NEM Grid Connection and Compliance

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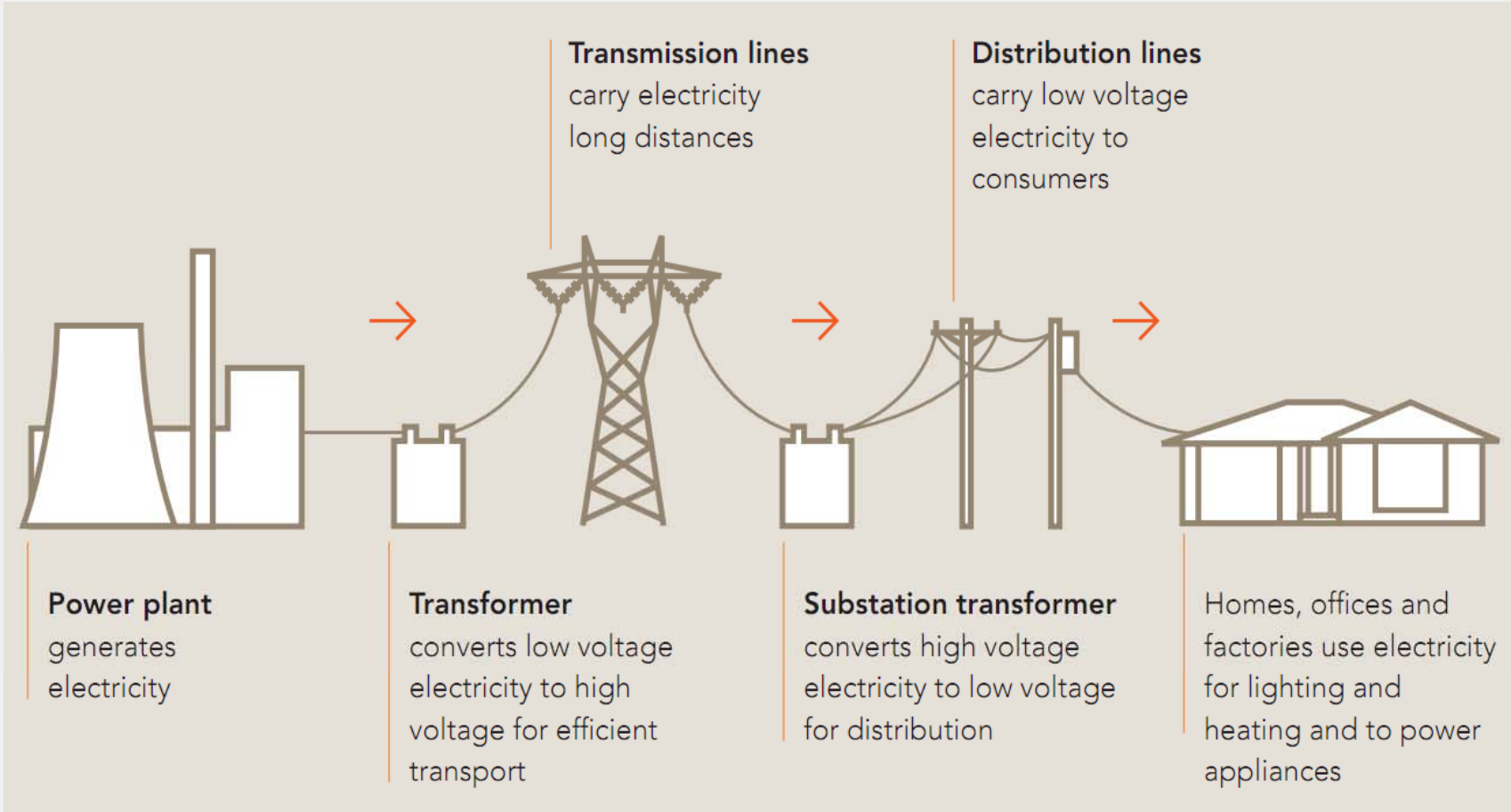
DIgSILENT Pacific

Presentation Outline

- Introduction to the Australian Electricity Market
- The Need for Compliance with the NER
- Validation of Compliance Process following a Plant Change
- Compliance & R2 Testing
- Q & A

Introduction



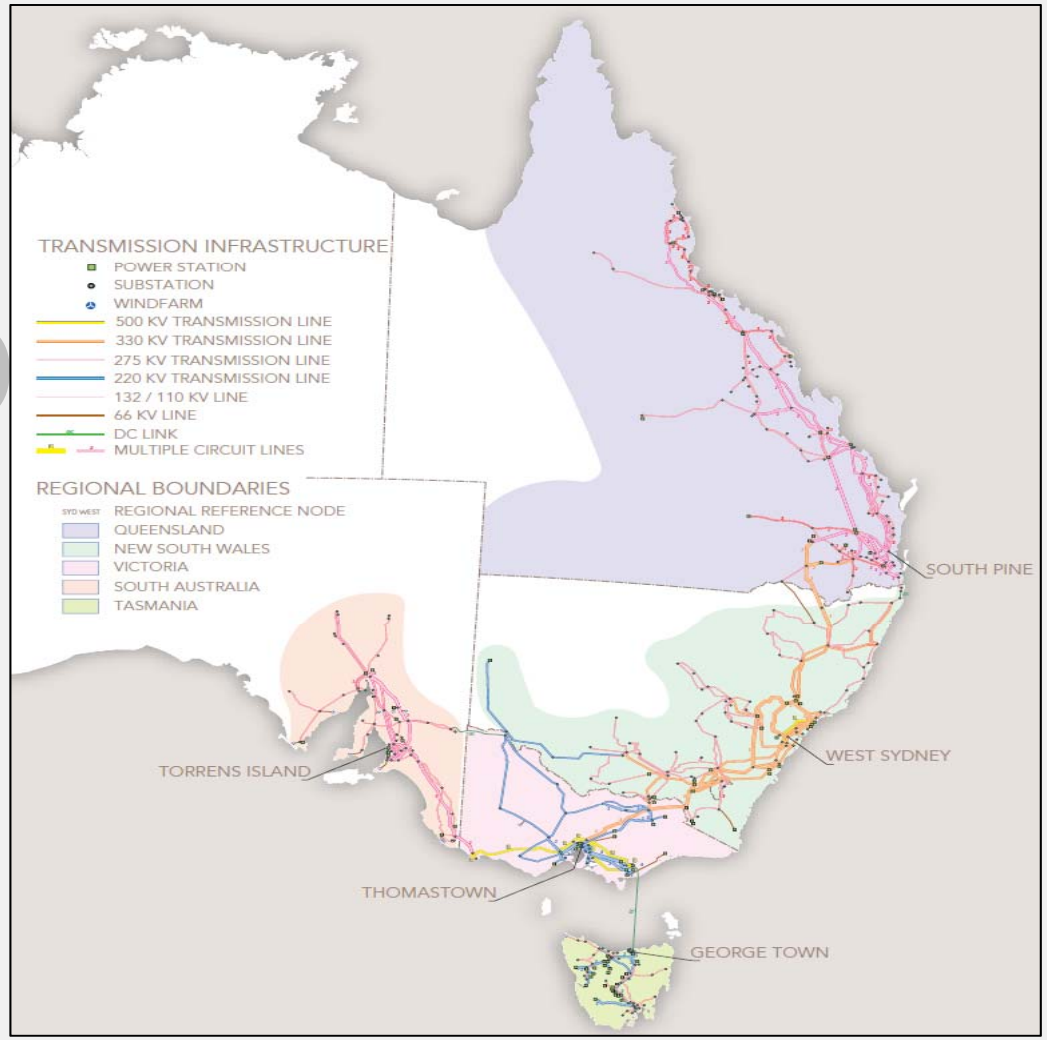
Source: AEMO (www.aemo.com.au)

Introduction – Australia's National Electricity Market

NEM – National Electricity Market

- A wholesale market for supply and purchase of electricity
- Output from all generators is combined and scheduled in real-time to meet consumer demand
- Commenced in 1988, the NEM operates one of the world's largest interconnected power system that runs for more than 5,000km *(Source: AEMO)*
- When NEM commenced, a Code provided guidelines for how the market was to operate
- In June 2005, the Code was replaced by the National Electricity Rules (NER)

Introduction – National Electricity Market



Source: AEMO (www.aemo.com.au)

Introduction – AEMC and AER

Australian Energy Market Commission – AEMC
www.aemc.gov.au

- Approves rules for the nation's energy markets
- National, independent body, they make and amend the detailed rules for the NEM and natural gas markets
- Responsible for oversight and regulation of the NEM since June 2005

Australian Energy Regulator – AER
www.aer.gov.au

- Regulates whole electricity market and responsible for economic regulation of transmission networks of the NEM
- Also responsible for economic regulation of gas networks and enforcing national gas law and gas rules

Introduction – AEMO

Australian Energy Market Operator – AEMO
www.aemo.com.au

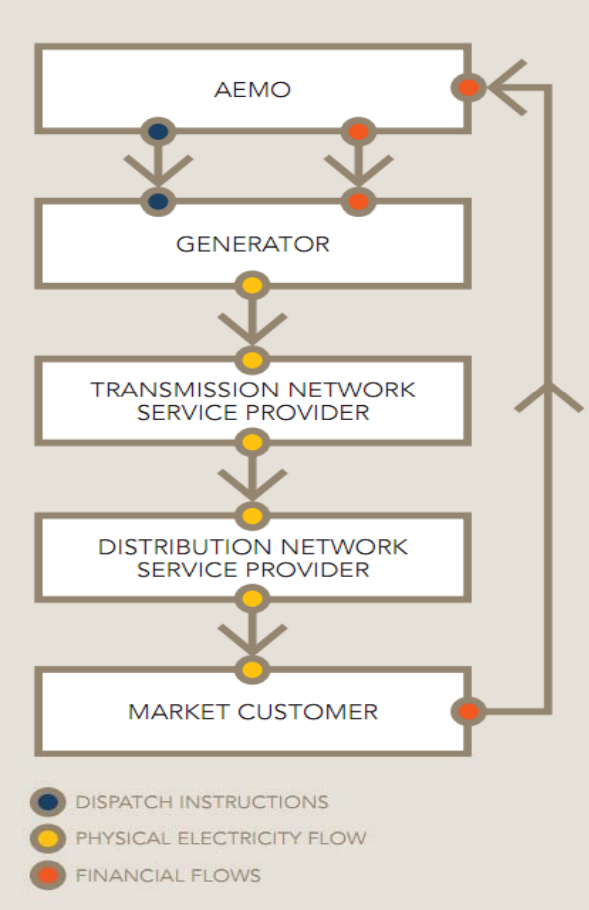
- AEMO's roles are:
  - Power System Operator
  - Market Operator
- Some of AEMO's responsibilities are:
  - Management of the NEM
  - Overseeing reliability and security of the NEM
  - Ensuring supply reserve to meet reliability standards
  - Directing generators to increase production during periods of shortfall
- Also responsible for gas market

