The importance of preventative maintenance in a substation

Author: Pinky Seshabela, Business Development Manager, Alectrix (Pty)Ltd
Co-Author: Martin Masemola, Sojo SA

1. Introduction

The paper emphasizes the crucial role of preventive maintenance in mitigating revenue loss by guaranteeing the reliability and efficiency of primary and secondary equipment within a substation environment. Malfunction of electrical equipment may result in voltage fluctuations, adversely affecting linked devices and systems. Routine maintenance is crucial for assessing equipment condition, preventing unanticipated outages, and mitigating risks such as accidents, equipment malfunction, power disruptions, and adverse environmental effects. Regular maintenance yields long-term cost savings ensures a consistent electrical supply and guarantees adherence to rules and standards. This study underscores the need for comprehensive inspections, testing, repairs, and documentation to monitor equipment history and strategize future maintenance actions, therefore prolonging equipment lifetime and yielding substantial long-term cost savings.

Utilities and power grid operators may maximize the efficiency and dependability of substation equipment via, predictive analytics, condition monitoring, proactive maintenance and cybersecurity measures. This will reduce the likelihood of power outages, equipment damage, and legal penalties.

Disruptions in substations may result in significant repercussions for both utilities and customers. The malfunction of a substation may lead to power outages, resulting in financial losses and interruptions for companies. A minor power outage may cause substantial disruptions and financial repercussions in critical sectors such as healthcare, industry, mining, data centres, and businesses. The effect of downtime on home customers reliant on power for essential activities, such as cooking, heating, and charging electric vehicles, is a major concern.

The health of the assets in a substation has a substantial impact on the overall reliability and availability of the electrical network. Considering the network's ageing installed base, planning and operation managers, as well as maintenance staff, are actively pursuing solutions to optimize the performance of their installed assets at a minimum total cost of ownership. Asset administrators have the option of either replacing the existing device with a new one or keeping it in service. The Substations System consist of Transmission Lines, Instrument Transformer, Busbar, Disconnectors, Surge Arrestor, Power Transformers and Breakers. The paper will focus more on Transformer and Breaker periodic testing.

2. Non-quantifiable costs

When an asset malfunctions, there will be a corresponding effect resulting from that failure. For instance, the absence of network redundancy may lead to a disruption in delivery to consumers or possible bodily harm due to a catastrophic failure. These repercussions are termed consequences of failure, and they will vary considerably based on the asset, its condition, as well as its surroundings and location. Some of the costs associated with are as follows:

2.1 Financial

The repair cost of assets may result in, component replacement, decommissioning, transportation, installation material, labour rates, reputation even lawsuits.

2.2 Environment

Probability analysis suggests that a failure may lead to an accident, severe injury, or mortality, affecting both firm employees and the public. In evaluating safety, several elements are assessed and scoring standards used. This may not be translatable into a cost estimate, owing to ethical considerations and complexity.

2.3 Safety

Various elements are evaluated, often dependent upon the user's sensitivity to each, influenced by law, exposure, prior experiences, and similar considerations.

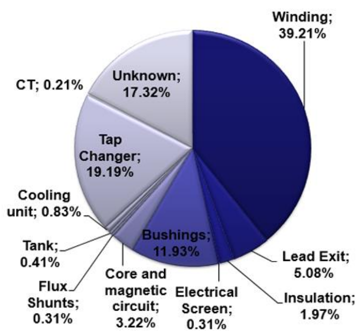
2.4 Network Performance

This is determined in every country, although using various methodologies. The primary factors are to the quantity of consumers affected by an asset failure and the length of those disruptions. The variations will be significant, both across different assets and across various regions.

3. Transformer Maintenance Strategy

Power transformers typically have a design life of between 25 and 40 years; however, there are instances where they have survived for as long as 60 years. When transformers are becoming older, it is essential to make an accurate prediction of their lifespan to prevent unexpected shutdowns. A power transformer's lifetime is primarily influenced by the condition of its paper-oil insulation system, which must be able to tolerate high temperatures, extreme electromechanical pressures, and enormous electric stresses to provide adequate protection against damage. It is possible for certain components of the transformer, such as bushings and tap changers, to be the reason for the transformer failure. On the other hand, they are simpler to repair or replace than the windings and insulation contained inside the transformer. As a result, the estimate of the remaining lifespan of a power transformer is primarily focused on the heat depreciation of the paper insulation. A typical 10MVA transformer can cost up to R5 million excluding labour.

The figure below shows the failure location analysis according to transformer application in units with voltages above 100kV respectively. The winding and tap changer are major failure sources and the tests were conducted on 536 failures recorded by CIGRE WG A2.37.



