Modelling of a Large Mining Network

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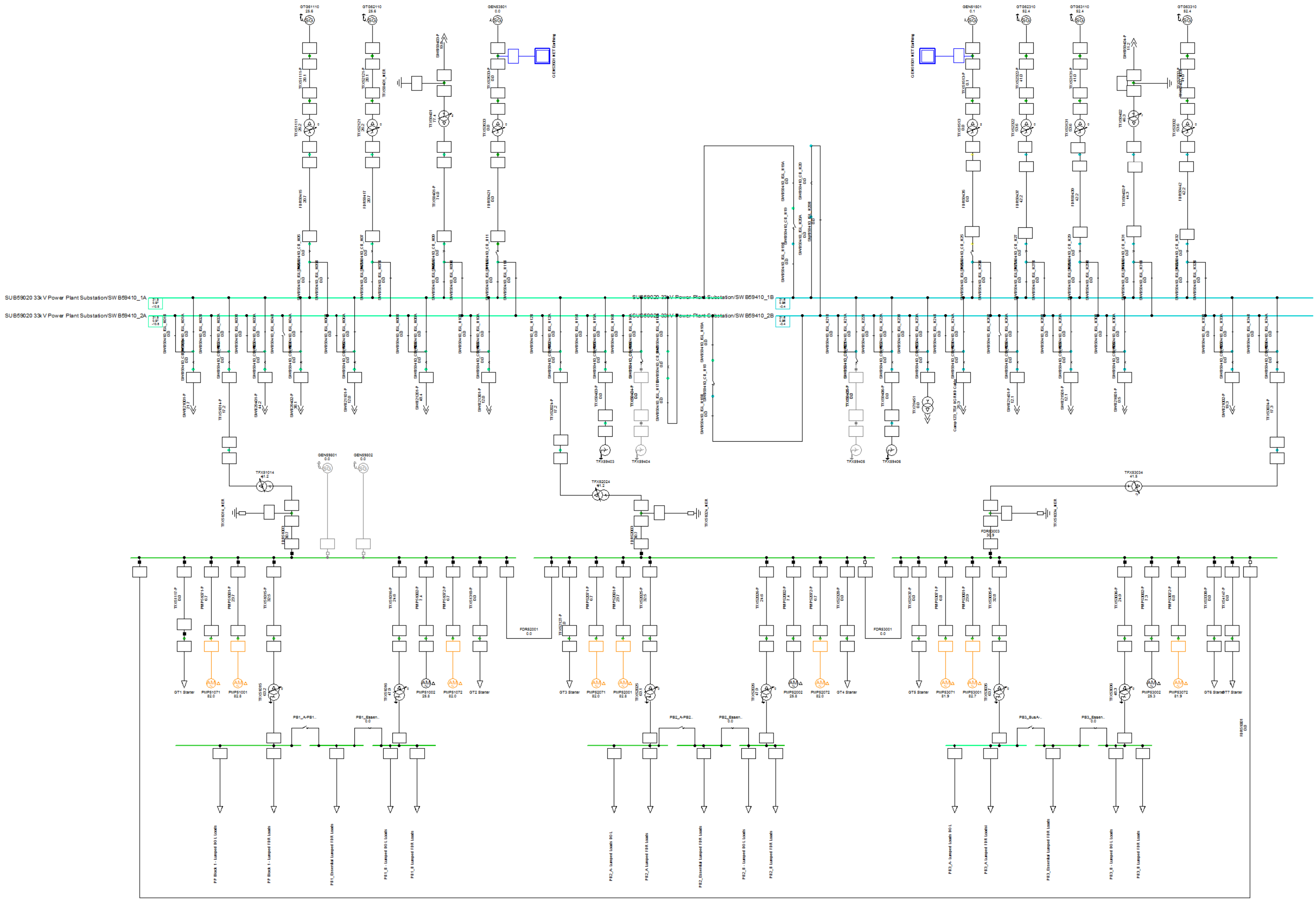
Background

- Large mine development in North-West of W.A
- 500MW on-site power plant (not grid connected)
  - Gas Turbines
  - Steam Turbines (Heat Recovery Steam Turbine)
- Network consisting of 220kV, 33kV, 11kV, 6.6kV and 415V
- Loads
  - 15MW Ball Mill
  - 28MW AG Mill (Cyclo-converter)



SUB59020 33kV Power Plant Substation/SW B59410_1A
SUB59020 33kV Power Plant Substation/SW B59410_2A
SUB59020 33kV Power Plant Substation/SW B59410_1B
SUB59020 33kV Power Plant Substation/SW B59410_2B
GTG61110
GTG62110
GEN63801
GEN61501
GTG62310
GTG63110
GTG63310
TFX51014
TFX52024
TFX53034
GEN59001
GEN59002
FDR52001
FDR53001
FDR53003
GT1 Starter
GT2 Starter
GT3 Starter
GT4 Starter
GT5 Starter
PB1_A-PB1..
PB1_Essen..
PB2_A-PB2..
PB2_Essen..
PB3_BusA-..
PB3_Essen..

