Comparison of Load Flow and Short Circuit Calculations between ETAP 5.5.6 and PowerApps for a Sample System

1. INTRODUCTION

We have compared the results obtained from the PowerApps with the results obtained from the ETAP 5.5.6 for the two area sample system taken from the text book **"Power System Stability and Control**" by Prabha Kundur in chapter 12 (McGraw-Hill; Mar 1 1994), page number 813. In this document results comparison for different types of power system studies are given. The two area system is shown in following figure 1

.

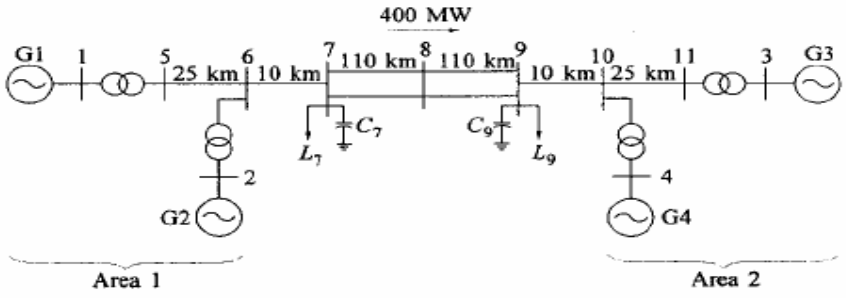

Figure A simple two-area system

The system consists of two similar areas connected by a weak tie. Each area consists of two coupled units, each having a rating of 900 MVA and 20 kV. The generator parameters in per unit on the rated MVA and kV base are as follows:

$X_d = 1.8$	$X_q = 1.7$	$X_l = 0.2$	$X'_d = 0.3$	$X'_q = 0.55$
$X''_d = 0.25$	$X''_q = 0.25$	$R_a = 0.0025$	$T'_{d0} = 8.0$ s	$T'_{q0} = 0.4$ s
$T''_{d0} = 0.03$ s	$T''_{q0} = 0.05$ s	$A_{Sat} = 0.015$	$B_{Sat} = 9.6$	$\psi_{T1} = 0.9$
$H = 6.5$ (for G1 and G2)		$H = 6.175$ (for G3 and G4)		$K_D = 0$

Each step-up transformer has an impedance of $0+j0.15$ per unit on 900 MVA and 20/230 kV base, and has an off-nominal ratio of 1.0.

The transmission system nominal voltage is 230 kV. The line lengths are identified in Figure E12.8. The parameters of the lines in per unit on 100 MVA, 230 kV base are

$r = 0.0001$ pu/km $\quad x_L = 0.001$ pu/km $\quad b_C = 0.00175$ pu/km

The system is operating with area 1 exporting 400 MW to area 2, and the generating units are loaded as follows:

G1:	$P = 700$ MW,	$Q = 185$ MVAr,	$E_t = 1.03\angle 20.2°$
G2:	$P = 700$ MW,	$Q = 235$ MVAr,	$E_t = 1.01\angle 10.5°$
G3:	$P = 719$ MW,	$Q = 176$ MVAr,	$E_t = 1.03\angle -6.8°$
G4:	$P = 700$ MW,	$Q = 202$ MVAr,	$E_t = 1.01\angle -17.0°$

The loads and reactive power supplied (Q_C) by the shunt capacitors at buses 7 and 9 are as follows:

Bus 7:	$P_L = 967$ MW,	$Q_L = 100$ MVAr,	$Q_C = 200$ MVAr
Bus 9:	$P_L = 1{,}767$ MW,	$Q_L = 100$ MVAr,	$Q_C = 350$ MVAr

Figure 1

2. ETAP Complete Load Flow Report

The complete load flow report from ETAP is reproduced in this section. The report consists of system data and load flow result output from ETAP. In the next section the corresponding load flow results between PowerApps and ETAP are compared.

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

ETAP
5.5.6C

Study Case: Load Flow

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Config.: Normal

Electrical Transient Analyzer Program

Load Flow Analysis

Loading Category (1): Design

Generation Category (1): Design

Load Diversity Factor: None

	Swing	V-	Load	Total
Number of Buses:	1	3	7	11

	XFMR	XFMR	Reacto	Line/C	Imped	Tie PD	Total
Number of	4	0	0	8	0	0	12

Method of Solution: Newton-Raphson Method

Maximum No. of Iteration: 99

Precision of Solution: 0.0001000

System Frequency: 50 Hz

Unit System: English

Project Filename: twoareasystem

Output Filename: C:\ETAP 556\twoareasystem\twoareasystem.lfr

Project:
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Contract:
Engineer:
Filename: twoareasystem

