A dynamically positioning system for the drillship "Gusto 10000"

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Abstract

In the early seventies, IHC Gusto Engineering developed the dynamic positioned drillship "Pelican class" design, with assistance from drilling operators for the drilling package. The "Pelican" design became the most widely used design for DP drillships, with 10 units built.

For the new challenge of ultra deep water, with water depths up to 10.000 ft, IHC Gusto Engineering developed a new generation DP drillships.

Two different designs were made, a "pure" drillship, the Gusto 10000 and a drillship with extended well testing capabilities, the Gusto P-10000.

This paper discusses the analytical studies to estimate the DP power requirements and to size the thruster system of the Gusto 10000 to satisfy the stationkeeping requirement for the specified metocean design criteria.

1. Introduction

Deepwater drilling requires specialised vessels, enabling economic exploration and further exploitation of deepwater prospects. In this paper the new generation drillship is described, which has been developed by IHC Gusto Engineering in close co-operation with the world's major drilling contractors (see also ref. [1]).

Drillships are historically associated with Gusto as ten DP vessels were already built to the original Pelican class design during the seventies and the eighties. Today Gusto once again has a drillship concept, which will meet the challenges of the next decades.

The Gusto 10000 type has been chosen by Foramer / Pride for their operations at the Girassol field, of which two vessels were constructed at Hyundai Shipyards in Korea. A derative of the Gusto P-10000 was selected by Global Marine Drilling and two of this type were constructed at Harland & Wolff Shipyard. A picture of the Gusto 10000 leaving the yard is given in figure 1.

This paper discusses the design of the thruster system to satisfy the dual but conflicting requirements for stationkeeping and propulsion.

2. Vessel Particulars

The main particulars of the Gusto 10000 are as follows:

Main Dimensions:

Length overall	: 210.0	m
Length b.p.p	: 195.0	m
Breadth (moulded)	: 30.0	m
Depth (moulded)	: 17.8	m
Design Draft	: 10.0	m

Moonpool dimensions : LxB = 12.8x12.0m

Power Generation:

Main Generator Sets	: 29.1 MW in total
Generators	: 6 x 6600 V, 60 Hz, 3-phase

Propulsion and Dynamic Positioning:

Vessel service speed : 13 knots

Triple redundant DP system

- 2x5000 kW azimuthing thrusters aft for propulsion and DP
- 3x3500 kW retractable azimuthing thrusters for DP at midship section
- 2x2000 kW tunnel thrusters forward for DP and manoeuvring

Power Plant: The vessel is designed for dual redundant and even triple redundant dynamic positioning operations (compatible with NMD2 / NMD3 notation). Again the economics are taken into account resulting in two 50 % engine rooms, each with their own cooling water, fuel oil and auxiliary systems.

Two separate pumprooms and auxiliary engine rooms are located next to the engine rooms. Power is generated by six 4860 kW diesel generator sets, three per engine room. The electric power is fed from two separate switchboard rooms to the consumers. Redundancy is also provided in the cable routing.

As a result the vessel will still be able to operate with one engine room out of order in a 10-year-return-period storm if it is allowed to select its optimum heading. The engine rooms are located in the aftship with one main exhaust (split internally in two parts) on starboard side to minimise deck occupancy. The aft location ensures that the exhaust gases do not interfere with the drilling operations on the vessel, as it is downwind.

Redundancy is also provided for the drilling systems by having two drilling switchboards, on starboard side and one on portside, located next to the moonpool in order to minimise cabling length.

A power management system is installed to ensure that sufficient power is available during all operations and possible failures.

3. Thruster System Design

Thruster system design consisted of the following steps:

- Preliminary estimate of total DP power requirements
- Number, placement, and sizing of thrusters
- Preliminary prediction of thruster system performance
- Model test verification of prediction

- Final thruster design

Thruster Features
The vessel is equipped with two underwater mountable azimuthing thrusters aft, three retractable azimuthing thrusters in the midship part and two bow tunnel thrusters. The two aft thrusters deliver sufficient propulsive power for a service speed of 13 knots. All thrusters, protruding below the base line of the vessel are retractable in order to manoeuvre in shallow waters, ease dry-docking and to be able to sail smoothly at 13 knots from one location to another using the minimum amount of fuel. All thrusters can be inspected and maintained inside the hull of the vessel as the entire units can be raised above the highest waterline by a dedicated retrieving mechanism. These thrusters can be retrieved all the way through the main deck and handled as necessary.

