

Simulation of Line Outage Distribution Factors (L.O.D.F) Calculation for N-Buses System

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ABSTRACT

System security involves practices designed to keep the system operating when components fail. A transmission line may be damaged by a storm lead to taken out by automatic relaying. If, in committing and dispatching generation, proper regard for transmission flows are maintain, the remaining transmission lines can take the increased loading with still remain within limit. Because the specific times at which initiating events that cause components to fail are unpredictable, the system must be operated at all times in such a way that the system will not be left in a dangerous condition should any credible initiating event occur. Power system equipment are designed to be operate within certain limits most pieces of equipment are protected by automatic devices that can cause equipment to be switched out of the system if these limits are violated. If any event occurs on a system that leaves it operating with limits violated, the event may be follow by a series of further actions that switch other equipment out of service. If this process of cascading failures continues, the entire system or large parts of it may completely collapse. In this paper, it has been building simulation program to study the cases outage lines of the network system. Three cases adopted for the purposes of the study. Where study and discuss those cases in detail and its impact on network performance. It was diagnosed lines, which causes increased power flow over the limit in addition to the reflection of the other feeding lines.

Keywords

Contingency analysis; dc power flow; power system security

1. INTRODUCTION

The dc power flow simplifies the power flow by making a number of approximations including 1) completely ignoring the reactive power balance equations, 2) assuming all voltage magnitudes are identically one per unit, 3) ignoring line losses and 4) ignoring tap dependence in the transformer reactance. Hence, the dc power flow reduces the power flow problem to a set of linear equations. The dc solution load value has increased to match the total ac load plus losses, a manner to make comparison between the ac and dc solution results possible. The effectiveness of the method developed is identified through its application to a 6 buses test system [1].

2. DC POWER FLOW

AC power flow algorithms have high calculation precision but do not have fast speed. In real power dispatch or power market analysis, the requirement of calculation precision is not very high, but the requirement of calculation speed is of most concern, especially for a large - scale power system. More simplification power flow algorithms than fast decoupled power flow algorithms are used. One algorithm is called "MW Only". In this method, the Q - V equation in the

fast decoupled power flow model is completely dropped. Only the following P - θ equation is used to correct the angle according to the real power mismatch [2].

$$\begin{bmatrix} \frac{\Delta P_1}{V_1} \\ \frac{\Delta P_2}{V_2} \\ \vdots \\ \frac{\Delta P_{n-1}}{V_{n-1}} \end{bmatrix} = \begin{bmatrix} -B_{11} & -B_{12} & -B_{13} \\ -B_{21} & -B_{22} & -B_{23} \\ \vdots & \vdots & \vdots \\ -B_{n-1,1} & -B_{n-1,2} & -B_{n-1,n-1} \end{bmatrix} \begin{bmatrix} \Delta \theta_1 \\ \Delta \theta_2 \\ \vdots \\ \Delta \theta_{n-1} \end{bmatrix} \quad (1)$$

In the MW - only power flow calculation, the voltage magnitude can be handled either as constant or as 1.0 during each P - θ iteration. For the convergence, only real power mismatch is checked no matter what the reactive power mismatch is. Another most simplified power flow algorithm is DC power flow. It is also an MW - only method but has the following assumptions:

1. All the voltage magnitudes are equal to 1.0.
2. Ignore the resistance of the branch; i.e., the susceptance of the branch is

$$B_{ij} = -\frac{1}{x_{ij}} \dots\dots(2)$$

3. The angle difference on the two ends of the branch is very small, so that we

$$\sin\theta_{ij} = \theta_i - \theta_j$$

$$\cos\theta_{ij} = 1$$

- (4) Ignore all ground branches; that is,

$$B_{i0} = B_{j0} = 0$$

$$\cos\theta_{ij} = 1$$

Therefore, the DC power flow model will be

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \vdots \\ \Delta P_{n-1} \end{bmatrix} = [B'] \begin{bmatrix} \Delta \theta_1 \\ \Delta \theta_2 \\ \vdots \\ \Delta \theta_{n-1} \end{bmatrix} \dots (3)$$

