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A new technique to Improve the dielectric strength of an multi-dielectric insulation system by applying the transverse electric field to main electric field

By

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Abstract:

In this study, an attempt is made to improve withstand ability of the multi-dielectric medium by the effect of an additional electric field in the transverse direction to the main applied electric field. H.V. insulation system is choosed in this study is air-solid insulation system. In this study, two types of gaps are used simultaneously : The first one is the main tested gap and the other is the transverse gap The main tested gap consists of two parts :

Part I is air insulation and part II is solid insulation. The transverse field is applied to part I, i.e.; air gap of the main tested gap. According to the results extracted from this work, the flashover voltage of the dielectric medium II increases as the transverse voltage within the region I increases; whereas the conduction current of the main tested gap decreases as the transverse voltage increases. Moreover, the effect of transverse voltage increases as gap pressure decreases. Actually, the effect of transverse voltage is much marked in low vacuum gaps than in atmospheric air gaps and compressed air gaps. The improvement in flashover behaviors in the presence of a transverse electrical field illustrate a marked dependence on the following: the item of pressure, the type of transverse applied electric field (a.c or d.c) and the transverse field plane level. However, the improvement does not depend on the specimen material. Moreover, it is worth mentioning that this improvement in the flashover behaviors of solid dielectric in the region II is related fundamentally to the process of lowering electric stress in the region I of the main tested gap.

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1. Introduction:

Many actual h.v. insulation systems are composed of various insulation materials whose permittivities differ from one another, stress is increased in medium of lower dielectric constant. Therefore, "Sandwished" or multidielectric insulation system can be dangerous if the insulation layers are of very different permittivities. Also, it is very difficult in h.v insulation technology to avoid such or similar arrangements due to the problem of production. One example is the continuous tight contact between metal electrode and solid insulation materials. Another one is the contact between the insulation material interfaces. A knowledge of electric field and the methods employed in controlling the electric stress is very important for h.v. technology. More practical methods of controlling stress have been previously done [1-5] Recently, more effects have directed in the field of improving the dielectric strength of multidielectric insulation system [6-9]. In any design, of course, the gaseous insulation works in conjunction with solid insulation, for which reason (because of this), the h.v. multidielectric insulation system is chosen for experimental tests in this work. In the present work, the author tries to introduce a new technique to control the electrical stress in the multidielectric insulation system by the effect of an additional electric field in the transverse direction to the main applied electric field. With this technique, the flashover voltage can easily be increased compared with that without the transverse field.

2- EXPERIMENTAL TECHNIQUE AND TEST ARRANGEMENTS :

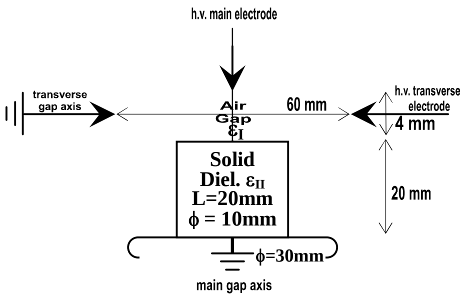

Figure (1) : Schematic diagram of the experimental set-up, electrode system with two dielectric εI and εII.

In this work, the one tries to introduce a new methodology technique in order to improve the withstandability of the multi-dieclectric arrangement by the effect of an additional electric field in the transverse direction to the main applied electric field. The experimental set-up used in this work is shown in Fig. (1) Two types of gaps in this study are used simultaneously : the main tested gap (M.G) and the additional gap of transverse type (T.G.). The main gap system was a needle-plane electrodes, while the T.G system used was a needle-needle electrodes. The plane was a circular disc of 30 mm diameter and 8 mm thickness, while the needle was a circular cone with an angle 15°. All needle electrodes used are of the same geometry and dimensions. All electrodes are made of brass. Tests are carried out under constant M.G distance of 24mm and constant T.G distance of 60 mm. H.V. insulation system used in this study is multidielectric insulation system, and it is composed of two dielectrics ε_I (air) and ε_{II} (solid diel.). The additional electric field is applied in the transverse direction to air gap, in other words; transverse field is applied to the transverse gap (air gap), whereas main tested field is applied to main tested gap. The solid dielectric specimens used are in the form of cylinders 20mm long and 10mm diameter; and are composed of Perspex (PMMA), Teflon (FEP) and polystyrene (PS). For each reading of flashover voltage, a new test specimen is utilized. The value for each flashover voltage represents the average of three flashover voltage readings. The flashover voltage for different transverse voltage (T.V's) of 0, 5, 10, 15, 20 and 25 KV are obtained. Power supply used in this work consists of two sources : one source is for M.G, known as main tested source, and the other is for T.G, known as transverse source. In this study, both the alternating and the direct high voltage are used. Several high voltage equipments are employed to obtain AC and DC high voltages. All the tests are carried out inside a P.V.C chamber. The P.V.C chamber is equipped with glass windows on top and sides, and, hence; the spark-over can be easily observed during the test. Three terms of pressure, in this work, are used : atmospheric pressure, below atmospheric (low vacuum) and above atmospheric (compressed air).

