

Fault Analysis

Introduction (1)

- ❖ **Several modules as follows are available in PSSE for fault-level study.**
 - ❑ **SCMU**
 - ✓ Gives a detailed fault analysis result.
 - ✓ Gives contribution to fault current at the faulted bus from all the network elements connected to that bus.
 - ❑ **ASCC**
 - ✓ Uses a simplified model
 - ✓ Uses FLAT (to specify zero-sequence and –ve sequence models)
 - ✓ With ASCC, it is possible to visualise not only effect on the faulted bus, but also on other buses of the system
 - ✓ The results of ASCC can be shown on a SLD (Slider) file

Introduction (2)

□ IEC 60909

- ✓ Most widely used method, although it tends to give a higher fault level value.
- ✓ Uses IEC 60909 standard to derive an equivalent network model i.e. and equivalent impedance. Main parameters used are
 - a) Short-circuit ratio i.e. $SCR (X/R)$,
 - b) Nominal Power,
 - c) Z source
- ✓ 2 options are available:
 - a) Maximum Short Circuit calculation: estimate CB rating
 - b) Minimum Short Circuit calculation: minimum possible fault current

Basics of Sequence parameters (1)



- In general, there would be 6 basic fault networks for all 10 types of Short-circuit faults
- The method of Symmetrical Components as developed by Charles Fortescue are used for simplified calculations.
- Only Positive Sequence network has a driving source and it will appear for all types of faults.
- The positive sequence impedance of network elements is same as that entered for Load-flow studies.
- Zero sequence network appears for faults involving ground (G) viz. LG / LLG / LLLG faults.

Basics of Sequence parameters (2)



- **Negative sequence network appears for Unbalanced faults viz. all faults other than 3-phase faults**
- **L-G fault => All 3 sequence networks are in Series, and fault impedance is multiplied by 3**
- **LL fault => Positive and Negative sequence networks come in parallel**
- **LL-G fault => All 3 networks come in parallel**
- **3-phase fault => Only +ve sequence network connected upon itself at Neutral by Fault impedance**

System Modeling (1)

□ System modeling

- Resistances & reactance, including all shunts and line charging in the three sequences
- Ratios and phase shift angles of transformers
- Loads converted to equivalent shunt admittances

□ Input data

- Generator sequence data
- Load sequence data
- Transformer sequence data
- Zero sequence non transformer
- Branch data

System Modeling (2)

❑ Load sequence data

- ✓ Negative sequence data is supplied only where load is different than positive sequence.
- ✓ If not supplied negative sequence load is assumed to equal the positive sequence value.
- ✓ All positive sequence loads (from power flow case) are automatically converted to constant shunt admittance values.
- ✓ Where no zero sequence load record is specified, PSS®E assumes no shunt load component (open circuit in zero sequence).

Assumptions in modeling of negative and zero sequence networks



- ❑ All branches (lines & transformers) have the same impedance, charging and line shunts in the negative sequence as in the positive.
- ❑ All transformers have phase shift in the negative sequence equal and opposite to that in the positive sequence.
- ❑ All zero sequence branches and shunts are assumed to have infinite impedance, unless a different value is entered specifically.
- ❑ All loads are represented by the same shunt admittance in the negative sequence as in the positive, unless a different value is entered for negative sequence specifically.
- ❑ Loads are open circuits in the zero sequence unless represented specifically by entry of a value for zero sequence shunt admittance.
- ❑ User appends negative and zero sequence data to the Power Flow Model. Data is saved and retrieved with SAVE and CASE.
- ❑ DC and FACTS devices are assumed either as a load or blocked. The default option is blocked, and thus they are ignored.

