Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

UE 23

USEP UNIDAD DE SISTEMAS ELÉCTRICOS DE POTENCIA

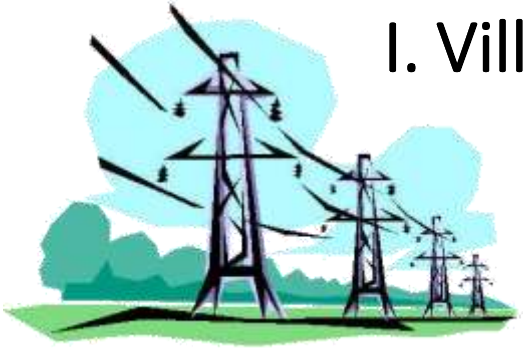
REMAR

CYTED PROGRAMA IBEROAMERICANO DE CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO

Challenges for the integration of ocean energy in Ibero-American power systems

Marcos Lafoz

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



PAMEC 2024

Pan American Marine Energy Conference

Barranquilla, Colombia Jan 22-24, 2024

Marine renewable energies and electric grid compliance

- Electric generation based on renewable energy is likely to deteriorate significantly the power quality due to the variability and unpredictability.
- It has been already documented and/or discussed for some interconnected electric power systems.
- Not a problem in the electric systems yet since the presence of renewable energy is not very high.
- The connection of marine renewable generation is usually taken place in grid nodes not very favourable in terms of power stability (islands).

- Renewable energy cannot be managed as much as desired, affecting the **Grid Codes.**

→

The success of marine energy integration plans needs to fulfil, among others, the compliance of the electric grid codes, ensuring the stability of electric grids.

Marine renewable energies and electric grid compliance

- Many countries are putting an eye on marine renewable energies to face energy crisis
- Ocean energies is considered a way to get flexibility to the energy matrix of the countries
- One of the main issues is the lack of robust electric grids or the condition of weak grids in coastal areas
- That is the case of areas or regions in many countries, for instance in Centre and South America

Trying to give response to this problem, the thematic Network REMAR, in the frame of CYTED Program, is developing its activities to analyse and foster the integration of ocean energies in electric grids in Latin-American countries.

REMAR Network – CYTED Programme

Integration in Electric Grids of Ibero-American countries of Ocean Energies

Groups of experts in Ocean Energies (wave, tidal, OTEC, saline gradient) | Groups of experts in power systems and grid integration

13 countries, 38 institutions, 140 researchers

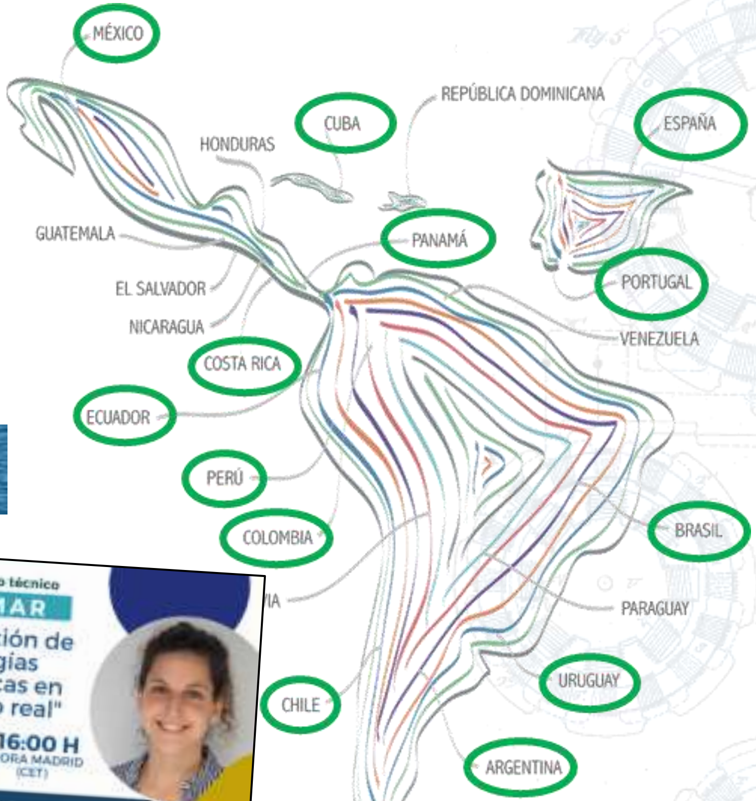
Fostering research activities

Map of experimental and validation facilities.

