Ref. Ares(2017)3371670 - 05/07/2017

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

D13.5 Executive summary of project interim report

PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
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This result is part of a project that has received funding form the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

DOCUMENT INFO SHEET

Document Name:	D13.5 Executive summary of project interim report
Responsible partner:	Stiftung OFFSCHORE-WINDERNERGIE (German Offshore Wind Energy Foundation)
Work Package:	WP 13
Work Package leader:	Andreas Wagner
Task:	Task 13.5
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DISTRIBUTION LIST

PROMOTioN partners, European Commission, Public

APPROVALS

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DOCUMENT HISTORY

Version	Date	Main modification	Author
1.0	27 March 2017		Philipp Kalweit
2.0	27 June 2016	Executive summary of deliverable 14.2 is incorporated is this deliverable	Cees Plet, Marga van Deelen

WP Number	WP Title	Person months	Start month	End month
WP13	Dissemination	0,5	M14	M47

Deliverable Number	Deliverable Title	Type	Dissemination level	Due Date
D13.5	Executive summary of project interim and final report	Report	Public	M15

LIST OF CONTRIBUTORS

Work Package and deliverable involve a large number of partners and contributors. The names of the partners, who contributed to the present deliverable, are presented in the following table.

PARTNER	NAME
DNV GL	Cornelis Plet, Marga van Deelen-Bremer
Stiftung OFFSHORE-WINDENERGIE	Andreas Wagner, Philipp Kalweit, Sebastian Menze

CONTENT

1 INTRODUCTION

Meshed high-voltage, direct current (HVDC) network technology is a potential candidate for the future electrical power infrastructure required to enable Europe to transition to a clean, reliable and affordable energy future. It supports the optimal exploitation of geographically spread renewable energy sources by enabling countries to efficiently and cost-effectively trade the electrical energy. Particularly, the rapid development of offshore wind power in the Northern Seas, which requires transporting large amounts of electrical power over long distances via submarine cables, is a key application. Traditionally, European companies have pioneered the application of offshore wind and HVDC technology through innovation, and applying this to meshed networks is the next logical step to maintain a competitive advantage.

In the past, several studies have shown the socio-economic benefits and technical implications of such a meshed HVDC network. The studies often assumed that the technology required to build a meshed HVDC network would be ready and available, and that regulatory hurdles could be overcome. PROMOTioN, Progress on Meshed Offshore HVDC Transmission Networks, aims to advance on those studies, by determining all technical, regulatory, legal and financial actions that are to be taken in order to implement a meshed HVDC grid, using the Northern Seas as an example case.

In PROMOTioN, the technical and operational requirements for meshed HVDC networks are developed to a deeper and realistic level of detail, and the key technical choices to be made are identified and supported. The technology maturity of key components, such as DC circuit breakers and DC protection schemes, is demonstrated, and recommendations for standardization, improving both technology and vendor interoperability, are provided. Current member state and EU level regulations and methodologies for cost- benefit analysis concerning the development of transnational transmission infrastructure are analysed to identify hurdles towards the implementation of a meshed offshore HVDC network. Based on this, changes are proposed to the existing EU financial and regulatory frameworks, to foster a healthy investment climate.

- Firstly, a project identity and dissemination plan has been developed.
- In the first year, PROMOTioN has created a sound basis for future work.
- A qualitative and quantitative description of the requirements of a meshed offshore HVDC network, its subparts, connected wind farms and their operational characteristics have been defined.
- A comprehensive literature review of previous studies on meshed HVDC networks and the required technology has been carried out, selecting suitable scenarios and reference network topologies for use as a basis for future work.
- Models of cables, converters and the reference network topologies in various levels of detail have been developed and made available.
- Detailed modelling of DC circuit breaker technologies and an analysis of their behaviour within HVDC networks during faults has been started, with the aim of developing standardized models for network studies, test procedures and test circuits.

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- Recommendations to make the current ENTSO-E cost benefit analysis methodology suitable for meshed HVDC network development have been made.
- At the end of the first year, a thorough understanding of the state-of-the-art meshed HVDC network development has been achieved, gaps in knowledge and challenges have been identified, and a clear idea of the required next steps to address these challenges has been gained, serving as a solid basis for further work.

During investigations in the first year, the technical maturity of the complex control and protection technology for a new type of diode-rectifier based offshore converter for offshore wind integration was determined to be insufficient to enable meaningful full scale demonstration within the project's timeframe. Investigations into gaining a deeper understanding of this technology and its implications continue.

The results have been reported in several deliverables, including journal papers, conference papers and workshops, which have been published on the project website. A stakeholder and reference group meeting has been organized, and two half-yearly internal project conventions were held. The results of which were exchanged and consultations with various project related stakeholder groups were held.

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2 OVERVIEW

This chapter aims to give an overview of the project, the progress that was made towards achieving the objectives, compliance with the work plan and the use of resources thus far. The progress made will be covered in detail in chapter 3 of D14.3 Periodic report.

2.1 MAIN RESEARCH / INNOVATION

Linking offshore wind parks and onshore grids in different countries. HVDC technology is envisaged but the deployment of meshed HVDC offshore grids is currently hindered by the high cost of converter technology, lack of experience with protection systems and fault clearance components and immature international regulations and financial instruments.

