



The importance of maintenance of designated technical equipment - kiosk substations 22/04 kV

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Abstract: Transforming stations 22/0.4 kV are endpoint devices that provide power to individual consumers in distribution grids. In addition to voltage transformation from MV (medium voltage) to LV (low voltage), they are also the starting point for secured low-voltage distribution. Due to their most common occurrence in outdoor environments, regular inspections are necessary for preventive reasons. It is important to emphasize the need and procedure for the course of preventive inspections or functional tests of transforming stations. The article describes in more detail the specific activities performed during the functional testing of transforming stations.

Keywords: transforming stations, functional test, kiosk substation, distribution grid, maintenance schedule.

1. Introduction

The distribution grid constitutes critical infrastructure that enables the transmission of electrical energy from generation sources to customers and is crucial for the operation of companies and households. Currently, the energy sector faces many challenges, including growing electricity consumption, increasing production costs, the need to reduce emissions, and improve energy efficiency. In response to these challenges, the energy sector strives to enhance the performance of the distribution grid and increase the utilization of renewable energy sources. A modern distribution grid aims to improve its efficiency and reliability. One of the main trends is the use of smart technologies for monitoring and managing the distribution grid. These technologies include smart metering

systems, sensors, and software systems that enable real-time monitoring and control of energy flow. The distribution grid must also address new challenges related to the utilization of renewable energy sources. These sources are often connected to the distribution grid, which means they must be properly integrated into the grid to minimize potential power outages and ensure a stable supply of electricity to end consumers.

Currently, there are increasing demands placed on the reliability of energy facilities in their operation. In addition to their technical-operational aspects, economic aspects are also coming to the forefront. Transformer stations are critical components in the distribution grid as they ensure the transmission and distribution of electrical energy between different voltage levels [1].

We can define an electric station as a comprehensive system node of the power grid, fulfilling the following tasks:

- Distribution of electrical energy and its transformation to other voltages while maintaining the same frequency.
- Distribution of electrical energy at the same voltage and frequency.
- Transformation of alternating voltage to another frequency or to direct voltage and utilization of this type of energy.
- Regulation or alteration of transmission parameters to balance the reactive components of alternating current.

According to their purpose, the following types of transformers are distinguished in the field of energy:

- Unit transformers, which are in series with the generator. They are used in power plants that do not have direct consumption at generator voltage. In terms of the number of windings, transformers with two or three windings are used. From a construction standpoint, they can be single-phase or three-phase units.
- Interconnecting transformers, which are used to connect two electrical stations with different voltages. Three-phase transformers are used for transformation between very high voltage (VHV) and high voltage (HV). When connecting VHV systems, three-phase, single-phase, or autotransformers can be used.
- Distribution transformer or self-consumption transformer, meaning three-phase transformers with input voltage at MV or LV.
- Isolation transformers, which have a 1:1 ratio and electrically isolate production sources from external lines, thereby protecting against atmospheric overvoltage's or serving to reduce short-circuit currents.

There are also transformers designed for specific purposes that do not provide electrical energy distribution. These transformers are designed for special applications, including transformers for arc furnaces, induction furnace transformers, medium-frequency transformers, dispersal transformers, resistance

welding transformers, spot and seam welding transformers, starting transformers, test transformers, chokes and reactors, and current transformers (CT) or potential transformers (PT).

The annual increase in electric vehicles, new electric stations will also be required to provide power to these new devices. To minimize space requirements, kiosk stations emerge as a simple and practical solution that can be implemented for any parking lot or highway rest areas. The currently most widespread kiosk stations have external dimensions of 2900x1800x2500 mm (LxWxH).

