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Analysis of ocean energy integration in Ibero-American electric grids

M. Lafoz, I. Villalba, J. Nájera, D. Ochoa, J. Peralta, R. Rojas, J. Ugaz, G. Guarniz, A. Haim, M. Blanco,

Abstract— **An analysis of ocean energy integration in Ibero-American electric grids have been summarized in this article. Offshore wind, floating solar PV, tidal, waves and even saline gradient are the technologies considered. Four different Ibero-American regions have been considered: Mesoamerica, South America, Iberian Peninsula and Macaronesia. Areas or countries have been selected from each region as representative of the critical conditions, in terms of grid integration. The development of the ocean renewable energy, as referenced in the objectives achievement of many energy roadmaps in such regions, is conditioned by the possibilities to integrate the marine generation power plants in the electric systems. The objective of this analysis is to give an overview of the opportunities and barriers for integrating ocean renewable energy into these electrical grids. Identifying grid limitations would help to implement mechanisms and strategies that minimize the electrical grid impact of the integration ocean renewable energy.**

Keywords—**Ocean energy, Grid codes, Grid integration.**

I. Introduction

The development of the ocean renewable energy, as referenced in the objectives achievement of many energy roadmaps [1], is conditioned by the possibilities to integrate the marine generation power plants in the electric systems. Offshore wind, floating solar PV, tidal, waves and even saline gradient are the technologies considered. The success of these plans needs to fulfil, among others, the compliance of the electric grid codes, ensuring the stability of electric grids.

The integration of ocean renewable energies is still not a problem at the electric grids since the penetration level is not so high. However, the objectives established in the energy roadmaps invite to analyse the expected effects of new power plants of this nature from the point of view of performance at the electric systems. In fact, some research works have already identified an increase in the number of frequency and voltage events in electric systems due to higher penetration of ocean energies [2].

The connection of marine renewable generation is usually taken place in nodes of the electric grids, not very favourable in terms of power capacity and voltage drops. Moreover, many of the locations where the ocean renewable energies result economically viable are linked to weak areas of the electric grid, meaning that frequency and voltage are more sensible. That is the case of remote isolated areas, as usually coastal areas, or islands. Additionally, some of the generation technologies considered, such as wave energy, present very oscillatory power profiles leading to stability problems due to the unbalance between generation and consumption profiles.

More and more countries are putting an eye on new sources of energy, integrating them in their energy policies to search alternatives to face energy crisis. This is the case of many countries in Centre and South America, that have included in their roadmaps the renewable ocean energies [3]. One of the main issues in these countries is the lack of robust electric grids or the condition of weak grids in coastal areas.

This paper presents the result of the analysis of different electric grids in Ibero-American countries. Four different regions have been considered: Mesoamerica, South America, Iberian Peninsula and Macaronesia, and particular areas or countries have been selected from each region as representative of the critical conditions in terms of grid integration. The selected case studies are: Ecuador, Peru, Costa Rica, Argentina and Spain, including the Canary Islands in this case.

To describe this analysis, the present paper is organized as follows: in Section II are summarized the grid integration aspects of ocean energy, in particular the electrical grid impact and the main regulations and grid codes aspects to ocean energy. In Section III is described an overview about ocean energy integration in Ibero-American regions. In Section IV some futures lines of work are proposed to minimize the impacts on the electrical grids and foster the integration of ocean renewable energies. Finally, Section V presents the main conclusions of the study.

This work has been accomplished in the frame of the activities carried out by the groups involved in the thematic network REMAR (Opportunities of Integration of Ocean Energies in Ibero-American Electric Grids), promoted, and funded by the Ibero-American Programme of Science and Technology for the Development (CYTED).

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II. GRID INTEGRATION ASPECTS OF OCEAN ENERGY

This section is presenting the main electrical grid problems when integrating ocean renewable energies and the main regulations and grid codes that ocean renewable energies facilities must comply.

