

Automation of AEMO Model Acceptance Testing and Benchmarking

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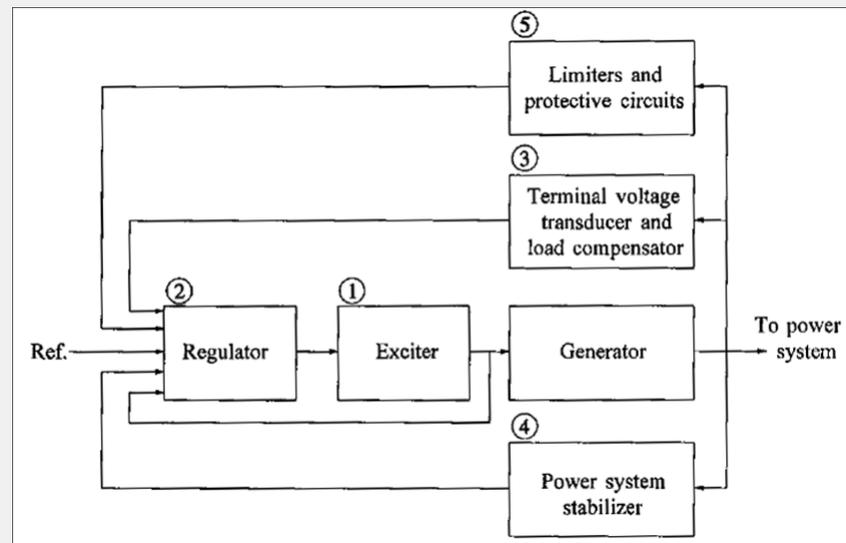


INTRODUCTION



Generator control systems

- A typical synchronous generator excitation system includes an exciter, regulator, voltage transducer, stabiliser, and limiting functions (Kundur, 1994).





Dynamic models

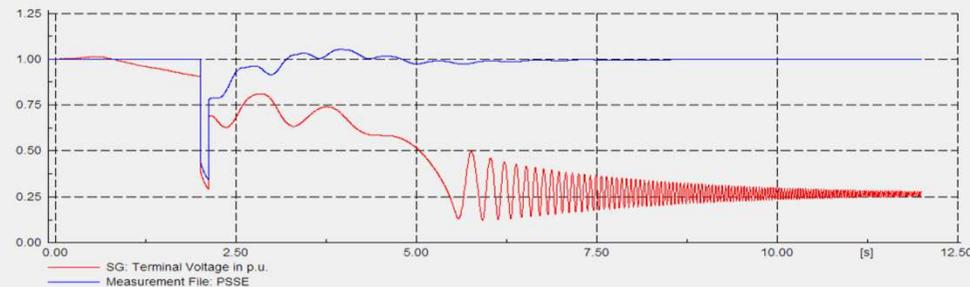
- Accurate, robust and functionally correct models of generator control systems are required to enable utilities and network operators to determine operational limitations and ensure stable operation of the power system.
- Often the models used by these organizations are developed by third parties, and without a stipulated set of simulation case studies can result in a series of updates and revisions to model source code as it is tested by model end user(s).





Model acceptance testing

- There are clear benefits associated with pre-defining a set of case studies to be performed by model developers, and AEMO has thus developed new model acceptance test guidelines.
- The guidelines require the model developer to demonstrate model performance and robustness for a range of time-domain simulation events.





