ALTERNATIVE METHODS FOR TESTING THE POLE-TO-GROUND INSULATION OF THYRISTOR VALVES IN UHVDC SYSTEMS

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Abstract: In the design of DC system, more than one MVU tower may be used between pole-to-neutral voltages. This is especially common for UHVDC systems. The insulation design of these MVU's need to be verified by dielectric type tests as specified by international standards. However, the application of several MVU's in series makes the test set-up complicated. One straightforward solution is to install all valve towers under the pole to neutral voltage for the dielectric tests. This multiple-tower solution brings with it the complexities and risks. This test set-up puts also high demands on the space and mechanical strength of the laboratory. From project engineering point of view, to assemble before the dielectric type tests and then to disassemble such a large test object is a labour and time consuming task. An alternative is to install only one valve tower with external voltage sharing components. Reduced complexity and risk are the main advantages to use the one-tower set-up. Such a one-tower set-up is a flexible solution with regard to the voltage at the terminals of valve towers. It has also advantages over multiple-tower set-up, with respect to requirement on laboratory conditions, labour and time consumptions. In this paper, the alternative test set-up's for the MVU dielectric tests are presented.

1 INTRODUCTION

In an HVDC system, depending on the system requirements, the DC pole voltage can be obtained with a six-pulse valve group, a twelve-pulse valve group, or two series connected twelve-pulse valve groups. Each valve function in such a group is formed by a number of series connected thyristors, called as a single valve. Shown in Figure 1 is the electric connection of single valves in a twelve-pulse valve group.

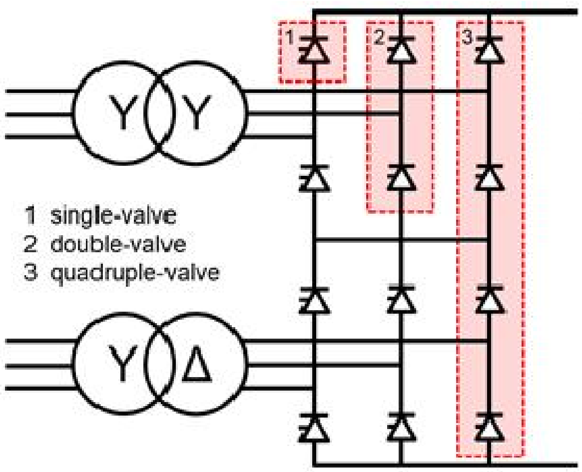

Figure 1: Typical connection of a twelve-pulse valve group.

To achieve an optimized valve hall and station layout, taking into account the insulation requirement and mechanical constraints, a suitable number of single valves in the valve groups may be integrated into one mechanical structure, i.e., a valve tower. Such a valve tower is referred to as a Multiple-Valve-Unit (MVU). Typically a MVU may contain two or four single valves and is referred to as a double-valve or a quadruple-valve, as shown also in Figure 1. These MVU valve towers are installed inside the valve hall with necessary insulation distances to its surrounding. Shown in Figure 2 is a quadruple-valve tower.

Figure 2: A quadruple-valve tower at test installation.

With the increase of DC pole voltage, the number of series connected thyristors will be increased. Consequently, the height of the valve towers and the insulation distances required will also need to be increased. The height of a valve tower may become so high that more than one tower will be needed to include all the series connected single valves. This is especially the case for UHVDC systems. In a few 800 kV projects, four double-valves have been used in series under one pole voltage, as shown in Figure 3 [1].

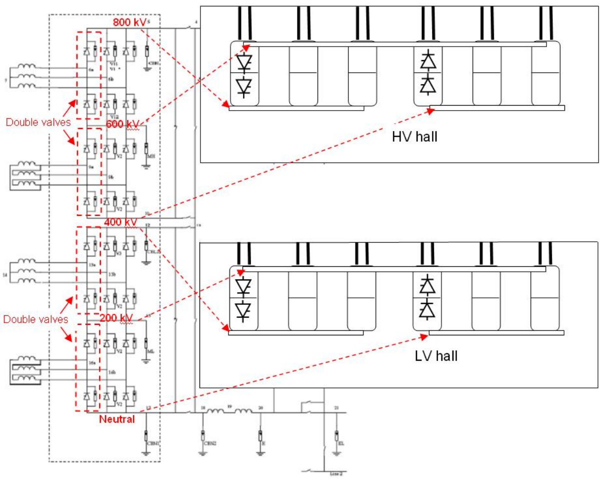

Figure 3: An 800 kV UVHDC system with two twelve-pulse valve groups at each pole and related valve hall arrangement with double-valves.