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Adjustments

Tolerance	Apply Adjustments	Individual/Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual/Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

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Contract:
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Bus Input Data

Bus			Initial		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub sys	% Mag	An g	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	20.000	1	103.	0.0								
Bus2	20.000	1	101.	0.0								
Bus3	20.000	1	103.	-6.8								
Bus4	20.000	1	101.	0.0								
Bus5	230.000	1	100.	0.0								
Bus6	230.000	1	100.	0.0								
Bus7	230.000	1	100.	0.0	967.00	100.00	0.000	-200.0				
Bus8	230.000	1	100.	0.0								
Bus9	230.000	1	100.	0.0	1767.0	99.999	0.000	-350.0				
Bus10	230.000	1	100.	0.0								
Bus11	230.000	1	100.	0.0								
Total Number of Buses: 11					2734.000	199.999	0.000	-550.000	0.000	0.000	0.000	0.000

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub sys	% Mag	An gl	MW	Mvar	% PF	Max	Min
Bus1	20.	Voltage	1	103.	0.0	700.00			553.	-22.2
Bus2	20.	Voltage	1	101.	0.0	700.00			553.	-22.2
Bus3	20.	Swing	1	103.	-6.8					
Bus4	20.	Voltage	1	101.	0.0	700.00			553.	-22.2
						2100.0	0.000			

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Line/Cable Input Data

Line/Cable			Ohms or Siemens/1000 ft per Conductor (Cable) or per Phase (Line)						
			Length						
ID	Library	Size	Adj. (ft)	% Tol	#/Pha	T /°	R	X	Y
Cable1			82021.0	0.0	1	75	0.016124	0.161239	0.000001
Cable2			32808.4	0.0	1	75	0.016124	0.161239	0.000001
Cable3			360892.	0.0	1	75	0.016124	0.161239	0.000001
Cable5			360892.	0.0	1	75	0.016124	0.161239	0.000001
Cable15			360892.	0.0	1	75	0.016124	0.161239	0.000001
Cable17			360892.	0.0	1	75	0.016124	0.161239	0.000001
Cable19			82021.0	0.0	1	75	0.016124	0.161239	0.000001
Cable21			32808.4	0.0	1	75	0.016124	0.161239	0.000001

Line / Cable resistances are listed at the specified temperatures.

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2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap		Adjust	Phase Shift	
ID	MVA	Prim kV	Sec kV	% Z	X/R	+ 5%	- 5%	% Tol	Prim	Sec	% Z	Type	Angle
T1	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	0.0
T2	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	0.0
T3	900.000	20.000	230.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	0.0
T4	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	0.0

2-Winding Transformer Load Tap Changer (LTC) Settings

Transformer	Connected Buses ("*" LTC Side)		Transformer Load Tap Changer Setting					
ID	Primary Bus ID	Secondary Bus ID	% Tap	% Tap	% Step	Regulated Bus ID	% V	kV

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Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus5	Bus1	0.00	1.67	1.67	
T2	2W XFMR	Bus6	Bus2	0.00	1.67	1.67	
T3	2W XFMR	Bus3	Bus11	0.00	1.67	1.67	
T4	2W XFMR	Bus10	Bus4	0.00	1.67	1.67	
Cable1	Cable	Bus5	Bus6	0.25	2.50	2.51	4.364250
Cable2	Cable	Bus6	Bus7	0.10	1.00	1.00	1.745700
Cable3	Cable	Bus7	Bus8	1.10	11.00	11.05	19.20270
Cable5	Cable	Bus7	Bus8	1.10	11.00	11.05	19.20270
Cable15	Cable	Bus8	Bus9	1.10	11.00	11.05	19.20270
Cable17	Cable	Bus8	Bus9	1.10	11.00	11.05	19.20270
Cable19	Cable	Bus10	Bus11	0.25	2.50	2.51	4.364250
Cable21	Cable	Bus9	Bus10	0.10	1.00	1.00	1.745700

