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Investigation of the Impact of Generator Tripping on Transient Stability in a Two-Generator Power System

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Abstract Transient stability is a crucial aspect of power systems that determines the system's ability to maintain synchronization after experiencing a sudden major disturbance. This study analyzes the response of the IEEE 30-Bus system to the scenario of tripping one of the two generators at the 1st second, simulated using the Electrical Transient Analyzer Program (ETAP 21). The system was modeled with two generators, where Generator 1 acts as the swing generator and Generator 2 as the voltage control generator, supported by 21 loads and two motors controlled by PWM and VFD. The case study focused on the disconnection of Generator 1, with system frequency response observed from the 1st to the 30th second. Results showed that system frequency dropped from 50 Hz to 49.4 Hz, then increased and stabilized at 49.7 Hz (99.4% of the initial condition) due to the inertia and governor action of the remaining generator. These findings highlight the importance of software-based transient studies in understanding the dynamic characteristics of power systems and in designing effective mitigation strategies.

Keywords:
Transient Stability
Power System
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IEEE 30 bus
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I. INTRODUCTION

In recent years, power systems have undergone significant changes due to the increasing integration of renewable energy sources. These changes have made power systems more complex and more vulnerable to various disturbances. One of the main challenges in maintaining power system reliability is the inability of certain systems to remain stable after experiencing major disturbances, such as three-phase faults. In this context, the ability of a system to remain synchronized within a short period following a disturbance is referred to as transient stability [1].

The specific problem addressed in this study is the analysis of how the power system, particularly the IEEE 30-Bus network, responds to a severe disturbance when one of its two main generators undergoes tripping. This scenario represents a highly critical real-world condition, as the sudden loss of a major generating unit can lead to significant imbalances in power flow distribution, deviations in system frequency, and variations in the rotor angle of the remaining generator. The inability of the system to maintain synchronization under such circumstances may result in widespread instability and even large-scale blackouts. Therefore, a comprehensive evaluation of the system's capability to preserve synchronization is essential to ensure the overall reliability, security, and sustainability of power system operation [2].

However, the analysis of generator tripping scenarios in large-scale power systems cannot be effectively carried out using conventional approaches alone. The complexity of the IEEE 30-Bus network topology, combined with the nonlinear dynamics of power system components, renders manual methods less adaptive to real-time conditions and requires relatively long analysis time. To address these limitations, this study employs ETAP software as a simulation tool capable of representing system behavior more accurately, comprehensively, and efficiently. ETAP provides an interactive graphical analysis environment, enabling disturbance simulations and transient studies to be conducted in a structured and timely manner, while closely approximating the actual operating conditions of power systems [3]. Through this approach, the study is expected to provide quantitative findings on the response of the IEEE 30-Bus system to the tripping of one generator, including the rotor angle dynamics and the acceleration profile of the remaining generator. These results are anticipated to not only enhance the understanding of the system's transient characteristics but also serve as a basis for more reliable preventive and corrective decision-making to ensure the future reliability and stability of power system operation.

II. LITERATURE REVIEW

A. Power System Stability

Reliability, quality, and stability are fundamental requirements for a power system to be considered effective, as the system must be capable of supplying electricity continuously. Frequency stability, voltage stability, and rotor angle stability are critical factors that significantly influence overall power system stability [4]. Distribution system reliability can be defined as a measure of the availability or the capability of the system to consistently supply electricity to consumers. The Distribution System Reliability Index serves as an indicator for measuring this reliability and is expressed in probabilistic terms [5]. In general, power system stability refers to the ability of the system to maintain operational equilibrium under normal operating conditions and to restore an acceptable state of equilibrium following a disturbance [6].

