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Contingency Analysis of an IEEE 30 Bus System

Maduri Manashwini Goud
Department of Electrical and Electronics Engineering

Kakatiya Institute of Technology and Science (Autonomous under Kakatiya University)
Warangal, India

b20ee037@kitsw.ac.in

Boddu Giridhar
Department of Electrical and Electronics Engineering

Kakatiya Institute of Technology and Science (Autonomous under Kakatiya University)
Warangal, India

b20ee023@kitsw.ac.in

Ankeshwarapu Ashwini
Department of Electrical and Electronics Engineering

Kakatiya Institute of Technology and Science (Autonomous under Kakatiya University)
Warangal, India

b20ee034@kitsw.ac.in

Anjani Prasanna Manthrutha
Department of Electrical and Electronics Engineering

Kakatiya Institute of Technology and Science(Autonomous under Kakatiya University)
Warangal, India

Dr. Y. Manju Sree
Department of Electrical and Electronics Engineering

Kakatiya Institute of Technology and Science(Autonomous under Kakatiya University)
Warangal, India

Abstract: Outage of generators, transmission lines and transformers are carried out and the results are analyzed. Contingency analysis is important for the system operation and planning and to ensure the grid reliability. Load flow before and after the contingency have been analyzed using MI power package. To rank the severity of each component the performance indices are used and the performance indices are calculated by active power and voltage performance indices. Severity index is also evaluated to know the effect on transmission lines in the power system network.

I. INTRODUCTION

Contingency analysis simulates the effects of disruptions on a power system. These disruptions, called contingencies, can be things like a failing generator, a tripped transmission line, or even a sudden increase in electricity demand. By modelling these scenarios, engineers can predict how the power system would react, such as to voltage changes or overloaded lines. Power interruptions are costly and inconvenient. Contingency analysis proactively detects any weaknesses in the system to help avert them. This enables engineers to bolster the grid by rerouting electricity flows or adding backup generators. By creating reaction strategies to reduce downtime, it also aids in getting ready for unforeseen disruptions. A crucial component of the power system network's safe operation is contingency analysis. Generally, contingency means any disturbance occurs during the steady state analysis. Load flow analysis is performed repeatedly on an equipment failure. When the transmission lines are overloaded the power system is completely blacked out. Contingency can occur on generator, transformer, transmission lines. Regular contingency analysis is essential for maintaining a robust power grid that can withstand in unexpected events. Here, contingency analysis is performed in Mi power software.

Contingency has three levels of problems they are

1.None - Without overloading, the power system can be balanced
2.Severe - Damaging of the elements due to overload.
3.Critical -There is a significant risk that the power system will fail.

For power systems to operate safely and dependably, contingency analysis is essential. System operators can reduce risks and preserve system stability by anticipating possible scenarios and assessing their effects. It assists in locating the power system's weak points or vulnerabilities so that the necessary corrective measures can be put in place. The ability of a power system to manage malfunctions and unforeseen circumstances without going above voltage and equipment loading restrictions is assessed through contingency analysis.

II. LITERATURE SURVEY

This paper does a contingency analysis on 6 bus system to calculate violations and the remedial actions are done to remove violations.

The computation of voltage stability relies on weak area clustering methodologies. Voltage stability analysis (VSA) and line outage contingency analysis (LOCA) are the methods.

MATLAB has been used to complete all line outage contingencies in a typical 6 bus and 5 bus power system. The Newton-Raphson method is the one that is found to be best suitable for the contingency selection approach.

Using a performance index, quick decoupled load flow is used for contingency screening and ranking. The IEEE 5 bus system is used for the contingency in MATLAB.

The fast decoupled method in the Mi power package on the IEEE 14 bus system is used to calculate the voltage performance index and the line performance index for single line transmission in the event of a line outage. This process is used to determine the contingency selection.

This paper describes the implementation of a static synchronous compensator (SSSC) using an IEEE 5 bus system. SSSC components lower real and reactive power losses.

