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 areanalysed with and without contingency. Simulationis performed with an outage of line L5-11(Line connected between buses 5 and 11) between 15 to 16 sec using OpenModelica and OpenIPSL.

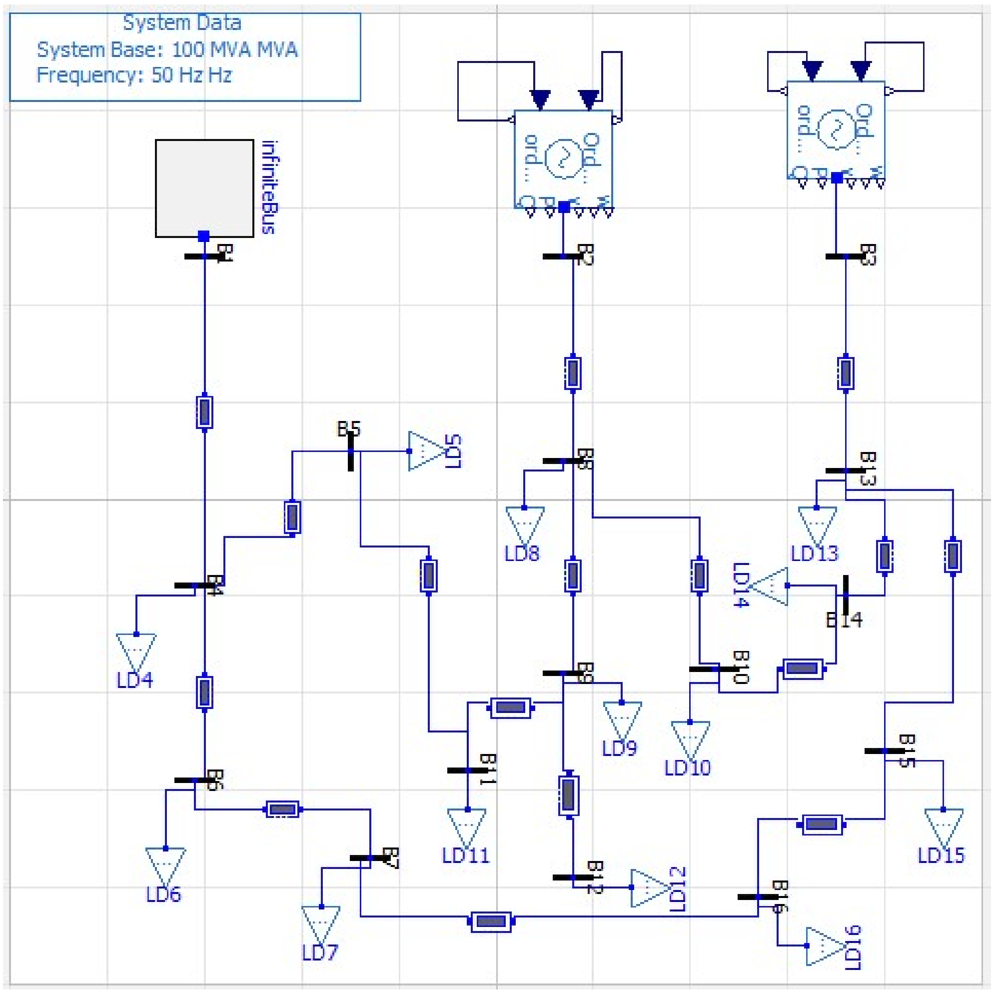

Figure 1: Implementation of IEEE 16 bus test system in OpenModelica and OpenIPSL

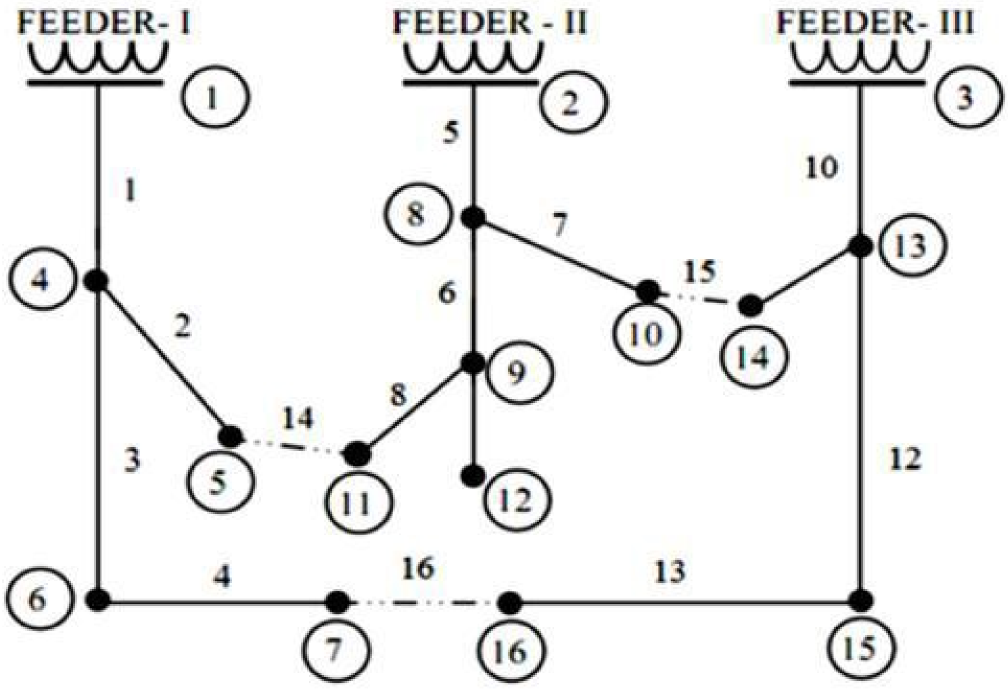

Figure 2: Singe Line Diagram of IEEE 16 bus distribution system

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 0.95pu 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.

Voltage Profile with Contingency outage:

The voltage profile of the system with line contingency (at line 5-11) is presented in figure 3. It is observed that all load buses except bus 4, 5&6 suffers little dip in