Collecting data for cathodic protection in the field of off-shore renewable energy

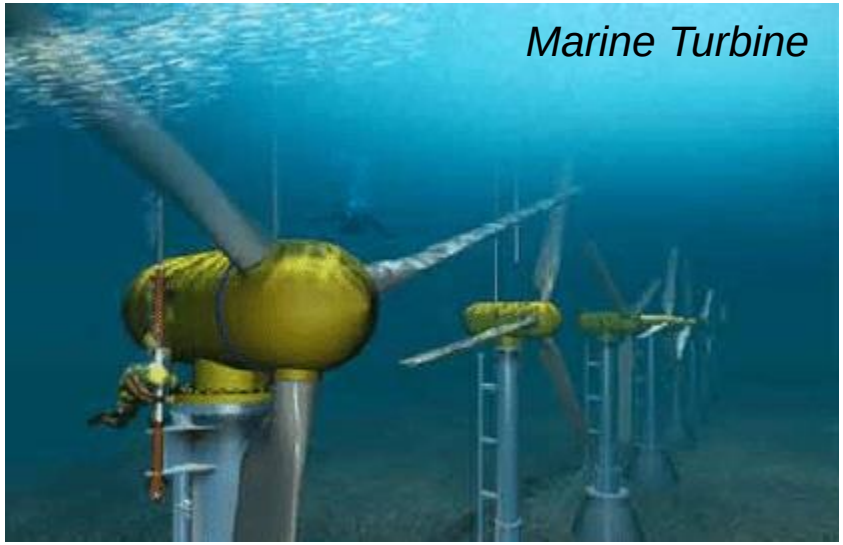
Nicolas Larché, Charles Leballeur and Dominique Thierry

CONTENT

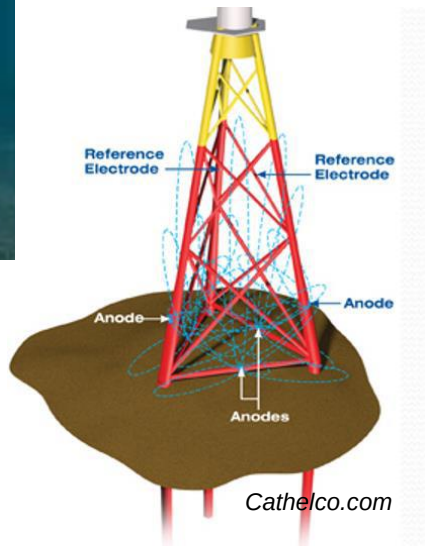
- **INTRODUCTION**
  - ✓ Corrosion & CP design for MARINE ENERGY
- **EXPERIMENTAL**
  - ✓ CP data collection in field OFFSHORE sites
- **RESULTS & DISCUSSIONS**
  - ✓ Effect of location / temperature / flow rates
  - ✓ CP data from bespoke seawater loop
  - ✓ Modeling of cathodic protection
- **CONCLUSION**

INTRODUCTION

- Offshore structures for Marine Energies are generally made of **carbon steel**



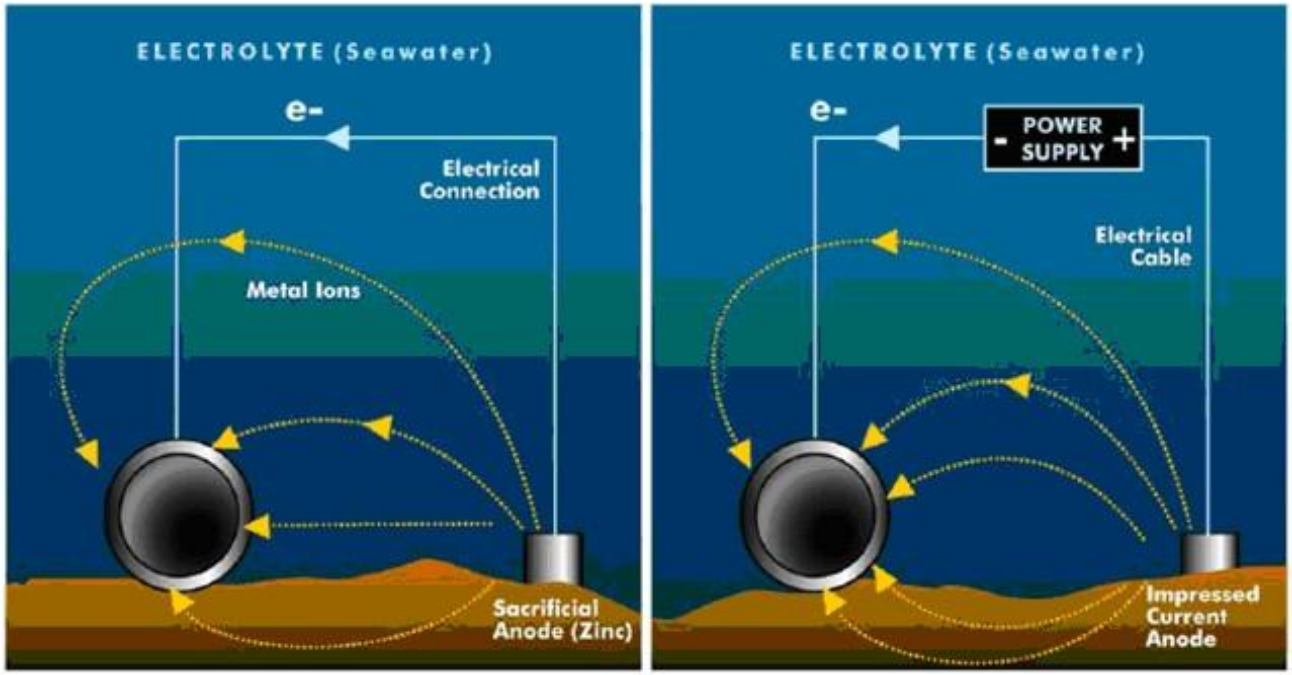
- Huge experience from the Oil & Gas industry