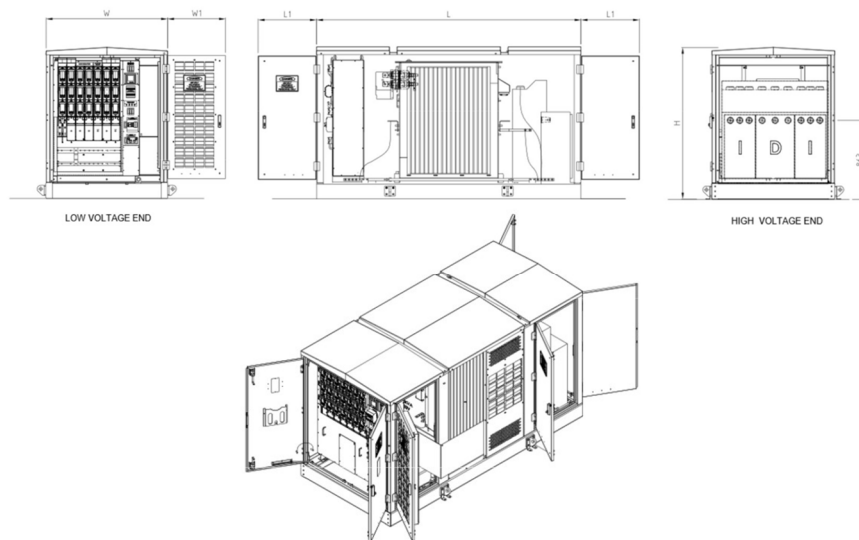


Figure 1.: Kiosk Substation and Switching Station [2].

In comparison to traditional electric stations, these dimensions are remarkably compact, making them ideal for installations in tight spaces or areas with limited real estate. For the integration of the maximum number of protective and measurement devices into such stations, further development is still necessary to achieve even more compact dimensions and increased safety. This is particularly important given the trend towards decreasing the size of these devices, necessitating innovations in design and technology to ensure optimal functionality while maintaining a smaller footprint.

The input voltage to the transformer is selected from a range of nominal voltages. The output voltage is usually about 5% higher. If the transformer converts higher voltage to lower voltage, it is called a step-down transformer, and if it converts lower to higher voltage, it is called a step-up transformer. When the input and output voltages are the same, the transformer is called an isolation

transformer, which serves to galvanically separate two grids. The nominal transformation ratio pp of the transformer is given by the equation:

$$pp = \frac{U_1}{U_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} \quad (1)$$

Where: U_1 represents the primary voltage, N_1 is the number of turns in the primary winding, I_1 is the primary current, U_2 represents the secondary voltage, N_2 is the number of turns in the secondary winding, and I_2 is the current on the secondary, or output, side.

Transformers for high and low voltage distribution are used as load regulating transformers. On the primary winding, taps are available with values of $\pm 5\%$ or $\pm 7\%$ from the average value, which may be mechanically interconnected only when the transformer is disconnected from the voltage, i.e., in a de-energized state. This voltage regulation is used to eliminate the influence of voltage drop on long lines and to compare voltage ratios at different points in the distribution grid.

Article [3] addressed the issue of the impact of electric and magnetic fields on the surroundings of an electric station. Over the past three decades, concerns about the potential effects of exposure to low-frequency magnetic fields on the public have significantly increased. Many epidemiological studies suggest that exposure to such fields correlates with various types of cancer. Measurements of these fields around a 630 kVA kiosk station were conducted in the low-frequency range. The measurements took place in a park in the center of the city of Chania, Greece. The results confirmed values lower than $100\mu\text{T}$ for all measurements, a threshold introduced by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and The European Committee for Electrotechnical Standardization (CENELEC). These standards have led many countries to adopt limits for recommended maximum exposure to the public.

Article [4] addressed the issue of online station monitoring for maintenance purposes. The article proposes the utilization of smart devices for measurement and the transmission of information via Zigbee to a central terminal, from where the data will be sent to a central server for evaluation. In the article, a monitoring model was constructed using fuzzy mathematics, which implements online monitoring of the operational safety of the substation environment. Experimental results demonstrate that this method effectively addresses problems present in traditional methods, with a total monitoring time shorter than 1.5 seconds and high accuracy in monitoring results, fully confirming the efficiency of this approach.