3- EXPERIMENTAL PROCEDURES AND TEST RESULTS :

The test procedures are carried out under different cases, as follows :

3-1 Flashover Voltage Test

The effect of applying a transfers electric field to the main tested gap , on the dielectric strength of an multi-dielectric insulation system :

3-1-1 Transfers field plane level

The effect of transverse field plane level variation on the flashover of solid dielectric in the air-to-solid insulation gaps is carried. To alter the transverse field plane level, the position of location of the T.G axis is altered. The transverse electrode gap axis is placed "S" (mm) apart from the grounded plane electrode of the M.G. The flashover voltage is measured with distance "S" under constant M.G. distance of 24mm and constant T.G distance of 60mm. In fact, the results are taken under a fixed T.V of 20 KV.

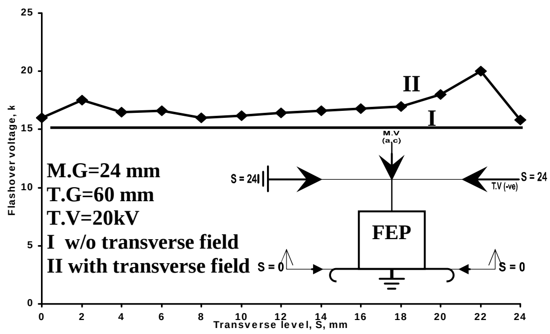

Figure (2) : Relationship between the flashover voltage and transverse field plane level within air-to-solid insulation gap, in atmospheric air.

In Fig 2., the flashover voltage of test specimen with distance "S" is shown. It is evident from this figure that the transverse field leads to the increase of the flashover voltage; but its effect is more obvious (maximum) if it is placed in the middle of spacing of the air gap. This position of location is chosen for the subsequent tests in this work; see Figs. 3 to 6. In this study, it is observed that the spark over occurs first in the air gap; and then it extends along the surface of the solid insulator.

3-1-2 Specimen material :

In this experiment the transverse field plane (transverse electrode gap axis) is placed 22 mm apart from the grounded plane electrode of the M.G, in other words; the transverse field plane is placed in the middle of spacing of the air gap. This test is done under constant M.G. distance of 24 mm and T.G distance of 60 mm. In this test, the flashover voltage for different applied transverse voltages T.V's to the T.G of 0, 5, 10, 15, 20 and 25 KV are recorded. For different solid dielectrics.

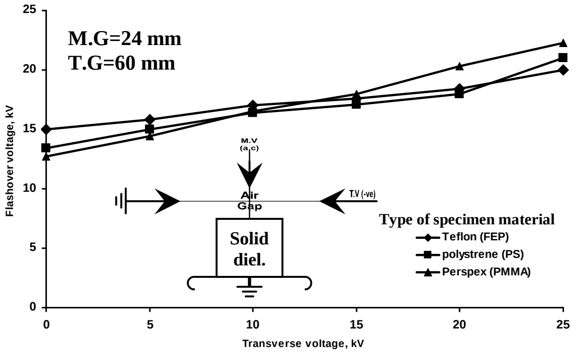

Figure (3) : Effect of transverse voltage on the flashover voltage in air-to-solid insulation gap, for different solid insulator materials, in atmospheric air.

Fig 3. shows the influence of DC transverse electric field on AC flashover voltage for different solid dielectrics. From this figure, it is noted that the effect of transverse field on flashover voltage is nearly independent on the material of the solid dielectric, i.e.; the effect of T.V so little to be not considered.

