National Renewable Energy Centre (Narec)

An Introduction to the Narec Grid Emulator

Alex Neumann, Director of Specialist Services

13th June 2013

narec

Advancing Offshore Renewable Energy

The National Renewable Energy Centre (Narec)

Overview

Open- access, independent, quality assured translational research, development and testing facilities for offshore wind, wave, tidal and electrical network technologies.

Clients and Collaborators

Manufacturers, project developers, utilities, universities, research organisations and supply chain companies.

Services

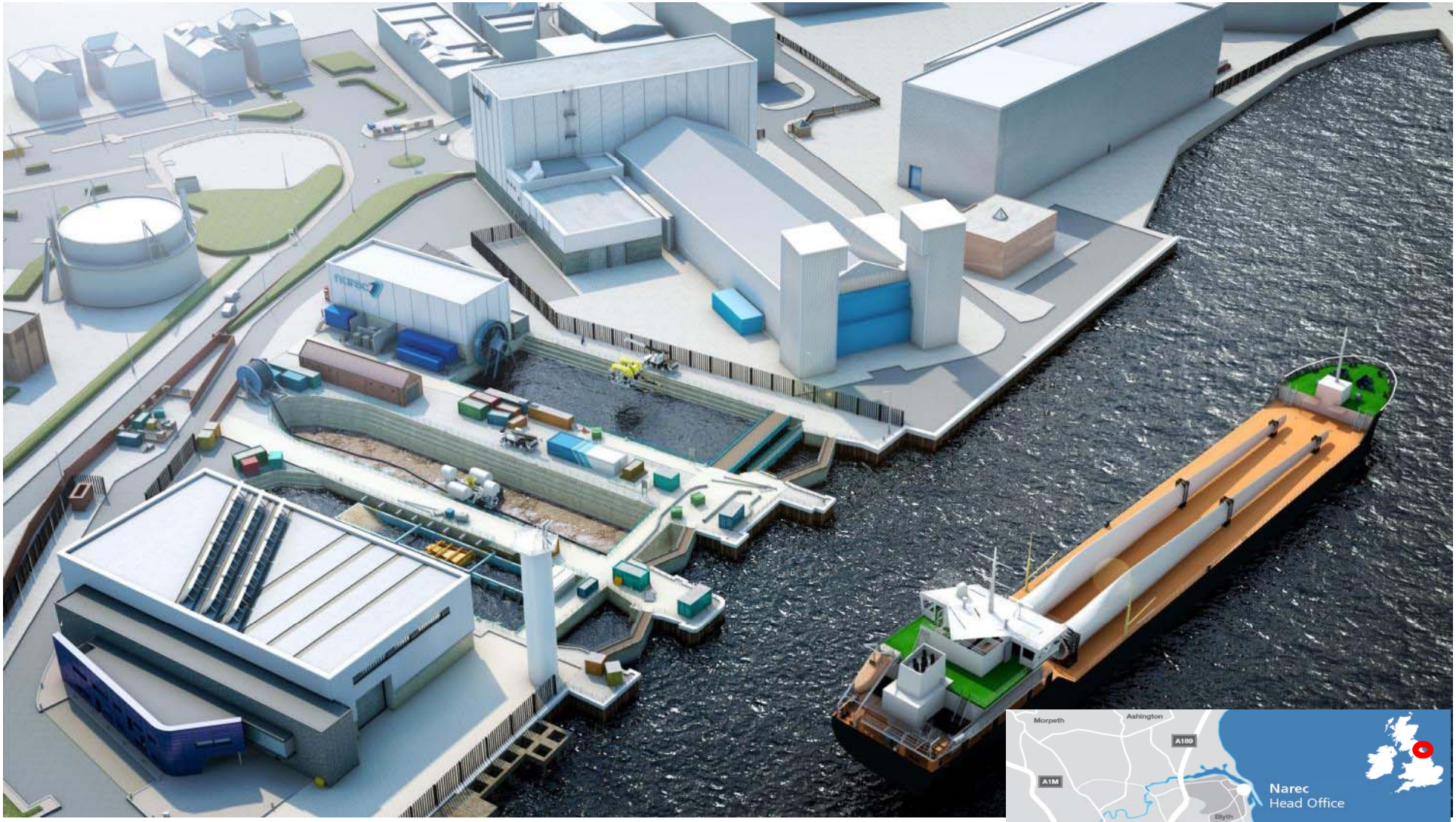
- Applied research and technology development services
- Specialist consultancy
- Certification and development testing
- Demonstration
- Systems integration
- Performance verification