PROMOTioN will overcome these barriers by development and demonstration of key technologies, a regulatory and financial framework and an offshore grid deployment plan for 2020 and beyond. A first key technology is presented by Diode Rectifier offshore converter. This concept is ground breaking as it challenges the need for complex, bulky and expensive converters, reducing significantly investment and maintenance cost and increasing availability. The second key technology is an HVDC grid protection system which will be developed and demonstrated utilizing multi-vendor methods within the full scale Multi-Terminal Test Environment. The multi-vendor approach will allow DC grid protection to become a “plug-and-play” solution. The third technology pathway will for the first time demonstrate performance of existing HVDC circuit breaker prototypes to provide confidence and demonstrate technology readiness of this crucial network component. The fourth pathway is non-technical, and will develop the international regulatory and financial framework, essential for funding, deployment and operation of meshed offshore HVDC grids. Considerable effort is placed in joining the efforts in the different pathways by setting the functional requirements jointly at the beginning of the project and to merge the different efforts at the end through a joint roadmap and standardization efforts in the second half of the project.

With 34 partners PROMOTioN is ambitious in its scope and advances crucial HVDC grid technologies from medium to high TRL. The consortium includes all major HVDC and wind turbine manufacturers, TSO’s linked to the North Sea, offshore wind developers, leading academia and consulting companies.

PROMOTioN started on the 1st of January 2016 and had a kick-off on the 21st of January 2016 and as such has been running for just over 11 months in the current reporting period. In this period, the following work packages were started:

Work package 1 - Requirements for meshed offshore grids
Work package 2 - Grid Topology & Converters
Work package 3 - Wind Turbine – Converter Interaction
Work package 4 - DC Grid protection system development
Work package 5 - Test environment for HVDC circuit breakers
Work package 6 - HVDC circuit breaker performance characterization

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Work package 7 - Regulation and Financing
Work package 8 - Wind Farm Demonstrator Prototype
Work package 13 - Dissemination
Work package 14 - Project management

The first year of PROMOTioN has been dedicated to creating a solid basis for the execution of the project. This entailed initiating the project governance structure, creating a project identity, setting up communication channels and carrying out the background research required to determine the starting point and initial research direction. The background research has resulted in an up-to-date understanding of the state-of-the-art, a set of requirements for the meshed offshore grid and its subsystems, as well as software models of its components. These requirements and models will be used as a common basis along which the work packages are aligned. This will be explained in further detail in the next sections.

2.2 PROGRESS TOWARDS THE OBJECTIVES

PROMOTioN's objectives have been listed in the Grant Agreement Annex 1 part B table 1. In this chapter, the progress made towards achieving each of these objectives is explained for each objective individually.

2.2.1 OBJECTIVE 1

'To establish interoperability between different technologies and concepts by providing specific technical and operational requirements, behaviour patterns and standardization methods for different technologies'

In the first year of PROMOTioN, work packages 1-6 have focused on developing requirements, both high level, and specific, technical and operational, for the system as a whole as well as for individual components. The outcomes of these tasks form a basis for the future work in PROMOTioN. In the following, the work done in each of the active work packages towards achieving this objective is discussed.

In work package 1 task 1 and task 5, a general set of qualitative, and where possible also quantified, requirements for meshed offshore HVDC grids have been formulated. In part derived from the fundamental network topologies which may evolve, these requirements relate to the functionality and operation of the meshed grid itself, it's interfaces with the onshore AC grid, with offshore generation, with offshore consumption, and non-functional aspects. A common set of requirements ensures a minimum performance level for a meshed grid, its subsystems and any future expansions. Enforcing these requirements from an early phase in development ensures future high level interoperability, both from a multi-technology and multi-vendor view. The ENTSO-E HVDC grid code has been taken as a starting point, ensuring uptake and contributing to already existing standardization. The general requirements have been classified according to the system, sub-system or component they relate to, which enabled a direct mapping towards the relevant work packages. The task was achieved by a large number of participants representing all other work packages in PROMOTioN ensuring the embedding of these requirements in PROMOTioN's future work for a cohesive end-result.

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A comprehensive set of simulation models of the meshed HVDC offshore grid's hardware components (converters, cables) and their associated control systems has been provided in work package 2. These models, along with two fully parameterized benchmark study networks will serve an in-depth analysis of the DC grids configurations and operational states with the aim of analysing the conditions and configurations in which different technologies or vendors are interoperable. The results of this study are to be included in recommendations for future grid codes.

In work package 3, a comprehensive list of detailed technical and operational requirements was developed for wind turbine generators which are connected to the diode rectifier unit based HVDC export link. These requirements can be seen as a grid code for this special type of offshore AC grid, defining the operational limits to ensure stable and safe operation in steady-state but also during disturbances such as onshore AC grid frequency deviations and offshore AC faults. An analysis of the behavioural patterns of diode rectifier based AC networks was carried out for a benchmark network, and then generalized. The results will be used in work package 11 to form the basis for future standardization. The requirements were formulated in close collaboration with work package 1, in which the general high level requirements were determined, and with work package 2, in which the operation of the meshed offshore HVDC grid, and the requirements for wind turbine generators connected to a voltage source converter based HVDC export link are studied in detail. The results of this task contribute to establishing interoperability as the formulated requirements for wind turbine generators are technology and vendor independent.

Work package 4 has established functional (what should the system do) and non-functional (how should the system work) requirements for DC grid protection and fault detection methodologies and has defined representative test cases for these methodologies. The work has started by achieving a common understanding of the limitations or system constraints resulting from combining AC and DC systems. A set of definitions, as much as possible in line with existing standardized definitions, was created with the aim of harmonizing the use of terminology throughout the project. An important step was the introduction of a maximum tolerable transient loss of infeed, which can be seen as a step away from the traditional AC system approach. This maximum tolerable transient loss of infeed builds on the already existing constraint on maximum permanent loss of infeed in existing AC synchronous zones. Three test cases based on the severity of the impact of a DC fault were defined, in which the size of the DC grid relative to its connected AC grid, and the required reaction of the DC grid protection to a fault are classified into three groups. The developed requirements and test cases provide insight into the desired behavioural patterns which will enable the comparison of various methodologies and technologies and determine under what conditions they are interoperable.

