the expected response.

Rationale: design experience [Ref. TBD] indicates meeting this requirement is a prerequisite for meeting REQ001 & braking requirements of [TBD]

Verification: by sub-system simulation

Example 1: Using `verify()` to test against a requirement

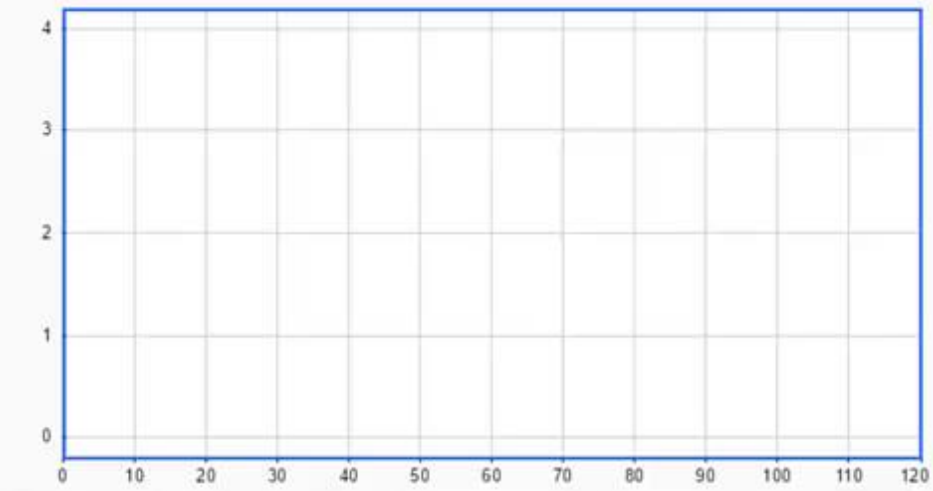
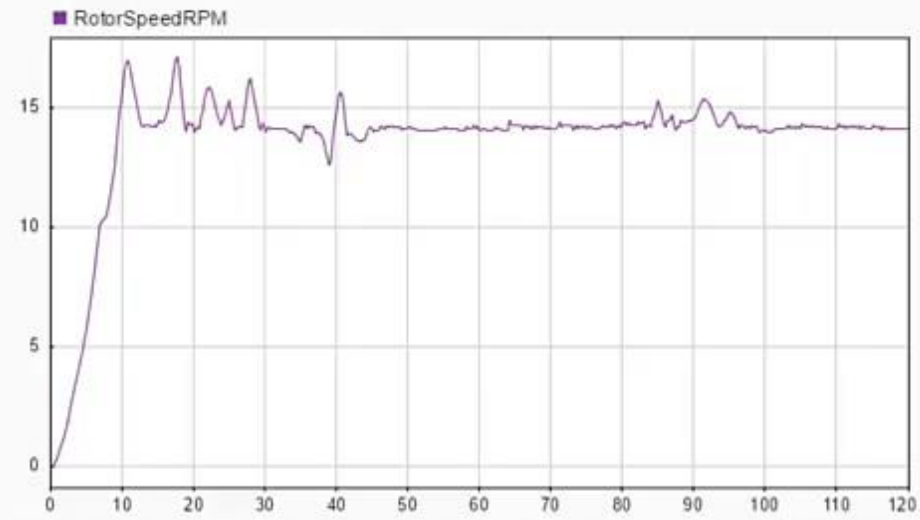
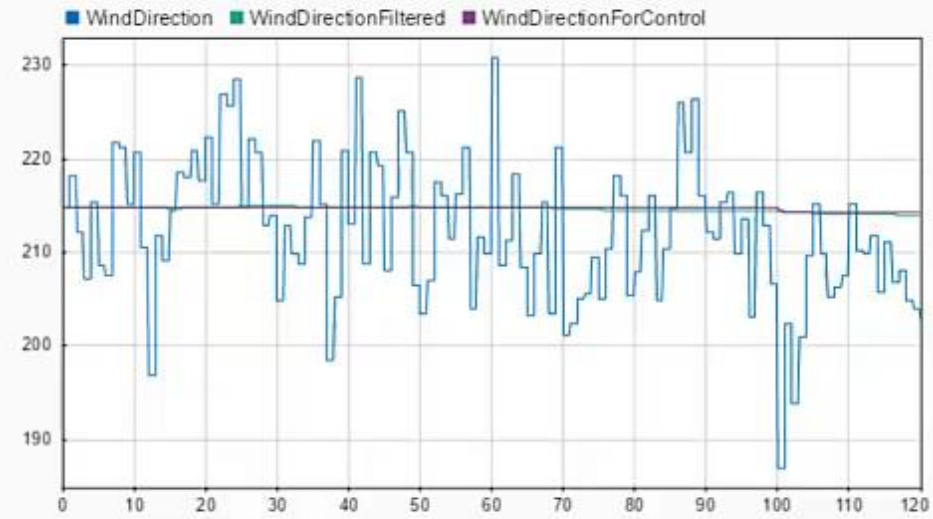
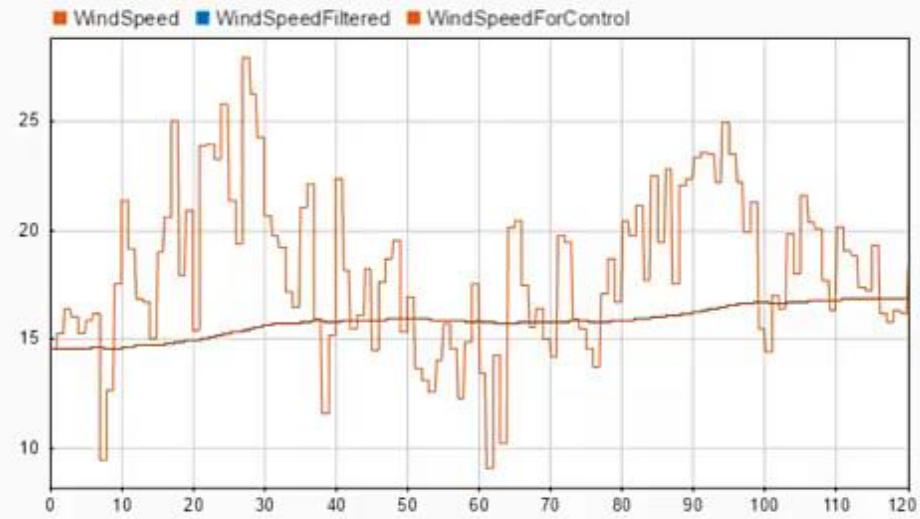
Test Browser Results and Artifacts

