NOVEL APPROACH FOR DESIGNING INSULATION OF MEDIUM VOLTAGE RECLOSERS

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ABSTRUCT

The aim of this article is to offer alternative design of an insulation which allows development of the medium voltage reclosers combined positive effects of manufactured at present time reclosers with SF6 and solid insulation.

INTRODUCTION

At present, the following media are used for the insulation of medium voltage reclosers:

- air,
- oil,
- SF6,
- solid dielectric.

Two of them may be considered as obsolete (air and oil), as they are associated with the big dimensions and weights that are not advantageous for pole-top equipment. Oil additionally creates environmental concern.

Therefore, modern pole top switchgear is generally either SF6 or solidly insulated [1], [2], [3], [4]. Both these system have advantages and disadvantages.

SF6 provides more design flexibility, in particular – ability to create dead tank designs. This becomes more and more attractive for utilities with the advance of ring lines and imbedded generation, as dead tank designs allow incorporating voltage sensing in all six bushings supporting these applications.

At the same time application of SF6 becomes subject for serious environmental concern that has been growing over last years. In particular, SF6 insulated switchgear requires special utilization means creating additional problem and expenses for utilities when considered from the total lifecycle standpoint. Another problem associated with this switchgear – necessity of continuous monitoring of the presence of SF6. This requirement contradicts the modern approach of the maintenance free switchgear that allows saving service expenses. At last, application of SF6 requires application of dead tank capable of withstanding pressure difference appeared at temperature variation. This substantially increases weight of the switchgear.

Solidly insulated reclosers have been developed in 1990-s as a competitive response to the problems related to SF6 switchgear [1], [2], [4]. These reclosers are based on the application of epoxy material having good track resistance, serving simultaneously as mechanical support structure and insulation. They escape disadvantages related to SF6 switchgear (monitoring of insulation consistency is not required, environmental hazards do not exist).

However, a solidly insulated switchgear offers limited design flexibility. In particular, the implementation of voltage sensing from both recloser sides becomes impossible. This shortcoming creates extra expenses for customer using this equipment in re-configurable lines, as requires installation of additional metering voltage transformers. Another problem with this equipment is related to lower track erosion resistance compared with dead tank designs, utilising bushings covered with silicon rubber. This feature inhibits application of solidly insulated switchgear in highly polluted area. At last, in this system solid dielectric is subjected to permanent electrical stresses that may cause ageing damage if insulating material if it has minor porous in it after manufacturing. So, the manufacturing technology shall be very precise and stable to avoid electrical puncture problems in the future use.

In the present paper authors offer the alternative design of the recloser insulation free of the abovementioned disadvantages and limitations.

CONCEPT OF COMBINED INSULATION FOR MEDIUM VOLTAGE RECLOSER

It is well known that breakdown in an air gap with the regular electric field appears when electrical field strength exceeds the critical 2.4kV/mm. This value seems high enough, as it should have allowed for recloser having 125Kv BIL level to provide required dielectric strength with air gap of just 52mm. For real designs, however, we cannot ignore non-even distribution of electrical field, i.e. its enhancement in particular weak points. For example, for two balls having diameter 10mm and separated by 100mm enhancement factor will be 5.4.

For real designs this factor is even higher, generally scattering between 4 and 20. Multiplying minimum contact gap on the enhancement factor, we end up with the required clearances 200-300mm that makes designing of air insulated dead tank recloser arduous.

At the same time slide modification of the air insulated system would have substantially improved its behavior. If we insert a thin dielectric plate between parts located at different potential we virtually will not change the distribution of the electrical field. At the same time dielectric strength of the insulation system will substantially increase – times compared with the dielectric strength of the mentioned plate.

This effect appears due to reverse polarization of the dielectric barrier at creation of leader discharge as schematically shown in the Fig.1. It is well known and widely used for example for insulation of paper impregnated cables.

