POST-CONTINGENCY ASSESSMENT BY SENSITIVITY FACTORS FOR POWER SYSTEM CONGESTION

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Abstract:

This paper outlines a calculation method for ac load flow for post contingency based on sensitivity factor for power system security calculated, the sensitivity factors are derived from dc power flow and implemented in MATLAB environment for post-contingency assessment. The contingency analysis plays a critical role in ensuring the safe, reliable, and efficient operation of power systems. It helps power system engineers identify potential problems and develop effective strategies for preventing or mitigating the impact of these problems on the power system. The dc power flow provides a simpler approach to power flow by performing a number of approximations and simplifies the power flow process to a simple equation system. To this end, we have developed a MATLAB program appropriate for contingency studies considering line outage distribution factors (LODFs) and generation Shift distribution factors (GSDFs). The programs in MATLAB are built to perform two-way communication between a load flow and contingency analysis routine. To validate the proposed algorithm, comparison is made between the ac power flow from PowerWorld and approximated solution obtained by our algorithm. The accuracy of the proposed approach is demonstrated by applying it to a 6-bus test system. The calculation outcomes indicate an improved efficiency of the developed approach in respect to the execution time and the result quality.

1 Introduction

Power system congestion happens when there is not sufficient power transmission system capacity to satisfy the demand for electricity. It can occur for a number of reasons, including rising electricity demand, declining generation capacity, or transmission equipment constraints. Congestion can result in a number of problems, such as voltage dips, power shortages and even blackouts. Congestion can also lead to an increase in electricity costs in impacted areas, as electricity providers can be required to pay more to supply electricity to clients. To alleviate power system congestion, power system operators can do many measures which can assist in balancing the demand and supply of electricity, thereby enabling the efficient and reliable operation of the power system [1,2]. Electrical system safety requires procedures aimed at keeping the system running in the event of component failure. For examples, a production unit can be shut down due to a failure of

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secondary equipment or a transmission line can be damaged by a weather storm and shut down by an emergency relay. When one failure results in another failure in the system, it is called cascading failure which leads to system blackout. System security is classified into three major functions which are carried out in an operation control centre. Which are, System monitoring (SCADA, state estimation), Contingency analysis and Security constrained OPF (SCOPF) [2]. As a next step, the second main safety task is contingency analysis. Results from this kind of analysis enable systems to be exploited in a protective manner. Most problems that arise on a power system can result in severe problems in such a short period of time that the system operator is unable to react quickly at all. Often this is the case with failures in sequence. Due to this feature of the system operation, modern operating systems are provided with contingency software to analyse potential problems in the system. Such reports are built on a pattern of the electrical system and are employed to examine failures and warn operators of possible overloading or out-of-range voltages. As a third safety function of the method, the optimal power flow under safety constraints is considered. With this option, a contingency analyse is used in combination with an optimal power flow that attempts to make adjustments to the optimal output dispatch, along with other corrections, such that when a safety analysis occurs, no contingency leads to a safety violation.

The power system operational states can be split into four different states: a. Optimal dispatch, b. Post-contingency, c. Secure dispatch and d. Secure post-contingency. Optimal economic dispatch: It is the condition of the power system before any eventuality. It is economically optimal, but may be insecure. Post-contingency: It is the condition of the power system after the occurrence of a disturbance. It is assumed that the condition has a security violation (transmission line or transformer outside its flow limit or bus voltage out of limit). Safe dispatch: It is the condition of the power system without any failure due to a contingency, but with adjustments to the operational settings to take into consideration the safety violation. Post-contingency security: is the condition of the power system when the contingency analysis is extended to basic operating conditions with adjustments. Impact of incident on a system is assessed by using the Line Failure Distribution Factor named d-factors or LODF and the generation shift distribution factor named a-factors or GSDF. Contingency analysis linear methods have been utilized for a number of years [2,4] in the assessment of the LODF matrix [5] and in the production shift distribution factor approximation. With the present paper, we report a computational program implemented within MATLAB for possible post-emergency scenarios based on the sensitivity factor to power system security which are estimated utilizing the dc power flow [6,7]. In common, failure affects any given system by shifting the amount of energy flowing on the interrupted elements in conditions prior to the failure to other locations in the system. Such variations can either decrease or increase the flow of energy on the facilities depending on the system architecture, load, and generation allocation. Computationally, dc load flow has many distinct advantages over conventional N-R power flow. As a result, dc power flow can be anticipated to be approximately ten time faster than standard power flow [8,9]. Therefore, the dc power flow is used to estimate the a and d sensitivity matrices, which are the focus of the developed post-contingency analysis program, more quickly [10,11].