The generation devices associated to ocean energies present different locations depending on their nature. For example, the wave energy converters (WECs) can be located onshore, nearshore, or offshore [4] [5]. This aspect reveals that ocean energy generation facilities tend to be connected to distribution grids instead of transmission grids. For this reason, stability problems occur in the electrical grid [4] [6] such as: frequency oscillations, undervoltage, overvoltage, voltage transients, harmonic distortion, power black-outs and power lines saturation due to temporal power increase. All these effects as well as the limited dispatchability associated to renewable energies produce stress on the electrical grid and other effects [7] like: reduction of efficiency, equipment malfunction or even disconnection, loss of information, overheating of conductors and electromagnetic interferences. These problems mainly depend on the size of the generation power plant and the characteristics of the point of common coupling (PCC). The impact of these problems is different for small-scale projects versus high-scale projects. Figure 1 summarizes the potential problems in the electrical grids when integrating ocean energies [8].

In the case of the limited dispatchability the transmission systems operators (TSO) have determined that the resource intermittency and interactions with network control systems may increase the levels of voltage flicker for ocean energy devices [9] [7], it compromises voltage and frequency stability. In the case of the stress on the electrical grid, the impact of these variations depends on the grid strength at the PCC [9] [7]. The WECs can cause continuous voltage variations at the connection node [9]. Operational challenges may be introduced by the effect of harmonics and thermal overload. Other problem is caused for the power electronics and the farm cables connection. The cables produce changes in the grid impedance and amplifying the harmonic emissions. In the case of high penetration effects, the small and medium scale ocean energy projects may cause impacts such faults, transient voltage and frequency stability oscillations and the high scale projects may cause impacts such low voltage ride through capability, transmission planning, planning, market operations, unit commitment and ancillary services [7].

Based on these possible problems in electrical grids, specific modifications and guidelines for ocean renewable energy have been included in the regulations and grid codes. Currently there are no common specific regulations or grid codes for all ocean renewable energies. This aspect is because ocean renewable energies such as wave energy, tidal energy or the saline gradient are at intermediate levels of technological maturity (TRL6-7). Only standards such as EQUINOR [10] [11] [7] and in laboratory test environments have been applied to these installations.

Only two of the Grid Codes under study, TenneT [12] [13] and National Grid [14], have a special focus on offshore wind and in the case of National Grid, the code considers in a general way "offshore power generating 216 units powered by intermittent sources [7].

The International Electrotechnical Commission (IEC) technical committee is currently working on power quality requirements for wave, tidal and other water current energy devices [15]. This document, based on [16], is willing to create an international standard as guidelines and recommendations. It will be focused on: power quality aspects and parameters for single/three-phase, grid connected/off-grid marine tidal, wave and other water current converter-based power system. This document also establishes the application techniques, measurement methods, and guidelines for results-interpretation. The consequences would be a limitation in the ocean energy systems connected to the electric grid considering: frequency and active power control, voltage and reactive power control, low voltage ride through (LVRT), and power quality issues like flicker and harmonics among others [7] [17]

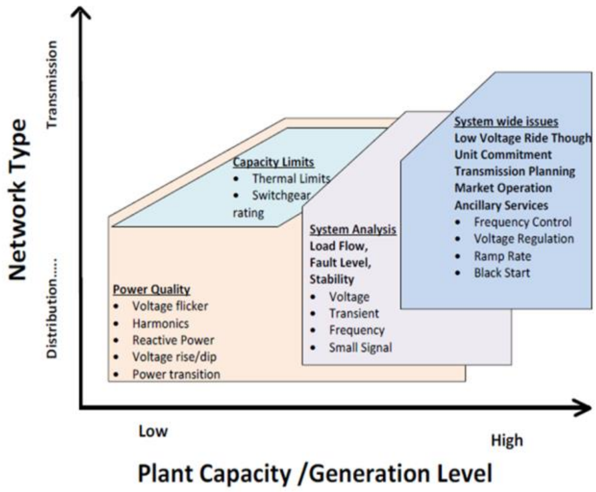

Figure 1. Grid impact issues of marine energy systems [7].

Therefore, grid codes will need to be reviewed for integration of ocean renewables into power grids. Ocean energy farms need the ability to control voltage and/or reactive power at the main point of connection to the grid. In addition, voltage control techniques must be considered, as it is currently done with wind farms, through reactive power exchange and frequency control when regulating active power generation. Reactive power losses become significant in the case of long submarine cables as well as dynamics due to the lower inductance of them, compared to overhead transmission lines.