2. Functional Test Procedure on Dedicated Technical Equipment

The preventive maintenance procedure (PMP) is a compilation of rules and instructions for conducting regular preventive maintenance for DTE (dedicated technical electrical) equipment, in this case, a transformer station (TS). The company VSD a.s. has developed these instructions independently and summarized them into Technological and Safe Work Procedures [5]. Each distribution company establishes its own rules. Before starting work, it is necessary to properly mark and secure the workplace. Additionally, before starting measurements, it is necessary to establish a procedure and brief other colleagues on it. Before requesting permission to shut down the equipment, voltage, current, and impedance of the fault loop on the LV part of the distribution transformer station MV/LV are measured. After measuring these quantities, permission to shut down the equipment is requested via telephone communication with dispatch. Upon the dispatcher's instruction, the MV disconnecting switch is turned off at the exact designated time, and the time of disconnection is reported. Before starting work at the substation, a Work Order B must be issued to secure the workplace and work activity, and a notification must be made to dispatch, along with an announcement of the planned work operation. Measurement of voltage, current, measurement of fault loop impedance and short-circuit current can indeed be conducted remotely, as described in the first chapter of article [4]. This capability will lead to a reduction in maintenance and inspection time for the kiosk station.



Figure 2.: The front side of the low-voltage switchgear (LVSG) type RST.

The next steps in the preparatory phase (in accordance with STN 343100) include testing, short-circuiting, or grounding, fencing, and labeling of the workplace. Testing for de-energized state means verifying in a safe and reliable manner that the electrical equipment and all its components on which work will be performed are de-energized on all poles, phases, and conductors [6].

In so-called kiosk substations, where MV switchgear is located, it is not necessary to use MV short-circuiting devices. MV switchgear is equipped with a short-circuiting system based on a disconnect switch principle, which, when switched by the worker, simultaneously short-circuits all three phases of the MV supply. For safety reasons, this short-circuiting disconnect switch is blocked in such a way that it can only be manipulated after the equipment is disconnected from the MV supply.

A kiosk substation is a type of distribution substation that is encapsulated and placed in outdoor environments, typically in areas with limited space, such as residential or industrial zones. This substation is enclosed by a concrete structure and contains the same elements as other types of substations (e.g., pole-mounted). They occupy less space, are compact, have a more aesthetically pleasing appearance, are easier to maintain, and the high-voltage input is located underground, with all live parts covered, providing higher safety for the operating personnel. All doors are designed to prevent access to the interior of the substation.

After performing the initial tasks that are part of the substation functional test, measurements of basic parameters are carried out. These include phase voltage, line voltage, current loading of all three phases, and fault loop impedance. These measurements are conducted using measuring instruments directly at the input of the main circuit breaker (main switch) of the substation.

Voltage was measured using conventional instruments designed for this purpose by attaching contact electrodes depending on the type of voltage being measured, either to the PEN terminal and phase for phase voltage, or to the two-phase conductors for line voltage. According to [7] the allowable voltage tolerance in the distribution network is $\pm 10\%$ from the rated voltage value. This represents values ranging from 207 volts to 253 volts. Additionally, the rated load is measured on the supply conductors to the main protective device of the substation. This value is used to monitor phase overload. It is typically measured using clamp ammeters.

An important measurement conducted nowadays is the measurement of fault loop impedance and short-circuit current. Fault loop impedance is measured to determine how quickly the protective device will trip and whether it is appropriately sized. Fault loop impedance is calculated as the ratio of fault voltage to fault current flowing through this loop. This ratio is also referred to as

"short-circuit impedance." Measuring fault loop impedance is crucial for the proper functioning of the protective system of electrical systems and for minimizing the risk of equipment damage or endangering the health and lives of individuals.

Measurement of the grounding resistance of the neutral point of the substation source is typically conducted only when the system is in a de-energized state. After setting the instrument for grounding resistance measurement, it's necessary to place the measuring earth probes in the space and connect them properly to the ground. To achieve a relevant measurement result, it's essential to disconnect all possible connections of the grounding system with protective conductors before the measurement. The measurement terminal of the instrument is then connected to the grounding system of the substation. A similar procedure is also used for measuring the overall grounding of the distribution substation.

