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SIMULATION OF POWER FLOW AND FAULT ANALYSIS OF 5-BUS 2-GENERATOR 4-LOAD POWER SYSTEM USING POWER WORLD SIMULATOR

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ABSTRACT:
Renewable energy based distributed generation plays an important role in electricity production. By using two renewable distributed generations todevelop power system. Short circuit problem is one of the most important and complex task in electric power engineering. The study and detection of these faults is necessary to ensure that the power system is reliable and stable. Inthis paper will examine the power flow analysis and behavior of a system under fault conditions and evaluates deferent types of faults of a simple 5-bus 2-generator 4-load power system using the power world simulator.

Keywords: distributed generation, loads, transmission lines,power world simulator

1.INTRODUCTION

During the junior year ,the electrical engineering technology students are required to complete an introductory course in power system analysis and design .Historically , this course was presented without requiring the use of the personal computer .with the power system analysis software , the students was given the capability to model complex power system consisting of generation ,transmission lines ,and rotating/non-rotating loads.the software was capable of performing a load flow analysis of a power system. Also the students could analyze various types of faults for determination of proper circuit breaker selection and bracing of bus work and cabling. With the use of the animated simulation tool , the students obtained good feel of what was happening within the complex power system.

Now a days,it has become a necessity to maintain synchronism because the system is expanding day-by-day and these results in installation of larger machines . The term stability refers to maintaining of synchronism and stability limit refers to maximum power flow possible in the system or a part of system of which system is the property of power system that enables it to remains on a state of equilibrium under normal operating condition an to regain equilibrium after being subjected to disturbances .

2.CREATION OF THE ONE-LINE DAIGRAM OF THE POWER SYSTEM

With this software tool, the students use the provided graphical user interfaces (GUI) to draw the power system being analyzed included in the library are symbols for generator ,buses, circuit breakers, transmission lines , and 3-phase loads the model power system for this paper is depicted in fig1 .the system consists of 5 132kv buses,2generators , 7transmision lines ,20circuit breaker and 4loads .text fields have been provided to allow for displaying actual electrical quantities on the one-line diagram .for example , the per unit(PU) voltages and phase angles (degrees)are provided for each voltage bus. The actual power out puts (real and reactive power)are displayed for each of the generators. The actual power flows (real and reactive power) are provided for all transmission lines. The ratings of the connected load are included on the one-line as well as .by careful creation of the power system one-line diagram using power world simulator , the diagram becomes the actual report for describing the results of the simulation.

Power system one-line diagram

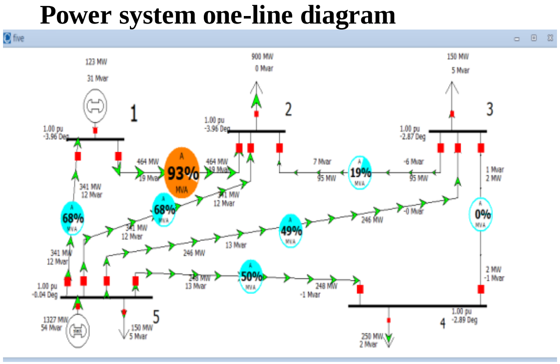


Fig1 one-line diagram of simulated power system

2.LOAD FLOW ANALYSIS

After the one-line diagram of the power system is completed the student invokes the simulation menu and choose the type of load flows (Newton –Raphson ,Gauss-Seidel ,etc)to be performed on the network .the appropriate power flow equation are solved and the voltages (magnitude and angles) are determined for each bus .the resulting power flows are shown as triangles ,green for real power and blue for reactive power .the movement of the triangles along the transmission lines depicts actual direction of real and reactive power flows.the triangles are scaled to show the magnitude of the power flowing on each transmission line.

2.1 power flow analysis absentof generator (G1).

Power system one-line diagram when absent of first generator connected to the bus-1. Animation of power flow when absent of G1 is show in the given fig2.

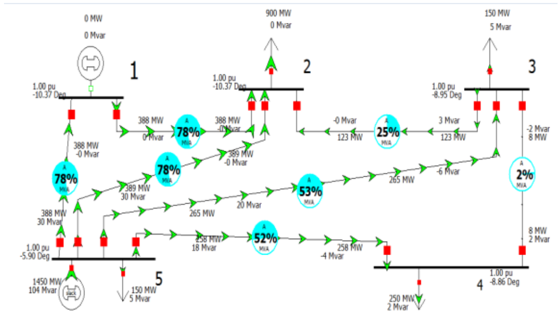


Fig2 simulation results for slag off

2.2 load flow analysis G1-ON, G2-OFF

Generator (G1)connected to the bus-1 is ON and Generator (G2)connected to the bus-5 is OFF. Simulating results are shown in fig 3.

