COLUMBIA POWER TECHNOLOGIES

power from the next wave

Direct Drive Wave Energy Converter

Title	Test Site Report
Document No.	DE-EE-0006399 M2.1
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Authored	J Prudell, E Hammagren, A Schacher, K Rhinefrank
Reviewed	
Approved	K Rhinefrank

Version	Date	Summary
1.0	July 15, 2014	Milestone 2.1 Test Site Report deliverable

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1 TASK 2.0: DYNAMOMETER SITE PREPARATION AND PLANNING, M0-M4

Plans for integrating Project activities will include pre-assembly and assembly procedures, disassembly procedures, emergency and safety plans, logistics, operations, transportation and personnel/office plans. Dynamometer interface specifications and plans will be addressed including: electric plant, control system, cooling system, PTO Module floor stand, PTO drive coupler to dynamometer, and emergency/safety controls.

M2.1: A report describing site conditions, test conditions, test plans, and schedule for the 5MW dynamometer test

1.1 NREL National Wind Technology Center (NWTC) Site

The NREL NWTC located near Louisville, Colorado is an advanced renewable energy testing center. The site has test laboratories, electronics and instrumentation laboratories, and machine shops which support work in the dynamometer industrial high bays. The LandRAY project will be tested using the 5MW dynamometer and the Controllable Grid Interface (CGI).

1.1.1 NREL Dynamometer and Non-Torque Loading (NTL) Specifications

The LandRAY design was specifically tailored for testing on the NREL 5MW dynamometer. The NTL output drive shaft height above the dynamometer floor is 4m with a 5 degree fixed inclination which set the designed diameter of the LandRAY PTO system. The LandRAY systems are all designed to be tested within the following dynamometer specifications:

- *NREL Dynamometer Test Facility.pdf*
- *NREL MTS NTL5U_006333.pdf*

1.1.2 Controllable Grid Interface (CGI) Specifications

The NREL Test Article Grid connection is a 13.2kV, 60Hz connection for a customer supplied transformer. Columbia Power has specified a pad mount transformer for interface between the Siemens Motion-to-Grid (M2G) and the CGI from 480Vac to 13.2kV. The interface connection point described as "Test Article" in the following CGI document will be connected by a licensed medium voltage (MV) electrician.

- *NREL NWTC Controllable Grid Interface.pdf*

1.1.3 Emergency Plan and Safety Plans

All Columbia Power personnel and contractors will comply with NREL's safe operating procedures. NREL Hoist and Rigging / Lift plans will be developed and signed by NREL lift masters and NREL Work Safety Planning (WSP) and Risk Assessment will be completed before proceeding with any task or activity which is inherently hazardous.

- *NREL 5MW Safe Operating Procedures.pdf*

1.2 NREL Interfaces

The LandRAY project was specifically designed to be tested at the NREL 5MW dynamometer. There are five major interfaces with the dynamometer; the output drive shaft coupler, the frame to floor mount, the electrical medium voltage interface to the test article grid, the SCADA data acquisition interface, emergency contacts, 120V power, and the cooling system to NREL cooling skid interface. The system interfaces are described in the M3.1 Component Design Report in each respective system section.

- *DE-EE0006399 M3.1 LandRAY Component Report PD v1.0 07-15-2014.pdf*

1.3 LandRAY Test Plan Outline

The LandRAY testing at NREL has been designed into ten stages. Each stage of testing has been developed to achieve specific test objectives and has associated system tasks. The system tasks include assembly, inspection, verification and set-up procedures which ensure the systems are ready for the specific stage of dynamometer test trials. The LandRAY test plan document is further developed following LandRAY pre-assembly experience and NREL review feedback.

- *DE-EE0006399 M8.1 LandRAY-Test Plan PD v1.0 07-20-2104.pdf*

1.3.1 Stage I – Main Bearing Testing

The objective of the main bearing testing is to characterize rolling resistance and vibrations from 0 to 24 rpm with and without non-torque loading (NTL). The main bearing test trails validate the design and performance of the main bearing and associated center structure, main shaft, frame structure and shaft coupler to the dynamometer.

1.3.2 Stage II – Secondary Bearing Testing

The objective of the secondary bearing testing is to characterize rolling resistance and vibrations from 0 to 24rpm with and without non-torque loading (NTL) of the main and secondary bearings combined. Data analysis comparison will determine the additional rolling resistance and vibration due to the secondary bearing. The secondary bearing assembly includes all PTO systems, but excludes testing stator cart assemblies and shaft seal assemblies, so neither is engaged.

1.3.3 Stage III – Shaft Seal Testing

The objective of the shaft seal testing is to characterize the performance of the seals, including leak tightness and rolling resistance. Data analysis comparison will determine the rolling resistance. A pressurized water system pressurizes and monitors the seals during testing. The shaft seal are engaged following the Stage II testing.