Motivation

- Islanded industrial networks present many unique challenges
- Finding the right solution(s) requires a good understanding of the problem
- In-depth analysis can be achieved with powerful computer simulation packages;
  - Load flow/short circuit
  - Dynamics (voltage frequency)
  - Power Quality (harmonics, flicker)
  - Transients
  - Protection

Problems in Large Industrial Networks

Classification	Risks	Cause	Control Measures
Frequency instability	Cascading tripping of; • Load: motors, VSDs • Generation	• Loss of Generation • Tripping of large motors of VSDs	• Load Shedding • Adequate control of generator reserves • Adequately tuned frequency control system
Voltage instability	Loss of load	• Motor Dynamics (start-up)	• Reactive Compensation (dynamic/static) • Voltage control schemes
Harmonic distortion	• Thermal stress • Control problems	• VVVF drives • Resonance	• Passive/Active harmonic filters • 12, 18 pulse front end converter VVVF drives
Protection	• Spurious tripping • Long tripping times	• Poor/incorrect setting of protection relays	• Appropriate setting of protection devices

Benefits of Computer Simulations

Solution	Type of Simulation	Outcomes
Load shedding	Dynamic (Frequency)	Optimised setting of U/F, ROCOF load shedding elements
Frequency control	Dynamic (Frequency)	Tuning of frequency controllers/governors
Reactive Compensation	-Dynamic (voltage) -Load flow	Optimised sizing and placement of capacitor banks, SVCs
Harmonic Filters	Harmonic load flow, frequency sweep	• Appropriate specification of harmonic filter banks • Assessment of different options (Active/Passive)
Setting of protection devices	Protection coordination	• Appropriate setting of protection relays • Management of network protection settings

Developing the Network Model

- The development of any model requires correct and accurate information. Sources of information for this project included;
  - Cable schedules (Cable lengths, size, type)
  - Overhead lines (conductor, geometric arrangement)
  - Transformer datasheets/nameplate (rating, vector group, impedance)
  - Load lists
  - Single Line Diagrams (CT ratios, VTs)
  - Generator datasheets (impedances, time constants)
  - Motor datasheets
  - Protection (relay models and settings)
  - Manufacturer AVR and governor control block diagrams
  - Power station control philosophy (frequency, voltage control)

- Due to the large size of the network, careful control and management of information sources was critical in ensuring an accurate model

Dynamic Models

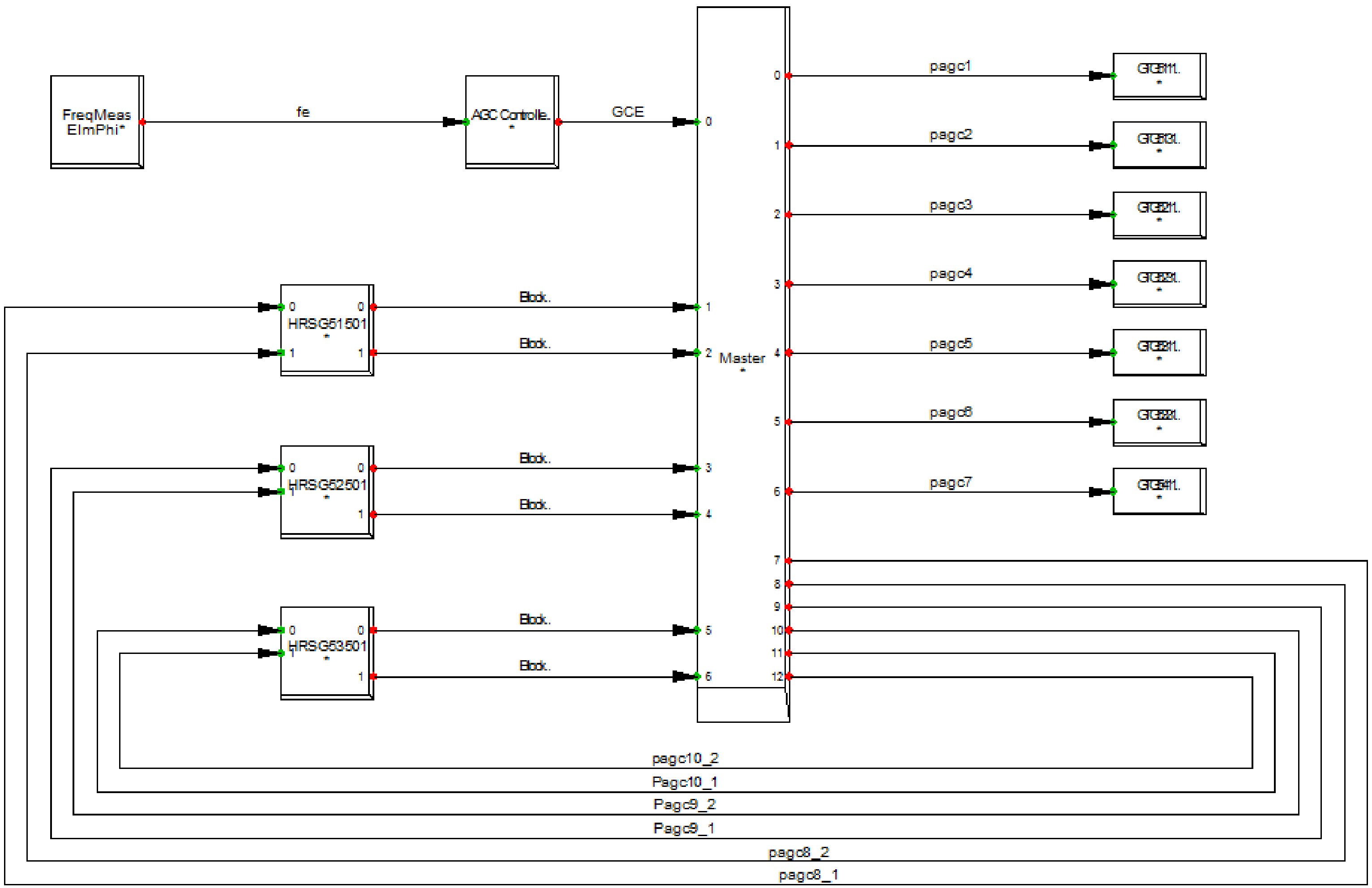
Generation

- Governors
- AVRs and exciters
- Secondary frequency and voltage controllers
- Automatic tap changing controllers