Among potential solutions to overcome these drawbacks, authors state energy storage systems as a solution for many of the problems identified. Control strategies based on grid stability instead of maximum power generation and demand control are also analysed.

III. OVERVIEW OCEAN ENERGY INTEGRATION IN IBERO-AMERICAN REGIONS

Some regions of Ibero-America have been analysed to provide an overview of their current situation in terms of power systems, detecting possible limitations for the integration of oceanic renewable energies the electrical grids. The countries under analysis are: Ecuador, Peru, Costa Rica, Argentina, and Spain. Additional information from the Canary Islands in Spain has been compiled as an example of integration in isolated electric systems.

The information collected gives a vision of the current situation of these electrical grids and their future evolution. The role of renewable energies will have in their energy models and specifically oceanic renewable energies has been analysed too. It also describes which of the problems described in section II are common in these grids, as well as what regulations or grid codes are being developed for a correct integration of ocean renewable energies in their systems. Some results are based on the energy policies identified in these countries [18].

A. Ecuador.

The use of renewable energy sources in Ecuador is limited to the generation of electricity, of which 78.5% is produced in hydroelectric plants, 18.8% in thermal plants and 1.5% from other renewable sources such as biomass, biogas and wind farms. In addition, despite the investment made in past decades for the implementation of hydroelectric generation plants and reconditioning of refineries, Ecuador still depends on imported energy.

In 2013 a study about wave energy, currents, and kinetic energy of rivers in Ecuador for electricity generation was presented by the National Institute of preinvestment, based on the information compiled by the Oceanographic and Antarctic Institute of the Navy (INOCAR) [19]. In this study, the coastal profile was analysed, including the Galapagos Islands, as well as the rivers of the coast. Wave energy research has mainly been developed in Ecuador. Several studies have evaluated the usability of these systems [20] [21]. From these studies it can be concluded that:

- Tidal energy and wave energy have a low potential for use in Ecuador, since the existing conditions are below what is required for the operation of these systems (14 kW/m for wave energy and 0.8 to 1 m/s for currents). An exception are the channels between Posorja and Puná and the channel between Puná and Puntilla de Jambelí, where there is an opportunity to generate current energy because they have current speeds between 3 and 4 m/s.
- Energy by temperature gradient does not reach temperature differentials greater than 20 °C, therefore, with current technologies, it would not be commercially applicable in the country.
- The values of salinity gradients detected in the Ecuadorian coasts suggest that this system would have great exploitation potential.

Ecuador's energy planning and the changes in its energy matrix are summarized in its Electricity Master Plan 2016-2025 [22]. The National Transmission System (S.N.T.) is administered by the Electricity Corporation of Ecuador (CELEC), through its Business Unit, Transelectric (CELEC-Transelectric) [23]. Ecuador's transmission system has a total of 37 substations: 14 operate at 230 kV (including one for sectioning: Zhoray); 21 to 138 kV (two sectioning: Pucará, San Idelfonso); and 2 mobile substations. The transmission lines that make up the S.N.T. they have a total length of 3654 km. Of which: 1901km correspond to lines with a voltage level of 138 kV; and 1753 km to 230 kV lines [24].

The TSO CENACE has identified the following problems in the Ecuadorian electrical grid: voltage drops and overloads. These problems have nothing to do with the renewable energy presence but there is a weakness in the Ecuadorian electrical network that would cause the presence of voltage and frequency events.

Although oceanic renewable energies have potential in Ecuador as described, currently there is no project of this type of renewable energy within its Electricity Master Plan.

One of the objectives of the Electricity Master Plan (2016-2025), to increase the integration of renewable energies, is the improvement of the transmission system of its electrical network. Two main actions: expansion of its base structure and interconnection with neighbouring countries to make the grid robust. The need to carry out specific studies is specified to study the impact of the integration of renewable energies in its electrical network. Energy storage projects are also proposed to support renewable energy projects, such as the one in the Galapagos Islands, where several renewable energy pilot projects are proposed. These modifications would facilitate the integration of ocean renewable energy into future energy plans for the country.

While the insular and oriental regions were not affected by the pandemic, the coastal and mountain regions had a significant change with negative growing in the energy consumption.

