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Multiobjective Optimization of a Wave Energy Farm

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ABSTRACT

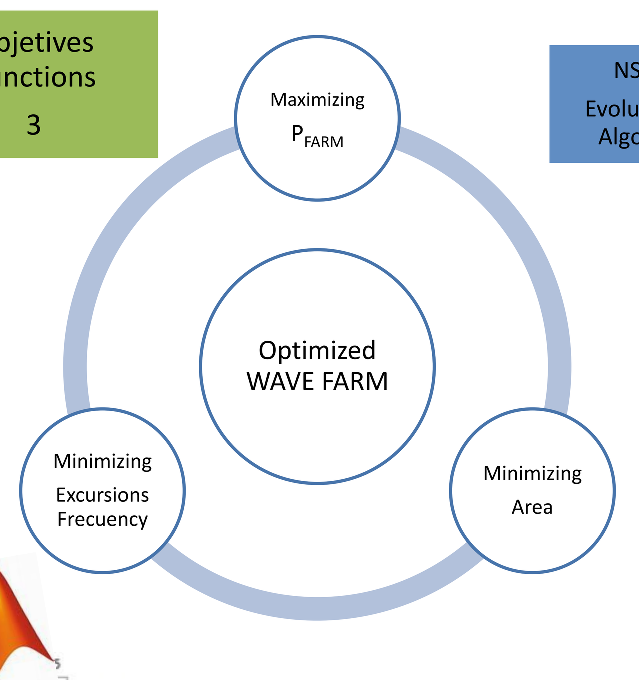
This paper presents the optimization of a wave energy farm configuration and its application in electrical network stability analysis. The influence of the spatial distribution in a wave energy farm power output, has been demonstrated. On the other hand, compliance with the limit values imposed by the European Systems Operator (ENTSO-E) for the stability of power systems, is a problem to be solved by the electrical generation devices with renewable sources.
The aim of the work is designing a wave farm configuration simultaneously maximizing the output of electric power, minimizing the frequency excursions (that affect the stability of the electrical grid), and minimizing total area occupied by the wave farm.
Once wave farm power has been obtained (first objective function) based on a series of decision variables that affect its final result, this wave farm power output has been injected into a weak and isolated electrical grid, where frequency excursions have been obtained (second objective function). Finally, the total area of wave farm has been calculated (third objective function). To carry out the multi-objective optimization of the three functions described above, evolutionary algorithms have been used.
As a solution we have obtained a non-dominated set of optimal wave farm configurations.