2 Contingency analysis

The contingency analysis in power systems refers to the process of identifying and analysing potential problems that may occur due to the failure of a power system component or a combination of components. These problems can range from voltage fluctuations to blackouts, which can have severe consequences for power system operations, reliability, and security. Contingency analysis is an essential tool used by power system engineers to assess the impact of equipment failures or outages on the power system's overall performance. The analysis involves simulating various failure scenarios and examining how the power system responds to these scenarios. The objective is to identify critical contingencies that could cause system instability, voltage collapse, or overloading of critical components. There are two main types of contingency analysis: deterministic and probabilistic. Deterministic contingency analysis involves analysing predetermined contingency scenarios, whereas probabilistic contingency analysis involves analysing a set of possible contingency scenarios based on their likelihood of occurrence [12].

The results of contingency analysis are used to develop strategies for preventing or mitigating the effects of contingencies. These strategies may include installing backup equipment, implementing load shedding or load transfer schemes, or reconfiguring the power system to increase its reliability and resilience [13]. In this regard, contingency analysis is key to maintaining the secure, efficient and reliable condition of power systems. It helps power system engineers identify potential problems and develop effective strategies for preventing or mitigating the impact of these problems on the power system. The n – 1 contingency analysis, is based on failure or outage of one component in a power system, i.e., one generator or a one line in a transmission system (single failure). Whereas if two components fail or, outage (two failures), then this event is called n – 2 contingency analysis [12]. The contingency analysis procedure is given with a flow chart as shown in Figure 1.

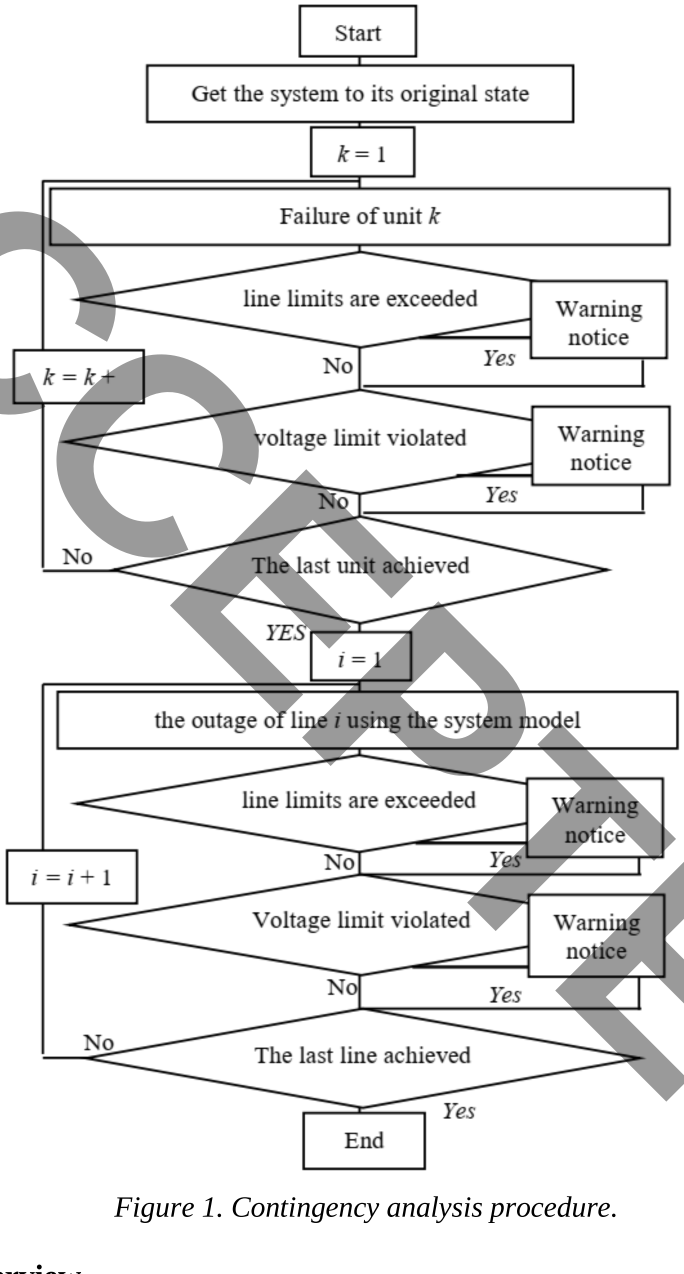

Figure 1. Contingency analysis procedure.

3 Safety analysis overview

The challenge of studying many thousands of potential failures can become very overwhelming if you want to report the results in a short period of time. An easy way to calculate potential overloads rapidly is to utilize linear sensitivity factors [14]. Such factors demonstrate the relative variation in line flows for production variations or in the system configuration and are obtained from the dc load flow.

