VERIFICATION MANUAL

IEA-22 MW Onshore

Linearization & Campbell diagram

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Turbine	IEA-22-280-RWT-Onshore (linearization-ready)
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Contents

TurbineX Linearization Verification Manual

1. Purpose

This document is a step-by-step record of how a TurbineX user reproduces the **linearization / Campbell-diagram** result for the **IEA-22 MW Onshore reference turbine** using nothing but the public TurbineX web application. It is the linearization counterpart to the steady-state operating-envelope manual, and follows the same format: every figure is generated by clicking through the same screens any user sees. No standalone OpenFAST runs, no editing of input files in storage.

> **Reference turbine** The IEA Wind Task 55 22 MW Reference Wind Turbine (IEA-22-280-RWT), onshore configuration — the same `IEA-22-280-RWT-Onshore` bundle used in the steady-state manual, with its `CompElast = 1` (ElastoDyn modal-blade) default. No second bundle is needed: the linearization-ready configuration is applied through the study's Advanced Settings (§2).

2. The linearization-ready configuration

Linearizing a 280 m rotor is where OpenFAST cold-start convergence bites. Run straight off the production Onshore bundle — gravity on, -6° shaft tilt, flexible tower — the model cold-starts into a tower strike around t = 37 s before it ever reaches the linearization time. The **linearization-ready configuration** removes the three production-physics terms that fight the eigenanalysis, so the linearization is about the turbine's *structural modes* rather than a cold-start transient. These are the same three changes that the retired `IEA-22-280-RWT-VT3` demo bundle once carried over the production bundle:

Setting	Production (Onshore)	Linearization-ready	Set in the UI via
Gravity	9.81 m/s^2	0	Advanced Settings → **Disable gravity**
Shaft tilt	-6°	0°	Advanced Settings → shaft tilt = 0
Tower DOFs	flexible	locked (rigid)	Advanced Settings → **Rigid support structure**

There is no longer a separate VT3 turbine in the Library — you recreate it inside the study, in the **Advanced Settings → Solver / module overrides** panel of the Run Simulation tab, together with the **Linearize** toggle. Turning Linearize on fills in the rest of the recipe automatically (a single linearization near the end of the run, the generator DOF locked so the rotor holds its speed, and the controller modes zeroed as OpenFAST requires).

3. Study configuration

Item	Value
Turbine	IEA-22-280-RWT-Onshore
Rated power / rotor diameter	22 MW / 284 m
Hub height	170 m
Configuration	Linearization-ready — gravity off, shaft tilt 0°, rigid tower (§2)
Study type	**Single Simulation** (one operating point per run)
Inflow	Steady uniform, no shear, no turbulence (required for linearization)
Simulation time	120 s

Linearization is a **single-operating-point** analysis. A Campbell diagram across wind speeds is built by running one Single Simulation per operating point and reading the modal results of each. In this manual we run the Region 2 $\longrightarrow$ rated grid **4, 6, 8, 10, 11.5 m/s**.

> **Rated-point note.** In this run the 11.5 m/s (rated) job did not converge: with gravity off there is no gravitational pre-load on the blade, and at rated aerodynamic thrust the ElastoDyn modal blade deflects far enough to violate OpenFAST's small-angle assumption, so the run diverges near t $\approx$ 1 s. The four below-rated points converge cleanly. Reaching rated would need the geometrically-exact BeamDyn blade (`CompElast = 2`), a separate exercise.

4. Walkthrough

4.1 Pick the turbine

Create a **Single Simulation** study and, on the Turbine tab, pick **IEA-22-280-RWT-Onshore** from the Turbine Library. The workbench binds the turbine and shows its planform, power curve and headline specs.

