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Article

N-1 Security Contingency Analysis through the IEEE Bus Application Performance Index Method 9

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Abstract. This research is to test the N-1 security contingency analysis using the IEEE 9 bus application performance index method. In this study, the N-1 contingency was carried out where only one discharge between buses occurred which was implemented on the IEEE 9 bus system using the Newton Raphson power flow method. . From the results of the power flow calculation, the active power value of the channel is taken with the maximum iteration limit that has been determined to achieve a convergent value in the method. Channel ranking is based on Performance Index (PI) values. PI calculation is done every channel release with the help of Etap 12.6 software. In the first channel discharge scenario, the largest PI value is found on channels 9-8 with PI 3.0658 because the bus is overloaded. Not all channels are overloaded when a channel is released, one of which is still able to accommodate the load, this occurs on channels 3 Bus 7 to Bus 8 of 0.5418. Then to overcome these advantages added loading power so as not to become too heavy and the value of the performance index is reduced.

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1. Introduction

In the activities of the electric power framework, there are many disturbances that cannot be avoided, but assuming we see a recurrence of disruptive influences, the transmission line is the best known [1-2]. A disturbing influence can be a short out or separation of one of the channels, etc. For safety efforts from the influence of skeletal interference, it is important to separate the channel from the framework organization, with the non-working of the line (Line outage) there will be a change in the development of forces in different directions due to changes in power flow [3-6].

Transmission lines play an important role in determining the degree of dependence of the electric power frame [7-11]. Composite unwavering quality assessment is one of the strategies for assessing generator and transmission reliability [12-16]. Events caused by disruptive influences (forced outages) or maintenance (regulated outages) that make electrical power frame components channeled (outages) are called N-1 possibilities [17-18].

The investigation likely expects to find out which channels are overloaded or which channels are most vulnerable to entering the base period. Aggravation events in feeders can be reactivated [19-20]. Investigation of possibilities should be possible with different techniques, one of which is the presentation file strategy (1P1Q). The investigation of possibilities using the exhibition file technique is carried out by creating a situation of disruptive influence event (likely) and focusing on the demand for presentation recordings by looking at the calculation of dynamic power and voltage after the probability occurs [21]. To aid exploration, the creators used ETAP 12.6 programming to calculate the value of the dynamic power flow framework results taken from the 9-bus framework in IEEE [22]. To determine changes in dynamic power and receptive power, the technique used in this last task is Newton Raphson [23-28]. After obtaining the results of power flow processing in ETAP 12.6 [29-34]

Therefore, it is important to direct the focus on the well-being and reliability of electric power systems by leading power flow testing against the possibility of (N-1) [35-39]. The results of this study can be used to improve the most common way of recognizing electric power system components with weak conditions [40]. So that further steps can be taken through the improvement of the electric power frame so that the electric power frame can work with a higher level of reliability [41].

In writing this final project, the author studied several studies taken, one of which was in a study entitled "Contingency Analysis of the Java-Bali 500 kV System to Design Operation Safety". This study discusses the contingency caused by the detachment of the transmission line that occurs in the Java-Bali 500kV interconnection system [42].

1.1 Electric Power System

An electric power frame is a variety of force and load focus that are connected to each other by a transmission and dispersion network so that they become interconnected [43].

1.2 Power Station

A fundamental part in the age sub-framework is the generator which is a source of electrical energy [44].

1.3 Transmission

Electric power from the focus of creation is disseminated to various points through transmission lines. The voltage of the PLN transmission line is 150kV known as SUTT and 275-500kV known as SUTET [45].

1.4 Electric Power System Reliability

The parameters that determine the reliability and quality of electricity a measure of reliability and quality of electricity in general is determined by several parameters as follows: (1) Frequency with hertz (Hz) units, which is the magnitude of the exchange current pattern (AC) every second and (2) Voltage with units of volts (V).

1.5 Power Flow Analysis

Power flow study is the determination or calculation of voltage, current, active power and reactive power contained at various points of the electrical network with the power equation formula is as follows:

$$Pp|Vp|\sum_{q=1}^{n}|Vq|[Gpq\ \cos(\delta p-\ \delta q)+Bpq\ \sin(\delta p-\ \delta q)]$$

$$Qp=\ |Vp|\sum_{q=1}^{n}|Vq|[Gpq\ \sin(\delta p-\ \delta q)+Bpq\ \cos(\delta p-\ \delta q)]$$

1.6 Newton Rapson Method

Din the iteration completion of the Newton Raphson method, the values of the active power (Pp) and reactive power (Qp) that have been calculated must be compared with the predetermined values. In general the equation can be written as follows:

$$\begin{bmatrix}\Delta p\\ \Delta q\end{bmatrix}(k)=\begin{bmatrix}H & N\\ J & K\end{bmatrix}(k)\begin{bmatrix}\Delta\delta\\ \dfrac{\Delta|v|}{|v|}\end{bmatrix}(k)$$

1.7 Power Triangle

The power triangle is a state that describes the state of complex power, active power and reactive power. The sketch of the power triangle is inductive with the angle between the complex power and the active power being θ. The components of the power triangle include active power, reactive power and power factor.