Focus of this presentation



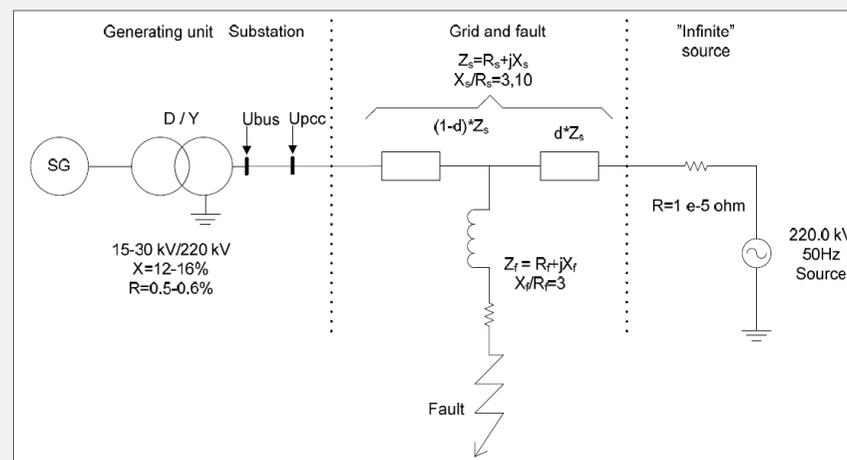
- This presentation commences with a description of the model acceptance tests required, describes dynamic model development in DlgSILENT PowerFactory, and provides an overview of the process of converting models for use in other programs.
- In a case study, automation scripts are developed for both PowerFactory and PSS/E to read study case parameters from a CSV file and produce results that demonstrate compliance with AEMO's model acceptance test guidelines, and additionally demonstrate alignment between the models.



ACCEPTANCE TESTS

Model acceptance testing

- The model setup is a generic single machine infinite bus (SMIB) case with pre-defined short-circuit ratio and system X/R parameters,
- The model does not provide for a connection point specific assessment - that is carried out independently of the model acceptance tests.



Calculation of source impedance

Consider a 100MW generator, for the case where the short circuit ratio (SCR) = 3 and the X/R ratio = 10:

$$S_{fault}(pu) = \frac{100MW \times 3}{100} = 3.00$$

$$Z_{total}(pu) = \frac{1.00}{3.00} = 0.333$$

$$Z_{line}(pu) = Z_{total} - Z_{tx} = 0.333 - 0.150 = 0.183 \quad Z_{base} = \frac{220^2}{100} = 484$$

$$R_{line}(pu) = \frac{0.183}{\sqrt{1 + 10^2}} = 0.0182 \quad \longrightarrow \quad R_{line}(\Omega) = 0.0182 \times 484 = 8.81$$

$$X_{line}(pu) = 10 \times 0.0182 = 0.182 \quad \longrightarrow \quad X_{line}(\Omega) = 0.182 \times 484 = 88.1$$

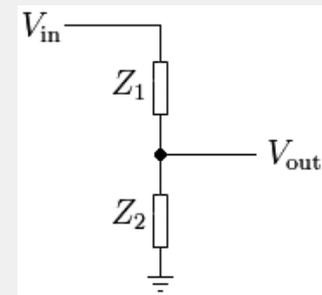
Calculation of fault impedance

For the same case, consider application of a fault at the transformer HV terminals with a residual voltage of 70%. The fault X/R ratio is 3.

$$Z_f(\Omega) = Z_s \frac{U_{dip}}{1 - U_{dip}} = 88.7 \times \frac{0.7}{1 - 0.7} = 207$$

