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Power System Static Security Assessment for Iraqi Super High Voltage Grid

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Abstract

The consideration of power system (PS) contingencies arises due to line outage or generator outage which prompting limit violations in system constraints represents an essential requirement of modern PS security. In this paper a developed model for static security assessment for Iraqi super high voltage grid is proposed. The impact of one line outage (n-1), double line outages (n-2) and generator outage contingencies on the static security of the 400 KV Iraqi super high voltage grid is investigated. The theoretical analysis of line outage contingencies based on several performance indices is presented. The experimental results to carry out the contingency selection and ranking are conducted using MatLab programming language and PSS/E software program. The results show that there are only three single line outage lead to line flow violations, while most generator outages made the generation power of the system to be violated. On other hand the most severe double line outages may lead to cascading outages and blackouts in the tested system. According to bus voltage magnitude it is found that no violations occur for all considered contingencies.

Keywords: Static security, System constraints, Contingency analysis, Line outages, Generator outage, MatLab and PSS/E.

INTRODUCTION

Large scale interconnection in modern power systems (PSs) has increased the complexity of the system in terms operation and control. PSs are continuously subject to unpredictable contingencies (disturbances) such as sudden changes in load demand, short circuit faults, losses of one or more transmission lines, equipment outages and generator failures[1-3]. Although PS planners endeavor to outline the system to deal with different possibilities that may emerge during operation, there could be a few contingencies that can cause a tragic cascading failures which may lead to blackout spread over extensive territories influencing an enormous number of customers[4-6]. Security of a PS refers to the degree of risk in its ability to survive imminent disturbances (contingencies) without interruption of customer service[7]. The static security assessment encompass steady-state analysis of post disturbance system conditions to verify that no violations in line flow or voltage constraints. The main target of the PS security is to keep the system intact under normal and disturbed conditions. Therefore, the successful security system should minimize the impact of disturbances on the operation, economics, and power quality of PSs[8]. The task of PS security assessment encompasses the following three parts: system monitoring, contingency analysis and corrective action analysis[9]. The updated information about real time PS conditions such as load changing, power generation, circuit breakers status ..etc. which supplied to operators is referred to the system monitoring[10]. The contingency analysis is an investigative simulation of supposed contingency for evaluating their impact on the system security. On the other hand, the corrective action analysis is the process of figuring the possible actions that may be taken for overcoming the consequences of security upsetting contingencies[11-12].

In this paper, the static security assessment for 400 kV Iraqi super high voltage grid is presented. The developed static security model investigates if any limit violations is occur in the system parameters and suggested a suitable control action to return the system to secure state.

POWER SYSTEM STATIC SECURITY CONSTRAINTS

The static security constraints comprise of equality and inequality constraints. The Equality constraints are the basic power balance equations in compliance with the fact that total generation equals total demand minus transmission losses. The inequality constraints define a feasible operation region represented by bus voltage security limits ($V_{min} \leq V \leq V_{max}$), line flow security limits ($MVA_{ij} \leq MVA_{Limit}$) and generation power security limits ($P_{Gmin} \leq P_G \leq P_{Gmax}$ and $Q_{Gmin} \leq Q_G \leq Q_{Gmax}$).

POWER SYSTEM CONTINGENCY ANALYSIS

Contingency severity calculation is one of the most important aspects of PS security. It is imperative to know which line or unit outages will cause line flows, bus voltages and generation power to violate their security limits. Contingency analysis techniques are required to carried out the impacts of outages. Contingency analysis comprises of three basic steps[13]: contingency creation (creating contingencies lists), contingency selection (selection of severe contingencies from the list) and contingency evaluation (necessary security actions to mitigate the effects of most severe contingencies). The performance indices are used to rank those contingencies according to their severity. In this paper real power performance index (PI_P) , severity index (SI) and voltage performance index (PI_v) are used. The line flow severity of the system for normal and contingency condition can be determined from PI_P and LS_I which given by[2,11,14]:

$$PI_P = \sum_{L=1}^{nTL} \left[\frac{P_{ij}(L)}{P_{ijmax}(L)} \right]^{2n} \qquad (1)$$

$$SI = \sum_{L=1}^{ovl} \left[\frac{(MVA_{ij})}{(MVA_{ij})_{Limit}} \right]^{2n} \qquad (2)$$

Where :

P_{ij} : is the real power flow

$P_{ij\,max}$: maximum real power flow in the line

n : is the exponent and may take its value as unity

n_{TL} : is the total number of lines in the network

ovl : overloaded lines

The value of maximum real power flow in the line is calculated as follows:

$$P_{ij\,max} = \frac{|V_i||V_j|}{\sqrt{R_{ij}^2 + X_{ij}^2}} - \frac{R_{ij}|V_j|^2}{R_{ij}^2 + X_{ij}^2} \qquad (3)$$

