Contingency Analysis of Power System

Veenavati jagadishprasad mishra
M. Tec P.T. (EPS - VI Sem)
Govt. College of Engineering, Amravati (MS), India

Manisha D. Khardenvis
Assistant Professor (Project Guide)
Govt. College of Engineering, Amravati (MS) , India

ABSTRACT

In the past many wide spread blackouts have occurred in interconnected power systems therefore it is necessary to insure that power system should be operated most economically such that power is delivered reliably. Contingency analysis is a well known function in modern Energy Management Systems (EMS). The goal of this power system analysis function is to give the operator information about the static security [4]. Contingency Analysis of a power system is a major activity in power system planning and operation. In general an outage of one transmission line or transformer may lead to over loads in other branches and/or sudden system voltage rise or drop. Contingency analysis is used to calculate violations.

This paper shows the example on 6 bus power system which gives information of violations & remedial action to remove violations. Detailed studies have been carried out to work out the contingency plans.

Keywords

Contingency analysis, LODFs, PTDFs, generation and transmission planning.

1. INTRODUCTION

Most power systems are designed with enough redundancy so that they can a withstand all major failure event. 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 [10].

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 approximate the change in the flow on one line caused by the outage of a second line.
- Typically they are only used to determine the change in the MW flow compared to the pre-contingency flow
- LODFs are approximately independent of flows but do depend on the assumed network topology [9].
- Power transfer distribution factors (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 [1-2].

2. CONTINGENCY ANALYSIS

Contingency Analysis (CA) is one of the "security analysis" applications in a power utility control center 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. Contingency analysis provides tools for managing, creating, analyzing, and reporting lists of contingencies and associated violations [6].

CA is used as a study tool for the off-line analysis of contingency events, and as an on-line tool to show operators what would be the effects of future outages.

- Security is determined by the ability of the system to withstand equipment failure.
- Weak elements are those that present overloads in the contingency conditions (congestion).
- Standard approach is to perform a single (N-1) contingency analysis simulation.
- A ranking method will be demonstrated to prioritize transmission planning [7].
- CA is therefore a primary tool used for preparation of the annual maintenance plan and the corresponding outage schedule for the power system.

3. TYPES OF VIOLATIONS

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

A. 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.

B. 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. Different types of remedial actions to solve this problem are explained later in this paper [11].

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). The RAS is designed to mitigate specific critical contingencies that initiate the actual system problems. There may be a 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 unsuccessful [8].

5. TYPES OF REMEDIAL ACTION

i. Shunt capacitor switching
ii. Generation Re-dispatch
iii. Load shedding
iv. Under load tap changing (ULTC) Transformer
v. Distributed Generation
vi. Islanding

6. POWER TRANSFER DISTRIBUTION FACTOR

A source and a sink are specified for each transaction. Active power will then flow from source to sink in a direction. For each direction, the ATC value is the maximum megawatt source injection that can be transferred to the sink without violating any of the operating limits such as line thermal limits, voltage limits and system stability limits. In order to investigate how far the system is from an insecure condition, and how a transaction of active power can affect the loading of the transmission system, it is necessary to analyze the sensitivities of line flows with respect to bus injections. These sensitivities are termed as Power Transfer Distribution Factors. Power transfer distribution factors of i-j elements, for the transaction between m-n will be given as,

$$PTDF_{if\,(mn)} = \frac{\Delta P_{ij}}{\Delta T_{mn}}$$

Where,
$PTDF_{if(mn)}$- Power Transfer Distribution Factors for line i-j for transaction between m-n
ΔT_{mn} - Change in transaction between m and n
ΔP_{ij} - Change in real power flow of line i-j for transaction between m-n,
These values provide a linear zed approximation of how the flow on the transmission lines and interfaces changes in response to transaction between the seller and buyer. The PTDFs are operating point dependent.

7. SIMULATION RESULTS AND DISCUSSION

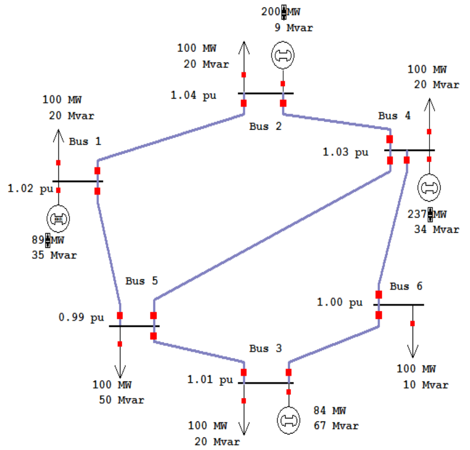

Figure 1: Base Case for 6 bus system

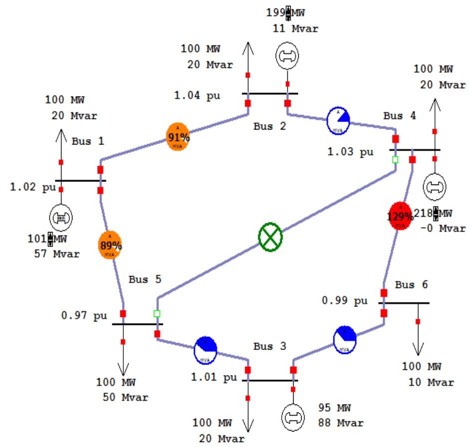

Figure 2: N-1 Line contingency on 6 bus system

A. Result & Discussion For 6 Bus System

TABLE I Contingency Analysis of 6 Bus System

Sr. No	Line details	Violations	Max branch % MVA limit
1	000001-000002	3	215.5
2	000001-000005	4	244.8
3	000002-000004	2	118.1
4	000003-000005	3	121.3
5	000003-000006	3	115.7
6	000005-000004	1	128.6
7	000006-000004	5	245.1