voltage whereas in buses4, 5&6, little voltage swell is observed during contingency period. This is because, since line 5-11 is opened, the loading at bus 5 reduces. Buses 4 and 6 which are closer to bus 5 also experiences little voltage swell during this period. After contingency, oscillation occurs at all buses and after certain time period the voltages reach the steady state value.

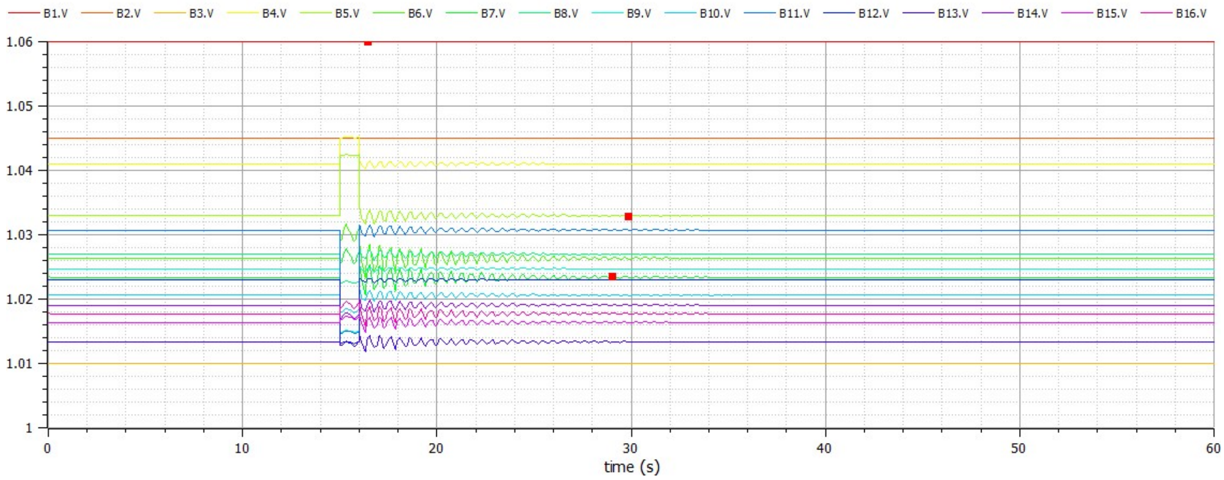

Figure 3: Graphical representation of Bus voltage .

Bus no.	Initial Bus Voltage magnitude (p.u.)
1	1.06
2	1.045
3	1.01
4	1.041
5	1.03295
6	1.02632
7	1.02336
8	1.02696
9	1.02471
10	1.0206
11	1.03072
12	1.023
13	1.01333
14	1.01906
15	1.01637
16	1.01772

Table 2: Initial Bus Voltage magnitudes for all the buses in pu.

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.

