

A Simplified Analysis of Load Flow for Distribution Network Load Profile

N.A M. Rosdi ^{#1}, A.Z. Abdullah ^{*2}, N. Azizan ^{#3}

Faculty of Electrical Engineering, UniMAP, Arau ,Malaysia

zaidiabdullah@unimap.edu.my

Article Info

Page Number: 1496-1509

Publication Issue:

Vol. 71 No. 3 (2022)

Article History

Article Received: 12 January 2022

Revised: 25 February 2022

Accepted: 20 April 2022

Publication: 09 June 2022

Abstract

This paper presents the analysis of load flow for the test system 5-Bus system to test the conveniences of the software. Then, the practical and efficient software selected to implemented load flow for IEEE 14-bus distribution network and load profiles. Load flow is an essential tool for resolving the power system planning issue. It aims to determine if the system can run safely, i.e., whether there are any equipment overloads or node voltages are too low or too high. The losses in individual components, as well as the overall network, are often estimated. The system is frequently examined for component overloads and voltages outside of permitted limits. The iterative method used in this project is Newton Raphson method to help an efficient analysis because of fast convergence speed. For fault analysis, ETAP short circuit analysis software was used to analyse line-to-ground and three-phase fault currents. 5-bus and 14-bus system only needs three iterations with zero mismatches in solving the load flow problem. The fault between 3 busses has been evaluated in IEEE 14 bus. The load profile for the system had been identified by using the load profile for commercial load with its percentage of the daily load. Finding from this study are important to improve future load flow analysis on distribution network system.

Keywords— NEPLAN, ETAP, Load Flow, Newton-Raphson, Fault analysis.

I. Introduction

Electric power distribution networks are one of the most significant ways to safely and reliably supply energy to households and businesses safely and reliably [1]. Distribution substations are classified into two types: primary substations and customer substations. The major substation acts as a load centre, while the customer substation connects to the low voltage (LV) network [2]. The load profile estimates the total energy requested from a power system or sub-system during a specified period, such as years, hours, and days. A load profile chart can be used to illustrate the load profile graphically. Currently, understanding the load curve is regarded as a critical aspect of ensuring the exact and correct functioning of a power system [3]. The purpose of load flow analysis is to calculate the flow of power, current, voltage, actual power, and reactive power in a system under any load state [4], [5].

The design magnitudes and phase angles of load bus voltages, active and reactive powers on the generator bus, actual power flow on transmission lines, and voltage phase angles at certain

bus bars are aims to determine if the system can run safely, i.e., whether there are any equipment overloads or node voltages are too low or too high. Additionally, the losses in individual components, as well as the overall network, are often estimated. The system is frequently examined for component overloads and voltages outside of permitted limits. To solve the power flow issue using the Newton-Raphson approach, a suitable software called ETAP was found and employed.

Power flow analysis is an essential method in power engineering that involves numerical analysis applied to a power system. In contrast to traditional circuit analysis, a power flow study often employs more straightforward terminology, such as a one-line diagram and per-unit system. It concentrates on various forms of alternating current power (reactive, real, and apparent) rather than voltage and current. Power flow analysis has shown to be a proactive technique by electrical engineers in the design of the grid network, taking into account the constraints put on the network for proper and efficient operation over the years [6]. The network equations take the form of simple algebraic equations under steady-state conditions. Loads and generations change continually in a real power system. However, for the purpose of solving load flow equations, it is assumed that loads and generations are fixed for a certain value across relevant time periods. Depending on the data, this may be an hour/monthly/etc. [7], [8].

Faults in power systems are typically caused by insulation failure, flashover, physical damage, or human mistake. Power system transmission line fault detection is critical for ensuring the quality functioning of the power system [9]. A three-phase fault is a scenario in which all three phases of the system are either short-circuited to each other or earthed [10]. An unsymmetrical or asymmetrical fault is one that affects just one or two phases of a three-phase system, as opposed to the previously discussed balanced or symmetrical faults, which impact all three phases equally [11].

Many experts have offered various ways to load flow analysis, simulation, and modelling in power systems in recent years. [12] provide a power flow analysis toolkit to make the analysis easier. A software suite for power flow analysis creates MATLAB programs and a MATLAB user interface. The same approach was also written by [8] and using the same data simulation is done with a Power world simulator, and better results were obtained. In addition, the analysis include the PV curve for the 5-bus system [13].

The load modelling by MATLAB (PSAT) using a standard IEEE 14 bus system performed by [7] where OPF analysis with load modelling find a significant finding. Next, [3],[14] uses NEPLAN software to determine the bus voltages, active power supplied by the generators, active power required by the loads, and power losses using the Newton- Raphson. Then, short circuit analysis in [9], has been carried out for the IEEE 14-bus system using ETAP software. Maximum and minimum short circuit currents, also known as sub-transient and steady-state fault currents, are used to determine the ratings of protective devices. Nevertheless, [15] determines the power losses for the system's steady-state condition and the entire day, considering load profile. The result for the load profile is categorized by nodes voltages, active power supply, and active power losses. This paper presents a simplified analysis of load flow

for distribution network load profile. In this study NEPLAN and ETAP software was used to simplified a load flow in IEEE bus system.