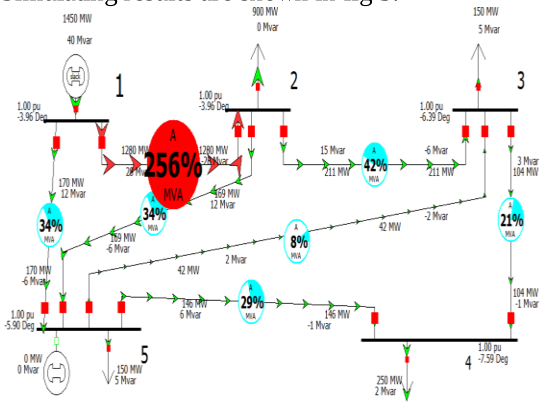


Fig 3 simulation results for G2-OFF

When slack bus generator (G2)is OFF position. the generator (G1) is act as slack bus generator. heavy current flowing through the transmission line 12(T12).

2.3 load flow analysis when absent of transmission line 54(T54)

Transmission line across bus-5 to bus-4 is absent.

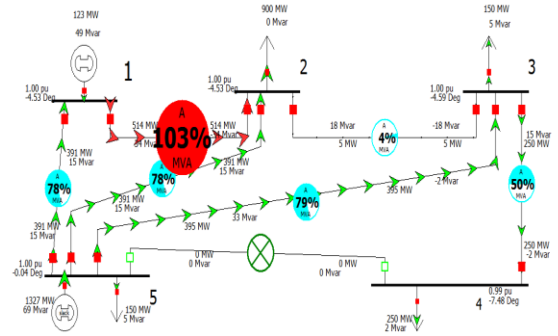


Fig4 simulation results for absent of transmission line T54.

2.4 load flow analysis when absent of transmission line T12

Transmission line across bus-1 to bus-2 is absent.

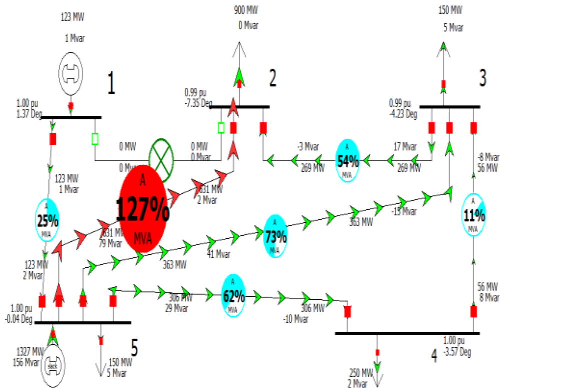


Fig 5 simulation results for absent of transmission line T12.

When transmission line T12 is absent then heavy current flowing through the transmission line T52.

2.5 load flow analysis when absent of load(L1)connected to the bus-2.

Load (L1) is connected to bus-2 is absent.

Simulation results are show in fig 6.

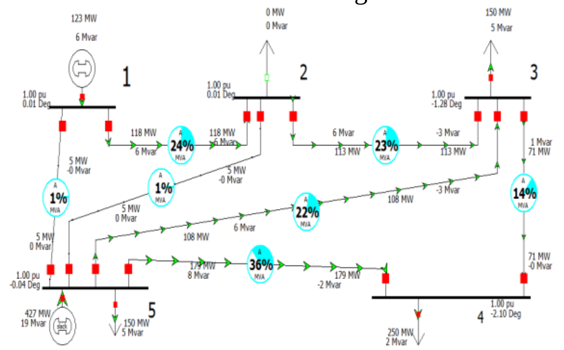


fig 6 simulation results for absent of load L1.

2.6 load flow analysis when absent of load L3.

Load L3 is connected to the bus-4 is absent. Then simulation results are show in fig7.

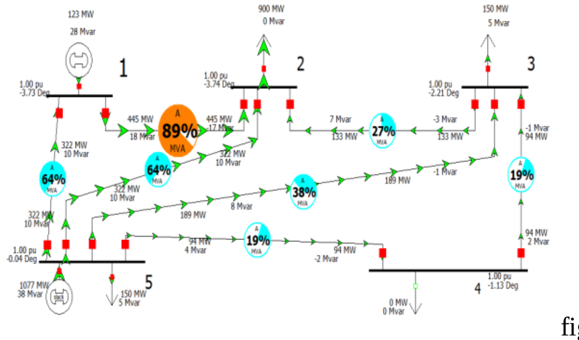


fig7 simulation results for absent of load L3.

2.7 load flow analysis absent of load L4.

Load L4 is connected to the bus-5 is absent then simulation results are show in fig8.