Work packages 5 & 6 carried out detailed modelling of three different types of DC circuit breaker technologies, with the aim of understanding their behavioural patterns and formulating technical operational requirements based on this. The stresses imposed by a DC grid on a DC circuit breaker during faults were studied and used to achieve a thorough understanding of DC grid fault behaviour. The different DC circuit breakers and associated control and self-protection systems were studied in detail, allowing to draw conclusions regarding the technologies speed of operation, behaviour during breaking operations, reclosing abilities, and directionality. A good generalized understanding of these technologies' characteristics enables an analysis of the conditions under which they are interoperable. Understanding the DC circuit breakers' behaviour during faults enables the

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definition of technical requirements from the system's perspective which will be used to formulate test requirements and procedures which in turn will be used as a first step towards standardization. Work packages 5 & 6 have collaborated closely, having joint work package meetings and many shared members.

The progress towards this objective can be considered to be in a high state of completion. This is in line with the planning.

2.2.2 OBJECTIVE 2

'To develop interoperable, reliable and cost-effective technology of protection for meshed HVDC offshore grids and the new type of offshore converter for wind power integration'

The development of the new type of cost-effective offshore converter for wind power integration consists of the development of new type of hardware components, such as the diode rectifier unit and the combined umbilical cable, as well as the development of the control and protection systems required to operate the wind turbine generators together with the HVDC link. The latter has been the focus of work package 3, in which specific technical requirements for the operation of the offshore AC grid by which the wind turbine generators are connected to the diode rectifier unit have been developed. The requirements are general, and vendor and technology independent and as such they contribute to ensuring interoperability. The requirements accurately describe the wind turbine generator's response to all steady-state, transient and abnormal operating conditions, with the aim of ensuring safe and stable operation. Avoiding large fluctuations in power, voltage, current, frequency etc. can reduced unwanted tripping or even damage to the system, thus improving the overall reliability of the system.

A protection system for meshed HVDC offshore grids is a complex system requiring a fault detection system, a fault clearing strategy, and fault clearing equipment such as DC circuit breakers. Key is the fault clearing strategy which is determined based on a techno-economic optimum between AC and DC system constraints, fault clearing equipment capabilities, the permissible impact of a DC fault on the AC and DC systems, and the required investment. In work package 4, a detailed list of specific technical requirements which a fault clearing strategy must satisfy in order to be interoperable and reliable, has been developed. Test cases which can be used to judge a clearing strategy's performance in light of these requirements were developed, enabling different technologies to be compared to one another and possibly determine conditions in which they are interoperable. In order to develop a reliable system which is cost effective, DC protection systems are expected to have different result when compared to AC systems. A risk based assessment of the criticality of DC faults has been proposed, dividing the potential occurring faults into four categories. This approach is going to be used as an input of a cost-benefit analysis. A first step towards determining the cost-effectiveness of implementation of different protections systems has been made through an ongoing development of a methodology which aims at investigating the cost-benefit analysis modifiers needed for HVDC grid protection.

In work package 5, the operation of DC circuit breakers in DC grids during faults was analysed to determine the electrical stresses which they experience. These results will be used to develop suitable test requirements, procedures and circuits which can adequately test future DC circuit breakers before use, thus contributing to the reliability of meshed HVDC grid. The outcomes will also be used to carefully consider well-balanced test

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requirements which will guarantee a minimum quality or performance level around which cost-savings can be realized as the technology matures.

Detailed modelling of the circuit breaker technologies in work package 6 has provided improved understanding of the technology's performance and limitations, which can be used as input to determining a technology's performance in a chosen fault clearing strategy. In order to determine the cost-effectiveness, the expertise from work package 6 was used to extend work package 4 with a comprehensive modelling of the costs of the different DC circuit breakers using a bottom-up approach.

The progress towards this objective can be considered to be in a medium state of completion. This is in line with the planning.

2.2.3 OBJECTIVE 3

'To demonstrate different cost-effective key technologies for meshed HVDC offshore grids and to increase their technology readiness level by investigating and overcoming early adopter issues and pitfalls'

The work packages in which demonstration will take place have not yet started. Therefore, although preparatory work for the demonstrations has been carried out in work packages 4, 5 and 6, no actual full scale demonstrations have been carried out in the reporting period. The large-scale demonstrations are planned to start in 2017 as work package 9 and 10 start. Some smaller laboratory tests have been carried out, however.

As part of work package 5, DNV GL's KEMA Laboratories have carried out an initial experimental investigation to explore the capability of the AC short-circuit generators to, when run at a low frequency of 16 Hz, establish the required rates-of-rise of current and voltage in order to adequately synthesize the test stresses. The tests verified the capability to achieve rates-of-rise of current of 3.1 kA at source voltages of up to 200 kV which is sufficient to test any DC circuit breaker module.

As part of work package 6, the experimental results of the development of a scaled-down hardware model of an ultra-fast disconnector were presented. Operation speeds in the range of milliseconds were achieved.

The progress towards this objective can be considered to be in an early stage of completion. This is in line with the planning which foresees the demonstration elements of the project to be finished by the end of the project.

