SRAS modelling data refresher session

For potential SRAS providers

This session will be recorded

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Welcome to country

We acknowledge the Traditional Owners of country throughout Australia and recognise their continuing connection to land, waters and culture.

We pay our respects to their Elders past, present and emerging.

Agenda

This session focuses on synchronous generation

1. Why does AEMO require detailed data for SRAS procurement assessments?
2. What data is required?

Follow along with us, download the Excel datasheets:

AEMO power system design data sheet

OR

Click the link in the chat window

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Modelling objectives

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SRAS assessed against System Restart Standard (SRS)

- Prospective SRAS providers and restart paths evaluated for **each electrical sub-network**

- SRAS contracted must be enough to meet the SRS for each electrical sub-network
  - The SRS is set by the Reliability Panel

1. Electrical Sub-Network	2. Level of Restoration (MW)	3. Restoration time (hours)	4. Required Aggregate Reliability
North Queensland	825	3.5	90%
South Queensland	825	3.0	90%
New South Wales	1500	2.0	90%
Victoria	1100	3.0	90%
South Australia	330	2.5	90%
Tasmania	300	2.5	95%

Note:

1. The QLD electrical subnetworks have been combined
2. The SRS for a single QLD electrical sub-network is currently being considered by the Reliability Panel. This may be finalised by January 2021.

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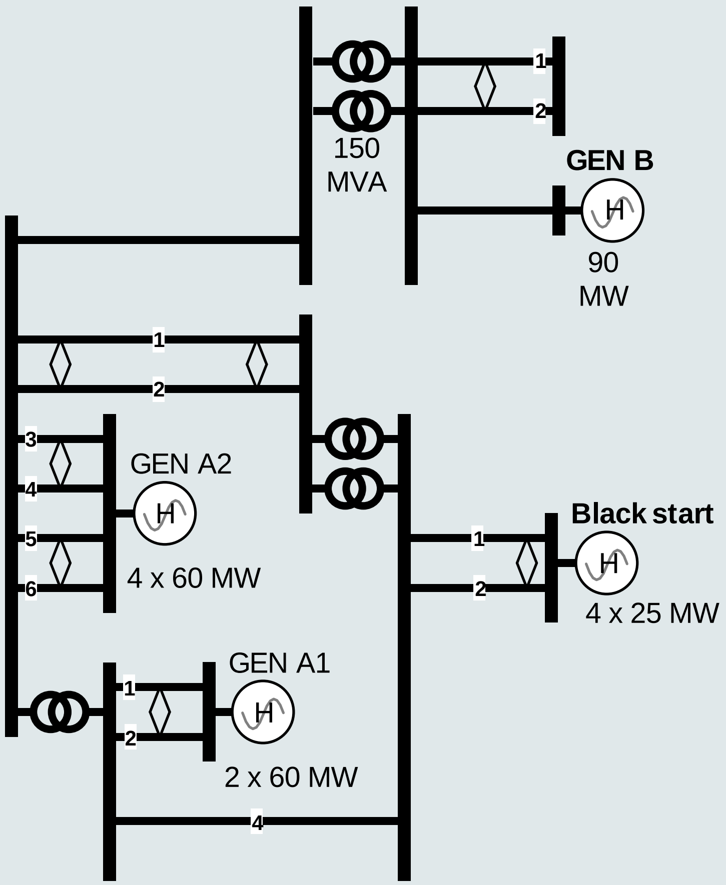
Technical analysis objectives



- Verify adequacy of proposed SRAS source
- Determine other generators that can be restored by the SRAS source
- Determine potential changes required to the SRAS source or network path
- Helps determine what combinations of prospective SRAS should be procured to meet the SRS
- Following procurement, this analysis also helps develop and verify restart paths

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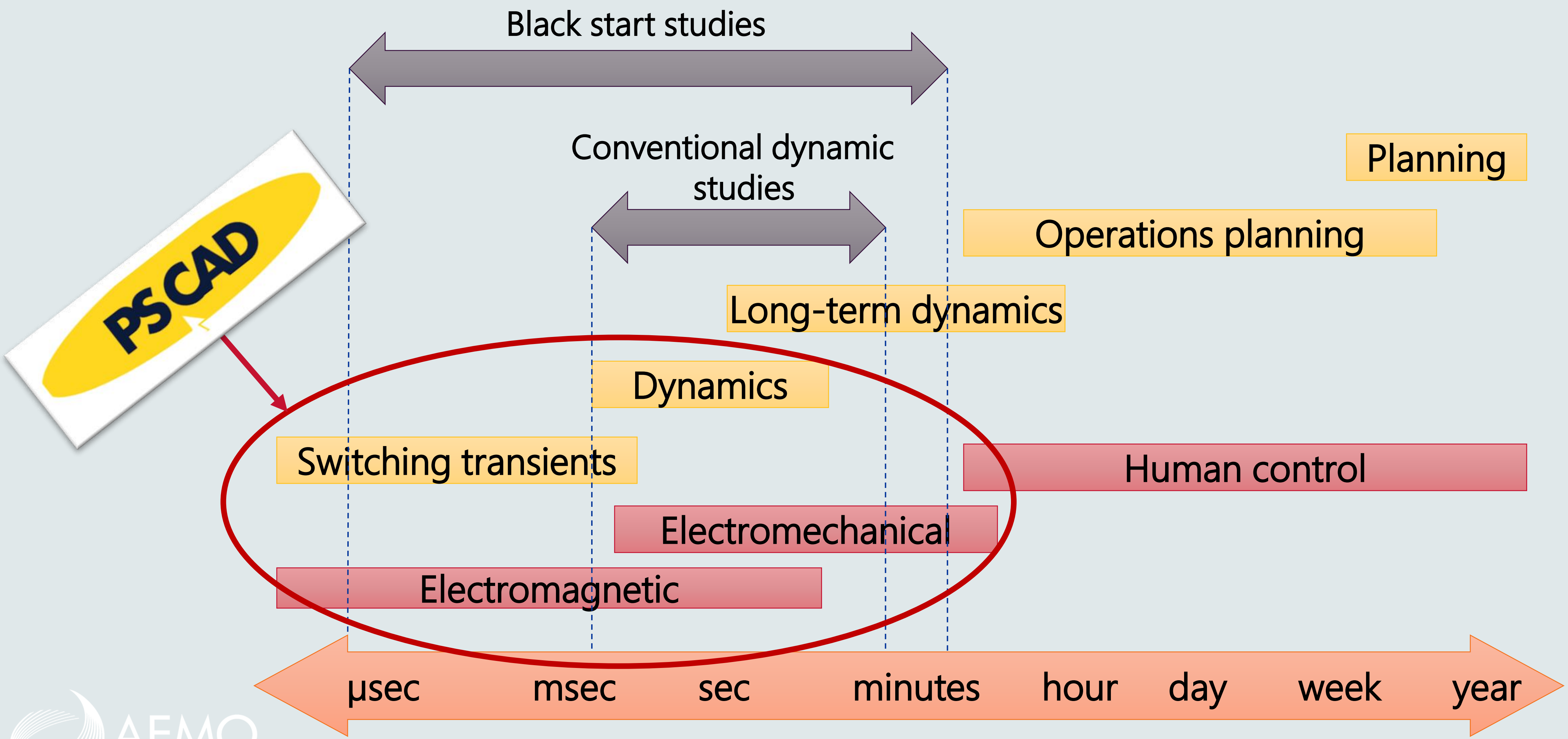
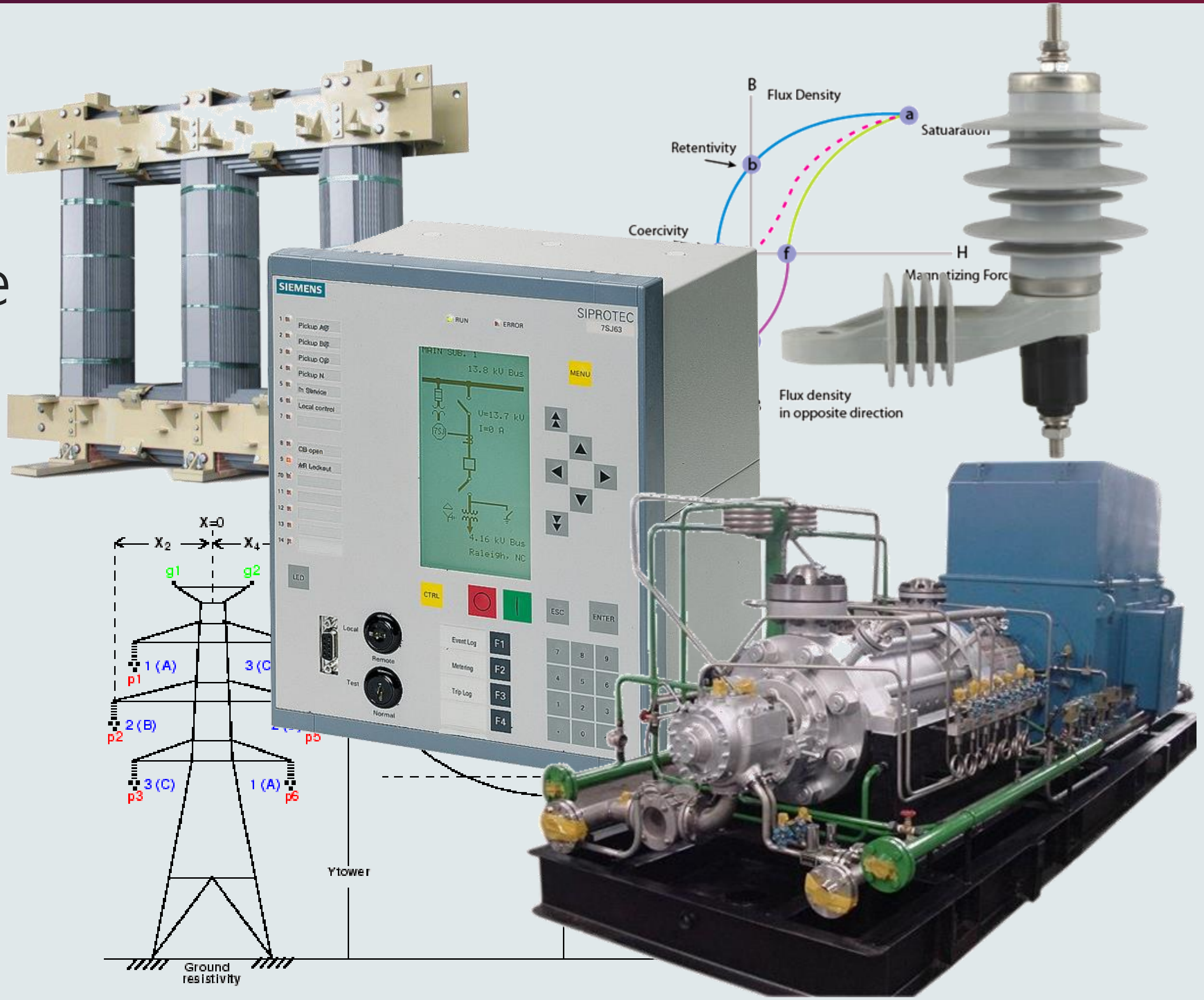
Modelling for black start



