Open Sea Operating Experience to Reduce Wave Energy Costs

Deliverable D3.3

Turbine and electrical equipment performance and reliability in shoreline OWC wave plant

Lead Beneficiary	Instituto Superior Técnico
Delivery date	2018-07-13
Dissemination level	Public
Status	Approved
Version	1.0
Keywords	Biradial turbine; Mutriku OWC plant; testing at-sea operation

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 654444

Disclaimer

This Deliverable reflects only the author's views and the Agency is not responsible for any use that may be made of the information contained therein

Document Information

Grant Agreement Number	654444
Project Acronym	OPERA
Work Package	WP 3
Task(s)	T3.3
Deliverable	D3.3
Title	Turbine and electrical equipment performance and reliability in shoreline OWC wave plant
Author(s)	L.M.C. Gato (IST); J.C.C. Henriques (IST); A.A.D. Carrelhas(IST); B.S. Lopes (IST); J. Varandas (Kymaner); F.X. Fay (Tecnalia)
File Name	OPERA_D3.3_Performance&reliability_IST_2018-07-13.docx

Change Record

Revision	Date	Description	Reviewer
1.0	23-05-2018	Initial outline	IST
0.5	09-07-2018	Full draft for peer review	Lars Johanning (UNEXE), Pablo Ruiz-Minguela (Tecnalia)
1.0	13-07-2018	Final version for submission	EC

EXECUTIVE SUMMARY

The main goal of WP3 Task 3.3 was to perform field tests of the Biradial turbine at Mutriku shoreline wave power plant, with grid connection, and to validate the reliability and performance of the novel turbine.

Specific objectives of WP3 are:

1. To improve the reliability of the power take-off: collect and share electrical component operating data, identify failure modes, their causes and test solutions;
2. To increase annual mean efficiency 50% by advancing the novel Biradial turbine to TRL 5.

The sea trial campaign provided test data to improve the reliability of the power take-off equipment (PTO), collect and share operating data, identify failure modes, their causes and test solutions.

This deliverable addresses the following topics:

- **PTO performance** providing the results of the Biradial turbine tests at Mutriku Power Plant and its comparison with the results from the Wavegen Wells turbine installed in the same plant;
- **PTO operating parameters and constraints** showing the Biradial turbine and generator characteristics and operating limits;
- **PTO fatigue-drivers** analysing the Biradial turbine and generator integrity;
- **Failures and risks** describing the guide vanes superficial traces of corrosion and the occurrence of only one electrical failure;
- **Maintenance requirements** after disassembling the Biradial turbine-generator set from the Mutriku Power Plant.

The Biradial turbine-generator set has been installed in Mutriku Power Plant for thirteen months (Jun17-Jul18). During that period, the operation of the PTO has been continuously monitored to analyse its performance. Operation beyond the design values has rarely happened. In general, the turbine has operated without incidences, being its performance in line with the results obtained in the dry tests.

During the tests at Mutriku, two issues deserve particular attention, with one of them leading to the interruption of the tests:

1. The guide vanes, manufactured in stainless steel, after the first month of tests exposed to a salty atmosphere started to show superficial traces of corrosion that have not progressed since.

2. The generator suffered a short circuit that led to its removal and repair by the supplier Siemens in Lisbon. This led to the interruption of the tests for three months.

The reinstallation and recommissioning were finally achieved in December 2017 leading to a three-month interruption of the tests. A filter was installed in between the power electronics and the PTO at Mutriku, and the PTO has been running ever since, for the past six months, without any failure. Real operating conditions at the Mutriku power plant improved the reliability of the power take-off, collected and shared electrical component operating data, identified failure modes, their causes and tested solutions, meaning that specific WP3 objective one was achieved.

For security reasons, it is recommended to keep the filter in place for the installation on the MARMOK-A5 device to avoid the manifestation of the same type of problems, given the apparent similarity of the power electronics to that of the Mutriku plant.

No measurements of noise were performed, but it was observed during the testing period at the Mutriku Plant that the noise produced by the Biradial turbine is significantly lower than that produced by the Wavegen Wells turbines.

The Biradial turbine operation for more than one year, at the Mutriku Power Plant, has shown that the OPERA Biradial turbine exhibits a mean efficiency higher by a factor of 1.55 in comparison with the current Wavegen Wells turbines installed at the Mutriku Power Plant. This demonstrates that WP3 specific objective two was also fully achieved with the testing at-sea operation at the Mutriku shoreline wave power plant.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

BiMEP	Biscay Marine Energy Platform
HSSV	High-Speed Safety Valve
OPERA	Open Sea Operating Experience to Reduce Wave Energy Costs
OWC	Oscillating Water Column
PTO	Power Take-off System (turbine-generator set)
WEC	Wave Energy Converter

1. INTRODUCTION

This document represents Deliverable 3.3 of WP3 Task 3.3 of the OPERA project. The main goal of WP 3 Task 3.3 was to perform field tests of the Biradial turbine at Mutriku shoreline wave power plant, with grid connection, and to validate the reliability and performance of the novel turbine.

The sea trial campaign provided test data for verifying turbine performance and numerical models, accumulate experience of a real sea validation and collect the sea trial data for further performance and reliability analysis. This document aims to analyse the performance of the Biradial turbine and its electrical generator at-sea operation at Mutriku Power Plant.

Turbine performance test data was used to estimate the annual power production of the biradial turbine in Mutriku Power Plant. For comparison, available experimental data from the existing Wavegen Wells turbines in operation in the Mutriku Power Plant was also analysed.

This deliverable addresses the following topics:

- **Power take-off (PTO) performance** providing the results of the Biradial turbine tests at Mutriku Power Plant and its comparison with the results from the Wavegen Wells turbine installed in the same plant (Section 2);
- **PTO operating parameters and constraints** showing the Biradial turbine and generator characteristics and operating limits (Section 3);
- **PTO fatigue-drivers** analysing the Biradial turbine and generator integrity (Section 4);
- **Failures and risks** describing the guide vanes superficial traces of corrosion and the occurrence of only one electrical failure (Section 5);
- **Maintenance requirements** after disassembling the Biradial turbine-generator set from the Mutriku Power Plant (Section 6).

2. PTO PERFORMANCE: OPERA BIRADIAL TURBINE VERSUS EXISTING MUTRIKU WELLS TURBINES

This chapter presents the performance analysis of the OPERA Biradial turbine and the existing Wavegen Wells turbines. A total of 4573 test cases were evaluated for the Biradial turbine-generator set. To make a fair comparison, data from the same range of dates from the Wavegen Wells turbines was analysed simultaneously with the Biradial turbine.

All the data was downloaded from the Database of the Mutriku Power Plant following the **Database Access Tool** user's manual [1]. The nomenclature for the pressure measurements used in the present calculations was the same that was defined by Kymaner during the turbine design stage, see Table 1. Kymaner's nomenclature differs from the one adopted in the database [1]. Kymaner numbered the pressure taps from 1 to 5, see Figure 1. Since there were two sensors measuring the same pressure but with different ranges, we appended the letters "l" or "h" to the sensor names to denote "low" or "high" ranges, respectively.

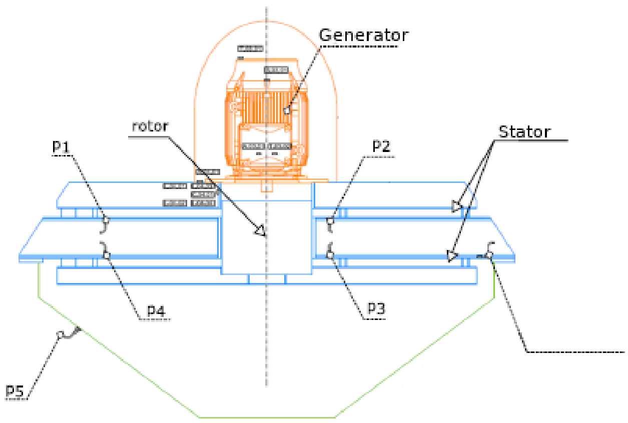


FIGURE 1 - KYMANER'S PRESSURE TAPS NOMENCLATURE.

TABLE 1. NOMENCLATURE USED FOR THE PRESSURE SENSORS.

Kymaner	Present report	Database	Database columns
p1	p1l, p1h	p3, p4	Col035, Col036
p2	p2l, p2h	p7, p8	Col039, Col040
p3	p3l, p3h	p5, p6	Col037, Col038
p4	p4l, p4h	p9, p10	Col041, Col042
p5	p5l, p5h	p1, p2	Col033, Col034

For this analysis, only sets of 10 minutes were considered, such that:

- The control law does not change;
- The plant´s butterfly valve was fully open in the entire set;

- If the high-speed safety valve (HSSV) closes, the rotational speed cannot drop below 1000 rpm.

Using this procedure, a total of 4,573 test cases were identified.

2.1 AVAILABLE PNEUMATIC POWER

The Biradial turbine was designed for offshore installation in the OCEANTEC MARMOK-5 Spar-buoy. This floating device produces high-pressure head and low flow-rate in comparison with that observed in the Mutriku Power Plant where, in design conditions, the pressure head is lower, and the volume flow rate is higher.

The mean pneumatic power versus the chamber pressure root-mean-square, $\mathrm{rms}(p)$, is represented in Figure 2 for both turbines. The mean pneumatic power, $\bar{P}_{\mathrm{pneu}}$, is higher for the Wells turbine, as could be expected because this turbine was designed for installation in the Mutriku Power Plant. The size of the Biradial turbine is too small for the Mutriku Power Plant, introducing excessive damping thus limiting the available pneumatic power. A Biradial turbine appropriately sized for the Mutriku Power Plant would operate with an available power similar to that of the existing Wavegen Wells turbines of the Mutriku plant.

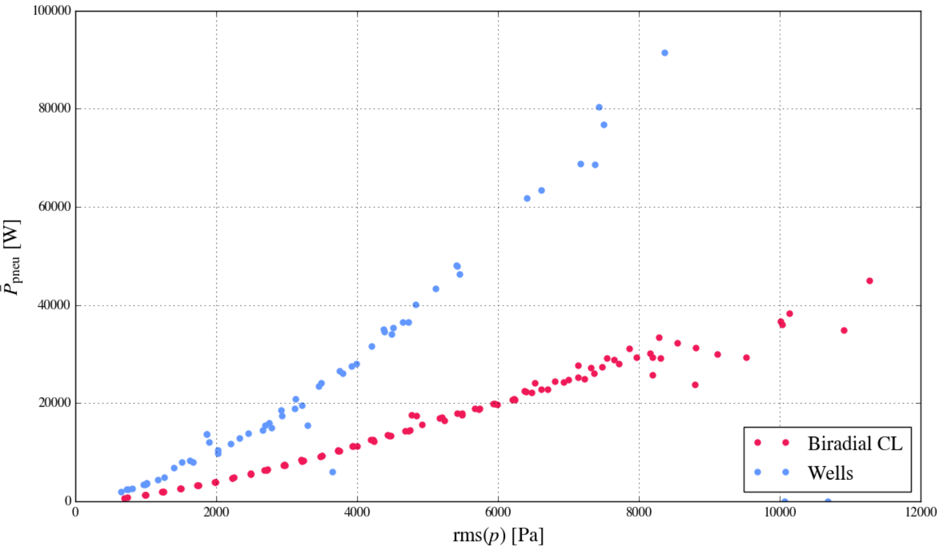
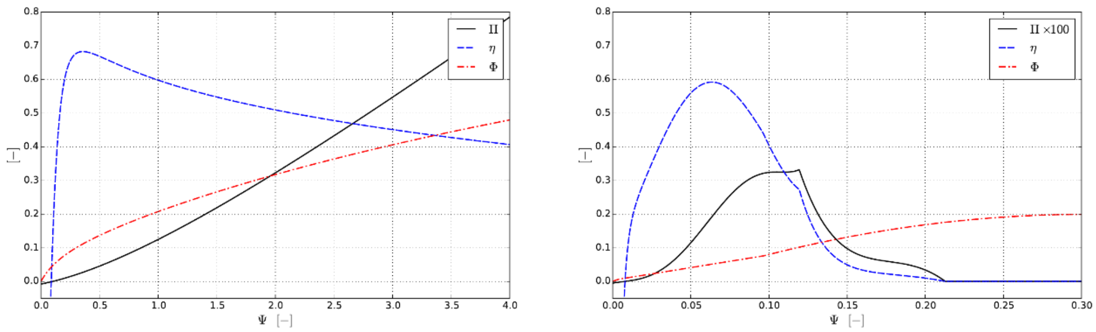


FIGURE 2. MEAN PNEUMATIC POWER VERSUS THE CHAMBER PRESSURE ROOT-MEAN-SQUARE FOR THE BIRADIAL AND WELLS TURBINES AT THE MUTRIKU PLANT.

2.2 TURBINE SHAFT POWER

The use of a torque-meter is not feasible to be assembled in a prototype. Therefore, the turbine shaft power was calculated from experimental results of dry-testing of both turbines. Results from the Biradial turbine are presented in the OPERA Deliverable D3.2 [2] (see Figure 3a)) and the experimental data for the Wavegen Wells turbines is reported in [3] (see Figure 3 b)).



(a) (b)

FIGURE 3 - PERFORMANCE CURVES OF OPERA BIRADIAL TURBINE (A) AND THE WAVEGEN WELLS TURBINES (B) EQUIPPING THE MUTRIKU PLANT. DIMENSIONLESS FLOW RATE Φ , POWER COEFFICIENT Π AND EFFICIENCY η VERSUS DIMENSIONLESS PRESSURE HEAD Ψ. BASED ON DATA FROM [2,3].

Figure 4 shows the mean turbine shaft power, $\bar{P}_{\mathrm{turb}}$, versus chamber pressure root-mean-square, $\mathrm{rms}(p)$, for the Biradial and Wavegen Wells turbines. Results shows that for $\mathrm{rms}(p) < 5500$ Pa the average turbine shaft power of the Wavegen Wells turbine is higher than that observed for the biradial turbine. This situation reverses when $\mathrm{rms}(p) \geq 5500$ Pa, where the mean turbine shaft power of the Biradial turbine becomes higher. The present behaviour is mainly due to two reasons: first, the lower power available to the Biradial turbine in the Mutriku Power Plant (see also Figure 2), as a consequence of the small size of the Biradial turbine, and, secondly, to the control algorithm of the Wavegen Wells turbines which partially closes the safety butterfly valve at $\mathrm{rms}(p) \geq 5000$ Pa.

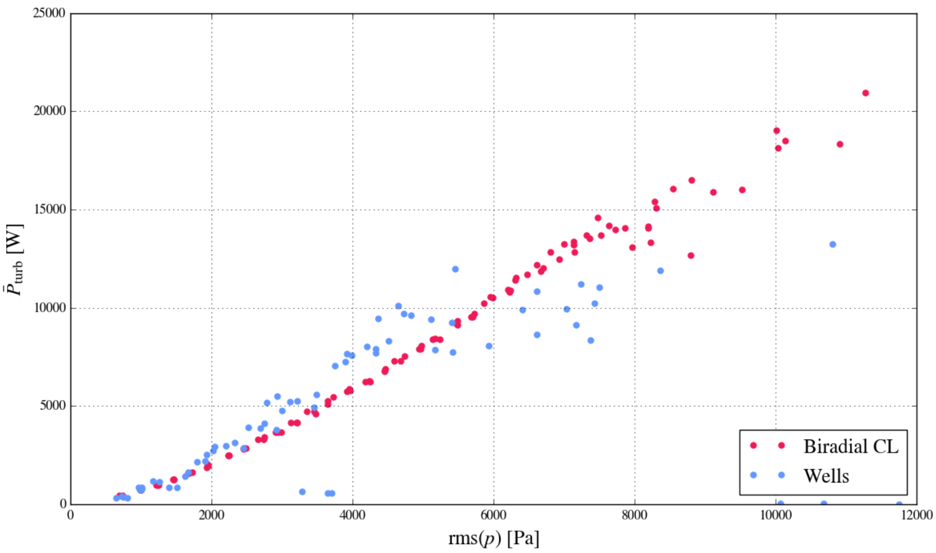


FIGURE 4. MEAN TURBINE SHAFT POWER VERSUS PRESSURE CHAMBER ROOT-MEAN-SQUARE FOR THE BIRADIAL AND WELLS TURBINES AT THE MUTRIKU PLANT.

2.3 MEAN ANNUAL POWER PRODUCTION OF THE OPERA BIRADIAL TURBINE IN THE MUTRIKU PLANT

The wave climate off the Mutriku power plant is described by *n* sea-states characterised by the significant wave height, H_s, the energy period, T_e, and the probability of occurrence, p_o, Table 2.

TABLE 2. CHARACTERISTIC WAVE CLIMATE OF MUTRIKU POWER PLANT (ADAPTED FROM [4]).

n *[-]*	$\boldsymbol{H_s}$ [m]	$\boldsymbol{T_e}$ [s]	$\boldsymbol{p_o}$ [%]
1	0.88	5.5	3.23
2	1.03	6.5	3.44
3	1.04	7.5	5.08
4	1.02	8.5	6.11
5	1.08	9.5	10.73
6	1.19	10.5	9.31
7	1.29	11.5	9.52
8	1.48	12.5	7.42
9	1.81	13.5	2.75
10	2.07	14.5	2.96
11	2.59	15.5	1.34
12	2.88	16.5	0.40
13	3.16	11.5	0.27
14	3.20	12.5	0.42

The turbine average power $\bar{P}_{\mathrm{turb}}$ calculated in the previous chapter can be used to estimate the mean annual power production of the Biradial turbine, $\bar{P}_{\mathrm{turb,BR}}^{\mathrm{annual}}$ at the Mutriku Power Plant. The calculation gives

$$\bar{P}_{\mathrm{turb,BR}}^{\mathrm{annual}} = \sum_{n=1}^{14}(p_o \,.\, \bar{P}_{\mathrm{turb,BR}}) = 3087\ \mathrm{W}.$$

Using the data available for the Wavegen Wells turbines, the correspondent estimation can be performed giving the mean annual power, $\bar{P}_{\mathrm{turb,Wells}}^{\mathrm{annual}}$, production of the Wavegen Wells turbines

$$\bar{P}_{\mathrm{turb,Wells}}^{\mathrm{annual}} = \sum_{n=1}^{14}(p_o \,.\, \bar{P}_{\mathrm{turb,Wells}}) = 3898\ \mathrm{W}.$$

As inferred, the mean annual power production of the Wavegen Wells turbines is higher than that of the Biradial turbine since, unlike the Biradial turbine, the Wavegen Wells turbines were sized for the Mutriku Power Plant.

Results indicate that the capacity factor of the Wavegen Wells turbine at the Mutriku Power Plant is about 0.22 whereas the lower value obtained for the Biradial turbine (0.10) is a consequence of its design to match the Oceantec MARMOK-A5 device instead of the Mutriku Power Plant.

2.4 ELECTRICAL GENERATOR POWER: MEASUREMENTS VERSUS ESTIMATION

The measured electrical generator average power can be compared with the estimated electrical generator average power, $\bar{P}_{\mathrm{gen,est}}$ The average electrical generator power is given by

$$\bar{P}_{\mathrm{gen,est}} = \frac{1}{\Delta t}\int_0^T \eta_{\mathrm{gen}} P_{\mathrm{mech}}\, \mathrm{d}t,$$

where η_{gen} is generator efficiency, $P_{\mathrm{mech}} = P_{\mathrm{turb}} - P_{\mathrm{loss}}$, P_{loss} is mechanical power losses and $\Delta t = 10\ \mathrm{min}$ the considered time interval. The instantaneous generator efficiency is defined as

$$\eta_{\mathrm{gen}} = \frac{P_{\mathrm{elect}}}{P_{\mathrm{mech}}},$$

where P_{elect} is the electrical power and P_{mech} mechanical shaft power. The results were obtained for different pairs of rotational speed and the shaft torque [2]. The contour plot of the generator efficiency as function of the rotational speed and mechanical power is depicted in Figure 5 . Figure 6 plots the efficiency of the set generator η_{gen}, as function of the generator load,

$$\Lambda = \frac{P_{\mathrm{gen}}}{P_{\mathrm{gen}}^{\mathrm{rated}}}.$$

The dots are the measured values used to obtain Figure 5 and the red line is a rational approximation obtain using least-squares.

