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PERFORMANCE COMPARISON OF SHORT CIRCUIT ANALYSIS

A graduation project is submitted to the Electrical Engineering

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of Bachelor of Science in

College of Engineering - Electrical Engineering

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2025 MISAN. IRAQ

بسم الله الرحمن الرحيم

قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَابِ

(الزمر:9)

SUPERVISOR CERTIFICATION

I certify that the preparation of this project entitled

“PERFORMANCE COMPARISON OF SHORT CIRCUIT ANALYSIS”, prepared by

Fatima Abdullah Jawad- Abdullah Rahim Helou,

Mujtaba Majed Khamas- Zainab Kazim Khashin,

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was made under my supervision at the General College of Engineering Electrical Engineering Department in partial fulfilment of the Requirements for the Degree of Bachelor of Science in College of Engineering - Electrical Engineering.

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CERTIFICATE OF EXAMINERS

We certify, as an examining committee, that we have read this project report entitled

" PERFORMANCE COMPARISON OF SHORT CIRCUIT ANALYSIS "

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(Fatima Abdullah Jawad- Abdullah Rahim Helou- Mujtaba Majed Khamas- Zainab Kazim Khashin- Hawra Jabbar Shaya) in its contents and found the project meets the standard for degree of B.Sc. in Electrical Engineering.

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Name	Name:
Date:	Date:

Signature:

Name:

Date

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Praise be to God alone, and peace and blessings be upon the One after whom there is no prophet. And then:

Thanks be to God - the Almighty - who has illuminated my path, opened the doors of knowledge for me, and provided me with the patience and willpower to complete this thesis. To Him be praise and thanks, a good and blessed praise befitting His Majesty, and in keeping with the saying of the Chosen One, may God's prayers and peace be upon him and his family, "He who does not thank people does not thank God."

Loyalty requires that credit be given to those who deserve it. Therefore, I extend my sincere thanks and gratitude to the one who, after God, contributed to the production of this scientific research: **Dr. Ahmed R. Hussein** for his kind supervision of this thesis. I found him to be a virtuous and generous professor who exerted great effort, provided sound guidance, and provided sound advice, helping me overcome many difficulties. May God reward him on my behalf and grant him continued health and wellness.

DEDICATION

“I dedicate this project to my parents, who spared no effort in helping me and contributed to my success with love and care. I am very grateful and appreciative to you. And to my dear friends, thank you for your continuous support and encouragement.”

ABSTRACT

Fault analysis is a fundamental component for ensuring the efficiency and continuity of electrical power network operations. Due to the variety of possible causes and the varying impacts of faults, it is impossible to eliminate them entirely. Therefore, fault analysis becomes a necessary and complex task in electrical engineering practices. This analysis provides a deep understanding of fault characteristics and their effects on network performance, contributing to improved system reliability and stability.

One of the key outcomes of fault analysis is identifying voltage and current values during fault conditions. This information is crucial for developing protective solutions that help safeguard electrical system components and reduce the likelihood of future problems. These measures also play a vital role in ensuring personnel safety and maintaining service continuity.

In this context, ETAP software was used to calculate power flow under normal operating conditions without faults. Subsequently, hypothetical faults were introduced into the model using "Maysan 400 Station" as a case study. The analysis of the results made it possible to draw practical conclusions that support the development of preventive strategies aimed at minimizing potential fault risks and enhancing overall network performance.

The work was compared with one of the studies used for the same purpose but using computer programs, where the superiority, performance, speed and accuracy of the program used in this study, ETAP, was shown.

الملخص

يُعد تحليل الأعطال عنصرًا أساسيًا لضمان كفاءة واستمرارية عمل شبكة الطاقة الكهربائية. ونظرًا لتعدد مسببات الأعطال وتفاوت تأثيراتها، فإن القضاء التام على حدوثها غير ممكن، مما يجعل من تحليل الأعطال مهمة ضرورية ومعقدة ضمن ممارسات الهندسة الكهربائية. ويتيح هذا التحليل فهماً معمقاً لطبيعة الأعطال وتأثيرها على أداء الشبكة، بما يساهم في تحسين موثوقية واستقرار النظام الكهربائي.

تُعد معرفة قيم الجهد والتيار أثناء ظروف الأعطال من أبرز نتائج هذا التحليل، حيث تُوظف هذه المعطيات في تطوير حلول وقائية تُسهم في حماية مكونات النظام الكهربائي وتقليل احتمالية تعرضه لمشكلات مستقبلية. كما أن هذه الإجراءات تسهم بشكل مباشر في الحفاظ على سلامة الأفراد وضمان استمرارية الخدمة.

في هذا السياق، تم استخدام برنامج ETAP لحساب تدفق الطاقة تحت ظروف تشغيل طبيعية خالية من الأعطال. لاحقًا، تم إدخال أعطال افتراضية إلى النموذج باستخدام " **محطة ميسان 400**" كمثال تطبيقي. وقد أتاح تحليل النتائج استخلاص استنتاجات عملية تساعد في تطوير استراتيجيات وقائية تقلل من مخاطر الأعطال المحتملة وتحسن أداء الشبكة.

تمت مقارنة العمل مع احد البحوث المستخدمة لنفس الغرض ولكن باستخدام برامج حاسوبية حيث تبين افضلية واداء وسرعة ودقة البرنامج المستخدم ETAP في هذا البحث المستخدم.

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Table 1 : Abbreviations List

Abbreviations	The Description
AC	Alternating Current
DC	Direct Current
ERN	Elman Recurrent Network
ETAP	Electrical Transient and Analysis Program
FFNs	Feed Forward back propagation Networks
L-G Fault	Line-to-Ground
L-L Fault	Line-to-Line
L-L-G Fault	Double Line-to-Ground
MMF	Multiple Model Filters
MSE	Mean Square Error
MVAr	Reactive mega-volt-amperes.
MW	Megawatts.
PDC	Phasor Data Concentrator
RBFs	Radial Basis Functions
WT	Wavelet Transform

Table 2 : List of Symbols

Symbols	The Description
I	Current
Y	Admittance matrix
V	Vector of the bus voltage
ik	current profile at node k
vk	voltage profile at node k
G_{km}	kmth component of the conductance matrix
P_k	nodal power injection/consumption at node k
P_k^g	for injection
P_k^d	for consumption
N	total number of voltage-controlled nodes.
P_d	vector that contains all the constant power consumptions
V_d	vector associated with the demand nodes
V_s	vector that contains all the voltage controlled nodes
G_{ds}	the sub - matrix that relates the demands with the voltage controlled nodes and the demands with demands , respectively.
x_{i0}, x_{j0}	coordinates of the linearization point
$\frac{d}{dxi}$	derivative of the function fj
F (X_0)	the vector of nonlinear functions
t	iterative counter

†Chapter one†

INTRODUCTION

1.1 INTRODUCTION

In modern power systems, short circuit analysis is indispensable for assessing the behavior of electrical networks under faulted conditions. Short circuits represent one of the most severe operating contingencies in power systems, resulting in high fault currents that can cause mechanical damage to equipment, insulation breakdown, and wide-scale system instability. Thus, accurately predicting fault currents is essential for the selection and coordination of protective devices, equipment sizing, and ensuring compliance with international standards such as IEC 60909 and IEEE Std C37.010.

Traditionally, fault current calculations were performed analytically using techniques such as symmetrical components and Thevenin equivalent modeling. These methods, while effective for balanced or small systems, often lack scalability and precision when applied to large interconnected power networks, especially with the presence of power electronics, distributed generation, and system nonlinearity.

Contemporary engineering practice increasingly relies on software-based tools like ETAP, DIgSILENT PowerFactory, PSS®E, and MATLAB Simulink, which offer dynamic modeling, automated fault analysis, and high-resolution results. However, there exists a gap in the literature that systematically evaluates the performance trade-offs between classical methods and simulation-based analysis. This research seeks to bridge this gap through an in-depth comparative study.