Introduction –NER

National Electricity Rules – NER

- The NER govern the operation of NEM. The Rules have the force of law, and are made under the National Electricity Law
- Specifies the objectives, functions, and responsibilities of AEMO
- Current version is 47, downloaded from AEMC website, and it covers some of the following:
  - Registered Participants and Registration
  - Market Rules
  - Power System Security & Network Connection
  - Economic Regulation of Distribution and Transmission Services
  - Administrative Functions
  - Derogations

Introduction – Energy Flow



Source: AEMO (www.aemo.com.au)

<u>Transmission Network Service Provider – TNSP</u>

Owner and operator of the high-voltage transmission towers and wires that transport electricity

Examples of TNSP:

TransGrid – NSW
PowerLink – Queensland
ElectraNet – SA
TransEnd - Tasmania

<u>Distribution Network Service Provider</u>

Owner and operator of substations and the wires that transport from distribution centres to end-use consumers.

Introduction – Market Participant

Market Participant: Registered to participate in the NEM as either:

1. Market Generator (sells electricity);
2. Market Customer (purchases electricity); or
3. Market Network Service Provider (owns and operates a network linked to the NER)

An example of some Market Participants

Section 2

The Need for Compliance with the NER

The Need for Compliance with the NER

- The integrations of generation and into the power system must be coordinated so that levels of quality, reliability of supply and power system security can be maintained

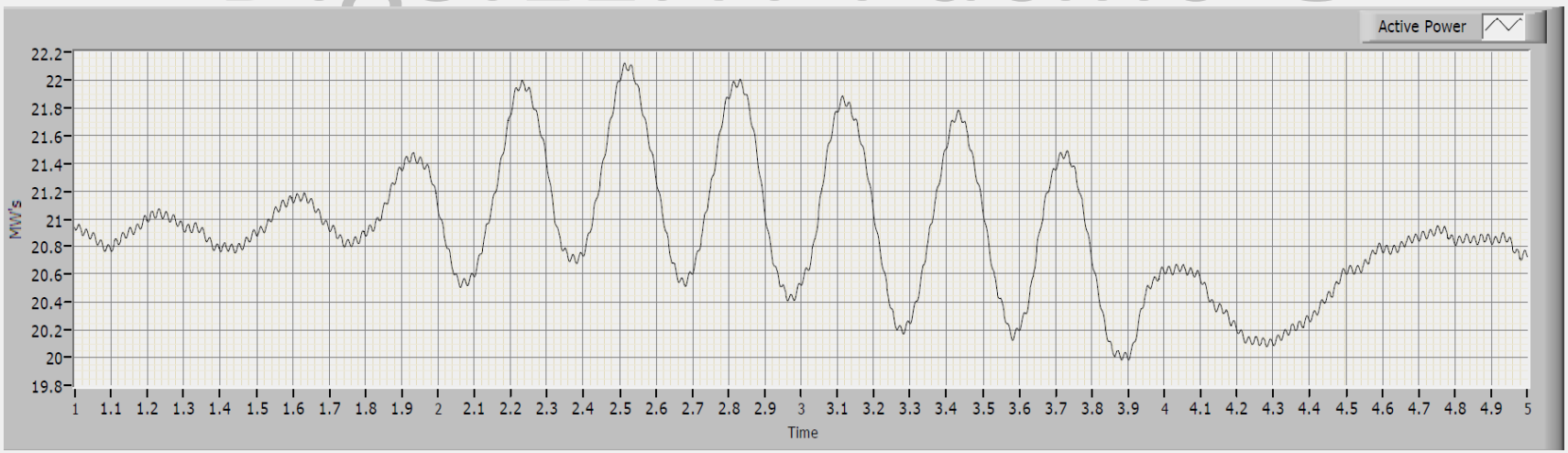
- Reliable and secure operation of a power system is tied to the ability of its mix of generation, transmission, and loads to operate under a variety of conditions

- For this reason, the NER includes processes to coordinate the technical interaction between new and existing generation and the power system

The Need for Compliance with the NER

- Accurate model data for generators, excitation systems, turbine governors and PSS is required to maintain accurate planning of the power system

- Assists organisations such as AEMO and TNSP's in planning and operation of the network



Commissioning of PSS on 100 MVA GT with settings designed on incorrect data

The Need for Compliance with the NER – Performance Standards

- Rules specify each generating unit must meet a number of technical requirements and these form part of the technical terms and conditions of the Connection Agreement

- These are met by ensuring generators meet a range of performance standards

- The Rules allow performance standards to be negotiated between the Proponent, the NSP, and AEMO

- An access standard is a benchmark for determining the appropriate performance standard for each unit:

    - Minimum Access Standard
    - Automatic Access Standard
    - Negotiated Access Standard

The Need for Compliance with the NER – Performance Standards

- Minimum Access Standard – minimum performance standard specified in Rules. If a generating unit does not meet this standard, plant will be denied access to network

- Automatic Access Standard – The upper bound for an access standard.

- Negotiated Access Standard – Falls somewhere between the automatic and minimum bounds for the standard of performance

- *Note that no generator will have 'minimum' as a standard, instead it will be 'negotiated' at the minimum level.*

Section 3

Validation of Compliance Process following a Plant Change

Validation of Compliance Process following a Plant Change

- Compliance process commences once a Generator proposes to install a new AVR (or for new generator connections)
- The following actions need to be taken for an AVR upgrade *before commissioning:*
  - ✓ Data sheets for the excitation system (incl. exciter, regulator, PSS, limiters, etc)
  - ✓ Design Report
  - ✓ Model – functional block diagram and source code
  - ✓ Releasable User Guide
  - ✓ Commissioning Plan

Validation of Compliance Process following a Plant Change – Data sheets

- Prior to the connection, generator must submit registered data related to the excitation system

- Registered data falls into two categories:

  (a) *Prior to actual connection and provision of access, data derived from manufacturers' data, detailed design calculations, works or site tests etc (R1);*

  (b) *After connection, data derived from on-system testing (R2)*

Validation of Compliance Process following a Plant Change – Data sheets

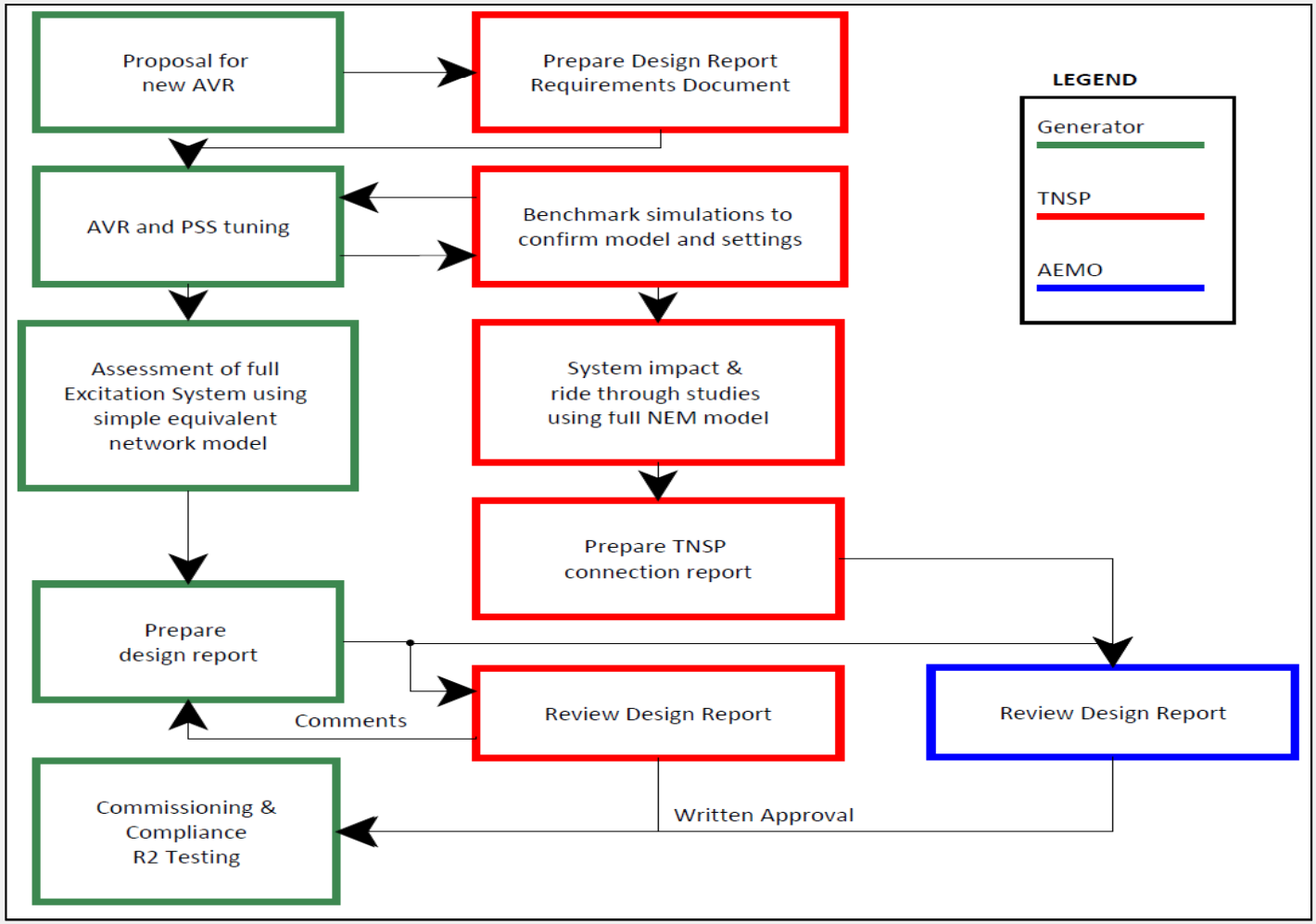
Datasheets can be downloaded
From AEMO website
www.aemo.com.au

