GENERATION RESCHEDULING FOR ALLEVIATING OVER LOADS CAUSED BY CONTINGENCY

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ABSTRACT

Contingency analysis is a valuable tool for a reliable planning and secure operation of a power system. Contingency analysis techniques must consider the impact of voltage effects as well as line flow effects. If the potential outage of a line or a generator would result in the overload of another line, then the system is said to be vulnerable. Without line overloading correction it may cause cascade outages and lead to failures in the whole system.

An efficient contingency analysis model for detecting both branch MVA flow violations and bus voltage limit violations is presented. A fast technique has been developed for automatic contingency ranking and selection of contingency cases for a power system contingency analysis study. A contingency list is built containing line and generator outages which are ranked according to their expected severity. System voltage performance index is used to assess events severity. Another model that was used for line over-loading correction is based on a pseudo inverse method that was used to solve a non-square system of equations based on Lagrange's theory in optimization. These proposed models have been tested on the Iraqi National Grid system(case study) with 29 buses and 46 branches.

الخلاصة

يعتبر تحليل حالات الاضطراب من الأهداف المهمة في تقييم أمان المنظومة وكذلك لأغراض الدراسات اللازمة لتخطيط وتشغيل المنظومات الكهربائية .

ان الهدف من هذا البحث هو معالجة تأثير حالات الاضطراب لابقاء المنظومة في حالة الأمان . لهذا الغرض تم استنباط نماذج رياضية حددت مستويات التحميل القصوى للخطوط وكيفية تصحيحها ، بالإضافة الى ذلك حددت مستويات الجهد لكل مجمع قضبان حيث تستخدم قيمة الجهد الناتجة كمعيار آخر لبيان شدة تأثير أي اضطراب .

ان نموذج تحليل الاضطراب المستخدم في هذا البحث اثبت كفاءة وفعالية حقيقية مع المنظومات المستخدمة في البحث . كما ان تقييم حالات الاضطراب بشكل متعاقب وبشكل ذاتي يعطي تسلسلاً لتأثير حالات الاضطراب حسب شدة كل منها على المنظومة وصولاً الى الاضطراب الذي لا يشكل أي تأثير عليها .

اما النموذج الأخر في البحث وهو نموذج التصحيح بعد حالات الاضطراب فانه يستند الى استخدام أسلوب شبه المعكوس لحل الأنظمة غير المربعة للمعادلات والتي تعتمد على نظرية لاكرانج في التوصل الى الحلول المثلى .

ان النموذجين سالفي الذكر قد تم تطبيقهما على المنظومة العراقية حيث بينت شدة تأثير أي اضطراب على عمل المنظومة وقد تم ترتيب الأحداث بشكل متسلسل حسب شدة تأثير ها على الشبكة وايضاً من خلال التعرف على مناطق الضعف والقوة في الشبكة الكهربائية .

KEY WORDS
Security assesment, contingency analysis, contingency ranking, overload alleviation by pseudo inverse method.

INTRODUCTION

In planning studies, the traditional approach for steady state contingency analysis is to test all contingencies sequentially to evaluate system performance and reliability. Such analysis consists of simulating outage of one or more generating units and transmission facilities to investigate their effects on bus voltages and line power flows [Ejebe and Wollnberg 1979].

For a large system, even if only single component contingencies were considered, and even if fast solution methods were employed, full AC analysis of all cases could be prohibitively time consuming. Contingency selection involves estimating in advance which contingencies are likely to cause limit violations followed by AC analysis of only these cases [Lauby and Mikolinnas 1983]. The objective is to reduce the number of potential cases under consideration and at the same time, to determine the ranking of these cases according to their severity of effects for further analysis, i.e., contingency selection method was developed which would select only those cases considered severe, requiring more detailed analysis [Dabbaghchi and Irisarri 1986,Gubina and Golob 1996].

If a single or multiple contingency occurs, some lines may become overloaded. Continued secure operation of the system involves the determination of a new state in which the system elements are not overloaded. The line overload can be alleviated by redistributing power injections between the sources taking into account that the load can be kept constant or changed during the correction process[Stroev and Rokotian 1991].

MATHEMATICAL FORMULATION OF THE PROBLEMS

In this study basic mathematical models to describe the problems of contingency analysis, automatic contingency selection, and line overload alleviation have been developed. Finally, main program is formed to show the operation sequence of these models.

Simulation of Line and Generating Unit Outage

Contingency analysis procedures model single failure events, i.e., one line or generator outage, one after another in sequence until "all credible outages" have been studied as shown below. The simulation of the line outage depends on the simulation of the admittance matrix as follows

Assume that the line p,q will be outaged, then the elements of the Y matrix which will be affected are Ypp,Yqq,Ypq, and Yqp.

where,

Ypp : Self admittance at bus p.
Yqq : Self admittance at bus q.
Ypq =Yqp : Mutual admittance between bus p and q.

The new values to these admittances after the simulation will be

$$Y_{pp}^{new} = Y_{pp}^{old} - ypq - j\frac{Bpq}{2.0} \qquad (1)$$

where,

Y_{pp}^{new} : New self admittance at bus p.

Y_{pp}^{old} : Old self admittance at bus p.

Bpq : Susceptance between bus p and q.

$$Y_{qq}^{new} = Y_{qq}^{old} - ypq - j\frac{Bpq}{2.0} \qquad (2)$$

where,

Y_{qq}^{new} : New self admittance at bus q.

Y_{qq}^{old} : Old self admittance at bus q.

$$Y_{pq}^{new} = Y_{pq}^{old} + \left(\frac{1}{Rpq + jXpq}\right) \qquad (3)$$

where,

Y_{pq}^{new} : New mutual admittance between bus p and q.

Y_{pq}^{old} : Old mutual admittance between bus p and q.

Rpq : Line resistance to be outage.
Xpq : Line reactance to be outage.

$$Y_{qp}^{new} = Y_{pq}^{new} \qquad (4)$$

It can be seen from the above eq. (1 to 4) that the model assumes an added line between buses p and q whose impedance(or admittance) is the negative of the original line. This in effect removes the original line from the system.
Simulation of the Generating Unit Outage depends mainly on the outage of one unit in one power station and shows the effect of reducing the generation amount (generator load) on the system Let the total generation for the station at bus q is P_{Gq}, and assume that there exist(g) units with equal generation, then

$$P_{Gq}^{new} = P_{Gq}^{old} - (P_{Gq}^{old}/g) \qquad (5)$$

where,

P_{Gq}^{new} : New generated active power at bus q.

