Title: Contingency Analysis of 16 bus test system using OpenModelica and OpenIPSL

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Abstract: Contingency Analysis refers to the performance of the system when there is any outage of any of the elements in the power system. This project performs N-1 line contingency of one of the line in 16 bus test system. The parameters will be analysed with and without contingency. Simulation will be performed with an outage of line L5-11(Line connected between buses 5 and 11) between 15 to 16 sec using OpenModelica and OpenIPSL.

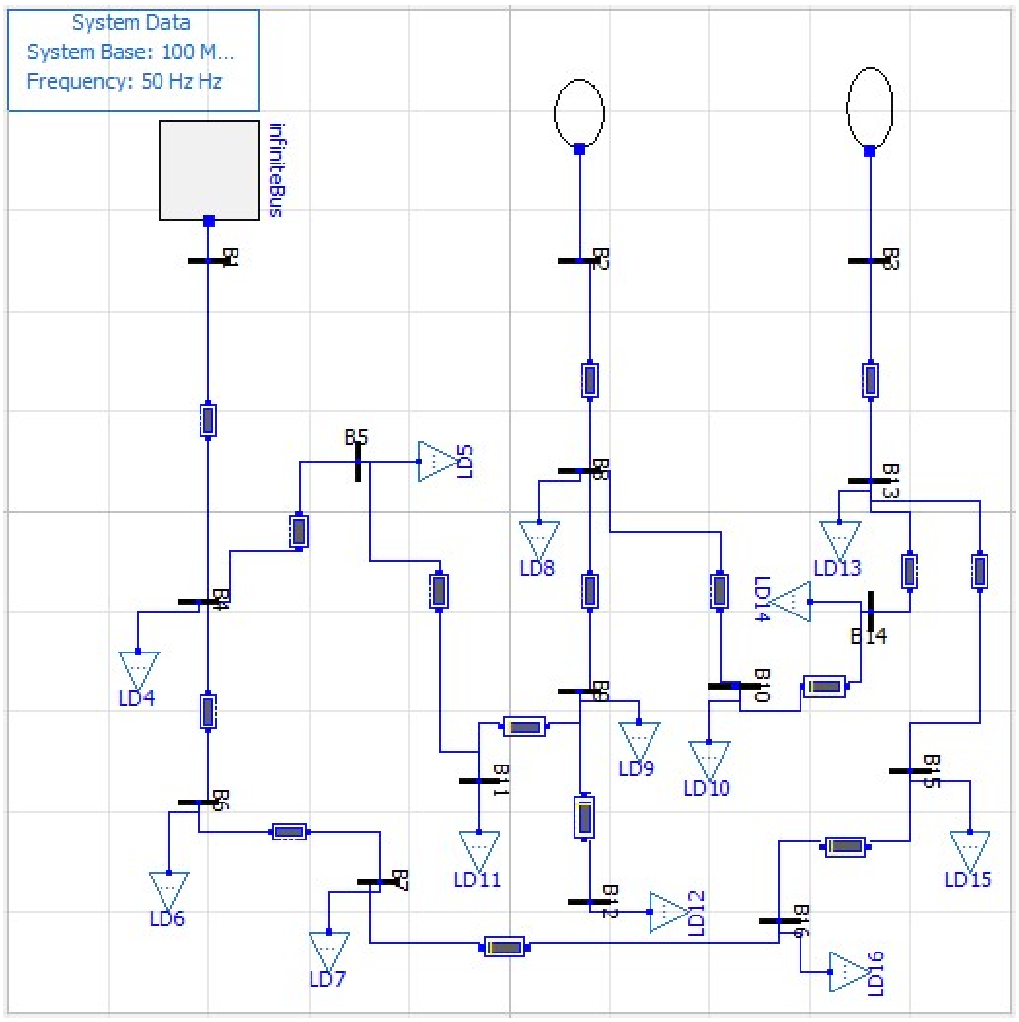

Figure 1: Implementation of IEEE 16 bus test system in OpenModelica and OpenIPSL

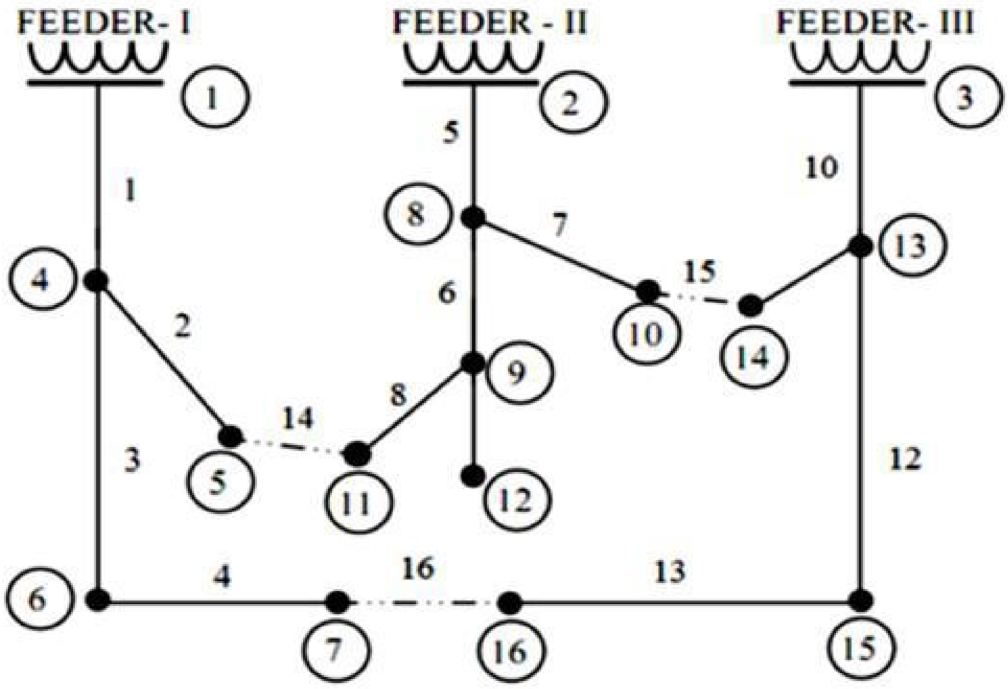

Figure 2: Singe Line Diagram of IEEE 16 bus distribution system

Explanation:

IEEE 16 bus test system is considered for the analysis in this project. The system consists of two generators. Generator 1 is connected at bus2 and generator 2 is connected at bus3 and one infinite bus which supplies power to consumers. There are 16 transmission lines in the system to transfer the power to the consumers. The base value for the system is 100 MVA. The minimum and maximum bus voltage limits are considered as 0.9 pu and 1.05 pu respectively. The base voltage for all the buses is 11 kV.

The model is created in OpenModelica and OpenIPSL. The model uses the following components

Component Name	**Class Path**	**Quantity**
Generator	Open IPSL.Electrical.Machines.PSAT.Order6	2
Infinite Bus	Open IPSL.Electrical.Buses.Infinite Bus	1
Buses	Open IPSL.Electrical.Buses.Bus	16
Constant PQ load	Open IPSL.Electrical.Loads.PSAT.LOADPQ	13
PwLine	Open IPSL.Electrical.Branches.PwLine	16
Sysdata Block	Open IPSL.Electrical.SystemBase	1

Table 1: Components used in system

Power Flow Details without Contingency outage:

The model is implemented in OpenModelica and OpenIPSL is used to study the study the Power flow through thetransmission lines.