1.2 PROBLEM STATEMENT

Despite the availability of various techniques for short circuit analysis, there remains a fundamental challenge in determining the most suitable approach for a given power system application. Classical methods, although theoretically sound and computationally light, rely on simplifications that may not capture the full dynamics of the system—particularly in networks involving:

Asymmetrical faults,High penetration of renewable energy, Unbalanced loads, and

Nonlinear power electronic interfaces.

Meanwhile, modern software platforms offer enhanced capabilities but require significant computational resources, licensing costs, and a steep learning curve. Furthermore, questions remain regarding the accuracy and repeatability of their results under diverse operating conditions.

The central research problem can be stated as follows:

What are the comparative strengths, limitations, and performance metrics of classical analytical and simulation-based methods for short circuit analysis in modern power systems?

1.3 OBJECTIVES

The objectives of this study are to:

Review the theoretical foundations and mathematical formulations underlying both classical and simulation-based short circuit analysis.

Model a representative test system (e.g., IEEE 9-Bus or 14-Bus system) using both analytical and software-based techniques.

Compare the computed fault currents for various fault types (LG, LL, LLG, LLL) using different methods.

Evaluate the methods based on accuracy, computation time, flexibility, user complexity, and compliance with standards.

Recommend appropriate analysis techniques for different use cases (e.g., industrial networks, utility grids, microgrids**).**

1.4 SIGNIFICANCE OF THE STUDY

This research holds significance for multiple stakeholders in the power industry:

System planners and protection engineers will gain guidance on choosing suitable tools and methods for fault analysis.

Researchers will benefit from a structured comparison that may serve as a basis for further studies on hybrid techniques or algorithm optimization.

Educational institutions will find the study useful in updating curricula to reflect the evolving balance between analytical rigor and simulation proficiency.

Moreover, the increasing complexity of modern power systems—due to renewable integration, smart grid technologies, and inverter-based resources—demands a re-examination of traditional analysis methods in light of contemporary tools.

1.5 SCOPE OF THE STUDY

The study focuses on the performance evaluation of two main categories of short circuit analysis methods:

Classical Analytical Methods

Based on symmetrical components and per-unit system models.

Calculation of fault currents using impedance matrices and sequence networks.

Simulation-Based Methods

Implementation using industry-standard platforms like ETAP and PowerFactory.

Automated short circuit modules that simulate real-time fault conditions.

The case study will utilize a standardized system model (e.g., IEEE 9-Bus or 14-Bus) to ensure consistency and comparability. The analysis will include:

Different fault types (LG, LL, LLG, LLL),

Varying system configurations (balanced/unbalanced),

Comparison of pre-fault and post-fault system conditions.

The results will be benchmarked against IEC and IEEE standards where applicable.

1.6 LAYOUT OF THESIS

Chapter Two:
This chapter includes an explanation of the types of faults that occur in power transmission lines, the fundamentals of fault analysis, fault classification, and a comparison between dynamic and static fault analysis. It also reviews various analytical study methods.

Chapter Three:
This chapter presents a brief introduction to the research methodology, including the approach used to solve the research problem and the evaluation of line parameters.

Chapter Four:
This chapter presents the results obtained through the research using the ETAP software. It includes the calculation of current and voltage values under different fault conditions in transmission lines, as well as an analysis of power flow behavior.

Chapter Five:
This chapter discusses the results presented in Chapter Four and provides a review of the references and sources used in the research.

†CHAPTER TWO†

THEORETICAL BACKGROUND

AND PREVIOUS STUDIES

2.1 INTRODUCTION

Short-circuit fault analysis is a fundamental aspect of power system design and protection. It involves calculating fault currents to ensure proper selection and application of switching devices such as circuit breakers and fuses. Different fault types—balanced and unbalanced—affect the system in distinct ways, requiring accurate modeling techniques like symmetrical components and dynamic simulations. This study explores these analytical foundations, compares international standards (IEC vs ANSI), and evaluates simulation tools like ETAP, DIgSILENT, and MATLAB to assess their accuracy in predicting fault behaviors under various fault scenarios. [6]

2.2 THEORETICAL BACKGROUND

We will limit our discussion to short-circuit current calculations and the basis for short-circuit ratings for switching devices, namely power circuit breakers and fuses. Since the primary purpose of short-circuit calculations is to select and correctly apply these devices, it is important that the calculations relate to current interruption phenomena and the rating structures of the switching devices.

The type of short-circuit currents required for each of these purposes may not be immediately apparent, but they will be clarified in this chapter.

In general, these faults give the maximum short-circuit currents and form the basis for short-circuit calculations on switching devices.

Faults involving one or more phases and ground are called asymmetric faults. Under certain conditions, line-to-ground fault currents, or double line-to-ground fault currents, may exceed the three-phase symmetrical fault currents, which will be discussed in this chapter. Asymmetric faults are more common than three-phase faults, meaning that a supporting insulator on one phase of a transmission line may begin to flash toward ground, ultimately resulting in a single fault between the line and ground. Therefore, short-circuit calculations are a fundamental consideration when designing a new power system or planning to expand or upgrade an existing one.

2.2.1 Fundamentals of Fault Analysis

A short circuit (fault) is an unintended connection with low impedance between two or more points of different potential. It causes excessive current to flow, often several times higher than the rated current, which can damage equipment or compromise system stability.

Fault analysis provides values such as:

Fault current magnitude,

Bus voltages during fault,

Power flow deviation, and

Thermal/mechanical stress on components.

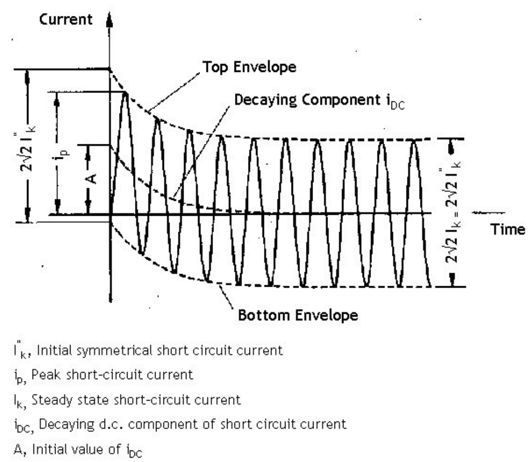

Fig. 2.1: Short circuit current

quasi-steady state, unless dynamic behavior is explicitly modeled

2.2.2 Classification of Fault Types

Faults are generally categorized into:

- **Balanced (Symmetrical) Faults**:
    - *Three-phase fault (LLL)*: All three phases are shorted together or to ground; rare but results in the highest fault current.
- **Unbalanced (Asymmetrical) Faults**:
    - *Single Line-to-Ground (LG)*

- *Line-to-Line (LL)*
- *Double Line-to-Ground (LLG)*

These asymmetrical faults require the use of **symmetrical components** for accurate analysis.

2.2.3 Symmetrical Components and Sequence Networks

The symmetrical components method decomposes unbalanced phasors into:

- **Positive Sequence** (normal rotation)
- **Negative Sequence** (opposite rotation)
- **Zero Sequence** (in-phase)

Each fault type corresponds to a unique combination of sequence networks:

Table 2.1: sequence networks

Fault Type	Network Connection
3-Φ	Positive only
LG	Series: $Z_0 + Z_1 + Z_2$
LL	Parallel: Z_1 and Z_2
LLG	Z_0, Z_1, Z_2 in combination

2.2.4 Sequence Network Modeling

a. Symmetrical Components

Using Fortescue's transformation, unbalanced systems can be transformed into three decoupled sequence networks:

Where a

$$\mathbf{e}^{j120} = \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

The sequence impedances are defined as:

- Z_1: Positive sequence impedance (dominates in balanced conditions),
- Z_2: Negative sequence impedance (reflects asymmetries),
- Z_0: Zero sequence impedance (depends on grounding and return paths).