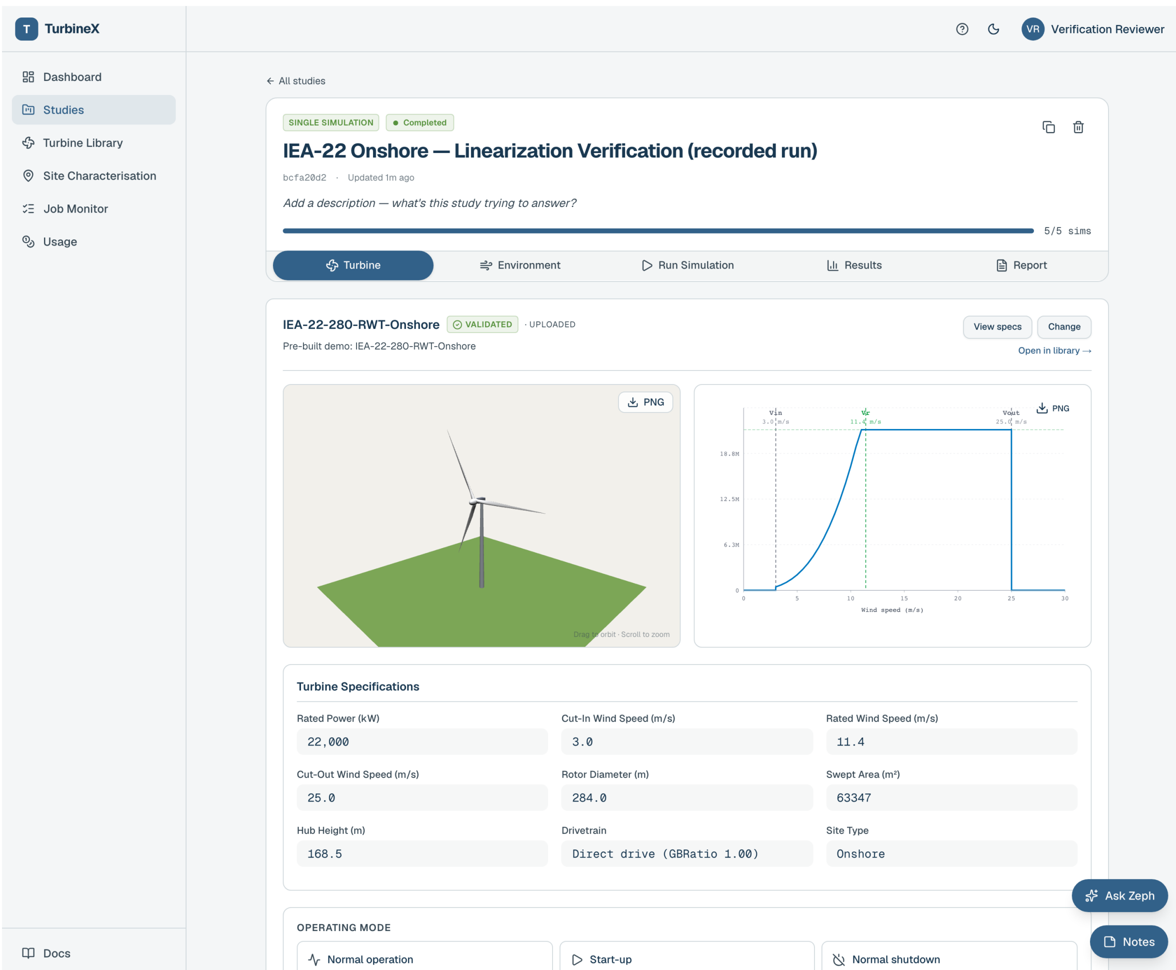

Figure 1: Study workbench — Turbine tab, IEA-22-Onshore bound

4.2 Set steady wind + the linearization Advanced Settings

On the Run Simulation tab, set the wind condition to **Steady** (here at 10 m/s for this operating point) and the simulation time. Open **Advanced Settings** $\longrightarrow$ **Solver / module overrides** and apply the linearization-ready configuration from §2 — enable **Linearize**, **Disable gravity**, **Rigid support structure**, and set shaft tilt to 0.

