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ANALYZING CIRCUIT BREAKERS IN SUBSTATIONS FOR ENHANCED RELIABILITY

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ABSTRACT: The "Powerful Protection: Analyzing Circuit Breakers in Substations for Enhanced Reliability" mini project examines substation circuit breakers' performance and dependability. By halting defective currents and isolating problematic parts, circuit breakers keep power systems stable.

This small project analyzes circuit breaker reliability variables and proposes ways to improve them. The research will examine substation air, oil, vacuum, and SF6 circuit breakers' operating characteristics and failure mechanisms. The project will use theoretical and practical methods to accomplish this. To understand circuit breaker action, a detailed literature research is required.Case studies and data from running substations will analyze circuit breaker performance and dependability in real-world circumstances.

The research seeks to discover common failure patterns and create techniques to reduce risks and increase circuit breaker dependability via data analysis and comparison. This short project will show circuit breakers' vital role in substation dependability.

INTRODUCTION

The substation serves as a crucial component inside a power utility, functioning as a primary connection point in the electrical energy transmission and distribution system. Additionally, they fulfill a virtual function in maintaining the dependability of the service. Several substations are built in Telangana with varying voltage ratings due to the varied power consumer demands.

Currently, the per capita electricity consumption in Telangana is at 1,394 kWh, although throughout India it is 1,100 kWh per capita, and in the United States, it amounts to 1,200 kWh per capita. Prior to the establishment of Telangana, there was a power shortfall ranging from 4 to 12 percent. Coal has been imported from Brazil. The calorific value (CV) of the subject in question spans a range of 3,000 to 6,000 calories per gram. However, the calorific value of the coal we possess falls within the range of 3,000 to 3,500 calories per gram.

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I. STUDY ON SUBSTATION EQUIPMENTS

SINGLE LINE DIAGRAM

The single-line diagram of a substation serves as a graphical depiction of its electrical elements and interconnections, facilitating the comprehension and examination of complex power distribution systems by condensing them into a simplified single-line style.

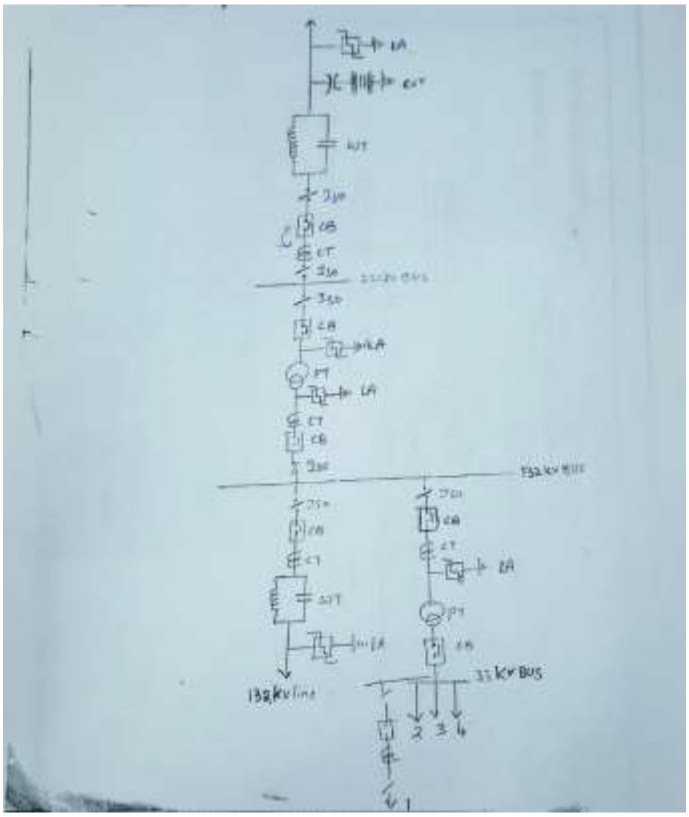

Fig. Single line diagram

TYPICAL OUTDOOR SUB-STATION

The transformer serves as the central component in any outdoor substation. The transformer is equipped with power supply and protective and control devices such as circuit breakers, current transformers, air break isolators, and lightning arresters. These components are installed on both the high voltage (HV) and low voltage (LV) sides of the transformer and are exposed to the surrounding air.

AN INDOOR SUBSTATION

The growing need for electrical energy in metropolitan regions and industrial zones has necessitated the direct implementation of high voltage systems in proximity to the load centers. Locating a suitable site for the installation of air-insulated switchgear may sometimes provide significant challenges, making the task arduous and perhaps unattainable. Simultaneously, in several regions, the air quality has significantly deteriorated, rendering the use of open-type

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insulation impractical due to heightened pollution levels. Huang et al. have introduced a unified configuration for a split-phase system designed for photovoltaic (PV) applications, using a Z-source inverter. The use of a configuration consisting of six switches running at high frequency is advised for applications that demand high power.

