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Optimal Load Flow and Short Circuit Analysis for IEEE-14 Bus Power System using ETAP

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Abstract
This paper presents optimal power flow and short circuit analysis of an IEEE-14 bus system using the Electrical Transient Analyzer Program (ETAP) software. The load flow and short circuit studies in power systems are very important for both design and operating stage performance evaluation, as well as ensuring dependable grid operations through appropriate protection scheme settings. In addition, a comparison between load flow analysis and its optimal load flow analysis, then the short circuit evaluations are carried out It is employed to determine the greatest and lowest fault currents for 3-phase and single-line to ground faults on different buses .Inductive loads that connect to the electrical system generally consume reactive power. Load flow analysis is used to calculate the voltage, the real power, and also the reactive power flow over each bus. Optimal power flow analysis is frequently used to reduce a system's fuel expenditures by minimizing actual and reactive power losses. In order to calculate protective device ratings, the IEEE-14 bus system uses maximum and minimum short circuit currents, also known as sub-transient and steady-state fault currents
Keywords: power system's,. load flow, Transient Analyzer Program, IEEE-14 bus system,

1. Introduction

To calculate the necessary loads in megawatts and perhaps even megavars on various transmission network sites, as well as the amplitudes of the voltage and a topological description of the network, including impedances, is how the classical power flow or load flow problem is handled. Planning and operating needs frequently demand that generated powers be adjusted according to specified criteria in order to achieve the best technique of power flow. The reduction of losses is one of the basic requirements [1],[2]. For load flow computation, the Newton Rapson method is explained in [3],[4]. The Newton Rapson method, the Gauss Siedel method, and the rapid decoupling approach are all explained [5],[6],[7]. The research describes an upgraded power flow technique as well as a contingency analysis of power system functioning [8], In publications, the optimal power flow approach is explained. [9]-[10].
The fault current magnitudes across the plant are measured at different sites using a short circuit test. The mechanical, thermal, as well as heating strains that the fault current generates should not be able to damage the plant's electrical equipment. The results of the short circuit analysis can then be utilized to calculate the short circuit values of the electrical components in the plant [11],[12].
Short circuit investigations are necessary for both equipment sizing and system differential protection. Short circuit analyses, a successful power system protection strategy requires the findings of the Relay Coordination research, which are necessary. The ETAP program was used in this work to simulate, analyze, and compare the load flow as well as optimal load flow of a sample testing network and an IEEE-14 bus network. Then, study the symmetrical three-phase failure and single phase to ground fault.
The rest of the essay is structured as follows: In Section 2, the ETAP Software is described. Section 3. of the document presents the block diagram and data for the IEEE 14 Bus System, while Section 4. of the paper discusses load flow modeling and analysis, further to the examination of the short circuit current waveform. In section 5, The outcomes of investigations on load flow and short circuits are displayed, contrasted, and discussed. The study is brought to a close in Section 6 by underlining the importance of the work.

2. The ETAP Software

A structured computer application called ETAP (Electrical Transient Analyzer Software) uses models that are theoretical and a commonly used data base. Moreover, ETAP is a software program that does numerical computations quickly, industrial requirements are immediately applied, and generates easy-to-understand reports on output. User-edited libraries allow for the substitution of common data depending on a request [13].
After the network has been modeled, Using the optimal power flow technique and the Newton-Rapson approach, the software calculates the load flow across each branch.

Each bus's actual and reactive power flow is computed. The voltage magnitude at the faulty phase is calculated for faults in three phases, faults from one phase to the ground, faults from two phases to the ground, and phase to phase faults. The fault currents' minimum and maximum values can also be evaluated, the circuit breaker's breaking and making ratings are determined using the lowest fault current for protection relay coordination and the maximum fault current for circuit breaker coordination. Different fault currents are calculated for various time intervals using the ETAP short-circuit software, including 1/2 cycle and 30 cycles. At faulty buses, At the 1/2 cycle, the transient short-circuit current in rms values is calculated by the 1/2 cycle studies., which are considered the highest short-circuit current values. The Sub-Transient network is referred to as a 1/2 cycle network. The 30 cycle investigations are used to estimate the steady state fault current following the fault [14].

