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Evaluation of Fault Voltage and Current in a Symmetric Power System Network

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Abstract: The subject of Evaluation of Fault voltages and currents in a power system network is very important part of power system analysis for stable and economical operations of a Power System. The main objective of the short circuit fault analysis is to simulate short circuit faults on different buses of a power system network and to estimate the state of the power system before and after a fault, which includes various bus voltages and current flow on various transmission lines. The analysis of power systems under faulted condition provides information regarding circuit breaker selection, relay setting, and the stability of the systems operation. Two different MATLAB based programs were written; one program was for Load Flow Studies to determine the pre-fault conditions based on Newton-Raphson method, while the other was for three-phase short-circuit studies. It was observed that the fault currents were mostly excessively high. In this paper, three-phase symmetrical fault was simulated on the standard IEEE 6 bus and IEEE 30 bus system and fault voltage and fault current level is calculated and short circuit MVA rating for the circuit breaker has been chosen.

Keywords: Evaluation of fault analysis, NR method, symmetrical fault (LLL) calculation, short circuit MVA.

I. INTRODUCTION

The use of Electrical energy increases more and more on a daily basis. Technological development is the reason for the use of electrical energy. Electric power is generated, transmitted and distributed via large interconnected power systems. The generation of electric power takes place in a power plant. Every year many more power stations, transmission lines and substations are constructed. This situation increases the fault current levels in power systems. During normal operating conditions, current will flow through all elements of the electrical power system within pre-designed values which are appropriate to these elements ratings. The fault phenomenon affects system's reliability, security, and energy quality, and can be considered stochastic. In 1956, L.W. Coombe and D. G. Lewis proposed the first fault analysis program. Many exiting texts offer an extensive analysis in fault studies and calculation.[1-3].

The Evaluation of fault analyses is are very important for the power system studies since they provide data such as voltages and currents during and after the various types of faults which are necessary in designing the protective schemes of the power system. Short circuit and protection studies are essential tools for the electric energy system engineer. The main task is to calculate fault conditions and provide protective equipments designed to isolate the faulted zone from the remainder of the system in the appropriate time. And also carefully designed to power system network subjected to damaging high magnitude current during a fault conditions. [4-6]

A Fault is defined as any failure which interferes with the normal current flow. If the insulation of the system fails at any point or if two or more conductors that normally operate with a potential difference come in contact with each other, a short-circuit, or fault, is said to be occur. Some of the common causes have their origins in natural disturbance like lightning, high speed winds, earthquakes, earth tremors, snow, frost etc. There may be accidental faults such as falling of trees along a line, vehicles colliding with supporting structures, airplane crashing with line. [7-10]

Fault analysis can be broadly grouped into symmetrical (LLL) and unsymmetrical (LG, LL, LLG) faults. A balanced three phase fault occurs when there is a simultaneous short circuit across all three phases. This is called as Symmetrical fault. If only some phases are affected, the resulting Unsymmetrical fault. The effects of faults on power system are: Overheating and mechanical forces developed by faults may damage the electrical equipment such as bus-bars, generators and transformers & the voltage profile of the system may be reduced to unacceptable limits as a result of fault. [11-16]

The process of evaluating the system voltages and currents under various types of short-circuits is called fault analysis. Fault analysis is necessary to improve the customer service reliability and security. Short-circuit currents may change from time to time. Therefore, a suitable fault analysis method is required for calculating the new settings of the protective elements (reclosers, sectionalizer switches, fuses etc.). Also short-circuit calculations are required to determine the short-circuit ratings of new switchgear and substation equipment to be installed in the system. Fault analysis can also be helpful in estimating the size of the additional reactors or fault current limiters which may be required to be inserted in the system to limit the short-circuit currents to a safe value which is below the withstand capacity of the installed circuit-breakers. Usually, the effect of load is neglected during short-circuit analysis [17-21]

Majority of faults occurring on power systems are unsymmetrical faults, however, the circuit breaker rated MVA breaking capacity is based on three-phase symmetrical faults. The main reason is that a three-phase fault produces the greatest fault current and causes the greatest damage to a power system when compare to unsymmetrical faults. The single line-to-ground fault mostly occurring very close to a solidly rounded generator terminal. For proper choice of circuit breakers and protective relaying, we must estimate the magnitude of currents that would flow under short circuit conditions-this is the scope of fault analysis. The three phase balanced fault information is used to select and set phase relays, while line-to-ground fault is used for ground relays. [22-25]

1.1 Need for Evaluation of Fault Analysis in Power System Network:

The fault analysis is one of the basic problems in power system engineering. The results of power system fault analysis are used to determine the type and size of the protective system to be installed on the system so that continuity of supply is ensured even when there is a fault on the power system. The system being planned is to be optimal with respect to construction cost, performance and operating efficiency. For this we can use better planning tools. The major power system tools are load Flow Analysis, short circuit analysis or fault calculations, stability analysis etc. The main purpose of an electrical power system is to generate and supply electrical energy to consumers with reliability and economy. The continuity of power system network is based on the short circuit fault analysis. The evaluation of fault currents on a power system is significant because the protective devices to be installed on the system depend on the values of the fault currents.

II. PROBLEM FORMULATION OF SYMMETRICAL FAULT ANALYSIS

2.1 Preliminary Calculations:

In cause of fault studies, it is necessary to know the pre-fault voltages and currents. These pre-fault conditions can be obtained from the results of load flow studies by the Newton Raphson method. The NR method consists high accuracies obtained in a few iterations. The number of iterations remains practically constant irrespective of the size of the power system.NR method begins with initial guesses of all unknown variables (voltage magnitude and angles at Load Buses and voltage angles at Generator Buses). The result is a linear system of equations that can be expressed as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J3 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad (1)$$

Where ΔP and ΔQ are called the mismatch equations. Real and reactive power in bus is:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \quad (2)$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \quad (3)$$

The liberalized system of equations is solved to determine the next guess (m + 1) of voltage magnitude and angles base on:

$$\delta_i^{(k+1)} = \Delta\delta_i^{(k)} + \delta_i^k \quad (4)$$

$$|V_i^{(k+1)}| = \Delta V_i^{(k)} + V_i^k \quad (5)$$

Where, i and j are ith and jth buses and k is no. of iterations. The flow chart of NR method is depicted in Figure below:

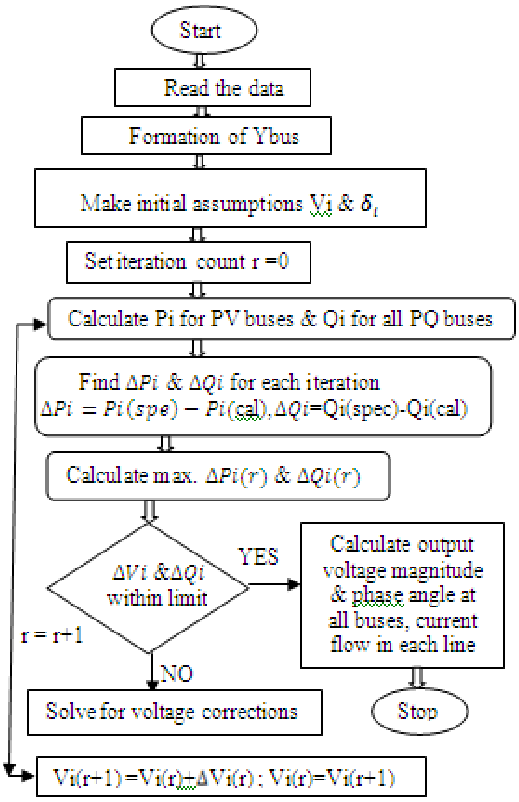

Fig 1: Flow Chart for Newton Raphson Method

2.2 Symmetrical Fault Analysis:

In transmission line faults, roughly 5% are symmetric. It is the most infrequent fault but the most severe type of fault encountered because the network is balanced, it is solved on per-phase basis. A general representation of a balanced three-phase fault is shown in Figure below 2. Where F is the fault point with impedances Zf and Zg and $\mathbf{Z_1}$ is positive sequence impedance.

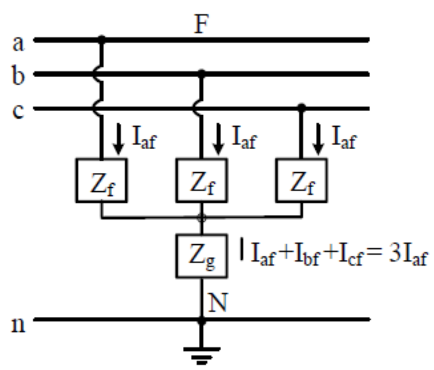

Fig 2: General representation of LLL fault

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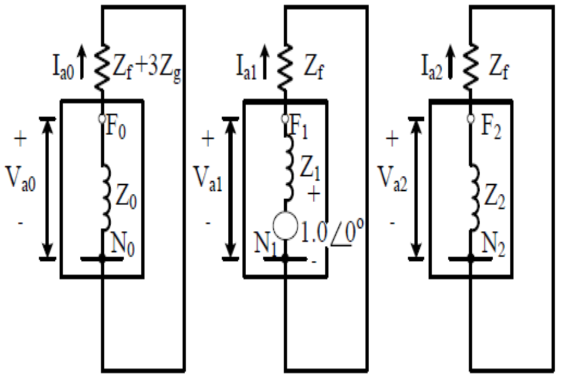

Fig.3: sequence network representation of LLL fault

From Fig. 3 it can be noticed that the only has an internal voltage source is the positive-sequence network. Therefore, the corresponding currents for each of the sequences can be expressed as

$$I_{a1} = I_{a2} = 0 \qquad (6)$$

$$I_{a1} = \frac{V_s}{Z_1 + Z_f} \qquad (8)$$

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_{a1} \\ 0 \end{bmatrix} \qquad (9)$$

From equation 6,7,8, & 9 can solve that,

$$I_{af} = I_{a1} = \frac{1.0<0^{\circ}}{Z_1 + Z_f} \qquad (10)$$

And also similarly, (11)

$$V_{a0} = V_{a2} = 0$$

$$V_{a1} = Z_f I_{a1} \qquad (13)$$

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ V_{a1} \\ 0 \end{bmatrix} \qquad (14)$$

Above equations can solve that,

$$V_{af} = Z_f I_{a1} \qquad (15)$$

The admittance bus matrix formed and used in load flow analysis has to be inverted to obtain the impedance bus matrix for easy calculation process. It is described in terms of modifying an existing bus impedance matrix designated as │Zbus│old. This new modified matrix is designated as │Zbus│new. The injected bus currents in terms of bus voltages for a n-bus network is calculated as:

$$I_{bus} = Y_{bus} . V_{bus} \qquad (16)$$

Where I_{bus} is the bus current vector entering the bus & Y_{bus} is the bus admittance matrix For a fault at bus k, the current entering every bus except the faulted bus k is zero thus equation (16) becomes:

$$\begin{bmatrix} 0 \\ 0 \\ \vdots \\ -Ik(F) \\ 0 \end{bmatrix} = \begin{bmatrix} Y11 & \cdots & Y1k & Y1n \\ Y21 & & Y2k & Y2n \\ \vdots & \ddots & & \vdots \\ Yk1 & \cdots & Ykk & Ykn \\ Yn1 & & Ynk & Ynn \end{bmatrix} \begin{bmatrix} \Delta V1 \\ \Delta V2 \\ \vdots \\ \Delta Vk \\ \Delta Vn \end{bmatrix} \qquad (17)$$

Above eq.can be Wright as

$$I_{bus}(F) = Y_{bus} . \Delta V_{bus} \qquad (18)$$

From above equation can get;

ΔVbus = inverse (Ybus).Ibus (F)

$$= Z_{bus} . I_{bus}(F) \qquad (19)$$

$$V_{bus} = V_{bus}(0) + \Delta V_{bus} \qquad (20)$$

$$\begin{bmatrix} V1(F) \\ V2(F) \\ \vdots \\ Vk(F) \\ Vn(F) \end{bmatrix} = \begin{bmatrix} V1(0) \\ V2(0) \\ \vdots \\ Vk(0) \\ Vn(0) \end{bmatrix} + \begin{bmatrix} Z11 & \cdots & Z1k & Z1n \\ Z21 & & Z2k & Z2n \\ \vdots & \ddots & & \vdots \\ Zk1 & \cdots & Zkk & Zkn \\ Zn1 & & Znk & Znn \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \vdots \\ -Ik(F) \\ 0 \end{bmatrix}$$

(21)

From eq. & can get ;

$$V_{bus} = V_{bus}(0) + Z_{bus} I_{bus}(F) \qquad (22)$$

The voltage at bus k during the fault is Vk (F). So;

$$V_k(F) = V_k(0) - Z_{kk} I_k(F) \qquad (23)$$

But $V_k(F) = Z^f I_k(F)$, equation (23) becomes;

$$Z^f I_k(F) = V_k(0) - V_k(F)$$

Solving $I_k(F)$ for gives;

$$I_k(F) = \frac{V_k(0)}{Z_{KK} + Z_f} \qquad (24)$$

Where, $Z_{kk} = Z_1$; for symmetrical faults (LLL Fault)

For any bus i the bus voltage during fault is;

$$V_i(F) = V_i(0) - Z_{ik} I_k(F) \qquad (25)$$

The short circuit current in the line connected between bus i and j is; $I_{ij}(F) = \frac{V_i(F) - V_j(F)}{Z_{ij}}$ (26)