The Transmission Corporation of Telangana Ltd (TSTransco) has successfully started the operation of its most extensive 400kV transmission line. The recently implemented dual-circuit transmission line, equipped with quadruple moose conductor, spans a distance of 462 circuit kilometers. It connects the 400kV Suryapet substation located in Suryapet district to the 400kV Shankarpally substation situated in Rangareddy district. The infrastructure in question consists of two distinct components, namely Suryapet Nandiwanaparthi spanning a length of 240 kilometers, and Nandiwanaparthi-Shankarpally, which extends for a distance of 222 kilometers.

The fabrication mills and pharmaceutical industries need a supply voltage of 33 kilovolts (33kV). The Railways are equipped with a 25kv single phase power supply for its traction system. In the context of electrical supply, it is observed that movie theaters and small mills often get power at a voltage level of 11 kilovolts (11kV). Conversely, the requirements of household customers are generally confined to lower voltage levels of 440 volts (440V) and 230 volts (230V).

II. CIRCUIT BREAKER

The electrical circuit breaker is a versatile device that serves the dual purpose of manual and automated operation, enabling it to effectively manage and safeguard electrical power systems. Given the substantial currents handled by the contemporary power system, it is essential to prioritize the meticulous design of circuit breakers to ensure the secure interruption of arc formations that occur during their operation. The above statement is a rudimentary explanation of a circuit breaker.

The contemporary power system manages a vast power network and a substantial quantity of interconnected electrical devices. During instances of short circuit faults or other electrical faults, both the equipment and power network experience a significant surge of fault current, potentially resulting in irreversible damage to the equipment and networks.

In order to preserve the integrity of the equipment and power networks, it is essential to expeditiously eliminate the fault current from the system. Once the issue has been resolved, it is essential for the system to promptly restore its normal operational state in order to ensure the provision of dependable and high-quality electricity to the receiving terminals. Furthermore, the effective management of power systems necessitates the execution of various switching procedures. In order to ensure the safe and efficient disconnection and reconnection of various components within a power system network for the purposes of protection and control, it is essential to use specialized switching devices that are capable of operating reliably under high current conditions. During the occurrence of a significant current interruption, there is a likelihood of substantial arcing between the switching contacts. Therefore, it is imperative to exercise caution in order to safely extinguish these arcs inside the circuit breaker. The circuit breaker is a specialized device that performs necessary switching actions while current is being carried. This serves as a rudimentary overview of the circuit breaker.

TYPES OF CIRCUIT BREAKER

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According to there are quenching media the circuit breaker can be divided as

1. Oil circuit breaker
2. Air circuit breaker
3. SF6 circuit breaker.
4. Vaccum circuit breaker

According to their services the circuit breaker can be divided as

1. Outdoor circuit breaker
2. Indoor breaker

According to the operating mechanism of circuit breaker they can be divided as

1. Spring operated circuit breaker
2. Pneumatic circuit breaker
3. Hydraulic circuit breaker

According to the voltage level of installation types of circuit breaker are referred as

1. High voltage circuit breaker
2. Medium voltage circuit breaker
3. Low voltage circuit breaker

WORKING PRINCIPLE OF CIRCUIT BREAKER

The circuit breaker primarily comprises stationary contacts and mobile contacts. In the operational state of a circuit breaker, the two contacts are mechanically interconnected as a result of the applied pressure on the moving contacts. The operational mechanism of a circuit breaker contains stored potential energy, which is subsequently released upon receiving a switching signal. Various methods exist for storing potential energy in a circuit breaker, including the deformation of a metal spring, the use of compressed air, or the use of hydraulic pressure. However, irrespective of the origin of the potential energy, its release is necessary over the course of operation. The rapid sliding of the moving contact is facilitated by the conversion and subsequent release of potential energy.

Operating coils, including tripping coils and closure coils, are included in all circuit breakers. These coils are powered by a switching pulse, causing displacement of the plunger located inside them. The operating coil plunger is commonly affixed to the operating mechanism of a circuit breaker. This connection allows for the conversion of mechanically stored potential energy within the breaker mechanism into kinetic energy. Consequently, the moving contact is set into motion. The movement of these contacts is achieved through a gear lever arrangement that is mechanically linked to the operating mechanism. Following a complete operational cycle of a circuit breaker, the accumulated energy is discharged, resulting in the restoration of potential energy inside the circuit breaker's functioning mechanism. This restoration is facilitated by the use of a spring charging motor, an air compressor, or other methods.