The insulation distances surrounding these MVU's need to be verified by dielectric type tests as specified by the international standard [2]. However, the application of several MVU's in series makes the test set-up complicated. In this paper, the requirement and constraints involved in the dielectric tests of MVU are discussed. An alternative test set-up, with only one valve tower for the MVU dielectric tests is presented.

2 REQUIREMENT AND CONSTRAINTS

2.1 Insulation requirement

In the valve design and testing, the insulation design between different components and inner structures of each single valve is handled in the single valve level. The insulation for a MVU, e.g., a valve tower, is in the most cases only external insulation. The external insulation is the air insulation between valve towers and neighbouring objects with different potentials, such as the ceiling, floor and the walls of the valve hall or other valve towers.

For air insulation between valve towers and neighbouring objects, under different waveforms of pole voltage, it is, in most cases, the slow-front transient, i.e., switching impulse that will dictate the required insulation distances. DC voltage is often the decisive voltage for the corona-free design. Fast-front transient, e.g., lightning impulse is, in most of cases, irrelevant to the external insulation design. This is because that the required insulation distance determined by switching impulse is longer than that determined by lightning impulse.

2.2 Verification

Converter valves are equipment with sensitive power electronic components, e.g., thyristors, as part of internal insulation. Rigorous verification of the external insulation directly on a completely assembled valve tower is unfeasible. In order to verify rigorously the design of external insulation with test procedures involving insulation breakdowns, e.g., the up-and-down procedure, it is necessary to use specially arranged test set-up. This is not the case for dielectric type tests.

For dielectric type tests with fully assembled converter valves compromise have to be made by replacing the rigorous verification with a simplified demonstration. Dielectric type tests on MVU are stipulated in IEC [2]. It is stated in this standard that the principal objectives of MVU dielectric tests are:

1. to verify the voltage withstand capability of the external insulation of the MVU with respect to its surroundings, especially for the valve connected at pole potential:

2. to verify the voltage withstand capability between single valves in a MVU structure:

3. to verify that the partial discharge levels are within specified limits.

For objective 1, relevant test voltages will be applied with limited numbers, e.g., 3 switching impulses at each polarity. If no breakdown has occurred, the test object is deemed to have passed the test.

Objective 2 is valid only for such a design that single valves are installed with terminals of different potentials near each other. Such design is very uncommon. Inside a valve-tower, single valves are connected in series. There is no insulation between the terminals of these single valves. Therefore, this objective is in most cases inapplicable.

Objective 3, is a rigorous and relevant requirement.

2.3 Constraints for dielectric tests

As shown in Figure 3, for this system, the pole voltage of 800 kV DC is supported by two 400 kV 12-pulse valve groups in series. These two groups are installed in separate valve halls, the high-voltage (HV) and the low-voltage (LV) valve halls. Each group can be operated separately, when the other group is taken out of service. This arrangement results in that total eight single valves are connected between 800 kV pole to neutral. These eight single valves are installed inside four double-valve towers. During operation, four of the eight single valves, one in each double-valve, will take the pole-to-neutral voltage while the other four in conduction. To test such a long link of single valves in MVU tests introduces some difficulties.

The valve functions under pole voltage is located between pole and neutral lines. However, as also indicated in Figure 3, the total pole-to-ground voltage, especially for the transient voltage is the sum of the pole-to-neutral voltage and neutral-to-ground voltage. Therefore, the insulation distances between the terminals of the valve towers to ground shall withstand pole-to-ground voltage which is often higher than the pole-to-neutral voltage. Special arrangements have to be made on the test objects during MVU tests to share correctly the pole-to-ground voltage.

For test objective 1, as give in previous section, the test voltage that will be applied during a switching impulse test is the so called switching impulse withstand voltage (SIWV). This is a margin added voltage value over the real operation conditions. During operation conditions, the voltage that may appear is the switching impulse protection voltage (SIPV). Commonly, and according to IEC recommendations, SIWV is 1.15 times of SIPV. Because that the SIWV value is higher than the arrester protection level i.e., SIPV, arresters cannot be connected during the test. In such a condition, the voltage sharing between single valves in the MVU tests cannot be ensured by the arrester as in real operation conditions.

