INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Contingency Analysis In Restructured Power System

Ch. Krishna Chaitanya
M.Tech Scholar, Department Of Electrical & Electronics Engineering
QIS College Of Engineering And Technology, Ongole, A.P, India
J. Krishna Kishore
Professor, Department Of Electrical & Electronics Engineering
QIS College Of Engineering And Technology, Ongole, A.P, India
G. Swapna
Assistant Professor, Department Of Electrical & Electronics Engineering
QIS College Of Engineering And Technology, Ongole, A.P, India

Abstract:
Maintaining power system security is one of the challenging tasks for the power system engineers. The security assessment is an essential task as it gives the knowledge about the system state in the event of a contingency. Contingency analysis is one of the basic power system studies. Contingency analysis technique is being widely used to predict the effect of outages like failures of equipment transmission line etc, and to take necessary actions to keep the power system secure and reliable. It refers to the security of the system operation under the loss of one or more of the major system components This paper shows the example of 6-Bus power system which gives the information about the violations and novel method proposed and is tested on 9-Bus system. Detailed studies have been carried out to work out the contingency analysis.

Key words: *Contingency analysis, LODFs, PTDFs, Single Contingency, Multiple Contingency*

1.Introduction

Electrical Energy is a vital commodity and an important resource for one and all, in all walks of life and all areas of application. Electrical power generation industry is a major industry. It is a long-term plan for the government involving not only huge amounts of money, men, time and various major resources but also social and political decision factors. Thus maintenance of the existing power-systems is very important. Economic prosperity, national security, public health and safety cannot be achieved without it. Communities that lack electric power, even for short periods, have trouble meeting basic needs for food, shelter, water, law and order. Due to increase in demand for power and technology advancements a large and varied restructuring of the electrical industry has been effected.

Most power systems are designed with enough redundancy so that they can withstand all major failure events. Contingency analysis is one of the major components in today's modern energy management systems. For the purpose of fast estimating system stability right after outages, the study of contingency analysis involves performing efficient calculations of system performance from a set of simplified system conditions.

Contingency analysis is one of the most important tasks encountered by the planning and operation engineers of bulk power system.

The Line Outage Distribution Factor (LODF) is one of the important linear sensitivity factors which play a key role in finding the effect of the critical contingencies and hence suggesting possible preventive and corrective actions to solve the violations in the system.

LODFs are used to appropriate the change in the flow on one line caused by the outage of a second line.

PTDFs show the linear zed impact of a transfer of power.

The increasing load demand in power systems without accompanying investments in generation and transmission has affected the analysis of stability phenomena, requiring more reliable and faster tools.

2.Contingency Analysis

A Contingency is defined as the unexpected failure or outage of a system component such as generator, transmission line, circuit breaker or switch. Contingencies are defined as potentially harmful disturbances that occur during the steady state operation of a power system.

Contingency analysis (CA) is one of the “security analysis” applications in a power utility control centre that differentiates an Energy Management System (EMS) from a less complex SCADA system. Its purpose is to analyze the power system in order to identify the overloads and problems that can occur due to a contingency.

Contingency analysis is abnormal condition in electrical network. It put whole system or a part of the system under stress. It occurs due to sudden opening of a transmission line. Generator tripping. Sudden change in generation. Sudden change in load value.

Systems are designed to withstand one contingency, i.e (N-1) criterion. However some events trigger others and cascading failures might occur. Therefore not all contingencies are equal, and the number of components in a given system makes it prohibitive to evaluate all (single) contingencies. The system is considered (N-1) secure when a single contingency will not cause any system limits to be violated.

3.Types Of Violations

Line contingency and generator contingency are generally most common type of contingencies. These contingencies mainly cause two types of violations –Low voltage violations and Line MVA violations.