R&D → TESTING → DEMONSTRATION → DEPLOYMENT

energy technologies Institute | BIS Department for Business Innovation & Skills | Department of Energy & Climate Change | European Union Investing in Your Future — European Regional Development Fund 2007-13

narec

Advancing Offshore Renewable Energy



A Controlled and Independent Development Platform

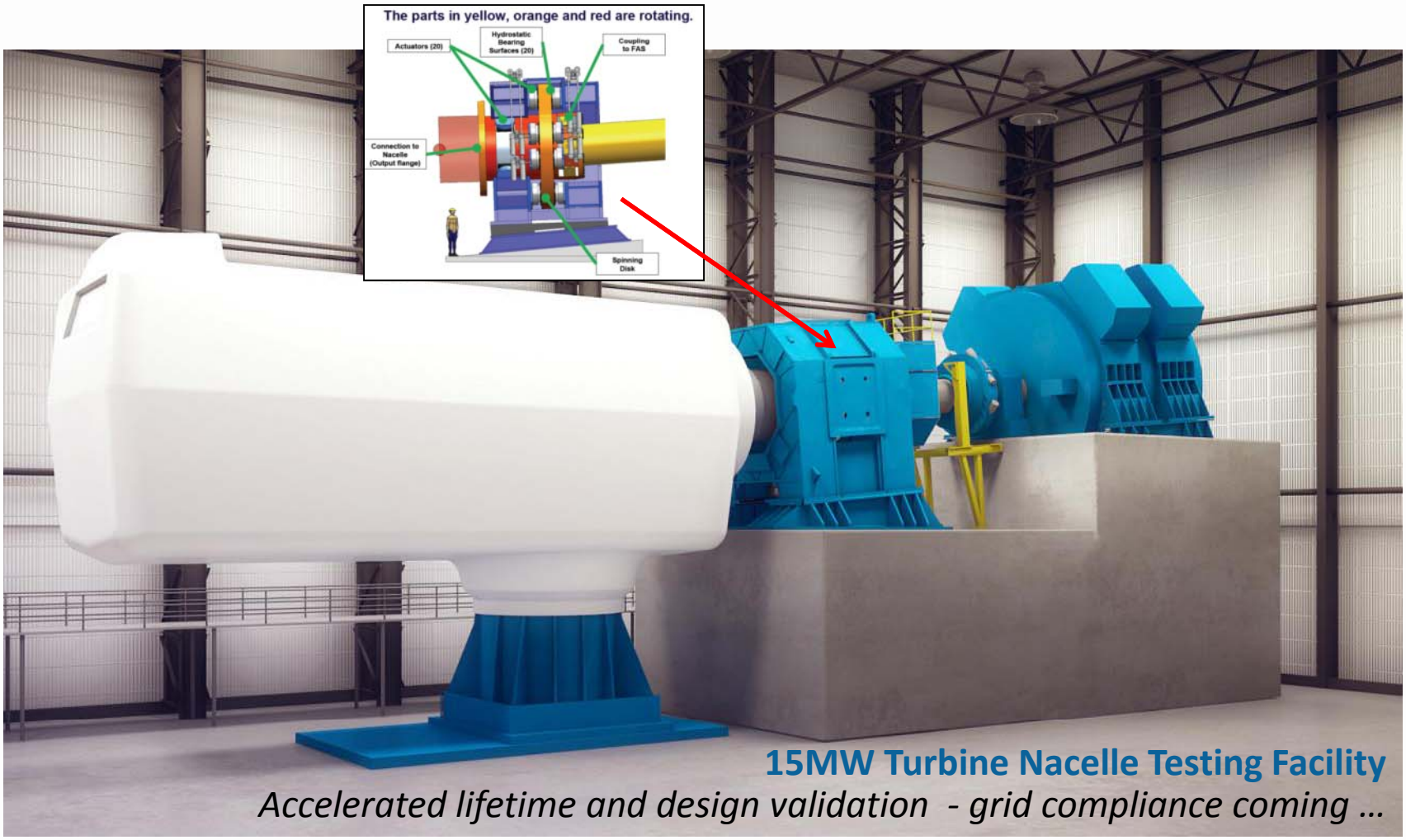
Existing

- 50m blade test
- Still water tank
- Wave flume
- Simulated seabed
- Wind turbine training tower
- Electrical and materials laboratories

New

- **3MW tidal turbine drive train**
- Offshore anemometry hub
- 100m blade test
- **15MW wind turbine drive train**
- 99MW offshore wind demo site
- **Narec Grid Emulator and LVRT**