2.3 Selection of Rating of Circuit Breakers:

The use of circuit breaker under short circuit conditions are open the contacts to clear the fault, to close the contacts onto a fault and to carry fault current for a short time while another circuit breaker is clearing the fault. The Breaking capacity of a circuit breaker is of two types i.e. Symmetrical Breaking capacity and Asymmetrical Breaking capacity. Symmetrical short circuit current is obtained by using sub transient reactance for synchronous machines. Momentary current (rms) is then calculated by multiplying the symmetrical momentary current by a factor of 1.6 to account for the presence of dc offset current. The current that a circuit breaker can interrupt is inversely proportional to the operating voltage over a certain range of time. Obviously, rated MVA interrupting capacity of a circuit breaker is to be more than (or equal to) to the short circuit MVA required to be interrupted. If voltage & current in p.u. values on a 3ph. Basis, then

SCMVA (3 ph) = | Vprefault | * |Isc|*(MVA base) (27)

III. IMPLEMENTATION PROCEDURE FOR SYMMETRICAL FAULT (LLL)

Algorithm for symmetrical fault analysis for power system network is below:

STEP 1: Read the bus data, line data and load data.
STEP 2: Run the Load flow with N-R method.
STEP 3: Obtain pre-fault voltages at all buses and Currents in all lines using load flow study.
STEP 4: Find Bus impedance matrix by inverting the bus Admittance matrix or using builds Programming (Z_{bus} = Z build (Z_1 data).
STEP 5: Choose MVAbase, KVbase & calculate Ibase.
STEP 6: Specify the faulty bus & obtain current at the Faulty bus and bus voltages during fault at all Buses using Eq. (23) and (24)

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STEP 7: Find current flows in each line of the power System network using equation (26).

STEP 8: Calculate SCMVA rating of circuit breaker (Choose acc. to the fault current magnitude) for Each transmission Line and each buses of IEEE 6 bus and 30 bus system using equation (27).

The flow chart of symmetrical fault on IEEE bus system is show in below figure

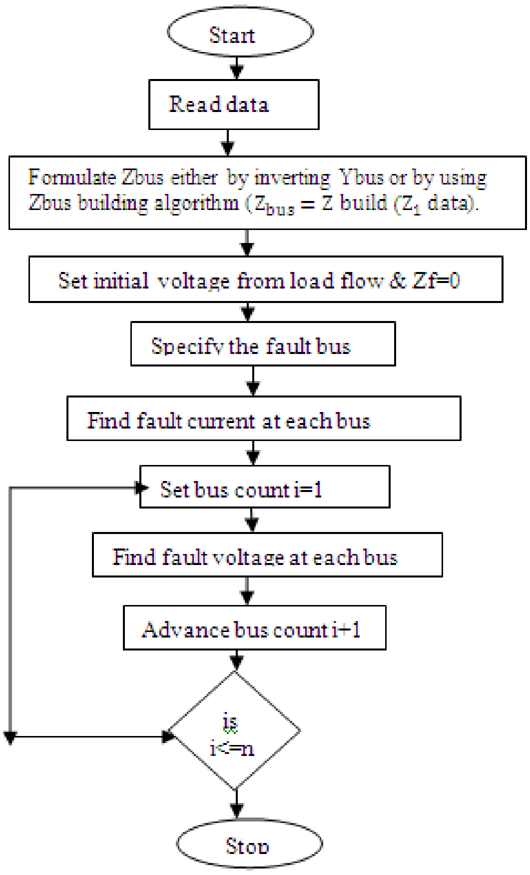

Fig 4: Flow Chart for the Calculations of Symmetrical Fault

IV. RESULTS AND DISCUSSION

4.1 Symmetrical fault (LLL) on IEEE 6 bus system:

Firstly, discuss the results when symmetrical fault (LLL Fault) occurs on IEEE 6 bus system. Pre-fault voltages are carried out by using NR method. After the pre-fault calculations, a LLL fault was simulated on the 6 bus system then calculated the fault voltage magnitude at each bus, fault current flows in the lines, SCMVA ratings based on the fault currents on each bus and lines was also calculated then the corresponding Circuit Breakers ratings are choose.

- Table 1: Prefault Voltage magnitude, phase Angle, Real and Reactive Powers using NR Method on IEEE 6 bus system :

Bus no	Voltage magnitude (p.u)	Angle (degree)	MW (L)	Mvar (L)	MW (G)	Mvar (G)
1	1.06	0.000	0.00	0.00	649.7	231.7
2	0.99	-30.448	150.0	0.00	0.00	174.4
3	1.00	-17.396	100.0	0.00	0.00	85.9
4	0.93	-27.178	100.0	70.00	0.00	0.00
5	0.968	-14.901	90.00	30.0	0.00	0.00
6	0.868	-21.177	160.0	110.0	0.00	0.00
Total			600.0	210.0	649.7	492.0

- Table 2: Compare the pre-fault voltage magnitude in p.u. and fault voltage magnitude in p.u at each bus:

Bus no	Pre-fault voltage magnitude (p.u)	When Fault at bus no.					
		1	2	3	4	5	6
1	1.06	0.00	0.64	0.58	0.55	0.44	0.50
2	0.99	0.61	0.00	0.76	0.19	0.70	0.51
3	1.00	0.43	0.71	0.00	0.64	0.14	0.53
4	0.93	0.48	0.17	0.66	0.00	0.59	0.43
5	0.968	0.32	0.64	0.22	0.56	0.00	0.43
6	0.868	0.38	0.43	0.50	0.33	0.39	0.00

Table 2 represents the Comparison between the pre-fault voltage magnitude in p.u. and fault voltage magnitude at each bus and it is observed that when a LLL fault occurs, the voltage at faulted bus is reduced to zero and voltage magnitude on other buses are also affected. Graphical Representation of post fault voltage magnitude in p.u when fault occurs at different buses of IEEE 6 bus system is show in below figure. From below graph it can observed that when fault at bus 1 corresponding voltage at bus no.1 is zero. And also when fault at bus 2, corresponding voltage at bus 1 is less affected. And also when fault at bus no. 5, voltage at bus no.1 is more affected.

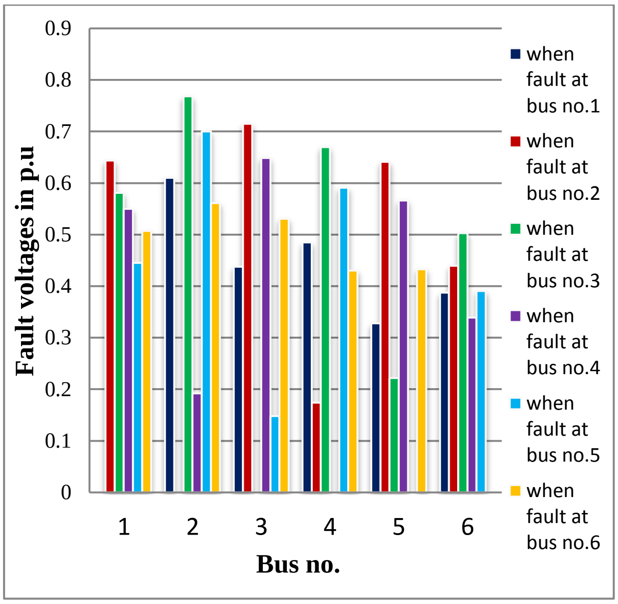

Fig 5: Graphical Representation of post fault voltages when fault occur at Different buses of IEEE 6 Bus system during LLL fault

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- Table 3: Fault current magnitude, Short circuit MVA and Circuit breaker ratings at each bus:

Bus no	Fault current magnitude(pu)	SCMVA (MVA)	Circuit Breaker Rating (MVA)
1	12.8156	1358	1360
2	12.0488	1192	1200
3	9.6018	960.18	970
4	11.0808	1030.5	1040
5	10.1313	980.70	990
6	8.9825	780.5	790

From Table 3 can observed that bus no.1 has higher fault current and circuit breaker rating i.e 12.8156 p.u, 1360 MVA.