Preparation of Base case

- To perform all types of fault analysis, it is necessary to *insert values of Zero sequence impedances (as per Highlighted portion in figure)*

File Edit View Diagram Power Flow Fault OPF Trans Access Dynamics Disturbance Subsystem Misc I/O Control Tools Window Integrations Help

100%

Output Bar Network data x SLD - NER GRID- AREA WISE-1

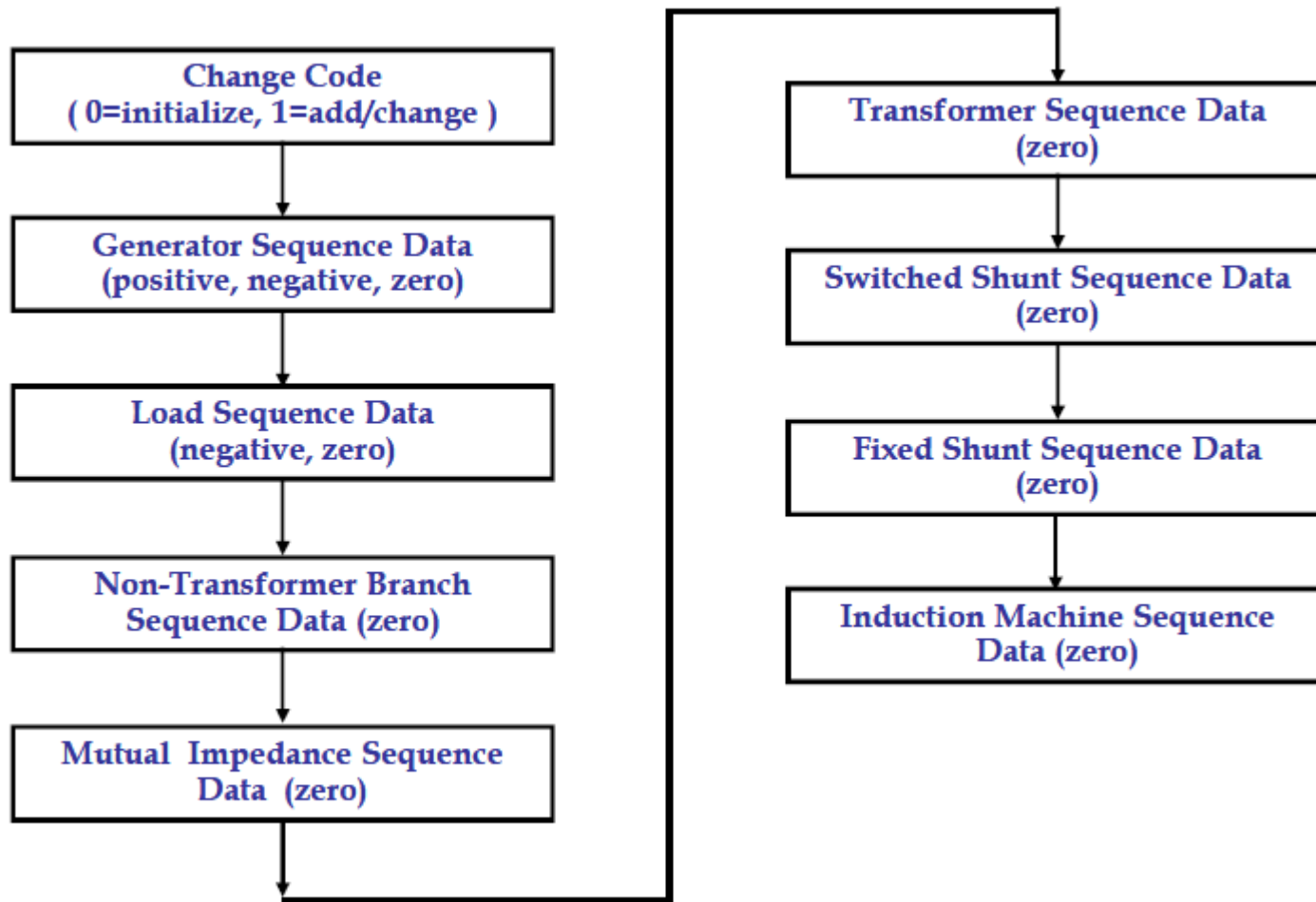
	From Bus Number	From Bus Name	To Bus Number	To Bus Name	Id	Fraction 4	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq G From (pu)	Zero Seq B To (pu)	Zero Seq B To (pu)	Protection Mode	MOV Rated Current (kA)
SIEMENS	511001	ZRO-PG1	511002	DAPORU01	1	1.000	0.203002	0.811832	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
50000 BUS PO	511001	ZRO-PG1	511005	RNGNDI1	1	1.000	0.103643	0.414481	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
INITII	511002	DAPORU01	511003	ALONG1	1	1.000	0.190198	0.780627	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
ALL INDIA PEAK AP 28TH DECEMBER 201	511005	RNGNDI1	511007	NAHARLAGUN1	1	1.000	0.041438	0.165718	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
The Saved Case in	511006	NRJUL1	511007	NAHARLAGUN1	1	1.000	0.010243	0.040964	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
The following opt	511006	NRJUL1	521029	GOHPURSPUT11	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
** BASE FREQUENCY	511009	KHUPI1	511015	BHALUKPONG1	1	1.000	0.155976	0.623770	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
** SHORT CIRCUIT	511015	BHALUKPONG1	521011	BALIPARA1	1	1.000	0.155976	0.623770	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
** SHORT CIRCUIT Successfully clean	512001	DEOMAL2	522014	AGBPP2	1	1.000	0.104760	0.418950	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	514001	RANGANADH	524003	BALIPARA4	1	1.000	0.008039	0.052383	0.016802	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	514001	RANGANADH	524003	BALIPARA4	2	1.000	0.027812	0.111631	0.610301	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	514001	RANGANADH	524007	BCHARIAL4	1	1.000	0.027812	0.111631	0.610301	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	514001	RANGANADH	524007	BCHARIAL4	2	1.000	0.034109	0.136904	0.748476	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520001	DIPHU6	520004	BOKAJAN6	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520002	MARIAN6	520003	GOLAGHAT6	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520002	MARIAN6	520003	GOLAGHAT6	2	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520002	MARIAN6	520007	NAZIRA6	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520002	MARIAN6	520007	NAZIRA6	2	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520003	GOLAGHAT6	520004	BOKAJAN6	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520003	GOLAGHAT6	520004	BOKAJAN6	2	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00
	520004	BOKAJAN6	520008	BOYFADHUS	1	1.000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	Not a protected branch	0.00