Extra elements modelled & simulated*

- Generator and transformer core saturation characteristics
- Transmission line geometry and cable bundling arrangements
- Generator and network protection relays
- Power station auxiliaries, major pumps and motors
- Surge arresters and custom V-I profiles



* compared to planning and R2 submitted information

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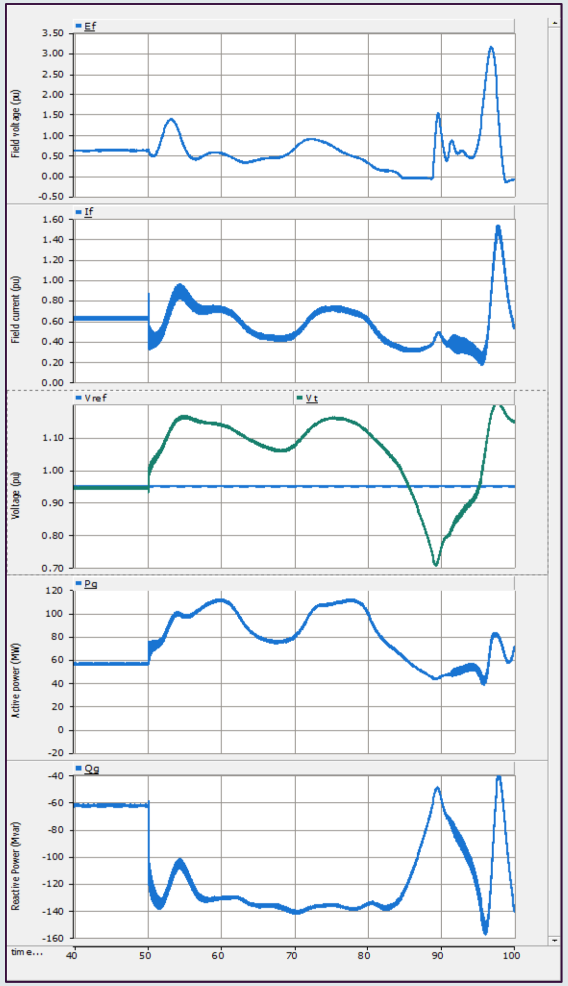
Why so detailed?

- System restoration has phenomena that doesn’t normally occur in a ‘healthy’ power system
- Power system components operating at extremes of their design
- A single power system component can have a huge impact on viability of an energisation path
- System restoration is prone to both correct and spurious operation of protection systems



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SRAS provider data requirements

Plus walkthrough of key data

Why provide SRAS plant data?

Data requirement

- NER 3.11.9(g) requirement for prospective SRAS providers
- Provide up to date Power System Design and Setting datasheets (ITT Schedule 2(c))
- This provides input into the technical assessment for each submission

Content

- Very similar content required compared to previous SRAS rounds
- Most new additions to datasheets for asynchronous plant, only a few fields changed for synchronous generators
- Protection aspects expanded

How AEMO uses the data

Understanding the configurability of your plant is key

- Can auxiliaries be energised by different paths?
- Can you close CBs without voltage? Can you soft-start beyond your PCC?
- Can your loading requirements be reduced? For how long?

EMT studies assume that the SRAS unit is in an island

- The unit is already at rated speed and rated voltage, unless soft starting is used
- Major SRAS unit auxiliaries online (for steam generators)

Tips for filling out the datasheet

Fill out as much as possible

The more relevant data you provide, the more confidence AEMO has in the modelling

Provide relevant information

Provision of lots of irrelevant/outdated data makes it difficult to assess your submission

Please be willing to discuss and clarify the information provided

Datasheets – Important sheets and fields

Where to find the Datasheets?

- Link is provided Schedule 2 ITT or search 'AEMO modelling requirements'
  - Power System Design and Setting Datasheets (Excel file)

Key aspects

- Generator (Inc. saturation)
- AVR & Limiters
- Governor (isochronous and droop)
- Key auxiliary motors (BFP, IDF etc.)
- Transformer (Inc. saturation)
- Protection relays

References to appendices/documents

- Can include reference but only if specific and appendix/document provided

Generating system data (Sheet S-6 and S-7)

Plant single line diagram

- Can be an appendix or specific reference to a file

Ratings

- Base MVA and Current

Voltage ratings and impedances

- Internal subsystems

Generating system data (Sheet S-6 and S-7)

7	Individual *Generating Unit* Data				
Symbol	**Data Description**	**Units**	**Data Category**	**Value**	**Remarks**
7.1.1	**Design Data Sheet**				
Symbol	**Data Description**	**Units**	**Data Category**	**Value**	**Remarks**
MBASE	Rated MVA	MVA	S, D, R1		Based on PMAX
IBASE	Base Current	Amps	S, D, R1		Based on PMAX
PMAX	*Nameplate Rating (Generated)*	MW	D, R1		Include voltage and temperature dependencies.
PDMAX	Maximum capacity MW *(Generated)* (e.g. short term rating or maximum *dispatchable* MW)				e.g. overload capacity. Include voltage and temperature dependencies.
	• *generated* MW value(s)	MW	S, D, R1		
	• time(s) that the *generated* MW applies; and	minutes	S, D, R1		
	• conditions for which the *generated* MW applies.	Text (or chart and text)			e.g. temperature range
	Ambient operating temperature de-rating curve, including maximum ambient operating temperature (if applicable)	Chart	S, D		Both active and reactive power de-rating curves.
Qmax	Rated *reactive power* injection (i.e. lagging)	MVAr *(Generated)*	S, D, R1		Temperature and voltage dependencies must be included.
Qmin	Rated *reactive power* absorption (i.e. leading)	MVAr *(Generated)*	S, D, R1		Temperature and voltage dependencies must be included.
GCD	Capability chart (Include corresponding transformer tap(s) for which this curve applies).	Graphical data	D, R1, R2		Temperature and voltage dependencies must be included.
VT	Nominal terminal *voltage*	kV	D, R1		
PAUX	Auxiliary *load* at PMAX	MW	S, D, R2		
ZGU1MIN	Minimum positive sequence impedance	% on 100 MVA base and VT	D, R1		
ZGU2MIN	Minimum negative sequence impedance	% on 100 MVA base and VT	D, R1		
ZGU0MIN	Minimum zero sequence impedance	% on 100 MVA base and VT	D, R1		

Step-up transformer (Sheet S-8.1)

Basic config & impedances

- Number windings, vector group, ratings, impedances
- If a transformer datasheet is available, it would be useful to reference this as well.

Earthing arrangements

- Including values, with diagram

Saturation data

- V-I curve

Tapping information

- Tap ranges, step size, nominal tap

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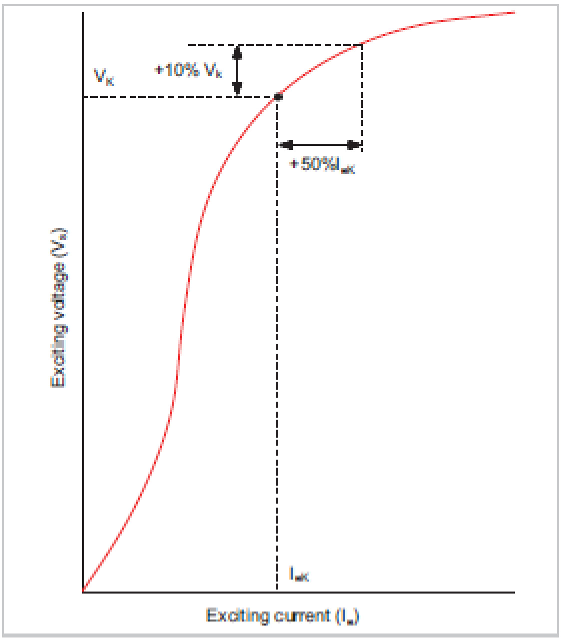
Step-up transformer (Sheet S-8.1)