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LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XF -
ID	kV	%	A	MW	Mva	MW	Mva	ID	MW	Mva	Amp	%	% Tap
* Bus1	20.0	103.	20.3	700.0	185.	0	0	Bus5	700.	185.	2029	96.	
* Bus2	20.0	101.	10.5	700.0	234.	0	0	Bus6	700.	234.	2110	94.	
* Bus3	20.0	103.	-6.8	719.1	176.	0	0	Bus11	719.	176.	2074	97.	
* Bus4	20.0	101.	-17.0	700.0	202.	0	0	Bus10	700.	202.	2082	96.	
Bus5	230.	100.	13.8	0	0	0	0	Bus6	699.	102.	1764	98.	
								Bus1	-699.	-102.	1764	98.	
Bus6	230.	97.8	3.7	0	0	0	0	Bus5	-687.	16.6	1765	-100	
								Bus7	138	128.	3576	99.	
								Bus2	-699.	-145.	1834	97.	
Bus7	230.	96.0	-4.7	0	0	967.0	-84.7	Bus6	-136	72.4	3576	-99.	
								Bus8	200.	6.14	523.	100	
								Bus8	200.	6.14	523.	100	
Bus8	230.	94.8	-18.6	0	0	0	0	Bus7	-195.	24.3	521.	-99.	
								Bus7	-195.	24.3	521.	-99.	
								Bus9	195.	-24.3	521.	-99.	
								Bus9	195.	-24.3	521.	-99.	
Bus9	230.	97.1	-32.2	0	0	1767.	-230.	Bus8	-190.	53.6	511.	-96.	
								Bus8	-190.	53.6	511.	-96.	
								Bus10	-138	123.	3595	-99.	
Bus10	230.	98.3	-23.7	0	0	0	0	Bus11	-706.	34.9	1804	-99.	
								Bus9	140	80.4	3595	99.	
								Bus4	-699.	-115.	1810	98.	
Bus11	230.	100.	-13.4	0	0	0	0	Bus10	719.	89.9	1804	99.	
								Bus3	-719.	-89.9	1804	99.	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

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Bus Loading Summary Report

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	%	Amp	Pe Lo adi
Bus1	20.		0	0	0	0	0	0	0	0	724.0	96.	20292.7	
Bus2	20.		0	0	0	0	0	0	0	0	738.2	94.	21101.7	
Bus3	20.		0	0	0	0	0	0	0	0	740.3	97.	20749.3	
Bus4	20.		0	0	0	0	0	0	0	0	728.6	96.	20824.9	
Bus5	230		0	0	0	0	0	0	0	0	707.4	98.	1764.6	
Bus6	230		0	0	0	0	0	0	0	0	1395.	99.	3580.8	
Bus7	230		967.0	100.0	0	-184.7	0	0	0	0	1379.	99.	3604.1	
Bus8	230		0	0	0	0	0	0	0	0	393.7	99.	1042.0	
Bus9	230		1767.	99.99	0	-330.2	0	0	0	0	1797.	98.	4645.5	
Bus10	230		0	0	0	0	0	0	0	0	1410.	99.	3601.3	
Bus11	230		0	0	0	0	0	0	0	0	724.7	99.	1804.3	

* Indicates operating load of a bus exceeds the bus critical limit (100.0% of the Continuous Ampere rating).

# Indicates operating load of a bus exceeds the bus marginal limit (95.0% of the Continuous Ampere rating).

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Branch Loading Summary Report

CKT / Branch		Cable & Reactor			Transformer				
						Loading (input)		Loading (output)	
ID	Type	Ampacity (Amp)	Loading Amp	%	Capability (MVA)	MVA	%	MVA	%
T1	Transfor				900.000	724.047	80.4	707.49	78.6
T2	Transfor				900.000	738.295	82.0	714.98	79.4
T3	Transfor				900.000	740.339	82.3	724.70	80.5
T4	Transfor				900.000	728.610	81.0	709.45	78.8

* Indicates a branch with operating load exceeding the branch capability.

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Branch Losses Summary Report

CKT / Branch	From-To Bus Fl		To-From Bus Fl		Losses		% Bus Volt		Vd %
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vm
T1	700.000	185.052	-699.999	-102.693	0.8	82358.4	103.	100.6	2.36
T2	700.000	234.691	-699.999	-145.634	0.9	89056.6	101.	97.8	3.19
T3	719.101	176.054	-719.100	-89.947	0.9	86106.3	103.	100.8	2.18
T4	700.000	202.168	-699.999	-115.433	0.9	86735.3	101.	98.3	2.66
Cable1	699.999	102.693	-687.634	16.659	12365.1	119352.8	100.	97.8	2.83
Cable2	1387.633	128.975	-1367.331	72.411	20302.7	201385.5	97.8	96.1	1.71
Cable3	200.165	6.145	-195.366	24.341	4799.2	30486.2	96.1	94.9	1.24
Cable5	200.165	6.145	-195.366	24.341	4799.2	30486.2	96.1	94.9	1.24
Cable15	195.366	-24.341	-190.670	53.607	4696.4	29265.9	94.9	97.1	2.28
Cable17	195.366	-24.341	-190.670	53.607	4696.4	29265.9	94.9	97.1	2.28
Cable21	-1385.661	123.011	1406.173	80.450	20512.9	203461.1	97.1	98.3	1.21
Cable19	-706.174	34.983	719.100	89.947	12925.9	124930.1	98.3	100.8	2.48
					85101.1	1112890.2			

