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Insulation Coordination in HV/A Substation Equipment Cells

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ABSTRACT

The development of electricity users induces significant design needs in the field of electrical installations. These needs naturally arise from increased requirements, with regard to the quantity and quality of service provided by these facilities. Therefore, the consumption of electrical energy is increasing day by day, and the assurance of its supply has become an unavoidable imperative. The continuity of this offer requires a suitable design and sizing of the HV/A transformer stations, which constitute the essential part in the field of the distribution of electrical energy. Through this report, we tried to make a study on the substations of distribution HV whereas our objective was to gather the most possible information in order to work out a document, which makes it possible to give the maximum of details on the coordination of insulation in HV/A substation equipment.

1. INTRODUCTION

Substations are the main elements of the electrical network. They receive electrical energy, transform it (by passing from one voltage level to another) and distribute it (by ensuring the junction of the various electrical networks). There are a number of electrical devices (transformers, circuit breakers, disconnectors, etc.) involved in the proper functioning of the network. Class A high-voltage substations are structures placed at a node of a network, which includes a set of equipment intended to provide protection and facilitate operation. HV/A/LV substations provide the interface between the HV and LV distribution networks, the supply of an electrical installation is carried out with a HV/LV transformer station which is placed as close as possible to the energy consuming elements. The HV/LV substation can be adapted to all operating modes and must therefore fulfill the following functions:

- Distribute power and protect LV outgoing lines.
- Isolate the substation from the network in the event of a fault.
- Manage the HV network in the event of a fault.
- Manage the HV network and the substation by remote control.

It should be noted that currently the protection using technology is the most used, it allows to design more and more advanced functions.

The substation is formed by assembling a determined number of elementary cells, each performing a specific function. Each cell is made from walls, uprights and mesh panels, in sheet steel, painted in light grey, the assembly of all the elements is carried out on site by bolting. The assembly is designed to withstand significant mechanical stresses. Fixing of devices, isolation distances, and mechanical interlocks meet the requirements for the safety of people and operations.

Composition of equipment:

- Incoming cubicles <<C.S.>> Disconnected.
- Arrival or departure cells <<C.I.>> switch.
- Cells Protection by <<C.P.>> circuit breaker.
- Cells protected by <<C.D.>> circuit breaker.
- General protection cells by 《C.D.G.》 circuit breaker.
- Downstream <<C.S.A.>> disconnected cells.
- <<C.T.>> power transformer cell.
- Voltage transformer cells <<C.T.T.>> [1, 2].

2. HIGH VOLTAGE CELLS (36 KV OR 24 KV)

The devices (circuit breakers, switches, disconnected bus bars, etc.) are integrated into metal enclosures which facilitate installation and operation, these enclosures are called cells, they make it possible to create the MV part of the transformer stations MV/LV public distribution, specific or MV distribution up to 36 kV.

- IM, IMC, IMB: Switch cell.
- EMB: Busbar earthed cubicle.
- PM: Associated switch-fuse cell.
- QM, QMC, QMB: Combined fuse switch cubicle.
- CRM: Contactor cell and fuse contactor.
- DM1-A, DM1-D, DM1-S: Single isolation circuit breaker cubicle (SF6).
- DM1: Circuit breaker cubicle (SF6) with single disconnection.
- DM2: Double isolation circuit breaker cubicle (SF6).
- CM, CM2: Potential transformer cell (counting cell).
- GBC-A, GBC-B: Current and/or voltage measurement cell.
- NSM-cables: Cell to arrive priority and emergency.
- NSM-bars: Cell for priority arrival and cables for emergency.
- GIM: Intercalary sheath cell. - GEM: Sheath extension cell.
- TM: MV/LV transformer cubicle for auxiliaries.
- SM: Disconnector cubicle, etc. [3].

3. INSULATION COORDINATION

Insulation coordination is a discipline that makes it possible to achieve the best technical and economic compromise in the protection of people and equipment against overvoltage that may appear on electrical installations, whether these overvoltage originate from the network or lightning. It contributes to obtaining a high availability of electrical energy. It is all the more useful when it concerns high voltage networks. To master the coordination of insulation it is necessary:

•To know the level of overvoltage that may exist on the network,

•To use the right protections when necessary,

•To choose the overvoltage withstands level of the various components of the network, among the insulation voltages making it possible to satisfy the determined constraints.