Symbol	Data Description	Units	Data Category	Value	Remarks
8.1	**Transformer (generating unit and generating system)**				
Symbol	**Data Description**	**Units**	**Data Category**	**Value**	**Remarks**
8.1.1	**Design Data Sheet**				
Symbol	**Data Description**	**Units**	**Data Category**	**Value**	**Remarks**
GTW	Number of windings		S, D		
GTVG	Vector group	Text	S, D		
	Core configuration	Text	D		
GTRn	Rated MVA of each winding	MVA	S, D, R1		
GTTRn	Principal tap rated *voltages*	kV/kV	S, D, R1		
GTZ1n	Positive sequence impedance of each winding (negative sequence impedance [GTZ2n] is expected to be identical to GTZ1n)	(a + jb) % on 100 MVA base and VCON	S, D, R1		
GTZOn	Zero sequence impedance of each winding	(a + jb) % on 100 MVA base and VCON	S, D, R1		
	Earthing arrangement	Text, diagram	S, D		
	Neutral earthing resistor (if applicable)	(a + jb) % on 100 MVA base and VCON	S, D, R1		
	Saturation curve	Diagram	R1		Not optional
	Tap changer type, on/off load	On/Off	D		
	Tapped winding	Text, diagram	S, D, R1		
	Controlled bus		D, R2		
GTAPR	Tap change range	kV – kV	S, D		
	Number of taps	Text	D		
	Nominal tap	Text	D, R1		
GTAPS	Tap change step size	%	D		
	Inverse Time characteristic curve for OLTC voltage regulation system (Tap Change Time vs Voltage Deviation)	Diagram	D		

Example saturation V-I curve



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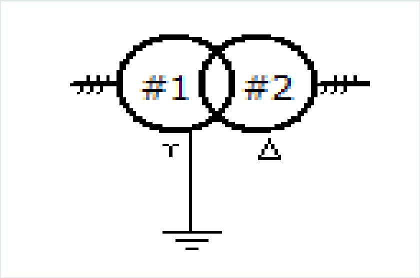
Transformer data and PSCAD model



TF configuration

- Impedance consistent with PSSE info
- Losses sourced from transformer datasheet

3 Phase 2 Winding Transformer — Configuration

General	
Transformer Name	
3 Phase Transformer MVA	500.0 [MVA]
Base operation frequency	50.0 [Hz]
Winding #1 Type	Y
Winding #2 Type	Delta
Delta Lags or Leads Y	Lags
Positive sequence leakage reactance	0.147 [pu]
Ideal Transformer Model	Yes
Eddy current losses	0.0005 [pu]
Copper losses	0.00212 [pu]
Tap changer on winding	None
Graphics Display	Single line (circles)
Display Details?	Yes

General

Ok Cancel Help...

3 Phase 2 Winding Transformer — Saturation

General	
Saturation enabled	Yes
Place saturation on winding	Middle
Hysteresis	Jiles_Atherton
Inrush decay time constant	0 [s]
Time to release flux clipping	0 [s]
Air core reactance	0.36 [pu]
Magnetizing current	0.4 [%]
Knee voltage	1.15 [pu]
Remanent Flux Core 1	0.8
Remanent Flux Core 2	-0.8
Remanent Flux Core 3	0.0
Loop Width	10
Nominal Flux Density [T]	**1.7**
Magnetic Material	default

General

Ok Cancel Help...

TF saturation

- Reactance and magnetising current derived from Transformer data sheets
- Knee point calculated from saturation V-I curve

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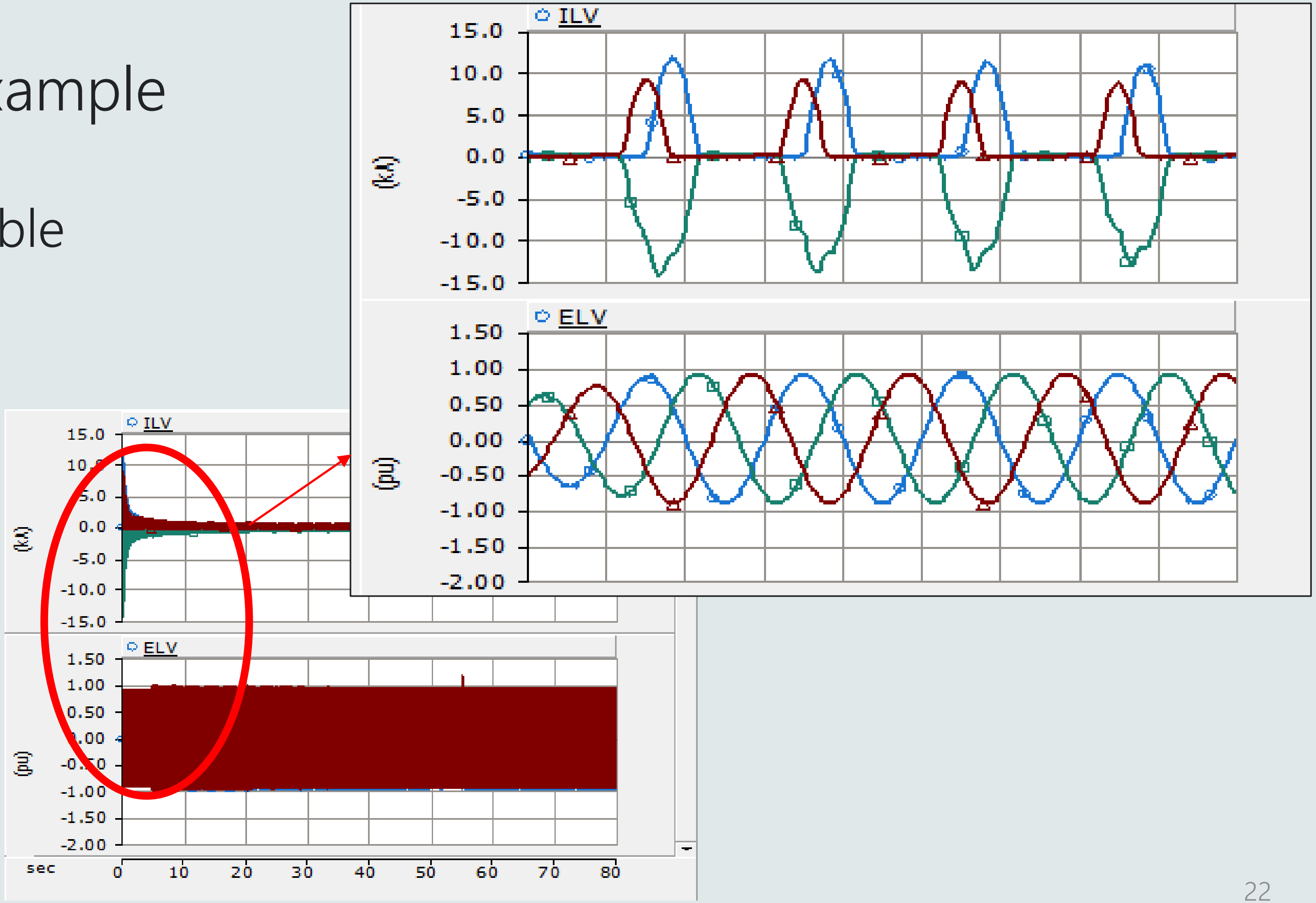
Transformer data and PSCAD results

- Transformer energisation example (successful!)
  - Harmonic distortion reasonable
  - No transformer differential protection tripped
  - Voltages reasonable
  - SRAS plant remained online



Synchronous Generator data (Sheet S-9.1)

Generator parameters

- Similar to standard PSSE fields
- Direct- and quadrature-axis reactances
- Operational time constants

Saturation characteristics

- Saturation curve preferred, if available

Additional Parameters

- Potier Reactance and Air Gap factors
- Stator resistance
- *Note: Can be typically estimated from standard data*

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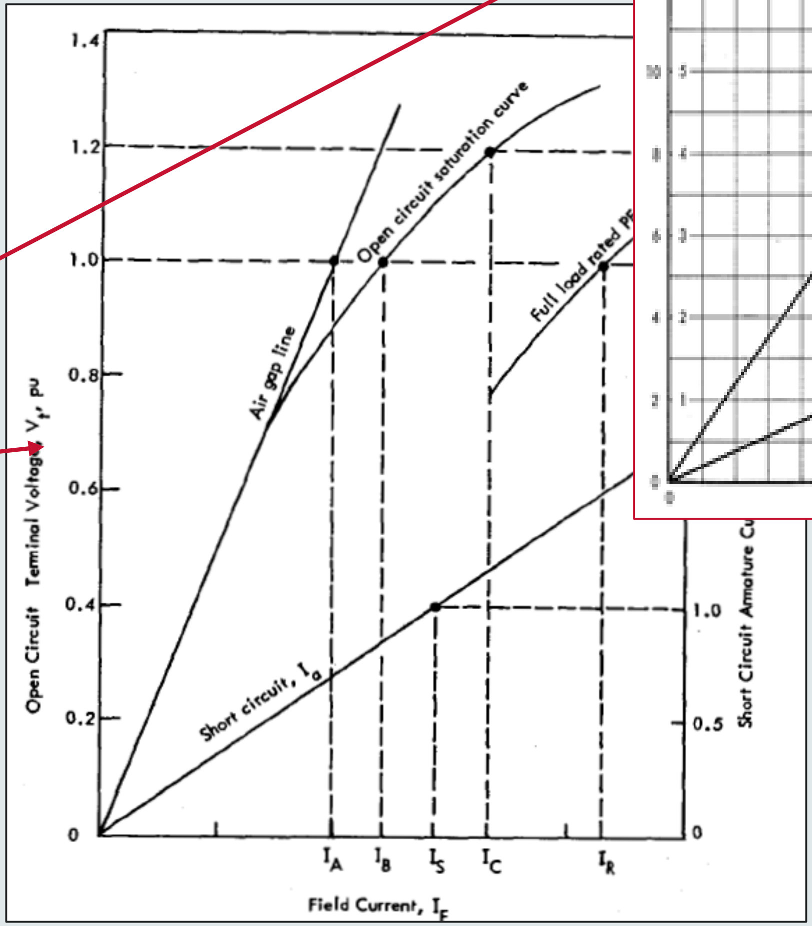
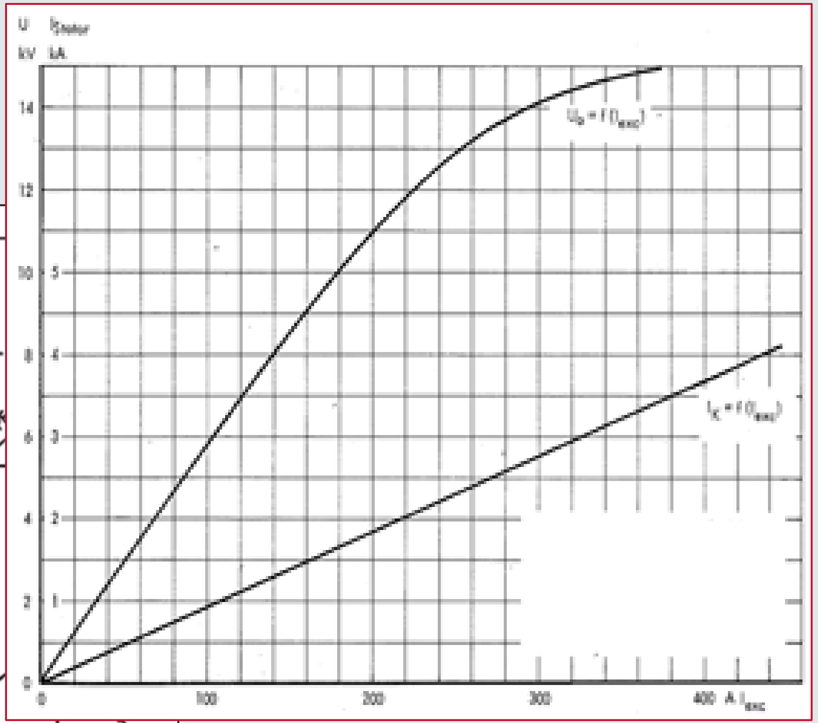
Synchronous Generator data (Sheet S-9.1)

