

# Development of the French Wave Energy Test Site SEM-REV

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## Abstract

Progress to date in different stages of the SEM-REV French Wave Energy test site development is highlighted in this paper. The SEM-REV will serve wave technology developers as well as research in hydrodynamics related to wave energy extraction. The test site comprises a 2.5MVA power cable connected to the national grid through an onshore substation. The offshore 1km<sup>2</sup> test zone is fully instrumented with 2 wave buoys and a matrix of current profilers hence providing continuous wave climate information.

After completing the initial site assessments [1] and defining the regulatory frame, the development of the project is undergoing several consultation phases.

The SEM-REV permitting process is aiming to obtain a consented zone with pre-arranged permits, which will enable developers to operate easily under the site's requirements. Nevertheless, the identified regulatory frame will be a good baseline for project development in French waters.

Assessment of the performance of wave energy converters relies on accurate measurement and knowledge of the wave climate. Additionally, the electrical analysis of the power systems requires accurate process and preparation of the electrical assets to perform different state measurements.

The SEM-REV wave test site planning is taking into account these requirements to prepare detailed performance testing and future certification.

**Keywords:** wave energy test site, wave energy converter, full-scale demonstration, power assessment

## 1 Introduction

The wave energy test site SEM-REV is running through a development schedule since October 2007. The project is financed under the regional development

French programme “CPER” of the Pays de la Loire Region during the 2007-2013 period. The SEM-REV project, French acronym for Experimental Test Site for Wave Energy Converters, will be located on the Atlantic coast in the Pays de la Loire region and will be operational by summer 2010.

The grid connected test site project planning and development is lead by the Ecole Centrale de Nantes through the Fluid Mechanics Laboratory “*Laboratoire de Mécanique des Fluides*” Hydrodynamics and Ocean Engineering team.

The wave energy test site will consist of an offshore zone including oceanographic monitoring instruments, sub-sea equipments and a high voltage export cable linked to an onshore substation.

## 2 Project description

The SEM-REV wave energy test site is located in the Pays de la Loire French region within 100km from the city of Nantes. The offshore wave test zone will be implemented at approximately 15km off the town of Le Croisic in 35 meters of water depth.

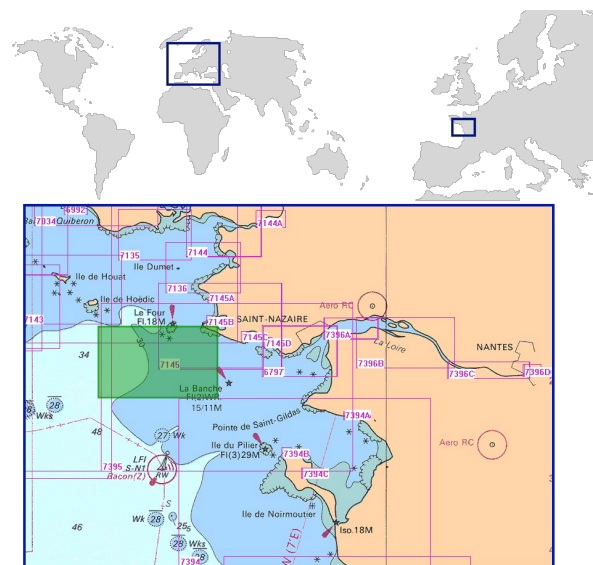
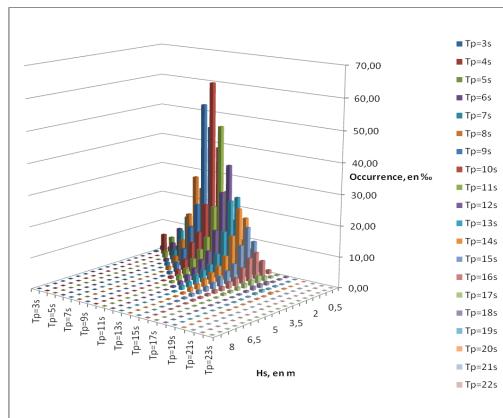


Figure 1: Project location. In green, large area of interest.

The wave test site aims to offer operational conditions for technology developers to demonstrate the operation of their WEC devices in real full scale sea conditions.