The another performance index parameter is voltage performance index (PI_v) which corresponding to bus voltage magnitude violations and mathematically given by[15]:

$$PI_v = \sum_{i=1}^{nL} \left[\frac{2\,(|V_i| - |V_{i\,nom}|)}{|V_{imax}| - |V_{imin}|} \right]^2 \qquad (3)$$

Where :

V_i : bus voltage magnitude

$V_{i\,max}$ and $V_{i\,min}$: maximum and minimum values of bus voltage

$V_{i\,nom}$: average value of $V_{i\,max}$ and $V_{i\,min}$ and given as ($V_{i\,max}$ + $V_{i\,min}$) / 2

nL : total number of load buses in the system

The PS contingency analysis can be carried out by using the flowchart depicts in Figure (1).

IRAQI SUPER HIGH VOLTAGE (SHV) GRID

The 400 kV Iraqi super high voltage (SHV) gird comprises (36) bus bars, (22) generators, (24) load buses, (84) autotransformers and (52) transmission lines. The (22) generators station are of different capabilities of MW generation and MVAR generation/absorption. Figure (2) shows the single line diagram of the 400 kV Iraqi SHV gird system. The data were taken from Iraqi National Control Center (INCC) and represented the state of operation for winter season at date of Jan., 1, 2017. All data for the 400 kV Iraqi SHV gird system, such as buses data, machines data, line data, …etc is given in Appendix. The minimum limit of bus voltage magnitudes is (0.94 pu) while the maximum limit is (1.05 pu). The maximum MVA limit for all lines is (1000 MVA) at normal operation and at emergency operation of (1140 MVA).