15MW Nacelle Test Rig - Fujin



15MW Turbine Nacelle Testing Facility

Accelerated lifetime and design validation - grid compliance coming …

narec

Advancing Offshore Renewable Energy

15MW Fujin Facility Build Status

narec

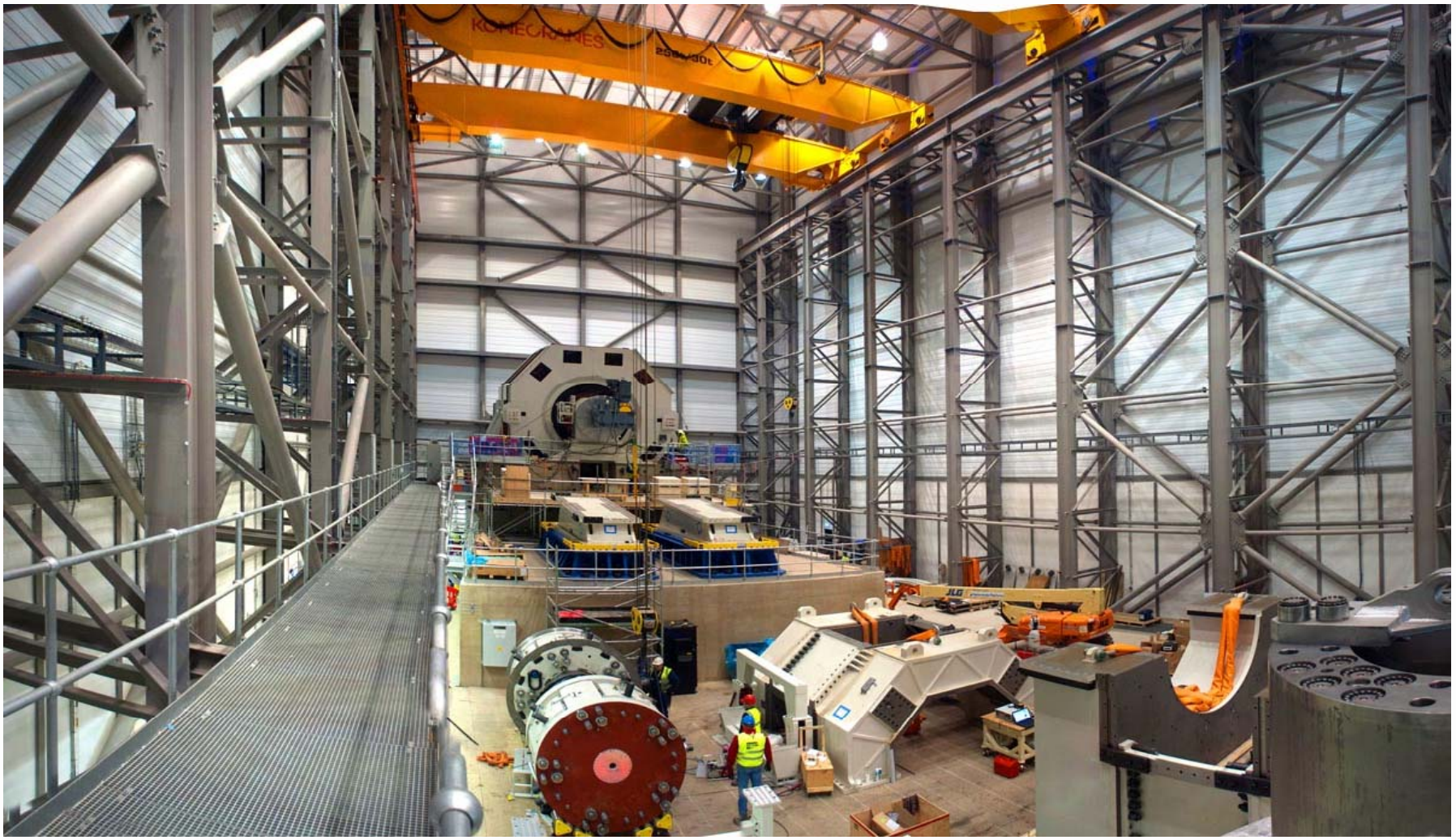
Advancing Offshore Renewable Energy

15MW Fujin Build Status

narec

Advancing Offshore Renewable Energy

15MW Fujin Build Status



narec

Advancing Offshore Renewable Energy

15MW Turbine Drive Train Testing Facility

Objective

To perform independent testing of wind turbines to de-risk infield activities by allowing Narec to perform reliability and performance appraisal of new devices and system components through accelerated lifetime testing.

Key Characteristics

- 15MW capacity for testing entire systems
- Representative variable torque (max 14.3MNm) and speeds (max 30rpm)
- 6 degrees of freedom for applying load forces
- Bending moment (max 56MNm)
- Force Application System (FAS) frequency response 2.5Hz

Typical Testing Activities

- Entire nacelle prototype test capability (system or major component within system)
- New supplier validation testing (major component)
- Internal manufacturing conformance testing (system or major component within system)
- Endurance testing
- Improvements to models physical and numerical – condition monitoring validation
- Research and development

Timescale

- Construction of facility almost complete
- Commissioning July/August 2013
- First test to start August/September

energy technologies institute

narec

Advancing Offshore Renewable Energy

3MW Tidal Turbine Nacelle Test Facility - Nautilus

3MW Turbine Nacelle Testing Facility

Accelerated lifetime and design validation - grid compliance coming …

narec

Advancing Offshore Renewable Energy

3MW Turbine Drive Train Testing Facility

Objective

- Perform accelerated lifetime testing of integrated turbine nacelle systems and the individual drive train components of prototype tidal power generation devices.
- Simulate the environmental loads likely to be experienced by a tidal device offshore, to reduce the financial risk and improve reliability for developers, before full demonstration and deployment at sea.

