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Integrative Fault Analysis of Transmission Lines using MATLAB and ETAP

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Abstract: This research paper investigates the major issue of power transmission line faults in electrical engineering. Through advanced simulation tools such as MATLAB and ETAP, the study aims to comprehensively analyze various fault circumstances, including symmetrical and unsymmetrical faults, to determine fault Kilovolt Ampere (KVA) or Megavolt Ampere (MVA). Through detailed fault analysis, insights are sought into improving the reliability and efficiency of power transmission networks, consequently minimizing risks of property damage, casualties, and economic disruptions.

Keywords: Power Transmission, Fault Analysis, MATLAB, ETAP, Symmetrical Faults, Unsymmetrical Faults.

1. INTRODUCTION

Power transmission line fault is a significant concern in the field of electrical engineering. A fault refers to any anomalous state or circumstance that deviates from the usual functioning of a power system. In normal circumstances, a three-phase AC power system demonstrates a uniform distribution of current and voltage magnitudes throughout each of the phases. However, a defect may emerge to disrupt this situation [1]. This defect may appear as either symmetric (equally proportioned) or unsymmetrical (unequally proportioned). An asymmetrical fault promptly impacts all phases, whereas an unsymmetrical fault solely influences one or two phases. Conducting a comprehensive examination of both symmetrical and unsymmetrical faults is essential to ascertain the quantity of fault currents and determine the fault Kilovolt Ampere (KVA) or Megavolt Ampere (MVA) for each type of fault. Such

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analysis aids in establishing appropriate ratings for circuit breakers utilized within the power system[2]. This research aims to investigate the fault MVA resulting from symmetrical or unsymmetrical faults at any specified place of interest. In addition, we have assessed the present current at the location of the fault, analyzed its distribution, and evaluated the protective measures in the event of a fault. In the case of symmetrical defects, the analysis is focused on a single phase due to the balanced nature of the system, where the properties of the system remain consistent over all three phases. The outcome will be same for the last two stages. The method employed for symmetrical fault analysis consists of the following stages: (1) Establishing a simplified diagram that illustrates a specific stage of the network, (2) Selecting a common-base KVA to transform all reactance and impedance values into relative values, (3) Formulating a diagram illustrating the reactance values based on the aforementioned simplified diagram, and (4) Identifying the Thevenin-resistance observed from the fault location. In this phase, the fault-current and fault-KVA are computed in (per unit) and then converted to their absolute values. The computational methodology may be systematically applied to ascertain the voltage and current distribution across the entire system. Furthermore, the short circuit may be classified into three discrete time periods: The electrical system undergoes three distinct phases during a fault: (1) an initial sub-transient phase marked by a rapid decline in current and high magnitude of short-circuit current, which causes the most harm, (2) a middle transient phase that endures for a relatively extended period and demonstrates a moderate decrease in current, and (3) the steady-state phase. Per Thevenin's theorem, the bus voltages during the fault may be derived by adding the voltages before the failure [3]. To calculate the variations in the bus voltages, the following formula may be used:

$$V_{bus}(F) = V_{bus}(0) + \triangle V_{bus}$$

Fault cur[1]rent $I_F = \frac{V_{(pu)}}{X_{th}}$

Short circuit, $A = \frac{Base\ kva}{X_{th}}$, or

Short Circuit, $KVA = V_{prefault} \times I_F$

Unsymmetrical faults deal to disparities that do not influence all three phases. The symmetrical components approach is applied to handle poly-phase challenges of any scale. In 1918, Dr. D. L. Fortescue claimed that any system showing unbalanced currents, voltages, or other sinusoidal variables might be mathematically described as a combination of three symmetrical components. The symmetrical coordinates approach may be employed to analyze unsymmetrical faults[4]. This approach turns any of the asymmetrical three-phase voltages (or currents) into three sets of symmetrical three-phase components, dubbed symmetrical components. All three balanced systems include three sequence networks, each of which is separately solved on a single-phase basis. In mathematically:

$$V_a = V_{a1} + V_{a2} + V_{a0}\ ; V_b = V_{b1} + V_{b2} + V_{b0}\ ;\ V_c = V_{c1} + V_{c2} + V_{c0}$$