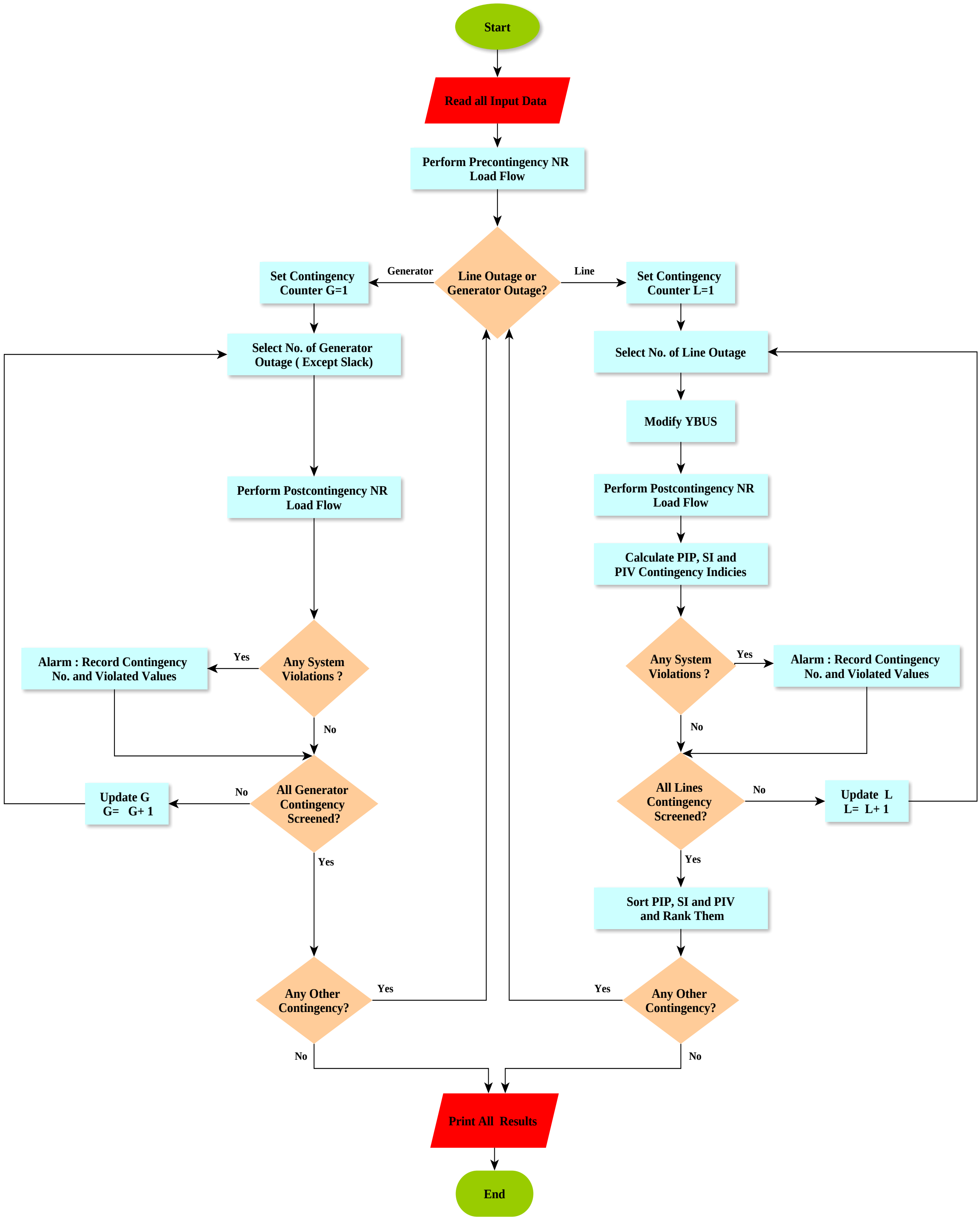

Figure 1: Flowchart for Power System Contingency Analysis

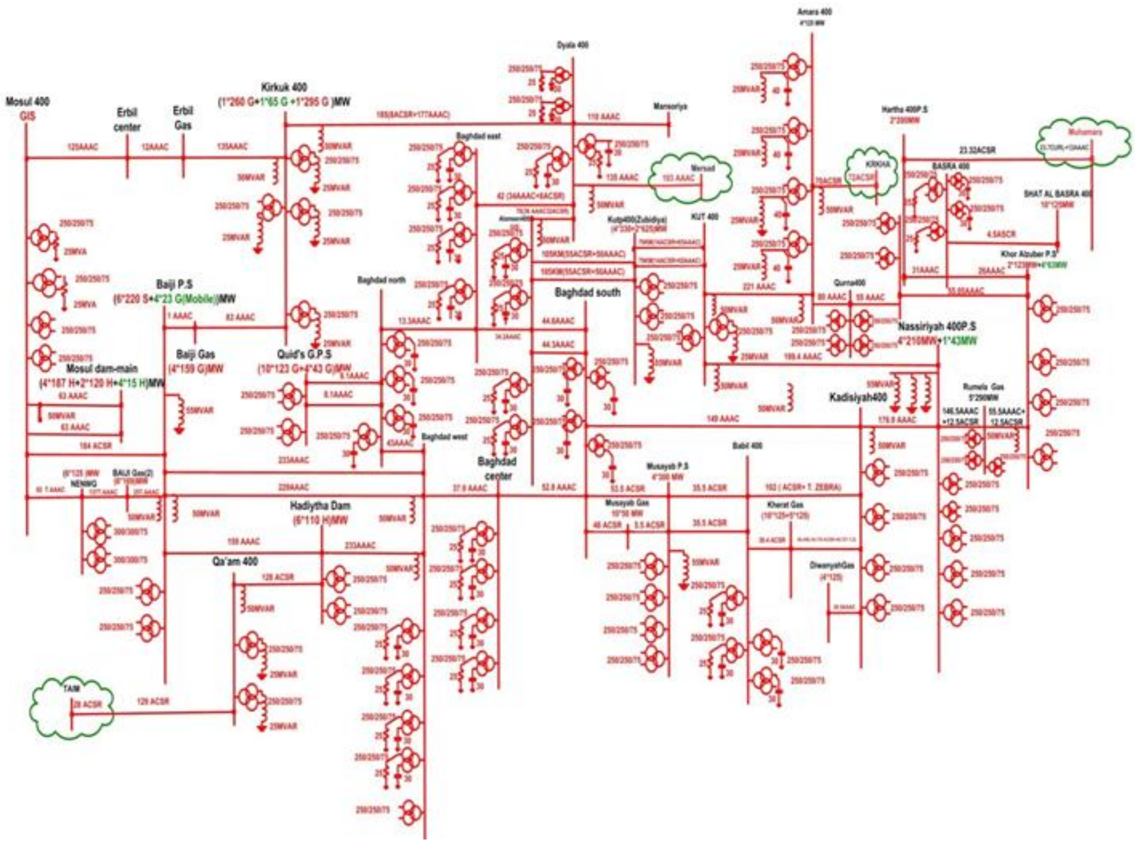

Figure 2: Single Line Diagram of the 400 kV Iraqi SHV Gird

EXPERIMENTAL RESULTS

Load Flow Analysis at Base (Initial) Case

The load flow analysis for the 400 kV Iraqi SHV gird is performed by using Newton-Raphson method. A comparison between the results obtained by the proposed MatLab program and PSS/E software for bus voltage magnitudes and angles at base case is given in Table (1).