The Interline Power Flow Controller (IPFC), which is based on the Composite Severity Index (CSI), has been developed in this paper as a probability of severity technique. Utilizing several IPFC devices allows the system to function reliably in an emergency.

In accordance with their priority on the IEEE 9 bus system, the critical and non-critical components of the power system are identified in this work. The busy power system operators benefit from congestion.

This research presents an accurate methodology for contingency ranking based on transmission line losses. On the WSCC-9 bus RTS system, N-1 and N-2 contingencies are shown below.

In this paper, line outages are performed on the IEEE 118 bus system. The load margin sensitivities are tested on a critical area of a 1390 bus system.

A radial basis function neural network (RBFNN) method for rating contingencies online on an IEEE-14 bus power system is presented in this paper. This network can manage a greater number of contingencies and requires less time.

III. CONTINGENCY ANALYSIS AND TECHNIQUES

Contingency analysis is performed in three steps. They are

1.Contingency Creation

In this process, possible contingencies are observed and they are listed.

2.Contingency Selection

In this analysis, severe contingencies are selected which violates the voltage and power limits. Least affected contingency is eliminated.

3.Contingency Evaluation

In this process, effects caused by the severe contingencies is solved and necessary actions and future plans are provided in order to protect the power system from power losses. Here, performance index is computed which is used to rank the severity of the contingency.

There are some common techniques used in contingency analysis. They are

1. N - 1 Contingency analysis
2. N - K Contingency analysis
3. Probabilistic contingency analysis

A)N - 1 Contingency analysis

In this technique, the power system is resilient to the loss of one component without any deviations in operational losses. Typical criteria for evaluating the security of power system is the N-1 contingency, which calls for the power system to be able to support all system loads and withstand the failure of any one component without compromising the integrity of other components. Modeling the outages and system modifications is done with the N-1 contingency analysis, which can be the only tool required if all practical system modifications are well understood. This process is performed in following steps:

Component Identification

List all the parts of the power system that are prone to failure, such as the generators, transformers, gearbox lines, and other important equipment. Techniques and Resources for Preventive Maintenance.

Data Preparation

Gather and arrange information on the configuration of the system, such as bus voltages, load demands, generator parameters, and line impedance's.

Model Development

Construct a mathematical model that depicts the component characteristics and network structure of the power system.

Contingency Selection

Choose which contingencies will be examined, usually by considering how likely or important they are to occur. Line outages, transformer failures, and generator tripping are examples of common contingencies.

Power Flow Analysis

To ascertain the system's initial operating state, perform power flow analysis.

Eventuality Simulation

Disconnect or de-energize the impacted components in the power system to replicate the occurrence of each chosen eventuality.

B)N -K Contingency analysis

Power system status variables following a disturbance are predicted, and numerous component failures are modeled using the N-K contingency analysis. It is a crucial instrument for assessing the security of power systems, particularly in situations where numerous component failures may require more than the N-1 contingency. The most important scenarios are determined, and their severity is ranked using the N-K contingency analysis. Next, load flow studies are used to assess each outage separately to make sure the system can handle unique conditions like grid supply failure. The N-K contingency analysis is also used to examine how the system behaves in a steady state following the breakdown of different pieces of equipment and to assess how equipment failure or maintenance affects the power system. It involves the electricity system's capacity to endure loss of two components simultaneously.

C)*Probabilistic Contingency analysis*

This technique involves different methods to assess the occurrence and impact of multiple contingencies according to the likelihood of occurrence. In probabilistic contingency analysis, load and generation data are taken into consideration while modeling the steady state contingency analysis using a probabilistic formulation. Some of the techniques used in this method are

Monte Carlo Simulation

This technique simulates various system configurations and contingencies by creating a large number of random samples. It is possible to ascertain the likelihood of various scenarios and how they might affect the power system by doing several power flow analyses.

Sensitivity-Based Analysis

This type of analysis aids in locating susceptible spots and important parts of the power system. The impact of uncertainties on the system reliability can be measured by analyzing how sensitive certain system characteristics are, such as line loading and generator capacities.

