THE MOUNTING OF MEDIUM VOLTAGE SURGE ARRESTERS IN NEPTUNE CONNECTION. SIZING AND ADVANTAGES

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Abstract – In special situations, in industrial applications but also in electrical grids, overvoltages are not enough limited by surge arresters mounted between phase and ground. In these cases, surge arresters have to be mounted also between phases. The mounting of surge arresters in Neptune connection provides an efficient technical and economical alternative. This paper analyses the Neptune connection, the advantages it offers and the sizing of surge arresters for this connection.

Keywords: surge arresters, Neptune connection,

1. THEORETICAL CONSIDERATIONS

One way to limit accidental overvoltages in electrical grids, especially in the vicinity of electrical equipment, can be achieved by using surge arresters and, among those [7], the most effective are the surge arresters with metal oxides.

As a result, choosing the surge arresters based on their correct sizing is very important for them to be able to limit temporary overvoltages (U_t) at safe limits for the electrical equipment. The correct choice of the surge arresters, as well as choosing the right connections, can also bring economic benefits [2].

For an appropriate choice of the surge arresters, there are two important conditions in determining the maximum operating voltage in permanent regime (U_c), namely [1,5]:

- U_c - must always be greater than the industrial frequency voltage, in permanent operating regime, applied on the surge arrester;
- $k \cdot U_c$ - must always be greater than the temporary overvoltage (U_t) which is expected to occur on the surge arrester's clamps in accidental cases;

where:

k - overvoltage coefficient of the surge arrester that is determined based on estimated maximum duration of the temporary overvoltage (t);

given that:

$$U_t = k \cdot U_c \quad (1)$$

2. TYPES OF CONNECTIONS. NEPTUNE CONNECTION

In order to determine the maximum operating voltage in permanent regime (U_c), we have to take account of the way that the neutral of electrical grids is treated, the surge arrester's connection place (between phase and ground, between phases or between the transformer's neutral and ground) and, implicitly, the type of connection [2,4].

For example, for an electrical grid with bare or insulated neutral we have:

- for the surge arrester mounted between phases or between phase and ground:

$$U_c \geq U_m \quad (2)$$

- for the surge arrester installed between the transformer's neutral and ground:

$$U_c \geq \frac{U_m}{\sqrt{3}} \quad (3)$$

where:

U_m - the actual value of the maximum nominal voltage between phases in normal operating conditions

Generally, in electrical grids we find the connection from Fig. 1, where the surge arresters are mounted between phase and ground.

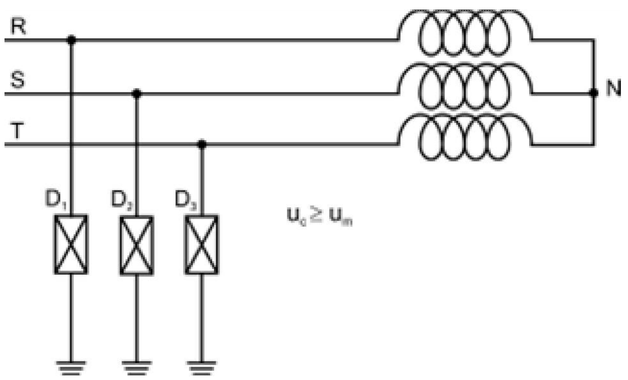

Fig. 1. Connection with 3 surge arresters

Sometimes in electrical grids or in industrial applications (for example at transformers that feed electric arc furnaces), mounting the surge arresters only between phase and ground is not enough to limit the voltage, especially in limiting switching voltages.

In this case, we have to mount six identical surge arresters to solve the situation, three between phases and ground and three between phases, as shown in Fig. 2.