Table 1: Experimental Results of Load Flow for Bus Voltage Magnitudes and Bus Angles

Bus No.	Bus Name	MatLab Proposed Program		PSS/E Software		Error in	
		V (pu)	δ (Deg.)	V (pu)	δ (Deg.)	V (pu)	δ (Deg.)
1	**MSL4**	1.0147	-8.7043	1.0161	-8.80	-0.0014	0.0947
2	**MMDH**	1.0201	-7.6449	1.0201	-7.71	0.0000	0.0641
3	**GNENW**	1.0332	-7.2674	1.0332	-7.31	0.0000	0.0424
4	**BAJP**	1.0344	-4.9987	1.0344	-6.04	0.0000	0.0413
4	**BAJG**	1.0344	-4.9664	1.0344	-6.01	0.0000	0.0436
6	**BAJG(2)**	1.0338	-6.2044	1.0362	-6.24	-0.0024	0.0446
7	**ERBG**	1.0417	-4.9614	1.0436	-6.00	0.0019	0.0384
8	**KRK4**	1.0326	-4.8974	1.0326	-4.94	0.0000	0.0426
9	**BSMG**	1.0274	-2.7212	1.0274	-2.74	0.0000	0.0188
10	**BGW4**	1.0284	-6.7943	1.0311	-6.86	-0.0026	0.0647
11	**BGS4**	1.0243	-3.1024	1.0271	-3.13	-0.0028	0.0276
12	**BGE4**	1.0266	-4.3044	1.0291	-4.34	-0.0024	0.0446
13	**BGN4**	1.0279	-4.9063	1.0317	-4.96	-0.0038	0.0437

14	**QDSG**	1.0320	-4.7449	1.0320	-4.80	0.0000	0.0441
14	**AMN4**	1.0241	-2.7869	1.0269	-2.82	-0.0018	0.0331
16	**BGC4**	1.0202	-4.7411	1.0242	-4.81	-0.0040	0.0689
17	**MANSG**	1.0367	-4.8342	1.0367	-4.88	0.0000	0.0448
18	**DAL4**	1.0273	-4.7841	1.0294	-4.83	-0.0022	0.0449
19	**KUT4**	1.0086	2.4624	1.0109	2.49	-0.0023	-0.0276
20	**KUTP**	1.0193	4.2437	1.0193	4.28	0.0000	-0.0363
21	**HDTH**	1.0337	-7.7208	1.0337	-7.78	0.0000	0.0492
22	**QIM4**	1.0201	-9.8978	1.0234	-10.03	-0.0033	0.1322
23	**MUSP**	1.0263	-2.0239	1.0263	-2.04	0.0000	0.0161
24	**MUSG**	1.0281	-1.9846	1.0281	-2.00	0.0000	0.0144
24	**BAB4**	1.0242	-1.8448	1.0247	-1.88	-0.0014	0.0242
26	**GKHER**	1.0342	-0.0483	1.0342	0.00	0.0000	-0.0483
27	**DWANG**	1.0228	-1.4442	1.0228	-1.46	0.0000	0.0148
28	**KDS4**	1.0148	-2.0698	1.0194	-2.09	-0.0036	0.0202
29	**NSRP**	0.992	-1.7643	0.992	-1.78	0.0000	0.0147
30	**AMR4**	1.0092	0.1204	1.0092	0.13	0.0000	-0.0094
31	**4QRN**	1.0021	-0.4948	1.0044	-0.61	-0.0033	0.0142
32	**HRTP**	0.992	-0.6449	0.992	-0.69	0.0000	0.0341
33	**KAZG**	0.9826	-0.9879	0.9826	-1.03	0.0000	0.0421
34	**RMULG**	0.9878	-0.4867	0.9878	-0.41	0.0000	0.0233
34	**4BSR**	0.9899	0.0416	0.9928	-0.04	-0.0029	0.0916
36	**SHBR**	0.9943	0.1487	0.9943	0.18	0.0000	-0.0313

From Table (1), it can be noted that the experimental results of MatLab proposed program are very close to the PSS/E software results and the error between them is very small. The maximum power flow is found in the line 24(BGE4-AMN4) which has an MVA of (713.8 MVA) and represents (71.38 %) of line security MVA.