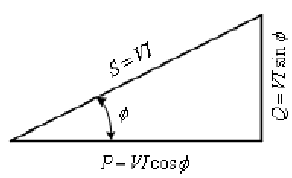

Figure 1. Of the power triangle

1.8 N-1 Contingency Analysis

The possibility of N-1 is a possibility resulting from the arrival of one part of the framework, in particular a transmission line or generator. Contigency selection to group channels, a parameter is needed that can be used to calculate how severely the channel affects the power system, the idea of index performance (PI) can meet this need

$$PI=PIv+PIp\ (1.17)$$

Information:

IP : Performation Index

PIv : Voltage Index performance value

PI p : Active power Index performance value

Active power index Performance Equation:

$$PIp = \sum_{n=1}^{L} \left(\frac{Pi}{Pi\ max}\right)^{2.1} \quad (1.18)$$

Information:
Pip : Performance of the Aktfi power index on the transmission line
Pi : Active power flowing after contigency (N-1) occurs on the channel (MW)
Pi max : maximum active power capacity flowing on the line (MW)
L : Number of transmission lines in the system
n : Specified exponent =1

Voltage index performance equation :

$$PIv = \sum_{i=1}^{N\ pq} \left[\frac{2(Vi - Vi\ nom)}{Vi\ max - Vi\ min}\right]^{2} \quad (1.19)$$

Information:
Piv : Performance of voltage index on bus
Vi : Bus voltage i after N-1 contigency (Kv) occurrence
Vimin : Minimum voltage limit (135 kV)
Vimax : Maximum voltage limit (165 kV)
Vinom : Average of Vimax and Vimin (150 kV)

1.9 Contigency Analysis Using ETAP 12.6
Contigency analysis carried out using the ETAP application is carried out by:
1. Running power flow.
2. Select contigency tools in the ETAP application.
3. Set up a contigency case study according to the contigency scenario to be simulated.
4. Running a simulation of N-1 contigency.
5. View the table of performance index sequence results.

2. Method
2.1 Type of Research
The type of research carried out is research with a qualitative approach. This research was conducted to test the effectiveness of the method used, a simulation was carried out on a system of 3 generators 9 buses and the software used was ETAP 12.6.