2.2.4 OBJECTIVE 4

'To develop a new EU regulatory framework, both in accordance with EU wide energy policy objectives and those of the Member States, and to increase the economic viability of meshed HVDC projects by providing a suitable financial framework'

The development of a new EU regulatory framework has started in work package 1 task 1.2 in which an extensive literature survey of reports and EU projects regarding regulation and financing of transnational infrastructures was carried out. The literature survey concluded that a vast amount of work has already been

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done, and that vast amount of information is already available, but that not all relevant topics, such as financing mechanisms especially for meshed offshore infrastructure systems, have been analysed as thoroughly as others. The survey also concluded that although consensus exists on many topics, regarding other topics conflicting recommendations are given in different sources. For example, while several reports recommend to align national support schemes, to appoint a single TSO or to harmonize grid rules, others state that these solutions are not feasible as they don't account for the legal context of international and EU law as well as for the choices under national law. It was also shown that perceptions on regulation and finance of transnational infrastructure have changed over the years. Remaining barriers have been identified and communicated to work package 7 in order to be addressed.
In work package 7, more focused literature and project surveys have been carried out regarding legal, regulatory and financial aspects of meshed offshore transnational infrastructure. A desk top study on offshore competences and legal basis for governing cables in territorial waters and EEZ was conducted. The United Nations Law of the Sea was compared with the EU law legal competences regarding territorial waters and beyond.

The legal analysis in 7.1 is being complemented with an economic analysis of how the legal framework has been implemented. A few case studies have been selected, including interconnectors (so-called Projects of Common Interest), and connections of large scale wind farms (e.g. the Offshore Transmission Owners in the UK). For these cases, we considered: the cost benefit analysis method that has been used and propose a theoretical framework, applied at case studies with different study networks (radial vs meshed) and local vs. international. Recommendations to adapt the application of the existing ENTSO-E cost benefit analysis method and make it suitable for the development of meshed networks, have been formulated.

Traditional mechanisms of financing transmission grid infrastructure onshore, as well as investor participation, including merchant investments, have been investigated (DE, DK, UK, NL, BE, NO). Focus is given on the investor of transmission grids onshore (private - public partnerships), financing structures (project finance, corporate finance) and financing sources (equity debt ratios). Also, research on the historical development of the ownership of the transmission grids has been conducted in order to understand the major drivers that affect governance structures. Existing national rules and requirements concerning grid infrastructure financing are examined for the countries mentioned, but also on EU level.

The progress towards this objective can be considered to be in an early but substantial stage of completion. This is in line with the planning which foresees this objective to be completed at the end of the project initiate the engagement with and harmonisation of standardisation activities in period 2.

2.2.5 OBJECTIVE 5

'To facilitating the harmonization of ongoing initiatives, common system interfaces and future standards by actively engaging with working groups and standardization bodies and actively using experience from the demonstrations'

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In line with the planning, no progress has been made towards this objective during the reporting period. Although several project participants also take part in standardisation bodies, no formal links have been made yet. The work packages which will contribute towards this objective are planned to do so later in the project. Work package 11 will initiate the engagement with and harmonisation of standardisation activities in period 2.

2.2.6 OBJECTIVE 6

'To provide concrete deployment plan for "phase two" in bringing key technologies for meshed HVDC offshore grids into commercial operation in Europe, taking into account technical, financial and regulatory aspects'

In line with the planning, no progress has been made towards this objective during the reporting period. The work packages which will contribute towards this objective are planned to do so later in the project. Work package 12 will initiate the development of a deployment plan in reporting period 2.

2.3 ACHIEVEMENTS

As the project is in its beginning phase during the reporting period, the work done has focussed mostly on forming a common basis of understanding and determining the starting point and direction for the research to go in. This means literature surveys were carried out to determine the state-of-the-art and identify gaps in the present knowledge and understanding. High level and specific requirements were qualitatively and quantitatively determined. Models, reference topologies and benchmark scenarios were developed as tools for the future research.

Some early achievements and contributions to the state-of-the-art can be noted:

- A clear and aesthetically pleasing project identity and website were developed, enabling the project's results to be communicated to a wider audience effectively
- A comprehensive set of technical requirements for offshore wind turbine generators connected to diode rectifier export links was developed and validated by key academic and industry partners from across the energy value chain. The requirements are publicly available and can be used by any interested party to learn to understand the technology and study the impact on any equipment connected to such a network. As such, the requirements contribute to an improved understanding and acceptance of this new type of technology
- Within work package 4, distinctions were made between the different severities of impact of faults in the DC side and the impact of a DC side fault on the connected AC system. The introduction of the concept of maximum transient loss of infeed was done in the same work package to enable a discussion about the required role of a DC circuit protection system and fault clearing strategy. These definitions will aid the quest to find the most cost-effective fault clearing strategy, a balance between availability, cost of equipment and the impact on the AC grid, and as such it will challenge conventional views on grid planning and operation
- Experimental validation was carried out in work package 5 to show that AC short circuit generators can in principle be used to synthesize the test stresses required to test DC circuit breakers. This means that conventional existing test installations in laboratories can be used verify DC circuit breaker

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operation, avoiding investments in the development of new test installations and enabling the reliability of DC circuit breakers to be verified before they are taken into service

- Both detailed and system level simulation models of three different DC circuit breaker technologies have been developed and made available to the general public. These well-documented models can be readily implemented into simulation studies by academics, industry and others in their studies of DC grids. The ready availability of DC circuit breaker models will thus contribute to an improved understanding and acceptance of this new type of technology
- Recommendations have been made in work package 7 to improve the ENTSO-E cost benefit analysis method and how it is applied to make it suitable for the development of meshed networks. By adopting these recommendations, amongst others the calculated social welfare costs of all projects of common interest can be readily compared and their positive impact on society visualized

2.4 PROJECT GOVERNANCE

The governance structure of PROMOTioN is shown below. In order to communicate internally to the consortium partners or selected consortium bodies, and to exchange documents and information between project participants, the online project management tool Project Place has been made available and configured for use.

