

COMPARATIVE ANALYSIS ON A CLB STATION KEEPING IN REGULAR AND IRREGULAR WAVES

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Abstract: The offshore industry gained a great development level in the past years, due to the necessity of sustainable and clean energy. This trend is determined by the new development and installation of more and more offshore wind farms. In the great effort of commissioning an offshore wind farm, one of the players will always be Cable Laying Vessels / Barges, which are required to lay submarine high voltage cables in the nearshore area. In order to prove the capabilities of the envisaged barge to lay the cable in the required conditions, there are carried several engineering studies, which are aiming the hull behavior in the most unfavorable conditions. One of the most important studies is represented by the station keeping studies. The article is aiming to present a comparative analysis between two simulation scenarios, by considering regular and irregular wave train.

Keywords: cable, laying, barge, wave, station keeping

Introduction

Throughout the development of offshore cable laying operations, it is very important to keep a precise position. For instance, during such operation, one wishes to minimize the Cable Laying Vessel / Barge movements, due to the fact that these movements may alter the cable lay route or, worst to damage the cable by reaching the Minimum Bending Radius during the laying operation, or by compressing the cable when it describes a "whipping" movement.

In the project stages that are carried prior to operation start, there are carried huge amounts of work, in order to prepare the barge / vessel for the operation and to prove that the proposed design for the operation is suitable for a safe completion.

This paper is aims to present a comparative analysis between the results obtained in two analysis scenarios for a CLB's mooring system. In order to provide a sufficient contingency, during the carried scenarios there were considered the worst weather conditions (wave height and wind speed) in the operation's area. Figures 1 and 2 presents the operation's map and the metocean data available for the considered area.

Simulation setup and assumptions

The load of the anchor lines was analyzed by performing a time-domain analysis in Orcaflex software. There have been considered three Load Cases for each incident environment direction, as described. In order to perform the redundancy check, it was identified the most loaded line and considered to be broken at a certain time.

For all situations, the considered time was a very conservative 6 hours, with a time step of 1 second. By considering the metocean data

provided, in order to follow a conservative approach, there was applied the following setup for all Load Cases:



Figure 1. Operation route

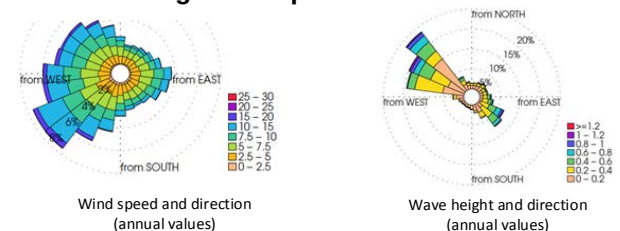


Figure 2 Annual metocean data for the operation area

The analysis was developed in several load-cases, by considering the following situations:

Table 1. Analysis setup

Parameter	Regular waves scenario	Irregular waves scenario
Wind Speed:	25 m/s	25 m/s
Wind Direction:	90° (considering 0° as being the barge heading)	90° (considering 0° as being the barge heading)
Wave Direction:	90°(considering 0° as being the barge heading)	90°(considering 0° as being the barge heading)
Wave type	Stokes 2nd Order Wave Theory	Johnswap wavetype with the spectral range (1.047 rad/s , 1.57 rad/s) and the peak at 1.256 rad/s; Hs=1.2m
Wave Significant Amplitude:	1,2 m	1,2 m
Wave Period:	8 s	N/A
Wave Frequency:	0.125 Hz	N/A
Current Speed:	1 m/s	1 m/s
Current Direction:	90° (considering 0° as being the barge heading)	90° (considering 0° as being the barge heading)
Water Depth	8m	8m
Analysis type	Regular Wave Response	Irregular Wave Response with Slow Drift
Start time	0 s	0 s
Finish Time	21600 s	21600 s

The mooring is considered to be as a short term and weather unrestricted mobile mooring in an open location, without interfering with any other structure;

- The mooring components are considered to be new;
- The export cable does not contribute to the mooring capacity / system's stiffness while attached to the vessel;
- The environmental loads act simultaneously from the same direction.

In a conservative approach, the pulling line was excluded from the carried simulations. The gradient of the seabed is maximum 3% around KP 8.8 and thus its effect on the station keeping behavior is negligible. Due to low water stream speed around the hull the shallow water effect is also negligible.

Regarding anchor lines and anchors,

- Anchor Line MBL = 932kN;

- Anchor Holding Capacity – HC (2t Delta Flipper) = 470.88 kN (an efficiency of 24 x m has been used for mud+clay+sand soil typology) – for anchor line

- Anchor Holding Capacity – HC (4t Delta Flipper) = 941.76 kN (an efficiency of 24 x m has been used for mud+clay+sand soil typology) – for pulling line.