2.2 Research Implementation

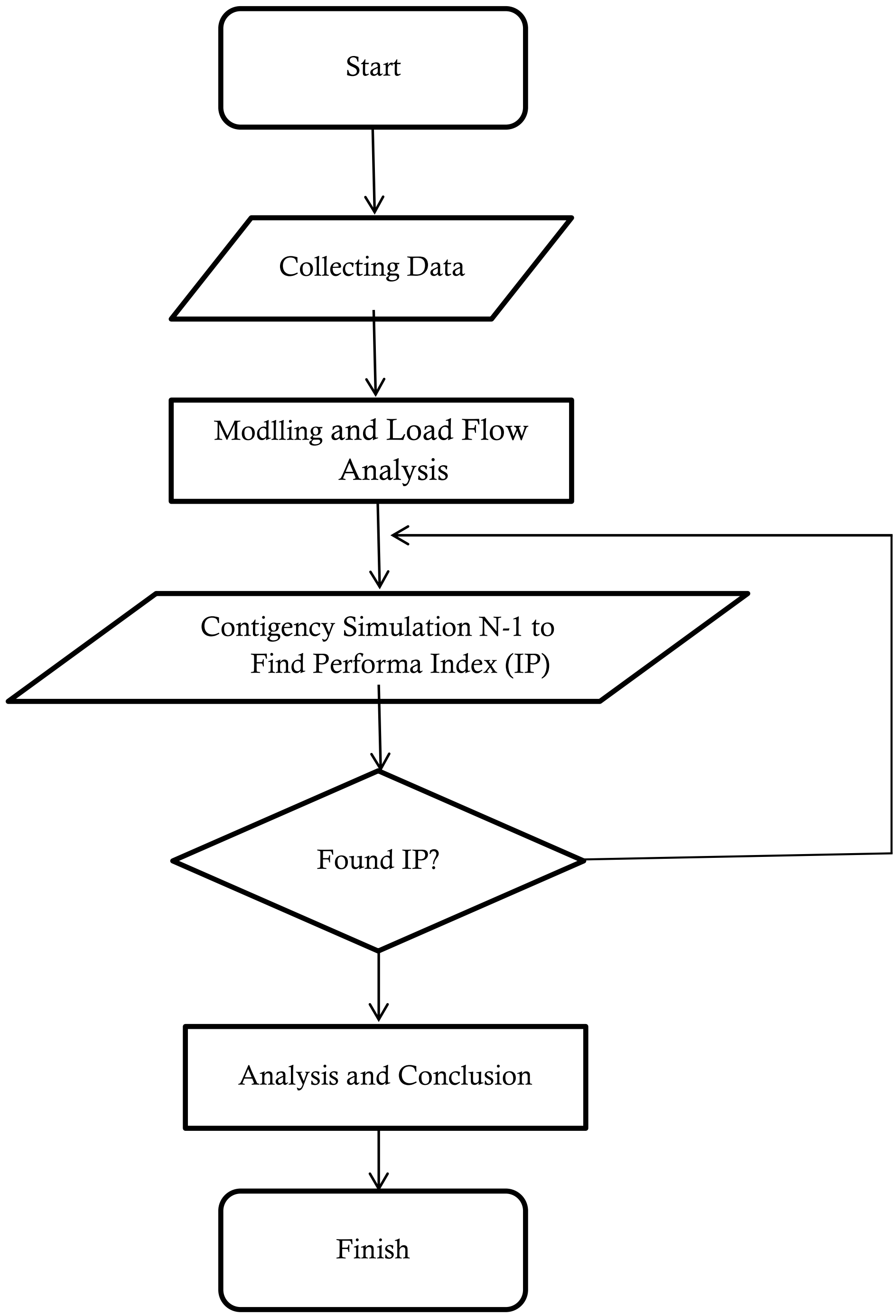

Figure 2. Flowchart of research implementation

3. Results and Discussion

3.1 Simulation Result

To achieve power output values with high accuracy, several value parameters are needed that are used in Newton Raphson mentioned in Chapter 3. Here are the parameter values used for contigency problem solving on Newton Raphson's method : Iteration : 9 Base Mva : 100 IEEE 9 Bus System to be analyzed can be seen from Figure 3. Data from this system can be seen in Tables 1, 2 and 3.

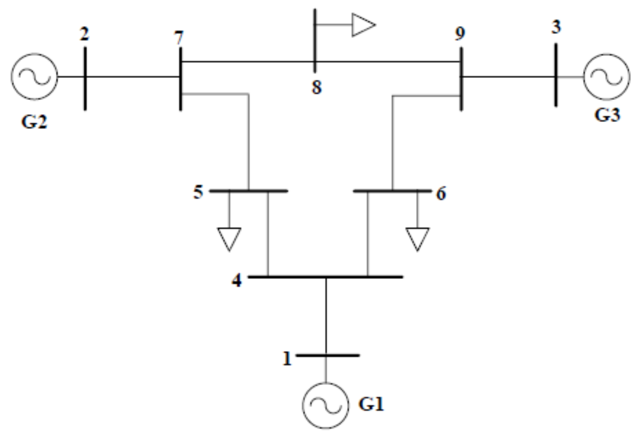

Figure 3 Single line diagram of 9 buses

Table 1. Data generator on IEEE 9 bus systems

ID Generator	XD' (pu)	M	Kd(pu)
G1	0.0608	0.1245	0.01
G2	0.1198	0.0340	0.01
G3	0.1813	0.0160	0.01

Table 2. Generation power and load data on IEEE 9 bus systems

Bus No.	Bus Voltage (pu)	Generator Power		Load Power	
		P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
1	1.040	2	0	0	0
2	1.025	163	6	0	0
3	1.025	85	6	0	0
4	1	0	0	0	0
5	1	0	0	12.5	5
6	1	0	0	9	3
7	1	0	0	0	0
8	1	0	0	10	3.5
9	1	0	0	0	0

Tabel 1. IEEE 9 bus system channel data

No.	Initial Bus	Final Bus	R (pu)	X (pu)
1	1	4	0	0.00576
2	2	7	0	0.00625
3	3	9	0	0.00586
4	4	5	0.001	0.0085
5	4	6	0.0017	0.0092
6	5	7	0.0032	0.0161
7	6	9	0.0039	0.017
8	7	8	0.00085	0.0072
9	8	9	0.00119	0.01008

3.2 Load Flow Simulation Results

The load flow simulation results applied to the IEEE 9 bus system are seen in figure 4 where the purple color indicates the bus is under normal conditions.