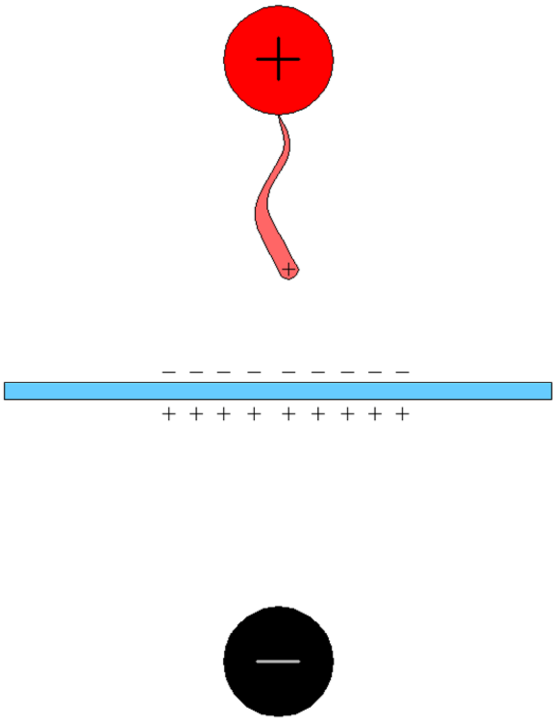

Fig. 1. Effect of combined insulation

In designing novel insulation system for recloser we used this approach creating a design where each live part is surrounded with the continuous insulated barrier as shown in the Fig.2 [5].
To make assembly possible we used silicon rubber joints where necessary (Fig.2).
All six bushings are equipped with voltage sensors. In addition one row of bushings is equipped with current Rogowsky sensors, while another row contains Rogowsky sensors with series connected coils providing direct measurement of the residual current. As a result we have the solid dielectric dead tank design that allows providing accurate measurements of phase to earth voltages from recloser sides, phase and residual currents. It is obvious that this structure is very suitable for supporting automation functionality for ring overhead lines.
This insulation system has particular advantages in comparison with conventional solid insulation systems. At rated voltage virtually all drop of electrical potential appears in air, i.e. solid dielectric is subjected to very low electric stress during majority of its lifetime. As a result this insulation system provides higher reliability and is less dependent on the variation of the insulation manufacturing technology.
Solid dielectric interferes into provision of dielectric strength only at lightning overvoltages when electrical field in air exceeds critical value and leader is created. However, in the course of its propagation it provides reverse polarization of the dielectric barrier in accordance with the schematics shown in the Fig.1. This polarization reduces electrical field in front of a leader below the level necessary for its propagation. So, the leader decays and breakdown does not appear.
Another advantage of this design is application of the light and inexpensive tank. This appears to be possible as in this case the tank is not sealed (it only provides dust proof protection). So, there is no necessity to withstand pressure difference appearing at variation of outside temperature.

PROPERTIES OF THE COMBINED INSULATION

Certainly the combined insulation has limited dielectric strength.
It would be preferable to be able to calculate this strength at design optimization.
Unfortunately we have not discovered reliable theoretical methods applicable for description these sorts of insulation systems.
So, experimental study allowing finding effective configurations has been undertaken. At this study we found out that the following factors provide most important impact on the dielectric strength of the combined insulation:
-curvature of the electrodes
-roughness of the electrodes
-location of the dielectric barriers
With regard to dielectric strength of silicon joints the most important factors are:
-rubber hardness
-compression force
-cleanliness of the adjacent surfaces of rubber and dielectric
The last factor creates additional requirements for an assembly process.

PARAMETERS OF THE NEW MEDIUM VOLTAGE RECLOSERS

Manipulating with the critical factors described in the previous section we achieved at the end configurations with typical separation between live parts about 80mm for 27kV application.
This allowed designing range of reclosers having tank dimensions 534x347x709 (width x height x depth, Fig 3) for rated voltages 15.5 and 27kV that is competitive with SF6 insulated switchgear.
These reclosers withstand standard BIL and 1 min power frequency tests in accordance with IEEE Std C37-60-2003 requirements for relevant rated voltage. Note that they employ bushing covered with silicon rubber having creepage distance 32mm/kV making them ideally suited for high-polluted applications.
Weights of the 15.5kV and 27kV reclosers do not exceed 65kg and 70 kg respectively presenting the lightest designs available in the market today.
Reclosers passed all type tests required by IEEE Std C37-60-2003 and are ready for commercialization.