PAMEC Energy Association

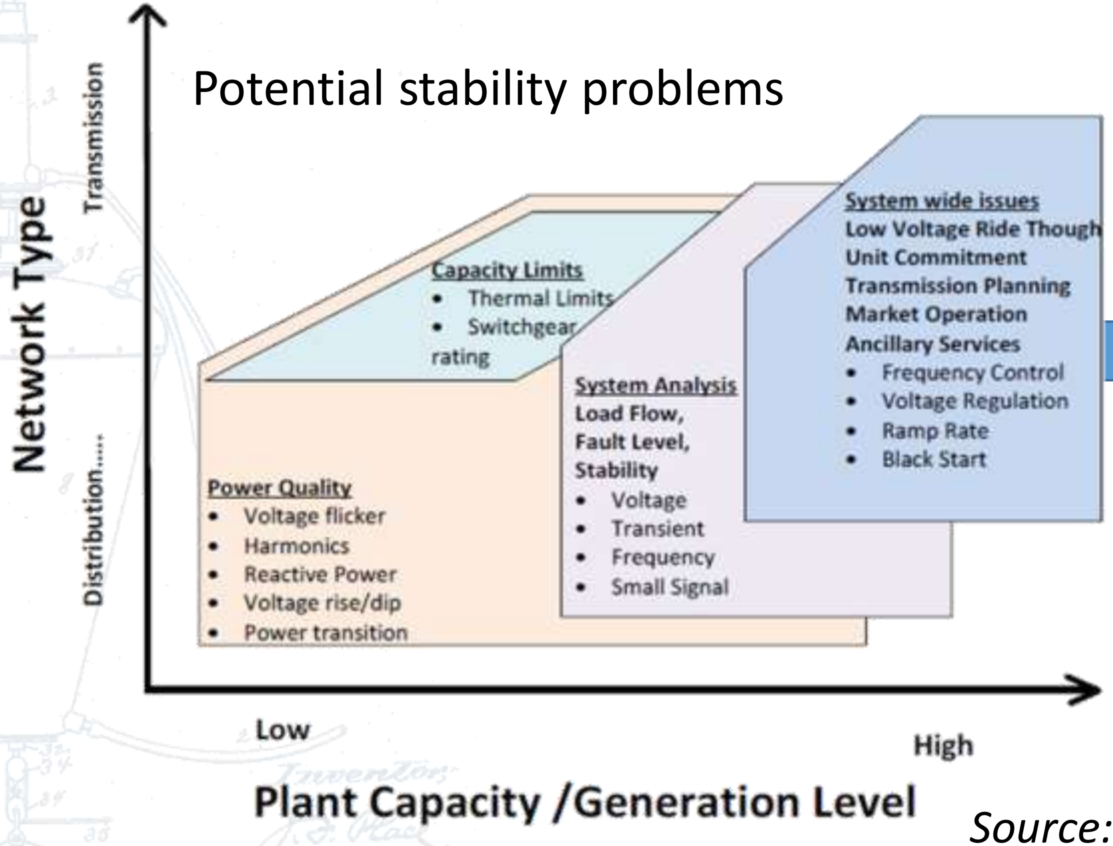
CONECTANDO PA AMÉRICA, APOYO A LA ENERGÍA MARINA

ICOE 2022



http://www.cyted.org/es/cyted

Problems and consequences of ocean energy integration



Consequences:

1. Limited dispatchability
2. Reduction of efficiency
3. Equipment malfunction or even disconnection
4. Loss of information
5. Overheating of conductors
6. Electromagnetic interferences