III. OPERATING MECHANISM FOR BREAKER OPERATION

Examining the operational mechanism of a circuit breaker inside a substation with the aim of enhancing dependability is a complex and varied undertaking. The process starts with a thorough examination, including a detailed assessment of mechanical components to identify any signs of wear, alignment discrepancies, or damage. It is of utmost importance to ensure that electrical contacts are both clean and properly aligned, as any deviations from the desired condition might result in the occurrence of arcing and a subsequent reduction in dependability. Functional testing is a crucial aspect of verifying the seamless functioning of a system, whereby any deviations from expected behavior are meticulously observed and

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resolved. Ensuring regular lubrication and strict attention to maintenance requirements are crucial in mitigating friction and minimizing wear. The assessment takes into account environmental elements and the capacity for emergency operations, while also evaluating redundancy characteristics to determine alternative possibilities for backup operations. The overall dependability of the circuit breaker and the continuous delivery of electrical power in the substation are contingent upon the implementation of comprehensive documentation and thorough operator training.

Fig: operating mechanism for breaker operation

It is crucial to use a complete methodology in order to analyze and sustain the operational mechanism of circuit breakers, since this is essential for ensuring reliable power distribution. Mechanical and electrical integrity are maintained by the implementation of comprehensive inspections, meticulous alignment procedures, and rigorous functional testing. Reliability is enhanced by the use of strategic maintenance practices, environmental precautions, and contingency measures like as redundancy and emergency operation. In the meanwhile, meticulous record-keeping and comprehensive training of operators serve as protective measures against potential operational mistakes. This extensive examination highlights the circuit breaker as a crucial element of the substation's architecture, playing a vital role in maintaining a continuous power supply and a robust electrical distribution system.

IV. CALCULATION OF CIRCUITBREAKER OPENING AND CLOSING TIMINGS OF CIRCUIT BREAKER

The primary characteristics that must be taken into consideration during the construction of a circuit breaker are the stroke distance between contacts and the velocity of the moving contacts during operation. The contact gap, traveling distance of moving contacts, and their velocity are contingent upon the specific characteristics of the quenching medium, as well as the current and voltage rating of a circuit breaker. The graph below illustrates the operating characteristic curve of a standard circuit

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breaker. In the provided graph, the horizontal axis is denoted as the X-axis, which represents time measured in milliseconds. Conversely, the vertical axis is labeled as the Y-axis, representing distance measured in millimeters.

At time T0, an electric current begins flowing through the closing coil. Following time T1, the mobile contact starts its movement towards the stationary contact. At time T2, the moving contact establishes physical contact with the stationary contact. At time T3, the moving contact achieves its closed position. The period of overload for both the moving and stationary contacts is denoted as T3 - T2. After the passage of time T3, the moving contact undergoes a little rebound before returning to its original closed position at time T4.

Next, we will discuss the tripping operation. At time T5, electrical current starts its flow via the trip coil of the circuit breaker. At time T6, the motion of the contact starts a retrograde trajectory in order to facilitate the separation of the contacts. Following the passage of time T7, the mobile contact ultimately separates from the stationary contact. The time interval (T7 - T6) represents an overlapping period. At time T8, the moving contact returns to its ultimate open state. However, it does not reach the rest position immediately, since there is a mechanical oscillation of the moving contact before it settles into its final resting position. At time T9, the moving contact reaches its ultimate stationary position.

AN OVERVIEW OF DYNAMIC CONTACT RESISTANCE MEASUREMENT OF HV CIRCUIT BREAKERS

The maintenance of circuit breakers deserves special consideration because of their importance for routine switching and for protection of other equipments. Electric transmission system breakups and equipment destruction can occur if a circuit breaker fails to operate because of a lack of preventive maintenance. Dynamic Contact Resistance Measurement (DCRM) is known as an effective technique for assessing the condition of power circuit breakers contacts and operating mechanism.

V. CONCLUSION

In conclusion, the analysis of a circuit breaker in a substation with the aim of improving reliability is a crucial and proactive undertaking that forms the foundation of a resilient and trustworthy electrical power distribution system. The primary aim of this detailed research is to ensure the continuous provision of electrical power to customers and mitigate the occurrence of unforeseen power outages. Through a comprehensive analysis of the operational aspects of the circuit breaker, including its mechanical and electrical constituents, performance attributes, environmental factors, and adherence to safety standards, it becomes feasible to discern potential vulnerabilities, modes of failure, and avenues for improvement.

The enhancement of circuit breaker dependability is achieved by the introduction of predictive maintenance techniques, efforts to optimize performance, and the integration of redundancy and backup systems. Furthermore, the inclusion of aspects such as thorough documentation and comprehensive operator training significantly contribute to the maintenance and long-term sustainability of the improvements attained via this research. The examination of a circuit breaker in a substation is not solely a process of assessing the equipment; rather, it represents a proactive commitment to enhancing the robustness and reliability of the overall electrical distribution system. This commitment ultimately guarantees the uninterrupted provision of electricity, the continuous operation of industries, and the

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sustained connectivity of communities, even in the presence of electrical difficulties.

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