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Generator Outage Contingency Analysis of an Interconnected Power System based on Time Domain Dynamic Simulation

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Abstract

Due to the continuous expansion of power systems and its inter-connection the stability of the power systems has become a major problem for its successful operation. Contingency which falls under the category of power systems security is one of the widely used methods for the detection of network problems as suggested by Wood and Wollenberg. The paper 14 bus system where a generator outage contingency i.e., of a generator going out of service affects the remaining power system to operate and supply the necessary load demand. The entire simulation is done in time domain using PSAT in MATLAB. BX Fast Decoupled method of analysis is used for power flow computation and trapezoidal integration method is used in the time domain dynamic simulation. Newton Rapson method is used for power flow computation.

Keywords: Time domain dynamic simulation, PSAT, stability, instability, generator contingency.

Introduction

The priorities for operation of modern power systems have evolved to the two basic scenarios modern power systems have evolved to the two basic scenarios. First being “Operate the system in such a way that power is delivered reliably”. Second to be” Within the constraints placed on the system operation by reliability considerations, the system will be operated most economically". It is highly uneconomical if not possible to build a power system with so much redundancy (i.e., extra transmission lines, reserve generation etc) that failures never cause lead to be dropped on a system. Rather systems are designed so that the probability of dropping load is acceptably small.

With in the design and economic limitations, it is the job of the operators to try to maximize the reliability of the system they have at any given time.

Contingency analysis [1, 2] which is one category in power system voltage stability [2, 5] falls under the category of power system security [8]. Basically there are two kinds of security threats or failure events that could occur in a power system namely transmission-line outages and generation -unit failures. In this paper we concentrate our focus on generation units going out of service and how an interconnected power system is able to cater the required load demands. This deals with generator contingency.

This analysis is carried out on an IEEE 14-bus system in MATLAB7.1 using PSAT toolbox [4]. The simulation is performed on Intel core 2 duo processor with 2.13GHz clock speed.

Operations personnel must know which line or generation outages will cause flows or voltages to fall outside limits. To predict the effects of outages, contingency analysis techniques [1] are used. In this paper we are modelling single failure events.

Problem Definition

In this paper we are analysing a 14 bus interconnected network where a contingency analysis is carried out on generators 1 and 2 connected to buses 1 and 2 separately and results of analysis are tabulated.

The line diagram of the 14 bus network used in this paper is shown in figure 1. Figure 2 shows a network where generator 1 goes out of order which is connected to bus 1. Figure 3 shows the scenario of generator 2 going out of operation which is connected to bus 2.

The voltages at the corresponding buses where we see drastic change (may be rise in voltage or fall in voltage) are noted down.

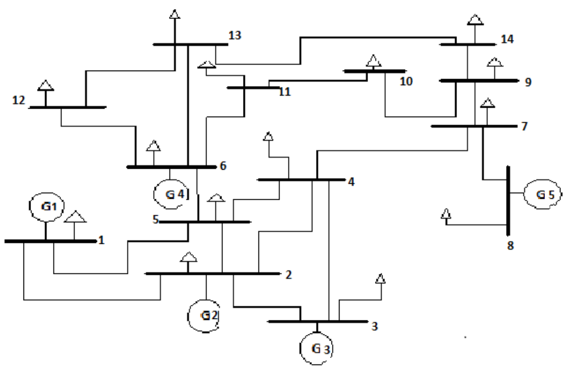

Figure 1: Line Diagram of 5-machine 14-bus model.

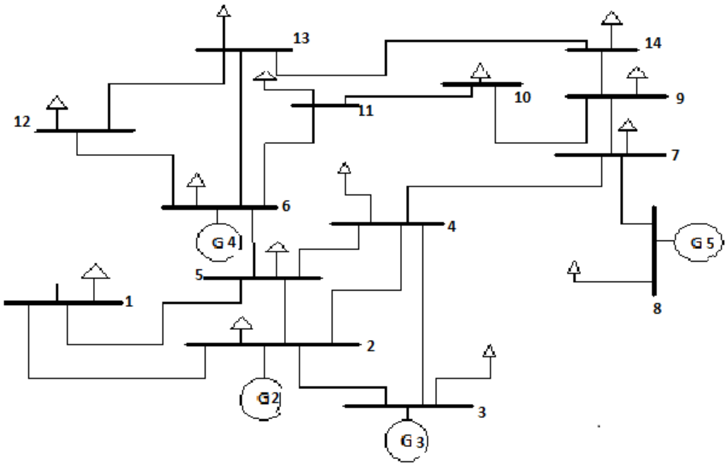

Figure 2: Generator 1 going out of operation.