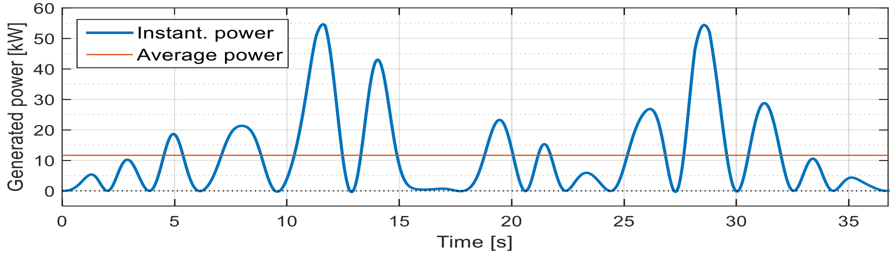
Grid codes do not include specific regulation for marine renewable energies. Only general considerations are evaluated.

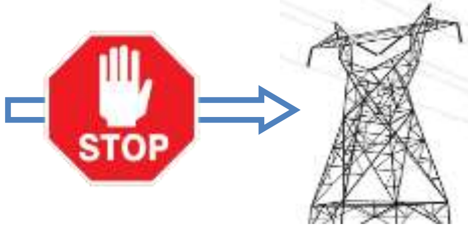
Source: Robles, E. et al.

Problems and consequences of ocean energy integration

Many times, instantaneous power cannot be directly injected into the grid for stability reasons.

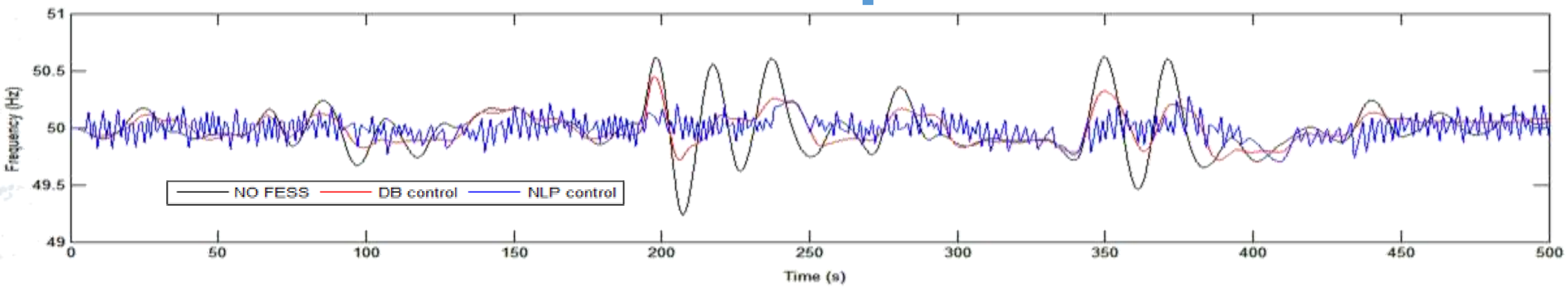
Example: Power generated by a single point absorber WEC under real wave conditions





Therefore, a power conditioning stage is required to smooth the instantaneous power profile, especially in weak grids

- -Sizing and locating of the generators
- -Control strategies
- -Energy Storage
- -Control of demand



Analysis of marine energy integration in Latin-American countries

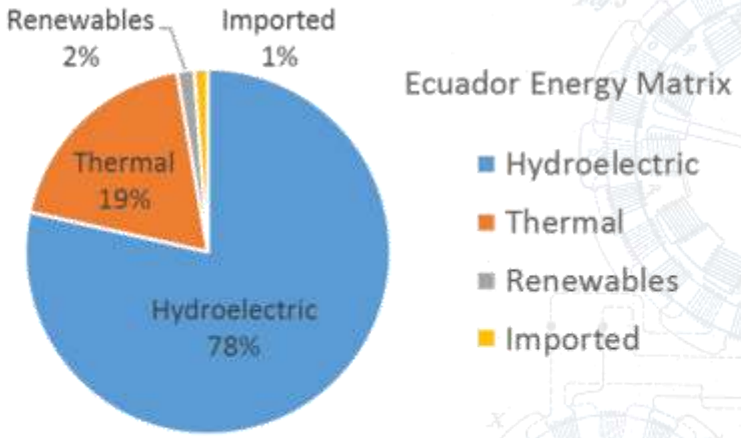
The analysis of particular situations or case-studies from different Latin-American countries will provide some guidelines and conclusions about the grid integration of ocean energies in electric power systems.