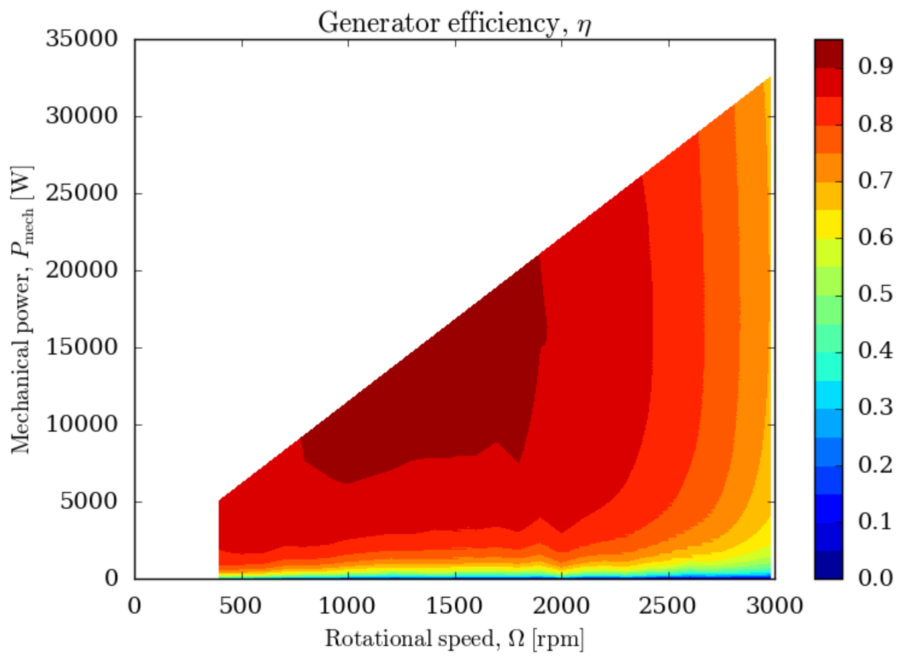


FIGURE 5. CONTOUR PLOT OF THE GENERATOR EFFICIENCY, η_{gen}, AS FUNCTIONS OF THE ROTATION SPEED Ω, AND MECHANICAL POWER P_{mech}.

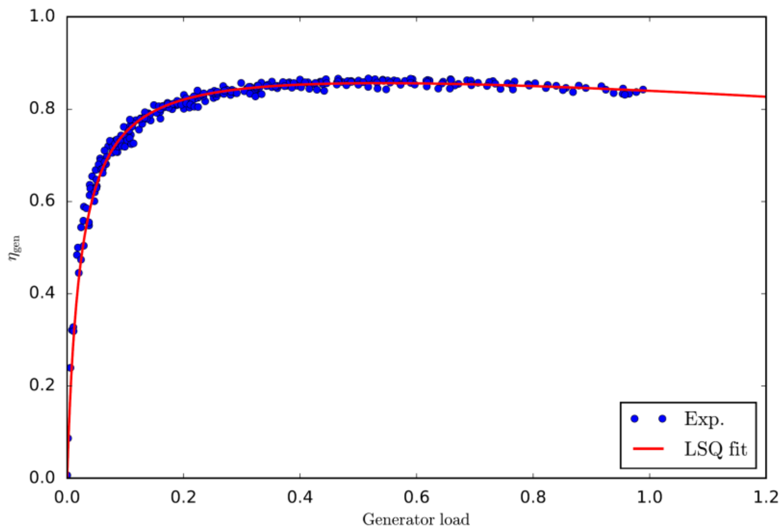


FIGURE 6 - EFFICIENCY OF THE OPERA TURBINE GENERATOR , η_{gen}, AS FUNCTION OF THE GENERATOR LOAD. THE DOTS ARE THE MEASURED VALUES USED TO OBTAIN FIGURE 5 AND THE RED LINE IS A LEAST-SQUARES CURVE FITTING.

Figure 7 shows the measured (in red) and the estimated (in blue) electrical generator power for different root-mean square values of the chamber pressure, $\mathrm{rms}(p)$. The estimated electrical power retrieved from the database ignores the electrical losses in $\mathrm{d}V/\mathrm{d}t$ filter being slightly higher than the measured one.

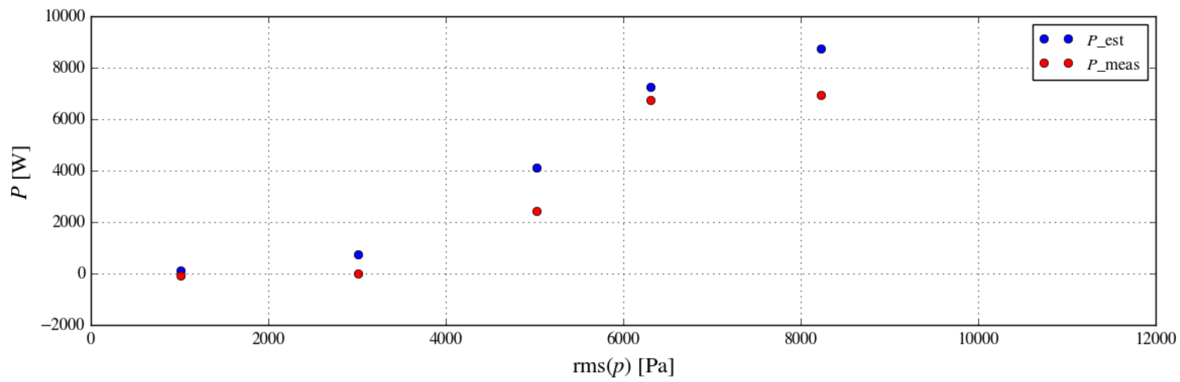


FIGURE 7. ESTIMATED AND MEASURED ELECTRICAL GENERATOR POWER VERSUS ROOT MEAN SQUARE OF PRESSURE CHAMBER.

2.5 BIRADIAL TURBINE VERSUS WELLS TURBINE

The average turbine efficiency in sea-operation at the Mutriku plant represents a fairer comparison between both turbines types rather than the mean pneumatic power, the mean turbine shaft power or the mean electrical power, since it is not affected by the mismatch of the Biradial turbine size relative to the Mutriku power plant.

Figure 8 shows the average efficiency versus the chamber pressure root-mean-square for the Biradial and the Wavegen Wells turbines. For $1500 < \mathrm{rms}(p) < 3500$ Pa the biradial turbine exhibits mean efficiency higher, by a factor of 1.55, in comparison with the Wavegen Wells turbines installed at the Mutriku Power Plant. For $\mathrm{rms}(p) \geq 6000$ Pa, the efficiency of the Wells turbines shows the typical sharp drop due to the flow stall conditions at the rotor blades, while the efficiency of the Biradial turbine remains almost constant. The rotational speed of the Wells turbine is limited [5]. To improve its performance at the higher values of $\mathrm{rms}(p)$ a three or more stages Wells turbine should be used instead. However, this solution increases the mechanical complexity, the turbine cost and also has a detrimental effect on the efficiency.

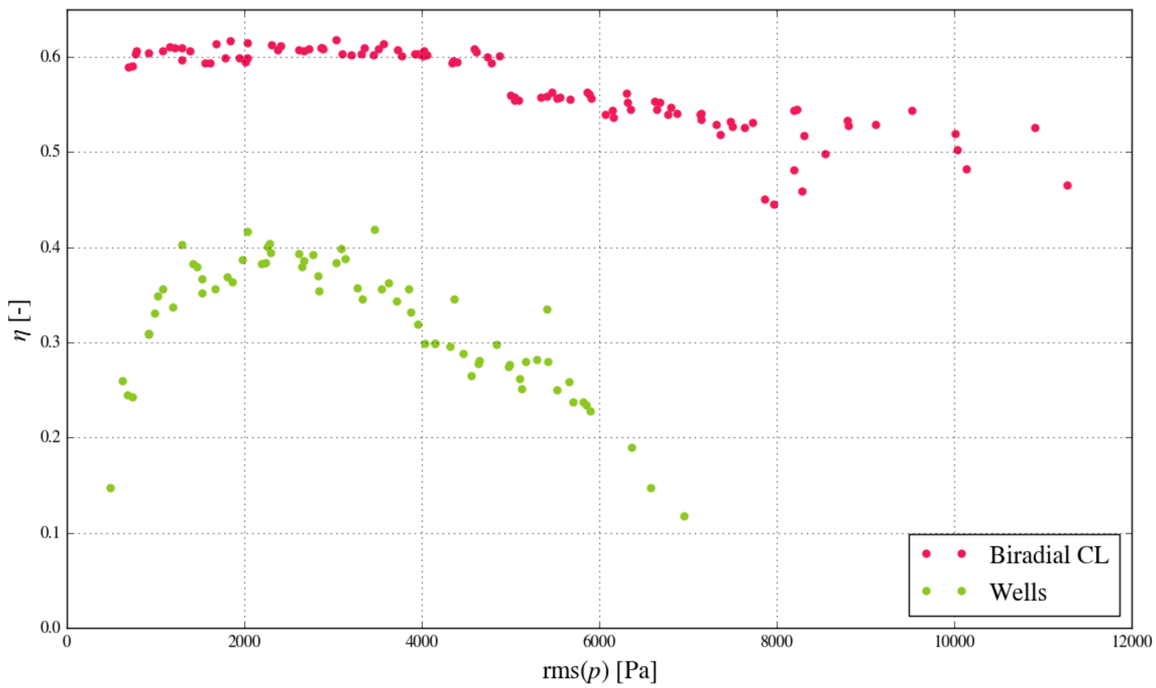
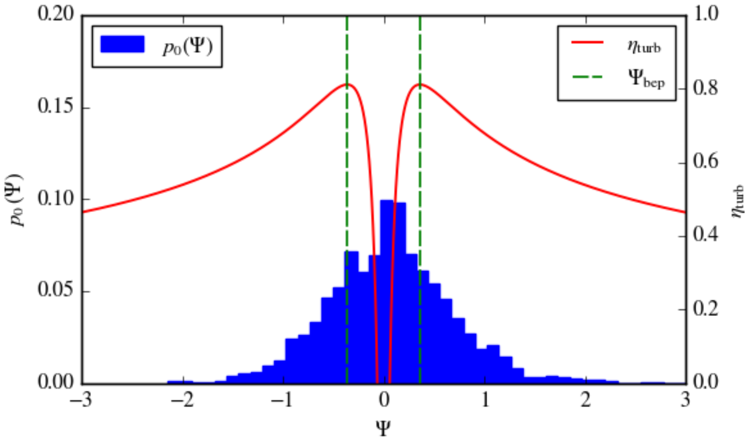


FIGURE 8. EFFICIENCY VERSUS ROOT-MEAN-SQUARE OF PRESSURE CHAMBER FOR THE BIRADIAL AND THE WELLS TURBINES.

Figure 9 to 12 show histograms of the probability of occurrence of pressure coefficients, $p_{\mathrm{o}}(\Psi)$, for four representative test-cases. Also represented in the same figures are the Biradial turbine instantaneous efficiency, η_{turb}, versus the pressure head coefficient, Ψ, and the pressure coefficient for the best efficiency point, Ψ_{bep}. The testing conditions are also presented in the figures.

Figure 13 to Figure 16 show the probability of occurrence histograms of pressure coefficients for the Wavegen Wells turbines considering the tests shown before for the Biradial turbine. In the same figures are represented the efficiency curve of the Wells turbine and the pressure coefficient for the best efficiency point, Ψ_{bep}.



$\bar{\eta} = 0.607$

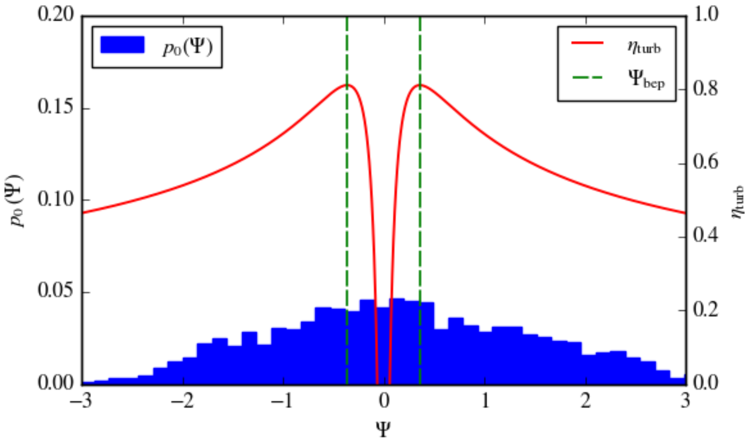
$\text{rms}(p) = 2672$ Pa

$\bar{\Omega} = 120.6$ rad/s

$\bar{P}_{\text{turb}} = 3.1$ kW

$\bar{P}_{\text{pneu}} = 5.2$ kW

FIGURE 9. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 1 FOR BIRADIAL TURBINE.



$\bar{\eta} = 0.535$

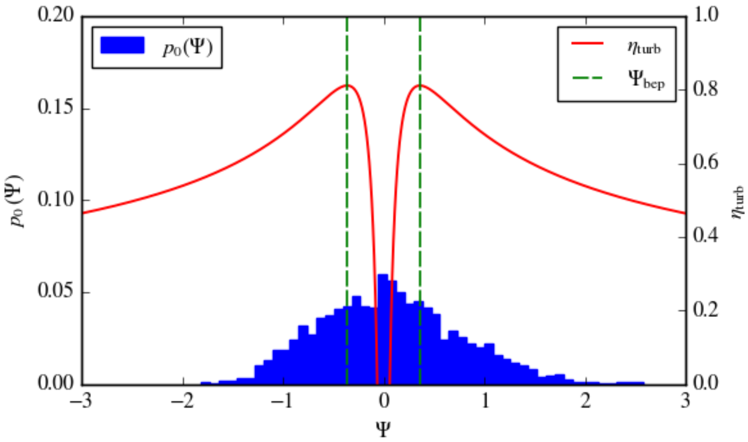
$\text{rms}(p) = 2393$ Pa

$\bar{\Omega} = 74.4$ rad/s

$\bar{P}_{\text{turb}} = 2.6$ kW

$\bar{P}_{\text{pneu}} = 4.9$ kW

FIGURE 10. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 2 FOR BIRADIAL TURBINE.



$\bar{\eta} = 0.601$

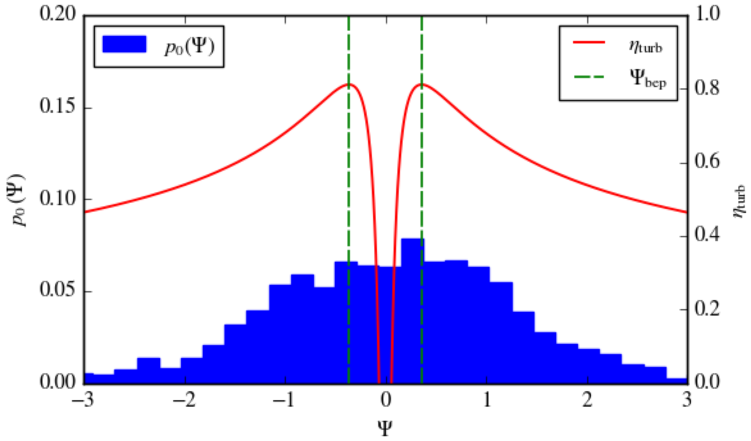
$\text{rms}(p) = 4880$ Pa

$\bar{\Omega} = 147.1$ rad/s

$\bar{P}_{\text{turb}} = 7.7$ kW

$\bar{P}_{\text{pneu}} = 12.9$ kW

FIGURE 11. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 3 FOR BIRADIAL TURBINE.



$\bar{\eta} = 0.556$

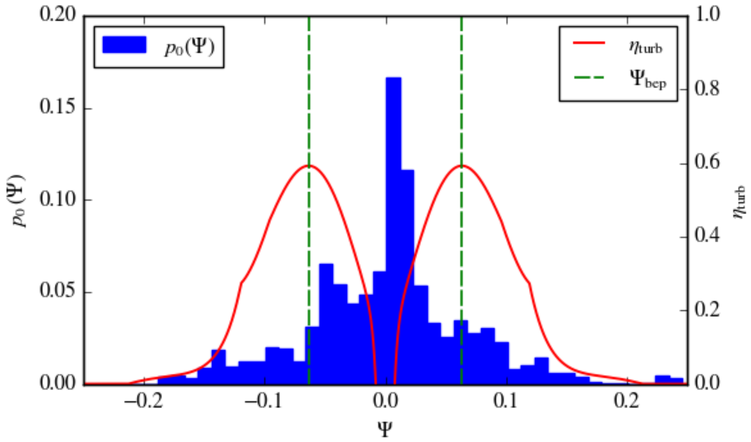
$\mathrm{rms}(p) = 4812$ Pa

$\bar{\Omega} = 116.7$ rad/s

$\bar{P}_{turb} = 7.7$ kW

$\bar{P}_{pneu} = 13.9$ kW

FIGURE 12. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 4 FOR BIRADIAL TURBINE.



$\bar{\eta} = 0.332$

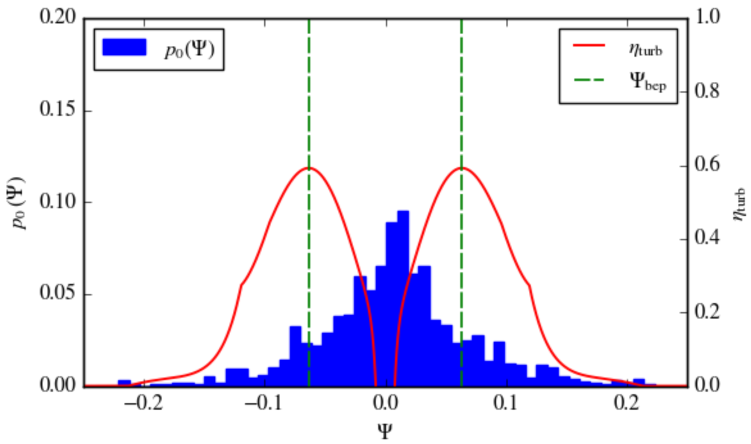
$\mathrm{rms}(p) = 2214$ Pa

$\bar{\Omega} = 224.7$ rad/s

$\bar{P}_{turb} = 3.6$ kW

$\bar{P}_{pneu} = 10.7$ kW

FIGURE 13. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 1 FOR WELLS TURBINE.



$\bar{\eta} = 0.322$

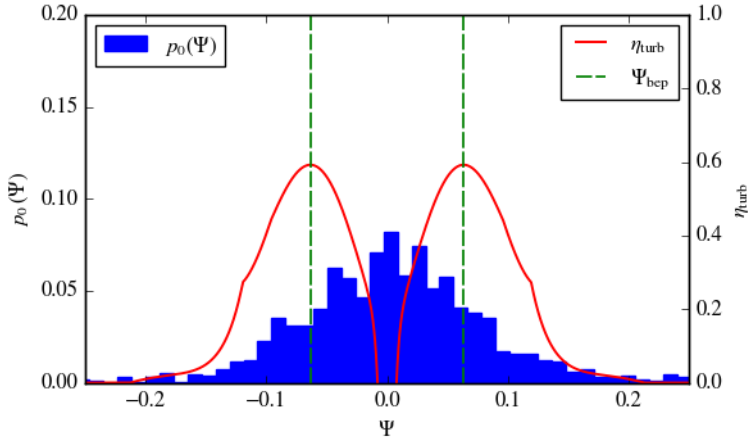
$\mathrm{rms}(p) = 2576$ Pa

$\bar{\Omega} = 240.5$ rad/s

$\bar{P}_{turb} = 4.3$ kW

$\bar{P}_{pneu} = 13.4$ kW

FIGURE 14. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 2 FOR WELLS TURBINE.



$\bar{\eta} = 0.290$

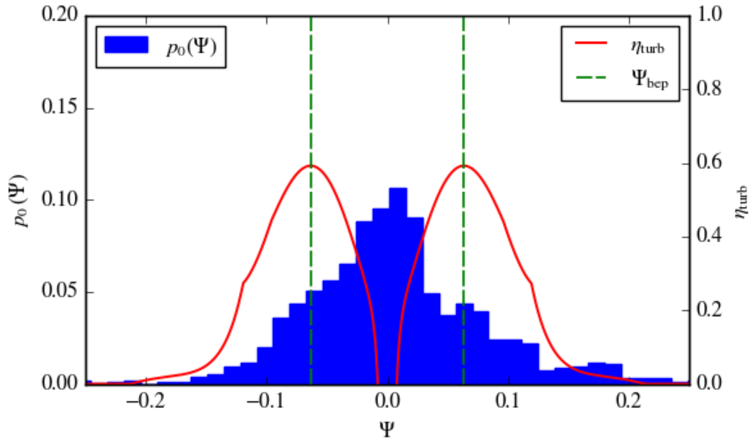
$\mathrm{rms}(p) = 4360$ Pa

$\bar{\Omega} = 298.4$ rad/s

$\bar{P}_{\mathrm{turb}} = 9.5$ kW

$\bar{P}_{\mathrm{pneu}} = 32.7$ kW

FIGURE 15. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 3 FOR WELLS TURBINE.