- Table 4 : Comparison of Pre & post Fault Currents in Each Line of IEEE 6 bus system during Symmetrical fault (LLL) :

Line no.	Pre-fault Current (p.u)	When fault at bus no.					
		1	2	3	4	5	6
1	0.0296	2.13	2.08	1.27	**2.42**	1.06	0.92
2	0.0102	3.72	1.38	3.33	1.08	**4.13**	1.03
3	0.02073	1.63	1.12	0.73	1.07	0.42	**2.31**
4	0.0021	3.72	4.98	3.11	**5.48**	3.29	3.77
5	0.00147	2.67	1.95	**5.28**	2.06	3.52	2.35
6	0.00794	1.23	2.07	1.55	2.64	1.73	**3.36**
7	0.01710	0.17	1.14	1.64	1.28	2.20	**2.44**

From the Table 4, it is analysed that in line no. 1 maximum fault current flowing up to 2.42 pu. when there is a fault at bus no.4 & line no. 1 is most effected when there is a fault at bus no.5 & line no.2 is most effected similarly check other lines and this effect is clearly shown from graphical representation of current flow in each line when short circuit fault occurs at different buses as shown in Fig.6 Now Choose the SCMVA rating of Circuit Breaker for each line according to the Table 4.

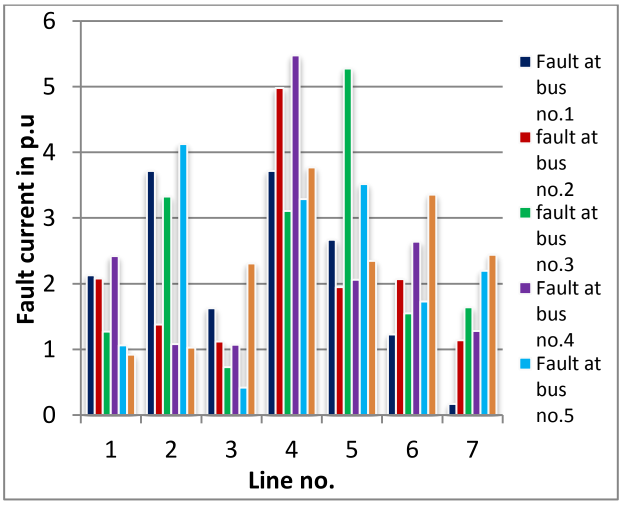

Figure 6: Graphical Representation of transmission line currents when fault occur at different buses

- Table 5 :SCMVA & Circuit Breaker Ratings in each line :

Line no.	SCMVA rating	Circuit Breaker rating (MVA)
1	225.45	230
2	399.89	400
3	201.36	210
4	510.14	520
5	528.85	530
6	291.65	300
7	211.83	220

4.2 Symmetrical fault (LLL) on IEEE 30 bus system:

Load flow analysis was carried out using the NR load flow method then after the pre-fault calculations, LLL fault was simulated on Each Bus of the IEEE 30 bus system then calculated the fault voltage magnitude at each bus, fault currents flows in the lines, SCMVA ratings based on the fault currents on each bus and line then the corresponding Circuit Breakers ratings are choosed.

- Table 6 : Voltage magnitude , phase Angle, Real & Reactive Powers by using NR Method on IEEE 30 bus system :

Bus no	Prefault voltage (p.u)	Angle (degree)	MW (L)	Mvar (L)	MW (G)	Mvar (G)
1	1.06	0.000	0.00	0.000	172.3	-1.43
2	1.04	-3.534	21.7	12.70	40.00	30.05
3	1.02	-5.174	2.40	1.200	0.000	0.0
4	1.01	-6.209	7.60	1.600	0.000	0.0
5	1.01	-10.125	94.2	19.00	20.00	26.24
6	1.016	-7.318	0.00	0.00	0.00	0.00
7	1.006	-8.996	22.8	10.90	0.00	0.00
8	1.01	-7.52	30.0	30.60	20.00	14.83
9	1.053	-8.65	0.00	0.000	0.000	0.0
10	1.047	-10.49	5.80	2.000	0.000	0.0
11	1.082	-6.564	0.00	0.000	20.00	15.18
12	1.06	-9.55	11.2	7.500	0.000	0.00
13	1.071	-8.13	0.00	0.000	20.00	7.814
14	1.047	-10.477	6.20	1.600	0.000	0.00
15	1.042	-10.606	8.20	2.500	0.000	0.0
16	1.031	-10.221	3.50	1.800	0.000	0.0
17	1.028	-10.621	9.00	5.800	0.000	0.0
18	1.032	-11.259	3.20	0.900	0.000	0.0
19	1.032	-11.456	9.50	3.400	0.000	0.0
20	1.038	-11.274	2.20	0.700	0.000	0.0
21	1.032	-10.968	17.5	11.20	0.000	0.0
22	1.026	-10.963	0.00	0.000	0.00	0.0
23	1.022	-11.114	3.20	1.600	0.000	0.0
24	1.004	-11.452	8.70	6.700	0.000	0.0
25	1.027	-11.475	0.00	0.000	0.000	0.0
26	1.014	-11.892	3.50	2.300	0.000	0.0
27	1.016	-11.231	0.00	0.00	0.000	0.0
28	1.014	-7.805	0.00	0.000	0.000	0.0
29	1.008	-12.452	2.40	0.900	0.00	0.0
30	0.996	-13.329	10.6	1.900	0.000	0.0
Total			**283.4**	**126.8**	**292.3**	**92.70**

- Table 7: fault current &circuit breaker ratings for each bus

Bus no.	Fault Current (pu)	SCMVA Rating	Circuit Barker Rating (MVA)
1	22.5228	2387.102	2400
2	25.510	2653.03	2660
3	18.329	1882.026	1900
4	24.198	2465.5	2470
5	13.929	14060.4	1470
6	23.04	2442.21	2450
7	11.719	1178.89	1180
8	12.645	1277.01	1280
9	6.361	670.12	680
10	6.259	650.6	660
11	2.901	313.25	320
12	5.678	611.3	620
13	3.291	352.6	360
14	3.250	348.34	350
15	4.563	474.5	480
16	4.025	421.82	430
17	4.779	486.65	490
18	3.260	364.132	370
19	3.307	373.18	380
20	3.528	386.120	390
21	5.0821	546.32	550
22	5.043	540.85	550
23	3.3065	364.87	370
24	3.9018	417.89	420
25	2.7726	282.74	290
26	1.2543	125.53	130
27	3.0521	313.44	320
28	11.1029	1125.83	1130
29	1.5446	155.48	160
30	1.4154	140.832	150