It is important to highlight the electric interconnection with Perú and Colombia, exporting 192 Gwh in 2022.

B. Perú.

Electricity production in Peru grew at an annual rate of 7.04% in the last 21 years, going from 12170 GWh to 50817 GWh between 1997 and 2018. The country's energy matrix has changed in the last two decades. From 1997 to 2003, the share of hydroelectric production was on average 89.7%. Renewable energy plants have gone from zero participation in 2008 to 7.2% in 2018.

The document "Elaboration of the new sustainable energy matrix and strategic environmental evaluation, as planning instruments" [25], includes the Development Plan for renewable energies 2012-2040. Among its results, the total installed capacity of renewable energies in Peru is expected to be 4321 MW (17.3% of the total).

Ocean renewable energies are not included in this new energy matrix for Peru. However, a study on Peru's potential in ocean energy has been carried out in [26]. In the case of wave energy, Peru presents a potential wave resource in latitudes between 30º and 60º degrees and the average power ranges between 15 kW/h and 25 kW/h. In the case of tidal energy, the area of greatest tidal range is present from south to north. Finally, the use of thermal energy from the oceans in Perú is very limited since only in a northern part of the country are high temperatures in its oceans.

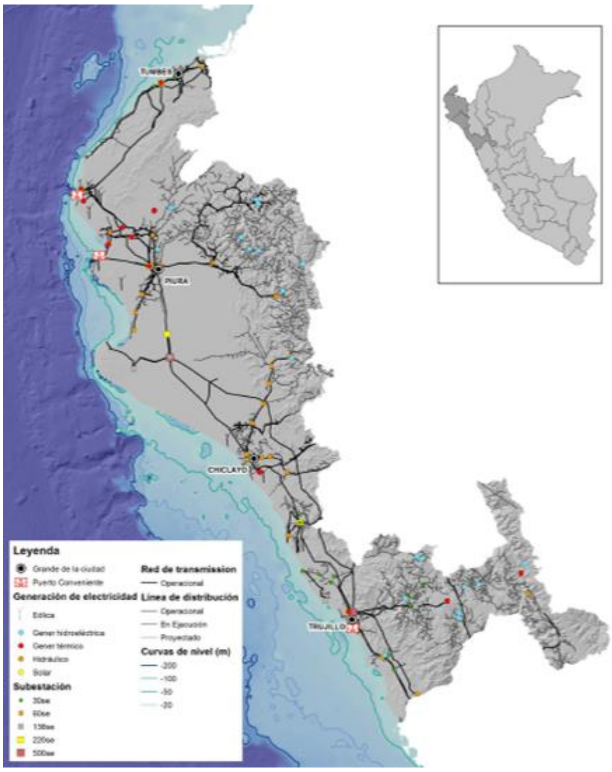

Figure 2. Perú transmission north grid [26].

The TSO in Peru is the COES [27]. COES has prepared the update of the Transmission network Plan (2025-2034) [28]. Within this transmission plan, a short and long-term diagnosis of the energy and electrical performance of the grid transmission in Peru has been carried out, considering the current state of the grid. The diagnosis has been divided by zones. It is concluded that in the long term there will be congestions in different transmission lines (500kV-220kV range) in the northern and southern areas of the country due to a high penetration of renewable energies. The main substations may present short-circuit current levels below the minimum short-circuit capacities of their facilities. Loss of synchronism is also expected to occur. No transient angular stability problems are expected. These aspects will limit the integration of ocean renewable energy into the Peruvian electricity grid.

C. Costa Rica.

Currently, the installed power capacity in Costa Rica is 3482 MW, made up of 67% hydroelectric plants, 12% thermal plants, 8% geothermal plants, 11% wind plants, and 0.16% solar plants.

The Costa Rica Electricity Institute (ICE) [29] has prepared the Generation Expansion Plan 2022-2040 (PEG 2022) [30] according to the detection of an important increase on the power demand. The objective is to increase the installed power of renewable energies in its electrical system. The expansion plan is designed considering Costa Rica as an isolated electric system.

As the most important renewable energy projects, a significant volume of wind and solar sources is expected (605 MW 2029-2035). The Fourth Cliff hydroelectric project (2030) and the Borinquen 2 geothermal project in 2032.