P_{Gq}^{old} : Old generated active power at bus q.

Automatic Contingency Selection Model

Contingency ranking requires a mathematical function which describes the network state. This function is a scalar value functions of the bus voltages. This function is called a performance index(PI). PI is defined as a penalty function to penalize severely any violation of bus voltage constraints and as given below [Yuan-Yin 1992,.Halpin 1984]

$$PIv = \sum_{i=1}^{NB} \frac{Wvi}{2n} \left(\frac{|Vi| - |Vi^{sp.}|}{\Delta Vi^{Lim.}} \right)^{2n} \qquad (6)$$

where,

PIv : Voltage performance index.

$|Vi|$: Voltage magnitude at bus i.

$|Vi^{sp.}|$: Specified (rated) voltage magnitude at bus i.

$\Delta Vi^{Lim.}$: Voltage unacceptable deviation limit

n : Exponent of penalty function(+ve integer).

NB : Number of buses in the system.

Wvi : Real non negative weighting factor.

The voltage deviation $\Delta Vi^{Lim.}$ represents the threshold above which voltage level deviations are outside their limit, any contingency load flow with voltage levels outside this limit yields a high value of the index PIv. Thus this index measures the severity of the out of limit bus voltages; and for a set of contingencies, this index provides a direct means of comparing relative severity of the different outages on the system [Ejebe and Wollnberg 1979].

Eq.(6) is applied after a specified contingency to calculate PIv which depends on the values of the bus bar magnitude voltages that are calculated from the load flow program. Eq. (1 to 5) are used to simulate the line and generating unit outages. After this process, contingencies are listed from the higher value of PIv(most severe ones) to the least ones.

The more important point in eq. (6) is how to choose an appropriate value for n. This positive integer value will have great effect on the ranking of contingencies as will be shown later in the results. Also the choice the threshold performance index (Jth) is another important parameter whose value will separate wether the contingencies will effect the power system operation or not.

Mathematical Model for the Line Overloading Correction

The basic mathematical model is developed to define line overload alleviation problem. Linear relationship between line currents and state variables (phase angle and voltage magnitudes at bus bars), and between bus injected powers and state variables are the basis of this model [Gubina and Golob 1996].

The line overloading alleviation technique consists of several steps:-

1- Load flow solution.
2- State variables calculation.
3- Generators response calculation.
4- New generators state.

Load flow solution involves the computation of Newton Raphson method in polar form.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = [J] \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \qquad (7)$$

State variables calculation describes linear relationship between line current and state variables. The current flowing in a transmission line from bus p to q are defined in equation below

$$Ipq = [(|V_p| \times \cos\delta p - |V_q| \times \cos\delta q) \times Gpq - (|V_p| \times \sin\delta p - |V_q| \times \sin\delta q)\, Bpq$$
$$-Bc \times |V_p| \times \sin\delta p] + j[(|V_p| \times \sin\delta p - |V_q| \times \sin\delta q) \times Gpq + (|V_p| \times$$
$$\cos\delta p - |V_q| \times \cos\delta q) \times Bpq + |V_p| \times Bc \times \cos\delta p] = Ir + jIj \qquad (8)$$

where,

Ipq : Current flowing in the transmission line connecting buses p and q.

$|V_P|$: Voltage magnitude at bus p.

$|V_q|$: Voltage magnitude at bus q.

δp : Voltage angle at bus p.

δq : Voltage angle at bus q.

Gpq+jBpq : Series admittance of the line connecting buses p and q.

Bc : Half of the line charging admittance

Ir, Ij : Real and imaginary parts of Ipq.

Let the current flowing through a line connecting buses p and q be I^0pq with a given set of variables $\delta^o p, \delta^o q, |V_p^o|$, and $|V_q^o|$ (calculated from the load flow program after a specified contingency). Assuming that I^0pq is greater than Ipqlim(current limit for the branch pq) and hence a new set of variables δp, δq, $|V_p|$, and $|V_q|$ are to be determined to reduce the current through the line from I^0pq to Ipqlim. **Eq.(9)** is obtained by expanding the function Ipq in the neighborhood of $(\delta^o p, \delta^o q, |V_p^o|, \text{and} |V_q^o|)$ using the Taylor series expansion and neglecting the second and higher order terms. The current over-load Δ Ipq, is defined in eq.(9) as (Ipqlim-I^0pq).

$$\Delta Ipq = \left(\frac{\partial Ipq}{\partial \delta p}\right)^0 \Delta\delta p + \left(\frac{\partial Ipq}{\partial \delta q}\right)^0 \Delta\delta q + \left(\frac{\partial Ipq}{\partial V_p}\right)^0 \Delta|V_P| +$$
$$\left(\frac{\partial Ipq}{\partial V_q}\right)^o \Delta|V_q| \qquad (9)$$

Relations similar to this equation can be written for any overloaded line only in a power system and in matrix form as[T.K.P.Medicherla, and R.Billinton ,1979]:-

$$[\Delta I] = [A]\begin{bmatrix}\Delta\delta \\ \Delta|V|\end{bmatrix} \qquad (10)$$

where the dimension of ΔI matrix is equal to $m \times 1$, m is the number of the overloaded lines in the system.

It should be remembered that the changes in the phase angle are calculated for all buses (except the slack bus bar), while the changes in the voltage magnitude are calculated at the load bus bars only. Now if we are assuming that there are K load bus bars in the system, then the dimension of the A matrix will be $m \times$ (N-1+K). N is the total number of bus bars in the system Eq.(10) can be written as

$$\begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} = [A]^{-1}[\Delta I] \qquad (11)$$

The matrix A is rectangular and its inverse does not exist. The concept of pseudo inverse of a matrix to find the inverse of equations is represented in Al-Shaikihly [1997] in detail.

$$[A_1]^{+} = [A]^{T}\left[[A][A]^{T}\right]^{-1} \qquad (12)$$

where $[A_1]^{+}$ is the pseudo inverse of $[A]$.

Generators response technique involves the calculation of changes in generated active powers with respect to the new changes in the state variables as follows

$$[\Delta p] = [J^{-}]\begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \qquad (13)$$

where ΔP has the dimension of G-1, G is the total number of generating stations (including the slack bus bar). The change in the generated power is calculated at all generation buses except the slack bus bar. J^{-} is the Jacobian matrix.