4. Operational Characteristics

DP capability : The Gusto 10000 is equipped with five azimuthing thrusters and two tunnel thrusters, while the Gusto P-10000 is equipped with six azimuthing thrusters and one tunnel thruster. For both designs, the two stern thrusters are used for DP as well as propulsion.

Type	Gusto 10000	Gusto P-10000
DP / Propulsion	2 * 5000 kW	2 * 5000 kW
DP – azimuth	3 * 3500 kW	4 * 3500 kW
DP – tunnel	2 * 2000 kW	1 * 2000 kW

Total installed power is 29.1 MW for Gusto 10000 and 38.8 MW for the Gusto P-10000.

In case of NMD-2 failure, the electric installation is designed in such a way that not more then one (1) fore thruster and one (1) stern thruster can be out of operation at the same time. A key-one line layout is given in figure 2.

Station Keeping Criteria. The maximum dynamic offset shall not be more then 1% of the water-depth. This means that for a water-depth of 10,000 ft the maximum allowable excursion will be approximately 30 m.
During operations with NMD-2 or NMD-3 failure the following situations can occur: (Example for Gusto 10000)

NMD-2 switchboard section failure		
Thruster inoperative	Available thruster power in MW	Available generator power in MW
1+6	15.2	23.4
2+7	15.2	23.4
4	18.4	18.8
5	18.4	18.8

NMD-3 engine room failure		
Thruster inoperative	Available thruster power in MW	Available generator power in MW
1+4+6	12.2	14.1
2+5+7	12.2	14.1

Environmental Conditions. Simulation studies were carried out for three environmental conditions, being typical for Gulf of Mexico, Brazil and West Africa situations:

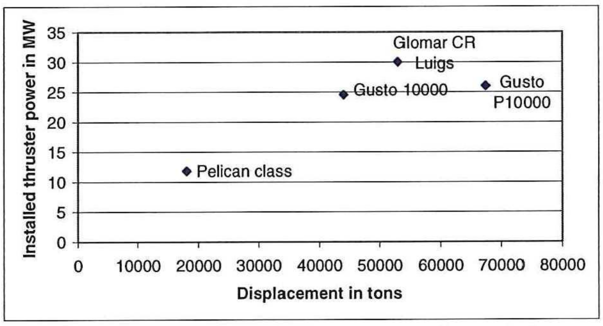
- ENV1 : Maximum drilling condition
- ENV2 : Standby conditions BOP disconnected
- ENV3: West Africa

This results in the following data for wind-speeds, wave conditions and current data.

Description		ENV.1	ENV.2	ENV.3
Wind-speed (1 hr)	m/s	23.9	28.7	17.3
Sign. wave height	m	6.0	10.0	3.4
Peak wave period	s	10.0	15.0	19.8
Current speed	m/s	1.1	1.1	1.2

5. Judging the operational capabilities of the vessel

During the various phases of the vessel design, various methods will be used for the sizing of the thruster system. First the amount of installed power will be compared with other (similar) vessels taking into account the correct main dimensions. This could for instance be done on the basis of



installed power per ton displacement, see figure below.

In the Gulf of Mexico (GOM), a so-called "sudden squall" will be determining factor for the sizing of the thrusters. A rule of thumb was formulated in ref. [2] "The wind load due to a 61-knot beam wind should not be greater than 80% of the total available thrust".
The next step in the design will be the generation of so-called "stationkeeping capability polar plots". These plots indicate the possibility of a vessel to withstand given environmental conditions (combination of wind, currentspeed and waveheight). The calculations are based on static forces.
An example of these capability plots can be found in the following figures/tables:

Figure [3] Capability plot Gusto 10000
Figure [4] Thruster power plot env3, NMD3 failure

Table [1] Thruster power env3, NMD3 failure

When the design continues the DP capability will be checked using time domain simulation. Time series of waveheight and windspeed will be generated and the actual DP performance of the vessel can be judged from the results of these simulations. The following output is normally generated:

Time series and statistics (mean, minimum, maximum and standard deviation) of excursion (longitudinal, transverse), heading, (individual & total) thruster force, consumed power.

An example of such a simulation is given in the following figure/table:

Figure [5] Example of Results of a time domain simulation.

Table [2] Simulation results Gusto 10000

6. Results

Results of simulations. The criteria on which the station keeping capability has been judged are the maximum excursion and the mean power consumption and the maximum power consumption.