II. METHOD AND MATERIALS

This section presents the method and materials of the study. In this study, the model for 5-Bus and IEEE 14-Bus system were developed in NEPLAN and ETAP.

System modelling in NEPLAN and ETAP

For the load flow studies, the system with three generators and two load buses was considered following design from the power system analysis [11]. Figure 1 shows a one-line diagram of 5 bus systems with three generators at buses 1, 2, and 3. Bus 1 is taken as the slack bus, and voltage magnitude and real power generation at buses 2 and 3. The data of line charging admittances are tabulated in Table 1.

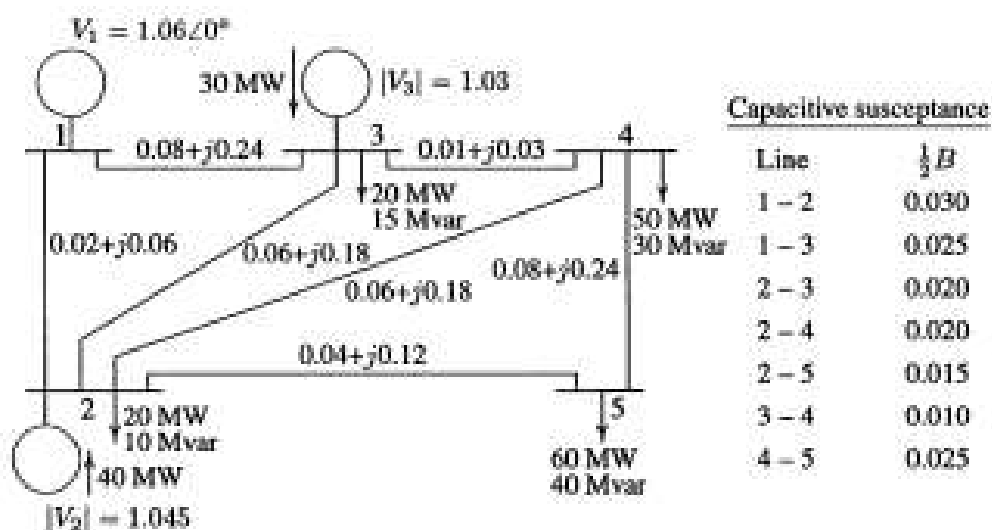


Figure 1 The one-line diagram distribution network model.

Table 1 Parameters for Line Charging Admittances

Line (bus to bus)	Impedance	Line charging (Y/2)
1-2	0.02+j0.06	0.030
1-3	0.08+j0.24	0.025
2-3	0.06+j0.18	0.020
2-4	06+j0.18	0.020
2-5	0.04+j0.12	0.015
3-4	0.01+j0.03	0.010
4-5	0.08+j0.24	0.025

The 5-Bus Power System model was developed in NEPLAN and ETAP programs for the purpose of load flow study. The system can be designed by opening a new window. To create a design in software, identify the slack bus, usually at bus 1, which is a generator bus that

carries the magnitude of the generator voltage and the phase angle. Furthermore, The generator bus is also known as the PV bus because it represents the active power of the generator P in MW and the magnitude of the generator voltage per unit. The synchronous machine (generator) parameter. The bus type in the parameter box of LF type for the slack bus is SL type, and for the generator bus is PV. The generator voltage magnitude is a percentage (%) of the per unit. In NEPLAN software, the design of a 5-bus system was constructed using One-Line Diagram (OLD). This ETAP program, which is capable of altering a one-line diagram (OLD) with many elements, will be added to the one line view (OLV), and equipment editors will be introduced.

The IEEE 14 bus test system is a simplified model of the 1962 American power grid. Figure 2 shows a one-line diagram of the IEEE 14-bus distribution system drawn under ETAP. It is made up of five synchronous machines with IEEE type-1 exciters, three of which are only utilized for reactive power support. The Generator data, Load data and Line data for the considered IEEE 14-Bus system are shown in Table 2.