New generators state the new required generated powers is found as follows

$$\Delta Pj = \Delta PGj - \Delta PLj \qquad (14)$$

where,

ΔPGj : Increment in the generated power at bus j.

ΔPLj : Increment in the loaded power at bus j.

For constant load at bus j, $\Delta PLj = 0$.

$$\Delta PGj = PGjnew - PGold \qquad (15)$$

where,

PGjnew : New generated power required at bus j.

PGold : Old generated power at bus j.

or,

$$PGjnew = \Delta PGj + PGjold \qquad (16)$$

Taking into account that

$$PGjmin. \le PGjnew \le PGjmax \qquad (17)$$

where,

PGjmin : Minimum permissible generated power at bus j.

PGjmax : Maximum permissible generated power at bus j.

After these steps, the load flow calculation is made on the new generated powers to determine whether the line overload are alleviated at all lines or not. If not, another iteration is applied to the overloaded lines only[Medicherla and Billinton 1979].

MAIN PROGRAM

The previous paragraphs describe the four mathematical models for contingency analysis, automatic contingency selection, line overloading correction, and load flow problems respectively. Each model was analyzed separately from the others. But in practice, these models are interconnected and inter-dependent. In general, each model depends at least on the results of one of the other three remaining models. So these programs are built in one main program that indicates the operation sequence of these models, **Fig. (1)**

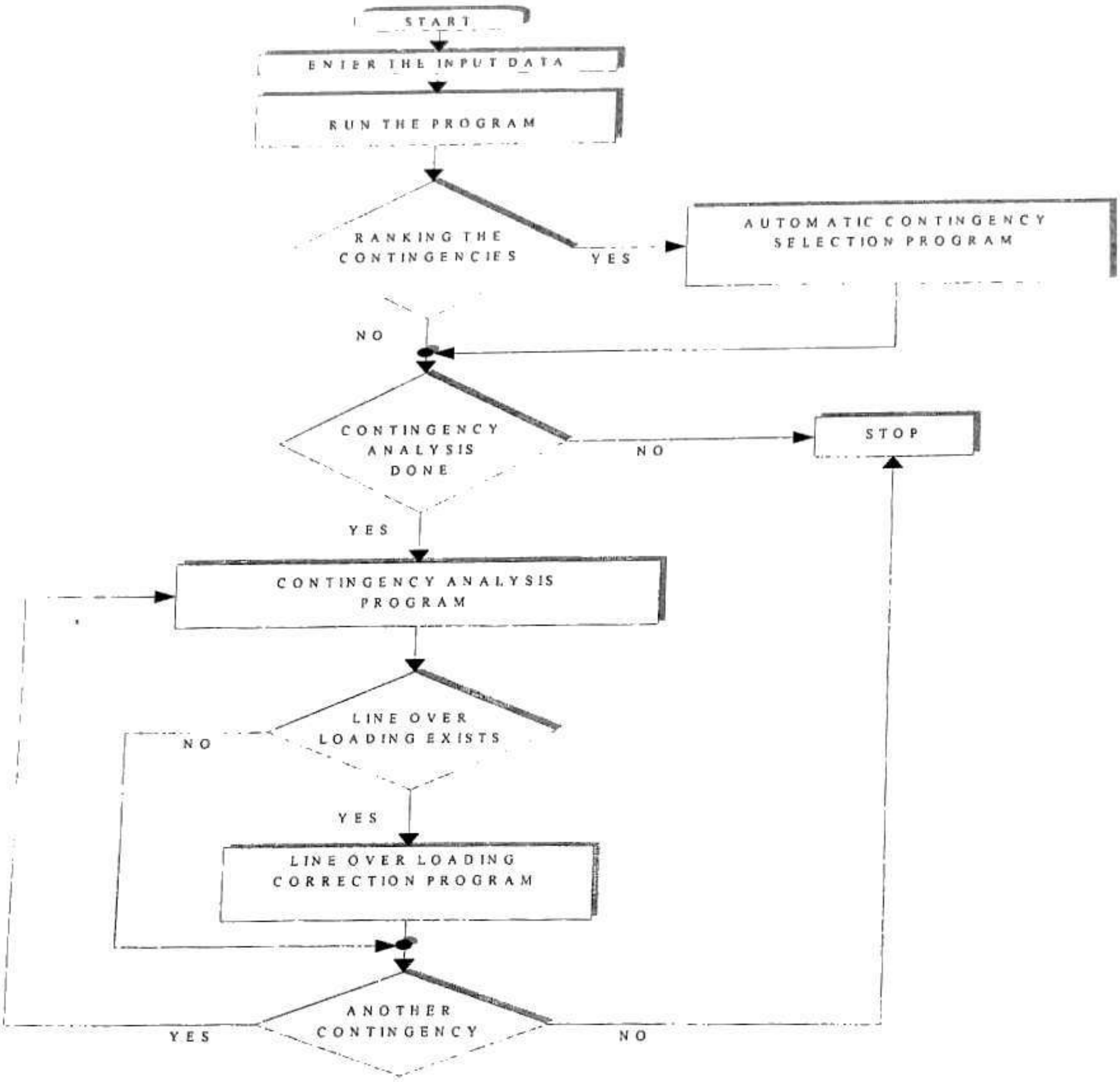
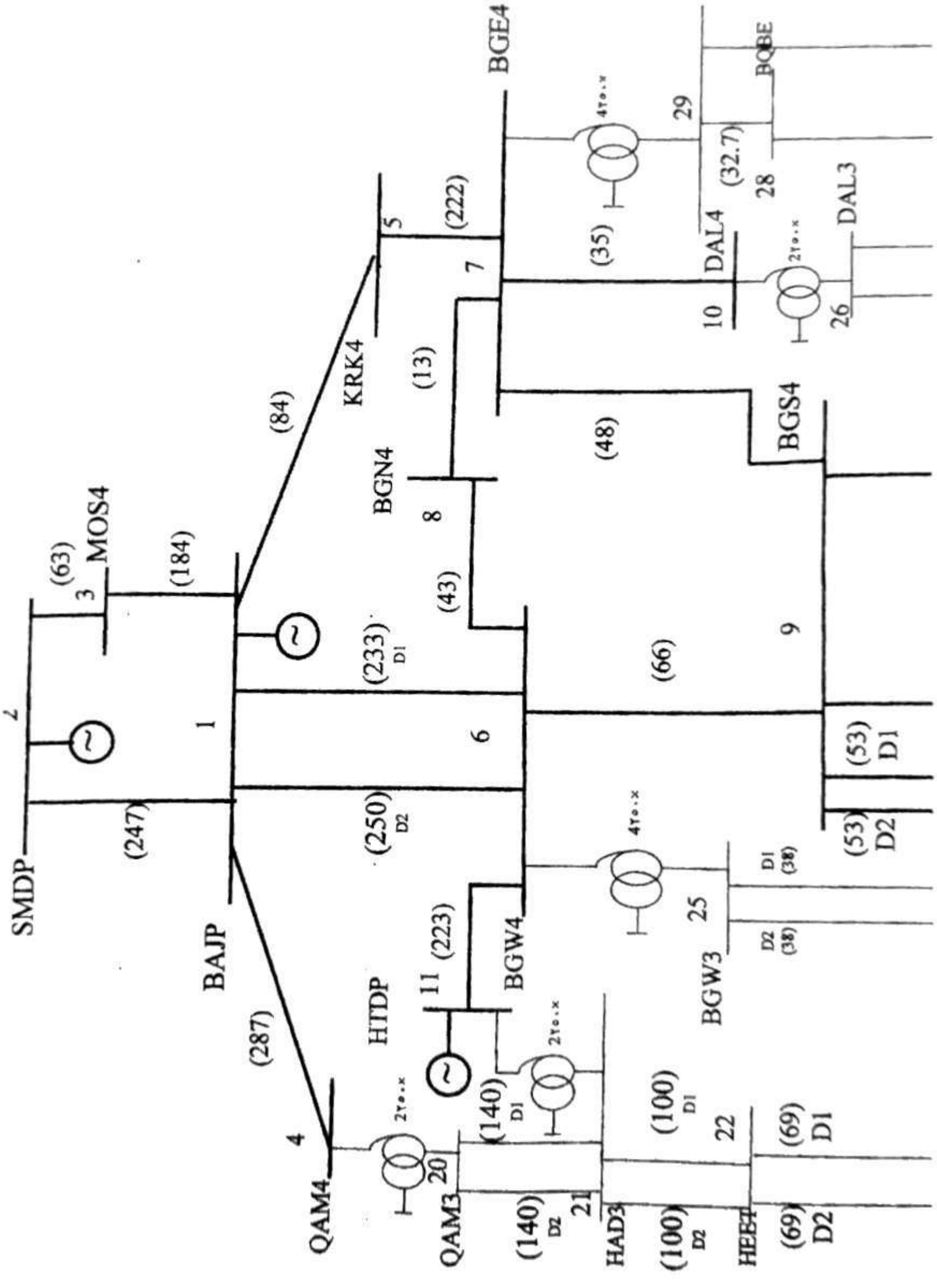