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Alert Summary Report

% Alert Settings

	Critical	Marginal
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective	100.0	95.0
Generator	100.0	95.0
Bus		
OverVoltag	105.0	102.0
UnderVolta	95.0	98.0
Generator		
OverExcited (Q	100.0	95.0
UnderExcited (Q	10	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus8	Bus	Under Voltage	230.000	kV	218.168	94.9	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus1	Bus	Over Voltage	20.000	kV	20.600	103.0	3-Phase
Bus3	Bus	Over Voltage	20.000	kV	20.600	103.0	3-Phase
Bus6	Bus	Under Voltage	230.000	kV	224.967	97.8	3-Phase
Bus7	Bus	Under Voltage	230.000	kV	221.028	96.1	3-Phase
Bus9	Bus	Under Voltage	230.000	kV	223.408	97.1	3-Phase
Gen1	Generator	Overload	720.000	MW	700.000	97.2	3-Phase
Gen2	Generator	Overload	720.000	MW	700.000	97.2	3-Phase
Gen3	Generator	Overload	720.000	MW	719.101	99.9	3-Phase
Gen4	Generator	Overload	720.000	MW	700.000	97.2	3-Phase

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SUMMARY OF TOTAL GENERATION , LOADING & DEMAND

	MW	Mvar	MVA	% PF	
Source (Swing Buses):	719.101	176.054	740.339	97.1	Laggin
Source (Non-Swing Buses)	2100.000	621.911	2190.154	95.8	Laggin
Total Demand:	2819.101	797.964	2929.860	96.2	Laggin
Total Motor Load:	2734.000	199.999	2741.305	99.7	Lagging
Total Static Load:	0.000	-514.925	514.925	0.00	Lagging
Total Constant I Load:	0.000	0.000	0.000		
Total Generic Load:	0.000	0.000	0.000		
Apparent Losses:	85.101	1112.890			
System Mismatch:	0.000	0.000			

Number of Iterations: 3

3. COMPARISON OF RESULTS FOR LOAD FLOW CALCULATIONS

The following table gives the comparison of bus voltage and angle obtained from PowerApps and ETAP 5.5.6. for the load flow solution of the two area system considered.

BUSNAME	PowerApps RESULT		ETAP RESULT		% DIFFERENCE	
	%VMAG	ANGLE	%VMAG	ANGLE	VOLTAGE	ANGLE
BUS1	103.000	20.3	103.000	20.3	0.000	0.0
BUS2	101.000	10.5	101.000	10.5	0.000	0.0
BUS3	103.000	-6.8	103.000	-6.8	0.000	0.0
BUS4	101.000	-17.0	101.000	-17.0	0.000	0.0
BUS5	100.646	13.8	100.645	13.8	0.001	0.0
BUS6	97.813	3.7	97.812	3.7	0.001	0.0
BUS7	96.102	-4.7	96.099	-4.7	0.003	0.0
BUS8	94.862	-18.6	94.856	-18.6	0.006	0.0
BUS9	97.137	-32.2	97.134	-32.2	0.003	0.0
BUS10	98.347	-23.7	98.345	-23.7	0.002	0.0
BUS11	100.826	-13.4	100.825	-13.4	0.001	0.0

It is seen that the results from PowerApps and ETAP 5.5.6 compares well for the test case considered.

4. COMPLETE REPORT FOR SHORT CIRCUIT CALCULATIONS FROM ETAP

For the system considered for the comparison, short circuit calculations were performed using ETAP and PowerApps. For the purpose of comparison, all types of shut faults were considered at all the buses. This section reproduces the complete short circuit report from ETAP software. The next section provides a comparison of the results from ETAP and PowerApps.