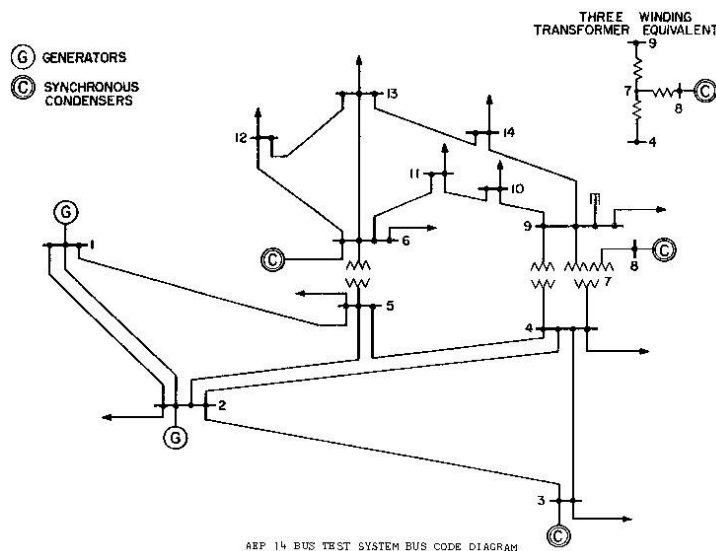


Figure 2 IEEE 14 Bus Standard System.

The dynamic model parameters for the synchronous generators included in the design are set to typical data values. Before beginning the process of designing the standard IEEE 14 bus system, the buses' data must be collected as shown in Table 2 below. Using the data gathered, the development of an IEEE-14 bus system can begin using ETAP software. In addition to developing the IEEE system, a power flow analysis study from the system development can be carried out concurrently

Table 2 Parameter for Standard IEEE Bus System.

Generator Data				
Bus	P (MW)	Q (Mvar)	$V \angle^\circ$ p.u	Bus Type
1	232.4	16.9	$1.060 \angle 0^\circ$	Swing
2	40.0	42.4	$1.045 \angle -4.98^\circ$	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

A. Newton-Raphson Based Load Flow Method

A Newton Raphson technique is a process for direct extension based on an initial approximation of the one dimensional problem supplied via power series. . The real power and imaginary reactive power constitute a set of nonlinear algebraic equations regarding the independent variables, voltage magnitude per unit, and phase angle in radians.

$$Y_{ii} = |Y_{ii}| \angle \theta_{ii} = |Y_{ii}|(\cos \theta_{ii} + j\sin \theta_{ii}) = G_{ii} + jB_{ii} \quad (1)$$

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij} = |Y_{ij}|(\cos \theta_{ij} + j\sin \theta_{ij}) = G_{ij} + jB_{ij} \quad (2)$$

$$P_i = \sum_{k=1}^n |Y_{ik}| V_i V_k \cos(\theta_{ik} + \delta_k + \delta_i) \quad (3)$$

$$Q_i = \sum_{k=1}^n |Y_{ik}| V_i V_k \sin(\theta_{ik} + \delta_k + \delta_i) \quad (4)$$

The Jacobian matrix shows the linear relationship between small changes in voltage angle and magnitude. In short, it can be written as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta |V| \end{bmatrix} \quad \text{A.} \quad (5)$$

The diagonal and the off-diagonal elements of J1

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ k \neq i}}^n |Y_{ik} V_i V_k| \sin(\theta_{ik} + \delta_k + \delta_i) \quad (6)$$

$$\frac{\partial P_i}{\partial \delta_k} = |Y_{ik} V_i V_k| \sin(\theta_{ik} + \delta_k + \delta_i), i \neq k \quad (7)$$

The diagonal and the off-diagonal elements of J2.

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}| \cos \theta_{ii} + \sum_{\substack{k=1 \\ k \neq i}}^n |Y_{ik} V_k| \cos(\theta_{ik} + \delta_k + \delta_i) \quad (8)$$

$$\frac{\partial P_i}{\partial |V_j|} = |Y_{ik} V_j| \cos(\theta_{ik} + \delta_k - \delta_i), j \neq k \quad (9)$$

The diagonal and the off-diagonal elements of J3.

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ k \neq i}}^n |Y_{ik} V_i V_k| \cos(\theta_{ik} + \delta_k + \delta_i) \quad (10)$$

$$\frac{\partial Q_i}{\partial \delta_k} = -|Y_{ik} V_i V_k| \cos(\theta_{ik} + \delta_k + \delta_i), i \neq k \quad (11)$$

The diagonal and the off-diagonal elements of J4.

$$\frac{\partial Q_i}{\partial |V_i|} = -2|Y_{ii} V_i| \sin \theta_{ii} + \sum_{\substack{k=1 \\ k \neq i}}^n |Y_{ik} V_k| \sin(\theta_{ik} + \delta_k + \delta_i) \quad (12)$$

$$\frac{\partial Q_i}{\partial |V_j|} = -|V_i||Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i), i \neq k \quad (13)$$

The line losses are computed as below.

$$S_{ij} = V_i I^*_{ij} \quad (14)$$

$$S_{ji} = V_i I^*_{ji} \quad (15)$$

In this load flow analysis, the comparison will be made between analysis using the NEPLAN program and ETAP program. The result's accuracy for both comparisons should be less than 5% tolerance.