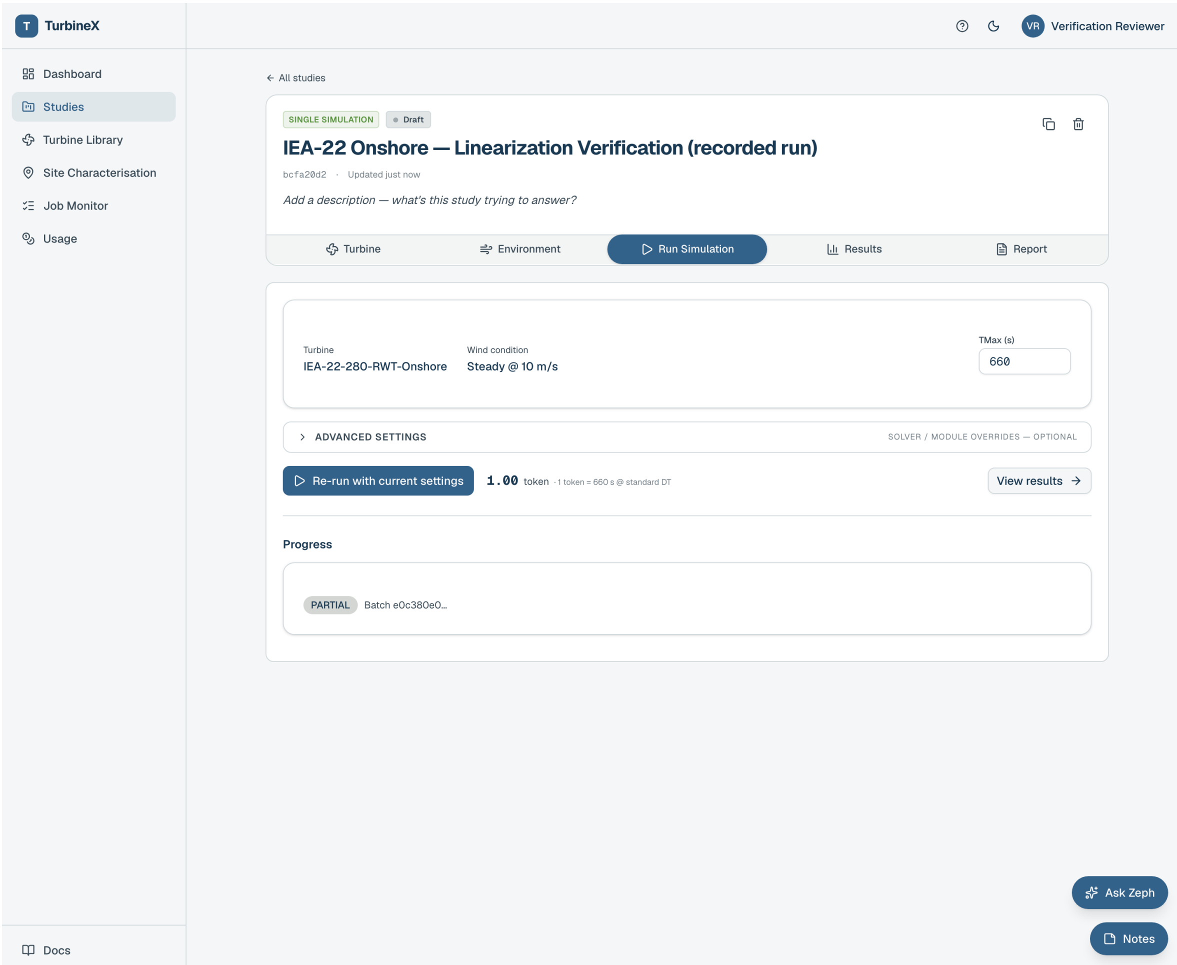

Figure 2: Run Simulation tab — steady wind + Advanced Settings (solver / module overrides)

4.3 Submit and monitor

Submit the run. The Job Monitor at `/runs` tracks the batch live. Running one Single Simulation per operating point in the 4–11.5 m/s grid produces the batch below — status **Mixed (4/5)**: the four below-rated points complete, the rated point fails (see the §3 rated-point note).

4.4 Open the Results tab

Back on the study, the Results tab carries a **Select job** picker (each operating point is one job) and an analysis tab bar. The linearization analyses — **Stability** (Campbell) and **Mode Shapes** — appear because the job was run with Linearize on.

4.5 Stability — the Campbell diagram

The **Stability** tab renders the Campbell diagram for the selected job: mode frequency versus wind speed, each point coloured by its damping (a red band flags any mode below 0 %, i.e. unstable), with the 1P / 3P / 6P / 9P per-rev excitation lines overlaid. Each Single Simulation contributes one operating point (one wind