2011_05_23 x Start Page x Visualize x

Filter tests by name or tags, e.g. tags: test

- tests_ForEXPO
 - IdealTestCases
 - OriginalTest
 - RealWorldScenarios
 - 2011_05_23

PROPERTY	VALUE
Name	tests_ForEXPO
Location	C:\fmacmill\Demos\Genera...
Enabled	<input checked="" type="checkbox"/>



Further considerations...

- Testing at an appropriate level
i.e. system – sub system – component
- Verification of more complex requirements

Example 2: Using custom criteria to test against a requirement

REQ002: under inertial load only (zero aerodynamic load) the rise time of the blade pitch angle to a $\pm 10^\circ$ step change in pitch angle demand shall be less than 3 seconds

Definition: rise time shall be measured as the time elapsed from initiation of the step to 90% of the expected response.

Rationale: design experience [Ref. TBD] indicates meeting this requirement is a prerequisite for meeting REQ001 & braking requirements of [TBD]

Verification: by sub-system simulation

REQ003: under inertial load only (zero aerodynamic load) the settling time of the blade pitch angle to a $\pm 10^\circ$ step change in pitch angle demand shall be less than 5 seconds

Definition: settling time shall be measured as the time elapsed from initiation of the step to the response remaining within 5% of the expected response.