- Corrosion protection with
  - ✓ COATING
  - ✓ Associated with **CATHODIC PROTECTION**

INTRODUCTION

- Cathodic protection principle



- Supply of current to the structure to be protected in aim to lower its corrosion potentiel using anodic material (Al or Zn anodes) or power supply (ICCP)
- Cathodic protection is ensured for carbon steel when potential below -800mV/AgAgCl
- A good CP design should allow to provide enough current to reach this potential during the whole lifetime of the structure

INTRODUCTION

- Cathodic Protection design requires **entrance data (current demand)** generally found in standards or specifications to calculate the anode mass to be used

DNV-RP-B401– June 2017 "Recommended Practice for Cathodic Protection Design"
DNV-OS-C201– July 2017 "DNV Structural Design of Offshore Units (WSD method)"
GS-EP-STR-101 "Design of Offshore Jacket and Subsea Structures"
GS-EP-STR-201 "Material for Offshore Steel Structures"
GS-EP-COR-100 "Design of Cathodic protection of offshore structures"

- However, these standards are limited
  - it does not consider specificities of project's sites (only averaged initial & mean current densities for main locations)
  - uncomplete data to do modeling → **need complete polarization curves**

INTRODUCTION

- Main parameters affecting current demand to protect steel
  - Temperature/dissolved oxygen
  - Flow rate
  - Formation of **calcareous deposit and/or biofilm** *(time dependent)*

→ **All these parameters can lead to very different polarization behavior**

RISK of UNDER or OVER design

- Offshore marine structures can be expected to face high flow rates and extrem conditions → not considered in standards

INTRODUCTION

- From this background FCI developed a system able to
  - Collect long-term CP data *in-situ* (effect of deposit/biofilm…)
  - Collect key environmental parameters (flow rate, temperature, oxygen…)

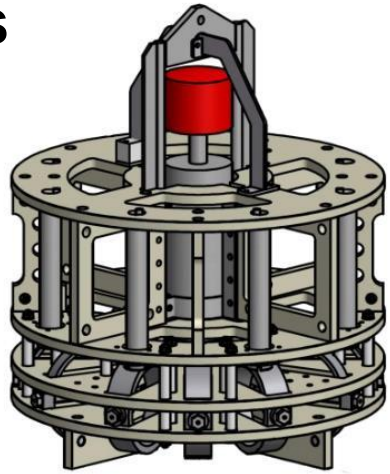
CP sensors and instrumented arrays for field deployement to get *in-situ* and complete site characterisation

EXERIMENTAL

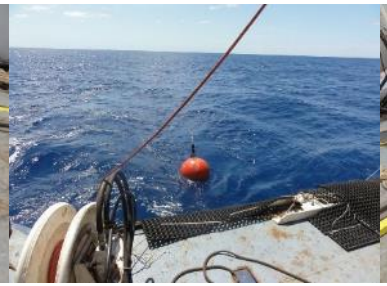
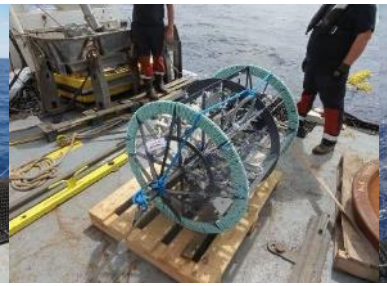
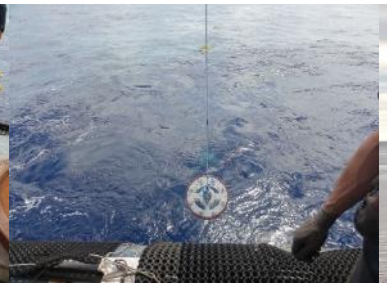
ANCHORED LINE - Instrumented Array

Environmental parameters

- ✓ Flow velocity
- ✓ Dissolved O_2
- ✓ Temperature
- ✓ Conductivity
- ✓ Salinity