In power systems, stability and supply reliability are primary priorities to ensure operational continuity and to prevent disturbances that may result in widespread impacts [7]. Power system instability can manifest in various forms and is influenced by multiple internal and external factors. Consequently, the analysis of stability issues becomes critical, involving the identification of key contributing factors to instability and the design of effective methods to enhance operational stability. Such analysis can be facilitated by classifying stability into appropriate categories, thereby enabling more targeted strategies to improve system reliability and performance [8]. Characteristic signals of power system stability can be seen in figure 1.

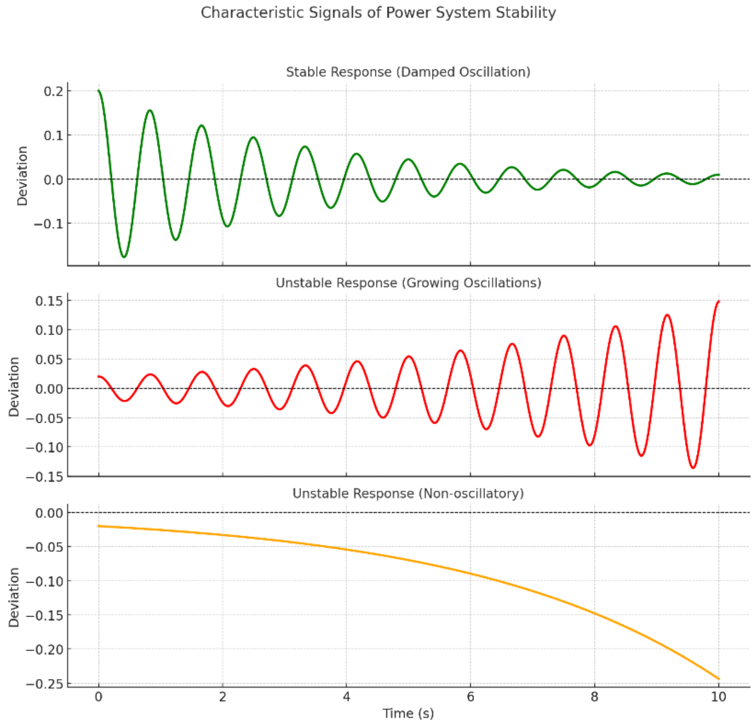


Figure 1. Characteristic of Power System Stability [12].

B. Voltage Stability of Power Systems

Voltage stability is a crucial aspect of power systems that plays a significant role in ensuring that the quality of electricity received by consumers remains within acceptable limits [9]. One of the common challenges is voltage drop, particularly in distribution networks where the distance between consumers and distribution transformers is relatively large. Such conditions increase the risk of voltage instability which, if left unmitigated, can adversely affect the quality of power supply. Unstable or fluctuating voltage not only reduces system efficiency but can also lead to operational disturbances and potential damage to various electrical equipment connected to the low-voltage distribution network [10].

C. Transient Stability of Power Systems

Transient stability is influenced by several factors, including the initial operating conditions, the severity of the disturbance, and the strength of the transmission network in delivering power [11]. In general, power system stability reflects the ability of the system to maintain equilibrium both during and after a disturbance. Significant imbalances within the power system increase the risk of widespread blackouts. Therefore, the implementation of automatic detection systems capable of rapidly responding to frequency declines is essential to prevent further disruptions and to ensure the reliability of power system operation [12].

III. METHODS

A. IEEE 30 bus Modelling

In this study, the IEEE 30-Bus distribution system was employed and modeled with two generators. Generator 1 was configured as the swing generator, while Generator 2 was designated as the voltage control generator. Each generator was equipped with a circuit breaker (CB) to disconnect power flow in the event of a disturbance. The system also included 21 loads, two of which were induction motors controlled using Pulse Width Modulation (PWM) and Variable Frequency Drive (VFD) [12]. The simulated system operated at a voltage level of 23 kV and was supplied by two generators, each with a capacity of 10 MW. The IEEE 30-Bus system data utilized in this study are presented in Tables 1 through 4 and figure 1, which provide detailed information on network parameters, generator data, load data, and other supporting elements. The presentation of these data aims to give a comprehensive overview of the system configuration employed in the simulation.