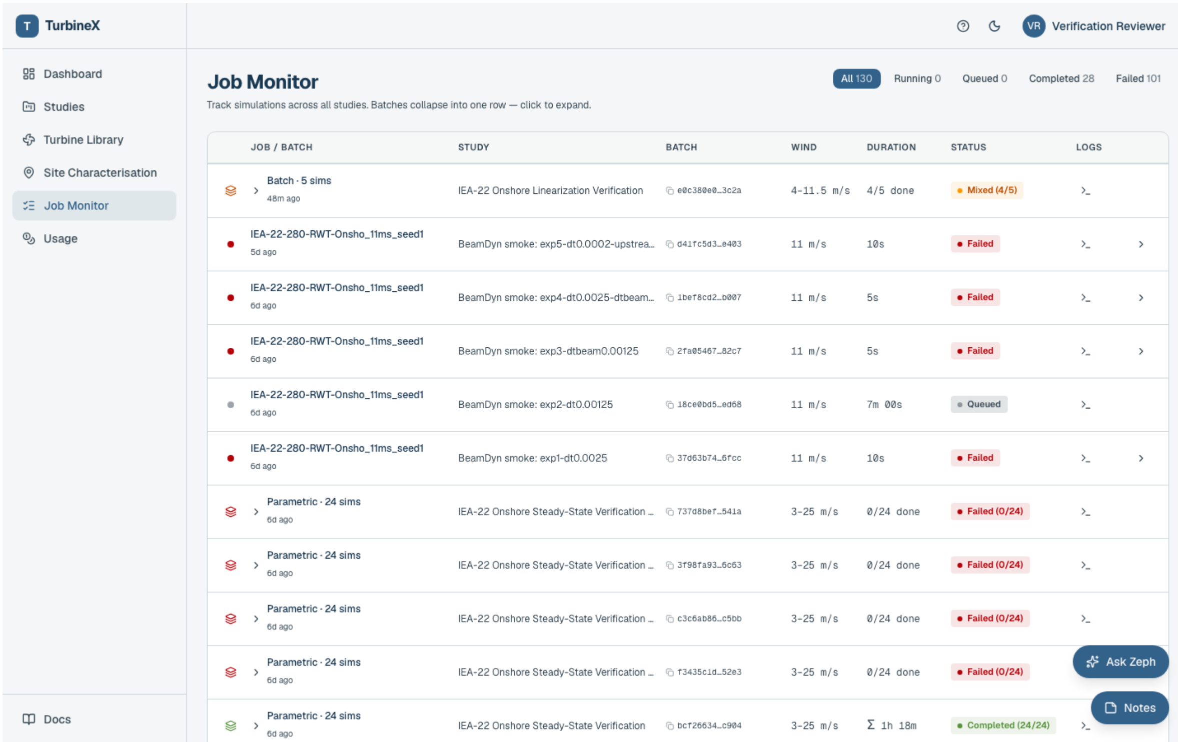

Figure 3: Job Monitor — linearization batch, 4/5 completed

speed), so a single job shows a vertical slice; stepping the Select-job picker through the grid walks across the diagram.

4.6 Mode Shapes — the 3D viewer

The **Mode Shapes** tab animates the eigenvectors extracted from the job's linearization output. The mode picker lists each mode with its frequency and damping; the 3D viewer deflects the tower and blades by the selected mode shape, with camera presets and a record-to-video control.

5. Aggregated results across the operating grid

Stepping the Select-job picker through the four converged operating points (4, 6, 8, 10 m/s) and collecting each one's modal data gives the full picture. The figures below aggregate that data — the same numbers the Stability and Mode Shapes tabs show per job, combined across the grid.

Campbell diagram (all operating points)

The reading to confirm:

- Because this is the **rigid-support** configuration (tower DOFs locked, §2), there are **no tower modes** in the eigenanalysis by construction — the modes shown are blade and drivetrain modes only.
- The upper cluster near **~3.2 Hz** and the **~0.55 Hz** line are the two blade families that ElastoDyn resolves; both are essentially flat with rotor speed, as expected for structural modes at these low per-rev speeds.
- **Every mode carries positive damping** across the operating range — no point crosses into the negative (unstable) band — and no mode sits on a per-rev excitation line within the operating envelope.

