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Big Data Management at Mutriku Wave Power Plant

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Abstract- Operation data in real conditions are generally essential to validate wave energy converter (hereinafter referred to as WEC) models and prototypes and to increase their operational safety, thus reducing costs. In this sense, the Mutriku Wave Power Plant, as one of the power plants with experience in generating energy from waves, makes its operation data from recent years available to developers. Furthermore, the plant has recently been adapted to house experimental tests of new concepts of turbines, equipment and control strategies, thereby creating the need to find new solutions to manage large amounts of data generated by the facility.

Keywords- Big Data, Data Acquisition System, Digital Twin, Experimental Data, Industrial Internet of Things (IIoT).

I. INTRODUCTION

In July 2018, the Mutriku Wave Power Plant will have been continuously in operation for 7 years. Since the plant was inaugurated in July 2011, it has supplied electricity 24/7 to the power grid. In January 2016, it generated and supplied its first GWh of cumulative energy to the grid, unquestionably a milestone in the field of marine energy and particularly in the wave energy industry. The plant operates on the principle of the Oscillating Water Column (OWC), being the first in the world to have more than one turbine of this type connected to the power grid [1]. Specifically, the plant consists of 16x18.5kW turbines, providing a total installed power of 296kW (see Figure 1).

Figure 1: Turbo-generator modules installed in Mutriku Wave Power Plant

At this point, it should be noted that, as the power plant was initially designed for experimental purposes, the turbine gallery and power electronics are equipped with a wide variety of sensors throughout. This has enabled the Basque Energy Agency (EEE/EVE) to compile a large database of historical data collected through these sensors. Moreover, the experimental power plant is currently open for testing, where new and innovative turbine prototypes, advanced control techniques and/or auxiliary equipment can be tested. By way of example, the Mutriku Wave Power Plant takes active part in the Marinet2 program as a wave energy facility.

For the technological development of WECs, it is of vital importance to make data more accessible for developers and researchers and to share acquired know-how with them. EVE and BiMEP (the Biscay Marine Energy Platform) have recently launched a web platform from which daily data can be downloaded. To date, a CSV flat file format is being used to share information. However, due to the large size of CSV files, data handling may often be very tedious, making it necessary to look for new formulas to share this information more efficiently. In this sense, this article aims to share our experience in data handling and to propose new alternatives.

Industry 4.0 has revolutionized the way information is handled. The latest technological advances in the Industrial Internet of Things (IIoT), together with machine learning techniques based on Big Data, significantly facilitate data handling between remote systems. For instance, through machine learning as part of cognitive computing, a digital twin of a WEC may be created, enabling its behavior to be replicated without the need to exchange large amounts of data between partners.

This paper is organized as follows: Section II describes the current status of the Mutriku Wave Power Plant and how data is collected in the database. The upgrading process carried out in the power plant to house experimental tests is detailed in Section III. In Section IV, novel formulas to facilitate data sharing and the deployment of the know-how are discussed. Finally, Section IV offers a series of conclusions.

II. MUTRIKU AS A POWER PLANT

The Mutriku Wave Power Plant was set up as a demonstration project within marine energies and, in particular, wave energy. The aim of the project was to demonstrate the feasibility of existing technology, being the first commercial power plant worldwide to supply wave energy to the power grid. These 7 years of continuous operation have shown that round-the-clock production can be achieved. However, there is still a lot to do to make profitable use of this energy source.

In response to the lack of experience in the area of wave energy power generation, the Mutriku Wave Power Plant provides essential knowledge to accelerate technology development. Sea operations are known to be expensive. Moreover, significant risks must be assumed on account of the harsh environmental conditions that WECs are often subject to. In this sense, the Mutriku Wave Power Plant offers a controlled environment and easy vehicle access by taking advantage of the construction of a breakwater at the entrance of the harbour of Mutriku. All these conditions have greatly facilitated both preventive and reactive maintenance works. Thus, the plant has survived extreme wave conditions during many winters, which has not been the case in many other projects. The capacity to conduct preventive maintenance work has enabled power to be generated 24/7 over 7 years of continuous operation. The plant achieved the goal of 1GWh of produced cumulative energy at the beginning of 2016, marking a significant milestone in the field of marine energy. For all these reasons, the Mutriku Wave Power Plant has become a benchmark among wave energy generation plants.