3.1 Recommended tests done on a Power Transformer:

1. **Transformer Turns Ratio** measurements are performed to verify the fundamental operating principle of a power transformer. By measuring the ratio and phase angle from one winding to the other, open circuits and shorted turns can be detected.

2. **Exciting Current** measurements are performed to assess the turn-to-turn insulation of the windings, the magnetic circuit of a transformer as well as the tap changer.

3. **DC Winding Resistance** are performed to assess possible damage in windings or contact problems, such as from the bushings to the windings, the windings to the tap changer, etc

4. **Dynamic Resistance Measurements** are performed as a supplementary measurement to analyze the transient switching process of a resistive diverter OLTC. It investigates the switching process of the diverter switch itself. When switching the tap changer during winding resistance measurements, the DC current temporarily decreases and this behaviour is recorded and analyzed.

5. **Static winding resistance measurements** are the most common and easiest way to check for issues regarding the winding and OLTC. It investigates the resistance of each subsequent tap position and compares it with the reference measurement data of the manufacturer.

6. **Short Impedance /Leakage Reactance** measurements are sensitive methods to assess possible deformation or displacement of windings

7. **The Frequency of Stray Losses** test is a measurement of the resistive component of the short-circuit impedances at multiple frequencies. It is the only electrical method to identify short-circuits between parallel strands and local overheating due to excessive eddy current losses

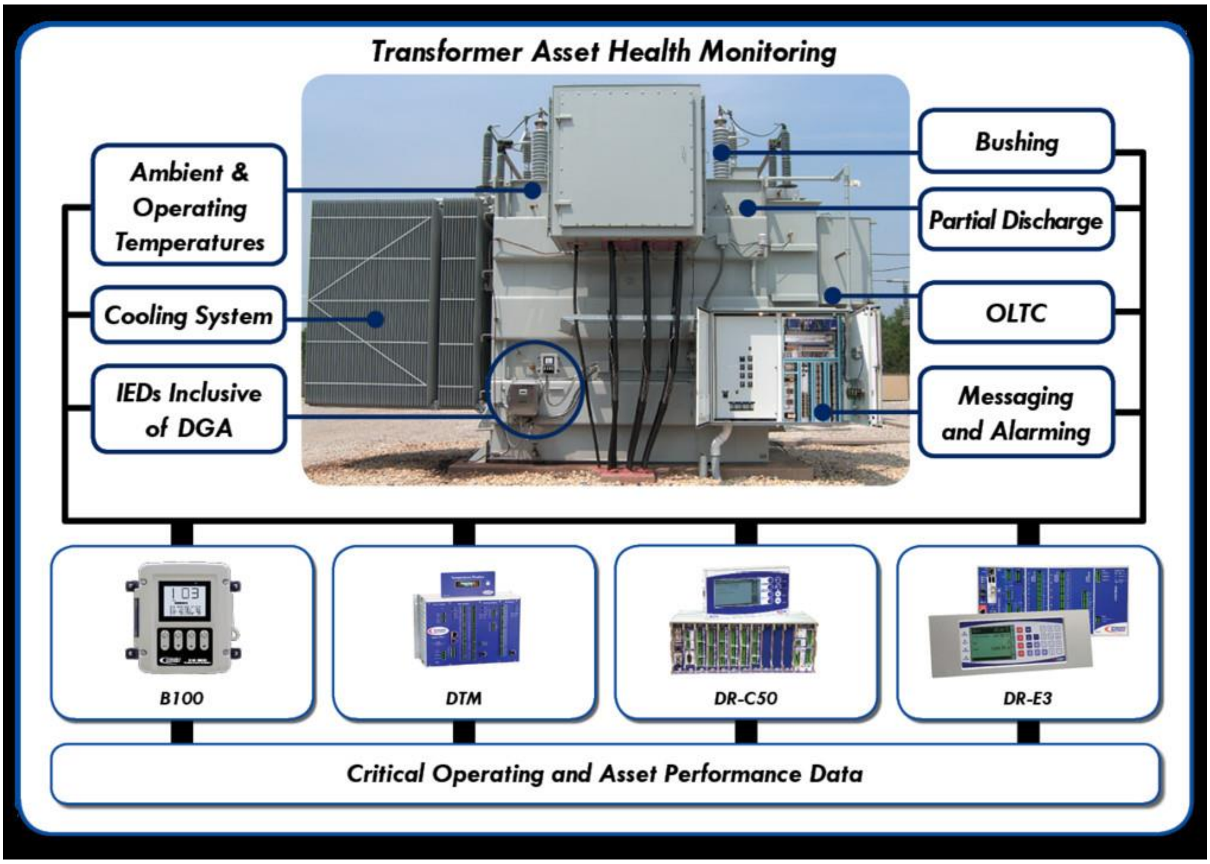
8. **Sweep Frequency Response Analysis (SFRA**) is used to identify mechanical or electrical problems in power transformer windings, contacts or cores. Severe short-circuits or shocks during the transformer's transportation may cause the winding to move or become deformed.