The maximum loads, after considering the safety factors, are:

- 60% of MBL for anchor line in intact condition and 80% of MBL for redundancy check
- 66.67% of HC for intact condition and 83.33% of HC for redundancy check
- The stall capacity for mooring winches: 500kN.
- There was considered a 33 kN pretension in all mooring lines and in all Load Cases.

The CLB's geometry was developed by considering the real blueprints and it is presented in figure 3.

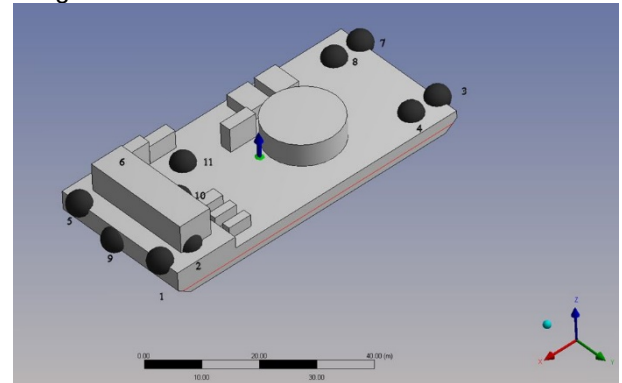


Figure 3 The CLB model and fairleads and winches position

No	Fairlead / Winch	X [m]	Y [m]	Z [m]
1	Fairlead Fw - PS	32.51	10.48	4.81
2	Winch Fw - PS	29.91	10.48	4.81
3	Fairlead Aft - PS	-32.5	10.03	2.3
4	Winch Aft - PS	-26.41	10.03	2.3
5	Fairlead Fw - SB	32.51	-10.51	4.81
6	Winch Fw - SB	25.91	-10.51	4.81
7	Fairlead Aft - SB	-32.5	-10.02	2.3
8	Winch Aft - SB	-26.41	-10.02	2.3
9	Fairlead 1 – Pull Line	32.53	-1.52	2.3
10	Fairlead 2 – Pull Line	17.55	-1.52	2.3
11	Pulling Winch	10.78	-7.90	2.3

Table 2. Winches and fairleads positions

The considered load cases were established by considering the most difficult stages of the cable laying operation and are presented in figures 4 to 6.

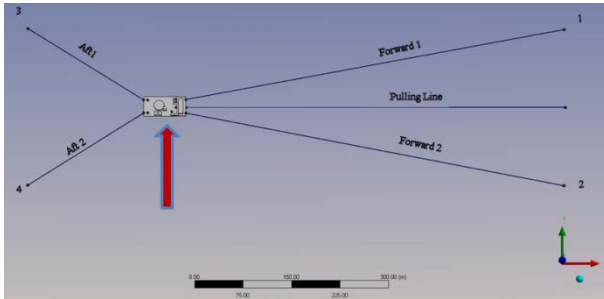


Figure 4 The anchor pattern LC1: Start Position

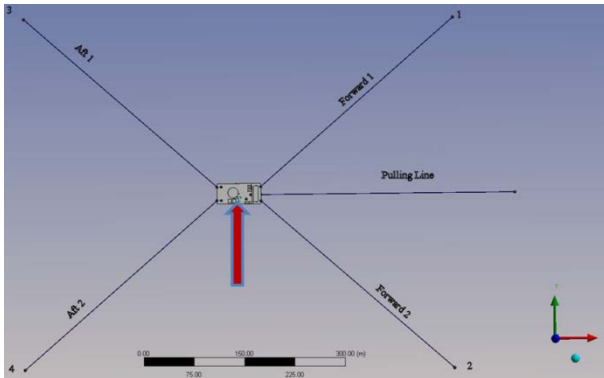


Figure 5 The anchor pattern LC2: Intermediate position

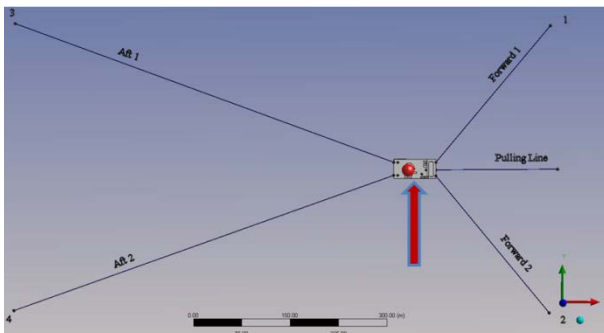


Figure 6 The anchor pattern LC3: End position

Analysis results

The load of the anchor lines was analyzed by performing a time-domain analysis in Orcaflex software pack. There were considered the three Load Cases, as described. In order to perform the redundancy check, it was identified the most loaded line and considered to be broken at a certain time.