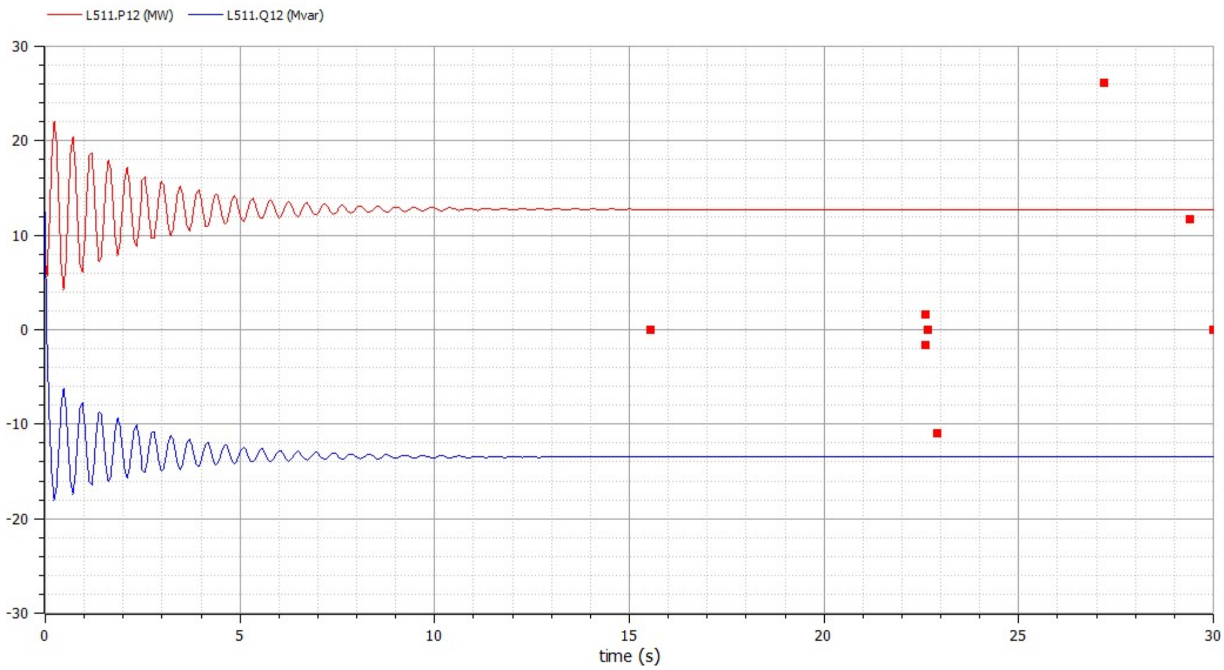

Figure 3: Graphical representation of Real and Reactive Power flow of line L5-11without outage.