$\bar{\eta} = 0.270$

$\mathrm{rms}(p) = 3692$ Pa

$\bar{\Omega} = 274.1$ rad/s

$\bar{P}_{\mathrm{turb}} = 6.8$ kW

$\bar{P}_{\mathrm{pneu}} = 25.3$ kW

FIGURE 16. HISTOGRAM OF THE PRESSURE COEFFICIENT AND DATA FOR TEST 4 FOR WELLS TURBINE.

Note that the probability density function is higher for pressure coefficients close to zero. A higher probability at Ψ_{bep} corresponds to higher turbine mean efficiency. Consequently, a less dispersive probability density function around Ψ_{bep} corresponds to higher mean efficiencies.

Figure 17 to Figure 20 show, for tests 1 to 4, the rotational speed, the turbine power and the chamber pressure as a function of time. As expected, the rotational speed of the Wells turbine is in general higher than that of the Biradial turbine for a given sea-state.

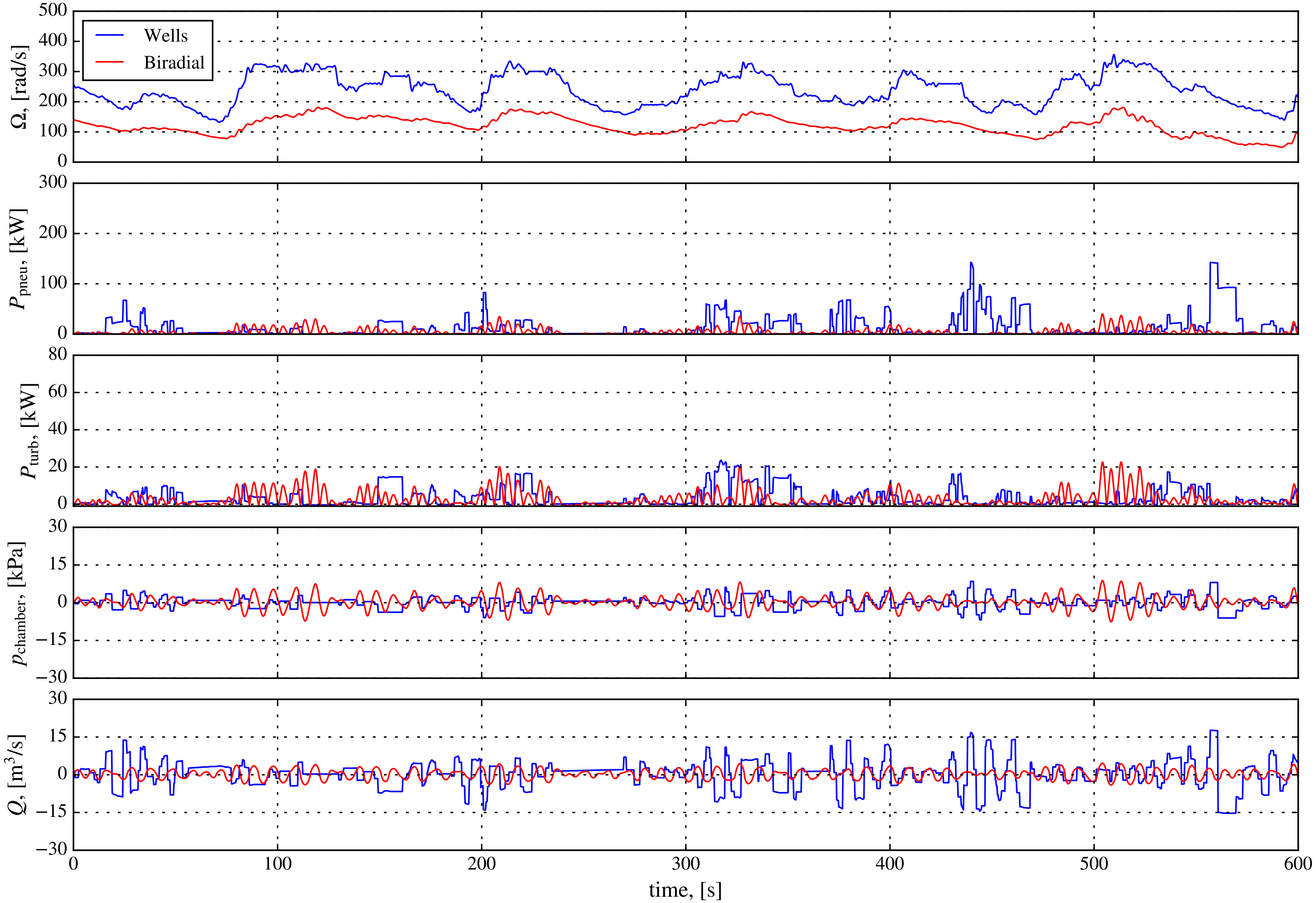


FIGURE 17. DATA FOR TEST 1.

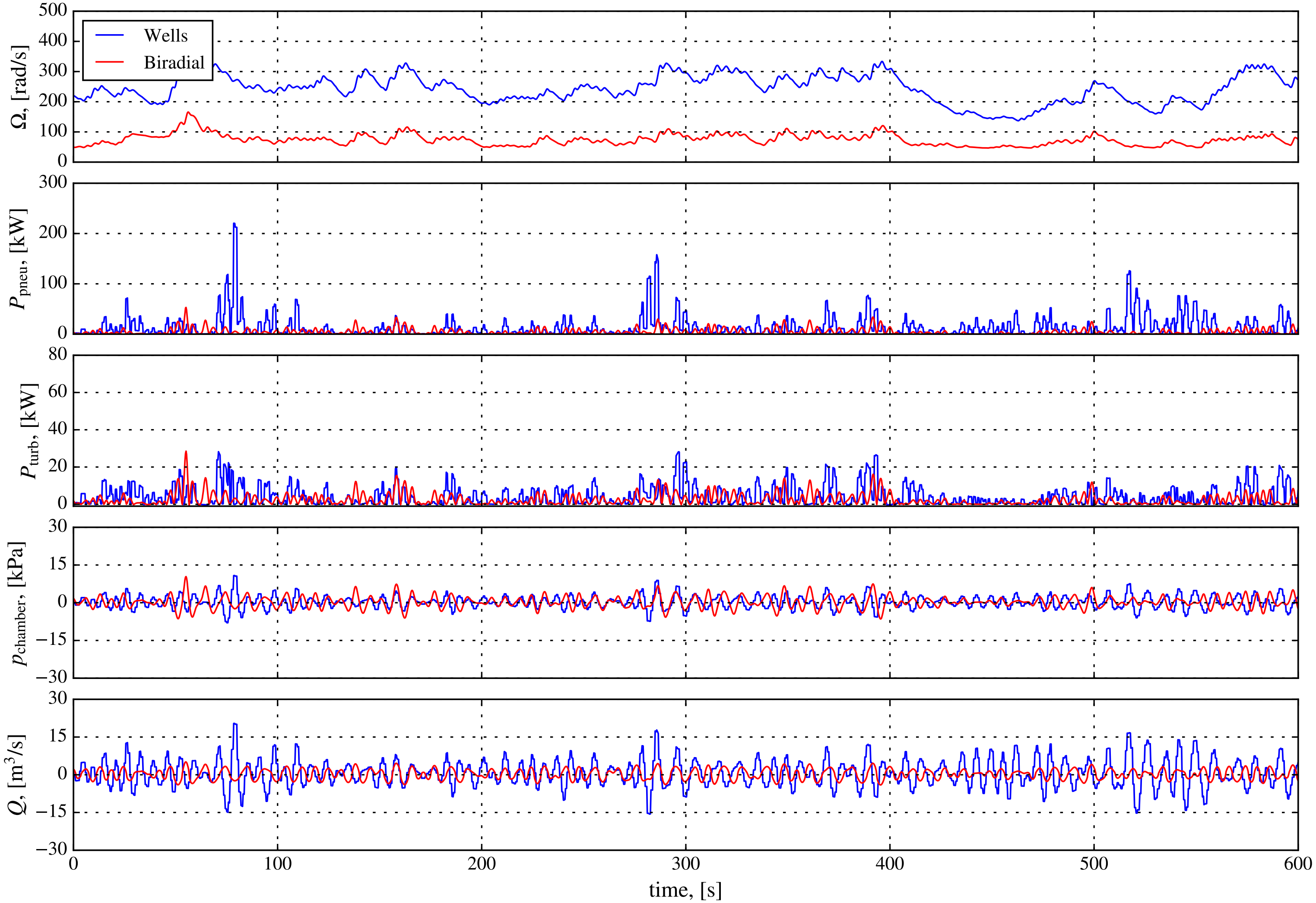


FIGURE 18. DATA FOR TEST 2.

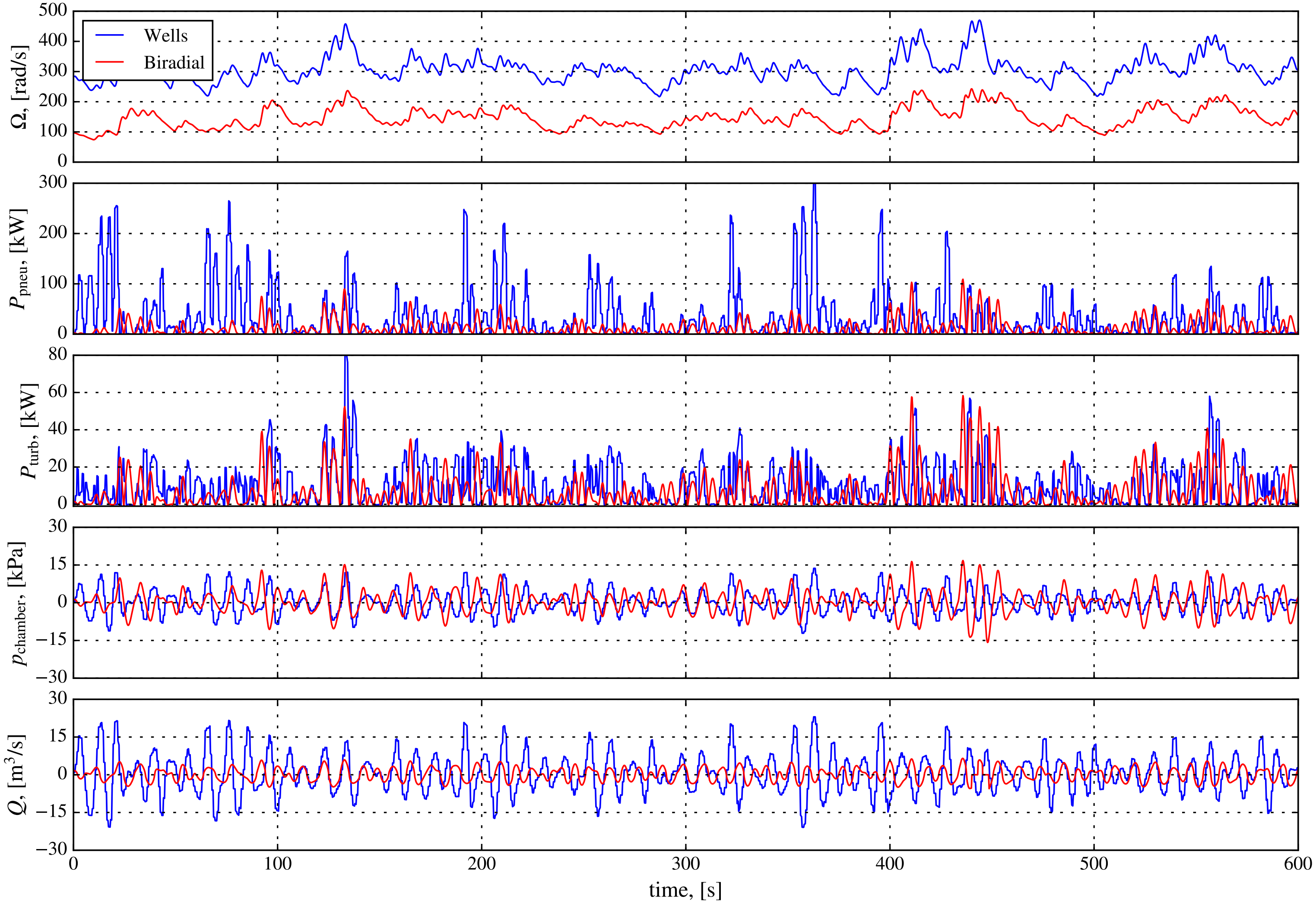


FIGURE 19. DATA FOR TEST 3.

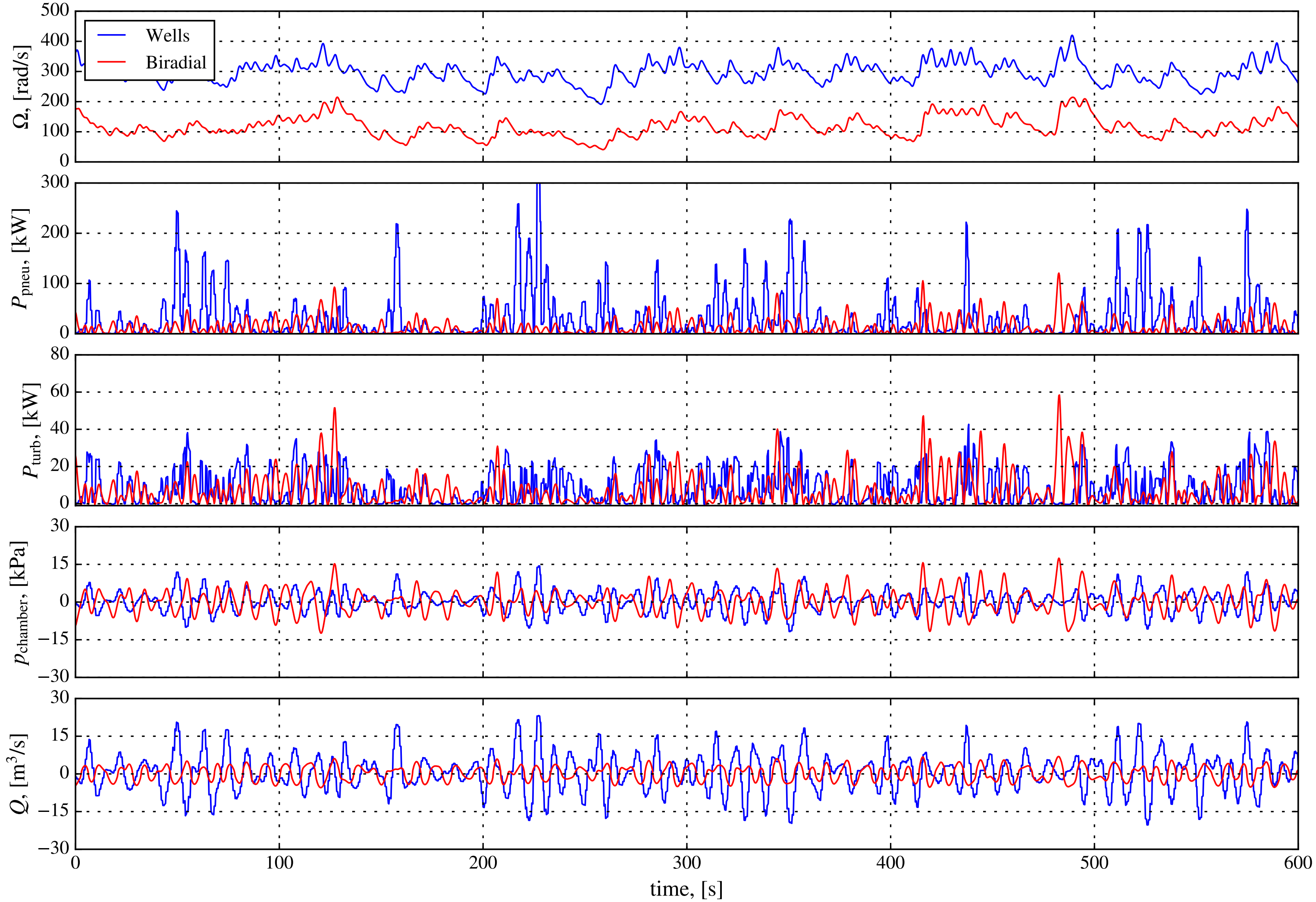


FIGURE 20. DATA FOR TEST 4.

2.6 STATISTICS OF THE BIRADIAL TURBINE ROTATIONAL SPEED AND POWER

Figure 21 shows the box plot of the biradial turbine rotational speed for five different tests. The non-monotonous variation of the median value of the rotational speed (represented in red), is a result of the different turbine-generator control laws used in the testing programme.

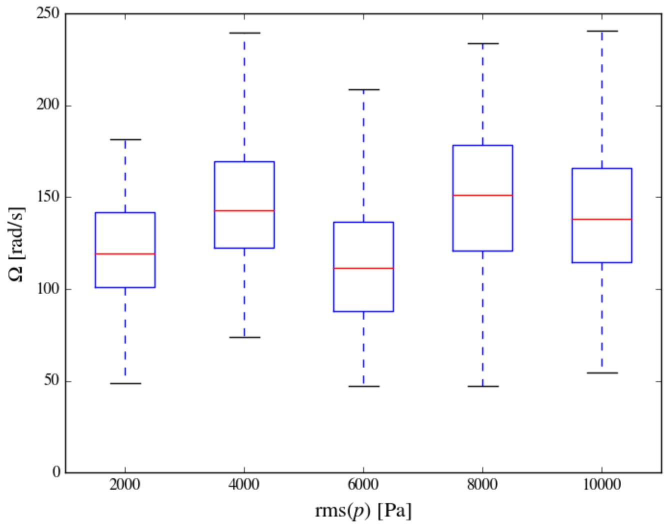


FIGURE 21. BOX PLOT OF THE BIRADIAL TURBINE ROTATIONAL SPEED FOR DIFFERENT ROOT-MEAN-SQUARE VALUES OF PRESSURE CHAMBER.

Figure 22 shows the box plot of dimensionless turbine power for the same five tests of the previous figure. The variability of $\frac{P_{\mathrm{turb}}}{\bar{P}_{\mathrm{turb}}}$ decreases with the increase of root-mean-square of pressure chamber due to rotor inertia. At the more energetic sea-states, the rotor inertia becames less significant and allows a fast response to the turbine-generator control law.

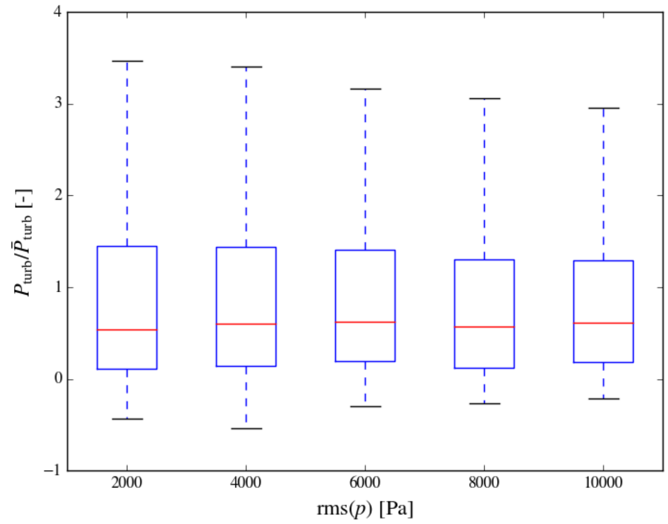


FIGURE 22. BOX PLOT OF THE BIRADIAL TURBINE DIMENSIONLESS TURBINE POWER FOR DIFFERENT ROOT MEAN SQUARE VALUES OF PRESSURE CHAMBER.

Figure 23 shows the box plot of the biradial turbine power. Unlike the results in Figure 21, the median value of the rotational speed increases with the increase in the root-mean-square pressure chamber. The variability of $P_{\rm turb}$ also increases in absolut value. Another important conclusion is that for the last three tests the generator power exceeded the rated power, $P_{\rm gen}^{\rm rated} = 30$ kW. This means that some of the control laws implemented for these tests were not designed to limit the turbine power, which can result in damage of the electrical and mechanical equipments.