3. Power System Modeling in Study

Figure 1 depicts the IEEE 14-bus systematic approach as just a single line diagram [15]. Five synchronous machines of the IEEE type-1 exciters comprise up the system, Synchronous compensators are three of them, and their main purpose is to assist with reactive power. On the system, 11 loads comprising 259 MW and 81.3 Mvar are present [16]. Using this technique, the generator exciters were given the data in real time. Eleven loads and 17 transmission lines are present in the system

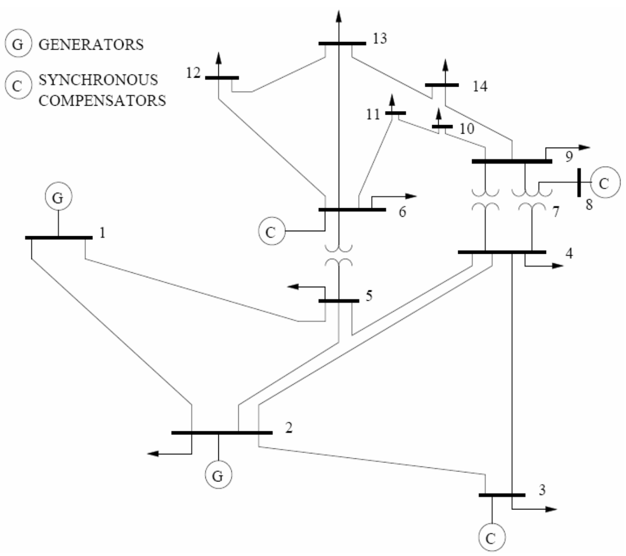

Figure. 1 Standards-Based Bus IEEE 14

From Tables 3.1 to 3.4, information from of the IEEE 14 bus standard is included for buses, transformers, transmission lines, and generators.

Table 1 Data of the Buses

Bus	V(pu)	Δ(deg)	P_G	Q_G	P_L	Q_L
1	1.06	0	232.9	-19.5	0	0
2	1.045	-5.015	40	36.92	21.7	12.7
3	1.01	-12.821	0	20.69	94.2	19
4	1.0231	-10.601	0	0	47.8	-3.9
5	1.0262	-8.755	0	0	7.6	1.6
6	1.0697	-16.496	0	24	11.2	7.5
7	1.0526	-11.766	0	0	0	0
8	1.0823	-11.766	0	18.24	0	0
9	1.0548	-14.41	0	0	29.5	16.6
10	1.0504	-15.06	0	0	9	5.8
11	1.0569	-15.889	0	0	3.5	1.8
12	1.0543	-17.158	0	0	6.1	1.6
13	1.0503	-17.035	0	0	13.5	5.8
14	1.0348	-16.551	0	0	14.9	5

Buses 1 through 5 are powered by 220 kV, whereas buses 6 through 14 are powered by 132 kV. Real and reactive power generation is represented by PG and QG, and real and reactive power of loads is represented by PL and QL. Active power is measured in megawatts (MW) while reactive power is measured in megavolt-hours-per-second-per-
second-per-second-per-second-per-

Table 2 Data of the Transformer

From	Positive		Negative		Zero	
Bus	R p.u	X p.u.	R p.u.	X p.u.	R p.u.	X p.u.
1	0.001	0.007	0.001	0.007	0.001	0.007
2	0.002	0.011	0.002	0.011	0.002	0.01
3	0.007	0.130	0.006	0.22	0.006	0.1
6	0.002	0.162	0.002	0.22	0.002	0.1
8	0.001	0.095	0.001	0.2	0.001	0.1

Table 3 Data of the Transmission Line

From Bus	To Bus	Positive		Zero		TAP
		p.u.	X p.u.	R p.u.	X p.u.	
5	6	0.00006	0.556	0.00006	0.556	0.93
4	7	0	0.048	0	0.048	0.98
4	9	0	0.556	0.00006	0.556	0.97