In this expansion plan, the consideration of batteries is introduced as an integral part of the generation system, considering them as necessary to maintain the system stability as support when integrating renewable energies. It is expected to incorporate around 300 MW of energy storage systems based on batteries by 2027.

Ocean energies are not considered so far in the Costa Rica Generation Expansion Plan. However, there is a study that evaluates the potential of oceanic energies in Costa Rica [31]. This study has concluded that:

• Wave resource. It is constant on the coasts of Costa Rica with an approximate gross potential of 16GW of which 2.3GW is usable with the possibility of achieving up to 7GW. With an annual production in the Caribbean Sea of 3.8TWh and 15TWh in the Pacific Ocean area.

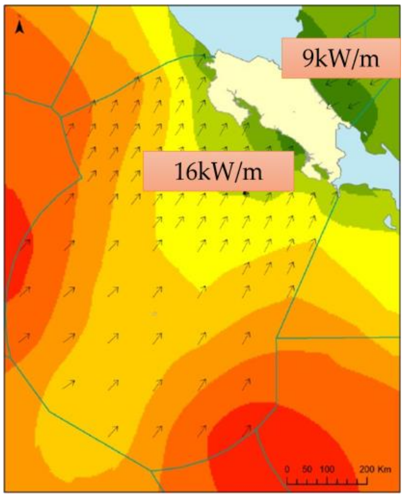

Figure 3. Wave energy resource in Costa Rica [31].

- OTEC (temperature difference). The geographical situation of Costa Rica, in tropical latitudes and its oceanic platform (depth 1000m) makes its potential in this marine renewable energy high. Studies have located 7 regions on the Guanacaste coast of Costa Rica (25 km from the coast) presenting a capacity between 44.8MW and 51.4MW [32].

In relation to grid integration, the Costa Rica national electricity system (SEN) and its operating procedures are managed by the National Electricity Control Center (CENCE) [33].

Within its operating procedures, the criteria for the operation of the system in safe conditions has summarized. It should be noted that an operating procedure for renewable energy and energy storage facilities is also presented. The record of the most common events that occurred in the Costa Rican transmission network was analysed, the most common being the appearance of sub-frequencies.

A comparison with the data summarized in Section II related to oceanic energies has been analysed. It is concluded that the Costa Rica electrical grid may present a greater number of events related to the stability of its grid frequency due to the integration of oceanic energies in its system.

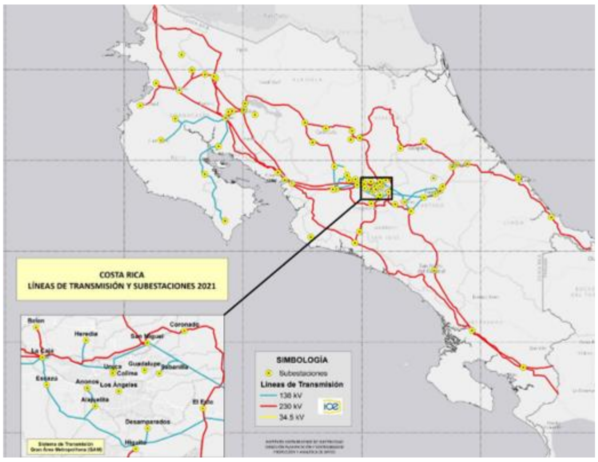

Figure 4. Costa Rica transmission grid [33].

D. *Spain.*

The document: "Integrated National Energy and Climate Plan (PNIEC) [34] compiles the current status and future energy forecast for the Spanish electricity system. The energy generation matrix in Spain is made up of 86% fossil fuels and 14% renewable energies. In the PNIEC, the integration of oceanic energies in the renewable generation park is contemplated, specifically a 50GW of wind power installed in 2030 consider both onshore and offshore wind (between 1-3GW in the case of offshore wind). In the PNIEC for other renewable technologies, among which are the energies of the sea, it is 80 MW by the year 2030 (case 40-60MW ocean renewable energies). These data show a large increase in renewable energy in Spain's energy park in 2030.