$$R_f(\Omega) = \frac{207}{\sqrt{1 + 3^2}} = 65.5$$

$$X_{line}(\Omega) = 3 \times 65.5 = 196.5$$





Model acceptance testing



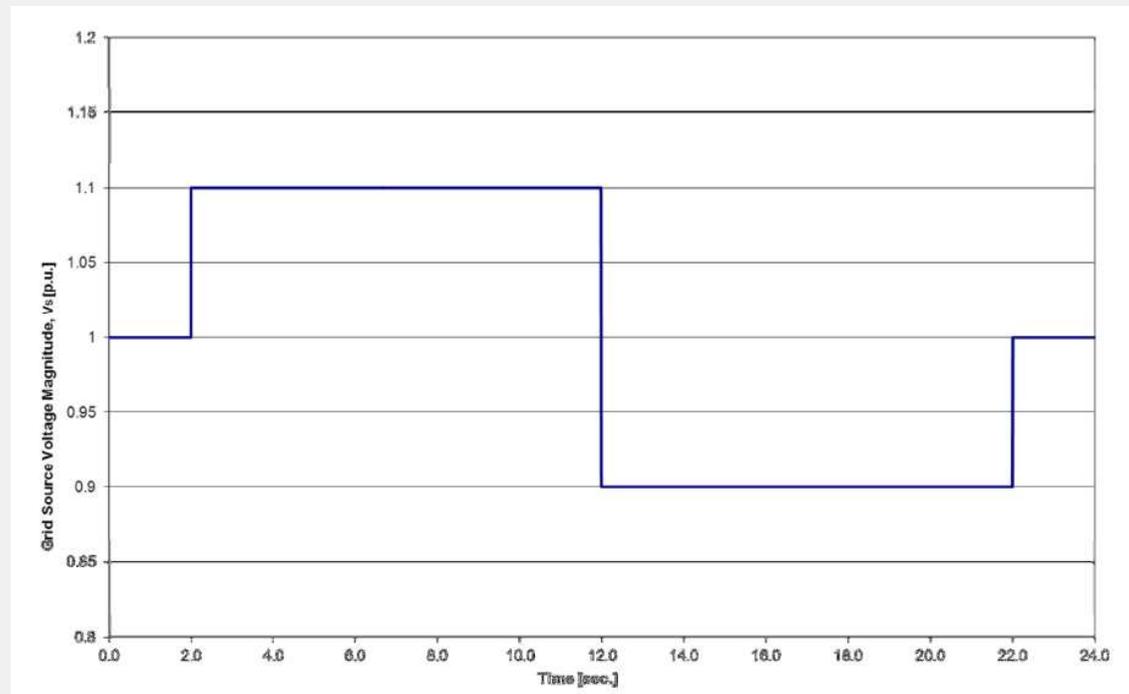
Simulation events relevant to synchronous plant excitation systems are as follows:

- Faults
- Grid voltage steps
- Grid voltage angle steps
- AVR reference voltage steps to reach and engage excitation limiters



