

1. Context the course:

This course was the second edition of a course that was run for the first in 2013 in Aalborg (Denmark) over the two weeks before the 10th European Wave and Tidal Energy Conference (EWTEC2013). This first edition was very successful with 25 participants. Thus the organizers wanted to run it again in the occasion of the EWTEC2015 conference.

The course provided training in the numerical and experimental modelling and control of wave energy converters. It is particularly suitable for PhD students starting a PhD project in the field of wave energy conversion. It is the only course providing such training worldwide, which explains why it has proven to be very popular.

2. Objectives of the course:

The main objective of the course was to train each participant to the numerical and experimental modelling and control of Wave Energy Converters (WECs).

The following topics were taught:

- The State of the Art of wave energy conversion techniques
- The State of the Art of numerical modelling of WECs, the limitations and the alternative numerical approaches
- The State of the Art of experimental modelling of WECs, the limitations
- The State of the Art of control of WECs

By the end of the course, the participants had carried out the following tasks:

- Wave measurement and generation in wave tank
- Numerical investigation of the performance of a WEC
- Experimental investigation of the performance of a WEC with and without control

3. Content:

The course was structured in parts that are described in the following:

- **Day 1 - Introduction to Wave Energy Utilization:** The objective was to introduce the students to wave energy utilization. It provided a screening of the history, the resource, the activities around the world, the technologies and the project development approaches. This part of the course was composed of lectures.



Some of the students performing wave analysis on day 2.

- **Day 2 - Ocean waves analysis:** The objective was to introduce the students to ocean waves, their analysis and their generation in wave tanks. The students had the opportunity to experiment wave generation and measurement in the large wave tank of Ecole Centrale de Nantes (ECN). Wave analysis was performed by the students on their measurements using the Wavelab software (developed by AAU). This part of the course was composed of lectures and a tutorial at the large wave tank of (ECN).
- **Day 3 to 4 and 6 – Numerical modelling of wave energy converters:** This part of the course covered the different aspects that need to be taken into account in the numerical modelling of WECs : wave modelling, wave/structure interaction, Power Take-Off (PTO) technologies and modelling, time domain modelling. Lectures were given on the state-of-the art modelling techniques. In tutorials, students had the opportunity to use these techniques and developed a frequency domain model of an absorbed of the Wavestar wave energy converter. The students used the Matlab and Nemoh softwares during the tutorials (Nemoh has been developed in ECN). In this part of the course, 2 guest lectures were given on advanced numerical modelling techniques for fluid/structure interaction.
- **Day 5 – Visit to the SEMREV full scale test:** A visit to the shore base of the SEMREV full scale test site was organized. A presentation of the site, its objectives and current activities was given to the students.



Picture of the 5 Wavestar absorbers installed in the wave tank of Ecole Centrale De Nantes. The participants performed experiments on these set-ups.

- Day 7 to 9 – Control and experimental modelling of wave energy converters:**
This part of the course introduced the students to the control of wave energy converter and the experimental modelling. It started with lectures. Then, the students had the opportunities to perform experiments on 1/20 scale model of absorbers of the Wavestar WEC that were provided by AAU and installed in ECN wave tank. In tutorials, the students investigated the performance of the Wavestar absorbed both in regular and irregular waves, first with resistive control and then with active control. Meanwhile, they carry on the development of their numerical models of the Wavestar absorbed and they made comparisons of numerical predictions and experimental measurements.
- Day 10 – Guest lectures:** 3 guest lectures were given by high level scientists on wave propagation modelling, wave interactions in arrays of wave energy converters, and practical experience with the experimental modelling of the Pelamis WEC. In the end of this day, the winners of the control competition (see next section) were announced and awarded with a prize.

The detailed course program is provided in appendix. A dropbox folder was created to store the material of the course (pdf of presentations and description of exercises) The course material can be found on:
<https://www.dropbox.com/sh/u42ndivfznbpgfb/AACv3HTbriieR0Gu8-Vx3ayXa?dl=0>

During the course, the students were given the opportunity to present themselves and their work to the other. It was done from time to time during the course on a voluntary basis. Most of the students prepared a few slides on their project and presented themselves. They added their presentation in their participant folder in the dropbox.

4. Control competition:

A control competition was organized. It was announced in the beginning of the course that the group (tutorials were carried out by groups of 3 students) that would be able to design the best active control for the Wavestar absorber would win a prize and would be awarded

with a certificate. Best control meant that the energy performance had to be maximized while taking into account the constraints (limited stroke and maximum PTO force delivered by the actuator). The performance was measured in the experiments. The students had to prepare a report and the results were judged based on this report.