Load

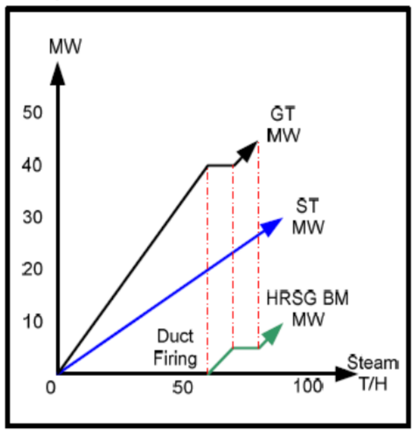
- Ball Mill
- Variable speed drives
- Direct On-Line (DOL) drives

Power Station Frequency Controller

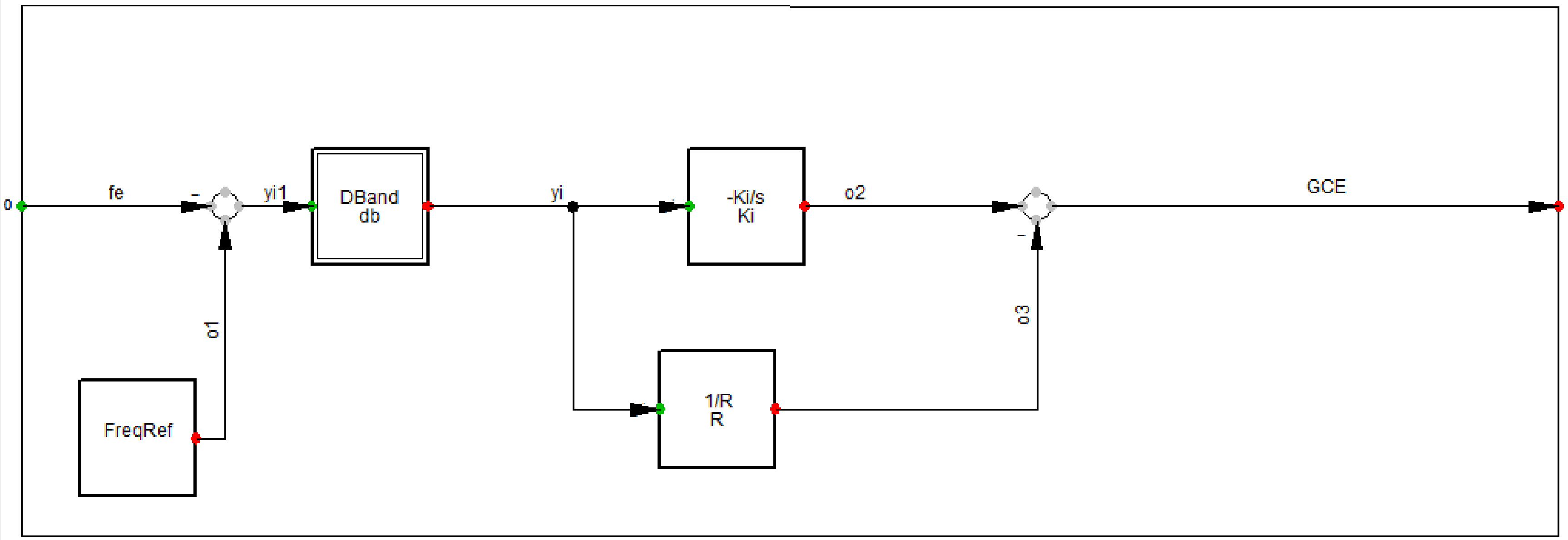