10.1	Synchronous Machine Excitation System				
Symbol	Data Description	Units	Data Category	Value	Remarks
	The list of *generating units* to which this information applies.	Text	S, D, R1, R2		
	Manufacturer and manufacturer's type designation or product name.	Text	R1, R2		

10.1.1	Design Data Sheet				
Symbol	Data Description	Units	Data Category	Value	Remarks
VCEIL	Rotor *voltage* capable of being supplied for 5s at rated *voltage* (VTGEN) and rated speed	V	D, R1		
VFMIN	Minimum field *voltage*	V	D, R1		
	Maximum rate of change of field *voltage*	Rising V/s	D, R1		
	Maximum rate of change of field *voltage*	Falling V/s	D, R1		
	Exciter description including type, ratings, connection schematic, source of any external supplies, etc.	Text	D, R1		
	If applicable, exciter saturation curve over 50%-120% of rated voltage.	Diagram	D, R1		
	Details of the excitation *control system* described in functional block diagram form showing: • *voltage control systems* (*AVR*); • *power system* stabiliser • exciter; • reactive current or *reactive power* compensation (if fitted) (e.g. Load drop compensation/VAr sharing, also referred to as line drop compensation or *reactive power* droop);	Functional block diagram	S, D, R1		

10.1.2	Setting Data Sheet				
Symbol	Data Description	Units	Data Category		
	DC gain of excitation control loop	V/V	D, R1		
	Active power operating range of the *generating unit* when the *PSS* is in operation.		D, R1		
	All functional block diagram parameters, in accordance with Rule s5.2.4 (b), (gains, time constants, mathematical functions, non-linear characteristics, limits, etc.) for:				
	• *voltage control systems* (*AVR*);		D, R2		
	• *power system* stabiliser; • exciter;		D, R2 D, R2		
	• reactive current or *reactive power* compensation;		D, R2		
	• over-excitation limiter;		D, R2		
	• under-excitation limiter;		D, R2		
	• stator current limiter;		D, R2		
	• flux (*V/f*) limiter; and		D, R2		
	• any other limiters that may restrict excitation *control system* operation.		D, R2		

Validation of Compliance Process following a Plant Change



Flow chart of activities and responsibilities associated with preparation and approval of a design report

Validation of Compliance Process following a Plant Change – Design Report

- The design report aims to evaluate compliance against the sections of the NER that the proposed alteration will affect. According to S5.3.9 (d), these are:
  - S5.2.5.5 “Generating system response to disturbances following contingency events”
  - S5.2.5.7 “Partial load rejection”
  - S5.2.5.12 “Impact on network capability”
  - S5.2.5.13 “Voltage and reactive power control”
- Evaluation of “S5.2.5.5, .7, .12” require full 5 state model of the NEM. Typically assessed by TNSP and/or AEMO;
- S5.2.5.13 is assessed in the design report prepared by the asset owner’s consultant;

Validation of Compliance Process following a Plant Change – Design Report

- Design report will present proposed settings and results of simulation studies to demonstrate that with the new excitation system the generating unit will comply with S5.2.5.13 – Voltage and reactive power control

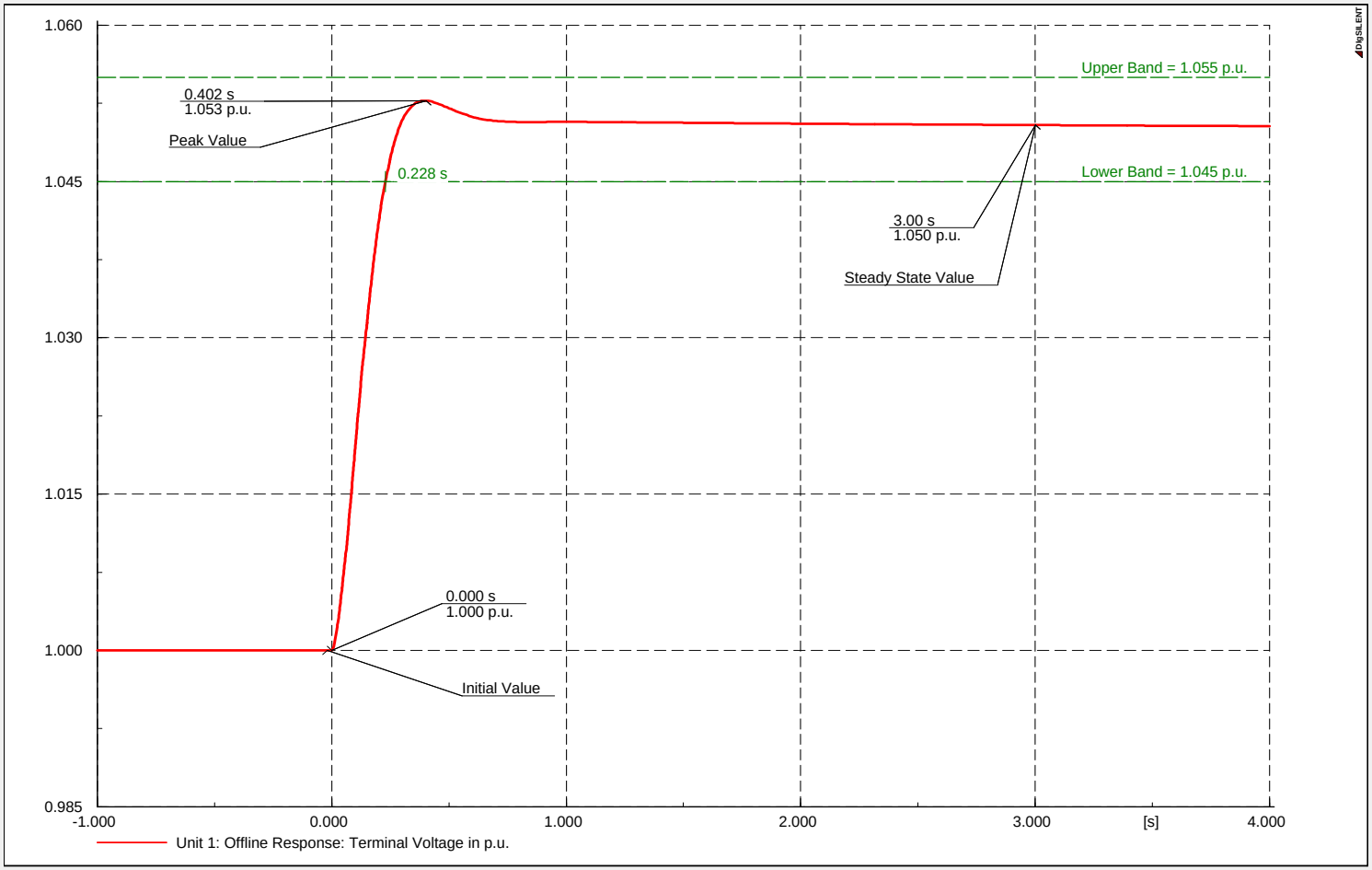
- The document will contain:

  - ✓ AVR design and assessment of performance offline and online
  - ✓ PSS design
  - ✓ Small signal stability analysis
  - ✓ Excitation limiter design and assessment of online performance
  - ✓ Co-ordination with generator protection
  - ✓ Recommend/propose settings

- AEMO will then consider the proposed settings as those values that will be used during commissioning. Any large deviations will need to be explained

