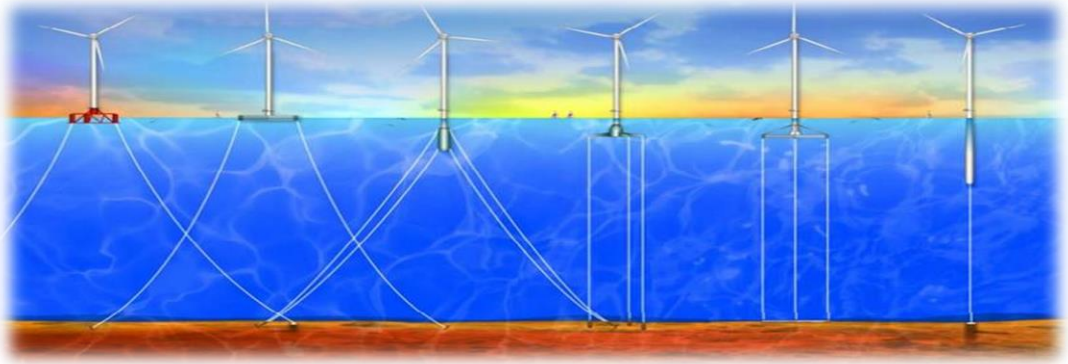
EFFECT OF DIFFERENT MOORING SYSTEMS ON HYDRODYNAMIC ANALYSIS OF AN OFFSHORE WIND TURBINE



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Presentation Outline

1. Goal of the research
2. Objectives of the research
3. Offshore wind turbines
4. Marine conditions for a floating offshore wind turbine
5. Degree of freedom for a floating offshore wind turbine
6. Relative advantages/disadvantages for platform of floating offshore wind turbines
7. Reference wind turbine and platform design & environmental conditions
8. Behavior of floating platform and mooring system of the offshore wind turbine under different sea conditions
9. Analysis & results
10. Conclusion

1. Goal of the Research

- The aim of this study is to compare hydrodynamic behavior of a floating offshore wind turbine under different mooring and sea conditions.

- The study focused on platform motions and mooring system load under different mooring systems and sea conditions.

2. Objectives of the Research

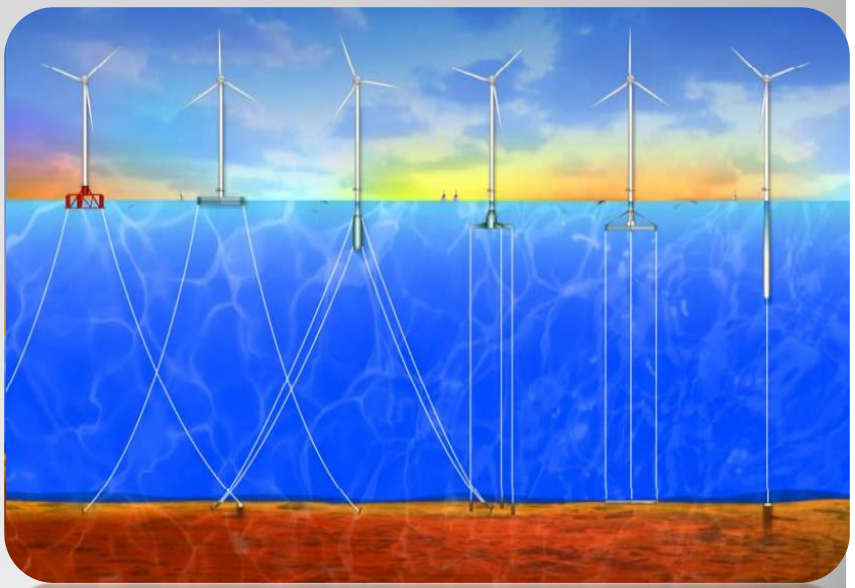
To fulfil this aim the following objectives are identified:

- By reviewing the existing offshore wind turbines to decide which one would be more appropriate to use.
- To combine best platform type and the best mooring system in terms of hydrodynamic characteristics.
- To make recommendations for the future research.