Intact conditions: It was observed that for all the simulation runs the vessel with intact DP system is capable of station keeping within specified excursion and power. For these cases, the maximum excursion is not exceeding 1% of the water depth. In the maximum drilling waveheight of 3.4 metres, the average power consumption is approximately 1.55 MW (optimum heading) with peak consumptions of 7.26 MW.

NMD-2 failure: In standby condition and a heading into waves, the vessel is slowly moving away from its set point, (without loss of heading) when thrusters T2 and T7 are out of order because of a switchboard section failure. This is allowed, because the riser is disconnected from the BOP. The power consumption is not exceeding the available generator power.

NMD-3 failure: In case of NMD-3 failure during drilling operation, the vessel is capable of station keeping with an optimum heading. At the moment of the failure, the drilling operations are slowed down to ensure station keeping, because the riser is connected to the BOP.

In standby condition, the vessel is capable of keeping its set point with an optimum heading keeping within specified excursion and power.

7. Validation

The simulation study was confirmed by full DP modeltesting, having a model outfitted with 7 thrusters and a DP system dynamically positioned in the modeltestbasin at MARIN (see also ref. [2,3])

8. References

[1] Willem Schoonmade, Wim Janse, Jeroen Lusthof, Bob Rietveldt, "A new generation DP drillships, the Gusto 10000 and Gusto P-10000", OTC 1998

[2] G.S. Virk, Hin Chin, D.R. Deter, C. van der Stoep, "Design of the dynamic positioning system for the drillship Glomar C.R. Luigs", OTC 2000

[3] C. van Stoep, "Design of hull 456 deepwater DP drillship, Modeltest evaluation report" IHC Gusto Engineering report No. 0197-1010-302, February 1998.