Being an experimental plant, historical operation data from it are carefully compiled in a specific database. The plant is currently equipped with 16 variable frequency drives and 2 regenerative inverter drives, together with a wide variety of sensors that continuously collect data 24/7 and every 100ms. Figure 2 shows the original network architecture diagram of the plant. Around 115 parameters are collected by each variable frequency drive and 35 parameters by each regenerative inverter drive.

The main problem of collecting so many parameters is the volume of data stored in the database, as well as the processing capacity needed to analyze operation data. The storage of a large number of parameters implies a very large database that is often difficult to manage. To provide a clear idea of the magnitude of the database, the data of each variable frequency drive and regenerative inverter drive, which corresponds to data on a single turbine, takes up approximately 18MB each day. This means that the data registered for the whole plant takes up around 300MB each day. In annual terms, the total amount of data collected by the power plant can be more than 100GB, thereby generating an excessively large database.

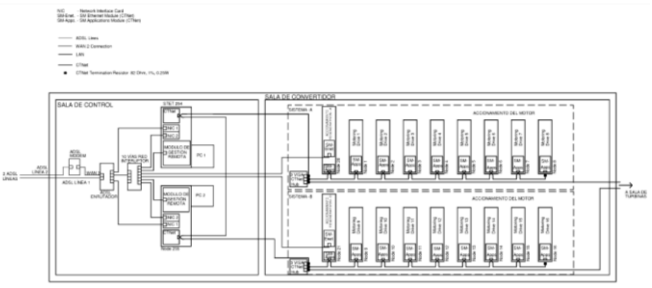

Figure 2: Original network architecture diagram of the Mutriku Wave Power Plant designed by Wavegen

With the aim of accelerating the technological development of WECs, developers and researchers can now access the operation data of the Mutriku Wave Power Plant. The parameters shown in Table I and Table II are fully available

Parameter	Unit	Definition
Active Current	A	Output active current of the generator
Availability		Identifies the turbine operating mode
Average Power 1 min.	W	1 minute average output power
Average Power 5 min.	W	5 minutes average output power
Current Magnitude	A	RMS active and reactive current from the output phase of the generator
Damper Position	deg.	Opening angle of the damper
Flow Coefficient		Estimated flow coefficient
Motor RPM	rpm	Rotational speed of the generator
Output Voltage	V	RMS line-to-line voltage at the generator output
Output Frequency	Hz	Output frequency of the generator
Percentage Load	%	Actual torque producing current as a percentage of rated active current
Power	kW	Generator output power
Chamber Pressure	Pa	Instantaneous air pressure in the chamber
Chamber RMS Pressure	Pa	RMS air pressure in the chamber
Vibration	mmps	Vibration level in the turbo-generator section casing
Pressure Drop	Pa	Pressure drop between the inlet and the outlet of the turbo-generator
Static Pressure	Pa	Static air pressure at the outlet of the turbo-generator
Generator Temperature	ºC	Temperature inside the generator
Wave Height	m	Water level inside the chamber

Table 2: Parameters collected by the variable frequency drive

Parameter	Unit	Definition
Active Current	A	Output active current of the inverter drive
Average Power 1 min.	W	1 minute average output power
Average Power 5 min.	W	5 minutes average output power
Current Magnitude	A	RMS active and reactive current from the output phase of the inverter drive
DC-link Voltage	V	Voltage across the internal DC bus of the power converter.
Output Voltage	V	RMS line-to-line voltage at the drive output
Output Frequency	Hz	Output frequency of the inverter drive
Power	kW	Inverter drive output power
Room Pressure	Pa	Relative air pressure in the turbine gallery

Table 2: Parameters collected by the regenerative inverter drive

and can be downloaded from the File Download Platform located in the website of BiMEP.

At the moment, CSV flat files are used to share the aforementioned historical data with third parties. The parameters are exported to a spreadsheet with a sampling period of half a second. Therefore, the main problem with this kind of file is the size of spreadsheet required for the reduced sampling period (172800 rows/day), meaning that a CSV flat file of a single turbine may easily reach 20MB of data each day.