Table 4 The generator's data

From	To	Rp(p.u)	Xp(p.u)	FB-MVA	TB-MVA	From
Bus1	Bus2	0.01938	0.05917	15242	15242	Bus1
Bus2	Bus3	0.04699	0.19797	15242	15242	Bus2
Bus2	Bus4	0.05811	0.17632	15242	15242	Bus2
Bus1	Bus5	0.05403	0.2234	15242	15242	Bus1
Bus2	Bus5	0.05695	0.17388	15242	15242	Bus2
Bus3	Bus4	0.06701	0.17103	15242	15242	Bus3
Bus4	Bus5	0.01355	0.04211	15242	15242	Bus4
Bus7	Bus8	0	0.17615	229	229	Bus7
Bus7	Bus9	0	0.11001	229	229	Bus7
Bus9	Bus10	0.03181	0.0845	229	229	Bus9
Bus6	Bus11	0.0949	0.1989	229	229	Bus6
Bus6	Bus12	0.12291	0.25581	229	229	Bus6
Bus6	Bus13	0.06615	0.13027	229	229	Bus6
Bus9	Bus14	0.12711	0.27036	229	229	Bus9
Bus10	Bus11	0.08205	0.19207	229	229	Bus10
Bus12	Bus13	0.22092	0.1998	229	229	Bus12
Bus13	Bus14	0.17093	0.34802	229	229	Bus13

4. Methodology

A. Standard Load Flow Technique:

The flow of both reactive and real power, as well as the voltage on each bus, are determined using a load flow analysis. The voltage and power across each bus are calculated in this study using the Newton-Rapson method. The Newton-Raphson approach and algorithm were chosen because they converge rapidly and requires less iterations than other strategies, and its dependability is comparable to other techniques [17]. For this approach, components that are both real and imagined of the resulting equation will be as illustrated in equations from (1- 4) [2]: Figure 2 shows a flow chart for the Newton Raphson approach [18].

$$\begin{bmatrix}\Delta & \theta \\ \Delta & |v|\end{bmatrix} = -\dot{J}^{1}\begin{bmatrix}\Delta & P \\ \Delta & Q\end{bmatrix} \quad (1)$$

where ΔP and ΔQ are called the mismatch equations:

$$\Delta Pi = -Pi \sum_{k=1}^{N} |\,Vi\,|\;|\,Vk\,| \quad (Gik\ cos\theta ik + Biksin\theta ik) \quad (2)$$

$$\Delta Qi = -Qi \sum_{k=1}^{N} |\,Vi\,|\;|\,Vk\,| \quad (Gik\ sin\theta ik - Bikcos\theta ik) \quad (3)$$

and J is a matrix of partial derivatives known as a Jacobian

$$J = \begin{bmatrix} \frac{\partial \Delta P}{\partial v} & \frac{\partial \Delta P}{\partial |V|} \\ \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial |V|} \end{bmatrix} \quad (4)$$

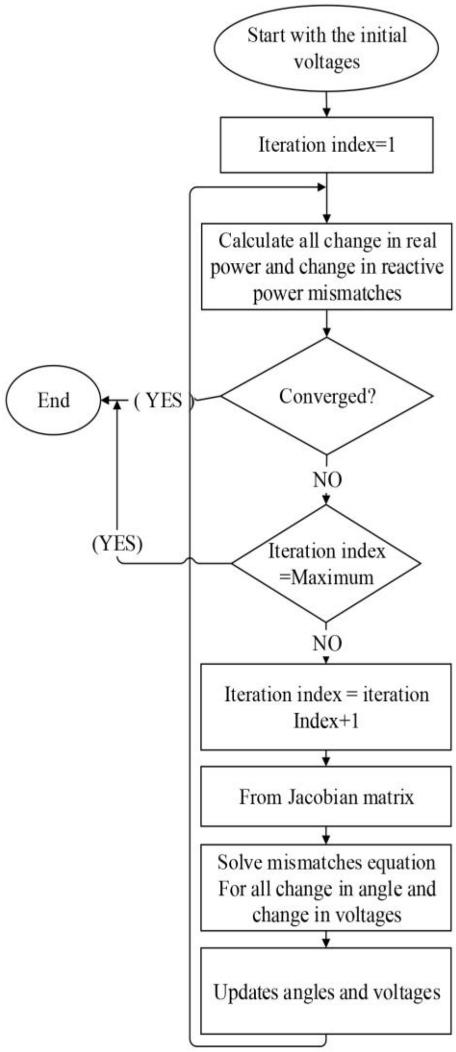

Figure. 2 Flowchart for the Newton-Rapson technique

B. The optimal power flow technique:

Minimize branch losses to reduce total system losses is the prime purpose of the Optimal Power Flow process [9,10].

