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Transmission Line Arrester and Its Application

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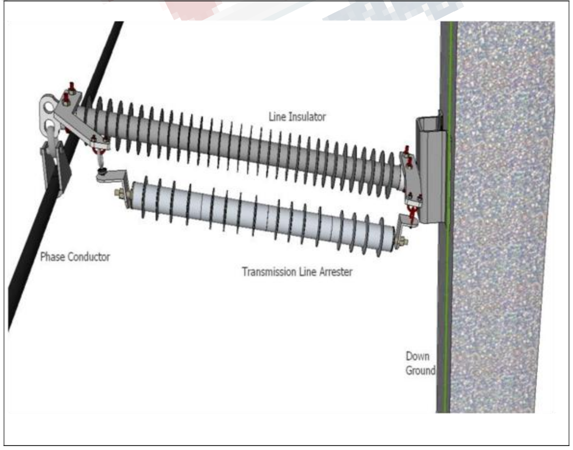
***Abstract*— In high-voltage transmission systems instrument transformers and circuit-breakers during the dead time of an auto-reclosing cycle are frequently damaged by direct multiple lightning strokes into the conductors of overhead lines nearby a substation. These devices can be protected by arresters at the line entrance. An efficient and economical solution of a standard arrester integrated into a standard arrester is covered here, which allows the arrester to be installed without additional space requirements. The new device has been applied in 245-kV- and 420-kV-systems so far.Only for the 420-kV-system some modifications to the grading ring of the arrester had to be introduced. This paper presents information on the requirements on the arrester and the various applications of transmission line arrester.**

I. INTRODUCTION

It was not realized at the time, but the 1992 introduction of the polymer-housed transmission line arrester (TLA) was clearly a game changer in the practice of lightning protection of transmission lines. Overhead shield wires had been the only cost-effective means of mitigating the effects of lightning until that moment. Since then, the TLA has shown its value not only in reducing lightning induced outages but also in numerous other power system protection, construction, safety, and operation scenarios.

THE TRANSMISSION LINE ARRESTER:

A TLA is manufactured and certified the same way as a standard arrester, but its application is different. A TLA is applied in parallel with transmission line insulators to prevent insulator back flashover. To mitigate backlash, the arrester conducts the lightning current from the down ground onto the phase conductor. This is quite the opposite of normal arrester installations.



THE BACK FLASHOVER

A back flashover is a flashover originating from the pole or the tower down ground that moves across the insulator onto the phase conductor, as shown at the top of Figure 1. This can occur during a lightning strike to the overhead shield wire, where the ground impedance is high. It is referred to as a back flashover since it is in the opposite direction of flashovers produced in a direct strike to a phase. The back flashover is usually followed by a standard forward flashover of the insulator, providing a path for power frequency current (fault) that require a breaker operation to terminate

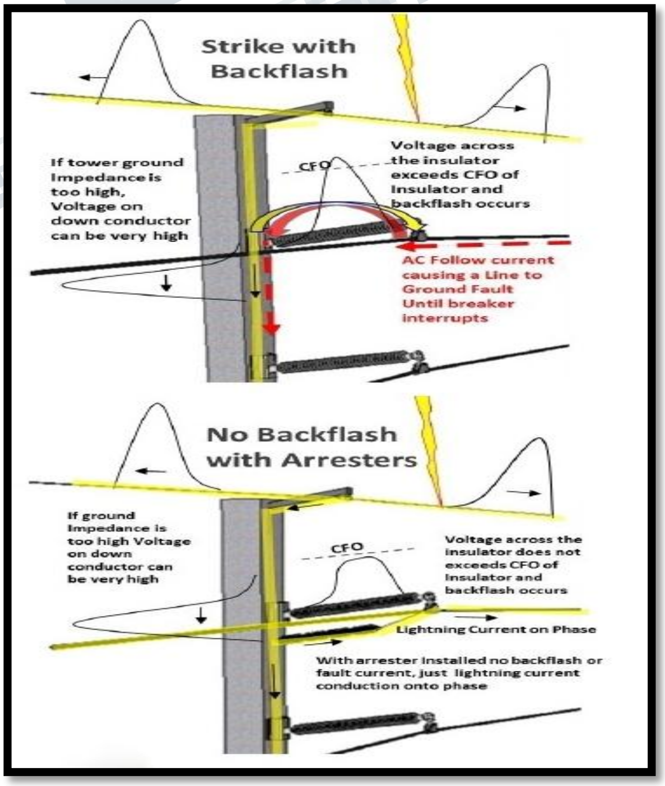


Fig 1:Back flashover overview

BACK FLASHOVER IMPACT:

The overall impact on the system is not limited to the damage of the devices themselves. Such failures use to cause a forced outage of the connected line as well as of all other lines feeding the related bus bar. The expenses of repair, replacement and fault clearance are immense. Fig2

Fig2.Back flashover in transmission lines during lightning

METHODS TO OVERCOME BACK FLASHOVER

Two main alternative means exist to overcome this problem. One is to improve the shielding of the overhead lines, e.g., by a second shield wire within two kilometres around the substation. This prevents direct lightning strokes from hitting the line and thus overvoltage's of extreme steepness from reaching the substation. In an existing transmission system, however, this is usually an extremely expensive solution and in many cases not applicable at all because of the limited mechanical strength of the towers.