2. RELATED WORK

“Integrating synchrophasor technology for the improvements in system integrity protection schemes under stressed conditions, Sādhanā.”, this academic inquiry scrutinizes the performance capabilities of three prominent System Integrity and Protection Schemes (SIPS) in the context of India's advanced power transmission system. Identifying deficiencies in existing SIPS, the study proposes a methodological framework, validated through rigorous simulations on an IEEE test system. The proposed technique demonstrates effectiveness in ensuring system integrity, with results corroborated by the reliable Electrical Transient Analyzer Program (ETAP) [6]. A. З. A. Aбacc, D. A. Pavlyuchenko, and Z. Hussain, “Survey about impact voltage instability and transient stability for a power system with an integrated solar combined cycle plant in Iraq by using ETAP,” J. Robot. Control JRC, vol. 2, May 2021, This article examines a 340 MW Integrated Solar Combined Cycle System (ISCCS) located in the southern region of Iraq. The analysis utilizes ETAP software to conduct tests on load flow, voltage stability, and short circuit scenarios. The Newton-Raphson method is used to tackle voltage instability in low-voltage load buses. This approach suggests using on-load tap changers, reactive power compensation, and appropriate capacitor placement as solutions to improve the stability of steady-state voltage [7]. A. Hassan, T. El-Shennawy, and A. Abou-Ghazala, “Modeling and Simulation of Integrated SVC and EAF using MATLAB & ETAP,” Dec. 2014, the study employs a combined chaotic and deterministic model for an Electric Arc Furnace (EAF), utilizing Sim-Power-System and ETAP to assess the efficacy of a Static Var Compensator (SVC) in mitigating voltage fluctuations [8]. “A Student Friendly Toolbox for Power System Analysis Using MATLAB.” Accessed: Feb. 10, 2024, In this study, the examination of premier commercial software accessibility reveals a pronounced divide between developed and developing countries, impacting student engagement and creating a nuanced understanding of the dynamics in power system education [9]. “Optimal Load Flow and Short Circuit Analysis for IEEE-14 Bus Power System using ETAP” Accessed: Feb. 10, 2024, this study investigates the optimization of relay settings in a multiloop power system to minimize power outages, employing ETAP for load flow and short circuit analysis, implementing the Dual-Simplex Method in MATLAB for optimal relay settings, comparing the integration of Distributed Generation (DG) in the IEEE 14-bus system with and without DG, and evaluating the efficacy of various ANSI/IEEE and IEC constants for standard overcurrent relays, with consistent results between Genetic Algorithm and MATLAB toolbox methodologies [10]. S. Zhang, Z. Hao, G. Chao, M. Huang, and Z. Bo, “A practical fault phase selection scheme for untransposed double-circuit transmission lines on the same tower,” this paper introduces a fault phase selection scheme for untransposed double-circuit transmission lines, employing six-sequence component analysis to accurately identify various fault types based on voltage, current, and phase angle information [11]. S. Abhyankar and Tushar, “Modeling of transmission line faults for transient stability analysis,” this paper introduces a direct modeling approach for transmission line faults in power system transient stability studies, eliminating the need for dummy buses and addressing computational inefficiencies, with demonstrated accuracy compared to commercial software [12]. S. Devi, N. K. Swarnkar, S. R. Ola, and O. P. Mahela, “Analysis of transmission line faults with linear and dynamic loads” this paper explores fault-generated transient components for robust fault