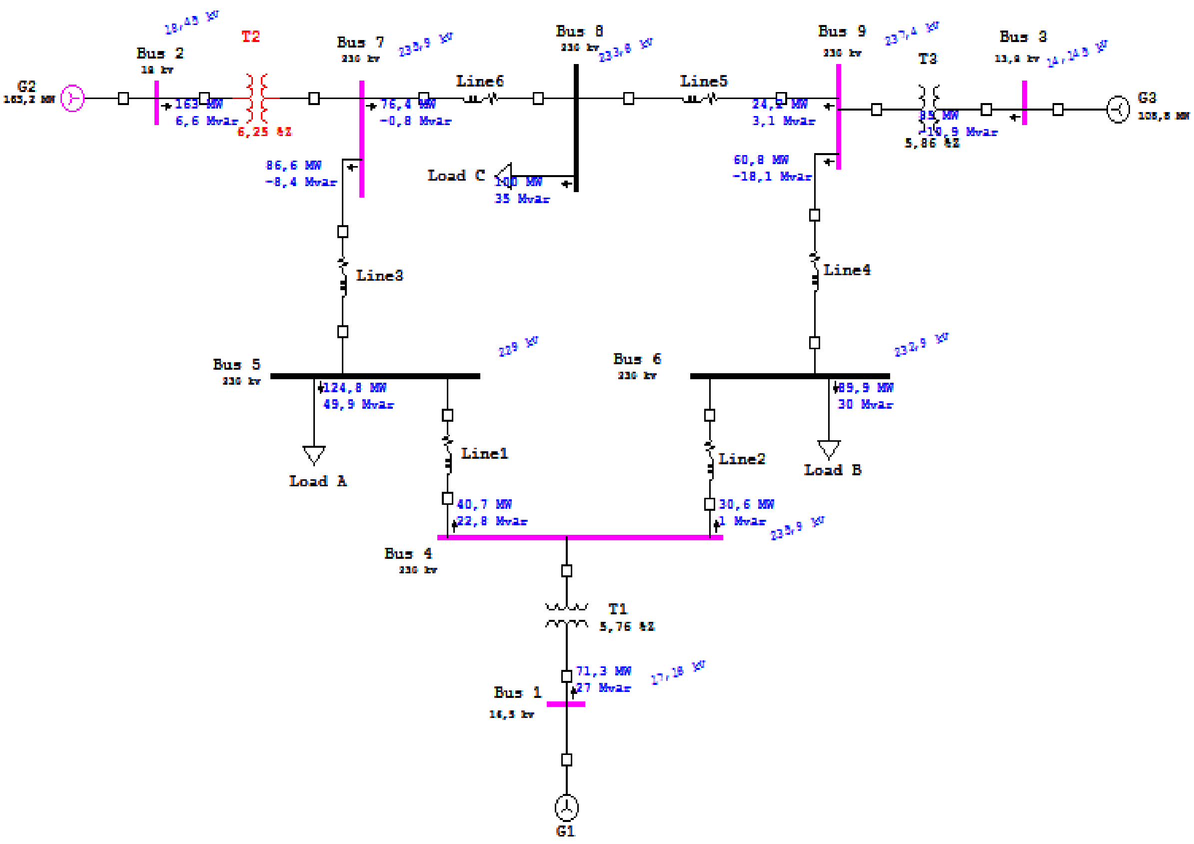

Figure 4. Single line diagram load flow results

3.3 Contigency Simulation Results (N-1)

3.3.1 First Scenario on Line 1

Table 4. Load flow results after N-1 contingency

Load Flow Kontigensi					
Bus		**Load Flow**			
From ID	To ID	MW	Mvar	Amp	%PF
Bus 1	4	48.128	4.474	1659.7	99.6
Bus 2	7	163	41.938	5266.8	96.8
Bus 3	9	85	-5.579	3476.9	-99.8
Bus 4	6	49.126	3.178	119.1	99.8
	1	-49.12	-3.178	119.1	99.8
Bus 5	7	-102.409	-40.956	306.9	92.9
Bus 6	4	-48.724	-17.735	127.6	94.0
	9	-42.577	-12.699	109.3	95.8
Bus 7	5	106.852	35.428	281.4	94.9
	8	56.131	-10.341	142.7	-98.3
	2	-162.98	-25.087	412.2	98.8
Bus 8	9	-41.47	-31.649	130.6	79.5
	7	-55.86	-2.404	140.0	99.9
Bus 9	6	43.269	-21.878	118.2	-89.2
	8	41.727	12.252	106.1	95.9
	3	-84.996	9.626	208.6	-99.4

The result of the power flow that occurs when after the N-1 contingency occurs the largest active power and reactive power is found in Bus 2 to Bus 7 with an active power result of 163 MW and a reactive power of 41.938 Mvar. After seeing the power flow, we can find the performance index that occurs when the channel is detached with the equations contained in the theoretical foundation. Contigency Performance Index Calculation The analysis in the simulation relies on the PI value to find out which channels are critical in the event of N-1 contigency in the IEEE Bus 9 system. Obtained Ranking of PI values when contigency occurs in the table.