The alternative is to protect the equipment from the effects of direct lightning strikes by metal oxide surge arresters which provide an optimized protection even against extremely steep overvoltage. Thus arresters close to the devices to be protected can easily avoid the damages described above at comparatively moderate costs. For their installation additional space is needed. However, this is not available in all cases.

In this paper a solution is presented which is based on the integration of surge arresters into disconnectors, and which allows the arresters to be located directly at the line entrance without any additional space requirements and foundations. It is therefore an economical and in many cases the only possible alternative of refitting existing substations, but also advantageous for new substations.

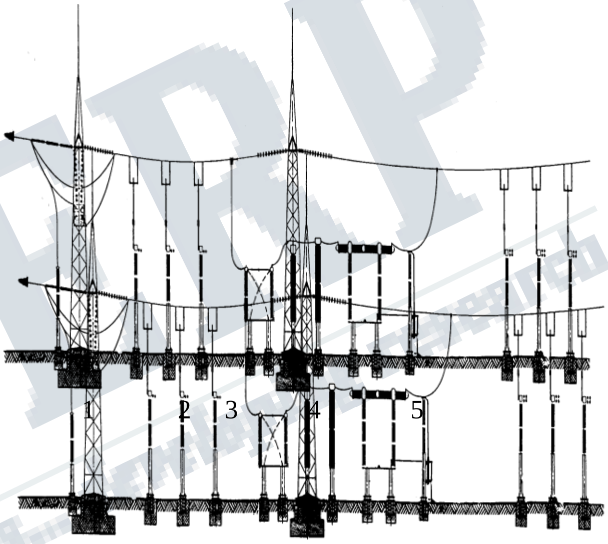


Fig. 3: Existing 420-kV-substation bay layout (1: line side disconnected with two earth switches, 2: voltage transformer, 3: current transformer, 4: circuit-breaker, 5: earth switch)

Fig. 3 gives an example of an existing bay layout of a 420-kV-substation. When evaluating all possible locations, integration of the arresters into the disconnector (Pos. 1 of Fig. 1) turns out to be the best option. Like the post insulator of a disconnector, an arrester has a simple linear structure, and hence it is not too difficult to replace one of the disconnector post insulators by the arrester. These are, roughly, the benefits of this device once it has been realized:

- fully type-tested design;
- no additional space requirements;
- no additional foundations;
- no specific engineering required for application;

- easy refitting of existing substations;
- Economical solution.

MOUNTING THE TLA

The mounting example in Figure 4 shows three methods that are used for mounting TLAs. An important consideration that must be made when using a TLA is lead management. Since disconnectors are used to isolate a failed arrester from the line, the line connected to the disconnector must not be able to touch another phase after it has disconnected. There are many options on how to do this.

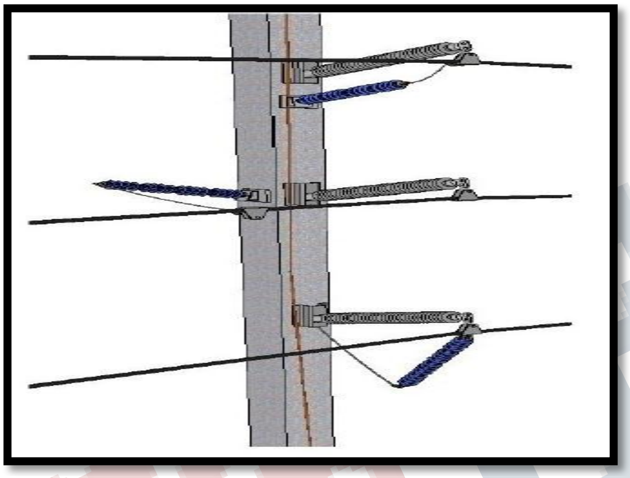


Fig 4: mounting the TLA

ENERGY HANDLING CONSIDERATIONS

This arrester type is similar to a distribution arrester in that it usually handles lightning currents only. This lightning-only option is possible because the TLA MCOV rating is high enough to prohibit it from going into conduction from a switching surge. This arrester is also normally used on shielded systems where the shield wire and down ground handle 80% of the lightning stroke current. Because it need not handle high lightning currents, it is rated the same as a distribution arrester and conducts lightning currents only. In some cases, where high fault currents are possible, a station class arrester is used for this purpose. If the TLA is applied to an unshielded transmission line, a station class arrester may be required to handle the surge energy from lightning. Figure 4 shows how the charge (in coulombs) is shared between arresters on a typical transmission line. In the model that produced the graph in Figure 5, the total strike charge was 16C at tower 0. Towers 1–5 are one side of the struck tower, and there is the same number of towers with arresters on the opposite side.