3. Offshore Wind Turbines

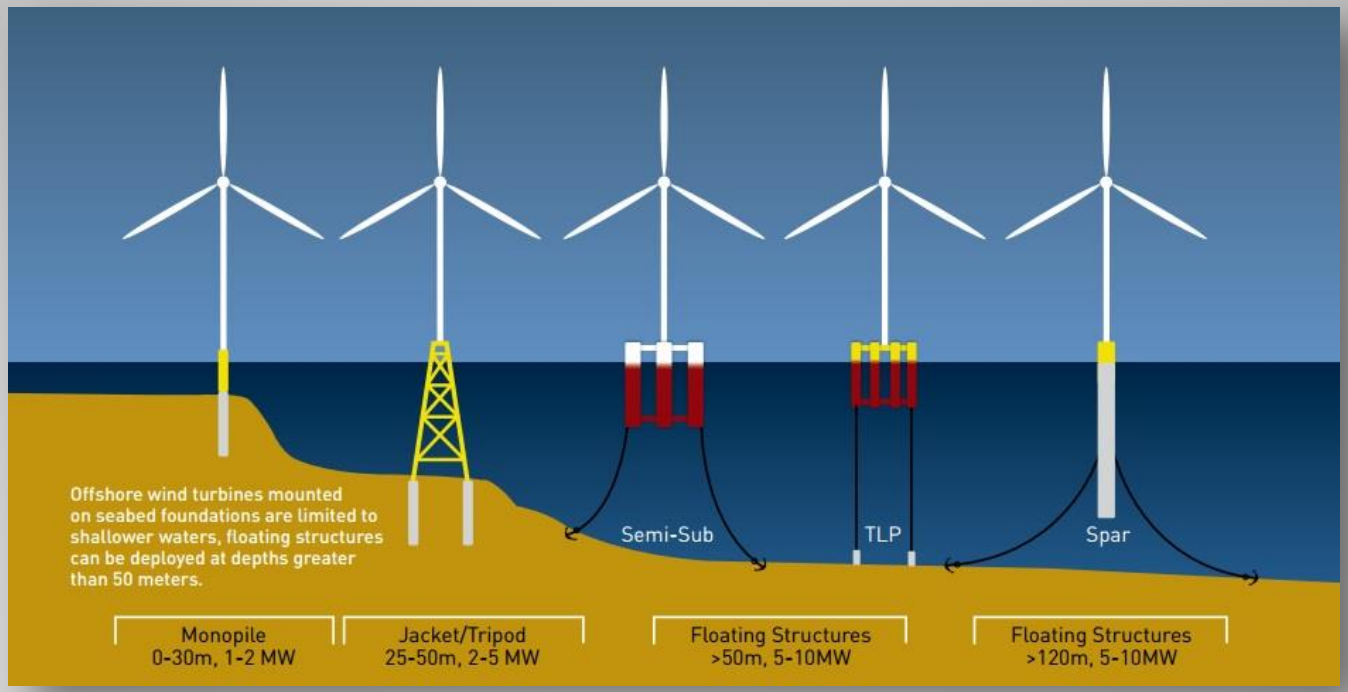
To classify offshore wind turbines:

1. Fixed Offshore Wind Turbines
2. Floating Wind Turbines



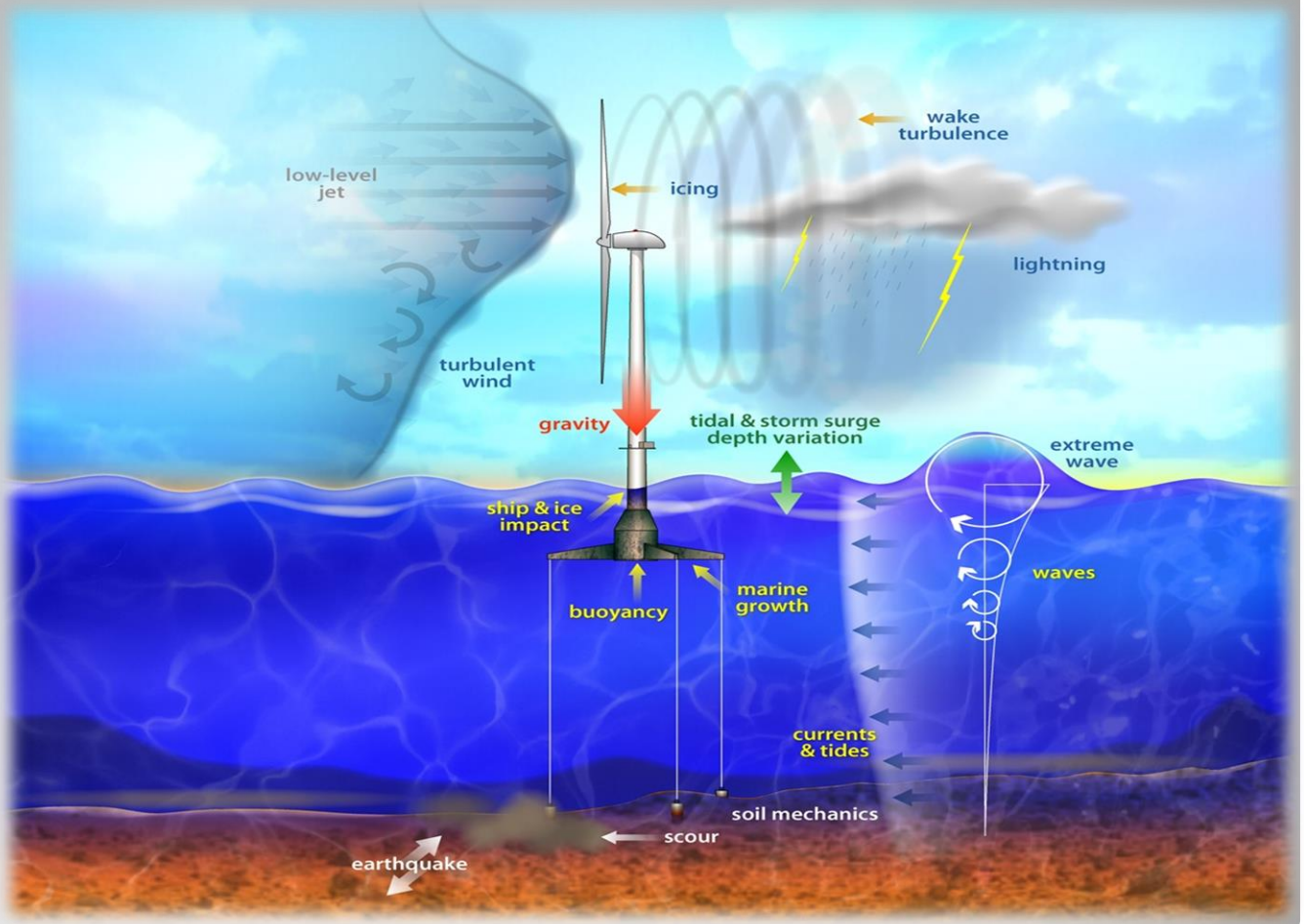
3. Offshore Wind Turbines

- Current situation in offshore wind turbine/power technology: Transitional stage to floating wind turbine technology.



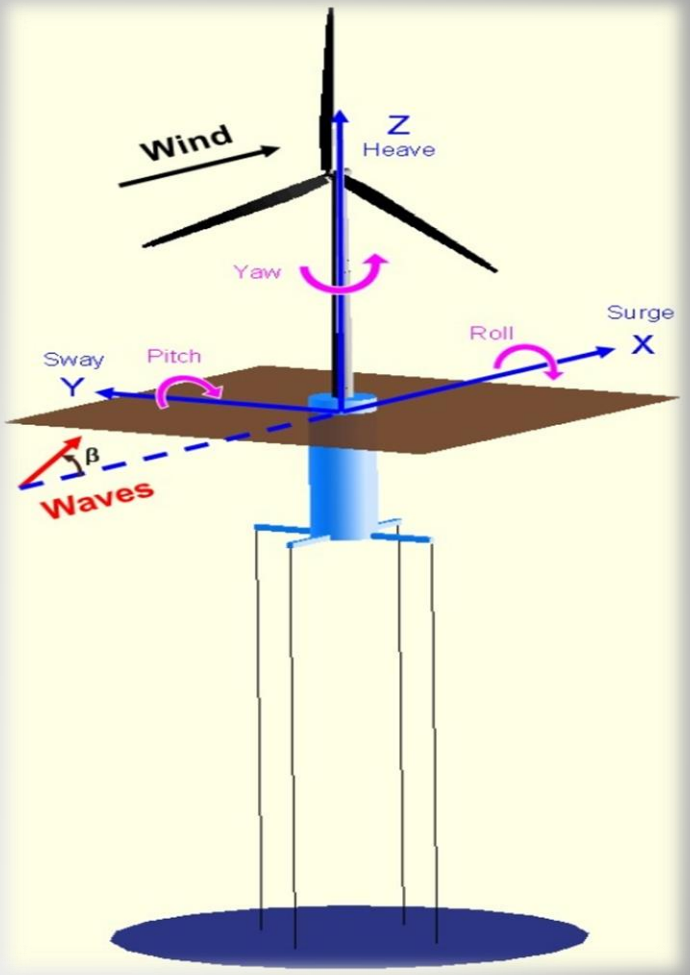
4. Marine Conditions for a Floating Offshore Wind Turbine