1.3.4 Stage IV – Stator Cart Testing

The objective of the stator cart testing is to characterize the performance of the wheels in the cart assembly. Data analysis comparison will determine the rolling resistance. Two stator cart assemblies are instrumented with torque, load and acceleration sensors to monitor individual segment performance. The rail bearings are engaged following the Stage III testing, and rotor segments are not installed.

1.3.5 Stage V – Generator Parameterization

The objective of the generator parameterization is to complete the generator pole alignment and Motion-to-grid (M2G) commissioning and parameterization. The rotor segments are installed and the stator rail bearing segments are engaged. Siemens engineers will work with Columbia Power engineers to complete all generator and M2G set-up commissioning tasks. Upon completion of stage V, the PTO and M2G will be fully operational and ready for standardized, no-load, loaded, and real seas testing.

1.3.6 Stage VI – No Load Testing

The objective of no-load testing is to characterize the PTO for all speeds between 0 and 23.8 rpm with and without NTL with no electrical connection, open-circuit. The no-load testing is included in the standard 115, *IEEE Guide to Test Produces for Synchronous Machines.* The characterization parameters include no-loading cogging torque and open circuit voltage.

1.3.7 Stage VII – Loaded Testing

The objective of loaded testing is to characterize the PTO for all speeds between 0 and 23.8 rpm with and without NTL over the full range of operating loads. The loaded testing is included in the standard 115, *IEEE Guide to Test Produces for Synchronous Machines.* The loading testing will characterized generators steady state parameters for temperature, efficiency, torque, and current, as well as transient testing characteristics within the S3 intermittent periodic duty classification of the G1 generator. The testing includes constant steady state and sinusoidal speed profiles between 0 and 23.8 rpm, with sinusoidal periods between 5 and 15 seconds. The applied torque loads are between 0 and 1.014MNm peak, with maximum damping values for sinusoidal testing up to 15MNms.

1.3.8 Stage VIII – Real Seas Testing

The objective of real seas testing is to test the PTO with simulated real wave motion profiles. The real seas testing trials will simulate the scaled performance and operation of the PTO in a WEC in the ocean. The testing includes controls algorithm testing. The design basis conditions for normal operation, survival, and maintenance and repair are included.

1.3.9 Stage IX – Post Test Characterization

The purpose of the post characterization testing is a spot check of the systems after all loaded and real seas testing to ensure the system characteristics have not changed significantly. The post testing characterization ensures that the components, such as the bearings and seals which experience a break-in period, have stabilized their characterized performance. If a post test varies significantly from the initial characterization test, a revised test regime will be developed and executed.

1.3.10 Stage X – Noise Testing

The purpose of the noise monitoring is to develop noise level data for WEC permitting reasons. The testing is performed with the shaft coupler disconnected from the dynamometer, the dynamometer shut down, and the NTL shaft moved away from the PTO. The noise testing gives us data that we will be used to validate our assumption of low operational noise level. It is common during the permitting process to address questions about underwater noise pollution.

1.4 Logistics

The LandRAY generator is being preassembled in Ridgefield, WA to perform critical mechanical checks in a controlled environment where inspections and adjustments can be easily made before going to NREL. This creates a need to disassemble the components into pieces which can be trucked over land.

1.4.1 Transportation

The transportation of large components for LandRAY is as follows:

- Siemens generator segments – Germany to Ridgefield, WA
- Siemens M2G components – Alpharetta, GA to Louisville, CO
- Kaydon bearings – Avon, OH to Ridgefield, WA
- LandRAY generator and frame– Ridgefield, WA to Louisville, CO

1.4.2 Assembly

The assembly of the LandRAY systems will begin at Ershigs in Ridgefield, WA. Once the system is fully assembled and checked, it will be disassembled and trucked to NREL in Louisville, CO. Once at NREL, the re-assembly follows the staged approach to our test plan as outlined in section 1.3 of this document and shown in:

- *LandRAY Assembly and Testing Procedures.pdf*

1.4.3 *Personnel/office plans*

1.4.3.1 NREL NWTC, Louisville CO

Columbia Power engineers and technicians will spend significant time onsite at the NWTC 5MW dyno in Louisville, CO. Assembly, commissioning, and disassembly activities will occur in the highbay area. In order to ensure work is performed safely, all CPwr personnel will undergo safety training and all activities will occur in accordance with the NREL Safe Operating Procedures and under the supervision of the NREL safety officer.

In addition to onsite personnel CPwr will have two engineers working as data analysts at their Corvallis, OR location who will process and quality control all operational and performance data in near real-time to ensure all trial data is collected at the highest quality.