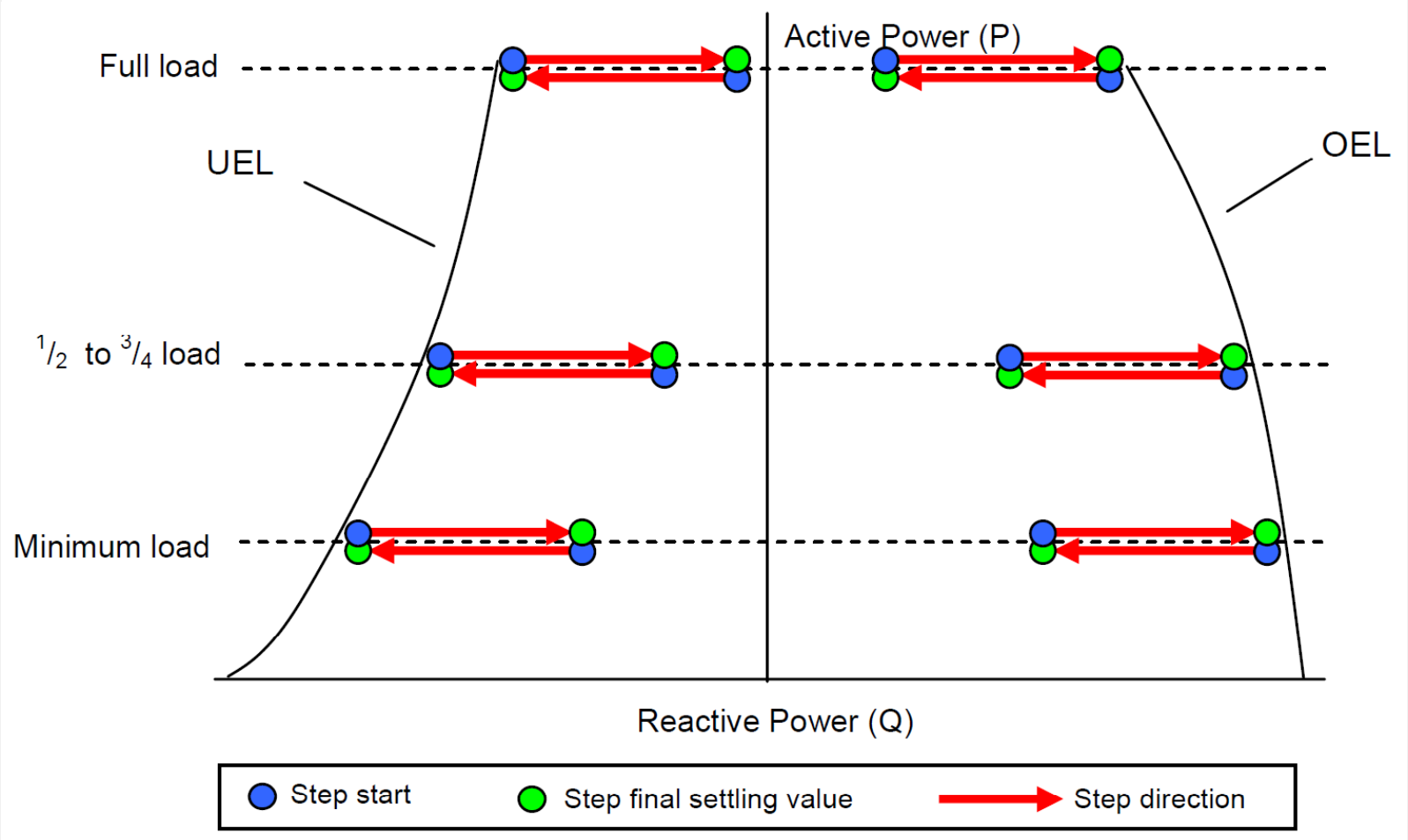
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Unsynchronised Settling Time < 2.5 seconds for 5% change



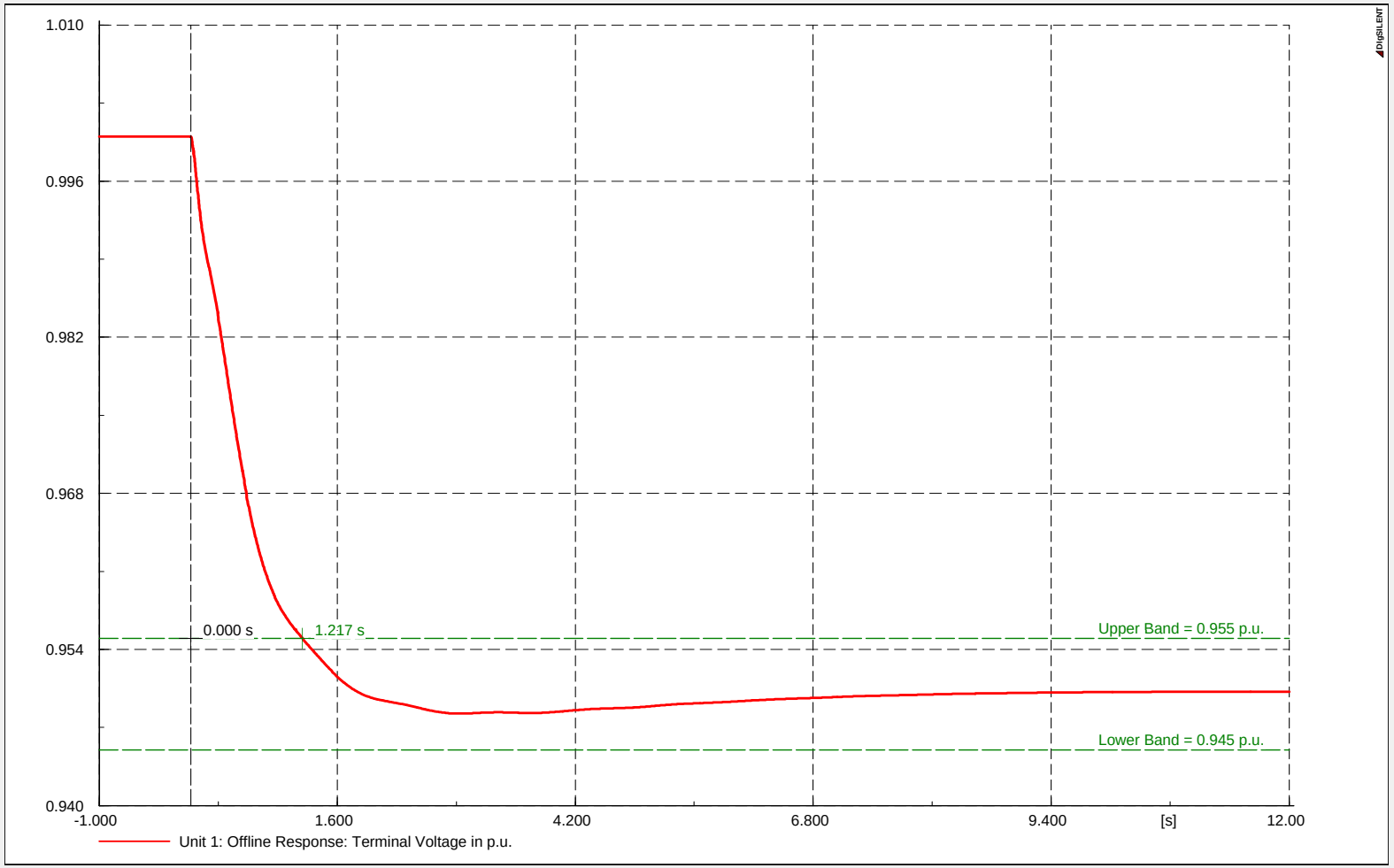
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Step response simulations without limiter operation



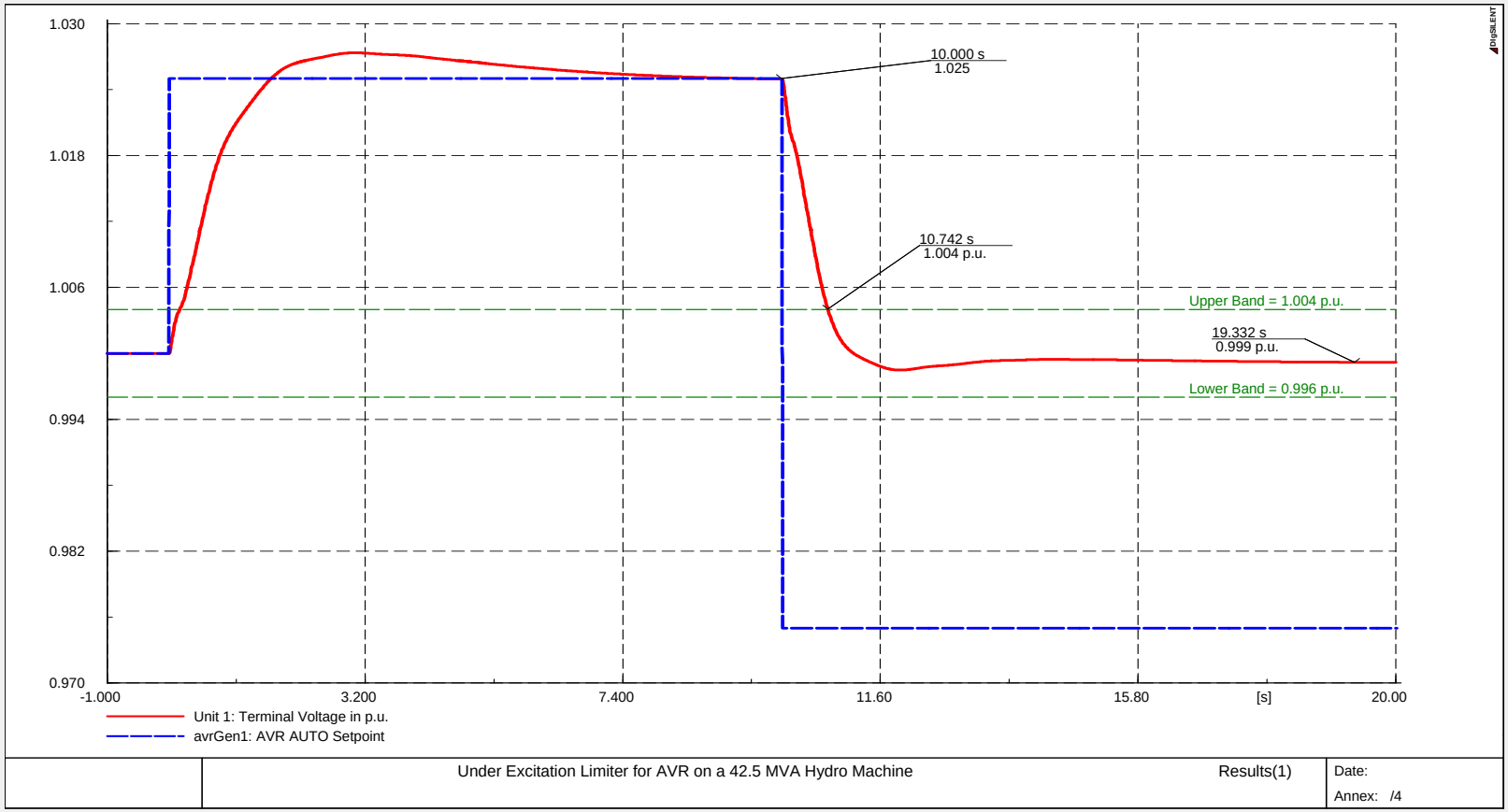
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Synchronised Settling Time < 5 seconds for 5% change