Single Line Outage Contingency or (n-1) Security

The total lines in the 400 kV Iraqi SHV grid are (52) lines, therefore, there are (52) possibilities of single line outage contingency. There are (9) possibilities of single line outage made the system solution not converged. These lines are 32(MANSG-DAL4), 37(HDTH-QIM4), 44(DWANG-KDS4), 45(KDS4-NSRP), 46(NSRP-RMULG), 48(4QRN-HRTP), 49(HRTP-KAZG), 51(KAZG-BSR) and 52(4BSR-SHBR).

Table (2) shows the MatLab proposed program results for ranking PI_P and SI indices for five top of single line outage contingency, while Table (3) shows the ranking for PI_V index.

Table 2: Top Five Contingency Ranking According to PI_P and SI Indices for (n-1) Security

Line Outage	From Bus	To Bus	PI_P	Rank PI_P	SI	Rank SI
30	AMN4	KUTP	0.139	1	1.455	1
31	AMN4	KUTP	0.139	2	1.455	2
20	BGS4	BGC4	0.094	3	1.086	3
29	AMN4	DAL4	0.004	4	0	---
41	BAB4	GKHER	0.001	5	0	---

Table 3: Top Five Contingency Ranking According to PI_V Index for (n-1) Security

Line Outage	From Bus	To Bus	PI_V	Rank PI_V
34	KUT4	NSRP	6.149	1
40	KAZG	RMULG	4.841	2
47	AMR4	4QRN	4.298	3
36	KUT4	AMR4	4.417	4
30	AMN4	KUTP	4.302	5

For all single line outage contingencies, it is found that the bus voltage magnitudes in the system are within security voltage limits. The minimum voltage magnitude of value (0.9642 pu) is found to be at bus 29(NSRP) when the line 34(KUT4-NSRP) is outage. According to system line flow overloads, it is found that only (3) contingences from all single line outage contingency will infect the system. The output security report of the MatLab proposed program when the Line 30(AMN4-KUTP) is outages is shown in Figure (3). The critical overloaded lines referred to those lines at which the MVA flow increased over (90%) of the security flow limits. Table (4) shows the results of the proposed program and PSS/E software for violated lines due to considering contingencies.

SECURITY REPORT

GENERATION REPORT:

Real power generation for all generators is within security limits.

Reactive power generation for all generators is within security limits.

BUS VOLTAGE MAGNITUDES AND BUS ANGLES REPORT:

All bus voltages are within security limits.

All bus angles are within security limits.

TL OVERLOADING AND CRITICAL OVERLOADING REPORT:

ALARM : TL is overloaded between buses 15 20 120.61%

All other lines have no critical overloaded.

ALARM : TL exceed the thermal limit between buses 15 20

Figure 3: Output Security Report of the MatLab Proposed Program when the Line 30(AMN4-KUTP) is Outages

Table 4: Violated Lines due to (n-1) Security

Line Outages	Overloaded Line	MatLab Proposed Program			PSS/E Software		
		Pre MVA	Post MVA	%Over Limit	Pre MVA	Post MVA	%Over Limit
30(AMN4-KUTP)	**31(AMN4-KUTP)(2)**	662.398	1206.10	20.61%	662	1206.3	20.60%
31(AMN4-KUTP)	**30(AMN4-KUTP)(1)**	662.398	1206.10	20.61%	662	1206.3	20.60%
20(BGS4-BGC4)	**24(BGE4-AMN4)**	713.824	1042.31	4.231%	714.1	1042.33	4.233%

Since all generators, except KUTP which connected to Slack bus, are work within their maximum generation limits then the violated power flow in the lines cannot alleviated by generation rescheduling. If the stopped two units of QDSG with their maximum generation (40 MW , 17 MVAR) inter back to the grid then the violated MVA of line24(BGE4-AMN4) will be reduced from (1042.33 MVA) to (979 MVA). If this action is not possible, then a load shedding action of 10% at bus BGE4, must be taken to reduce the line MVA to its permissible limits. For the violated line 30(AMN4-KUTP) the load shedding of (40 %) in buses AMN4 and BGE4, or load shedding of (70 %) in bus AMN4 can reduce the line MVA below maximum limits of (1000 MVA).

Double Line Outage Contingency or (n-2) Security

There are a large number of possibilities for double line outage contingency and many number of these contingencies make the load flow solution to be diverged. It is found that the voltage magnitudes for all buses are within security limits and there is no voltage violations for all double line outage contingency. On other hand, a hundred of these contingences cause line flow violations. Table (5) shows the MatLab proposed program results for ranking PI_P and SI indices for top ten of double line outage contingency. Since all bus voltage magnitude are within security limits, therefore, there is no need to evaluate PI_V index. Table (6) lists the top ten power flow violations due to double line outage contingency.