B. Load Profiles

During analysis, all generators and loads defined with separate load curves (hours/days/months/years) or mixed load curves (depending on the kind of consumption). The load flow calculation performed for 1 month period to accomplish the energy calculation. The input data of user defined load, as shown in Fig. 4 below, can be in a day, week, month, and year factor. Moreover, the unlimited number of profile types, consumers and generators import the data and load profiles that want to be used for analysis.

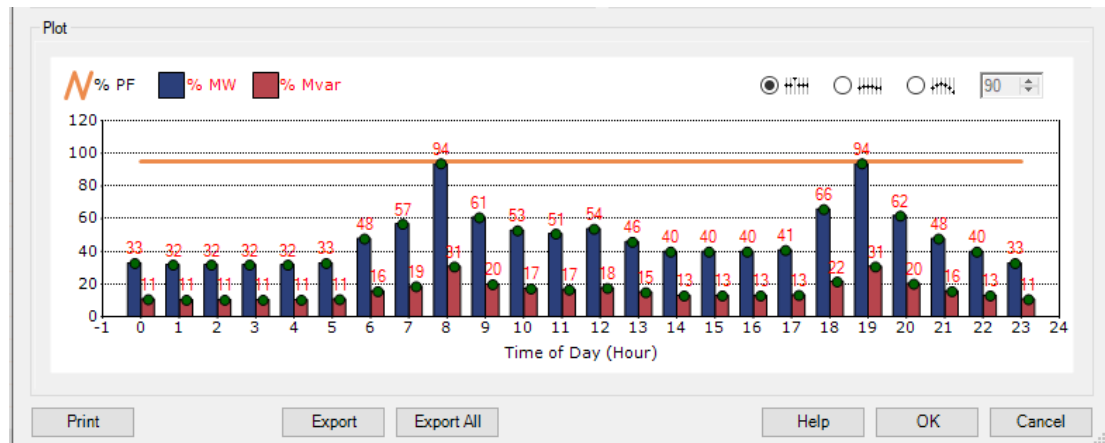


Figure 3 The input data of user-defined load in ETAP software.

Results And Discussion

This section presents the results and discussion of the study. In this study, the model for 5-Bus and IEEE 14 -Bus were modelled in NEPLAN and ETAP.

A. 5-bus system

For the load flow analysis study, the development of 5 buses system has been used for this project. The one-line diagram system is illustrated by following the problems on the power system stated in the reference book Power System Analysis. The one-line diagram illustrated in NEPLAN Software in Figure 4 and ETAP software is shown in Figure 5 below.

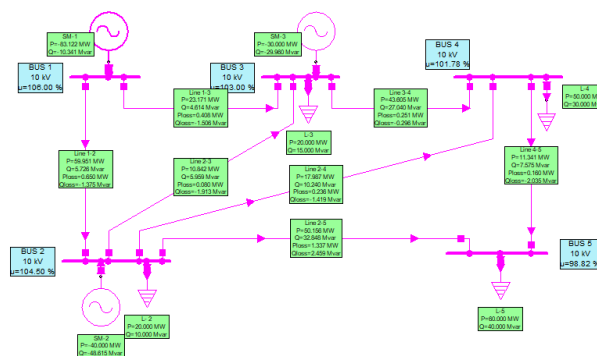


Figure 4 The 5-bus test system using NEPLAN software.

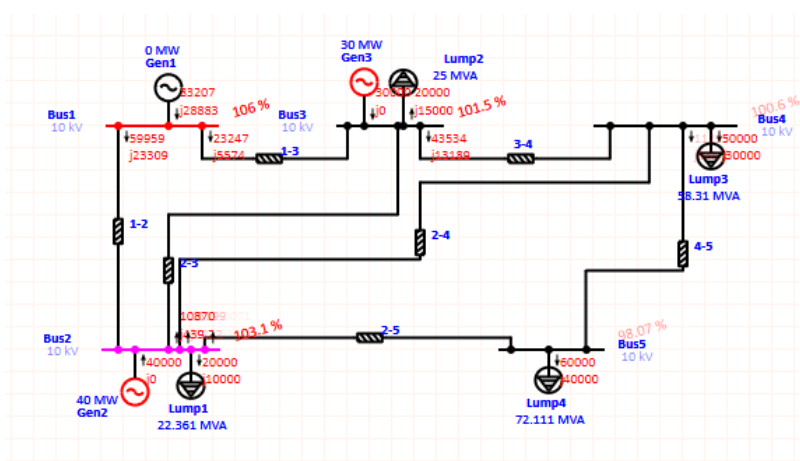


Figure 5 The 5-bus test system using ETAP software.

In this study, a one-line diagram of the five bus system has been developed to provide a graphical view of the system to assess power losses in each line. The analysis of the result for both software, NEPLAN and ETAP, is shown in Table 3 and 4 below.