During testing CPwr engineers and NREL dyno control staff will occupy the second floor control room unless otherwise allowed into the highbay by the safety officer. The following spread sheet covers the proposed personnel plan for all stages of testing.

- *LandRAY Personnel v1.0- Confidential.pdf*

1.5 Schedule

LR-SCH-G1 v3.10.mpp

ID	Task Name	Start	Finish	% Complete
1	**Design Phase**	**Jun 3 '13**	**Aug 15 '14**	**84%**
122	DOE FOA 848 Approval and Contracting	Sep 2 '13	Jan 2 '14	100%
123	**FOA 848 Topic 2 DDR PMG build and test**	**Dec 16 '13**	**Jan 19 '16**	**11%**
124	**Task 1.0 Project development**	**Jan 3 '14**	**Apr 30 '14**	**100%**
129	**Task 2.0 Dynamometer site preparation & planning**	**Jun 16 '14**	**Sep 26 '14**	**68%**
141	**Task 3.0 Design completion, review and build approval**	**Dec 16 '13**	**Sep 3 '14**	**58%**
156	**Task 4.0 PTO component manufacture**	**Jan 17 '14**	**Jan 28 '15**	**2%**
189	**Task 5.0 PTO pre-assembly and test-fit**	**Jul 31 '14**	**Jan 29 '15**	**0%**
203	**Task 5.5 Interim SPA goal assessment**	**Jan 3 '14**	**Jan 29 '15**	**14%**
206	**Task 6.0 PTO disassembly and transport to test facility**	**Jan 28 '15**	**Feb 18 '15**	**0%**
209	**Task 7.0 PTO assembly and installation at test facility**	**Feb 11 '15**	**Jun 8 '15**	**0%**
259	**Task 8.0 Verification & Validation**	**May 5 '14**	**Jun 9 '15**	**0%**
324	**Task 9.0 Disassemble and ship**	**Jan 3 '14**	**Aug 21 '15**	**0%**
328	**Task 10.0 PTO design report**	**Jun 9 '15**	**Nov 3 '15**	**0%**
332	**Task 11.0 Data analysis and Final Test Report**	**Aug 11 '15**	**Dec 29 '15**	**0%**
338	Task 12.0 Final Report	Dec 29 '15	Jan 19 '16	0%
339	**Deliverables**	**Jan 16 '14**	**Jan 30 '16**	**0%**
340	M1.1 Intellectual property management plan	Feb 13 '14	Feb 13 '14	100%
341	M1.2 Project management plan	Mar 4 '14	Mar 4 '14	100%
342	M2.1 Site plan report	May 2 '14	May 2 '14	100%
343	M3.1 Component Design Report / PTO design	May 2 '14	May 2 '14	100%
344	M3.2 Generator build begins	Jan 16 '14	Jan 16 '14	100%
345	M3.3 Mechanical build begins	Apr 2 '14	Apr 2 '14	0%
346	M4.1 Generator segments built	Sep 2 '14	Sep 2 '14	0%
347	M4.2 Mechanical PTO built	Jul 2 '14	Jul 2 '14	0%
348	M5.1 Pre-Assembly complete and verified	Dec 2 '14	Dec 2 '14	0%
349	M5.6 Interim metrics review	Dec 2 '14	Dec 2 '14	0%
350	GO/NO-GO	Dec 2 '14	Dec 2 '14	0%
351	M6.1 PTO arrives at test center	Jan 2 '15	Jan 2 '15	0%
352	M7.1 PTO build and test setup complete	Feb 2 '15	Feb 2 '15	0%
353	M8.1 Test Plan	Jul 25 '14	Jul 25 '14	10%
354	M8.2 Verification and Validation complete	Jul 2 '15	Jul 2 '15	0%
355	M9.1 PTO relocated	Aug 3 '15	Aug 3 '15	0%
356	M10.1 PTO design report	Dec 2 '15	Dec 2 '15	0%
357	M11.1 Final Test Report	Dec 2 '15	Dec 2 '15	0%
358	M11.2 SPA and Integration Report	Dec 2 '15	Dec 2 '15	0%
359	M12.1 Final Report	Jan 4 '16	Jan 4 '16	0%
360	M12.2 Technical data documentation, compilation, and delivery	Dec 22 '15	Jan 4 '16	0%
361	**QTRLY reports**	**Jan 30 '14**	**Jan 30 '16**	**0%**
371	**Annual peer reviews**	**May 11 '15**	**May 11 '15**	**0%**
372	Annual peer reviews 1	May 11 '15	May 11 '15	0%
373				
374	Prior project scope			
375	DE-EE-0006399 Project Scope