The SEM-REV under construction test site will be connected to the grid through a single 3-core 20kv/2.5MVA sub-sea cable. A new substation will be built on land and will receive the power cable junction and further switchgears, protection and power monitoring equipment. This substation will be the connection point to the 20kv local electricity distribution grid which is connected to the national Electricity Transport Network through an existing substation.



**Figure 2:** SEM-REV sea-state occurrence diagram

### 3 Development pathway

#### a. Initial assessments

A baseline study established the basic environmental facts and figures of the intended implementation zone (in green fig. 1). Different criteria have been specified and compared to the project's technical requirements. Based on this feasibility study, a list of environmental, risk and economic factors have been initially evaluated:

- Large and local zones wave regime
- Zone bathymetry
- Local tides and currents
- Grid connection capacity and layout
- Operational capabilities
- Port infrastructures and supply chain availability
- Ecological and environmental factors
- Social acceptance
- Project economic assessment

Also a study of the regulatory and consent requirements in French waters has been undertaken and revised by both a law firm and public authorities. Environmental impact assessment procedures have followed the same process.

Navigation and fisheries activities related to the area of interest have been assessed. A more developed GIS mapping exercise helped to identify zones of possible incompatibility such as military or archaeological protected zones.

#### b. Consultation process

After a first phase of stakeholder identification, the latter have been classified in three categories:

- Statutory regulators
- Strategic stakeholders
- Community stakeholders

| Category               | Stakeholder                                              |
|------------------------|----------------------------------------------------------|
| Statutory regulators   | Energy, Sustainable Development and Environment Ministry |
|                        | National Maritime Affairs                                |
|                        | Pays de la Loire Regional Council                        |
|                        | Loire Atlantique Local Council                           |
| Strategic stakeholders | Fishermen's Organisation                                 |
|                        | Regional Maritime Affairs Agency                         |
|                        | National Coastal Conservatorium                          |
|                        | Electrical Distribution Grid Utility                     |
|                        | Regional Environmental Agency                            |
|                        | Local township representatives                           |
| Community stakeholders | Local and nearby residents                               |
|                        | Leisure fishermen's organisation                         |
|                        | Recreational groups                                      |
|                        | Sailing and diving clubs                                 |

**Table 1:** Stakeholder identification and classification

A core group including the key stakeholders was formed in order to ensure a thorough communication during the consultation process. This technical committee was contacted within different scopes of the consultation phases. A generic plan including project technical information was made and presented to the stakeholders at each event of the consultation time frame.

#### c. Environmental impact assessment

The SEM-REV wave energy test site is a front-runner project in France with regard to offshore wave energy. Environmental legislation is thus lacking specific requirements for this new type of energy project [2]. As to the European Union, a Directive (85/337) on environmental impact assessment (EIA) imposes an evaluation of all environmental consequences for power production projects. The study is required before permit delivery for construction. This legislation has been completed and amended by recent legislative texts, which apply to most power production projects implicitly including wave energy yet not cited.

France has also built a reference national network of environmentally protected zones called "Natura 2000". This networking, in response to the Birds Directive (79/409/CEE) and the Habitats Directive (92/43/CEE),

was established at sea since June 2008 with the enlargement of some previously protected locations.

The French legislation has an Environmental Code that specifies the content of EIA studies. The results of the EIA are compulsory for the permitting process and are regarded as a key component. The EIA comprises the following parts:

**1° Initial state analysis** of the precise zone and its area, including the environmental natural value, marine and coastal resources, leisure and recreational resources and all natural fields impacted by the potential constructions.