Rationale: design experience [Ref. TBD] indicates meeting this requirement is a prerequisite for meeting REQ001 & braking requirements of [TBD]

Verification: by sub-system simulation

Types of Qualifications

Qualifications are functions for testing values and responding to failures. There are four types of qualifications:

- Verifications — Produce and record failures without throwing an exception, meaning the remaining tests run to completion.
- Assumptions — Ensure that a test runs only when certain preconditions are satisfied and the event should not produce a test failure. When an assumption failure occurs, the testing framework marks the test as filtered.
- Assertions — Ensure that the preconditions of the current test are met.
- Fatal assertions — Use this qualification when the failure at the assertion point renders the remainder of the current test method invalid or the state is unrecoverable.

Type of Test	Verification	Assumption	Assertion	Fatal Assertion
Value is true.	<code>verifyTrue</code>	<code>assumeTrue</code>	<code>assertTrue</code>	<code>fatalAssertTrue</code>
Value is false.	<code>verifyFalse</code>	<code>assumeFalse</code>	<code>assertFalse</code>	<code>fatalAssertFalse</code>
Value is equal to specified value.	<code>verifyEqual</code>	<code>assumeEqual</code>	<code>assertEqual</code>	<code>fatalAssertEqual</code>
Value is not equal to specified value.	<code>verifyNotEqual</code>	<code>assumeNotEqual</code>	<code>assertNotEqual</code>	<code>fatalAssertNotEqual</code>
Two values are handles to same instance.	<code>verifySameHandle</code>	<code>assumeSameHandle</code>	<code>assertSameHandle</code>	<code>fatalAssertSameHandle</code>
Value is not handle to specified instance.	<code>verifyNotSameHandle</code>	<code>assumeNotSameHandle</code>	<code>assertNotSameHandle</code>	<code>fatalAssertNotSameHandle</code>
Function returns true when evaluated.	<code>verifyReturnsTrue</code>	<code>assumeReturnsTrue</code>	<code>assertReturnsTrue</code>	<code>fatalAssertReturnsTrue</code>
Test produces unconditional failure.	<code>verifyFail</code>	<code>assumeFail</code>	<code>assertFail</code>	<code>fatalAssertFail</code>
Value meets given constraint.	<code>verifyThat</code>	<code>assumeThat</code>	<code>assertThat</code>	<code>fatalAssertThat</code>
Value is greater than specified value.	<code>verifyGreaterThan</code>	<code>assumeGreaterThan</code>	<code>assertGreaterThan</code>	<code>fatalAssertGreaterThan</code>
Value is greater than or equal to specified value.	<code>verifyGreaterThanOrEqual</code>	<code>assumeGreaterThanOrEqual</code>	<code>assertGreaterThanOrEqual</code>	<code>fatalAssertGreaterThanOrEqual</code>
Value is less than specified value.	<code>verifyLessThan</code>	<code>assumeLessThan</code>	<code>assertLessThan</code>	<code>fatalAssertLessThan</code>
Value is less than or equal to specified value.	<code>verifyLessThanOrEqual</code>	<code>assumeLessThanOrEqual</code>	<code>assertLessThanOrEqual</code>	<code>fatalAssertLessThanOrEqual</code>
Value is exact specified class.	<code>verifyClass</code>	<code>assumeClass</code>	<code>assertClass</code>	<code>fatalAssertClass</code>
Value is object of specified type.	<code>verifyInstanceOf</code>	<code>assumeInstanceOf</code>	<code>assertInstanceOf</code>	<code>fatalAssertInstanceOf</code>
Value is empty.	<code>verifyEmpty</code>	<code>assumeEmpty</code>	<code>assertEmpty</code>	<code>fatalAssertEmpty</code>
Value is not empty.	<code>verifyNotEmpty</code>	<code>assumeNotEmpty</code>	<code>assertNotEmpty</code>	<code>fatalAssertNotEmpty</code>
Value has specified size.	<code>verifySize</code>	<code>assumeSize</code>	<code>assertSize</code>	<code>fatalAssertSize</code>
Value has specified length.	<code>verifyLength</code>	<code>assumeLength</code>	<code>assertLength</code>	<code>fatalAssertLength</code>
Value has specified element count.	<code>verifyNumElements</code>	<code>assumeNumElements</code>	<code>assertNumElements</code>	<code>fatalAssertNumElements</code>
String contains specified string.	<code>verifySubstring</code>	<code>assumeSubstring</code>	<code>assertSubstring</code>	<code>fatalAssertSubstring</code>
Text matches specified regular expression.	<code>verifyMatches</code>	<code>assumeMatches</code>	<code>assertMatches</code>	<code>fatalAssertMatches</code>
Function throws specified exception.	<code>verifyError</code>	<code>assumeError</code>	<code>assertError</code>	<code>fatalAssertError</code>
Function issues specified warning.	<code>verifyWarning</code>	<code>assumeWarning</code>	<code>assertWarning</code>	<code>fatalAssertWarning</code>
Function issues no warnings.	<code>verifyWarningFree</code>	<code>assumeWarningFree</code>	<code>assertWarningFree</code>	<code>fatalAssertWarningFree</code>