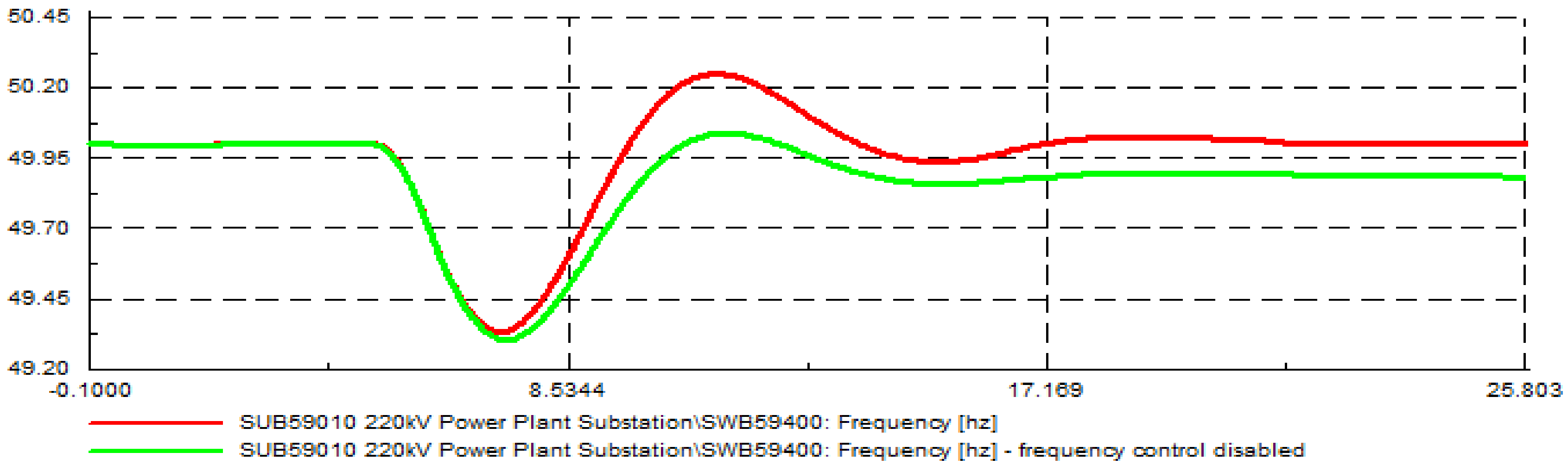
$$\sum_{i=1}^{10} P_i = 1$$

$$Pagc_i = P_i * GCE$$

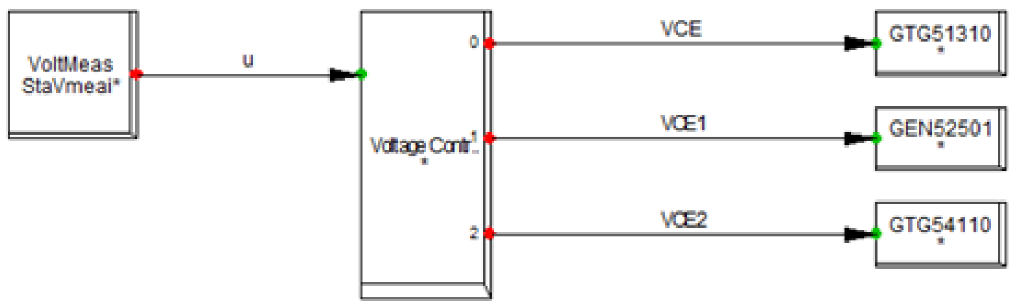


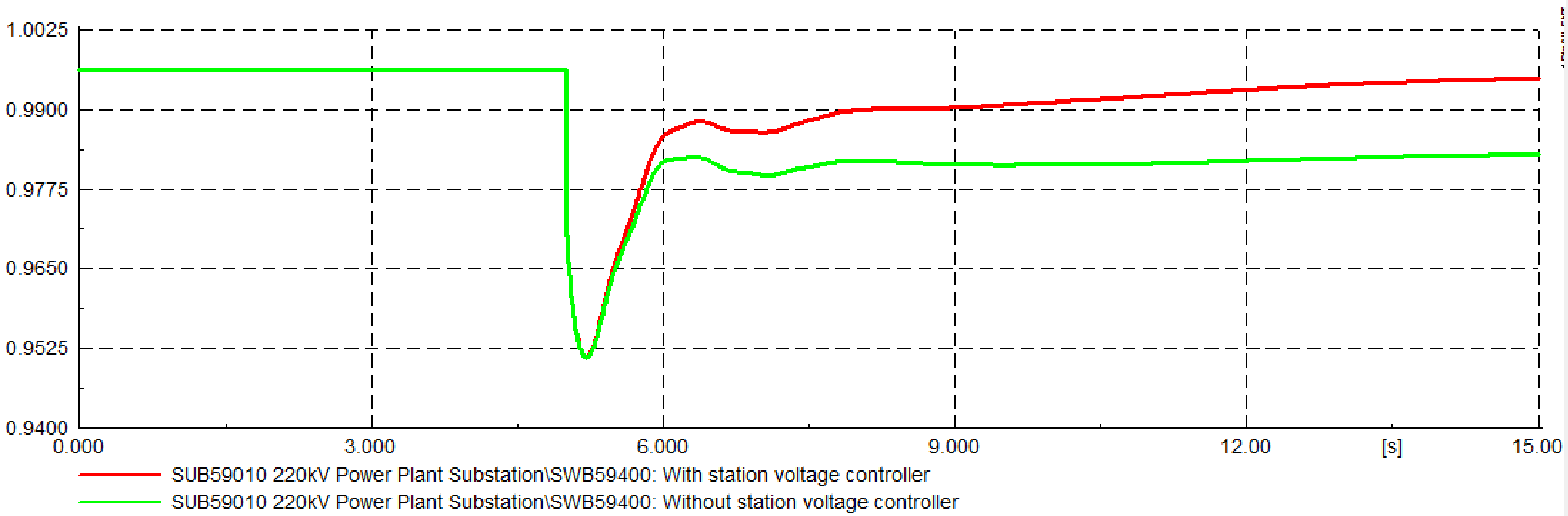
Power Station Frequency Controller