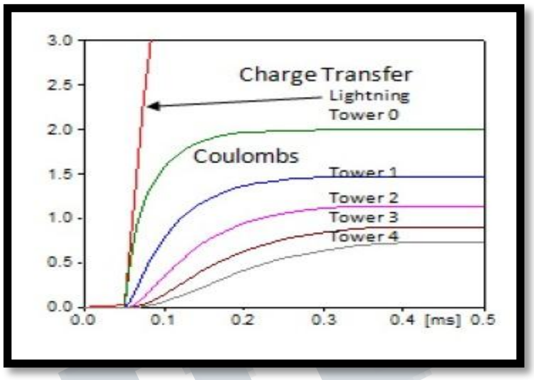


Fig5: Typical charge and current sharing between towers and arresters

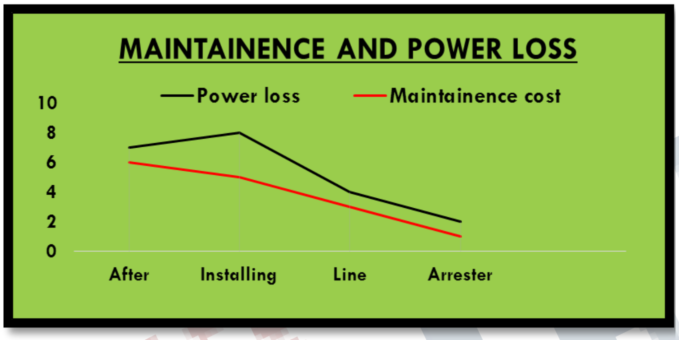
TOWER GROUND RESISTANCES:

Another potentially high return on an investment in arrester protection is the reduction in importance of tower ground resistance. When a line is fitted with arresters on each tower and each phase, the tower ground resistance becomes a non-factor in the system lightning protection, even if the lines are equipped with an OHGW. This is because the arresters do an excellent job of sharing the current of the lightning stroke with nearby towers and other phases. This study shows the details of this sharing and how arresters on all phases affect the performance of the line with high tower ground resistances

EXTENDING THE LIFE OF BREAKERS IN THE STATION:

The application of TLAs along a transmission line reduces the stress on and extends the life of breakers in the substation. Transmission lines protected from lightning by shield wires will still experience single line to ground faults when there is a back flashover of an insulator due to high ground resistance or an extra-high-current lightning stroke. When this happens, a breaker between the fault and power source will need to operate to interrupt the current flow. Since breakers have a finite number of operations before maintenance is required, any reduction in the number of operations will extend the life of the breaker.

REDUCING COST OF EMERGENCY STANDBY CAPACITY:



Some utilities must deal with significant risk of lightning outages in the summer. For example, if a power source is a long distance from the urban centre where most of the power is consumed, and if the transmission lines pass through high-lightning areas, the risk of a momentary outage can be very high. One means of mitigating this type of risk is to run local generators and depend less on the lower-cost distant source. If arresters are used on the transmission line in addition to the present OHGW, the probability of a lightning induced outage becomes zero. The cost of installing several hundred miles of arrester protection is very likely to be much less than the cost of running higher-cost local generators. This application of arresters can generate enormous savings for the end consumer and an equal amount for the utility.

LOWERING SYSTEM LOSSES

This application is more for new construction but could be applied to older lines if the OHGW should age out. It is a well-known fact that OHGWs can generate losses on the system if they are grounded at the tower tops. The losses are inductive in nature from the load flowing in the phase conductors. The closer the OHGW is to the phase conductors, the higher the losses. The losses are dependent on the type of line, number of shield wires, and the current load on the system. As you can see in Figure 11 for single-pole, two-circuit 115-kV lines, a lifetime savings of heavily loaded lines can result in $4.6 million per 100 miles of line.

II. CONCLUSION

The TLA can improve power systems in many ways. It can not only can it make a line lightning proof but also lower construction costs, increase system reliability, reduce the size of a right of way, and many more applications. Those responsible for power system reliability or planning can make a significant difference when considering the possibilities offered by TLAs.

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