Figure-1 Flow chart for the main program.

RESULTS AND DISCUSSIONS

Results were obtained from a case study **Fig. (2)** whose bus data belong to the peak load of Iraqi National Grid system for August 1997. This case study consists of 29 bus bars and 46 branches. Five equivalent auto transformers were added and were considered as a branch in the line data sheet with zero values for R and B. Number and rating (thermal) of auto transformers are indicated in **Fig. (2)**. **Fig. (2)** shows the single line diagram of the super high voltage (400 kV) Grid system with some transmission lines from the high voltage (132 kV) Grid system (case study) [Iraqi National Control Center 1991].

The input line and bus data is given in **Table (1) and (2)**. The results of the contingency analysis program for this case study are shown in **Table (3)** only for the lines and generating unit outages that affect the system. The permissible voltage change at each bus is 0.05 P.U above or lower its rated value for the S.H.V Grid system and 0.1 P.U for H.V Grid system. The rated value is one in P.U.


SMDP
2
BAJP
1
MOS4
3
(63)
(184)
(247)
(287)
(84)
KRK4
5
(222)
BGE4
7
(13)
BGN4
8
(43)
(233) D1
(250) D2
6
(223)
11
HTDP
BGW4
QAM4
4
QAM3
20
21
(140) D1
(140) D2
HAD3
22
(100) D1
(100) D2
HEE4
(69) D1
(69) D2
(66)
9
(53) D1
(53) D2
BGW3
25
D1 (38)
D2 (38)
(48)
BGS4
(35)
DAL4
10
DAL3
26
28
(32.7)
29
BQBE
4To.x
2To.x