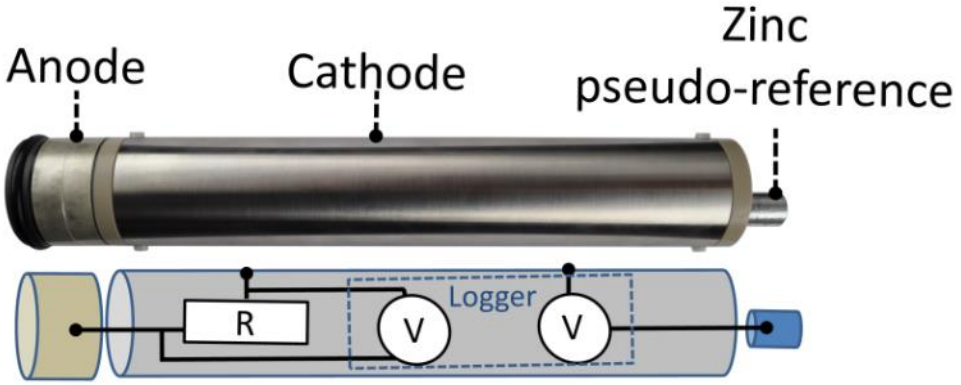
Cathodic Protection (CP) sensors

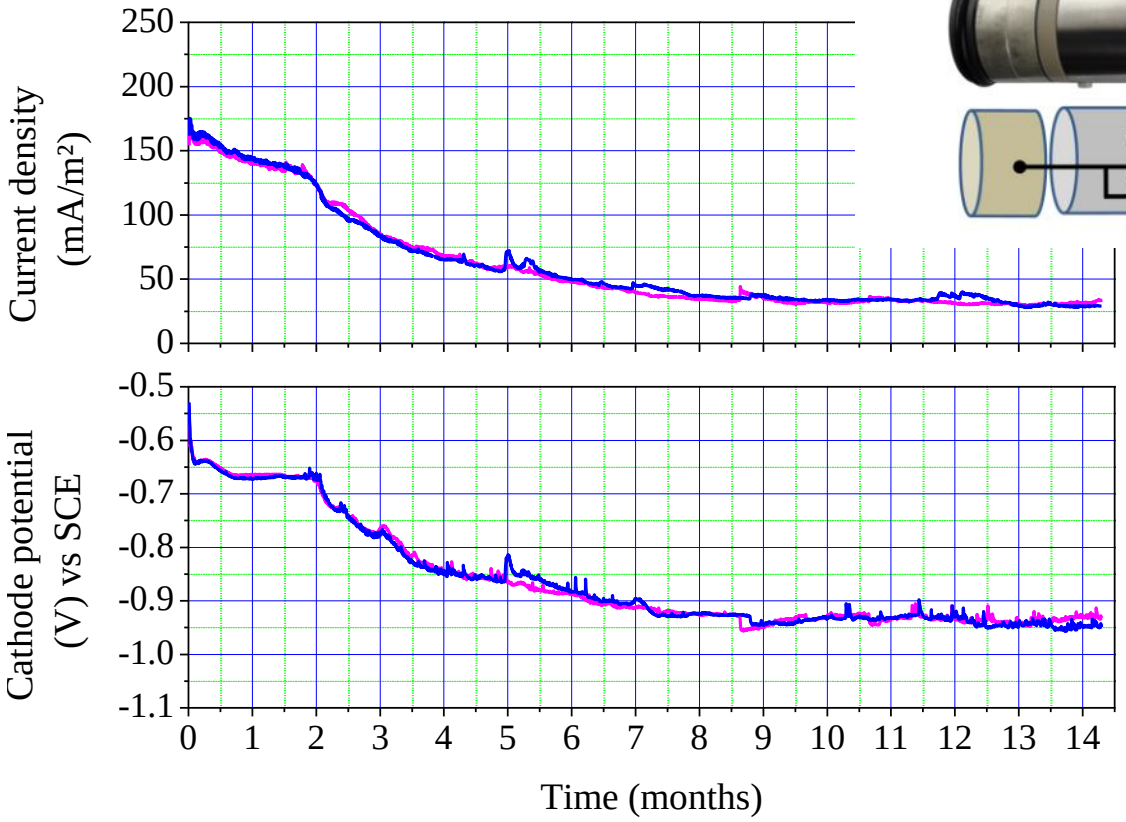






EXERIMENTAL

Potential and current density logger in seawater

- Cathodic protection criteria *in situ*





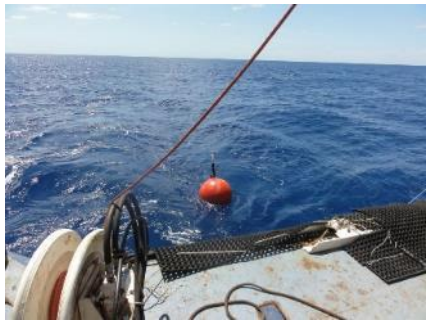
1 sensor = 1 current/potential couple

EXERIMENTAL

Field data collection

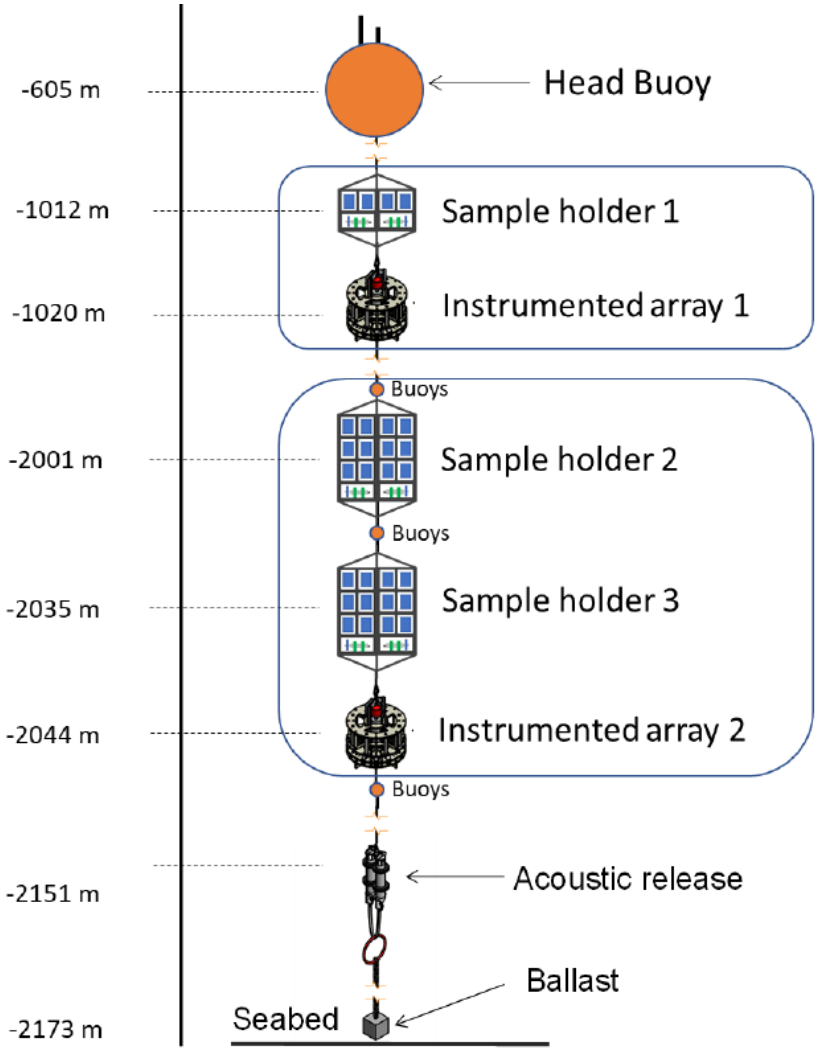