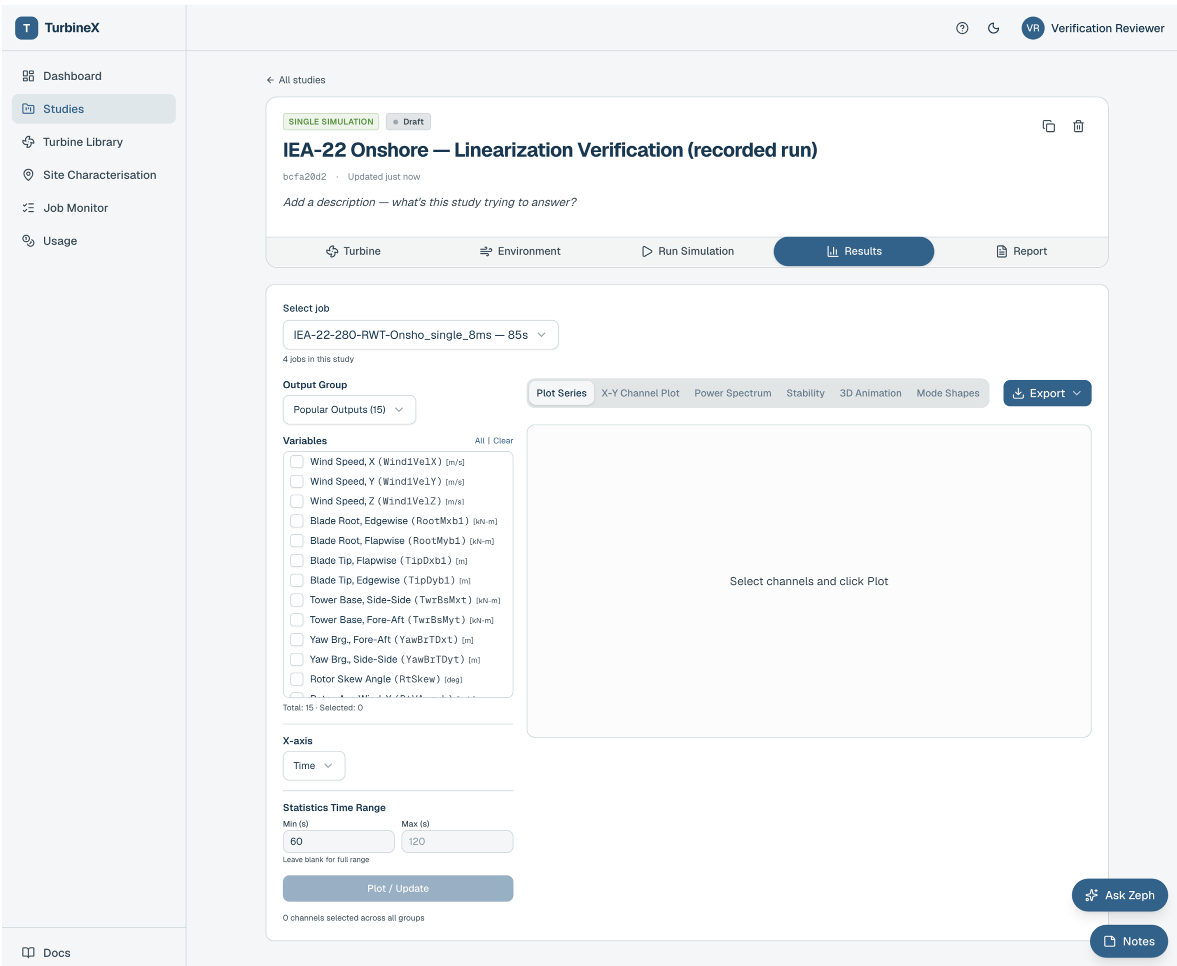

Figure 4: Results tab — job picker + analysis tabs (Stability, Mode Shapes)