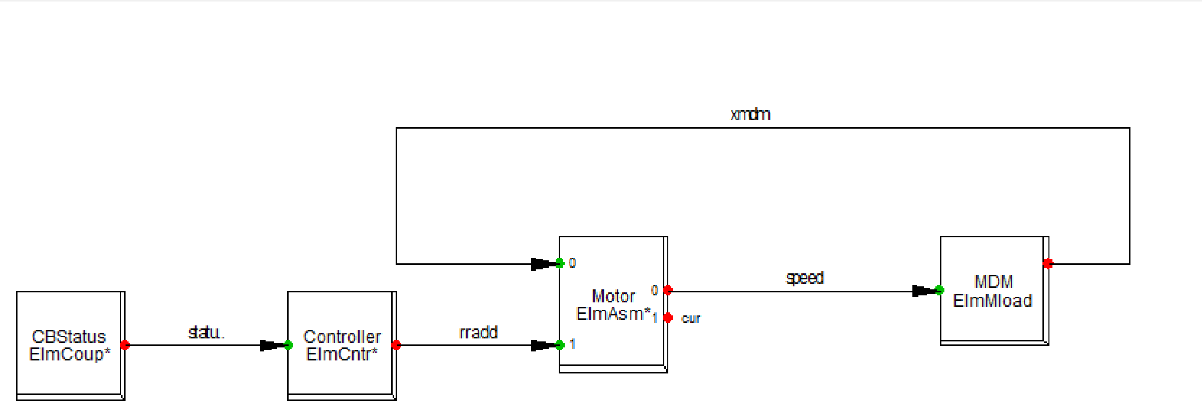


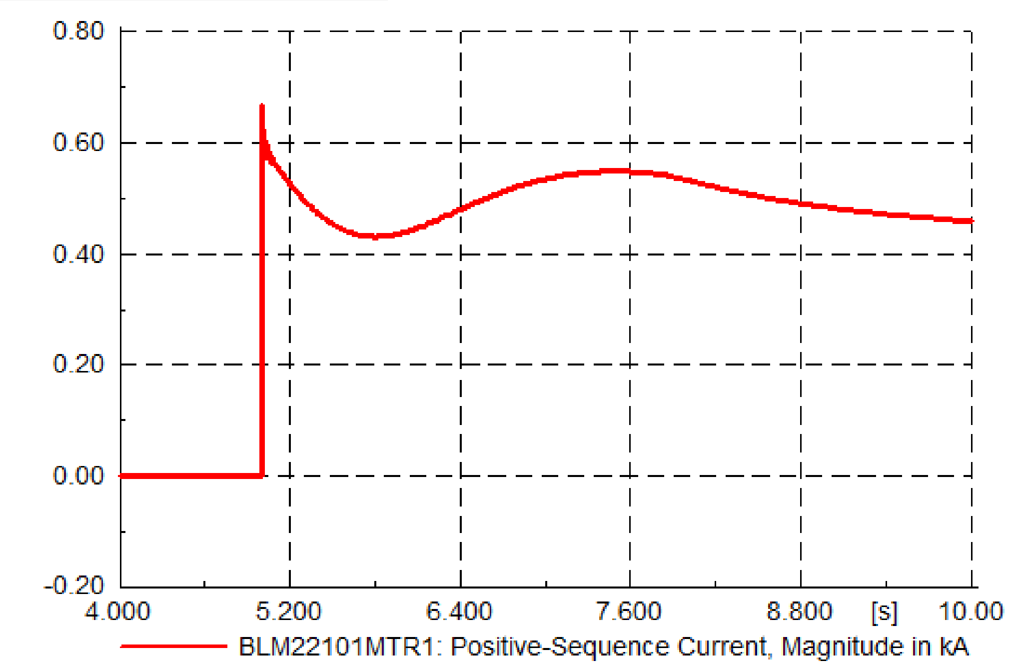
Power Station Voltage Controller

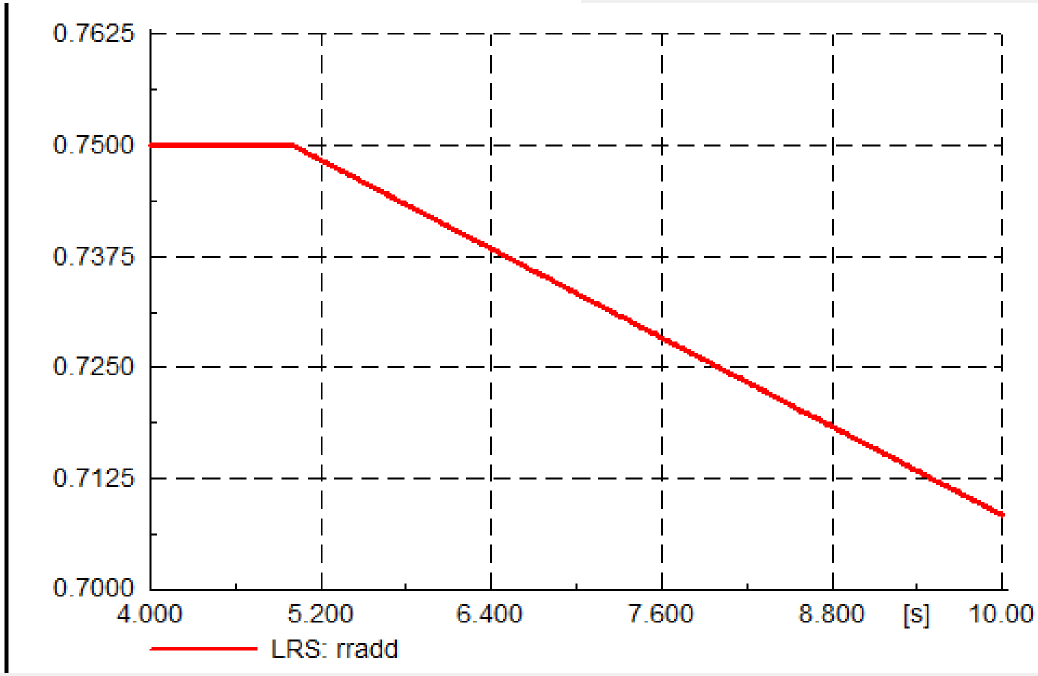




Ball Mill Motor Model







