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SHORT CIRCUIT ANALYSIS OF IEEE 14-BUS SYSTEM USING ETAP

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***Abstract*—In this paper, short circuit analysis has been carried out for IEEE 14-bus system using ETAP software. The Maximum short circuit currents and the Minimum short circuit currents, referring as Sub-Transient and Steady state fault currents are used for determination of ratings of protective devices. In IEEE 14-Bus system, the Maximum and Minimum short circuit currents for Three-phase and Single line to ground faults applied at various buses are obtained in ETAP software.**

***Index Terms*—ETAP software, Maximum short circuit current, Minimum Short circuit current**

I. INTRODUCTION

A power system operating under balanced condition, which when disrupted by a fault due to either flashover, insulation failure, physical damage or human error creates excessive high currents to flow through the system that causes the system to operate in the abnormal state which is not desired. The short circuit faults seen by the system can be classified as:

1. Symmetrical Faults
2. Asymmetrical Faults

Symmetrical faults are those in which, (a) the three phases are short-circuited to each other (L-L-L), (b) the three phases are grounded (L-L-L-G). In this, the three phases are equally affected and so can be called as Balanced faults. Fortunately, these faults occur infrequently, that has the severity level much higher than of all types.

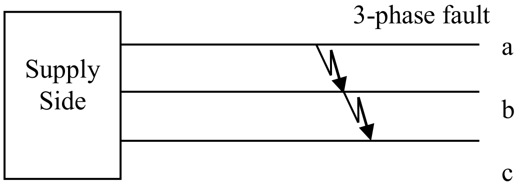

Fig. 1: Balanced Three phase fault

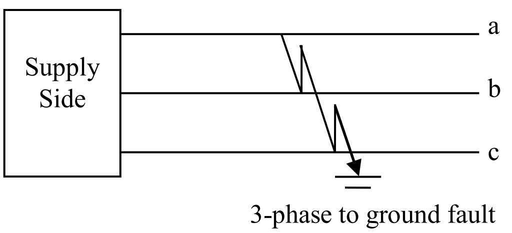

Fig. 2: Balanced Three phase to ground fault

Asymmetrical faults are the single phase to ground (L-G), double to phase to ground (L-L-G), phase to phase faults (L-L), in which the single phase to ground fault occurs frequently.

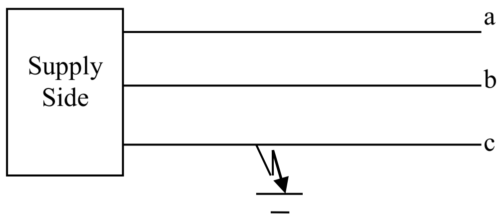

Fig. 3: Single phase to ground fault

Short circuit studies are important for sizing in of equipment and protection coordination of system. For an efficient protection scheme of a power system, short circuit studies are to be performed, which are essential for Relay Coordination studies. In this paper, a sample test case system and IEEE-14 bus system has been modeled and analyzed for symmetrical three-phase fault and Single phase to ground fault using ETAP software.

II. ETAP SOFTWARE

The Electrical Transient Analyzer Program (ETAP) is a structured computer program that uses technically correct models, common data base. In addition, ETAP performs numerical calculations with tremendous speed, automatically applies industry accepted standards, and provides easy to follow output reports. With the help of User-edited libraries, typical data can be substituted based on request [1].

Once the network is modeled, the software will calculates for 3 phase fault, single phase to ground fault, double phase to ground fault, phase to phase fault, voltage magnitude at the faulted phase, and voltage magnitude at the healthy phase. Also, the minimum and maximum currents can be calculated in which the minimum fault current is used for protection relay co-ordination and maximum fault current is used to determine the breaking and making rating of the circuit breakers.

The ETAP short-circuit program calculates different fault currents corresponding to different time periods, specifically, 1/2 cycle, 1.5 to 4 cycle, 30 cycles. The 1/2 cycle studies calculate momentary short-circuit current in their rms values at the ½ cycle at faulted buses, which are considered the maximum short-circuit current values. The 1/2 cycle network is referred as the Sub-Transient network. The 1.5 to 4 cycle studies calculate interrupting short circuit current 1.5 to 4 cycles after the fault, and this network is referred as the Transient network. The 30 cycle studies calculate the steady state short circuit current after the fault.

III. ANALYSIS USING A TEST SYSTEM

Firstly, for a considered test bus system (Fig. 4), the fault analysis has been performed. The assumed data for the test system is shown in Table-1, Table-2.