Project:	ETAP	Page:	1
Location:	5.5.6C	Date:	04-17-2008
Contract:		SN:	IDEA-LTD
Engineer:	Study Case: ShortCircuit	Revision:	Base
Filename: twoareasystem		Config.:	No Load SCA

Electrical Transient Analyzer Program

Short-Circuit Analysis

ANSI Standard
3-Phase, LG, LL, & LLG Fault Currents
1/2 Cycle Network

	Swing	V-Control	Load	Total
Number of Buses:	1	3	7	11

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of	4	0	0	8	0	0	12

	Synchron Generator	Power Grid	Synchrono Motor	Inductio Machin es	Lumpe Load	Total
Number of	4	0	0	0	0	4

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Config.: No Load SCA

Adjustments

Tolerance	Apply Adjustments	Individual/Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual/Global	Degree C
Transmission Line Resistance:	Yes	Global	75
Cable Resistance:	Yes	Global	75

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Bus Input Data

Bus					Initial	
ID	Type	Nom. kV	Base kV	Sub sys	%Ma	An g
Bus1	G	20.000	20.000	1	103.00	0.0
Bus2	G	20.000	20.000	1	101.00	0.0
Bus3	S	20.000	20.000	1	103.00	-6.8
Bus4	G	20.000	20.000	1	101.00	0.0
Bus5	Lo	230.000	230.000	1	100.00	30.
Bus6	Lo	230.000	230.000	1	100.00	30.
Bus7	Lo	230.000	230.000	1	100.00	30.
Bus8	Lo	230.000	230.000	1	100.00	30.
Bus9	Lo	230.000	230.000	1	100.00	30.
Bus10	Lo	230.000	230.000	1	100.00	30.
Bus11	Lo	230.000	230.000	1	100.00	30.

11 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

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Line/Cable Input Data

Line/Cable						Ohms or Siemens per 1000 ft per Conductor (Cable) or per Phase (Line)					
			Length								
ID	Library	Size	Adj. (ft)	% Tol	#/P bas	T (°C)	R1	X1	Y1	R0	X0	Y0
Cable1			82021.0	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable2			32808.4	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable3			360892.	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable5			360892.	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable15			360892.	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable17			360892.	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable19			82021.0	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000
Cable21			32808.4	0.0	1	75	0.016123	0.161239	0.00000	0.016123	0.161239	0.0000

Line / Cable resistances are listed at the specified temperatures.

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2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap		Adjust	Phase Shift	
ID	MVA	Prim kV	Sec kV	% Z	X/R	+ 5%	- 5%	% Tol	Prim	Sec	% Z	Type	Angle
T1	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	-30.0
T2	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	-30.0
T3	900.000	20.000	230.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	30.0
T4	900.000	230.000	20.000	15.00	99999.00	0	0	0	0	0	15.000	Std Pos. Seq.	-30.0

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding							
				Co	Primary				Secondary			
ID	MVA	Prim kV	Sec kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	900.000	230.000	20.000	D/Y					Solid			
T2	900.000	230.000	20.000	D/Y					Solid			
T3	900.000	20.000	230.000	Y/D	Solid							
T4	900.000	230.000	20.000	D/Y					Solid			

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Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus5	Bus1	0.00	1.67	1.67	
T2	2W XFMR	Bus6	Bus2	0.00	1.67	1.67	
T3	2W XFMR	Bus3	Bus11	0.00	1.67	1.67	
T4	2W XFMR	Bus10	Bus4	0.00	1.67	1.67	
Cable1	Cable	Bus5	Bus6	0.25	2.50	2.51	4.364250
Cable2	Cable	Bus6	Bus7	0.10	1.00	1.00	1.745700
Cable3	Cable	Bus7	Bus8	1.10	11.00	11.05	19.20270
Cable5	Cable	Bus7	Bus8	1.10	11.00	11.05	19.20270
Cable15	Cable	Bus8	Bus9	1.10	11.00	11.05	19.20270
Cable17	Cable	Bus8	Bus9	1.10	11.00	11.05	19.20270
Cable19	Cable	Bus10	Bus11	0.25	2.50	2.51	4.364250
Cable21	Cable	Bus9	Bus10	0.10	1.00	1.00	1.745700

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Synchronous Generator Input Data

Synchronous Generator		Rating			Positive Seq. Impedance					Grounding			Zero Seq. Impedance		
							% Xd"								
ID	Type	MVA	kV	R	X"	%	Adj	To	% Xd	Conn	Type	Am	X/R	% R0	% X0
Gen1	Turbo	900.000	20.000	1500	100.	0.250	25.00	0.0	30.00	W	Solid		100.00	0.250	25.00
Gen2	Turbo	900.000	20.000	1500	100.	0.250	25.00	0.0	30.00	W	Solid		100.00	0.250	25.00
Gen3	Turbo	900.000	20.000	1500	100.	0.250	25.00	0.0	30.00	W	Solid		100.00	0.250	25.00
Gen4	Turbo	900.000	20.000	1500	100.	0.250	25.00	0.0	30.00	W	Solid		100.00	0.250	25.00