Figures

Tables

Figure 1 : The Gusto 10000 leaving the yard

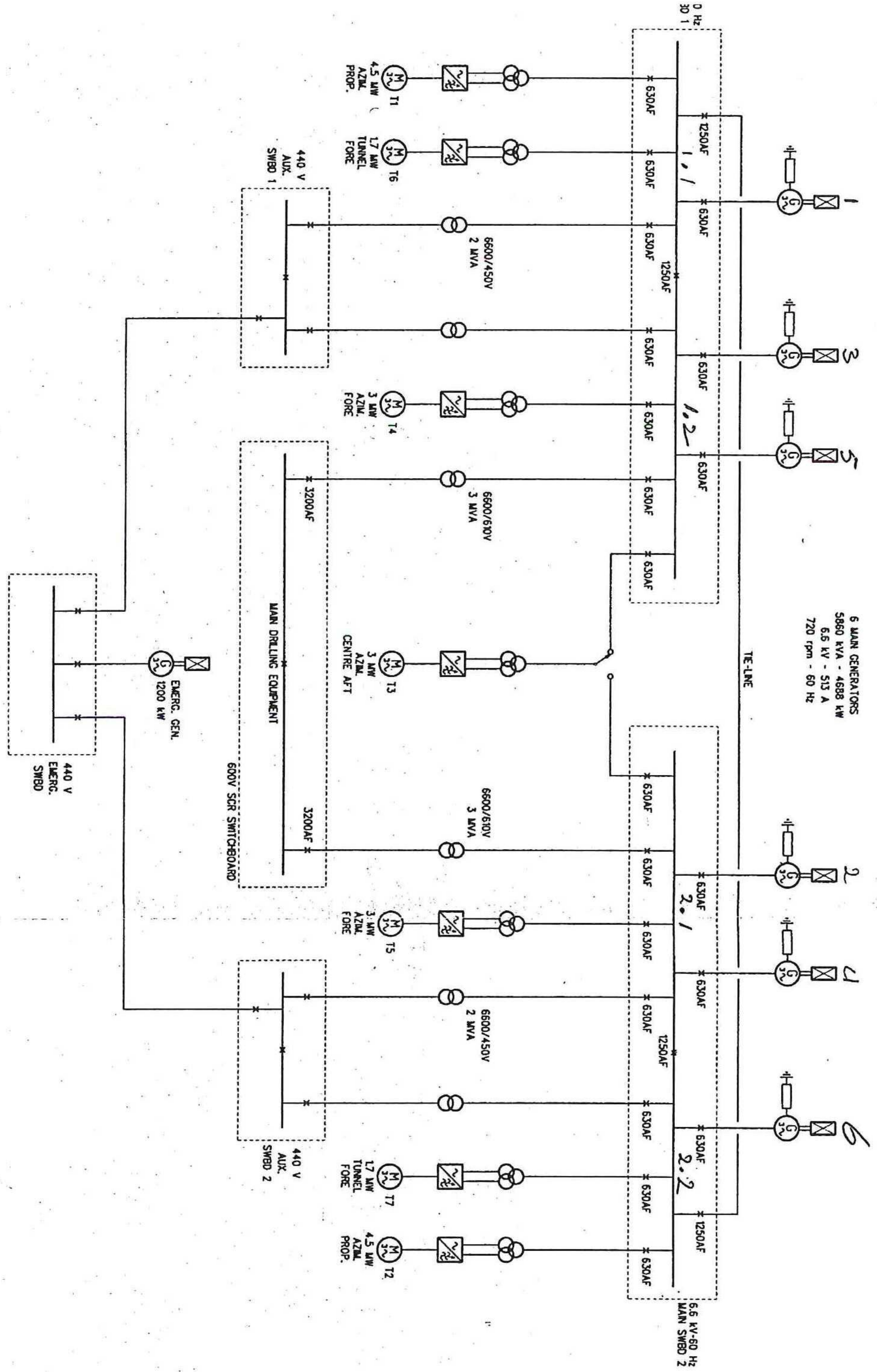


Figure 2 : Key-one line layout

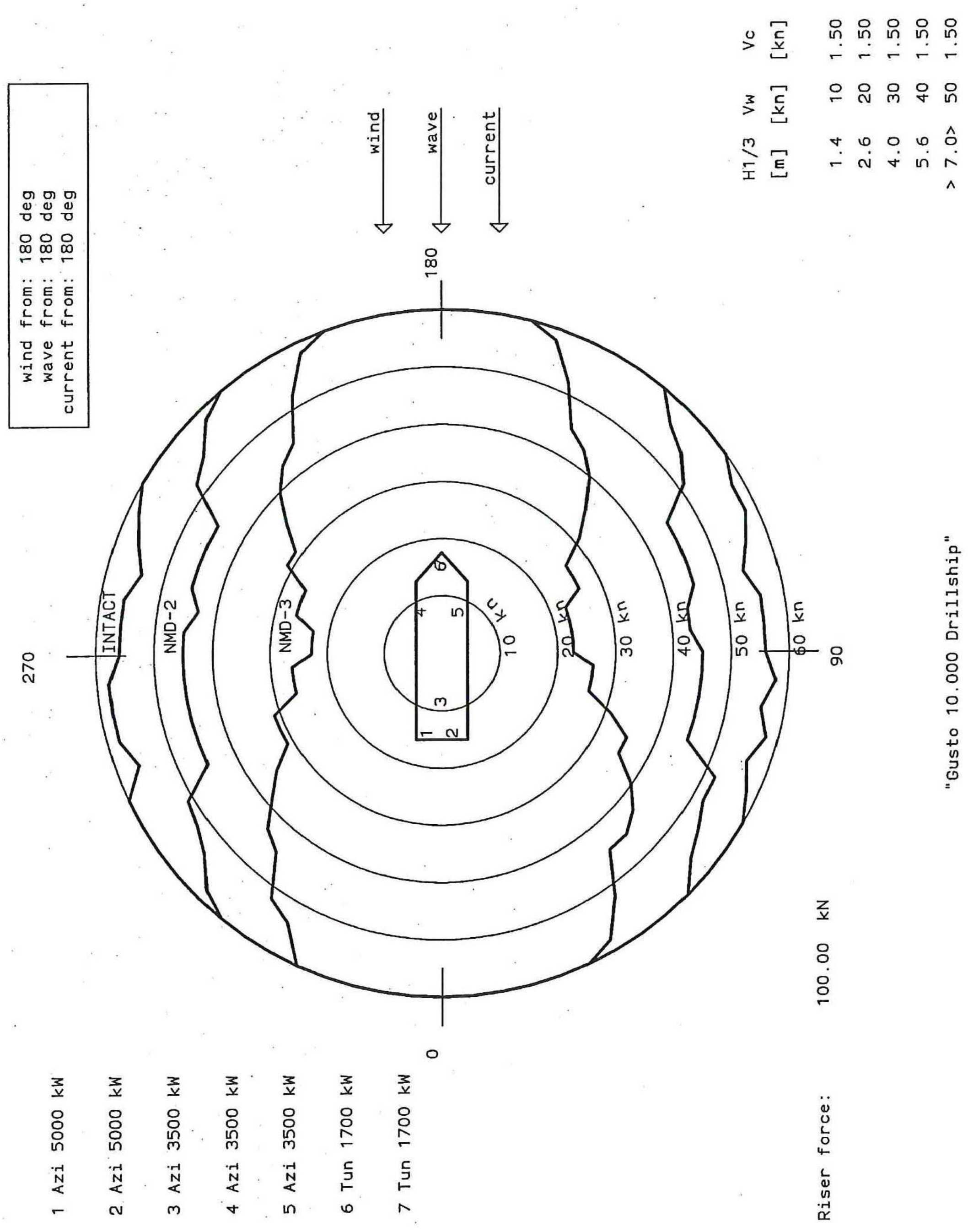


Figure 3 : Capability plot Gusto 10000

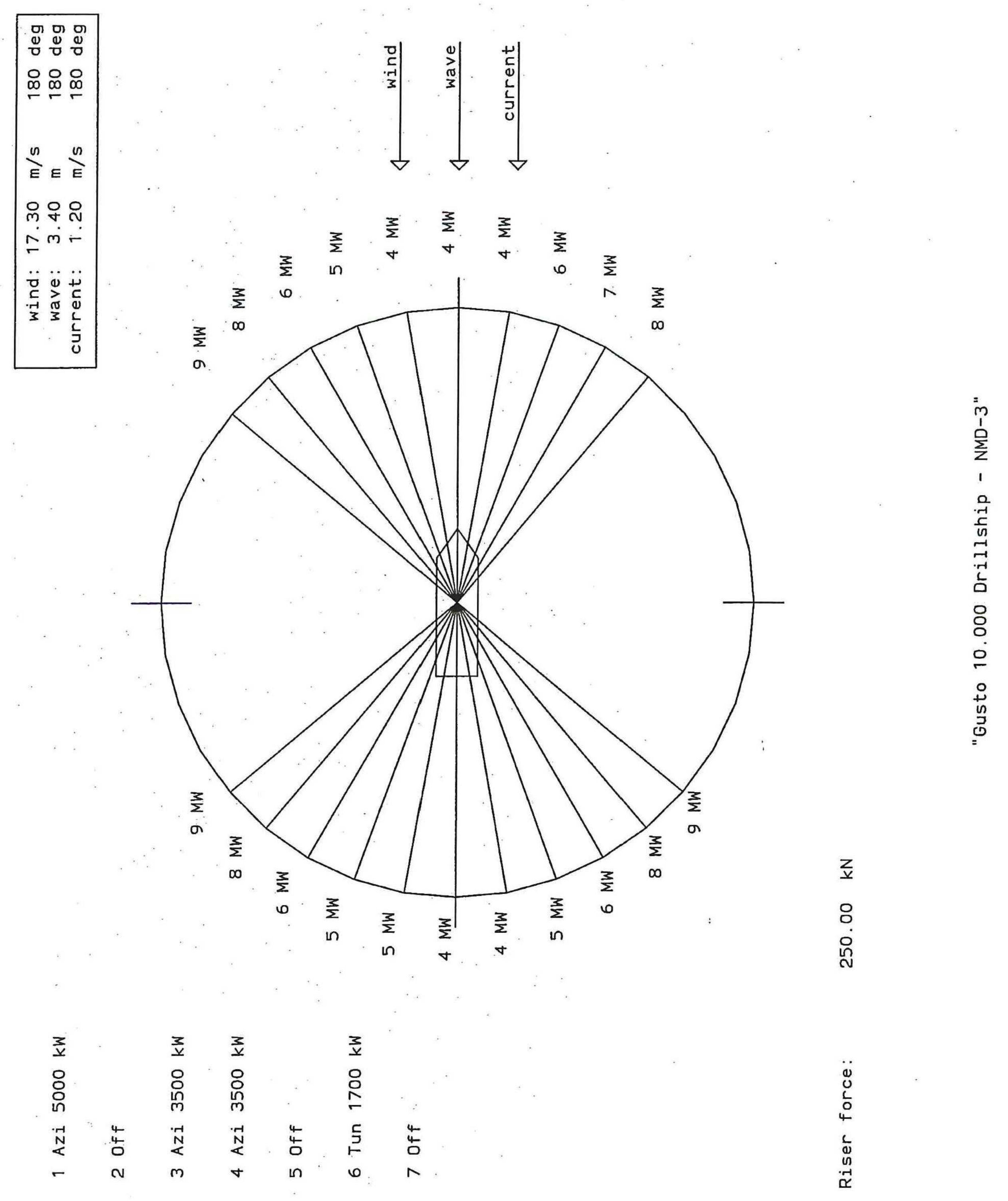


Figure 4 : Thruster power plot, env 3, NMD 3 failure

Table 1 : Thruster power, env 3, NMD 3 failure

FEASIBILITY SUMMARY

alfa_ship	F_total		Moment	feasible	Thruster use (% of max.)						
	|F|	angle									
[deg]	[kN]	[deg]	[kNm]		T1	T2	T3	T4	T5	T6	T7
0	593.57	-179.19	-617.72	+	25.%	0.%	36.%	35.%	0.%	9.%	0.%
10	624.06	161.81	3779.23	+	25.%	0.%	36.%	36.%	0.%	22.%	0.%
20	778.75	146.03	6409.03	+	29.%	0.%	42.%	44.%	0.%	53.%	0.%
30	934.11	132.49	8863.24	+	32.%	0.%	46.%	51.%	0.%	86.%	0.%
40	1156.25	122.28	10813.75	+	34.%	0.%	53.%	71.%	0.%	100.%	0.%