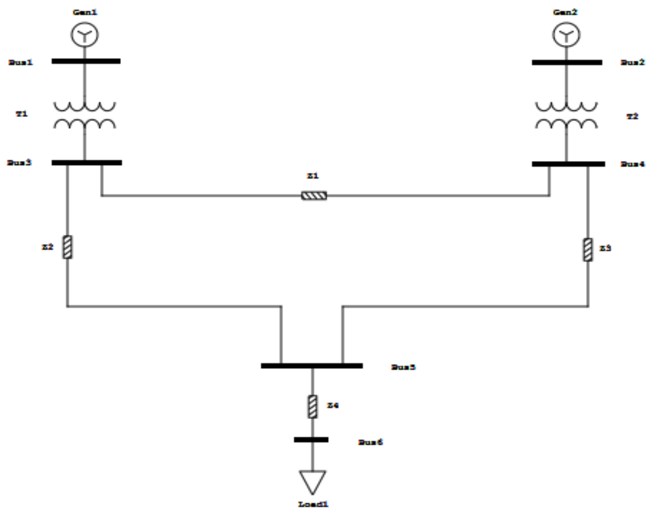

Fig. 4: Single Line Diagram of Test System

Generator Data				
Bus	**P (MW)**	**Q (Mvar)**	**V∠° p.u.**	**Bus Type**
1	85	52.678	1.00∠0°	Swing
2	50	30.987	1.00∠0°	Voltage Controlled
3	0	0	1.00∠0°	-
4	0	0	1.00∠0°	-
5	0	0	1.00∠0°	-
6	0	0	1.00∠0°	Load Bus

Load Data		
Bus	**P (MW)**	**Q (Mvar)**
6	80	0

Table-1: Bus Data of Test System

Bus to Bus	R p.u.	X p.u.	Y p.u.
3-4	0.1	0.2	0
3-5	0.05	0.15	0
4-5	0.15	0.1	0
5-6	0.1	0.2	0

Table-2: Line Data

Three phase fault and L-G fault are created at Bus-1 and is validated with hand calculation. The L-G fault currents are severe than the 3-phase fault currents at synchronous generator terminal.

Maximum Short circuit current (1/2 Cycle) in kA when fault created at Bus-1		
Fault Type	**Design Output**	**Hand Calculation**
3-Phase Fault	35.745	35.74
L-G Fault	43.987	43.97

Minimum Short circuit current (30 Cycle) in kA when fault created at Bus-1		
Fault Type	**Design Output**	**Hand Calculation**
3-Phase Fault	25.334	25.33
L-G Fault	37.655	37.65

Table–3: Three-phase & L-G fault currents when fault at Bus-1

At Bus-5, 3-phase fault and L-G fault are created and the maximum, minimum short circuit currents are validated with hand calculation and are tabulated below.

Maximum Short circuit current (1/2 Cycle) in kA when fault created at Bus-5		
Fault Type	**Design Output**	**Hand Calculation**
3-Phase Fault	3.517	3.517
L-G Fault	2.508	2.508

Minimum Short circuit current (30 Cycle) in kA when fault created at Bus-5		
Fault Type	**Design Output**	**Hand Calculation**
3-Phase Fault	2.872	2.87
L-G Fault	2.43	2.43

Table–4: Three-phase & L-G fault currents when fault at Bus-5

IV. IEEE 14-BUS SYSTEM

The single line diagram of IEEE 14-Bus system is shown in below Fig. 5. The parameters of dynamic model for the synchronous generators considered in design are taken with typical data values. The per unit sequence resistance and reactance of machine are R_2 = 2%, R_0 = 1%, X_2 = 18% and X_0 = 7%.

X_d''	19%	**X_q''**	19%
X_d'	28%	**X_q'**	65%
X_d	155%	**X_q**	155%
T_{d0}''	0.035 sec	**T_{q0}''**	0.035 sec
T_{d0}'	6.5 sec	**T_{q0}'**	1.25 sec

Table-5: Dynamic Model Parameters

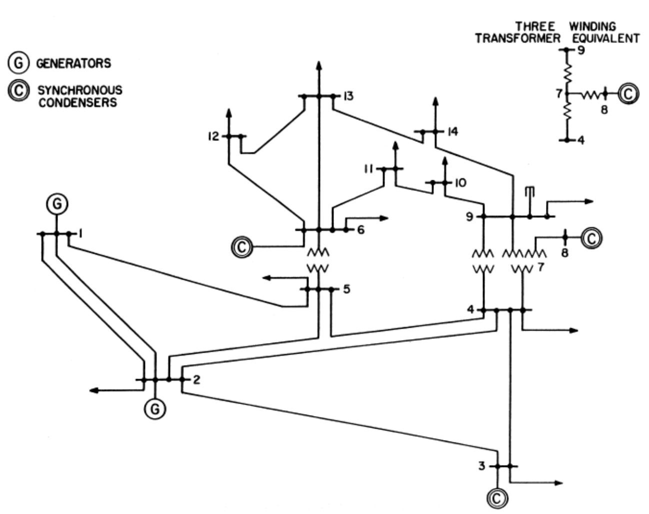

Fig. 5 Single Line Diagram of IEEE 14-Bus System

The Generator data, Load data and Line data for the considered IEEE 14-Bus system are shown in Table-5.