For all considered situations (3 Load Cases and 3 redundancy checks for each wave type), the considered time was 6 hours, with a time step of 0.5 seconds. For the redundancy check for Load Case 1 the time step was considered 0.25 seconds.

The obtained results were compared with the minimum acceptable values, for both lines loads and anchor loads [1]. The acceptable values are different in normal versus redundancy check conditions and have the following magnitudes:

	Normal conditions	Redundancy checks
Line loads	547200 kN	729600 kN
Anchor hold capacity	313935.7 kN	392384.3 kN

After comparing the obtained results with the predefined thresholds, there were obtained the Unity Checks tables, presented below:

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.14	0.11	0.1	0.05
Fwd2	0.18	0.11	0.16	0.08
Aft1	0.2	0.1	0.15	0.08
Aft2	0.27	0.13	DAMAGED	
Regular waves scenario				
Fwd1	0.00	0.00	0.00	0.09
Fwd2	0.35	0.30	DAMAGED	
Aft1	0.03	0.02	0.00	0.02
Aft2	0.31	0.29	0.09	0.27

Table 3. Unity checks for the line loads, LC1

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.11	0.06	0.14	0.08
Fwd2	0.18	0.09	DAMAGED	
Aft1	0.13	0.06	0.08	0.04
Aft2	0.17	0.09	0.14	0.09
Regular waves scenario				
Fwd1	0.02	0.01	0.00	0.00
Fwd2	0.47	0.33	0.19	0.23
Aft1	0.01	0.01	0.25	0.32
Aft2	0.58	0.34	DAMAGED	

Table 4. Unity checks for the line loads, LC2

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.24	0.11	0.22	0.08
Fwd2	0.25	0.14	DAMAGED	
Aft1	0.19	0.09	0.14	0.04
Aft2	0.22	0.12	0.24	0.09
Regular waves scenario				
Fwd1	0.03	0.03	0.02	0.01
Fwd2	0.28	0.29	0.28	0.22
Aft1	0.00	0.00	0.58	0.45
Aft2	0.31	0.31	DAMAGED	

Table 5. Unity checks for the line loads, LC3

Lines	Max value	Mean value	Max value R.C.	Mean value R.C.
LC1				
Fwd1	-0.14	-0.11	-0.10	0.04
Fwd2	0.17	0.19	n/a	
Aft1	-0.17	-0.08	-0.15	-0.06
Aft2	0.04	0.16	n/a	
LC2				
Fwd1	-0.09	-0.05	-0.14	-0.08
Fwd2	0.29	0.24	n/a	
Aft1	-0.12	-0.05	0.17	0.28
Aft2	0.41	0.25	n/a	
LC3				
Fwd1	-0.21	-0.08	-0.20	-0.07
Fwd2	0.03	0.15	n/a	
Aft1	-0.19	-0.09	0.44	0.41
Aft2	0.09	0.19	n/a	

Table 6. Comparison Regular Vs Irregular Waves

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.25	0.19	0.18	0.08
Fwd2	0.32	0.19	0.29	0.15
Aft1	0.35	0.18	0.28	0.15
Aft2	0.48	0.23	DAMAGED	
Regular waves scenario				
Fwd1	0.00	0.02	0.56	0.17
Fwd2	0.61	0.58	DAMAGED	
Aft1	0.05	0.02	0.08	0.03
Aft2	0.54	0.60	0.84	0.49

Table 7. Unity checks for anchor hold, LC1

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.20	0.11	0.26	0.14
Fwd2	0.31	0.16	DAMAGED	
Aft1	0.23	0.11	0.14	0.08
Aft2	0.30	0.16	0.26	0.16
Regular waves scenario				
Fwd1	0.03	0.02	0.01	0.00
Fwd2	0.82	0.58	0.67	0.43

CONCLUSIONS AND FINAL DISCUSSIONS

It may be easily seen that the dynamic behavior of the anchoring lines is different in the two considered situations. The most loaded lines in the irregular waves scenario are Aft 2 for LC1 and Fw2 for LC 2 and 3; when concerning about the regular waves scenario, it can be seen that the most loaded lines are Fw2 for LC1 and Aft 2 for LC 2 and 3.