Progress

Netw... Plot T... Outp...

Bus Plant Machine Load Fixed Shunt Switched Shunt Induction Machine Branch Breaker 2 Winding 3 Winding Impedance table FACTS 2-Term DC VSC DC N-Term DC

Fault Analysis Modeling



Automatic Sequencing Fault Analysis (ASCC)



Fault Options:

- ✓ Fault types: 3Ph, SLG, LLG, L-L, line out, line end.
- ✓ Fault calculations with each branch connected to “faulted” bus in turn removed from service
- ✓ Fault calculations with far end of each branch connected to “faulted” bus in turn opened, and fault applied at line end location

Output Options:

- ✓ Outputs momentary symmetrical RMS fault current and branch current contributions up to N levels away from “faulted” bus
- ✓ Selection of Output File containing summary of calculation for each fault.

Automatic Sequencing Fault Analysis (ASCC)



- **Fault current calculation carried out for:**
 - All system buses
 - All buses of a selected bus subsystem
 - Individually selected buses

Automatic Sequencing Fault Calculation

Set options for pre-fault conditions

☒ Default ☐ Linear power flow ☐ Specified voltage at faulted bus ☐ FLAT Classical Apply

Select faults to apply

☒ Three phase fault ☐ Line Line to Ground (LLG) fault ☐ Line Out (LOUT) fault

☐ Line to Ground (LG) fault ☐ Line to Line (LL) fault ☐ Line End (LEND) fault

☐ Represent DC lines and FACTS devices as load ☒ Apply transformer impedance correction to zero sequence

☐ Set synchronous and asynchronous machine P and Q power outputs to 0

Output option: Fault current summary table

Tap and phase angle: Leave tap ratios and phase shift angles unchanged

Generator reactance: Subtransient

Line charging: Leave unchanged

Shunt: Leave unchanged

Load: Leave unchanged

Pre-fault bus voltage option

☒ From power flow ☐ All buses at specified voltage and 0 deg ☐ Faulted bus at specified voltage and 0 deg Specified voltage: 1.00

0 [1] Number of levels back for contribution output

Fault control input file: ... Edit...

Relay file: ... Edit...

Save results to file: ...

Select

☐ All buses

☐ Selected bus subsystem Select...