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detection and classification in power systems, conducting detailed simulations in MATLAB/Simulink under varying loads to reveal discernible impacts on system voltages and load currents during different fault conditions [13]. S. Devi, N. K. Swarnkar, S. R. Ola, and O. P. Mahela, "Detection of transmission line faults using discrete wavelet transform," This study presents a technique for detecting different types of faults in transmission lines using the discrete wavelet transform (DWT) in MATLAB/Simulink. The proposed approach aims to improve protection systems and reduce power supply failures in electric power systems, a problem that has been present since 1945[14]. W. Irfan, M. Awais, Dr. N. Zareen, and I. Ahmed, "N-1 Contingency Analysis for Offsite Power System of an HPR-1000 Power Plant Using ETAP Software," this research analyzes the 500 kV offsite power network of an HPR-1000 nuclear power plant using ETAP software. It assesses the impact of component outages on system stability, highlighting potential disruptions in power flow, frequency, and bus voltages within the NTDC grid. [15].

Background

The efficient functioning of transmission lines is essential for sustaining the stability and functionality of electricity networks. However, these systems are subject to many faults, which could disrupt power flow and undermine system consistency. Traditional fault analysis techniques frequently include manual calculations and considerable field testing, resulting in time-consuming and resource-intensive operations. In recent years, the development of advanced simulation software, including MATLAB and ETAP, has given researchers and engineers strong tools for studying and enhancing transmission line performance. MATLAB provides a broad platform for modeling and simulating complicated electrical systems, whereas ETAP specializes in power system analysis, including additional tools for fault analysis and mitigation [5]. This research article aims to examine the integrated technique of fault analysis in transmission lines using MATLAB and ETAP software. By maximizing the capabilities of these tools, we want to establish a complete framework for modeling and evaluating diverse fault situations, including three-phase faults, single-line-to-ground failures, and double-line faults. Through thorough simulations and analysis, we hope to acquire insights into the behavior of transmission lines under fault circumstances and suggest ways for boosting system dependability and performance.

Objectives

The main objectives that are wants to be achieved in this work are:

- Understanding different types of fault analysis.
- To obtain knowledge about simulation and analysis of fault in transmission line using MATLAB & ETAP software.
- Determining the KVA rating for circuit breaker.

Motivation

Power transmission line fault is a major issue in electrical engineering. Faults may cause a fire to break out, which would then cause property damage, human casualties, and the devastation of a power system network. In industrial regions, faults may also result in the power supply being shut off. So it interferes with industrial and commercial activities and

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affects economic growth. So, we are focused on transmission line fault analysis[16]. In this paper, we are going to do fault analysis and how to solve this problem quickly. In addition, we want to improve the efficiency and efficacy of fault analysis operations by using advanced approaches and technologies, such as MATLAB and ETAP. Through our work, we hope to improve the safety and dependability of power transfer networks, which will lead to long-term economic growth and better community health and safety.

3. METHODOLOGY

Required Equipment: The work have done by using some software.

1. Laptop / Computer
2. ETAP Software
3. MATLAB Software

ETAP Approach:

1. First of all, open ETAP software and Open a new file. Save the file name, location and the fixed the unit system in Matric[17].

Fig.1: ETAP File setup

2. Select the equipment from the right-side box. All kind of power system equipment from cable to a power grid are here.

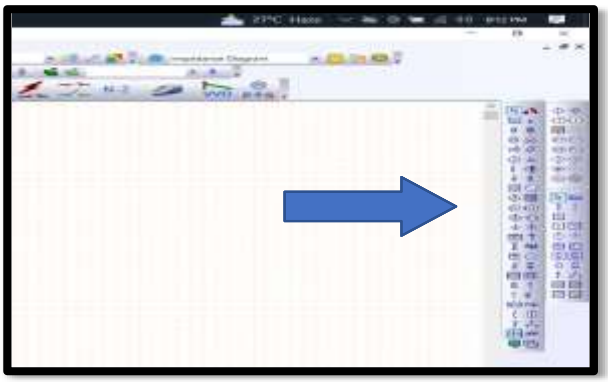

Fig.2: ETAP tools

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3. Necessary Equipment: Generator, Bus, Transformer, Cable, Load and a Motor.