Generator Data				
Bus	**P (MW)**	**Q (Mvar)**	**V∠° p.u**	**Bus Type**
1	232.4	16.9	1.060 ∠0°	Swing
2	40.0	42.4	1.045∠-4.98°	Voltage Control
3	0.0	23.4	1.01∠-12.72°	Voltage Control
4	0.0	0.0	1.019∠-10.33°	Load Bus
5	0.0	0.0	1.020∠-8.78°	Load Bus
6	0.0	12.2	1.07∠-14.22°	Voltage Control
7	0.0	0.0	1.062∠-13.37°	Load Bus
8	0.0	17.4	1.09∠-13.36°	Voltage Control
9	0.0	0.0	1.056∠-14.94°	Load Bus
10	0.0	0.0	1.051∠-15.10°	Load Bus
11	0.0	0.0	1.057∠-14.79°	Load Bus
12	0.0	0.0	1.055∠-15.07°	Load Bus
13	0.0	0.0	1.05∠-15.16°	Load Bus
14	0.0	0.0	1.036∠-16.04°	Load Bus

Load Data		
Bus	**P (MW)**	**Q (Mvar)**
1	0.0	0.0
2	21.7	12.7
3	94.2	19.0
4	47.8	-3.9
5	7.6	1.6
6	11.2	7.5
7	0.0	0.0
8	0.0	0.0
9	29.5	16.6
10	9.0	5.8
11	3.5	1.8
12	6.1	1.6
13	13.5	5.8
14	14.9	5.0

Table-6: Generator and Load Data of IEEE 14-Bus System

Bus to Bus	**R p.u.**	**X p.u.**	**Y p.u.**
1-2	0.01938	0.05917	0.0528
1-5	0.05403	0.22304	0.0492
2-3	0.04699	0.19797	0.0438
2-4	0.05811	0.17632	0.0340
2-5	0.05695	0.17388	0.0346
3-4	0.06701	0.17103	0.0128
4-5	0.01335	0.04211	0.0
4-7	0.0	0.20912	0.0
4-9	0.0	0.55618	0.0
5-6	0.0	0.25202	0.0
6-11	0.09498	0.19890	0.0
6-12	0.12291	0.25581	0.0
6-13	0.06615	0.13027	0.0
7-8	0.0	0.17615	0.0
7-9	0.0	0.11001	0.0
9-10	0.03181	0.08450	0.0
9-14	0.12711	0.27038	0.0
10-11	0.08205	0.19207	0.0
12-13	0.22092	0.19988	0.0
13-14	0.17093	0.34802	0.0

Table-7: Line Data of IEEE 14-Bus System

V. RESULTS

The design of IEEE 14-Bus in ETAP software is shown in below Fig. 6. The Maximum and Minimum short circuit currents of three-phase and single line to ground faults when occurred at Bus-3, Bus-6 and Bus-9 are simulated and tabulated in below Table-7, Table-8, Table-9, Table-10, Table-11, Table-12.

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus3	Total	0.00	696.945	0.00	106.38	101.60	644.961
Bus2	Bus3	65.57	186.068	67.9	101.01	99.18	192.681
Bus4	Bus3	59.98	188.535	57.1	104.4	101.72	179.459
Gen3	Bus3	100	71.007	100	100.0	100.00	118.340
Load3	Bus3	100	255.750	100	100.0	100.00	156.955

Table-8: Maximum short circuit currents when 3-Phase & L-G Fault occurs at Bus-3

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus3	Total	0.00	315.257	0.00	87.26	87.86	396.948
Bus2	Bus3	50.19	142.419	58.05	89.18	90.58	164.730
Bus4	Bus3	39.92	125.469	45.16	89.00	90.65	141.938
Gen3	Bus3	100	48.219	100	100	100	91.273

