Design and Implementation of SF6 Gas Insulated Medium Voltage Instrument Transformer

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Abstract

The main goal of the proposed model is to design the modular measurement voltage transformer at medium voltage level and to operate it safely within the distribution panel. In this respect, it is one of the main objectives of this paper to raise the level of safety of the technical personnel who fulfil the responsibilities of commissioning, maintenance etc. of metal-enclosed medium voltage panels to the highest level (in terms of work safety and worker health).The design principles of the SF6 gas insulated voltage transformer (optimized) have been drawn in line with the results obtained from computer simulations.

In this paper, SF6 gas insulated voltage instrument transformer (VIT) is designed and implemented and also tested electrostatically. A complex model consisting of air bubbles inside the epoxy cast resin is used for computer tests. The standard lightning over voltages is applied according to IEC 66076-3 and IEC 61869-3-2011. Computer tests show that SF6 gas insulated VIT is cost effective, lighter than that of epoxy cast resin, and environmentally friendly.

Introduction

Electric power consumption is increasing day by day and this leads to the need of a large number of switchboards.Nowadays, in big cities where the concept of security is to be kept at a high level due to economic and environmental reasons, there are examples of underground switch rooms in the city.If voltage and current transformers, which are indispensable elements of switchgear, are not designed correctly, they have very serious negative consequences.

Issues such as environmental awareness, work health and worker safety have been of great importance recently, and even governments are sometimes under pressure to comply with bilateral agreements.Epoxy resin is undoubtedly a good insulation material in medium voltage levels.However, it should not be forgotten that the voltage transformers are also caused by electrical accidents such as ferro-resonance, causing serious accidents resulting in death of the person near the distribution panel where voltage transformer is located.

Epoxy resin can also contain small particles, moisture and metal fragments at the time of casting.In this case, particles with a high dielectric constant according to the chain reaction theory are aligned in the direction of the maximum electric field strength and may lead to partial discharges and punctures at low voltage levels in oil.Compared to gasses, the resistance of such particles to electric field strength is not stable and is influenced by non-uniform electric field intensity distributions.Distortion in solid insulators such as epoxy resin is different from liquids and gases.Once the gases have deteriorated, they can return to their original state. Once the liquid has been deteriorated, some of it may return to its original state. However, the solids cannot go back to their former states.Breakdown in solids depends on the duration of the voltage level applied to the insulator.Breakdown in solids occurs in three different groups as electrical deterioration mechanisms, thermal deterioration mechanisms and electromechanical deterioration mechanisms.The corruption event (breakdown mechanisms) occurs as a result of each of these processes or collectively.As a result, the insulating material ages in electrical terms. Aging manifests itself in the epoxy as negative effects such as channel formation, partial discharge and warming, and shortening the life span of the material.However, it may be advisable to clean the outer surface with a dry cloth at certain times. It should be absolutely checked that no water or any other liquid is sprayed and that the neutral terminal is always grounded.

For this reason, casting in SF6 gas pressurized environments, such as the resin is recommended, will increase the reliability of the measurement transformer.For this reason, SF6 gas insulated transformer specifications have entered into force today, especially where there is a risk of safety today.

Some of the few important concepts that must be observed are the protection of the environment from the design and manufacturing process to the installation stages of the voltage and current instrument transformers, ensuring operational safety, minimizing maintenance requirements and minimizing fire risks. This plays an even more important role, especially in medium voltage (MV) and low voltage (LV) instrument transformers because it is one of the most important components of distribution systems. In order to meet the increased energy demand, a large number of distributed production systems and distribution panels are being manufactured in today's conditions, which is rapidly increasing the number of instrument transformers in MV and LV level [1].

It should be noted that these transformers, especially insulated with medium voltage level, are also sensitive to breakdowns in the energy system. Therefore, it is very risky for the personnel working in these types of transformers located outside the panel to operate for any reason (such as ferrorezonance, lightning impulse voltage, switching on / off high voltages), breakdown, fire etc [2].

Material and Method

In this paper, SF6 gas is used as insulating material inside the VIT due to its properties such as high dielectric strength, chemical stability and non-toxicity. Critical points between the high voltage winding and core material are defined and the associated electric field and breakdown voltages are calculated by simulation. Analytically, Equation (1) is then used to obtain the breakdown voltage of SF6.

$$V_{SF6} = 1321 pd^{0.915}\ \text{kV} \qquad (1)$$

In Eq. (1), p is pressure and d is distance between the selected (critical) points.

V_{SF6} is calculated analytically using Eq. (1) and COMSOL simulations. Since the electric field is non-uniform, the multiplication of SF6 pressure and distance between the selected points is calculated within a range of $50 \leq pd \leq 1200$ for the simulations. The standard lightening impulse voltage is defined in Eq. (2) [3].

$$V_L = 175000(e^{-14600t} - e^{-2469135t}) \qquad (2)$$

The model (Fig. 1) is prepared using SolidWorks and exported to Comsol Environment. To see the effect of air inside the transformer a few air bubbles are located around high voltage conductor and core section. The materials used are air, aluminum, copper, SF6 gas, epoxy cast resin, acrylic plastic and soft iron. Electrostatic physics is chosen to see electric fields between the critical points and stationary solution is done.

Results and Discussions

SF6 gas will easily reach all the coils as it is pressed into the housing under pressure in the pressurized environment (after drying for the body, after necessary pretreatments such as gas pressure under negative pressure). On the other hand, compared with the traditional model, the weight will be reduced to a great extent and will occupy less space in the panel due to its small size. The outer body will be earthed as long as the metal is shielded. This means the safety of touch (if necessary) for the working personnel. The following figures shows the model and computer simulations of SF6 gas insulated VIT.