Table 3 The result of active power (MW) and reactive power (MVAR) for line.

Element	NEPLAN software		ETAP Software	
	P (MW)	Q (MVar)	P (MW)	Q (MVar)
Line 1-2	59.951	5.726	59.959	5.574
Line 1-3	23.171	4.614	23.247	4.390
Line 2-3	10.922	4.046	10.870	3.822
Line 2-4	18.223	8.821	18.199	8.821
Line 2-5	50.156	32.848	50.071	32.553
Line 3-4	43.605	27.04	43.534	25.04
Line 4-5	-11.181	-9.61	-11.158	-12.503

Table 4. The result of line losses.

Element	NEPLAN Software		ETAP Software	
	P loss (MW)	Q loss (MVar)	P loss (MW)	Q loss (MVar)
Line 1-2	0.649	-1.374	0.819	-1.394
Line 1-3	0.408	-1.506	0.497	-1.196
Line 2-3	0.080	-1.912	0.085	-1.020

Line 2-4	0.236	-1.418	0.228	-0.969
Line 2-5	1.336	2.4585	1.229	3.905
Line 3-4	0.250	-0.2958	0.208	-0.448
Line 4-5	0.160	-2.0351	0.138	-1.192
Total	3.122	-6.085	3.2044	-6.221

Table 3 shows the result for active power and reactive power for bus-to-bus. The result, shows that the NEPLAN and ETAP software computed a similar value of active power and reactive power. Table 4 summarises the result of line losses for each line in the system. It should be noted that the real and reactive power of the slack bus and the reactive power of the PV bus are calculated after the load flow has converged. The result for both software is almost similar to which total line losses computed from NEPLAN and ETAP, which is 3.122 MW and 3.2044 MW, respectively.

B. IEEE 14-BUS SYSTEM

The Newton Raphson method is used to analyse power flow in the IEEE-14 bus system. The results of the power flow study on branches of the electric power system are shown in Figure 6.

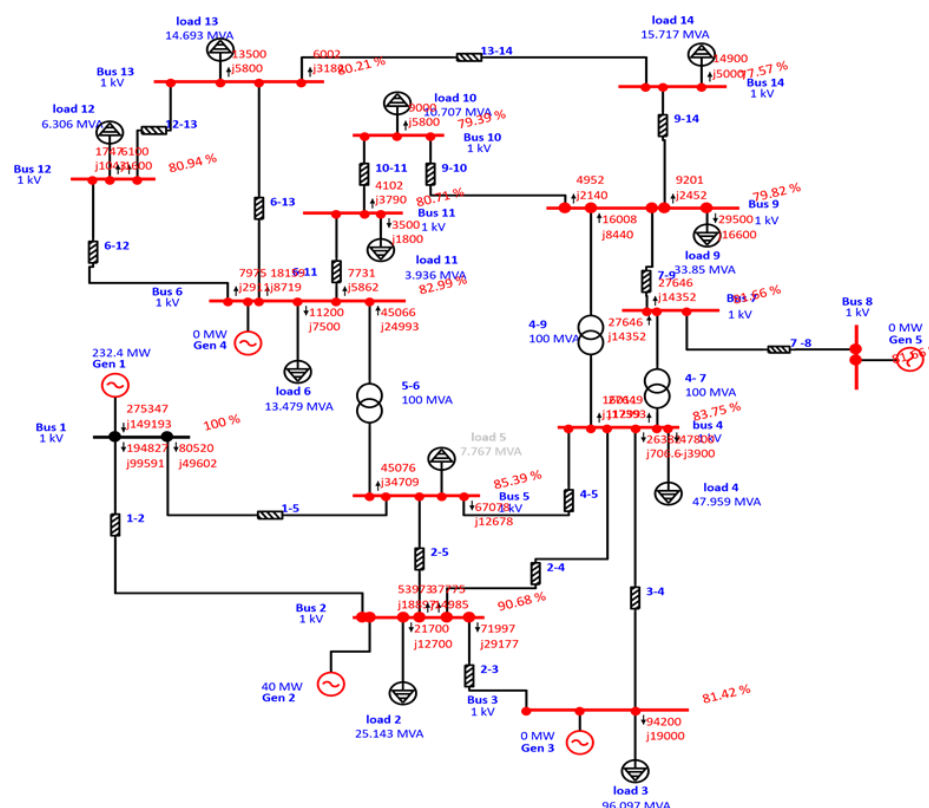


Figure 6 The result that forms on OLD in ETAP software.

Table 5 This table shows the result of load and losses after load flow analysis at 1 kV.