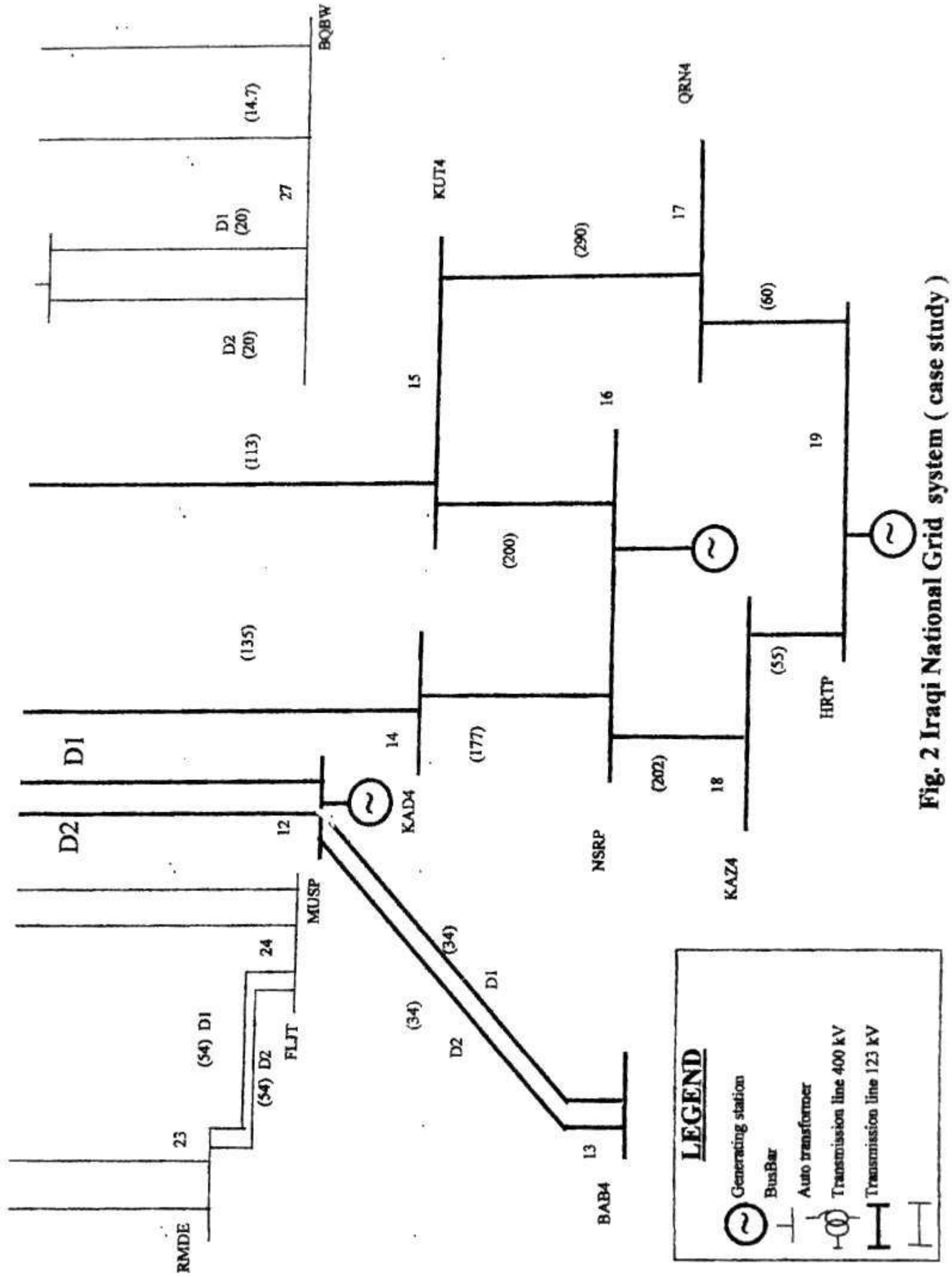


Fig. 2 Iraqi National Grid system (case study)

Table (1). Input branch data for the Iraqi National Grid system (case study).

Branch Name	R P.U	X P.U	B P.U	Limit MVA
SMDP-MOS4	0.00143	0.01252	0.36439	1210
SMDP-BAJP	0.00541	0.04876	1.43839	755
MOS4-BAJP	0.00398	0.03624	1.074	965
BAJP-BGW4-D1	0.00483	0.04393	1.30165	815
BAJP-BGW4-D2	0.00541	0.04925	1.45925	755
BAJP-QAM4	0.00639	0.05682	0.94487	705
BAJP-KRK4	0.00191	0.01669	0.48585	1210
KRK4-BGE4	0.00481	0.04373	1.29581	815
BGW4-BGN4	0.00093	0.00847	0.25099	1210
BGE4-BGN4	0.00028	0.00256	0.07588	1210
BGW4-HDTP	0.00483	0.04393	1.30165	815
BGE4-DAL4	0.00075	0.00689	0.20429	1210
BGE4-BGS4	0.00104	0.00945	0.28017	1210
BGW4-BGS4	0.00143	0.013	0.38524	1210
BGS4-KUT4	0.00244	0.02226	0.65958	1110
BGS4-KAD4	0.00292	0.02659	0.78799	1043
BGS4-MUSP-D1	0.0012	0.01005	0.31598	1210
BGS4-MUSP-D2	0.0012	0.01005	0.31598	1210
KAD4-NSRP	0.00383	0.03486	1.03314	935
KUT4-NSRP	0.00433	0.0394	1.1674	846
KUT4-QRN4	0.0052	0.04728	1.40088	703
NSRP-KAZ4	0.00437	0.03979	1.17907	844
MUSP-BAB4-D1	0.00077	0.00644	0.2027	1210
MUSP-BAB4-D2	0.00077	0.00644	0.2027	1210
KAZ4-HRTP	0.00119	0.01083	0.32103	1210
QRN4-HRTP	0.0013	0.01182	0.35022	1210
BGW4-BGW3	0.0	0.018	0.0	1000
QAM4-QAM3	0.0	0.036	0.0	500
HDTP-HAD3	0.0	0.036	0.0	500
QAM3-HAD3-D1	0.11838	0.3212	0.07	112
QAM3-HAD3-D2	0.11838	0.3212	0.07	112
HAD3-HEET-D1	0.05563	0.2221	0.0517	124
HAD3-HEET-D2	0.05563	0.2221	0.0517	124
HEET-RMDE-D1	0.03838	0.1532	0.0357	137
HEET-RMDE-D2	0.03838	0.1532	0.0357	137
RMDE-FLJT-D1	0.03004	0.11993	0.0279	137
RMDE-FLJT-D2	0.03004	0.11993	0.0279	137
FLJT-BGW3-D1	0.0106	0.05931	0.028	150
FLJT-BGW3-D2	0.0106	0.05931	0.028	150
DAL4-DAL3	0.0	0.036	0.0	500
DAL3-BQBW-D1	0.0439	0.01754	0.004	137
DAL3-BQBW-D2	0.0439	0.01754	0.004	137
BQBW-BQBE	0.01389	0.03258	0.0069	89
BQBW-BGE3	0.04154	0.04154	0.0175	89
BQBE-BGE3	0.01891	0.07551	0.0176	89
BGE4-BGE3	0.0	0.018	0.0	1000

Table (2). The input bus data for Iraqi National Grid system (case study) according to the peak load for 1997.

Bus No.	V P.U	P_G MW	Q_G MVAR	P_L MW	Q_L MVAR
1	1.01	872.54	-62.49	220.0	80.0
2	1.02	600.0	10.0	0.0	0.0
3	0.0	0.0	0.0	300.0	180.0
4	0.0	0.0	0.0	80.0	30.0
5	0.0	0.0	0.0	100.0	130.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	150.0	50.0
9	0.0	0.0	0.0	100.0	20.0
10	0.0	0.0	0.0	0.0	0.0
11	1.0	500.0	20.0	2.0	1.0
12	1.0	600.0	150.0	200.0	80.0
13	0.0	0.0	0.0	100.0	50.0
14	0.0	0.0	0.0	250.0	100.0
15	0.0	0.0	0.0	150.0	70.0
16	1.01	500.0	200.0	120.0	20.0
17	0.0	0.0	0.0	120.0	60.0
18	0.0	0.0	0.0	300.0	100.0
19	1.025	400.0	50.0	0.0	0.0
20	0.0	0.0	0.0	60.0	20.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	50.0	25.0
23	0.0	0.0	0.0	15.0	5.0
24	0.0	0.0	0.0	100.0	35.0
25	0.0	0.0	0.0	400.0	100.0
26	0.0	0.0	0.0	30.0	10.0
27	0.0	0.0	0.0	70.0	20.0
28	0.0	0.0	0.0	70.0	20.0
29	0.0	0.0	0.0	450.0	180.0

Table (3). Results of contingency analysis program for the Iraqi National Grid system.