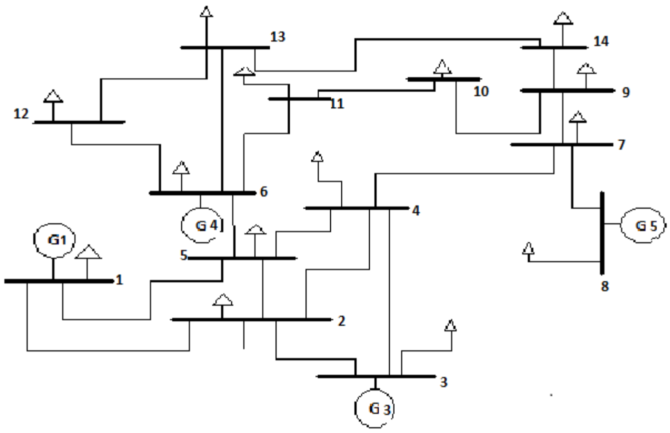

Figure 3: Generator 2 going out of operation.

Implementation

The line diagram of the network with generator 1 going out of operation is shown below.

All the above analysis is carried using power system analysis toolbox in MATLAB. This toolbox provides us with features of dynamic simulation for contingency analysis needed for us.

The line diagram of the network with generator 2 going out of operation is shown below.

We present a flow diagram how this entire process is carried out in the figure below.

BX Fast Decoupled method [2] of analysis is used for power flow computation. Trapezoidal Integration method is used in the time domain dynamic simulation. Newton Rapson method [2] is used for power flow computation.

Practical Analysis

With generator 1 contingency, power flow was achieved in 0.812 seconds. Time Domain Dynamic simulation was completed in 3.1235 seconds.

With generator 2 contingency, power flow was achieved in 0.828 seconds. Time Domain Dynamic simulation was completed in 6.6579 seconds.

In both of the above cases Newton Rapson method [2] is used as PF solver.

Flow chart

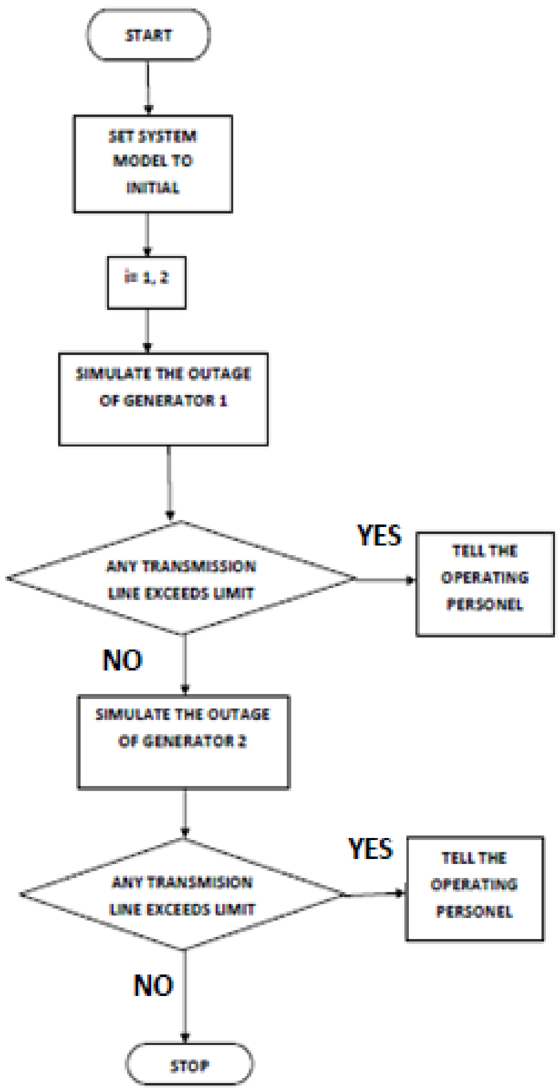

Figure 4: Flow Diagram.

Results and Analysis

The following are the results obtained at generator 1 before stalling and after stalling.

The first two results shown in figures 5 and 6 indicate the normal operation of the interconnected power system before the removal of generator1 or stalling of generator1 from bus1 the three e high bus voltages which are affected are resulting at buses 1,2 and 3 are shown. Similarly three low bus voltages which are affected are resulting at buses 5, 7 and 9 are shown respectively.