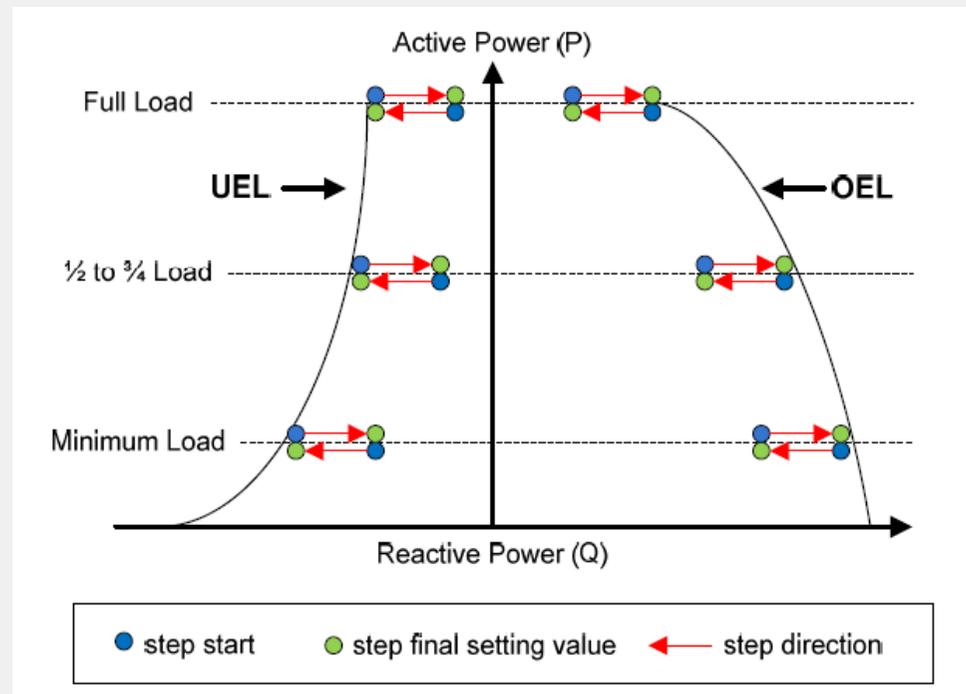


Step changes to grid voltage



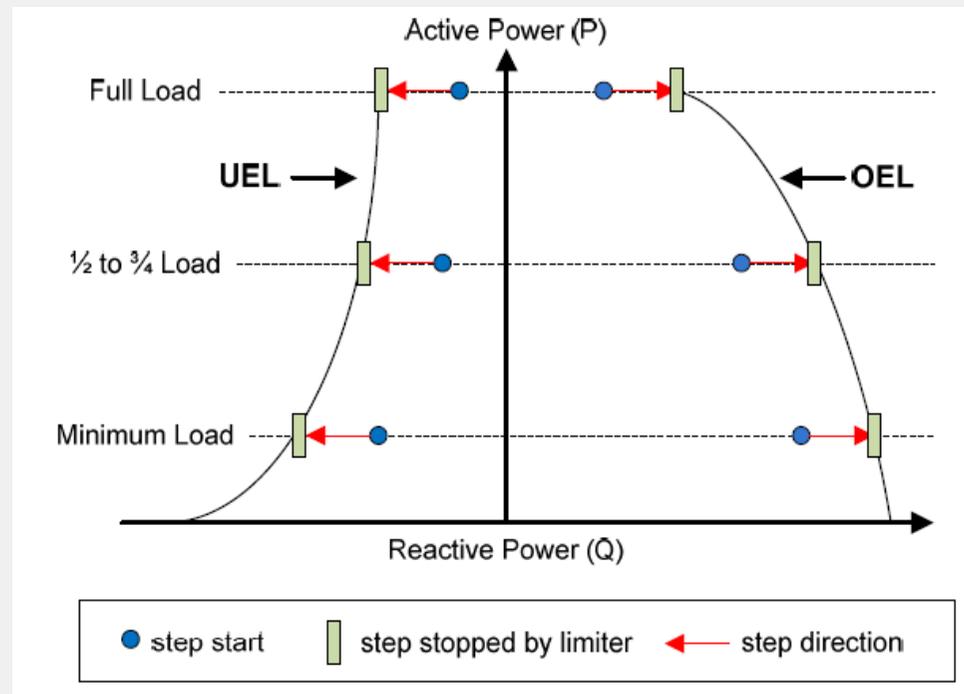


Step changes to limiters





Step changes to engage limiters



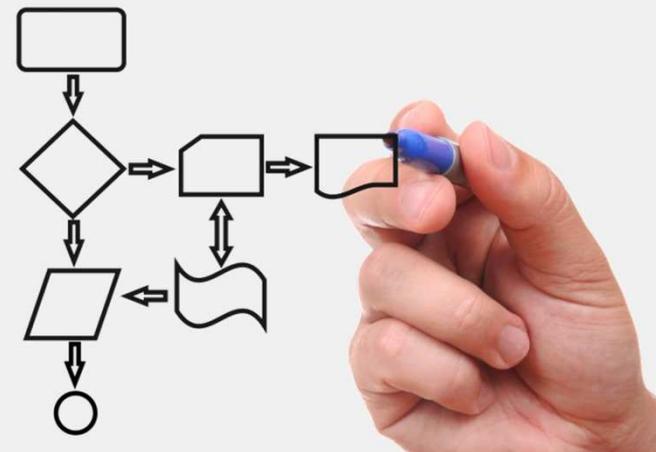
MODEL DEVELOPMENT



Model development

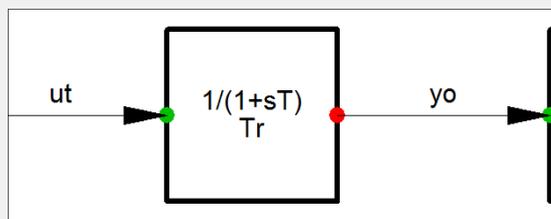
There are two key steps in the model development process:

1. Develop the control system block diagram that represents the functionality of the physical plant, thus defining how the simulation program calculates derivatives and other algebraic functions
2. Define calculation of control system model initial conditions



Conversion of dynamic models

Consider a simple time delay block.

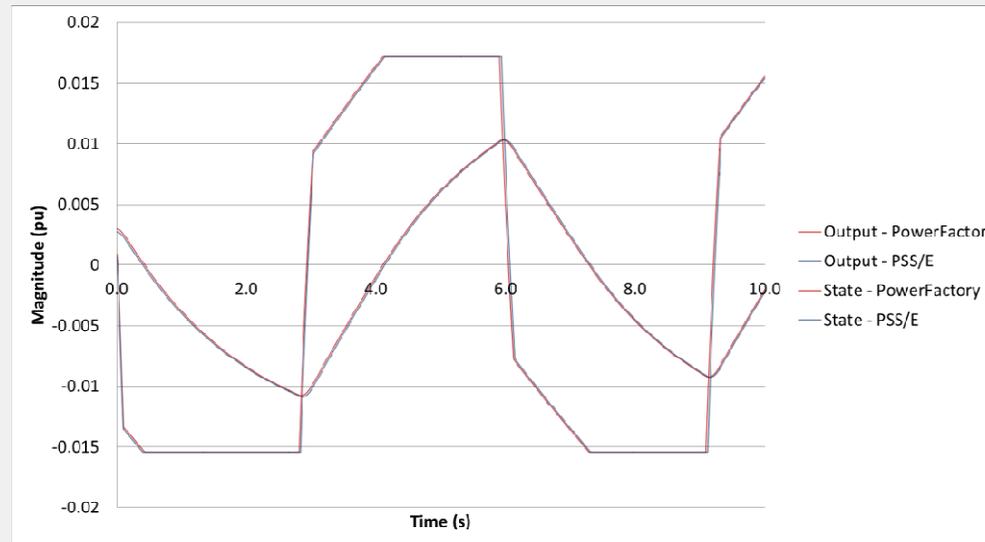


	PowerFactory	PSS/E
State-space equations	$\dot{x} = (y_i - x)/T$ $y_o = x$	$DSTATE(K) = (YI - STATE(K))/CON(J)$ $YO = STATE(K)$
Initial conditions	$inc(x) = ut$	$STATE(K) = ECOMP(I)$



Example block testing

Open loop tests can be completed by applying sinusoidal input signals to control system blocks to verify model functionality. This example shows the output and state of a non-windup lead-lag limiter in PowerFactory and PSS/E.



STUDY AUTOMATION



Study cases



- The study cases discussed previously were considered for model acceptance testing of an ABB Unitrol F excitation system.
- Scripts in both DIGSILENT Programming Language (DPL) for PowerFactory and Python for PSS/E refer to study case parameters stored in the CSV file. The table below shows parameters for a fault case of 0.12 s duration at the transformer HV terminals.