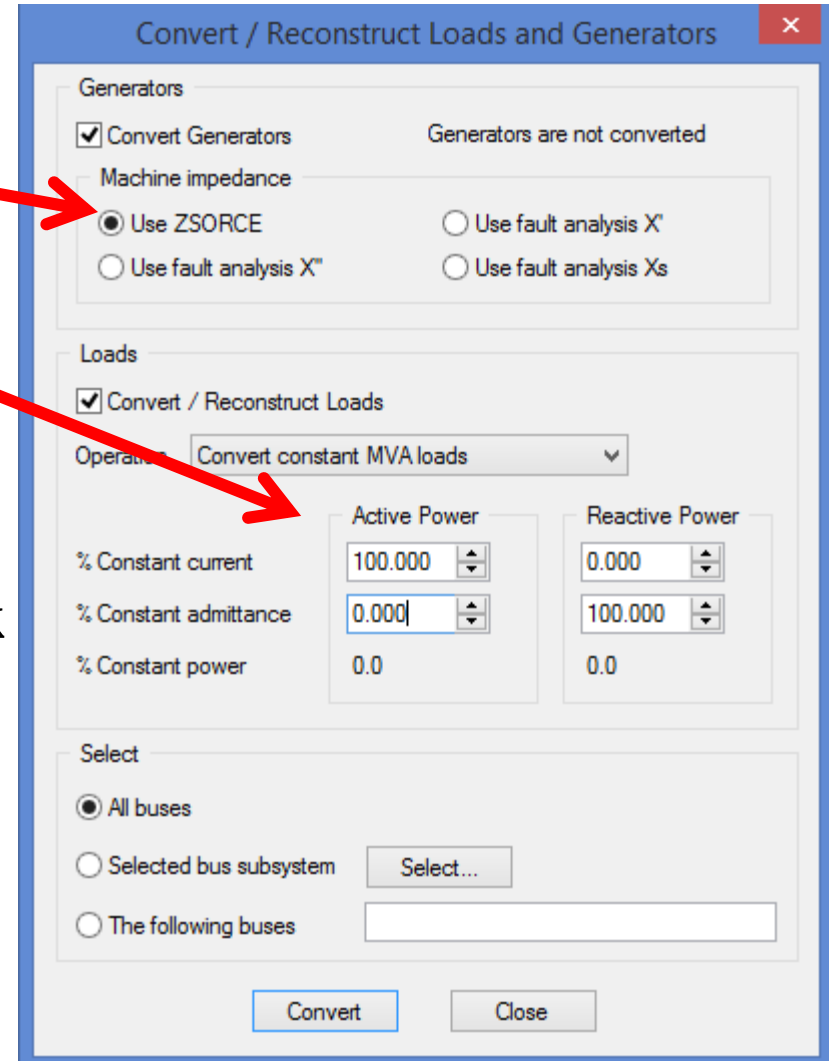
☒ The following buses

Go Close

Balanced Switching Calculation (1)

➤ Steps to follow:

- ✓ Generator Conversion
- ✓ Load Conversion
- ✓ Solve pre-switching network
- ✓ Apply a fault
- ✓ Solve post-switching network
- ✓ View results



Convert / Reconstruct Loads and Generators

Generators

☒ Convert Generators Generators are not converted

Machine impedance

☒ Use ZSORCE ☐ Use fault analysis X'

☐ Use fault analysis X'' ☐ Use fault analysis Xs

Loads

☒ Convert / Reconstruct Loads

Operate Convert constant MVA loads

% Constant current Active Power: 100.000 Reactive Power: 0.000

% Constant admittance 0.000 100.000

% Constant power 0.0 0.0

Select

☒ All buses

☐ Selected bus subsystem Select...

