MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Welcome

Welcome!

Welcome to the third MEDOW newsletter!

This issue reports on our network training week at DTU Wind in Roskilde in June and shares another researcher's secondment experience.

The MEDOW (Multi-Terminal DC Grid for Offshore Wind) project is investigating DC (direct current) grids for transmitting offshore wind power. MEDOW researchers are working on the technology that we hope will form the basis of a future European 'supergrid'.

Please pass the newsletter to those who you think will be interested and ask them to contact me to join the mailing list.

A newsletter will be issued 3-4 times per year and will aim to communicate not only news from MEDOW but also news of interest to the wider research community and the public, so contact me if you have news from the DC grids, HVDC, offshore wind, power electronics or renewable energy communities that can be included in the next issue.

Cath Roderick
MEDOW Project Officer
RoderickCH@cardiff.ac.uk

Find us on Facebook

MEDOW is funded by the Seventh Framework Programme of the European Union under grant agreement no. 317221

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Network Training

Whenever possible, our 'network training activities' will be open to researchers from outside the network so as to ensure that as many people as possible benefit from the project.

Want to take part?

Email Cath Roderick
RoderickCH@cardiff.ac.uk

Network training week at DTU Wind, Roskilde, Denmark June 2015

As an 'Initial Training Network', we aim to give our researchers wide-ranging training in the technical and supporting skills that they need to embark upon successful and productive research careers in the private sector as well as in academia.

Our last meeting took place in June in Roskilde. You can see reports on what we did on our website and on pages 3 and 4 of this newsletter.

The following activities were open to researchers from outside the network and we were really pleased to be joined by a number of researchers from DTU Wind Energy department.

Monday 15 June
Giving Power Presentations
Tuesday 16 June and Wednesday 17 June
Wind Power Summer School:
Visit to Middelgrunden Offshore Wind Farm
Lectures by DTU Wind experts
Thursday 18 June
Assembly Meeting—MEDOW work packages presented their objectives and results.
Lecture on *Modular Multilevel Converters in HVDC Applications* by Prof Remus Teodorescu of Aalborg University

Our next network event will take place from 30 November in Barcelona; certain activities will be open to researchers from outside the network. check our website for details soon!

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

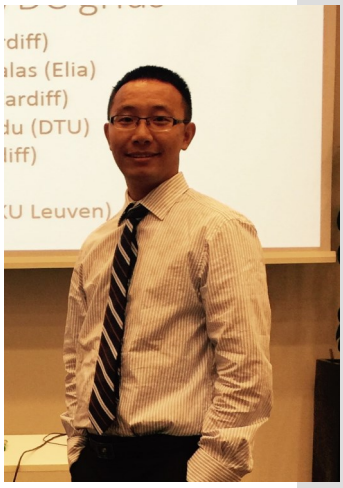
Newsletter
July 2015
Issue 3

Network Training

Photos: Ataollah Mokhberdoran, Marc Cheah

Visit to Middelgrunden Offshore Wind Farm, June 2015

Along with some other researchers from the DTU Wind Energy Department, the MEDOW ESRs and ERs visited the Middelgrunden offshore wind farm which consists of 20 fixed-speed turbines with a combined capacity of 40MW and is situated 3.5 km outside Copenhagen harbour. The trip was led by Hans Christian Sørensen of SPOK Consultancy, who oversaw the planning and commissioning of the wind farm.



ESR Gen Li said: “After around 20 minutes on the boat, we arrived at the very left wind turbine of the wind farm. The capacity of the turbine is 2 MW. The height of the hub is 64 meter. The rotor diameter is 76 meter. The total height is 102 meter! All of us climbed to the top of the turbine. We looked around inside the narrow hub, the generator and the turbine. The generator is from ABB, it was still warm when we touch it! Outside the window, we could look at the panorama of the whole OWF. It was a magnificent sight on the top of an offshore wind turbine! It was very cool to have an experience on the top of an offshore wind turbine.”

This was a really unique opportunity for the MEDOW researchers to visit a working wind farm and to see how their research might be applied.

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Network Training

Training on 'Giving Powerful Presentations', June 2015

Along with some other researchers from the DTU Wind Energy Department, the MEDOW ESRs received training on how to deliver better presentations and talks.