Experience in instrumented anchored line

Design is adpated for each test site and targets



Can be deployed at 3000 m depth

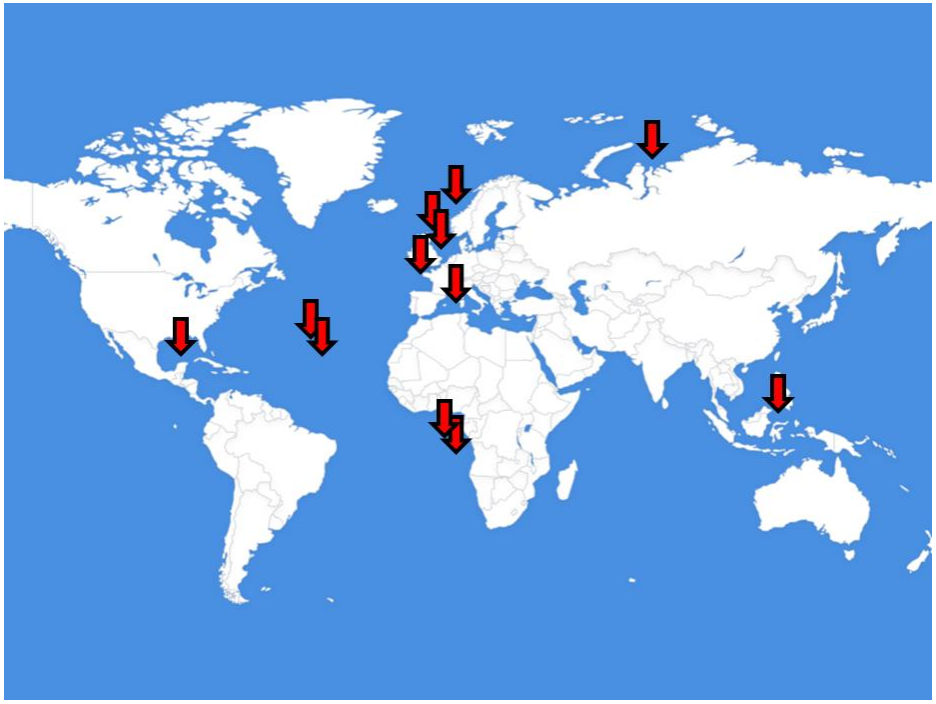
Autonomous >2years



EXERIMENTAL

Some sites where we have collected CP data

Oil & Gas structures : *√Angola √Congo √Gulf of mexico √Norway (North sea) √Scotland √Momar (Atlantic Ocean at -1000 and -2000 m) √Indonesia √Mediteranean sea √Siberia (Yamal)…*