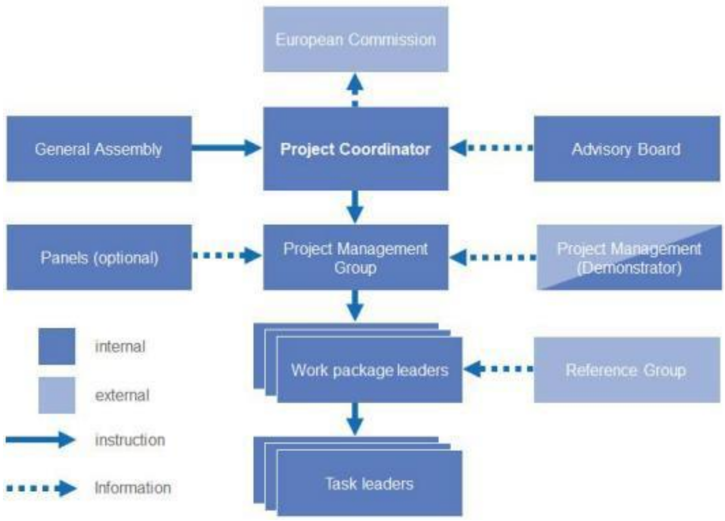

Figure 1 – Project governance structure

The Project Management Group, consisting of all work package leaders, has been activated and monthly meetings have been organized. Initially, the meetings were organized by online teleconference, however, it was found that the virtual environment was not sufficient when discussing critical items, so it was decided to meet in person every quarter and have monthly telephone conferences in between.

A Reference Group has been formed by inviting selected members from across a wide range of industry, academia, governmental organisations, industry bodies, research institutes and other research projects. A successful first reference group meeting was held along with the WindEnergy conference in Hamburg. Issues relating to protection system operation requirements (WP4) and the strains it places on the AC grid, as well as

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early results from the cost-benefit-analysis review (WP7) were presented to and discussed with the reference group.

The need to form an Advisory Board has been discussed, but it was decided that during the reporting period there have been no issues requiring the advice of an advisory board, and that one can be assembled once the need arises.

As part of the governance, in addition to the periodic reporting to the EU, a project internal reporting schedule has been set-up in order to maintain visibility on the project's progress. Financial and technical reports are requested of each partner on a half-yearly basis, technical progress reports are requested of each active work package every quarter and discussed during the PMG meetings.

In order to assess and control the quality of the deliverables and to ensure consistency between them, a review procedure has been set up. The procedure foresees in two review rounds by two reviewers chosen from the PMG. The first review round is meant to ensure the correct approach and structure, whereas the second round focusses on content, layout and clarity of argument. A review history is kept in review sheets.

To ensure consistent and high quality external communication, publication review procedures for presentations, conferences and papers have been developed.

As coordinator, DNV GL manages the consortium and grant agreement. In the reporting period one amendment has been carried out to remove small errors, improve planning, cohesion and alignment between work package descriptions and ensure the use of a common vocabulary.

In the reporting period, three project conferences including the project kick-off, or half-yearly meetings, were organized in Arnhem, Netherlands, Stockholm, Sweden and Berlin, Germany. The next one is planned in Aberdeen, UK. These three-day meetings follow the same concept and consist of joint work package meetings, a plenary meeting and a general assembly meeting. The work package meetings are organized in such a way as to enable work packages with interfaces to have joint meetings and align.

2.5 PROJECT IDENTITY AND COMMUNICATION

A clear recognisable project identity has been created, consisting of a logo, colour scheme, document styling and fonts. The project identity has been used to create templates for Word and PowerPoint documents such as presentations, letters and deliverables.

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Figure 2 – Project Logo

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Using the project identity, a website (**www.promotion-offshore.net**) has been created on which deliverables, presentations and publications have been made available to the general public. To website contains a separate section for PROMOTioN partners only.

A half yearly newsletter is developed and distributed to all consortium partners and any external stakeholder who has signed up to the mailing list. The newsletter provides updates on achievements and progress, reminders about upcoming events, updates from the project context and highlights from the project.

A stakeholder communication distribution list was drafted. One stakeholder meeting was organised during the reporting period with good turnout and lively discussions.

To increase visibility of the project and improve the understanding of the key messages and goals, six testimonials from project participants have been filmed and placed online.

2.6 COMPLIANCE WITH THE WORK PLAN, DEVIATIONS AND CORRECTIVE ACTIONS

The work carried out during the first reporting period has largely been carried out in accordance with the work plan in terms of scope and planning. Some minor delays were reported on the submission of deliverables. These delays were in most cases attributable to the additional time required to achieve agreement on the deliverable's contents by a large number of partners. In all cases, the delay in submission date did not adversely affect any other work within PROMOTioN.

In work package 5, the submission dates of deliverables 5.2 and 5.3 were swapped around as their submission dates were in reverse chronological order to the natural order for the work to be carried out.

Some minor adjustments were carried out to the scope of deliverables to avoid overlap and duplication. This was most obvious for deliverable 1.4 in which no reference topologies were introduced as described in the work plan, because these reference topologies are developed in work package 2.

One partner, Stattkraft, decided to discontinue its partnership in the consortium prior to the start of the project due to a changed company strategy and staffing issues. Stattkraft did not have a significant planned contribution to the project, so their leave did not cause any major impact on the rest of the project.