3.1.Low Voltage Violations

This type of violation occurs at the buses. This suggests that the voltage at the bus is less than the specified value. The operating range of voltage at any bus is generally 0.95-1.05 p.u. Thus if the voltage falls below 0.95 p.u then the bus is said to have low voltage. If the voltage rises above the 1.05 p.u then the bus is said to have a high voltage problem. It is known that in the power system network generally reactive power is the reason for the voltage problems. Hence in the case of low voltage problems reactive power is supplied to the bus to increase the voltage profile at the bus. In the case of the high voltage reactive power is absorbed at the buses to maintain the system normal voltage.

3.2.Line MVA Limits Violations

This type of contingency occurs in the system when the MVA rating of the line exceeds given rating. This is mainly due to the increase in the amplitude of the current flowing in that line. The lines are designed in such a way that they should be able to withstand 125% of their MVA limit. Based on utility practices, if the current crosses the 80-90% of the limit, it is declared as an alarm situation.

4.Remedial Action Scheme

Remedial Action Schemes (RAS) are the key components for any power system utility planning. These are the steps which the utilities need to take in order to get the system back to its normal operation. Remedial Action Scheme (RAS) as the name suggests are the necessary actions which need to be taken to solve the violations caused by a contingency. Remedial Action Schemes are also defined as Special Protection Schemes (SPS) or System Integration Schemes (SIS). There may be single critical outage or there may be several critical single contingency outages for which remedial action is needed. There may also be credible double or other multiple contingencies for which remedial action is needed. Each critical contingency may require a separate arming level and different remedial actions. The terms SPS and RAS are often used interchangeably, but WECC generally and this document specifically uses the term RAS.

Automatic single-phase or three-phase reclosing following temporary faults during stressed operating conditions may avoid the need to take remedial action. Appropriate RAS action may still be required if reclosing is un successful.

4.1.Types Of Remedial Action

- Shunt capacitor switching
- Generation Re-dispatch
- Load shedding
- Under load tap changing (ULTC) Transformer
- Distributed Generation
- Islanding

5.Simulation Results Of 6-Bus System

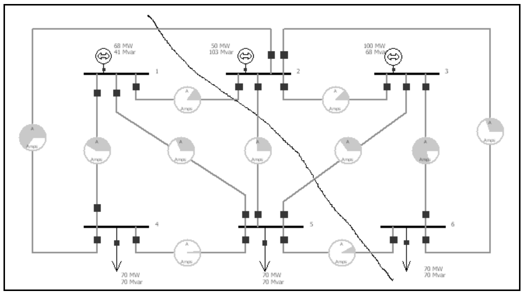


Figure 1: Base Case For 6-Bus System

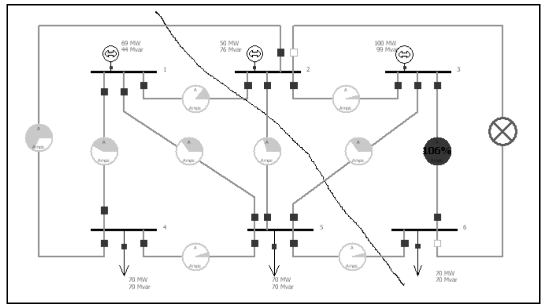


Figure 2: N-1 Line Contingency On 6-Bus System

5.1.Results And Discussion For 6-Bus System

Sl. No	From line	To line	Violations	Max Branch % MVA Limit
1	1	2	1	105.1
2	1	4	3	106.4
3	1	5	3	114.1
4	2	3	1	106.3
5	2	4	3	111.4
6	2	5	3	113.4
7	2	6	1	105.5
8	3	5	3	118.7
9	3	6	3	107.7
10	4	5	1	106.8
11	5	6	1	108.6

Table 1: Contingency Analysis Of 6-Bus System

Total No. of Contingencies	11	Start Time	7/25/2013 19:59:32 PM
No. of Processed	11	End Time	7/25/2013 19:59:32 PM
No. of Unsolvable	0	Total Run Time	0.13 Seconds
No. of Violations	23	Avg Time per ctg	0.011 Seconds