- Table 8:Compare the pre-fault voltage magnitude in p.u. and fault voltage magnitude in p.u for IEEE 30 Bus system:

Bus no	Pre Fault voltage (p.u)	When fault at bus no.															
		1	3	4	5	6	9	10	14	16	17	23	24	26	27	28	30
1	1.06	0.00	0.73	0.70	0.90	0.76	0.97	0.98	1.01	1.00	0.99	1.01	1.01	1.04	1.02	0.92	1.04
2	1.04	0.51	0.75	0.63	0.79	0.64	0.93	0.94	0.99	0.97	0.96	0.99	0.98	1.02	0.99	0.85	1.02
3	1.02	0.64	0.00	0.22	0.86	0.50	0.87	0.87	0.94	0.92	0.90	0.94	0.93	0.99	0.95	0.77	0.99
4	1.01	0.71	0.42	0.00	0.83	0.37	0.83	0.83	0.91	0.88	0.87	0.91	0.90	0.98	0.93	0.70	0.97
5	1.01	0.77	0.80	0.69	0.00	0.60	0.90	0.91	0.96	0.95	0.93	0.96	0.95	0.99	0.95	0.81	0.98
6	1.016	0.74	0.61	0.33	0.76	0.00	0.76	0.77	0.91	0.87	0.83	0.90	0.87	0.96	0.89	0.53	0.95
7	1.006	0.75	0.68	0.48	0.45	0.25	0.82	0.82	0.92	0.90	0.87	0.91	0.89	0.96	0.91	0.64	0.96
8	1.01	0.74	0.61	0.34	0.76	0.16	0.73	0.77	0.90	0.87	0.83	0.89	0.86	0.95	0.87	0.44	0.94
9	1.053	0.77	0.60	0.30	080	0.09	0.00	0.27	0.81	0.68	0.50	0.76	0.67	0.96	0.91	0.55	0.96
10	1.047	0.76	0.58	0.28	0.81	0.14	0.28	0.00	0.74	0.55	0.31	0.67	0.55	0.93	0.87	0.55	0.94
11	1.082	0.79	0.62	0.31	0.83	0.09	0.00	0.28	0.83	0.69	0.52	0.78	0.69	0.98	0.87	0.56	0.99
12	1.06	0.76	0.52	0.18	0.84	0.26	0.52	0.47	0.51	0.47	0.53	0.61	0.66	0.96	0.87	0.63	0.97
13	1.071	0.76	0.53	0.18	0.85	0.26	0.59	0.47	0.51	0.47	0.54	0.62	0.67	0.97	0.88	0.64	0.98
14	1.047	0.75	0.53	0.21	0.83	0.25	0.55	0.42	0.00	0.48	0.51	0.52	0.60	0.94	0.84	0.61	0.95
15	1.042	0.75	0.54	0.22	0.82	0.23	0.52	0.37	0.40	0.50	0.49	0.42	0.54	0.92	0.81	0.60	0.94
16	1.031	0.75	0.55	0.22	0.82	0.21	0.45	0.27	0.60	0.00	0.26	0.63	0.61	0.94	0.84	0.59	0.95
17	1.028	0.75	0.57	0.26	0.81	0.61	0.33	0.08	0.69	0.38	0.00	0.66	0.57	0.93	0.82	0.64	0.94
18	1.032	0.75	0.55	0.25	0.81	0.21	0.44	0.25	0.53	0.51	0.43	0.51	0.54	0.91	0.81	0.56	0.93
19	1.032	0.75	0.56	0.26	0.80	0.19	0.39	0.17	0.60	0.52	0.39	0.56	0.54	0.91	0.80	0.58	0.92
20	1.038	0.75	0.57	0.26	0.80	0.16	0.36	0.13	0.63	0.53	0.37	0.58	0.54	0.92	0.81	0.57	0.93
21	1.032	0.77	0.58	0.28	0.80	0.15	0.32	0.05	0.72	0.56	0.34	0.62	0.45	0.90	0.77	0.56	0.92
22	1.026	0.75	0.55	0.28	0.80	0.15	0.32	0.06	0.72	0.56	0.34	0.60	0.42	0.89	0.76	0.53	0.91
23	1.022	0.75	0.57	0.25	0.80	0.21	0.48	0.32	0.53	0.53	0.47	0.0	0.30	0.87	0.73	0.53	0.89
24	1.004	0.75	0.59	0.28	0.80	0.17	0.43	0.24	0.67	0.58	0.45	0.48	0.00	0.80	0.62	0.55	0.84
25	1.027	0.75	0.58	0.30	0.79	0.13	0.55	0.44	0.76	0.70	0.60	0.59	0.32	0.56	0.24	0.48	0.66
26	1.014	0.74	0.58	0.31	0.78	0.15	0.55	0.44	0.76	0.69	0.59	0.59	0.33	0.00	0.25	0.32	0.60
27	1.016	0.75	0.60	0.32	0.77	0.11	0.63	0.57	0.82	0.77	0.69	0.71	0.52	0.71	0.00	0.22	0.51
28	1.014	0.74	0.60	0.33	0.78	0.01	0.75	0.75	0.89	0.86	0.81	0.87	0.82	0.93	0.79	0.00	0.91
29	1.008	0.74	0.59	0.33	0.76	0.13	0.63	0.57	0.81	0.76	0.68	0.70	0.52	0.70	0.02	0.24	0.29
30	0.996	0.73	0.56	0.33	0.76	0.15	0.63	0.56	0.80	0.75	0.68	0.69	0.52	0.70	0.04	0.25	0.00

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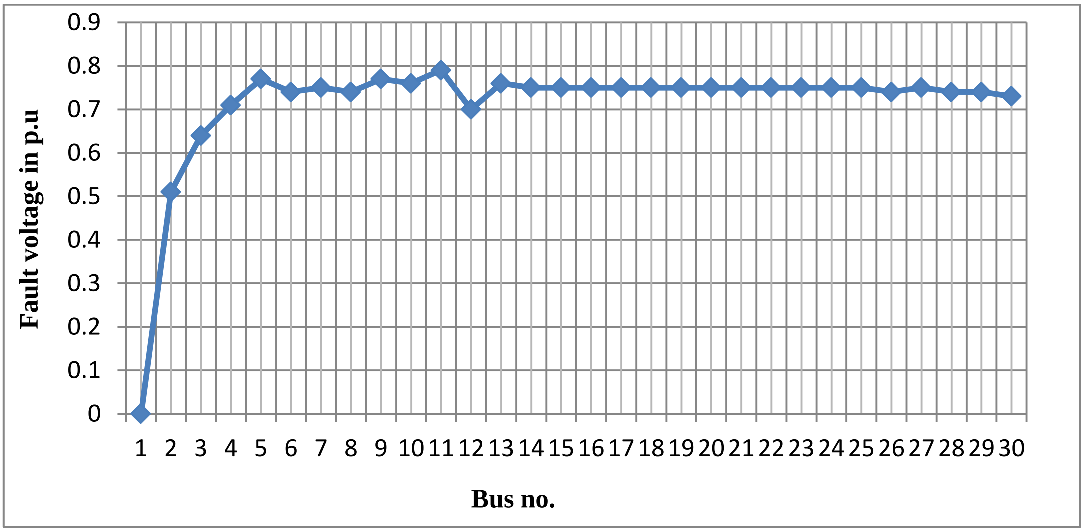