EirGrid decided to substantially reduce its involvement in PROMOTioN due to the person who was supposed to work on PROMOTioN leaving the company. EirGrid was originally planned to carry out a substantial amount of work in work package 1 which has now been picked up by Tractebel. Therefore, their reduction of contribution did not have a negative impact on the project. EirGrid continues to be a partner in the consortium and contribute in a review role.

All changes were carried out in dialogue with the coordinator. In each case the impact on the other work packages and deliverables were considered and negative impact minimized as much as possible by shifting

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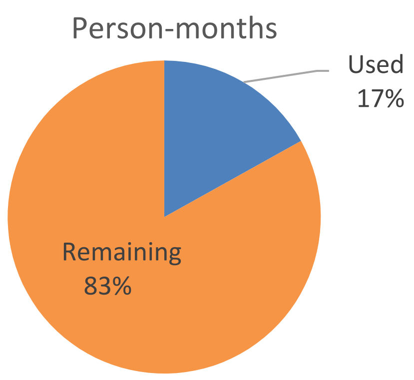
tasks to other partners. The changes were formally registered in the last amendment or in the upcoming amendment.

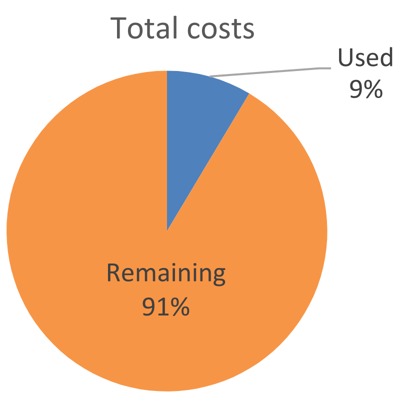
At the end of the reporting period, Siemens communicated that they had decided on a NO GO with respect to the Klim demonstrator of the diode rectifier technology in work package 8. This decision has a major impact on the project's budget, the other activities in work package 8 and the demonstration character of the project. This and the impact on the project's objectives will be further detailed in a separate report.

2.7 USE OF RESOURCES

The total PROMOTioN project has a person month budget of 2,589 person-months of which 438 person-months were used during the reporting period, which equals 17% of the total budget. Likewise, the total actual costs budget is EUR 51,685,330 of which EUR 4,436,519 has been used, representing 9% of the total budget, as shown in the diagrams below.



a) Person-months budget use



b) Actual cost budget use

Figure 3 – Use of budget

Taking into account that the reporting period represents 25% of the total project's duration, it can be thought that the spent budget should be close to this percentage too. However, when considering that the project started about a month after the start of the reporting period, and that many work packages started later during the reporting period, the difference can be explained. It is expected that the lag in spending will be compensated for in the following reporting periods.

Similarly, with respect to the actual budget spend, it should be remembered that the more budget intensive activities, the demonstrations, do not start until the second half of the project. It is anticipated that the apparent lag in spending will be compensated for when the demonstrations start taking place.

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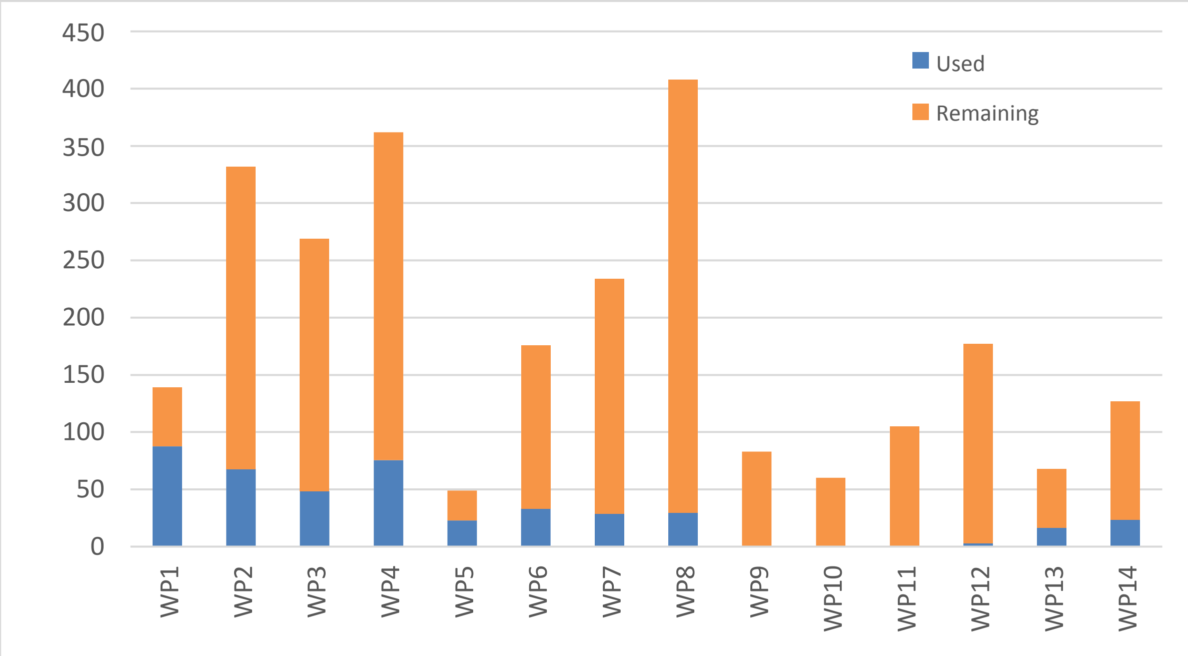

Figure 4 – Use of person-month budget per work package

The spent person-months budget can be broken down and shown per work-package, as in the above figure. It can be seen that in work package 1, which started immediately and will finish the majority of its tasks within the reporting period, the budget expenditure is accordingly, with 2/3rds of the budget spent. Similarly, in work package 5, which will be active for the first two years with a relative even distribution of work load during this period, about half of the budget is spent. In most other work packages, less than a quarter of the person-month budget has been spent, partly because they started later during the reporting period, or due to a delay in staffing recruitment. In the work packages that have not started yet, naturally no budget has been spent yet.