Table 1.
Line data in IEEE 30 bus

From Bus	To Bus	R (Ohm)	X (Ohm)	R (pu)	X (pu)	From Bus	To Bus	R (Ohm)	X (Ohm)	R (pu)	X (pu)
1	2	0.0021	0.0365	0.0004	0.0069	9	16	0.8639	0.7512	0.1633	0.1420
2	3	0.2788	0.0148	0.0527	0.0028	16	17	0.1463	0.7739	0.2597	0.1463
3	4	0.4438	0.4391	0.0839	0.0830	17	18	0.1463	0.7739	0.2597	0.1463
4	5	0.8639	0.7512	0.1633	0.1420	7	19	0.8639	0.7512	0.1633	0.1420
5	6	0.8639	0.7512	0.1633	0.1420	19	20	0.8639	0.7512	0.1633	0.1420
6	7	1.3738	0.7739	0.2597	0.1463	20	21	1.3738	0.7739	0.2597	0.1463
7	8	1.3738	0.7739	0.2597	0.1463	7	22	0.8639	0.7512	0.1633	0.1420
8	9	1.3738	0.7739	0.2597	0.1463	4	23	0.4438	0.4391	0.0839	0.0830
9	10	1.3738	0.7739	0.2597	0.1463	23	24	0.4438	0.4391	0.0839	0.0830
10	11	1.3738	0.7739	0.2597	0.1463	24	25	0.8639	0.7512	0.1633	0.1420
11	12	1.3738	0.7739	0.2597	0.1463	25	26	0.8639	0.7512	0.1633	0.1420
12	13	1.3738	0.7739	0.2597	0.1463	26	27	0.8639	0.7512	0.1633	0.1420
13	14	1.3738	0.7739	0.2597	0.1463	27	28	1.3738	0.7739	0.2597	0.1463
14	15	1.3738	0.7739	0.2597	0.1463	2	29	0.2788	0.0148	0.0527	0.0028
30	31	1.3738	0.7739	0.2597	0.1463	29	30	0.2788	0.0148	0.0527	0.0028

TABLE 2.
Load data in IEEE 30 bus

Bus Number	P (kW)	Q (kVar)	P (pu)	Q (pu)	Bus Number	P (kW)	Q (kVar)	P (pu)	Q (pu)
1	0	0	0	0	17	55	18.1	0.55	0.181
2	52.2	17.2	0.522	0.172	18	47.8	15.7	0.478	0.157
3	0	0	0	0	19	43.2	14.2	0.432	0.142
4	0	0	0	0	20	67.3	22.1	0.673	0.221
5	93.8	30.8	0.938	0.308	21	49.6	16.3	0.496	0.163
6	0	0	0	0	22	20.7	6.8	0.207	0.068
7	0	0	0	0	23	52.2	17.2	0.522	0.172
8	0	0	0	0	24	192	63.1	1.92	0.631
9	0	0	0	0	25	0	0	0	0
10	18.9	6.2	0.189	0.062	26	111.7	36.7	1.117	0.367
11	0	0	0	0	27	55	18.1	0.55	0.181
12	33.6	11	0.336	0.11	28	79.3	26.1	0.793	0.261
13	65.8	21.6	0.658	0.216	29	88.3	29	0.883	0.29
14	78.4	25.8	0.784	0.258	30	0	0	0	0
15	73	24	0.73	0.24	31	88.4	29	0.884	0.29
16	47.8	15.7	0.478	0.157					