Table 2: Results Of Contingency Analysis

Sl. No	From line	To line	% LODF	MW From	MW To
1	1	2	-100	11.6	-11.4
2	1	4	60.8	31.3	-30.4
3	1	5	39.2	26.3	-25.3
4	2	3	-16.2	-3.8	3.8
5	2	4	-61.8	46	-43.8
6	2	5	-22	19.2	-18.3
7	2	6	0	0	0
8	3	5	-9.8	27	-25.5
9	3	6	-6.4	69.2	-67
10	4	5	-1	4.1	-4.1
11	5	6	6.4	3	-3

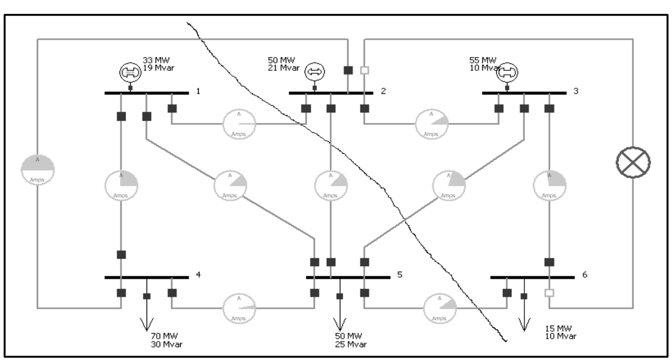
Table 3: LODFs Of 6-Bus System

Sl. No	From line	To Line	% PTDF From	% PTDF To
1	1	2	42.57	-42.57
2	1	4	30.17	-30.17
3	1	5	27.26	-27.26
4	2	3	18.5	-18.5
5	2	4	-24.81	24.81
6	3	5	-19.09	19.09
7	3	6	-12.41	12.41
8	4	5	5.36	-5.36
9	5	6	12.41	-12.41

Table 4: PTDFs Of 6-Bus System

The table I show the contingency analysis when 2 to 6 line is open. The overloaded line is as shown in figure 2. The numbers of violations are 23 as shown in table II. The LODF and PTDF calculations for 6-bus system are shown in table III and table IV respectively.
Results, when corrective and preventive remedial actions taken to solve the violations are given below.

6.After Remedial Action Taken On 6 Bus System



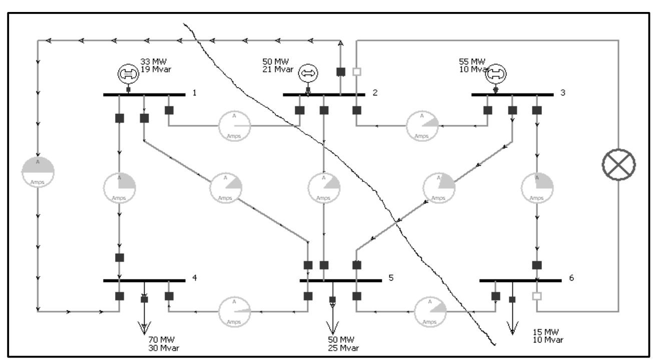


Figure 3: N-1 Line Contingency On 6-Bus System
Figure 4: N-1 Line Violations Solved After Action Taken On 6-Bus System

6.1.Result & Discussion For Violations Solved After Action Taken On 6-Bus System

Sl. No	From line	To line	Violations	Max Branch % MVA Limit
1	1	2	0	-
2	1	4	0	-
3	1	5	0	-
4	2	3	0	-
5	2	4	0	-
6	2	5	0	-
7	2	6	0	-
8	3	5	0	-
9	3	6	0	-
10	4	5	0	-
11	5	6	0	-

Table 5: Contingency Analysis Violations Solved After Action Taken On 6-Bus System

Total No. of Contingencies	11	Start Time	7/26/2013 9:52:50 AM
No. of Processed	11	End Time	7/26/2013 9:52:50AM
No. of Unsolvable	0	Total Run Time	0.13 Seconds
No. of Violations	0	Avg Time per ctg	0.011 Seconds

Table 6: Results Of Contingency Analysis Violations Solved After Action Taken On 6-Bus System