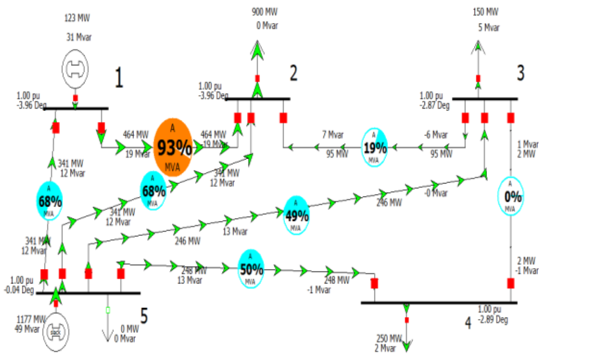


Fig 8 simulation results for absent of load L4.

3.FAULT ANALYSIS

Faults can be defined as the flow of a massive current through an improper path which could cause enormous equipment damage which will lead to interruption of power ,personal injury, or death. The process of evaluating the system voltage and currents under various types of short circuits is called fault analysis Which can determine the necessary safety measures and the required protection system. The analysis of faults leads to appropriate protection settings which can be computed in order to select suitable fuse, circuit breaker size and type of relay.

When a fault exists within the relay protection zone at any transmission line, a single will trip or open the circuit breaker isolating the faulted line. To complete this task successfully, fault analysis has to be conducted in every location assuming several fault conditions. The goal is determine the optimum protection scheme by determine the fault currents and voltages. In reality, power system can consists of thousands of busses which complicate the task of calculating these parameters without the use of computer software.

There are two types of faults which can occur on any transmission line; in addition, unbalanced faults can be classified into single line-to-ground faults, double line faults and double line-to-ground faults.

3.1 No fault occurring on power system

Fig9 show power world simulator underno fault condition.

Firstly no fault occurring on power system then the resulting voltages (magnitude and phase angles) at each bus are regarding in the table given above.

3.2 SLG fault occurring on power system.

The single line-to-ground fault is usually referred as "short circuit" fault and occurs when one conductor falls to ground or makes contact with the neutral wire the general representation of a single line-to-ground fault.

Where F is the fault point with impedance Zf. Phase is usually assumed to be the faulted phase. This is for simplicity in the fault analysis calculations.

Since the zero-, positive-,and negative-, sequences currents are equals.

Therefore,

$$I_{a0} = I_{a1} = I_{a2} = \frac{1.0\angle 0^\circ}{Z_0 + Z_1 + Z_2 + 3Z_f} \quad \text{...1}$$

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad \text{..2}$$

Solving equation the fault current for phase **a** is

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \quad \text{..3}$$

It can also be

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \quad \text{..4}$$

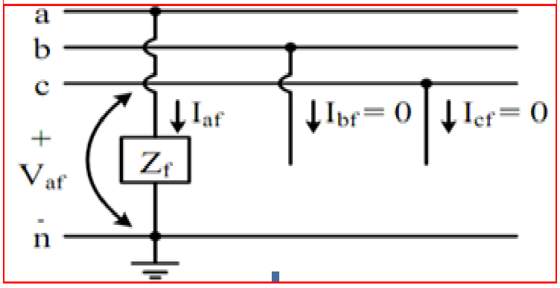


Fig 10 equivalent circuit of SLG fault.

From fig10 it can be observed that,

$$V_{af} = Z_f I_{af} \quad \text{.................................5}$$

The voltage at faulted phase **a** can be obtained by substituting equation2 into equation 5.

Therefore

$$V_{af} = 3Z_f I_{a1} \quad \text{..6}$$

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \quad \text{..................7}$$

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \quad \text{..8}$$

$$V_{af} = Z_f I_{af} \quad \text{..9}$$

$$V_{a0} = -Z_0 I_{a0}$$

$$V_{a1} = 1.0 - Z_1 I_{a1}$$

$$V_{a2} = -Z_2 I_{a2} \quad \text{..10}$$

$$V_{bf} = V_{a0} + a^2 V_{a1} + a V_{a2}$$

$$V_{cf} = V_{a0} + a V_{a1} + a^2 V_{a2} \quad \text{..11}$$

Fig11 shows power world simulator to calculate fault current the type single line to ground.

3.3 line to line fault

F is the fault point with impedances Zf. Phase **b** and **c** are usually assumed to be the faulted phases : this is for simplicity in the fault analysis calculation.

$$I_{af} = 0$$

$$I_{bf} = -I_{cf}$$

$$V_{bc} = Z_f I_{bf} \quad \text{..12}$$

And the sequence current can be obtained as

$$I_{a0} = 0$$

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2 + Z_f} \quad \text{...13}$$

If $Z_f = 0$, ...14

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2}$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0\angle 0^\circ \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad \text{...................................15}$$

The sequence voltages can be found similarly by substituting equation 13 and 14 into equation 14.

$$V_{a0} = 0$$
$$V_{a1} = 1.0 - Z_1 I_{a1}$$
$$V_{a2} = -Z_2 I_{a2} = Z_2 I_{a1} \quad \text{.......................................16}$$