ESR Mohammad Meraj Alam reports back on the session:

The lecture was exceptionally focused on the effective style of presenting ideas - with a focus not only on verbal communication and on scientific ideas, but also on the body language of the presenter.
Some real experiences were shared by our trainer, Miss Birte, together with collaborative real time activities. The Early Stage Researchers actively took part in the presentations. One of the valuable and handy materials distributed to all of the researchers is a small, laminated paper, with helpful hints for presentation printed on it.
It is worth mentioning a few of the points that should be taken into consideration while presenting:

<u>Before the presentation</u>

⇒ Have extra topics ready for extra time
⇒ Prepare and use only 3/4 of your time, reserve the rest for the audience
⇒ Do a rehearsal
⇒ Memorize opening and closing remarks
⇒ Organize a timekeeper

<u>During the presentation</u>

⇒ Smile and keep eye contact
⇒ Vary your vocal pitch and volume
⇒ Remember your facial expression and gesture
⇒ Show enthusiasm about your subject
⇒ Be humorous and involve your audience as much as possible

<u>After the presentation</u>

⇒ Make notes on time and other participants
⇒ Write down comments and suggestions and evaluate your presentation

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Network Training

Invitation to the 6th Annual HVDC Doctoral Colloquium

The HVDC Doctoral Colloquium first took place in 2010 and has grown into an international meeting of some of the most active European universities in the HVDC domain, providing an opportunity for PhD students and researchers to present and exchange their work.

Danmarks Tekniske Universitet (DTU) is honored to host the 6th HVDC Doctoral colloquium at the ***DTU Risø campus in Roskilde*** on ***16-18 September 2015***.

The colloquium will allow researchers and PhD students to discuss the research they are doing in the rapidly growing field of HVDC transmission for integration of large scale offshore wind power plants and offshore grids. Presentations will include topics such as HVDC transmission, control of RES, protection of DC grids, modular multi-level converters (MMC), AC/DC grids interaction and stability and scaled laboratory setups.

The event is co-organized and supported by the FP7 ITN MEDOW consortium, the Nordic Energy Research OffshoreDC consortium and the WINDGRID network. Participation is free of charge, but participants (outside the organizing/Partners/consortia) will have to cover catering expenses and participation in the dinner/social event. The estimated cost is 400 DKK for the catering and 600 DKK for the dinner/social event.

For Registration, please send an **e-mail to Jayachandra Sakamuri** jays@dtu.dk with your details (Name, Designation, Organization). Please mention if you would like to participate in the social event/dinner.

Partners:
DTU, Wind Energy Department
Imperial College London
Universitat Politècnica de Catalunya
KU Leuven
Universidade do Porto, Faculdade de Engenharia
Cardiff University

WINDGRID

OffshoreDC.dk

Co-organized/supported by:
MEDOW
OffshoreDC.dk
WINDGRID

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Other Training

PSCAD™ User Group Meeting, Valencia, May 2015

As an 'Initial Training Network', we aim to give our researchers wide-ranging training in the technical and supporting skills that they need to embark upon successful and productive research careers in the private sector as well as in academia.

In May, ESRs Muhammad Raza and Kevin Schönleber, both enrolled on PhD programmes at Universitat Politècnica de Catalunya , Barcelona, too part in three days of technical discussions, presentations and tutorial workshops led by the Manitoba HVDC Research Centre (MHRC), in collaboration with INDIELEC.

PSCAD™ is software which allows power systems researchers to build, simulate, and model power systems, an essential part of the kind of researcher which MEDOW's team is carrying out.

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Secondments

KU Leuven ESR Robert Renner spent some months earlier this year on secondment to Elia System Operator, the electricity transmission system operator of Belgium

Industry, especially transmission system operators, are confronted with challenges every day. Thus, the secondment corresponds to a current problem, which is the description of voltage source converter in steady state and transient conditions. This is caused by the fact that VSC for electrical transmission systems were developed in the 90's and, until now, only some VSC HVDC systems are in operation. Thus, the experience and knowledge of this new equipment in combination with the AC power system is still limited.

A description of the real time operation behaviour would help system operators and planners to decide how electric transmission systems could be extend in the most efficient way. One question that is relevant for real time operation is how the dynamic behaviour of VSC HVDC is, if the short circuit power of the connected AC power system is strongly variable. This could be the case if a VSC HVDC station is connected to a EHV level and at the same bus bar via a transformer to a lower voltage level. If the EHV connection has a failure the HVDC VSC is still connected to the AC system but with a strongly reduced short circuit power. How will it react with common controller design, is it stable and if not, are solutions available.