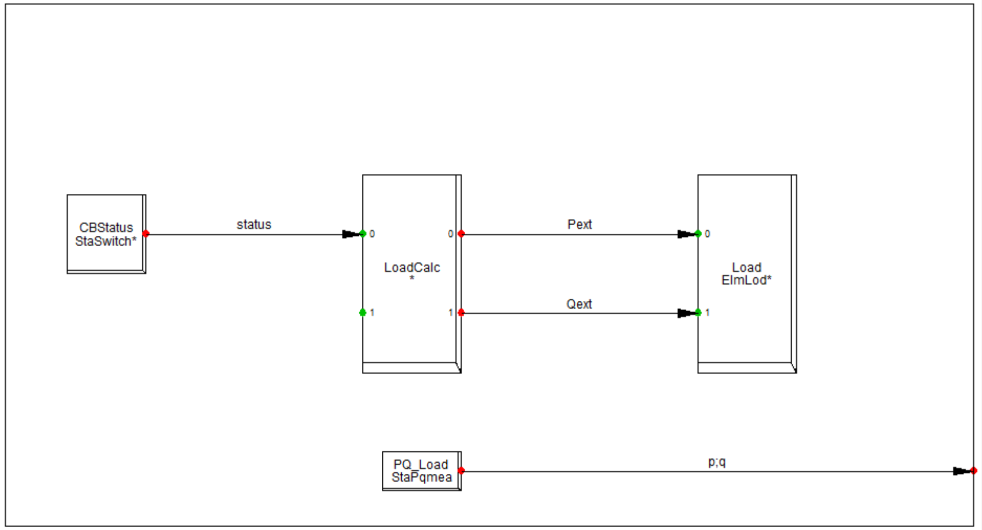
Variable Speed Drive Model

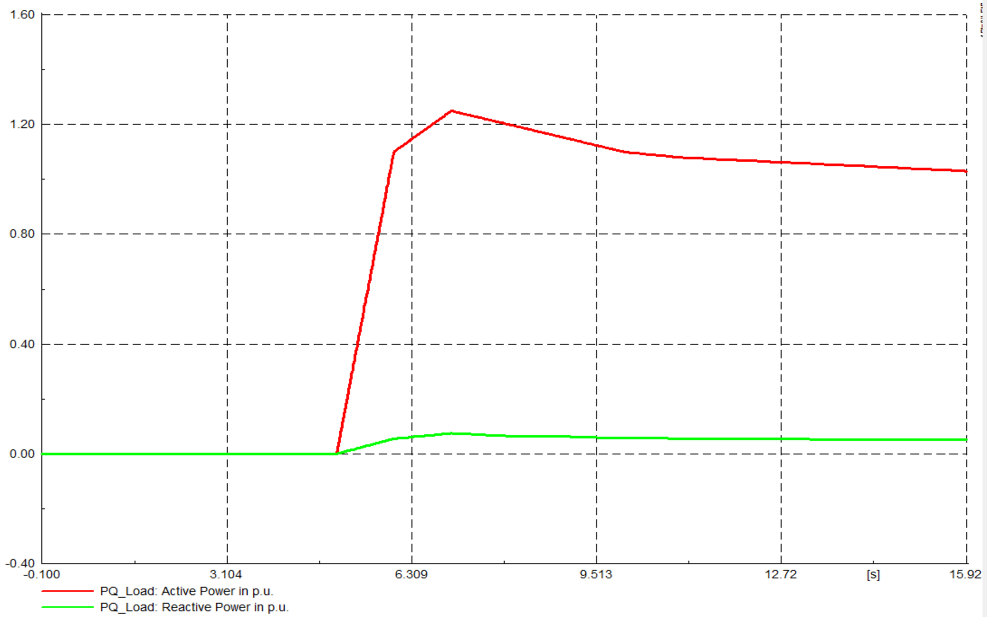
- Dynamic loads using the PowerFactory *ElmLod element has been used to model the VSDs