III. MUTRIKU AS A TEST SITE

The main objective of the Basque Energy Agency in the field of marine energy is to promote the development of WECs to make profitable use of wave energy. In this sense, since the beginning of 2016, the Mutriku Wave Power Plant has been upgraded to house experimental tests of different OWC-based devices, namely air turbines, control strategies and/or auxiliary equipment. The Mutriku OWC Test Site also offers the possibility of testing other equipment such as air valves, energy storage devices and marine sensors.

Mention must also be made of the effort that different Basque Country public administration bodies are making to promote technology development within marine energy. The two testing areas that the Basque Government has launched through the Basque Energy Agency in the last decade are proof of its commitment to technology developers. In this sense, the BiMEP, an open sea test area off the coast of Armintza (Bizkaia, Basque Country) shown in Figure 3, together with the Mutriku OWC Test Site, offer developers a wide range of possibilities to test different types of WEC, including floating prototypes and their subsystems and components.

In addition, the Basque Energy Agency works in close collaboration with nearby research centers and universities to jointly promote technology development. Proof of this is the joint offer launched by the Basque Energy Agency and Tecnalia Research & Innovation Center in Marinet2. Tecnalia owns a WEC emulator test bench of Figure 4 consisting of an induction motor capable of emulating turbine dynamics in OWC devices, and an induction generator with a corresponding fully equipped power converter and control system [2]. The test bench emulates the same operation conditions as in the Mutriku Wave Power Plant. The collaboration between the two parties offers the possibility of carrying out two consecutive tests in Marinet2, which enables new equipment and control strategies to be tested in a laboratory test bench before being tested in real prototypes in the Mutriku OWC Test Site.

Furthermore, BiMEP and IH Cantabria have also launched the TRL+ project, the aim of which is to support marine energy initiatives in the development of novel technologies and activities [3]. The TRL+ project involves a series of activities, ranging from the development of advanced metocean assessment methodologies to developing hybrid modeling methodologies combining advanced numerical models, laboratory modeling and field testing, with the aim of developing accurate operational systems capable of reducing risks, costs and improving the quality and benefits derived from field testing. All these services involve real time monitoring of test site conditions and device performance. To address this issue, a directional metocean buoy was installed in BiMEP that measures wind, waves and current conditions. The buoy (see Figure 5) provides data on

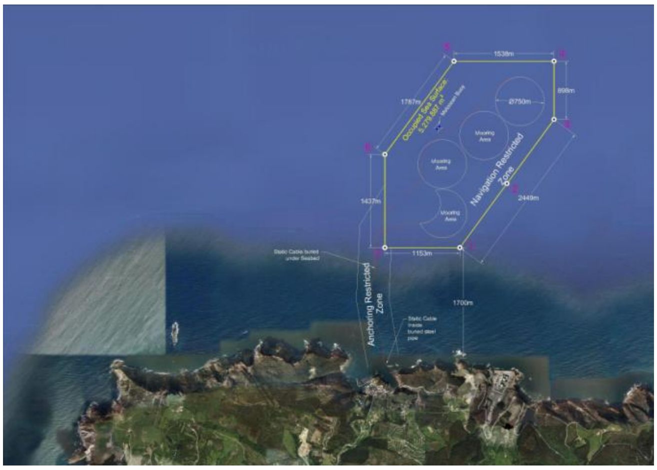

Figure 3: Biscay Marine Energy Platform (BiMEP). An open sea test area in Armintza (Bizkaia, Basque Country)

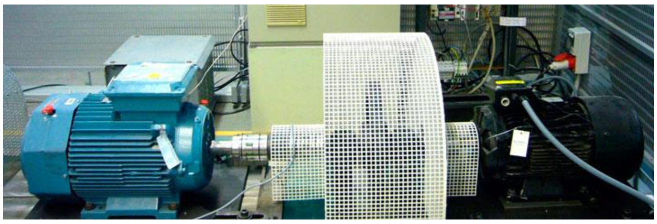

Figure 4: Electrical PTO test bench of Tecnalia Research & Innovation

Figure 5: The metocean buoy provides wave and wind parameters in hourly basis

wave and wind parameters on an hourly basis. In addition, BiMEP is currently immersed in a licensing process for permission to house offshore wind tests. A LIDAR (Light Detection and Ranging) device is due to be installed in the test area to predict wind speed and direction patterns.