- Ecuador
- Peru
- Costa Rica
- Spain
- Argentina

Analysis of marine energy integration in Latin-American countries

Ecuador

Ecuador's energy planning and the changes in its energy matrix are summarized in its Electricity Master Plan 2016-2025.



Tidal energy and wave energy have a low potential for use in Ecuador (14 kW/m for wave energy and 0.8 to 1 m/s for currents).

Exception: the channel between Puná and Puntilla de Jambelí, current speeds between 3 and 4 m/s.

The TSO CENACE has identified the following problems in the Ecuadorian electrical grid: **voltage drops and overloads**.

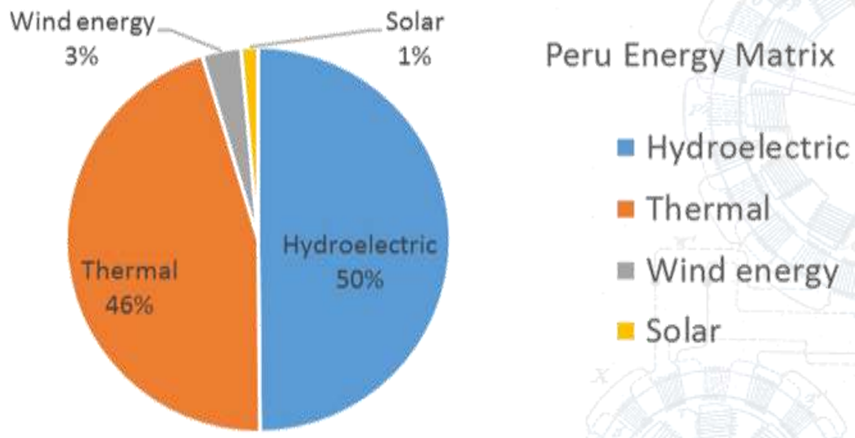
These problems have nothing to do with the renewable energy presence but demonstrate that there is a **weakness in the Ecuadorian electrical network to be solved before a higher level of renewables is achieved**.

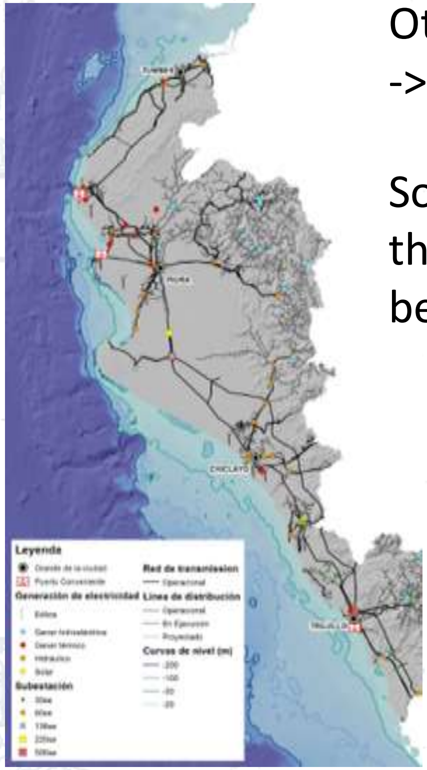
- Reinforce interconnection with Peru and Colombia
- Energy storage projects are also proposed to support renewable energy projects, such as the one in the Galapagos Islands

Analysis of marine energy integration in Latin-American countries

Peru

New sustainable energy matrix and strategic environmental evaluation. Development Plan for renewable energies 2012-2040.