$$P = k * P_0 \left(\frac{V}{V_0}\right)^{\alpha}$$

$$Q = k * Q_0 \left(\frac{V}{V_0}\right)^{\beta}$$

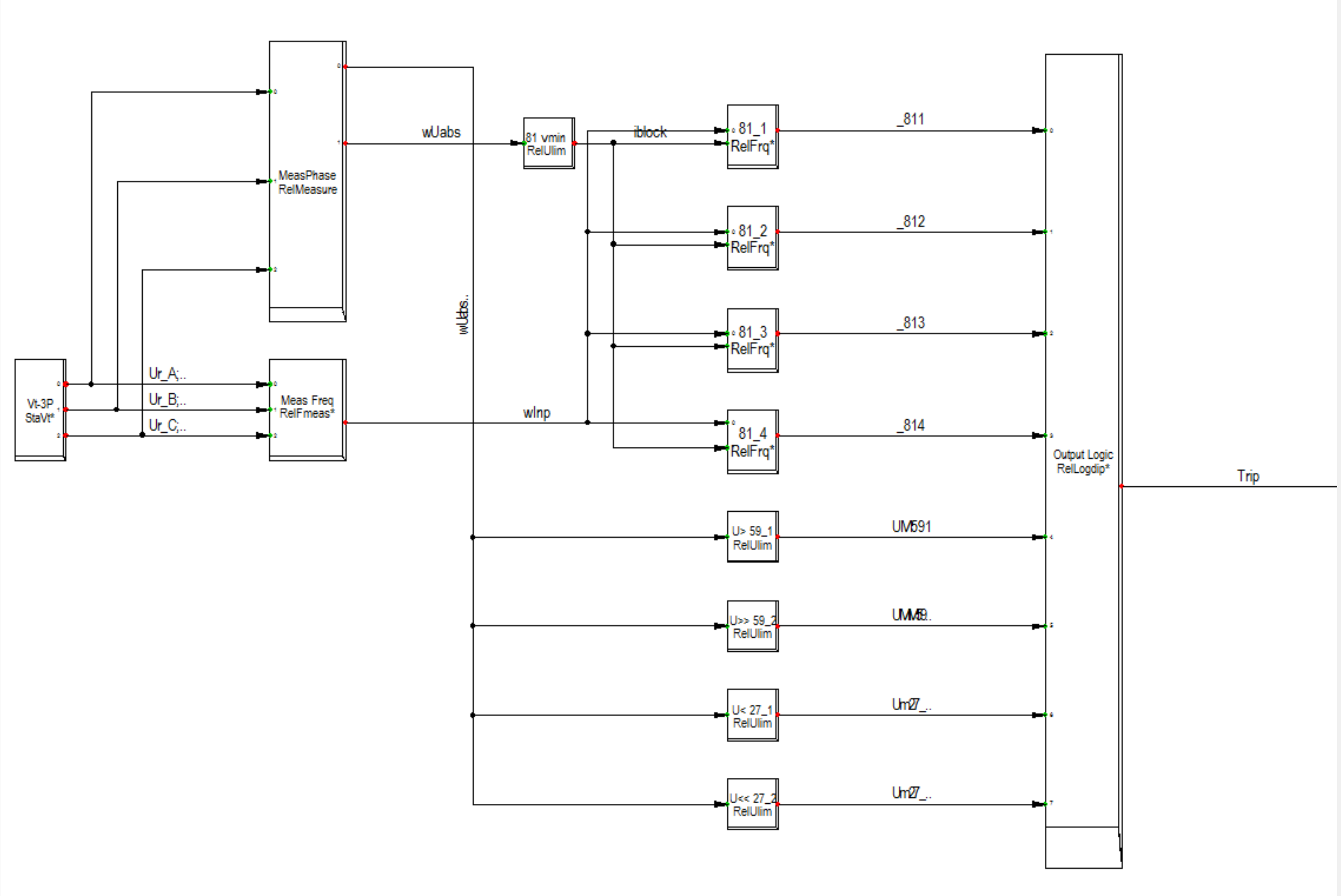
- Exponents have been set to 0 to represent a constant power load
- Large VSDs and the cyclo-converter have been modelled with a user defined PQ starting characteristic to represent the actual starting characteristic as measured on site





Variable Speed Drive Model

- VSD controllers have voltage and frequency set-points that disconnect the drive on a voltage/freq event



Protection Model

- Total of 600 protection relays associated with the HV distribution system
- 25 different relay models/type
- DPL scripting enabled protection relay settings to be managed in an excel spread sheet and imported into the respective PowerFactory relay model
- Protection elements models included;
  - Direction and non-directional over-current/earth fault
  - Differential, Restricted Earth Fault
  - Frequency (U/F, O/F), Voltage (U/V,O/V, negative phase sequence)
  - Motor protection (Thermal overload)

	Description/Location					Protection functions																				
	Substation	Voltage	Panel	Relay Model	Part No	CTR 1		CTR N		50		51			50N1		50N2		50BF		Thermal overload (49)		67 General		67-1	
						P	S	P	S	Pickup	Time Delay	Curve	Pickup	Time Delay	Pickup	Time Delay	Pickup	Time Delay	Pickup	Time Delay	49 K Factor	Time Constant	Forward/ Reverse	Rotation Angle	Pickup	Time Delay
Status		kV				A	s	A	s	A	s		A	s	A	s	A	s	A	s	p.u	s		°	A	s
C	59020	33	H05	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	3.74	0	C1	0.64	0.27	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H07	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	3.74	0	C1	0.64	0.27	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H09	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	5.25	0	C1	1.17	0.16	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	oo
C	59020	33	H11	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	4.7	0	C1	0.84	0.25	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H25	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	4.7	0	C1	0.84	0.25	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H27	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	3.74	0	C1	0.64	0.27	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H29	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	3.74	0	C1	0.64	0.27	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0
C	59020	33	H31	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	5.25	0	C1	1.17	0.16	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	oo
C	59020	33	H32	7SJ64	7SJ6471-5EB21-3FG4/EE	2000	1	2000	1	3.74	0	C1	0.64	0.27	0.05	3	0.05	oo	0.05	0.2	N/A	N/A	Forward	45	oo	0