The role of insulation coordination is to determine the necessary and sufficient insulation characteristics of the various network components in order to obtain uniform resistance to normal voltages, as well as to overvoltage of various origins. Its final aim is to allow safe and optimized distribution of electrical energy. Optimizing means looking for the best economic relationship between the different parameters depending on this coordination:

- Cost of isolation,
- Cost of protection,
- Cost of failures (operating loss and repair) given their probabilities.

Overcoming the harmful effects of overvoltage requires a first step: tackling their generating phenomena, a task that is not always simple. In fact, if, using appropriate techniques, switchgear switching overvoltage can be limited, it is impossible to act on lightning. It is therefore necessary to locate the point of weakest withstand through which the current generated by the overvoltage will flow, and to provide all the other elements of the network with a higher level of dielectric withstand.

3.1 Insulation distance

This name combines two concepts:

- Distance in gases (air, SF6, etc.), this is the shortest path between two conductive parts.
- Creep age distance: this is also the shortest path between two conductors, but following the external surface of a solid insulator (insulator for example) the insulation distance is directly linked to the resistance of the equipment to the various overvoltages [4].

3.2 Cutting techniques

To break load or fault currents, manufacturers have developed and perfected breaking devices, circuit breakers and contactors in particular, using various breaking media: air, oil, vacuum and SF6. If breaking in air or oil tends to disappear, the same does not apply to breaking in vacuum or SF6, "queen" of medium voltage.

- The cut in the air.
- The cut in the oil.
- The cut in the vacuum.
- The cut in the SF6.

We are interested in two techniques: air and SF6.

3.3 The cut in the air

Devices using air breaking at atmospheric pressure were the first to be used (magnetic circuit breaker). Air at atmospheric pressure, despite its relatively low dielectric strength and high de-ionization time constant (10 µs), can be used for breaking up to voltages close to 20 kV. To do this, sufficient cooling power and a high arcing voltage must be available after the current has passed zero to avoid thermal runaway [5].

3.4 The break in the SF6

Sulfur hexafluorideSF6 is a gas appreciated for its many chemical and dielectric qualities. The cutting technique in this gas was developed in the 1970s, like that of vacuum.

It is a non-polluting, colorless, odorless, non-flammable and non-toxic gas in its pure state. It is insoluble in water. It is chemically inert: its molecule has all its chemical bonds saturated and high dissociation energy (+1096 kJ/mol) as well as a great capacity to evacuate the heat produced by the arc (high enthalpy). During the arcing period, under the effect of the temperature which can reach 15,000 to 20,000 K, the SF6 decomposes. This decomposition is almost reversible: when the current decreases the temperature decreases, the ions and the electrons then recombine to reconstitute the SF6 molecule. A small amount of by-products results from the degradation of SF6 in the presence of impurities such as sulfur dioxide or carbon tetra fluoride.

The thermal conductivity of SF6 is equivalent to that of air, but the study of the thermal conductivity curve of SF6 at high temperatures reveals a peak at the dissociation temperature of SF6.

SF6 has a very high dielectric strength thanks to the very electronegative properties of fluorine.

- The lifetime of its free electrons remains very low and they form heavy ions with low mobility with the SF6 molecules. The probability of dielectric breakdown by avalanche is thus delayed.
- It gives its medium an extremely low deionization time constant, of the order of 0.25 µs [6, 7].

4. PRESENTATION AND DISCUSSION OF THE RESULTS OBTAINED

4.1 Classic type cell

A typical medium voltage cubicle having the arrangement and geometric coordinates shown in the figures presented below (Figures 1-4), the service voltage is 30kV. We proceeded within the framework of this work to calculations carried out on the electrostatics. The calculation of the electric field and the potential in our study is carried out on the following dimensions:

- Height of conductors: H1=H2=H3=2.4m.
- Spacing between conductors: DI2=40cm, D23=40cm,
- Spacing between the cell grounds is the conductor
- DM1=DM3=46cm.
- Cell height: H=350cm.
- Cell width: L=172cm.
- Radius of the phase conductor=5cm.