TOOLS

NEMOH | WEC-SIM | PLAT-EMO

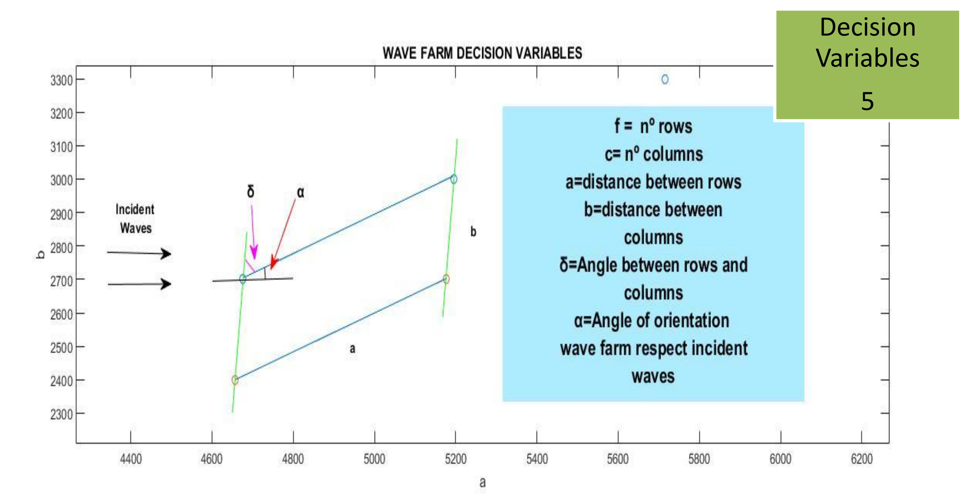
OPTIMIZATION MULTIOBJETIVE

Objetives Functions 3



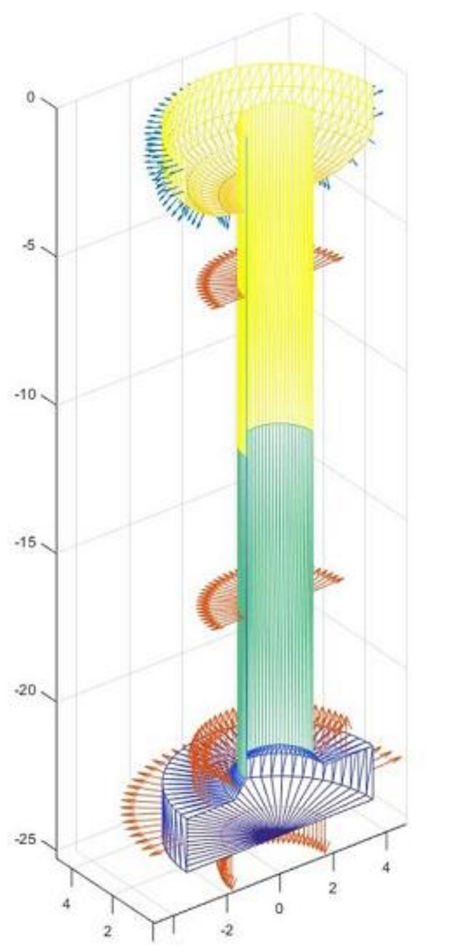
NSGAII Evolutionary Algorithm | E@real Operator | Hiper-Volume (HV) Metric | Initial Population 100 | Number of evaluations 10000

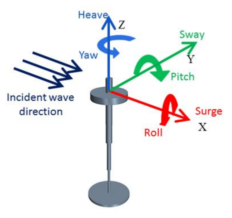
Decision Variables 5



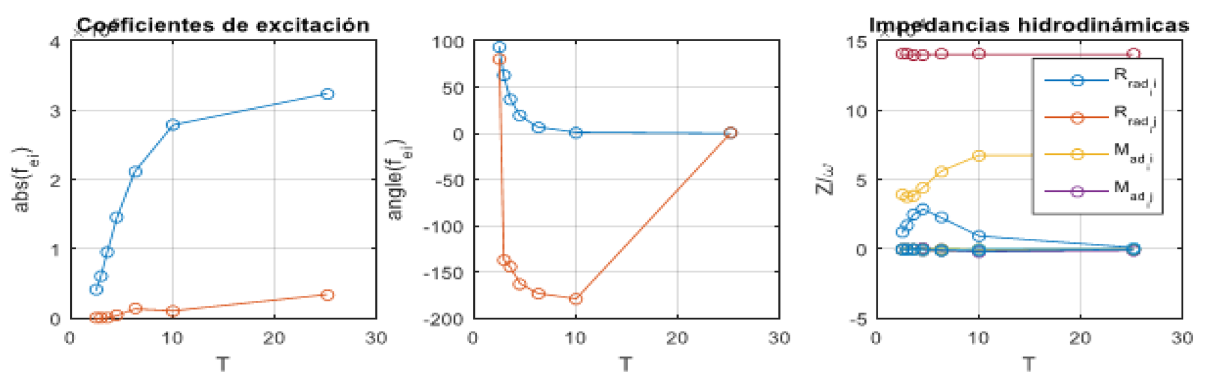
MODELING WAVE ENERGY CONVERTER (WEC)

POINT ABSORBER





$$m\ddot{X} = F_{exc}(t) + F_{rad}(t) + F_{PTO}(t) + F_v(t) + F_{ME}(t) + F_B(t) + F_m(t)$$



The electrical power output (W) produced by the WEC is calculated using the Nemoh and WEC-SIM applications. Nemoh is based on the Finite Element Method. WEC-SIM uses the Boundary Element Method to solve the force equation of the WEC.