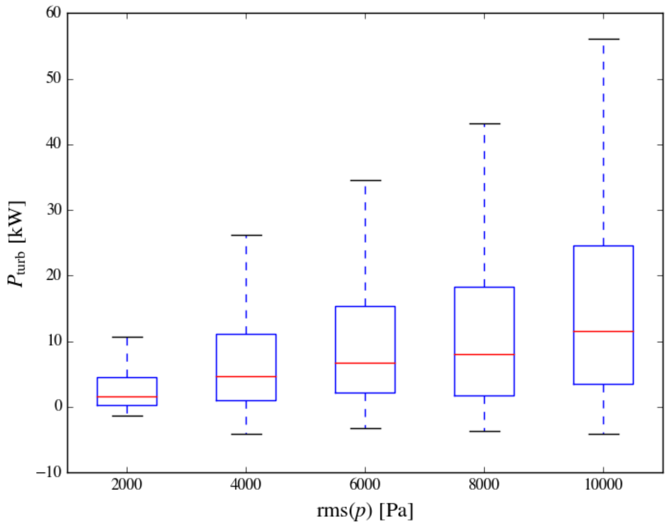


FIGURE 23. BOX PLOT OF THE BIRADIAL TURBINE POWER FOR DIFFERENT ROOT MEAN SQUARE VALUES OF PRESSURE CHAMBER.

3. PTO OPERATING PARAMETERS AND CONSTRAINTS

3.1 INTRODUCTION

The Biradial turbine based PTO, supplied by Kymaner, has been dry tested at IST and tested at sea in the Mutriku Power Plant.

In the course of the design, specifications, requirements and generic constraints have been agreed upon between the partners in what concerns the Biradial turbine. This chapter describes the boundaries that must be respected during the Biradial turbine based PTO tests at sea.

The strict observation of these limits is of paramount importance to evaluate the PTO performance, its mechanical integrity and longevity within the boundaries that have been established.

FIGURE 24. BIRADIAL TURBINE PTO OPERATING AT MUTRIKU.

3.2 PTO CHARACTERISTICS

3.2.1 GENERAL CHARACTERISTICS

The main PTO characteristics are summarised in the table hereunder.

TABLE 3. PTO CHARACTERISTICS.

WEC type	Spar-buoy
Rated power/Frequency	30 kW/50 Hz
Rated Speed/Voltage	1470 rpm/400 VAC
Type of air turbine	Biradial
Number of turbines	1
Assembly position	Vertical axis
Turbine rotor diameter	500 mm
Runaway speed	3000 rpm (*)
Assembly type and position	Flange mount vertically
Insulation class	H (180ºC)
Protection index	IP 65

(*) – To ensure the mechanical protection and integrity of the generator, Siemens advises this limit to be restrained to 2500 rpm actuating the high-speed safety valve (HSSV).

3.3 HIGH-SPEED SAFETY VALVE CHARACTERISTICS

The integrated high-speed safety valve (HSSV) consists of a cylindrical shutter that operates within a short stroke (~60 mm), closing the passage of one of the Biradial turbine ducts. The position of the valve allows a double function to be explored: limit the energy available to the turbine-generator set, protecting it in case of storm conditions by controlling runaway speed and latching control.

In Mutriku the valve shall be tested as a latching control device and will otherwise remain open as the safety valve function is assumed by the series butterfly valve inside the vertical duct.

The table hereunder summarises the key characteristics of the HSSV.

TABLE 4. HSSV GENERAL CHARACTERISTICS.

Valve type	Cylindrical
Shutter material	Low friction (PEHD)
Valve operating system	Linear actuators
Actuator housing	Inside nacelle
Protection index of actuators	IP 65
Latching operation mode (MUTRIKU)	
Operating time	60 days
Acting speed	~0.3 m/s
Operating period	4 s
Safety operation mode (BiMEP)	
Operating time	2 years
Acting speed	~ 0.06 m/s
Operating period	1 day
Emergency power supply at BiMEP	UPS, batteries (provision Oceantec)

FIGURE 25. HIGH-SPEED SAFETY VALVE (HSSV) DURING PRELIMINARY TESTING AT KYMANER.

3.4 PTO OPERATION LIMITS

If any of the below-mentioned conditions occur, the operation must be interrupted to protect the system from deteriorating and potentially fail.

3.4.1 OPERATING LIMITS TURBINE/GENERATOR

MUTRIKU

TABLE 5. CHAMBER PRESSURE AT MUTRIKU.

Operation with Latching Valve			
Condition	Description	Value	Unit
1	Max. Pressure in the chamber	2	bar
2	Min. Pressure in the chamber	-0.7	bar

TABLE 6. PTO MAXIMUM HORIZONTAL ACCELERATION.

Horizontal acceleration generator	15	mm/s

BiMEP

TABLE 7. CHAMBER PRESSURE AND BUOY ACCELERATIONS AT BIMEP.

Operating under exceptional load			
Condition	Description	Value	Unit
3	Max. Pressure in the chamber	2.5	bar
4	Min. Pressure in the chamber	-1	bar
	Gz Vertical acceleration (max.)	13.2	m/s^2
	(Gx^2+Gy^2)^0,5 Horizontal acceleration (max.)	18.5	m/s^2

TABLE 8. PTO MAXIMUM HORIZONTAL ACCELERATION.

Horizontal acceleration generator	15	mm/s

BOTH LOCATIONS

TABLE 9. MAXIMUM GENERATOR TEMPERATURE.

Generator winding temp	155	ºC

3.4.2 OPERATING LIMITS HIGH-SPEED SAFETY VALVE

The expected life of the HSSV valve is 2.5 years of operation, and no maintenance operation is foreseen during that period. The operation situations planned are summarised in Table 9 and detailed hereunder.

TABLE 10. HSSV OPERATING CONDITIONS.

LOCATION	TEST	OPERATING CONDITION	DAMPER SERIES VALVE	HSSV Status/Action
Mutriku	Biradial (<>Wells)	Normal	Opened	Opened/Blocked
		Emergency	Closed	Opened/Blocked
	Latching Control	Normal	Opened	Acting as Latching Valve
		Emergency	Closed	Closed
BIMEP	Biradial (<>Wells)	Normal	-	Opened/Blocked
		Emergency	-	Closed/Blocked
		Operability test	-	Close/Open

The ordinary mode of operation is “bang-bang”, responding to a command “open/close” (see operation speeds associated with safety or latching control in Table 3.

The valve will not operate if something is blocking the movement. Operation of the turbine must cease until the troubleshooting of the situation is completed successfully.

During the IST dry-tests, it has been concluded that the HSSV can effectively control the air flow and limit the pneumatic power significantly without having to close down the valve to protect the turbine from over speeding. This is not an original requirement and because it may affect the expected life of the HSSV valve actuators this operation mode must not be used.

3.5 EXPANDING THE LIMITS OF THE OPERATING CONDITIONS

In the final stages of the project (winter 2019) the exploitation of a runaway speed of **3000 rpm** should be tested to evaluate the impact on the performance but not before for the safeguarding of the equipment integrity.

The operation of the HSSV **inside the limiting positions** (opened/closed) for “peak-shaving control” could also be tested at the same time as the potential to expand the operating range without complete loss of power (as the result of shutting the valve completely). This is a potential feature of the HSSV that may prove to be of significant importance to the power delivery of the system and complement the evaluation and capabilities of the Biradial turbine performance.

4. PTO FATIGUE-DRIVERS

The turbine-generator set has been installed in Mutriku Power Plant for thirteen months (Jun17-Jul18). During that period, the operation of the PTO has been continuously monitored to analyse its performance.

Due to the characteristics of the resource, it was expected that the PTO would be exposed to mechanical and thermal load cycles that could origin progressive and localized structural damage. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit. Damage incurred is cumulative. Materials do not recover when rested. Fatigue life is influenced by a variety of factors, such as temperature, surface finish, metallurgical microstructure, the presence of oxidising or inert chemicals, residual stresses, scuffing contact (fretting), etc.

During data analysis, different parameters that can be the drivers of fatigue have been filtered, and three cases have been analysed:

- Case 1 (Turbine integrity): rotational speed and vibrations;
- Case 2 (Generator integrity): temperature of stator windings;
- Case 3 (Generator integrity): power.

Table 11 shows, for each case, which parameter has been analysed as critical, the threshold value considered in the design and the maximum values obtained during operation. Besides, the operation time (not necessarily continuous) in each condition is registered too.

It can be observed that the operation beyond the design values has rarely happened. In general, during the testing period, the turbine has operated without incidences, being its performance in line with the results obtained in the dry tests. The threshold value of rotational speed has only been exceeded in punctual periods. As it can be observed in Figure 26 (left), in the cases of higher vibration values, the high-speed safety valve (HSSV) was closed, preventing so over speed and contributing to the security of the PTO. With comparison purposes, in Figure 26 (right) it can be observed the influence of the damping valve (opening shutter position >45°, and closing shutter position when <45°), as its operation time is higher that HSSV one, the risk of over speed is higher.

TABLE 11. OPERATION TIME AND MAXIMUM VALUES OF MORE ADVERSE OPERATIONS.

Case	Analyzed parameter	Threshold value	Maximum value	Time	N. of data
1	Rotational speed (Ω)	245 rad/s	265 rad/s	13 min	4000
	Vibration		11.4 mm/s		
2	Winding temperature (T_{winding})	65°C	73.4 °C	2 h	37000
3	Output power (P_{drive})	30 kW	62 kW	2 h	37200

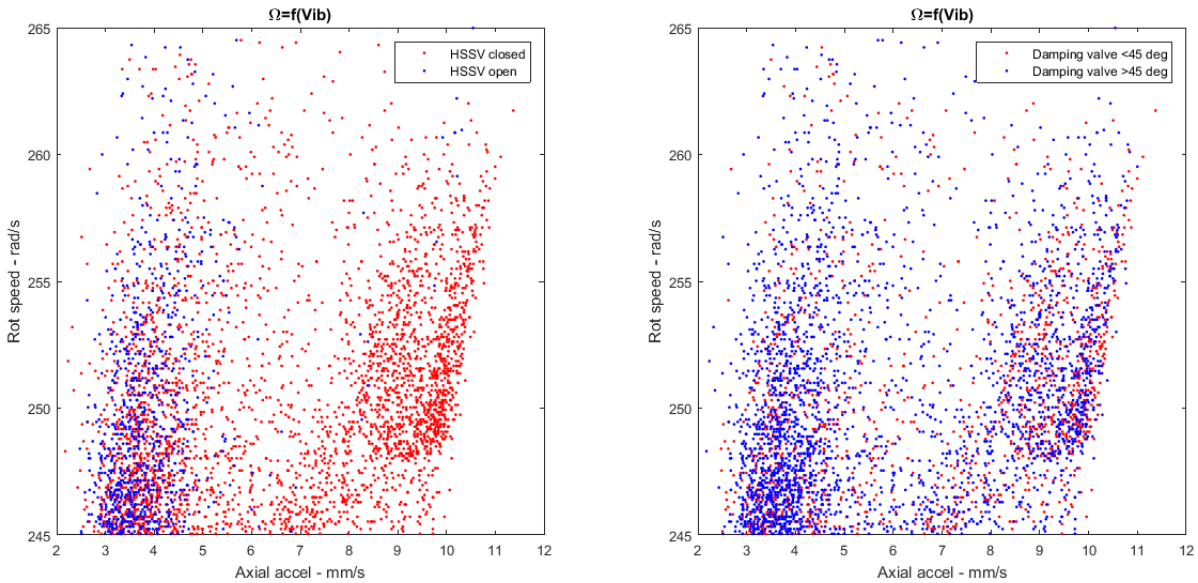


FIGURE 26. VIBRATION VALUES WITH ROTATIONAL SPEED, OPERATING HSSV (LEFT) AND DAMPING VALVE (RIGHT).

Relating to the electric generator, the temperature of the stator windings has not suffered wide thermal cycles. Besides, its isolation was defined as Class H (see Tab. 2), withstanding so with temperatures until 180°C. As it is shown in Figure 27, the temperature did not exceed 74°C in any case.

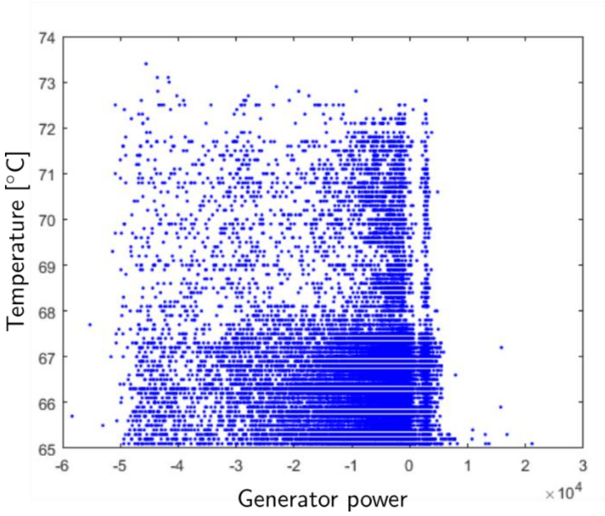


FIGURE 27. HIGHER TEMPERATURES REGISTERED IN STATOR WINDING AS FUNCTION OF THE GENERATOR POWER.

5. FAILURES AND RISKS

5.1 INTRODUCTION

As the risk management related activities are covered extensively in WP7 and in D7.1, we will focus on the failures of the PTO that have happened during the tests that have already taken place at IST and Mutriku.

During the IST tests, there was no PTO failure to report. The commissioning of the HSSV had a slow start related with its control fine tuning but did not have finally an effect on the test program that was run under a very compressed schedule to fit the available window.

During the Mutriku tests there were two issues deserving particular attention, with one of them leading to the interruption of the tests, namely:

1. The guide vanes, manufactured in stainless steel, after the first month of tests exposed to a salty atmosphere started to show superficial traces of corrosion that have not progressed since.
2. The generator suffered a short circuit that led to its removal and repair by the supplier Siemens in Lisbon. This led to the interruption of the tests for three months.

5.2 GUIDE VANES

The stator of the turbine has 256 guide vanes arranged into concentric rows to direct the flow onto the rotor for optimal effect. The machining process that has been selected was electrical wire discharge essentially for throughput reasons and surface finishing.

The vanes were polished and all imperfections removed. As a result of the process, it is apparent that the material surface suffered a chemical change and the resistance to corrosion agents was affected.

In Figure 28 to Figure 30 the guide vanes are shown:

a) during the fabrication process and
b) during the tests in IST and at present, during the tests in Mutriku.

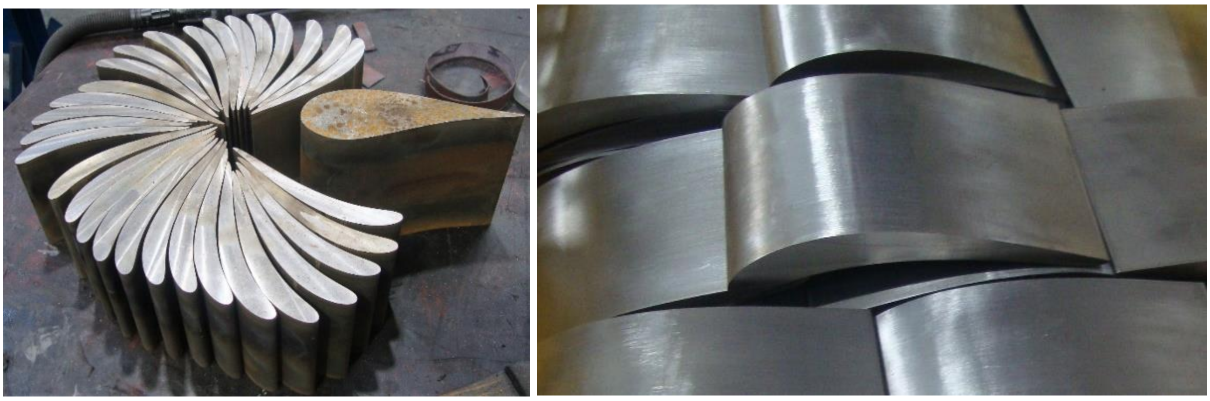


FIGURE 28. GUIDE VANES PRE AND POST FINISHING.

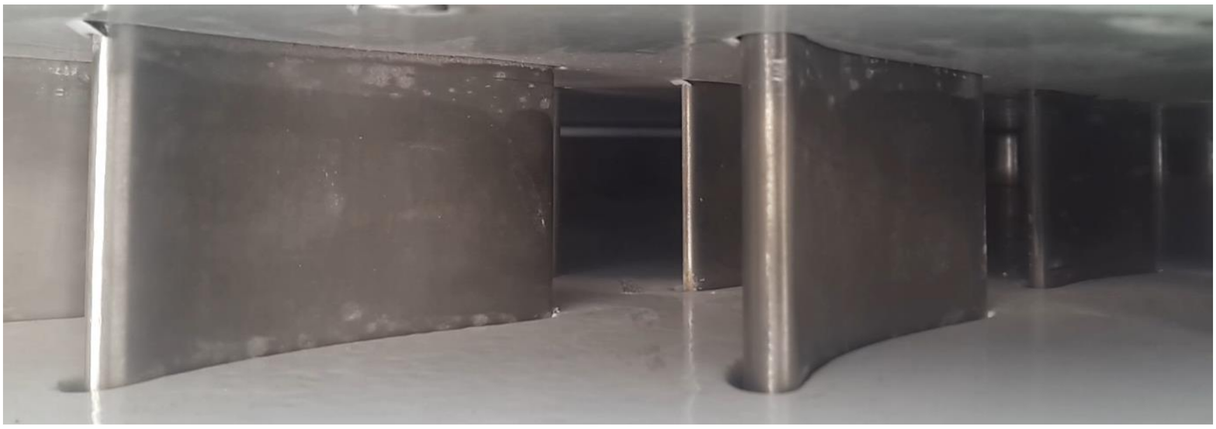


FIGURE 29. GUIDE VANES IN PLACE DURING IST DRY TEST.

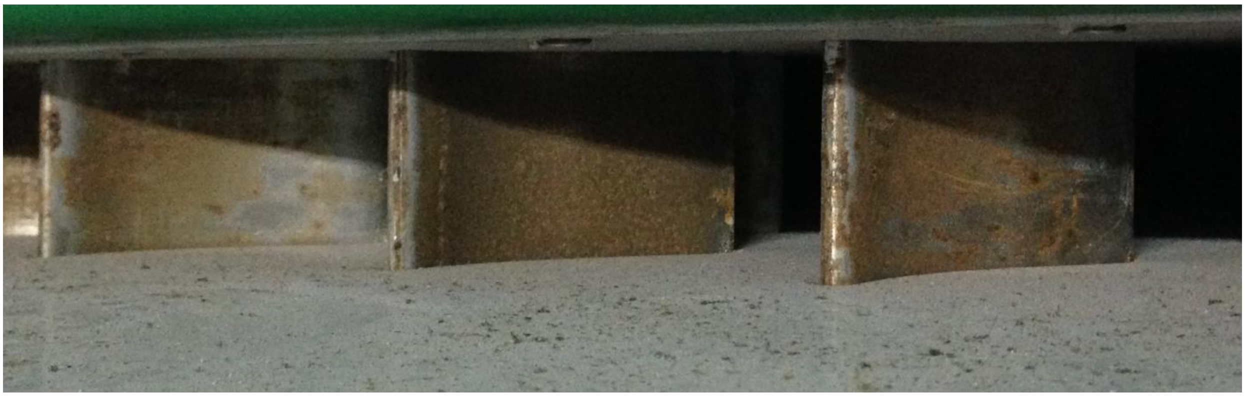


FIGURE 30. GUIDE VANES DURING TEST IN MUTRIKU.

No material loss is visible, and the defects are superficial not affecting the performance of the PTO. Nevertheless, in future installations, other alternative fabrication options will be explored because the choice for this material quality should have prevented this occurrence.

5.3 GENERATOR FAILURE

5.3.1 DESCRIPTION

On October the 2nd 2017, there was a shutdown of the installation, apparently due to a short circuit in the generator. In the moment of failure, the operation of the PTO was not very demanding, being a very low energetic sea-state. The priority was given to the rundown of the possible causes and a team of technicians from Tecnalia, EVE and Oceantec went on site to attempt a diagnosis.