Table-9: Minimum short circuit currents when 3-Phase & L-G Fault occurs at Bus-3

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus6	Total	0.00	400.03	0.00	101.93	94.30	415.857
Bus11	Bus6	29.14	76.339	28.76	102.44	95.26	75.332
Bus12	Bus6	12.31	25.045	9.96	103.06	95.93	20.260
Bus13	Bus6	17.53	69.285	15.06	103.11	96.20	59.505
Bus5	Bus6	70.92	162.468	87.51	99.80	83.45	183.672
Gen6	Bus6	100	37.021	100	100.0	100.00	56.972
Load6	Bus6	100	35.873	100	100.0	100.00	24.760

Table-10: Maximum short circuit currents when 3-Phase & L-G Fault occurs at Bus-6

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus6	Total	0.00	215.440	0.00	87.69	86.38	276.058
Bus11	Bus6	15.74	41.229	18.93	88.04	87.04	49.592
Bus12	Bus6	2.68	5.448	3.22	87.77	86.47	6.553
Bus13	Bus6	5.39	21.285	6.48	87.81	86.61	25.603
Bus5	Bus6	54.07	123.866	75.47	95.00	72.83	150.661
Gen6	Bus6	100	25.14	100	100.0	100.00	45.542

Table-11: Minimum short circuit currents when 3-Phase & L-G Fault occurs at Bus-6

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus9	Total	0.00	452.268	0.00	104.89	95.88	449.674
Bus7	Bus9	27.90	146.410	32.74	101.27	94.62	171.818
Bus10	Bus9	13.70	87.577	12.95	105.01	96.43	82.783
Bus14	Bus9	32.34	62.489	29.70	105.48	97.77	57.390
Bus4	Bus9	69.05	71.679	87.59	99.82	82.93	82.906
Load9	Bus9	100	90.087	100	100.0	100.00	59.540

Table-12: Maximum short circuit currents when 3-Phase & L-G Fault occurs at Bus-9

Contribution		3-Phase Fault		L-G Fault			
From Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				V_a	V_b	V_c	
Bus9	Total	0.00	223.315	0.00	88.85	86.76	282.116
Bus7	Bus9	20.64	108.303	26.42	88.73	86.57	138.663
Bus10	Bus9	6.05	38.679	7.53	88.79	86.90	48.162
Bus14	Bus9	12.95	25.016	16.12	88.70	87.05	31.149
Bus4	Bus9	50.57	52.497	74.31	94.89	70.89	65.899

Table-13: Minimum short circuit currents when 3-Phase & L-G Fault occurs at Bus-9

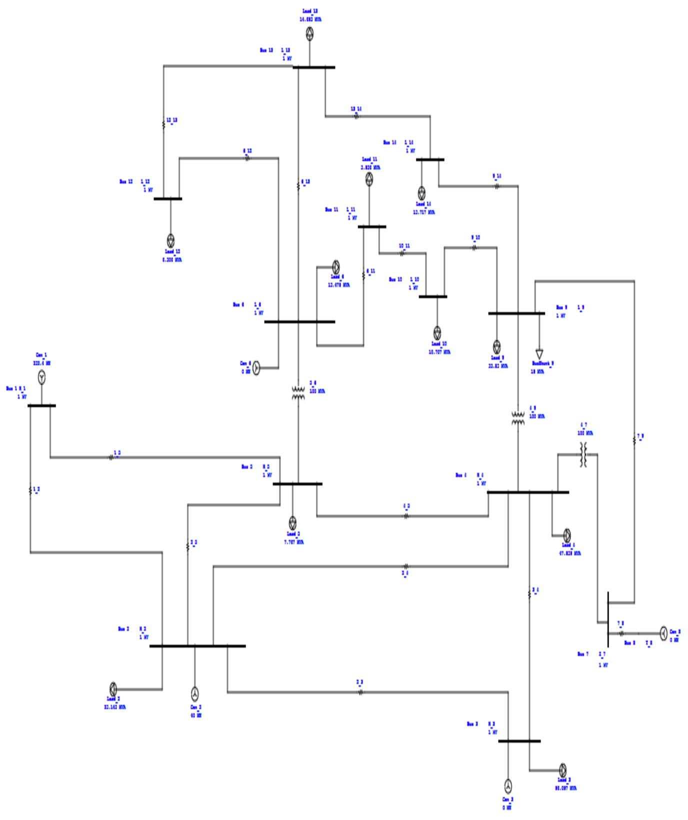

Fig. 6 Design of IEEE 14-Bus System in ETAP Software

CONCLUSION

For the test system considered, the maximum and minimum short circuit currents are obtained when three-phase and single line to ground fault are created, and the values are validated with hand calculation.

The same is implemented for IEEE 14-Bus system with faults at Bus-3, Bus-6 and Bus-9. The maximum short circuit current can be used to determine the breaking and making rating of the circuit breakers. The value of minimum short circuit current can be used for protection relay co-ordination scheme.

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