Other enewable energies in Perú: 2008: 0% -> 2018: 7.2% -> Expected 2040: 17.3%

Some **<u>wave energy resource</u>** has been identified in Peru in the North part of the country, with average power ranges between 15 kW/m and 25 kW/m.

The TSO in Peru, COES, has prepared the update of the Transmission network Plan (2025-2034):

→ In the long term there will be **<u>congestions in different transmission lines</u>** (500kV-220kV range) in the northern and southern areas of the country due to a high penetration of renewable energies.

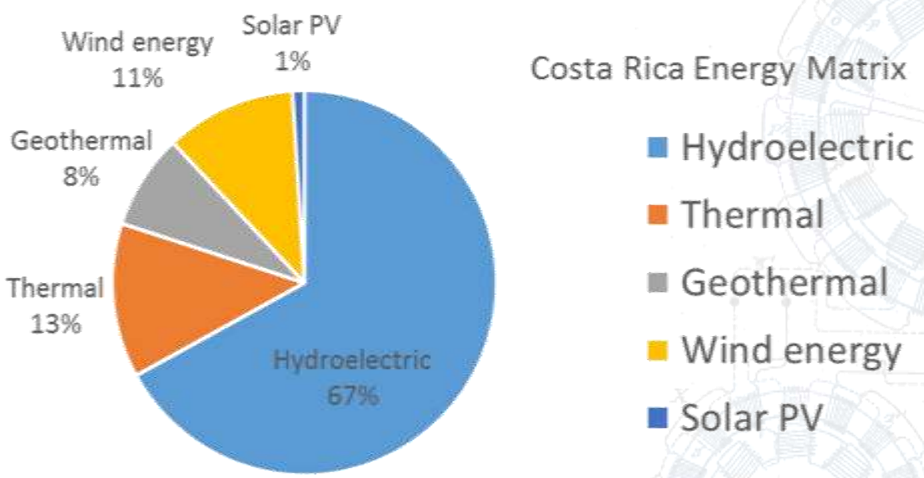
Analysis of marine energy integration in Latin-American countries

Costa Rica

Generation Expansion Plan 2022-2040 (PEG 2022) developed by the Costa Rica Electricity Institute.

The objective is to increase the installed power of renewable energies (offshore wind -> 14400MW) in its electrical system. Looking for a diversification of the renewable energy.

Turning the attention towards the sea (10 times more sea than land)



The Costa Rica national electricity system (SEN) and its operating procedures are managed by the National Electricity Control Center (CENCE)

The most common events occurred in the Costa Rican transmission network are sub-frequencies.

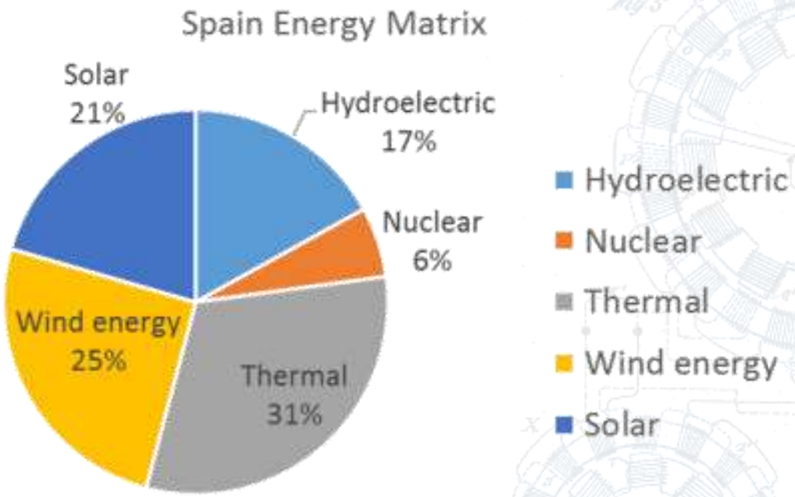
Remarkable the consideration of energy storage as part of the energy management.