b. Network Interconnection Based on Fault Type

- Single Line-to-Ground (SLG) Fault at phase A:

$$I_f = \frac{3V_a}{Z_0 + Z_1 + Z_2 + Z_f}$$

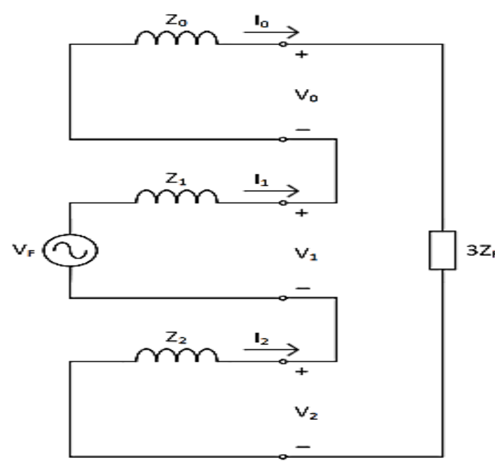

Fig. 2.2 Single Line-to-Ground Fault

- **Line-to-Line (LL) Fault (e.g., phase B-C)**

$$I_f = \frac{V\sqrt{3}}{Z_1 + Z_2 + Z_f}$$

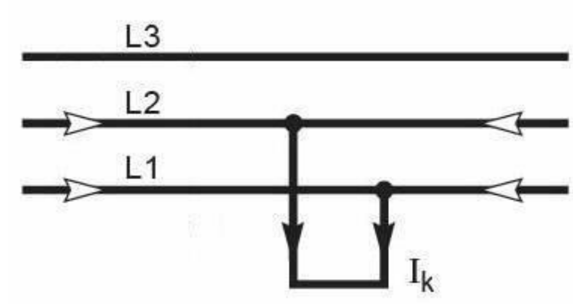

Fig.2.3 Line-to-Line (LL) Fault

- **Double Line-to-Ground (LLG)**:

Requires solving interconnected zero, negative, and positive sequence networks using KVL/KCL.

- **Three-Phase (LLL) Fault**:

Simplest mathematically:

$$I_f = \frac{V_{pre}}{Z_1 + Z_f}$$

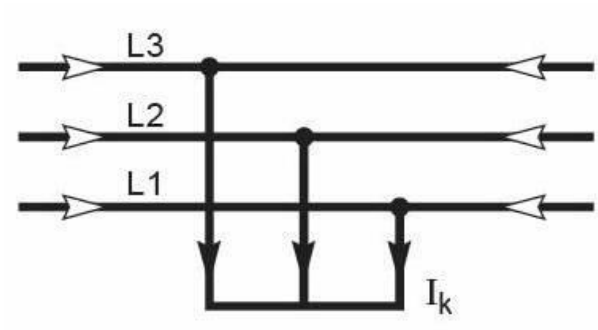

Fig. 2.4 Double Line-to-Ground

2.2.5 Thevenin Equivalent and Bus Impedance Matrix

Thevenin's theorem is applied by reducing the entire network seen from the fault location into an equivalent source and impedance.

$$I_f = \frac{V_{prefault}}{Z_{th} + Z_f}$$

Where:

- Z_{th} is obtained from the **bus impedance matrix Z_{bus},**
- $Z_{th}=Z_{ii}$ where i is the faulted bus.

The matrix Z_{bus} is derived by inverting the **admittance matrix Y_{bus}**:

$Z_{bus} = Y^{-1}_{bus}$

2.2.6 Dynamic vs Static Fault Analysis

- **Static (Steady-State) Analysis**:
  Assumes constant voltages and currents. Suitable for protection settings and initial fault level estimation.
- **Dynamic Analysis**:
  Includes machine transients (sub transient, transient, steady-state) modeled via differential equations:

$$I' = \frac{E'}{X' + Z} \quad , \quad I'' = \frac{E''}{X'' + Z}$$

Where:

- E', E'': internal transient and sub transient voltages,
- X', X'': transient and sub transient reactance.

2.2.7 Factors Affecting Fault Current

1. **System topology** (more meshed = higher contribution),
2. **Source impedance** (lower $Z_s \rightarrow$ higher I_f),
3. **Transformer grounding** (affects zero-sequence paths),
4. **Presence of DGs/inverters** (limit contribution, fast control),
5. **Fault impedance** Z_f (arc resistance can reduce fault current).

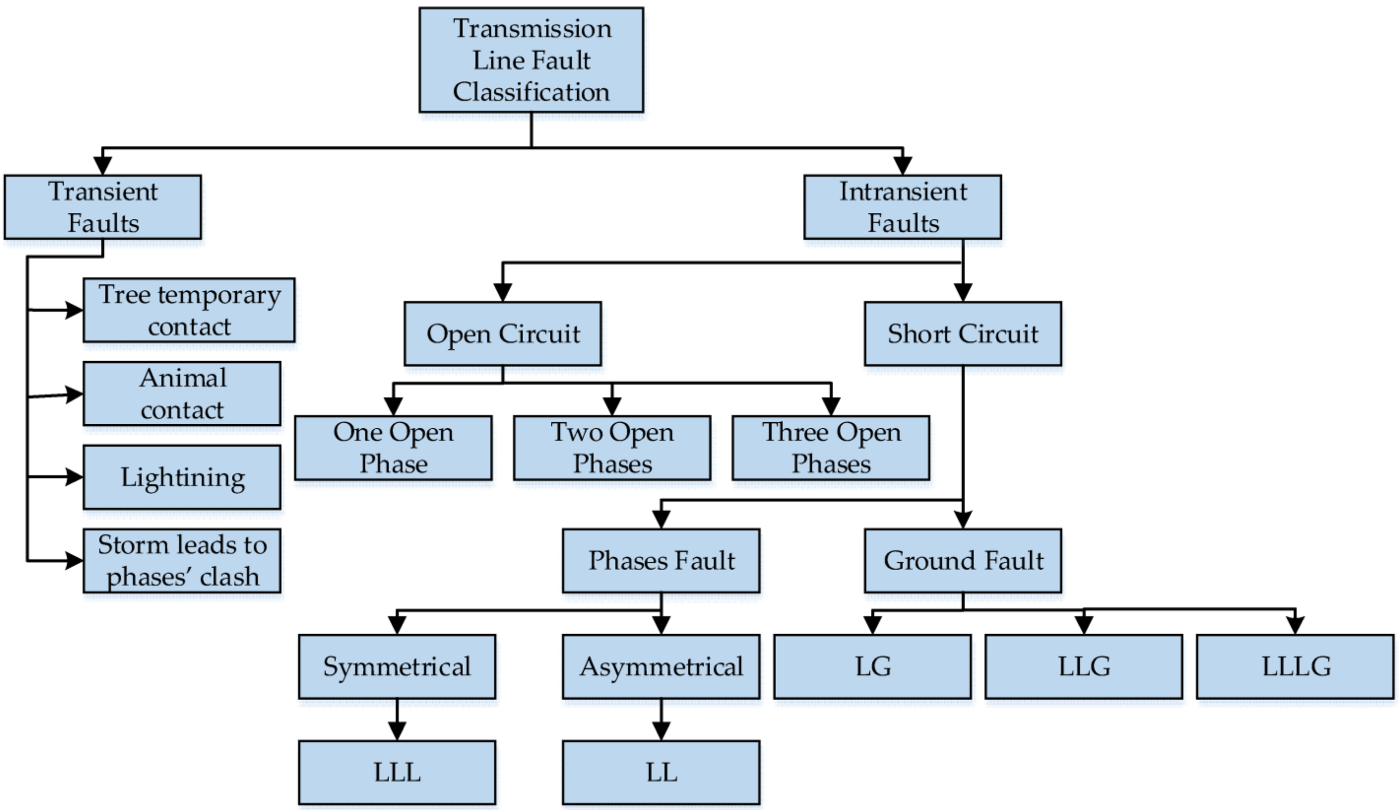

Fig.2.5 TL fault classification

2.3 PREVIOUS STUDIES

This section reviews significant previous studies related to short circuit analysis, tools used, and findings that inform this project's direction.

Mehtre, V. V., & Jha, A. K. (2021). *Performing 3 Phase Short Circuit Analysis on Single Line Diagram of a Power System using ETAP*. International Journal of Engineering Research & Technology (IJERT), 10(07), 50–53. [1]

Objective

To demonstrate how to use ETAP to analyze short-circuit faults in a single-line power system.