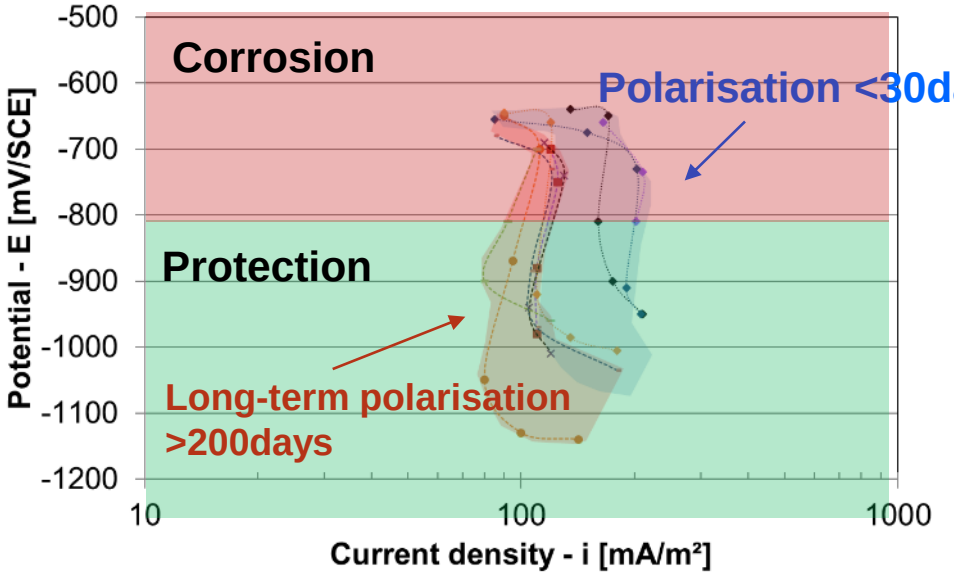


Offshore wind –monopile
√Sheringam shoal (UK)

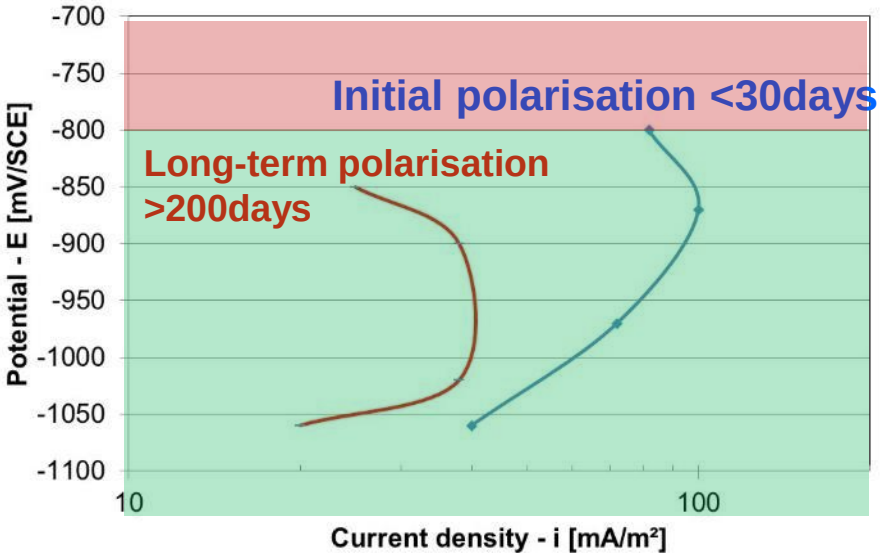
Tidal Marine Turbine
√ Fromveur Brittany (high flow rate)

RESULTS

Atlantic Ocean
Quiescent Flow ~ 0,1m/s – T°C = 5 to 15°C – SHALLOW WATER



Tropical Sea
Quiescent Flow ~ 0,1m/s -T°C = 30°C
SHALLOW WATER



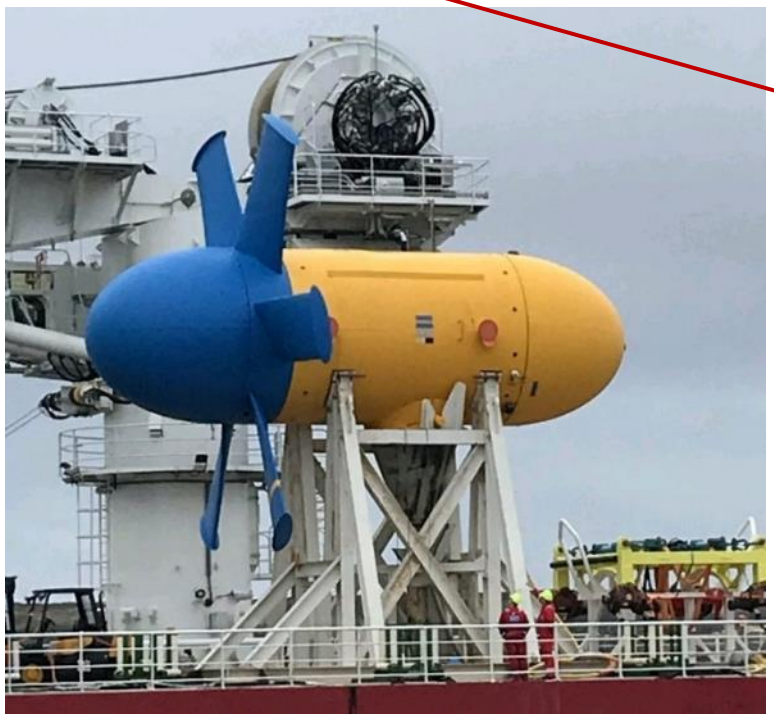
- ❑ Specific results for each test sites
- ❑ Significant effect of calcareous deposit
- ❑ More current densities globally required at lower temperatures (higher DO)