Or

$$[\Delta P] = [B'][\Delta \theta] \quad \dots\dots (4)$$

Where: B' matrix are the same as those in the XB version of fast decoupled power flow but we ignore the matrix B". That is,

$$B'_{ij} = -\frac{1}{x_{ij}} \quad \dots\dots (5)$$

$$B'_{ij} = -\sum_{j \neq i} B'_{ij} \quad \dots\dots (6)$$

The DC power flow is a purely linear equation, so only one iteration calculation is needed to obtain the power flow solution. However, it is only good for calculating real power flows on transmission lines and transformers. The power flowing on each line using the DC power flow is then

$$P_{ij} = -B_{ij}(\theta_i - \theta_j) = \frac{\theta_i - \theta_j}{x_{ij}} \quad \dots\dots (7)$$

3. SENSITIVITY CALCULATION

The sensitivity analyses are becoming more and more important in practical power system operations including in power market operations. These are analyzes and discusses all kinds of sensitivity factors such as loss sensitivity factor, generator shift factor (GSF), constraint shift factor, line outage distribution factor (LODF) and response factor for the transfer path. It also addresses the practical application of these sensitivity factors including a practical method to convert the sensitivities with different references. The power operator uses these to study and monitor market and system behavior and detect possible problems in the operation. These sensitivity calculations are also used to determine whether the online capacity as indicated in the resource plan is located in the right place in the network to serve the forecasted demand. If congestion or violation exists, the generation scheduling based on the sensitivity calculations can determine whether or not a different allocation of the available resources could resolve the congestion or violation problem [3].

The problem of studying thousands of possible outages becomes very difficult to solve if it is desired to present the results quickly. One of the easiest ways to provide a quick calculation of possible overloads is to use linear sensitivity factors. These factors show the approximate change in line flows for changes in generation on the network configuration and are derived from the DC load flow presented in the flowing steps. These factors can be derived in a variety of ways and basically come down to two types [3]:

1. Generation shift factors.
2. Line outage distribution factors.

Setp1:- Now calculate the Y_{bus} from impedance x_{ij} as equation

$$y_{ij} = -\frac{1}{x_{ij}} \quad \dots\dots (8)$$

$$y_{ii} = \sum_{j=1}^n y_{ij} \quad \dots\dots (9)$$

We gets

$$Y_{bus} = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1n} \\ y_{21} & \ddots & \dots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{n1} & y_{n2} & \dots & y_{nn} \end{bmatrix} \quad \dots\dots (10)$$

Step2:- Since bus one is a slack bus and eliminate (1st row & the 1st column) from matrix in equation (10). We get

$$Y_{eliminate} = \begin{bmatrix} y_{22} & y_{23} & \dots & y_{2n} \\ y_{32} & \ddots & \dots & y_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{n2} & y_{n3} & \dots & y_{nn} \end{bmatrix} \quad \dots\dots (11)$$

Step3:- Find the inverse of $Y_{eliminate}$, we gets

$$M = Y_{eliminate}^{-1} \quad \dots\dots (12)$$

Step4:- Determine the sensitivity matrix by :

$$X = \begin{bmatrix} 0 & 0 \\ 0 & M \end{bmatrix} \quad \dots\dots (13)$$

Step5:- Determine the generation shift sensitivity factor by performing the outage of the generation connected to selected bus (k) with connected line (ll) from the following equation:

$$a_{ll,k} = \frac{1}{x_l} (X_{nk} - X_{mk}) \quad \dots\dots (14)$$

Step6:- Determine of the line outage distribution sensitivity factor by performing the outage of the line connected to bus i called (kk) that affected on the line in bus another line is called (ll) from the following equation:

$$d_{ll,kk} = \frac{\frac{x_{kk}}{x_{ll}}(X_{in} - X_{jn} - X_{im} + X_{jm})}{x_{kk} - (X_{ii} + X_{jj} - 2X_{ij})} \quad \dots\dots (15)$$

The generation shift factors are designated ($a_{ll,i}$) and have the following definition:

$$a_{ll,i} = \frac{\Delta f_{ll}}{\Delta P_i} \quad \dots\dots (16)$$

Where:

ll = line index.

i = bus index.