50	1390.99	115.67	11696.78	+	36.%	0.%	61.%	100.%	0.%	100.%	0.%
60	1606.05	109.67	13448.87	-							
70	1765.06	104.11	14230.61	-							
80	1846.80	98.18	13672.07	-							
90	1850.51	92.54	11201.82	-							
100	1833.70	85.88	8959.04	-							
110	1752.31	82.07	6442.20	-							
120	1621.28	76.12	3311.19	-							
130	1426.01	68.95	-1197.80	+	38.%	0.%	66.%	97.%	0.%	100.%	0.%
140	1168.80	60.19	-6012.35	+	38.%	0.%	57.%	62.%	0.%	100.%	0.%
150	961.02	46.06	-8789.17	+	36.%	0.%	51.%	50.%	0.%	69.%	0.%
160	766.22	32.28	-8011.64	+	30.%	0.%	43.%	42.%	0.%	39.%	0.%
170	691.92	16.15	-3551.13	+	28.%	0.%	40.%	41.%	0.%	23.%	0.%
180	659.37	0.26	290.01	+	28.%	0.%	39.%	39.%	0.%	8.%	0.%
190	691.66	-16.52	3702.27	+	29.%	0.%	42.%	40.%	0.%	8.%	0.%
200	755.86	-32.86	8179.25	+	32.%	0.%	45.%	40.%	0.%	24.%	0.%
210	934.41	-46.75	8807.73	+	37.%	0.%	52.%	46.%	0.%	53.%	0.%