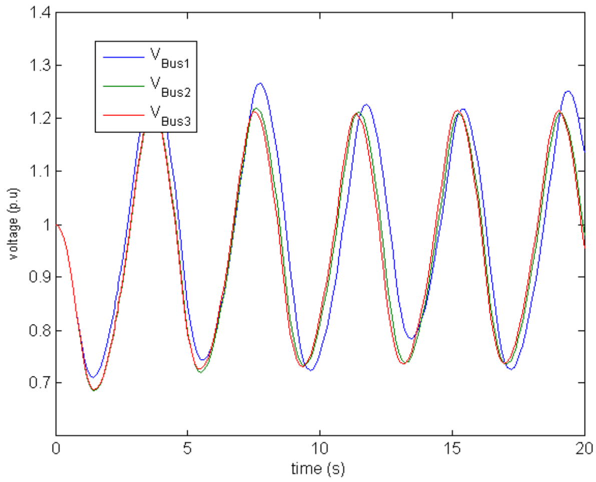

Figure 5: Three high voltages with generator 1 before stalling at bus1.

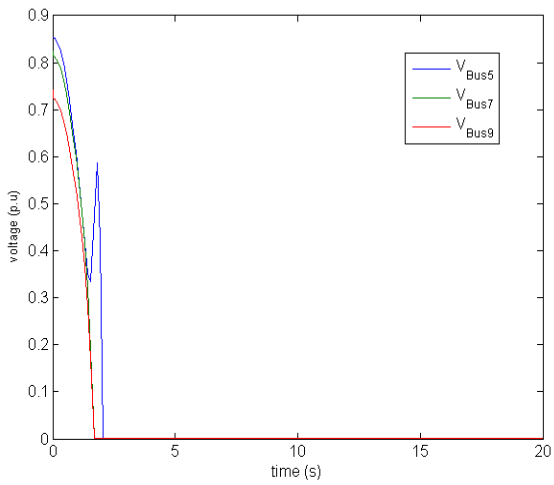

Figure 6: Three low voltages with generator before stalling at bus 1.

The voltages at buses 2, 6 and 8 vary showing the highest voltage levels obtained during the removal of generator1 at bus1 due to in-operable condition. This is indicated in figure 7.

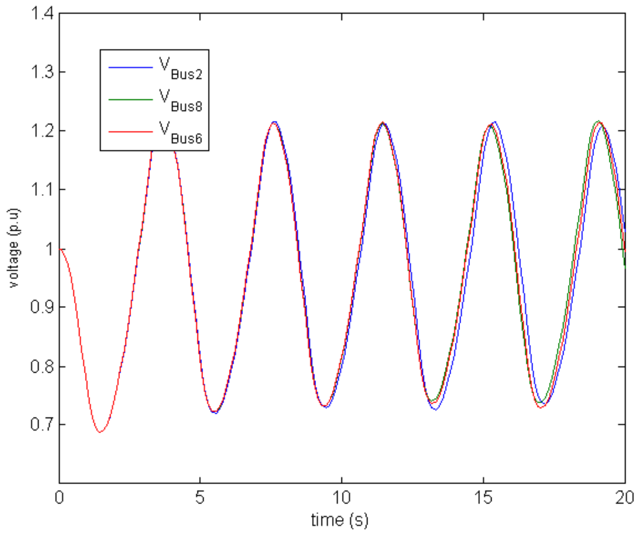

Figure 7: Three high voltages with generator 1 after stalling at bus1.

The voltages at buses 9, 10 and 14 vary showing the lowest voltage levels obtained during the removal of generator1 at bus1 due to in-operable condition. This is indicated in figure 8.

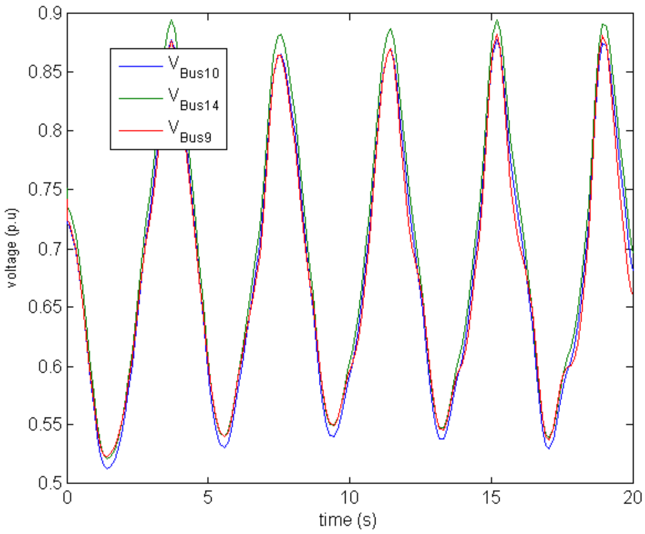

Figure 8: Three low voltages with generator1 after stalling at bus 1.