- Wind-inflow:
- Waves:
  - Regular
  - Irregular
- Aerodynamics:
- Hydrodynamics:
  - Diffraction
  - Radiation
  - Hydrostatics
- Structural dynamics:
  - Gravity / inertia
  - Elasticity
  - Foundations / moorings
- Control system:
  - Yaw, torque, pitch

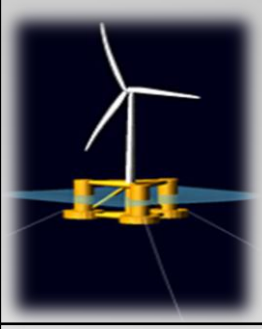
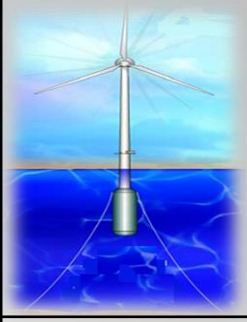
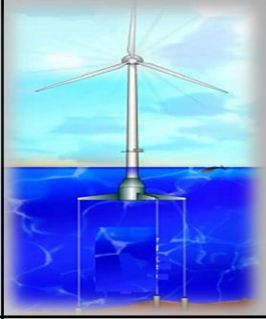


5. Degree of Freedom for A Floating Offshore Wind Turbine

- Displacements are surge, sway, and heave.
- The rotational displacements are roll, pitch, and yaw.
- Angles of the platform rotations are assumed to be small.



6. Relative Advantages/Disadvantages for Platform of Floating Offshore Wind Turbines

+ (PLUS): Relative advantege - (MINES): Relative disadvantage	Floating Platform Classification			
	BARGE	SEMI-SUB.	SPAR	TLP
				
Buoyancy Tank Cost/Complexity	-	-	-	+
Mooring Line System Cost/Complexity	-	-	-	+
Anchors Cost/Complexity	+	+	+	-
Decommissioning & Maintainability	+	+	+	-
Corrosion Resistance	-	-	+	+
Depth Independence	+	+	-	-
Minimum Footprint	-	-	-	+
Wave Sensitivity	-	-	-	+
Tower Top Motion, Controls Complexity, Maximum Heeling Angle	-	-	-	+

7. Reference Wind Turbine and Platform Design & Environmental Conditions

5 MW Wind Turbine Specifications

Specification	Unit	Value
Maximum Power	kW	5000
Rotor Diameter	m	126
Number of Blades	piece	3
Hub Height (from Main Sea Level)	m	90
Tower Height	m	87.6
Tower Weight	t	347
Total Turbine Weight	t	697
Nominal Speed	m/s	11.4

Environmental Conditions

Specification	Unit	Value
Current Speed	m/s	1
Wind Speed @90m	m/s	11
Temperature	° C	10
Sea Water Density	t/m^3	1,025
Air Density	t/m^3	0,0013
Water Depth	m	100
Current & Wind Direction	From +x direction to –x direction	

7. Reference Wind Turbine and Platform Design & Environmental Conditions

Platform Specifications

Specification	Unit	Value
Diameter	m	20
Draft&Height	m	30
Water Depth	m	100
Steel Weight	t	805
Concrete Weight	t	7700
Concrete Height	m	8.65
Displacement	t	9424
Center of Gravity	m	(0,0,-25)

Mooring System Specifications

Specification	Unit	Value
Rope Outer Dia.	m	0.350
Rope Inner Dia.	m	0.250
Rope Mass per Unit	t/m	0.180
Bending Stiffness	$kN.m^2$	120.0
Mooring Unit	unit	4