It is expected to incorporate around 300 MW of energy storage systems based on batteries by 2027 as part of the expansion plan, for stability support.

Analysis of marine energy integration in Latin-American countries

Spain

Integrated National Energy and Climate Plan (PNIEC) stablished 80MW of ocean energy by 2030.



The Spanish TSO, REE, presents specific guidelines for the participation of renewable energies in conditions of safe operation.

→ The integration of ocean energies planned for 2030 in the Spanish electrical system will increase the number of events outside the operating limits established.

Analysing the Spanish grid code, voltage (0.9 pu < U < 1.15 pu), frequency (48Hz < f < 51.5Hz) and low voltage ride trough capability are the aspects that would be affected by integrating ocean energies.

→ Isolated electrical systems have specific characteristics: no interconnection, low system inertia, low power/frequency ratio and high resistance/reactance ratio.

→ The ranges of the frequency are smaller (49.85Hz < f < 50.15 Hz) → Wave energy would significantly increase frequency events

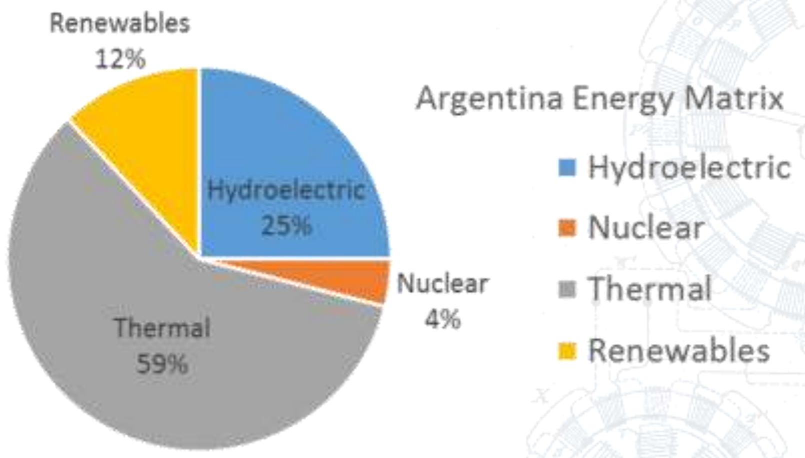
Analysis of marine energy integration in Latin-American countries

Argentina

National Promotion Regime for the use of renewable energy sources for the production of electricity

This legislation will promote in 2030 a 69% increase in renewable energy installed in Argentina.

The current transport infrastructure only allows reaching just over 12% of the demand with renewable sources.



→ Developing the transmission system in approximately 2200 km of high voltage lines (500 kV), giving flexibility and capacity to the system

Argentina is electrically interconnected with Brazil, Chile, Paraguay, and Bolivia. It presents a robust electrical network whose main events are due to equipment failures.

→ Once the transmission system is updated, Argentina is one of the best scenarios for the integration of ocean energies.