Δf_{ll} = change in megawatt power flow on line ll when a change in generation, ΔP_i occurs at bus i .

ΔP_i = change in generation at bus i .

It is assumed in this definition that the change in generation, ΔP_i , is exactly compensated by an opposite change in generation at the reference bus, and that all other generators remain fixed. The $a_{ll,i}$ factor then represents the sensitivity of the flow on line ll to a change in generation at bus i . Suppose one wanted to study the outage of a large generating unit and it was assumed that all the generation lost would be made up by the reference generation (we will deal with the case where the generation is picked up by many machines shortly). If the generator in question was generating P_i^0 MW and it was lost, we would represent ΔP_i , as [4]:

$$\Delta P_i = -P_i^0 \quad \dots\dots (17)$$

And the new power flow on each line in the network could be calculated using a pre calculated set of "a" factors as follows:

$$f_{ll} = f_{ll}^o + a_{ll,i} \Delta P_i \text{ for } ll = 1 \dots LL \dots \dots (18)$$

Where:

f_{ll} = flow on line ll after the generator on bus i fails.

f_{ll}^o = flow before the failure.

The “outage flow,” f_{ll} on each line can be compared to its limit and those exceeding their limit flagged for alarming. This would tell the operations personnel that the loss of the generator on bus i would result in an overload on line ll .

The line outage distribution factors are used in a similar manner; only they apply to the testing for overloads when transmission circuits are lost. By definition, the line outage distribution factor has the following meaning:

$$d_{ll,k} = \frac{\Delta f_{ll}}{f_k^o} \dots \dots (19)$$

$d_{ll,k}$ = line outage distribution factor when monitoring line l after an outage on line k .

Δf_{ll} = change in MW flow on line l .

f_k^o = original flow on line k before it was outaged (opened).

If one knows the power on line ll and line k , the flow on line ll with line k out can be determined using "d" factors.

$$f_{ll} = f_{ll}^o + d_{ll,k} f_k^o \dots \dots (20)$$

Where:

f_{ll}^o, f_k^o = preoutage flows on lines ll and k , respectively.

f_{ll} = flow on line ll with line k out.

4. RESULT AND DISCUSSION

The line and bus data of the IEEE-6 Bus test system. The system input data is shown in tables (1, 2, & 3).

Table 1: Line Data [5].

From Bus	To Bus	R (pu)	X (pu)
1	2	0.10	0.20
1	4	0.05	0.20
1	5	0.08	0.30
2	3	0.05	0.25
2	4	0.05	0.10
2	5	0.10	0.30
2	6	0.07	0.20
3	5	0.12	0.26
3	6	0.02	0.10
4	5	0.20	0.40
5	6	0.10	0.30

Table 2: Bus Data [5].

Bus Number	Bus Type	Voltage Schedule (pu V)	P _{gen.} (pu MW)	P _{load} (pu MW)
1	Swing	1.05	1.078	0.0
2	Gen.	1.05	0.50	0.0

3	Gen.	1.07	0.60	0.0
4	Load		0.0	0.70
5	Load		0.0	0.70
6	Load		0.0	0.70

Table 3: The MW Limits on The Transmission Line.

