International Journal Of Health, Engineering And Technology (IJHET) *E-ISSN 2829 - 8683*
Volume 5, Number 4, November 2026, *Page. 4154 - 4159*
Email : editorijhess@gmail.com

The Role Of Substations As A Link Between Electrical Transmission And Distribution Systems

Diyajeng Luluk Karlina
Department of Electrical Engineering Vocational Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia

*Corresponding Author
Email: diyajeng@untirta.ac.id

Abstract

Substations are an essential part of the electric power system, serving as a link between electrical transmission and distribution systems. This study aims to analyze the role of substations in maintaining the reliability of electrical energy transmission and supporting the stability of electric power distribution systems. The approach applied in this study is a literature review, conducted by examining various scientific references, including national journals, books, and scientific papers relevant to the research questions. The references were obtained from academic databases such as Google Scholar, DOAJ, and ProQuest. The collected data were analyzed using descriptive and thematic analysis approaches to identify the functions, components, and influence of substations on electric power distribution systems. The results indicate that substations have several primary functions, including voltage transformation, power flow regulation, protection systems, and voltage quality control. The reliability of distribution systems is influenced by the performance of substation components, such as power transformers, circuit breakers, busbars, and OCR (Overcurrent Relay) and GFR (Ground Fault Relay) protection systems. Furthermore, faults such as short circuits, transformer overloads, and inadequate maintenance can affect the continuity of electrical energy distribution. Therefore, regular maintenance, optimization of protection systems, and the development of monitoring technologies are highly recommended to improve the efficiency and reliability of modern electric power systems.

Keywords: Substation, Transmission System, Distribution System, Protection System

INTRODUCTION

Electrical energy is a primary necessity in supporting various activities in society, industry, education, and the development of modern technology. The increasing demand for electrical energy from year to year requires power systems to operate reliably, stably, and efficiently to ensure the continuity of electricity services to consumers. In an electric power system, the process of delivering electrical energy involves several stages, namely generation, transmission, and distribution. At these stages, substations play a crucial role as the link between electrical transmission and distribution systems (Isfihana et al., 2022).

Substations function to step down electrical voltage from high-voltage transmission networks to medium-voltage levels before distributing electricity to consumers through distribution networks. In addition, substations are responsible for regulating power flow, protecting the electric power system, and maintaining voltage quality and stability in accordance with operational standards. The existence of substations plays a crucial role in ensuring the reliability of electrical energy distribution, as disturbances within substations can lead to power outages and instability in the distribution system (Annisa & Mardiansah, 2023).

As the demand for electrical energy continues to increase, distribution systems also face various challenges, such as rising electrical loads, short-circuit faults, transformer overloads, and power losses in the network. These conditions require substations to have effective operational and protection systems to ensure the optimal distribution of electrical energy. Therefore, substations do not merely serve as power distribution centers but also play a vital role in maintaining the continuity and security of the overall electric power system (Idriana et al., 2021).

Furthermore, the development of monitoring technologies and substation management systems has become an important factor in improving the efficiency and availability of electric power distribution systems. The implementation of monitoring systems, equipment maintenance, and digital data management of distribution substations can help improve the continuity of electricity services and facilitate the monitoring of distribution networks. This demonstrates that the modernization of substation systems is an essential effort in supporting the reliability of electric power distribution in the modern era (Gianto, 2021).

Based on the above discussion, a study of the role of substations as a link between electrical transmission and distribution systems is important to conduct. This research employs a literature review method by examining various scientific journals, books, and relevant references to understand the functions, components, and contributions of substations in maintaining the reliability of electric power distribution systems.

Literature Review

Electric Power System

An electric power system is an integrated system consisting of various interconnected electrical components designed to generate, transmit, and distribute electrical energy to consumers. This system includes power generation plants, transmission networks, substations, and distribution networks, all of which operate in an integrated manner to ensure that electrical energy demands are met safely, reliably, and efficiently (Feizifar & Diagnosis, 2017).

Electrical power transmission is the process of delivering electrical energy from power generation plants to substations or distribution centers through high-voltage transmission lines. The application of high voltage is intended to reduce power losses during the transmission of electrical energy over relatively long distances. The transmission system functions as a link between power generation plants and electric power distribution systems. The effectiveness of electrical energy transmission is influenced by network quality, voltage levels, and the transmission distance used (Yang et al., 2013).

Furthermore, power losses in transmission networks can occur due to resistance or impedance in transmission lines and electrical equipment. Therefore, transmission systems are designed to operate at high voltage levels to improve the efficiency of electrical energy transmission. The distribution system is a part of the electric power system that plays a role in delivering electrical energy directly to consumers. At this stage, power losses may still occur due to both technical and non-technical factors within the distribution network (Swierczynski et al., 2004).