Methodology

A single-line circuit model was created in ETAP, and short-circuit analysis was applied to determine fault currents and assess the equipment's tolerance.

Results

The analysis demonstrated the effectiveness of ETAP in determining fault currents and assisting engineers in making informed decisions regarding the selection of protective devices.

Yaabari, N., Odu, P. O., & Ojobe, O. S. (2017). *Analysis of Three-Phase Transmission Line Fault Using Matlab/Simulink*. International Journal of Scientific & Engineering Research, 8(6), 1340–1347.[2]

Objective

To analyze the behavior of three-phase transmission lines under various fault conditions using MATLAB/Simulink.

Methodology

A three-phase transmission line simulation model was built in MATLAB/Simulink, introducing various fault types such as L-G, L-L, and L-L-G, and analyzing their impact on voltage and current.

Results

The simulation demonstrated that the program can accurately represent system behavior under various fault conditions, which helps improve the design of protection systems.

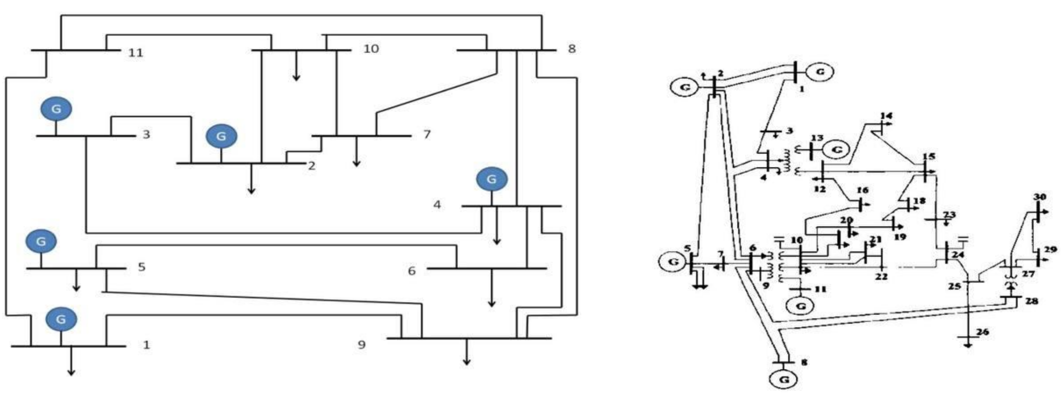

Fig.2.6 power grid in MATLAB

Table 2.2: MATLAB results

Bus no.	Pre-fault Voltage (p.u)	When fault at bus no. 1	When fault at bus no. 2	When fault at bus no. 3	When fault at bus no. 4	When fault at bus no. 5	When fault at bus no. 6	When fault at bus no. 7	When fault at bus no. 8	When fault at bus no. 9	When fault at bus no.10	When fault at bus no.11
1	**0**	0	166.64	164.97	156.93	151.86	154.35	34.24	5.715	13.736	58.96	11.02
2	**1.6622**	153.47	0	161.85	121.56	139.59	144.71	6.7601	3.406	16.942	5.420	39.91
3	**8.5206**	153.47	160.55	0	19.582	130.87	135.24	16.64	5.286	13.519	22.31	60.41
4	**3.9906**	162.79	167.92	167.78	90.00	154.81	154.66	61.242	7.773	19.246	125.36	139.28
5	**2.2811**	165.85	169.05	167.86	167.37	0	160.91	130.04	14.91	4.8034	153.95	153.92
6	**2.4221**	164.77	168.64	167.96	168.20	159.26	0	121.35	14.49	18.781	150.64	151.93
7	**-3.0409**	169.47	174.86	170.69	171.39	166.56	165.52	0	12.08	153.87	171.61	166.52
8	**-3.3570**	171.28	174.47	171.75	173.60	169.16	167.91	169.96	0	165.09	173.20	170.44
9	**-1.5303**	170.98	172.60	171.09	173.49	171.32	168.19	165.21	148.4	-90.00	169.50	168.38
10	**-1.9984**	167.67	174.21	169.35	168.67	163.53	162.78	89.66	7.220	120.80	90.00	159.64
11	**-2.4009**	171.14	171.74	168.90	168.69	164.05	163.08	141.04	9.816	110.24	162.13	0

DIgSILENT GmbH. (2018). *Short-Circuit Analysis – DIgSILENT PowerFactory User Manual*. Gomaringen, Germany: DIgSILENT GmbH.

Objective

To provide a practical and comprehensive guide to performing short circuit analysis using DIgSILENT PowerFactory software according to IEC and ANSI standards.

Methodology

This guide provides an overview of how to perform short-circuit fault analysis using DIgSILENT PowerFactory software, with support for IEC 60909 and ANSI standards.[3]

Results

PowerFactory provides advanced fault analysis tools, including the ability to calculate fault currents in DC and AC networks, making it easier for engineers to evaluate system performance under various fault conditions.

Bhosale, K., Kadam, S., & Patil, S. (2018). *Analysis of Fault in Transmission Line by Using MATLAB/Simulink*. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 7(4), 1419–1425.[4]

Objective

To analyze the behavior of three-phase transmission lines under various fault conditions using MATLAB/Simulink.

Methodology

A three-phase transmission line simulation model was built in MATLAB/Simulink, introducing various fault types such as L-G, L-L, and L-L-G, and analyzing their impact on voltage and current.

Results

The simulation demonstrated that the program can accurately represent system behavior under various fault conditions, which helps improve the design of protection systems.

Patwardhan, M. A., & Chopade, D. P. (2020). *Faults Unveiled: An In-depth MATLAB Simulation Study of Transmission Line Anomalies*. International Journal of Recent Technology and Engineering (IJRTE), 8(6), 1254–1260.[5]

Objective

To create a simulation model in MATLAB to study symmetrical and asymmetrical faults in long-distance transmission lines.

Methodology

A model was built to simulate a long-distance transmission line in MATLAB, introducing different fault types such as L-G, L-L, and L-L-G, and analyzing their impact on voltage and current.

Results

The simulation demonstrated that the program can accurately represent system behavior under various fault conditions, which helps improve the design of protection systems and fault localization.

†CHAPTER THREE†
RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter provides a comprehensive description of the methodology adopted to solve the research problem. It elaborates on the system configuration, modeling techniques, fault types considered, tools used (both software and mathematical), and criteria for performance comparison. The aim is to ensure that the methodology is reproducible, accurate, and aligned with real-world engineering practice.

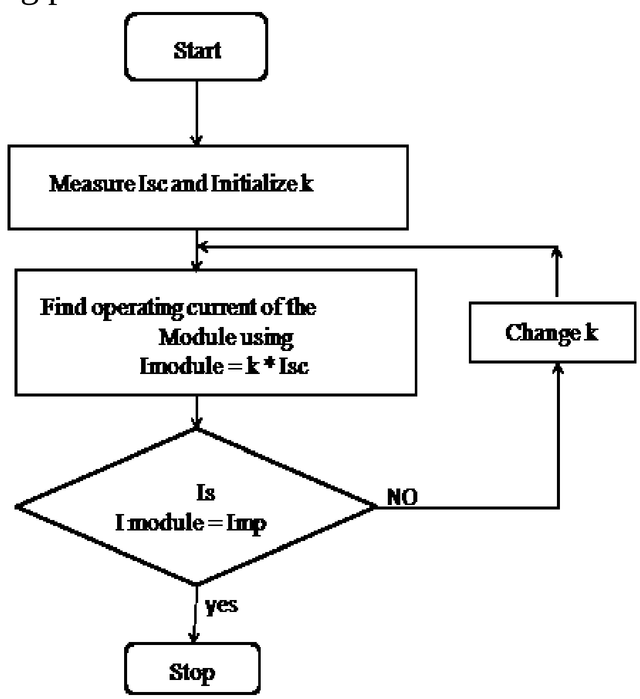

Fig.3.1 Flow Chart For the SC fault

3.2 **SOLUTION PROBLEM**

The ETAP19 software was used to model the 132 kV Misan network. Data was entered for the lines, transformers, and loads present in the network, which includes 10 busbars, 12 transmission lines (132 kV), two power sources, a power grid, and several power transformers at each station.