The ambient conditions in a valve hall are often different from the standard reference atmospheric conditions. Therefore, the test voltage need to be adjusted accordingly, often to an higher value than SIWV. This leads to the situation that the test voltage for the external insulation is higher than the design voltage for the internal insulation.

The above constraints manifest themselves more for dielectric type tests on MVU's for UHVDC systems. In such cases, even the laboratory conditions, such as space and mechanical strength of the building may become constraints.

3 ALTERNATIVE SOLUTIONS

3.1 Test with multiple towers

With the system design as that in Figure 3, one straightforward solution is to install all four valve towers, each a double-valve, for the MVU tests. For the total eight single valves, four of them may be short circuited during the tests. However, to share the voltage between neutral and ground as well as the increased voltage due to the atmospheric correction, only three single valves could be short-circuited. Such a test set-up bring in certain technique complexities, i.e., to ensure the correct voltage sharing among the five active single valves.

Since arresters are removed, not as in real operation, under unexpected uneven voltage distribution, the valve internal insulation is not protected. Such unexpected uneven voltage distribution could be the result of unfavourable laboratory arrangement. There is also a risk that one of the single valves in this long link of valves might be triggered into conduction, accidentally, during a voltage application. As the result, the whole test voltage will have to be shared by other valves that have not yet been triggered. This could lead to the damage of the thyristors. Proper protection arrangement is necessary to reduce such a risk.

This set-up, with multiple valve towers, will also put a high demand on the free space and mechanical strength of the laboratory. Certainly, from project engineering point of view, to assemble before the dielectric type tests and then to disassemble such a large test object with four double-valves is a labour and time consuming task.

3.2 Test with one tower

With the same system design as in Figure 3, instead of setting-up four double-valve towers, the MVU tests can be performed with only one double-valve tower. In this solution, external components, like capacitors, resistors, and reactors will be used to replace other valve towers in order to share the test voltage. An example circuit diagram of this solution is shown in Figure 4.

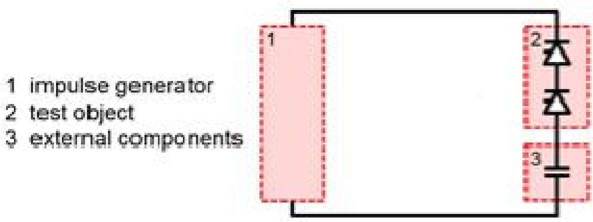

Figure 4: Circuit diagram of one valve-tower with voltage sharing external components during switching impulse test.

In this double-valve tower, one of the two single valves could be short-circuited. There is only one single valve that is active during the test. The risk of overstress the valve internal insulation can be eliminated by select the external components with suitable parameters. Even if this single valve is accidentally triggered into conduction, the full test voltage will only be applied on the external components, not on other valves. These external component shall be selected to be able to withstand the full test voltage with good margin.

Actually, one could also utilize both single valves in this double-valve structure to share the test voltage. With such a test set-up, with correctly selected external components, terminal to ground insulation of different valve towers at different voltage levels can be represented correctly. The precondition of applying this solution is the structure of all valve towers in the same project are identical from insulation point of view which is the case in most designs.

With such a one-tower set-up, the advantages over multiple-tower set-up, with respect to requirement on laboratory conditions, labour and time consumptions are obvious. Difficulties resulted by the increasing of DC pole voltage, as for UHVDC, is resolved. This one-tower solution has been successively applied by the authors on many projects from 500 kV up to 800 kV.

4 CONCLUSIONS

In the design of DC system, more than one MVU tower may be used between pole-to-neutral voltages. This is especially common for UHVDC systems. In such cases, for the MVU dielectric type tests, one could choose from to install all the valve towers or to install only one valve tower with external voltage sharing components. Reduced complexity and risk are the main advantages to use the one-tower set-up. Such a one-tower set-up is a flexible solution with regard to the voltage at the terminals of valve towers. It has also advantages over multiple-tower set-up, with respect to requirement on laboratory conditions, labour and time consumptions.

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