PROPAGATION OF DISTURBANCES FROM 6-20 KV GRIDS TO LOW VOLTAGE GRIDS ACCORDING TO THE 6-20 KV GRID NEUTRAL EARTHING MODE

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The over-voltage levels of the 6-20 kV networks, mainly resulted from the single-phase faults or the lightning over-voltages can damage both the low voltage networks (equipment) operational safety and also the power consumers security. Considering this aspects, first it shall be identified the way of over-voltage transmission from the 6-20 kV networks taking into account the type of fault causing these over-voltage and the way of neutral earthing for the 6-20 kV network, as well and then it shall be presented the necessary solutions for limiting these over-voltage.

Keywords: medium voltage, disturbance, over-voltages, earth electrode.

1. Introduction

The connection between the two grids, the power distribution (6-20 kV) and the low voltage grid respectively, is always performed through some transformers. That is why, we have to take into account the specific aspect of these transformers which make a connection between a power distribution grid, under the authority of one specialized company and one low voltage grid, to which the power consumers (technically non-authorized persons) and their electricity operating equipment, are connected. For these equipments, available to residential consumers, the electrocution-fighting protection measures are severe and this requests a careful study on over-voltages transmission from the power distribution grid to the low voltage grid. It is assumed that these over-voltages are the main risk, in terms of both electrocution-fighting protection and in terms of equipment insulation load, as the over-voltage generating opportunities in the low voltage grids, themselves, are far more limited than in the higher voltage grids.

As the urban power distribution grids are, generally speaking, underground grids both in terms of distribution (6-20 kV) and in terms of low voltage, they are less exposed to lightning over-voltages, especially due to power discharges between clouds (cloud-cloud discharge). The problems related to

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internal over-voltages are mainly important for the transformers low voltage part, in the medium voltage compact secondary transformer stations and for the afferent low voltage grid. These over-voltages can occur on the low voltage part, both resulting from the transformer inductive and galvanic transmission, as well, through the earthing system.

2. Lightning over-voltages- resulting disturbances transmitted from the power distribution (medium voltage – m.v.) 6-20 kV grid to low voltage grid, through power transformers

During the operation of the overhead power distribution grid, there are frequently damages of the medium voltage (m.v.) compact secondary transformer stations insulation, occurred on the low voltage (l.v.) part and which are located either in the transformer winding, or in the l.v. equipment, such as circuit-breaker, surge counters, etc.

Such faults are more often than not, determined by the transmission of some over-voltages from the power distribution grid.

If we assume the case of one m.v. compact secondary transformer station, protected by air-gap arresters (AGA), on the m.v. part, earthed either to the compact secondary transformer (CST) earth electrode (fig. 1.a) or to one independent earth electrode (fig. 1.b) [5]

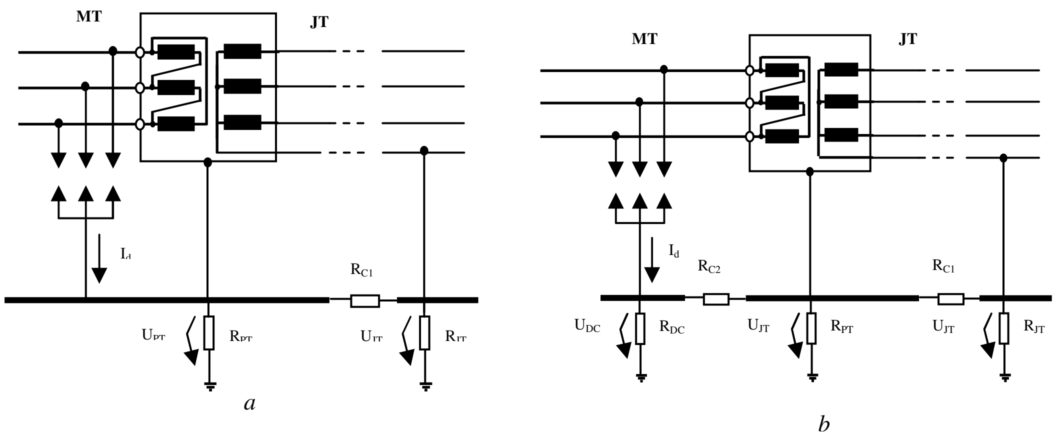

Fig. 1. Connecting modes for the grid diagram afferent connections [5]

One lightning impulse wave on the overhead power distribution line (6-20 kV) causes the air-gap arrester priming on the hit phase. The potential of the compact secondary transformer earth electrode (CST), in the diagram of figure 1 will be:

$$U_{PT} = R_{PT} \cdot I_d \quad (1)$$

this is, in fact, the potential of the hit phase, as we can assume the voltage drop on the spark gap arrester to be negligible.

Therefore, on the sound phases, the power distribution winding insulation to the transformer casing is stressed reversely to the voltage:

$$U_{MT-C}=U_{PT} \quad (2)$$

whereas on the hit phase, this stress is null. In fact, this is valid only after the air-gap arrester priming (AGA). Up to this moment, the hit phase insulation is stressed with the lightning impulse voltage, cut by the arrester. Depending on the resistance value of the compact secondary transformer earth electrode (RCST), this stress can get more importance than that on the sound phases.