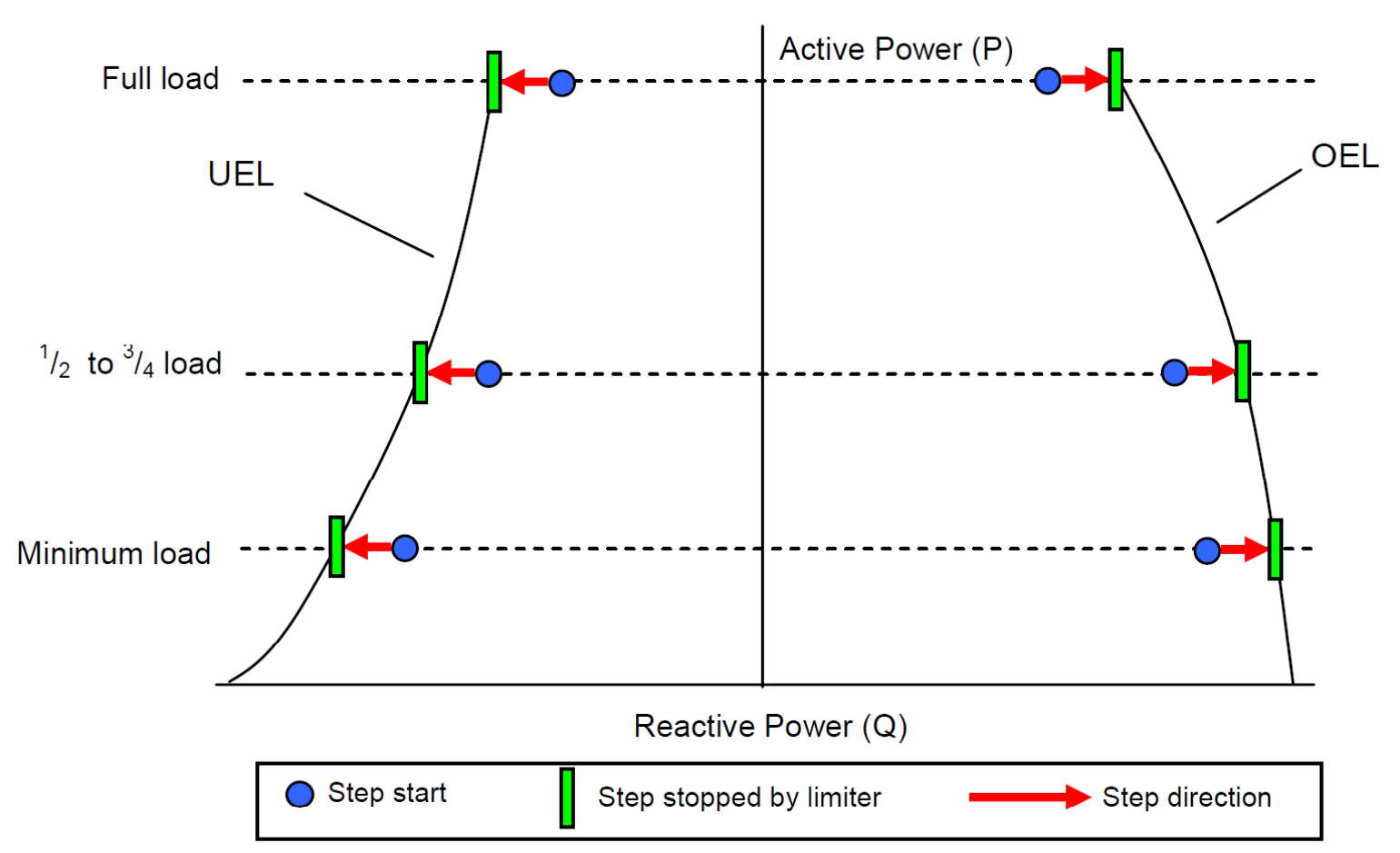
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Excitation Limiter Settling Time < 7.5 seconds for 5% disturbance when operating into a limiter from a point where a disturbance of 2.5% would just cause the limiter to operate



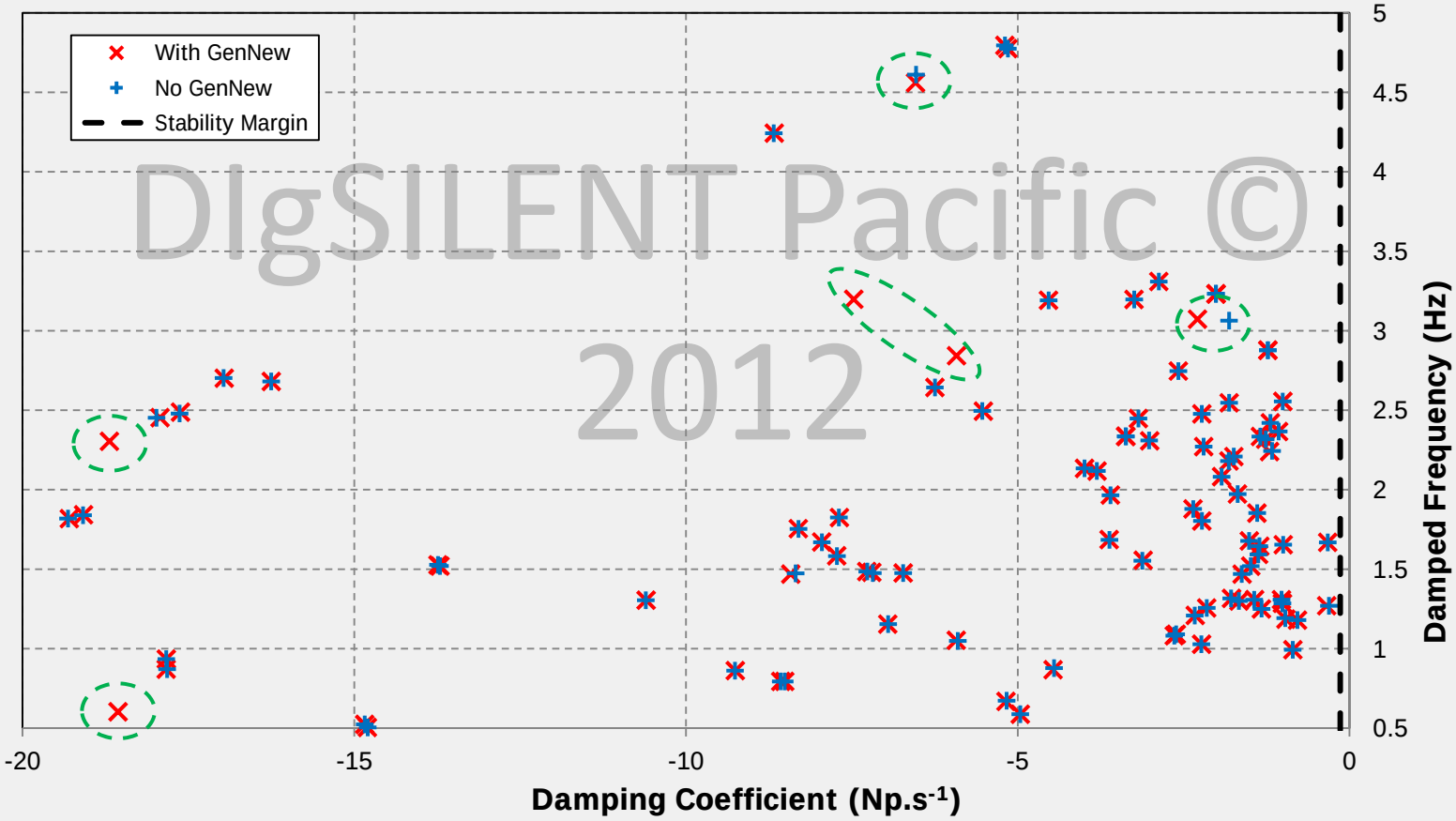
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Step response simulations into excitation limiters



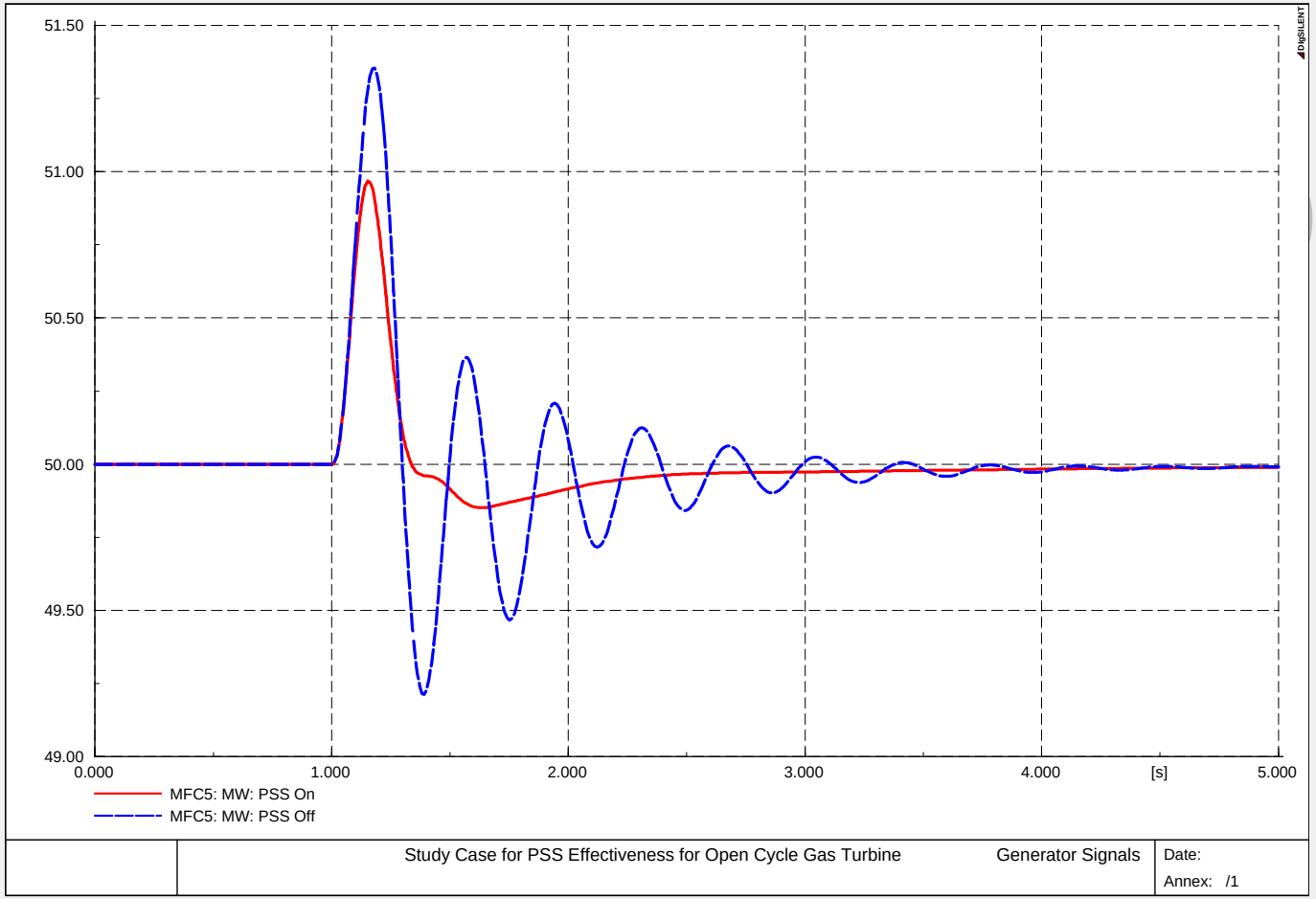
Validation of Compliance Process following a Plant Change – S5.2.5.13