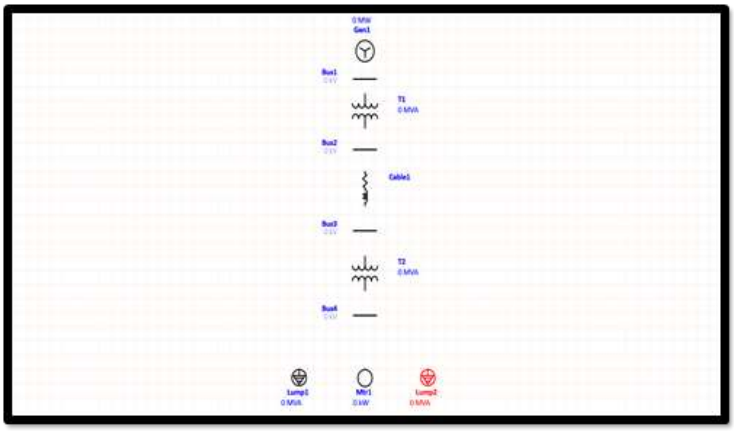

Fig.3: Necessary Equipment Selection

4. Then connect the equipment through the wire. And put their Ratings.

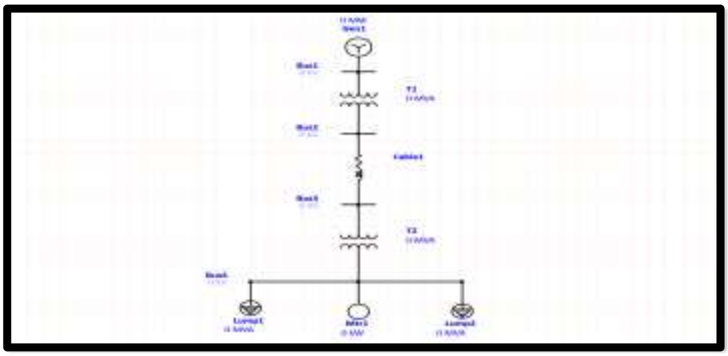

Fig.4: Connection of the Equipment

5. Ratings for Generator are:

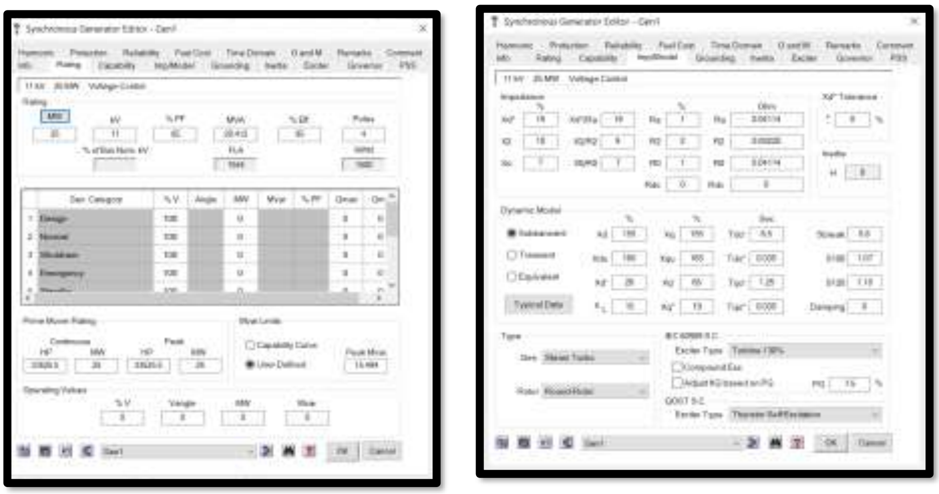

Fig.5: Ratings of the Generator

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6. Rating for Transformers are:

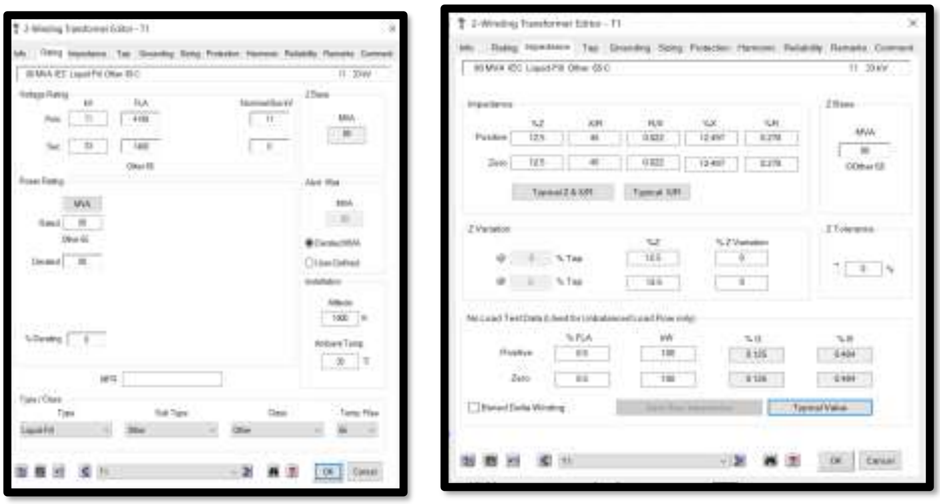

Fig.6: Rating of the Transformers

7. Rating for Cables:

Fig.7: Rating of the cables

8. Ratings for Load:

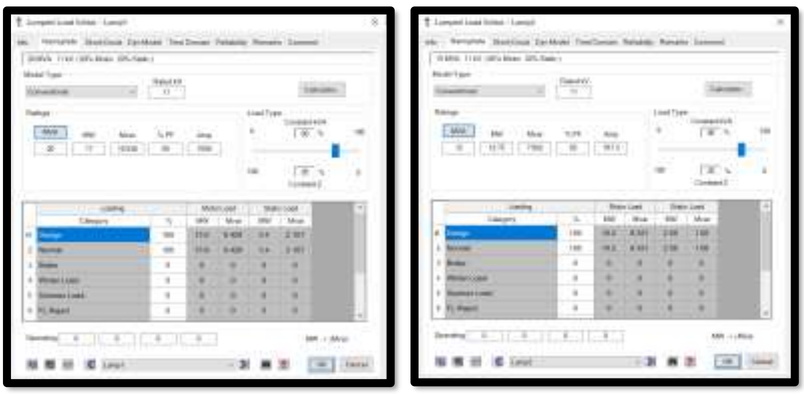

Fig.8: Rating of the loads

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9. Rating for Motor:

Fig.9: Rating of the Motor

1. The simulation by clicking on the Load Flow analysis option. Choose the display option to the KVA, Ampere and Power Factor.
2. To see the fault analysis, click on the fault analysis option. From the unit option, choose for the following fault types: line to ground fault, line to line fault, double line to ground fault, and 3-phase to ground fault.

MATLAB Simulation

The analysis of three-phase defects was conducted using MATLAB Simulink software. This powerful tool provided an extensive framework for simulating and analyzing fault scenarios in three-phase systems, enabling detailed insights into system behavior and parameters[18].