Finally, the line-to-line voltages for line-to-line fault can be expressed as

$$V_{af} = V_{a1} + V_{a2} = 1.0 + I_{a1}(Z_2 - Z_1)$$
$$V_{bf} = a^2 V_{a1} + aV_{a2} = a^2 + I_{a1}(aZ_2 - a^2 Z_1)$$
$$V_{cf} = aV_{a1} + a^2 V_{a2} = a + I_{a1}(a^2 Z_2 - aZ_1) \quad \text{..................17}$$

$$V_{ab} = V_{af} - V_{bf}$$
$$V_{bc} = V_{bf} - V_{cf}$$
$$V_{ca} = V_{cf} - V_{af} \quad \text{...................................18}$$

Fig 12 shows using power world program to calculate current in the type fault line-to-line.

4 Bus view one line diagram

Consider one 138kv bus to design one line diagram.

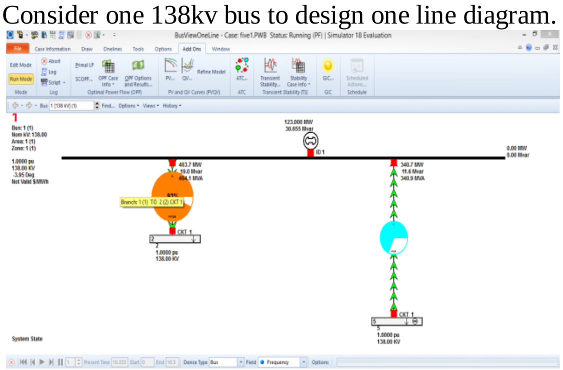
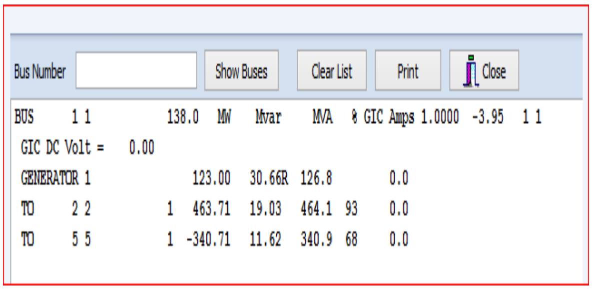


Fig 13 shows bus view one line diagram

4.1 Generator ratings



Bus Number | Show Buses | Clear List | Print | Close

BUS 1 1	138.0	MW	Mvar	MVA	% GIC Amps 1.0000	-3.95	1 1
GIC DC Volt = 0.00							
GENERATOR 1		123.00	30.66R	126.8	0.0		
TO 2 2	1	463.71	19.03	464.1 93	0.0		
TO 5 5	1	-340.71	11.62	340.9 68	0.0		

Fig 14 shows generator rating of power world simulator.

4.2 Generator input output curve

below fig shows the input output curves of generator.

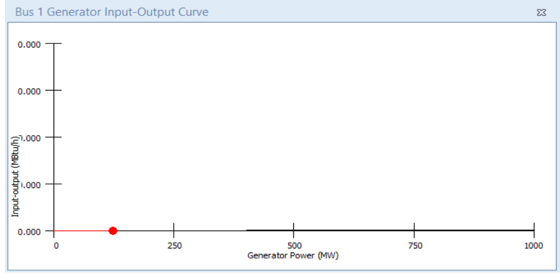


Fig 15 generator fuel cost curve.

4.3 Bus 1 generator fuel- cost curve

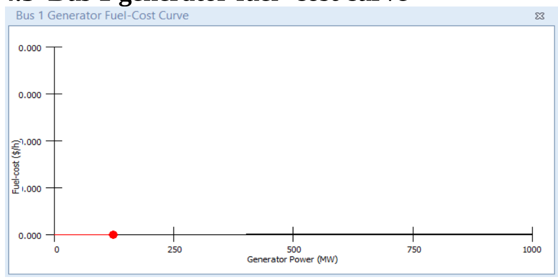


Fig 16 shows bus1 generator fuel- cost curve

4.4 bus1 generator incremental cost curve

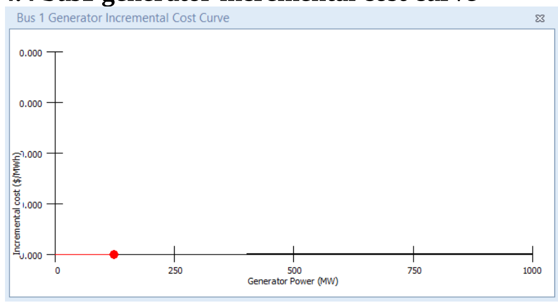


Fig 17 shows bus1 generator incremental cost curve.