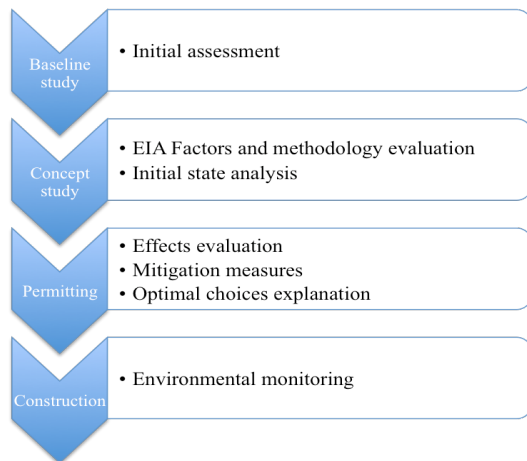
**2° Direct and indirect effects** evaluation of temporary and permanent modifications related to the project incidence on the environment. This analysis is decomposed as follows:

- Physical environment
- Ecosystems
- Landscape
- Human and vicinity aspects
- Security
- Health impacts
- Miscellaneous activities, land and sea use

**3° Explanation of the optimal choices** which lead to the current layout of the project's overall specifications, location and programmed infrastructures.

**4° Mitigation and compensation measures** programmed to reduce or avoid project's damageable consequences for the environment or health. An economic estimation of the mitigation measures is to be provided.

**5° Methodology analysis** of the initially chosen environment aspects assessed or monitored.



**Figure 3:** EIA methodology for SEM-REV

## 4 Permitting process

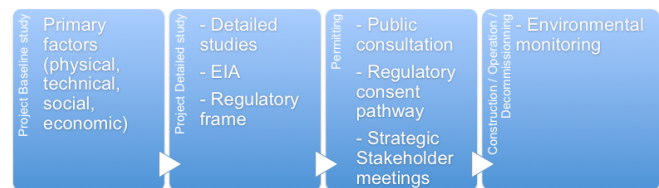
Gaining consent to install a full-scale wave energy test site in France has to follow the existing regulatory frame for power production projects at sea. There are mainly three permits allowing the operation and production of power from the waves:

- A power exploitation permit delivered by the Ministry of Energy

- A temporary concession for the occupation of a restricted sea zone
- An approval related to the French “Water Act”

Other consents such as local construction permits are necessary for coastal constructions and land infrastructure.

The regulatory pathway is an important part of the consent process due to a presence of a relatively important number of strategic stakeholders concerned by the project's evaluation and by the delivery of the permits. It is an important part of the work to phase the pathway as the project advances and to maintain a strengthened communication in the course of regular meetings with the stakeholders.



**Figure 4:** Phasing of the permitting process

Power production and grid connection requires a specific permitting process, which concerns the French utility distribution grid operator ERDF (*Electricité Réseau Distribution de France*) in the case of SEM-REV. The process of grid connection has to run through the following time frame:

1. Power exploitation permit approval
2. Grid connection agreement
3. Power purchase agreement

The grid connection agreement has to undergo a project electrical assessment conducted by ERDF following the project's technical specification provided by the Ecole Centrale de Nantes. Following the conclusion of the detailed electrical study, which verifies the agreement of the technical specifications to the existing distribution grid requirements, a financial and technical proposal is then emitted.

The electrical network assessment is based on the electrical analysis and potential grid impact evaluation of power production on the SEM-REV. Power quality has to respect networks specifications on terms of harmonics, voltage flicker, reactive power, voltage rise and dip and power equilibrium. A system analysis is modelled using generic tools to produce interval limitations that will have to be used by developers. Different states and information is provided to ERDF concerning the electrical behaviour of the production machines under multiple load levels (up to 2.5 MW). Ancillary equipment can be required by the grid operator, such as frequency control and voltage regulation.

## 5 Performance assessment of WECs

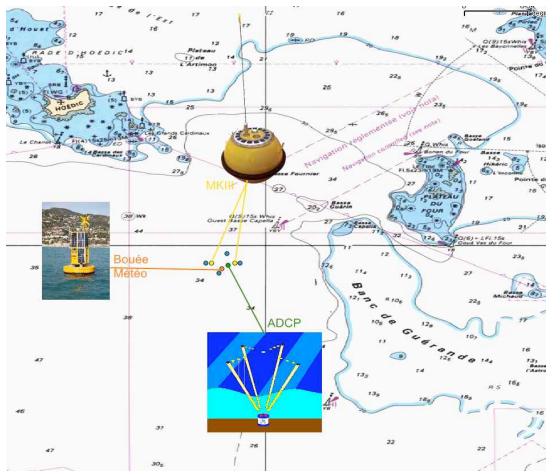
### a. Oceanographic monitoring

The SEM-REV pilot wave test site is equipped with metrology sensors in order to provide the real time monitoring of the environment variables. The test site operates an analysis of the environment variables using the Fluid Mechanics Laboratory ocean engineering tools.