Key Characteristics

- 3MW shaft input power rotary test rig
- Max torque 5MNm (≤6rpm)
- Max speed 30rpm
- Load application system
- Grid connection
- Comprehensive range of data measurements
- Max bending moment applied by Force Application System (FAS) – 15MNm

Typical Testing Activities

- New supplier validation testing (major component)
- Internal manufacturing conformance testing (system or major component within system)
- Improvements to models physical and numerical – condition monitoring validation
- Research and development
- Power curve assessment
- Design verification of control system
- System performance and endurance
- Highly Accelerated Lifetime Testing (HALT)

DEPARTMENT OF ENERGY & CLIMATE CHANGE
EUROPEAN UNION Investing in Your Future
European Regional Development Fund 2007-13

narec
Advancing Offshore Renewable Energy

Deployment, demonstration and validation

narec

Advancing Offshore Renewable Energy

Blyth Offshore Wind Demonstration Site

Objective

- Allow developers and OEMs to demonstrate and test prototype and pre-commercial full-scale offshore wind turbines
- Opportunity to study alternative foundation types, construction methods and remote monitoring

Key features

- Total of 15 turbines, 3 arrays, max number of 5 turbines in each array
- Water depths range from 35m - 58m
- Site can accommodate machines up to 195m tip height
- Distances from the coast range from 5.7km - 13.8km
- Total facility capacity up to 100MW
- Offshore Anemometry Hub
- Grid connection agreement with distribution network operator

Timescale

- Construction expected between 2015 - 2016
- Timescale for single array construction around 3-6 months
- The Offshore Anemometry Hub installed Q3 2012

BIS Department for Business Innovation & Skills | THE CROWN ESTATE

narec

Advancing Offshore Renewable Energy

Wind Turbine Blade Testing Centre
Development and certification

Can test blades up to 100m, three test stands, static and fatigue capability

narec

Advancing Offshore Renewable Energy

Certification, development, accelerated lifetime, endurance.