4 Linear sensitivity factors

Two factors are considered in this approach: the generation change sensitivity factor noted here ($a_{l,i}$) and the line interruption distribution factor noted here ($d_{l,k}$). Derivation of the latter factors by using the dc load flow is described as follows [2,4].

4.1 Generation shift sensitivity factor (a_{li})

The GSDFs or a factor will supply line flow variations as a result of a changed production. GSDFs are determined as follows,

$$\Delta P_{n-m} = a_{n-m,i} \Delta P_{Gi} \tag{1}$$

$$\Delta P_{Gr} = -\Delta P_{Gi} \tag{2}$$

Were, (ΔP_{n-m}) is the change in active power flow between buses (n) and (m), (a_{n-m}) is the GSDF factor of a line joining buses n and m corresponding to change in generator at bus i; (ΔP_{Gi}) is change in generation at bus (i), with the reference bus excluded. (ΔP_{Gr}) is change in generation at the reference bus (generator) (r);
($a_{n-m,j}$) is calculated using the definition of a reactance matrix and the dc load flow approximation. The GSDF factor measures the incremental use of transmission network by generators and loads (consumers). We also notice that GSDFs are dependent on the selection of reference (marginal) bus and independent of operational conditions the system. For each line l between buses (n-m) of voltage angle (δ_n, δ_m) respectively, the power flow (P_l) on each line (n-m) using the dc PF may be expressed by the formula:

$$P_l = \frac{1}{x_l}\left(\delta_n - \delta_m\right) \tag{3}$$

$$P_i = \sum_{k(\text{bus conected to } i)}^{n} P_{ki} \tag{4}$$

It is worth noting that the main approximation made in the dc load flow is the lack of line losses in the dc load flow solution, which may be fairly balanced by adding to the dc power the expected losses in AC. Hence, in dc method, the losses assessed for the transmission system might be assigned to bus loadings. The need to estimate losses first is generally not difficult because the identified total "load" of the control zone is in fact the actual load added to losses.
Express the sensitivity matrix [X] with the dc load flow equation. Considering bus 1 is a slack bus, eliminate the 1st row and the first column from the admittance matric Y_{bus}, the inverse will constitute the sensitivity matrix X.

$$\theta = [X][P] \tag{5}$$

From definition of GSDF factors:

$$a_{li} = \frac{\partial P_l}{\partial P_{Gi}} = \frac{\partial}{\partial P_{Gi}}\left(\frac{\theta_n - \theta_m}{X_l}\right) = \frac{1}{X_l}\left(\frac{\partial \theta_n}{\partial P_{Gi}} - \frac{\partial \theta_m}{\partial P_{Gi}}\right) \tag{6}$$

$$a_{li} = \frac{\partial P_l}{\partial P_{Gi}} = \frac{\partial}{\partial P_{Gi}}\left(\frac{\theta_n - \theta_m}{X_l}\right) = \frac{1}{X_l}\left(\frac{\partial \theta_n}{\partial P_{Gi}} - \frac{\partial \theta_m}{\partial P_{Gi}}\right) \tag{7}$$

with (l) is the number of lines under study. From (1) and (2), it is concluded that $\partial\theta_n/\partial P_{Gi} = X_{ni}$ and $\partial\theta_m/\partial P_{Gi} = X_{mi}$, thus,

$$a_{li} = (1/x_l)\left[X_{ni} - X_{mi}\right] \tag{8}$$

Where (i) corresponds to bus in which the generator is connected, (l) corresponds to the line under study, i.e., between the buses n and m, x_l is the reactance of the line, (X_{ni}) and (X_{mi}) are the corresponding values in the sensitivity matrix. In (1) As all production variations are balanced in slack bus bar, total production is supposed to be invariant.

$$\sum_{i=1}^{ng} P_{Gi} = \sum_{k=1}^{nl} P_k \tag{9}$$

here ng is number of generating units and (nl) represent the total active loads. Utilizing the GSDF values from (8), the resulting line flows, may be written using (13) as:

$$P_l = P_l^0 + a_{li}\Delta P_{Gi} \qquad (l = 1, 2, ..., nl;\ i = 2, .., ng) \tag{10}$$

in which (P_l^0) is the base case line active power flow.