Test across multiple operating points? (trim conditions)

Filter tests by name or tags, e.g. tags: test

- tests_ForEXPO*
 - IdealTestCases
 - RealWorldScenarios
 - PitchControlTests
 - AllOperatingPoints
 - TimeResponse

Test Suite

Select releases for simulation: Current

CALLBACKS

SETUP



Runs before test suite executes

```
1
```

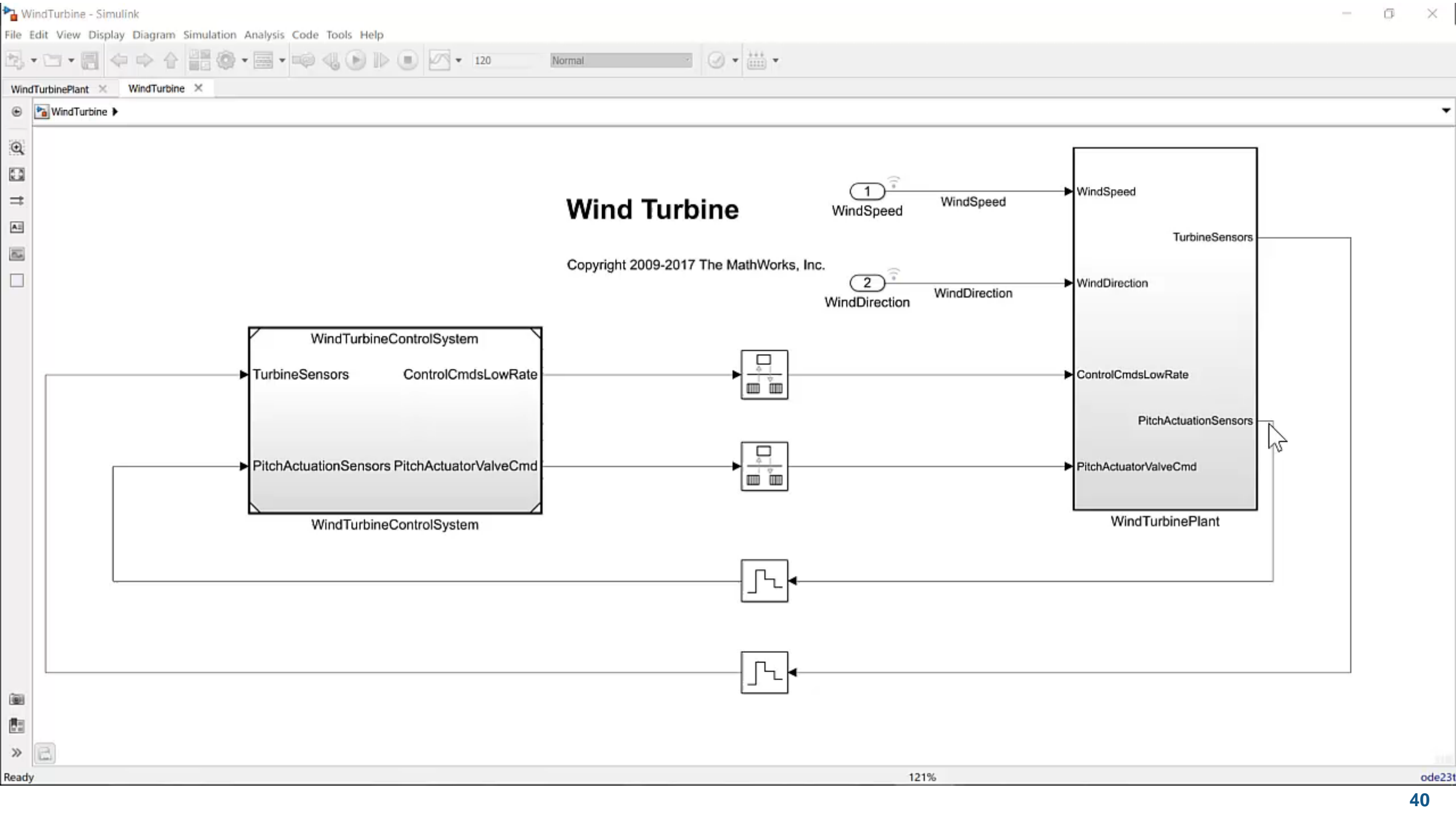
CLEANUP



Runs after test suite executes

```
1
```

Incorporating coverage analysis



Wind Turbine

Copyright 2009-2017 The MathWorks, Inc.