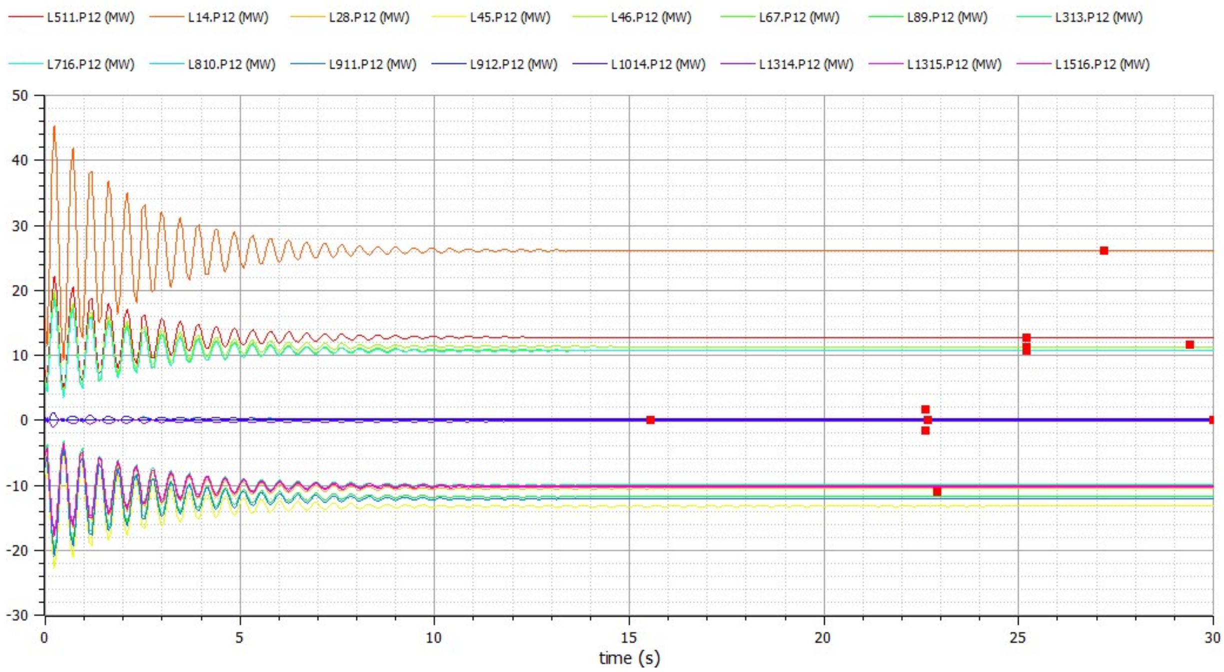

Figure 4: Graphical representation of Real Power flow in other lineswithout outage.

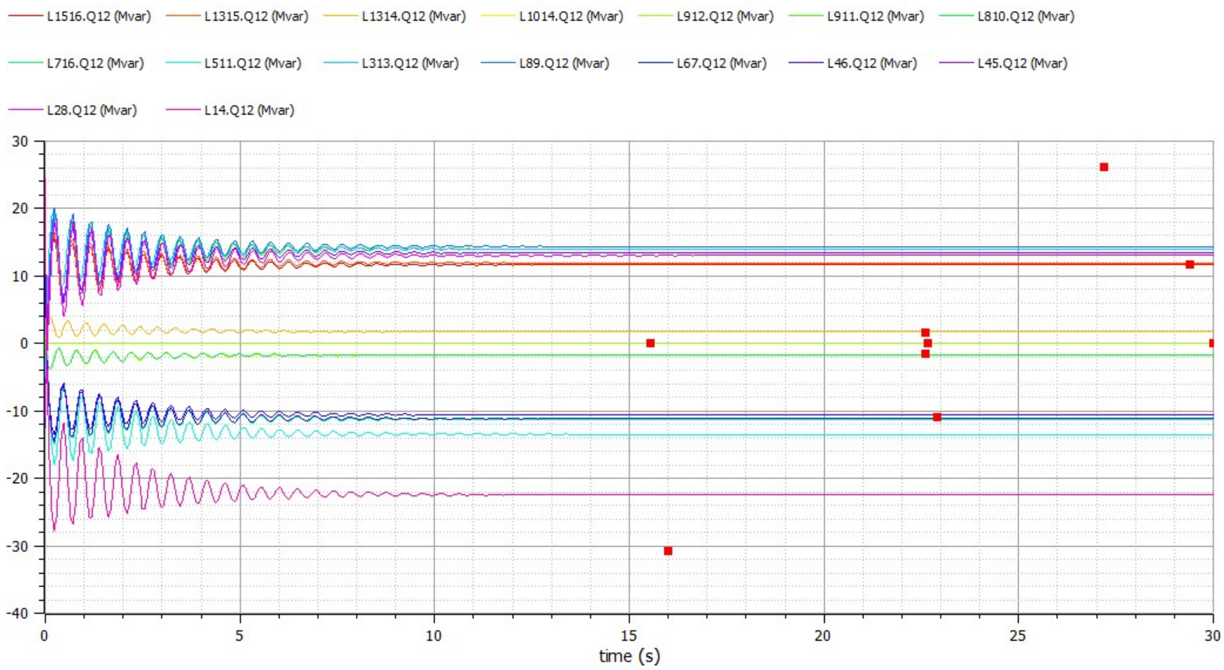

Figure 5: Graphical representation of Reactive Power flow in other lineswithout outage.