IV.TYPES OF CONTINGENCIES

A) GENERATOR CONTINGENCY

Generator contingency means a generator on a power system unexpectedly loses generating capacity. Generator contingency has a impact on the reliability of the system. If a generator outage occurs, it decreases the amount of available generation which causes blackout or voltage instability. There are several tools and strategies to avoid the risks caused by the generator contingency. One common approach to compensate the loss of a generator is to use reserve generation. Another common approach is to use remedial action schemes (RAS). RAS involves disconnecting of loads or generators or rerouting the power flows. By modeling the generator contingencies operators can develop the strategies to ensure the system reliability.

Generator contingency plan is as follows:

1. Power outage detected.
2. Generator starts.
3. Critical loads connected to the generator.
4. Generator performance is monitored.
5. Power is restored.

B)Transformer Contingency

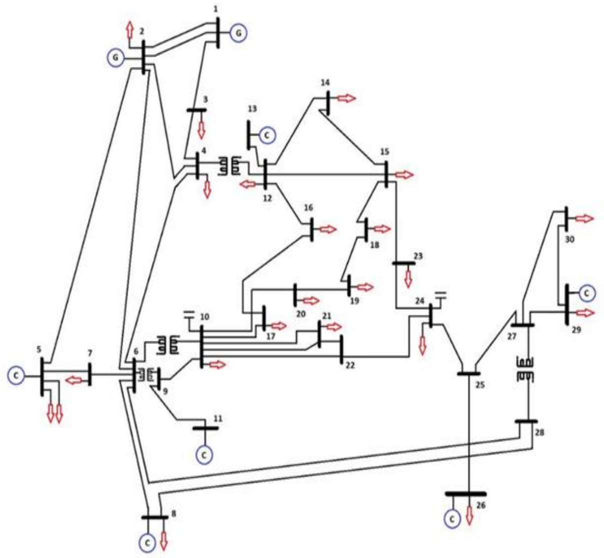
A transformer contingency occurs when a power transformer fails. It has a impact on the reliability of the power grid, as transformers are essential for the transfer of electricity. Transformer contingency is caused by different factors i.e., overloading, aging, faults, maintenance.

The impact of the transformer contingency on the power grid will depends on the number of factors that includes:

1. The size and importance of the transformer.
2. The availability of other resources.
3. The location of transformer.

Some common mitigation strategies are

1. Rerouting the power flows around the failed transformer.
2. Operating generators at higher or lower output levels.
3. Reducing loads in affected areas.
4. Installing standby transformers.
5. Using backup sources.



C)Transmission line contingency

Transmission line contingency is an occurrence that results in the loss of a power system's transmission lines.

Contingency for transmission lines has the significant impact on the system reliability, stability, voltage instability or can lead to overloads.

Single line outage

A single transmission outage is conducted, and the most serious instances are examined. Single line outages are caused by different factors that includes lightning strikes, weather related damages, equipment failures and human error. When the single line outage occurs the power system operator must take a quick action to reconfigure the grid and restore the power in affected areas.

There are mitigation strategies to reduce the impact the effect of single line outage and they are

1. N-1 planning.
2. Transmission line redundancy.
3. Protective relaying.
4. Special protection schemes.

double circuit line outage

When two transmission lines connected to the same bus are removed and examined, this is referred to as a double circuit line outage. When a double circuit outage occurs there will be a power loss to the customers. Transmission system operators have a contingency plan to prepare for a double circuit outage i.e., rerouting power, shedding load, emergency imports.

C)Single circuit line with compensator outage

A compensator and a single circuit line are taken out and examined. When the compensator is out of service it can affect the voltage and power flow on the transmission line. There are many ways to mitigate the effects of single circuit line with compensator i.e., reducing the loads on the line, using a static VAR compensator, using a STATCOM, using a thyristor-controlled series compensator.

Increase or decrease in load

A number of factors, including variations in the weather, shifts in client demand, and equipment failure, can cause an increase or decrease in load. This may have an effect on the power flow of the system patterns and cause problems with voltage stability.