Hereunder is a summary of the findings compiled by Oceantec, following the discussions held with Kymaner:

1. *The diagnostic made by Oceantec isolated the issue to the generator. Here is the scenario when tried to repeat the failure. While the power electronics is ready to operate, as soon as the generator is asked to rotate the turbine (in motor, with all valves closed) the main plant breaker jumps, shutting down the power electronics and some electrical systems in the plant.*
2. *The power electronics remains operational. It is only when there is current being injected to the generator that this current leaks to the plant's earth through the damaged generator and the residual current monitoring of the plant trips, thus disconnecting the whole power plant.*
3. *The fault was not in the cable, by disconnecting the Weidmuller contacts and turning ON the power electronics, and it did run without any problem, with no leakage being detected.*
4. *The generator winding temperatures show values of around 50ºC in operation being constant during the tests. The absolute maximum value for these was recorded back in the 13th of July and have a value of around 65ºC. It does not seem to be an overheating problem right now.*

The next concern was to detect if the failure had been a consequence of some mechanical fault leading to abnormal friction and excessive wear on the bearings of the rotating parts. A series of tests were prescribed and run, with no obvious mechanical failure being suggested. This led to the focus on the generator, where a problem related to the wiring insulation had been detected. After contacting Siemens the decision was taken to extract the generator from the PTO and ship it to Lisbon where the Siemens engineer assigned to the project could follow up the diagnosis and the repair procedures.

Before removing the generator to make a more detailed analysis and proceed to its reparation, the last test was carried out. It consisted of accelerating the turbine until 2500 rpm (limit) and measure vibrations. This test was made twice by Oceantec and Tecnalia on 6th October, obtaining two associated files and the maximum recorded values:

- Rundown 1:
    - Max. Speed: 2450.8 rpm
    - Max. Vibration: 8.0 mm/s
- Rundown 2:
    - Max. Speed: 2529.5 rpm
    - Max. Vibration: 8.7 mm/s

The diagnosis and the repair activities report, carried out by Siemens, is transcribed hereunder.

5.3.2 DIAGNOSIS

1. A visual analysis of the generator exterior was carried out to verify damages, and no external damage was registered.

2. Electrical tests were carried out on the phases of the generator, with a galvanometer with a voltage of 1000 V, and it was observed that two of the phases were in perfect conditions and one was with direct passage to the ground.

3. The equipment was disassembled, and visual analysis of the interior of the machine was carried out.

4. After verifying all the mechanical components inside the generator, we verified that they were in perfect condition, which led to conclude that the failure did not occur as a result of any mechanical action.

5. After the verification of the stator windings of the generator, we verified that there was no sign of any rupture, leading us to conclude that the yield of the insulation was inside one of *the channels of the stator. In these cases, due to the characteristics of the construction of the generator, it is not possible to visualise it.*

We can thus conclude that this type of failure is a consequence of the operation with frequency inverter and occurs when, due to the characteristics of the operation, high current peaks are generated in the stator windings, which cause the insulation to incur accelerated wear leading to the detected fault.

For these reasons, this fault was not considered to be covered by the guarantee of manufacturing defects.

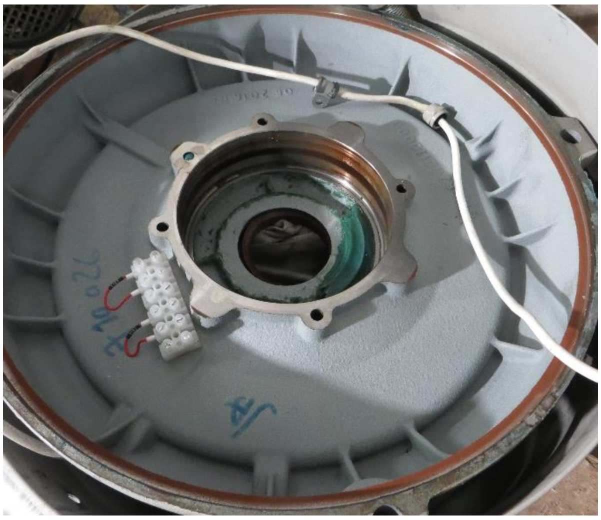


FIGURE 31. GENERATOR INSPECTION FOR FAULT DIAGNOSIS AT THE SIEMENS SHOPFLOOR.

5.3.3 REPAIR PROCEDURE

We proposed the following generator repair actions to prevent future anomalies:

1. *Stator rewinding with copper wire with class H insulation.*
2. *Application of double insulation card in the stator channels and closure with high resistance bits.*
3. *Double impregnation with high resistance varnish and drying in a kiln at the recommended temperature.*
4. *Finishing with an air-drying varnish of high rigidity.*
5. *Replacement of the following components: thermistors, anti-condensation resistances and bearings.*

NOTE: This procedure has been carried out, culminating with the test of the generator, having proven its full functionality.

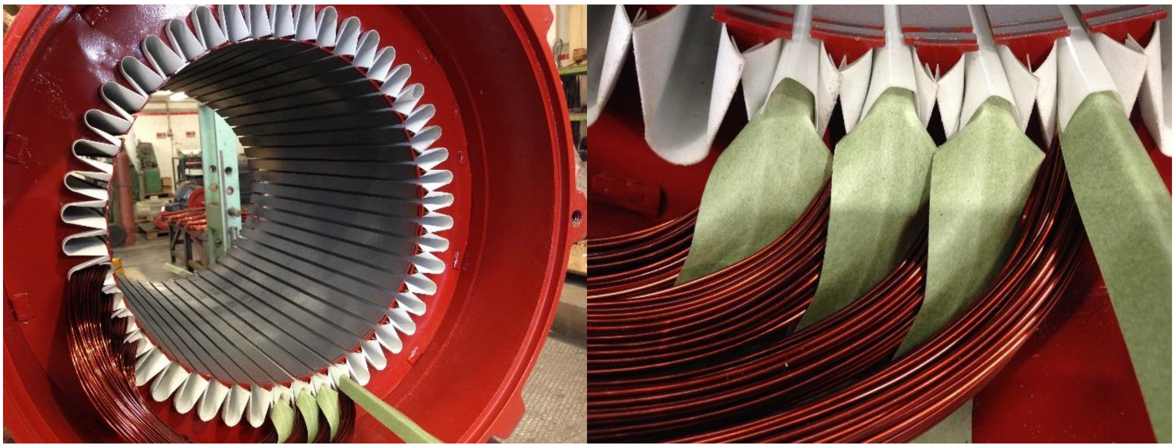


FIGURE 32. INSULATION REINFORCEMENT AND REWINDING OF GENERATOR AT SIEMENS SHOPFLOOR.

5.3.4 PREVENTION MEASURES TO IMPLEMENT

1. Finally and to avoid this type of anomaly we recommend the use of a dv/dt *filter. This filter must be installed before connecting the generator. Suggestion: Siemens 6SL3202-0AE28-0000 (or equivalent).*

2. We also recommend the measurement and the register of the current and the voltage of each phase in the database, at a frequency 8 to 10 times higher than the PWM frequency of the inverter. The sampling could be performed on an hourly base, for 10 minutes, if the electrical power peak exceeds 20 kW in the previous hour.

5.3.5 CONCLUSION

The reinstallation and recommissioning were finally achieved after Christmas leading to a three-month interruption of the tests.

The prescribed filter was installed in between the power electronics and the PTO at Mutriku, and the PTO has been running ever since, for the past six months, without any failure. For security reasons, it is recommended to keep the filter in place for the installation on the MARMOK-A5 device to avoid the manifestation of the same type of problems, given the apparent similarity of the power electronics to that of the Mutriku plant.

6. MAINTENANCE REQUIREMENTS

The number of hours associated with the test campaign, including the dry tests at IST, the shore testing at Mutriku and the offshore testing at BIMEP fall within the preventive maintenance boundaries for the systems installed.

For this reason, no regular maintenance plan has been defined. Nevertheless, a series of tests following every major step, location change, and test run have been made to troubleshoot any offset from the reference operating parameters.

Before the disassembly of the PTO from Mutriku, the following inspections will be carried out:

- With the help of a strobe check for salt accumulation in the rotor;
- Spray the rotor with a hose using fresh water and spin the turbine in motor mode at low speed < 500 rpm;
- Open the top cover and check for water ingress onto the nacelle after the rotor has stopped;
- Run commissioning test protocol to record horizontal vibration.

These steps will determine if any further action needs to be taken.

7. Conclusions

Main conclusions are presented below:

- The Biradial turbine, in operation for more than one year at the Mutriku Power Plant, has shown that the **OPERA Biradial turbine exhibits a mean efficiency higher by a factor of 1.55 in comparison with the current Wavegen Wells turbines installed at the Mutriku Power Plant. This demonstrates that WP3 specific objective two was fully achieved with the testing at-sea operation at the Mutriku shoreline wave power plant**.
- A failure of the electrical generator occurred as a consequence of the operation with the frequency inverter due to high current peaks generated in the stator windings, which caused the insulation to incur accelerated wear leading to the detected fault. The electrical generator was repaired and a $\mathrm{d}V/\mathrm{d}t$filter was installed in the Mutriku plant before reconnecting the generator, to avoid this type of anomaly. The electrical generator was re-commissioned and restarted operation in December 2017;
- Real operating conditions at the Mutriku power plant improved the reliability of the power take-off, collected and shared electrical component operating data, identified failure modes, their causes and tested solutions, **meaning that specific WP3 objective one was achieved.**
- No measurements of noise were performed, but it was observed that the noise produced by the Biradial turbine is much lower than that produced by the Wavegen Wells turbines. The noise produced by the Wells turbines are mainly due to the stall-flow conditions at the rotor blades. The noise is an important characteristic near inhabited areas.

8. REFERENCES

[1] - OPERA - Open Sea Operating Experience to Reduce Wave. “Database access tool.” 2017.

[2] - Gato, L.M.C., A.A.D. Carrelhas, F.X. Correia da Fonseca and J.C.C. Henriques. *Turbine-generator set laboratory tests in variable.* OPERA - Open Sea Operating Experience to Reduce Wave, Deliverable D3.2, 2017.

[3] - W.K. Tease, J. Lees and A. Hall. “Advances in oscillating water column air turbine.” *Proceedings of the 7th European Wave and Tidal Energy Conference.* Porto, Portugal, 2007.

[4] - J.C.C. Henriques, W. Sheng, A.F.O. Falcão and L.M.C. Gato. “A comparison of Biradial and Wells air turbines on the Mutriku breakwater OWC wave power plant.” *Proceedings of the 32th International Conference on Ocean, Offshore and Artic Engineering, Trondheim, Norway*, 2017.

[5] - A.F.O. Falcão, J. C. C. Henriques, L. M. C. Gato. “Air turbine choice and optimization for floating oscillating-water-column wave energy converter.” *Ocean engineering*, 2014: 75: 148-156.

9. APPENDIX A1

The analysis of the pressure signals revealed that the pressure measurements have significant zero drift. Physically, when the HSSV was closed, pressure sensors p1l, p1h, p2l and p2h, located between the HSSV and the turbine gallery, should measure zero relative pressure. Using the same reasoning, pressure sensors p3l, p3h, p4l, p4h, p5l and p5h located between the air chamber and the HSSV should also measure the same (non-constant) value as a result of the OWC oscillations. However, this is not the case for these two sets of sensors, see Figure 33. All the data from the WP3 test campaign was processed considering individual files with a full day of recorded data. The mean values of the two sets of pressures with the HSSV closed were computed for each data file and, afterwards, the mean values were subtracted to the measured signals. This procedure allowed the overlap of the pressure signals when the HSSV was closed, see Figure 34.

The following Python code shows the adopted procedure and the computation of the turbine dimensionless parameters, Ψ, Φ, and Π, the volumetric flow rate, Q, the pneumatic power, P_{pneu}, and the turbine power, P_{turb}.

```
def Phi_Psi( Psi ):
  apsi = abs( Psi )
  aphi = (0.0 + 539581725.354*apsi + 638407403.112*apsi**2) \
        /(844010065.844 + 4360645489.11*apsi + 468212474.631*apsi**2 + apsi**3)
  return np.sign( Psi ) * aphi

def Pi_Psi( Psi ):
  apsi = abs( Psi )
  return (-8311615.56473 + 69022248.16*apsi + 136450487.222*apsi**2) \
        /(1067882948.21 + 512641214.194*apsi + 76229.0830089*apsi**2 + apsi**3)

def eta_Psi( Psi ):
  apsi = abs( Psi )
  return (-0.0698294618409 + 0.408116075959*apsi + 4.38745266305*apsi**2) \
      /(0.073510236828 - 0.259269785174*apsi + 7.08676177897*apsi**2 + apsi**3)

hf = h5py.File( filename, 'r+')

damper_max = 85 # above 85 degrees the damper effect should be negligible

TimeStamp = hf[ 't9data/TimeStamp' ]

print( filename, "--> Start:", TimeStamp[0].decode("utf-8") )

delta_t = hf[ 't9data/delta_t' ]
delta_t0 = delta_t[0]

delta_t -= delta_t0

CL      = np.array( hf[ 't9data/Col002' ] )
Omega   = np.array( hf[ 't9data/Col052' ] )
```

```
HSSV    = np.array( hf[ 't9data/Col028' ] ).astype('int')
damper  = np.array( hf[ 't9data/Col020' ] ).astype('int')
Pgen    = np.array( hf[ 't9data/Col065' ] )

time_flt, Omega_flt   = filter_signal( LP_coefs, delta_t, Omega )

NS   = HSSV.shape[0]
NC   = LP_coefs.shape[0]
hNC = int( NC / 2 )
CL   = CL[ hNC: NS-hNC ]
HSSV = HSSV[ hNC: NS-hNC ]
damper = damper[ hNC: NS-hNC ]

NN = HSSV.shape[0]

rho = 1.2
D = 0.5

Psi = np.zeros( NN )
Phi = np.zeros( NN )
Pi   = np.zeros( NN )
Eta = np.zeros( NN )

Pturb   = np.zeros( NN )
Ppneu   = np.zeros( NN )
Q       = np.zeros( NN )

p_1l   = np.array( hf[ 't9data/Col035' ] )
p_1h   = np.array( hf[ 't9data/Col036' ] )
p_2l   = np.array( hf[ 't9data/Col039' ] )
p_2h   = np.array( hf[ 't9data/Col040' ] )
p_3l   = np.array( hf[ 't9data/Col037' ] )
p_3h   = np.array( hf[ 't9data/Col038' ] )
p_4l   = np.array( hf[ 't9data/Col041' ] )
p_4h   = np.array( hf[ 't9data/Col042' ] )
p_5l   = np.array( hf[ 't9data/Col033' ] )
p_5h   = np.array( hf[ 't9data/Col034' ] )

time_flt, p_1l = filter_signal( LP_coefs, delta_t, p_1l )
time_flt, p_1h = filter_signal( LP_coefs, delta_t, p_1h )
time_flt, p_2l = filter_signal( LP_coefs, delta_t, p_2l )
time_flt, p_2h = filter_signal( LP_coefs, delta_t, p_2h )
time_flt, p_3l = filter_signal( LP_coefs, delta_t, p_3l )
time_flt, p_3h = filter_signal( LP_coefs, delta_t, p_3h )
time_flt, p_4l = filter_signal( LP_coefs, delta_t, p_4l )
time_flt, p_4h = filter_signal( LP_coefs, delta_t, p_4h )
time_flt, p_5l = filter_signal( LP_coefs, delta_t, p_5l )
time_flt, p_5h = filter_signal( LP_coefs, delta_t, p_5h )
time_flt, Pgen = filter_signal( LP_coefs, delta_t, Pgen )

p_1l_mean = 0.0
p_1h_mean = 0.0
p_2l_mean = 0.0
p_2h_mean = 0.0
p_3l_mean = 0.0
p_3h_mean = 0.0
p_4l_mean = 0.0
p_4h_mean = 0.0
p_5l_mean = 0.0
p_5h_mean = 0.0

p_mean = 0.0
n = 0
for i in range( NN ):
  # when the HSSV is closed, p3, p4 and p5 should have the same mean
```

```
  if HSSV[i] < 1.0:
    p_mean = p_mean+(p_3h[i] + p_4l[i] + p_4h[i] + p_5l[i] + p_5h[i]) / 5.0
    p_1l_mean = p_1l_mean + p_1l[i]
    p_1h_mean = p_1h_mean + p_1h[i]
    p_2l_mean = p_2l_mean + p_2l[i]
    p_2h_mean = p_2h_mean + p_2h[i]
    p_3l_mean = p_3l_mean + p_3l[i]
    p_3h_mean = p_3h_mean + p_3h[i]
    p_4l_mean = p_4l_mean + p_4l[i]
    p_4h_mean = p_4h_mean + p_4h[i]
    p_5l_mean = p_5l_mean + p_5l[i]
    p_5h_mean = p_5h_mean + p_5h[i]
    n = n+1

if n == 0:
  continue

p_mean    = p_mean / n
p_1l_mean = p_1l_mean / n
p_1h_mean = p_1h_mean / n
p_2l_mean = p_2l_mean / n
p_2h_mean = p_2h_mean / n
p_3l_mean = p_3l_mean / n
p_3h_mean = p_3h_mean / n
p_4l_mean = p_4l_mean / n
p_4h_mean = p_4h_mean / n
p_5l_mean = p_5l_mean / n
p_5h_mean = p_5h_mean / n

# correct the mean value of p3, p4 and p5
p_3l -= p_3l_mean - p_mean
p_3h -= p_3h_mean - p_mean
p_4l -= p_4l_mean - p_mean
p_4h -= p_4h_mean - p_mean
p_5l -= p_5l_mean - p_mean
p_5h -= p_5h_mean - p_mean

p_1l -= p_1l_mean
p_1h -= p_1h_mean
p_2l -= p_2l_mean
p_2h -= p_2h_mean

for i in range( NN ):
  if HSSV[i] > 0 and damper[i] >= damper_max and Omega_flt[i] > 1.0:
    Psi[i] = p_5h[i] / ( rho * ( Omega_flt[i] * D )**2 )
  else:
    Psi[i] = 0.0

  Phi[i] = Phi_Psi( Psi[i] )
  Pi[i]  = Pi_Psi ( Psi[i] )
  Eta[i] = eta_Psi( Psi[i] )

  Kt = rho * Omega_flt[i]**3 * D**5

  Pturb[i] = Kt * Pi[i]
  Ppneu[i] = Kt * Psi[i] * Phi[i]
  Q[i]     = Omega_flt[i] * D**3 * Phi[i]

hf.close()
```

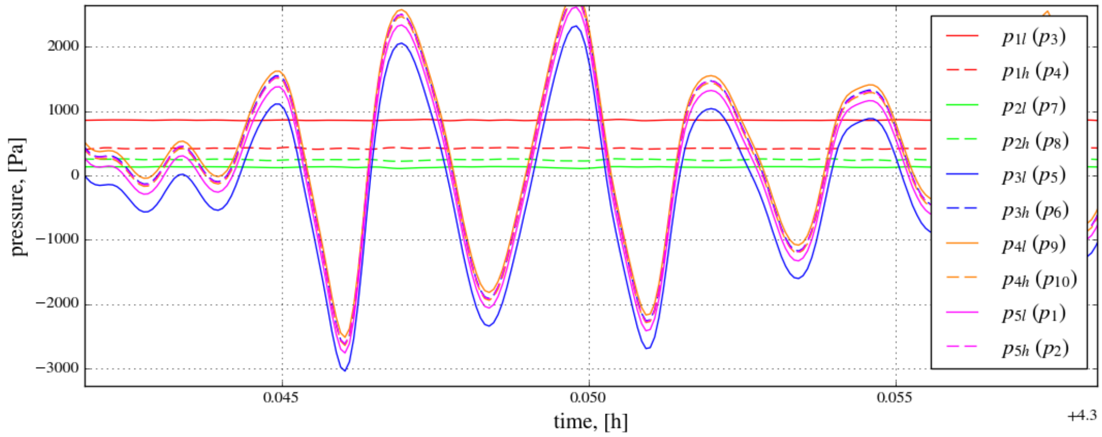


FIGURE 33. PRESSURE SIGNALS WITH THE HSSV CLOSED BEFORE CALIBRATION OF THE ZERO.