MODELING WAVE ENERGY FARM

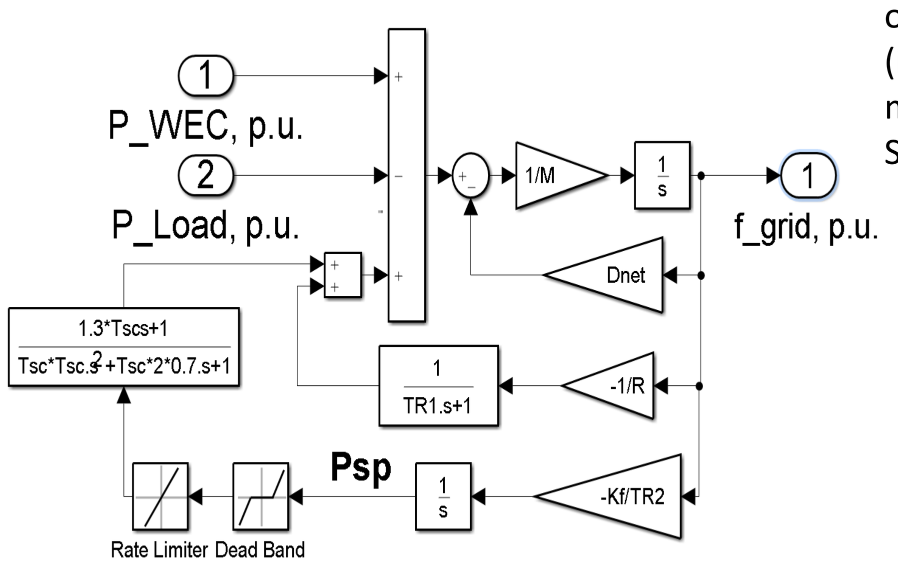
To calculate the total power of our wave park we have used the methodology exhibited in [1].
This methodology states that, for network stability studies, total power output of wave farm can be calculated based on the following equations, not affecting to the final result of network stability study.

$$P_{farm} = \sum_{i=1}^{60} P_{WEC1}\,(t + \Delta_{ti})$$

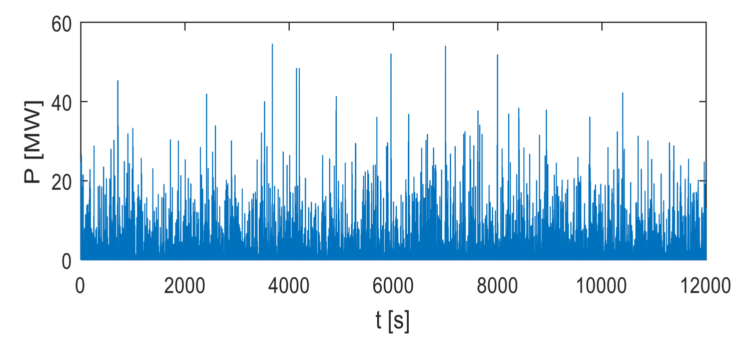
$$\Delta_{ti} = \frac{d_{td}}{v_g} = \frac{4\pi\, d_{td}}{g\, T_p}$$