Line	MW Limit
1-2	70
1-4	90
1-5	70
2-3	20
2-4	50
2-5	40
2-6	60
3-5	30
3-6	70
4-5	30
5-6	20

The simulation program figures (1 & 2) was used to study multi cases of line outage network as follows:

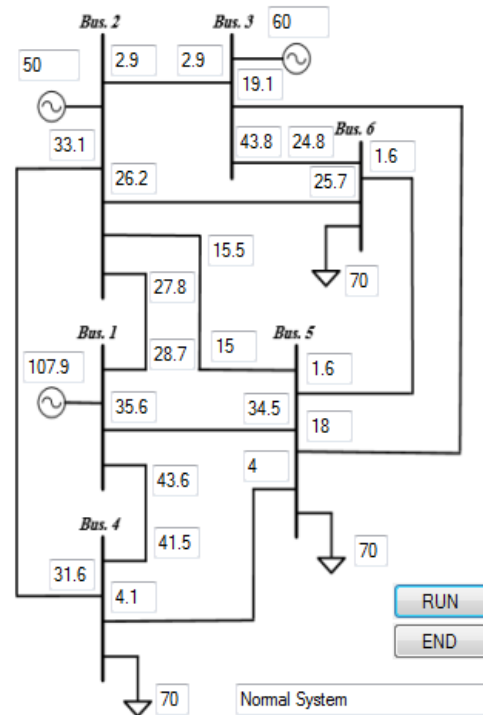


Figure 1: Test System Six-bus network.

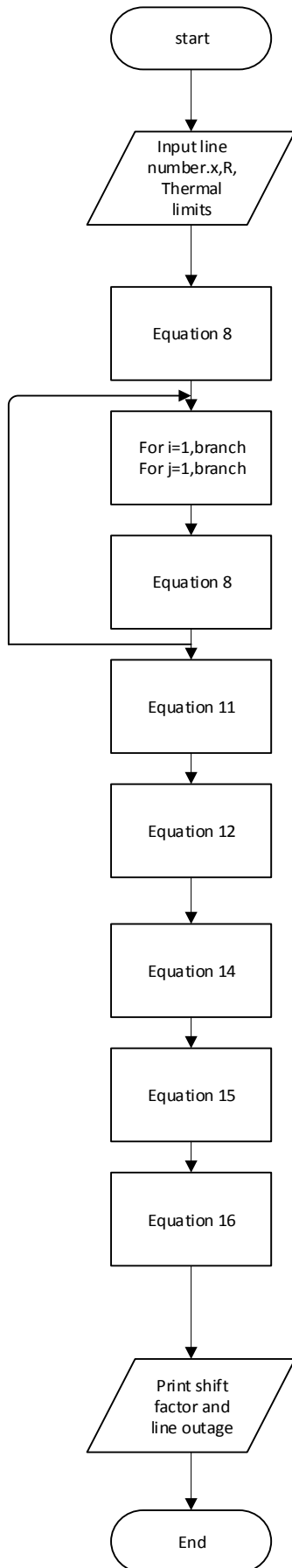


Figure 2: Flow chart multi cases of line outage network.

Case 1: (1-2) outage line.

Figures (3 & 4), it shows that the effect of power flow of the line due to effects of line outage (1-2). This affects leads to redistributing the power flow on the lines of the network system, see table (4). Therefore we see increment and discernment in power flow lines to make that operation of network system. Line (1-4) increase (39.15%), line (1-5) increase (32.67%). Those lines are directly affected by the works to compensate for the network to take advantage of the generator at Bus1. Other lines affected indirectly where the line (2-3) reflected a decrease in the direction of the force of the ability to read (52 kW). Decreasing power flow lines (2-4, 2-5, 2-6, and 3-5) by (51%, 34.71%, 13.3%, and 17.64%), respectively, at the same time increasing power flow lines (3-6, 4-5, and 5-6) by (0.01%, 4.63%, and 191%), respectively.

Case 2: (1-4) outage line.