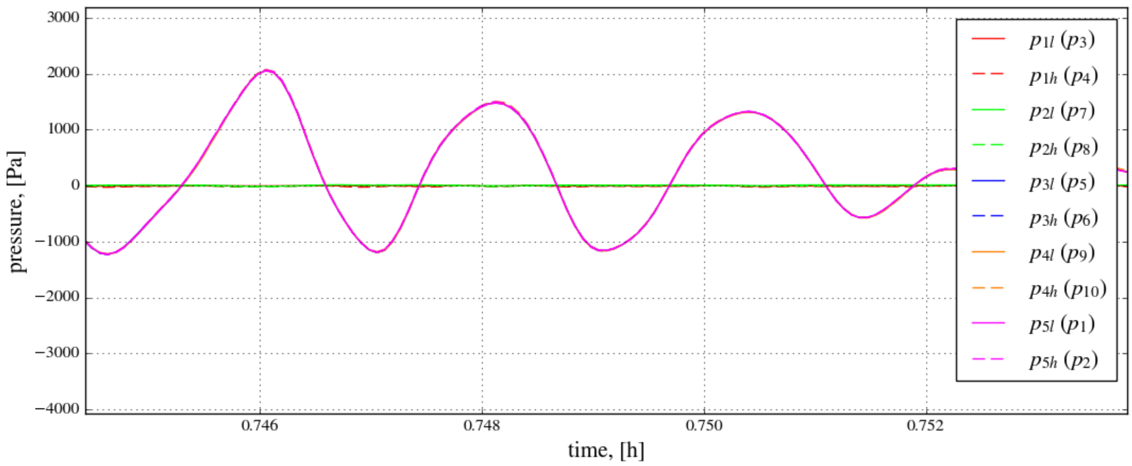


FIGURE 34 – PRESSURE SENSORS WITH THE HSSV CLOSED AFTER CALIBRATION OF THE ZERO OF THE PRESSURE SENSORS.

10. APPENDIX A2

Figures 35 and 36 plots the frequency response of the centred non-causal zero-phase filter used in the post-process of all experimental data. The filter uses 1801 points. Figure 37 compares non-filtered and filtered chamber pressure signals.

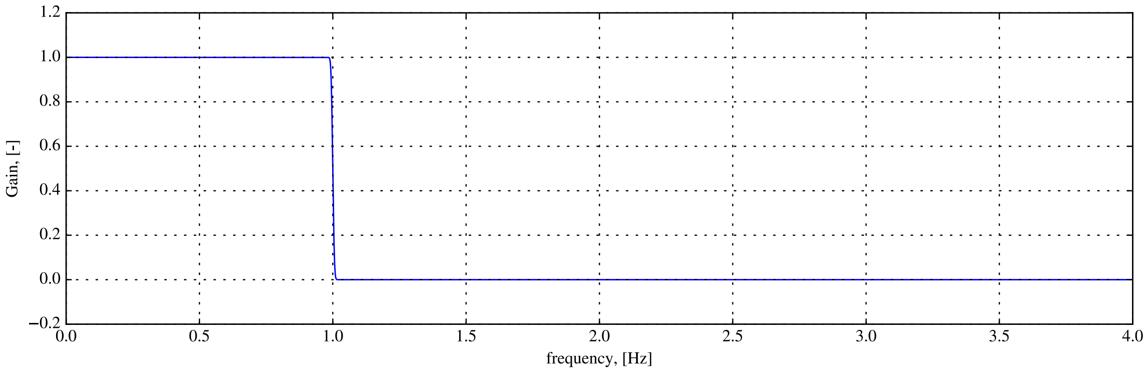


FIGURE 35. FILTER RESPONSE IN A LINEAR SCALE.

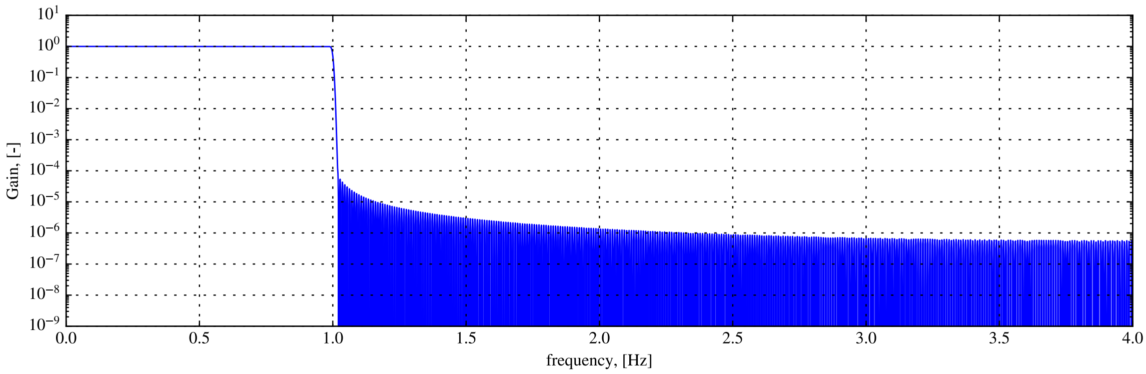


FIGURE 36. FILTER RESPONSE IN A SEMI-LOG SCALE.

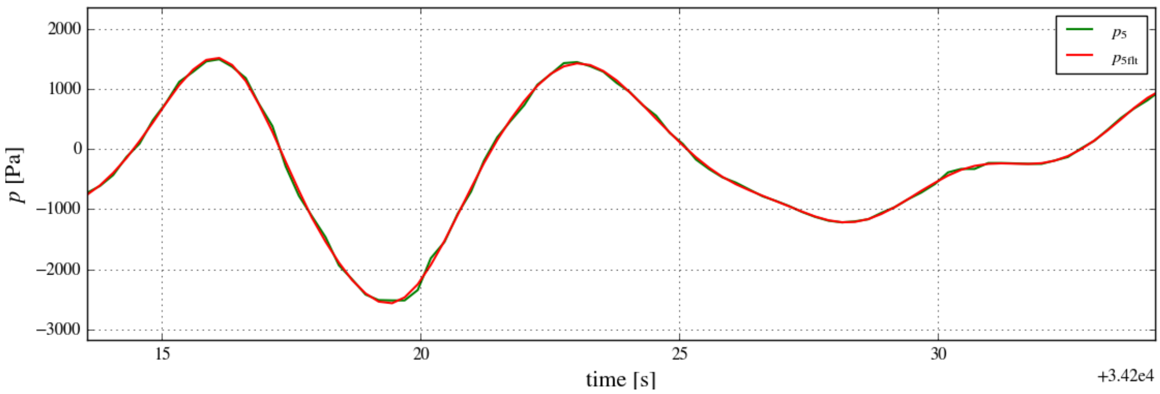


FIGURE 37. NON-FILTERED (IN GREEN) AND FILTERED (IN RED) CHAMBER PRESSURE SIGNALS.

11. APPENDIX A3

A summary of the computed results for the biradial turbine and the Wells can be found in the following pages.

Table of results for the Biradial turbine. The values of H_s, T_e, T_p and tide were taken from the site http://www.puertos.es/.

Biradial turbine filename	Time Stamp	Start Index	CL	RMS p	Eff	Pturb Mean	Ppneu Mean	RMS Psi	RMS Phi	RMS Pi	RMS Omega	Omega Mean	Hs	Te	Tp	Tide
Mutriku_B064944500.h5	2017-09-06 14:11:49.070941	196058	5	3030.1	0.618	3915.7	6332.4	0.5218	0.1259	0.0592	138.5	135.6	0.68	9.11	10.51	3.70
Mutriku_B064271500.h5	2017-09-04 15:53:11.034012	219127	5	1838.1	0.616	1811.8	2939.1	0.4883	0.1201	0.0547	112.3	110.1	0.68	9.26	10.68	3.86
Mutriku_B056195500.h5	2017-08-11 13:51:46.971644	179228	5	2030.4	0.615	2110.3	3430.5	0.4356	0.1121	0.0462	124.6	123.5	0.61	6.12	7.06	1.13
Mutriku_B070328500.h5	2017-09-22 12:51:19.454217	181398	5	1683.5	0.614	1596.5	2600.5	0.4948	0.1195	0.0578	111.8	109.3	0.64	5.03	5.80	0.98
Mutriku_B071338000.h5	2017-09-25 17:28:02.758026	247461	5	3568.0	0.614	4876.6	7948.0	0.5339	0.1269	0.0623	147.2	143.6	0.88	11.36	13.11	3.25
Mutriku_B064271500.h5	2017-09-04 14:53:01.982523	205064	5	2305.5	0.612	2626.2	4288.5	0.5574	0.1317	0.0645	117.3	116.2	0.68	9.12	10.52	3.90
Mutriku_B068982500.h5	2017-09-18 16:23:12.262023	230472	5	1155.6	0.611	897.4	1469.8	0.4393	0.1123	0.0470	95.8	94.4	0.40	6.10	7.04	3.57
Mutriku_B064608000.h5	2017-09-05 12:37:38.460344	173707	5	2413.7	0.611	2678.4	4381.0	0.4920	0.1204	0.0553	126.5	124.1	0.55	11.38	13.13	2.61
Mutriku_B053840000.h5	2017-08-04 14:09:26.921439	181214	2	3357.1	0.610	4727.2	7750.6	0.6561	0.1458	0.0819	132.4	130.7	0.67	10.82	12.49	3.60
Mutriku_B060906500.h5	2017-08-25 12:28:51.614378	166048	5	1296.5	0.610	1069.6	1754.8	0.4983	0.1210	0.0565	94.0	92.8	0.39	4.26	4.91	0.70
Mutriku_B064944500.h5	2017-09-06 15:11:59.421404	210111	5	2878.8	0.610	3434.2	5629.9	0.3910	0.1046	0.0398	158.8	155.4	0.67	9.11	10.51	4.15
Mutriku_B060570000.h5	2017-08-24 11:38:13.697064	153738	5	1221.1	0.609	980.3	1609.2	0.5308	0.1256	0.0624	90.2	88.5	0.45	3.88	4.48	0.51
Mutriku_B071674500.h5	2017-09-26 10:43:43.121968	152939	5	2891.3	0.609	3402.8	5589.3	0.3997	0.1046	0.0425	155.1	151.9	0.73	10.42	12.02	2.42
Mutriku_B071674500.h5	2017-09-26 18:47:10.372035	265935	5	2861.6	0.609	3557.9	5839.7	0.6779	0.1493	0.0844	115.1	111.2	0.65	9.85	11.37	3.18
Mutriku_B071674500.h5	2017-09-26 13:44:47.635195	195261	5	3512.3	0.609	4630.9	7610.1	0.5223	0.1246	0.0612	149.1	145.9	0.70	10.26	11.84	1.34
Mutriku_B066627000.h5	2017-09-11 16:33:33.708700	230631	2	4589.4	0.608	7312.7	12027.1	0.5991	0.1362	0.0736	162.8	159.8	1.73	9.95	11.48	2.71
Mutriku_B064608000.h5	2017-09-05 09:36:54.379004	131473	5	2378.3	0.608	2613.0	4300.9	0.4640	0.1142	0.0532	139.0	136.1	0.58	11.49	13.26	0.90
Mutriku_B071674500.h5	2017-09-26 20:47:20.271139	294021	5	2725.4	0.608	3291.2	5413.3	0.7164	0.1539	0.0920	110.1	105.4	0.62	9.74	11.24	3.26
Mutriku_B049129000.h5	2017-07-21 13:14:27.191521	163527	1	2671.6	0.607	3177.1	5235.7	0.6405	0.1390	0.0840	124.0	120.6	0.50	7.92	9.14	3.94

Mutriku_B055186000.h5	2017-08-08 14:58:21.074858	193818	2	3732.0	0.607	5486.5	9037.7	0.6484	0.1452	0.0793	137.2	135.9	0.83	6.14	7.08	3.36
Mutriku_B068982500.h5	2017-09-18 17:35:04.012522	247272	5	1077.2	0.607	798.9	1316.9	0.4877	0.1183	0.0559	87.3	86.0	0.39	6.08	7.02	2.74
Mutriku_B060233500.h5	2017-08-23 13:53:31.033645	184876	5	1392.1	0.607	1176.9	1940.1	0.5046	0.1207	0.0594	98.4	96.8	0.35	9.14	10.55	2.05
Mutriku_B064944500.h5	2017-09-06 13:11:29.265280	181968	5	2616.5	0.607	3153.4	5193.5	0.6228	0.1399	0.0768	118.1	116.2	0.69	9.12	10.52	2.93
Mutriku_B071674500.h5	2017-09-26 11:44:15.971767	167091	5	4025.2	0.607	6045.9	9963.7	0.6791	0.1489	0.0859	139.9	136.5	0.72	10.37	11.97	1.88
Mutriku_B059560500.h5	2017-08-21 13:53:32.484323	182432	5	783.9	0.606	490.6	809.5	0.4297	0.1106	0.0459	81.5	79.6	0.72	4.07	4.70	3.37
Mutriku_B066627000.h5	2017-09-11 16:43:49.158638	233031	2	4608.5	0.605	7195.3	11893.2	0.6226	0.1408	0.0755	155.4	153.1	1.73	9.95	11.48	2.71
Mutriku_B068982500.h5	2017-09-18 15:52:23.880646	223272	5	922.6	0.604	630.6	1044.1	0.4712	0.1156	0.0540	83.7	82.4	0.41	6.12	7.06	4.07
Mutriku_B071674500.h5	2017-09-26 19:27:10.330048	275284	2	3105.7	0.603	4098.3	6799.3	0.7336	0.1555	0.0960	121.0	117.9	0.64	9.79	11.30	3.33
Mutriku_B071674500.h5	2017-09-26 18:27:08.928212	261255	2	3313.6	0.603	4426.5	7338.3	0.7176	0.1527	0.0938	126.9	122.7	0.65	9.85	11.37	3.18
Mutriku_B055186000.h5	2017-08-08 14:18:10.488704	184413	2	3925.4	0.603	5761.8	9554.1	0.6804	0.1476	0.0870	140.8	137.5	0.83	6.14	7.08	3.36
Mutriku_B071674500.h5	2017-09-26 12:24:23.405005	176469	2	3959.0	0.603	5854.0	9704.3	0.6649	0.1458	0.0842	142.1	139.4	0.71	10.32	11.91	1.48
Mutriku_B059560500.h5	2017-08-21 11:53:31.493659	154385	5	772.1	0.603	481.6	799.1	0.4465	0.1111	0.0512	79.2	78.3	0.59	4.08	4.71	1.56
Mutriku_B071338000.h5	2017-09-25 18:48:32.524154	266276	1	4058.4	0.602	6053.7	10054.6	0.7018	0.1524	0.0884	137.2	133.7	0.88	11.29	13.03	3.53
Mutriku_B071674500.h5	2017-09-26 17:27:00.709336	247201	2	3460.0	0.602	4749.6	7883.4	0.6970	0.1501	0.0897	130.3	126.7	0.66	9.91	11.44	2.83
Mutriku_B071674500.h5	2017-09-26 16:27:00.606990	233175	2	4013.1	0.602	5457.8	9073.3	0.6410	0.1420	0.0805	142.6	138.0	0.67	9.99	11.53	2.35
Mutriku_B071338000.h5	2017-09-25 18:28:32.271219	261601	5	3205.5	0.602	4172.8	6931.6	0.6967	0.1500	0.0894	121.8	118.1	0.88	11.29	13.03	3.53
Mutriku_B066627000.h5	2017-09-11 17:37:43.132098	245637	1	4880.4	0.601	7742.4	12889.6	0.7023	0.1510	0.0901	151.1	147.2	1.82	10.26	11.84	3.41
Mutriku_B071674500.h5	2017-09-26 16:47:00.693158	237851	5	3770.8	0.601	5409.6	8994.1	0.6900	0.1494	0.0880	133.9	130.9	0.67	9.99	11.53	2.35
Mutriku_B062925500.h5	2017-08-31 12:25:27.525859	168805	1	4734.7	0.600	7558.9	12588.0	0.7042	0.1515	0.0904	149.3	145.5	0.92	10.20	11.77	3.03
Mutriku_B070328500.h5	2017-09-22 11:51:16.754779	167363	5	1788.5	0.599	1676.7	2798.0	0.6630	0.1433	0.0859	94.5	91.0	0.68	4.94	5.70	0.51
Mutriku_B071674500.h5	2017-09-26 21:47:22.225268	308050	5	1941.6	0.599	2025.4	3382.4	0.7258	0.1544	0.0943	94.4	92.6	0.61	9.70	11.19	2.98
Mutriku_B064608000.h5	2017-09-05 11:37:37.912966	159685	5	2035.6	0.599	2062.1	3440.4	0.6272	0.1380	0.0802	105.4	102.8	0.56	11.42	13.18	1.81

Mutriku_B053503500.h5	2017-08-03 09:29:56.673631	115302	2	1300.0	0.597	1038.1	1739.5	0.5115	0.1186	0.0634	103.3	100.1	0.38	9.25	10.67	2.22
Mutriku_B065281000.h5	2017-09-07 13:26:39.710572	185811	1	4350.8	0.596	6570.5	11025.1	0.7137	0.1518	0.0929	141.7	137.8	0.79	10.61	12.24	2.43
Mutriku_B056195500.h5	2017-08-11 12:51:39.456996	165151	5	2008.9	0.595	2107.7	3543.4	0.7584	0.1565	0.1029	95.1	93.0	0.63	6.14	7.09	0.73
Mutriku_B060233500.h5	2017-08-23 15:14:38.307596	203844	1	1558.5	0.594	1465.0	2468.2	0.7655	0.1596	0.1013	82.7	81.5	0.34	9.06	10.45	3.86
Mutriku_B071674500.h5	2017-09-26 15:05:48.714486	214196	1	4396.0	0.594	6321.4	10634.8	0.7127	0.1511	0.0934	140.0	134.5	0.68	10.09	11.64	1.85
Mutriku_B066627000.h5	2017-09-11 17:17:36.448833	240932	5	4785.1	0.594	7478.2	12588.9	0.7590	0.1579	0.1018	144.3	140.7	1.82	10.26	11.84	3.41
Mutriku_B060233500.h5	2017-08-23 16:15:03.020825	217980	1	1608.2	0.593	1496.1	2521.2	0.7781	0.1607	0.1042	82.5	80.2	0.33	9.02	10.41	4.34
Mutriku_B062925500.h5	2017-08-31 12:05:24.722453	164121	5	4337.9	0.593	6707.1	11303.8	0.7948	0.1630	0.1068	135.4	131.7	0.92	10.20	11.77	3.03
Mutriku_B059560500.h5	2017-08-21 14:13:32.783417	187107	1	740.6	0.590	472.1	800.3	0.7620	0.1605	0.1000	55.4	54.7	0.72	4.13	4.76	4.05
Mutriku_B059560500.h5	2017-08-21 15:13:33.252809	201131	1	690.3	0.589	434.2	737.3	0.7752	0.1626	0.1013	53.6	53.3	0.70	4.10	4.73	4.36
Mutriku_B109026000.h5	2018-01-22 17:08:44.621339	35156	1	5469.3	0.563	9226.3	16383.6	1.2631	0.2081	0.2121	134.9	129.7	2.06	10.50	12.11	3.01
Mutriku_B109026000.h5	2018-01-23 08:13:52.764949	246654	1	5868.4	0.563	10223.5	18170.4	1.2521	0.2092	0.2063	139.8	134.1	1.86	15.37	17.74	3.57
Mutriku_B131571500.h5	2018-04-11 14:50:45.375182	330539	1	6309.6	0.562	11421.0	20312.2	1.1852	0.2037	0.1905	143.4	138.8	2.62	12.71	14.66	3.30
Mutriku_B132581000.h5	2018-04-14 03:09:29.144854	167230	1	5886.0	0.561	9813.4	17504.9	1.2671	0.2144	0.2043	134.2	127.3	1.41	12.71	14.66	3.86
Mutriku_B139647500_C75.h5	2018-05-05 10:01:14.901404	270707	4	4998.9	0.560	7860.8	14045.0	1.4175	0.2253	0.2418	122.3	114.1	1.34	10.50	12.11	2.13
Mutriku_B123159000.h5	2018-03-16 17:54:52.839727	34014	1	5338.4	0.558	8906.9	15970.4	1.3039	0.2134	0.2188	129.4	124.3	1.84	11.54	13.32	3.47
Mutriku_B132581000.h5	2018-04-14 03:19:45.585213	169630	1	5558.1	0.558	9154.6	16409.8	1.3082	0.2171	0.2152	129.8	123.7	1.41	12.71	14.66	3.86
Mutriku_B106670500.h5	2018-01-16 08:43:36.690910	251993	5	5411.0	0.558	8973.4	16071.5	1.2380	0.2060	0.2044	136.5	130.2	1.92	10.50	12.11	1.25
Mutriku_B142676000_C75.h5	2018-05-14 06:24:19.003188	221910	1	5048.9	0.557	8257.2	14812.3	1.2894	0.2156	0.2107	125.6	120.4	1.57	11.54	13.32	1.90
Mutriku_B142676000_C75.h5	2018-05-13 17:20:14.513795	38555	1	5517.3	0.557	9086.8	16314.2	1.2863	0.2104	0.2159	132.0	126.4	1.80	12.71	14.66	2.51
Mutriku_B109026000.h5	2018-01-22 18:30:27.898962	54250	1	5673.0	0.556	9058.0	16302.5	1.3609	0.2191	0.2303	131.9	125.0	2.14	10.50	12.11	3.39
Mutriku_B109026000.h5	2018-01-23 06:42:03.688009	225196	1	5906.5	0.556	9518.8	17112.1	1.2845	0.2109	0.2151	135.1	128.8	1.95	12.71	14.66	3.44
Mutriku_B122149500.h5	2018-03-13 16:22:06.205476	10204	1	5046.0	0.555	8185.4	14757.2	1.3499	0.2167	0.2305	124.0	118.0	1.52	9.54	11.01	2.69