1
WindSpeed

WindSpeed

WindSpeed

TurbineSensors

2
WindDirection

WindDirection

WindDirection

ControlCmdsLowRate

PitchActuationSensors

PitchActuatorValveCmd

WindTurbinePlant

WindTurbineControlSystem

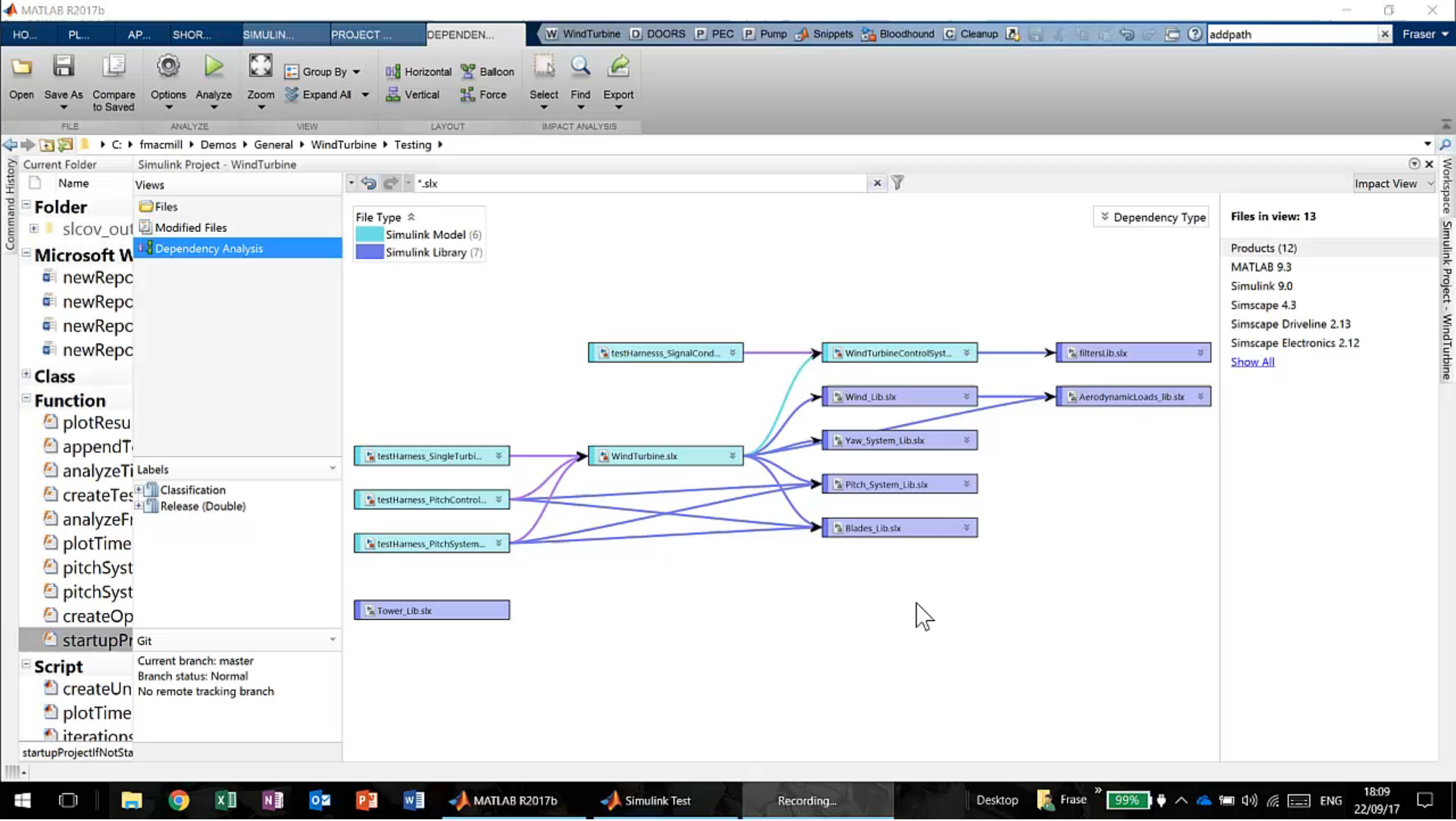
TurbineSensors

ControlCmdsLowRate

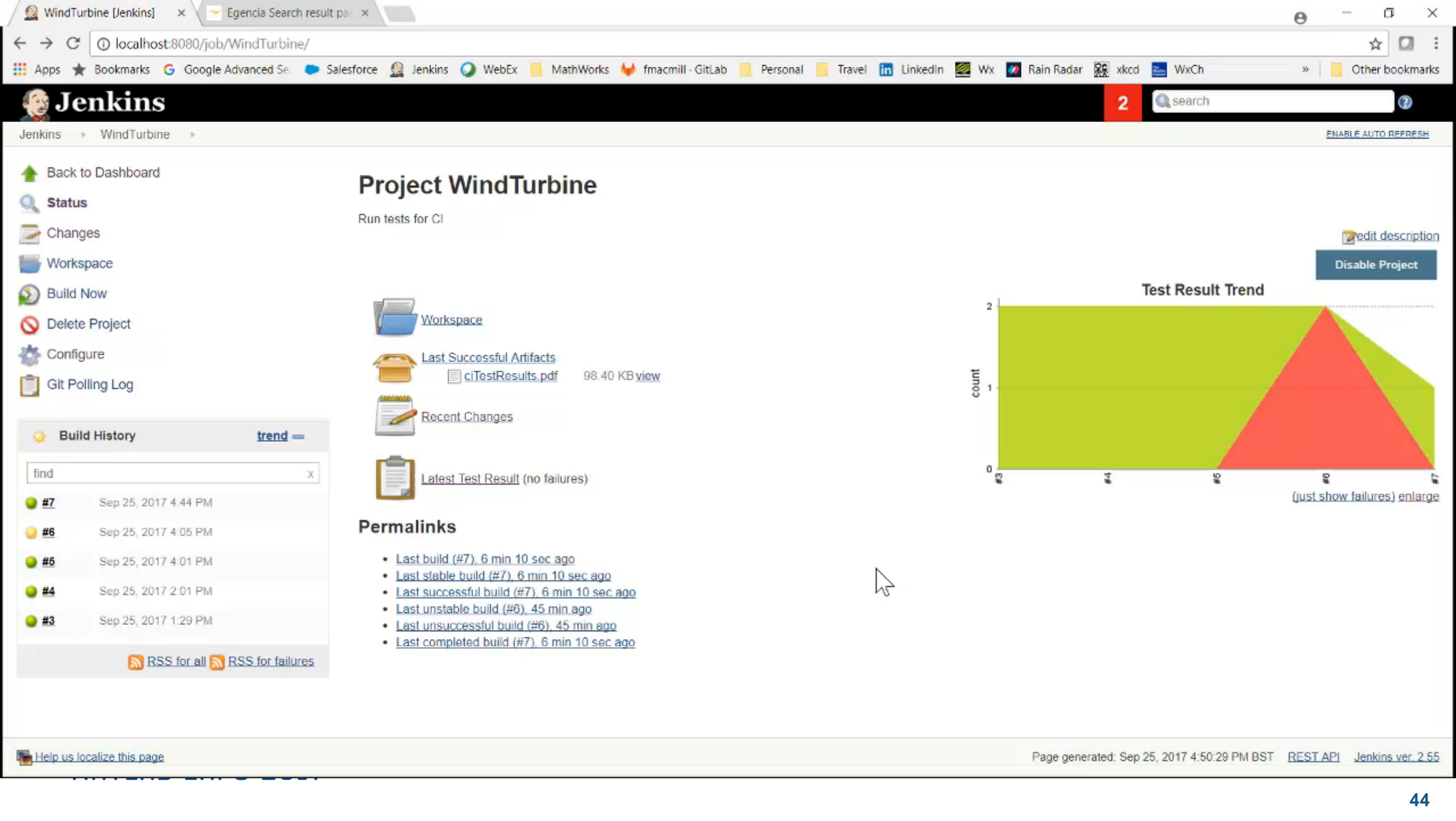
PitchActuationSensors
PitchActuatorValveCmd

