SIMUS — Introduction to MATLAB & Simulink

Moein SARBANDI

École Centrale de Nantes

September 17, 2025

Goal

Goal. Get used to MATLAB & Simulink for simulating dynamic systems.

With a few simple examples, the session will show how to:

- build and run models of different systems,
- set solver and sampling options,
- look at and use the results in MATLAB.

What is MATLAB/Simulink?

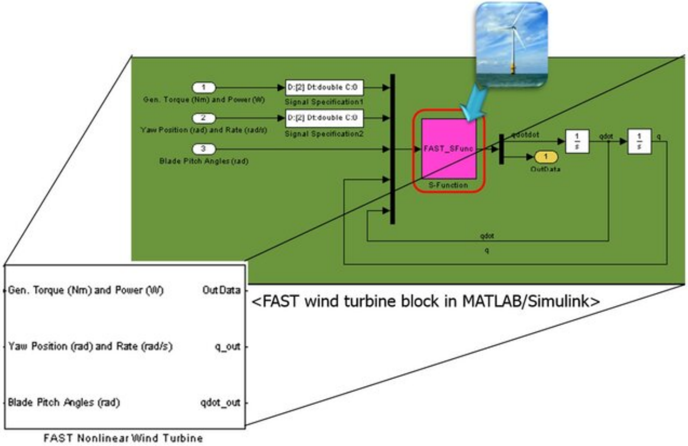
- **MATLAB:** high-level language for numerical computing, data analysis, visualization.
- **Simulink:** graphical block-diagram environment for modeling & simulating dynamic systems.
- Fast iteration, integration with code generation and SIL/HIL testing.

Why it matters (for control)

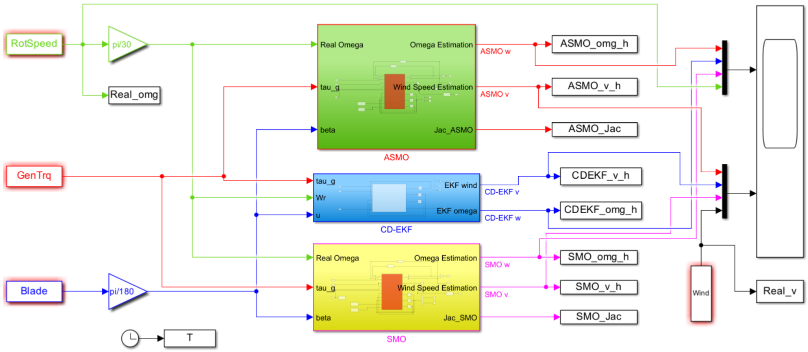
- Bridges **theory** (ODEs, state-space) and **practice** (implementation, sampling).
- Industry-standard across automotive, aero, energy, robotics.
- Clear visualization of closed-loop behavior and design trade-offs.

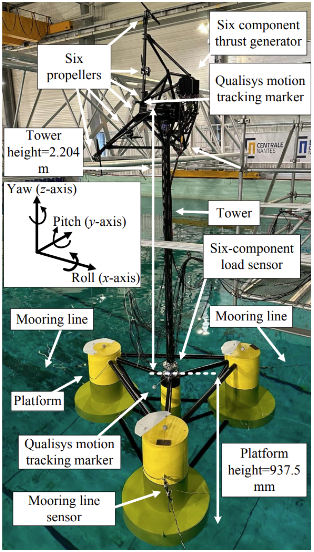
Workflow Example:

- **OpenFAST:** Detailed aero-elastic model of a wind turbine (real simulator).
- **MATLAB:** used for data processing, analysis, and control design.
- Allows safe and fast validation of control algorithms for complex systems like offshore wind turbines.



Real Example





State-Space Representation

- Nonlinear time-varying system:

$$\begin{cases} \dot{x}(t) = f\big(x(t), u(t), t\big) \\ y(t) = g\big(x(t), u(t), t\big) \end{cases}$$

- Nonlinear time-invariant system:

$$\begin{cases} \dot{x}(t) = f\big(x(t), u(t)\big) \\ y(t) = g\big(x(t), u(t)\big) \end{cases}$$

- Nonlinear system affine in the input:

$$\begin{cases} \dot{x}(t) = f\big(x(t)\big) + g\big(x(t)\big)u(t) \\ y(t) = h\big(x(t)\big) \end{cases}$$

State-Space Representation (Linear Systems)

- Linear time-varying system (LTV):

$$\begin{cases} \dot{x}(t) = A(t)x(t) + B(t)u(t) \\ y(t) = C(t)x(t) + D(t)u(t) \end{cases}$$

- Linear time-invariant system (LTI):

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) + Du(t) \end{cases}$$

  - LTI system are easier to analyze and simulate.
  - Nonlinear systems can be **linearized** around an equilibrium point.
  - This is why we usually begin with linear systems.

Reference Linear System

We consider:

$$\dot{x}_1 = x_2,$$
$$\dot{x}_2 = K\omega_n^2 u - \omega_n^2 x_1 - 2\zeta\omega_n x_2$$

with parameters K, ω_n, ζ.
Output: $y(t) = x_1(t)$.

Transfer function (Task 1)
With $Y(s)$ the Laplace transform of y and $U(s)$ of u:

$$\boxed{G(s) = \frac{Y(s)}{U(s)}}$$

Hello World! in Simulink

Goal: open Simulink and run your first model.

1. In MATLAB, type `simulink` → `Blank Model`.
2. Add a **Sine Wave** (Source) and a **Scope** (Sink).
3. Connect, run, and inspect the waveform.
4. Insert a **Gain** block between them as a quick exercise.