The low voltage winding insulation to the transformer casing undergoes the following stress:

$$U_{JT-C}=U_{PT}-U_{JT} \quad (3)$$

where:

$$U_{JT}=k_1 \cdot U_{PT} \quad (4)$$

resulting:

$$U_{JT-C}=U_{PT}(1-k_1) \quad (5)$$

k_1 is the connecting coefficient between the earth electrodes of the compact secondary transformer station (CST) and the low voltage grid neutral.

From the point of view of the insulation stress, afferent to the transformer low voltage part, it would be better that the low voltage grid neutral were connected to the earth electrode of the compact secondary transformer station, an event in which $k_1 = 1$. But this would result in the transmission of some highly risky over-voltages to the neutral conductor of the distribution transformer and therefore, we can also use the solution of independent earth electrodes.

If $k_1 = 0$, then the stress of the low voltage winding insulation and of the auxiliary equipment is the same as that for the power distribution part (6-20 kV), which certainly means its or their failure.

In the event in which the air-gap arrester is connected to one independent earth electrode, with the connecting coefficient k_2, where $k_2 \neq k_1$, in relation to the compact secondary transformer station earth electrode, the stress of the insulation on the power distribution part, will be:

$$U_{MT-C}=k_2 \cdot U_{DC} \quad (6)$$

the relation (6) represents the stress for the sound phases, whereas for the lightning hit phase:

$$U_{MT\text{-}C} = U_{DC} (1 - k_2) \tag{7}$$

But, having in view that the insulation of the lightning-hit phase is stressed only by the air-gap arrester- cut voltage impulse, it is used k_2=0.

The insulation of the compact secondary transformer station l.v. part (CST) will undergo the stress:

$$U_{JT\text{-}C} = k_2(1-k_1)U_{DC} \tag{8}$$

From the relation (8) it results the necessity of isolating the surge arrester earth electrode, so that k_2= 0, which coincides with the condition for the power distribution part (6-20 kV). In this case, the protection of the low voltage insulation is solved without using the surge arresters on the low voltage part.

In the case of the earthing system general operation, both on the power distribution and on the low voltage part, the technical norms require that the dispersion resistance $R_{CST} \leq 1\ \Omega$ [1]

3. Disturbances transmitted from the power distribution grid (MV) 6-20 kV to the low voltage grid, through the grids earthing connections

3.1. General

The temporary over-voltages, occurring in the power distribution grids (6-20 kV), caused by one phase earthing connection (a fault that can last from a couple of seconds, specific to the case of neutral earthing by resistor, up to tens of minutes, which is the case of neutral earthing by reactor), are transmitted to the low voltage grid, through the galvanic connection, due to the general earthing system of the compact secondary transformer stations. These over-voltages can endanger the people's life, operating the earthing system downward the compact secondary transformer station [2].

3.2. Compact secondary transformer stations MV/LV with one general earthing system

If we assume the case in which the low voltage grid neutral is connected to the same earthing system as that of the compact secondary transformer station, as in fig.2, then various restrictions can occur, according to the power distribution grid neutral earthing, as follows:

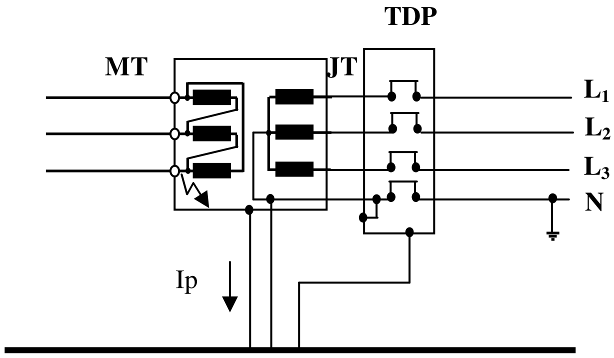

Fig. 2. Common earthing system

Where: TDP – main power distribution panel

a) If the neutral is not earthed to the ground and it is earthed by the reactor, in the event of one single-phase earthing, the grid earthing point voltage will be approx. equal to the phase voltage and the voltage on the sound phases will be equal to the voltage between the phases of the grid, which would result in one residual current, noted IP, up to 10 A and which is closed through the earth electrode resistance [3].
It results that the earth electrode voltage U_p will be:

$$U_p = I_p \cdot R_p \tag{9}$$

According to the location zone of the earth electrode, the main protection time, the grid neutral earthing mode and the type of the equipment or electrical system, the maximum touch and step voltage must not go over the values of 1RE Ip30-2004.

Regarding the compact secondary transformer stations, both in the frequently circulated zones and in those of reduced circulation, sharing the same general protection system, irrespective of the calculation results regarding the compliance with the touch or step voltages and regarding the thermal stability check, the permitted value of the protection earthing system resulted resistance shall be maximum 4 Ω [3].