☐ The following buses

Convert **Close**

Balanced Switching Calculation (2)



- ✓ **Generator Conversion**
Convert generators using ZSORCE machine impedance

- ✓ **Load Conversion**
Convert loads using 100% constant current active power and 100% constant admittance reactive power

Convert / Reconstruct Loads and Generators

Generators

☒ Convert Generators Generators are not converted

Machine impedance

☒ Use ZSORCE ☐ Use fault analysis X'

☐ Use fault analysis X'' ☐ Use fault analysis Xs

Loads

☒ Convert / Reconstruct Loads

Operation: Convert constant MVA loads

	Active Power	Reactive Power
% Constant current	100.000	0.000
% Constant admittance	0.000	100.000
% Constant power	0.0	0.0

Select

☒ All buses

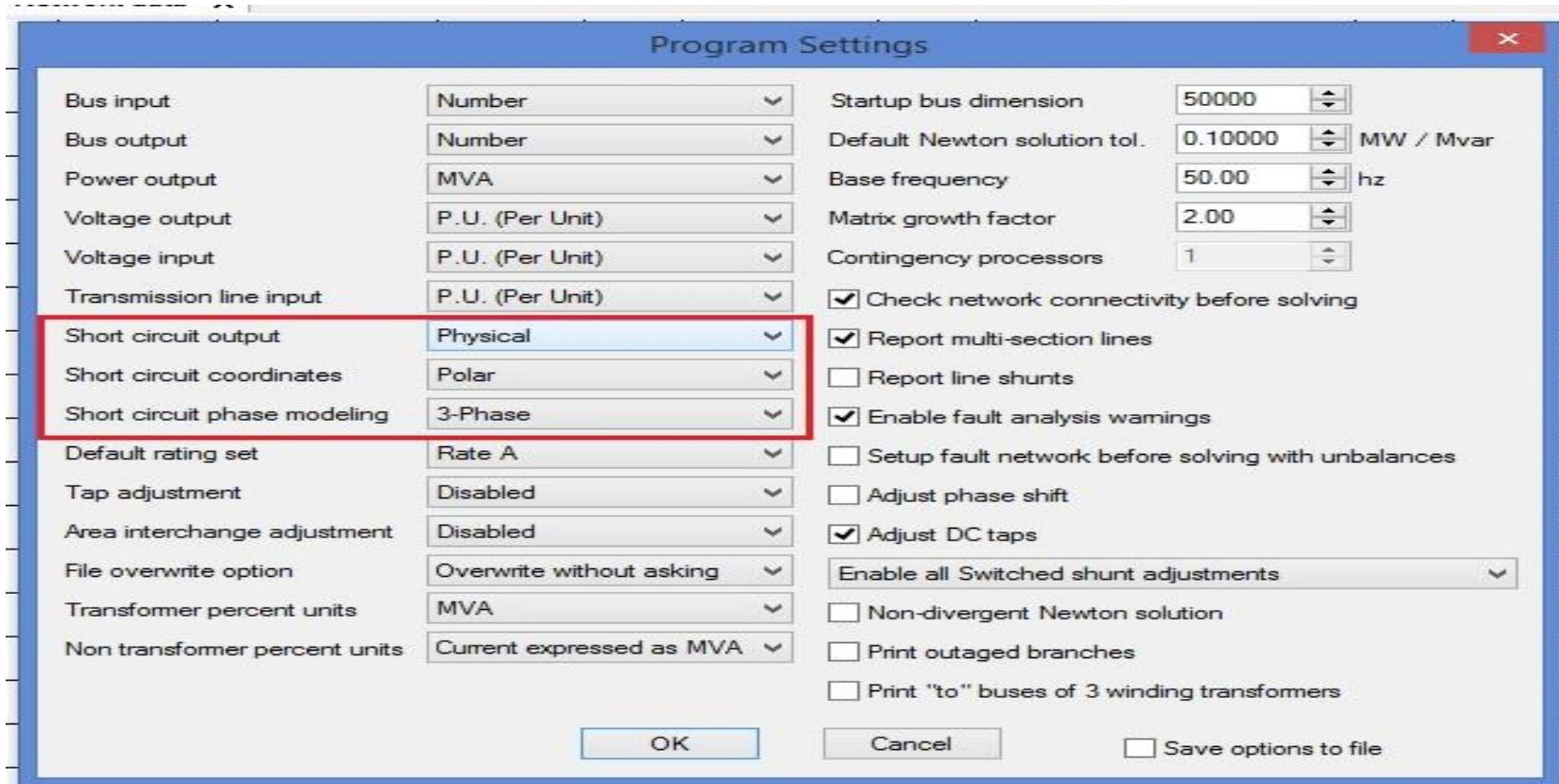
☐ Selected bus subsystem Select...