Substation

Substations have several main functions in electric power systems, namely serving as connection points for electrical networks, regulating power flow, transforming voltage levels, and providing protection against disturbances occurring in electrical networks. Substations function as facilities where electrical power transmission systems from various transmission lines are interconnected before the electrical energy is distributed to the loads. Substations are also equipped with various protection devices designed to maintain the reliability of electric power systems against disturbances that may disrupt the electricity transmission process (Dewi & Yusdartono, 2023).

Substations also serve as facilities for operating protection, measurement, control, and safeguarding electrical power equipment against overcurrent and overvoltage disturbances that could endanger the power system. Therefore, substations play a crucial role in maintaining the stability, safety, and reliability of electric power systems, ensuring that electrical energy can be distributed optimally to consumers.

Main Components of an Electrical Substation

Power transformers function to step up or stepdown electrical voltage according to the requirements of the electric power system. Transformers are the main equipment in substations because they play an essential role in transmitting electrical energy from the transmission system to the distribution system.

Circuit breakers function to connect and disconnect electrical current under both normal operating conditions and fault conditions. This equipment is used to protect electric power systems from damage caused by short-circuit currents and overloads.

Busbars function as the main conductors used to collect and distribute electrical power to various equipment within a substation. Busbars facilitate the regulation and distribution of electrical energy within the electric power system.

Disconnecting switches (isolators) function to isolate specific sections of an electrical power system that are not energized, ensuring safety during maintenance or repair activities. They are operated after the circuit breaker has first opened the circuit.

Current transformers (CT) function to reduce high electrical currents to standardized levels that are safe for measuring instruments and protection relays. CTs are used to support measurement and protection processes in electric power systems.

Potential transformers (PT) function to reduce high voltage levels to standardized voltages that can be used by measuring instruments and protection systems. PTs support voltage monitoring and control processes within substations.

Lightning arresters function to protect substation equipment against over voltages caused by lightning strikes or switching surges. Lightning arresters operate by diverting surge currents to the grounding system, thereby protecting electrical equipment from potential damage.

RESEARCH METHODS

This research employs a literature review method to understand and analyze various theories, perspectives, and research findings related to the topic under discussion. This method was selected because it provides a comprehensive overview based on relevant scientific sources. The literature collection process was conducted through several academic databases, such as Google Scholar, DOAJ, and ProQuest.

The selection of literature sources was based on several criteria, including relevance to the research topic, publication year, source credibility, and the quality of the research. Furthermore, the quality and reliability of the literature were evaluated based on the research methods employed, the relevance of the discussion, and the reputation of the authors and journal publishers.

The data and information obtained from various sources were subsequently analyzed and synthesized using descriptive and thematic analysis approaches. The main findings from each literature source were identified and examined to provide a more comprehensive understanding of the research topic. Through this literature review method, the study identifies various theories, perspectives, and previous research findings related to the role of substations in electric power distribution systems. This approach also provides a strong foundation for developing a conceptual understanding and supporting the systematic implementation of the research.

RESULTS AND DISCUSSION

The Role of Substations as a System Interconnection Link

The electric power system consists of three main interconnected systems operating sequentially: generation, transmission, and distribution. Substations occupy a strategic position as the interconnection point between high-voltage transmission systems and medium-voltage distribution systems. The flow of electrical energy from power generation plants to consumers is illustrated in Figure 1.