Fig.7: Graphical Representation for fault voltage of IEEE 30 Bus system LLL fault occurs at bus no.1

Line no	From - To	Prefault current (p.u)	When fault occurs at bus no.														
			1	3	4	5	6	8	9	14	16	17	24	26	27	28	30
1	1-2	0.0036	**8.45**	0.68	1.43	1.96	2.09	1.50	1.1	1.1	1.12	1.13	1.14	1.12	1.11	1.42	1.12
2	1-3	0.0178	**3.76**	4.27	2.85	0.51	1.58	1.04	0.7	0.7	0.71	0.72	0.71	0.62	0.64	0.97	0.61
3	2-4	0.0127	1.10	1.82	**3.45**	0.30	1.52	1.91	0.5	0.5	0.54	0.55	0.50	0.34	0.40	0.83	0.34
4	3-4	0.0009	1.75	**10.4**	5.63	0.96	3.4	1.95	1.0	0.8	0.91	0.97	0.89	0.59	0.71	1.76	0.59
5	2-5	0.0134	1.30	0.44	0.40	**3.90**	0.38	0.47	0.5	0.5	0.59	0.54	0.55	0.58	0.56	0.48	0.58
6	2-6	0.0168	1.26	0.79	1.58	0.35	**3.49**	1.95	0.9	0.5	0.62	0.72	0.67	0.47	0.60	1.76	0.48
7	4-6	0.0009	0.81	4.38	7.84	1.65	**8.62**	4.72	1.5	0.4	0.45	0.77	0.78	0.57	0.93	4.09	0.62
8	5-7	0.0034	0.19	0.96	1.69	**3.62**	2.82	1.55	0.7	0.3	0.39	0.49	0.45	0.21	0.41	1.37	0.24
9	6-7	0.0005	0.18	0.90	1.69	**3.60**	2.90	1.52	0.7	0.1	0.14	0.13	0.39	0.30	0.40	1.32	0.31
10	6-8	0.0006	0.03	0.05	0.18	0.34	0.38	**10.6**	0.1	0.3	0.99	0.54	0.24	0.24	0.46	2.00	0.29
11	6-9	0.0126	0.11	0.04	0.22	0.19	0.46	0.36	**3.6**	0.3	0.61	1.61	1.02	0.20	0.26	0.11	0.18
12	6-10	0.0531	0.04	0.04	0.13	0.85	0.26	0.12	0.8	0.8	0.43	**0.96**	0.62	0.16	0.19	0.12	0.13
13	9-11	0.0094	0.16	0.11	0.06	0.17	0.02	0.11	0.0	1.6	1.21	**1.79**	0.14	0.21	0.18	0.04	0.21
14	9-10	0.0044	0.16	0.17	0.25	0.16	0.45	0.01	**2.5**	0.1	1.70	1.39	1.24	0.45	0.50	0.28	0.32
15	4-12	0.0269	0.19	0.43	0.73	0.05	0.46	0.20	0.9	**1.8**	0.14	0.01	1.07	0.33	0.38	0.12	0.40
16	12-13	0.0050	0.14	0.09	0.35	0.16	0.04	0.11	0.1	**0.5**	0.08	0.07	0.12	0.18	0.16	0.07	0.29
17	12-14	0.0071	0.03	0.02	0.09	0.05	0.05	0.01	0.1	0.0	**2.15**	0.28	0.22	0.31	0.11	0.27	0.18
18	12-15	0.0045	0.08	0.11	0.28	0.15	0.23	0.02	0.4	**1.4**	0.19	1.25	0.85	0.11	0.11	0.17	0.27
19	12-16	0.0020	0.03	0.12	0.25	0.09	0.25	0.17	0.6	0.4	0.05	**1.18**	0.22	0.05	0.37	0.17	0.10
20	14-15	0.0022	0.00	0.02	0.06	0.02	0.06	0.04	0.1	0.4	**1.86**	0.57	0.20	0.08	0.13	0.06	0.04
21	16-17	0.3540	0.02	0.12	0.23	0.07	0.28	0.01	0.6	0.4	0.07	0.08	0.21	0.09	0.08	0.16	0.07
22	15-18	0.0045	0.03	0.06	0.14	0.05	0.14	0.01	0.3	0.4	0.07	**3.48**	0.03	0.05	0.10	0.07	0.05
23	18-19	0.0009	0.01	0.06	0.12	0.04	0.15	0.08	0.3	0.4	0.08	**1.24**	0.04	0.06	0.04	0.06	0.02
24	19-20	0.0004	0.03	0.07	0.10	0.02	0.19	0.08	**1.2**	0.2	0.08	0.25	0.05	0.00	0.02	0.06	0.05
25	10-20	0.0047	0.04	0.07	0.10	0.03	0.21	0.08	0.3	0.1	0.05	0.26	0.05	0.38	0.03	0.16	0.06
26	10-17	0.0009	0.04	0.12	0.19	0.02	0.34	0.16	0.6	**2.4**	0.04	0.27	**1.22**	0.22	0.04	0.15	0.01
27	10-21	0.0013	0.08	0.03	0.06	0.09	0.16	0.01	0.4	0.2	0.07	0.33	**0.80**	0.45	0.05	0.09	0.32
28	10-22	0.0024	0.04	0.01	0.03	0.04	0.08	0.01	0.2	0.4	0.16	0.21	**1.21**	0.23	0.45	0.18	0.18
29	21-22	0.0010	0.01	0.01	0.03	0.01	0.02	0.01	0.3	0.1	0.11	0.28	**1.03**	0.01	0.30	0.22	0.16
30	15-23	0.0040	0.02	0.07	0.15	0.06	0.15	0.01	0.1	0.2	0.29	0.08	**1.98**	0.02	0.38	0.24	0.20
31	22-24	0.0002	0.03	0.03	0.04	0.03	0.09	0.02	0.5	0.4	0.01	0.48	**1.02**	0.42	0.37	0.22	0.34
32	23-24	0.0041	0.01	0.07	0.13	0.06	0.16	0.12	0.1	0.4	0.32	**1.39**	0.86	0.63	0.67	0.24	0.18
33	24-25	0.0032	0.01	0.44	0.08	0.09	0.11	0.14	0.3	0.2	0.03	0.01	0.01	**1.23**	0.35	0.43	0.47
34	25-26	0.0043	0.02	0.07	0.01	0.03	0.03	0.01	0.1	0.1	0.31	0.40	0.85	0.64	**1.00**	0.01	0.01
35	25-27	0.0036	0.02	0.04	0.07	0.01	0.14	0.14	0.3	0.2	0.03	0.00	**0.83**	0.64	0.02	0.48	0.46
36	28-27	0.0032	0.07	0.03	0.07	0.08	0.25	0.19	0.3	0.1	0.03	0.08	0.86	0.02	**1.02**	0.56	0.94
37	27-29	0.0016	0.03	0.01	0.02	0.03	0.05	0.09	0.1	0.1	0.32	0.14	0.01	0.03	**2.00**	0.03	0.57
38	27-30	0.0035	0.03	0.01	0.02	0.03	0.05	0.01	0.1	0.3	0.01	0.02	0.01	0.01	0.06	0.04	**0.82**
39	29-30	0.0040	0.02	0.00	0.01	0.02	0.03	0.01	0.0	0.1	0.32	0.40	0.01	**0.63**	0.03	0.02	0.56
40	8-28	0.0005	0.01	0.02	0.03	0.01	0.02	1.73	0.1	0.2	0.28	0.07	0.15	0.10	0.38	**2.11**	0.17
41	6-28	0.0008	0.03	0.05	0.09	0.05	0.21	1.61	0.2	0.1	0.61	0.34	0.69	0.54	1.6	**8.54**	0.78

