DeepWind Deliverable

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Description of Deliverable

D3.2) Design of generator system: *Design the generator system and optimise the generator speed and torque by selection of a gear ratio. A prototype submersible generator rated about 1kW for a scaled wind turbine will be built and tested in the laboratory for WP7. The 1 kW machine will be similar to existing machines and will be designed using existing in-house software with a minimum of adaptation. An appropriate power electronics controller will be designed and built, suitable for onshore mounting. This prototype generator is for testing by the partners in open water. The 1 kW prototype will utilise existing technology for the generator and rolling bearings with a gearbox integrated in a watertight construction with a single shaft seal. Existing in-house and commercial software will be used for design and modelling purposes. This will reveal the weaknesses of the existing software, providing some of the starting data for task 3.1. The two larger machines will require major adaptations to the existing construction principles and thus existing software tools. Especially for the 20 MW machine, steps will need to be taken to reduce the machine size, by increasing the torque density and by optimising the gear ratio. Various tools provided by Task 3.2 will be used for the different operations. For design purposes, a steady state, analytic model will provide rapid calculations yielding operating characteristics and material usage. The analytic result will be refined using finite element analysis to optimise the geometry. Subsequently the FEM geometry will be inserted in the analytic program to obtain the final performance and material usage.*

Work Completed

Taking the phrases from the above description, comments are added. Where appropriate, Deep Wind reports are referred to. These reports are available to the consortium on the Deep Wind Teamsite Homepage.

Design the generator system and optimise the generator speed and torque by selection of a gear ratio. The 1 kW prototype will utilise existing technology for the generator and rolling bearings with a gearbox integrated in a watertight construction with a single shaft seal. This prototype generator is for testing by the partners in open water. Existing in-house and commercial software will be used for design and modelling purposes. This will reveal the weaknesses of the existing software, providing some of the starting data for task 3.1.

The 1 kW generator system was designed. Existing technology and rolling bearings were used. The drawings are available to the consortium in Solid Works (2011-2012) CAD files available to the consortium on the Deep Wind teamsite web page. The generator is a standard induction motor, controlled to act as a generator. A gearbox was not used, but the speed ratio between the turbine rotor main shaft and the motor shaft (shaft ratio=80/24=3.333) was obtained using a single stage toothed belt drive. The shaft is sealed using an SKF Rotary Seal, type **R01-F60x90x10 PTFE/NBR70/1.4310**. Stainless Steel SKF bearings were used, of types **W6208 2RS1 and W6210 2RS1**. Existing in-house software is included in the Design Tool for use in designing the 5 MW and the 20 MW rated versions. The software files used are listed in *DeepWindSnapshotListOfFilesInTheGeneratorDesignToolQuickies2012-10-16.pdf,* which is available to the consortium on the DeepWind teamsite.

A prototype submersible generator rated about 1kW for a scaled wind turbine willbe built and tested in the laboratory for WP7. The 1 kW machine will be similar to

existing machines and will be designed using existing in-house software with a minimum of adaptation.

The 1 kW generator system was designed, built and has been delivered to WP7. The generator is a standard induction motor, controlled to act as a generator. It was bench tested in the laboratory in combination with the power electronics controller of the following section. Design was using existing software and by collaboration with the supplier. The main shaft was provided with slip rings and electric circuits to carry the instrument power supply and a signal representing rotor position to instruments mounted inside the turbine rotor shaft by WP7. A watertight connector Type SMG-4-BCR by SeaCon Europe was fitted in the shaft at the turbine rotor end, to enable disconnection of the turbine rotor for maintenance, and in inclement weather. This was complemented by a SMG-4-CCP on 2 m PU4C cable, supplied to WP7. To protect both parts during maintenance operations, dummy connectors were also supplied to WP7, types SMG-4-DSP, and SMG-4-DSR. These are listed in the file ***SeaConSeaMateOrderAcknowledgement.pdf*** available to the consortium on the DeepWind teamsite web page. The laboratory arrangement for the bench tests is detailed and the test results are detailed in ***DeepWind_Converter_Progress_Report_Sept_2012_itr.pdf***, available to the consortium on the Deep Wind teamsite web page. Suitable 12 way cable and connectors were obtained from Macartney (a supplier to the offshore oil industry) and supplied for undersea connection from the indoor panel to the offshore raft, and from the raft to the generator box. At the generator box, an undersea connector was moulded on tto the cable by the supplier, see file ***DeepWindDemonstratorUnderseaCableAndConnector.pdf*** available to the consortium on the DeepWind teamsite web page. On the raft, a suitable 24 [V], 10 [A] D.C. power supply, by RS, was provided, fitted in a watertight cabinet. The power supply was for instruments provided on the demonstrator by WP7.

An appropriate power electronics controller will be designed and built, suitable for on shore mounting. (for the 1 kW demonstrator)

A suitable four quadrant power electronics controller was selected and built on a panel for indoor on shore mounting with the necessary wiring to terminals. The controller is a type OA131538, by ABB, and an order sheet and data sheets are available to the consortium on the Deep Wind teamsite web page. A PC was supplied, equipped for remote control of the system, with the required ABB control 'Drive Studio' software installed and set up to control the operation of the generator in four quadrants.

The two larger machines will require major adaptations to the existing construction principles and thus existing software tools. Especially for the 20 MW machine, steps will need to be taken to reduce the machine size, by increasing the torque density and by optimising the gear ratio.

Adaptations to the existing construction principles are planned. The software tools are prepared to accommodate the adaptations. Methods for improvements to the torque density are selected for study. In order to maximise the reliability, every effort is being made to avoid the use of a gearbox on the 5 MW and 20 MW rated versions because of the reduced reliability and risk of oil pollution of the sea that will result if a gearbox is applied. This study is reported in ***WP3 generator technical status report oct 2012 DeepWind.pdf***, available to the consortium on the Deep Wind teamsite web page. The results will be used in WP3 and included in D3.4.

Various tools provided by Task 3.2 will be used for the different operations. For design purposes, a steady state, analytic model will provide rapid calculations yielding operating characteristics and material usage. The analytic result will be

refined using finite element analysis to optimise the geometry. Subsequently the FEM geometry will be inserted in the analytic program to obtain the final performance and material usage.

The Design tools are ready for use and the first FEM models of radial flux machines and transverse flux machines are available and test runs have been performed. The technical status of the generator and design tool may be found in the file ***WP3 generator technical status report oct 2012 DeepWind.pdf***, available to the consortium on the Deep Wind teamsite web page. The files included in the design tool are listed in ***DeepWindSnapshotListOfFilesInTheGeneratorDesignToolQuickies2012-10-16.pdf***. Sample design sheets showing the output obtained from the software are given in ***DeepWindTFPMCNessieDesignSheet5MW_A.pdf***, & ***DeepWindTFPMUNessieDesignSheet5MW_A.pdf***. All files are available to the consortium on the Deep Wind teamsite web page.

Appendices detailing the findings reported in this report are to be found in the following files:

DeepWind_Converter_Progress_Report_Sept_2012_itr.pdf
DeepWindSnapshotListOfFilesInTheGeneratorDesignToolQuickies2012-10-16.pdf
DeepWindTFPMCNessieDesignSheet5MW_A.pdf
DeepWindTFPMUNessieDesignSheet5MW_A.pdf
WP3 generator technical status report oct 2012 DeepWind.pdf
SeaConSeaMateOrderAcknowledgement.pdf
DeepWindDemonstratorUnderseaCableAndConnector.pdf