Independent and accredited

HV: Cables, insulating materials, generator windings, switchgear, transformers. etc…

LV: grid conformance, network simulation

narec

Advancing Offshore Renewable Energy

Micro renewables: ER G83 certification

Engineering Recommendation (ER) G83/2 – 2012 revision - technical requirements for the connection ***of small scale embedded generators*** in parallel with public low voltage distribution networks. This recommendation covers small scale generator equipment ***connected at LV up to and including 16A per phase.***

- Over/under frequency and voltage
- Loss of mains protection
- Harmonic emissions , and flicker to BS EN 61000-3-2/3
- Over current protection to BS7671
- Power factor range
- Short circuit contribution
- DC injection
- Environmental testing
- Wiring regulation compliance

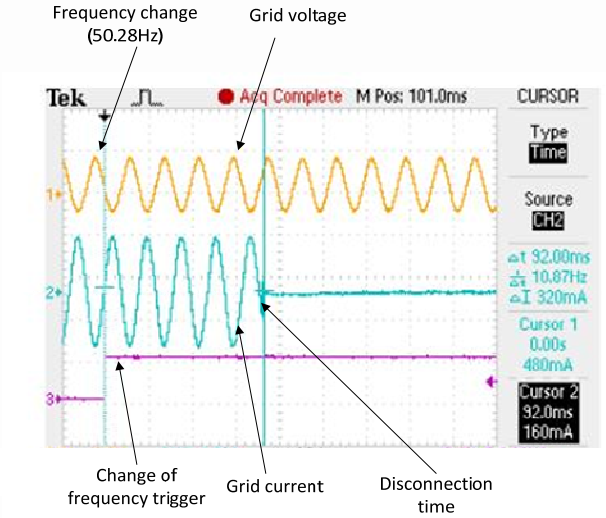


Figure shows typical 'over frequency' measurement for an inverter under test validating the protective equipment

LV electrical lab also used for conducting small-scale LVRT testing (up to 100kW)…

narec

Advancing Offshore Renewable Energy

Introduction

Narec "Large System" Grid Conformance Testing

Narec operates a number of cutting edge facilities to accelerated validation of wind and marine renewable energy devices in a controlled environment reducing time to market, improving reliability and mitigating the risks associated with deployment of these devices.

The Grid Emulator and Low Voltage Ride Through (LVRT) test rigs will allow Narec to perform endurance testing and power quality validation for the wind turbines based on the requirements of:

- International Grid Codes
- Standards (e.g. IEC, BS, etc.), and
- Guidelines (e.g. IEEE, GL, DUV, etc.)

Design and procurement underway, Narec electrical test systems in place Q3/4 2014.