On the failure of one arc suppression coil, the current value exceeds the calculation value of the earth fault current (for the earthing system), after the occurrence of a single earth fault, the respective line must be tripped, within a quite short time in order not to endanger the integrity of the earthing system and as more diminish as possible, the probability of some touch and step voltages occurrence, over the permitted voltage range. The time to the tripping operation must not be longer than 10 minutes.

If we insert the resistance value of 10 Ω in the relation (9) and we take into account that the residual current value is approx. 10 A, it will result a voltage of 100 V, which is transmitted to the low voltage grid, due to the galvanic link between the substation earthing system and the neutral on the low voltage part.

The equipment casings are connected to the low voltage grid neutral. If the low voltage grid neutral is energized, catching voltage due to one earth fault on the power distribution part, this voltage is conducted and the equipment casing will be energized too, which can result in the electrocution of the personnel who touch the equipment casing.

The most serious case is that of one double-earth fault current establishing (I_{pdp}) not capable of disconnecting through the provided current protections (under the protection control), in the power distribution grid. In this case, in the relation (9) $I_P = I_{pdp}$ which means very high voltages transmitted to the low voltage grid and for a long time, with very serious effects (electric shocks and equipment damage).

b) If the neutral of the power distribution grid is direct earthed or earthed by resistance, in the case of one single earth fault occurrence, the line earth fault protection detects this earth fault and trips the faulty line. The time delay up to the fault clearance must not be longer than 3 seconds, 1.2 seconds respectively, in the event of earthing operation by resistance (resistor R_n). [4]
In a similar way as in the case of a not-earthed grid, the neutral of the low voltage grid catches one hazardous voltage, endangering the humans life. In the case of power distribution grid, under T_2T configuration, the maximum permitted voltage range of 1RE Ip30 – 2004 must be observed, according to the operating time of the current earth fault protections.

3.3 MV/LV Compact secondary transformer stations sharing the general earthing system

To avoid the transmission of hazardous voltages to the low voltage grid, the earth electrodes must be isolated in-between, as in figure 3.

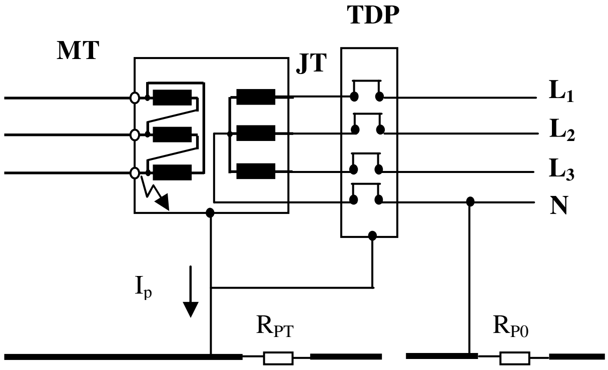

Fig. 3. Separated earthing system

where:

R_{PT} – compact secondary transformer station resistance;

R_{P0} – auxiliary earth electrode resistance.

In this way, the low voltage grid neutral is connected to one earth electrode isolated from that of the compact secondary transformer station. Usually, this earth electrode is found at the first tower to the compact secondary transformer station. Still, there is one connection in-between the two earth electrodes.

In the even of the grids, under T_2T configuration, the operation of the earthing system for the compact secondary transformer station (CST) is shared, if the dispersion resistance of the compact secondary transformer station (R_{CST}) meets the following condition:

$$R_{PT} \leq U_a / I_P \qquad (10)$$

where:

U_a - is the limit touch permitted voltage, according to the main protection time of the earth fault protection;

I_P – is the current in the fault place, limited by the resistor Rn.

The condition of relation (10), for the majority of events, is easy to meet, as RCST represents the dispersion resistance of the entire system, made of the low voltage grid conductor PEN and all the earth electrodes to which this is connected.

3. CONCLUSIONS

To ensure the protection of transformers insulation, on the low voltage part, as the insulation can be damaged due to the waves, transmitted through the transformers inductive connection, surge arresters must be mounted on the low voltage part, especially for the equipment with electronics.

The potential distribution earth electrodes isolation is preferable for limiting the voltages that can be conducted, in this way, to the low voltage grid, even if the cost is higher as it requires one additional earth electrode, only in the event in which the condition (10) cannot be met.

R E F E R E N C E S

[1]. *1RE Ip 30 – 2004,* Guide for earthing systems design and mounting.

[2]. *Norm NTE 001/03/00;*

[3]. *Norm SC Electrica SA,* Guide on the design and mounting of power distribution grids, with the neutral not earthed or earthed by shunt reactor.

[4]. *1RE Ip 35/2 – 92,* Design guide for power distribution grids, with the neutral earthed by resistance. Earth electrodes systems for overhead lines, underground h.v. cables, transformer substations and compact secondary transformer stations.

[5]. *M. Guşă, M. Istrate, N. Gavrilaş, C. Ciobanu – Technical University Iaşi,* Aspects regarding the protection of the compact secondary transformer stations of the power distribution overhead lines, against lightning over-voltages.