Sl. No	From line	To line	% LODF	MW From	MW To
1	1	2	-100	-0.5	0.5
2	1	4	60.8	22.2	-21.9
3	1	5	39.2	11.1	-10.9
4	2	3	-16.2	-8.9	8.9
5	2	4	-61.8	46.7	-45.5
6	2	5	-22	11.7	-11.5
7	2	6	0	0	0
8	3	5	-9.8	21	-20.4
9	3	6	-6.4	25.1	-24.9
10	4	5	-1	-2.7	2.7
11	5	6	6.4	-9.8	9.9

Table 7: LODFs Violations Solved After Action Taken On 6-Bus System

Sl. No	From line	To line	% PTDF From	% PTDF To
1	1	2	42.57	-42.57
2	1	4	30.17	-30.17
3	1	5	27.26	-27.26
4	2	3	18.5	-18.5
5	2	4	-24.81	24.81
8	3	5	-19.09	19.09
9	3	6	-12.41	12.41
10	4	5	5.36	-5.36
11	5	6	12.41	-12.41

Table 8: PTDFs Violations Solved After Action Taken On 6-Bus System

As shown in figure 2. One of the lines has been carrying the power more than the limit. Action should be taken to solve these MVA violations. After reducing the generation at bus 1 to 33MW, bus 3 to 55MW also shedding the load at bus 5 to 50MW, bus 6 to 15MW and the MVAR rating has also been reduced at buses 2,3,4,5,6 are 21,10,30,25,10 MVAR respectively on the lines have come back to within its operational limits. As seen in table V, the MVA limit of the lines and all line flows are within operating limits. The LODF and PTDF values after action taken are shown in table VII and table VIII respectively.
With proposed study various sets of system adjustment are identified based on type of violations and the type of contingency being applied. The corrective actions effectively removed the limit violations in the system. More importantly can identify location in system where new generation can provide grid reliability benefits.

7.Simulation Results Of 9-Bus System

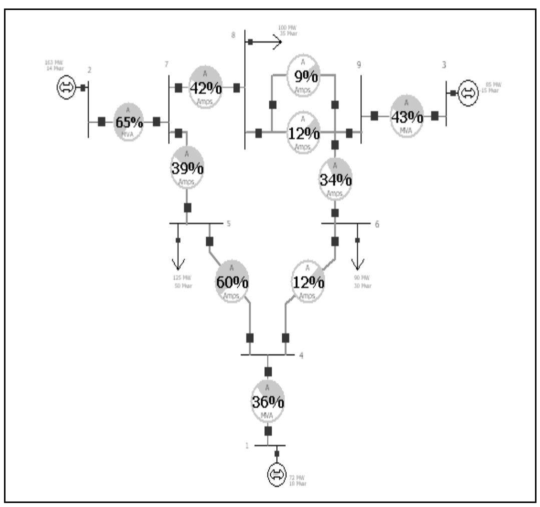


Figure 5: One Line Diagram Of 9-Bus System

7.1.Results And Discussion For 6-Bus System

Generator No	Output(MW)
G1	71.96
G2	163
G3	85

Table 9: Generator data

Sl. No	From Number	To Number	Power Flow (MW)
1	4	1	-71.96
2	2	7	163
3	9	3	-84.24
4	5	4	-48.81
5	6	4	-22.55
6	7	5	78.64
7	9	6	67.93
8	7	8	84.36
9	8	9	-13.75
10	8	9	-2.49

Table 10: Line Flow Data

Run optimal power flow program on the system to obtain the Base Case results. The Base Case results are Generator Outputs, Line-Flow and Bus voltage profile. For the 9-Bus system under study the generator output data is given in table IX, Line-Flow data in Table X and Bus data in Table XI.