2. Evaluation and Recommendations for Practice

According to [7] the voltage in the distribution network must not exceed 10% of the rated voltage value. This means that the voltage in the distribution network must be within the range of 207 V to 253 V (phase voltage). The measured voltage values (243 V, 243.8 V and 244V) were in accordance with the standard, and there is no need for any adjustments or changes in the tapping of the transformer.

The measurement of the fault loop impedance in the LV switchboard of the transformer station serves to verify or control circuits, connections, and other parts of the switchboard and their potential damages. In practice, it often happens that even minor contamination, such as bird droppings, causes oxidation of conductors or contacts of various circuit parts, resulting in increased values of fault loop impedance. The measured impedance values (0.05 Ω , 0.06 Ω and 0.06 Ω) indicate that the circuits of all three phases of the transformer station are in order, and the connections are not damaged or otherwise compromised anywhere, which would lead to an increase in the value of the fault loop impedance.

Grounding of the transformer station is a critical safety feature that must be regularly inspected and measured (0.33 Ω). According to STN 33 3201, the requirement for the grounding of transformer stations is not to exceed the value of 2 Ω . The grounding of the neutral point of the transformer station, or the so-called separate grounding, is measured during functional testing only for preventive purposes. This measurement determines the condition of the grounding system.

During the initial inspection of the transformer station as part of the functional testing, it would be beneficial to use a thermal camera. In the field of transformer stations, the use of a thermal camera is highly valuable. This modern tool can

detect thermal anomalies, allowing for the identification of overheating, overload, or faults inside transformers, main switches, and other components. With the help of a thermal camera, it is possible to inspect the equipment of the transformer station and identify potential problems before any damage occurs. Using a thermal camera can also enhance operational safety by preventing hazardous situations such as overheating or fire outbreaks. Overall, a thermal camera is a highly suitable tool for diagnosing and monitoring transformer stations.

Digital control systems with smoke and temperature sensors enable automated monitoring of transformer stations and early detection of fires or other hazardous situations. Integrating them with a remote alarm at the dispatching center allows for an immediate response in case of any issues. Smoke sensors detect smoke and can activate an alarm, while temperature sensors monitor thermal conditions inside the stations. If the sensors detect a significant increase in temperature, the dispatching center is promptly alerted, enabling quick identification and resolution of problems, minimizing the risk of fire and damage to equipment.

Measuring the insulation resistance of the transformer in the de-energized state is an important diagnostic method. These measurements focus on checking the quality of insulation and detecting possible problems such as insulation material faults, moisture, corrosion, or other deficiencies. Insulation resistance measurements of the transformer allow for the detection of potential weak points, reducing the risk of electrical faults and transformer failures. Typical measurements include insulation resistance measurement, insulation resistance over time measurement, low voltage testing, and moisture measurement. Insulation resistance measurements help identify potential problems early and enable actions to address them. Due to the time-consuming nature of these measurements, where the transformer needs to be completely disconnected from both the primary and secondary sides, such measurements could be performed every other functional test, meaning once every eight years. By incorporating these measurements into the functional test performance, insulation failure can be prevented, ensuring even greater reliability of transformer operation or transformer station.

3. Conclusion

The aim of the article was to outline the importance and process of inspection, or preventive maintenance, while adhering to all regulations, safe work procedures, and rules from the initial visual inspection to the re-energization of the TS and its return to operation. The article detailed specific activities performed during the functional test of the TS. After the initial visual inspection, the process continues with parameter measurements and testing of the substation's performance characteristics, checking all its components, and all other necessary

activities during the functional test. Measurements of basic parameters such as voltage, current, fault loop impedance, and grounding were conducted at the substation, and they were evaluated as satisfactory. These equipment functionality tests at the substation are crucial for ensuring the safety, reliability, and optimal functioning of the distribution system. Based on the findings, targeted improvements in work and technological procedures were proposed, which could contribute to a more efficient and effective implementation of functional tests for substations, whether using a thermal camera during the initial inspection of the substation or the utilization of various modern technologies for early identification of possible damage or complete destruction of the substation, for example, by fire.

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