Red Eléctrica España (REE) is the Spanish transmission system operator (TSO) [35]. REE has its operating procedure [36] and presents the operating ranges of the system in operational safety conditions. It also presents specific guidelines for the participation of renewable energies in the coverage of demand in conditions of operational safety.

REE compiles the events that have affected the stability of the electrical grid. These events can be found in the document [37] prepared by the European system operator (ENTSO-E) [38]. The ENTSO-E have stablished a scale for these events in the European Synchronous area [37]. In Spanish electrical system have occurred these events: incident of network elements (Scale0-T0), loss of tools means and facilities (Scale 0-LT0) and incidents on load (L1) (see Figure 5).

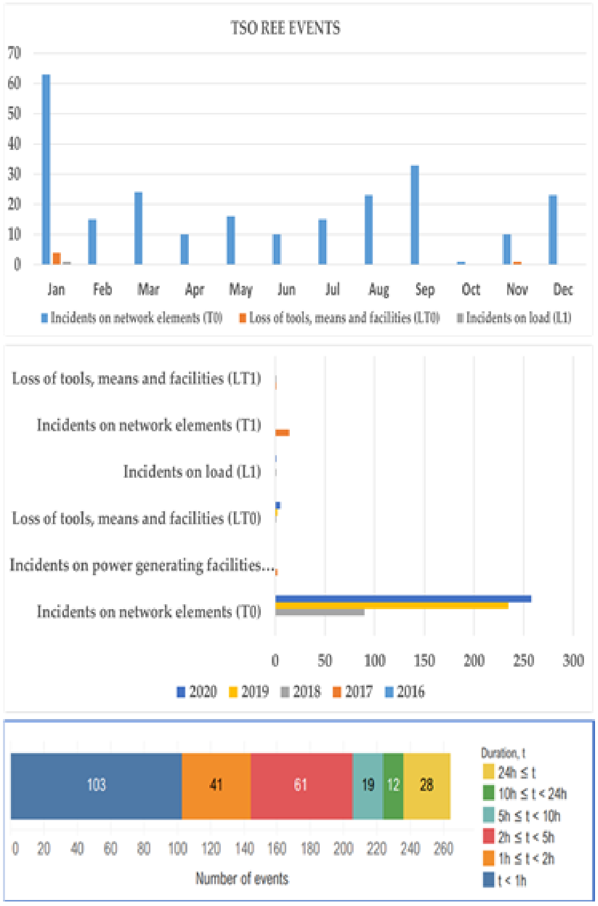

Figure 5. Events in Spain transmission grid.

Considering the events associated with ocean renewable energies described in Section II, it is concluded that the integration of ocean energies planned for 2030 in the Spanish electrical system will increase the number of events outside the operating limits established by REE in the Spanish electrical grid. Analysing the REE grid codes, the following aspects have been found that in the future may affect the Spanish electricity grid by integrating ocean renewable energies [7]:

- Voltage and Reactive Power Control. The voltage ranges and reactive power regulation requirements are: 0.9-1.15 pu (400-110 kV nominal voltage).
- Control of frequency and active power. Spain has the narrowest frequency operating range (between 47.5 and 51.5 Hz) and operation within 47.5 – 48 Hz is allowed only up to 3 seconds. Other European grid codes hope to incorporate specific strategies for

ocean energy and frequency control, in the case of Spain not.

- Low Voltage Ride Through capabilities. Spain requires a 15% voltage ride capability. Spanish grid codes require strategies that provide voltage support by injecting reactive current during voltage falls.

In Spain, strategies have begun to be developed for the development of offshore wind and ocean renewable energies in Spain [39]. Within these strategies, a section is included to define the deployment of ocean energy facilities. These strategies will aim to meet TSO requirements and adapt ocean energy facilities to meet operating procedures.

E. *Isolated electrical grid. Case: Canary Island.*

Isolated electrical grids, generally islands, present significant potential for the integration of oceanic energies [40] [41] [42]. As an example of an isolated electrical system, the case of the Canary Islands in Spain has been considered. Numerous studies have shown the potential of the Canary Islands for oceanic energy [43] [44].