Branch ID	From-to-Bus Flow		To-From Bus Flow		Losses		%Bus Voltage		Voltage Drop (%)
	MW	MVar	MW	MVar	kW	kVar	From	To	in Vmag
1-2	156.834	-20.393	-152.539	27.656	4294.9	7263.6	106.0	104.5	1.50
1-5	75.559	3.432	-72.796	2.651	2763.8	6083.7	106.0	102.0	3.96
2-3	73.182	3.566	-70.862	1.582	2319.8	5147.8	104.5	101.0	3.50
2-4	56.151	-2.416	-54.473	3.524	1677.8	1107.8	104.5	101.9	2.62
2-5	41.506	0.674	-40.604	-1.547	901.8	-873.3	104.5	102.0	2.46
3-4	-23.338	2.681	23.708	-5.295	370.8	-2614.3	101.0	101.9	0.88
4-7	28.140	-9.651	-28.138	11.356	1.7	1704.3	101.9	106.3	4.37
4-5	-61.296	15.852	61.815	-15.548	518.3	304.1	101.9	102.0	0.16
4-9	16.121	-0.529	-16.120	1.838	1.3	1308.9	101.9	105.8	3.88
5-6	43.985	12.844	-43.980	-8.430	4.4	4414.2	102.0	107.0	4.96
6-11	7.299	3.209	-7.246	-3.098	52.7	110.4	107.0	105.8	1.24
Branch ID	From-to-Bus Flow		To-from-Bus Flow		Losses		%Bus Voltage		Voltage Drop (%)
	MW	MVar	MW	MVar	kW	kVar	From	To	in Vmag
6-12	7.769	2.459	-7.697	-2.311	71.3	148.4	107.0	105.5	1.47
6-13	17.713	7.035	-17.503	-6.621	209.9	413.3	107.0	105.1	1.94
7-8	0.000	-16.548	0.000	16.975	0	427.2	106.3	109.0	2.74

7-9	28.138	5.192	-28.138	-4.394	0.0	797.7	106.3	105. ₈	0.50
9-10	5.279	4.565	-5.266	-4.529	13.9	36.8	105.8	105. ₂	0.52
9-14	9.477	3.832	-9.358	-3.580	118.7	252.6	105.8	103. ₇	2.10
10-11	-3.734	-1.271	3.746	1.298	11.5	27.0	105.2	105. ₈	0.52
12-13	1.597	0.711	-1.591	-0.705	6.1	5.5	105.5	105. ₁	0.47
13-14	5.594	1.526	-5.542	-1.420	52.1	106.0	105.1	103. ₇	1.40
TOTAL LOSSES					13390.8	26171.7			

Technical losses might have occurred, which are caused by energy dissipation in conductors, transmission lines, transformers, sub-transmission lines, and distribution line equipment, and magnetic losses in transformers. Figure 7 and 8 represent the losses of every transmission line. The highest losses were dissipated by line connecting bus 1 and bus 2 worth 4.29 MW and 7.26 MVar while the total active power losses and reactive power losses for this standard IEEE 14 bus are 13.391 MW and 26.171 MVar, respectively.

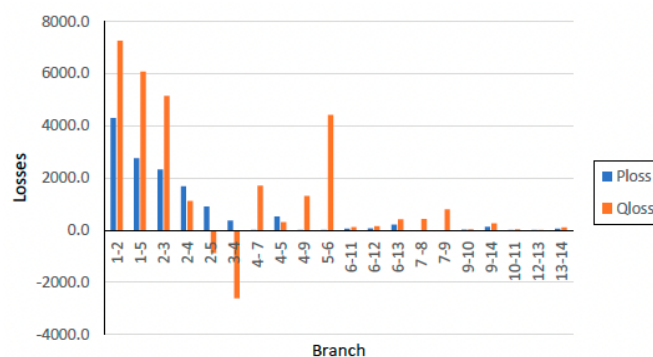


Figure 7 The apparent losses (P_{loss} and Q_{loss}) of IEEE 14 bus system

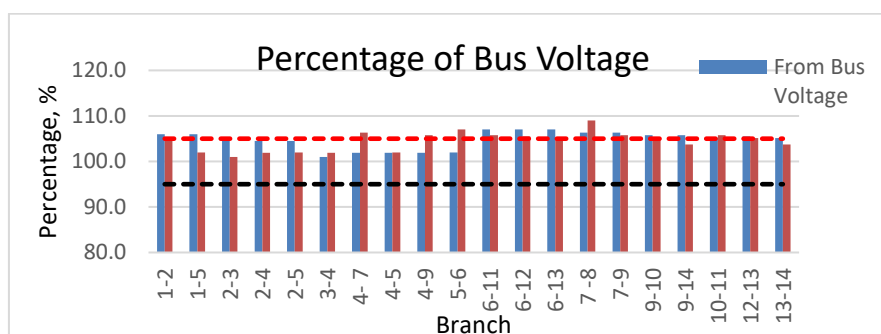


Figure 8 The percentage of from-to bus voltage.