☐ The following buses

Convert **Close**

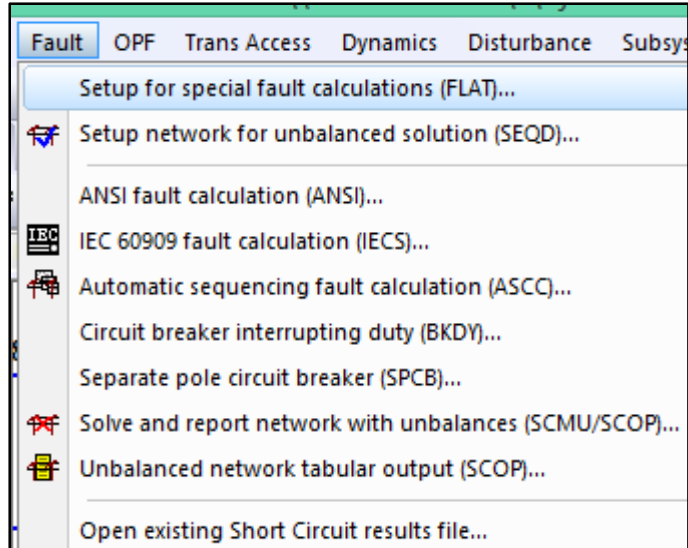
Changes in Program Options

- Go to => Misc > Program Options > Change
 - a) 'Short Circuit Output' to Physical and
 - b) 'Short Circuit Co-ordinates' to Polar