Total Connected Synchronous Generators (= 4): 3600.000 MVA

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SHORT- CIRCUIT REPORT

Fault at bus: **Bus1**

Prefault voltage = 20.000 kV = 100.00 % of nominal bus kV (20.000 kV)
= 100.00 % of base kV (20.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus1	Total	0.00	141.677	0.00	92.18	91.48	169.254	169.254	3.86E-002	2.04E+000	3.91E-003	1.04E+000
Bus5	Bus1	21.81	37.774	60.41	100.00	59.04	65.341	105.787 *	3.32E-001	7.63E+000	1.67E-005	1.67E+000
Gen1	Bus1	100.00	103.918	100.00	100.00	100.00	103.918	63.469	2.78E-002	2.78E+000	2.78E-002	2.78E+000

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
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Fault at bus: **Bus2**

Prefault voltage = 20.000 kV = 100.00 % of nominal bus kV (20.000 kV)
= 100.00 % of base kV (20.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm.	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus2	Total	0.00	148.385	0.00	92.57	91.86	175.575	175.575	3.70E-002	1.95E+000	3.91E-003	1.04E+000
Bus6	Bus2	25.68	44.481	62.21	100.00	60.80	71.662	109.738 *	2.61E-001	6.48E+000	1.67E-005	1.67E+000
Gen2	Bus2	100.00	103.918	100.00	100.00	100.00	103.918	65.839	2.78E-002	2.78E+000	2.78E-002	2.78E+000

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

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Fault at bus: **Bus3**

Prefault voltage = 20.000 kV = 100.00 % of nominal bus kV (20.000 kV)
= 100.00 % of base kV (20.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus3	Total	0.00	141.677	0.00	92.18	91.48	169.254	169.254	3.86E-002	2.04E+000	3.91E-003	1.04E+000
Bus11	Bus3	21.81	37.774	60.41	100.00	59.04	65.341	105.787 *	3.32E-001	7.63E+000	1.67E-005	1.67E+000
Gen3	Bus3	100.00	103.918	100.00	100.00	100.00	103.918	63.469	2.78E-002	2.78E+000	2.78E-002	2.78E+000

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
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Fault at bus: **Bus4**

Prefault voltage = 20.000 kV = 100.00 % of nominal bus kV (20.000 kV)
= 100.00 % of base kV (20.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus4	Total	0.00	148.385	0.00	92.57	91.86	175.575	175.575	3.70E-002	1.95E+000	3.91E-003	1.04E+000
Bus10	Bus4	25.68	44.481	62.21	100.00	60.80	71.662	109.738 *	2.61E-001	6.48E+000	1.67E-005	1.67E+000
Gen4	Bus4	100.00	103.918	100.00	100.00	100.00	103.918	65.839	2.78E-002	2.78E+000	2.78E-002	2.78E+000

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

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Fault at bus: **Bus5**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus5	Total	0.00	9.844	0.00	173.21	173.21	0.000	0.000	6.96E-002	2.55E+000		
Bus6	Bus5	42.03	4.199	0.00	173.21	173.21	0.000	0.000	3.32E-001	5.97E+000		
Bus1	Bus5	37.50	5.648	100.00	100.00	100.00	0.000	0.000	2.78E-002	4.44E+000		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

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Fault at bus: **Bus6**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm.	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus6	Total	0.00	10.847	0.00	173.21	173.21	0.000	0.000	6.75E-002	2.31E+000		
Bus5	Bus6	36.15	3.612	0.00	173.21	173.21	0.000	0.000	2.78E-001	6.94E+000		
Bus7	Bus6	6.37	1.592	0.00	173.21	173.21	0.000	0.000	1.35E+000	1.57E+001		
Bus2	Bus6	37.50	5.648	100.00	100.00	100.00	0.000	0.000	2.78E-002	4.44E+000		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

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Fault at bus: **Bus7**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus7	Total	0.00	8.458	0.00	173.21	173.21	0.000	0.000	1.48E-001	2.96E+000		
Bus6	Bus7	27.06	6.759	0.00	173.21	173.21	0.000	0.000	1.53E-001	3.71E+000		
Bus8	Bus7	37.44	0.850	0.00	173.21	173.21	0.000	0.000	2.51E+000	2.94E+001		
Bus8	Bus7	37.44	0.850	0.00	173.21	173.21	0.000	0.000	2.51E+000	2.94E+001		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