Case	Contingency Effect				
Outage	Bus Bar Voltage			Overloaded Lines	
	Bus No.	Bus Name	V P.U	Branch Name	S MVA
Line 1-4 (BAJP-QAM4)	4 20	QAM4 QAM3	0.6153 0.6341		
Line 7-10 (BGE4-DAL4)	10 26 27 28	DAL4 DAL3 BQBW BQBE	0.8588 0.8588 0.8605 0.8683	BQBE-BGE3	97.37
Line 6-11 (BGW4-HDTP)	4 22 23 24	QAM4 HEET RMDE FLJT	0.9485 0.8374 0.8452 0.8808	HDTP-HAD3 QAM3-HAD3-D1 QAM3-HAD3-D2 HAD3-HEET-D1 HAD3-HEET-D2	525.025 113.97 113.97 140.14 140.14
Line 1-5 (BAJP-KRK4)	5	KRK4	0.9207		
Line 7-9 (BGE4-BGS4)	7 10 28	BGE4 DAL4 BQBE	0.9453 0.9402 0.8983		
Line 2-3 (SMDP-MOS4)	3	MOS4	0.9403		

It is clear from the results obtained from **Table (3)** that:-

1- Only six events from 32 events (6 generating stations with 26 branches for Iraqi National S.H.V Grid system) will have been effect on the power system.

2- Large dropping in bus bar voltages (0.6153 P.U at QAM4 and 0.6341 P.U at QAM3) due to the line of BAJP-QAM4 (line 1-4) is outage. The reason for this is because this line is very long(287 km), so its outage from the system making the Q charging from this line equal to zero(56.8 MVAR Q charging for each 100 km),i.e., large dropping in voltage magnitude especially at the buses that connect this line(bus voltage at BAJP is constant because it was taken as a slack bus bar to the system) and that those nearest to it.

3- For the lines BGE4-DAL4(line 7-10) and BGW4-HDTP(line 6-11) outages, it is found that the dropping in bus voltages(out of the permissible limits) is due to the higher reactive power load at these buses or at the adjacent buses as well as to that Q charging from this line outage will be equal to zero.

4- Also it is found that the line of BGW4-HDTP will cause the most sever overloading in the adjacent branches. The reason for this overloading is that the only path to the generated active power from HADITHA power station (500 MW) is through the branch of HDTP-HAD3 see **Fig. (2)** which will be over loaded and then will be divided through the branches of QAM3-HAD3(double line) and HAD3-HEET(also double line) which will also be overloaded.

From the results of automatic contingency analysis model, we can estimate in advance to contingency analysis, which contingencies will cause problem(critical) and which do not and then will specify threshold performance index that decides the group of the critical contingencies from those non critical. The same case study that was taken in contingency analysis is applied to the automatic contingency selection program. This program depends mainly on equation-6. In this equation, $V_i^{sp.}$ is taken to be equal to 1 P.U(rated value), $\Delta V_i^{Lim.}$ is equal to 0.05 P.U for 400 kV Grid system and 0.1 P.U for 132 kV Grid system.

From equation-6, it is found that there are two factors affecting on the ranking operation. These two factors are the weighting and exponent integer(n) factors. So to investigate the effect of these two factors, it should take one of them to be constant and change the others. In most studies, the weighting factor is usually taken to be equal to one and the exponent factor is changeable.
From the results in **Table (4)** (contingencies are listed from the higher value of PIv to the smallest ones for each integer value to n), it is found that n=1 in equation-6 leads to the masking problem. From the contingency analysis results we see that the lines outages 8-6, 5-7, and 1-6D1 have no effect on the system(on the voltage bus bars or lines power flow) while the line 2-3(SMDP-MOS4) outage leads to an effect on the bus bar voltage in MOS4(0.9403 P.U). As a values to PIv(with n=1), this outage is small than those for events outage that were mentioned above. This problem(masking problem) can be solved by increasing the value of n, increasing n also increases the accuracy of ranking(listing) according to severities. It is shown for the Iraqi National Grid system that after n=5, the ranking process will be approximately constant. Also with increasing n, values of the PIv will be very large for those greater than one and very small for those less than one. So in this case n=5 is a better choice to the ranking process.
From the results that were obtained from the various types of data (taken for the peak load of years 1990,1991,......................,1997), it is found that the best choice to the Jth is 0.15 with n=5.

Table (4). Results of the automatic contingency selection program for the Iraqi National Grid system with various values to n.