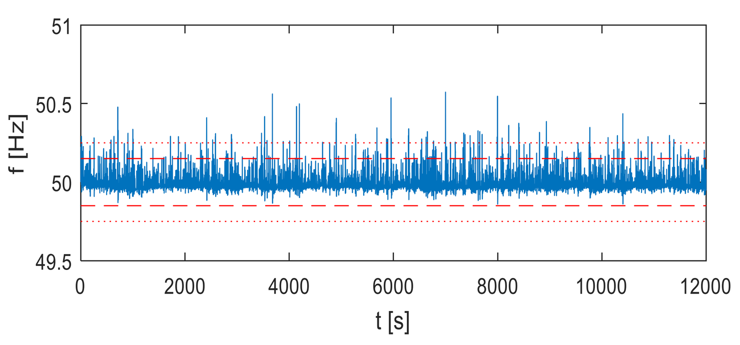
$$d_{td} = d + d_{rand}$$

MODELING ELECTRICAL GRID



Electric model in frequency regime of the power grid of the island of Tenerife, Canary Islands, Spain (isolated and weak electrical network). It has been modeled using frequency events ceded by the Spanish TSO: *Red Eléctrica Spain.*

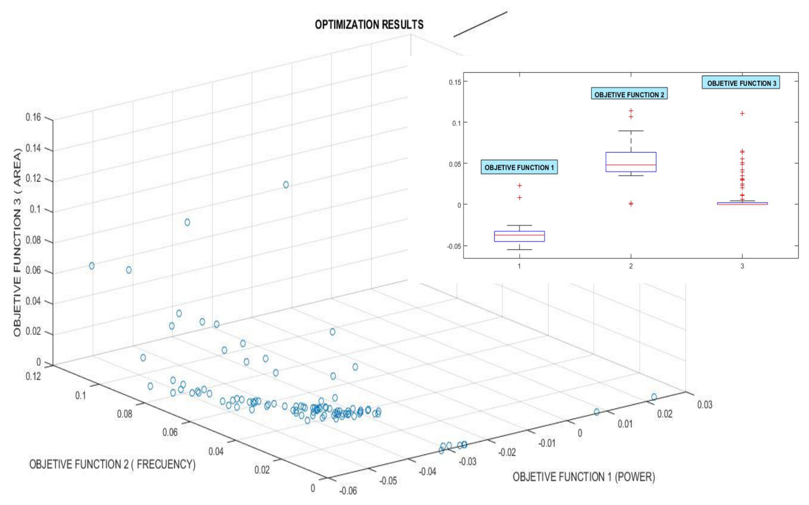


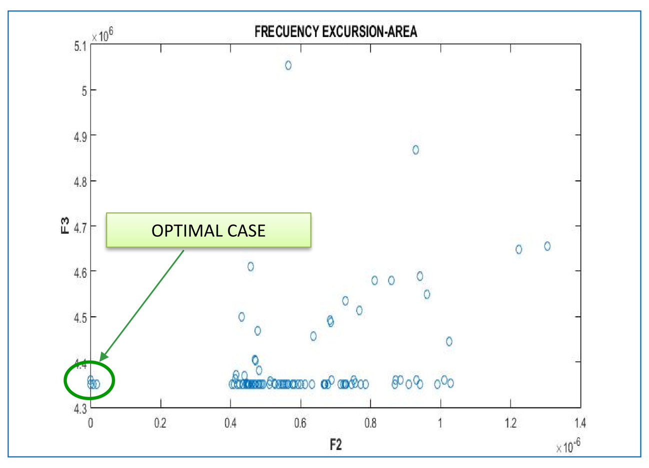


P_{FARM} → Electrical Grid → Frecuency Profile

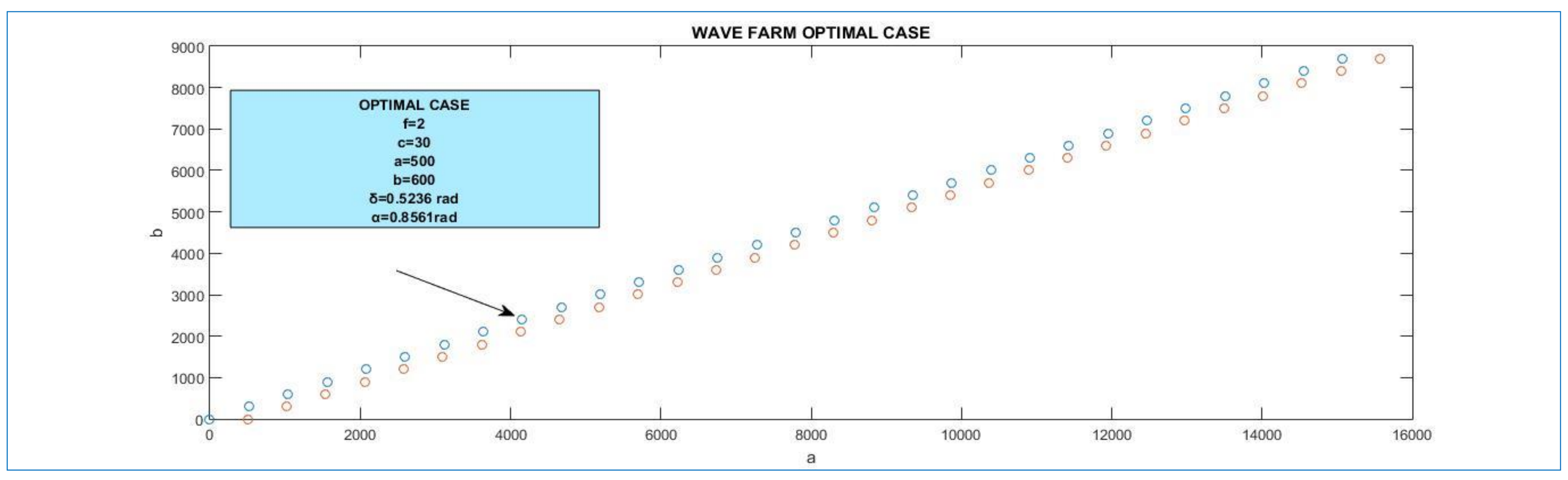
SIMULATIONS AND RESULTS

This figure shows the results of optimizing the objectives functions by using PLAT-EMO[2]. The 1st objective function represents maximum values of the mean of wave farm power output. The 2nd objective function represents the variance of the minimization of frecuency excursions. The 3st function represents the minimization values of area surface that occupies the wave farm. Although it is represented in three-dimensional form, we can clearly observe the Pareto frontier which forms the optimal values of the three functions.





In this figure we have represented 2nd objective function (frequency excursions) in front of 3st objective function (area). Consider this case of interest because it is clearly seen in the graphic representation as there are cases in which 2nd objective function values are null. This result is of interest as it informs us that this park configuration does not