RA	Stator resistance (at normal or typical operating temperature – specify temperature)	% on MBASE and VTGEN (temperature in °C)	S, D, R1, R2		
RF	Rotor resistance (at normal or typical operating temperature – specify temperature)	% on MBASE and VTGEN (temperature in °C)	S, D, R1, R2		
DAMPER	Damper windings and number of axis windings	Text	D, R1		
XL	Stator leakage reactance	% on MBASE and VTGEN	D, R1, R2		
X2	Negative sequence reactance	% on MBASE and VTGEN	D, R1		
Z0	Zero sequence impedance (including any neutral earthing impedance)	(a+jb) % on MBASE and VTGEN	D, R1		
XD	Direct axis unsaturated synchronous reactance	% on MBASE and VTGEN	S, D, R1, R2		
XDD	Direct axis unsaturated transient reactance	% on MBASE and VTGEN	S, D, R1, R2		
XDDD	Direct axis unsaturated sub-transient reactance	% on MBASE and VTGEN	S, D, R1, R2		
XQ	Quadrature axis unsaturated synchronous reactance	% on MBASE and VTGEN	D, R1, R2		
XQQ	Quadrature axis unsaturated transient reactance	% on MBASE and VTGEN	D, R1, R2		
XQQQ	Quadrature axis unsaturated sub-transient reactance	% on MBASE and VTGEN	D, R1, R2		
TD0	Direct axis open circuit transient time constant	s	S, D, R1, R2		
TDD0	Direct axis open circuit sub-transient time constant	s	S, D, R1, R2		
TKD	Direct axis damper leakage time constant	s	S, D, R1, R2		
TQ0	Quadrature axis open circuit transient time constant	s	D, R1, R2		
TQQ0	Quadrature axis open circuit sub-transient time constant	s	D, R1, R2		
GOCC	Open circuit saturation characteristic	Graphical data	R1		
S10	Saturation Parameter at 1.0pu terminal voltage on GOCC (the ratio between measured voltage and the air-gap line).		R1		
S12	Saturation Parameter 1.2pu terminal voltage on GOCC(the ratio between measured voltage and the air-gap line).		R1		
Xp	Potier Reactance	% on MBASE and VTGEN	R1		
Agf	Air Gap Factor	% on MBASE and VTGEN	R1		
GSCC	Short circuit saturation characteristic	Graphical data	R1		
GZPC	Zero power factor curve	Graphical data	R1		





Synchronous Generator data (Sheet S-9.1)

Synchronous Machine — Configuration

General	
Machine name	NAME
No. of Q-axis Damper Windings	One
Data Entry Format:	Generator
Multimass interface:[Enables Speed Ctrl]	DISABLE
Armature Resistance as:	Resistance
D-axis Saturation	Enabled
Type of settings for initial condition	Powers
Machine scaling factor?	Yes
Graphics Display	Single line view
External Neutral Connection	Disable

General

Ok Cancel Help...

Synchronous Machine — Generator Data Format

General	
Armature Resistance [Ra]	0.00445 [p.u.]
Armature Time Constant [Ta]	.11 [sec]
Potier Reactance [Xp]	0.199 [p.u.]
D: Unsaturated Reactance [Xd]	2.104 [p.u.]
D: Unsaturated Transient Reactance [Xd_]	0.414 [p.u.]
D: Unsaturated Transient Time (Open) [Tdo_]	5.075 [sec]
D: Unsaturated Sub-Transient Reactance [Xd__]	0.251 [p.u.]
D: Unsaturated Sub-Transient Time (Open) [Tdc	0.04585 [sec]
D: Real Transfer Admittance (Armat-Field)	1.0E+2 [p.u.]
D: Imag Transfer Admittance (Armat-Field)	0.0 [p.u.]
Q: Unsaturated Reactance [Xq]	1.064 [p.u.]
Q: Unsaturated Transient Reactance [Xq_]	0.216 [p.u.]
Q: Unsaturated Transient Time (Open) [Tqo_]	7.199 [sec]
Q: Unsaturated Sub-Transient Reactance [Xq__]	0.251 [p.u.]
Q: Unsaturated Sub-Transient Time (Open) [Tqc	0.2006 [sec]
Air Gap Factor	1.0

General

Ok Cancel Help...

Saturation curve data

Stator resistance

Potier reactance, Air gap factors

Time constants

Synchronous Machine — Saturation Curve

Currents	
Point 1 - Current	0.0
Point 2 - Current	0.4647
Point 3 - Current	0.5745
Point 4 - Current	0.8222
Point 5 - Current	0.9397
Point 6 - Current	1.0641
Point 7 - Current	1.3146
Point 8 - Current	1.6342
Point 9 - Current	2.6943
Point 10 - Current	4.1316
Voltages	
Point 1 - PU Voltage	0.06
Point 2 - PU Voltage	0.6
Point 3 - PU Voltage	0.7
Point 4 - PU Voltage	0.87
Point 5 - PU Voltage	0.95
Point 6 - PU Voltage	1
Point 7 - PU Voltage	1.05
Point 8 - PU Voltage	1.1
Point 9 - PU Voltage	1.2
Point 10 - PU Voltage	1.35

Currents

Ok Cancel Help...

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AVR & limiters (Sheet S-10.1)

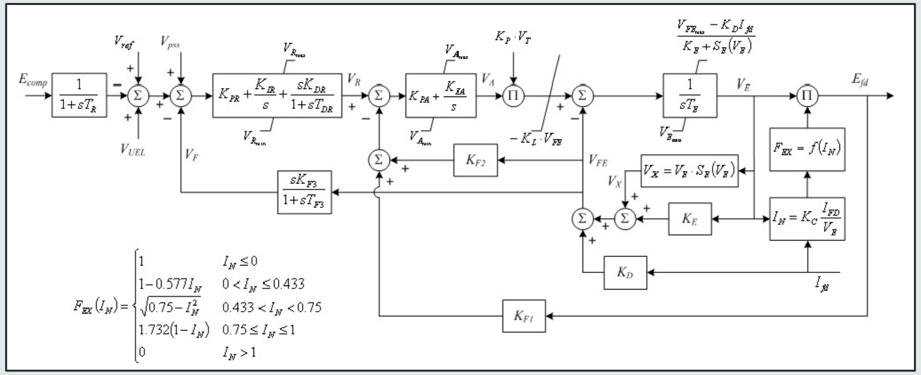
Block diagrams

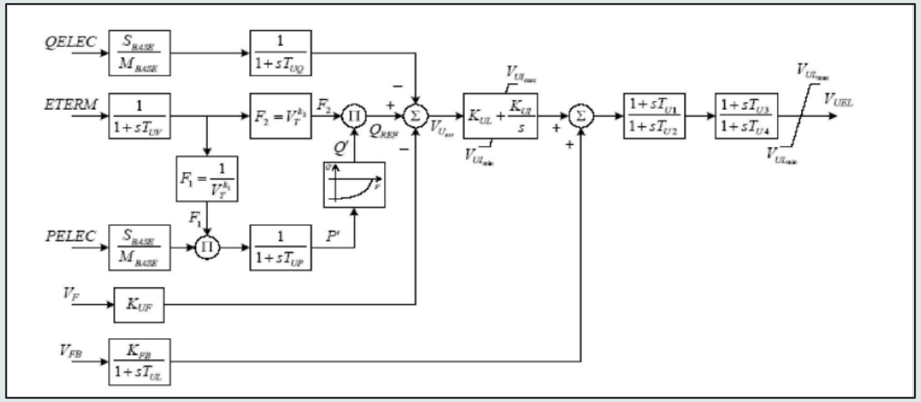
- Include corresponding settings
- Exciter, AVR and limiters
- Similar to standard PSSE models

Limiters

- OEL & UEL performance often critical

AVR & limiters (Sheet S-10.1)

