



On-line workshop:

## 'Avanzamento Delle Energie Rinnovabili Marine: Strategia Europea, Attività In Corso In Italia, e Aggiornamento Del Piano D'azione Nazionale Del Cluster-Big'

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# 'WaveSAX: towards improving PTO through sea tests at the Port of Civitavecchia'

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## WaveSAX device

### **Potential benefits:**

- flexibility to be installed in different structural configurations (existing or new);
- reduced cost of installation and connection to the grid;
- reduced cost of maintenance directly from the dock;
- flexibility to be dimensioned for the specific local wave conditions;
- replicability that allows the device to be installed in array of several number of similar units;
- modular construction that reduces maintenance costs
- .....

### Issues to be investigated:

- optimize the design of the Wells turbine;
- assess the best parameters for the PTO control system;
- derive the power matrix for real sea conditions;
- evaluate the actual electricity generation

• .....



## WaveSAX device





Pressure (left) and velocity (right) fields



Wells turbine inside the device

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General layout



## WaveSAX device



Behaviour for incoming waves: water levels and

## Bige Italian Growth

### Numerical simulation of different turbine layout (3, 4, 5, 6 and 7 blades)





Reference schemes

Average hydraulic power calculated at the P3 plane (red dots) and the working section (green dots); total forces acting on the turbine blades in the X-Y plane (blue squares) and total torque transmitted to the axis, in Z direction (blue diamonds)



7 blades (H=2m ; T=7.5s)



### WaveSAX installation at the Civitavecchia port

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WaveSAX device (scale 1:5) installation at Darsena Traghetti breakwater of the Port of Civitavecchia







### WaveSAX sea tests



Measurement points:

[A], [B], [C], [D] and [E] pression measurements (mm H2O)
[F] rotation velocity (rpm) and Torque (Nm)
[G] current intensity (A) and tension (V) to/from the battery

Test case:

reference speed 160 rpm ; stiffness constant 0.024 As/rad



Incoming waves (left) and external and internal water levels for a reference period of three waves (right)

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### WaveSAX sea tests





- > Hydraulic power
- > Mechanical power
- Electric power generation



Outside water level (red); water level inside the oscillating column (blue)



Hydraulic power (blue), turbine power (violet), mechanical power (red) and electric power generation (green), for a referenced 3 wave period (Vr= 160 rpm; Kc=0.024 As/rad)

### WaveSAX-2 sea test (November 2021)







**Power Matrix** of the WaveSAX-2 devise: from the sea tests performed in November 2021

Report RSE n. 200010731 (December 2021)

## **Big**

Evaluation of the wave energy potential and WaveSAX power generation in the coastal area around the Civitavecchia port







Study area reporting the anemometric station (black triangle); the wave buoy of the C-CEMS (yellow circle); ADP-1.0MHz (green diamond); WaveSAX device sea trial site (red star).

Computed wave energy potential (left) and WaveSAX power generation (right), considering the climate of the 2021 year, using the SWAN wave model



### SWAN model validation



The SWAN model has been validated with the wave height acquired by ADP (on the left) and with wave directional spectrum measured with X-band radar (on the right), located on the harbor breakwater at 10 m above sea level. The model simulates with high accuracy the wave height (R2=0.8405, r = 0.9168) in the shallow waters and shows high performance to reproduce the incident and reflected waves (r = 0.96) near the external breakwater, chosen as the best site to place the WaveSAX devices.

## Big Italian Growth

Evaluation of the wave energy potential and WaveSAX power generation in the coastal area around the Civitavecchia port



Breakwater with an array of 2200 units: estimated installed power of 13 MW and annual mean energy production of about 4 GWh/year

> WaveSAX to WaveSAX-2 about + 30% production

Preliminary evaluation of the WaveSAX power generation along the breakwater



	Points		Offshore	Along the breakwaters				
				WS	RW	FA	MA	IA
	Generazione potenziale del	PM2020	1.26	1.01	1.06	1.54	1.47	0.80
	WaveSAX (MWh/m/anno)	PM2021	1.85	1.39	1.41	2.01	1.93	1.2



# Conclusions

- Nominal power per unit, in the wave climate of Civitavecchia, equal to 15 KW
- Control parameters of the turbine, which maximize the conversion capacity: reference speed: 72 rpm <ω <85 rpm ; stiffness constant: 0.016 <kc <0.028</p>
- Preliminary "power matrix", with ample room for improvement, related to positioning (submersion) of the device, optimization of the turbine design, lower mechanical losses (in the prototype 1: 1)
- Development in progress: processing of sea trials of the improved WaveSAX-2 device, carried out in the autumn of 2021

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