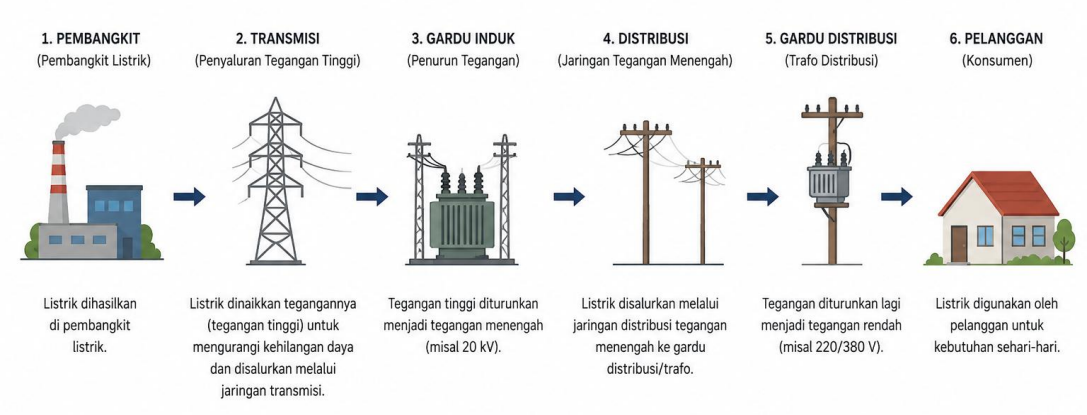


Figure 1. Electricity Distribution Flow

The process begins at the power generation plant, which produces electrical energy at a voltage level of 6–24 kV. The voltage is then increased by a step-up transformer to 150 kV or 500 kV for long-distance transmission through Extra High Voltage Overhead Lines (SUTET) or High Voltage Overhead Lines (SUTT). At the substation, the voltage is stepped down to 20 kV before being distributed through the distribution network. It is then further reduced to 220 V or 380 V at the distribution substation before reaching end consumers. Voltage transformation is carried out by power transformers equipped with an On-Load Tap Changer (OLTC), which helps maintain distribution voltage within a range of ±5% of the nominal voltage, even when load fluctuations occur.

The Impact of Substations on Distribution System Reliability

Substations play an important role in maintaining the reliability of electric power distribution systems because they function as power flow control centers and interconnection points between transmission and distribution systems. The reliability of a distribution system can be assessed based on its ability to continuously deliver electrical energy with minimal interruptions. One of the indicators used to measure distribution system reliability is the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). The lower the SAIFI and SAIDI values, the higher the reliability of the distribution system (Gianto, 2021).

Furthermore, substations also influence voltage stability and electrical power quality within distribution networks. An effective protection system in a substation can minimize the impact of short-circuit faults, thereby maintaining the continuity of electricity services to consumers. Research conducted by (Yang et al., 2013) indicates that protection coordination using Overcurrent Relays (OCR) and Ground Fault Relays (GFR) in substations can accelerate the fault isolation process, resulting in a more reliable distribution system.

In their operation, substations also support improvements in power quality through power factor regulation and voltage control. The installation of capacitors in substations has been proven to improve the power factor and reduce voltage drops in both transmission and

distribution networks. Therefore, the presence of substations significantly influences the overall efficiency and stability of electric power systems (Annisa & Mardiansah, 2023).

Substation Problems

In electric power systems, substations often experience several problems that can affect the reliability of electricity distribution. One of the most common disturbances is a short-circuit fault in the distribution network. Short-circuit faults can cause a significant increase in electrical current, potentially damaging electrical equipment if the protection system does not operate properly. Therefore, proper coordination of the substation protection system is essential to ensure that faults can be isolated immediately without interrupting the entire distribution system.

Another problem is transformer overload caused by continuously increasing electricity demand. Unbalanced loads in distribution transformers can lead to increased temperatures, the occurrence of neutral currents, and higher power losses in the distribution system. Such load imbalances can also shorten the operational lifespan of transformers if they occur continuously.

In addition to technical factors, disturbances in substations can also be caused by equipment deterioration and inadequate system maintenance. Damage to protection components and switching equipment can delay fault interruption, potentially resulting in wider power outage areas. Therefore, regular evaluations of protection systems and substation equipment conditions are necessary to maintain the reliability of electric power distribution systems.

Efforts to Improve Substation Performance

Improving substation performance can be achieved through the optimization of protection systems, routine maintenance, and modernization of electric power distribution equipment. Protection systems such as Overcurrent Relays (OCR) and Ground Fault Relays (GFR) must have proper operational coordination to detect and isolate faults quickly and selectively. With an optimized protection system, disturbances in distribution networks can be minimized, thereby maintaining the continuity of electricity supply.

Furthermore, improving the reliability of distribution systems can also be achieved by installing automatic devices, such as motorized Load Break Switches (LBS) on distribution feeders. The use of motorized LBS enables faster network switching and restoration processes when disturbances occur. Recent studies have shown that optimizing motorized LBS in 20 kV distribution networks can improve the reliability of distribution systems supplied by substations.

Another effort involves periodically evaluating distribution system reliability indices using methods such as the Section Technique and Failure Mode and Effects Analysis (FMEA). These evaluations aim to determine the reliability level of distribution systems and identify the necessary corrective actions. The development of monitoring technologies and substation digitalization also represents an important solution in supporting modern electric power distribution systems, as it facilitates real-time system monitoring and control.