In the event of a defect in the line (1-4), that causes a change in the power flow to the lines of the network, as shown in the table (4). Figures(5 & 6) shows an increase in the power flow lines (1-2, 1-5, 3-6, and 5-6) by (96.5%, 44.7%, 0.46%, and 91.25%) respectively, while the decrease happen applicability capacity of lines (2-3, 2-5, 2-6, and 3-5) by (48.6%, 16.58%, 6.33%, and 8.43%), respectively. The privacy of the line (4-5) was reflected feed direction to become (6.16 MW). There is a problem in the line (2-4), where the amount of the increase of the power flow is higher than the thermal limits by (132.88%).

Case 3: (3-6) outage line.

The outage line (3-6) for technical reasons lead to an increase in the power flow is higher than the thermal limit in two lines, the first (3-5) be increase (133%) The second line (2-3) which become counterproductive by feeding (20.11 MW), see table (4). In the other hand are increase in lines (1-2, 1-4, 2-6, and 5-6) by (2%, 0.4%, 97.67%, and 113%), respectively. In the same time decrease in lines (1-5, 2-5, 2-4, and 4-5) by (2.13%, 7.48%, 2.5%, and 16.1%), respectively, see figures (7 & 8).

Table 4: variation in Power Flow for multi cases.

Line	MW Limit	Flow at normal state (MW)	Flow at (1-2) outage line (MW)	Flow at (1-4) outage line (MW)	Flow at (3-6) outage line (MW)
1-2	70	28.7	0.0	56.4	29.29
1-4	90	43.6	60.67	0.0	43.77
1-5	70	35.6	47.23	51.5	34.84
2-3	20	2.9	-0.052	1.49	-20.11 overload
2-4	50	33.1	16.21	66.44 overload	32.27
2-5	40	15.5	10.12	12.93	14.34
2-6	60	26.2	22.72	24.54	51.79
3-5	30	19.1	15.73	17.49	39.89 overload
3-6	70	43.8	44.22	44.0	0.0
4-5	30	4.1	4.29	-6.16	3.44
5-6	20	1.6	4.66	3.06	19.81

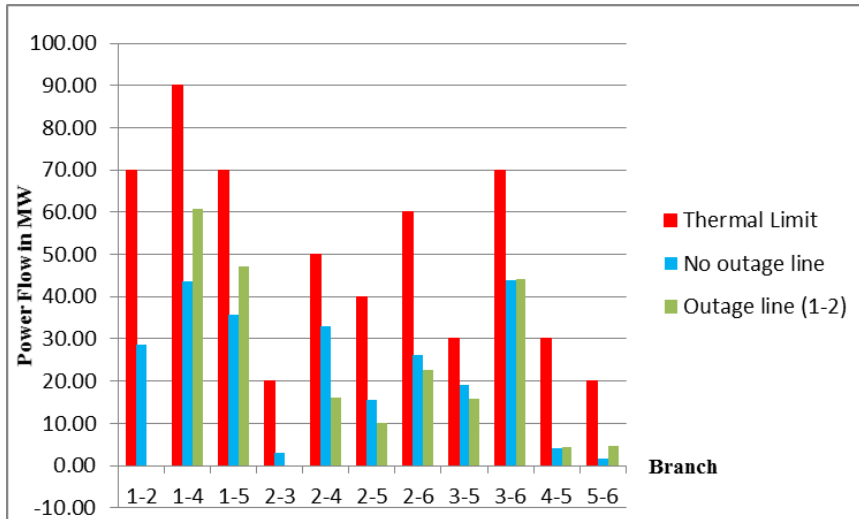


Figure 3: Power Flow for network lines system under outage line (1-2).