3.3 THE PROPOSED SOLUTIONS TO THE IDENTIFIED PROBLEM ARE AS FOLLOWS:

1. Controlling the generator's prime mover and excitation system.
2. Switching shunt capacitor banks, shunt reactors, and static var compensators.
3. Adjusting tap changers and regulating transformers.
4. Selecting appropriate protection systems for the power lines.
5. Applying FACTS-based technology [5].

These solutions are suitable when the disconnection of a line is planned (e.g., for maintenance). However, in cases of unexpected disconnections (such as short circuits, overloads, or faults), these methods are less effective because the system's response is too slow.

The best way to prevent this issue is to add new transmission lines. These additional lines should have lower power transfer capacity under normal conditions but can handle the load during an outage. When designing new lines, it is important to select the correct protection systems and calculate the expected increase in emergency load across the network.

3.4 PARAMETERS LINES

In this project, the information and values attached in the table below were used in the ETAP simulation program as shown in figure (3.2).

Table 3.1: Parameters List

Line Number	Type	Length	Positive Sequence`		Negative Sequence	
			R1	X1	R0	X0
1	Twin teal	14.5 km	0.0485	0.301	0.2805	1.113
2	Twin teal	34 km	0.0485	0.301	0.2805	1.113
3	Twin teal	15.5 km	0.0485	0.301	0.2805	1.113
4	Twin teal	9.5 km	0.0485	0.301	0.2805	1.113
5	Lark	28 km	0.147	0.428	0.378	1.231
6	Oriole	38 km	0.174	0.433	0.406	1.236
7	Oriole	55 km	0.174	0.433	0.406	1.236
8	Teal	13 km	0.097	0.445	0.3275	1.218
9	Teal	117 km	0.097	0.445	0.3275	1.218
10	Oriole	76 km	0.174	0.433	0.406	1.236

- Line (1) between bus bar (1) AND bus bar (2).
- Line (2) between bus bar (1) AND bus bar (3).
- Line (3) between bus bar (1) AND bus bar (4).
- Line (4) between bus bar (2) AND bus bar (5).
- Line (5) between bus bar (3) AND bus bar (5).
- Line (6) between bus bar (5) AND bus bar (6).
- Line (7) between bus bar (6) AND bus bar (7).
- Line (8) between bus bar (5) AND bus bar (8).
- Line (9) between bus bar (8) AND bus bar (9).
- Line (10) between bus bar (4) AND bus bar (10).

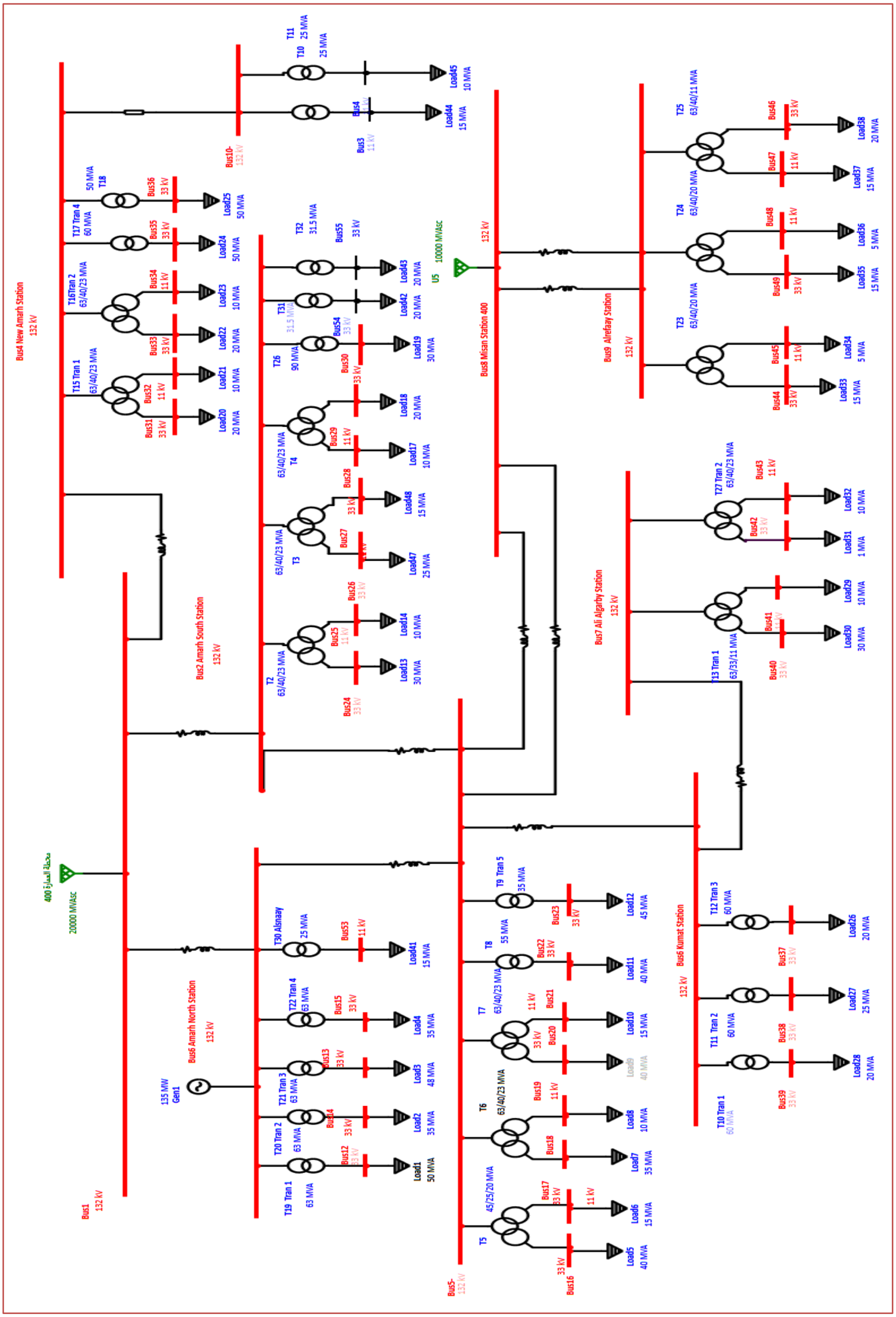

Fig. 3.2 The power grid

3.5 SIMULATION

In this project, the inputs to the electrical power grid were used as listed in the attached tables.

Table 3.2 The Branch Connections

Location:			Date: 05-01-2022		
Filename: Eng			Config.: Normal		
Branch Connections					
CKT/Branch		**Connected Bus ID**			
ID	Type	From Bus	To Bus	X	Z
T8	2W	Bus5-	Bus22	22.72	22.73
T9 Tras 5	2W	Bus5-	Bus23	35.71	35.71
T10	2W	Bus10-	Bus3	39.95	40.00
T10 Tras 1	2W	Bus6 Kumat Station	Bus39	20.83	20.83
T11	2W	Bus10-	Bus4	4.98	50.00
T11 Tras 2	2W	Bus6 Kumat Station	Bus38	20.83	20.83
T12 Tras 3	2W	Bus6 Kumat Station	Bus37	20.83	20.83
T18	2W	Bus4 New Amarh Station	Bus36	24.99	25.00
T19 Tras 1	2W	Bus6 Amarh North Station	Bus12	19.84	19.84
T20 Tras 2	2W	Bus6 Amarh North Station	Bus14	19.84	19.84
T21 Tras 3	2W	Bus6 Amarh North Station	Bus13	19.84	19.84
T22 Tras 4	2W	Bus6 Amarh North Station	Bus15	19.84	19.84
T26	2W	Bus2 Amarh South Station	Bus30	13.89	13.89
T30 snaay	2W	Bus6 Amarh North Station	Bus53	39.95	40.00
T31	2W	Bus2 Amarh South Station	Bus54	39.67	39.68
T32	2W	Bus2 Amarh South Station	Bus55	39.67	39.68
Tras 4	2W	Bus4 New Amarh Station	Bus35	20.83	20.83
T2	3W	Bus2 Amarh South Station	Bus24	16.70	16.79
	3W	Bus2 Amarh South Station	Bus25	-125.16	125.78
	3W	Bus24	Bus25	16.70	16.79
T3	3W	Bus2 Amarh South Station	Bus26	16.70	16.79
	3W	Bus2 Amarh South Station	Bus27	-125.16	125.78
	3W	Bus26	Bus27	16.70	16.79