CONCLUSION

Based on the results of the literature review, it can be concluded that substations play an important role as a link between electrical transmission and distribution systems. Substations function to step down voltage levels, regulate power flow, and maintain the safety and stability of electric power systems to ensure that electrical energy can be delivered to consumers reliably and efficiently. The reliability of distribution systems is influenced by the performance of substation components, such as power transformers, circuit breakers, and protection systems. Problems such as short-circuit faults, transformer overloads, and

inadequate maintenance can affect the quality of electricity distribution. Therefore, improvements in protection systems, routine maintenance, and modernization of substation equipment are necessary to enhance the reliability of electric power distribution systems. Future research is recommended to include direct field observations to obtain more in-depth data regarding substation operating conditions. Furthermore, research on the implementation of smart grid technology and digital monitoring systems is also worth exploring to support the development of modern electric power systems.

REFERENCES

Annisa, S. C., & Mardiansah, A. (2023). *Analisis Permasalahan Disconnecting Switch Pada Unit Induk Transmisi Jawa Barat*. *10*(2).

Corzine, K. A., & Member, S. (2017). *A New-Coupled-Inductor Circuit Breaker for DC Applications*. *32*(2), 1411–1418.

Dewi, N., & Yusdartono, H. M. (2023). *STUDI DROP TEGANGAN PADA JARINGAN DISTRIBUSI 20 KV ANTARA GARDU INDUK SIGLI DENGAN GARDU HUBUNG EXPRESS TRIENGGADENG MENGGUNAKAN*. *12*, 31–35.

E-issn, E. L. P., Teknik, J., Pratito, A. A., & Irawan, D. (2022). *ANALISIS SETTING RELAY LINE DIFFERENTIAL GARDU INDUK PLTU GRESIK*.

Feizifar, B., & Diagnosis, A. M. (2017). *Condition Monitoring of Circuit Breakers : Current Status and Future Trends*. 0–4.

Gianto, R. (2021). *MODEL STEADY STATE PEMBANGKIT LISTRIK TENAGA ANGIN YANG BERBASIS PMSG UNTUK ANALISIS ALIRAN DAYA*. *4*, 134–142.

Harjian, M. R., Muljono, A. B., & Putra, R. R. E. (2025). *MENGGUNAKAN METODE SECTION TECHNIQUE AND FAILURE MODE EFFECT & ANALYSIS (FMEA)*. *13*(2).

Idriana, E., Putri, R., Meliala, S., Fariadi, D., Elektro, J. T., Teknik, F., Malikussaleh, U., & Utara, A. (2021). *ANALISA SETTING KOORDINASI PROTEKSI OVER CURRENT RELAY PADA JARINGAN DISTRIBUSI DI PT . PLN (PERSERO) ULP PANGKALAN BRANDAN*. *10*, 22–29.

Isfihana, R., Suyono, H., & Hasanah, N. (2022). *CONSTRAINT STABILITAS SISTEM AKIBAT INJEKSI HYBRID DISTRIBUTED GENERATION*. *1*, 1–8.

Kerusakan, I., Bay, P. M. T., Metode, M., Analyzer, B., & Kontak, T. (2021). *Identification Damage of PMT 500KV BAY 7A1 Using the Breaker Analyzer and Contact Resistance Methods at the Substation*. *5*(2), 156–164.

Rauf, R., & Najif, H. (n.d.). *STUDI ANALISIS PERBAIKAN JATUH TEGANGAN RENDAH DENGAN PEMASANGAN TRAFO SISIPAN PADA PT . PLN ULP*. *14*(2), 1078–1086.

Swierczynski, B., Gonzalez, J. J., Teulet, P., Freton, P., & Gleizes, A. (2004). *Advances in low-voltage circuit breaker modelling*. *37*, 595–609. https://doi.org/10.1088/0022-3727/37/4/011

Wang, D. (2025). *HIGH-VOLTAGE CIRCUIT BREAKER FAULT VOICEPRINT RECOGNITION BASED ON PROTOTYPE SIMILAR DOMAIN ADAPTIVE SPECTRAL MORPHOLOGICAL NEURAL NETWORK*. *26*(3). https://doi.org/10.29354/diag/206079

Yang, F., Wu, Y., Rong, M., Sun, H., Murphy, A. B., Ren, Z., & Niu, C. (2013). *Low-voltage circuit breaker arcs — simulation and measurements*. *273001*. https://doi.org/10.1088/0022-3727/46/27/273001

Yasmin, S. Y., Permata, E., Vokasional, P., Elektro, T., Sultan, U., Tirtayasa, A., Yogyakarta, U. N., & Proteksi, S. (2022). *SISTEM PROTEKSI SWITCH GEAR 5P1 _ 1S1 _ U5 UNTUK MOTOR CEMENT MILL DI PT*. *1*(1), 106–115.