9. **Dielectric response analysis** is used to assess the moisture content of the cellulose insulation and, thus, determine its condition.

3.2 Conditioning Monitoring

An online monitoring system is more suitable for power transformers, aimed at ensuring a dependable electrical power supply while minimizing maintenance costs and optimizing the use of the active component. To assess the risk of unforeseen failure, it is essential to evaluate both the potential effects and the likelihood of failure happening. According to the CIGRE Transformer Reliability Survey, about one in every 200 transformers experiences failure annually. Another research indicates that significant failures incur around R2 million per MVA in property damage. Unforeseen failures may result in significant costs.

Transformer monitoring methods differ according on the sensors used, the parameters assessed, and the measurement techniques utilized. As monitoring equipment is often affixed permanently to a transformer, it must be both dependable and cost-effective. Figure below illustrate online transformer diagnosis and monitoring concept.



4 Circuit Breakers Maintenance

Malfunctioning circuit breakers that do not trip correctly during a fault may lead to flames, equipment damage, and increased arc flash hazards which may put maintenance team lives at risk. Circuit breakers may stay inactive, either in an open or closed state, for prolonged durations, limiting the identification of maintenance requirements. The need to predict the effective operation of circuit breakers has grown as transmission networks have developed and sent larger amounts of electricity to customers. A primary objective for doing circuit breaker maintenance is to achieve long-term cost savings. A single failure might incur costs many times more than standard maintenance and lead to significantly increased downtime. A typical Vacuum MV breaker can range from R150 000 to R450 000. MV Breakers

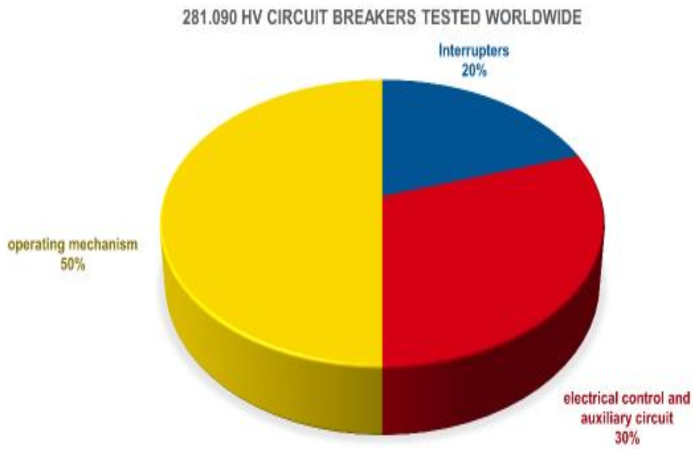
4.1 Different Types of Breakers

SF6 Breakers, GIS and MV Breakers



4.2 Failure Statistics

The CIGRE Working Group (WG A3.06) conducted a global survey that analysed 281,090 circuit breakers in utility applications that were above 60kV. The survey categorized the origins, causes, and failed subcomponents of 840 main faults and 6,655 minor faults. A statistic, as illustrated below, emphasizes the outages that are caused by the primary components of circuit breakers.



4.3 Below are typical tests done on MV Breakers

1. **Static Contact Resistance** this test checks the status of the main contact/bus bar junctions, ensuring they can carry the rated current with minimal losses.

2. **Timing** this assessment ensures the circuit breaker operates safely and reliably.

3. **Motor Current** this test detects issues with the motor or operating mechanism drive, such as insufficient lubrication or problems with the spring/hydraulic/pneumatic drives.

4. **Coil Current** this test identifies potential problems in actuating coils.

5. **Minimum Pickup** this test checks the lowest voltage required to operate the trip or close coil, ensuring the circuit breaker responds correctly under low-voltage conditions

6. Conclusion

While the natural ageing process is inevitable, conducting maintenance on transformers and circuit breakers might mitigate early deterioration. The maintenance helps utilities save costs, prolong equipment life, increase energy efficiency, and encourages satisfy customers. By continuously monitoring the condition of transformers utilities can spot and address issues before they become major issues, reducing equipment breakdowns and electrical issues. A thorough maintenance program, new technologies and tools, and training and skill development may help utilities maximize maintenance efforts and ROI operators can take proactive steps to address any potential problems and prevent costly failures.

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