4.5 bus1 generator reactive capability curve

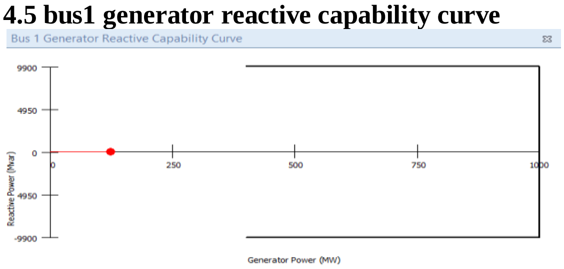
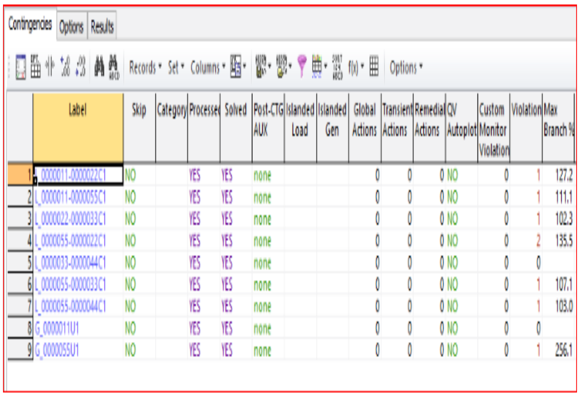


Fig 18 show bus1 generator reactive capability curve.

5 CONTINGENCIES ANALYSIS

Stressed power system, either due to increased loading or due to severe contingencies, it will lead to situation where system no longer remains in the secure operating region.

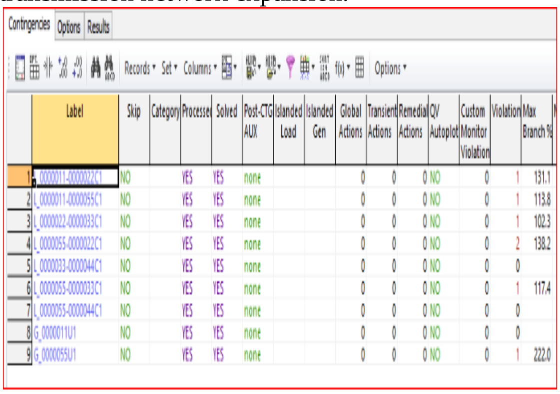


	Label	Skip	Category	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	QV Autoplot	Custom Monitor Violation	Violation	Max Branch %
1	L_0000011-0000022C1	NO		YES	YES	none			0	0	0	NO	0	1	127.2
2	L_0000011-0000055C1	NO		YES	YES	none			0	0	0	NO	0	1	111.1
3	L_0000022-0000033C1	NO		YES	YES	none			0	0	0	NO	0	1	102.3
4	L_0000055-0000022C1	NO		YES	YES	none			0	0	0	NO	0	2	135.5
5	L_0000033-0000044C1	NO		YES	YES	none			0	0	0	NO	0	0	
6	L_0000055-0000033C1	NO		YES	YES	none			0	0	0	NO	0	1	107.1
7	L_0000055-0000044C1	NO		YES	YES	none			0	0	0	NO	0	1	103.0
8	G_0000011U1	NO		YES	YES	none			0	0	0	NO	0	0	
9	G_0000055U1	NO		YES	YES	none			0	0	0	NO	0	1	256.1

Fig 19 contingency analysis results

Stressed power system, either due to increased loading or due to severe contingencies, it will lead to situation where system no longer remains in the secure operating region.

In fact, contingencies results into voltage limit violations and leads to overloading of lines. The system overloading can be recover by two alternatives firstly by restructuring the power system and secondly by controlling the line parameters. The power system restructuring requires expanding unused potentials of transmission system but environmental, right-of-way, and cost problems are major hurdles for power transmission network expansion.



	Label	Skip	Category	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	QV Autoplot	Custom Monitor Violation	Violation	Max Branch %
1	L_0000011-0000022C1	NO		YES	YES	none			0	0	0	NO	0	1	131.1
2	L_0000011-0000055C1	NO		YES	YES	none			0	0	0	NO	0	1	113.8
3	L_0000022-0000033C1	NO		YES	YES	none			0	0	0	NO	0	1	102.3
4	L_0000055-0000022C1	NO		YES	YES	none			0	0	0	NO	0	2	138.2
5	L_0000033-0000044C1	NO		YES	YES	none			0	0	0	NO	0	0	
6	L_0000055-0000033C1	NO		YES	YES	none			0	0	0	NO	0	1	117.4
7	L_0000055-0000044C1	NO		YES	YES	none			0	0	0	NO	0	0	
8	G_0000011U1	NO		YES	YES	none			0	0	0	NO	0	0	
9	G_0000055U1	NO		YES	YES	none			0	0	0	NO	0	1	222.0

Fig 20 contingency analysis simulator result

6. CONCLUSION

In this paper, the author has presented a load flow and short circuit analysis of a simple 5 bus power system using a new software tool power world simulator. The simulator tool greatly enhances the student's ability to visualize power flows and fault current contributions in a power system network. The presented analysis was created using the student version of power world simulator that is limited to 12 buses. The full version is relatively inexpensive and gives the user the capability to model much larger and complex power system networks.