Aft1	0.02	0.02	0.70	0.60
Aft2	1.01	0.60	DAMAGED	

Table 8. Unity checks for anchor hold, LC2

Lines	UC for Max value	UC for Mean value	UC for Max value	UC for Mean value
Irregular waves scenario				
Fwd1	0.42	0.19	0.42	0.15
Fwd2	0.44	0.24	DAMAGED	
Aft1	0.33	0.15	0.26	0.08
Aft2	0.38	0.20	0.44	0.17
Regular waves scenario				
Fwd1	0.06	0.06	0.04	0.02
Fwd2	0.50	0.50	0.52	0.41
Aft1	0.00	0.00	1.09	0.84
Aft2	0.56	0.55	DAMAGED	

Table 9. Unity checks for anchor hold, LC3

Lines	Max value	Mean value	Max value R.C.	Mean value R.C.
LC1				
Fwd1	-0.25	-0.17	0.38	0.09
Fwd2	0.29	0.39	n/a	
Aft1	-0.30	-0.16	-0.20	-0.12
Aft2	0.06	0.37	n/a	
LC2				
Fwd1	-0.17	-0.09	-0.25	-0.14
Fwd2	0.51	0.42	n/a	
Aft1	-0.21	-0.09	0.56	0.52
Aft2	0.71	0.44	n/a	
LC3				
Fwd1	-0.36	-0.13	-0.38	-0.13
Fwd2	0.06	0.26	n/a	
Aft1	-0.33	-0.15	0.83	0.76
Aft2	0.18	0.35	n/a	

Table 10. Comparison Regular Vs Irregular Waves

After the initial iteration there were found the most loaded lines in the both considered scenarios. In order to perform the Redundancy Checks; these most loaded lines were broken at second 1000 of the total simulation time and the loads in the undamaged lines were compared to the acceptable values.