Sl. No	Bus Number	Volt (Mag) P.U	Voltage Angle (Deg)	Load MW	Gen MW
1	1	1	-8.61		71.96
2	2	1	0		163
3	3	1	-4.9		85
4	4	0.99432	-11		
5	5	0.96208	-13.45	125	
6	6	0.99213	-12.32	90	
7	7	1.00608	-5.81		
8	8	1.00484	-9.28	100	
9	9	1.01063	-9.11		

Table 11: Bus Data

8.Contingency Study

Contingency study is conducted by running the contingency analysis tool of the power world simulator software. In this study only Generators, buses and transmission lines have been taken in to consideration for contingency studies. The 9-Bus system consists of nine buses, three generators and ten lines.

8.1.Single Contingency

It is the loss of one component. It corresponds to the N-1 criterion i.e the system should be able to support the load when one of the N basic transmission system components (transmission lines, generators or transformers) is out of operation only one bus, or one generator or one line failure for the 9 Bus system 22 Single Contingencies were studied. The results are tabulated in Table XII.

8.2.Multiple Contingency

For the study of two contingencies occurring at a time are considered i.e any two generators, any two buses or any two lines. This is N-2 criterion. The results of Multiple Contingencies are tabulated in Tables XIII.

Contingency Number	Component	State	Effect of Contingency
C1	G1	Open	NV
C2	G2	Open	2V,Branch 5-4 137% Loaded, Branch 4-1 119% Loaded
C3	G3	Open	NV
C4	B1	Faulty	G1 Isolated
C5	B2	Faulty	G2 Isolated
C6	B3	Faulty	G3 Isolated
C7	B4	Faulty	G1 Isolated
C8	B5	Faulty	L5 Isolated
C9	B6	Faulty	L6 Isolated
C10	B7	Faulty	G1 Isolated
C11	B8	Faulty	L8 Isolated
C12	B9	Faulty	G3 Isolated
C13	L1(4-1)	Open	NV
C14	L2(2-7)	Open	2V
C15	L3(9-3)	Open	NV
C16	L4(5-4)	Open	NV
C17	L5(6-4)	Open	NV
C18	L6(7-5)	Open	1V
C19	L7(9-6)	Open	NV
C20	L8(7-8)	Open	NV
C21	L9(8-9)	Open	NV
C22	L10(8-9)	Open	NV

Table 12: Single Contingency Results

Notations:
Bn – Bus n
Cn – Contingency Number
CBn – Contingency effect at Bus n
En – Effect n
Gn – Generator n
Ln(a-b) – Line n(From Bus to Bus)
MCn – Multiple Contingency Number
NV – No Violation
O – Open
1V – One Violation

Contingency Number	Components	State	Effect of Contingency
MC1	G1 & G2	Open	3V
MC2	G1 & G3	Open	2V
MC3	G2 & G3	Open	2V
MC4	B1 & B2	Faulty	CB1 & CB2
MC5	B1 & B3	Faulty	CB1 & CB3
MC6	B1 & B4	Faulty	CB1 & CB4
MC7	B1 & B5	Faulty	CB1 & CB5
MC8	B1 & B6	Faulty	CB1 & CB6
MC9	B1 & B7	Faulty	CB1 & CB7
MC10	B1 & B8	Faulty	CB1 & CB8
MC11	B1 & B9	Faulty	CB1 & CB9
MC12	B2 & B3	Faulty	CB2 & CB3
MC13	B2 & B4	Faulty	CB2 & CB4
MC14	B2 & B5	Faulty	CB2 & CB5
MC15	B2 & B6	Faulty	CB2 & CB6
MC16	B2 & B7	Faulty	CB2 & CB7
MC17	B2 & B8	Faulty	CB2 & CB8
MC18	B2 & B9	Faulty	CB2 & CB9
MC19	B3 & B4	Faulty	CB3 & CB4
MC20	B3 & B5	Faulty	CB3 & CB5
MC21	B3 & B6	Faulty	CB3 & CB6
MC22	B3 & B7	Faulty	CB3 & CB7
MC23	B3 & B8	Faulty	CB3 & CB8
MC24	B3 & B9	Faulty	CB3 & CB9
MC25	B4 & B5	Faulty	CB4 & CB5
MC26	B4 & B6	Faulty	CB4 & CB6
MC27	B4 & B7	Faulty	CB4 & CB7
MC28	B4 & B8	Faulty	CB4 & CB8
MC29	B4 & B9	Faulty	CB4 & CB9
MC30	B5 & B6	Faulty	CB5 & CB6
MC31	B5 & B7	Faulty	CB5 & CB7
MC32	B5 & B8	Faulty	CB5 & CB8
MC33	B5 & B9	Faulty	CB5 & CB9
MC34	B6 & B7	Faulty	CB6 & CB7
MC35	B6 & B8	Faulty	CB6 & CB8
MC36	B6 & B9	Faulty	CB6 & CB9
MC37	B7 & B8	Faulty	CB7 & CB8
MC38	B7 & B9	Faulty	CB7 & CB9
MC39	B8 & B9	Faulty	CB8 & CB9