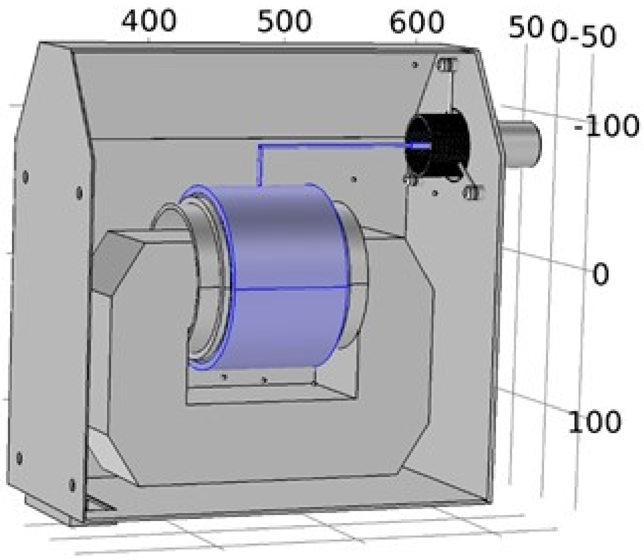

Figure 1. Inner parts of SF6 gas insulated VIT with air bubbles

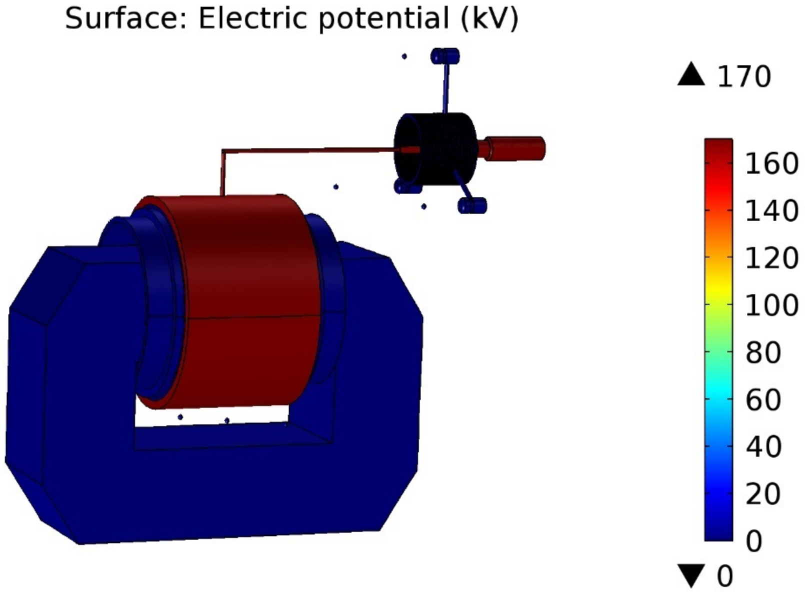

Figure 2. Electrostatic analysis of VIT under lighting condition

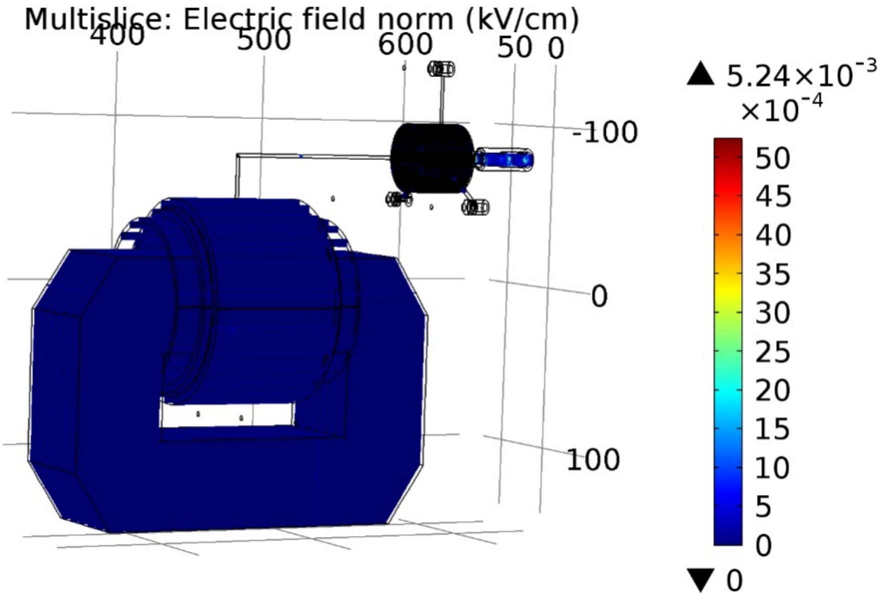

Figure 3. Electric field norm inside the VIT

Verification tests results are given in Table 1 and Table 2.

	Burden 25%		Burden 100%	
Primary Voltage (Un%)	Error Ratio	Phase Error	Error Ratio	Phase Error
80	+0.02	+0	+0.00	+0
120	+0.02	+0	+0.00	+0

Partial discharge test results are given in Table 2.

Voltage (kV)	1.2Un	1.2Un/√3
Level (pC)	10	5

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Conclusions

In today's conditions, the concepts of work safety and worker health are at the forefront and every manufacturer seems to try to comply with this concept to the maximum extent. This work is mainly concerned with this concept and the safety of the personnel working on the distribution panels has been maximized.

SF6 gas insulated measurement type voltage transformer is electrostatically analysed using COMSOL and the obtained outcomes reveal that the proposed model is safe and has many advantages compared to traditional epoxy cast resin samples.

References

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