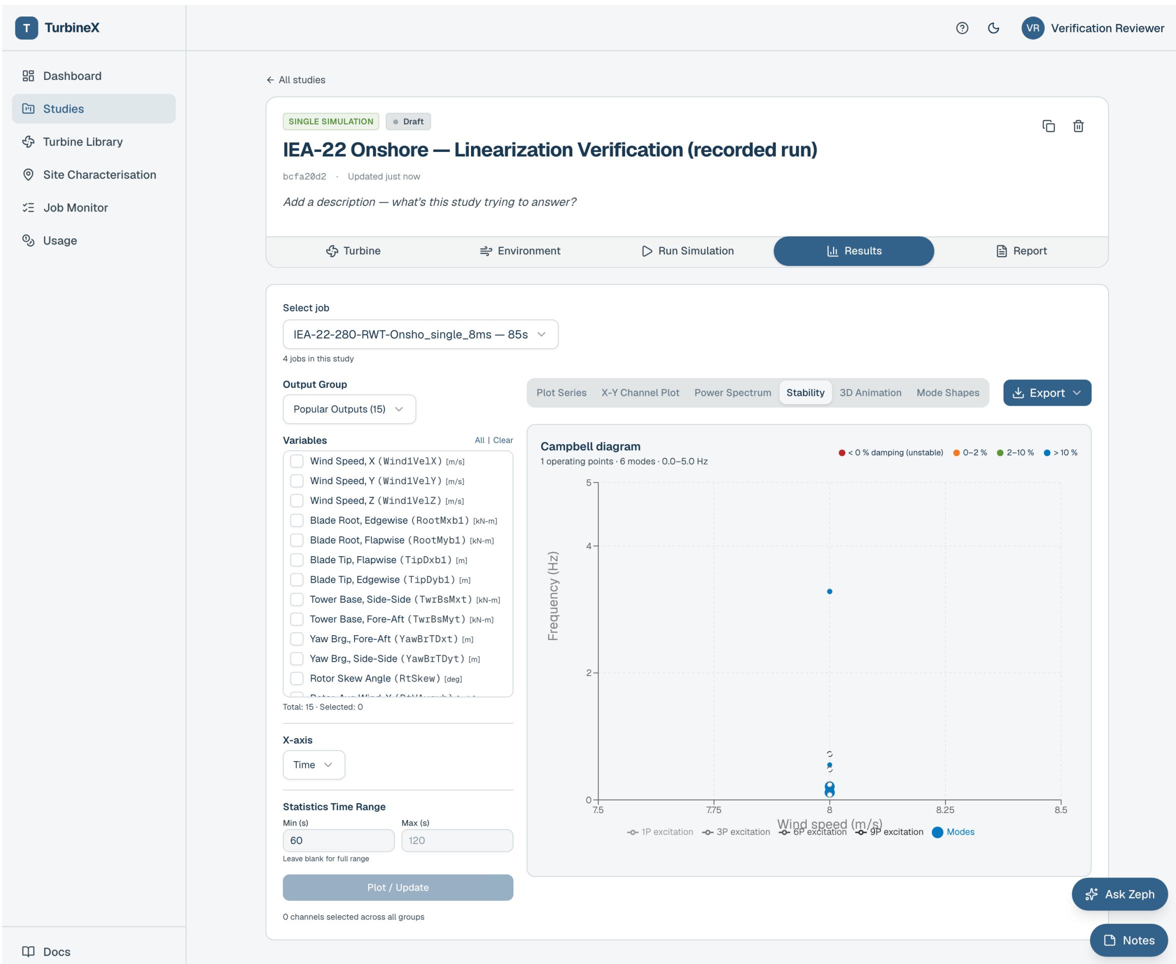

Figure 5: Results → Stability — Campbell diagram for one operating point

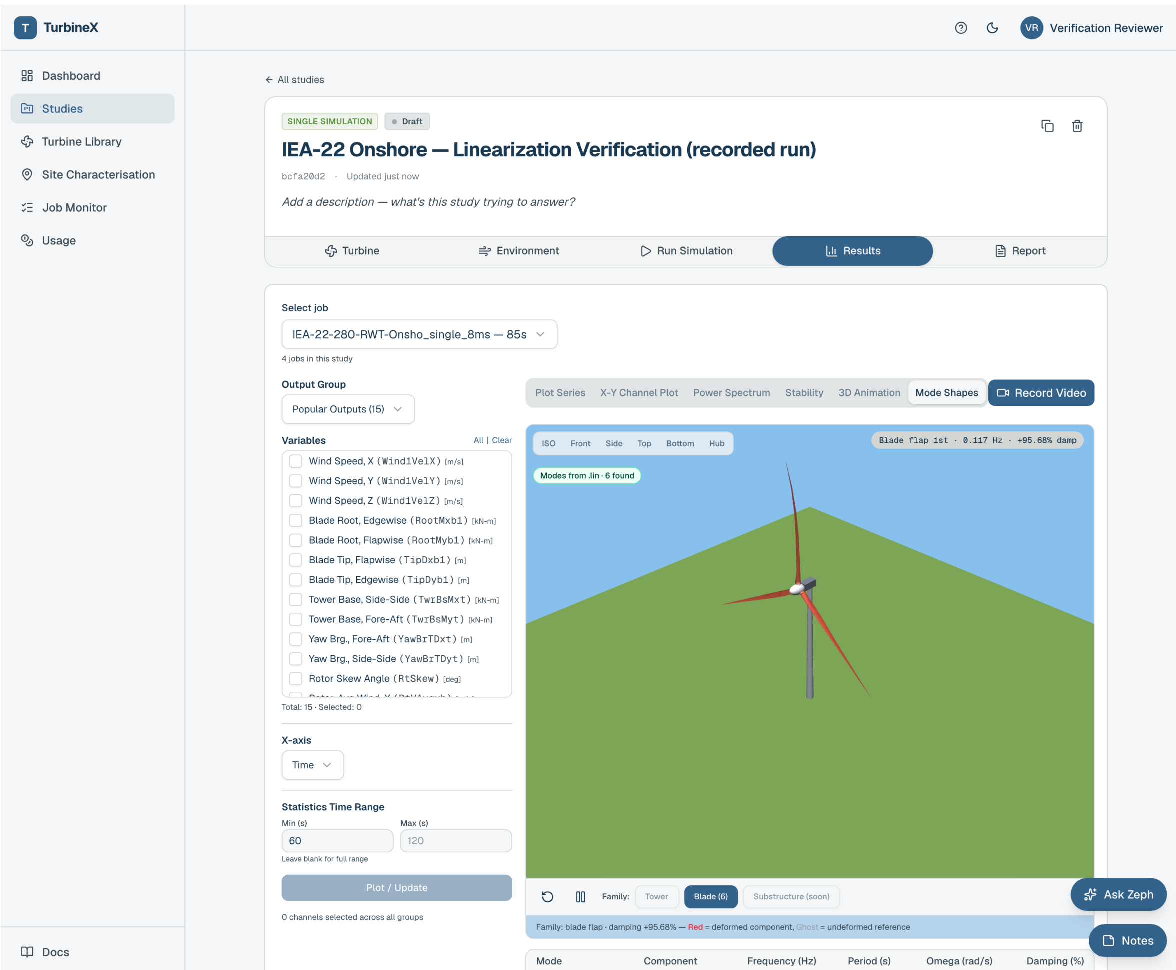

Figure 6: Results → Mode Shapes — animated eigenmode of the IEA-22 rotor

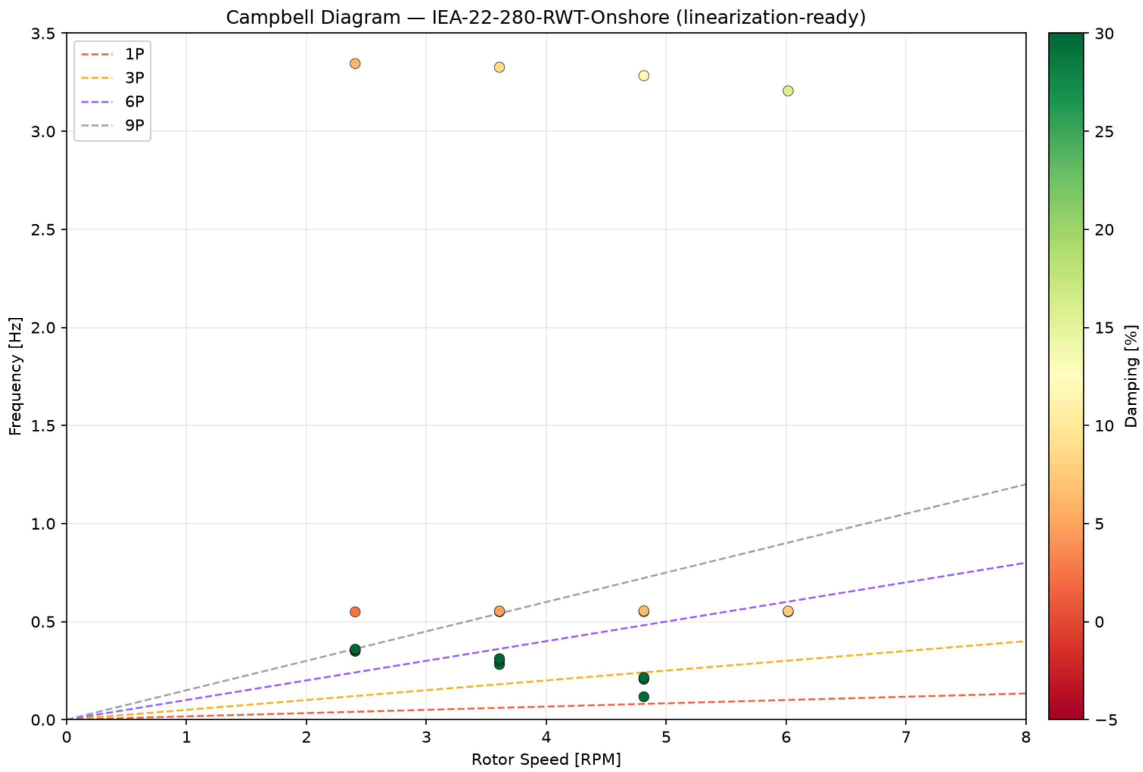

Figure 7: IEA-22 Onshore Campbell diagram — mode frequency vs rotor speed, coloured by damping

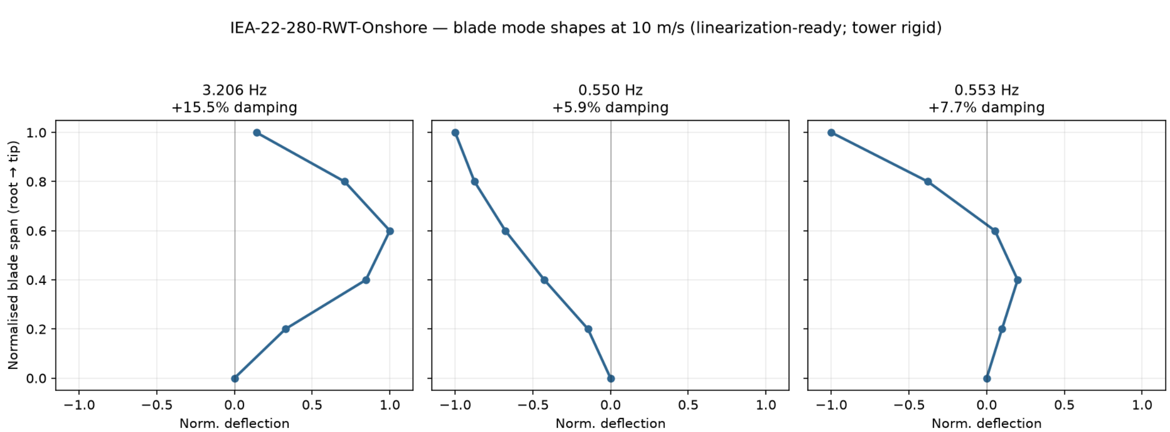

Figure 8: IEA-22 Onshore blade mode shapes at 10 m/s

Blade mode shapes (10 m/s operating point)

Tower deflection is omitted — the rigid-support configuration locks the tower DOFs. Note the 3.206 Hz shape has an interior node (a *higher-order* shape), which is why the platform's auto-assigned "1st blade flap" family label for it should be treated as indicative only — the mode picker's family labels are not authoritative.