Pj (V,θ) = PGj - PDj
Qj (V, θ) = QGj - QDj
PGmn ≤ PG ≤ PGmx
QGmn ≤ QG ≤ QGmx
Vjmn ≤ Vj ≤ Vjmx
Plmn ≤ Pl ≤ Plmx

Where:
PGj : using the generator connected to bus j to provide actual power;
QGj : using the generator connected to bus j to provide reactive power;
PDj the actual power load tied to bus j;
QDj : the reactive power load tied to bus j;
Pj : at bus j, the actual power requirement;
Qj: at bus j, the reactive power requirement;
Vj : at bus j, the voltage;
Pl : The power flow at line l is from bus j to bus f.

C. Short – Circuit Analysis

The amplitudes of symmetrical and unsymmetrical fault currents are determined by short-circuit analysis, considering the contribution per each electrical device up to the failure site to the fault current. The outcomes of the short circuit analysis can be conducted to establish an electrical system's machinery as well as equipment's short circuit ratings, there are several sorts of faults that can produce short circuits. Short circuits with three phases, double lines, double line-ground, and line-ground are all examples. Since single-phase circuits and three-phase short circuit faults are identical, short-circuit analysis is performed in this paper. The remaining classes of short-circuits will be the focus of future research [18].

The current waveform for a short circuit "close to generator" according to the IEC 60909-0 Standard [19], the problem is represented in Figure 3.

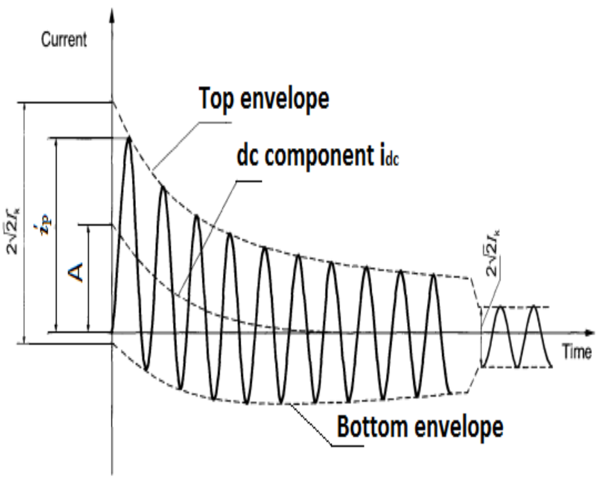

Figure. 3 Waveform of current in a short circuit [14].

5. Simulation Results

For each, a model is simulated, where the results are shown.

A. Results of load Flow Analysis

The simulated circuit is shown in figure 4 of the simulation analysis software ETAP. The power flow in the IEEE-14 bus network is evaluated to use the Newton-Raphson method. Implementing the optimal power flow approach and the Newton-Rapson methodology, the load flow over each branch is evaluated.as seen in tables (1-2). On each bus, the flow of actual and reactive power is computed. The power flow between buses is tabulated and compared to the optimal power flow method.

Figures 5-6 illustrate the values of current, voltage, and angle in the IEEE-14 bus system at load flow but rather optimal load flow, the generators can resume normal operation with just a slight change in voltage levels at power system busses. The power factor is also not affected significantly. The load has been met in cost-effective operating circumstances.

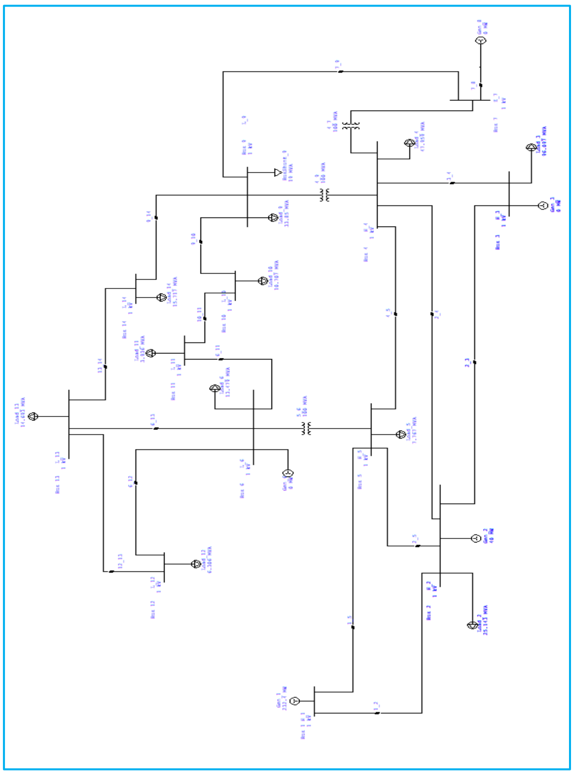

Figure.4 On ETAP software, this figure depicts the IEEE-14 bus system simulation circuit