Faults

There are several causes of faults, including lightning strikes, malfunctioning machinery, and human error. This could result in a short-circuit situation in the system, which could halt operations or harm system parts.

Switching operations

These include connecting and disconnecting capacitors and transformers, among other system components. If not properly coordinated, this could affect the system's power flow patterns and result in overloading or voltage instability.

V.MATHEMATICAL MODELLING OF PERFORMANCE INDEX

Contingency analysis is calculated based on the screening, ranking and evaluation.

1. *Screening:* It is used to identify and prioritize the contingencies which causes problems and lowering the real time power system to a simulation implementable method one which can be implemented in a simulation.
2. *Ranking:* It refers to the process of arranging contingencies based on their severity.
3. *Evaluation:* The influence of each component in a power system is calculated by calculated power flows both before and after the contingency.

Performance index:

Using the performance index (PI), one can rank the seriousness of different contingencies. The higher PI value the higher the severity of the contingency.

$$PI = PI_V + PI_{MW}$$

Where, PI_V= Voltage performance index

PI_{MW} = active power performance index

Voltage performance index:

$$PI_V = \sum_{i=0}^{n} \frac{W}{2z}\left\{\frac{\left(|V_i| - |V_i^{sp}|\right)}{\Delta V_i^{lim}}\right\}^{2z}$$

Where, n= quantity of buses.

z=penalty factor's exponent.

W=factor of weighting.

$|V_i|$=Bus I's Voltage magnitude.

$|V_i^{sp}|$=Bus I's Specified voltage magnitude.

$\Delta V_i^{\lim}$=voltage derivative limit, which is the mean of the bus I permissible maximum and minimum voltages.

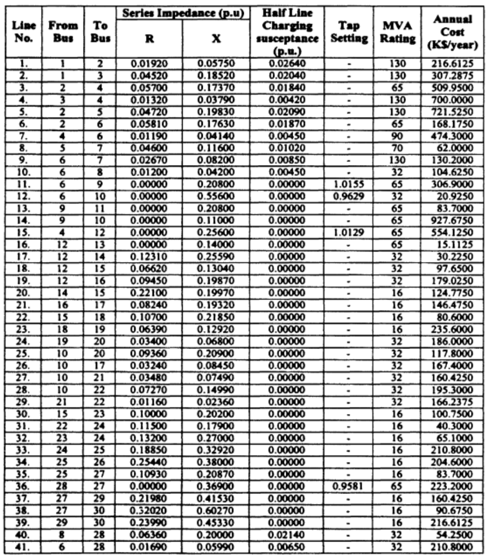
Active power performance index:

$$PI_{MW} = \sum_{m=1}^{N_L} \frac{W_m}{2n}\left(\frac{P_{im}}{P_{im}^{max}}\right)^{2n}$$