Table 9: Compare the pre-fault & post fault line current magnitude in p.u. of each line of IEEE 30 Bus system:

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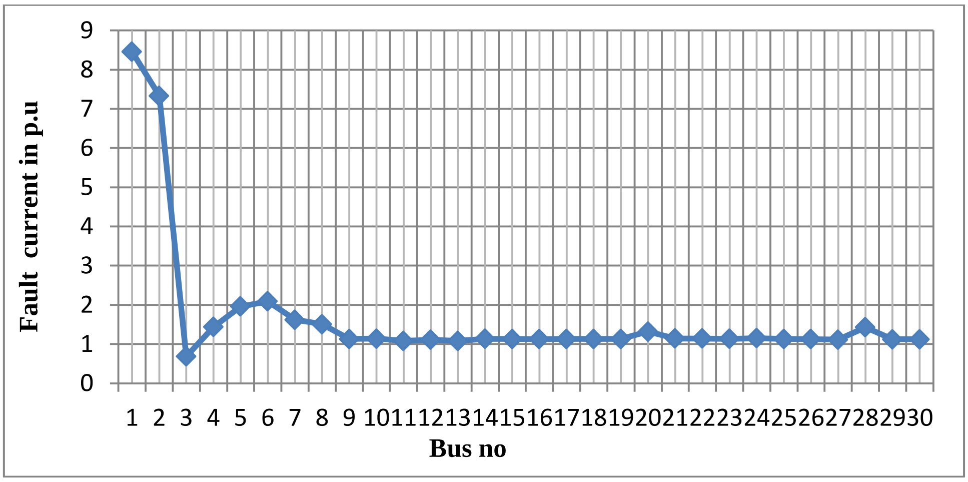

Figure 8: Graphical Representation for Current flow in line no.1 when there is a fault occurs on IEEE 30 bus

Table no.9 represents the comparison of line flow currents during LLL fault with the pre-fault line flow currents; it is analysing that line currents increases from their normal value when there is a fault at different buses.

- Table 10: SCMVA and Circuit Breaker Ratings in each line of the IEEE 30 bus system:

Line no.	SCMVA	Circuit breaker rating (MVA)
1	895.7	900
2	398.5	400
3	348.4	350
4	1060.8	1070
5	393.9	400
6	354.5	360
7	870.62	880
8	365.62	370
9	379.0	380
10	1070	1070
11	387.5	390
12	146.58	150
13	184.0	190
14	268.51	270
15	189.5	190
16	60.72	70
17	212.6	220
18	152.8	160
19	186.7	190
20	191.9	200
21	124.8	130
22	357.7	360
23	124.4	130
24	123.5	130
25	248.08	250
26	122.48	130
27	248.2	250
28	156.9	160
29	248.2	250
30	198.79	200
31	144.4	150
32	139.5	140
33	124.7	130
34	101.6	110
35	83.3	90
36	103.6	110
37	203.2	210
38	81.6	90
39	63.8	70
40	213.9	220
41	865.9	870

From Table 10, in line no. 1 maximum current flowing when there is a fault occur at bus no.1 i.e. 8.458 p.u & in line no. 2 maximum current flowing when there is a fault at bus no.1.& in line no.3 maximum current flowing during fault at bus no.4 & in line no. 4 maximum current flowing when there is a fault at bus no.3 & similarly check other lines for fault at each bus of the system and choose the SCMVA rating of CB for each line acc. to above table. This effect is cleared by a graph that showing the current flow in line no.1 when fault occur at different buses, as shown in fig.8.

From table 10 it can be observed that transmission line no. 10 having a higher fault current & higher circuit breaker rating i.e. 1070MVA. And also line no flows higher fault current. And line 16 is less affected.

V. CONCLUSION

The evaluation of Fault analysis or short circuit analysis is very important part of power system analysis for stable and economical operations of a Power System network. The Short circuit studies and hence the fault analyses is are very important for the power system studies since they provide data such as voltages and currents during and after the various types of faults which are necessary in designing the protective schemes of the power system. The main task is to calculate fault conditions and provide protective equipments designed to isolate the faulted zone from the remainder of the system in the appropriate time. The simulation is take place on symmetrical fault (LLL) on different buses of a power system network and to estimate the state of the power system before and after a fault, which includes various bus voltages and current flow on various transmission lines. From above results, it is seen that during short circuit fault (LLL) voltage magnitude at faulty buses reduced to zero and current flow in the lines increases. During LLL fault In IEEE 6 bus system, line no. 4 is most affected i.e. in line no.4 maximum fault current flows during fault at bus no.4 and in IEEE 30 bus system, line no. 10 is most effected when there is faults occur at bus no.8. So according to the values of fault current flows in the lines, circuit breaker rating is chosen.). It is concluded that in the lines of 6 bus system

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circuit breaker rating ranges within 210 MVA and 530MVA and in the lines of 30 bus system circuit breaker rating ranges within 70MVA and 1070 MVA.

APPENDIX

APPENDIX - 1: Test System Data of IEEE 6 bus system:
Fault analysis has been done on standard IEEE 6 bus systems, and it consists of 6 buses and 7 lines. Line data and load data for IEEE 6 bus system is given below.