<table>
<tr><td rowspan="3">T4</td><td>3W</td><td>Bus2 Amarh South Station</td><td>Bus28</td><td>17.35</td><td>17.44</td></tr>
<tr><td>3W</td><td>Bus2 Amarh South Station</td><td>Bus29</td><td>-139.57</td><td>140.26</td></tr>
<tr><td>3W</td><td>Bus28</td><td>Bus29</td><td>17.00</td><td>17.08</td></tr>
<tr><td rowspan="3">T5</td><td>3W</td><td>Bus5-</td><td>Bus16</td><td>12.11</td><td>12.49</td></tr>
<tr><td>3W</td><td>Bus5-</td><td>Bus17</td><td>-30.08</td><td>31.12</td></tr>
<tr><td>3W</td><td>Bus16</td><td>Bus17</td><td>8.36</td><td>8.50</td></tr>
<tr><td rowspan="3">T6</td><td>3W</td><td>Bus5-</td><td>Bus18</td><td>8.65</td><td>8.92</td></tr>
<tr><td>3W</td><td>Bus5-</td><td>Bus19</td><td>-21.49</td><td>22.23</td></tr>
<tr><td>3W</td><td>Bus18</td><td>Bus19</td><td>5.97</td><td>6.07</td></tr>
<tr><td rowspan="3">T7</td><td>3W</td><td>Bus5-</td><td>Bus20</td><td>61.91</td><td>63.79</td></tr>
<tr><td>3W</td><td>Bus5-</td><td>Bus21</td><td>-53.35</td><td>55.18</td></tr>
<tr><td>3W</td><td>Bus20</td><td>Bus21</td><td>-37.32</td><td>38.78</td></tr>
<tr><td rowspan="3">T13 Trans. 1</td><td>3W</td><td>Bus7 Ali Algarby Station</td><td>Bus40</td><td>8.65</td><td>8.92</td></tr>
<tr><td>3W</td><td>Bus7 Ali Algarby Station</td><td>Bus41</td><td>-21.49</td><td>22.23</td></tr>
<tr><td>3W</td><td>Bus40</td><td>Bus41</td><td>5.97</td><td>6.07</td></tr>
<tr><td rowspan="3">T15 Trans. 1</td><td>3W</td><td>Bus4 New Amarh Station</td><td>Bus31</td><td>16.70</td><td>16.79</td></tr>
<tr><td>3W</td><td>Bus4 New Amarh Station</td><td>Bus32</td><td>-125.16</td><td>125.78</td></tr>
<tr><td>3W</td><td>Bus31</td><td>Bus32</td><td>16.70</td><td>16.79</td></tr>
<tr><td rowspan="3">T16 Trans. 2</td><td>3W</td><td>Bus4 New Amarh Station</td><td>Bus33</td><td>16.70</td><td>16.79</td></tr>
<tr><td>3W</td><td>Bus4 New Amarh Station</td><td>Bus34</td><td>-125.16</td><td>125.78</td></tr>
<tr><td>3W</td><td>Bus33</td><td>Bus34</td><td>16.70</td><td>16.79</td></tr>
<tr><td rowspan="3">T23</td><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus44</td><td>8.65</td><td>8.92</td></tr>
<tr><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus45</td><td>-21.49</td><td>22.23</td></tr>
<tr><td>3W</td><td>Bus44</td><td>Bus45</td><td>5.97</td><td>6.07</td></tr>
<tr><td rowspan="3">T24</td><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus48</td><td>8.65</td><td>8.92</td></tr>
<tr><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus49</td><td>-21.49</td><td>22.23</td></tr>
<tr><td>3W</td><td>Bus48</td><td>Bus49</td><td>5.97</td><td>6.07</td></tr>
<tr><td rowspan="3">T25</td><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus46</td><td>9.00</td><td>9.00</td></tr>
<tr><td>3W</td><td>Bus9 Alrefaay Station</td><td>Bus47</td><td>-22.34</td><td>22.38</td></tr>
<tr><td>3W</td><td>Bus46</td><td>Bus47</td><td>6.11</td><td>6.11</td></tr>
<tr><td rowspan="3">T27 Tran 2</td><td>3W</td><td>Bus7 Ali Algarby Station</td><td>Bus42</td><td>8.82</td><td>8.91</td></tr>
<tr><td>3W</td><td>Bus7 Ali Algarby Station</td><td>Bus43</td><td>-21.89</td><td>22.22</td></tr>
<tr><td>3W</td><td>Bus42</td><td>Bus43</td><td>5.94</td><td>6.06</td></tr>
</table>

CKT/ Branch	Connected Bus ID			
ID	From Bus	To Bus	X	Z
Line1	Bus1 Misan Station 400	Bus2 Amarh South Station	2.50	2.54
Line3	Bus2 Amarh South Station	Bus5-	1.64	1.66
Line7	Bus1 Misan Station 400	Bus6 Amarh North Station	5.87	5.95
Line9	Bus8 Misan station 400	Bus5-	3.32	3.40
Line10	Bus8 Misan station 400	Bus5-	3.32	3.40
Line11	Bus5-	Bus6 Kumat Station	9.44	10.18
Line12	Bus6 Kumat Station	Bus7 Ali Algarby Station	8.49	9.15
Line13	Bus8 Misan station 400	Bus9 Alrefaay Station	0.26	0.26
Line14	Bus8 Misan station 400	Bus9 Alrefaay Station	0.26	0.26
Line15	Bus6 Amarh North Station	Bus5-	4.93	5.07
Line20	Bus4 New Amarh Station	Bus10-	13.13	13.30
Line22	Bus4 New Amarh Station	Bus1 Misan Station 400	1.66	1.69

Table 3.3 2-Winding Transformers

2-Winding Transformer Input Data								
Transformer	Rating					Adjusted	Phase Shift	
D	MVA	P. kV	S. kV	% Z1	X1/R2	% Z	Type	Angle
T8	55.000	132.00 0	33.000	12.50	45.00	12.5000	Dyn	0.000
T9 Tras 5	35.000	132.00 0	33.000	12.50	45.00	12.5000	Dyn	0.000
T10	25.000	132.00 0	11.000	10.00	20.00	10.0000	Dyn	0.000
T10 Tras 1	60.000	132.00 0	33.000	12.50	45.00	12.5000	Dyn	0.000
T11	25.000	132.00 0	11.000	12.50	0.10	12.5000	Dyn	0.000
T11 Tras 2	60.000	132.00 0	33.000	12.50	45.00	12.5000	Dyn	0.000
T12 Tras 3	60.000	132.00 0	33.000	12.50	45.00	12.5000	Dyn	0.000

T18	50.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T19 Tras 1	63.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T20 Tras 2	63.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T21 Tras 3	63.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T22 Tras 4	63.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T26	90.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T30 snaay	25.000	132.000	11.000	10.00	20.00	10.0000	Dyn	0.000
T31	31.500	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
T32	31.500	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000
Tras 4	60.000	132.000	33.000	12.50	45.00	12.5000	Dyn	0.000

Table 3.4: 3-Winding Transformer

3-Winding Transformer Input Data											
ID	**Rating**							**Z Variation**		**Phase Shift**	
	Winding	MVA	kV	% Z1		X1/R1	MVAb	+ 5%	- 5%	Type	Angle
T2	Primary:	63	132	Zps	12.5	10	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	10	63				0
	Tertiary:	23	11	Zst	12.5	10	63				0
T3	Primary:	63	132	Zps	12.5	10	63	0	0		