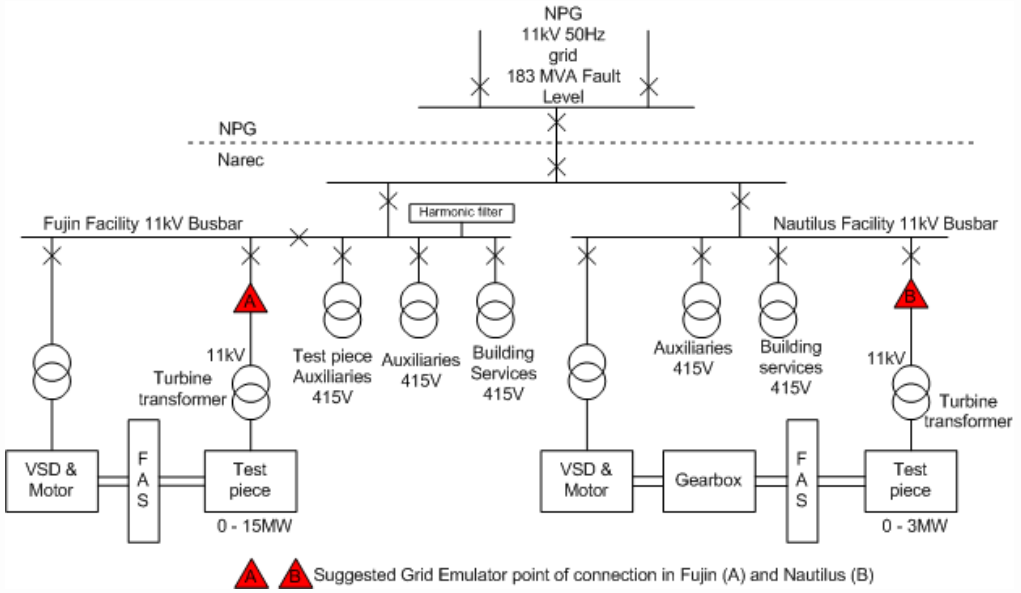
narec

Advancing Offshore Renewable Energy

Narec Grid Emulator

Outline Functional specification

- Rated at 10MW
- Cross functionality, i.e. able to switch between testing on the 3MW Nautilus test facility and the 15 MW Fujin test facility



- Equipped with power quality supervisory system to monitor and log the quality of power at the output of the test piece (DUT) and incoming 11kV supply
- Ability to perform electrical “Hardware in the Loop” (HIL) operation (optional at this stage) to simulate virtual grid applications
- Capable of generating 140% overvoltage (test piece end) for at least 500ms to allow High Voltage Ride Through (HVRT) test

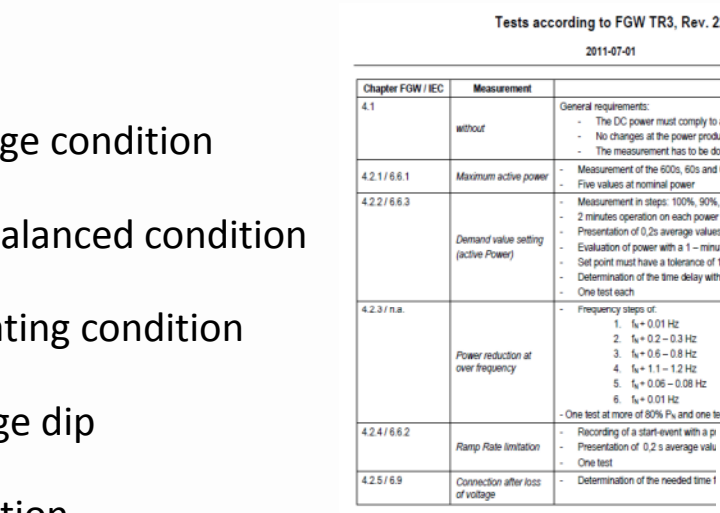
narec

Advancing Offshore Renewable Energy

Narec Grid Emulator

Capabilities

- 50/60Hz grid voltage condition
- Asymmetrical/unbalanced condition
- 3 and 4 wire operating condition
- Symmetrical voltage dip
- Grid voltage distortion
- Voltage fluctuation
- Lagging and leading reactive power grid condition
- Grid fault level condition (i.e. simulate different grid Z)
- Harmonic distortion condition replication (i.e. THD and ind)
- Both symmetrical and asymmetrical voltage dip feature to perform Low Voltage and Zero Voltage Ride Through (LVRT and/or ZVRT)