6. Bottom-line verdict

Driven entirely through the TurbineX web application, the IEA-22 MW Onshore reference turbine, in its linearization-ready configuration, produces a clean modal picture across its Region 2 operating range:

- The four below-rated Single Simulations (4, 6, 8, 10 m/s) each complete and expose a **Stability (Campbell)** panel and an animated **Mode Shapes** viewer — no cold-start divergence, no tower strike.
- The Campbell diagram shows blade families flat with rotor speed, **all positively damped**, with no mode resonant with a per-rev line inside the operating envelope. Tower modes are absent by construction (rigid support).
- The rated (11.5 m/s) point does **not** converge — the ElastoDyn modal blade violates the small-angle assumption at rated thrust with gravity off (§3). This is a real, reportable model limitation, not a platform defect, and the app surfaces it (batch status **Mixed (4/5)**) rather than hiding it.

An auditor can therefore confirm that TurbineX reproduces the IEA-22 MW Onshore reference modal behaviour through its standard user interface across the below-rated operating range, given the linearization-ready configuration of §2, and that the platform is honest about the rated-point convergence limit.

Generated by the TurbineX verification harness. UI figures captured from the study's Turbine, Run Simulation, Job Monitor, and Results (Stability / Mode Shapes) screens; aggregate figures combine the per-job modal data across the operating grid.