Line OR Generating. Unit Outage	PIv N=1	Line OR Generating. Unit Outage	PIv n=2	Line OR Generating Unit Outage	Piv n=3	Line OR Generating. Unit Outage	PIv n=4	Line OR Generating. Unit Outage	Piv n=5
1-4 L	39.00	1-4 L	921.2	1-4 L	very large	1-4 L	very large	1-4 L	very large
7-10 L	8.588	7-10 L	18.90	7-10 L	88.1	7-10 L	511	7-10 L	3241.2
6-11 L	6.822	6-11 L	4.703	6-11 L	6.34	6-11 L	11.	6-11 L	21.647
7-9 L	4.915	1-5 L	2.37	1-5 L	2.93	1-5 L	5.12	1-5 L	10.131
1-5 L	4.606	7-9 L	2.042	7-9 L	1.40	7-9 L	1.19	7-9 L	1.1477
8-6 L	2.98	2-3 L	0.790	2-3 L	0.53	2-3 L	0.52	2-3 L	0.5893
5-7 L	2.906	8-6 L	0.683	8-6 L	0.24	8-6 L	0.11	8-6 L	0.0545
1-6D1 L	2.805	5-7 L	0.571	5-7 L	0.17	5-7 L	0.062	5-7 L	0.0255
2-3 L	2.788	1-6D1 L	0.510	1-6D1 L	0.14	1-6D1 L	0.046	1-6D1 L	0.0169
1-6D2 L	2.772	1-6D2 L	0.498	1-6D2 L	0.13	1-6D2 L	0.044	1-6D2 L	0.016
14-16 L	2.571	14-16 L	0.421	14-16 L	0.10	14-16 L	0.032	7-8 L	0.0113
9-15 L	2.489	9-15 L	0.387	7-8 L	0.09	7-8 L	0.031	14-16 L	0.011
6-9 L	2.415	6-9 L	0.377	9-15 L	0.09	6-9 L	0.025	6-9 L	0.0081
12 g	2.312	7-8 L	0.376	6-9 L	0.08	9-15 L	0.025	9-15 L	0.008
7-8 L	2.286	12 g	0.348	12 g	0.07	12 g	0.022	12 g	0.0069
9-12D1 L	2.248	9-12D1 L	0.330	9-12D1 L	0.07	9-12D1 L	0.020	9-12D1 L	0.0063
9-12D2 L	2.248	9-12D2 L	0.330	9-12D2 L	0.07	9-12D2 L	0.020	9-12D2 L	0.0063
9-14 L	2.241	9-14 L	0.312	15-17 L	0.066	15-17 L	0.018	15-17 L	0.0056
18-19 L	2.177	18-19 L	0.309	9-14 L	0.066	16 g	0.0173	16 g	0.0051
16 g	2.164	15-17 L	0.306	16 g	0.066	9-14 L	0.0173	9-14 L	0.0051
19 g	2.145	16 g	0.306	18-19 L	0.065	15-16 L	0.017	15-16 L	0.0051
15-17 L	2.116	19 g	0.301	15-16 L	0.064	18-19 L	0.017	19 g	0.0049
15-16 L	2.105	15-16 L	0.298	19 g	0.064	19 g	0.0168	18-19	0.0049
3-1 L	2.082	3-1 L	0.283	19-17 L	0.061	19-17 L	0.0161	19-17 L	0.0048
12-13D2 L	2.080	12-13D2 L	0.283	16-18 L	0.059	16-18 L	0.015	16-18 L	0.0043
12-13D1 L	2.080	12-13D1 L	0.283	12-13D1 L	0.059	12-13D1 L	0.0149	12-13D1 L	0.0043
2 g	2.079	2 g	0.283	12-13D2 L	0.059	12-13D2 L	0.0149	12-13D2 L	0.0043
1 g	2.077	1 g	0.283	1 g	0.058	1 g	0.0149	1 g	0.0043
2-1 L	2.076	2-1 L	0.283	3-1 L	0.058	3-1 L	0.0149	3-1 L	0.0043
11 g	2.058	16-18 L	0.282	2 g	0.058	2 g	0.0149	2 g	0.0043
16-18 L	2.054	19-17 L	0.282	2-1 L	0.058	2-1 L	0.0149	2-1 L	0.0043
19-17 L	1.992	11 g	0.278	11 g	0.057	11 g	0.0144	11 g	0.0041

From **Table (3)** (contingency analysis results), two states of overloaded lines are taking place. Firs when a line of HDTP-BGW4 outage and the second when a line of BGE4-DAL4 outage. **Table (5)** shows the overloaded lines values (in MVA and AMP) with its need for correction and **Table (6)** shows the power redistribution at power stations which needed for overloaded lines correction due to line HDTP-BGW4 outage.

Table (5). Branches over loading MVA and current before and after the correction due to line HDTP-BGWS outage.

Branch Over-Loading Name	Before the Correction				After the Correction			
	S MVA	I AMP	Limit AMP	ΔI AMP	S MVA	I AMP	Limit AMP	ΔI AMP
HDTP-HAD3	525.0	758.6	721.6	36.9	414.5	598.3	721.6	-123.3
QAM3-HAD3-D1	113.9	520.9	489.8	31.0	85.9	383.6	489.8	-106.2
QAM3-HAD-D2	113.9	520.9	489.8	31.0	85.9	383.6	489.8	-106.2
HAD3-HEET-D1	140.1	640.5	542.3	98.1	119.1	531.7	542.3	-10.6
HAD3-HEET-D2	140.1	640.5	542.3	98.1	119.1	531.7	542.3	-10.6

Table (6). Power redistribution at power stations with its state variables before and after correction due to line HDTP-BGW4 outage.

Power	Before the Correction			After the Correction			ΔP	Δδ
Station	P_G MW	V P.U	δ Deg.	P_G MW	V P.U	δ Deg.	MW	Deg.
BAJP	872.54	1.01	0.0	1006.55	1.01	0.0	134.01	0.0
SMDP	600	1.02	5.1	600	1.02	5.1	0.0	0.0
HDTP	500	1.0	41.38	407.69	1.0	29.15	-92.31	-12.23
MUSP	600	1.0	-8.95	600	1.0	-9.09	0.0	0.14
NSRP	500	1.01	-7.02	500	1.01	-7.16	0.0	0.14
HRTP	400	1.025	-7.33	400	1.025	-7.47	0.0	0.11
$\sum P_G$	3472.54			3514.24			41.7	

From the results in **Table (5)**, it is clear that to alleviate the line over loading, power flow through these lines must be reduced. So the nearest power stations from these lines must respond. From **Table (6)**, it is found that only two stations are changed. Single line diagram **Fig. (2)** shows that these two stations are the nearest ones from the overloaded lines. This is one advantage in this method in that it takes into account the nearest and farthest stations from the overloaded lines. HADITHA power station is the nearest one from the overloaded lines region. BAJI power station will compensate this reduction and other changes (operating conditions) in the system and to keep on the same load demand.

Changes in power flow before and after the correction as well as the changes in active power redistribution at power stations can be shown graphically in **Fig. (3) and (4)** respectively.