As shows in Figure 8, for bus voltage that over 105% (red dotted line) are consider as Over Voltage and under 95% (black dotted line) are under voltage. There are certain busses with voltage drops ranging from 5% to 10% of nominal (below TNB standard), some busses with rated voltage nominal, and some busses with voltage crucial (less than 5%). Voltage drop occurs when the voltage at the end of a cable run is lower than it was at the start. Any wire, regardless of length or diameter, will have some resistance, and passing a current through this dc resistance will cause the voltage to drop. As shows in Figure 9, the busses with voltage drops ranging from 5% to 10% of nominal voltage is basically below TNB standard, some busses with rated voltage nominal, and some busses with voltage crucial which is less than 5%. Most of the time, bus voltages that are far from the source are lower due to voltage loss. The highest percentage drop is on line 5-6 which is 4.96 %. So the result is basically follow the TNB standard

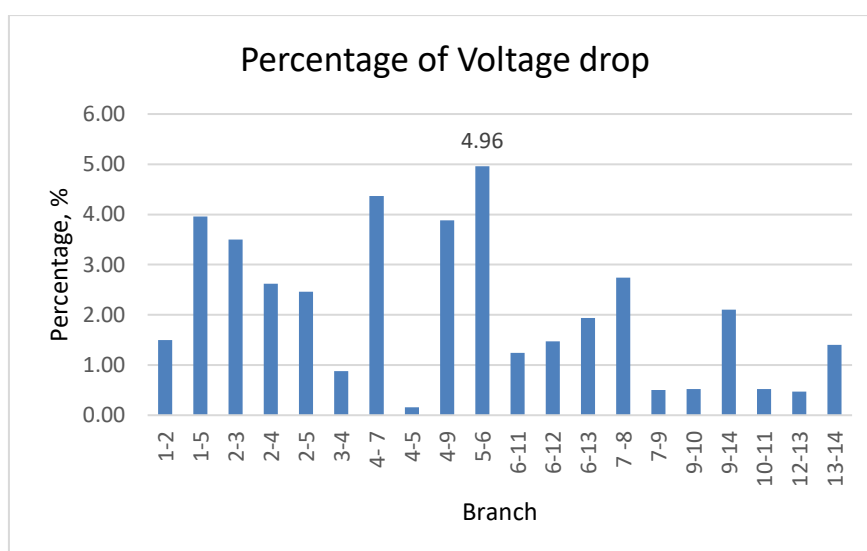


Figure 9 Percentage of voltage drop for the 14 bus system.

Result of the three-phase fault current for the load centre (bus 7) and the fault current for the generator terminal (bus 1) are 414.668 kA and 1145.893 kA, respectively based on steady state short circuit current after the fault is calculated using 30 cycle testing illustrated in Fig.8. According to the analysis, the fault current at the generator terminal is significantly higher than at the load centre due to the reference to Ohm's law ($V=IR$). As a result of the very low impedance and the constant voltage, the current becomes extremely high. Bus 7 (load centre) has a high impedance due to branches must be paralleled throughout the circuit reduction.

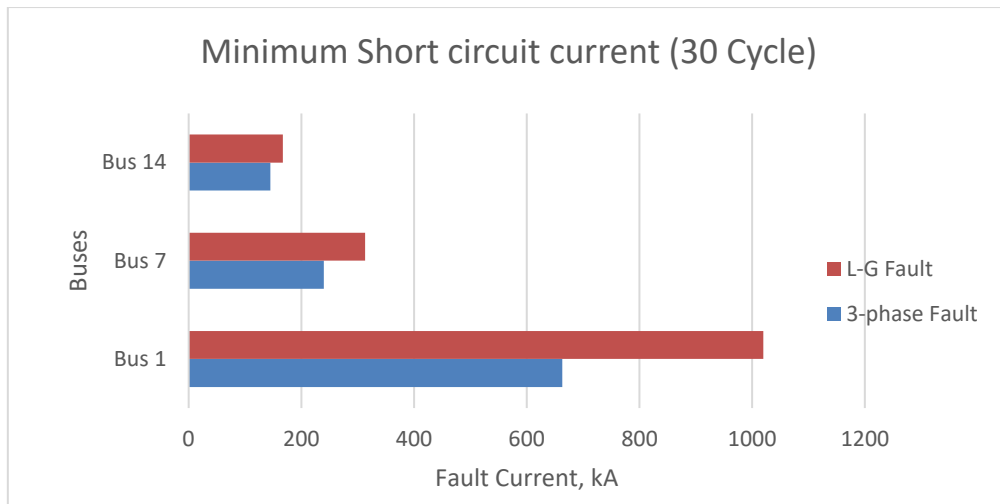


Figure 10 Minimum short circuit current (30 cycle) at bus 1, 7 and 14.