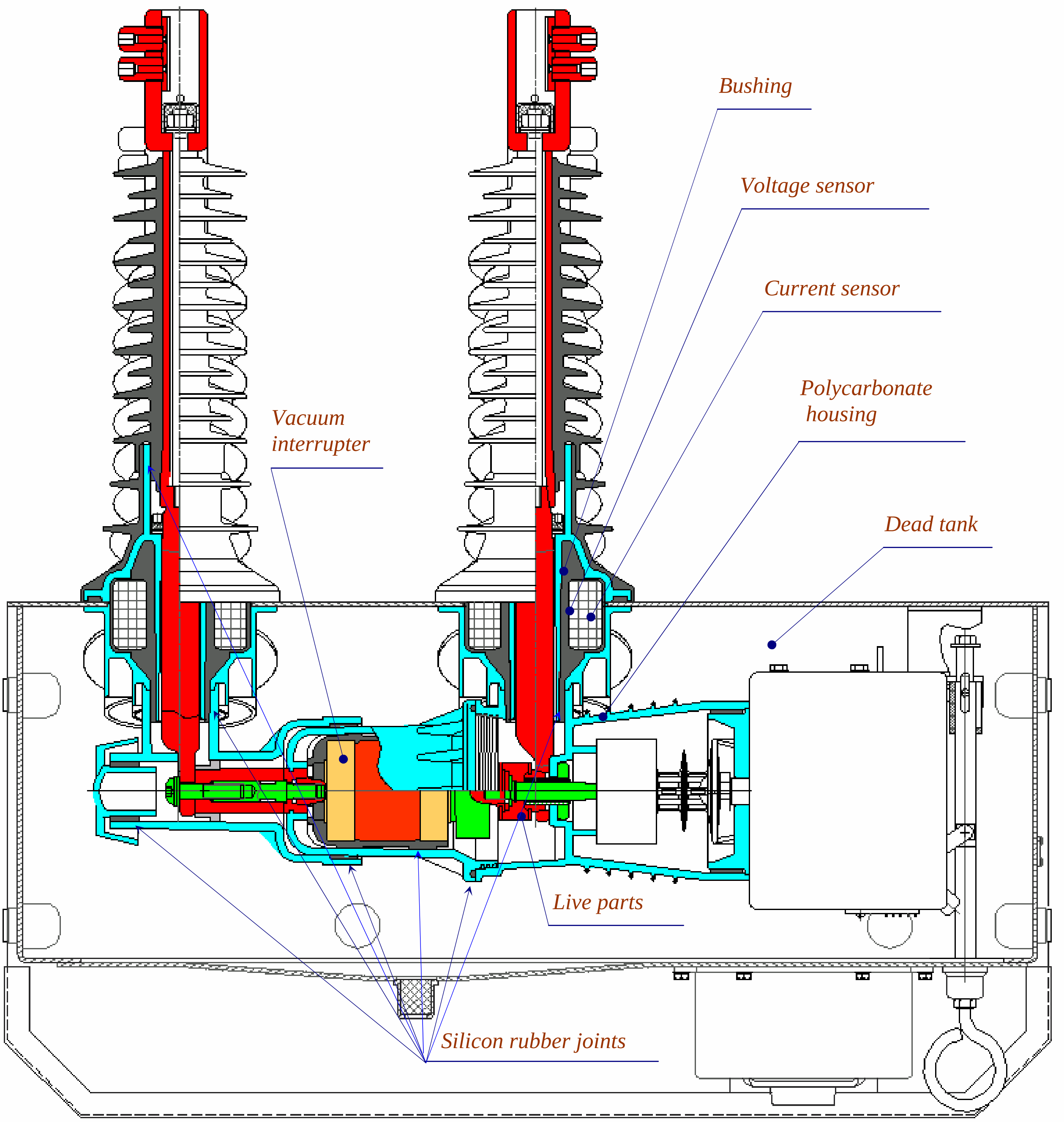

Fig.2. General arrangement view of the outdoor switching module

CONCLUSION

The novel insulation system developed for medium voltage reclosers based on the effect of the combined insulation presents effective alternative to SF6 and solidly insulated system. It combines positive effects of both systems, providing design flexibility that can be offered by SF6 insulated switchgear and being environmental friendly as solidly insulated switchgear.
At the same time this system does not have shortcomings relevant for abovementioned insulation systems.