	Secondary:	40	33	Zpt	28.9	10	63			Std Pos. Seq.	0
	Tertiary:	23	11	Zst	12.5	10	63				0
T4	Primary:	63	132	Zps	12.8	10	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	10	63				0
	Tertiary:	23	11	Zst	12.5	10	63				0
T5	Primary:	45	132	Zps	12.5	5	45	0	0	Std Pos. Seq.	
	Secondary:	25	33	Zpt	28.9	7	45				0
	Tertiary:	20	11	Zst	7.0	9	45				0
T6	Primary:	63	132	Zps	12.5	5	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	7	63				0
	Tertiary:	23	11	Zst	7.0	9	63				0
T7	Primary:	63	132	Zps	125.0	5	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	7	63				0
	Tertiary:	23	11	Zst	7.0	9	63				0
T13 Tran. 1	Primary:	63	132	Zps	12.5	5	63	0	0	Std Pos. Seq.	
	Secondary:	33	33	Zpt	28.9	7	63				0
	Tertiary:	11	11	Zst	7.0	9	63				0
T15 Tran. 1	Primary:	63	132	Zps	12.5	10	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	10	63				0
	Tertiary:	23	11	Zst	12.5	10	63				0
T16 Tran. 2	Primary:	63	132	Zps	12.5	10	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	10	63				0

	Tertiary:	23	11	Zst	12.5	10	63				0
T23	Primary:	63	132	Zps	12.5	5	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	7	63				0
	Tertiary:	20	11	Zst	7.0	9	63				0
T24	Primary:	63	132	Zps	12.5	5	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	7	63				0
	Tertiary:	20	11	Zst	7.0	9	63				0
T25	Primary:	63	132	Zps	12.5	7	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	6	63				0
	Tertiary:	11	11	Zst	7.0	9	63				0
T27 Tran. 2	Primary:	63	132	Zps	12.5	9	63	0	0	Std Pos. Seq.	
	Secondary:	40	33	Zpt	28.9	7	63				0
	Tertiary:	23	11	Zst	7.0	5	63				0

†CHAPTER FOUR†
SIMULATION RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the simulation results of the electrical power grid using the ETAP software, encompassing both normal operational scenarios and fault conditions, particularly transmission line faults. The simulation outputs are detailed in comprehensive tables that illustrate voltage levels, current magnitudes, load values, and power factor for each substation. These results offer clear insight into the dynamic behavior of the electrical network, highlighting events such as voltage sags or abnormal load increases, which may indicate system stress or potential instability.

Additionally, the simulation facilitates the identification of weak points in the grid that are susceptible to overloading or under-voltage during fault conditions. It also allows for evaluating the effectiveness of protection coordination and the adequacy of system design under faulted and non-faulted conditions. By analyzing these outcomes, engineers can make informed decisions regarding system upgrades, relay settings, and preventive maintenance schedules. The ETAP environment further enables the visualization of real-time responses, supporting both operational planning and fault mitigation strategies.

4.2 THE FAULT RESULTS

This part of the report covers the results and analysis of a fault in the electrical power grid, specifically at Bus8, "**Maysan Station 400**." The corresponding data is presented in the following tables.

Table 4.1: L-G Fault

Project:		ETAP	Page: 1
Location:		19.0.1C	Date: 05-26-2025
Contract:			SN:
Engineer:		Study Case: SC	Revision: Base
Filename:	Graduation project		Config.: Normal

SHORT- CIRCUIT REPORT

Fault at bus: **Bus8 محطة ميسان400**

Prefault voltage = 132.000 kV = 100.00 % of nominal bus kV (132.000 kV)
= 100.00 % of base kV (132.000 kV)

Line-To-Ground Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)						Sequence Current (kA)		
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic				
ID	ID	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	I1	I2	I0
Bus8 محطة ميسان400	Total	0.00	0.0	100.39	-116.6	101.57	116.5	49.824	-83.3	0.000	0.0	0.000	0.0	16.608	16.608	16.6
Bus57	Bus8 محطة ميسان400	41.20	0.6	96.18	-113.6	99.36	112.7	4.334	-76.5	1.432	-104.5	1.671	-44.6	1.449	0.548	2.3
Bus57	Bus8 محطة ميسان400	41.20	0.6	96.18	-113.6	99.36	112.7	2.867	-79.7	0.860	179.6	0.724	17.7	1.449	0.548	0.8
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	0.43	-21.8	100.35	-116.4	101.25	116.3	0.263	-96.7	0.263	-96.7	0.263	-96.7	0.000	0.000	0.2
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	0.43	-21.8	100.35	-116.4	101.25	116.3	0.600	-75.4	0.600	-75.4	0.600	-75.4	0.000	0.000	0.6
U5	Bus8 محطة ميسان400	97.78	0.0	97.78	-120.0	97.78	120.0	41.816	-84.3	2.479	63.7	2.687	138.1	13.717	15.523	12.5

# Indicates fault current contribution is from three-winding transformers.

Table 4.2: L-L Fault

Project:		ETAP 19.0.1C	Page:	1
Location:			Date:	05-26-2025
Contract:			SN:	
Engineer:		Study Case: SC	Revision:	Base
Filename:	Graduation project		Config.:	Normal

SHORT- CIRCUIT REPORT

Fault at bus: **Bus8 محطة ميسان400**

Prefault voltage = 132.000 kV = 100.00 % of nominal bus kV (132.000 kV)
= 100.00 % of base kV (132.000 kV)

Line-To-Line Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)						Sequence Current (kA)		
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic				
ID	ID	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	I1	I2	I0
Bus8 محطة ميسان400	Total	106.18	0.1	53.09	-179.9	53.09	-179.9	0.000	0.0	41.139	-173.6	41.139	6.4	23.751	23.751	0.000
Bus57	Bus8 محطة ميسان400	105.40	-0.1	60.56	-152.0	59.31	151.1	1.292	-82.4	2.515	176.4	2.595	25.6	2.072	0.784	0.000
Bus57	Bus8 محطة ميسان400	105.40	-0.1	60.56	-152.0	59.31	151.1	1.292	-82.4	2.515	176.4	2.595	25.6	2.072	0.784	0.000
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	106.18	0.1	53.09	-179.9	53.09	-179.9	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.000	0.000
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	106.18	0.1	53.09	-179.9	53.09	-179.9	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.000	0.000
U5	Bus8 محطة ميسان400	97.78	0.0	97.78	-120.0	97.78	120.0	2.583	97.6	36.196	-172.2	36.278	3.7	19.617	22.199	0.000

# Indicates fault current contribution is from three-winding transformers.

Table 4.3: L-L-G Fault

Project:		ETAP	Page:	1
Location:		19.0.1C	Date:	05-26-2025
Contract:			SN:	
Engineer:		Study Case: SC	Revision:	Base
Filename:	Graduation project		Config.:	Normal

SHORT- CIRCUIT REPORT

Fault at bus: Bus8 محطة ميسان400

Prefault voltage = 132.000 kV = 100.00 % of nominal bus kV (132.000 kV)
= 100.00 % of base kV (132.000 kV)

Line-To-Line-To-Ground Fault

Contribution		% Voltage at From Bus						Current at From Bus (kA)								
From Bus	To Bus	Va		Vb		Vc		Ia		Ib		Ic		Sequence Current (kA)		
ID	ID	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	I1	I2	I0
Bus8 محطة ميسان400	Total	100.87	-0.3	0.00	0.0	0.00	0.0	0.000	0.0	50.799	153.2	50.204	40.1	33.606	15.043	18.565
Bus57	Bus8 محطة ميسان400	92.70	-1.4	40.42	-132.3	37.86	132.2	0.323	159.1	4.964	140.4	4.723	64.9	2.932	0.496	2.616
Bus57	Bus8 محطة ميسان400	92.70	-1.4	40.42	-132.3	37.86	132.2	1.462	-79.3	3.630	153.7	3.750	46.6	2.932	0.496	0.975
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	100.42	-0.2	0.49	158.7	0.49	158.7	0.294	83.7	0.294	83.7	0.294	83.7	0.000	0.000	0.294
Bus9 محطة الرفاعي	Bus8 محطة ميسان400	100.42	-0.2	0.49	158.7	0.49	158.7	0.671	105.0	0.671	105.0	0.671	105.0	0.000	0.000	0.671
U5	Bus8 محطة ميسان400	97.78	0.0	97.78	-120.0	97.78	120.0	0.419	65.8	41.816	155.7	41.816	35.7	27.757	14.060	14.060