Item	Duration	Residual	SCR	XR	Power	Step	Accel	Reactive
1	0.12	0	5	3	1	2	1	0



Study case automation



- The DPL script reads simulation case parameters from the CSV file and modifies network source impedance, fault impedance (for fault cases) and simulation events accordingly.
- The script can optionally read in simulation results from other programs or from commissioning tests for comparison.
- After each simulation, a WMF file is exported that includes a plot page from PowerFactory with the key quantities of interest:
 - Machine terminal voltage
 - Machine active and reactive power
 - Machine angle
 - Machine field voltage and field current



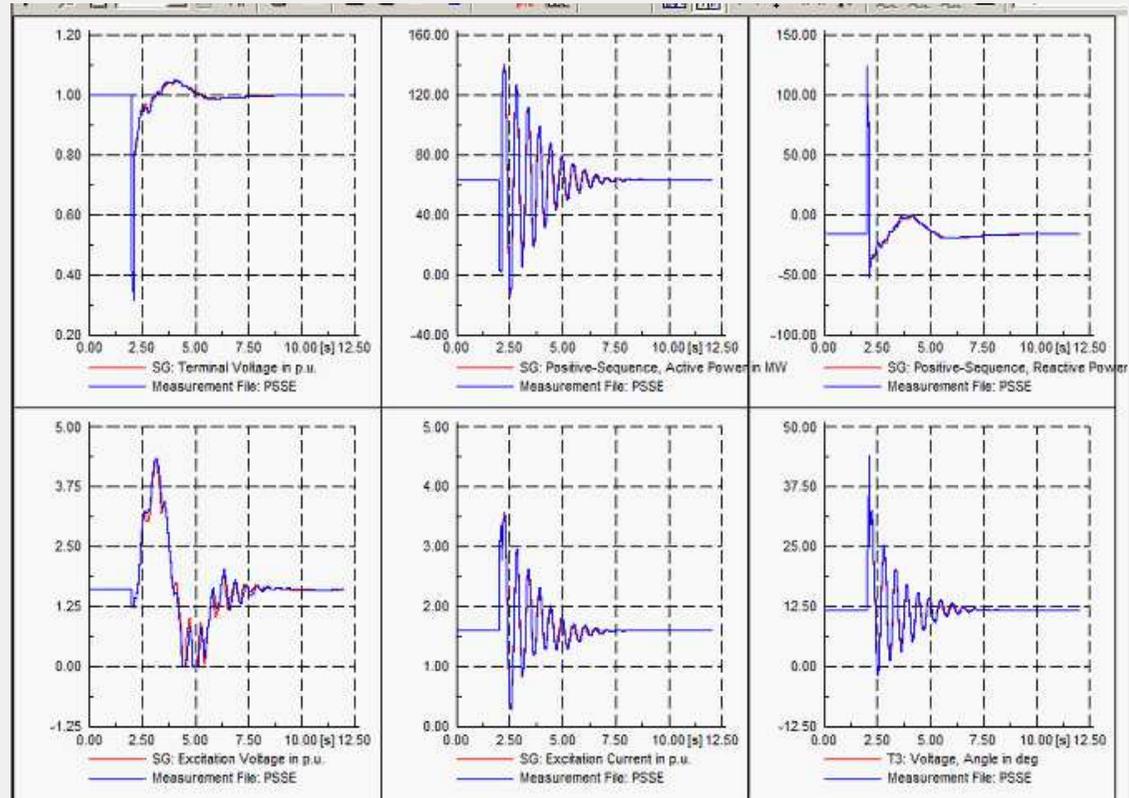
Automation script overview

- Functional description of DPL and Python automation files as follows:
 - Read in CSV input parameters
 - For each event:
 - Classify the event type
 - Set load flow parameters (generator output and system source impedance)
 - Modify simulation parameters
 - Initialise the case
 - Run simulation to 2.0 seconds
 - Apply event/disturbance
 - Run simulation to 12.0 seconds
 - Depending on the case, stop the simulation, or continue with additional events
 - Export results to a WMF file
 - End script.

REPEAT
FOR
ALL
CASES



VIDEO



CONCLUSION



Conclusion



- The development of control system models for dynamic simulation has been presented, and the procedure for automating model performance assessments with respect to the AEMO guidelines has been described.
- This paper has also demonstrated an automated procedure for thoroughly testing model functionality and performance that could be used to assess conversion of models from and to PowerFactory format.





Questions and discussion