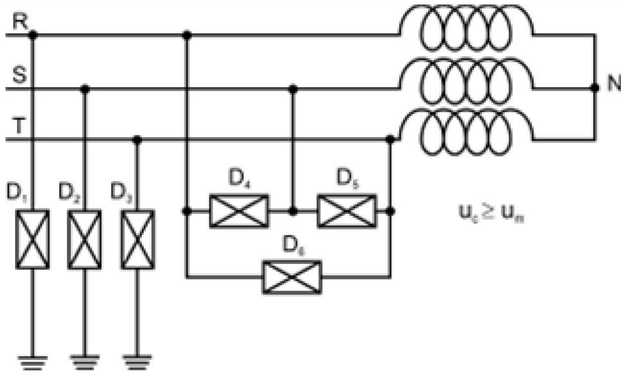

Fig. 2. Connection with 6 surge arresters

A modern way of solving the situation from the previous case is to choose a Neptune connection [3] using four identical surge arresters, as in Fig. 3.

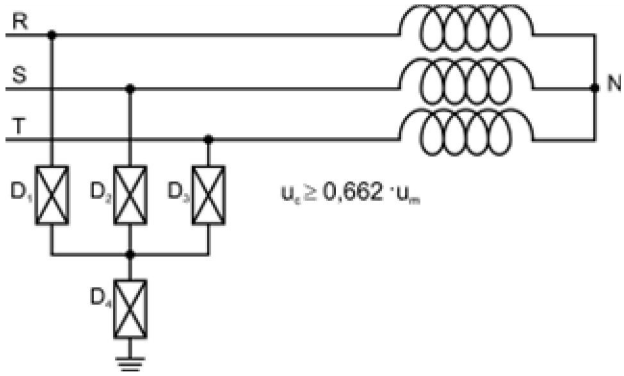

Fig. 3. Connection with 4 surge arresters. Neptune connection

As shown in Fig. 3., groups of two surge arresters are mounted in series both between phases (D1 - D2, D1 - D3, D2 - D3) and between phase and earth (D1 - D4, D2 - D4, D3 - D4), which shows that, theoretically, this connection is equivalent with the connection with 6 surge arresters and, moreover, the discharge values of the Neptune connection would be:

$$U_{c_{Neptun}} = 0.5 \cdot U_{c_{conex6}} \tag{4}$$

or:

$$U_c \geq 0.5 \cdot U_m \tag{5}$$

for the Neptune case connection [3,4].

In fact things are not like this. For example, for a fault with the ground on phase R, the surge arresters D_1 and D_4 are connected in parallel and, since the surge arresters working in permanent operating regime behave like capacities [6], we conclude that on the surge arresters D_2 and D_3 the following condition must be met:

$$U_c \geq 0.662 \cdot U_m \tag{6}$$

and since the four surge arresters must be identical, the relation (6) is valid when choosing the four surge arresters.

Given that the surge arresters are always two in series (both between phases and between phase and ground), it means that the effect is the same as having a single surge with:

$$U_c \geq 1.324 \cdot U_m \tag{7}$$

or that, in the case of Neptune connection, the level of protection is with 33% higher compared with the case of the connection with six surge arresters.

3. ECONOMICAL EQUIVALENCE FOR DIFFERENT TYPES OF CONNECTION

We consider the case of a 20 kV grid, where U_c = 24 kV and the value of a surge arrester is E (referring everything to the value of a 24 kV, surge arrester this value is v_{24} = E). For the case of the Neptune connection, for $U_c = 0.662 \cdot U_m$, the corresponding surge arresters are with U_c = 16 kV, for which, according to data received from different vendors and making an average, we have:

$$v_{16} = 0.74 \cdot E \tag{8}$$

where v_{16} is the value of a surge arrester with U_c = 16 kV.