Table 5. Etap simulation results of PI values and rankings at N-1 contigency

No	Bus Channel		PI Value in Line 1 Scenario	Rank
	From Bus	To Bus		
1	9	8	3.0658	1
2	8	9	2.9704	2
3	4	6	2.718	3
4	6	4	2.5872	4
5	5	7	2.433	5
6	7	5	1.5238	6
7	9	3	1.0858	7
8	3	9	1.0643	8
9	2	7	1.0625	9
10	7	2	1.0858	10
11	1	4	0.63	11
12	4	1	0.613	12
13	9	6	0.5858	13
14	6	9	0.5532	14
15	7	8	0.5418	15
16	8	7	0.5414	16
Total PI Value			**22.97794**	

For the lowest PI values, namely on channels 1-4 with a PI value of 0.63, channels 4-1 with PI 0.613, channels 9-6 with PI 0.5858, channels 6-9 with PI 0.5532, channels 7-8 with PI 0.5418 and channels 8-7 with PI values 0.5414. When the lowest PI value during the contigency of the line is minimal, there will be overload, this is because the load is not too large and is still able to support not so much power.

3.4 Curve of P-V when Contigency

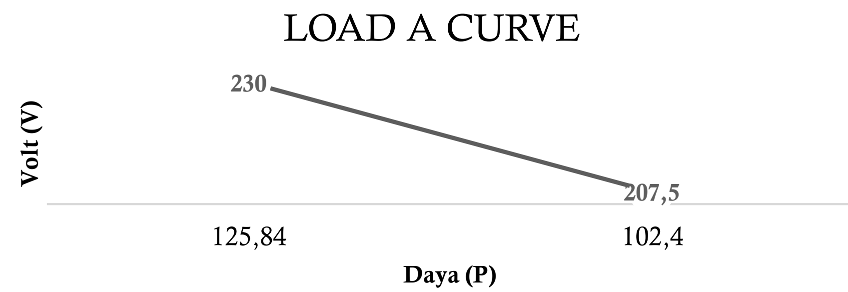

Figure 5. Curve of P-V contigency

In figure 4.4 at the time of the line break or the so-called contigency load A with a normal state power of 125.84 MW, with a voltage of 230 kV still in a safe condition in the PLN standard, to achieve the critical voltage of load A added power of 102.4 MW, with a voltage of 207.5. Therefore, when the contigency takes place with added power to the load, the bus voltage will be more critical Skenario Kontigensi Generator 2