It is a type of electrical cell where the conductors are arranged on the same horizontal plane, that is to say the same height in relation to the ground is between them. Used in conventional type electrical substations (air insulation).

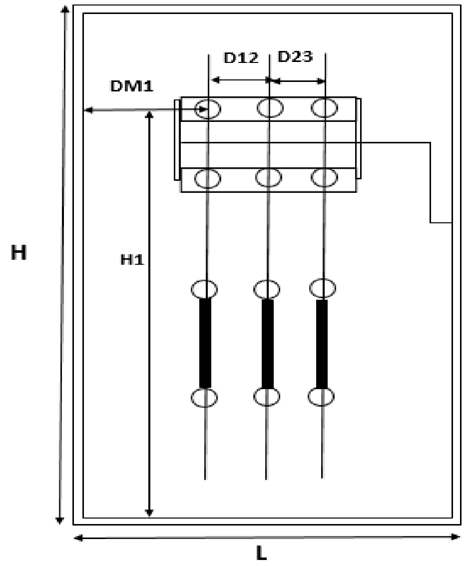

Figure 1. Diagram of a classic protection cell

Figure 2. Classic protection cell switch

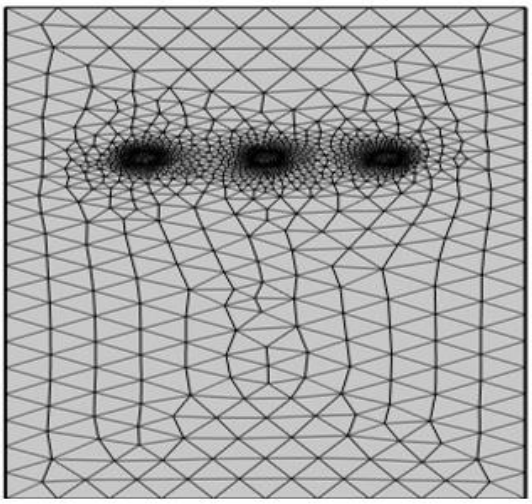

Figure 3. Mesh of the classic cell

For this type of cell we have calculated the electric field and the potential, for a service voltage of 30kV.
We found the following results.

4.1.1 Electrical potential

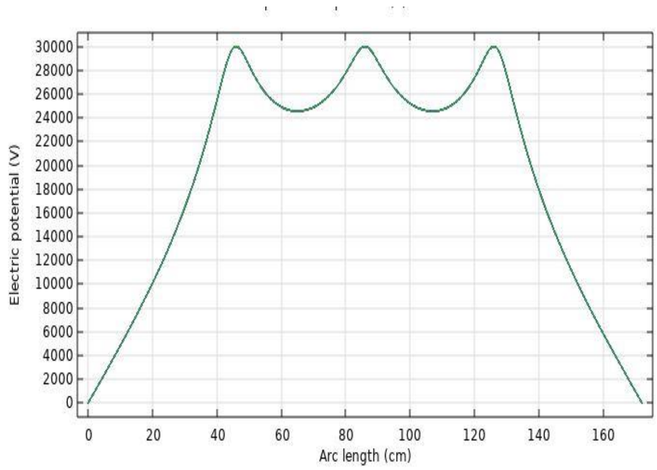

Figure 4. Potentiel électrique

It is noted that the values obtained for the potential are confused with the exact values for the majority of the points V=30 kV the value of electric potential reaching the maximum value at the level of the three conductors but it decreases between them.