Table 5: Top Ten Contingency Ranking According to PI_P and SI Indices for (n-2) Security

Lines Outage	PI_P	Rank PI_P	SI	Rank SI
24(BGE4-AMN4) 29(AMN4-DAL4)	0.413	1	3.469	1
20(BGS4 -BGC4) 29(AMN4-DAL4)	0.330	2	1.890	2
30(AMN4-KUTP) 41(BAB4-GKHER	0.246	3	1.584	3
31(AMN4-KUTP) 41(BAB4-GKHER)	0.246	4	1.584	4
30(AMN4-KUTP) 33(KUT4-KUTP)	0.229	5	1.576	5
31(AMN4-KUTP) 33(KUT4-KUTP)	0.229	6	1.576	6
30(AMN4-KUTP) 34(KUT4-KUTP)	0.229	7	1.576	7
31(AMN4-KUTP) 34(KUT4-KUTP)	0.229	8	1.576	8
30(AMN4-KUTP) 36(KUT4-AMR4)	0.185	9	1.561	9
31(AMN4-KUTP) 36(KUT4-AMR4)	0.185	10	1.561	10

Table 6: Most Ten Violated Lines due to (n-2) Security

Line Outages	Overloaded Line(s)	MatLab Proposed Program			PSS/E Software		
		Pre MVA	Post MVA	%Over Limit	Pre MVA	Post MVA	%Over Limit
24(BGE4-AMN4) 29(AMN4-DAL4)	20(BGS4 -BGC4) 17(BGW4 -BGC4)	468.38 260.4	1415.7 1210.1	41.57% 21.01%	468 260.2	1415.5 1210.4	41.55% 21.04%
20(BGS4 -BGC4) 29(AMN4-DAL4)	24(BGE4-AMN4)	713.82	1373.6	37.36%	714.1	1375.7	37.57%
30(AMN4-KUTP) 41(BAB4-GKHER	31(AMN4-KUTP)	662.39	1258.6	25.86%	662	1258	25.8%
31(AMN4-KUTP) 41(BAB4-GKHER)	30(AMN4-KUTP)	662.39	1258.6	25.86%	662	1258	25.8%
30(AMN4-KUTP) 33(KUT4-KUTP)	31(AMN4-KUTP)	662.39	1255.2	25.52%	662	1254.3	25.43%
31(AMN4-KUTP) 33(KUT4-KUTP)	30(AMN4-KUTP)	662.39	1255.2	25.52%	662	1254.3	25.43%
30(AMN4-KUTP) 34(KUT4-KUTP)	31(AMN4-KUTP)	662.39	1255.2	25.52%	662	1254.3	25.43%
31(AMN4-KUTP) 34(KUT4-KUTP)	30(AMN4-KUTP)	662.39	1255.2	25.52%	662	1254.3	25.43%
30(AMN4-KUTP) 36(KUT4-AMR4)	31(AMN4-KUTP)	662.39	1249.5	24.95%	662	1249.2	24.92%
31(AMN4-KUTP) 36(KUT4-AMR4)	30(AMN4-KUTP)	662.39	1249.5	24.95%	662	1249.2	24.92%

It is found that the minimum voltage magnitude of (0.9609) pu is found to be at bus 29(NSRP) when the line 34(KUT4-NSRP) and Line 41(BAB4-GKHER) are outage. The most overloaded line is Line 24(BGE4-AMN4) due to outages of Line 29(AMN4-DAL4) and Line 20(BGS4-BGC4) with a violation MVA of percentage (141.46%). It can be noted that any double line outages contingency which contains any line of parallel circuit of Line 30(AMN4-KUTP) and Line 31(AMN4-KUTP) causes violation to the another one.

Generation Station Outage Contingency

Except the generation station (KUTP) which connected to the slack bus, all other (18) possibilities of generation station outages are conducted and the experimental results are tabulated as shown in Table (7).

Table 7: Generator Outage Contingency for the 400 kV Iraqi SHV Grid

Generator Outage	Violated Lines	Violated Voltages	Violated P_G	Violated Q_G
MMDH	----	----	24.1100%	----
GNENW	----	----	16.6700%	----
BAJP	----	----	12.4400%	----
BAJG	----	----	14.9400%	----
KRK4	----	----	30.0800%	----
BSMG	----	----	6.4600%	----
QDSG	----	----	81.7700%	3%
HDTH	----	----	----	----
MUSP	----	----	31.9800%	----
MUSG	----	----	18.3800%	----
GKHER	----	----	86.7900%	1.21%
DWANG	----	----	----	----
NSRP	Solution not Converged			
AMR4	----	----	14.43%	----
HRTH	Solution not Converged			
KAZG	----	----	----	----
RMULG	Solution not Converged			
SHBR	Solution not Converged			

It can be seen that there are three station outage :KAZG, DWANG and HDTH does not infect the system and the generation of KUTP is within security limits. On other hand, there are four station outage which they are : NSRP, HRTP, RMULG and SHRB will diverged the load flow solution of the system. The outage of the other generation station will cause the generation station KUTP to exceed its generation security limits. In such case the system is in emergency state and to return the generation of KUTP to its security limits some loads in the system must be shedding.