- Impact of Connecting a Generating Unit with PSS



Validation of Compliance Process following a Plant Change – S5.2.5.13

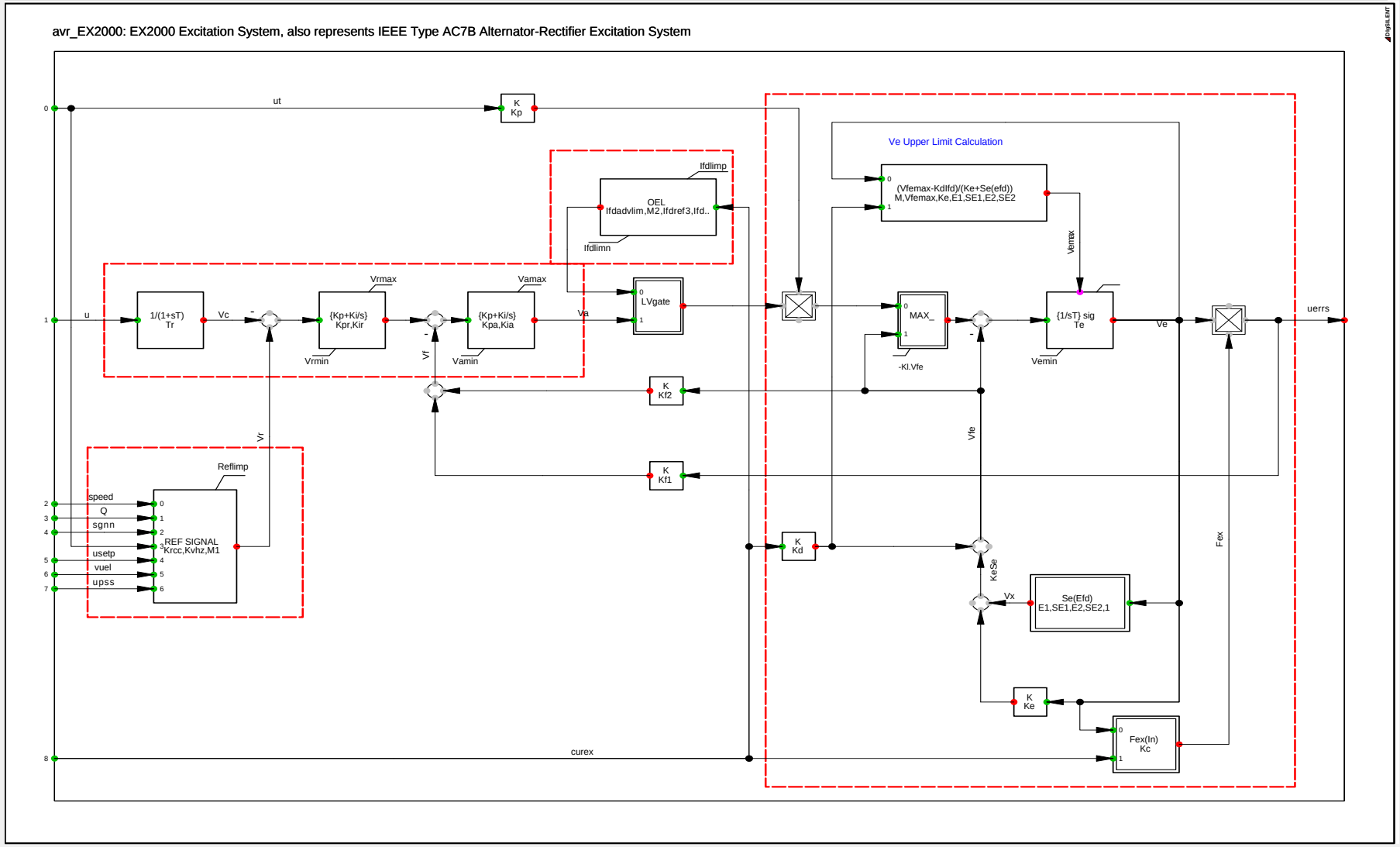
- Effectiveness of the PSS in Time Domain



Validation of Compliance Process following a Plant Change – Functional Block Diagram

- The functional block diagram is required by TNSP and AEMO. It should include as a minimum when studying the excitation system of a synchronous machine:
  - Exciter and AVR;
  - Reactive power/current compensation;
  - PSS;
  - Excitation Limiters (UEL/OEL);
- A governor (if not previously provided) may need to be provided and is decided on a case-by-case basis. For example:
  - If there is a risk that the new AVR and PSS can interact with the governor

Validation of Compliance Process following a Plant Change – Functional Block Diagram (cont.)



Validation of Compliance Process following a Plant Change – Model Source Code

- As per AEMO Model Guidelines and Clause S5.2.4(b)(6), model source code must be provided in an unencrypted form suitable for at least one of the software simulation products nominated by AEMO
  - PSS/E
  - PowerFactory
  - TSAT
- The model source code is expected to contain the model of the plant being altered/upgraded, and any other plant that might have an impact on the unit or system performance

Source: AEMO (http://www.aemo.com.au/registration/118-0001.html)

Validation of Compliance Process following a Plant Change – Releasable User Guide

- As per AEMO Model Guidelines and Clause S5.2.4(b)(6), the generator must also provide a Releasable User Guide (RUG)
- The RUG is a document associated with the functional block diagram and model source code and explains how to include the plant in the system model
- It must contain sufficient information so that a Registered Participant can use the encrypted model source code to carry out studies
- It should contain (but not limited to)
  - ✓ Model parameters and values
  - ✓ Instructions on how to use the encrypted model source code
  - ✓ Connection point details
  - ✓ Commissioning dates

Validation of Compliance Process following a Plant Change – Commissioning Plan

- The generator must supply detailed commissioning program 3 months in advance (for transmission connected generator) as per **S5.2.4** of the NER

- The TNSP and AEMO must agree with the program and have the right to witness commissioning tests