5. Participation



Group picture of the participants on Day 5 after the visit to the SEMREV test site

With 36 participants, the course was a great success. It was fully booked as early as April 2015. There are 13 names on the waiting list. 17 different nationalities were represented at the course:

- Australia (2)
- USA (1)
- Canada (2)
- South Korea (1)
- China (1)
- Ireland (3)
- Sweden (2)
- Spain (2)
- UK (2)
- Germany (1)
- Netherlands (1)
- Portugal (4)
- Denmark (6)
- Lebanon (1)
- Italy (1)
- France (6)

5. Conclusion

This second edition of the course was a great success. The number of participants was initially seen as a challenge but it was ok in the end. However, we don't recommend increasing it any further.

The participants were highly motivated and worked very hard. Even though we believe that they would have worked hard anyway, the control competition was a plus and gave them a final goal to achieve. We recommend implementing it again for the next edition of the course.

According to the participant feedback, the course content is excellent with a good balance between lectures and tutorials. The experimental activities are a big plus. It was found to be very interesting to perform numerical and experimental modelling on the same case study in parallel. This should be kept as much as possible.

The course was also judged intensive by the students. If possible, it may be beneficial to extend it in time.

Given the number of participants and number of names on the waiting list, it may be considered re-running this course earlier than the next EWTEC conference (EWTEC2017). An opportunity may be the next Asian Wave and Tidal Energy Conference in 2016.

5. Acknowledgments

The organizers of the course gratefully acknowledge the financial support from Ecole Centrale De Nantes, Aalborg University, Labex MER (ANR-10-LABX-19-01).

The course was organized in collaboration with OceaNET (Marie Curie actions of the European Commission, FP7-PEOPLE-2013-ITN) and WavEC Offshore Renewables.

6. Appendix : detailed program of the course

Course program: Numerical and experimental modelling and control of Wave Energy Converters

Week 1/2

	Tuesday 25 Introduction to wave energy utilization	Wednesday 26 Ocean waves	Thursday 27 Wave structure interaction	Friday 28 Wave to wire modelling	Saturday 29 SEMREV visit	
LHEEA - Ecole Centrale de Nantes, 1 rue de la Noë, 43000 Nantes, France +33 (0)2 40 57 16 25 - www.ec-nantes.fr	8:30 - 9:00	Ocean Waves 1: time and frequency domain time series analysis JPK	Follow-up AB	Follow-up AB	Drive to Le Croisic AB	
	9:00 - 9:30		General introduction to the course AB & JPK	Ocean Waves 2: Linear waves GD		PTO modeling, from floating body to WEC AB
	9:30 - 10:00		Introduction to wave energy utilization JPK		Linear floating body response - open source BEM code Nemoh AB	
	10:00 - 10:30					
	10:30 - 11:00	Visit of ECN facilities + introduction of exercise JPK & MK & SB & FB				
	11:00 - 11:30					Lunch at Le Croisic
	11:30 - 12:00					
	12:00 - 12:30					
	12:30 - 13:00					
	13:00 - 13:30					
13:30 - 14:00	Introduction to wave energy utilization JPK	Wave measurement and generation in ECN's wave tank JPK & MK & SB & FB	Linear floating body response - open source BEM code Nemoh (cont.) AB	W2W modeling - frequency domain AB - MA	Outdoor activities AB	
14:00 - 14:30			Numerical investigation of response of floating structures in waves AB - MA			
14:30 - 15:00						
15:00 - 15:30	Experimental performance investigation of WECs JPK					
15:30 - 16:00						
16:00 - 16:30						
16:30 - 17:00						
17:00 - 17:30					Drive back to Nantes AB	

AB: Aurélien Babarit - JPK: Jens Peter Kofoed - MK: Morten Kramer - SB: Sylvain Bourdier - FB : Félicien Bonnefoy - GD: Guillaume Ducrozet - LG : Lionel Gentaz - MA: Marco Alves

Lecture
 Visit
 Exercise
 Guest lecture



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Course program: Numerical and experimental modelling and control of Wave Energy Converters

Week 1/2

	Tuesday 25	Wednesday 26	Thursday 27	Friday 28	Saturday 29			
	Introduction to wave energy utilization	Ocean waves	Wave structure interaction	Wave to wire modelling	SEMREV visit			
8:30 - 9:00			Follow-up AB	Follow-up AB				
9:00 - 9:30	General introduction to the course AB & JPK	Ocean Waves 1: time and frequency domain time series analysis JPK	Ocean Waves 2: Linear waves GD	PTO modeling, from floating body to WEC AB	Drive to Le Croisic AB			
9:30 - 10:00	Introduction to wave energy utilization JPK				Visit of ECN facilities + introduction of exercise JPK & MK & SB & FB	Linear floating body response - open source BEM code Nemoh AB	CFD modeling - RANSE + SWENSE LG	SEMREV visit & presentation, DanWEC presentation CB
10:00 - 10:30								
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Lecture Visit
 Exercise Guest lecture

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