Observation:

Sl.No	From Bus	To bus	Real Power (MW) (*Steady state value*)	Reactive Power (MVar) (*Steady state value*)
1	1	4	26.1059	-22.445
2	2	8	-10.532	13.0322
3	4	5	-13.2557	13.4525
4	4	6	11.3372	-10.5912
5	6	7	10.7787	-11.1584
6	8	9	-11.7787	14.3783
7	3	13	-9.97031	13.9897
8	5	11	12.7412	-13.4782
9	7	16	16.6597	-11.2728
10	8	10	0.262677	-1.69038
11	9	11	-12.1324	14.0013
12	9	12	0.0771797	0.60343644
13	10	14	0.242406	-1.70894
14	13	14	-0.221484	1.72559
15	13	15	-10.0758	11.9388
16	15	16	-10.2808	11.6652

Table 2: Real and Reactive Power Flows in transmission lines without outage.

Power Flow Details with Contingencyoutage:

The model is implemented in OpenModelica and OpenIPSL is used to study the study the Power flow at thetransmission line during contingency. The transmission line L5-11 which is connected between buses 5 and 11 is opened at 15 sec and closed at 16 seconds and the results are presented.

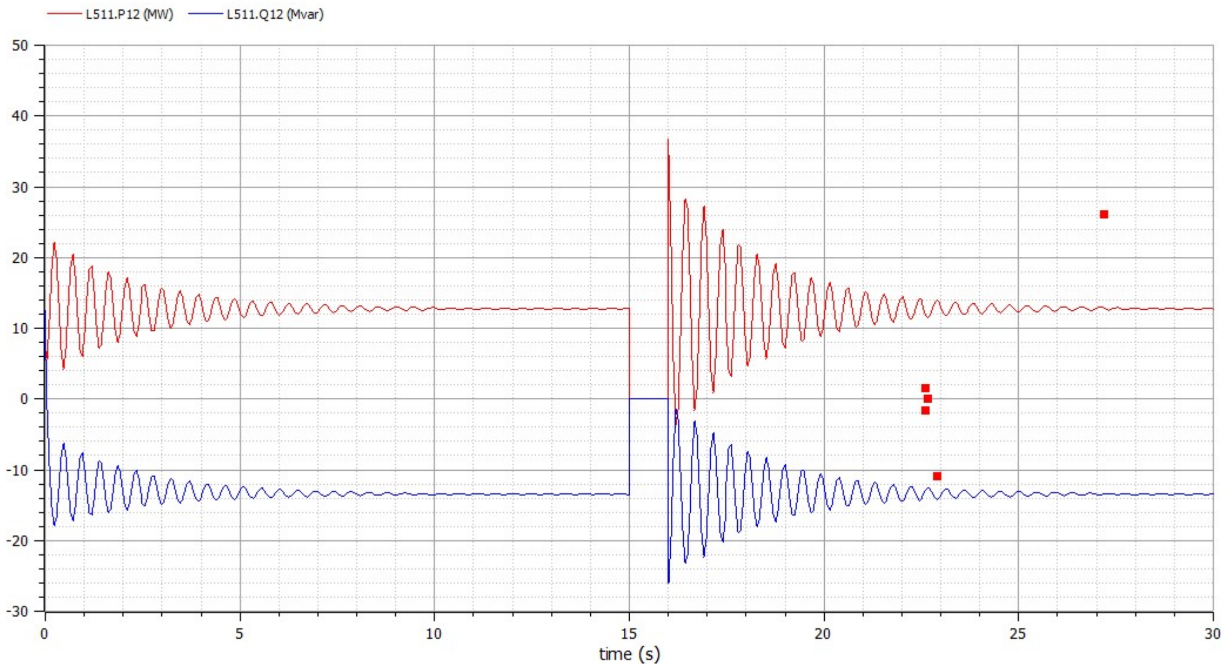

Figure 6: Graphical representation of Real and Reactive Power flow of line L5-11.