Although no formal data was collected regarding the students responses to this new tool, the courses evaluation were very favorable with the introduction of the simulation tool to the curriculum. At least 75% of the students who registered for the power system1 course enrolled in the follow-up course, power system 2.

7. REFERENCES

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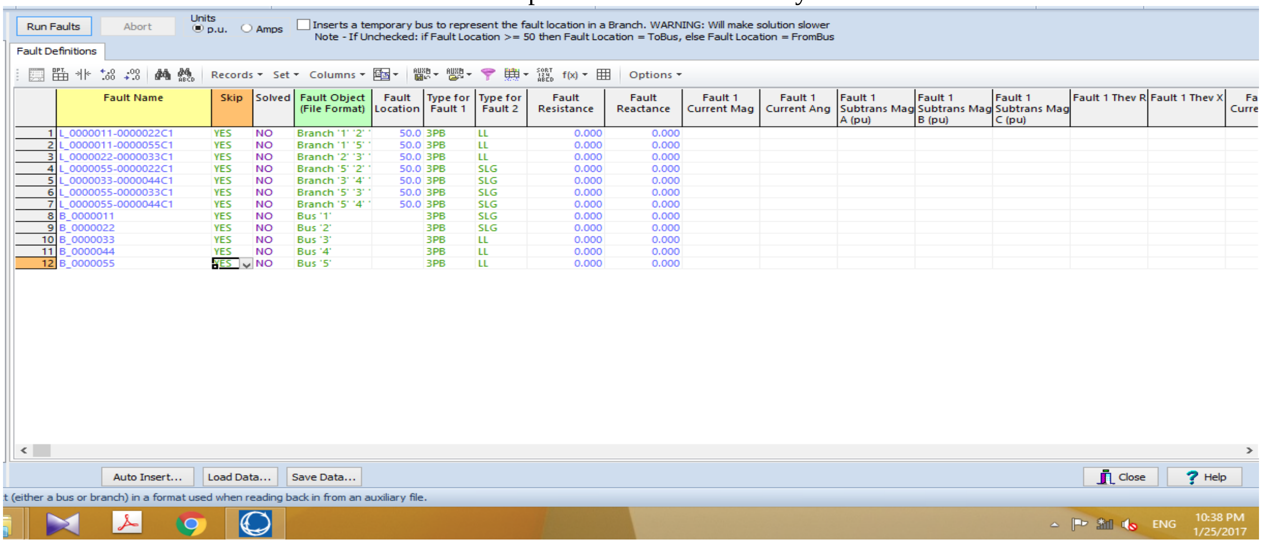
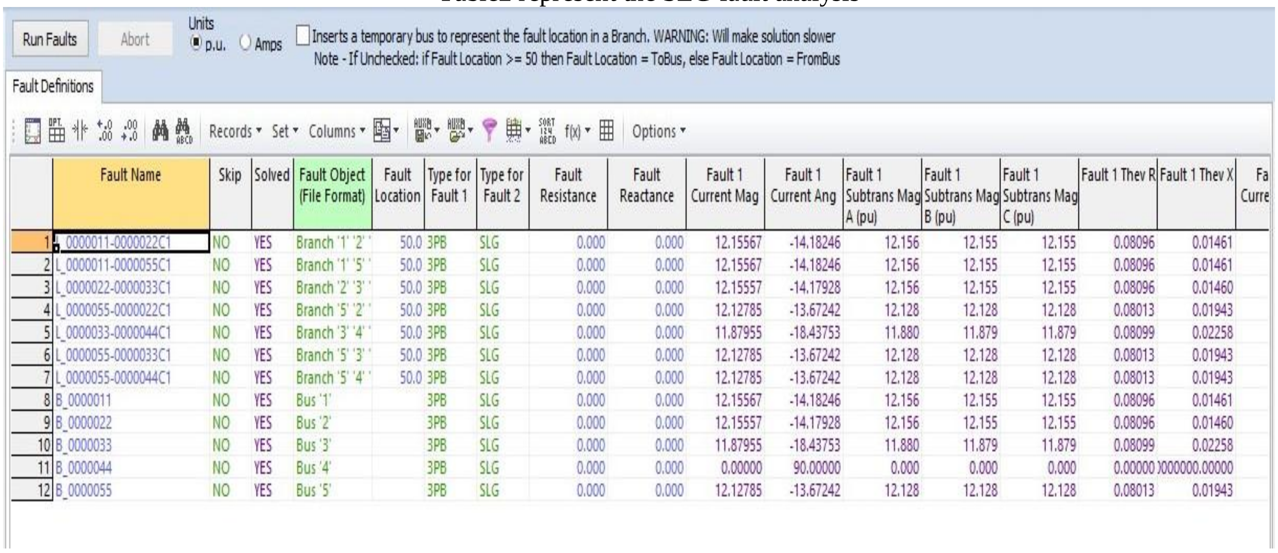
Table 1 represents the no fault analysis