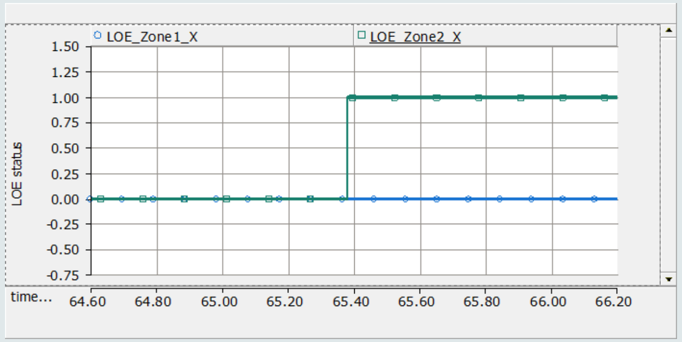




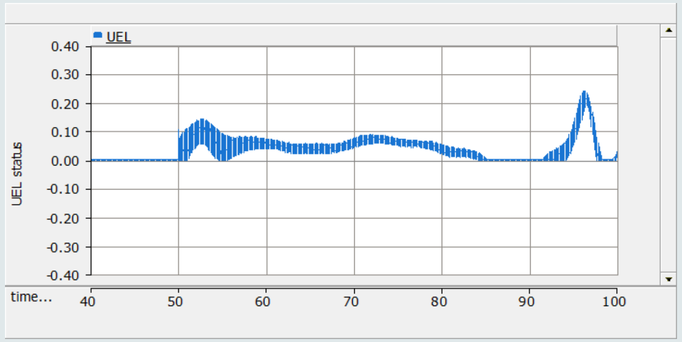
	Exciter description including type, ratings, connection schematic, source of any external supplies, etc.	Text	D, R1		
ALPHA	Maximum and minimum firing angle	Degree	D, R1		
	If applicable, exciter saturation curve over 50%-120% of rated voltage.	Diagram	D, R1		
	Details of the excitation *control* system described in functional block diagram form showing:	Functional block diagram	S, D, R1		
	• *voltage control systems* (*AVR*);				
	• *power system* stabiliser (*PSS*);				
	• AC or DC exciter/exciter machine;				
	• 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);				
	• power factor, reactive power or other superimposed controllers and regulators (if fitted);				
	• over-excitation limiter;				
	• under-excitation limiter;				
	• stator current limiter (if fitted);				
	• flux (*V/f*) limiter (if fitted);				
	• manual restrictive limiter (if fitted); and				
	• any other limiters that may restrict excitation system operation.				
	Internal protection or monitoring systems (e.g. earth fault, rotor temperature, excitation transformer temperature, ripple, short-circuit detection, rotating diode, converter etc.) that could result in failover or generator trip				
	Details of excitation *control system* components failover (e.g. for multiple *AVR* channels, or *AVR* to manual control) or generator trip, describing conditions that cause the failover or trip.	Text	D, R1		

AVR & limiters (Example)

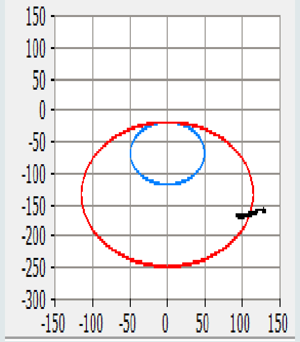
LOE relay response during line energization



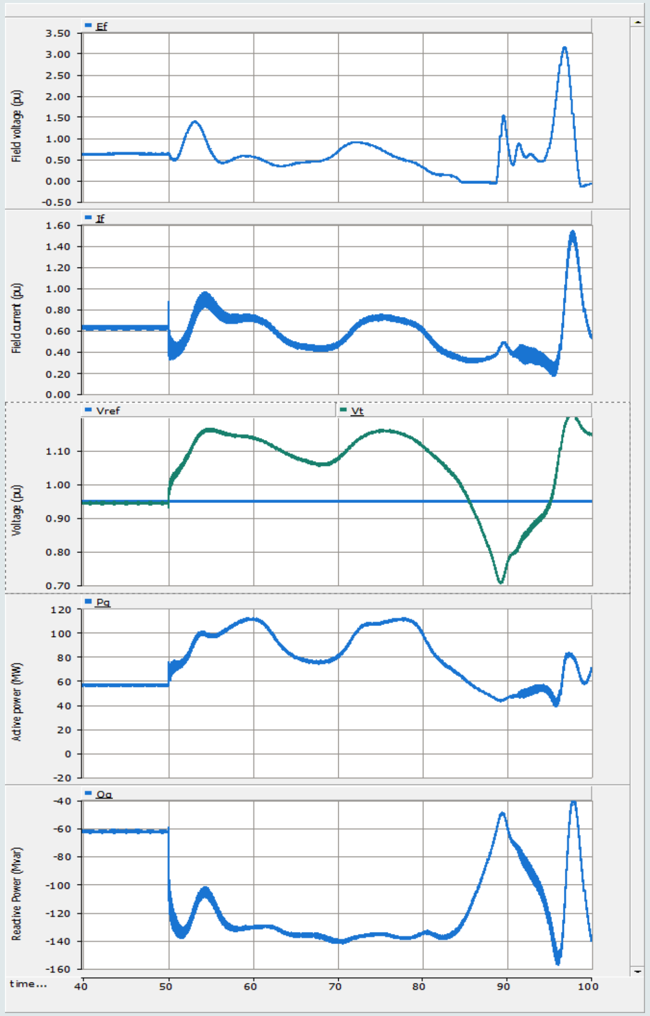
UEL response during line energization



Impedance trajectory (Ω) during line energization superimposed on the dual circle mho LOE relay



Black start generator dynamic response during line energization



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Governor (Sheets S-12.1to S-12.3)

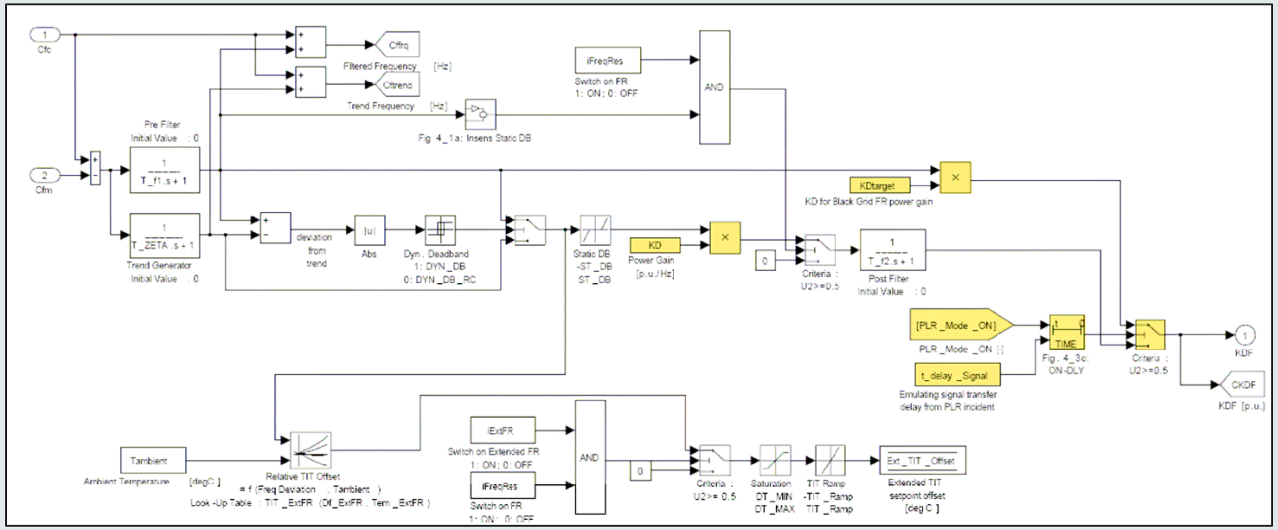
Block diagrams

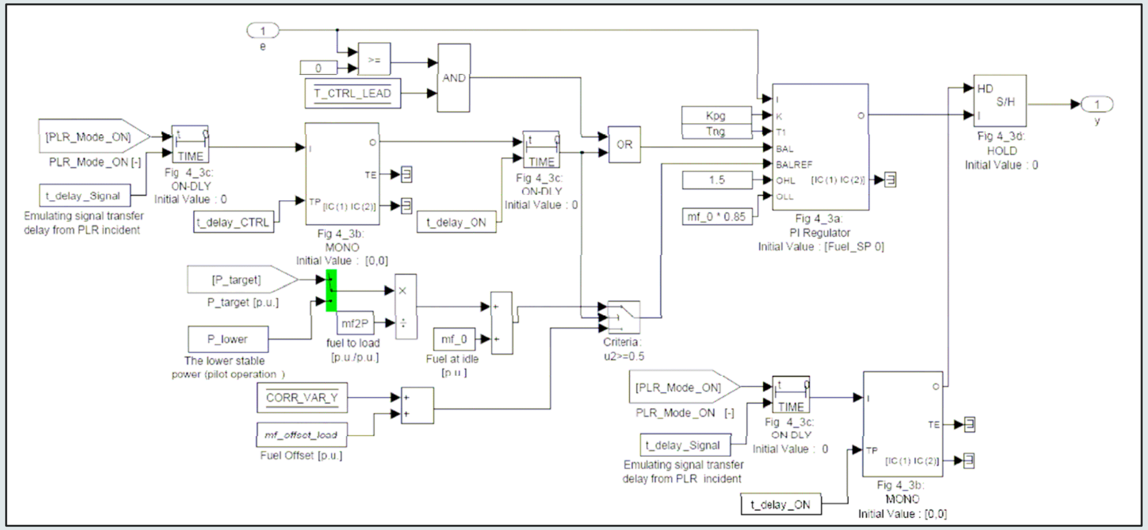
- Include corresponding settings (e.g. changeover settings)
- As detailed as possible, incl. subfunctions that may exist
- Similar to standard PSSE models