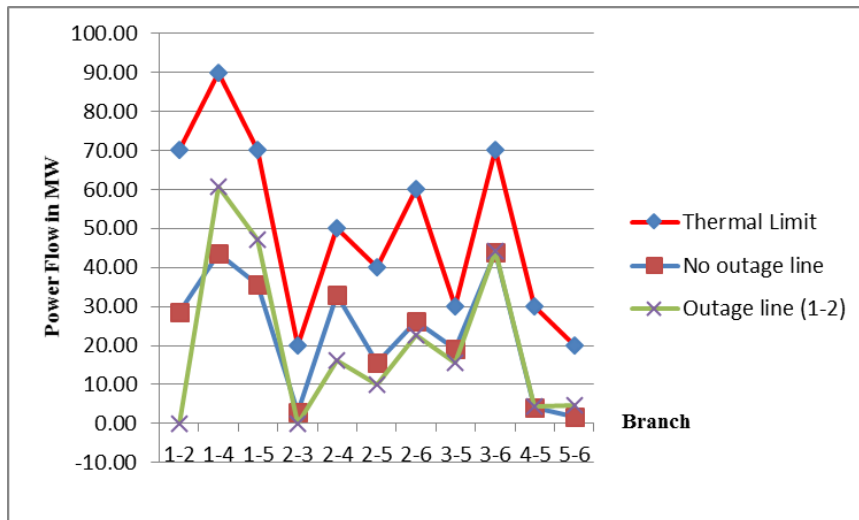


Figure 4: Value of power flow lines for network lines (case 1).

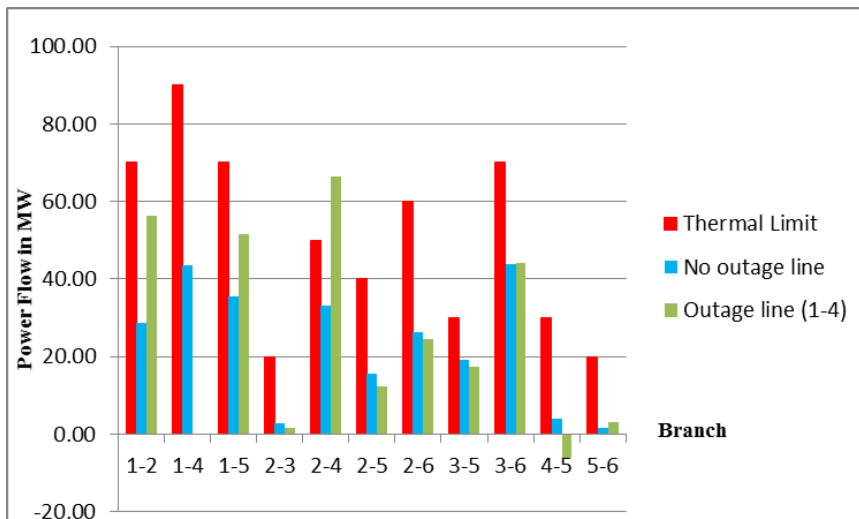


Figure 5: Power Flow for network lines system under outage line (1-4).

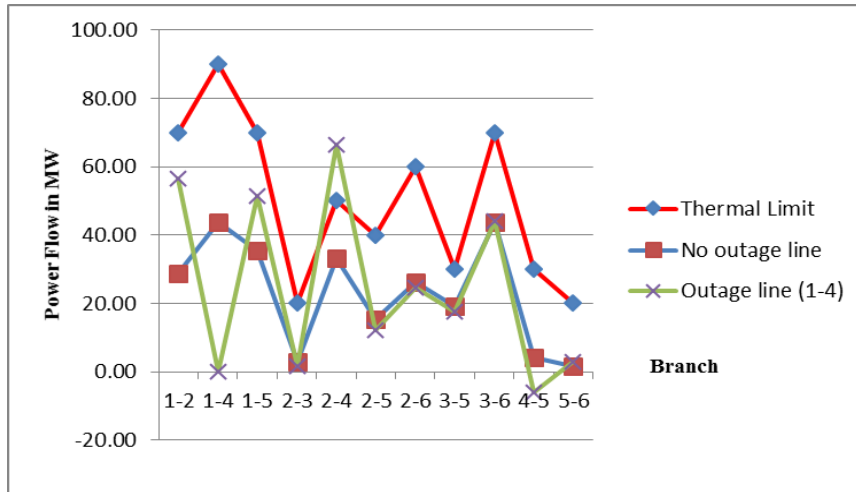


Figure 6: Value of power flow lines for network lines (case 2).