Therefore if we consider that V_3, V_6 and V_4 are the total values of the surge arresters mounted in connection with 3, with 6, respectively with 4 surge arresters (Neptune connection), these values are:

$$V_3 = 3 \times v_{24} = 3 \times E = 3E \tag{9}$$

$$V_6 = 6 \times v_{24} = 6 \times E = 6E \tag{10}$$

$$V_4 = 4 \times v_{16} = 4 \times 0.74 \times E = 2.96E \tag{11}$$

which shows that the cheapest connection is the connection with 4 surge arresters (Neptune connection), which has the approximate value of the connection with 3 surge arresters (but much better from the technical point of view) and about half of the value of the connection with 6 surge arresters, both solving the same situations.

The example above was referring to medium voltage surge arresters with U_c = 24 kV. For the usual voltage levels in medium voltage grids we have built, for example, the graphs in Fig. 4 (the value of the connection for the versions with 6 and 4 surge arresters) and Fig. 5. (the percentage advantage if we use the connection with

4 surge arresters instead of the connection with 6 surge arresters).

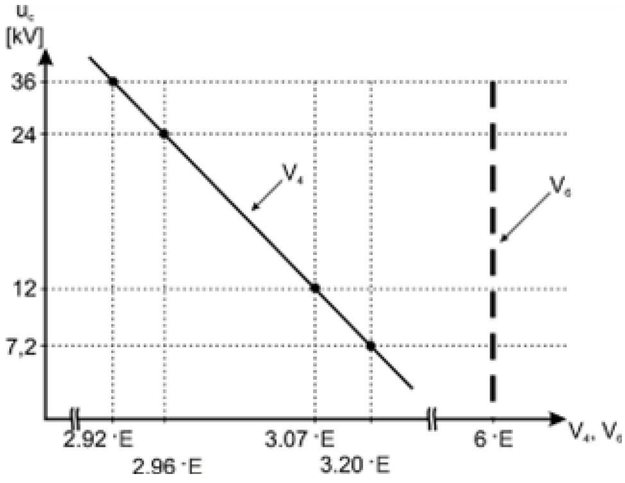

Fig. 4. Value of the connection for the versions with 6 and 4 surge arresters

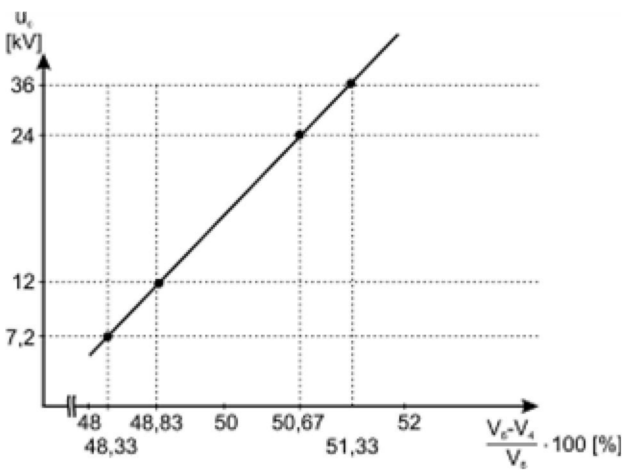

Fig. 5. The percentage differences of the value of the connection for the versions with 6 and 4 surge arresters

From the graphs above we can conclude that as the voltage level of a medium voltage grid is higher, the economic advantage of the connection with 4 surge arresters is stronger compared with the connection with the 6 surge arresters.

4. CONCLUSIONS AND OBSERVATIONS

The use of the Neptune connection can solve the problem of reducing dangerous overvoltages reduction in grids or for consumers where surge arresters are mounted between phase and ground.

Compared with the connection with 6 surge arresters, that has the same role as the connection with 4 surge arresters (Neptune connection), the Neptune connection has important economic benefits leading to a reduction of investment costs of around 50%.

This advantage is even stronger as the voltage level of the medium voltage grid is higher.

However using the Neptune connection has a disadvantage, because the level of protection is about 33% higher. But considering that switching or atmospheric overvoltages usually exceed this threshold, the downside is minimal.

As a final conclusion, using the Neptune connection is a modern approach of protection systems against accidental overvoltages, with important economic consequences.

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