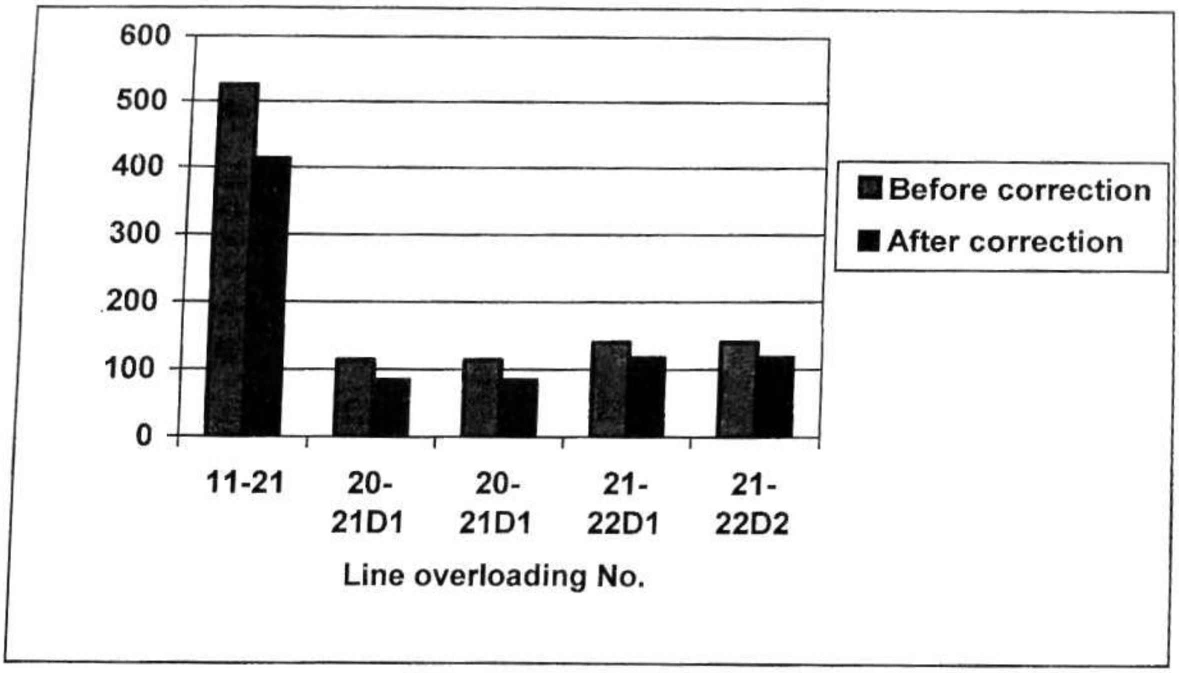


Fig. (3) Changes in MVA power at over loaded lines before and after the correction process

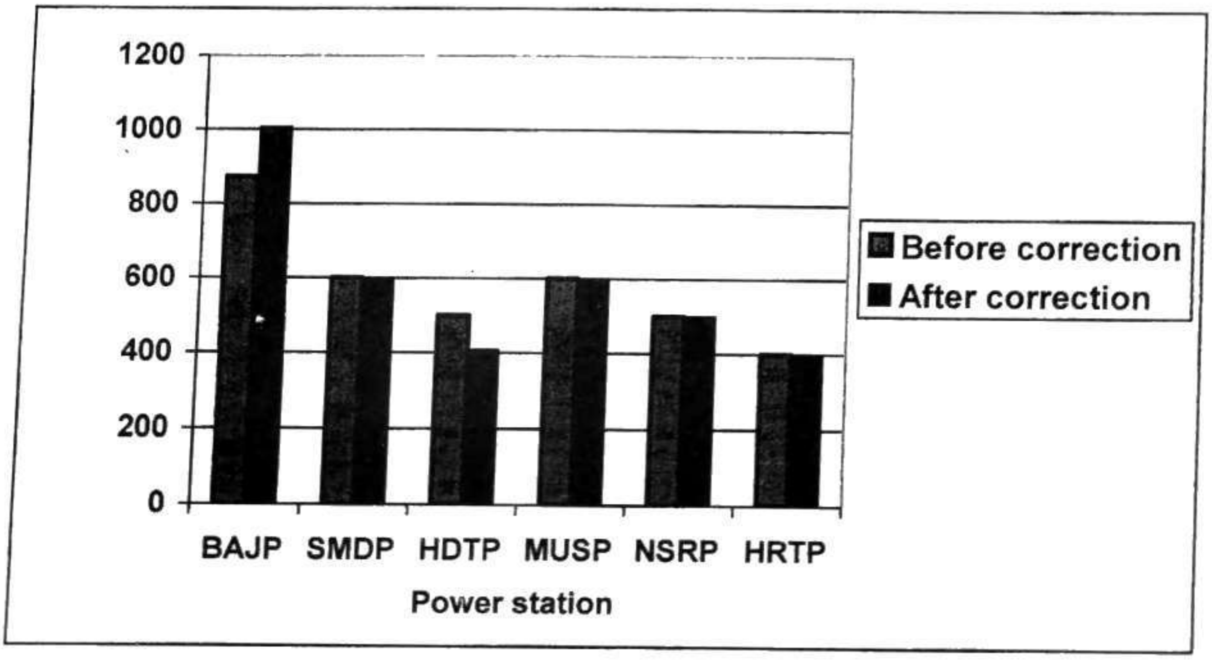


Fig. (4) Changes in MW power at each station before and after the correction process.

Also it is found from the line overloading correction program results that as well as line overloading was alleviated, effective voltage bus bars(out of the permissible limits) are improved. These improvement are shown in **Table (7)** below

Table (7). Changes in effective voltage bus bars after line overloading correction due to line HDTP-BGW4 outage.

Bus No.	Bus Name	Voltage Bus Bar Before the Correction	Voltage Bus Bar After the Correction
4	QAM4	0.9485	0.9721
22	HEET	0.8374	0.8881
23	RMDE	0.8452	0.8879
24	FLJT	0.8808	0.9054

MAIN CONCLUSIONS

This research attempts to solve contingency problems in power system Proposed model set to the contingency analysis depends on the simulation of the Y matrix to simulate any line outage (single line outage). The method is particularly suitable for long term transmission planning studies. An important feature of the algorithm is that the execution times are extremely short. Thus, this algorithm is suitable for large system evaluation. Simulation of the generating unit outage means reducing the total generation of the station suffering from the outages, assuming that all units are equal in generation. Contingency ranking algorithm has been applied to a single outage contingency cases, especially with respect to voltage problem analysis to find those combinations of equipment outages which may cause future trouble on a system. System performance index (PI) is defined as a penalty function to penalize severely any violation of bus voltage constraints. Finally, basic line overload alleviation model consisting of a set of linear relationships between line currents and state variables, and between bus power injections and state variables are developed. This model considers the load constant during the correction process and takes into consideration its capacity at each power station. The results of this technique will also serve as an operating guide for generation rescheduling to a system dispatcher in the event of line overloads. Newton Raphson method is used in these models and it has proved to be reliable in convergence.

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