Wave climate modelling is an active research field within the team. The SEM-REV facility allows monitoring and treatment of real time data, as well as short and mid-term wave climate and incoming energy prediction. The ocean engineering research programme of the test site is focused on the deterministic modelling and prediction of the ocean surface.

The oceanographic operational sensors used within SEM-REV are as follows:

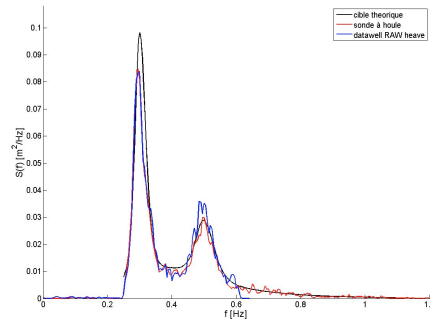
- 2 directional waverider databuoys
- a matrix of current profilers providing reconstruction of wave data
- an offshore weather and HF transmission buoy



**Figure 5:** Layout of the oceanographic sensors

Time series of the marine environment variables recorded are transmitted in real time to shore where the monitoring is operated. In complex sea states, numerical methods [3] are applied to extract from the raw directional wave spectra the significant systems that compose them. The energy distribution is hence obtained with a higher accuracy by using these partitioning methods.

A comparison between the raw wave spectrum provided by the data buoys and a numerically corrected spectrum has been carried out at the Ecole Centrale de Nantes wave tank. These tests showed a good accuracy on the high frequencies, representative of wind swells, which are on the limits of the sensor.



**Figure 6:** Example of peak separation and comparison of the raw spectral accuracy

### b. Power absorption and analysis

WEC power production will be assessed at the SEM-REV substation. The power quality is assessed at the same point. Sea state measurements are related to the real time monitoring of the power quality and the energy flux. Time series can thus be produced corresponding to the instantaneous energy flux in different electrical states of the power take off (PTO). The generator is analysed on three electrical states: operational, with failure and transient. Voltage and frequency stability represent an important part of the system analysis study.

## 6 Conclusion

The SEM-REV wave energy test site will be operational summer 2010. The detailed studies for the design and construction of the electrical infrastructures including the offshore cable and the substation are under revision within the strategic stakeholders. The development of the project is now into the regulatory pathway which is the important key to the success of the publicly funded wave energy test site.

The research programme associated to the instruments deployed all year round at the test zone is being launched based on the experience of the Ecole Centrale de Nantes Fluid Mechanics Laboratory. The real time met-ocean monitoring is a key issue for power production assessment of the WECs.

Finally, the SEM-REV test site is a new facility, which will help the marine renewable energy industry mature and grow faster in a new country aiming to participate in its development.

## Acknowledgements

The SEM-REV infrastructures are the result of a jointly financed project under the regional development programme “CPER 2007 – 2013” of Pays de la Loire region in France.

The governance of the project takes place among a Pilot Committee which includes representatives of the following organizations:

- The Regional Affairs General Secretary (SGAR)
- The Regional Council

- The Local Council
- The National French Research Centre (CNRS)
- The Ecole Centrale de Nantes

## References

- [1] H. Mouslim, A. Babarit and N. Jordana. Project Development of a Wave Energy Test Site in the French Atlantic Coast. In *Proc. 2nd International Conference on Ocean Energy (ICOE 2008), Brest, France.*
- [2] C. Huertas-Olivares, F. Neumann and A. Sarmento. Environmental management recommendations for the wave energy Portuguese Pilot Zone. In *Proceedings of the 7th European Wave and Tidal Energy Conference, Porto, Portugal, 2007.*
- [3] M-A Kerbiriou, M. Prevosto, C. Maisondieu, A. Clément, A. Babarit. *Influence of sea-states description on wave energy production assessment.* In *Proceedings of the 7th European Wave and Tidal Energy Conference, Porto, Portugal, 2007.*