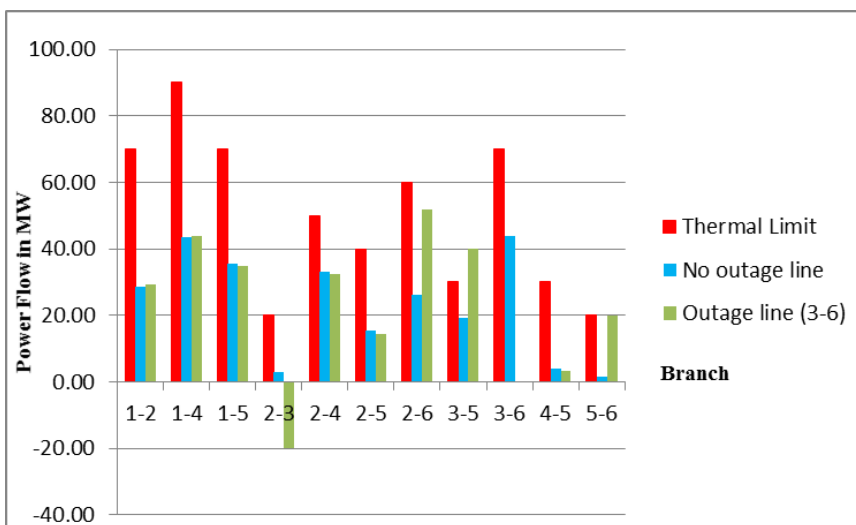


Figure 7: Power Flow for network lines system under outage line (3-6).

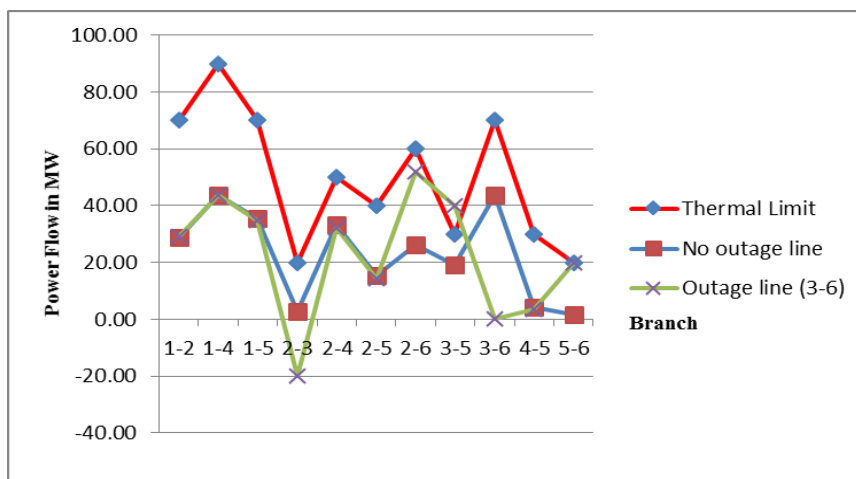


Figure 8: Value of power flow lines for network lines (case 3).

5. CONCLUSION

Through study and discussion out power flow lines for ensuring the network system, we suggest the following:

1. Control through regeneration organization in Buses.
2. Taking into consideration when designing the network system to the limits Permitted to lines of power flow to avoid a collapse in the network system.
3. Add lines to power flow in parallel-diagnosed lines, which happens rise in the power flow outside the

limit to avoid weaknesses in the design of system network.

4. Add secondary line of power flow parallel to the main lines of power flow to avoid the outage occur frequently in some lines.

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