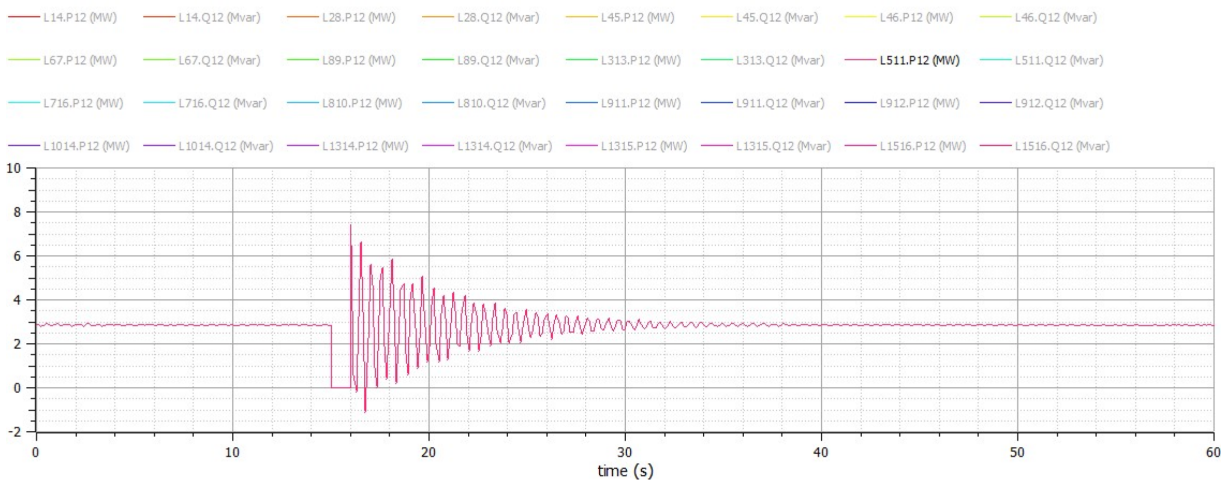

Figure 4: Graphical representation of Real Power flow of line L5-11.

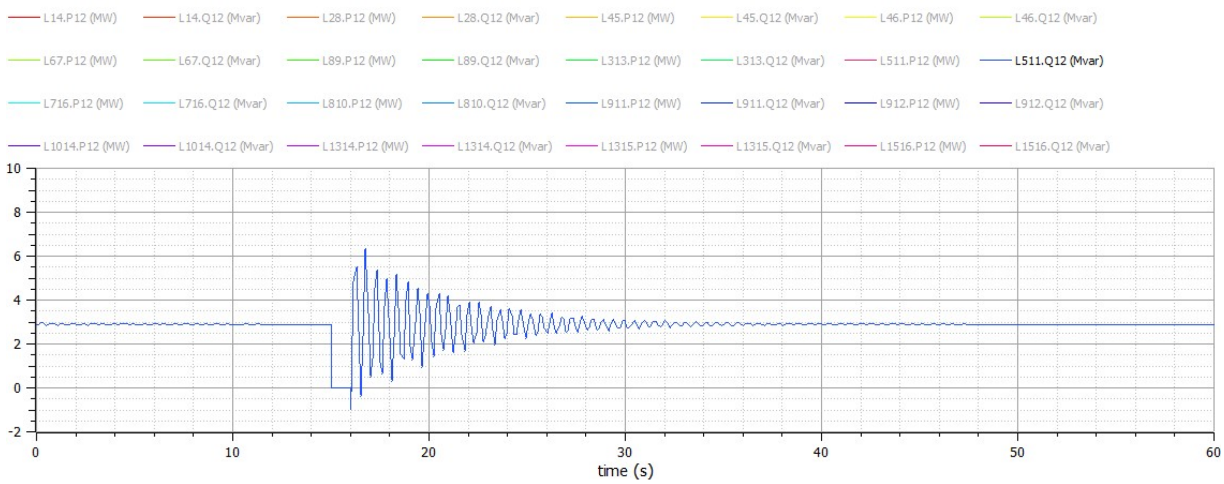

Figure 5: Graphical representation of Reactive Power flow of line L5-11.

The line between bus 5 & bus 11 are opened at 15 sec and closed at 16 sec. During this time the power flow in line 5-11 becomes 0 and starts flowing with oscillation which is shown in fig:4&5. The oscillation of power flow is due to switching of the transmission line. During the period of outage of line 5-11, it is also being noted that, the power flows in other lines increase. 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 6& 7 and table 3.