Table 13: Multiple Contingency Results

9.Analysis Of Case Study

The effects of the various contingencies in the 9 Bus study system have been classified in to three categories. The first category is Highly critical (HC) if there are three violations. This indicates that all preventive measures and precautions should be taken to ensure that the probability of occurrence of such contingency is zero. The second category is Medium Critical (MC) if there are two violations. This indicates that all preventive measures and precautions should be taken to ensure that the probability of occurrence of such contingency is low. The third category is Less critical (LC) if there is one violation. This indicates that all preventive measures and precautions should be taken to ensure that the probability of occurrence of such contingency is very low. Hence, steps should be taken to prevent low critical contingencies.

Level of Contingency	**Contingency Number**
Highly Critical(HC)	MC1
Medium Critical(MC)	C2,MC2,MC3
Less Critical(LC)	C18

Table 14: Analysis Of Single And Multiple Contingency Results

10.Conclusion

The corrective actions effectively removed the limit violations in the system. The results obtained through the proposed algorithm are found to be quite accurate and thus, this work provides new tool for developing remedial control actions for higher order contingencies. Contingency analysis study helps to strengthen the initial basic plan. It is also helpful to develop system operators to improve their ability to resolve problem.

11.References

1. K.Bhattacharya, M.Bollen and J.Daalder, Operation of Restructured power systems (Kluver, Academic publishers , 2001).
2. M.K Enns, J.J Quada, and B.Sackett, “Fast Linear Contingency analysis”, IEEE Trans. On PAS-98, pp. 97-109, jan/feb 1979.
3. Guide for Remedial Action Schemes. “WECC Remedial Action Scheme Design Guide,” November 28,2006.
4. T. Guler, G.Gross, M.Liu, “Generalized Line Outage Distribution Factors”, Power Systems, EEE Trans. Vol.22, Issue 2, May 2007, pp.879-881.
5. K.Radha Rani, J. Amarnath, and S. Kamakshaiah, “Contingency Analysis under Deregulated Power Systems”, ICGST-ACSE Journal, Volume 11, Issue 2, November 2011.
6. Da Silva Filho J.I, Rocco A, Onuki A.S, Ferrara L. F.P., Camargo J.M. “Electric Power Systems Contingencies Analysis by Paraconsistent Logic Application ”, The 14th International Conference on Intelligent System Applications to Power Systems, ISAP 2007 November 4-8,2007, Kaohsiung, Taiwan.
7. Veenavati Jagadish Prasad Mishra, Manisha D.Khardenvis,”Contingency Analysis of Power System”, International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA) 2012, Proceedings published in International Journal of Computer Applications®(IJCA).
8. Consortium for Electric Infrastructure to support Digital Society, “ IntelliGrid Architecture, Transmission Operation ContingencyAnalysisBaselineFunction”,online http://www.intelligrid.info/IntelligGrid_Architecture/Use_Cases/To_Contingency_Analysis_Baseline.htm
9. Silva I.De J., Rider M.J., Garcia A.V., and Murari C.A, “Transmission network expansion planning with security constraints,” IEE Proceedings on Generation, Transmission and Distribution, vol.152, no.6, pp.828-836, November 2005.S