Where ,

$$P_{im}^{max} = \frac{V_i}{x} z$$

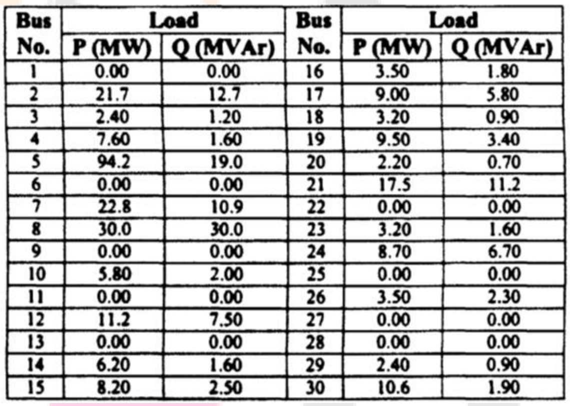
Transmission line data



Line No.	From Bus	To Bus	Series Impedance (p.u)		Half Line Charging susceptance (p.u.)	Tap Setting	MVA Rating	Annual Cost (K$/year)
			R	X				
1.	1	2	0.01920	0.05750	0.02640	-	130	216.6125
2.	1	3	0.04520	0.18520	0.02040	-	130	307.2875
3.	2	4	0.05700	0.17370	0.01840	-	65	509.9500
4.	3	4	0.01320	0.03790	0.00420	-	130	700.0000
5.	2	5	0.04720	0.19830	0.02090	-	130	721.5250
6.	2	6	0.05810	0.17630	0.01870	-	65	168.1750
7.	4	6	0.01190	0.04140	0.00450	-	90	474.3000
8.	5	7	0.04600	0.11600	0.01020	-	70	62.0000
9.	6	7	0.02670	0.08200	0.00850	-	130	130.2000
10.	6	8	0.01200	0.04200	0.00450	-	32	104.6250
11.	6	9	0.00000	0.20800	0.00000	1.0155	65	306.9000
12.	6	10	0.00000	0.55600	0.00000	0.9629	32	20.9250
13.	9	11	0.00000	0.20800	0.00000	-	65	83.7000
14.	9	10	0.00000	0.11000	0.00000	-	65	927.6750
15.	4	12	0.00000	0.25600	0.00000	1.0129	65	554.1250
16.	12	13	0.00000	0.14000	0.00000	-	65	15.1125
17.	12	14	0.12310	0.25590	0.00000	-	32	30.2250
18.	12	15	0.06620	0.13040	0.00000	-	32	97.6500
19.	12	16	0.09450	0.19870	0.00000	-	32	179.0250
20.	14	15	0.22100	0.19970	0.00000	-	16	124.7750
21.	16	17	0.08240	0.19320	0.00000	-	16	146.4750
22.	15	18	0.10700	0.21850	0.00000	-	16	80.6000
23.	18	19	0.06390	0.12920	0.00000	-	16	235.6000
24.	19	20	0.03400	0.06800	0.00000	-	32	186.0000
25.	10	20	0.09360	0.20900	0.00000	-	32	117.8000
26.	10	17	0.03240	0.08450	0.00000	-	32	167.4000
27.	10	21	0.03480	0.07490	0.00000	-	32	160.4250
28.	10	22	0.07270	0.14990	0.00000	-	32	195.3000
29.	21	22	0.01160	0.02360	0.00000	-	32	166.2375
30.	15	23	0.10000	0.20200	0.00000	-	16	100.7500
31.	22	24	0.11500	0.17900	0.00000	-	16	40.3000
32.	23	24	0.13200	0.27000	0.00000	-	16	65.1000
33.	24	25	0.18850	0.32920	0.00000	-	16	210.8000
34.	25	26	0.25440	0.38000	0.00000	-	16	204.6000
35.	25	27	0.10930	0.20870	0.00000	-	16	83.7000
36.	28	27	0.00000	0.36900	0.00000	0.9581	65	223.2000
37.	27	29	0.21980	0.41530	0.00000	-	16	160.4250
38.	27	30	0.32020	0.60270	0.00000	-	16	90.6750
39.	29	30	0.23990	0.45330	0.00000	-	16	216.6125
40.	8	28	0.06360	0.20000	0.02140	-	32	54.2500
41.	6	28	0.01690	0.05990	0.00650	-	32	210.8000

Fig.8.1. Transmission line data

Load data



Bus No.	Load		Bus No.	Load	
	P (MW)	Q (MVAr)		P (MW)	Q (MVAr)
1	0.00	0.00	16	3.50	1.80
2	21.7	12.7	17	9.00	5.80
3	2.40	1.20	18	3.20	0.90
4	7.60	1.60	19	9.50	3.40
5	94.2	19.0	20	2.20	0.70
6	0.00	0.00	21	17.5	11.2
7	22.8	10.9	22	0.00	0.00
8	30.0	30.0	23	3.20	1.60
9	0.00	0.00	24	8.70	6.70
10	5.80	2.00	25	0.00	0.00
11	0.00	0.00	26	3.50	2.30
12	11.2	7.50	27	0.00	0.00
13	0.00	0.00	28	0.00	0.00
14	6.20	1.60	29	2.40	0.90
15	8.20	2.50	30	10.6	1.90

Fig.8.2. Load data

VI.SIMULATION

In IEEE 30 bus system, there are 30 buses, 2 generators, 4 transformers, 43 transmission lines, 21 loads and 6 compensators which are shunt type.