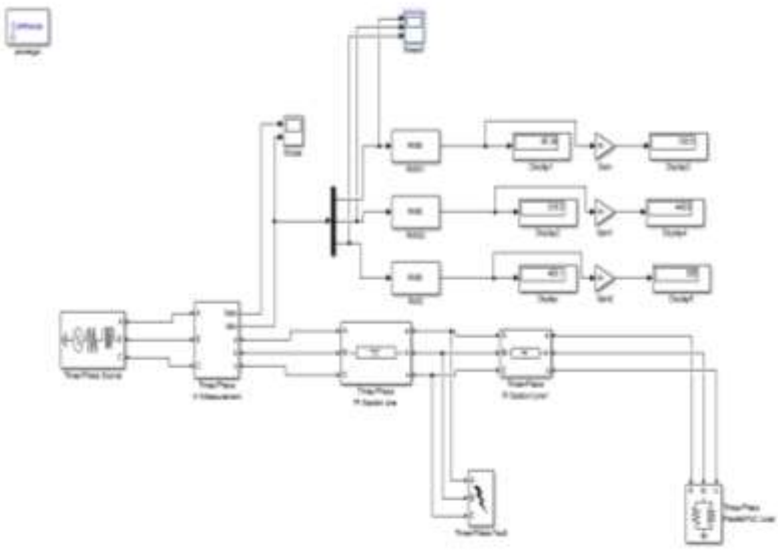

Fig.10: Simulation Model in MATLAB

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4. RESULT AND DISCUSSION

Fault Analysis refers to the process of identifying and examining the causes and consequences of errors or malfunctions in a system or process. The fault investigation was conducted on a 4-bus system, with bus number 4 being the one that experienced the issue. During a three-phase failure, the voltage at the defective bus phases becomes completely depleted. The fault current experienced many increments. The bus that is experiencing a malfunction is bus number 4, where the voltage potential is zero. In a single line to ground fault (L-G), just the phase that is experiencing the fault carries current. This fault current is the second highest among all kinds of faults. Due to the line-to-line fault, when lines B and C are in contact, the voltage of both phases is identical. The fault current is flowing from phase B to C. During phase A, the current is negligible in comparison to the fault current. During a double line to ground fault, two phases experience a voltage drop to zero, and the fault current flows exclusively via these two phases.