In this way, different test sites in the Basque Country provide WEC manufacturers with the opportunity to test their equipment in real sea conditions and demonstrate their potential to harness marine energy, ranging from very low TRLs up to technology demonstration at higher TRLs.

To consolidate the Mutriku Wave Power Plant as a test site, several adaptation works have recently been carried out to house the aforementioned tests. In this sense, an independent controller (PLC) and 90kW power converter have been installed in one of the turbine locations. These are fully available to technology developers testing in Mutriku. The equipment has already been used within the OPERA project supported by the European Commission through the H2020 program, where a bi-radial turbine (see Figure 6) has been tested in the Mutriku OWC Test Site over the period May 2017 to June 2018 [4].

Figure 6: The bi-radial turbine during a test in Mutriku OWC Test Site

Figure 7: An operator accessing the chamber through the turbine orifice during sensor installation process

With a view to improving the services offered as a test site, a significant effort is being made to improve data collection and plant monitoring. In this sense, sensors are being installed to provide all necessary data that may be useful for developers and the research community. Nevertheless, the adaptation works may often be tedious as some areas of the power plant are not easily accessible. Figure 7 shows an operator accessing the chamber through one of the turbine orifices during installation of a sensor in April 2018 within the OPERA project framework.

IV. DISCUSSION

The Mutriku Wave Power Plant started life in 2007 as a demonstration project of wave energy technology. 10 years later, interest in the research and development of this technology has increased considerably, and with it the number of people requesting and requiring real experimental data from existing facilities with the aim of analyzing, developing and validating the technology. In this sense, 7 years of operation data from the Mutriku Wave Power Plant offers a unique opportunity to meet those needs.

Nevertheless, the large amount of data continuously generated by the power plant is a challenge for storage and information processing systems, which limits the quantity and quality of the results that can be obtained. Through the application of Big Data Analytics technologies, it is possible to overcome these limitations and efficiently manage the operation data. In addition, the creation of behavioral models is a complex and multidisciplinary task which generates an approximate version of reality at a specific moment. Advances in machine learning techniques based on Big Data will generate new concepts of so-called digital twins, much more accurate and versatile than existing models and which enable realistic simulations to be made adapted to real operations.

Different test sites and players are also working together to improve the quality of services provided by the infrastructures and to facilitate the work of the developers. This involves the need to connect different test sites in a comprehensive system network, often requiring real time applications that need large data streams at high speeds through remote connections. Emerging concepts such as the Industrial Internet of Things (IIoT) may help to interconnect a number of remote sensors and users. In this sense, different devices upload data to the Internet cloud, from there, the data is accessible and may be used in different platforms or eventually run on the cloud computational resources.

In addition, the power plant stores lots of operation data but analyzes little. Nevertheless, this kind of power plants also require more advanced solutions to diagnose the plant status, determine the performance and detect failures. In this sense, analysis of data also provides actionable predictive information from raw sensor data.

By connecting the systems to the Internet, access to data from the plant can be granted to selected external user and developers anywhere in the world. With IIoT architecture, independent technology developers can remotely monitor the operation of the power plant. This can also be subscription-based service, where users pay a fee per asset. Considering different asset classes in a power plant, several types of users may be granted access to the operation data. This requires security to be developed with specific access rights for each user. Such solution already exists through IIoT.

However, the resulting IIoT solution must be an extension that is backwards compatible with the existing networks in the power plant, i.e. fieldbus and OPC applications that form the software layer for IIoT. Moreover, the equipment monitoring system should be separated from the control system to avoid any external connection to the control system.

To summarize, with IIoT, the power plant can be run in a more proactive and a less reactive manner. Thus, service providers spend less time collecting data, and have more time to work on the data.

V. CONCLUSION

In the course of seven years of continuous operation, a valuable amount of data has been compiled on the Mutriku Wave Power Plant which may be used by developers to validate their WEC models. Furthermore, as a testing infrastructure, the plant also offers developers the possibility to test air turbines, auxiliary equipment and/or control strategies. This new functionality as a test site, both the continuous demand for operation data and the need to connect the different test sites to the players involved, thereby facilitating collaboration between suppliers and developers, has meant that new formulas need to be found to share operation data. In this sense, new concepts and advances in machine learning techniques and the Industrial Internet of Things (IIoT) may help to overcome the current barriers to sharing information.

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