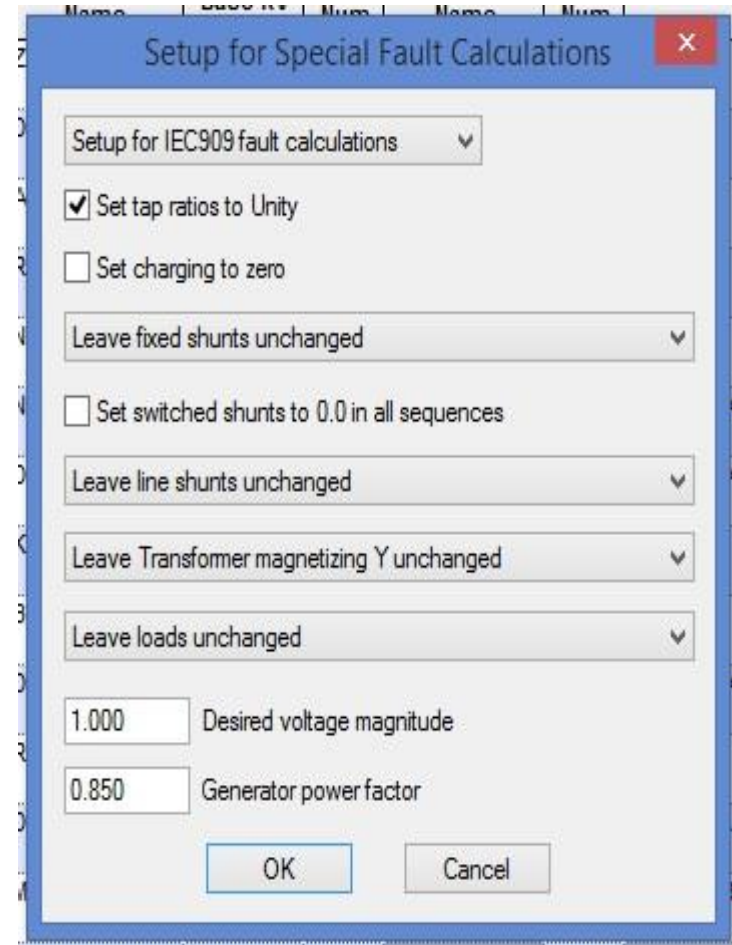


Program Settings	
Bus input	Number
Bus output	Number
Power output	MVA
Voltage output	P.U. (Per Unit)
Voltage input	P.U. (Per Unit)
Transmission line input	P.U. (Per Unit)
Short circuit output	Physical
Short circuit coordinates	Polar
Short circuit phase modeling	3-Phase
Default rating set	Rate A
Tap adjustment	Disabled
Area interchange adjustment	Disabled
File overwrite option	Overwrite without asking
Transformer percent units	MVA
Non transformer percent units	Current expressed as MVA
Startup bus dimension	50000
Default Newton solution tol.	0.10000 MW / Mvar
Base frequency	50.00 hz
Matrix growth factor	2.00
Contingency processors	1
<input checked="" type="checkbox"/> Check network connectivity before solving	
<input checked="" type="checkbox"/> Report multi-section lines	
<input type="checkbox"/> Report line shunts	
<input checked="" type="checkbox"/> Enable fault analysis warnings	
<input type="checkbox"/> Setup fault network before solving with unbalances	
<input type="checkbox"/> Adjust phase shift	
<input checked="" type="checkbox"/> Adjust DC taps	
Enable all Switched shunt adjustments	
<input type="checkbox"/> Non-divergent Newton solution	
<input type="checkbox"/> Print outaged branches	
<input type="checkbox"/> Print "to" buses of 3 winding transformers	
<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="checkbox"/> Save options to file	

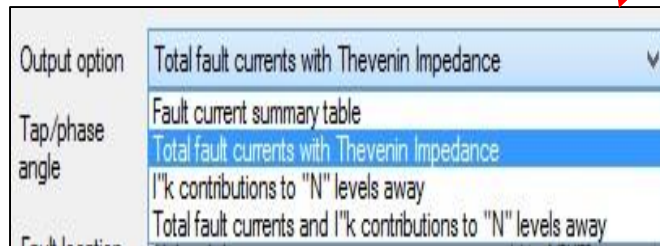
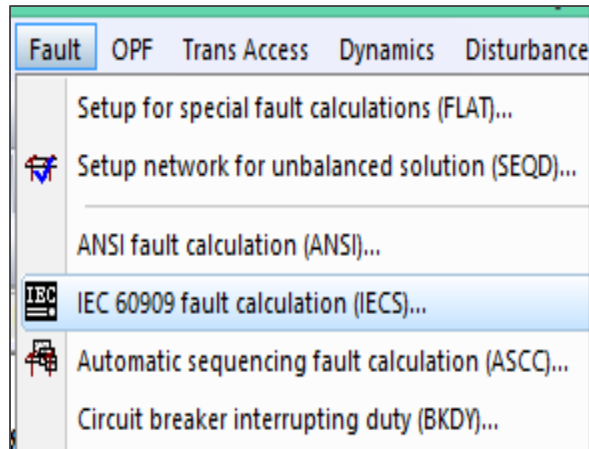
IEC 60909 Fault Calculation (1)



- **Leave voltage magnitude at present value or set all at specified magnitude and set all phase angles at zero.**



IEC 60909 Fault Calculation (2)



- To see the fault contributions from Individual feeders at the Faulted Bus, choose the appropriate option (*Option 3 or Option 4*).

IEC 60909 Fault Calculation

Select faults to apply **Choose any 1 type of fault to apply at one time**

☒ Three phase fault ☐ Line Line to Ground (LLG) fault ☐ Line Out (LOUT) fault

☐ Line to Ground (LG) fault ☒ Line to Line (LL) fault ☐ Line End (LEND) fault

☒ Represent DC lines and FACTS devices as load ☐ Apply transformer impedance correction to zero sequence

Output option: Total fault currents with Thevenin Impedance **Choose type of Output (Summary / Full etc.)**

Tap/phase angle: Leave tap ratios and phase shift angles unchanged

Fault location: Network bus Shunt: Set to 0.0 in the pos. and neg. sequence:

Line charging: Set to 0.0 in the pos. and neg. sequences Generator reactance: Subtransient

Load: Set to 0.0 in the pos. and neg. sequences

0 [1] Number of levels back for contribution output

0.10000 [1 cycle] Breaker contact parting time in seconds

Select voltage factor C

☐ Maximum fault currents ☒ Minimum fault currents ☐ Specified 1.00000

IEC data input file: Edit...

Fault control input file: Edit...

Save results to file: Edit...