Governor Modes

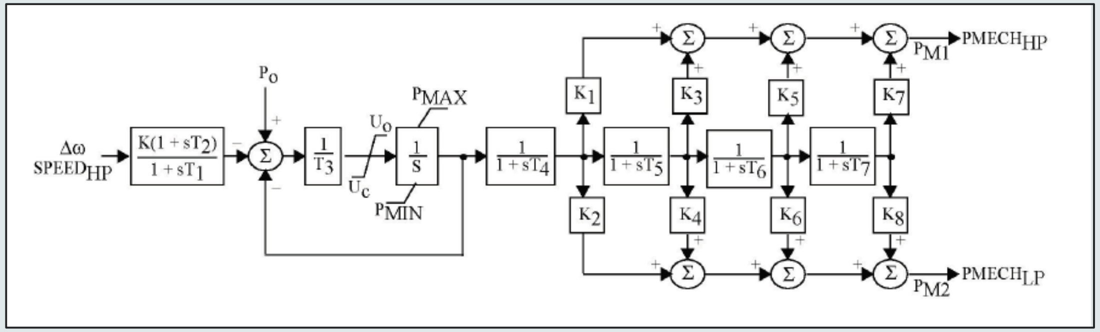
- Both <u>isochronous</u> and **droop** modes (also applicable to TTHL)
- Include any switchover logic

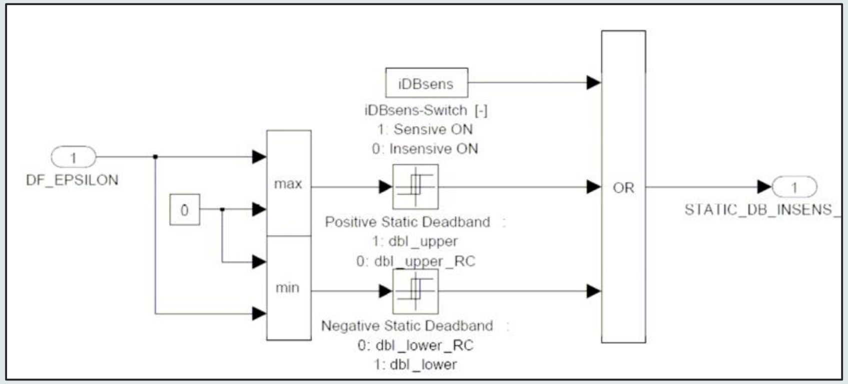
Governor (Sheets S-12.1to S-12.3)





<u>Isochronous</u> and **droop** modes are required





Asynchronous motor (Sheet S-15.5)

Requirements

- Mostly applies to steam-based plants
  - Boiler feed water pump
  - Induced draft fan
  - Forced draft fan

Modes

- At a minimum, the major motor MVA ratings, voltage, and likely stall voltage
- Reactive power consumption over range of asynchronous machine output (0 to PMAX)
- Speed (slip) vs torque (power) curve(s)

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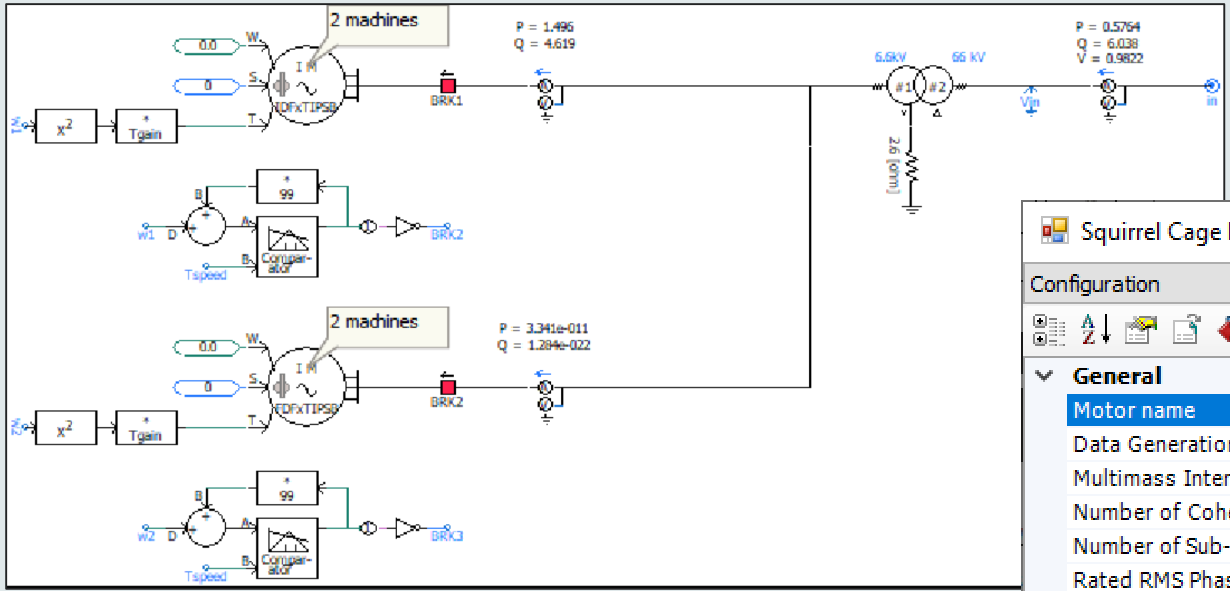
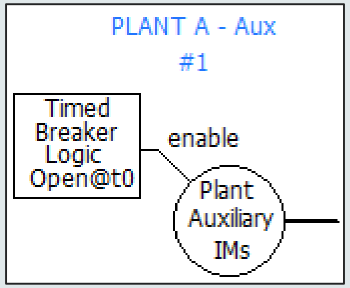
Asynchronous motor (Sheet S-15.5)





Squirrel Cage Induction Machine — Configuration

General	
Motor name	**IDFxPLANTA**
Data Generation/Entry:	Explicit
Multimass Interface	DISABLE
Number of Coherent Machines	2
Number of Sub-Iteration Steps	1
Rated RMS Phase Voltage	3.811 [kV]
Rated RMS Phase Current	0.098 [kA]
Base Angular Frequency	314.159 [rad/s]
Graphics Display	Single line view

Motor name
Enter a name for identification

Ok | Cancel | Help...

Squirrel Cage Induction Machine — Explicit Data Format

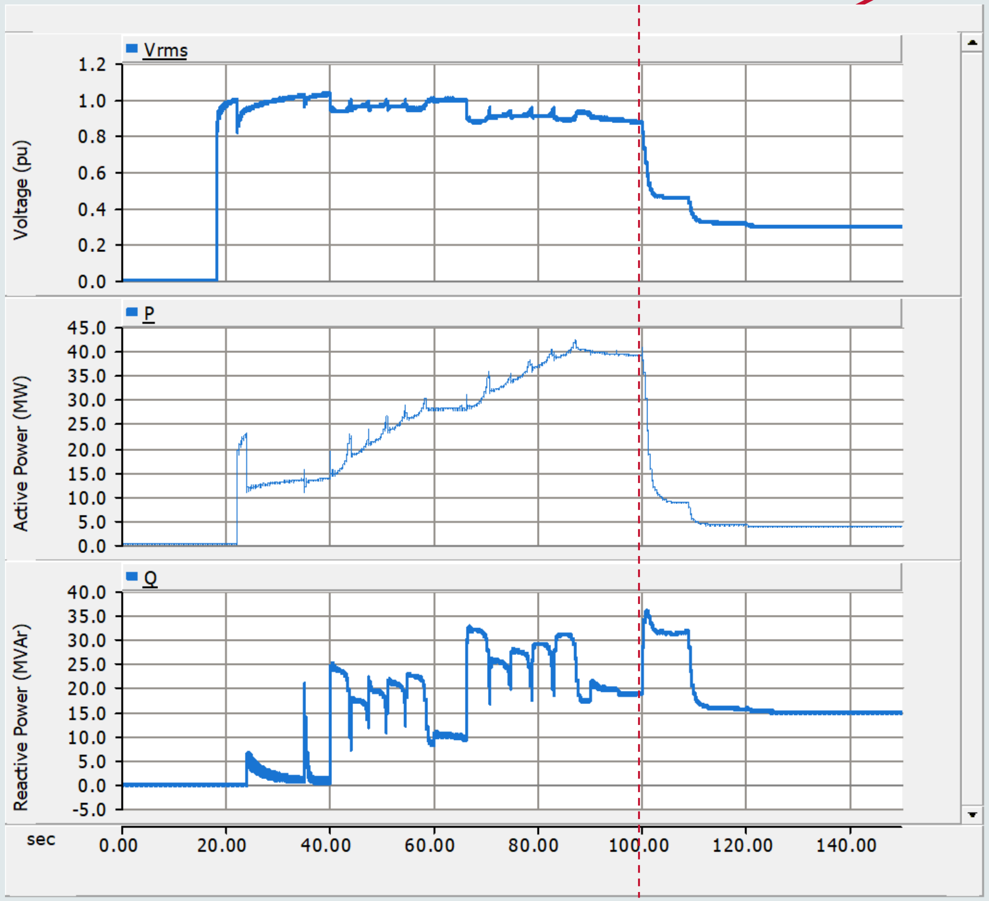
General	
Mutual Saturation	Disabled
Leakage Saturation	Disabled
Stator Resistance	0.001920 [pu]
First Cage Resistance	0.034696 [pu]
Second Cage Resistance	0.008350 [pu]
Stator Unsaturated Leakage Reactance	0.123153 [pu]
Unsaturated Magnetizing Reactance	25.3689 [pu]
Rotor Unsaturated Mutual Reactance	0.098208 [pu]
Second Cage Unsaturated Reactance	0.170812 [pu]
Polar Moment of Inertia (J=2H)	1.5 [s]
Mechanical Damping	0.001 [pu]