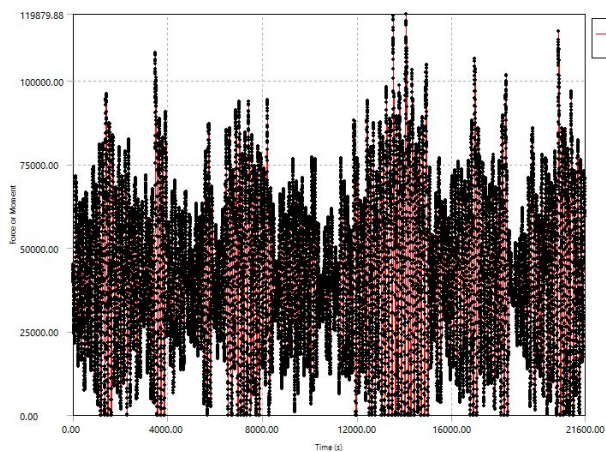


Figure 7 Loads in Aft2 line, LC1, irregular waves scenario

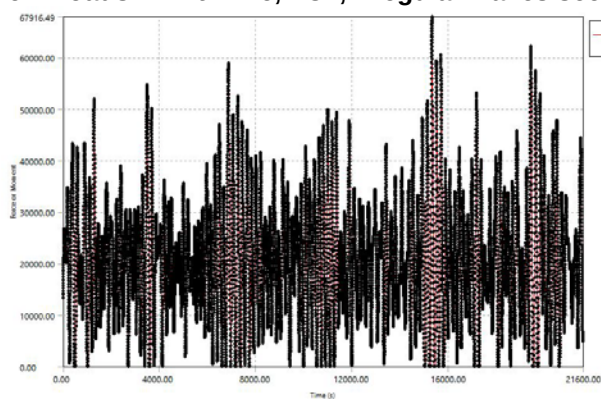


Figure 8 Loads in Fw2 line, LC2, irregular waves scenario

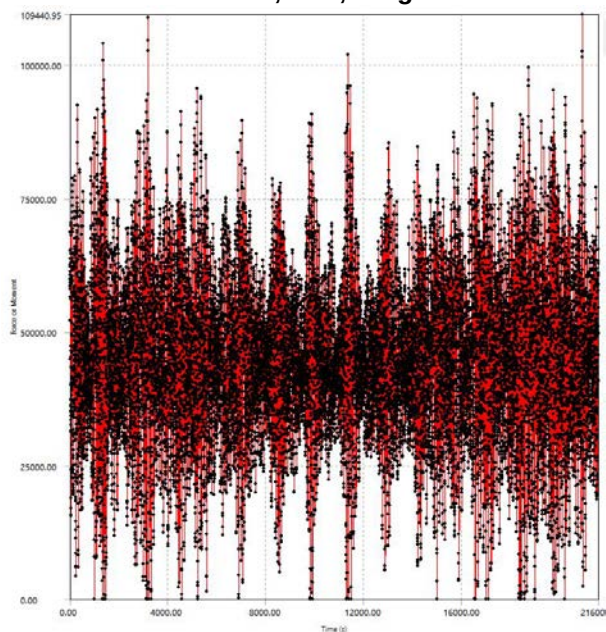


Figure 9 Loads for Fw3 line, LC3, irregular waves scenario

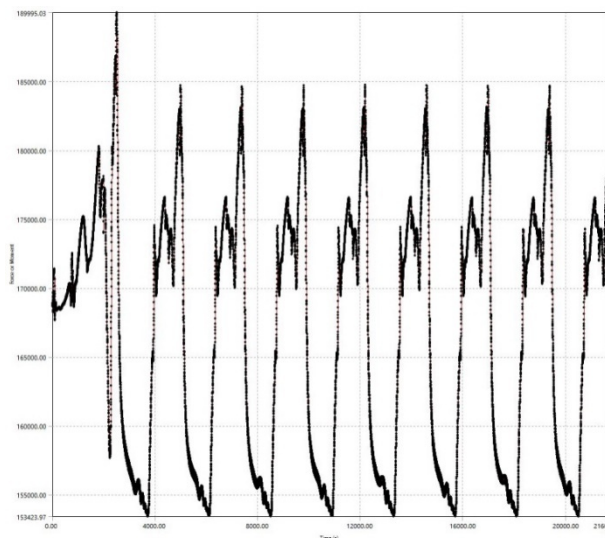


Figure 10 Loads in Fw2 line, LC1, regular wave scenario

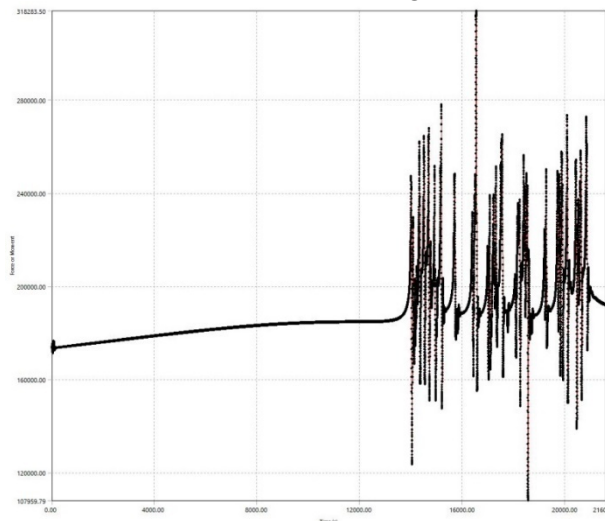


Figure 11 Loads in Aft 2 line, LC2, regular wave scenario

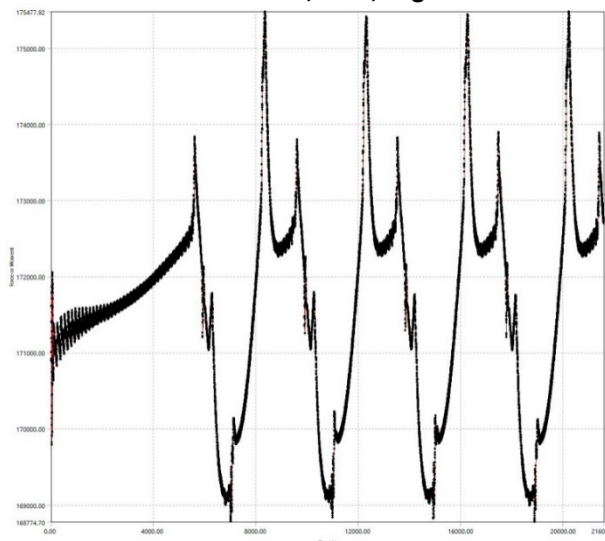


Figure 12 Loads in Aft2 line, LC3, regular waves scenario

It can be concluded that the dynamic response in the two considered situations generates a higher extreme response for the regular wave scenario due to resonance achievement. In Table 4 is emphasized the situation established during LC2 and LC3 for Aft 2 line, where the maximum allowable value is lower with 1 percent (LC2) and correspondingly 9 percent than the obtained value, in normal conditions.

This issue shows that, for an ultraconservative approach when developing station keeping analysis there can be considered the regular wave approach, even if this specific situation is not exactly realistic in metocean data terms.

ACKNOWLEDGMENTS

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