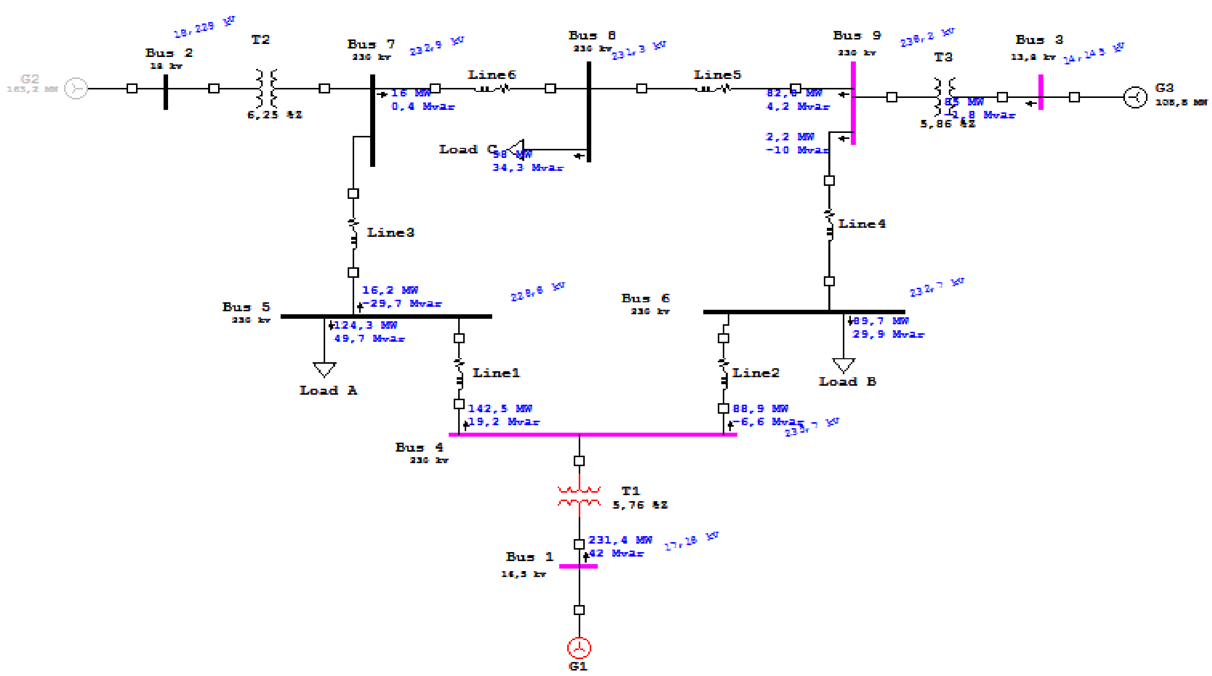

Figure 6. Contigency in generator

Table 6. Contigency power flow results

LOAD FLOW KONTIGENSI					
Bus		Load Flow			
From ID	To ID	MW	Mvar	Amp	%PF
Bus 1	4	231.384	42.009	7912.2	98.4
Bus 2	7	0	0	0	0
Bus 3	9	85	-1.785	3470.2	-100
	5	142.494	19.190	352.2	99.1
Bus 4	6	88.861	-6.633	218.3	-99.7
	1	-231.354	-12.558	567.6	99.9
Bus 5	4	-140.483	-20.029	358.4	99.0
	7	16.176	-29.685	85.4	-47.8
Bus 6	4	-87.582	-2.824	217.5	99.9
	9	-2.160	-27.089	67.4	7.9
	5	-16.022	-0.352	39.7	100
Bus 7	8	16.022	0.352	39.7	100
	2	0	0	0	0
Bus 8	9	-82.006	-18.981	210.1	97.4
	7	-15.996	-15.306	55.3	72.3
	6	2.191	-9.972	25.0	-21.5
Bus 9	8	82.805	4.156	202.6	-99.9
	3	-84.996	5.816	208.2	-99.8

In table 6 when contigency runs on generator 2 there is a lot of lack of power against the bus, therefore generator 1 has a large active power of 231.384 MW and reactive power of 42.009 Mvar so that the slack bus has considerable power against the power system lines.

3.5 Contigency Performance Index Calculation

Obtained Ranking of PI values when contigency occurs in the table

Table 7. Contigency PI value results

No	Channel Buses		PI Value in Generator 2 Scenario	Rank
	From Bus	To Bus		
1	4	5	12.25198	1
2	5	4	12.0537	2
3	9	8	11.8226	3
4	8	9	11.62019	4
5	1	4	10.69	5
6	4	1	10.52198	6
7	6	4	8.2337	7
8	4	6	4.76198	8
9	9	3	1.0726	9
10	3	9	1.0643	10
11	9	6	0.07391	11
12	7	8	0.0588	12
13	7	5	0.0498	13
14	8	7	0.04749	14
15	5	7	0.0397	15
16	6	9	0.01501	16
Total PI Value			**84.37774**	