4.2 The line outage distribution factor

Effect of a one-line break can be approximated in a linear fashion by calculating state-independent d factors [15].

$$d_{n-m,i-j} = \Delta P_{n-m} / P_{i-j}^0 \tag{11}$$

where (ΔP_{n-m}) represent the MW variation flow on line n-m after the opening of line (i-j), and (P^0_{i-j}) is the initial active power flow of the i-j line before it was taken out of service. The matrix d stores the LODFs for the controlled transmission lines. Same results can be computed for the line closing cases as well. As LODFs are independent of the state, it can be computed only ones and applied repeatedly. Once the sensitivity matrix [X] is obtained, calculation of the line (d) factor is possible using Eq (12);

$$d_{l,k} = \frac{x_k}{x_l}\frac{(X_{in} - X_{jn} - X_{im} + X_{jm})}{x_k - (X_{ii} + X_{jj} - 2X_{ij})} \tag{12}$$

Where, (l) corresponds to the line under study, i.e., between the buses (n) and (m) and (k) corresponds to the outage of the line which is connected between the buses (i) and (j). From eq. (12), the post contingency power flow can be obtained by:

$$P^c_{n-m} = P^0_{n-m} + d_{n-m,i-j} \times P^0_{i-j} \tag{13}$$

In Eq (13), the notation (c) and (0) stand for the base condition and the contingency conditions, correspondingly, subscript n-m is defined as the whole of the supervised lines, a, and subscript (i-j) is the set of lines on failure. (P_{n-m}^0) and (P_{n-m}^c) are pre-contingency and post-contingency PFs on examined lines. P_{i-j}^0 is pre-contingency PFs for lines on outage. ($d_{n-m,i-j}$) is element of LODF matrix. It enables us to obtain a linear approximation of the contingencies much faster than the approach of resolving the FP for the system under contingency conditions. The proposed contingency analysis algorithm using sensitivity factors is presented in flowchart of Figure 2.

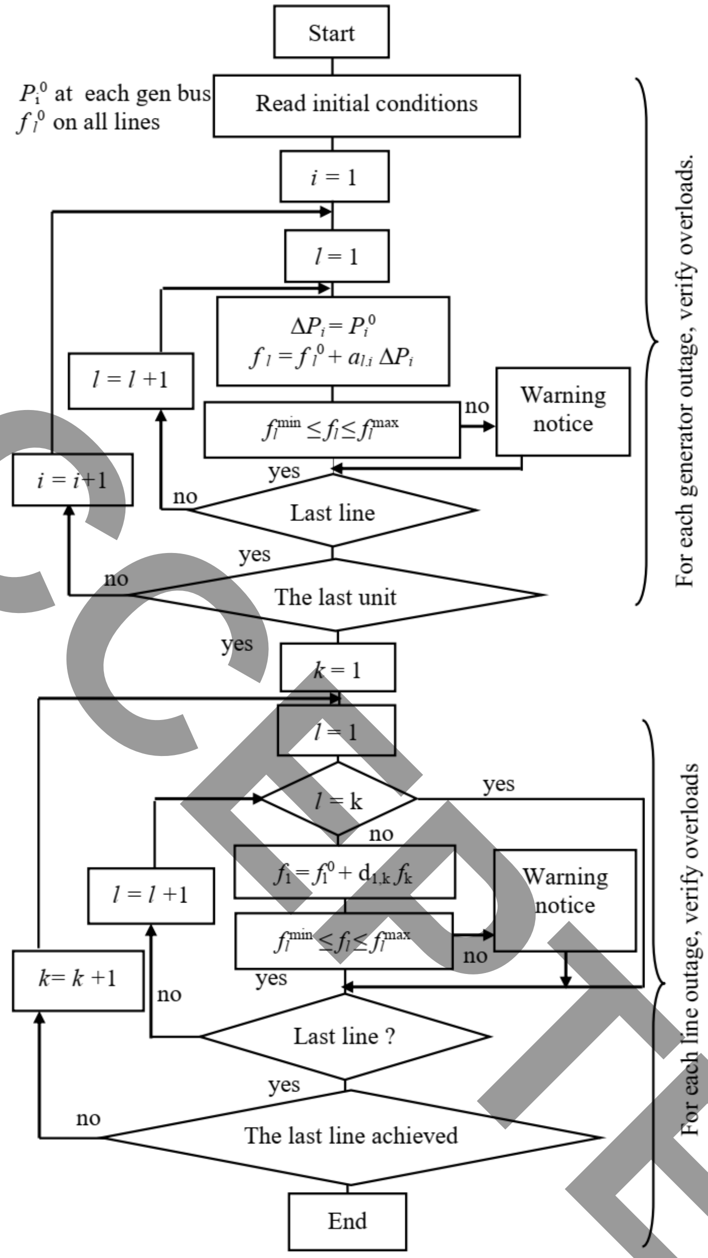

Figure 2. Contingency analysis using sensitivity factors.