produce frequency excursions in the network while the total area of the park is also minimal. The values represented in the figure are true magnitudes. These are not values with the previous scaling setting. The Pareto frontier can be clearly seen in this case.



In this last figure we have represented the configuration of the wave farm optimised according to the optimal decision variables that satisfy the optimal solution of the objective functions posed.

REFERENCES

[1]"**Influence of the wave dispersion phenomenon on the flicker generated by a wave farm**" Anne Blavette, Thibaut Kovaltchouk, François Rongère, Marilou Jourdain de Thieulloy, Paul Leahy, Bernard Multon, Hamid Ben Ahmed. 11035. *Proceedings of the 12th European Wave and Tidal Energy Conference 27th Aug -1st Sept 2017, Cork, Ireland.*
[2] **" PlatEMO: A MATLAB Platform for Evolutionary Multi-Objective Optimization"** *, Ye Tian, Ran Cheng, Xingyi Zhang, Yaochu Jin . November 2017, IEEE Computational Intelligence Magazine .*

CONCLUSIONS

We can conclude that applications for troubleshooting numerical methods as well as optimization tools based on evolutionary algorithms present a great potential for use as computational tools applied in engineering . This article has demonstrated its application within the stability studies of the electricity grid in the face of the integration of renewable energy sources, in particular the wave energy.