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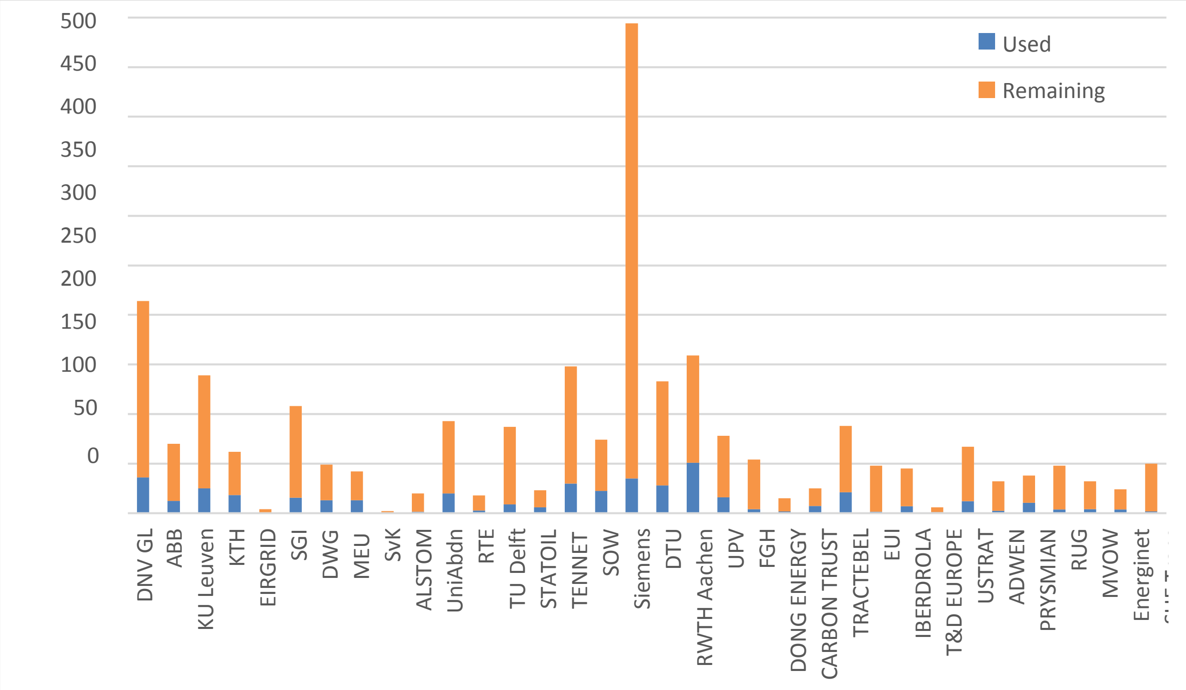

Figure 5 – Use of person-month budget per partner

The person-month budget expenditure are plotted per partner, as shown in diagram above. No excessive expenditure is noted, in most cases the partners stay below a quarter of their budget, in line with the previous explanations. From the budget expenditure and the above discussion, it follows that the use of budget can be considered on track.