Though this approach seems being very productive and has resulted in development practically advantageous designs, further development of its application is limited because of the lack of effective theoretical methods that could allow predicting dielectric performance of the systems with the combined insulation. Development of such methods seems being important task for future investigation.

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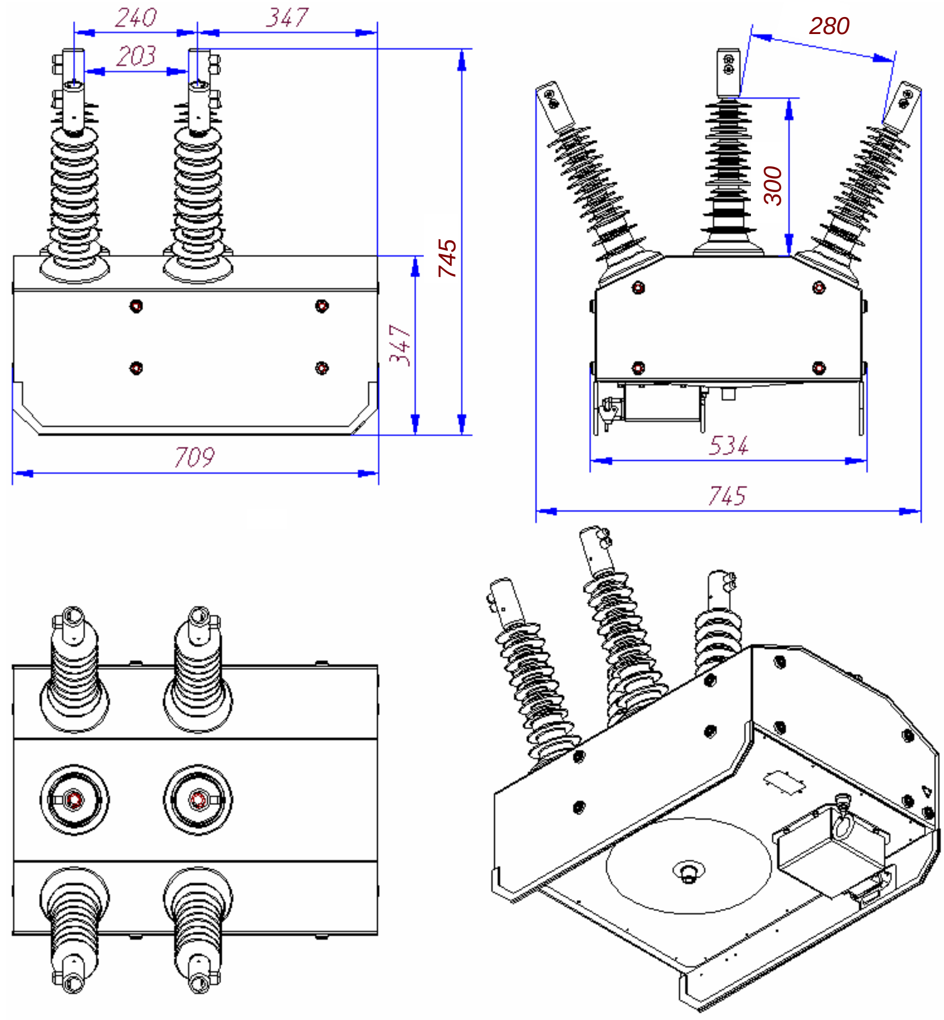

Fig.3. Overall design of the 27 kV recloser

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