The line between bus 5 & bus 11 are opened at 15 sec and closed at 16 sec. During this time,initial power start flowing reaches 24.0461 MW at 0.24 sec then start oscillating till 12.66 sec and reachessteady state value of 12.7545 MW from 12.66-15 sec. The line is opened between 15-16 sec the power flow reacheszero during this period, which is shown in fig.6. The oscillation of power flow is due to switching of the transmission line. It is also observed that, after closing of line at 16 seconds, the power flow oscillates and again reaches the steady state value of 12.7545 MW. During the period of outage of line 5-11, it should also be noted that, the power flow in other lines increases. This is because, the power flow lost in this line will be compensated through other line depending on its transfer capability. This can be noted in figures 7 & 8 and table 3.

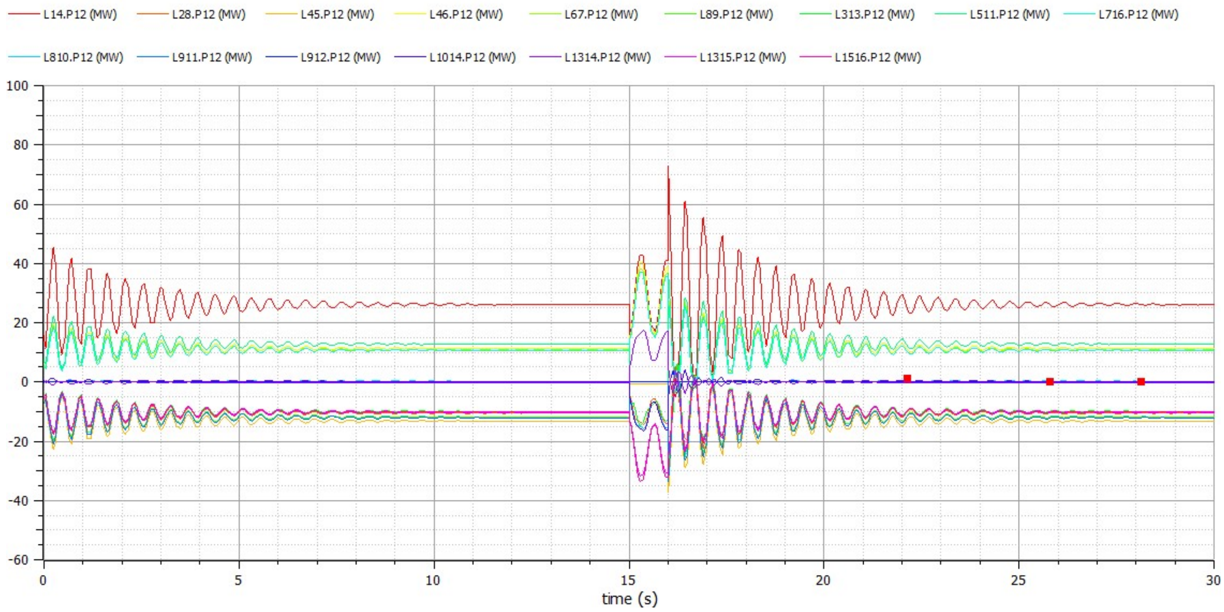

Figure 7: Graphical representation of RealPower flow through the other lines during outage of line L5-11 at 15-16 sec.