Section 4
Compliance & R2 Testing

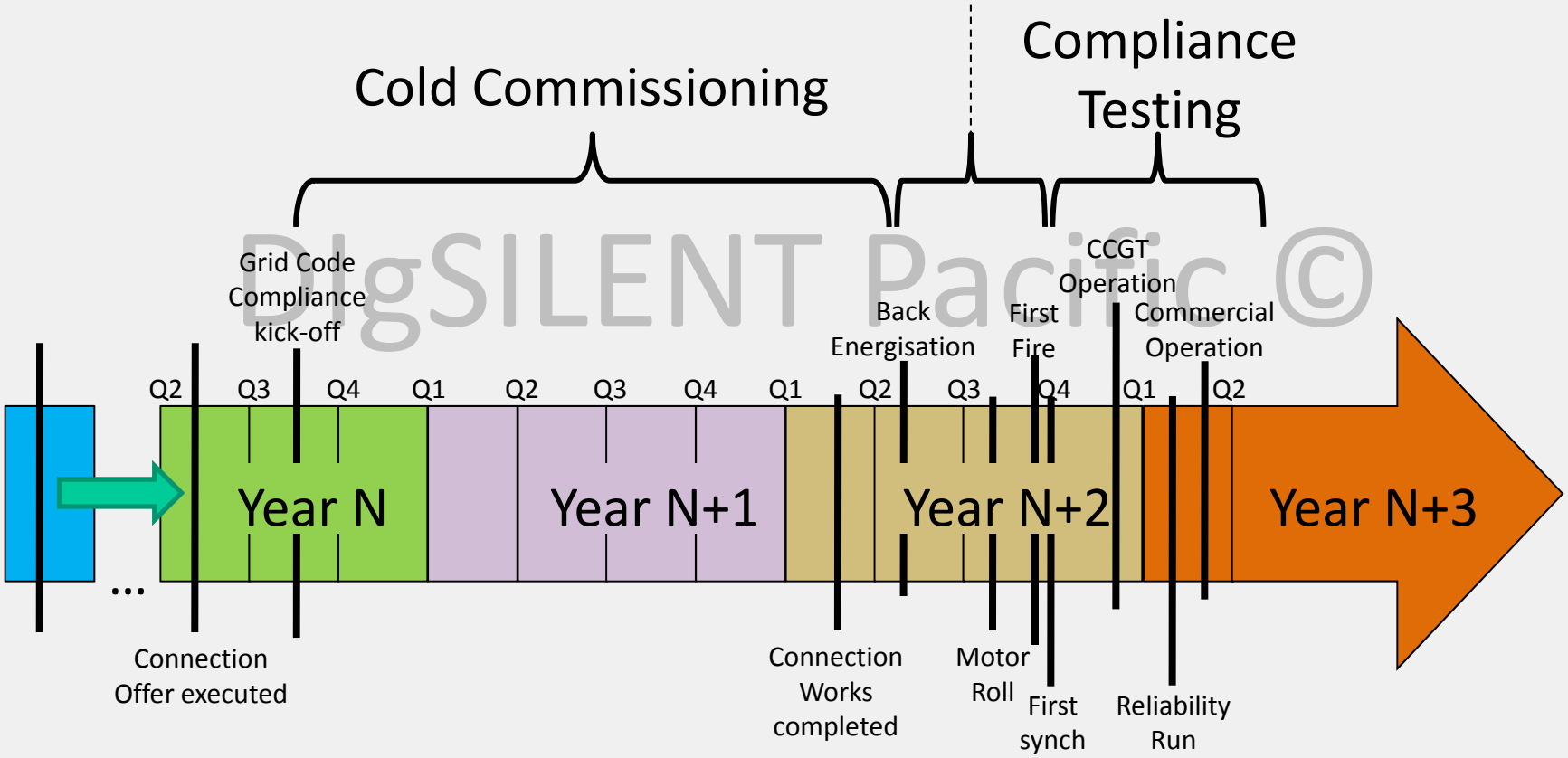
Compliance & R2 Testing

- Compliance Testing is the process of performing on-site tests to evaluate compliance with the relevant Performance Standards affected by the upgrade
- R2 testing is the process of performing on-site tests to validate R1 data
- "Type-testing" of plant is permissible, but excludes plant that has settings that can be applied on-site (includes AVR control systems)
  - Therefore R2 and Compliance testing is required on all AVR's of each unit

Compliance & R2 Testing – Compliance Program

- The onus is on the generator and their consultants to develop a “Compliance Program”
- A Reliability Panel, put together by the AEMC, have developed a template that Generators can follow to develop a “Compliance Program”
  - ***www.aemc.gov.au/Market-Reviews/Completed/Template-for-Generator-Compliance-Programs.html***
- A compliance program will consider all clauses within the Generators Performance Standard and be valid for the life of the plant
- It is the framework to assist generators in evaluating and maintaining compliance

Compliance & R2 Testing – Compliance Program



Compliance & R2 Testing – Compliance Program

- Compliance testing of the AVR for the Performance Standards it affects, S5.2.5.13, would occur every 4 years as recommended in the template

- R2 testing of the excitation system must occur following any plant change, i.e. installation of AVR, change in software or software version, etc.

- Test methodology includes:
  - Unsynchronised and synchronised AVR step response tests
  - AVR step response test of excitation limiters
  - AVR and PSS transfer function measurements over required frequency range

Compliance & R2 Testing – cont.

- As the control system is the system being tested, the recording system is required to be independent of the control system

- Therefore, an independent data logger, or Data Acquisition (DAQ) is required to measure the quantities during each test

Compliance & R2 Testing – Data Acquisition

- Typical signals measured during tests and the AEMO required resolution:
  - Terminal voltage (5 V)
  - Active power (0.01 MW)
  - Reactive power (0.05 MVAr)
  - Rotor voltage (2 V)
  - Rotor current (1 A)
  - Stator frequency (0.01 Hz)
- Overall measurement time constants for each of the quantities must not exceed 20 msec
- Results to be made available in electronic format (Excel) to allow for assessment by AEMO and/or TNSP

Refer to AEMO's "Commissioning requirements for generating systems" for full details (www.aemo.com.au)

Compliance & R2 Testing – Process

- When commissioning a new (or retrofit) excitation system:

1. Perform R2 testing in the form of frequency response (transfer function) testing;
2. Carry out time domain measurements and recordings during commissioning of new excitation system;
3. Prepare comparisons between measured and modelled responses in frequency and time domain to meet requirements specified by AEMO;
4. Produce a Compliance & R2 Test Report;
5. Provide data and reports to TNSP and AEMO within 3 months after commissioning as per S5.2.4 of the NER;

Compliance & R2 Testing – Accuracy Requirements

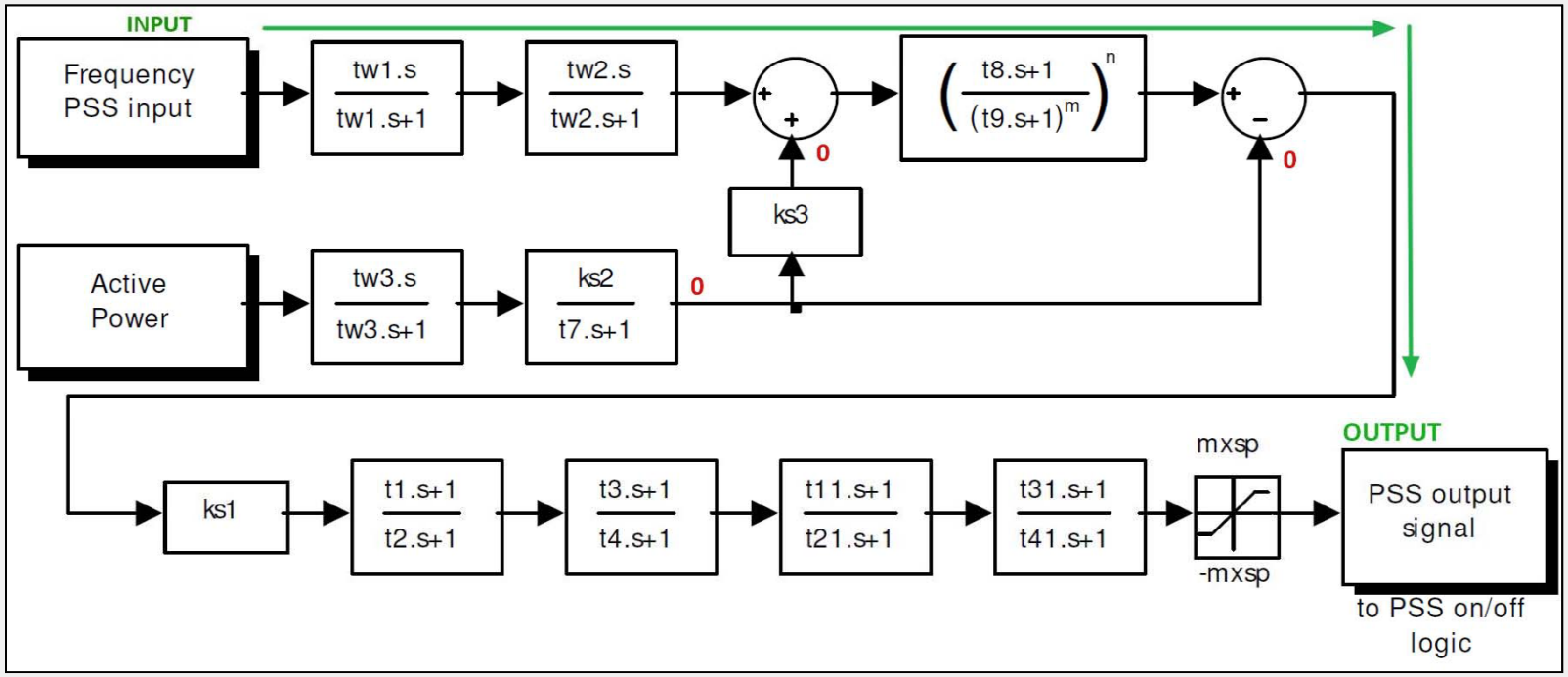
- For control system models, overall linear response over 0.1 – 5 Hz must be within:
  - Magnitude within 10% of actual control system magnitude
  - Phase must be within 5 degrees of the actual control system phase

- For time domain response
  - Rapid slopes in simulated response compared to actual plant response must be within
    - 10%; and
    - From start to finish of the slope, 20 msec

Refer to AEMO's "Generating System Model Guidelines" for full details (www.aemo.com.au)