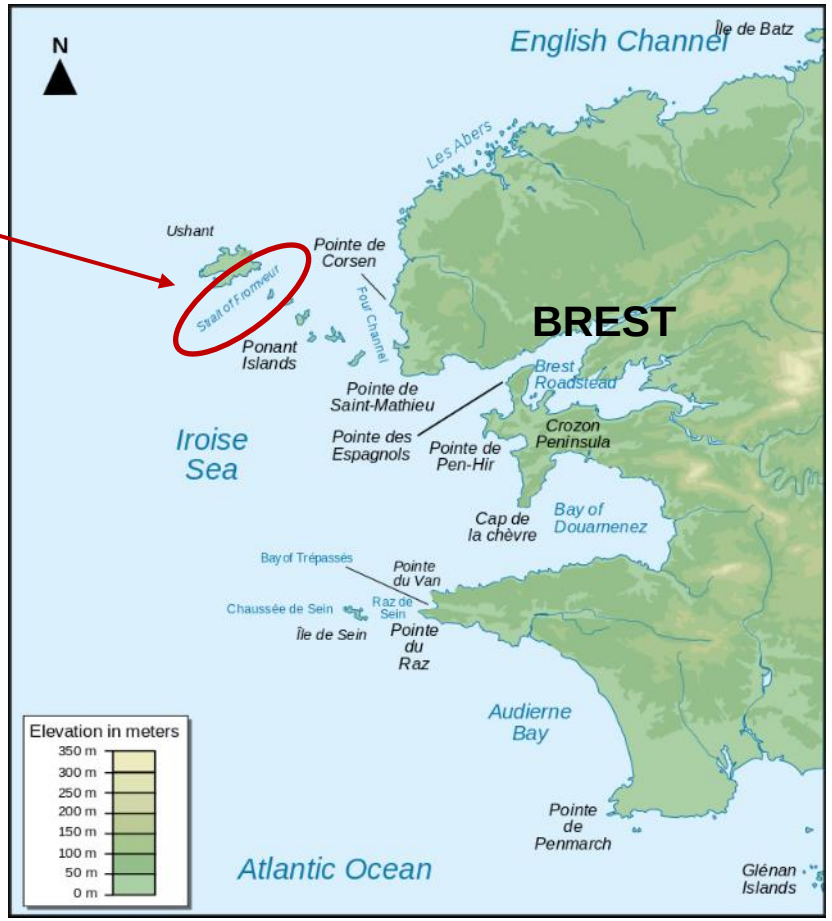
RESULTS

Field data collection

Marine Energy, CP-data of carbon steel at high flow rates

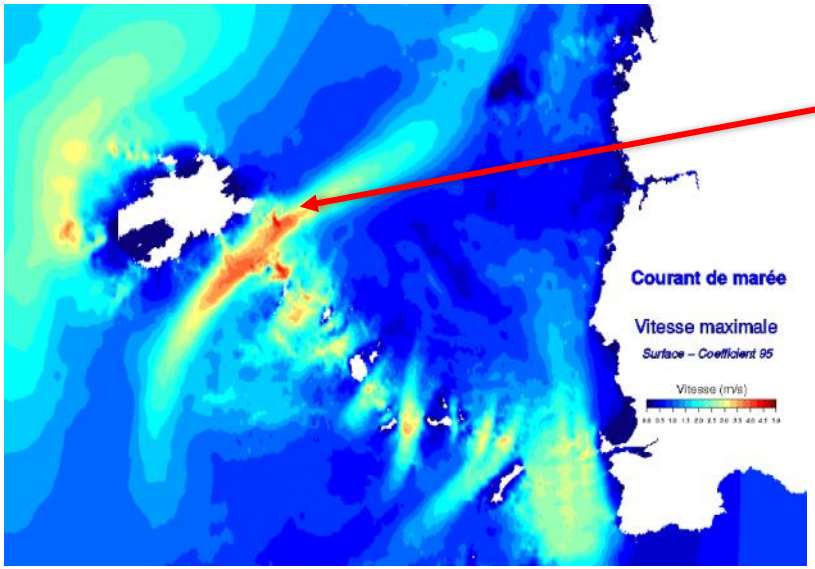
Cathodic protection sensors have been installed on a Tidal turbine in the strait of Fromveur close to Brest (second strongest currents in France)