4.1.2 Electric field

- Between ground-phase

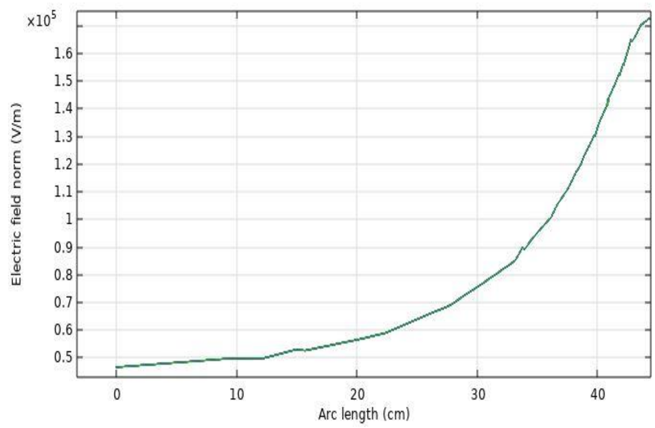

Figure 5. Electric field between phase-ground

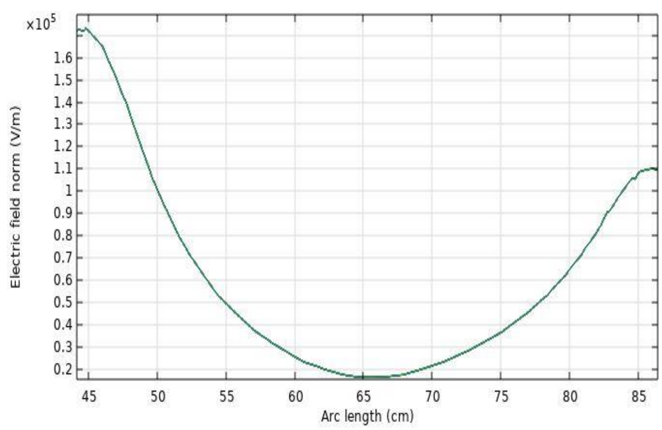

Figure 6. Electric field between phases

According to Figure 5, we have seen that the electric field created between the cell mass and the conductor increases up to a value of $1.72*10^5$(V/m).

- Between phase-phase

According to Figure 6, we have seen that the electric field intensity decrease when we go so far from the electric conductor has a very low value then it increases up to a value of $1.1*10^5$ (V/m).

4.1.3 Electric field

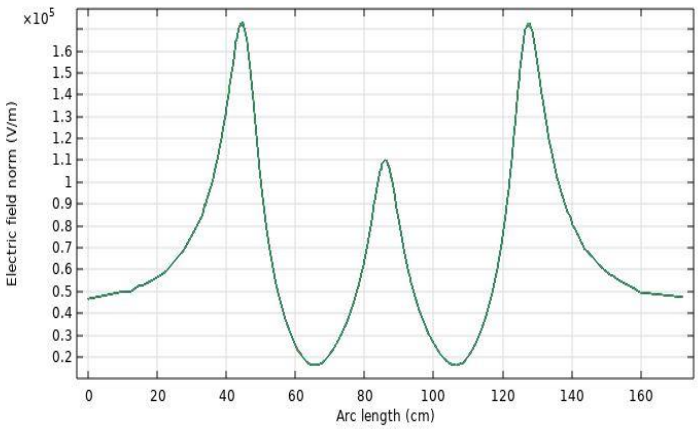

Figure 7. Electric field

According to Figure 7 for a tension V=30 kV, one can then deduce that the calculation presents a good precision, the curve shows that the electric field increases in the conductors with dimensions up to E max= $1.72*10^5$ (V/m) then it reaches a minimum at a distance between the conductors, it then increases slowly to the point of symmetry of $1.1*10^5$(v/m) then increases again, is because of the mutual electric fields created by both conductors.

5. CELL OF REDUCED TYPE

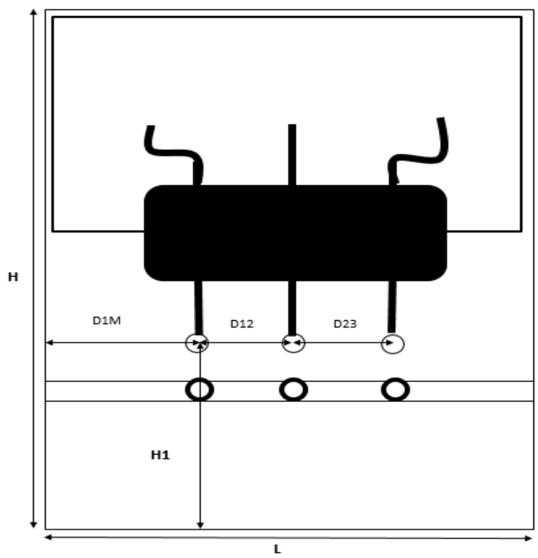

Figure 8. Diagram of a reduced type cell

We consider a reduced type medium voltage cell having the arrangement and geometric coordinates shown in the figures presented (Figure 8 and Figure 9), the operating voltage is 30kV. We proceeded within the framework of this work to calculations carried out on the electrostatics. The calculation of the electric field and the potential in our study is carried out at a height of 1.10 m from the ground. Height of conductors:

- H1=H2=H3=1.10m.