5 Case study and simulation outcomes

To show the effectiveness of the suggested algorithm to predict the post contingency PF using the sensitivity factors derived from dc load flow, a 6-bus IEEE test system is used [16]. The results are achieved by the approach based on sensitivity factors developed with MATLAB language. As all the variations in output are picked up by the reference bus, the whole output of the system stays the same. This system has six buses and 11 lines, network data on this test system are listed in Table 1 and Table 2, transformer tap amount for the line is 0 and for the transformer the value is set to the tap rating.

Table 1. IEEE 6-bus test system data.

Bus	Type	Voltage Mag.	Angle (°)	Load		Production		Mvar production limits		Static Mvar
N°				MW	Mvar	MW	Mvar	Q^{min}	Q^{max}	
1	1	1.05	0	0	0	0	0	0	0	0
2	2	1.05	0	0	0	50	0	-10	80	0
3	2	1.07	0	0	0	60	0	-10	95	0
4	0	1	0	70	70	0	0	0	0	0
5	0	1	0	70	70	0	0	0	0	0
6	0	1	0	70	70	0	0	0	0	0

Table 2. Transmission lines parameters of IEEE 6-Bus test system.

From bus	To bus	*r* (p.u)	*x* (p.u)	$B/2$ (p.u)	Tap
1	2	0.10	0.20	0	0
1	4	0.05	0.20	0	0
1	5	0.08	0.30	0	0
2	3	0.05	0.25	0	0
2	4	0.05	0.10	0	0
2	5	0.10	0.30	0	0
2	6	0.07	0.20	0	0
3	5	0.12	0.26	0	0
3	6	0.02	0.10	0	0
4	5	0.20	0.40	0	0
5	6	0.10	0.30	0	0

For comparison, we performed the same system with Newton Raphson power flow calculation and the result are shown in Table 3.

Table 3. Newton-Raphson power flow solution for the IEEE 6-bus test system (base case).

Line N°	From	To	*P*	*Q*	Abs (S) (MVA)
1	1	2	28.6897	-15.4187	32.5704
2	1	4	43.5849	20.1201	48.0049
3	1	5	35.6009	11.2547	37.3375
4	2	3	2.9303	-12.2687	12.6138
5	2	4	33.0909	46.0541	56.7097
6	2	5	15.5145	15.3532	21.8270
7	2	6	26.2489	12.3995	29.0302
8	3	5	19.1168	23.1745	30.0418
9	3	6	43.7732	60.7242	74.8567
10	4	5	4.0832	-4.9421	6.4107
11	5	6	1.6142	-9.6635	9.7973

Table 4. Matrix (A) for IEEE 6-bus test system.

Bus	line $_{1-2}$	line $_{1-4}$	line $_{1-5}$	line $_{2-3}$	line $_{2-4}$	line $_{2-5}$
2	-0.4706	-0.3149	-0.215	0.0544	0.3115	0.0993
3	-0.4026	-0.2949	-0.3026	-0.3416	0.2154	-0.0342
Bus	line$_{2-6}$	line $_{3-5}$	line $_{3-6}$	line $_{4-5}$	line $_{5-6}$	/
2	0.0642	0.0622	-0.0077	-0.0034	-0.0565	/
3	-0.2422	0.2890	0.3695	-0.0795	-0.1273	/

Table 5. The line outage distribution factor matrix.

0	0,635343	0,542705	-0,11268	-0,5031	-0,21029	-0,12209	-0,13693	0,013457	0,009587	0,131585
0,594831	0	0,457295	-0,03314	0,612144	-0,06185	-0,03591	-0,04027	0,003958	-0,32694	0,038701
0,405169	0,364657	0	0,145827	-0,10905	0,272136	0,157996	0,1772	-0,01742	0,317355	-0,17029
-0,10285	-0,03231	0,178289	0	0,124162	0,226175	0,466166	-0,39954	-0,52533	0,170574	0,132015
-0,58837	0,764657	-0,17082	0,159083	0	0,296875	0,172359	0,19331	-0,019	-0,67306	-0,18577
-0,18751	-0,05891	0,325029	0,220949	0,226352	0	0,239387	0,268486	-0,02639	0,310963	-0,25801
-0,12127	-0,0381	0,210205	0,507283	0,146388	0,266663	0	-0,19919	0,584168	0,201108	0,443346
-0,11746	-0,0369	0,203602	-0,37548	0,14179	0,258286	-0,17202	0	0,474674	0,194791	-0,42464
0,014603	0,004587	-0,02531	-0,62452	-0,01763	-0,03211	0,638187	0,600464	0	-0,02422	0,556654
0,006461	-0,23534	0,286477	0,125941	-0,38786	0,235026	0,136451	0,153037	-0,01504	0	-0,14707
0,106664	0,033508	-0,18489	0,117239	-0,12876	-0,23455	0,361813	-0,40128	0,415832	-0,17689	0