Select

☐ All buses

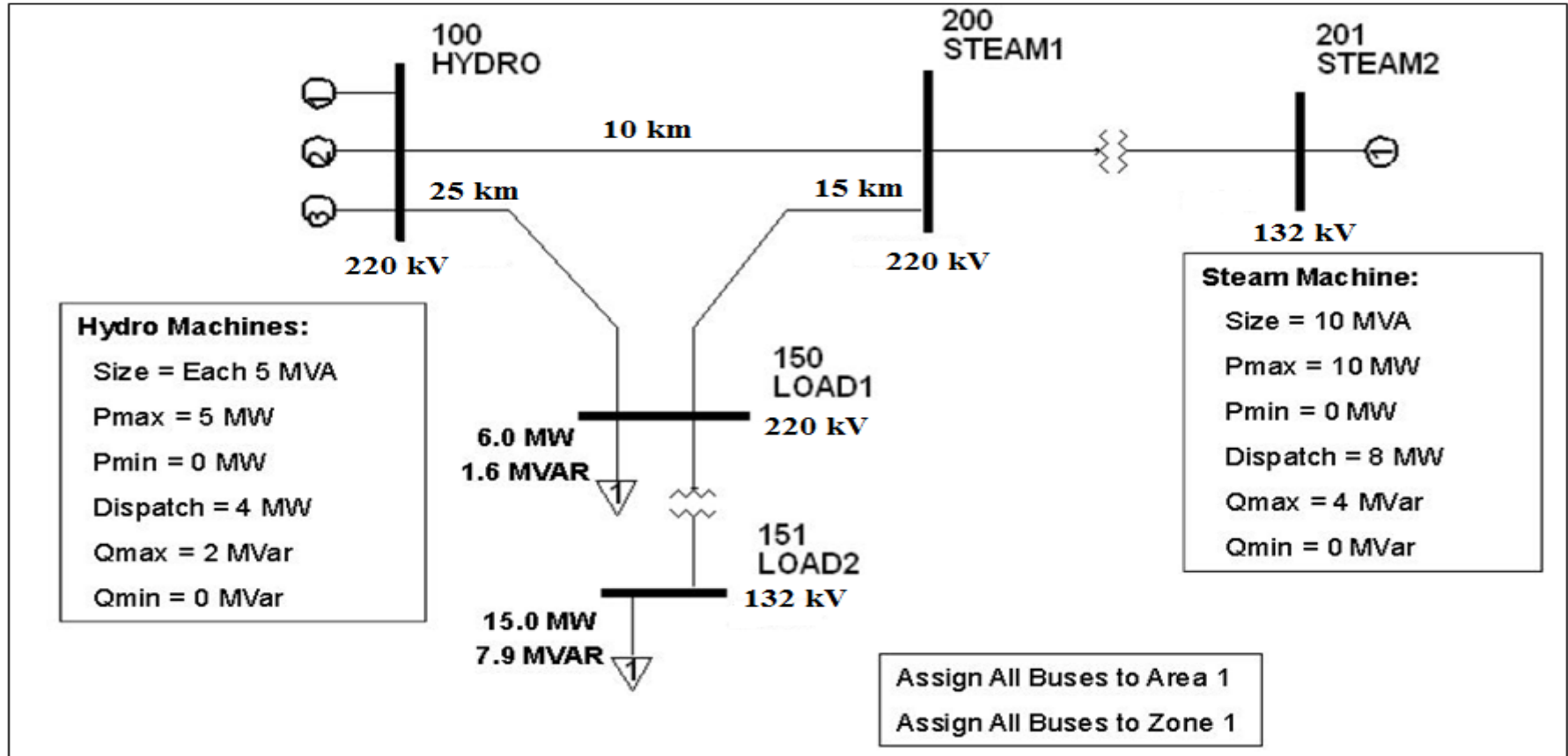
☐ Selected bus subsystem Select...

☒ The following buses

Copy and Paste the bus numbers from the Notepad file of Buses

Defaults Go Close

Exercise



Zero sequence data for Branches:

$R_0 = 0.0004545 \text{ per unit / km / circuit}$

$X_0 = 0.002767 \text{ per unit / km / circuit}$

$B_0 = 0.0008906 \text{ per unit / km / circuit}$

Exercise



1. Calculate the fault level of all bus.



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