The Canary Islands are a benchmark in the testing of ocean energy technologies within its Oceanic Platform for the Canary Islands (PLOCAN) [45]. Numerous ocean energy technologists have chosen the Canary Islands as a development and research (R&D) space for their technological development projects. An important fact is that the Canary Islands will be the first Spanish territory to integrate offshore wind into its electrical system [46] [47].

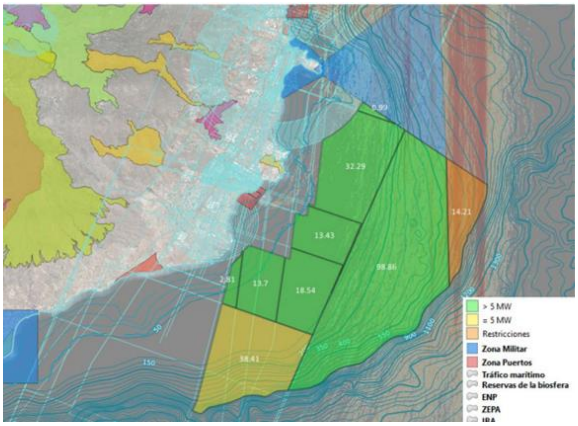

Figure 6. Authorized area for offshore wind (Gran Canaria Island) [46].

Isolated electrical systems have specific characteristics such as: systems not interconnected with other networks, low system inertia, high consumption demand, low power/frequency ratio and high resistance/reactance ratio. For these reasons, the operating ranges established by the TSO of the Canary Islands (REE) are stricter than for interconnected systems [48]. For example, the ranges of the frequency values for these isolated systems to operate in safe conditions are smaller (49.85Hz < f < 50.15 Hz) than the interconnected electrical systems (48 Hz < f < 51.5 Hz). These characteristics make these systems more vulnerable to the integration of renewable energies. For this reason, within the document: "Marine renewable energy strategy for the Canary Islands" [46], a specific section is developed

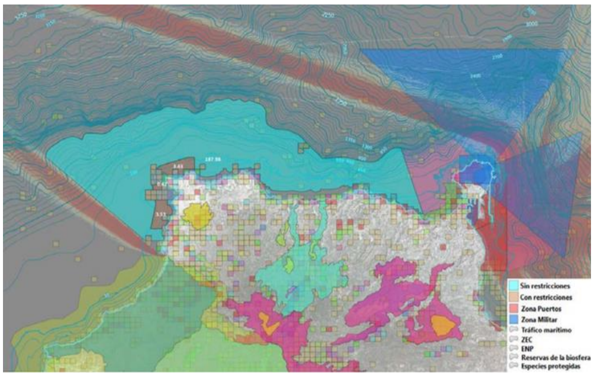

Figure 7. Area great potential for wave energy farms (Gran Canaria Island) [46].

on the restrictions of the electrical system before the integration of ocean renewable energies.

Other studies [49] [50] has been analysed the effect on the stability of the frequency in isolated electrical systems before the integration of wave energy. These studies concluded that a significant increase in the installed power of wave energy would cause significant oscillations in the grid frequency. In this study, the integration of energy storage systems was also proposed as a solution strategy to this problem, obtaining positive results.

F. *Argentina.*

The Argentine electrical matrix has an installed electrical capacity (2021) of 42989 MW, of which 59% corresponds to thermal power plants with fossil fuels, 25% to hydroelectric power plants, 4% to nuclear energy, and 12% to other renewable energies. The Argentine Secretariat of Energy determines that there are 187 renewable energy projects in operation in Argentina: 64% correspond to onshore wind, 20% to solar, 11% to hydroelectric and 5% to biomass.

The most relevant law is the "National Promotion Regime for the use of renewable energy sources for the production of electricity" [51]. This law has a section dedicated to the national scheme to promote the use of renewable energy sources to produce electricity. Therefore, it is concluded that in 2030 there will be a 69% increase in renewable energy installed in Argentina due to the existence of this legislation [52].