TABLE 3.
Data of Capacitor bank

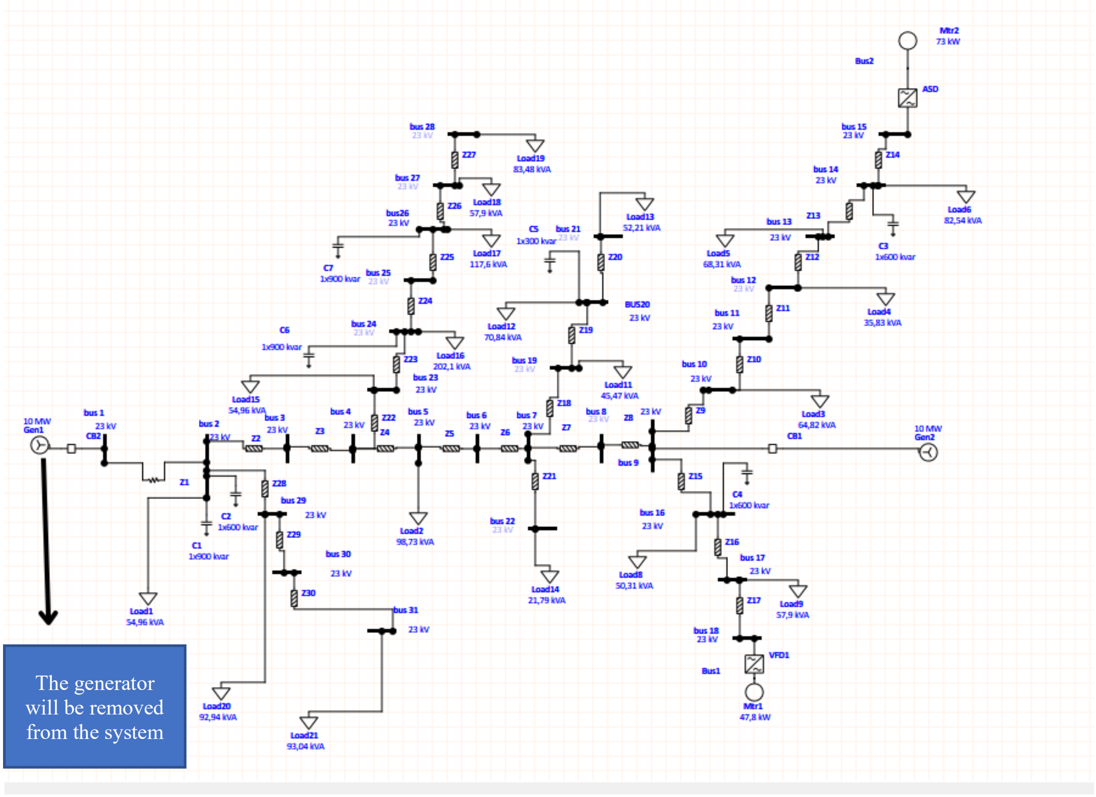
Capacitor	C1	C2	C3	C4	C5	C6	C7
Bus Location	2	2	14	16	20	24	26
kVar	900	600	600	300	900	900	900

TABLE 4.
Data of VFD and PWM

Harmonic Orde h	Variable-frequency drive		PWM adjustable-speed drive	
	Magnitude (%)	Phase Angle (Degree)	Magnitude (%)	Phase Angle (Degree)
1	100	0	100	0
5	23.52	111	82.8	-135
7	6.08	109	77.5	69
11	4.57	-158	46.3	-62
13	4.2	-178	41.2	139
17	1.8	-94	14.2	9
19	1.37	-92	9.7	-155
23	0.75	-70	1.5	-158
25	0.56	-70	2.5	98
29	0.49	-20	0	0
31	0.54	7	0	0

TABLE 5.
Generato Data

Generator Number	Capacity	Bus Type
Generator 1	10MW	Swing bus
Generator 2	10MW	PV bus



The generator will be removed from the system

Figure 2. IEEE 2 Generator Systems

B. *Step of the Research*

The following are the research stages used in this study:

1. Start. The analysis begins by defining the research objective, namely, to evaluate the stability of a power system using the standard IEEE 30 Bus Test System**.**
2. Data Collection. The system data are taken from the IEEE 30 Bus model, consisting of 30 buses, 6 generators, 24 loads, and 41 transmission lines. The collected parameters include line impedances, generation capacities, load characteristics, and operational limits. The use of the IEEE 30 Bus test system ensures measurable, consistent results that can be compared with previous studies
3. Load Flow Analysis. A load flow calculation is performed on the IEEE 30 Bus system to determine voltage profiles, active power, and reactive power distribution at each bus. This analysis helps identify the system's normal operating condition as well as potential weak points that may cause instability
4. Generator Outage Simulation. A contingency scenario is simulated by disconnecting one of the generators in the IEEE 30 Bus system. This step aims to observe the impact of generator loss on power distribution and overall system stability.
5. Transient Stability Analysis. The system's dynamic response following the generator outage is evaluated through transient stability analysis. This stage examines whether the IEEE 30 Bus system can maintain synchronism among generators and voltage stability under short-term disturbances. The results provide insight into stability margins and the reliability of the system under contingency conditions.

End. The process concludes with findings regarding the IEEE 30 Bus system's ability to maintain stability after disturbances, along with recommendations for system improvement or reinforcement.

IV. RESULT AND DISCUSSION

In this study, a simulation using ETAP software was conducted to analyze the response of the IEEE 30 Bus standard electric power system to a transient case study. The case study studied is the condition of the release of one of the two generators in the system. At the 1st second, Generator 1 is modeled to experience a release, which is then followed by the opening of Circuit Breaker (CB) 2 as a system response. Transient stability is one of the crucial aspects in an electric power system because it determines the system's ability to maintain synchronization after experiencing a large disturbance in a short duration. The purpose of this study is to analyze the dynamic response of the power system to disturbances by utilizing the IEEE 30 Bus standard system**.**

The simulation was conducted by modeling three-phase short-circuit faults at various network locations to evaluate the stability of the generator rotor angle through swing curve analysis. The simulation results show that the fault location and the timing of the outage play a very important role in determining the stability of the system. The system shows indications of instability when the fault occurs on a strategic line without timely corrective action. Thus, this analysis provides important insights into the urgency of simulation-based transient stability studies to support the planning, operation, and mitigation strategies of electric power systems facing potential dynamic disturbances. Figure 4 shows a simulated case study of the system, which is then observed to study the system's response to the given conditions. Figure 5 shows the simulation results after the generator is removed from the system.

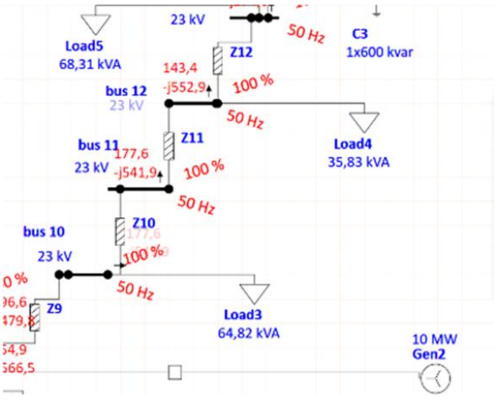


Figure 3. Condition before disturbance

When Generator 1 trips at 1 second, the system condition, as illustrated in Figure 4, remains stable at 50 Hz, indicating that no disturbance has yet occurred that could adversely affect the system frequency.