The outcome of this secondment is a presentation and will be a paper which describes VSC stability, regarding short circuit power at point of common coupling (PCC) for systems between short circuit ratio 5 and 1. In addition, a PQ diagram for VSC converters was derived. Therefore, the stability related components in VSC were identified and their influence and range described. The theoretical part is complemented with simulations of case studies to validate the theoretical limits for a defined situation. Control parameters in the voltage and power control loop were set during initialization and not changed while simulation.

Results were discussed with Elia experts for controllable devices, synchronous generators and system operation. Each of them gave valuable input to the results and especially to the current state of electrical power systems. The knowledge gained was increasing the understanding how VSC work and which influence they have to AC power systems. It was also valuable to present the results to increase presenting skills and come in contact with experts from industry.

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Results

Research outputs

Recent publications by MEDOW researchers include:

IEEE PowerTech2015, 29 June-02 July 2015, Eindhoven Netherlands
Paper on *Subsynchronous Oscillatory Stability Analysis of an AC/DC Transmission System* presented by Tibin Joseph

International Conference on Power Systems Transients 2015
Cavtat, Croatia, 15 – 18 June 2015
Paper on *Fast Breaker Failure Backup Protection for HVDC Grids* co-authored by Sahar Pirooz Azad

9th International Conference on Power Electronics – ECCE Asia (ICPE 2015-ECCE Asia), 01-05 June 2015, Seoul, Korea
Paper on *Elimination of MMC Differential Currents via a feedback LTI control system* presented by Abel Ferreira and Rodrigo Teixeira Pinto

ACROSS BORDERS - HVDC SYSTEMS AND MARKETS INTEGRATION, 2015 CIGRE Symposium, 27-28 May 2015, Lund, Sweden
Paper on *Investigating Distance Relay Behaviour on an EHV AC Lines Connected with Voltage Source Converter Based HVDC* presented by Mohammad Meraj Alam

MEDOW also plans to participate actively in future large international conferences, including:

2015 IEEE Power & Energy Society General Meeting, 26-30 July 2015, Denver, United States

7th Conference on Power Electronics and Applications (EPE'15-ECCE Europe), 8-10 September 2015, Geneva, Switzerland

Take a look at the full list on our dissemination webpages at www.medow.engineering.cf.ac.uk

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Results:

PowerTech 2015

In June 2015, MEDOW doctoral student Tibin Joseph presented a paper at IEEE Powertech 2015 in Eindhoven.

The paper, *Subsynchronous Oscillatory Stability Analysis of an AC/DC Transmission System*, was presented as part of the session on 'Hybrid AC/DC distribution technologies'.

In the paper, a formal analysis of torsional interactions -a form of subsynchronous resonance (SSR)- in series-compensated systems featuring voltage source converter (VSC) based high voltage direct-current (HVDC) links are investigated. Two AC/DC systems are studied. The first one consists of the IEEE First Benchmark Model for SSR studies which has been upgraded with a point-to-point VSC-based HVDC link. The second system represents a simplified yet upgraded future GB power system, where reinforcement is achieved through onshore series compensation and offshore submarine VSC HVDC transmission. Detailed state-space representations of the systems under study have been constructed. Stability assessments have been carried out using eigenanalysis, with results agreeing well with those obtained through time-domain simulations.

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Results:

2nd Annual Conference of EPSRC Centre for Power Electronics

In June 2015, MEDOW doctoral student Jorge Gonçalves presented a poster at the 2nd Annual Conference of the Engineering & Physical Sciences Research Council (EPSRC) Centre for Power Electronics.

The poster, *Dynamic Current Limits to Manage IGBT Temperature in Modular Multilevel Converters for HVDC Applications*, proposes an additional control loop to extend the power transmission capability while keeping the temperature within safe limits by dynamically setting the current limit in response to the estimated semiconductor temperature.

You can see the full version of the poster on our Dissemination webpages.