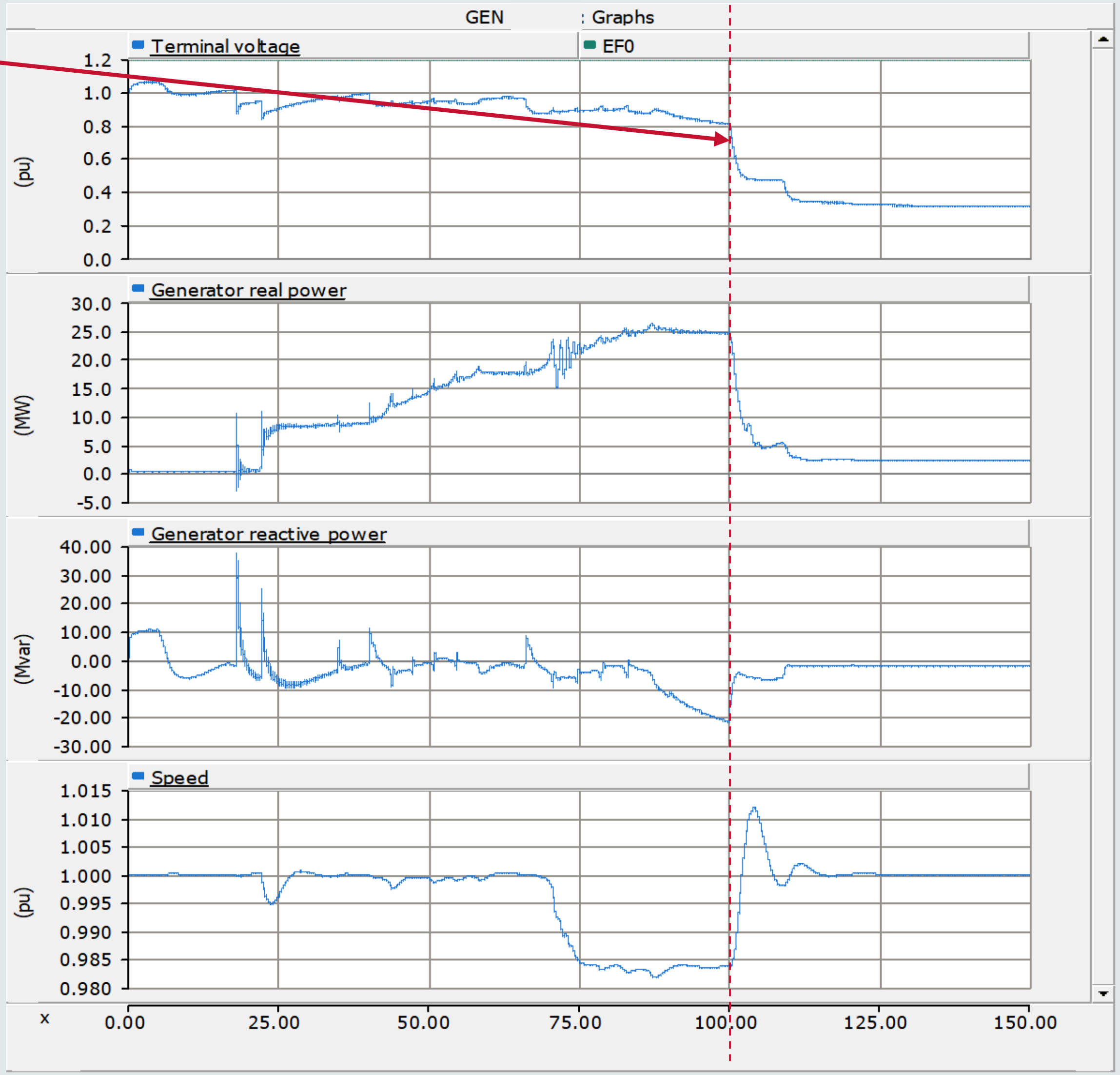
General

Ok | Cancel | Help...

Asynchronous motor (Example)

At 100 seconds, 3rd auxiliary unit, is energized





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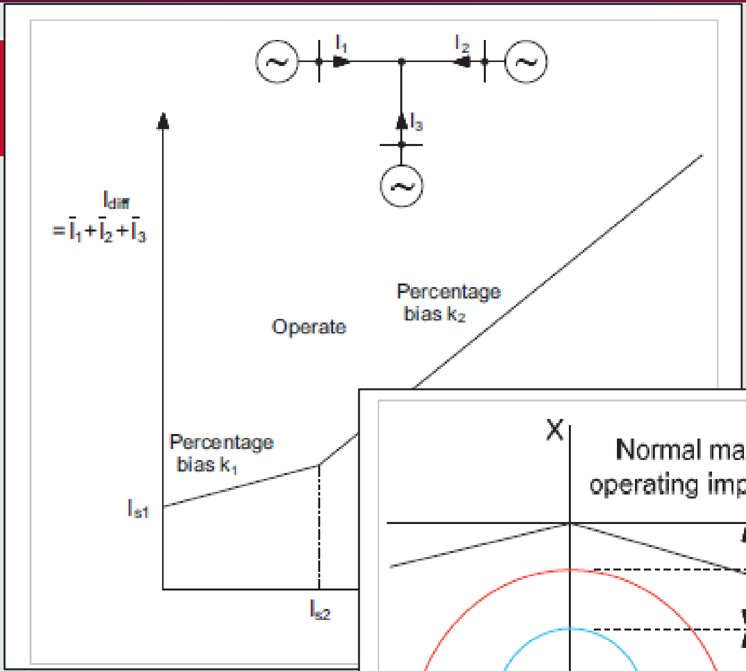
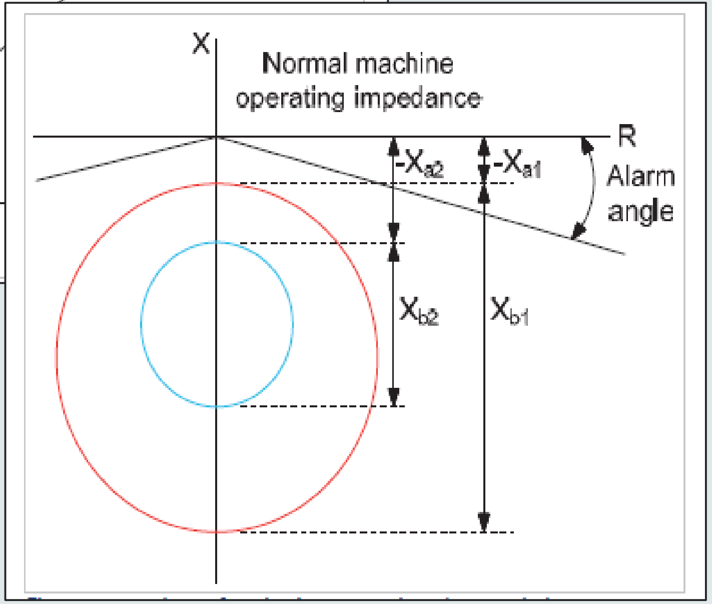
Protection (Sheet S-16.1)

Protection

- Generator/transformer differential protection
  - Including harmonic blocking capability
- Loss of excitation/field
- Over-flux (V/Hz)
- Out-of-step (Pole Slip)
- Negative Phase Sequence
- Reverse Active Power
  - Critical where multiple units initially operating together at no load





CT and VT ratios

Auxiliary loads

- For e.g. BFP, IDF and trip points (e.g. < 0.8 p.u. undervoltage)

Please provide up-to-date, specific, and human-readable data

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Protection (Sheet S-16.1)

[SA_Transmission_Lib

Configuration

CT ratio (HV/MW/LV side)

Transformer voltage hi side	275
Transformer voltage low side	66
Trasformer phase shift- HV leading (+ d	0
CT ratio hi side	400
CT ratio low side	1600
Second harmonic set point	0.2
Second harmonic blocking time	5
Selection of N-th harmonic	5th harmonic
N-th harmonic set point	111
N-th harmonic blocking time	111 [s]

Second harmonic set point
Second harmonic blocking time
Selection of N-th harmonic (typically 5th, but can be 2nd, 3rd or 4th)

General

Ok Cancel Help...

[SA_Transmission_Lib

Characteristics

General

Basic differential threshold setting (IS1)	0.2
Hi side reference current	314.9
Gradient in the range 1 (K1)	0.3
Gradient in the range 2 (K2)	0.7
Selection of K1 or K2	K1
Bias current constant (K=0, 0.5 or 1)	1
Time delay I_Diff low	0
I_Diff hi value	10
Time delay I_Diff hi	0.0

General

Ok Cancel Help...