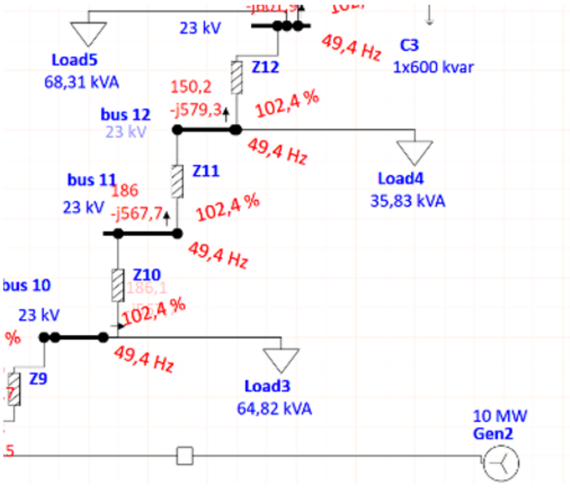


Figure 4. Condition after disturbance.

In Figure 5, the system exhibits a frequency decline due to the conditions defined in the study case, where Generator 1 trips at 1 second. The frequency continues to decrease, reaching 49.4 Hz. From this point until approximately 30 seconds, the generator's inertia and governor mechanisms attempt to restore system stability by adjusting the operating conditions, which gradually increases the frequency. The maximum recovery achieved is 49.7 Hz, corresponding to approximately 99.4% of the nominal value. The system frequency response after generator 1 can be seen in figure 6.

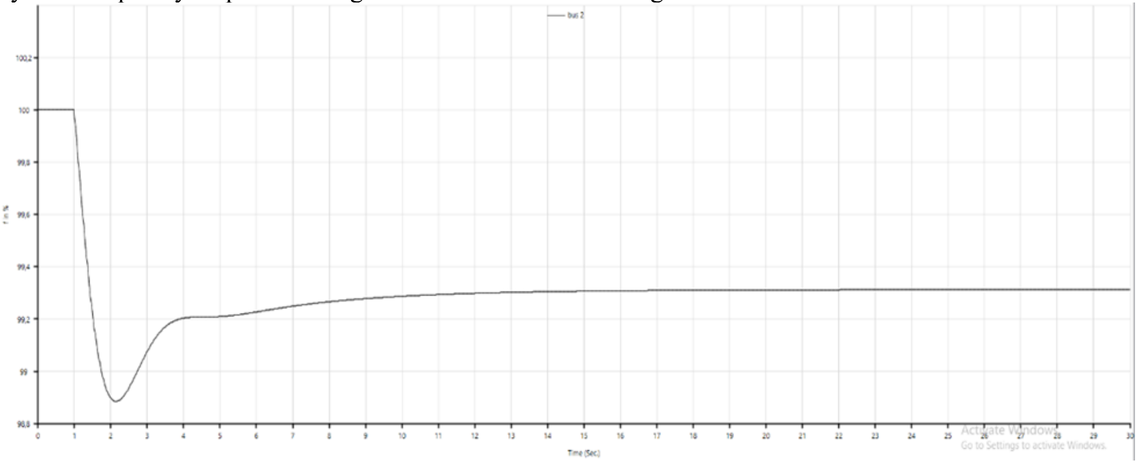


Figure 5. Frequency system response.

At the beginning of the observation, the system output remains close to 100%. However, at 1 second, a sharp decline is observed, reaching a minimum of approximately 98.8% at 2.5 seconds. This rapid drop reflects the immediate impact of the disturbance caused by the generator outage. Following this event, the system demonstrates a gradual recovery process, with a stable upward trend beginning at 3 seconds. The response approaches a near-steady condition around 15 seconds and achieves full stability by 20 seconds, with a final settled value of approximately 99.4% of the nominal. This dynamic behavior highlights the transient nature of the disturbance and the critical role of system inertia and governor action in damping oscillations and restoring frequency stability. The results confirm that, despite the initial deviation, the system is capable of re-establishing synchronism and maintaining operational reliability under the given disturbance scenario.