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Dynamic Current Limits to Manage IGBT Temperature in Modular Multilevel Converters for HVDC Applications

EU Marie Curie Initial Training Network (ITN)

Jorge Gonçalves, Daniel J. Rogers, Jun Liang

Research Background

- Modular Multilevel Converters (MMC) for HVDC applications, composed by thousands of IGBTs with a limited overload capability;
- IGBTs junction temperature must be tightly controlled for increased lifetime and reliability and a fixed current limit is implemented in the converter control system to avoid IGBT over-temperature stresses;
- Limited overload is particularly relevant when VSC-based multi-terminal DC grids are expected to provide power and frequency support to a distressed AC grid and temporary overload capability is not provided.

Converter

Sub-Module

Thermal Network

Electro-Thermal Model for Junction Temperature Estimation

Research Overview

- Conservative fixed limits are set low enough such that the maximum junction temperature of the semiconductor die in the IGBT modules is never violated, even under worst-case operating conditions (e.g. high system voltage and high ambient temperature)
- During other operating conditions (e.g. nominal system voltage and low ambient temperature), the limits prevent the full capability of the converter from being used to support the AC or DC grid.
- A combined electro-thermal model based on IGBT module information is used to provide an estimation of the junction temperature under any operating condition;
- We propose an additional control loop to extend the power transmission capability while keeping the temperature within safe limits by dynamically setting the current limit in response to the estimated semiconductor temperature:

$$I_{lim}(T_j) = I_{nom} \cdot k(T_{j(nom)} \square T_j)$$

Where:

- T_j is the semiconductor junction temperature estimation;
- I_{nom} is the design (nominal) current limit of the system;
- $T_{j(nom)}$ is the nominal operating temperature of the IGBT module;
- k, defined in [A/°C], is the temperature-current droop constant.

- The proposed control scheme acts to enforce a current magnitude limit that ensures the electrical and thermal limits are kept within safe bounds;
- This offers the potential to extend the power transmission capability of the converter when semiconductor junction temperature is below the maximum limit, i.e. there is thermal headroom available.
- Only the absolute current limit is defined, as the individual current components limits are shared according to the control objective.

- A Half-Bridge MMC with 10 sub-modules per arm was considered;
- Converter fixed limits are defined at ±1.1 p.u. and the IGBT Module 5SNA 0650J450300 from ABB was used.

Calculation of Dynamic Temperature-Dependent Current Limits

Stability Analysis: Eigenvalues Sensitivity

Controller Gain Variation

Estimated Junction Temperature Variation

The Eigenvalues of the system show that the controller succeeds in keeping the junction temperature within the limit for a wide range of the gain k and under different operating temperatures.

Simulation Results

Power Reference Change

AC Phase-Ground Fault

Junction Temperature Estimation

Current Limit

Active Power Order and Injected Power

Transmission Extension Period

Stability analysis and simulation results validate the capability of the proposed control method to extend the power transmission capacity in MMC-HVDC applications without violating the junction temperature of IGBT modules. The controller is able to cope with additional power order requests and capable of maintaining some power transmission capacity during fault conditions.

A test bed has been designed and experimental validation using a small-scale model or a converter will be performed at Cardiff University, where the problem of having a physical measurement of semiconductors junction temperature will be addressed.

For more information:
Jorge Gonçalves (Goncalvesj@Cardiff.ac.uk)
Dr Dan Rogers (RogersDJ@Cardiff.ac.uk)
Dr. Jun Liang (LiangJ1@Cardiff.ac.uk)

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

MEDOW has joined forces with Friends of the Supergrid and other European bodies with an interest in the future European 'supergrid'

The initiative aims to enhance and streamline communication on the concept of a European Supergrid by creating a network of the following key projects and groups: the e-Highway2050, the GridTech project, the Market4RES project, the MEDOW project, the North Sea Grid project, the North Sea Transnational grid, NSCOGI and the Supergrid Institute.

Communicating beyond the research community

Read more

FOSG joins forces to communicate on Supergrid research

Friends of the Supergrid, Europe's largest industrial alliance for electricity interconnections, is delighted to announce that it will enhance and streamline communication on the concept of a European Supergrid by joining forces with the following key projects and groups: the **e-Highway2050**, the **GridTech** project, the **Market4RES** project the **MEDOW** project, the **North Sea Grid** project, the **North Sea Transnational grid, NSCOGI** and the **Supergrid Institute**.

All these projects investigate various **technological, financial, regulatory** or **geographical aspects that would enable the Supergrid. Their results add to the body of knowledge** that a pan-European Supergrid will provide stability and security of supply to the European electricity market by the reliable delivery of renewable electricity and market integration.