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Fault at bus: **Bus8**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus8	Total	0.00	5.435	0.00	173.21	173.21	0.000	0.000	3.51E-001	4.61E+000		
Bus7	Bus8	59.84	1.359	0.00	173.21	173.21	0.000	0.000	1.41E+000	1.84E+001		
Bus7	Bus8	59.84	1.359	0.00	173.21	173.21	0.000	0.000	1.41E+000	1.84E+001		
Bus9	Bus8	59.84	1.359	0.00	173.21	173.21	0.000	0.000	1.41E+000	1.84E+001		
Bus9	Bus8	59.84	1.359	0.00	173.21	173.21	0.000	0.000	1.41E+000	1.84E+001		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
Engineer:
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Fault at bus: **Bus9**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus9	Total	0.00	8.458	0.00	173.21	173.21	0.000	0.000	1.48E-001	2.96E+000		
Bus8	Bus9	37.44	0.850	0.00	173.21	173.21	0.000	0.000	2.51E+000	2.94E+001		
Bus8	Bus9	37.44	0.850	0.00	173.21	173.21	0.000	0.000	2.51E+000	2.94E+001		
Bus10	Bus9	27.06	6.759	0.00	173.21	173.21	0.000	0.000	1.53E-001	3.71E+000		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Project:
Location:
Contract:
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Fault at bus: **Bus10**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm.	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus10	Total	0.00	10.847	0.00	173.21	173.21	0.000	0.000	6.75E-002	2.31E+000		
Bus11	Bus10	36.15	3.612	0.00	173.21	173.21	0.000	0.000	2.78E-001	6.94E+000		
Bus9	Bus10	6.37	1.592	0.00	173.21	173.21	0.000	0.000	1.35E+000	1.57E+001		
Bus4	Bus10	37.50	5.648	100.00	100.00	100.00	0.000	0.000	2.78E-002	4.44E+000		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

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Location:
Contract:
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Fault at bus: **Bus11**

Prefault voltage = 230.000 kV = 100.00 % of nominal bus kV (230.000 kV)
= 100.00 % of base kV (230.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Sym rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus11	Total	0.00	9.844	0.00	173.21	173.21	0.000	0.000	6.96E-002	2.55E+000		
Bus10	Bus11	42.03	4.199	0.00	173.21	173.21	0.000	0.000	3.32E-001	5.97E+000		
Bus3	Bus11	37.50	5.648	100.00	100.00	100.00	0.000	0.000	2.78E-002	4.44E+000		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

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Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag	Mag	Real	Imag	Mag	Real	Imag	Mag	Real	Imag	Mag
Bus1	20.00	2.682	-141.651	141.677	2.681	-169.2	169.254	122.674	2.323	122.696	121.490	107.395	162.153
Bus2	20.00	2.825	-148.358	148.385	2.776	-175.5	175.575	128.482	2.446	128.505	127.285	109.921	168.179
Bus3	20.00	2.682	-141.651	141.677	2.681	-169.2	169.254	122.674	2.323	122.696	121.490	107.395	162.153
Bus4	20.00	2.825	-148.358	148.385	2.776	-175.5	175.575	128.482	2.446	128.505	127.285	109.921	168.179
Bus5	230	0.269	-9.841	9.844	0.000	0.000	0.000	8.522	0.233	8.526	8.522	0.233	8.526
Bus6	230	0.316	-10.843	10.847	0.000	0.000	0.000	9.390	0.274	9.394	9.390	0.274	9.394
Bus7	230	0.422	-8.447	8.458	0.000	0.000	0.000	7.316	0.365	7.325	7.316	0.365	7.325
Bus8	230	0.413	-5.419	5.435	0.000	0.000	0.000	4.693	0.358	4.707	4.693	0.358	4.707
Bus9	230	0.422	-8.447	8.458	0.000	0.000	0.000	7.316	0.365	7.325	7.316	0.365	7.325
Bus10	230	0.316	-10.843	10.847	0.000	0.000	0.000	9.390	0.274	9.394	9.390	0.274	9.394
Bus11	230	0.269	-9.841	9.844	0.000	0.000	0.000	8.522	0.233	8.526	8.522	0.233	8.526

All fault currents are symmetrical momentary (1/2 Cycle network) values in rms kA

* LLG fault current is the larger of the two faulted line currents

Project:
Location:
Contract:
Engineer:
Filename: twoareasystem

ETAP
5.5.6C

Study Case: ShortCircuit

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Revision: Base
Config.: No Load SCA