Table 4 and Table 5 show the *a* and *d* factors calculated using the developed engine for post-contingency assessment. As an example, we can perform contingency analysis using the sensitivity factors as in Table 4 and 5. Assume an outage of the generator on bus 2 with all pick up of lost generation coming on the generator at bus 1. To calculate the flow on line 1–5 after the outage of the generator on bus 2, we need base case flow on line 1–5 from Table 3 which is 35.6009 MW, the base case generation on bus 2 is 50 MW (Table 1), generation shift distribution factor a1–5, 2 is -0.2145 (Table 4), which correspond to position (2,2) in GSDF matrix, then the flow on line 1–5 after generator outage can be calculated by (11).

$$P_{1-5} = P_{1-5}^{0} + a_{1-5,\,2}\Delta P_{G2} \;\; = 35.6009 + (-0.2145)\,(-50\text{ MW}) = 46.325\text{ MW}$$

The line flow for the post contingency with generators outages using the algorithm-based factors which are shown in Table 6.

Table 6. The line flow for the post contingency with generators outages based on (A) factors.

Line N°	From bus	To bus	P_l (MW) Base case	P_l (MW) G_2 out	P_l (MW) G_3 out
1	1	2	28.6897	52.2209	52.8435
2	1	4	43.5849	59.3294	61.2772
3	1	5	35.6009	46.3252	53.7548
4	2	3	2.9303	0.2079	23.4235
5	2	4	33.0909	17.5175	20.1680
6	2	5	15.5145	10.5514	17.5659
7	2	6	26.2489	23.0392	40.7811
8	3	5	19.1168	16.0079	1.7788
9	3	6	43.7732	44.1597	21.6044
10	4	5	4.0832	4.2543	8.8525
11	5	6	1.6142	4.4374	9.2508
The slack bus generation P_{G1}			107.87	157.87	167.87

The slack bus generation P_{G1} for each post contingency is calculated by (4) and given in the last line in the same table. Similarly, assume an outage of the line 5–6. To calculate the flow on line 1–5 after the outage of the line 5–6, we need base case flow on line 5–6 from Table 3 which is 1.6142 MW, base case flow on line 1–

5 is 35.6009 MW, line outage distribution factor d5–6, 1–5 is -0.1703 (Table 5), which correspond to position (3,11) in GSDF matrix, then the flow on line 1–5 after the outage of the line 5–6 can be calculated by (14).

$$P_{1-5}^{c} = P_{1-5}^{0} + d_{1-5,5-6} \times P_{5-6}^{0} = 35.6009 + (-0.1703)\,(1.6142) = 35.326 \text{ MW}$$

The line flow for the post contingency with lines outages calculated using the algorithm-based d factors shown in Table 7.

Table 7. The line flow for the post contingency with lines outages based on (d) factors.

line		P_l (MW) Base case	P_l (MW) $l_{1\text{-}2}$ out	P_l (MW) $l_{1\text{-}4}$ out	P_l (MW) $l_{1\text{-}5}$ out	P_l (MW) $l_{2\text{-}3}$ out	P_l (MW) $l_{2\text{-}4}$ out	P_l (MW) $l_{2\text{-}5}$ out	P_l (MW) $l_{2\text{-}6}$ out	P_l (MW) $l_{3\text{-}5}$ out	P_l (MW) $l_{3\text{-}6}$ out	P_l (MW) $l_{4\text{-}5}$ out	P_l (MW) $l_{5\text{-}6}$ out
1	2	28.68968	0	56.38109	48.01044	28.35948	12.0417	25.42718	25.48501	26.07206	29.27875	28.72883	28.90208
1	4	43.58495	60.65046	0	59.86506	43.48783	63.84136	42.62539	42.6424	42.81506	43.7582	42.24997	43.64742
1	5	35.60087	47.22503	51.49441	0	36.02819	31.99243	39.82293	39.74809	38.98838	34.83855	36.8967	35.326
2	3	2.93032	-0.02055	1.522017	9.277568	0	7.038948	6.439315	15.16669	-4.70753	-20.0649	3.626812	3.143413
2	4	33.09095	16.2108	66.41847	27.00965	33.55711	0	37.69683	37.61519	36.78641	32.25932	30.34269	32.79109
2	5	15.51453	10.13497	12.94713	27.08585	16.16198	23.00474	0	21.79819	20.64712	14.35949	16.78426	15.09806
2	6	26.24894	22.76984	24.58854	33.73243	27.73545	31.09307	30.38609	0	22.44112	51.81984	27.07012	26.96458
3	5	19.11682	15.74701	17.50858	26.36522	18.01656	23.80878	23.12401	14.60147	0	39.89484	19.9122	18.43139
3	6	43.77318	44.19213	43.97313	42.87203	41.94313	43.18986	43.27499	60.52491	55.25215	0	43.6743	44.67171
4	5	4.083237	4.268604	-6.17419	14.28205	4.452285	-8.7513	7.72956	7.664927	7.008814	3.424869	0	3.84585
5	6	1.614165	4.674321	3.074627	-4.96817	1.957714	-2.64664	-2.02479	11.11138	-6.05698	19.81646	0.891876	0
P_{G1}			107.87	107.87	107.87	107.87	107.87	107.87	107.87	107.87	107.87	107.87	107.87