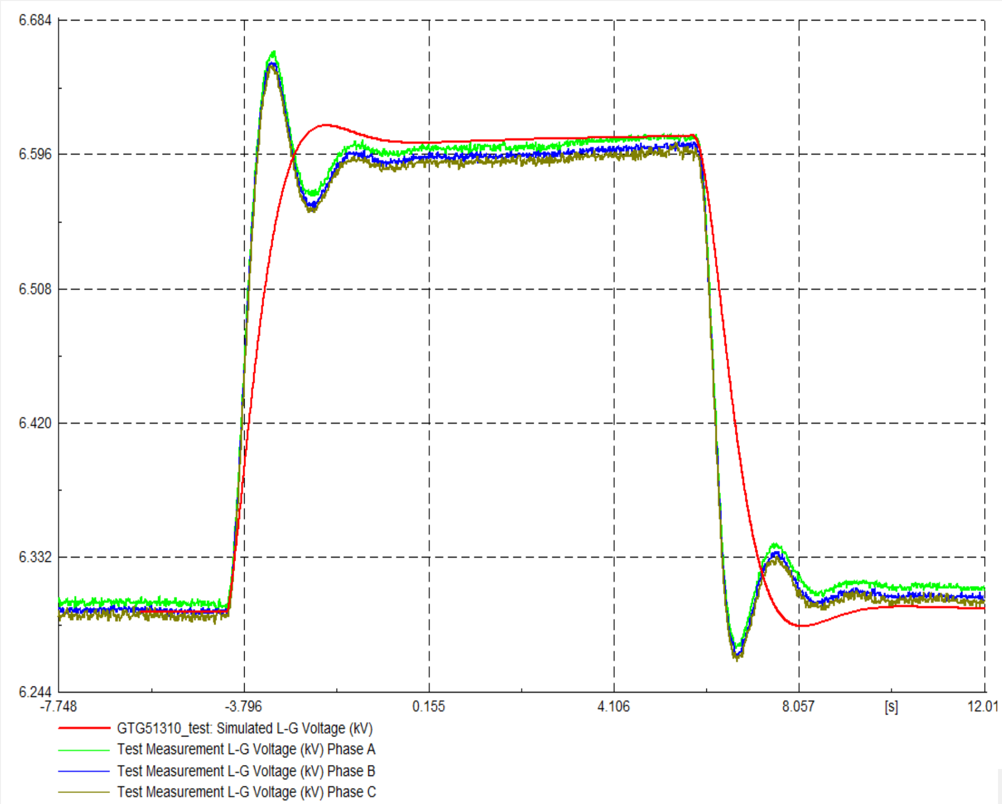
Model Validation

- Accuracy of dynamic models needs to be confirmed against actual site test measurements
- Parameters from manufacturers, or typical parameters, do not always accurately represent the true performance of the system
- Models that require validation include;
  - Exciter
  - Governor
  - Automatic voltage regulator
  - Power station controllers (voltage, frequency)
  - Ball Mill start-up characteristic (ramp time, peak inrush current)
  - Cyclo-converter start-up characteristic (Active/reactive power)
- Models are verified by undertaking a series of site tests (generator voltage/frequency step, motor start-up) and simulating the same test in the PowerFactory model

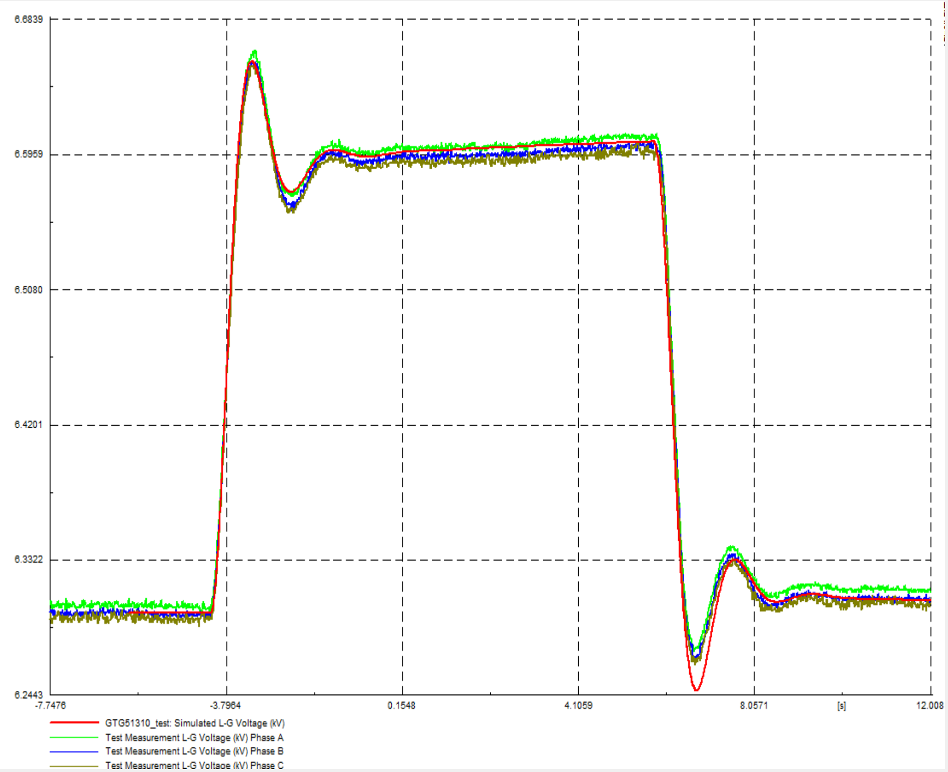
Model Validation

Generator unsynchronised voltage step test

Original Exciter Model Parameters



Revised Exciter Model Parameters



Conclusion

- A power system model has been developed for a large mine that can facilitate the following types of studies;
  - Load flow: Equipment loading, voltage regulation
  - Short-circuit: Equipment fault ratings
  - Dynamic simulations: Start-up of Mills/large motors, frequency and voltage stability following loss of generation or load
  - Protection coordination: Grading of over-current and earth fault protection elements

- The dynamic performance of the generators and the loads models have been verified against site tests (ongoing process)

- The model will serve as a useful tool for;
  - Future planning
  - Diagnosing problems before they occur