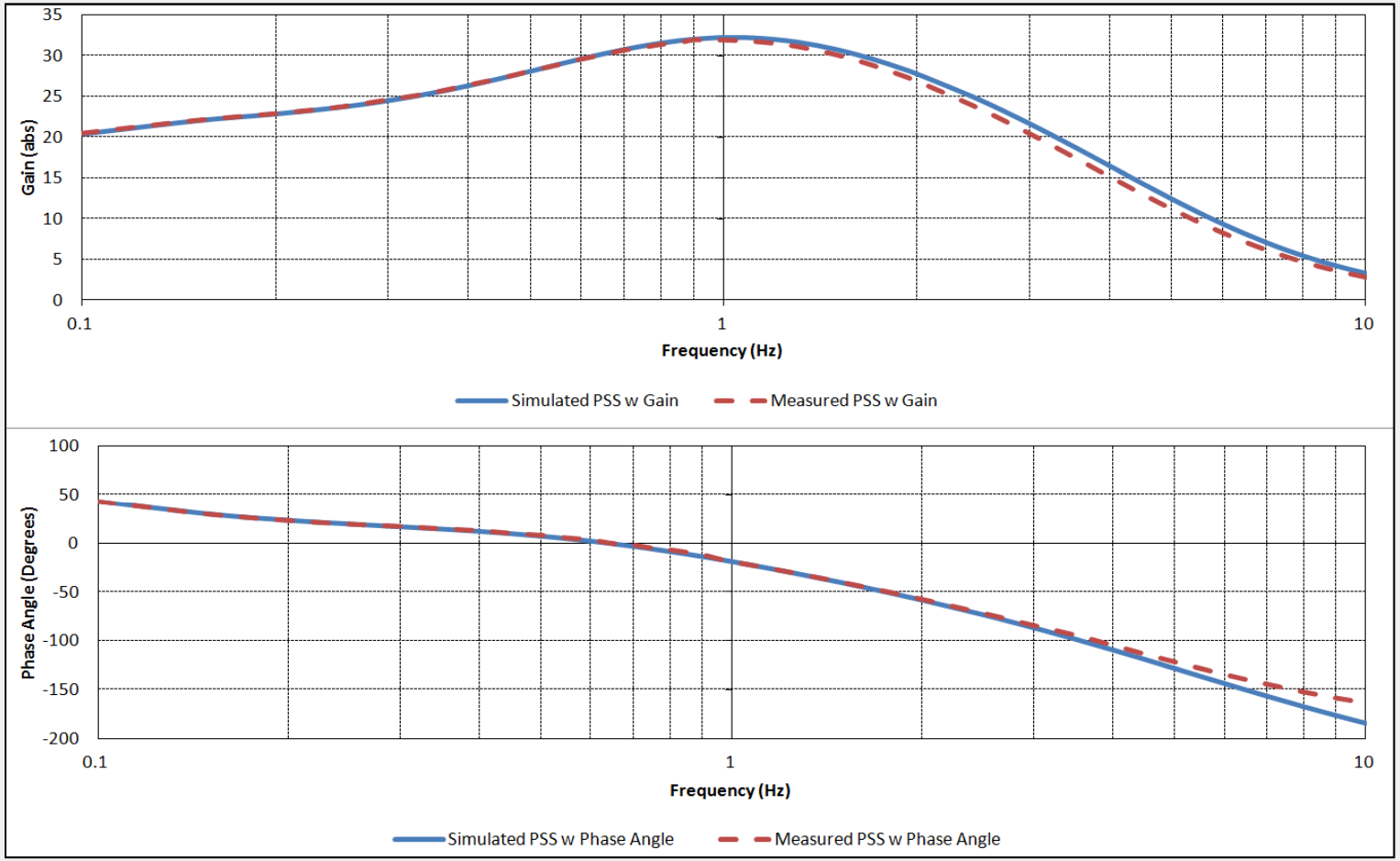
Compliance & R2 Testing – R2 Testing

- Set up for a Transfer Function test of the PSS frequency channel



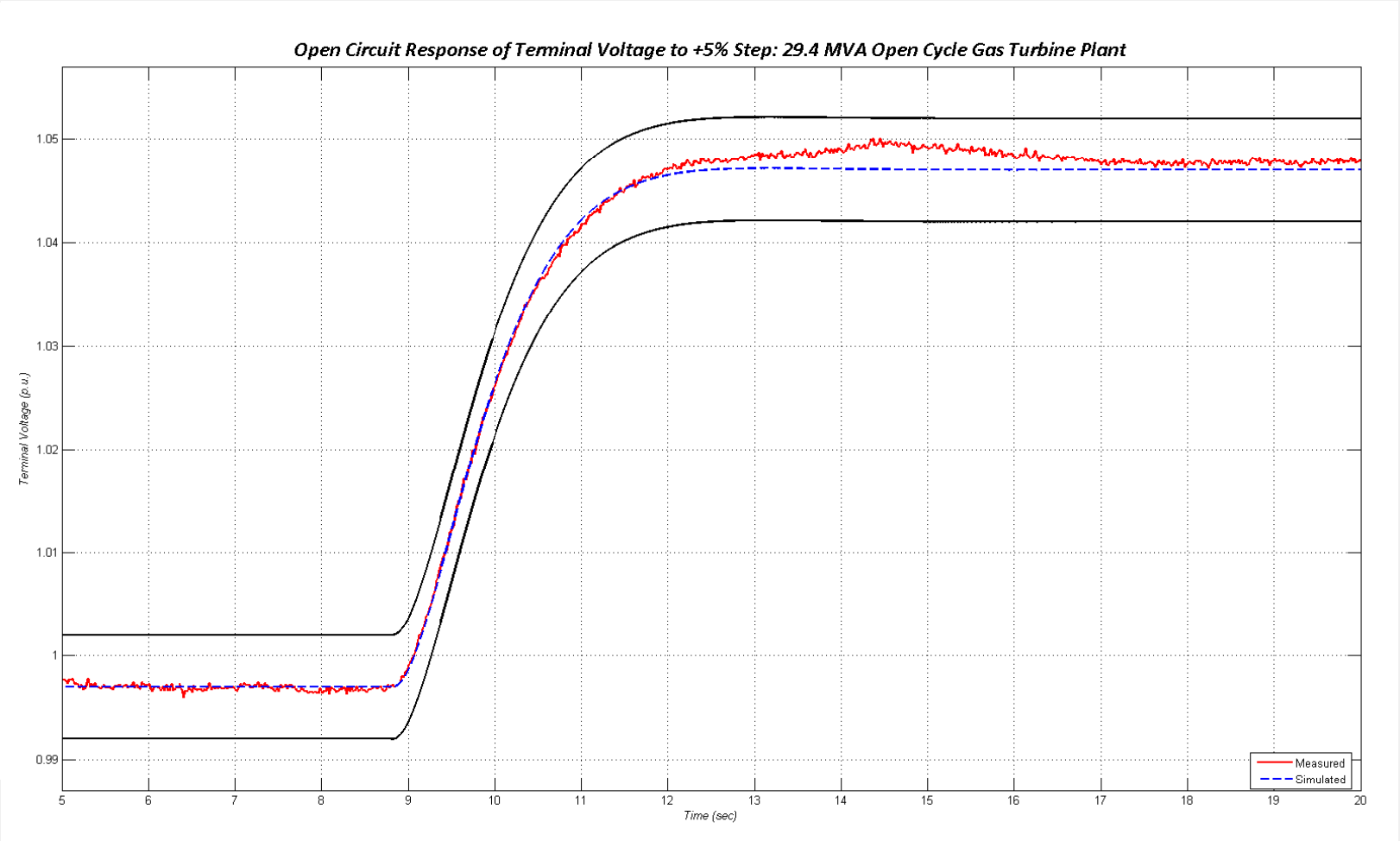
Compliance & R2 Testing – R2 Testing

- Transfer function testing of the PSS Frequency Channel



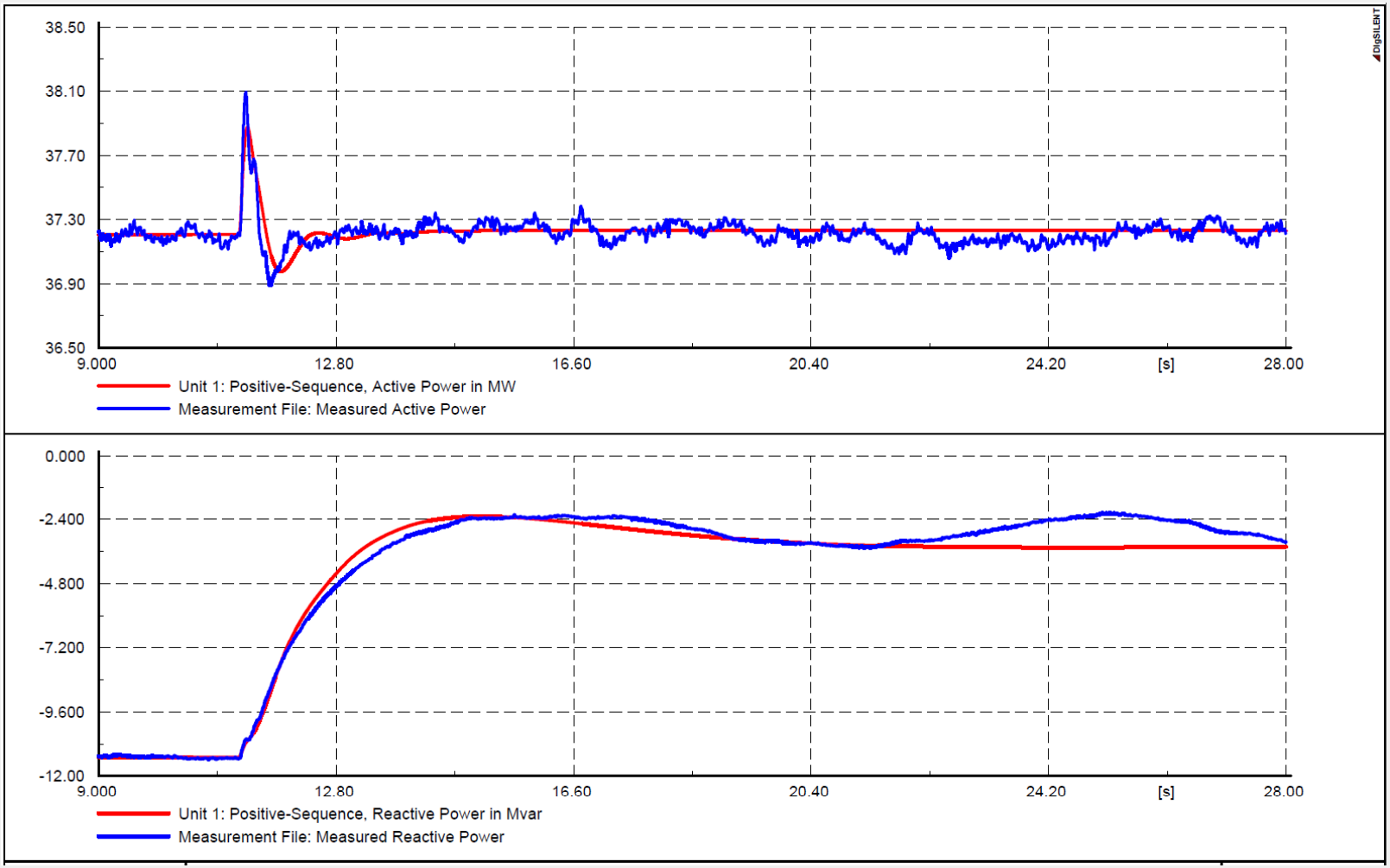
Compliance & R2 Testing – Example of Accuracy Requirements

- Unsynchronised +5% step response on 29.4MVA open cycle GT



Compliance & R2 Testing – Example of Accuracy Requirements

- Synchronised +2.5% step response on a 42.5MVA hydro machine



Thank You!