	Fault Name	Skip	Solved	Fault Object (File Format)	Fault Location	Type for Fault 1	Type for Fault 2	Fault Resistance	Fault Reactance
1	L_0000011-0000022C1	YES	NO	Branch '1' '2' '	50.0	3PB	LL	0.000	0.000
2	L_0000011-0000055C1	YES	NO	Branch '1' '5' '	50.0	3PB	LL	0.000	0.000
3	L_0000022-0000033C1	YES	NO	Branch '2' '3' '	50.0	3PB	LL	0.000	0.000
4	L_0000055-0000022C1	YES	NO	Branch '5' '2' '	50.0	3PB	SLG	0.000	0.000
5	L_0000033-0000044C1	YES	NO	Branch '3' '4' '	50.0	3PB	SLG	0.000	0.000
6	L_0000055-0000033C1	YES	NO	Branch '5' '3' '	50.0	3PB	SLG	0.000	0.000
7	L_0000055-0000044C1	YES	NO	Branch '5' '4' '	50.0	3PB	SLG	0.000	0.000
8	B_0000011	YES	NO	Bus '1'		3PB	SLG	0.000	0.000
9	B_0000022	YES	NO	Bus '2'		3PB	SLG	0.000	0.000
10	B_0000033	YES	NO	Bus '3'		3PB	LL	0.000	0.000
11	B_0000044	YES	NO	Bus '4'		3PB	LL	0.000	0.000
12	B_0000055	YES	NO	Bus '5'		3PB	LL	0.000	0.000

Fig 9 show power world simulator to calculate no fault analysis.

Table2 represent the SLG fault analysis



	Fault Name	Skip	Solved	Fault Object (File Format)	Fault Location	Type for Fault 1	Type for Fault 2	Fault Resistance	Fault Reactance	Fault 1 Current Mag	Fault 1 Current Ang	Fault 1 Subtrans Mag A (pu)	Fault 1 Subtrans Mag B (pu)	Fault 1 Subtrans Mag C (pu)	Fault 1 Thev R	Fault 1 Thev X
1	L_0000011-0000022C1	NO	YES	Branch '1' '2' '	50.0	3PB	SLG	0.000	0.000	12.15567	-14.18246	12.156	12.155	12.155	0.08096	0.01461
2	L_0000011-0000055C1	NO	YES	Branch '1' '5' '	50.0	3PB	SLG	0.000	0.000	12.15567	-14.18246	12.156	12.155	12.155	0.08096	0.01461
3	L_0000022-0000033C1	NO	YES	Branch '2' '3' '	50.0	3PB	SLG	0.000	0.000	12.15557	-14.17928	12.156	12.155	12.155	0.08096	0.01460
4	L_0000055-0000022C1	NO	YES	Branch '5' '2' '	50.0	3PB	SLG	0.000	0.000	12.12785	-13.67242	12.128	12.128	12.128	0.08013	0.01943
5	L_0000033-0000044C1	NO	YES	Branch '3' '4' '	50.0	3PB	SLG	0.000	0.000	11.87955	-18.43753	11.880	11.879	11.879	0.08099	0.02258
6	L_0000055-0000033C1	NO	YES	Branch '5' '3' '	50.0	3PB	SLG	0.000	0.000	12.12785	-13.67242	12.128	12.128	12.128	0.08013	0.01943
7	L_0000055-0000044C1	NO	YES	Branch '5' '4' '	50.0	3PB	SLG	0.000	0.000	12.12785	-13.67242	12.128	12.128	12.128	0.08013	0.01943
8	B_0000011	NO	YES	Bus '1'		3PB	SLG	0.000	0.000	12.15567	-14.18246	12.156	12.155	12.155	0.08096	0.01461
9	B_0000022	NO	YES	Bus '2'		3PB	SLG	0.000	0.000	12.15557	-14.17928	12.156	12.155	12.155	0.08096	0.01460
10	B_0000033	NO	YES	Bus '3'		3PB	SLG	0.000	0.000	11.87955	-18.43753	11.880	11.879	11.879	0.08099	0.02258
11	B_0000044	NO	YES	Bus '4'		3PB	SLG	0.000	0.000	0.00000	90.00000	0.000	0.000	0.000	0.00000	0.00000
12	B_0000055	NO	YES	Bus '5'		3PB	SLG	0.000	0.000	12.12785	-13.67242	12.128	12.128	12.128	0.08013	0.01943

Fig 11 show power world simulator to calculate fault current the type SLG

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Table3 represent the Line to Line fault analysis.