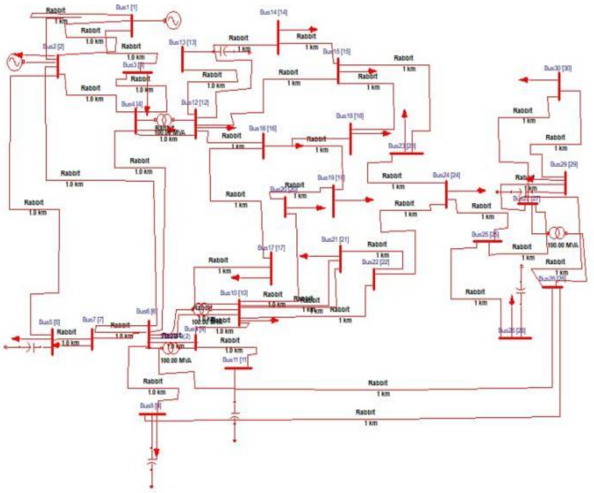
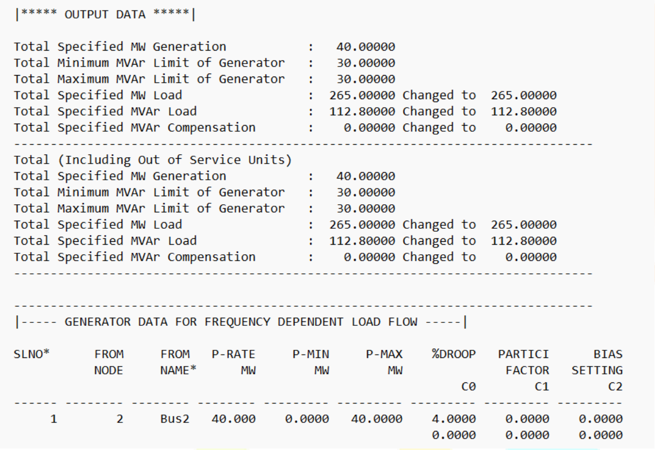


Fig.6.1. Simulation diagram of IEEE 30 bus system

Among all the buses, one bus is used as slack bus at bus 1. There is a PV generator. Two winding transformers are used. Arrow marks upwards or downwards indicates load at desired point.

Load flow analysis



```
|***** OUTPUT DATA *****|

Total Specified MW Generation           :   40.00000
Total Minimum MVAr Limit of Generator   :   30.00000
Total Maximum MVAr Limit of Generator   :   30.00000
Total Specified MW Load                 :  265.00000 Changed to  265.00000
Total Specified MVAr Load               :  112.80000 Changed to  112.80000
Total Specified MVAr Compensation       :    0.00000 Changed to    0.00000
-------------------------------------------------------------------------------
Total (Including Out of Service Units)
Total Specified MW Generation           :   40.00000
Total Minimum MVAr Limit of Generator   :   30.00000
Total Maximum MVAr Limit of Generator   :   30.00000
Total Specified MW Load                 :  265.00000 Changed to  265.00000
Total Specified MVAr Load               :  112.80000 Changed to  112.80000
Total Specified MVAr Compensation       :    0.00000 Changed to    0.00000
-------------------------------------------------------------------------------


-------------------------------------------------------------------------------
|----- GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD FLOW -----|

SLNO*      FROM     FROM   P-RATE     P-MIN     P-MAX    %DROOP   PARTICI      BIAS
           NODE     NAME*      MW        MW        MW              FACTOR   SETTING
                                                             C0        C1        C2
------ -------- -------- -------- --------- --------- --------- --------- ---------
     1        2     Bus2   40.000    0.0000   40.0000    4.0000    0.0000    0.0000
                                                         0.0000    0.0000    0.0000
```