Analysis of marine energy integration in Latin-American countries

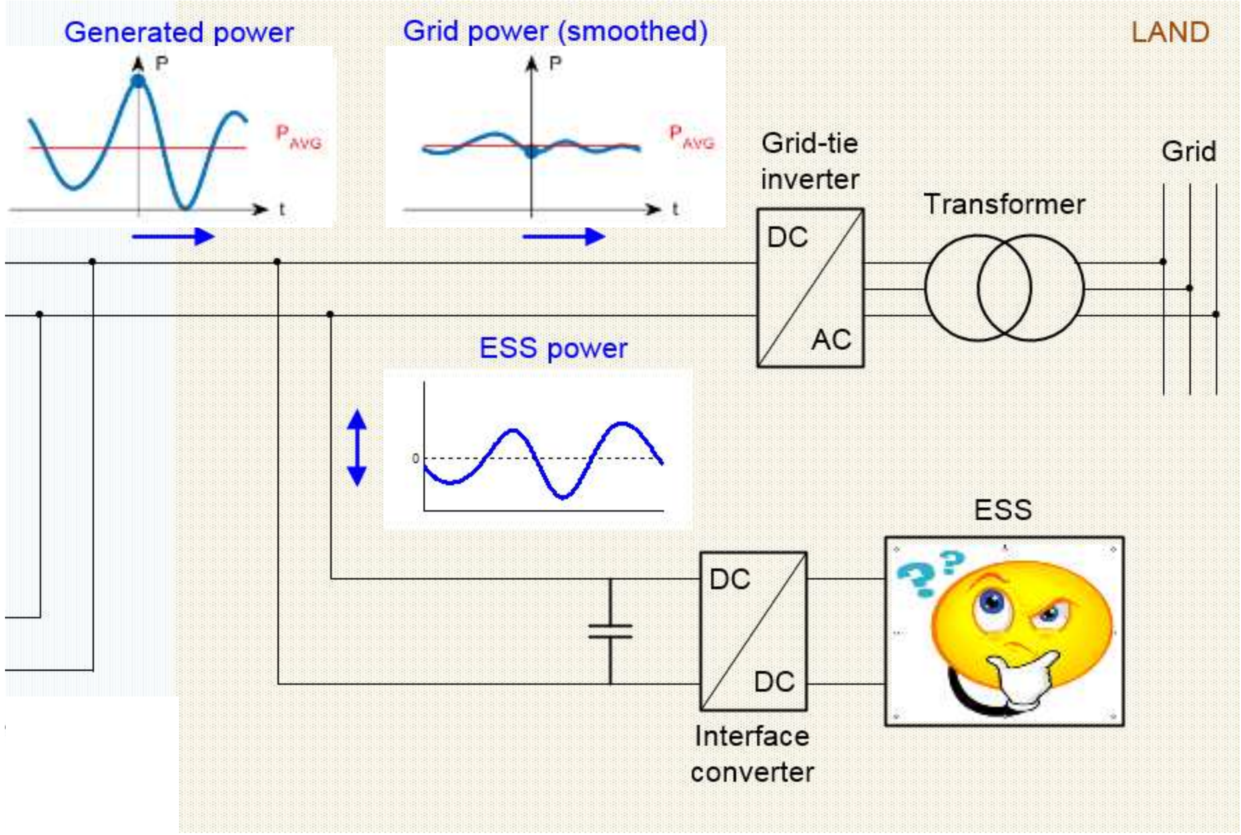
- Every country has their own energy **plans considering renewable energies** in the energy matrix.
- Ocean Energies are not mostly in the energy policies but **some resources has been identified for specific areas** of many of the countries under analysis.
- The main problems identified are related to **voltage drops, overloads or congestion of power lines**.
- The **power grids need to be renovated or reinforced** in order to integrate a higher amount of renewable energy, **specially in the more isolated areas**.
- **Energy storage has been already identified as a solution** to enhance the integration in the power grids (that is the case of Galapagos Islands in Ecuador, Costa Rica or the Canary Islands in Spain)
- The **weaker is the power grid, the more restrictions** in terms of frequency and voltage are applied in order to ensure the grid stability.

→ Isolated electrical systems have specific characteristics: no interconnection, low system inertia, low power/frequency ratio and high resistance/reactance ratio.

→ The ranges of the frequency go from (48Hz < f < 51.5Hz) to (49.85Hz < f < 50.15 Hz)