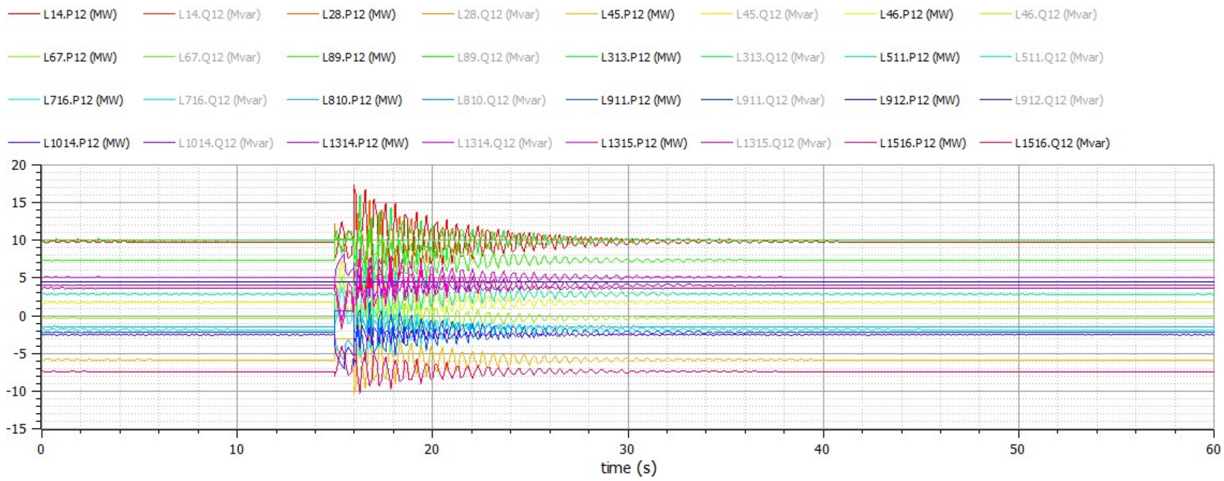

Figure 6: Graphical representation of RealPower flow through the other lines during outage of line L5-11 at 15-16 sec.

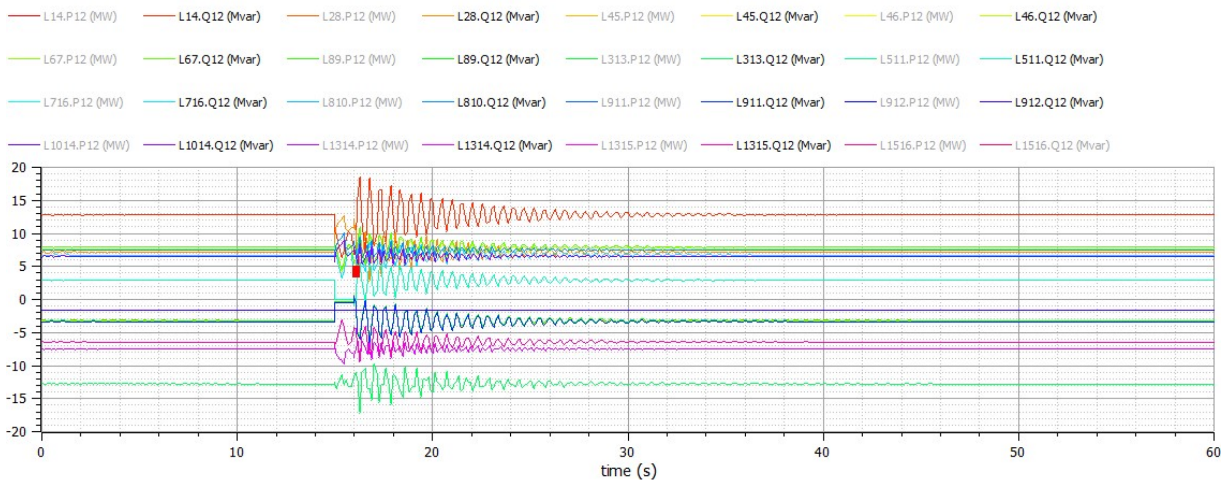

Figure 7: Graphical representation of ReactivePower flow through the other lines during outage of line L5-11 at 15-16 sec.

Tabulation:

Sl.No	From Bus	To bus	Real Power (MW)			Reactive Power (MVar)		
			Before	During	After	Before	During	After
1	1	4	9.7835	12.4538	9.7835	12.8058	6.70686	12.8058
2	2	8	10	12.1821	10	7.14002	12.6785	7.14002
3	4	5	-5.85284	-3	-5.85284	-3.29587	-0.4	-3.29587
4	4	6	1.7235	6.92422	1.7235	7.63227	4.22866	7.63227
5	6	7	-0.327347	4.86072	-0.327347	7.93058	4.511	7.93058
6	8	9	7.33668	10.1983	7.33668	-3.18153	-0.265122	-3.18153
7	3	13	9.99981	11.2692	9.99981	-12.7763	-11.342	-12.7763

8	5	11	2.85284	0	2.85284	2.89587	0	2.89587
9	7	16	-1.85127	3.34312	-1.85127	6.70665	3.29296	6.70665
10	8	10	-1.48876	-5.89148	-1.48876	7.466946	10.026	7.466946
11	9	11	-2.22952	0.600651	-2.22952	-3.37255	-0.499348	-3.37255
12	9	12	4.51769	4.51809	4.51769	-1.67568	-1.6752	-1.67568
13	10	14	-2.54929	-7.03334	-2.54929	6.50896	8.96627	6.50896
14	13	14	3.62899	8.29895	3.62899	-7.50891	-9.82422	-7.50891
15	13	15	5.08697	-0.595686	5.08697	-6.45124	-3.14642	-6.45124
16	15	16	4.03438	-1.20779	4.03438	-7.42355	-4.05741	-7.42355

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 is performed 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 system.