220	1164.02	-60.39	6269.44	+	42.%	0.%	59.%	55.%	0.%	96.%	0.%
230	1415.72	-69.09	1187.03	+	42.%	0.%	66.%	89.%	0.%	100.%	0.%
240	1613.08	-76.19	-3315.68	-							
250	1748.97	-82.07	-6400.00	-							
260	1826.39	-86.81	-8904.57	-							
270	1850.17	-92.51	-11224.26	-							
280	1848.58	-98.17	-13572.10	-							
290	1769.78	-104.12	-14157.58	-							
300	1613.17	-109.72	-13423.43	-							
310	1398.45	-115.76	-11746.46	-							
320	1161.41	-122.43	-10990.03	+	31.%	0.%	54.%	80.%	0.%	100.%	0.%
330	950.38	-132.87	-8983.26	+	30.%	0.%	46.%	53.%	0.%	100.%	0.%
340	784.96	-146.33	-6742.14	+	28.%	0.%	42.%	45.%	0.%	68.%	0.%
350	623.14	-162.16	-4240.43	+	25.%	0.%	36.%	37.%	0.%	35.%	0.%
360	593.57	-179.19	-617.72	+	25.%	0.%	36.%	35.%	0.%	9.%	0.%

wind: 17.30 m/s 180 deg
wave: 3.40 m 180 deg
current: 1.20 m/s 180 deg

"Gusto 10.000 Drillship - NMD-3"