Solutions to potential poblems of marine energies penetration

Energy storage to compensate power oscillations from wave energy converters



Solutions to potential poblems of marine energies penetration

Energy storage to compensate power oscillations from wave energy converters

Prediction reduces the requirements of Energy Storage

H: Wave height

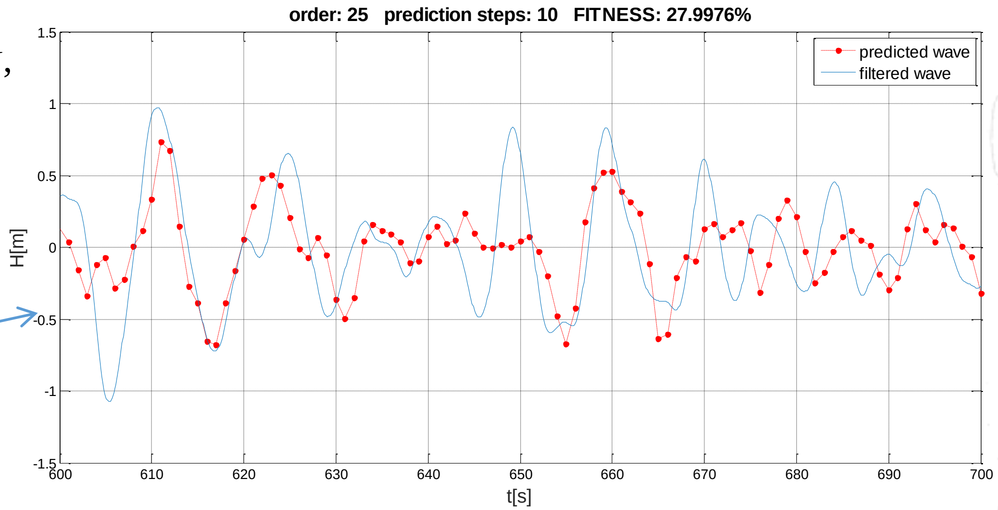
- The accuracy of the predictions is checked by the index of fitness (FIT)

$$FIT(l) = \left(1 - \frac{\sqrt{\sum_k \left[H(k+l) - H_{pred}(k+l \mid k) \right]^2}}{\sqrt{\sum_k \left[H(k) \right]^2}} \right) \cdot 100\%$$

→ balance between the order of the prediction (complexity in the online calculations) and the steps ahead for the prediction

INDEX OF FITNESS (FIT) FOR L-STEPS AHEAD PREDICTION, N2=20

n: order (past values); l: steps ahead					
n / l	10	15	20	25	30
1	77.09	77.01	87.23	92.01	88.79
5	43.67	45.15	50.44	57.38	57.87
10	16.09	19.40	24.09	28.00	28.35
15	3.96	6.32	11.39	13.99	14.49



Guidelines for a better integration of Marine Energy Devices

Searching for a greater participation of renewable energies in the coverage of demand, decreasing the number of events outside the limits of safe operation of electrical systems.

1. **Device design and operation optimization**. Especially related to some components of wave energy generators that produce problems associated with power quality. *Be gentle with the power grid !!!*
2. **Energy storage systems (ESS)**. The installation of ESS together with renewable generation will contribute to reducing the events associated with the electrical grid stability. Smooth the power generation peaks of the power of oceanic renewable energies curves. In addition, it allow to storage surplus of generation.
3. **Control strategies**. Advanced control strategies and faster power electronic topologies will improve the quality of the energy to be poured into the power grid, minimizing the appearance of harmonics or flicker.
4. **Prediction of the renewable resource**. The use of computational tools that help to predict renewable resources will contribute to improve the scheduling and dispatch actions in the TSOs. It also reduces the use of energy storage,

Conclusions

1. Although nobody cares now, the general situation of the electric grids **alerts about the difficulties in a massive integration** of renewable energy generation in the power systems.
2. The integration of **some types of marine energy is even worse**, since the coastal areas are many times even weaker than the continental ones (where more viable). Special attention must be put on the islanded regions.
3. An **adaptation of the transmission and distribution grid infrastructures** must be carried out for the integration of marine renewable energies in the electrical systems.
4. The diversity of technologies, the location of the power plants, the evacuation systems for the energy produced and the particular characteristics of the connection points conclude that it is **necessary to update grid codes for marine renewable energy.**
5. Marine energy plants should be **designed and operated considering grid stability criteria**, not only maximum power criteria.
6. The main supporting tools for the integration of renewable energies are: change of **control strategies** in generation systems, use of **energy storage systems** and **control of the demand**.

Thank you for your attention

marcos.lafoz@ciemat.es