The resulting voltage at bus 1 due to the above changes is shown in figure 9.

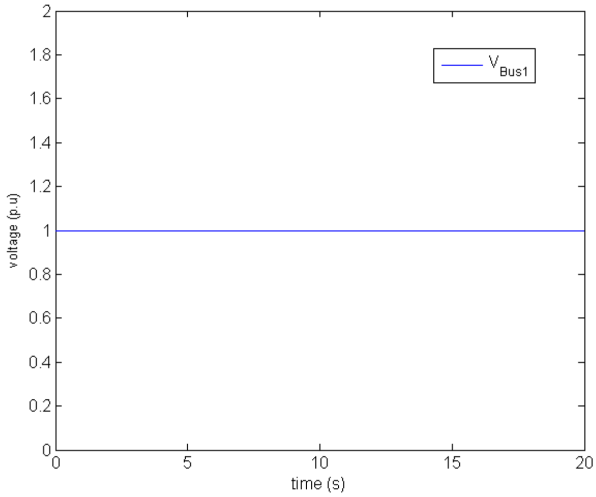

Figure 9: The resulting voltage at bus1 where generator1 was removed from operation.

The voltages at buses 1, 6 and 8 vary showing the highest voltage levels obtained during the removal of generator2 at bus2 due to in-operable condition. This is indicated in figure 10.

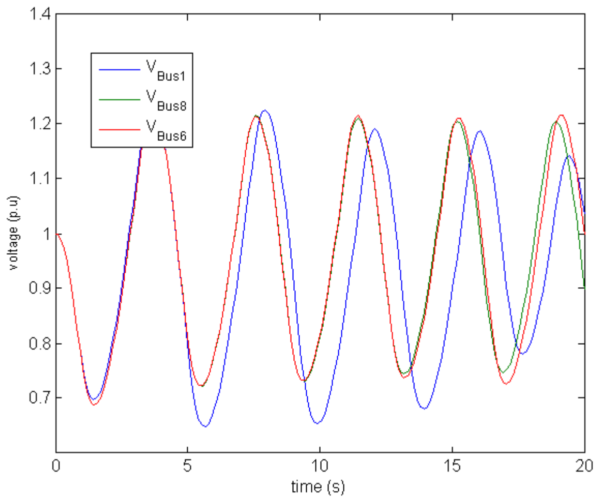

Figure 10: Three high voltages with generator 2 aftern stalling at bus2.

The voltages at buses 7, 9 and 10 vary showing the lowest voltage levels obtained during the removal of generator2 at bus2 due to in-operable condition. This is indicated in figure 11.

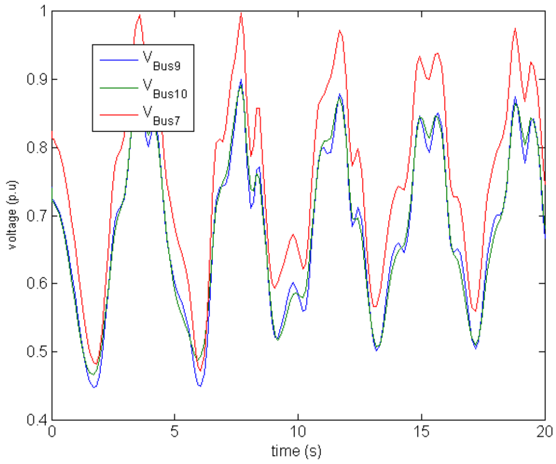

Figure 11: Three low voltages with generator2 after stalling at bus2.

The resulting voltage at bus 2 due to the above changes is shown in figure 12.