V. CONCLUSION

Based on the simulation results using ETAP software on the IEEE 30-Bus system, the tripping of Generator 1 at the 1st second caused the system frequency to drop from 50 Hz to 49.4 Hz (a decrease of

1.6%), before gradually increasing and stabilizing at 49.7 Hz (equivalent to 99.4% of the initial frequency). From Table 2, it can be concluded that although a sudden frequency drop occurred due to the disturbance, the system was still able to maintain frequency stability within the tolerance limits allowed by the PLN standard, which specifies a maximum deviation of 1%. These findings indicate that the system remained transiently stable, as the inertia and governor action of the generator successfully restored the system condition within 30 seconds after the disturbance. Therefore, the tripping of a single generator in this scenario did not result in loss of synchronism, and frequency control strategies through mechanical components proved sufficiently effective in maintaining the reliability of the power system against sudden disturbances.

VI. REFERENCE

[1] S. Cheng, Q. Xu, H. Wang, Z. Yu, R. Wang, and T. Ran, "A transient stability assessment method for power systems incorporating residual networks and BiGRU-attention," Global Energy Interconnection, vol. 8, no. 1, pp. 143-159, 2025/02/01/ 2025, doi: https://doi.org/10.1016/j.gloei.2024.09.001.

[2] K. Alzaareer, A. Agha, Q. Salem, C. Z. El-Bayeh, M. Zellagui, and M. Al-Omary, "Development of voltage stability-based bus dependency matrix for modern power networks," Energy, vol. 318, p. 134875, 2025/03/01/ 2025, doi: https://doi.org/10.1016/j.energy.2025.134875.

[3] A. B. Laksono and Z. Abidin, " Power Flow Analysis and Stability of Multi-Machine Power Systems with ETAP," JE-Unisla, vol. 5, no. 1, pp. 297-302, 2020.

[4] R. Isfihana, H. Suyono, and R. N. Hasanah, " Evaluation of Distribution System Reliability with System Stability Constraints Due to Hybrid Distributed Generation Injection," Jurnal Ilmiah Teknik Elektro, vol. 1, p. 24, 2022.

[5] H. Suyono, R. N. Hasanah, W. A. Syahri, H. Mokhlis, M. T. Rahman, and R. Omar, "Power system distribution reliability enhancement of pujon feeder malang-indonesia case study using bat and cuckoo search algorithms," in 2020 10th Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS), 2020: IEEE, pp. 87-92.

[6] S. E. SANTOSO, " Study of the Application of Single Pole Auto-Recloser (SPAR) and Three Pole Auto-Recloser (TPAR) on System Stability at the PLTU Outlet," Tesis, 2025.

[7] H. ALEXCANDRA, " Power Flow Analysis and Protection Relay Coordination Simulation in Electric Power Systems Using ETAP 2021," E-JOINT (Electronica and Electrical Journal Of Innovation Technology), vol. 6, no. 1, pp. 17-21, 2025.

[8] A. D. Novfowan, W. Kusuma, and M. Mieftah, " Analysis of Voltage and Frequency Transient Stability in Steam Power Generation Systems," ELPOSYS: Jurnal Sistem Kelistrikan, vol. 8, no. 1, pp. 28-33, 2021.

[9] N. Anasta, I. Kesuma, and A. Wardana, " Optimization of Electric Power Distribution System Using Genetic Algorithm," Jurnal Elektronika Listrik dan Teknologi Informasi Terapan, vol. 6, no. 2, pp. 73-77, 2024.

[10] S. A. Khan, R. Sulistyowati, and N. S. Erwanti, " Voltage Stability Analysis Using the Continuation Power Flow Method," Jurnal JREEC–Volume, vol. 4, no. 01, 2024.

[11] Y. Zhou et al., "Transient Rotor Angle and Voltage Stability Discrimination Based on Deep Convolutional Neural Network with Multiple Inputs," in 2021 IEEE 4th International Electrical and Energy Conference (CIEEC), 28-30 May 2021 2021, pp. 1-6, doi: 10.1109/CIEEC50170.2021.9510199.

[12] Mohammad A.S. Masoum dan Ewald F. Fuchs,2015, Power Quality in Power System and Electrical Machines Second Edition.