Mutriku_B142003000_C75.h5	2018-05-11 15:21:55.217164	10600	1	5094.5	0.554	8064.0	14553.0	1.3732	0.2203	0.2331	125.0	118.5	1.72	12.71	14.66	2.76
Mutriku_B121813000.h5	2018-03-13 08:47:14.311814	239971	1	6619.7	0.553	11263.2	20373.7	1.1519	0.1977	0.1855	145.0	140.3	1.90	10.50	12.11	1.65
Mutriku_B109026000.h5	2018-01-22 16:04:10.952594	20072	2	6316.4	0.553	11558.5	20916.8	1.4472	0.2232	0.2544	142.6	136.3	1.98	10.50	12.11	2.39
Mutriku_B109362500.h5	2018-01-23 20:17:47.284028	79580	1	6684.5	0.552	10524.3	19069.0	1.3055	0.2132	0.2188	141.0	133.9	1.31	11.54	13.32	3.36
Mutriku_B109026000.h5	2018-01-22 15:44:02.041080	15365	1	6805.7	0.547	9895.9	18088.7	1.2523	0.2084	0.2062	139.0	132.7	1.91	10.50	12.11	1.72
Mutriku_B109026000.h5	2018-01-23 09:28:34.894292	264108	1	6642.1	0.545	10034.1	18411.2	1.3364	0.2149	0.2262	137.6	130.8	1.82	15.37	17.74	3.20
Mutriku_B134263500.h5	2018-04-18 20:39:08.386480	77899	1	8228.3	0.545	13317.7	24432.7	1.2376	0.2032	0.2065	154.1	147.2	1.48	13.97	16.12	2.55
Mutriku_B137292000_C75.h5	2018-04-28 01:16:20.552313	145575	1	9522.0	0.544	16006.9	29409.7	1.0550	0.1864	0.1649	167.6	163.6	2.28	11.54	13.32	3.76
Mutriku_B108016500.h5	2018-01-19 16:48:04.039313	29712	2	8197.6	0.544	14051.0	25816.2	1.3045	0.2097	0.2231	153.4	147.5	2.39	12.71	14.66	3.61
Mutriku_B114746500.h5	2018-02-09 12:06:05.644008	307127	5	6142.3	0.544	9879.3	18169.2	1.5359	0.2354	0.2690	130.3	121.7	1.78	16.91	19.51	2.89
Mutriku_B114746500.h5	2018-02-09 12:17:35.818799	309820	5	6351.3	0.544	9551.6	17547.3	1.5569	0.2350	0.2768	128.0	119.3	1.78	16.91	19.51	2.89
Mutriku_B117102000.h5	2018-02-15 17:05:26.546517	44472	1	6872.5	0.541	10600.0	19593.1	1.5137	0.2320	0.2654	134.9	127.1	2.99	16.91	19.51	3.49
Mutriku_B109026000.h5	2018-01-23 09:58:42.360554	271148	2	7148.7	0.541	12831.1	23724.1	1.3992	0.2239	0.2376	141.0	136.5	1.82	15.37	17.74	3.20
Mutriku_B108689500.h5	2018-01-22 13:02:55.063901	314219	2	6071.5	0.540	10230.9	18956.4	1.5626	0.2329	0.2799	136.8	128.5	1.75	9.54	11.01	0.89
Mutriku_B119121000.h5	2018-02-22 10:31:56.180654	292794	1	7136.7	0.539	13209.4	24489.5	1.3732	0.2241	0.2292	136.8	132.6	1.92	11.54	13.32	2.90
Mutriku_B109362500.h5	2018-01-23 21:59:51.455152	103450	2	6772.0	0.539	11851.2	21979.1	1.6521	0.2471	0.2937	134.5	126.4	1.28	11.54	13.32	3.14
Mutriku_B109026000.h5	2018-01-22 17:33:55.829559	41040	2	6154.6	0.537	10268.0	19138.8	1.7374	0.2497	0.3181	131.3	122.9	2.06	10.50	12.11	3.01
Mutriku_B109026000.h5	2018-01-23 00:57:58.363885	144798	2	7149.0	0.535	12654.8	23669.8	1.5814	0.2349	0.2847	141.5	134.4	2.23	13.97	16.12	1.20
Mutriku_B115756000.h5	2018-02-12 12:18:26.501481	311269	1	8792.3	0.533	12692.4	23804.8	1.1693	0.1966	0.1913	154.7	149.1	2.15	11.54	13.32	2.94
Mutriku_B121813000.h5	2018-03-13 12:52:52.426279	297609	6	7479.9	0.532	14591.2	27416.4	1.4867	0.2374	0.2502	135.3	130.8	1.74	10.50	12.11	3.16
Mutriku_B113737000.h5	2018-02-05 22:29:16.554544	116066	2	7726.6	0.531	13994.9	26367.8	1.4112	0.2229	0.2417	144.2	140.2	2.24	7.89	9.10	2.60
Mutriku_B109026000.h5	2018-01-23 10:33:33.497680	279290	6	7315.2	0.529	13682.4	25847.9	1.5865	0.2473	0.2722	129.9	124.6	1.77	15.37	17.74	2.60
Mutriku_B108016500.h5	2018-01-19 15:46:28.072668	15311	6	9109.9	0.529	15900.9	30069.6	1.3975	0.2276	0.2322	143.6	138.8	2.41	12.71	14.66	3.09

Mutriku_B108016500.h5	2018-01-19 15:36:12.085066	12911	6	8802.5	0.528	16519.2	31314.4	1.4319	0.2305	0.2400	143.1	138.6	2.41	12.71	14.66	3.09
Mutriku_B134263500.h5	2018-04-19 02:57:46.374684	166397	1	7502.7	0.527	11897.4	22588.6	1.3187	0.2065	0.2307	145.3	138.8	1.34	13.97	16.12	2.05
Mutriku_B137292000_C75.h5	2018-04-28 03:02:55.347575	170507	6	7631.9	0.526	14199.7	26996.3	1.6458	0.2499	0.2885	130.3	124.8	2.09	11.54	13.32	3.96
Mutriku_B114410000.h5	2018-02-08 12:08:30.695997	307123	2	10913.4	0.525	18358.7	34939.2	1.2913	0.2109	0.2161	165.0	160.7	2.16	12.71	14.66	2.59
Mutriku_B112391000.h5	2018-02-01 14:28:07.129720	1203	6	10008.8	0.520	19042.9	36642.0	1.5181	0.2400	0.2573	144.8	140.4	2.87	11.54	13.32	3.20
Mutriku_B113737000.h5	2018-02-05 20:38:06.081100	90074	6	7362.5	0.518	13526.8	26117.1	1.6661	0.2515	0.2923	127.5	122.6	2.25	7.89	9.10	3.66
Mutriku_B121813000.h5	2018-03-13 10:20:36.820156	261865	6	8308.6	0.517	15077.3	29157.1	1.5952	0.2426	0.2803	135.9	130.5	1.84	10.50	12.11	2.35
Mutriku_B112391000.h5	2018-02-02 09:58:14.791517	274888	2	10032.9	0.503	18143.3	36097.9	1.5286	0.2223	0.2804	156.4	151.9	2.61	12.71	14.66	1.03
Mutriku_B112391000.h5	2018-02-02 10:20:33.751064	280105	6	8550.2	0.498	16045.2	32226.2	1.7692	0.2488	0.3307	136.4	131.6	2.55	12.71	14.66	0.33
Mutriku_B117102000.h5	2018-02-15 23:07:20.881570	129373	2	10131.0	0.483	18507.0	38332.9	1.9155	0.2445	0.3825	150.7	145.3	3.35	16.91	19.51	1.18
Mutriku_B112391000.h5	2018-02-02 11:17:09.044567	293343	2	8190.3	0.481	14147.4	29393.2	2.0065	0.2552	0.3969	136.8	131.0	2.48	12.71	14.66	0.16
Mutriku_B131571500.h5	2018-04-11 11:50:03.322221	288329	2	11274.4	0.465	20962.0	45089.6	3.0349	0.3448	0.6263	130.0	120.0	2.93	12.71	14.66	3.12
Mutriku_B131571500.h5	2018-04-11 12:01:43.222844	291053	2	8281.9	0.459	15394.8	33515.5	3.2012	0.3663	0.6566	111.0	103.4	2.85	12.71	14.66	3.37
Mutriku_B131571500.h5	2018-04-11 13:53:10.225970	317091	2	7862.7	0.450	14061.8	31236.0	3.5666	0.3922	0.7425	104.1	95.7	2.73	12.71	14.66	3.44
Mutriku_B131908000.h5	2018-04-11 19:07:15.073367	53946	6	7964.1	0.445	13100.8	29409.9	2.3405	0.3093	0.4458	99.4	96.9	2.24	12.71	14.66	1.69

Table of results for the Wells turbine. The values of H_s, T_e, T_p and tide were taken from the site http://www.puertos.es/.

Wells turbine filename	Time Stamp	Start Time	CL	RMS p	Eff	Pturb Mean	Ppneu Mean	RMS Psi	RMS Phi	RMS Pi	RMS Omega	Omega Mean	Hs	Te	Tp	Tide
Mutriku_B139647500_Wells129110569.h5	2018-05-06 03:53:02.654904	233630	1	2246.3	0.405	4207.1	10381.8	0.0572	0.0476	0.0015	228.3	224.7	1.07	9.54	11.01	1.71
Mutriku_B140993500_Wells130456595.h5	2018-05-09 11:10:03.355546	0	1	2039.9	0.400	3713.5	9294.0	0.0612	0.0505	0.0015	225.5	222.9	1.57	13.97	16.12	3.02
Mutriku_B146714000_Wells136177193.h5	2018-05-26 23:24:58.336856	176998	1	3201.4	0.386	7383.8	19134.8	0.0653	0.0542	0.0017	272.3	269.2	0.70	8.68	10.01	2.69
Mutriku_B132244500_Wells121707786.h5	2018-04-13 15:17:23.663620	49337	1	4205.9	0.384	4595.7	11977.7	0.1232	0.0898	0.0016	263.6	258.4	1.45	12.71	14.66	3.63
Mutriku_B137628500_Wells127091512.h5	2018-04-29 17:33:08.319132	86477	1	1821.9	0.370	2926.0	7898.2	0.0606	0.0507	0.0015	205.7	202.8	0.99	4.45	5.13	3.56
Mutriku_B140993500_Wells130456595.h5	2018-05-09 11:37:11.893937	6348	1	2253.6	0.366	3989.6	10910.9	0.0638	0.0516	0.0017	247.4	244.8	1.57	13.97	16.12	3.02
Mutriku_B146714000_Wells136177193.h5	2018-05-27 04:05:17.873891	242555	1	1901.5	0.361	3053.0	8467.2	0.0640	0.0528	0.0015	210.6	207.1	0.72	7.89	9.10	3.14
Mutriku_B137292000_Wells126755008.h5	2018-04-29 04:22:40.583008	238160	1	2044.1	0.361	3371.9	9344.9	0.0625	0.0521	0.0015	217.4	213.0	1.03	7.89	9.10	3.99
Mutriku_B140657000_Wells130120091.h5	2018-05-08 22:26:57.028731	158037	1	2364.9	0.361	4188.3	11611.8	0.0611	0.0510	0.0015	230.9	226.2	1.13	10.50	12.11	3.12
Mutriku_B147050500_Wells136513704.h5	2018-05-27 18:55:11.988299	114166	1	1707.0	0.359	2549.2	7103.1	0.0610	0.0511	0.0014	197.6	194.1	0.67	7.89	9.10	1.84
Mutriku_B053840000_Wells043008816.h5	2017-08-04 12:14:55.958222	154356	1	2429.2	0.359	4438.8	12361.5	0.0652	0.0541	0.0016	246.4	242.7	0.70	11.03	12.73	3.32
Mutriku_B132581000_Wells122043973.h5	2018-04-15 06:18:13.194169	260817	1	2707.0	0.359	5304.8	14794.0	0.0672	0.0557	0.0016	251.1	247.5	1.00	10.50	12.11	2.38
Mutriku_B145368000_Wells134831172.h5	2018-05-23 00:34:03.249727	191572	1	1791.8	0.356	2637.6	7416.0	0.0676	0.0533	0.0014	201.2	196.8	0.78	9.54	11.01	2.98
Mutriku_B134936500_Wells124399477.h5	2018-04-21 13:34:54.234118	28037	1	1459.3	0.351	1967.5	5611.6	0.0623	0.0521	0.0015	178.7	175.0	0.63	10.50	12.11	1.00
Mutriku_B145031500_Wells134494670.h5	2018-05-22 00:14:43.367858	186732	1	1515.4	0.351	2131.8	6075.5	0.0673	0.0550	0.0015	185.3	181.9	0.72	10.50	12.11	2.26
Mutriku_B145031500_Wells134494670.h5	2018-05-21 19:04:22.158305	114171	1	1453.0	0.349	2033.1	5824.1	0.0699	0.0579	0.0016	182.4	179.5	0.78	10.50	12.11	3.39
Mutriku_B136955500_Wells126418495.h5	2018-04-27 19:35:43.733802	114680	1	2886.6	0.347	5616.5	16198.8	0.0640	0.0529	0.0015	256.9	253.6	1.90	11.54	13.32	0.88
Mutriku_B130562000_Wells120025468.h5	2018-04-08 23:42:50.053627	167305	1	1591.3	0.346	2211.2	6386.7	0.0604	0.0504	0.0014	188.4	185.1	0.65	10.50	12.11	3.08
Mutriku_B053840000_Wells043008816.h5	2017-08-04 14:09:25.292075	181214	1	2786.4	0.345	5191.8	15062.0	0.0645	0.0527	0.0014	255.6	251.0	0.67	10.82	12.49	3.60
Mutriku_B055859000_Wells045027833.h5	2017-08-10 13:29:02.987320	173585	1	3380.8	0.342	7187.1	21012.8	0.0695	0.0558	0.0016	284.9	283.1	0.98	6.80	7.85	1.54

Mutriku_B142003000_Wells131466112.h5	2018-05-12 19:43:00.542341	120615	1	3054.1	0.341	6054.1	17760.0	0.0662	0.0544	0.0015	266.9	264.8	1.46	11.54	13.32	1.02
Mutriku_B055186000_Wells044354834.h5	2017-08-08 15:18:28.320473	198530	1	3658.2	0.341	8005.1	23461.6	0.0673	0.0557	0.0015	290.4	287.8	0.81	6.21	7.17	3.90
Mutriku_B140320500_Wells129783579.h5	2018-05-08 03:13:53.864529	224892	1	3078.4	0.340	5903.2	17352.1	0.0649	0.0519	0.0015	256.0	251.9	1.10	11.54	13.32	1.58
Mutriku_B119457500_Wells108920872.h5	2018-03-07 03:20:39.148153	210188	1	3416.1	0.340	7317.3	21498.8	0.0662	0.0551	0.0016	278.0	275.7	1.34	7.89	9.10	2.07
Mutriku_B139984000_Wells129447074.h5	2018-05-06 22:43:44.472906	161492	1	2721.2	0.338	5055.3	14978.6	0.0703	0.0581	0.0016	250.1	246.2	0.97	10.50	12.11	2.78
Mutriku_B119794000_Wells109257370.h5	2018-03-07 17:40:31.557139	74735	1	3623.0	0.338	7959.5	23530.8	0.0666	0.0557	0.0016	282.7	280.1	1.48	9.54	11.01	3.11
Mutriku_B130225500_Wells119689013.h5	2018-04-07 22:01:54.837689	143710	1	2718.6	0.336	4879.0	14540.5	0.0657	0.0549	0.0014	249.3	245.2	1.03	12.71	14.66	3.12
Mutriku_B111718000_Wells101181415.h5	2018-01-31 12:27:48.961345	21379	1	2899.3	0.334	5616.0	16799.4	0.0686	0.0571	0.0016	264.6	261.8	0.89	10.50	12.11	1.86
Mutriku_B119794000_Wells109257370.h5	2018-03-08 00:10:53.784950	165986	1	3332.4	0.332	6989.1	21030.6	0.0712	0.0595	0.0017	274.1	271.4	1.31	9.54	11.01	1.69
Mutriku_B072011000_Wells061179907.h5	2017-09-27 12:10:18.822088	173362	1	810.5	0.326	821.2	2521.1	0.0652	0.0544	0.0016	135.7	135.7	0.48	10.37	11.96	1.92
Mutriku_B119794000_Wells109257370.h5	2018-03-07 22:40:49.582187	144931	1	3712.9	0.325	8058.8	24806.8	0.0686	0.0575	0.0017	280.8	278.0	1.39	9.54	11.01	2.85
Mutriku_B120130500_Wells109593872.h5	2018-03-09 10:41:57.289555	313567	1	1399.0	0.324	1765.0	5447.9	0.0698	0.0573	0.0014	173.4	169.8	0.67	11.54	13.32	3.18
Mutriku_B055186000_Wells044354834.h5	2017-08-08 13:38:05.560075	175034	1	3873.6	0.322	8736.6	27103.1	0.0741	0.0615	0.0017	299.0	297.5	0.84	6.05	6.98	2.57
Mutriku_B138974500_Wells128437553.h5	2018-05-04 06:47:34.187408	273947	1	3869.2	0.317	8349.8	26299.3	0.0791	0.0608	0.0017	283.7	280.8	1.59	10.50	12.11	3.59
Mutriku_B072011000_Wells061179907.h5	2017-09-27 13:10:20.519954	187389	1	797.6	0.316	771.5	2444.7	0.0642	0.0536	0.0015	135.7	135.7	0.47	10.60	12.23	1.63
Mutriku_B147387000_Wells136850208.h5	2018-05-28 12:35:39.147173	25669	1	1068.4	0.315	1181.0	3748.0	0.0723	0.0588	0.0016	150.3	147.8	0.62	7.17	8.27	2.68
Mutriku_B119457500_Wells108920872.h5	2018-03-07 11:00:07.369408	317646	1	3759.3	0.312	7894.7	25262.9	0.0697	0.0582	0.0017	279.8	276.7	1.63	8.68	10.01	2.01
Mutriku_B119457500_Wells108920872.h5	2018-03-06 16:51:11.336357	62998	1	4188.9	0.311	9645.3	31031.6	0.0781	0.0646	0.0018	297.6	296.1	2.16	8.68	10.01	3.05
Mutriku_B072011000_Wells061179907.h5	2017-09-27 13:50:27.609090	196765	1	766.3	0.309	700.1	2264.1	0.0616	0.0517	0.0014	135.7	135.7	0.47	10.60	12.23	1.63
Mutriku_B134936500_Wells124399477.h5	2018-04-22 04:24:39.136562	236136	1	1237.0	0.309	1496.4	4850.4	0.0734	0.0608	0.0017	167.6	165.9	0.61	9.54	11.01	1.66
Mutriku_B068982500_Wells058151461.h5	2017-09-18 17:14:34.138724	242472	1	1076.3	0.306	1194.2	3907.0	0.0774	0.0613	0.0016	152.1	149.9	0.39	6.08	7.02	2.74
Mutriku_B121476500_Wells110939890.h5	2018-03-13 04:47:13.516805	232508	1	4102.4	0.296	8935.1	30156.0	0.0787	0.0644	0.0017	293.9	292.1	1.86	11.54	13.32	2.54
Mutriku_B066627000_Wells055795973.h5	2017-09-11 17:17:36.419806	240932	1	4360.1	0.290	9454.0	32639.4	0.0775	0.0637	0.0016	301.2	298.4	1.82	10.26	11.84	3.41