WindTurbineControlSystem

Regression & cross-release testing



Continuous Integration



- Back to Dashboard
- Status
- Changes
- Workspace
- Build Now
- Delete Project
- Configure
- Git Polling Log

Project WindTurbine

Run tests for CI

[edit description](#)

Disable Project

- Workspace
- Last Successful Artifacts
 - ciTestResults.pdf 98.40 KB [view](#)
- Recent Changes
- Latest Test Result (no failures)



Build History [trend](#)

find

Build	Time	Status
#7	Sep 25, 2017 4:44 PM	Success
#6	Sep 25, 2017 4:05 PM	Failure
#5	Sep 25, 2017 4:01 PM	Success
#4	Sep 25, 2017 2:01 PM	Success
#3	Sep 25, 2017 1:29 PM	Success

RSS for all RSS for failures

Permalinks

- Last build (#7), 6 min 10 sec ago
- Last stable build (#7), 6 min 10 sec ago
- Last successful build (#7), 6 min 10 sec ago
- Last unstable build (#6), 45 min ago
- Last unsuccessful build (#6), 45 min ago
- Last completed build (#7), 6 min 10 sec ago

Conclusions

Benefits of Simulink Test

- Ease of creation, organisation & control of test harnesses
- Ease of driving your models with data from various sources
- Ease of `verify()` for in-harness/model verification of requirements
- Ease of test case set-up for multiple inputs, parameters, operating points, etc.
- Ease of reporting
- Ease of integration: requirements, coverage, MATLAB Unit Test, continuous integration, ...

TESTS VISUALIZE FORMAT

Subplots Clear Subplot Legend Data Cursors Highlight in Model Send to Figure

VIEWS ZOOM & PAN MEASURE & TRACE SHARE

Test Browser Results and Artifacts

Filter results by name or tags, e.g. tags: test

NAME	STATUS
Results: 2016-Sep-19 14:06:01	2 ✓ 1
testMotorPlant	1 ✓
Open Loop Tests	1 ✓
Thermal requirement test	✓
testMotorSystem	1 ✓ 1
System Tests	1 ✓ 1
chirpCustomCriteriaTest	✓
Sim Output (myMotorSystem)	
Custom Criteria Result	
Gain upper bound exceedance	✓
Gain lower bound exceedance	✓
Phase upper bound exceedance	✓
Phase lower bound exceedance	✓
chirpTempTests Table Iterations	⊘

chirpCustomCriteriaTest

Baseline Test

TAGS: myMotorSystem

DESCRIPTION

REQUIREMENTS

SYSTEM UNDER TEST

Model: myMotorSystem

TEST PARAMETERS

SIMULATION SETTINGS OVERVIEW

PARAMETER OVERRIDES

CALLBACKS

INPUTS

OUTPUTS

Figure 1: chirpFreq_

File Edit View Insert Tools Desktop Window Help

w/V Gain [dB]

w/V Phase / deg

Freq / Hz

Nonlinear

Questions?