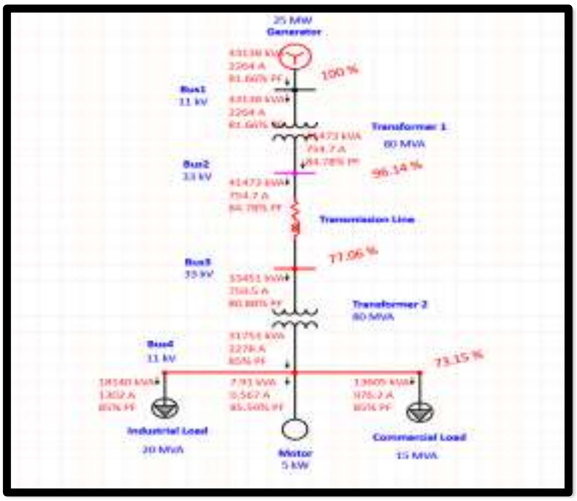

Fig.11: Primary Power Flow Analysis

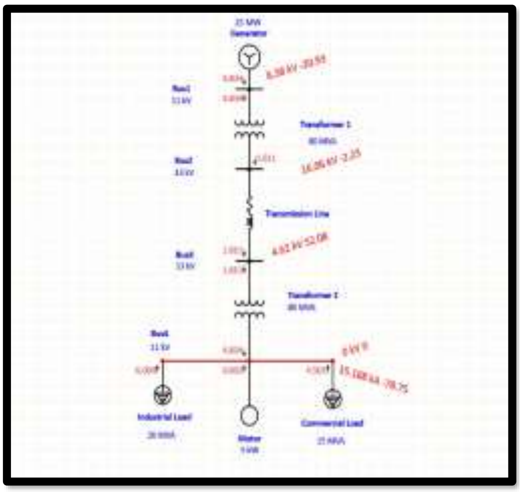

Fig.12: 3-Phase Fault Analysis

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ETAP Results

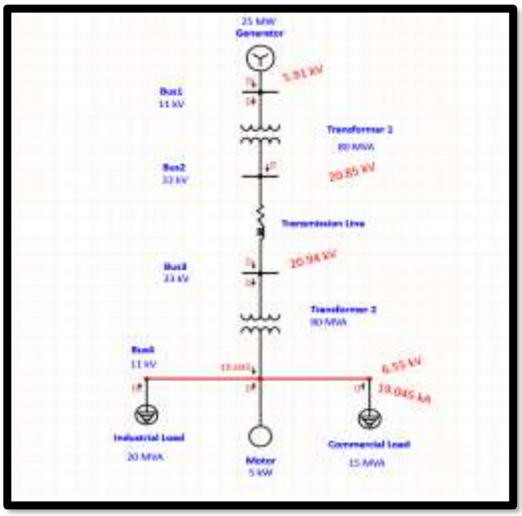

Fig.13: Line to Ground - Fault Analysis

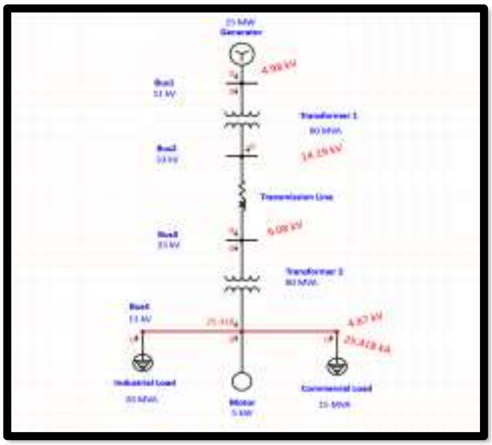

Fig.14: Line to Line - Fault Analysis

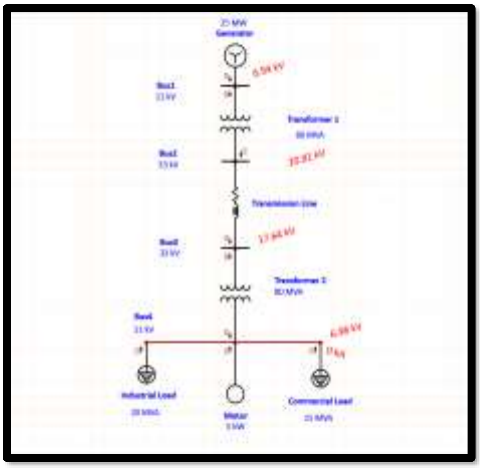

Fig.15: Double Line to Ground - Fault Analysis

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MATLAB Results

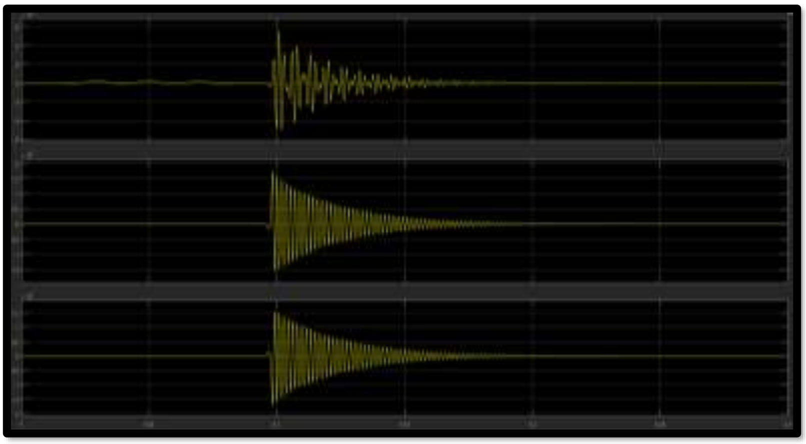

Fig.16: Output Waveform

5. CONCLUSION

Analyzing faults in three-phase transmission lines becomes significantly simpler with the aid of MATLAB and ETAP tools. Our work focuses on modeling these problems to understand transmission line properties better. We simulate several sorts of faults such three-phase faults, single line-to-ground faults, and double line faults, among others. This simulation technology considerably simplifies problem detection in transmission lines, making it more accurate and user-friendly. Plus, it's adaptable enough to be used to bigger power systems as well.

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