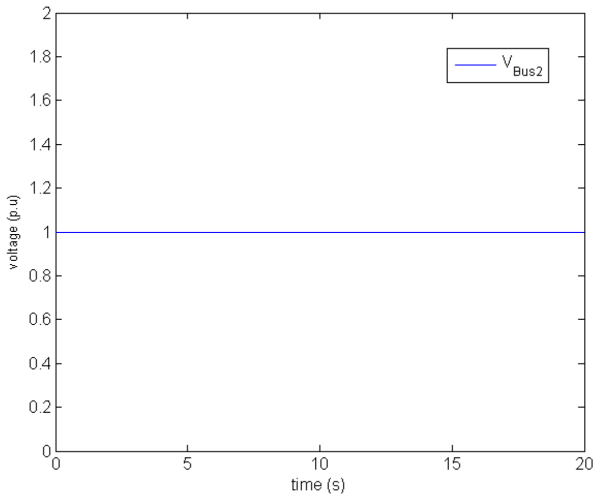

Figure 12: The resulting voltage at bus2 where generator2 was removed from operation.

All the above results have been observed in per-unit values for voltage and time in seconds.

Below shown are the results tabulated for generator 1 at bus 1 for an entire simulation period. For simplicity we have shown only the high voltages obtained in per-unit for generator 1 contingency in the table 1 . Also we have shown the low voltages obtained in perunit for generator 2 contingency in the table 2. All the results obtained here are maaintained in time frame of 0 to 20 seconds. The results obtained are simulated using BX fast decoupled method of analysis using power system analysis toolbox [4] in matlab.

Table 1: Results for Generator 1.

C_Time(S)	V_(Bus2)	V_(Bus8)	V_(Bus6)
0.00000	1.00000	1.00000	1.00000
0.02500	0.99993	0.99993	0.99993
0.05750	0.99951	0.99951	0.99952
0.09975	0.99811	0.99810	0.99811
0.15468	0.99460	0.99459	0.99460
1.06457	0.74128	0.74055	0.74057
2.06457	0.76308	0.76388	0.76393
3.06457	1.08098	1.08410	1.08431
4.06457	1.17703	1.17470	1.17456
5.06457	0.78741	0.78461	0.78447
6.06457	0.78435	0.78962	0.78994
7.06457	1.09277	1.10207	1.10267
8.06457	1.15256	1.14035	1.13958
9.06457	0.76968	0.76285	0.76274
10.06457	0.81448	0.82871	0.83039
11.06457	1.13458	1.15460	1.15683
12.06457	1.11193	1.08839	1.09074
13.06457	0.74282	0.74605	0.74349
14.06457	0.84350	0.88499	0.87802
15.06457	1.17274	1.19827	1.19752
16.06457	1.07545	1.00528	1.02251
17.06457	0.73874	0.73801	0.72848
18.06457	0.88742	0.94437	0.91985
19.06457	1.20011	1.21747	1.21423
20.00000	1.02810	0.96456	0.99350

Table 2: Results for Generator 2.

C_Time(S)	V_(Bus9)	V_(Bus10)	V_(Bus7)
0.00000	0.74212	0.74022	0.82451
0.02500	0.72384	0.72102	0.81353
0.05750	0.72343	0.72063	0.81312
0.09975	0.72214	0.71939	0.81183
0.15468	0.71915	0.71646	0.80882
1.06457	0.55121	0.54190	0.61967
2.06457	0.49390	0.51375	0.53091

3.06457	0.75687	0.76064	0.85741
4.06457	0.82060	0.82683	0.91174
5.06457	0.59209	0.57782	0.67061
6.06457	0.44867	0.49253	0.47152
7.06457	0.74555	0.75746	0.82823
8.06457	0.71054	0.73849	0.78720
9.06457	0.52084	0.52471	0.59368
10.06457	0.57466	0.58148	0.64017
11.06457	0.79960	0.80987	0.87815
12.06457	0.72977	0.74171	0.81508
13.06457	0.51593	0.52106	0.56654
14.06457	0.66029	0.64890	0.74325
15.06457	0.83218	0.84171	0.91962
16.06457	0.70811	0.71135	0.79522
17.06457	0.51863	0.51929	0.56514
18.06457	0.70101	0.68402	0.79379
19.06457	0.80542	0.82537	0.89228
20.00000	0.66587	0.67939	0.74415

Conclusion

The above results show an in depth nature of an interconnected power system when one of the generators going out of service. The stability and instability of the entire network depending on the contingencies selected in the above paper vary according to the needed power output to be supplied to the load. The stability criterion can be chosen by the operating personal from the studies made from the above dynamic time domain simulation. The results can be stored in a central station to always refer to it, to maintain a system free of instability problems.

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