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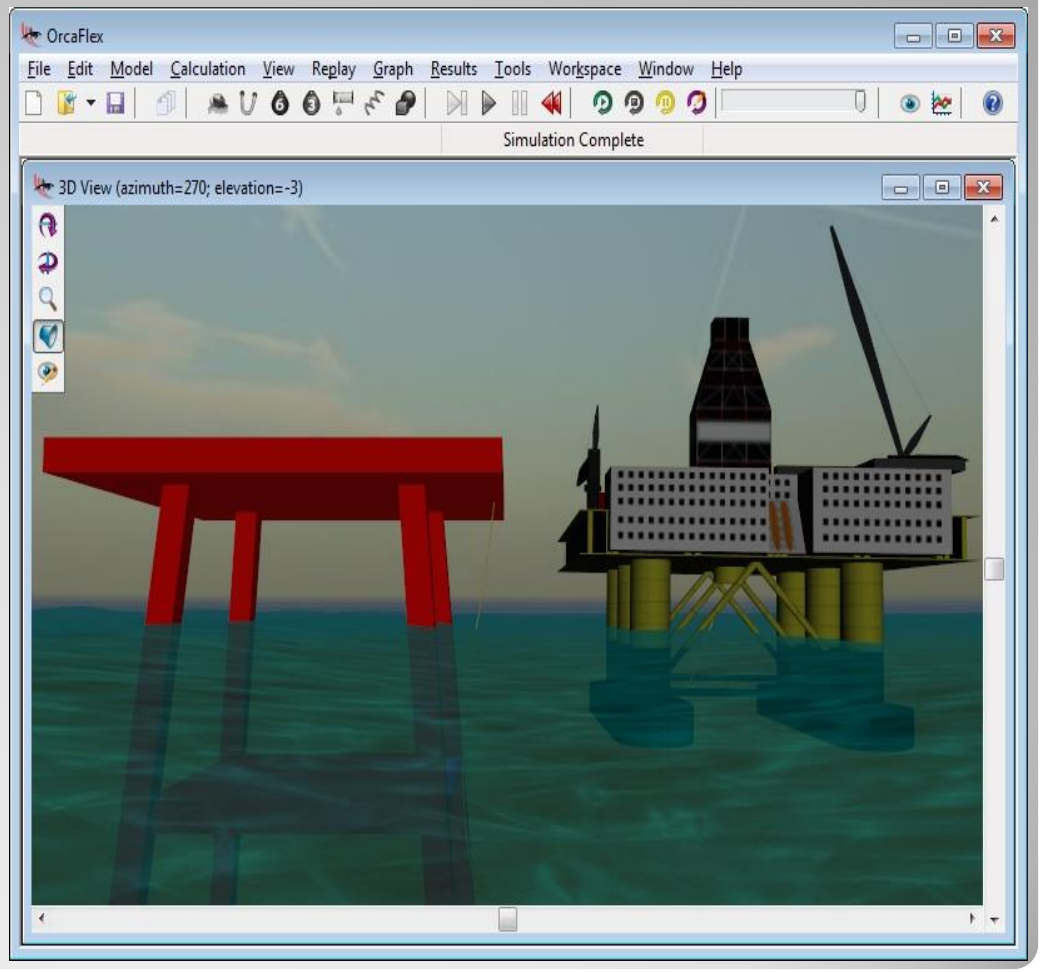
Mooring Lines	piece	4

7. Reference Wind Turbine and Platform Design & Environmental Conditions

Design Tools – Orcina Orcaflex Software

- OrcaFlex is in use, mainly in the offshore engineering business, with others in seismic, defence, ocean engineering, oceanographic research, aquaculture, compliant marine renewables and related fields.