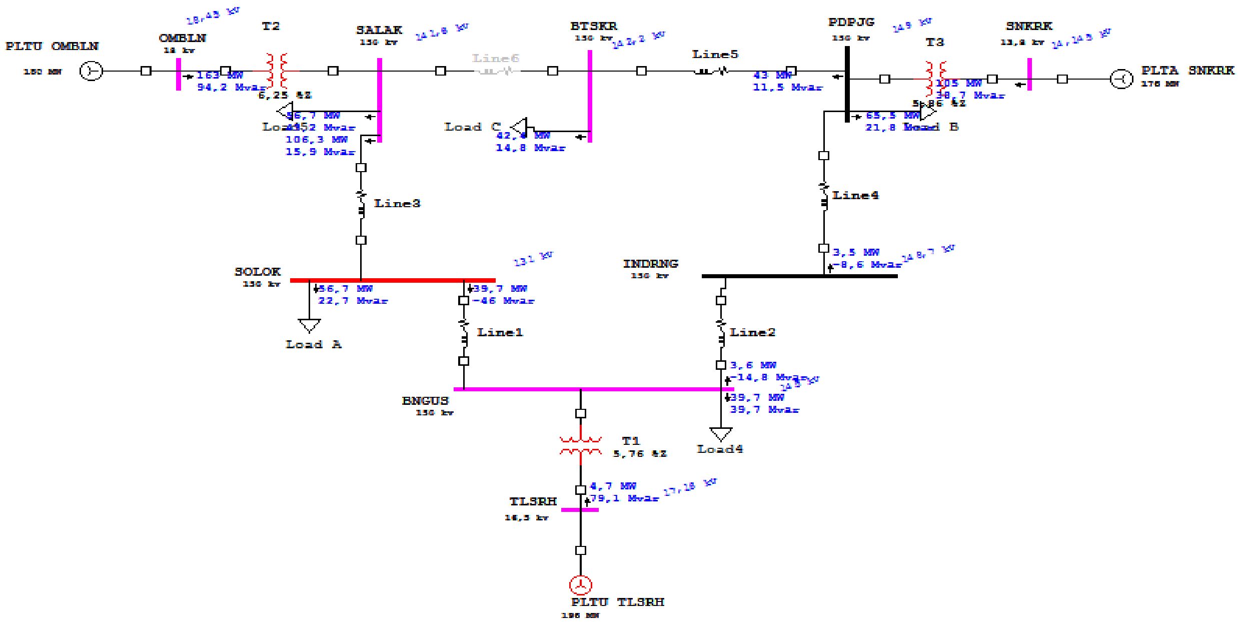

Figure 7. Contingency scenario against Salak-Btskr

After conducting experiments using Etap, a P value was obtained in each channel, where the value was used to find the PI value. After getting the PI value, it will be directly ranked from the largest value to the smallest value to see which channels cross the voltage limit. Analysis in the simulation relies on PI values to find out which channels are critical in the event of N-1 contigency in the system (Salak - Btskr).

Table 8. Salak- Btskr performance index results (Pi value results on line 6 (Salak-Btskr)

No	From	To	Pi Value Result	Rank
1	Tlsrh	Bungus	0.342	11
2	Ombln	Salak	1.0625	8
3	Snkrk	Pdpjg	1.0643	7
4	Bungus	Solok	291.891	2
5		Indrng	0.1236	13
6		Tlsrh	0.293	12
7	Solok	Bungus	370.534	1
8		Salak	4.098	5
9	Salak	Solok	3.038	6
10		Ombln	1.0313	9
11	Btskr	Pdpjg	71.402	3
12	Pdpjg	Indrng	0.015	16
13		Btskr	71.325	4
14	Indrng	Snkrk	1.004	10
15		Bungus	0.0193	14
16		Pdpjg	0.0192	15

Table 8 shows the results of the output values of PI values and rankings on power system channels with N-1 contigency and Newton Raphson's power flow method. It can be seen from the table of the largest PI values found on the Solok-Bungus channel with a PI value of 370.534, because the channel is not able to accommodate such a large amount of power, the channel is declared very bad or Overload on a channel. In the large N-1 contigency of channels after the Solok-Bungus channel, there is a channel that has the largest PI value, namely the Btskr-Pdpjg channel with a PI value of 71.402, the channel exceeds the operating limit of the power system. For the result of the lowest value in the PI when the occurrence of N-1 contigency there are several channels that are said to be in a normal state or either in the state of contigency occurring. for the lowest PI value, namely on the Pdpjg-Indrng channel with a PI value of 0.015, the Indrng- Bungus channel with a PI of 0.0193, when the lowest PI value occurs the contigency of the channel is minimal, there will be overload, this is because the load is not too large and is still able to support not so much power.