3-1-3 Type of transfers voltage :

The effect of applying transverse electric field on the flashover voltage of dielectric solid in air-to-solid insulation gaps is carried out. The effect is clear for different applied AC and DC voltages on T.G electrodes, with the M.G at 24 mm and T.G at 60 mm. The test's results are given in Fig. 4. From this figure, it is clear that the flashover voltage increases as the transverse voltage (T.V) increases. Also it is clear that flashover voltage is larger for D.C T.V than under A.C T.V, with more improvement under D.C –ve polarity.

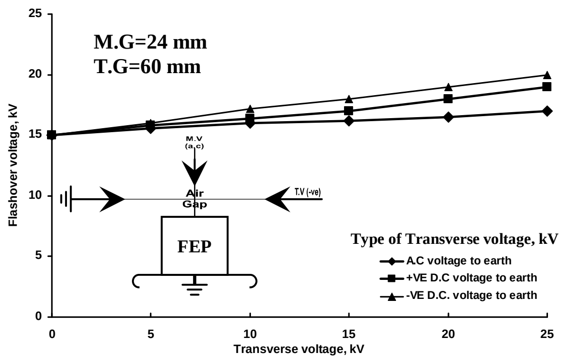

Figure (4) : Relation between flashover voltage and transverse voltage of different modes, within air-to-solid insulation gap, in atmospheric air.

3-1-4 Gap pressure :

3-1-4-1 Compressed air gap :

The test is done under constant M.G. distance of 24mm and T.G distance of 60mm. The flashover voltage for different specified T.V's of 0, 5, 10, 15, 20 and 25 KV is obtained for different gap pressure, above atmospheric of 1, 2, 4, and 6 ata; as shown in Fig. 5. From this figure, it is clear that flashover voltage for a given P value increase with the increase in T.V. Also, it is observed from this figure, that the effect of transverse electric field increases with the decrease in gap pressure.

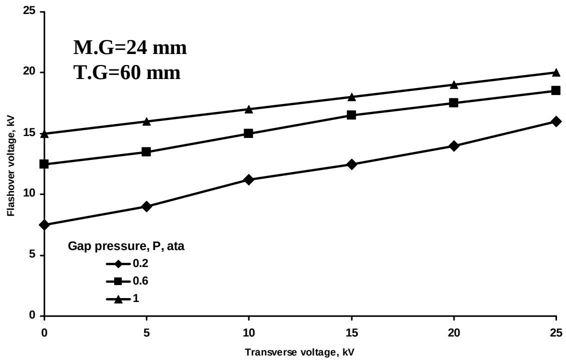

Figure (5) : Effect of transverse voltage on flashover voltage in air-to-solid insulation gap for different gap pressure, below atmospheric (low vacuum).

3-1-4-2 Low vacuum gap :

The test is done under constant M.G distance of 24 mm and T.G distance of 60 mm. The flashover voltage for different T.V's of 0, 5, 10, 15, 20 and 25 KV is obtained for different gap pressure of 1, 0.6 and 0.2 ata, as shown in Fig. 6. From this figure, it is clear that the flashover voltage for a given P value increases as the T.V increases. The effect of T.V increases as the gap pressure decreases, this is to say; the flashover voltage increases as the degree of vacuum increases.

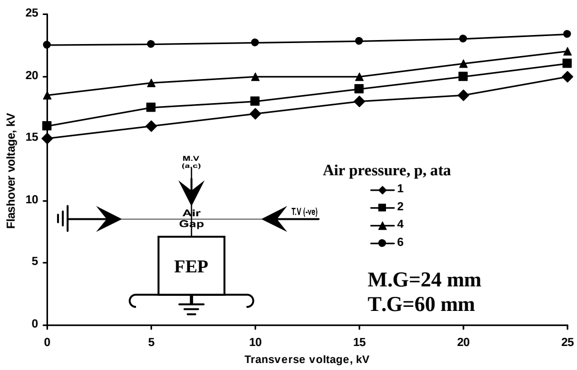

Figure (6) : Effect of transverse voltage on flashover voltage in air-to-solid insulation gap for different gap pressure, above atmospheric pressure (low pressure)

3-2 Conduction Current Test :

This tests is carried out under constant M.G. distance of 24mm and T.G distance of 60 mm. The conduction current for different T.V's is recorded for a fixed main applied voltage of 20 KV DC-ve, which is lower than the flashover voltage; as shown in Fig.7. The conduction current can be read directly on the micro/milliameter. From this figure it is clear that as the T.V increases the conduction current decreases, which is in line with the results obtained in Ref. [14].