7. Reference Wind Turbine and Platform Design & Environmental Conditions

Concept Design of Floating Offshore Wind Turbine

Tension Leg

Catenary

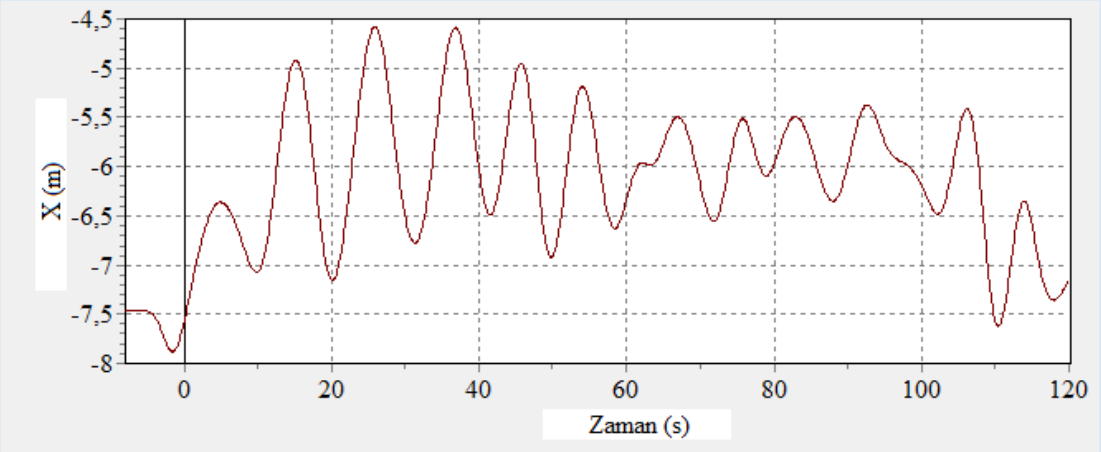
8. Behavior of Floating Platform and Mooring System of the Offshore Wind Turbine Under Different Sea Conditions

- Different Mooring Systems:
  TLP and Catenary Mooring System
- Different Wave Heights:
  4m-6m &10m
- Comparative Analysis in terms of different mooring system and wave. Focused on:
  - Platform Displacements and
  - Mooring Lines Loads

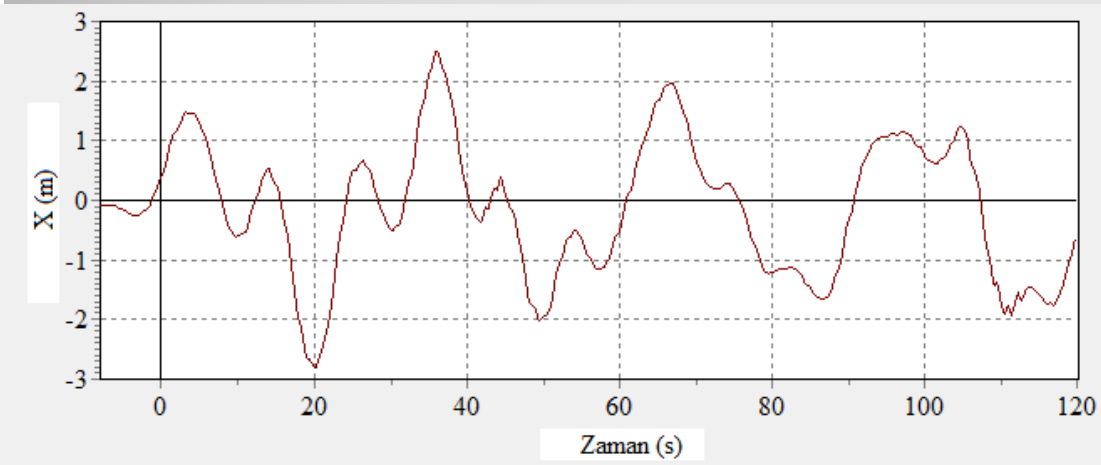
9. Analysis & Results

- For 6m wave height comparative analysis:

  Surge Displacements



Slack Catenary System

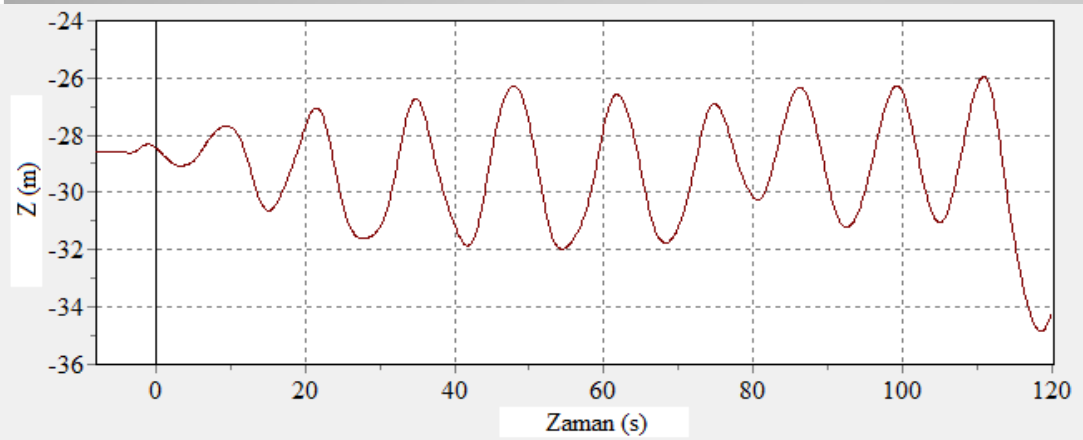


Tension Leg System

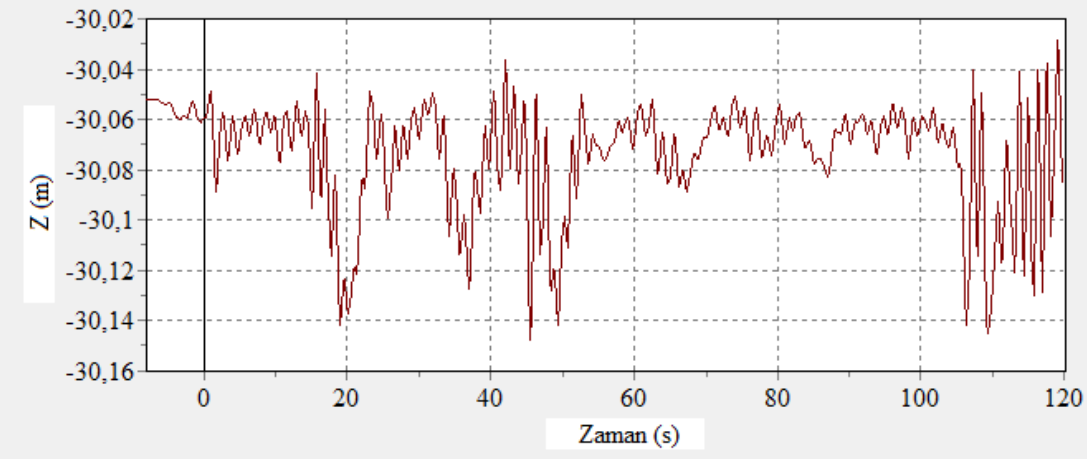
9. Analysis & Results

- For 6m wave height comparative analysis:

  Heave Displacements



Slack Catenary System

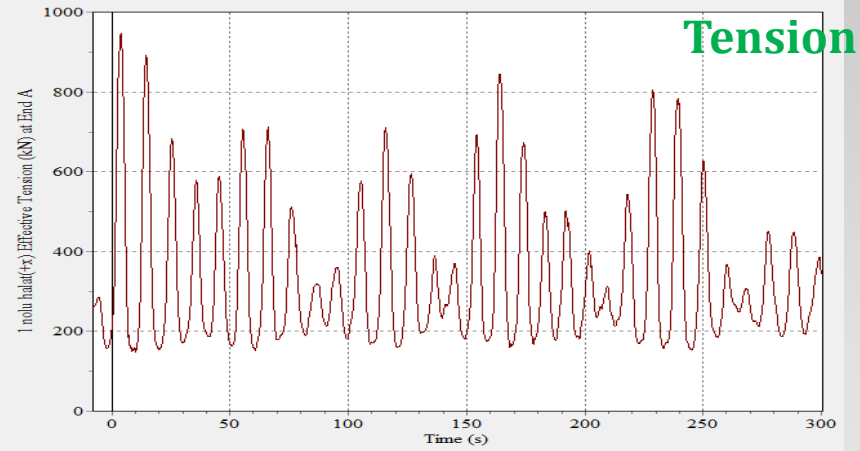


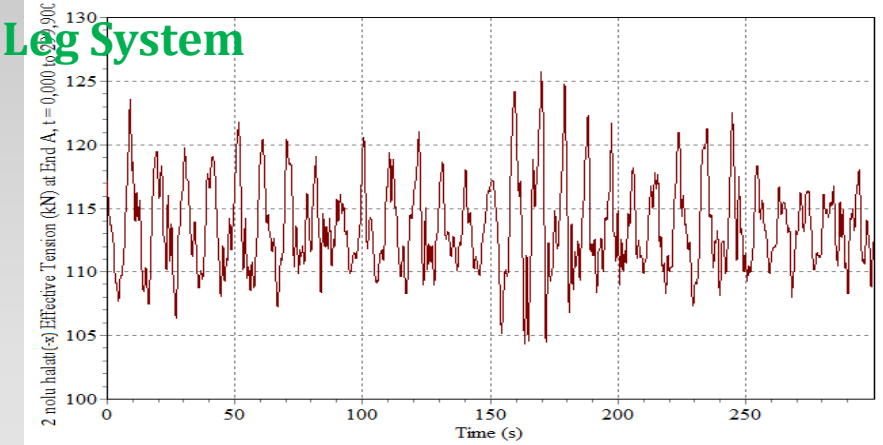
Tension Leg System

9. Analysis & Results

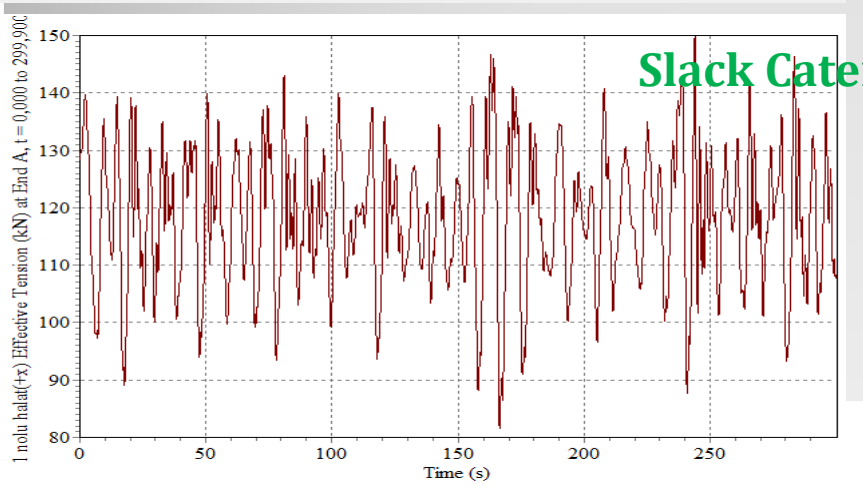
- For 6m wave height comparative analysis:
  (+x) and (-x) Direction Mooring Line Loads

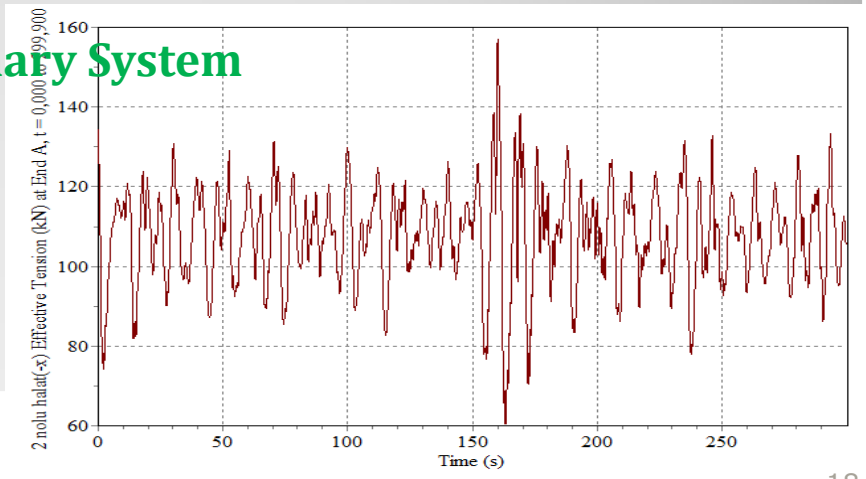
Tension Leg System





Slack Catenary System





10. Conclusion

- To use cylinderical platform shape made easy comparing data.
- Orcina Orcaflex software 9.6a version is used to simulate model and perform hydrodynamic analysis.
- TLP and Catenary system are tested on Orcina Orcaflex software to realize different wave effects.
- Comparative analysis has been conducted to understand which mooring system is effective for stability: Catenary or TLP
- TLP mooring sytems must be pre-tensioned. Thus, mooring lines of TLP have big load potential than catenary system.
- TLP has chosen for detailed research to achieve the goal
- TLP system tested on software at different wave heights (4m,6m & 8m) to observe 6 degree of freedom and mooring lines load.
- This study is not yet fully completed, the model tests are on going at ATA NUTKU SHIP MODEL EXPRIMENT LABORATUARY in ITU.