The slack bus generation P_{G1} for each post contingency is calculated by (4) and given in the last line in the same table. Table 3 present the results of ac PF using Newton-Raphson for the IEEE 6-bus test system and Table 4 present a matrix. The line outage distribution factor matrix is shown in Table 5. Before use the approximation of sensitivity matrix based on dc power flow, the base case is simulated and solved with the NR method of PowerWorld solver [17] as showed in Figure 3.

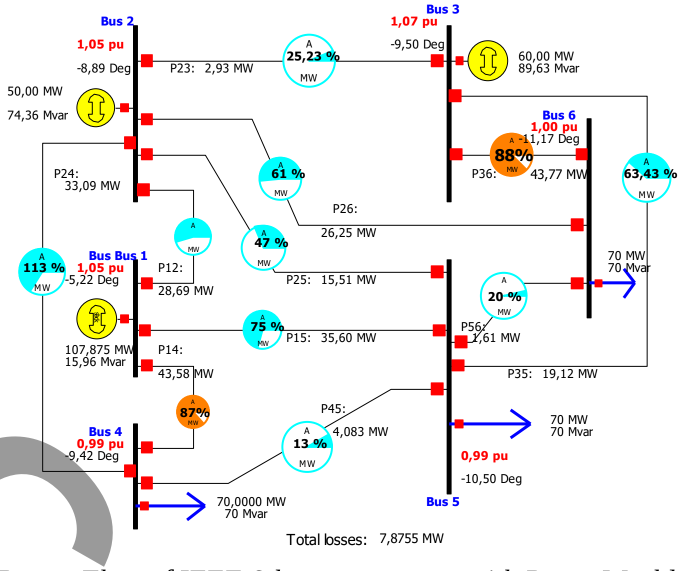

Figure 3. Power Flow of IEEE 6-bus case system with PowerWorld simulator.

The computational time of the proposed MATLAB program for ACPF for the IEEE 6-bus test system is approximately 0.01 seconds for all the scenarios. The results of power flow from PowerWorld simulator are the same obtained from the developed MATLAB program for power flow calculation as an initial case for post contingency analysis. To illustrate the effectiveness of the program developed for post contingency calculation based on sensitivity matrix method and for comparison seek, the power transit limit in each line is fixed to 50 MW for all the lines of network. The post contingency analysis is done using the *a* and *d* matrix approximation derived from dc load flow. For comparison, the 6-bus test system is solved again for two contingency scenarios where generator 2 is outaged in the first one, the results are shown in Figure 4 and for a second contingency scenario where line 2-6 is outaged, the result are shown in Figure 5.

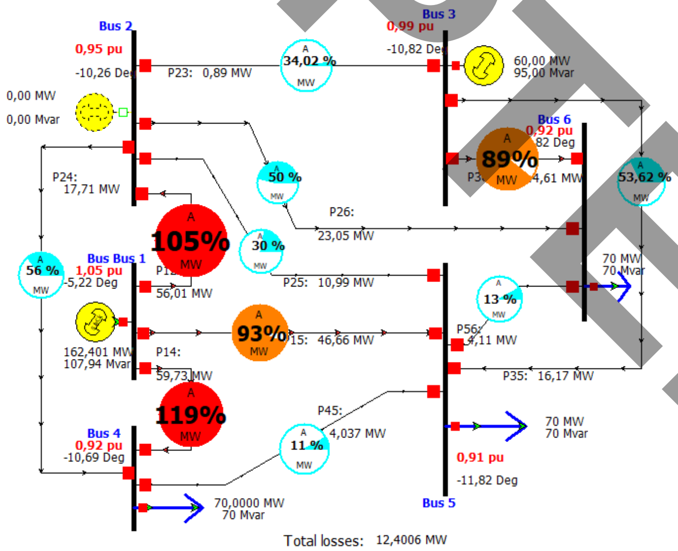

Figure 4. Power Flow of the IEEE 6-bus case system with PowerWorld simulator with unit 2 outaged.