Table 2 : Simulation results Gusto 10000

IHC Gusto Engineering b.v.
simula2

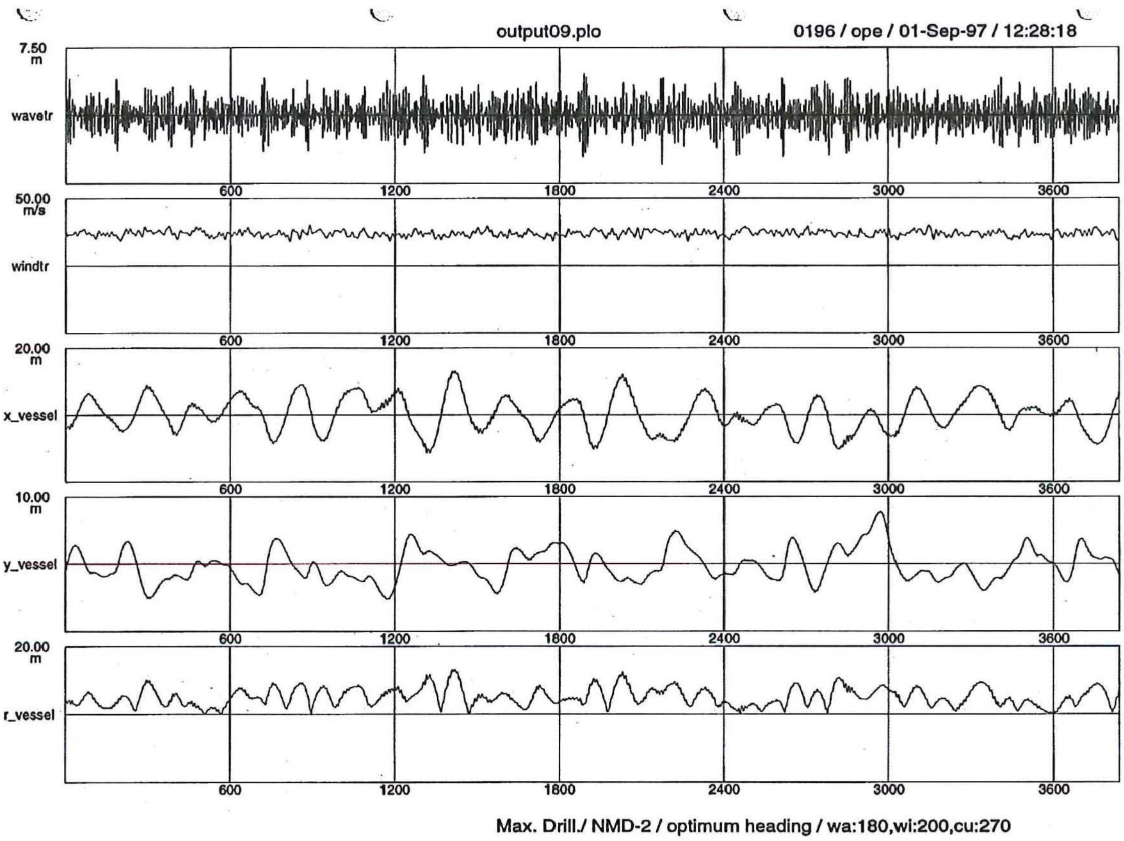
inputfile: gen09.dat

date: 01-Sep-97 time : 12:08:51
user: ope order: 0196

S T A T I S T I C A L A N A L Y S I S of SIMULA-run: 9

Max. Drill./ NMD-2 / optimum heading / wa:180,wi:200,cu:270

DESCRIPTION		MEAN	STDEV	MAX	MIN	total A1/3	total TM	LF A1/3	LF TM	HF A1/3	HF TM
wavetr	m	0.00	1.43	4.64	-5.39	2.80	8.81	0.00	72.22	2.80	8.81
windtr	m/s	23.90	2.04	29.85	18.21	4.00	43.77	3.60	66.58	1.74	17.73
x_vessel	m	.17	5.10	13.06	-11.38	10.12	210.96	10.10	225.06	.61	11.74
y_vessel	m	-.26	2.39	7.79	-5.23	4.74	256.76	4.74	260.73	.11	9.26
r_vessel	m	5.00	2.60	13.06	.07	5.24	141.26	5.21	159.13	.53	11.89
yaw	deg	30.04	2.27	37.16	25.08	4.51	182.01	4.47	257.43	.60	10.60
heave	m	0.00	.37	1.23	-1.14	.72	10.50	0.00	46.40	.72	10.50
roll	deg	0.00	.35	1.29	-1.31	.69	9.30	0.00	40.77	.69	9.30
pitch	deg	0.00	.78	2.61	-2.75	1.53	10.46	0.00	68.10	1.53	10.46