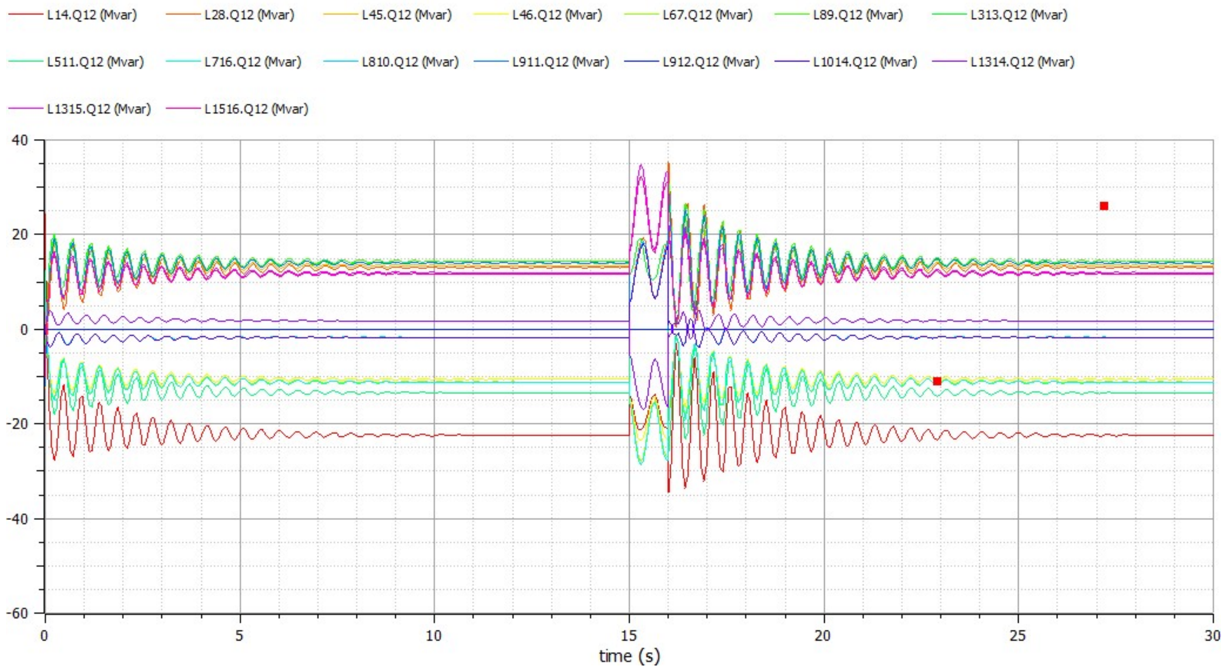

Figure 8: Graphical representation of Reactive Power flow through the other lines during outage of line L5-11 at 15-16 sec.

Sl.No	From Bus	To bus	Real Power (MW)			Reactive Power (MVar)		
			Before	During	After	Before	During	After
1	1	4	26.1059	42.9562	26.1059	-22.445	-14.1871	-22.445
2	2	8	-10.532	-6.26935	-10.532	13.0322	19.3923	13.0322
3	4	5	-13.2557	-0.5145	-13.2557	13.4525	-0.025725	13.4525
4	4	6	11.3372	40.3741	11.3372	-10.5912	-23.6574	-10.5912
5	6	7	10.7787	38.6237	10.7787	-11.1584	-27.8094	-11.1584
6	8	9	-11.7787	0.188694	-11.7787	14.3783	0.0257826	14.3783
7	3	13	-9.97031	-7.05481	-9.97031	13.9897	18.7481	13.9897
8	5	11	12.7412	0	12.7412	-13.4782	0	-13.4782
9	7	16	16.6597	37.1133	16.6597	-11.2728	-28.7147	-11.2728
10	8	10	0.262677	-15.8551	0.262677	-1.69038	18.6948	-1.69038
11	9	11	-12.1324	0.102912	-12.1324	14.0013	0.0171618	14.0013
12	9	12	0.0771797	0.0771797	0.0771797	0.60343644	0.00343646	0.60343644
13	10	14	0.242406	-16.524	0.242406	-1.70894	18.0275	-1.70894
14	13	14	-0.221484	17.3116	-0.221484	1.72559	-17.0673	1.72559
15	13	15	-10.0758	-31.7849	-10.0758	11.9388	34.7185	11.9388
16	15	16	-10.2808	-33.5715	-10.2808	11.6652	32.27	11.6652

Table 3: Steady State values of real and reactive power flows in Lines before, during and after contingency (Outage of Line 5-11 during 15 to 16 sec).

Conclusion:

In this project contingency analysis technique is used to predict the effect of outages caused by line outage in a power transmission system.For outage test, the contingency analysis procedure checks all power flows andviolations in the network against their respective limits. Contingencies may results in severe violations of the operatingconstraints. Consequently, planning for contingencies forms an important aspect of secure operation. The contingencyanalysis was successfully tested on IEEE 16 bus test systems.