A load flow analysis is necessary to determine whether all transmission lines as well as transformers were loaded to the specified beginning state. And then determines whether or not a transmission line or transformer is overloaded

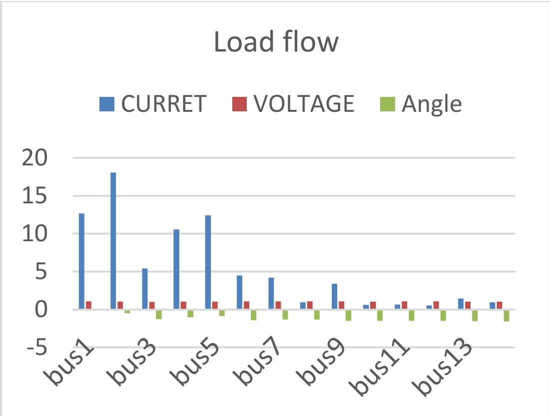

Figure. 5 Voltage and current of the IEEE-14 bus system represented graphically for the analysis of the load flow

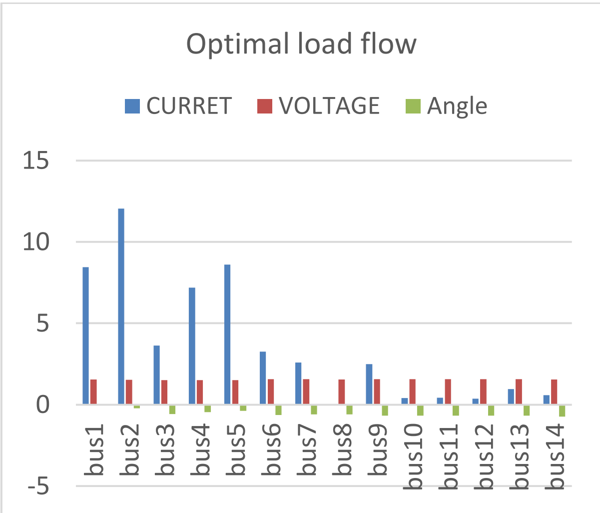

Figure. 6Voltage and current of the IEEE-14 bus system represented graphically for the analysis of the optimal load flow

B. Analysis and Comparison of Short Circuit Results

Figure 4 of the ETAP program shows the IEEE 14-Bus design. The following table simulates and lists the maximum and minimum three-phase and single line to ground fault short circuit currents for Bus-2, Bus-4, and Bus-8. Tables 5, 6, 7, 8, 9, and 10.

Table5 The maximum short circuit currents at Bus-2

Contribution		3-Phase Fault		L-G Fault			
via Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				Va	Vb	Vc	
Bus 2	**Total**	**0.00**	**1024.337**	**0.00**	**96.72**	**95.23**	**1110.551**
Bus 1	**Bus 2**	**42.85**	**397.293**	**94.1**	**94.56**	**94.90**	**455.914**
Bus 3	**Bus 2**	**49.20**	**139.617**	**44.58**	**101.68**	**98.67**	**126.509**
Bus 4	**Bus 2**	**41.12**	**127.890**	**35.50**	**101.11**	**99.60**	**110.411**
Bus 5	**Bus 2**	**38.05**	**120.070**	**33.96**	**100.10**	**98.80**	**107.167**
Gen_2	**Bus 2**	**100.00**	**176.881**	**100.00**	**100.00**	**100.00**	**265.177**
Load_2	**Bus 2**	**100.00**	**66.915**	**100.00**	**100.00**	**100.00**	**47.824**

during a three-Phase & L-G fault.

Table6 The minimum short circuit currents at Bus-2 during a three -Phase & L-G fault.

Contribution		three-Phase Fault		L-G Fault			
via Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				Va	Vb	Vc	
Bus 2	Total	0.00	540.618	0.00	80.12	81.79	**758.374**
Bus 1	Bus 2	31.41	291.273	41.15	80.97	83.39	**381.617**
Bus 3	Bus 2	14.21	40.320	19.74	80.14	81.87	**56.012**
Bus 4	Bus 2	13.78	42.861	16.87	80.66	83.11	**52.466**
Bus 5	Bus 2	14.73	46.480	18.14	80.70	83.15	**57.225**
Gen_2	Bus 2	100.00	120.116	100.00	100.00	100.00	**211.806**

Table7 The maximum short circuit currents at Bus-4 during a 3-Phase & L-G fault.