Short-Circuit Summary Report

Bus		Positive Sequence Imp.			Negative Sequence Imp.			Zero Sequence Imp. (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus1	20.000	0.00154	0.08149	0.08150	0.00154	0.08149	0.08150	0.00016	0.04167	0.04167
Bus2	20.000	0.00148	0.07780	0.07782	0.00148	0.07780	0.07782	0.00016	0.04167	0.04167
Bus3	20.000	0.00154	0.08149	0.08150	0.00154	0.08149	0.08150	0.00016	0.04167	0.04167
Bus4	20.000	0.00148	0.07780	0.07782	0.00148	0.07780	0.07782	0.00016	0.04167	0.04167
Bus5	230.000	0.36838	13.48385	13.48888	0.36838	13.4838	13.4888			
Bus6	230.000	0.35689	12.23656	12.24177	0.35689	12.2365	12.2417			
Bus7	230.000	0.78336	15.68061	15.70016	0.78336	15.6806	15.7001			
Bus8	230.000	1.85843	24.36246	24.43324	1.85843	24.3624	24.4332			
Bus9	230.000	0.78336	15.68061	15.70016	0.78336	15.6806	15.7001			
Bus10	230.000	0.35689	12.23656	12.24177	0.35689	12.2365	12.2417			
Bus11	230.000	0.36838	13.48385	13.48888	0.36838	13.4838	13.4888			

5. COMPARISON OF RESULTS FOR SHORT CIRCUIT CALCULATIONS

The following comparison tables give the fault current for different types of faults obtained from PowerApps and ETAP 5.5.

5.1. Single Line to Ground Fault

FAULTEDBUS	FAULT CURRENT IN KA		
	PowerApps	ETAP	DIFFERENCE
BUS1	169.253	169.254	0.001
BUS2	175.574	175.575	0.001
BUS3	169.253	169.254	0.001
BUS4	175.574	175.575	0.001
BUS5	0.000	0.000	0.000
BUS6	0.000	0.000	0.000
BUS7	0.000	0.000	0.000
BUS8	0.000	0.000	0.000
BUS9	0.000	0.000	0.000
BUS10	0.000	0.000	0.000
BUS11	0.000	0.000	0.000

5.2. Line to Line Fault

FAULTEDBUS	FAULT CURRENT IN KA		
	PowerApps	ETAP	DIFFERENCE
BUS1	122.696	122.696	0.000
BUS2	128.505	128.505	0.000
BUS3	122.696	122.696	0.000
BUS4	128.505	128.505	0.000
BUS5	8.526	8.526	0.000
BUS6	9.394	9.394	0.000
BUS7	7.325	7.325	0.000
BUS8	4.707	4.707	0.000
BUS9	7.325	7.325	0.000
BUS10	9.394	9.394	0.000
BUS11	8.526	8.526	0.000

5.3. Double Line to Ground Fault

FAULTEDBUS	FAULT CURRENT IN KA		
	PowerApps	ETAP	DIFFERENCE
BUS1	162.255	162.153	0.101
BUS2	168.273	168.179	0.094
BUS3	162.255	162.153	0.101
BUS4	168.273	168.179	0.094
BUS5	8.526	8.526	0.000
BUS6	9.394	9.394	0.000
BUS7	7.325	7.325	0.000
BUS8	4.707	4.707	0.000
BUS9	7.325	7.325	0.000
BUS10	9.394	9.394	0.000
BUS11	8.526	8.526	0.000

5.4. Three Phase Fault

FAULTEDBUS	FAULT CURRENT IN KA		
	PowerApps	ETAP	DIFFERENCE
BUS1	141.677	141.677	0.000
BUS2	148.385	148.385	0.000
BUS3	141.677	141.677	0.000
BUS4	148.385	148.385	0.000
BUS5	9.844	9.844	0.000
BUS6	10.847	10.847	0.000
BUS7	8.458	8.458	0.000
BUS8	5.435	5.435	0.000
BUS9	8.458	8.458	0.000
BUS10	10.847	10.847	0.000
BUS11	9.844	9.844	0.000

Note: The small and negligible difference in some fault current is possibly due to PowerApps takes zero transformer winding resistance given as per the book input data. But ETAP 5.5.6 takes some X/R ratio for transformer.

In short circuit studies all shunt elements are not considered. (PowerApps has provision for considering all shunt elements, line charging, transformer taps, initial power flow solution, motor contributions, in the short circuit calculations, ETAP treats constant power loads as Motors for short circuit calculations, whereas, in PowerApps motors needs to be modeled explicitly).