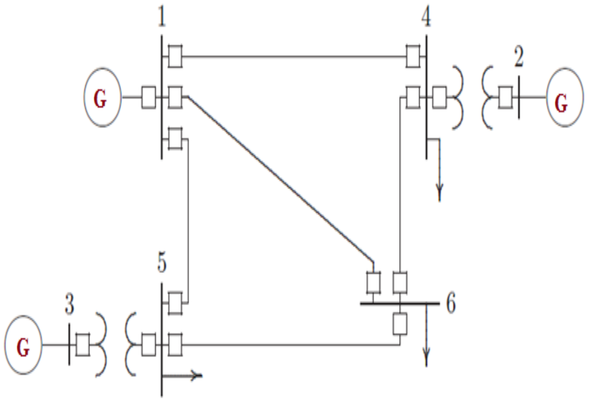

Fig 9: IEEE 6 bus system

- Line data for IEEE 6 bus system:

Line no.	From – To bus	Resistance, R (p.u)	Reactance, X(p.u)	Half line charging Susceptance, ½ B(p.u)
1	1-4	0.035	0.225	0.0065
2	1-5	0.025	0.105	0.0045
3	1-6	0.04	0.215	0.005
4	2-4	0.00	0.035	0.000
5	3-5	0.00	0.042	0.000
6	4-6	0.028	0.125	0.0035
7	5-6	0.026	0.175	0.030

- Load data for IEEE 6 bus system:

Bus no	Bus Voltage		Load (p.u)		Generation (p.u)	
	Voltage magnitud e (p.u)	Angle (rad)	MW (L)	Mvar (L)	MW (G)	Mvar (G)
1	1.06	0.00	0.00	0.00	0.00	0.00
2	1.04	0.00	150.0	0.00	0.00	0.00
3	1.03	0.00	100.0	0.00	0.00	0.00
4	1.0	0.00	100.0	70.00	0.00	0.00
5	1.0	0.00	90.00	30.0	0.00	0.00
6	1.0	0.00	160.0	110.0	0.00	0.00

APPENDIX - 2: Test System Data of IEEE 30 bus system:

Fault analysis has been done on standard IEEE 30 bus systems, and it consists of 30 buses and 41 lines. Line data and load data for IEEE 30 bus system is given below.

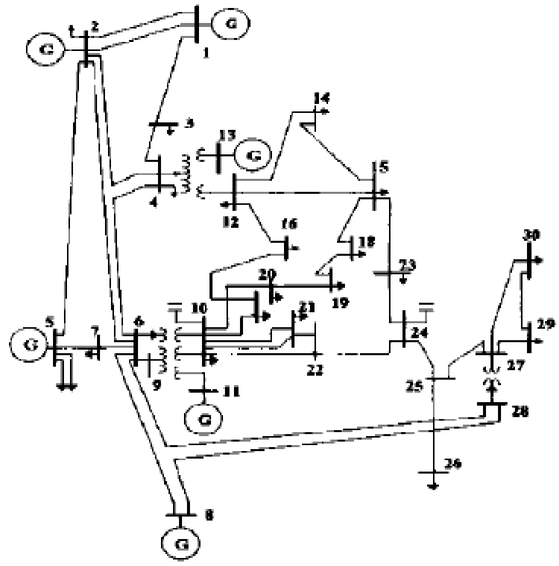

Fig .10: IEEE 30 bus system

- Line data for IEEE 30 bus system:

Line no.	From – To	Resistance R (p.u)	Reactance X(p.u)	Half line charging Susceptance $\frac{1}{2}$B (p.u)
1	1-2	0.0192	0.0575	0.0264
2	1-3	0.0452	0.1652	0.0204
3	2-4	0.057	0.1737	0.0184
4	3-4	0.0132	0.0379	0.0042
5	2-5	0.0472	0.1983	0.0209
6	2-6	0.0581	0.1763	0.0187
7	4-6	0.0119	0.0414	0.0045
8	5-7	0.046	0.116	0.0102
9	6-7	0.0267	0.082	0.0085
10	6-8	0.012	0.042	0.0045
11	6-9	0	0.208	0
12	6-10	0	0.556	0
13	9-11	0	0.208	0
14	9-10	0	0.11	0
15	4-12	0	0.256	0
16	12-13	0	0.14	0
17	12-14	0.1231	0.2559	0
18	12-15	0.0662	0.1304	0
19	12-16	0.0945	0.1987	0
20	14-15	0.221	0.1997	0
21	16-17	0.0524	0.1923	0
22	15-18	0.1073	0.2185	0
23	18-19	0.0639	0.1292	0
24	19-20	0.034	0.068	0
25	10-20	0.0936	0.209	0
26	10-17	0.0324	0.0845	0
27	10-21	0.0348	0.0749	0
28	10-22	0.0727	0.1499	0
29	21-22	0.0116	0.0236	0
30	15-23	0.1	0.202	0
31	22-24	0.115	0.179	0
32	23-24	0.132	0.27	0
33	24-25	0.1885	0.3292	0
34	25-26	0.2544	0.38	0
35	25-27	0.1093	0.2087	0
36	28-27	0	0.396	0
37	27-29	0.2198	0.4153	0
38	27-30	0.3202	0.6027	0
39	29-30	0.2399	0.4533	0
40	8-28	0.0636	0.2000	0.0214
41	6-28	0.0169	0.0599	0.065

- Load data for IEEE 30 Bus system:

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Bus no	Bus voltage		Load		Generation	
	Voltage magnitude (p.u)	Angle (rad)	MW (L)	Mvar (L)	MW (G)	Mvar (G)
1	1.06	0.00	0.00	0	0	0
2	1.045	0.00	21.7	12.7	40	0
3	1.000	0.00	2.4	1.2	0	0
4	1.060	0.00	7.6	1.6	0	0
5	1.010	0.00	94.2	19	20	-40
6	1.000	0.00	0.00	0	0	0
7	1.000	0.00	22.8	10.9	0	0
8	1.010	0.00	30	30.6	20	-10
9	1.000	0.00	0.00	0	0	0
10	1.000	0.00	5.8	2	0	0
11	1.082	0.00	0.00	20	0	-6
12	1.000	0.00	11.2	7.5	0	0
13	1.071	0.00	0.00	20	0	-6
14	1.000	0.00	6.2	1.6	0	0
15	1.000	0.00	8.2	2.5	0	0
16	1.000	0.00	3.5	1.8	0	0
17	1.000	0.00	9	5.8	0	0
18	1.000	0.00	3.2	0.9	0	0
19	1.000	0.00	9.5	3.4	0	0
20	1.000	0.00	2.2	0.7	0	0
21	1.000	0.00	17.5	11.2	0	0
22	1.000	0.00	0.00	0.00	0	0
23	1.000	0.00	3.2	1.6	0	0
24	1.000	0.00	8.7	6.7	0	0
25	1.000	0.00	0.00	0.00	0	0
26	1.000	0.00	3.5	2.3	0	0
27	1.000	0.00	0.00	0.00	0	0
28	1.000	0.00	0.00	0.00	0	0
29	1.000	0.00	2.4	0.9	0	0
30	1.000	0.00	10.6	1.9	0	0

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