# Indicates fault current contribution is from three-winding transformers.

Table 4.4: Three Phase Fault

Project:	ETAP 19.0.1C	Page:	1
Location:		Date:	05-26-2025
Contract:		SN:	
Engineer:	Study Case: SC	Revision:	Base
Filename: Graduation project		Config.:	Normal

SHORT-CIRCUIT REPORT

3-phase fault at bus: **Bus8 400محطة ميسان**

Prefault voltage = 132.000 kV = 100.00 % of nominal bus kV (132.000 kV)
= 100.00 % of base (132.000 kV)

Contribution		1/2 Cycle					1.5 to 4 Cycle				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	Imag. /Real	kA Symm. Magnitude	% V From Bus	kA Real	kA Imaginary	Imag. /Real	kA Symm. Magnitude
Bus8 400محطة ميسان	Total	0.00	5.723	-50.304	8.8	50.629	0.00	5.723	-50.304	8.8	50.629
Bus57	Bus8 400محطة ميسان	34.32	0.781	-4.348	5.6	4.417	34.32	0.781	-4.348	5.6	4.417
Bus57	Bus8 400محطة ميسان	34.32	0.781	-4.348	5.6	4.417	34.32	0.781	-4.348	5.6	4.417
Bus9 محطة الرفاعي	Bus8 400محطة ميسان	0.00	0.000	0.000	999.9	0.000	0.00	0.000	0.000	999.9	0.000
Bus9 محطة الرفاعي	Bus8 400محطة ميسان	0.00	0.000	0.000	999.9	0.000	0.00	0.000	0.000	999.9	0.000
U5	Bus8 400محطة ميسان	97.78	4.161	-41.609	10.0	41.816	97.78	4.161	-41.609	10.0	41.816

Table 4.5: Summary Report

Project:	ETAP 19.0.1C	Page:	1
Location:		Date:	05-26-2025
Contract:		SN:	
Engineer:	Study Case: SC	Revision:	Base
Filename: Graduation project		Config.:	Normal

Short-Circuit Summary Report

1.5-4 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus8 400محطة ميسان	132.000	5.723	-50.304	50.629	5.808	-49.485	49.824	40.885	4.564	41.139	-45.339	22.911	50.799

All fault currents are symmetrical (1.5-4 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

4 .3 DISCUSS THE RESULTS

#	L-G Fault	L-L Fault	L-L-G Fault
Ia	The current in the first phase is significantly high, indicating that the fault occurred in this phase. As shown in Table 4.1	The first phase current is zero, indicating it is not involved in the fault. As shown in Table 4.2	The first phase current is zero, suggesting no fault current passes through it. As shown in Table 4.3
Ib	The second phase current is zero, meaning all the current was directed through the fault in the first phase. As shown in Table 4.1	The second phase current is equal to the third phase current, indicating a two-phase fault. As shown in Table 4.2	The second phase and third phase currents are equal in magnitude but opposite in direction. As shown in Table 4.3
Ic	The third phase current is also zero, further confirming that the fault current is localized in the first phase. As shown in Table 4.1	The third phase current mirrors the second phase current, confirming a phase-to-phase short circuit. As shown in Table 4.2	The third phase and second phase currents are equal and oppositely directed, confirming the nature of the fault. As shown in Table 4.3
Va	The voltage of the first phase drops to zero, indicating a high fault current and voltage collapse in that phase. As shown in Table 4.1	The voltage of the first phase remains high as it is unaffected by the fault. As shown in Table 4.2	The first phase voltage is high and remains largely unaffected by the fault. As shown in Table 4.3
Vb	The second phase voltage is equal in magnitude but opposite in polarity to that of the third phase. As shown in Table 4.1	The second phase voltage equals the third phase voltage, confirming the L-L fault condition. As shown in Table 4.2	The voltages of the second and third phases drop to zero during the fault. As shown in Table 4.3
Vc	The third phase voltage is equal in magnitude and opposite in polarity to that of the second phase. As shown in Table 4.1	The third phase voltage equals the second phase voltage, supporting the L-L fault scenario. As shown in Table 4.2	The voltages of the second and third phases are both zero, confirming a line-to-line-to-ground fault. As shown in Table 4.3

4.4 RESULTS COMPARISON

I will compare the findings of this research with those Research paper by **Yaabari, N., Odu, P. O., and Ojobe, O. S.** (2017) in their study titled "Analysis of Three-Phase Transmission Line Fault Using Matlab/Simulink," published in the International Journal of Scientific & Engineering Research, Volume 8, Issue 6, pages 1340–1347.

Upon reviewing the simulation results, it is clear that ETAP software provides highly detailed, accurate, and comprehensive data. Results are presented in a structured format, offering clear insights into the electrical network's performance under both normal and fault conditions. ETAP's interface and reports enhance understanding of voltage levels, current flows, and load distribution across buses and substations, making it valuable for engineers and researchers.

In contrast, MATLAB/Simulink offers flexibility in modeling and is well-suited for academic and theoretical studies. However, its outputs are more abstract and require additional processing or scripting to reach the same level of detail and clarity as ETAP.

ETAP also includes advanced fault analysis modules with built-in libraries for various fault types, making it more practical for protection studies. MATLAB requires manual fault modeling and lacks integrated power system components, which may reduce analysis efficiency.

Moreover, ETAP provides professional reports and one-line diagrams for easier interpretation, while MATLAB outputs are often limited to plots and numerical data that need further analysis.

In conclusion, both tools have strengths, but ETAP excels in detailed visualization and practical analysis for comprehensive fault studies. MATLAB remains useful for custom simulations and control logic development, yet lacks the ready-to-use visuals and system diagnostics ETAP offers. Therefore, ETAP is the preferred choice for tasks requiring accuracy, clarity, and actionable insights.

†Chapter Five†
CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

This project presents an evaluation of different numerical methods used for analyzing power flow in AC networks, starting with the classical Gauss-Seidel and Newton-Raphson techniques. Power flow analysis is a critical process in both the planning and operational stages of a power system. Therefore, it is essential to consider all factors that might affect the accuracy of the results. In this study, the effect of faults on power flow analysis parameters was examined to understand how such disturbances influence system behavior. The findings clearly show that considering faults is vital for achieving accurate and reliable power flow calculations. Fault analysis is performed to avoid the risks and complications that faults can cause, aiming to resolve them with minimal cost and effort. Unbalanced faults, in particular, create challenges in the transmission of electrical energy. For this reason, it is important for engineers and technicians to be well-informed about such issues. This knowledge enables quick detection and correction of faults through timely maintenance, helping to prevent excessive stress on the system and reduce the risks associated with fault-related failures.

5.2 FUTURE WORK

Several researchers emphasize the need to expand future studies on short circuit faults in electrical power systems, particularly within transmission lines. Recommended directions include the development of advanced fault detection and classification algorithms using Artificial Intelligence (AI) and Machine Learning (ML) to improve accuracy and response speed. Integration with smart grid technologies and the use of Phasor Measurement Units (PMUs) are also encouraged to enhance protection system performance and situational awareness. Additionally, the impact of renewable energy sources on fault current characteristics is a critical area of study, necessitating adaptive protection schemes suitable for variable generation conditions. Cybersecurity of protection and control systems has emerged as a key concern, calling for secure communication protocols and resilient architectures. Furthermore, researchers propose improving simulation fidelity using advanced tools such as ETAP, PSCAD, and MATLAB/Simulink, along with shifting toward predictive maintenance strategies based on historical fault data. Standardization of testing methods and the creation of benchmark fault datasets are also recommended to ensure reliable evaluation of new techniques. [19]

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