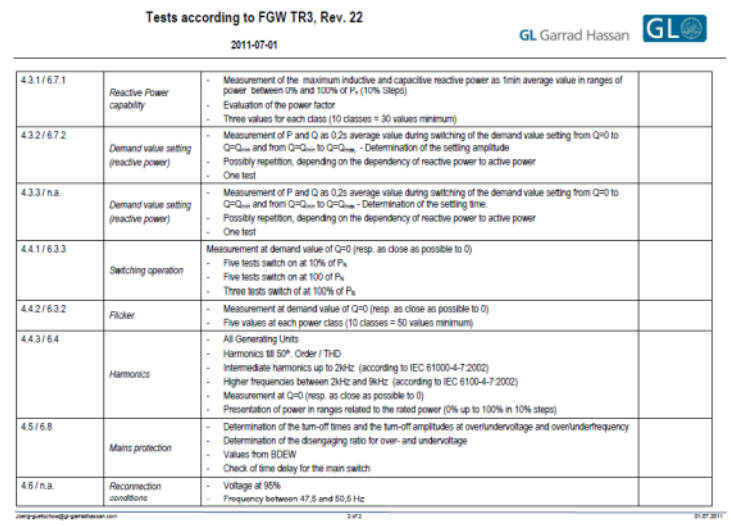


Tests according to FGW TR3, Rev. 22

2011-07-01

GL Garrad Hassan

Chapter FGW / IEC	Measurement	Content	Done?
4.1	*without*	General requirements: - The DC power must comply to annex E **(PV)** - No changes at the power producer are allowed which might change the electrical characteristics - The measurement has to be done at the specified connection terminals	
4.2.1 / 6.6.1	*Maximum active power*	- Measurement of the 600s, 60s and 0,2s average value - Five values at nominal power	
4.2.2 / 6.6.3	*Demand value setting (active Power)*	- Measurement in steps: 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 15%, 0 % of P_N - 2 minutes operation on each power step - Presentation of 0,2s average values - Evaluation of power with a 1 – minute average value - Set point must have a tolerance of 1 % maximum - Determination of the time delay with one test with a step of 100% to 30% of P_N - One test each	
4.2.3 / n.a.	*Power reduction at over frequency*	- Frequency steps of: 1. f_N + 0.01 Hz 2. f_N + 0.2 – 0.3 Hz 3. f_N + 0.6 – 0.8 Hz 4. f_N + 1.1 – 1.2 Hz 5. f_N + 0.06 – 0.08 Hz 6. f_N + 0.01 Hz - One test at more of 80% P_N and one test between 40% to 60% P_N	
4.2.4 / 6.6.2	*Ramp Rate limitation*	- Recording of a start-event with a p - Presentation of 0,2 s average valu - One test	
4.2.5 / 6.9	*Connection after loss of voltage*	- Determination of the needed time t	



Tests according to FGW TR3, Rev. 22

2011-07-01

GL Garrad Hassan

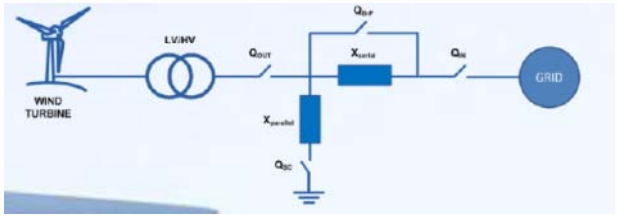
4.3.1 / 6.7.1	*Reactive Power capability*	- Measurement of the maximum inductive and capacitive reactive power as 1min average value in ranges of power between 0% and 100% of P_N (10% steps) - Evaluation of the power factor - Three values for each class (10 classes = 30 values minimum)	
4.3.2 / 6.7.2	*Demand value setting (reactive power)*	- Measurement of P and Q as 0,2s average value during switching of the demand value setting from Q=0 to $Q=Q_{min}$ and from $Q=Q_{min}$ to $Q=Q_{max}$ - Determination of the settling amplitude - Possibly repetition, depending on the dependency of reactive power to active power - One test	
4.3.3 / n.a.	*Demand value setting (reactive power)*	- Measurement of P and Q as 0,2s average value during switching of the demand value setting from Q=0 to $Q=Q_{min}$ and from $Q=Q_{min}$ to $Q=Q_{max}$ - Determination of the settling time. - Possibly repetition, depending on the dependency of reactive power to active power - One test	
4.4.1 / 6.3.3	*Switching operation*	Measurement at demand value of Q=0 (resp. as close as possible to 0) - Five tests switch on at 10% of P_N - Five tests switch on at 100 of P_N - Three tests switch of at 100% of P_N	
4.4.2 / 6.3.2	*Flicker*	- Measurement at demand value of Q=0 (resp. as close as possible to 0) - Five values at each power class (10 classes = 50 values minimum)	
4.4.3 / 6.4	*Harmonics*	- All Generating Units - Harmonics till 50th, Order / THD - Intermediate harmonics up to 2kHz (according to IEC 61000-4-7:2002) - Higher frequencies between 2kHz and 9kHz (according to IEC 6100-4-7:2002) - Measurement at Q=0 (resp. as close as possible to 0) - Presentation of power in ranges related to the rated power (0% up to 100% in 10% steps)	
4.5 / 6.8	*Mains protection*	- Determination of the turn-off times and the turn-off amplitudes at overlundervoltage and overlunderfrequency - Determination of the disengaging ratio for over- and undervoltage - Values from BDEW - Check of time delay for the main switch	
4.6 / n.a.	*Reconnection conditions*	- Voltage at 95% - Frequency between 47,5 and 50,5 Hz	