Fault Definitions

Records ▾ Set ▾ Columns ▾ Options ▾

	Fault Name	Skip	Solved	Fault Object (File Format)	Fault Location	Type for Fault 1	Type for Fault 2	Fault Resistance	Fault Reactance	Fault 1 Current Mag	Fault 1 Current Ang	Fault 1 Subtrans Mag A (pu)	Fault 1 Subtrans Mag B (pu)	Fault 1 Subtrans Mag C (pu)	Fault 1 Thev R	Fault 1 Thev X
1	L_0000011-0000022C1	NO	YES	Branch '1' '2'	50.0	3PB	LL	0.000	0.000	12.15567	-14.18246	12.156	12.155	12.155	0.06095	0.01461
2	L_0000011-0000055C1	NO	YES	Branch '1' '5'	50.0	3PB	LL	0.000	0.000	12.15567	-14.18246	12.156	12.155	12.155	0.06095	0.01461
3	L_0000022-0000033C1	NO	YES	Branch '2' '3'	50.0	3PB	LL	0.000	0.000	12.15557	-14.17928	12.156	12.155	12.155	0.06095	0.01460
4	L_0000055-0000022C1	NO	YES	Branch '5' '2'	50.0	3PB	SLG	0.000	0.000	12.12785	-13.57242	12.128	12.128	12.128	0.06013	0.01943
5	L_0000033-0000044C1	NO	YES	Branch '3' '4'	50.0	3PB	SLG	0.000	0.000	11.87955	-18.43753	11.880	11.879	11.879	0.06099	0.02258
6	L_0000055-0000033C1	NO	YES	Branch '5' '3'	50.0	3PB	SLG	0.000	0.000	12.12785	-13.57242	12.128	12.128	12.128	0.06013	0.01943
7	L_0000055-0000044C1	NO	YES	Branch '5' '4'	50.0	3PB	SLG	0.000	0.000	12.12785	-13.57242	12.128	12.128	12.128	0.06013	0.01943
8	B_0000011	YES	NO	Bus '1'		3PB	SLG	0.000	0.000							
9	B_0000022	YES	NO	Bus '2'		3PB	SLG	0.000	0.000							
10	B_0000033	NO	YES	Bus '3'		3PB	LL	0.000	0.000	11.87955	-18.43753	11.880	11.879	11.879	0.06099	0.02258
11	B_0000044	NO	YES	Bus '4'		3PB	LL	0.000	0.000	0.00000	90.00000	0.000	0.000	0.000	0.00000	000000.00000
12	B_0000055	NO	YES	Bus '5'		3PB	LL	0.000	0.000	12.12785	-13.57242	12.128	12.128	12.128	0.06013	0.01943

Options ▾

	Fault Name	Fault 1 Thev X	Fault 2 Current Mag	Fault 2 Current Ang	Fault 2 Subtrans Mag A (pu)	Fault 2 Subtrans Mag B (pu)	Fault 2 Subtrans Mag C (pu)	Fault 2 Thev R	Fault 2 Thev X
1	L_0000011-0000022C1	0.01461	10.52712	-104.18246	0.000	10.527	10.527	0.15192	0.02922
2	L_0000011-0000055C1	0.01461	10.52712	-104.18246	0.000	10.527	10.527	0.15192	0.02922
3	L_0000022-0000033C1	0.01460	10.52703	-104.17928	0.000	10.527	10.527	0.15192	0.02921
4	L_0000055-0000022C1	0.01943	5.29162	-73.52303	5.292	0.000	0.000	0.15027	0.54381
5	L_0000033-0000044C1	0.02258	5.05531	-77.00043	5.055	0.000	0.000	0.15198	0.57016
6	L_0000055-0000033C1	0.01943	5.29162	-73.52303	5.292	0.000	0.000	0.15027	0.54381
7	L_0000055-0000044C1	0.01943	5.29162	-73.52303	5.292	0.000	0.000	0.15027	0.54381
8	B_0000011								
9	B_0000022								
10	B_0000033	0.02258	10.28800	-108.43753	0.000	10.288	10.288	0.15198	0.04516
11	B_0000044	000000.00000	0.00000	90.00000	0.000	0.000	0.000	0.00000	000000.00000
12	B_0000055	0.01943	10.50303	-103.57242	0.000	10.503	10.503	0.15027	0.03886

Fig 12 show power world simulator to calculate fault current the type line to line fault and single line to ground fault.