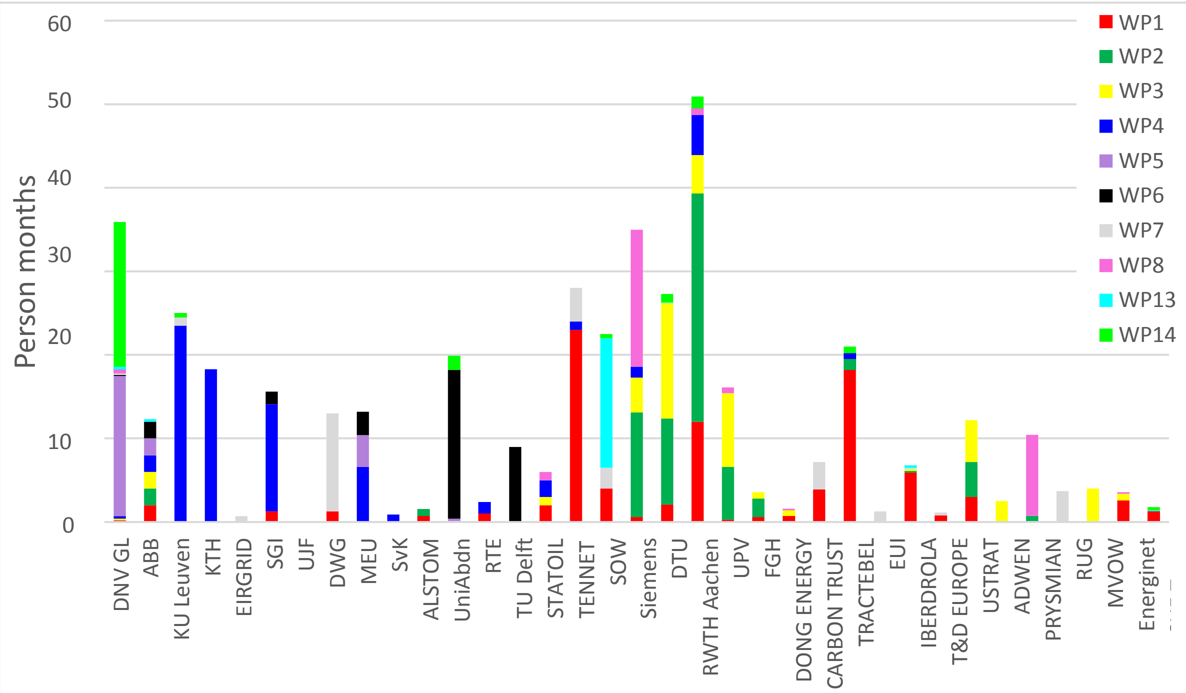

Figure 6 – Participation of partners in various work packages

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Finally, the person-month expenditure per partner per work package can be plotted as shown in the diagram above. The diagram shows that almost all partners are involved in several work packages. It also shows that for example work package 1 involved nearly all partners. This cross-work package involvement is an informal way to ensure cross-collaboration and alignment between work packages. This is further achieved by shared work package meetings, close collaboration between for example work package 2&3 and 5&6, and by the bi-annual project conferences. The work package leaders meet on a monthly basis (virtually or in person) to discuss ongoing issues and ensure alignment.

2.8 PLANNING

Figure 7 shows the updated Gantt chart for the project. Some small changes were made as described in section 1.6 above. The major change is the cessation of WP8 activities from M13 onwards following the Siemens NO GO decision. The NO GO decision and its impact are discussed in greater detail in the separate report titled 'Report on impact of Siemens NO GO decision in WP8'

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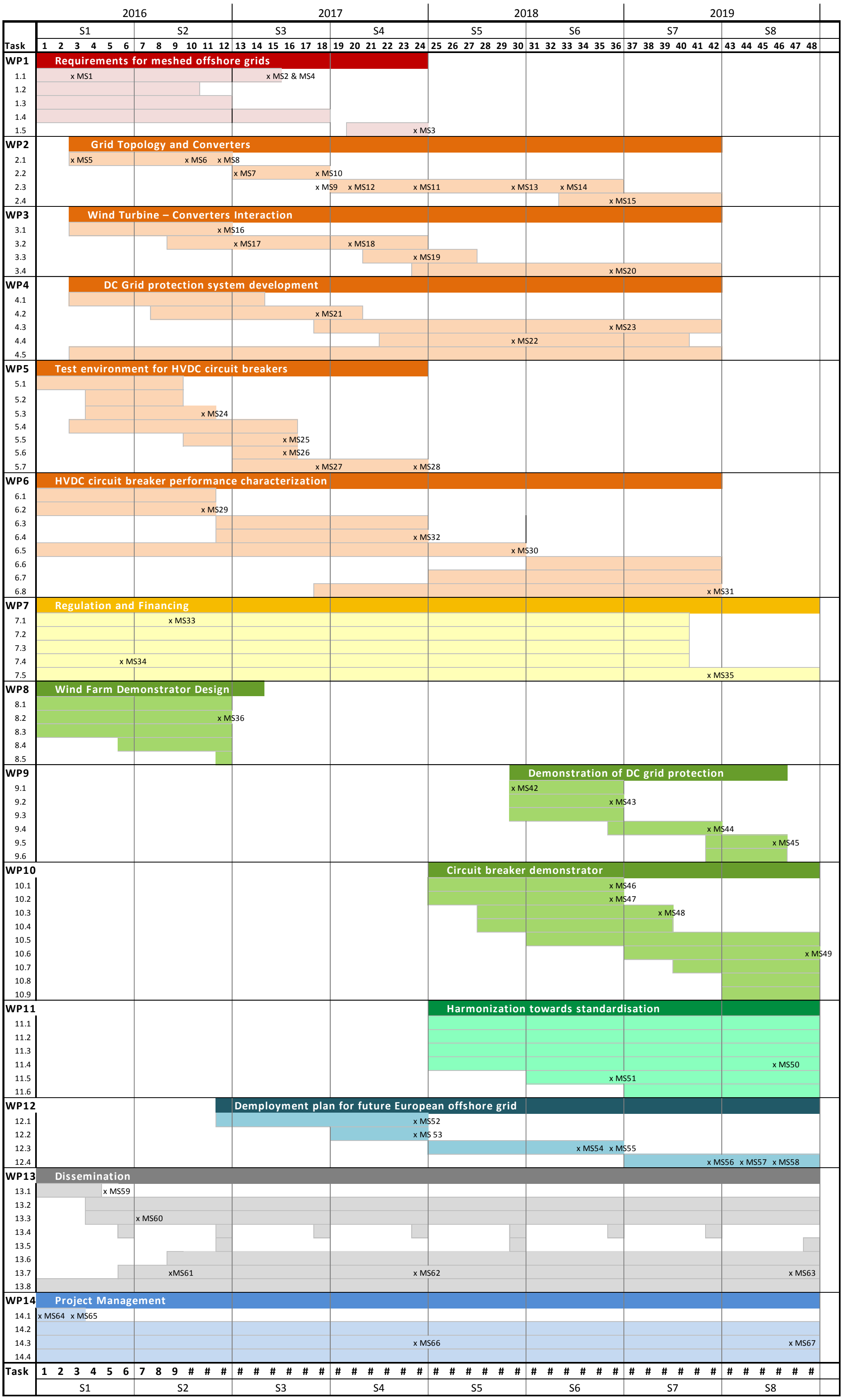

Figure 7 - Updated Gantt chart

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