Friends of the Supergrid will provide a friendly accessible and **central dissemination webpage** platform enabling these projects and groups to **publish the results of their respective research and recommendations. By increasing access to and visibility** of the Supergrid studies and data, the said projects and Friends of the Supergrid will greatly facilitate the work of policy makers, stakeholders and researchers when designing the future European energy policies.

Bringing these projects together will also improve coordination among the different initiatives and will allow a wide range of stakeholders to benefit from a **complete picture of the results** achieved.

The concrete development of the European Supergrid, essential part of the Energy Union, will be greatly facilitated by this new central platform. FOSG and its partners in this initiative invite other interested projects and studies to join them

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Communication

So in which other ways does MEDOW communicate its work?

As a Marie Curie project, MEDOW has communication high on its agenda. We aim to communicate with as wide a variety of people as possible so as to share our work, to increase its impact and to let European taxpayers know how their money is being spent! We are keen to find news ways of sharing our project news, so do get in touch with us if you can help!

Public outreach

We have already taken part in a number of activities with people outside the research community including participating in a 'renewable energy project day' at a school in Cardiff and hosting a group of Spanish and Swedish school students at a workshop on 'HVDC Towards the Future' in Barcelona.

MEDOW in One Minute

Take a look at out bite-size explanation of MEDOW and life as a Marie Curie researcher on Youtube.

Facebook

https://www.facebook.com/medowproject

LinkedIn

Group: 'MEDOW'

In the press

Articles on MEDOW have targeted a wide range of audiences in renewable energy news-site reNews, in the national newspaper of Wales and on OffshoreWind.biz

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

KU Leuven and Cardiff University partnership

Two MEDOW partner institutions have signed a formal agreement for research collaboration and student and staff exchange

Earlier this month, KU Leuven and Cardiff University formalised their collaborative partnership.

The agreement between Cardiff University, a top-5 UK University for research excellence and impact, and KU Leuven, a world top-100 university, is geared towards boosting funding for research, creating new research collaborations and offering more opportunities for students and staff to study and teach abroad.

Read more here

See profiles of all our network members on our website

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

MEDOW Consortium

Members and roles

MEDOW is co-ordinated by Cardiff University and has four other university partners, five private sector partners and one associate partner.

Collectively, staff from the partners organisations have the wide-ranging experience and expertise to provide the appointed researchers with broad-ranging training in DC grid technologies.

All partners will host at least one researcher, and associate partner National Grid will provide training and steering to the consortium.

MEDOW partners:

- Cardiff University (Co-ordinator)
- Universitat Politècnica de Catalunya
- Control Intel.ligent de l'energia
- Alstom Renovables España
- Universidade do Porto
- EFACEC
- Katholieke Universiteit Leuven
- Elia System Operator
- Danmarks Tekniske Universitet
- China Electric Power Research Institute
- National Grid (Associated Partner)

MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Newsletter
July 2015
Issue 3

Useful Information

Principal Investigator
Dr Jun Liang
Cardiff School of Engineering,
Cardiff University, Queen's Buildings,
The Parade,
Cardiff CF24 3AA
UK

LiangJ1@cf.ac.uk

Tel: +44 (0) 29 2087 0673

Project Officer
Cath Roderick
Cardiff School of Engineering,
Cardiff University, Queen's Buildings,
The Parade,
Cardiff CF24 3AA
UK

RoderickCH@cf.ac.uk

Tel: +44 (0) 29 2087 0673

A DC grid based on multi-terminal voltage-source converter is a newly emerging technology, which is particularly suitable for the connection of offshore wind farms. Multi-terminal DC grids will be the key technology for the European offshore 'supergrid'.

The project's anticipated achievements will greatly contribute to integrating offshore wind power into the onshore AC grids of European countries and to the European 'supergrid'.

Read more about supergrid at friendsofthesupergrid.eu

MEDOW offers a development path to researchers across Europe in the area of DC grids, in addition to fostering greater ties between industry and academia in this key development area.

The MEDOW project has received funding from the Seventh Framework Programme of the European Union under grant agreement number 317221.

Deadline for contributions to next newsletter: 05 October 2015

www.medow.engineering.cf.ac.uk

Find us on Facebook

MEDOW is funded by the Seventh Framework Programme of the European Union under grant agreement no. 317221.