CONCLUSION

In this paper, the static security assessment for 400 kV Iraqi super high voltage grid is carried out under single line outage, double line outages and generator outage contingencies. Based on three different indices (PI_P, SI and PI_V) the ranking of severity contingencies is evaluated. The top severe contingencies are identified and given the highest priority so that the operator can take necessary control actions to maintain the system security when these contingencies are occurred. At base case, it is found that the grid has no limit violations and found to be secure. The grid bus voltage magnitudes can withstand (n-1) and (n-2) security. On other hand only three single line outages and a hundred of double line outages contingencies lead to line overloaded which required to shed some loads in the system. Most of the generator outages make the generator (KUTP) which connected to the slack bus to violate its generation power.

Appendix : Data of the 400 kV Iraqi SHV grid

The bus data of the 400 kV Iraqi SHV grid system is given in Table (A.1) while the machine data is given in Table (A.2). Table (A.3) shows the data constant of the transmission lines of the 400 kV SHV grid.

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Table A.1: The Bus Data for the 400 kV Iraqi SHV Grid System

Bus NO.	Bus Name	Bus Type	V p.u	δ Deg.	P_G MW	P_d MW	Q_d MVar
1	**MSL4**	3	1	0	0	668.4	258.8
2	**MMDH**	2	1.0201	0	340	0	0
3	**GNENW**	2	1.0332	0	300	194.6	57.4
4	**BAJP**	2	1.0344	0	280	190.2	94.6
5	**BAJG**	2	1.0344	0	300	0	0
6	**BAJG(2)**	2	1.0338	0	0	0	0
7	**ERBG**	2	1.0417	0	0	0	0
8	**KRK4**	2	1.0326	0	380	427.2	144
9	**BSMG**	2	1.0275	0	250	0	0
10	**BGW4**	3	1	0	0	679.5	89.3
11	**BGS4**	3	1	0	0	217.3	12
12	**BGE4**	3	1	0	0	176	40
13	**BGN4**	3	1	0	0	425	-110.6
14	**QDSG**	2	1.032	0	680	255.4	95
15	**AMN4**	3	1	0	0	276.6	-1.9
16	**BGC4**	3	1	0	0	327.4	100
17	**MANSG**	2	1.0367	0	0	0	0
18	**DAL4**	3	1	0	0	325.5	102.3
19	**KUT4**	3	1	0	0	317.6	169.8
20	**KUTP**	1	1.0193	5.28	2220	278.4	112.2
21	**HDTH**	2	1.0337	0	180	141.8	54.6
22	**QIM4**	3	1	0	0	176	58
23	**MUSP**	2	1.0263	0	400	387.3	153
24	**MUSG**	2	1.0281	0	320	0	0
25	**BAB4**	3	1	0	0	370.4	129
26	**GKHER**	2	1.0352	0	720	0	0
27	**DWANG**	2	1.0228	0	200	0	0
28	**KDS4**	3	1	0	0	402	253.5
29	**NSRP**	2	0.992	0	430	686.5	423.5
30	**AMR4**	2	1.0092	0	300	313.6	142.8
31	**4QRN**	3	1	0	0	59.6	-63.6
32	**HRTP**	2	0.992	0	280	244.8	150.4
33	**KAZG**	2	0.9826	0	190	664	384.4
34	**RMULG**	2	0.9878	0	580	442.8	217.4
35	**4BSR**	3	1	0	0	155.9	69.9
36	**SHBR**	2	0.9953	0	500	0	0