Mutriku_B111718000_Wells101181415.h5	2018-02-01 05:27:05.806217	259857	1	4389.4	0.290	9601.2	33055.6	0.0726	0.0609	0.0017	302.0	299.4	1.91	7.17	8.27	4.18
Mutriku_B121813000_Wells111276401.h5	2018-03-13 16:55:51.702344	66948	1	4427.0	0.290	9799.9	33836.3	0.0767	0.0633	0.0017	299.1	297.1	1.52	9.54	11.01	2.69
Mutriku_B066627000_Wells055795973.h5	2017-09-11 17:37:43.478256	245637	1	4652.1	0.276	10111.6	36607.6	0.0802	0.0655	0.0016	309.3	306.9	1.82	10.26	11.84	3.41
Mutriku_B121476500_Wells110939890.h5	2018-03-12 19:18:39.463616	99143	1	4663.6	0.268	9944.0	37076.9	0.0764	0.0639	0.0016	300.1	297.8	1.84	9.54	11.01	1.77
Mutriku_B119457500_Wells108920872.h5	2018-03-06 16:40:54.864173	60598	1	4554.8	0.266	9657.8	36288.1	0.0780	0.0657	0.0017	298.6	296.0	2.16	8.68	10.01	3.05
Mutriku_B112391000_Wells101854334.h5	2018-02-03 06:27:01.593495	274888	1	5456.0	0.259	11983.3	46245.1	0.0818	0.0660	0.0017	322.6	319.5	1.90	10.50	12.11	4.42
Mutriku_B109362500_Wells098826037.h5	2018-01-24 22:43:09.514474	162908	1	4769.7	0.245	8024.3	32686.1	0.0828	0.0602	0.0014	303.2	298.2	1.48	15.37	17.74	3.08
Mutriku_B111381500_Wells100844957.h5	2018-01-30 17:24:49.624170	90360	1	4777.9	0.245	7568.9	30874.3	0.1130	0.0844	0.0016	301.2	296.2	1.22	11.54	13.32	2.88
Mutriku_B111381500_Wells100844957.h5	2018-01-30 14:54:42.051586	55227	1	5120.9	0.244	8702.8	35638.6	0.1139	0.0760	0.0017	299.0	291.2	1.27	11.54	13.32	3.89
Mutriku_B142339500_Wells131802614.h5	2018-05-14 04:01:45.409741	237404	1	5088.3	0.243	10662.3	43920.4	0.0850	0.0700	0.0017	307.0	304.5	1.61	11.54	13.32	3.60
Mutriku_B132917500_Wells122380446.h5	2018-04-16 03:17:49.956916	219621	1	4774.4	0.240	8912.0	37205.2	0.0890	0.0672	0.0016	298.2	295.2	1.71	13.97	16.12	4.22
Mutriku_B136955500_Wells126418495.h5	2018-04-28 07:13:43.051651	277978	1	5021.9	0.234	10163.9	43418.6	0.0849	0.0703	0.0017	304.3	302.1	1.71	10.50	12.11	1.00
Mutriku_B140320500_Wells129783579.h5	2018-05-07 23:24:10.203935	171163	1	5587.0	0.233	9673.9	41503.0	0.1035	0.0783	0.0017	305.3	302.0	1.13	11.54	13.32	2.76
Mutriku_B142676000_Wells132139114.h5	2018-05-14 13:15:29.907303	30364	1	5414.2	0.232	11224.2	48463.7	0.0857	0.0706	0.0017	311.9	309.8	1.44	10.50	12.11	3.50
Mutriku_B142339500_Wells131802614.h5	2018-05-14 04:15:23.393539	240592	1	5514.4	0.231	11583.7	50077.8	0.0859	0.0712	0.0017	308.8	306.7	1.61	11.54	13.32	3.60
Mutriku_B068982500_Wells058151461.h5	2017-09-18 20:24:56.717517	286963	1	727.3	0.223	531.5	2386.5	0.0967	0.0747	0.0018	114.5	113.2	0.37	6.03	6.96	0.60
Mutriku_B122149500_Wells111612906.h5	2018-03-14 16:16:09.980348	59481	1	625.0	0.222	411.0	1853.9	0.1121	0.0821	0.0017	96.1	93.2	0.74	7.89	9.10	3.24
Mutriku_B122149500_Wells111612906.h5	2018-03-15 01:17:33.606307	186170	1	723.3	0.220	536.7	2436.4	0.0951	0.0776	0.0018	112.6	109.5	0.58	12.71	14.66	3.76
Mutriku_B121813000_Wells111276401.h5	2018-03-13 14:36:44.952148	34329	1	5296.3	0.220	10213.6	46500.5	0.0889	0.0714	0.0017	308.0	305.0	1.63	10.50	12.11	3.36
Mutriku_B136955500_Wells126418495.h5	2018-04-28 06:42:33.949605	270694	1	5579.1	0.218	11288.5	51774.1	0.0919	0.0743	0.0017	314.6	312.3	1.80	10.50	12.11	1.76
Mutriku_B109362500_Wells098826037.h5	2018-01-24 22:59:19.499418	166688	1	5908.3	0.204	9038.7	44340.2	0.1063	0.0795	0.0015	318.4	312.8	1.48	15.37	17.74	3.08
Mutriku_B132244500_Wells121707786.h5	2018-04-13 17:47:48.866734	84488	1	5757.9	0.203	9833.4	48441.1	0.0987	0.0741	0.0016	308.2	304.4	1.45	12.71	14.66	2.51
Mutriku_B108689500_Wells098153038.h5	2018-01-23 08:03:07.878812	292962	1	5900.7	0.197	10393.8	52732.4	0.0916	0.0712	0.0016	323.5	319.1	1.86	15.37	17.74	3.57

Mutriku_B109026000_Wells098489534.h5	2018-01-23 11:28:04.203079	4354	1	6185.6	0.196	11161.5	56927.8	0.0974	0.0740	0.0016	336.2	332.0	1.72	15.37	17.74	1.91
Mutriku_B112054500_Wells101517873.h5	2018-02-01 12:27:06.643826	21668	1	6638.4	0.190	12791.0	67457.7	0.0935	0.0754	0.0017	332.9	330.5	2.70	11.54	13.32	1.17
Mutriku_B109026000_Wells098489534.h5	2018-01-23 15:35:06.551614	62235	1	6064.7	0.183	9846.8	53718.4	0.1038	0.0746	0.0016	324.0	318.9	1.53	12.71	14.66	1.41
Mutriku_B132917500_Wells122380446.h5	2018-04-15 18:35:50.737043	97473	1	6189.1	0.176	10638.7	60521.4	0.0924	0.0757	0.0016	313.7	308.7	1.41	15.37	17.74	2.63
Mutriku_B121476500_Wells110939890.h5	2018-03-13 10:17:02.950486	309865	1	7082.2	0.176	12451.8	70844.3	0.1131	0.0819	0.0017	318.9	316.4	1.84	10.50	12.11	2.35
Mutriku_B122822500_Wells112285918.h5	2018-03-17 05:28:43.716848	245056	1	6439.3	0.175	10880.1	62090.5	0.1017	0.0776	0.0017	310.1	306.4	2.13	12.71	14.66	3.82
Mutriku_B108689500_Wells098153038.h5	2018-01-23 08:38:09.017284	301146	1	6851.7	0.174	12589.5	72200.1	0.1003	0.0806	0.0017	325.3	317.9	1.86	15.37	17.74	3.57
Mutriku_B109026000_Wells098489534.h5	2018-01-23 23:43:53.950855	176609	1	6345.8	0.173	10042.9	58185.7	0.1130	0.0779	0.0016	320.1	316.3	1.24	11.54	13.32	2.12
Mutriku_B122822500_Wells112285918.h5	2018-03-17 04:17:52.227831	228477	1	6278.5	0.171	10355.4	60478.9	0.1043	0.0786	0.0016	313.0	310.0	2.15	12.71	14.66	4.26
Mutriku_B109026000_Wells098489534.h5	2018-01-23 15:01:01.375843	54250	1	6609.4	0.171	10828.5	63439.5	0.0965	0.0734	0.0015	340.7	336.9	1.53	12.71	14.66	1.41
Mutriku_B131235000_Wells120698396.h5	2018-04-10 22:33:40.796074	151068	1	6605.0	0.170	10813.3	63721.8	0.1017	0.0764	0.0016	313.5	309.3	2.56	15.37	17.74	3.03
Mutriku_B108689500_Wells098153038.h5	2018-01-23 06:15:29.035805	267808	1	6754.7	0.170	11466.1	67426.0	0.1023	0.0783	0.0016	330.6	325.7	1.95	12.71	14.66	3.44
Mutriku_B115756000_Wells105219389.h5	2018-02-12 11:56:15.920976	18400	1	6777.8	0.161	11165.7	69386.2	0.1138	0.0838	0.0017	320.6	317.7	2.21	11.54	13.32	2.47
Mutriku_B115756000_Wells105219389.h5	2018-02-12 12:19:38.989380	23873	1	7070.9	0.161	11390.6	70821.3	0.1058	0.0789	0.0017	317.2	313.8	2.15	11.54	13.32	2.94
Mutriku_B118448000_Wells107911328.h5	2018-02-21 05:57:34.288433	276137	1	7052.0	0.161	12707.8	79152.5	0.1085	0.0871	0.0017	322.7	320.9	3.01	15.37	17.74	3.41
Mutriku_B122822500_Wells112285918.h5	2018-03-17 00:48:03.127929	179393	1	7466.5	0.158	11210.6	70996.4	0.1201	0.0803	0.0017	318.8	315.4	2.16	12.71	14.66	2.40
Mutriku_B122822500_Wells112285918.h5	2018-03-17 01:58:16.861697	195818	1	7472.7	0.155	12084.9	77907.2	0.1155	0.0829	0.0016	325.0	321.1	2.17	12.71	14.66	3.26
Mutriku_B115756000_Wells105219389.h5	2018-02-12 11:38:48.479580	14314	1	7309.9	0.154	11448.7	74340.2	0.1119	0.0807	0.0017	321.0	317.4	2.21	11.54	13.32	2.47
Mutriku_B106670500_Wells096134034.h5	2018-01-16 11:59:58.599506	10281	1	7926.4	0.150	12803.1	85381.6	0.1153	0.0835	0.0016	344.7	340.5	1.92	10.50	12.11	1.51
Mutriku_B108689500_Wells098153038.h5	2018-01-23 10:30:57.225585	327504	1	7768.0	0.147	12867.0	87538.9	0.1134	0.0867	0.0016	335.7	326.9	1.77	15.37	17.74	2.60
Mutriku_B112054500_Wells101517873.h5	2018-02-01 12:57:07.415028	28688	1	7595.2	0.146	11951.1	81797.0	0.1109	0.0830	0.0016	334.2	330.8	2.70	11.54	13.32	1.17
Mutriku_B109362500_Wells098826037.h5	2018-01-25 00:19:07.184099	185348	1	7676.8	0.145	11711.8	80550.9	0.1126	0.0818	0.0017	327.9	319.5	1.77	15.37	17.74	2.17
Mutriku_B118448000_Wells107911328.h5	2018-02-21 07:11:19.557551	293518	1	8273.8	0.145	13597.4	93741.1	0.1177	0.0855	0.0017	332.0	328.9	3.04	13.97	16.12	3.95

Mutriku_B133590500_Wells123053463.h5	2018-04-18 07:42:16.640701	281589	1	10120.1	0.145	15019.9	103532.1	0.1818	0.2373	0.0017	276.6	223.5	1.78	15.37	17.74	3.14
Mutriku_B121813000_Wells111276401.h5	2018-03-13 13:16:58.041601	15593	1	7680.4	0.142	12273.1	86527.6	0.1226	0.0899	0.0017	327.4	325.0	1.68	10.50	12.11	3.37
Mutriku_B106670500_Wells096134034.h5	2018-01-16 14:30:27.878307	45491	1	9207.3	0.138	15630.0	112961.0	0.1221	0.0897	0.0017	348.0	343.7	3.45	13.97	16.12	3.44
Mutriku_B122822500_Wells112285918.h5	2018-03-17 05:58:03.671844	251918	1	7946.4	0.137	12185.4	89259.2	0.1198	0.0883	0.0017	328.8	325.5	2.13	12.71	14.66	3.82
Mutriku_B106670500_Wells096134034.h5	2018-01-16 12:20:01.387026	14972	1	8062.4	0.132	12445.8	94356.8	0.1220	0.0919	0.0017	331.0	322.5	1.92	10.50	12.11	2.16
Mutriku_B122822500_Wells112285918.h5	2018-03-17 01:48:01.286989	193418	1	8536.0	0.132	12918.2	97744.4	0.1357	0.0952	0.0018	333.1	330.9	2.17	12.71	14.66	3.26
Mutriku_B141330000_Wells130793101.h5	2018-05-10 23:30:33.317614	173351	1	9171.1	0.132	14535.8	109718.1	0.1225	0.0874	0.0018	341.4	339.5	2.77	13.97	16.12	3.22
Mutriku_B109362500_Wells098826037.h5	2018-01-25 03:59:45.716354	236959	1	9327.5	0.131	13198.3	100767.0	0.1289	0.0832	0.0016	344.4	339.6	2.14	15.37	17.74	1.33
Mutriku_B108016500_Wells097480082.h5	2018-01-20 12:16:45.095138	15311	1	8366.8	0.130	11887.4	91436.7	0.1246	0.0859	0.0015	347.8	343.8	2.43	9.54	11.01	0.86
Mutriku_B118448000_Wells107911328.h5	2018-02-21 05:28:50.708874	269367	1	8628.9	0.130	13357.1	102983.7	0.1199	0.0895	0.0017	329.9	327.7	3.01	15.37	17.74	3.41
Mutriku_B131235000_Wells120698396.h5	2018-04-11 11:06:13.666923	326846	1	8961.4	0.130	13313.1	102096.6	0.1260	0.0872	0.0016	332.1	329.3	2.93	12.71	14.66	3.12
Mutriku_B118448000_Wells107911328.h5	2018-02-21 07:26:58.726674	297209	1	8009.3	0.129	11895.4	92049.9	0.1181	0.0889	0.0017	325.9	322.5	3.04	13.97	16.12	3.95
Mutriku_B141330000_Wells130793101.h5	2018-05-11 07:30:18.186250	285596	1	8210.7	0.128	11245.6	87972.7	0.1211	0.0840	0.0016	323.3	320.6	2.19	12.71	14.66	1.34
Mutriku_B118784500_Wells108247840.h5	2018-02-21 14:53:18.990527	65563	1	8343.6	0.127	11170.4	88044.3	0.1327	0.0869	0.0016	326.0	323.5	2.58	13.97	16.12	1.14
Mutriku_B131571500_Wells121034864.h5	2018-04-11 13:33:49.163209	24855	1	8937.2	0.126	13752.0	109027.3	0.1231	0.0908	0.0017	337.7	335.4	2.73	12.71	14.66	3.44
Mutriku_B109362500_Wells098826037.h5	2018-01-25 03:29:41.020836	229923	1	9582.2	0.125	13895.1	110731.5	0.1227	0.0828	0.0016	350.0	345.2	2.14	15.37	17.74	1.33
Mutriku_B109699000_Wells099162548.h5	2018-01-25 16:00:20.319406	69012	1	9775.9	0.125	13905.8	111577.3	0.1331	0.0855	0.0016	346.7	342.4	2.10	13.97	16.12	1.39
Mutriku_B109362500_Wells098826037.h5	2018-01-25 01:09:45.133429	197198	1	8946.6	0.124	12625.0	101845.3	0.1262	0.0869	0.0016	347.7	342.9	1.92	15.37	17.74	1.70
Mutriku_B109362500_Wells098826037.h5	2018-01-25 03:01:24.649964	223311	1	9183.2	0.123	12854.3	104083.4	0.1260	0.0853	0.0015	347.9	343.4	2.14	15.37	17.74	1.33
Mutriku_B118448000_Wells107911328.h5	2018-02-21 06:57:09.806048	290182	1	8650.9	0.122	11856.2	97355.0	0.1245	0.0875	0.0016	327.7	324.2	3.04	15.37	17.74	3.86
Mutriku_B109362500_Wells098826037.h5	2018-01-25 01:42:56.292164	204959	1	9785.3	0.121	13884.4	115052.8	0.1352	0.0885	0.0016	348.1	343.8	1.92	15.37	17.74	1.70
Mutriku_B109699000_Wells099162548.h5	2018-01-25 15:00:20.209053	54970	1	9802.9	0.121	14830.5	122232.6	0.1251	0.0890	0.0016	348.4	344.6	2.08	13.97	16.12	1.33
Mutriku_B131235000_Wells120698396.h5	2018-04-11 07:26:40.530500	275554	1	10051.3	0.118	14707.6	124746.9	0.1286	0.0885	0.0017	338.6	336.3	3.01	13.97	16.12	1.70

Mutriku_B109699000_Wells099162548.h5	2018-01-25 17:40:35.687390	92471	1	10287.8	0.118	14977.5	126461.8	0.1318	0.0886	0.0016	350.1	346.8	2.16	13.97	16.12	1.68
Mutriku_B109699000_Wells099162548.h5	2018-01-25 16:30:20.523542	76031	1	9365.2	0.117	12997.7	111062.5	0.1282	0.0891	0.0016	349.4	345.9	2.10	13.97	16.12	1.39
Mutriku_B109699000_Wells099162548.h5	2018-01-25 20:00:36.798524	125239	1	9564.5	0.117	13731.7	117684.7	0.1351	0.0937	0.0017	349.6	346.2	2.25	13.97	16.12	2.99
Mutriku_B131235000_Wells120698396.h5	2018-04-11 08:26:40.048433	289568	1	9649.1	0.117	12027.9	102856.2	0.1476	0.0888	0.0016	336.1	333.8	2.97	13.97	16.12	1.93
Mutriku_B109699000_Wells099162548.h5	2018-01-25 15:40:36.267411	64394	1	10691.4	0.117	16383.7	140145.4	0.1289	0.0908	0.0017	364.4	360.8	2.08	13.97	16.12	1.33
Mutriku_B118784500_Wells108247840.h5	2018-02-21 17:23:11.681459	100701	1	9278.6	0.116	13426.2	116242.3	0.1260	0.0922	0.0016	340.4	337.8	2.35	13.97	16.12	3.01
Mutriku_B109362500_Wells098826037.h5	2018-01-25 05:29:51.684952	258032	1	10015.8	0.113	13651.2	120978.5	0.1376	0.0906	0.0015	355.1	351.7	2.21	13.97	16.12	1.97
Mutriku_B109699000_Wells099162548.h5	2018-01-25 15:10:35.698548	57370	1	10827.8	0.112	16029.4	142509.6	0.1330	0.0923	0.0016	359.2	355.7	2.08	13.97	16.12	1.33
Mutriku_B141330000_Wells130793101.h5	2018-05-11 01:30:31.884500	201420	1	10318.2	0.110	15170.5	137432.1	0.1323	0.0953	0.0017	348.7	346.3	2.62	13.97	16.12	3.33
Mutriku_B109699000_Wells099162548.h5	2018-01-25 16:40:36.068217	78431	1	10524.4	0.110	15076.0	137503.3	0.1315	0.0925	0.0016	359.4	355.4	2.10	13.97	16.12	1.39
Mutriku_B109362500_Wells098826037.h5	2018-01-25 06:40:08.451684	274468	1	11246.2	0.108	17355.5	160625.6	0.1391	0.0997	0.0018	289.7	238.7	2.21	13.97	16.12	2.50
Mutriku_B109699000_Wells099162548.h5	2018-01-25 14:30:19.969602	47950	1	10600.7	0.107	15002.9	139833.6	0.1286	0.0913	0.0016	363.7	359.7	2.08	13.97	16.12	1.54
Mutriku_B141330000_Wells130793101.h5	2018-05-10 23:40:48.858091	175751	1	10384.5	0.106	14170.6	134043.2	0.1321	0.0927	0.0016	344.6	341.8	2.77	13.97	16.12	3.22
Mutriku_B106670500_Wells096134034.h5	2018-01-16 15:00:35.283289	52544	1	10894.1	0.105	15614.8	148557.1	0.1455	0.1000	0.0017	358.2	354.8	3.56	13.97	16.12	3.74
Mutriku_B109699000_Wells099162548.h5	2018-01-25 14:10:35.155097	43330	1	10917.0	0.102	14754.2	145247.0	0.1402	0.0962	0.0017	356.9	353.4	2.08	13.97	16.12	1.54
Mutriku_B109362500_Wells098826037.h5	2018-01-25 04:10:01.370360	239359	1	11013.7	0.102	14558.2	142053.1	0.1370	0.0906	0.0016	363.6	359.9	2.19	15.37	17.74	1.55
Mutriku_B106670500_Wells096134034.h5	2018-01-16 16:30:48.209707	73642	1	11589.4	0.102	17535.0	172175.5	0.1368	0.1012	0.0017	366.8	364.3	3.67	13.97	16.12	3.72
Mutriku_B133590500_Wells123053463.h5	2018-04-18 06:12:18.068572	260551	1	11377.5	0.101	16810.2	167014.9	0.1450	0.1051	0.0017	286.7	238.0	1.80	15.37	17.74	3.90