TABLE II Results of Contingency Analysis

Total # of contingencies	7	Start Time	31/12/2011 5:26:11 PM
# Processed	7	End Time	31/12/2011 5:26:11 PM
# Unsolvable	0	Total Run Time	0.23 Seconds
# Violations	21	Avg. Time per Ctg	0.033 Seconds

TABLE III LODFs of 6 Bus System

Sr. No.	From Line	To Line	% LODF	MW From	MW To
1	1	2	-100	-86.2	89.2
2	1	5	100	87.6	-84.6
3	2	4	-100	10.3	-10.2
4	3	5	-100	16.1	-15.4
5	3	6	100	-21.3	21.9
6	5	4	0	0	0
7	6	4	100	-121.9	128.1

TABLE IV PTDFs of 6 Bus System

Sr. No	From line	To line	% PTDF from	% PTDF To
1	1	2	50	-50
2	1	5	50	-50
3	2	4	50	-50
4	3	5	-50	50
5	3	6	50	-50
6	6	4	-50	50

The table (I) show the contingency analysis when 4 to 5 line is open. The Overloaded Line is As Shown in fig. (2). the numbers of violations are 21 as shown in table (II). The LODF and PTDF calculations for 6 bus system are shown in table (III) & table (IV) resp.

Results, when corrective and preventive remedial actions taken to solve the violations are given below.

8. AFTER REMEDIAL ACTION TAKEN ON 6 BUS SYSTEM

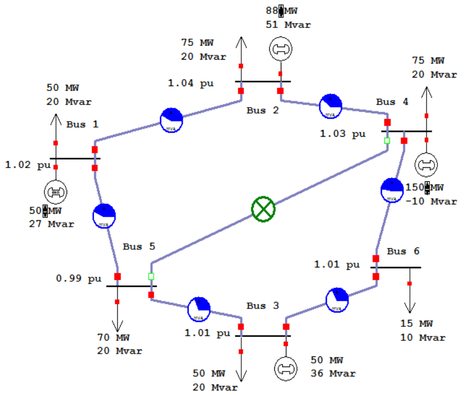

Fig 3: N-1 Line contingency on 6 bus system

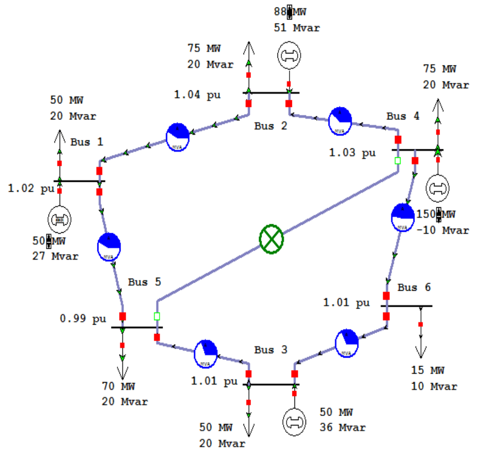

Fig 4: N-1 line violations solved after action taken on 6bus system.

A. Result & discussion for violations solved after action taken on 6 bus system:

TABLE V Contingency Analysis violations solved after action taken on 6bus system.

Sr. No	Line details	Violations	Max branch % MVA limit
1	000001-000002	0	-
2	000001-000005	0	-
3	000002-000004	0	-
4	000003-000005	0	-
5	000003-000006	0	-
6	000005-000004	0	-
7	000006-000004	0	-

TABLE VI Result of Contingency Analysis violations solved after action taken on 6bus system.

Total # of contingencies	7	Start Time	31/12/2011 6:02:19 PM
# Processed	7	End Time	31/12/2011 6:02:19 PM
# Unsolvable	0	Total Run Time	0.22 Seconds
# Violations	0	Avg. Time	0.031 Seconds

TABLE VII LODFs violations solved after action taken on 6bus system.

Sr. No.	From Line	To Line	% LODF	MW From	MW To
1	1	2	-100	-40.4	41.1
2	1	5	100	40.7	-40.0
3	2	4	-100	27.8	28.3
4	3	5	-100	30.4	-30.0
5	3	6	100	-30.4	30.8
6	5	4	0	0	0
7	6	4	100	-45.8	46.7

TABLE VIII PTDFs violations solved after action taken on 6bus system.

Sr. No	From line	To line	% PTDF from	% PTDF To
1	1	2	50	-50
2	1	5	50	-50
3	2	4	50	-50
4	3	5	-50	50
5	3	6	50	-50
6	6	4	-50	50

As shown in figure (2). Some of the lines have been carrying the power more than the limit. Action should be taken to solve these MVA violations. After reducing the generation at bus(4) to 150MW and also shedding the load at buses(2&4) to 75MW, bus 5 to 70MW and at bus (6) to 15MW, at bus(1&3) to 50MW the MW 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 after action taken is shown in table (VII) and table (VIII) resp.

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 [5].

9. 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. This tool helps especially the busy power system operators.

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