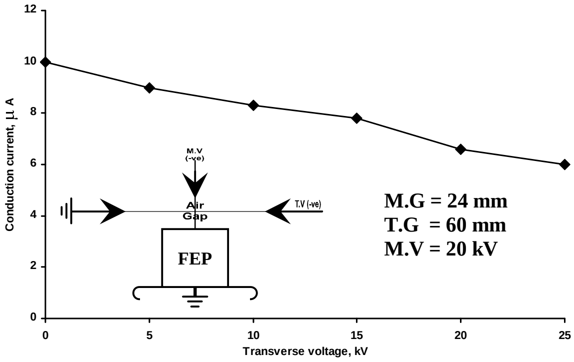

Figure (7) : Effect of transverse voltage on conduction current within air-to-solid insulation gap, in atmospheric air.

4 - RESULTS AND DISCUSSIONS:

The new technique utilized in this study enables us to investigate the influence of a transverse electric field on the flashover behaviors of the dielectric solid in air-to-solid insulation gap. In this study, a possible method of reducing the flashover stress is achieved by the effect of an additional electric field in the transverse direction on the main applied electric field. In general, the results obtained in this work can be discussed through the following : the lowering of electric stress in the dielectric medium II depends on the lowering of stress in the dielectric medium I, i.e.; the improvement in the flashover characteristics of dielectric medium II is related mainly to the lowering of stress in the dielectric medium I.

From this study, it is clearly seen that the flashover voltage with T.V indicates higher value, compared with that without T.V. Also, the flashover voltage increases as the T.V increases. As a result of comparing Figs. (4 – 6), the effect of T.V is more effective in air vacuum gap, compared with both atmospheric and compressed air gap. Furthermore, the conduction current decreases as the T.V increases. The effect of T.V on the flashover voltage shows a marked dependence on the item of pressure, transverse field plane level and the type of voltage applied on the transverse gaps. However, this effect does not depend on the specimen material.

The improvement in the flashover voltage and the conduction current in the presence of a transverse electrical field may be due to the elimination of charges by the sweeping action of the transverse field (out of air gap). This in turn increases the flashover voltage and reduces the conduction current. This assumption is in accordance with that given by (10).

Also, the improvement in flashover voltage and conduction current of air-to-solid insulation gap, in the presence of a transverse field across the air gap, can be interpreted through that in the presence of a transverse field the main electric field E (along which the electron travel) is reduced from E to the resultant electric field of the main and transverse applied field E cos θ. While on the other hand, the path length in the main electric field direction is increased by 1/cos θ. Where θ is the angle of avalanches inclination of the electric field. This assumption is in accordance with the previous given results after [11-15]

Moreover, the improvement in flashover voltage in the presence of a transverse field can be interpreted through that transverse field acts as if it is a barrier to the moving charged particles (1), as a result to that the electron multiplication within the air gaps is blocked and hence the cascade multiplication of electrons on the surface of the insulator is arrested. This in turn increases the flashover voltage and reduces the leakage current. This assumption agrees with that given by [6, 7].

Furthermore, the effect of a transverse electric field might be regarded as equivalent to an increase in air pressure, which is in accordance the previous results given in Ref. [2]. It can be said that transverse electric field is analogous in its effect to the effect of shirkable – heat creepage extenders which cause a reduction of surface electric stress and hence higher flashover strength [16].

5. Conclusions:

According to the results extracted from this work, the improvement in the flashover behaviors in the presence of a transverse electrical field depends on the type of transverse applied electric field and the transverse field plane level as well as the air pressure of the M.G. However, this improvement does not depend on the specimen material. In general, the flashover voltage increases as the T.V. increases, the flashover voltage is larger for DC T.V than under A.C T.V. the increase in flashover voltage in the presence of T.V is more obvious if it is placed in the middle of spacing of the air gap. The effect of T.V increases as the gap pressure decreases. Also, the effect is more effective in low vacuum gaps, compared with that in atmospheric air gaps and compressed air gap. Moreover, the conduction current decreases as the T.V. increases. It can be said, that the transverse filed can be used as a means of controlling flashover stress in air-to-solid insulation gap through the control in the sparking stress in air gap.

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