Fig.6.2. Load flow analysis results

Transmission line results

S.NO	LINE OUTAGE	SEVERITY INDEX	RANK
1.	1-2	16.3033	1
2.	1-3	7.3224	2
3.	3-4	7.15225	3
4.	2-5	6.394	4
5.	4-6	4.621	5
6.	6-7	2.348	6

Fig.6.3. Transmission line results

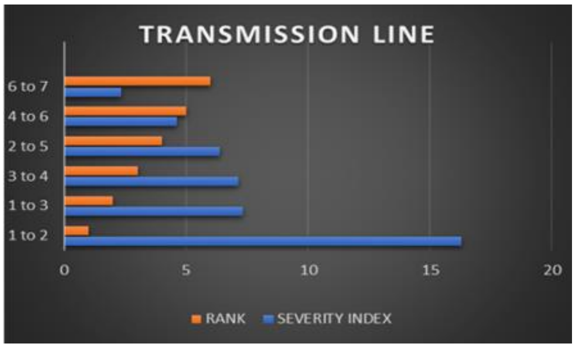


Fig.6.4. Bar graph of Transmission line

Transformer results

S.NO	LINE OUTAGE	SEVERITY INDEX	RANK
1	17-16	12.415	1
2	16-19	4.212	2
3	17-10	2.954	3
4	16-12	2.0454	4
5	10-20	0.909	5

Fig.6.5. Transformer results

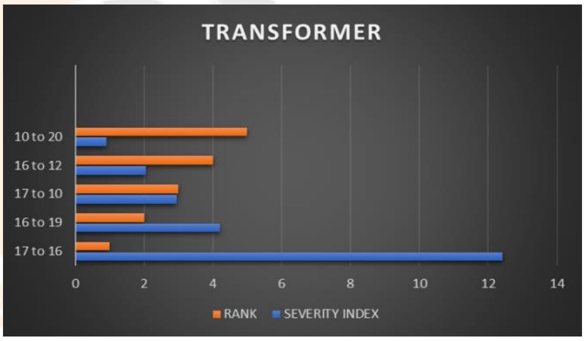


Fig.6.6. Bar graph of Transformer

Generator results

S.NO	LINE OUTAGE	SEVERITY INDEX	RANK
1	6-4	0.0346	1
2	1-3	0.0515	2
3	1-2	0.3260	3

Fig.6. Generator results

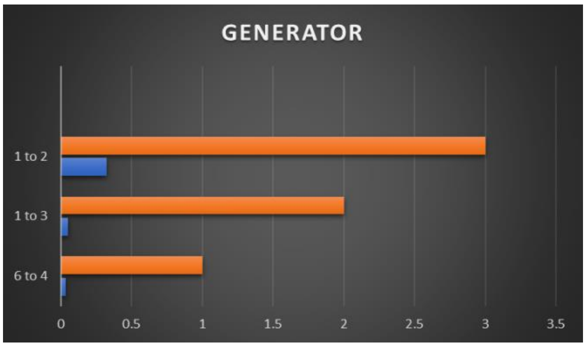


Fig.11.7. Bar graph of Generator

When all results are observed, transmission line severity index is high compared to generator and transformer contingencies with the severity index of 16.3033. Generator has least severity index with severity index of 0.0346.

Advantages

1.Identification of system sensitivities like voltage instability, overloads etc.

2.Increases the system's stability and dependability.

3.Provides valuable information to operators and planners related to equipment and maintenance.

CONCLUSION

To find serious contingencies in the power system, contingency analysis is carried out. It entails examining how component failures affect a power system's stability, dependability, and security. The contingency's severity is ranked according to the computed performance index. The reliability and security of the electricity system are ensured by the decisions made by planners and system operators on expansion, maintenance, and operation. Through the integration of this methodology into their risk management and strategic planning procedures, organizations may improve their capacity and preparedness to navigate through unpredictable and demanding situations. A vital technique for power system planning and management is contingency analysis, which aids in locating possible weak points and formulating plans to keep the system safe and dependable. By assisting power systems in being ready for the unexpected, contingency analysis ensures stability and dependability.

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