Dual Slope Current Differential Relay

Main

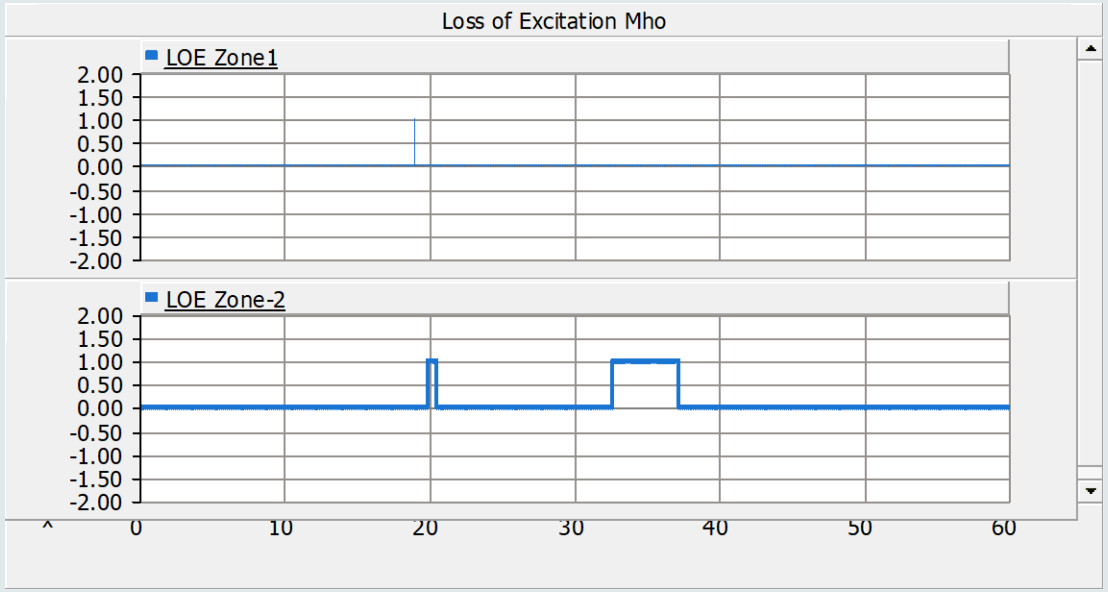
General

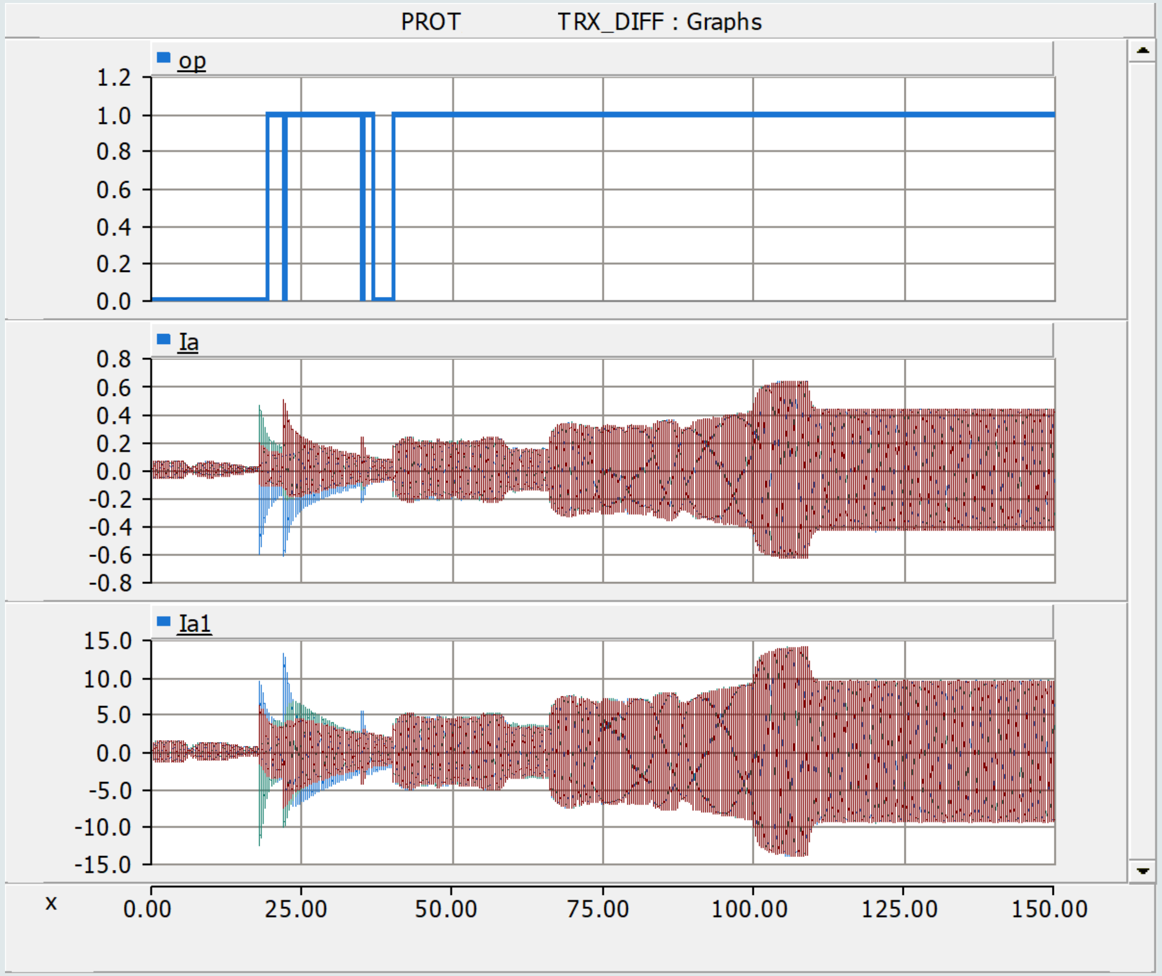
Input angles are given in	Degrees
Differential current threshold	1.0
Lower percentage bias setting	0.3
Bias current threshold setting	2.0
Higher percentage bias setting	1.5
Hold time	4.0 [ms]

General

Ok Cancel Help...

Protection (Example)





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Reliability data summary

SRS Individual and Aggregate Reliability

SRAS Equipment Reliability
- Availability
- Start-up performance

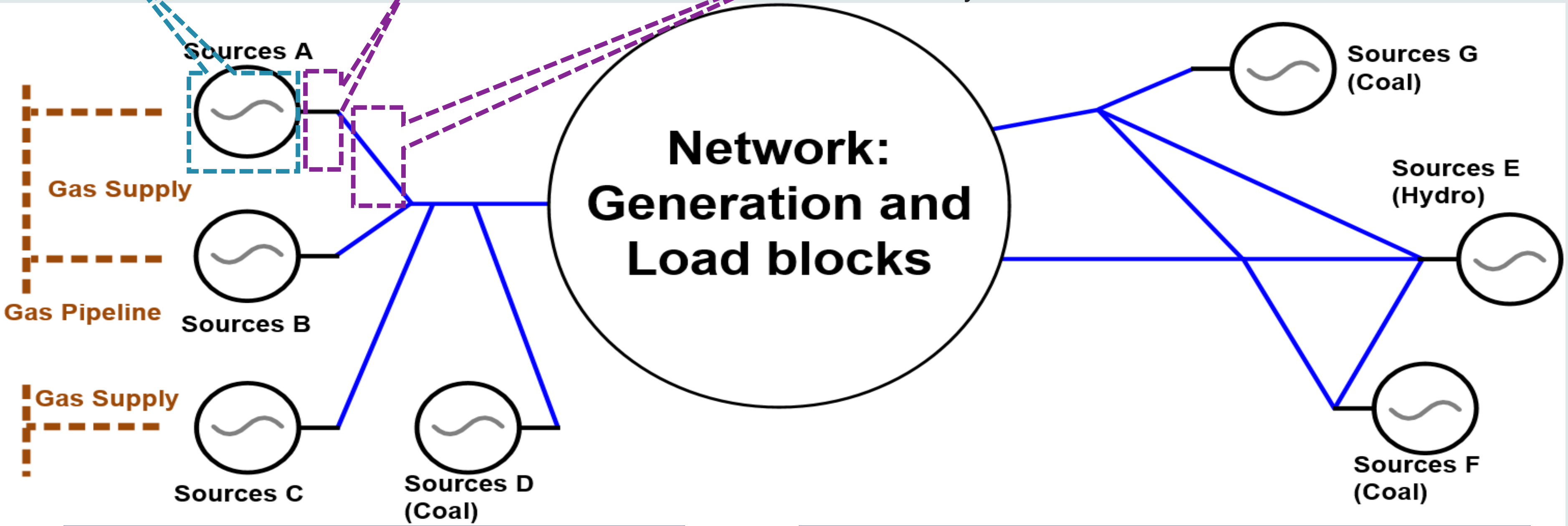
SRAS Transmission Reliability
- Transmission network

SRAS Individual Reliability

Location:
- Strategic Location
- Restart Path

Diversity

Aggregate Reliability



SRAS Sources	Individual Reliability	Location
A	High	Good
B	Medium	Good
C	High	Good
E	Low	Poor
G	High	Good

SRAS Sources	Electrical Diversity	Geographical Diversity	Energy Source Diversity
A + B	No	No	No
B + C	Yes	No	Yes
C + E	Yes	Yes	Yes
A + G	Yes	Yes	Yes
C + G	Yes	Yes	Yes

Strong contenders

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SRAS ITT Reliability data - Schedule 2(b) &(c)

How is this data used?

- Assists AEMO calculate the individual reliability component for each prospective SRAS

Data to be provided

- Included in ITT Schedule 2(b) and (c)
- Reliability of major SRAS equipment & points of failure?
- Understanding of resilience and reliability of communications
- Availability information (maintenance, energy source)
- Upgrades that improve SRAS equipment performance (this includes any type of major SRAS equipment)

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SRAS ITT Reliability data tips

Fill out as much data as possible

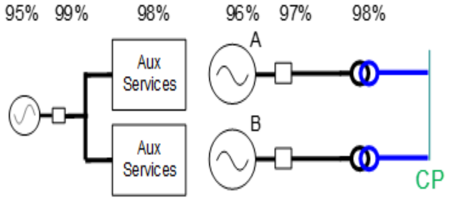
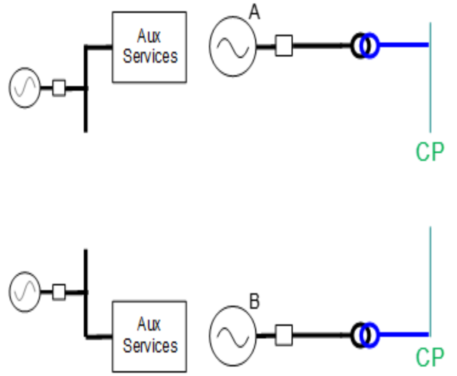
- Don't assume AEMO already knows details of your plant
- Description of primary/protection upgrades
- Description of Primary and backup fuel sources
- Include diagrams to show reliability calculations

Provide relevant information

- Referencing other sources (GPS, LBSP) is suitable as long as specific, clear and current.
- For example "*refer to LBSP Rev 1 dated 20 July 2020, response to questions 3E and 3F*"

Be willing to discuss

- Further clarification on your submission may be required

Configuration		Description of Configuration	SRAS Equipment Reliability: Points of failure calculation	SRAS Equipment Availability
Configuration 1		Single diesel generator used to start either one of two main units	93%	92%
Configuration 2		Single diesel generator used to start single main unit	84% (for either variation)	8%

Example diagram & calculation from the SRAS ITT Appendix A

Questions

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