Spacing between conductors:

- DI2=D23=D13=25cm,
- D1M=47cm

Phase conductor radius=7cm

It is a type of electrical cell where the conductors are arranged on the same horizontal plane, that is to say the same height in relation to the ground is between them. Used in reduced type substations (air insulation).

Figure 9. Reduced type departure cell

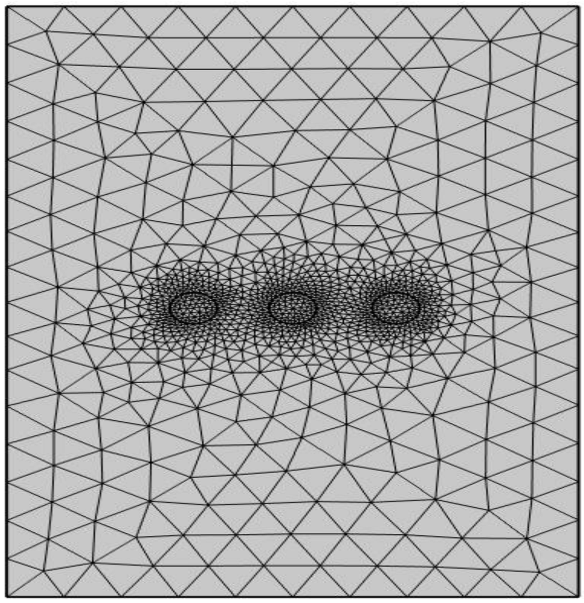

Figure 10. Reduced cell mesh

Figure 10 is reduced cell mesh. For this type of cell we calculated the electric field and the potential, for a voltage of 30 kV. We found the following results:

5.1 Electrical potential

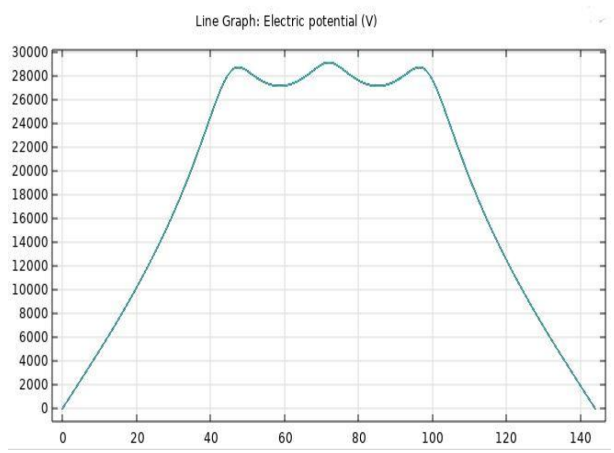

Figure 11. Electric potential in the typical reduced cell

According to Figure 11, the value of the calculated potential is equal to V=30kV, these values obtained coincide with the exact values for the majority of the points, both for the phase conductors and those of the terminals.

5.2 Electric field in the reduced type

- Between ground-phase

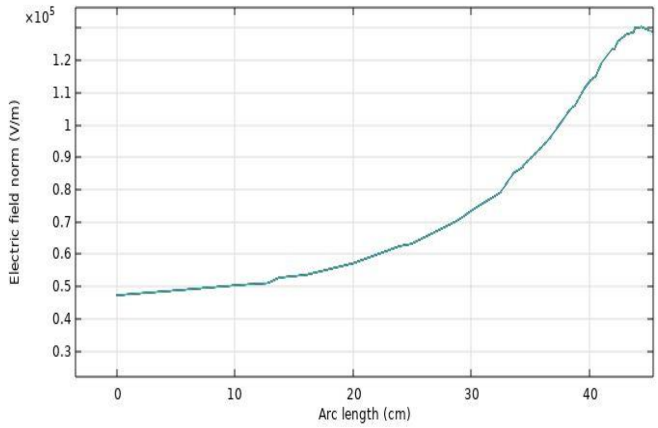

Figure 12. Mass-phase electric field

According to Figure 12, we have seen that the electric field created between the cell mass and the conductor increases up to a value of $1.3*10^5$ (V/m).