RESULTS

Field data collection



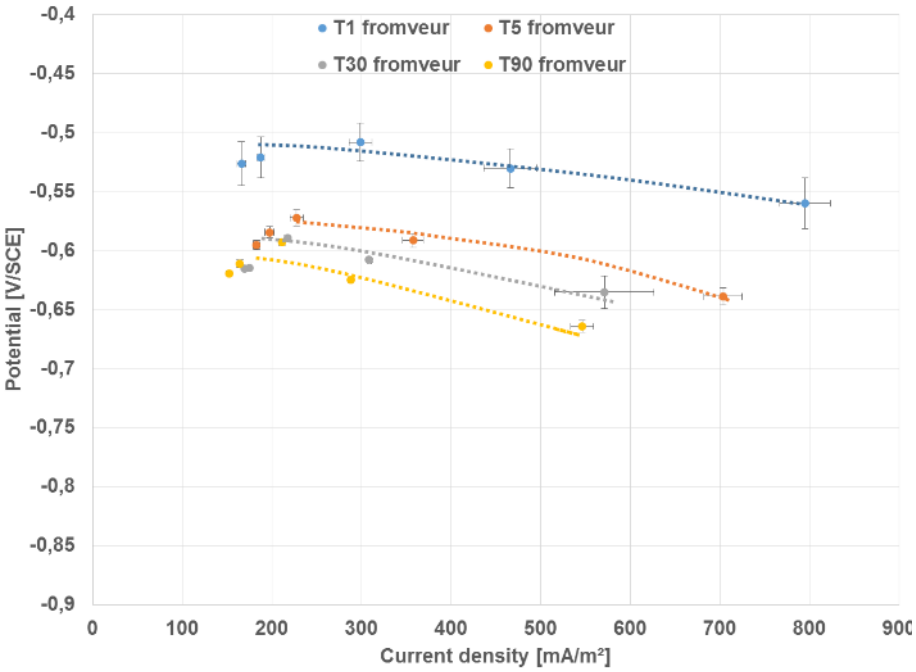
Tide flow rate ~ 6 m/s

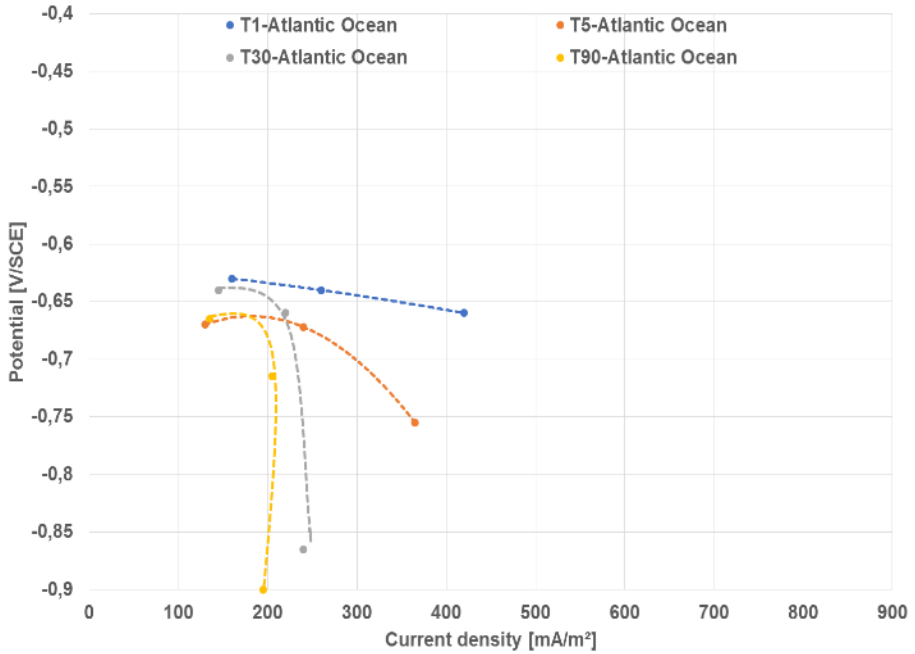
- 90 days exposures for a preliminary testing

- Turbulence close to the turbine

RESULTS

Preliminary results in 6m/s Fromveur vs quiescent Atlantic Ocean



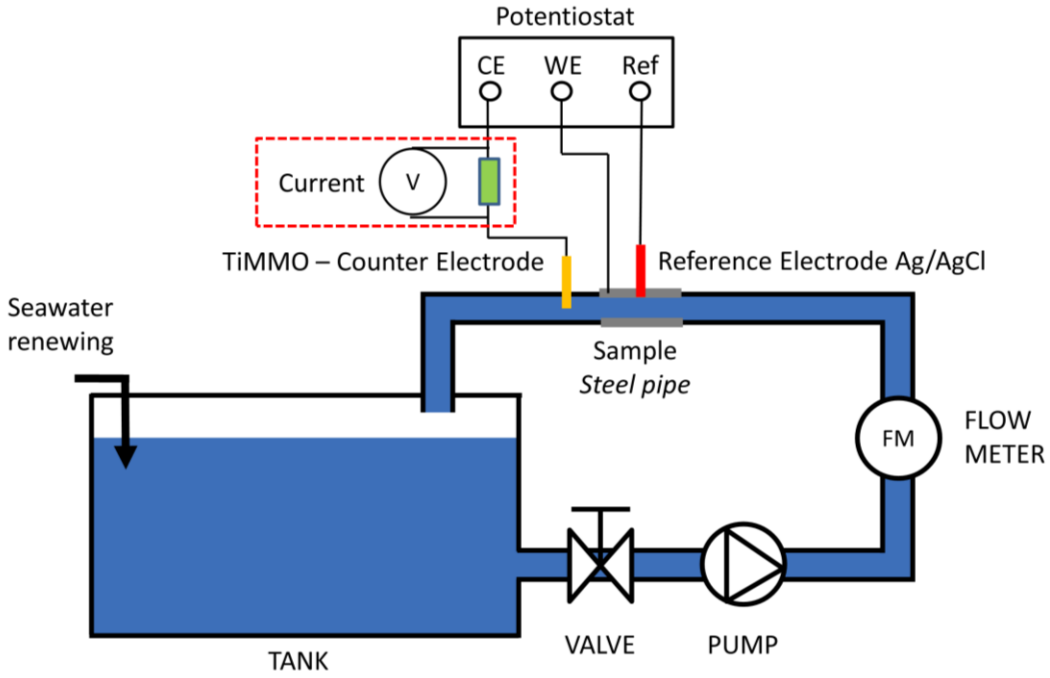


- The standard sensor configuration did not allow the polarization to CP criteria after 90 days due to the extremely high current demand observed in Fromveur
- Sensors with other configuration (allowing higher current) have been re-deployed for longer exposure (*in progress*)