Contribution		three-Phase Fault		L-G Fault			
via Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				Va	Vb	Vc	
Bus 4	Total	0.00	402.905	0.00	87.21	90.20	496.178
Bus 2	Bus 4	36.06	112.130	45.87	87.00	89.20	142.637
Bus 3	Bus 4	23.40	73.540	31.81	86.31	88.46	99.972
Bus 5	Bus 4	13.44	175.717	16.67	87.26	90.07	217.882
Bus 7	Bus 4	10.97	30.288	55.21	55.12	91.06	26.112
Bus 9	Bus 4	11.09	11.516	55.21	55.20	91.06	9.824

Table8 The minimum short circuit currents at Bus-4 during a 3-Phase & L-G fault.

via Bus ID	three-Phase Fault	L-G Fault	L- L Fault	L- L -G Fault
Bus 2	1024.337	1110.551	897.132	1079.712
Bus 4	853.538	761.844	743.159	820.780
Bus 8	259.054	279.720	225.702	272.061

Table9 The maximum short circuit currents at Bus-8 during a 3-Phase & L-G fault.

Contribution		three-Phase Fault		L-G Fault			
via Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				Va	Vb	Vc	
Bus 8	Total	0.00	259.054	0.00	96.74	95.68	279.720
Bus 7	Bus 8	39.31	206.278	44.31	96.44	94.33	200.695
Gen_8	Bus 8	100.00	52.800	100.00	100.00	100.00	79.085

Table10 The minimum short circuit currents at Bus-8 during a 3-Phase & L-G fault.

Contribution		three-Phase Fault		L-G Fault			
via Bus ID	To Bus ID	%V From	kA	%V at From Bus			kA
				Va	Vb	Vc	
Bus 4	Total	0.00	853.538	0.00	106.38	105.28	761.844
Bus 2	Bus 4	51.21	159.250	55.93	100.82	99.67	173.952
Bus 3	Bus 4	50.80	159.683	49.29	105.19	102.07	154.933
Bus 5	Bus 4	21.66	283.040	21.69	105.02	103.94	283.465
Bus 7	Bus 4	29.32	80.942	68.96	72.71	99.65	48.263
Gen_9	Bus 4	43.77	45.436	73.26	79.08	99.71	26.991
Load_4	Bus 4	100.00	127.636	100.00	100.00	100.00	75.544

Conclusion

The load-flow study is vital for monetary scheduling depth provisioning and also arranging its future expansion. The principle outcomes acquired from power flow studies are nodal voltages, phase angles, system transmission losses and the real and reactive power streaming in each line. This paper simulated in power flow analysis by using cracked version of ETAP program it is limit capability and take long time we recommended searching by original version to analysis large system. ETAP is the most powerful program to study power flow analysis compering with other program because it's easy in use and faster solution

The standard load flow method and also the optimal power flow approach for the IEEE-14 bus system are compared in this paper. In comparison to the traditional load flow method, the optimal power flow methodology is preferable.The method decreases system losses and provides greater cost-cutting benefits.

For the test problem in operation, three-phase and single line to earth fault are induced. the maximum and minimum short circuit currents are measured. Short circuit researches are essential for both discussing future power network improvement and determining how protective devices should be operated. The same implementation is used in the IEEE 14-Bus system, that has faults with Buses 2, 4, and 8. Circuit breakers' breaking and making ratings can be calculated using the maximum short circuit current. For protective relay coordination, the value of the minimal short circuit current might be employed. Short circuit studies with ETAP software are a great process of planning and protect a system. line-to-line faults, line-to-ground faults, and also line-line-to-ground faults additional the 3-phase faults, are some of the operational processes that are evaluated. This can be performed to choose the best size and placement for relays and circuit breakers. It can additionally be used to determine system voltages under various failure scenarios.