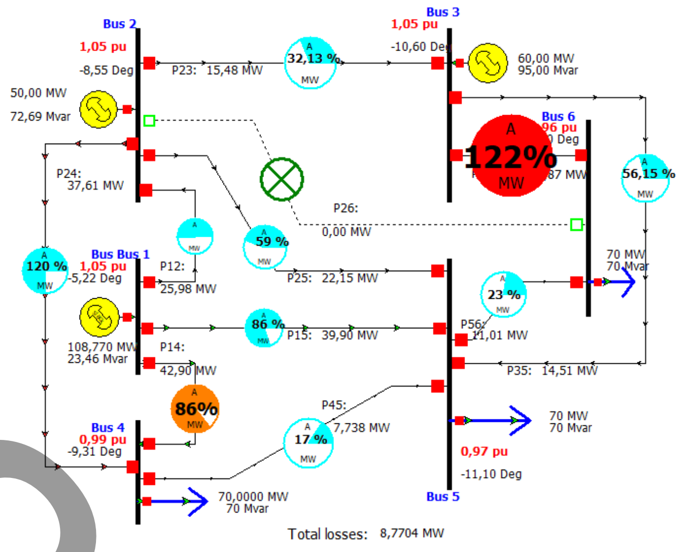

Figure 5. Power Flow of 6 IEE bus system with PowerWorld simulator with line 2-6 outaged.

Table 8. The Comparison of the results between PowerWorld and our the proposed method.

Line N°	From bus	To bus	P_l (MW) G_2 out PW	P_l (MW) G_2 out Calc	P_l (MW) $l_{2\text{-}6}$ out PW	P_l (MW) $l_{2\text{-}6}$ out Calc
1	1	2	52.637	52.2209	25.234	25.48501
2	1	4	59.73	59.3294	42.896	42.6424
3	1	5	46.661	46.3252	39.897	39.74809
4	2	3	0.893	0.2079	15.482	15.16669
5	2	4	17.71	17.5175	37.607	37.61519
6	2	5	10.988	10.5514	22.145	21.79819
7	2	6	23.046	23.0392	0	0
8	3	5	16.171	16.0079	14.506	14.60147
9	3	6	44.61	44.1597	60.867	60.52491
10	4	5	4.037	4.2543	7.738	7.664927
11	5	6	4.11	4.4374	11.012	11.11138

From the results shown in Table 8, we can show the similitude of results, e.g., for the first scenario (generator 2 is outaged) and scenario 2 (line 2-6 is outaged). The 4th and 5th column of Table 8, present the comparison of line flows in the post contingency first scenario from PowerWorld (full ac power flow), and the results obtained from the MATLAB program based on GSDF estimation. The 6th and 7th column of Table 8, present the comparison of line flows in the post contingency second scenario (line 2-6 outgaed) from PowerWorld (full ac power flow), and the results obtained from the MATLAB program based on LODF estimation. The little difference is justified by the lack of losses and reactive power in the post contingency algorithm assessment where the a and d sensitivity matrices are approximated using dc load flow. Contingency analysis using the developed algorithm results shows a good prediction of the post-contingency system. To demonstrate the efficiency of the designed algorithm for post contingency analysis based on sensitivity matrix, many simulations are carried out for different test system, the 14-unit, 5 units IEEE test system, 30-unit test system, 6 units IEEE, 57 units test system, 7 units IEEE test system and 118 units test system, 54 units IEEE test system was successfully tested as well. The test system findings were checked against the PowerWorld simulator, and in order to confirm the power flow through the lines whenever the line limitations are unavailable, a fixed percentage limit of MW was chosen as the boundary for all the lines in the given network. When comparing the sensitivity matrices and the PowerWorld simulator, a better outcome for the predicted post-contingency system is shown. The results demonstrate that the newly formulated approach of using sensitivity matrices could be applied to compute the line boundary constraint and many additional contingency studies with ease using the suggested algorithm and in a shorter computation time.

6 Conclusion

The contingency analysis plays a critical role in ensuring the safe, reliable, and efficient operation of power systems. It helps power system engineers identify potential problems and develop effective strategies for preventing or mitigating the impact of these problems on the power system, therefore, we designed a program appropriate for contingency analysis for the line outage distribution factor (LODF) and the generation shift distribution factor (GSDF). The programs are implemented in MATLAB and designed to provide the communication from a load flow and contingency analysis programs. The developed programs gave highly satisfying outcomes, as a result of their successful application to the simulation of a 6-bus test problem, which explored the efficiency of the proposed software algorithm. The results showed the differences in the power flow output among the developed method and the AC power flow for the identical post contingency scenarios are successful, thus verifying the effectiveness of the proposed algorithm. Regarding the implementation speed, the performance of our approach is very fast because it is a straightforward solution and not a non-iterative one.

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