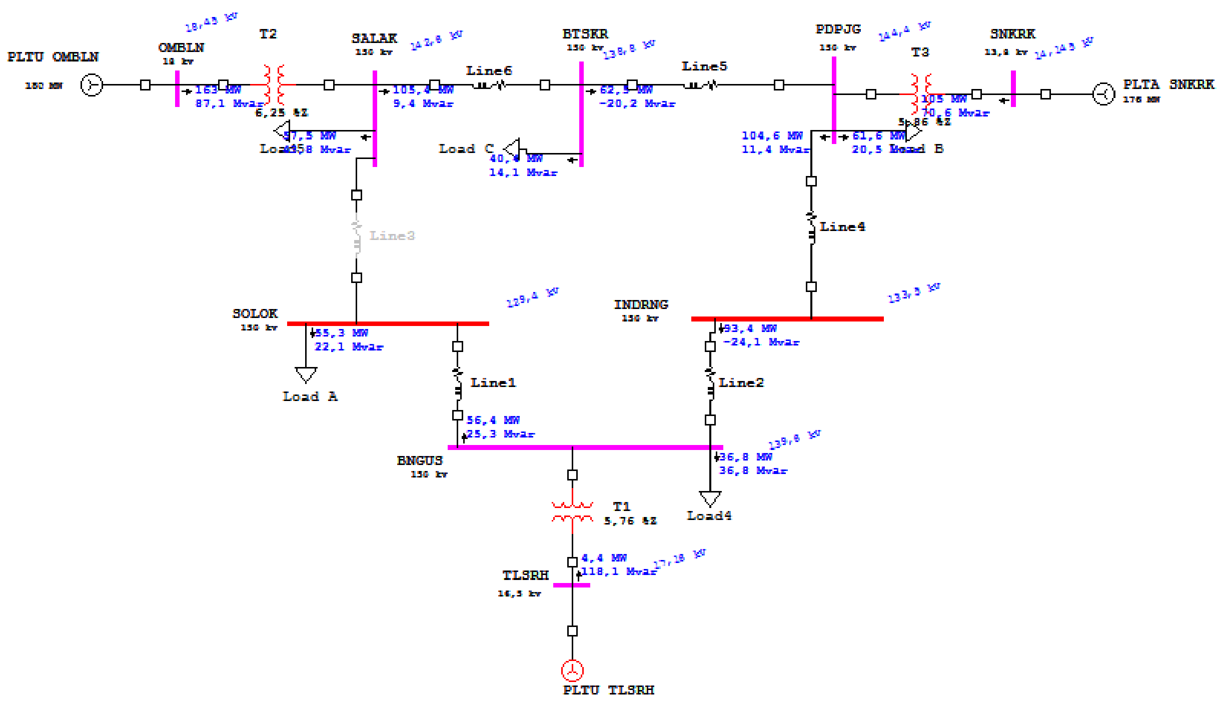

Figure 8. Contingency Scenario against Solok-Salak

After conducting experiments using Etap, a P value was obtained in each channel, where the value was used to find the PI value. After getting the PI value, it will be directly ranked from the largest value to the smallest value to see which channels cross the voltage limit. Analysis in the simulation relies on PI values to find out which channels are critical in the event of N-1 contingency in the system (Solok - Salak).

Table 9. Solok-Salak performance index results (Pi value results in line 3 (Solok-Salak))

No	From	To	Pi Value Result	Rank
1	Tlsrh	Bungus	0.32	16
2	Ombln	Salak	1.0625	14
3	Snkrk	Pdpjg	1.0643	13
4	Bungus	Solok	623.29	2
5		Indrng	8.151	8
6		Tlsrh	0.641	15
7	Solok	Bungus	719.83	1
8	Indrng	Bungus	9.495	6
9		Pdpjg	9.494	7
10	Salak	Btskr	7.463	10
11		Ombln	1.243	11
12	Btskr	Pdpjg	155.027	3
13		Salak	7.587	9
14	Pdpjg	Indrng	9.879	5
15		Btskr	144.239	4
16		Snkrk	1.129	12

Table 9. shows the results of the output value of PI values and rankings on power system lines with N-1 contigency and Newton Raphson's power flow method. It can be seen from the table of the largest PI values found on the Solok-Bungus channel with a PI value of 719.83, because the channel is not able to accommodate such a large amount of power, the channel is declared very bad or Overload on a channel. In the large N-1 contigency of channels after the Solok-Bungus channel, there are 5 channels that have the largest PI value, namely the Bungus-Solok channel with a PI value of 623.29, the Btskr-Pdpjg channel with PI 155.027, the Pdpjg-Btskr channel with PI 144.239 and the Pdpjg-Indrg channel with PI 9.879 the channel exceeds the predetermined operating limit. For the result of the lowest value in the PI when the occurrence of N-1 contigency there are several channels that are said to be in a normal state or either in the state of contigency occurring. for the lowest PI value, namely on the Tlsrh-Bungus channel with a PI value of 0.32, when the lowest PI value when the contigency of the channel is minimal, there will be overload, this is because a generator supplies power flow so that it is still able to support power.

4. Conclusion

Based on the results of research in the simulation of contigency analysis with the Newton Raphson power flow method on the Etap 12.6 software and the calculation of PI values to see the ranking in the N-1 contingency problem on the IEEE 9 bus system, the following conclusions can be drawn : When the N-1 contigency occurred there were 4 scenarios carried out on the system of 9 IEEE buses, including the first scenario on line 1 with a total PI value of 22.97794, the second scenario on line 3 with a total PI value of 62.81934, the third scenario on line 6 with a total PI value of 65.04814 and the last scenario of an outage on generator 2 with a total PI value of 84.37774.

The highest ranking on the total PI value at the time of N-1 contigency on the IEEE bus 9 system is when the generator scenario 2 is extinguished with a total PI value of 84.37774. because the main function of the generator is to convert energy from mechanical energy into electrical energy, so when the generator scenario 2 occurs the generator 2 does not conduct the power obtained as normal circumstances, therefore when the contigency takes place the power obtained only generators 1 and generators 3 and 2 generators are also not capable of providing large power to each bus and also load.

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