- Between phases

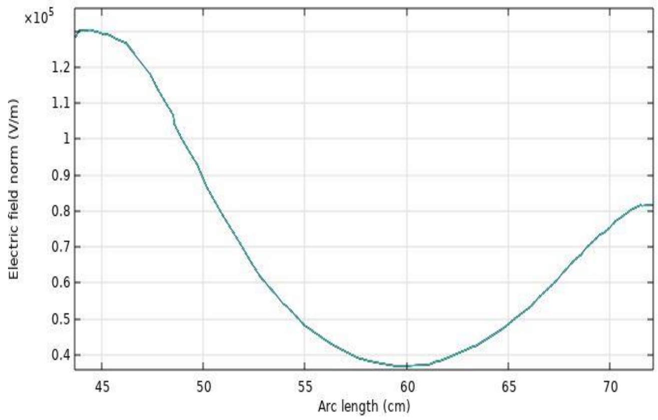

Figure 13. Electric field between phases

From Figure 13, we have seen that the electric field intensity decrease when we go so far from the electric conductor then it increases up to a value of $1.1*10^5$(V/m).

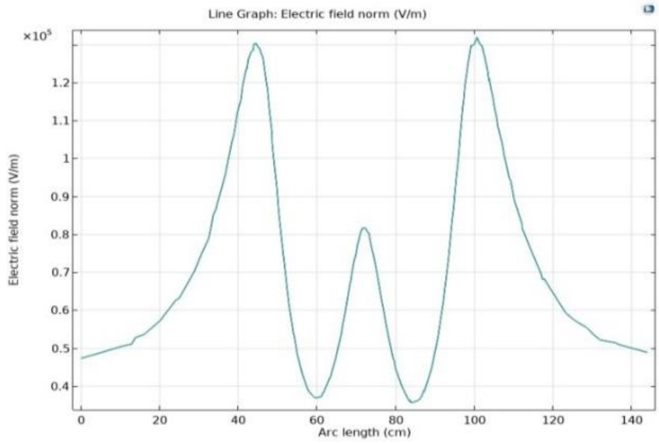

Figure 14. Global electric field between three phases

From Figure 14, we notice that the distribution of the field is almost similar to the previous configuration, the electric field increases slightly at the level of the side conductors up to $E_{max}=1.3*10^5$ (V/m). Is reduced in the centered conductor for a value of $E=0.8*10^5$(v/m) by the effect of the mutuality of the adjoining electric fields. The intensity of the electric field is compared to the maximum value obtained but the potential remained the same.

6. COMPARISON BETWEEN CLASSIC AND REDUCED CELL

Below is Table 1.

Table 1. Comparison between classic and reduced cell

	Classic cell	Reduced cell	Difference
Width (m)	1.72	1.40	20%
Height (m)	3.50	2.25	36%
Phase-to-phase distance (cm)	40	25	37.5%
Type of insulation	air	SF_6	SF_6 better than air
Electric field strength (v/m)	$2.2*10^5$	$1.95*10^5$	11%
Facility	Achievable by a service company	Requires manufacturer support	Requires manufacturer support

7. CONCLUSIONS

The electricity and gas company in recent years has discarded conventional type equipment for all while replacing reduced type equipment. For our practical contribution, we have numerically studied the influence of the type of insulation used (Air, SF6, etc.) on the variation of the electric field as well as the electric potential. According to the results of simulation we note that the choice of the type of insulator has a great influence on the coordination of insulation affects much on the variation of electric field as well as the potential. This gives many advantages for the development of HV/A substations. Among these advantages:

•Minimize the cost of construction of the civil engineering of the electrical substations:

•Minimize the sizing of electrical equipment (volume)

•Development of remote control and protection technologies

•Minimize human intervention during the operation of substation cells

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NOMENCLATURE

HV	High voltage
LV	Low voltage
IEC	International Electrotechnical Commission
V	Phase-to-neutral voltage
SF6	Sulfur Hexafluoride
ACC	Accompanied circuit breaker
GIS	Gas Insulated Switchgear
AIS	Air Insulated Switchgear
L	Width
H	Height