References

1. Mashauri A. Kusekwa, Electrical Engineering Department, Dar es Salaam Institute of Technology (DIT), Dar es Salaam, Tanzania, "Load flow solution of the Tanzanian power network using Newton-Raphson method and MATLAB software". International Journal of Energy and Power Engineering. 3,.6. December 05, 2014

2. Benedetto-G Risi , Francesco Riganti-F and A. Laudani , " Modern Techniques for the Optimal Power Flow Problem: State of the Art" ,Energies 2022, 15, 6387

3. Ali M. Eltamaly, Yehia Sayed, Abou-Hashema M. EL-sayed, and Amer Nasr A. Elchaffer, "Optimum Power Flow Analysis by Newton Raphson Method, A Case Study" , A NNALS of Faculty Engineering Hunedoara – International Journal of Engineering Tome XVI [2018] | Fascicule 4 [November]

4. Gaganpreet Kaur, Student, Power Engineering (M.Tech), GZS PTU Campus, Bathinda, "Comparative Analysis of Load Flow Computational Methods Using MATLAB". International Journal of Engineering Research & Technology (IJERT). ISSN: 2278-0181,. 3, 4, April – 2014.

5. Fathy. Ghonima , M. Ezzat ,and T.S. Abdel-Salam , " Power Flow Analysis of Hybrid Renewable Energy Sources in Power System Applied For IEEE Six Buses" , Journal of International Society for Science and Engineering. 3, 3, 36 (2021)

6. Sreemoyee Chatterjee,and Suprovab Mandal " A Novel Comparison of Gauss–Seidel and Newton–Raphson Methods for Load Flow Analysis" , IEEE 2017 International Conference on Power and Embedded Drive Control (ICPEDC) - Chennai, India (2017.3.16-2017.3.18)] 2017 International Conference on Power and Embedded Drive Control (ICPEDC) , doi:10.1109/ICPEDC.2017.8081050

7. R. Ashokkumar and P. Aravindhababu, "An Improved Power Flow Technique for Distribution Systems," Journal of Computer Science, Informatics and Electrical Engineering,.3, I,9,2009.

8. A.Y Dewi and S.P Hadi,"Contigency Analysis of Power System Operation," Proceedings of the International Confrence on Electrical Engineering and Informatics, June 17, 2007

9. Abido MA. Optimal power flow using particle swarm optimization, International Journal of Electrical Power & Energy Systems,. 24,. 7, 2002, 563.

10. Roy PK, Ghoshal SP, Thakur SS. Biogeography based optimization for multi-constraint optimal power flow with emission and non-smooth cost function, Expert Systems with Applications, 37,. 12, 2010, 8221.

11. Namhum.Cho,Myungseok yoon and sungyum Choi "Impact of Transformer Topology on Short-Circuit Analysis in Distribution Systems with Inverter-Based Distributed Generations" Distributed generation sustainability 2022, 141,9781.

12. Nedic, Dusko, Bathurst , Graeme & Heat h, John, " A Comparison of Short Circuit Calculation Methods and Guidelines for Distribution Networks, CIRED 2007 session3, paper No. 0562. 19th International Conference on Electricity Distribution, Vienna; 21-24 May 2007.

13. K. Brown, F. Shokoo, H. Abcede, G. Donner, Eason, "Interactive simulation of Power Systems: ETAP applications and Techniques", Conference Record of the 1990 IEEE Industry Applications Society Annual Meeting, 1990, 2,. 1930

14. A. CHilakala & B. Rao,'' ShortT Circuit Anlaysis OF IEEE 14-Bus System Using ETAP.

15. S. Kamel, M. Kodsi and C. A. Canizares, "Modeling and simulation of IEEE 14 bus system with facts controllers", Technical Report, (2003),. 3.

16. Hadi Saadat, Power System Analysis, McGraw-Hill, 2006.

17. Raheel Muzzammel, Ibrahim Khail, Muhammad Huzaifa Tariq, Abubakar Muhammad Asghar, Ali Hassan, "Design and Power Flow Analysis of Electrical System Using Electrical Transient and Program Software", Energy and Power Engineering, 2019, 11, 186.

18. Ullah, Muhammad Aman; Qaiser, Arslan; Saeed, Qamar; Abbasi, Abdul Rehman; Ahmed, Iftikhar; Soomro, Abdul Qadir (2017). "Load flow, voltage stability & short circuit analyses and remedies for a 1240 MW combined cycle power plant using ETAP'', IEEE 2017 International Conference on Innovations in Electrical Engineering and Computational Technologies (ICIEECT) - Karachi, Pakistan (2017.4.5-2017.4.7)] 2017 International Conference on Innovations in Electrical Engineering and Computational Technologies (ICIEECT).

19. International Electrotechnical Commission, IEC (2001). International Standard - IEC 60909-0:2001.