CONCLUSION

In this case study, the standard IEEE 14-bus system was utilized with Newton-Raphson method to solve a nonlinear load flow problem. ETAP software provided the formulation, load flow, fault analysis, and load profile, as well as the findings. Based on the results, it is possible to infer that the installation can improve the bus voltage system, allowing the entire bus system to satisfy the PLN standard. The IEEE 14-Bus system with faults on Bus-1, Bus-7, and Bus-14 was implemented with a three-phase and single-line to-ground fault. The maximum short circuit current used to calculate the circuit breakers' breaking and to make ratings. The minimum short circuit current value can be employed in the protection relay coordination method. Based on the load flow analysis research performed with the ETAP program, this paper suggest that the planning of a power system can be carried out by using ETAP for a simple or complex system with less computational complexity due to the good computational characteristics it exhibited. The system operating conditions can then be improved at the same time to decrease installation or operation costs, improve overall performance, and increase dependability and security utilizing ETAP software.

REFERENCES

- [1] K. Prakash, A. Lallu, F. R. Islam, and K. A. Mamun, "Review of Power System Distribution Network Architecture," *Proc. - Asia-Pacific World Congr. Comput. Sci. Eng. 2016 Asia-Pacific World Congr. Eng. 2016, APWC CSE/APWCE 2016*, no. December, pp. 124–130, 2017, doi: 10.1109/APWC-on-CSE.2016.030.
- [2] F. C. Chan, "Electric power distribution systems," vol. III.
- [3] L. I. Dulău and D. Bică, "Power Flow Analysis with Loads Profiles," *Procedia Eng.*, vol. 181, pp. 785–790, 2017, doi: 10.1016/j.proeng.2017.02.466.
- [4] "Load Flow Study & Analysis," *Omazaki Group*, 2021. <https://www.omazaki.co.id/en/load-flow-study-analysis/> (accessed Nov. 05, 2021).

- [5] A. Mohiden, "Load flow calculation and Network planning for medium voltage networks." MSc Thesis 2008, Institute of Electrical Power Systems, Graz University of Technology.
- [6] "Analysis of Distributed Generation (DG) Based A Thesis Submitted to the Faculty of the Graduate School of in partial fulfillment of the requirements for the degree of Master of Engineering Department of Electrical and Computer Engineering by Ayobami Osa," no. May, 2013.
- [7] S. K. Dwivedi *et al.*, "Load Modeling in Optimal Power Flow Studies A PROJECT THESIS SUBMITTED IN PARTIAL FULFILLMENT OF Load Modeling in Optimal Power Flow Studies," *2019 IEEE Milan PowerTech, PowerTech 2019*, no. September, pp. 509–523, 2015.
- [8] A. Sharma, M. Saini, and M. Ahmed, "Power Flow Analysis Using NR Method," *Int. Conf. Innov. Res. Sci. Technol. Manag.*, pp. 324–329, 2017, [Online]. Available: <http://data.conferenceworld.in/MIMT/P324-329.pdf>.
- [9] A. CHILAKALA, "Short Circuit Analysis Of IEEE 14-Bus System using ETAP," *Int. Conf. Innov. Electr. Electron. Power, Smart Grids Adv. Comput. Technol.*, vol. 1, no. 1, pp. 309–313, 2018.
- [10] S. S. B. R. (UniMAP), "Development of Malaysian Grid System Model for Power Flow and Fault Analysis Study," 2011. Library Depository.
- [11] J. C. Castro-Galeano, W. J. Cabra-Sarmiento, and J. F. Ortiz-Portilla, "Fault and load flows analysis of electricity transmission and distribution system in Casanare (Colombia)," *Rev. Fac. Ing.*, vol. 26, no. 44, pp. 9–21, 2017, doi: 10.19053/01211129.v26.n44.2017.5768.
- [12] S. S. Khalse and D. M. Kakre, "Computer Oriented Load Flow Study of Five Bus System using Matlab," *Int. J. Eng. Adv. Technol.*, no. 3, pp. 2249–8958, 2014.
- [13] M. Parihar, M. K. Bhaskar, D. Jain, D. Bohra, and D. Sarvate, "Analysis of Power Flow In IEEE Five Bus Power System Based on PV Curve Assessment," no. April, 2018.
- [14] M. Mahmood and A. Eng, "Mathematical Calculation and Graphical User Interface of NEPLAN for Load-Flow in Power System," *Int. J. Sci. Eng. Investig.*, vol. 6, no. 60, pp. 153–156, 2017.
- [15] L.-I. Dulău, M. Abrudean, and D. Bică, "Optimal Power Flow Analysis of a Distributed Generation System," *Procedia Technol.*, vol. 19, no. October 2014, pp. 673–680, 2015, doi: 10.1016/j.protcy.2015.02.095.