Although ocean energy is not part of the electrical matrix in Argentina, there are the first studies on the potential of ocean energy in Argentina. Most of the research is related to wave and tidal energy [53]. Research projects around wave energy have been carried out by the wave energy team of the Universidad Tecnológica Nacional, Facultad Buenos Aires [54]. Projects related to tidal energy have been carried out by researchers from the Hydraulics Laboratory of the National Water Institute (INA) [55]. They have also carried out studies on currents in Patagonian estuaries. Therefore, it is expected that ocean

Figure 8. Main electrical grid of Argentine, Brazil, Chile, Colombia, and Uruguay [3].

energies will form part of Argentina's energy matrix. The national electrical system requires an expansion plan for the high-voltage transmission network due to the integration of renewable energies in Argentina.

The Argentine Interconnection System (SADI) is the electrical network of high voltage lines that interconnects the regions of Argentina (see Figure 8). The network collects and transports all the electrical energy generated in the country. The current transport infrastructure only allows reaching just over 12% of the demand with renewable sources. The need to reach 10 GW of power in 2025 implies adding electricity generation that could not be transported. The allocation of nearly 6 GW of renewable energy from the RENOVAR and MATER [56] programs, together with the allocation of thermal plants in recent years, pushed transmission capacity to the limit. According to the projections of SENER (2019) [57] , the expansion of the transmission network to respond to this limitation implies developing the transmission system in approximately 2200 km of high voltage lines (500 KV), giving flexibility and capacity. to the system so that generators can enter new long-term contracts [52].

The TSO of the Argentine electricity grid is CAMMENSA [58]. It should be noted that there are four operating procedures for the Argentine electricity grid. This particularity is because Argentina is electrically interconnected with Brazil, Chile, Paraguay, and Bolivia. It presents a robust electrical network whose main events are due to equipment failures. The integration of ocean energies is not expected to create events outside the normal operating state of the network (see Section II) once the expansion plan of the planned transmission network is carried out. This aspect makes Argentina one of the Ibero-American countries that presents better conditions from the point of stability of the network for the integration of oceanic energies.

IV. FUTURE GUIDELINES.

In view of the information compiled in Section III, some guidelines are established in which electrical systems must be worked on to achieve a correct grid integration of oceanic energies.

- Energy storage systems (ESS). Energy storage systems as allies before the integration of renewable energies. The potential installation of ESS together with renewable generation will contribute to reducing the events associated with the stability of the electrical grids. The ESS will be a complement to the electricity grid management systems. They will serve to smooth the generation peaks of the power curves of oceanic renewable energies. In addition, they will help to make better use of renewable resources, by storing surplus renewable generation. These surpluses may be used by the TSOs in a controlled manner as is currently done with non-renewable generation.
- Device design optimization. Especially for wave energy technologies and their electrical components. In this way, problems associated with power quality will be minimized.
- Control strategies. By integrating power electronic systems. This need has been identified both on the ocean technologies side and on the power grid side. The control strategies will improve the quality of the energy to be poured into the network, minimizing the appearance of harmonics or flickers.
- Prediction of the renewable resource. Knowing the power of renewable generation parks in advance is one of the basic pieces to increase the penetration of renewable energies in electricity networks. The creation of computational tools that help to predict renewable resources will contribute to improve the scheduling and dispatch actions in the TSOs. Decreasing the number of events outside the limits of safe operation of electrical systems. This will cause a greater participation of renewable energies in the coverage of demand.

VI. CONCLUSION.

The state of the art carried out in this article concludes that ocean renewable energies present an important potential in several regions of Ibero-American countries. However, the general situation of the electric grids alerts about the difficulties in a massive integration of renewable energy generation in the systems. Ocean energy integration is even worse, since the coastal areas are even weaker than the continental ones. Special attention must be put on the islanded regions.

From the collection of data on the current situation of its electrical networks, it is concluded that an adaptation of the transmission network infrastructures must be carried out for the integration of ocean renewable energies in these electrical systems.

From the diversity of technologies, the location of the parks, the evacuation systems for the energy produced and the characteristics of the connection points, it is concluded that it is necessary to develop own grid codes for ocean renewable energy.

Additional measures such as change of control strategies in generation systems, control of the demand and mainly the integration of energy storage systems have been identified as supporting tools for the integration of renewable energies. Some countries have already identified the potential of ESS as allies for the integration of renewable energy into their systems. TSOs have also identified the potential of ESS including specific procedures for these electrical systems. Evidencing that they are already one more piece in the management of the electrical systems of many countries.

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