Table A.2: Machine Data for the 400 kV Iraqi SHV Grid System

Generator Name	Direct reactance X_d (p.u)	Machine inertia H (sec)	Damping Factor (D)
MMDH	0.3	54.332	0
GNENW	0.43	19.048	0
BAJP	0.377	66	0
BAJG	0.2447	23.16	0
BAJG2	0.554	10.944	0
KRK4	0.4605	2.883	0
BSMG	0.3905	9.169	0
QDSG	0.09444	48.25	0
MANSG	0.425	20	0
KUTP	0.4	25.91	0
HDTH	0.425	12.032	0
MUSP	0.313	104	0
MUSG	0.554	10.944	0
GKHER	0.10625	122.4	0
DWANG	0.425	32.3	0
NSRP	0.2335	95	0
AMR4	0.49	2.275	0
HRTH	0.465	47.5	0
KAZG	0.465	14.5	0
RMULG	0.3905	9.169	0
SHBR	0.43	6.916	0

Table A.3: Transmission Lines Data Constants for the 400 kV Iraqi SHV Grid

Line NO.	From Bus	To Bus	Length Km	R p.u	X P.u	B/2 p.u
1	MSL4	MMDH	63	0.00144	0.01177	0.36439
2	MSL4	MMDH	63	0.00144	0.01177	0.36439
3	MSL4	GNENW	82	0.001777	0.016154	0.478634
4	MSL4	BAJP	184	0.0042	0.03437	1.06426
5	GNENW	BAJG(2)	137	0.002969	0.026989	0.799669
6	BAJP	BAJG	1	0.00002	0.0002	0.00584
7	BAJP	BAJG(2)	25	0.000542	0.004925	0.145925
8	BAJP	BGW4	223	0.00483	0.04393	1.30165
9	BAJP	BGW4	229	0.00496	0.04511	1.33667
10	BAJP	HDTH	159	0.00345	0.03132	0.92808
11	BAJG	KRK4	83	0.0018	0.01635	0.48447
12	ERBG	KRK4	135	0.002925	0.026595	0.787995
13	KRK4	DAL4	185	0.004018	0.036387	1.080845
14	BSMG	BGS4	16	0.000347	0.003152	0.093392
15	BSMG	AMN4	34	0.000737	0.006698	0.198458

16	BGW4	BGN4	43	0.00093	0.00847	0.25099
17	BGW4	BGC4	39	0.000845	0.007683	0.227643
18	BGW4	HDTH	233	0.005049	0.045901	1.360021
19	BGS4	AMN4	38	0.00082	0.00749	0.22181
20	BGS4	BGC4	44	0.000953	0.008668	0.256828
21	BGS4	MUSP	53.5	0.00122	0.01015	0.31897
22	BGS4	MUSG	48	0.001094	0.009106	0.286176
23	BGS4	KDS4	141.9	0.00308	0.02795	0.82827
24	BGE4	BGN4	13.3	0.00029	0.00262	0.07763
25	BGE4	AMN4	20	0.00043	0.00394	0.11674
26	BGE4	DAL4	40	0.00087	0.00788	0.23348
27	BGN4	QDSG	7	0.00015	0.00138	0.04086
28	BGN4	QDSG	7	0.00015	0.00138	0.04086
29	AMN4	DAL4	70	0.001553	0.013556	0.41259
30	AMN4	KUTP	112	0.002427	0.022064	0.653744
31	AMN4	KUTP	112	0.002427	0.022064	0.653744
32	MANSG	DAL4	110	0.002384	0.02167	0.64207
33	KUT4	KUTP	80	0.001734	0.01576	0.46696
34	KUT4	KUTP	80	0.001734	0.01576	0.46696
35	KUT4	NSRP	199.4	0.00432	0.03928	1.1639
36	KUT4	AMR4	221	0.00479	0.04354	1.28998
37	HDTH	QIM4	128	0.00292	0.02391	0.74035
38	MUSP	MUSG	5.5	0.000125	0.001043	0.032791
39	MUSP	BAB4	35.5	0.00081	0.00673	0.21165
40	MUSP	BAB4	35.5	0.00081	0.00673	0.21165
41	BAB4	GKHER	39.4	0.000898	0.00736	0.22789
42	BAB4	KDS4	102	0.00233	0.01935	0.60812
43	GKHER	KDS4	90.456	0.002062	0.016897	0.523197
44	DWANG	KDS4	26.5	0.000604	0.00495	0.153276
45	KDS4	NSRP	176.9	0.00383	0.03485	1.03256
46	NSRP	RMULG	159	0.00346	0.031232	0.929646
47	AMR4	4QRN	78	0.00169	0.015366	0.455286
48	4QRN	HRTP	56.3	0.00122	0.011091	0.328623
49	HRTP	KAZG	54.6	0.00118	0.01076	0.3187
50	KAZG	RMULG	68	0.001488	0.013305	0.398479
51	KAZG	4BSR	26	0.000563	0.005122	0.151762
52	4BSR	SHBR	4.5	0.000103	0.000841	0.026028

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