narec

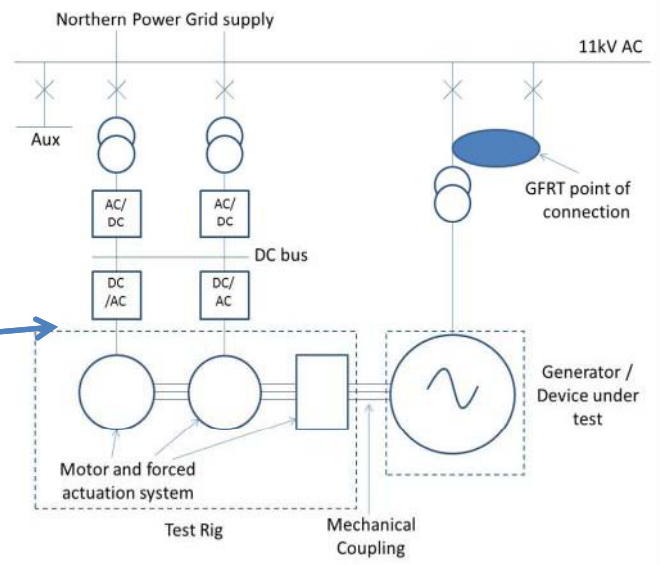
Advancing Offshore Renewable Energy

LVRT testing at Narec

- Developing the capability to accept mobile LVRT rigs to perform testing on the Narec drive train test stands.
- 8MVA rating now available through third parties, for operation at 33kV, 20kV or 11kV



- Procurement underway to Narec LVRT system, also able to work with (some) third party mobile test facilities
- Grid connection agreement expected July 2013

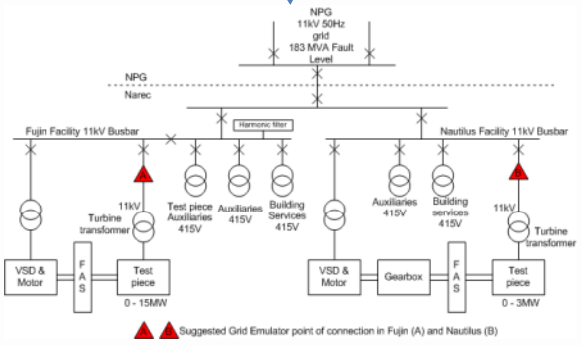


narec

Advancing Offshore Renewable Energy

Summary

- 3MW FAS drive train test operational
- 15MW FAS drive train test rig imminent commissioning
- Grid connection expected soon to allow LVRT through third parties
- Procurement underway for grid emulator and mobile LVRT, both expected to be in-service by end 2014…



Ambition/Opportunity

Mechanical and electrical drive train testing with HIL on both sides to provide realistic control system testing and system validation…

What level of certification can we realistically achieve on these facilities?

narec

Advancing Offshore Renewable Energy

Thanks for listening, any questions?


narec

Advancing Offshore Renewable Energy