fx-env_v	kN	-866.68	183.19	-89.92	-1629.05	356.48	41.65	312.94	66.76	170.73	18.40
fy-env_v	kN	160.32	387.85	1628.95	-773.65	747.47	60.60	712.49	78.63	225.98	18.48
fm-env_v	kNm	-6936.40	20439.00	83116.90	-115079.30	39375.29	41.26	36586.04	51.98	14555.94	17.92
thrust_1	kN	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
thrust_2	kN	329.70	73.03	521.94	172.43	143.56	197.87	143.50	199.38	4.23	20.34
thrust_3	kN	325.41	70.08	470.00	170.67	137.65	201.44	137.61	202.66	3.56	20.25
thrust_4	kN	319.08	65.05	470.00	165.37	127.87	205.29	127.83	206.29	2.91	19.82
thrust_5	kN	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
thrust_6	kN	16.50	61.03	145.40	-145.20	122.63	246.47	122.62	247.10	1.77	18.58
thrust_7	kN	18.31	60.82	146.28	-144.34	122.20	247.91	122.19	248.59	1.82	18.55
power	kW	5238.54	1515.68	9687.83	2554.66	3000.63	195.59	2999.73	196.62	73.60	20.09



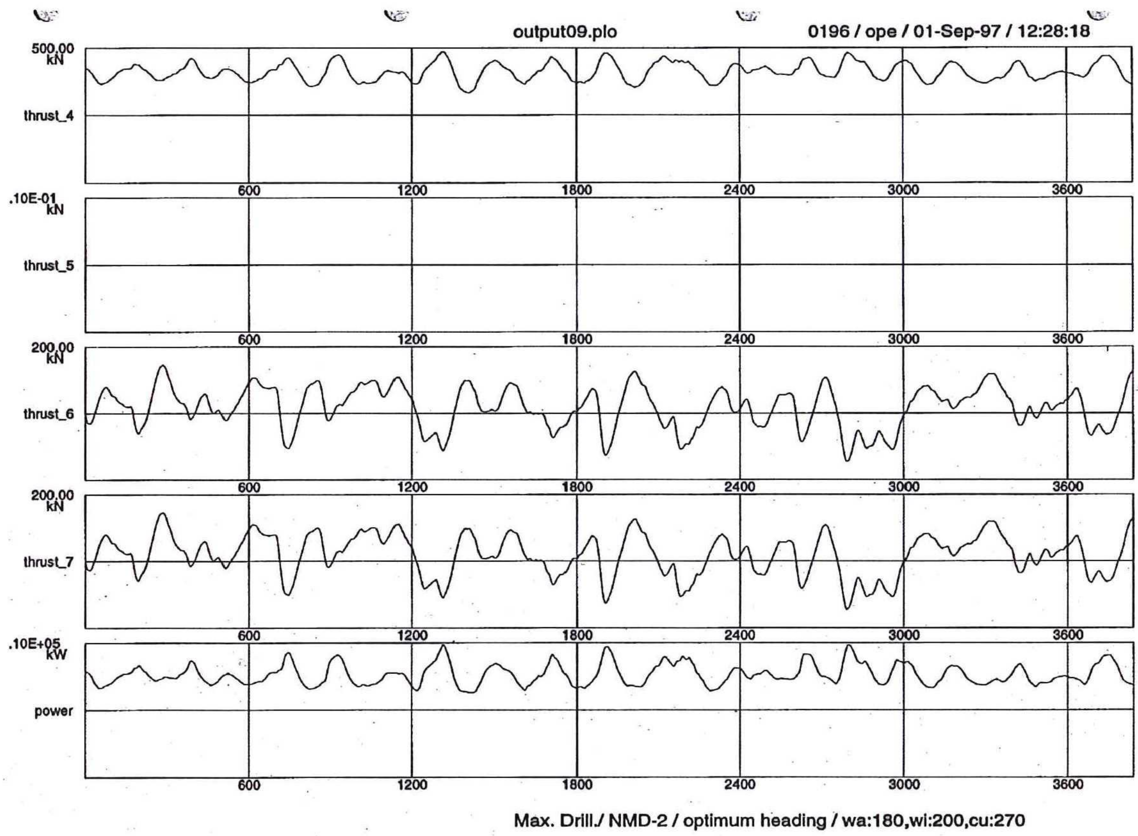


Figure 5 : Example of time domain simulation