Laboratory Data collection

BESPOKE FLOW LOOPS

Effect of geometry (internal CP) / Effect of flow rate



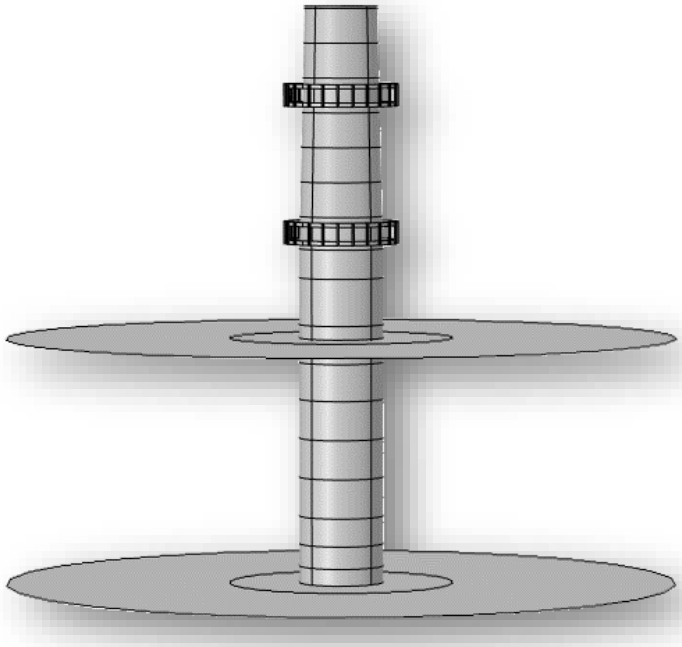
- ❑ Brest natural seawater station
- ❑ Temperature from 4 to 90°C
- ❑ **Control of the flow** from <0,2m/s to 6m/s
- ❑ Continuous monitoring of CP data potential+current

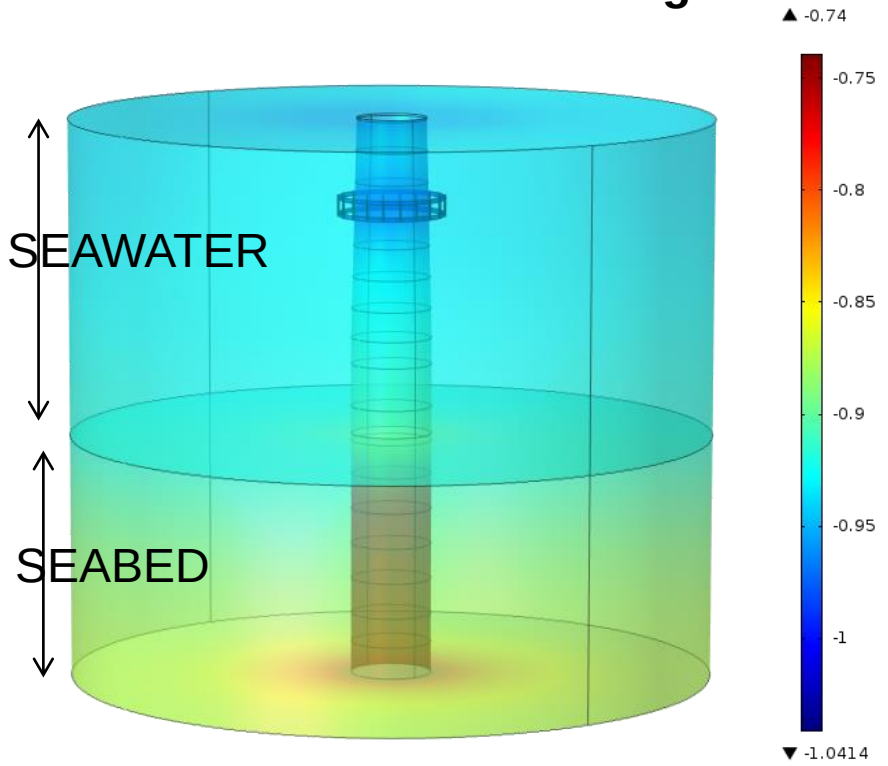
PARAMETRIC STUDIES

- ❑ **Measurements**
  - ➢ Fixed potential
  - ➢ Current (evolution)
  - ➢ Flow rate, temperature, pH, conductivity
- ➢ Corrosion evaluation
- ➢ Calcareous deposit (mass loss)

Modeling

Field polarisation curves are used in COMSOL software for modeling





- CP Design optimization for anode bracelets
  - *E gradient including seabed*
  - *Anode interference*

  (optimized space between anodes)

CONCLUSION

- CP data from commonly used standard does not allow accurate CP design and modeling
- Instrumented arrays have been developed and deployed to collect long-term CP data in different field conditions
- The flow rate very significantly affects the polarisation and CP design, which cannot be done from standards
- The sites dedicated for offshore marine energies shall be further characterized for accurate CP design of the immersed structures

ACKNOWLEGMENTS

Most results of this presentation are selected from published parts of a Joint Industrial Project and Consultancies

All the sponsors of these studies are gratefully acknowledged

charles.leballeur@institut-corrosion.fr

THANK YOU !