Influence of Oxygen on Dielectric Properties of HFO1336Mzz(E)/CO_2 Gas Mixture

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***Abstract*— HFO1336Mzz(E) gas is regarded as a viable replacement gas for SF6 in gas-insulated equipment due to its superior insulating properties and low greenhouse gas potential (Global warming potential, GWP). This study analyses the power frequency breakdown characteristics, charge scattering, and insulation stability of HFO1336mzz(E) under the influence of O_2 at different mixing levels. It is concluded that the addition of oxygen enhances the breakdown strength of the proposed gas mixture. The insulation strength of HFO1336Mzz(E) mixture with 2,4,6,8,10 % concentration increases the breakdown voltage by 5.35 %, 8.55%, 12.30%, 14.48%, and 15.10% respectively as compared to HFO1336Mzz(E)-CO_2 mixture. The insulation stability of the gas mixture is improved with O_2 addition up to 8 % above that level, and the stability is reduced. For engineering applications, 2-8% of O_2 to the HFO1336Mzz(E)-CO_2 gas combination is advised to enhance insulating performance.**

Keywords—SF_6, gas insulation, gas breakdown, high voltage, global warming potential

I. INTRODUCTION

The electrical power industry's reliance on sulfur hexafluoride (SF6) gas has raised significant concerns regarding its contribution to global warming potential (GWP). Despite its effective role in insulating high-voltage equipment, SF6 possesses an alarmingly high GWP compared to other greenhouse gases. [1]. The high GWP, estimated to be approximately 23,500 times greater than carbon dioxide over a 100-year period and prolonged 3200 atmospheric lifespan, underscores the urgency of addressing SF6 emissions [2]. Furthermore, the electrical power industry has been the principal producer and user of SF_6 since the 1970s [3-6]. Approximately 80% of SF_6 sales are directed toward the power sector. A popular topic in recent years has been the search for environmentally suitable replacement gases for medium and high voltage applications in an effort to significantly reduce the widespread usage of SF_6 [6-8].

Recently, a new refrigerant gas, HFO1336Mzz(E), has been proposed as a viable replacement to SF6 for medium voltage applications. HFO1336Mzz(E) is an electronegative gas with a good insulation strength of 1.4-1.6 times SF6 and a global warming potential of only 18 [9-14]. A comprehensive investigation into the insulating capabilities of HFO-1336mzz(E) is currently missing. In a study conducted by Rabie et al. in 2015, computational screening was employed to assess various insulating gases, revealing that the dielectric properties of HFO1336mzz(E) were estimated to be nearly 1.8 times superior to SF_6 [15]. Additionally, Kothe et al. undertook experiments in 2020 involving a range of novel environmentally friendly gases. Their results indicated that the insulation effectiveness of mixtures involving HFO-1336mzz(E) with either CO_2 or N_2 is comparable to mixtures such as $C_5F_{10}O/CO_2$ and C_4F_7N/CO_2 [16]. Ahmed et al. discovered that the power frequency alternating current (AC) breakdown voltage of pure HFO-butene surpasses that of SF6 by more than 1.2-1.6 times. Additionally, the dielectric strength of a gas mixture containing 30% HFO1336mzz(E) and 70% CO_2, subjected to a highly non-uniform electric field, exceeds that of SF6 by 1.4 times. This superiority is notably greater than the value of 1.2 observed under a weakly non-uniform electric field [6]. Nevertheless, further investigation remains necessary to gain a comprehensive grasp of its synergistic characteristics with different buffer gases and their responses to breakdown in heterogeneous electric fields. The molecular arrangement of HFO1336Mzz(E) is depicted in Figure 1, while its physiochemical attributes are presented in Table 1.

This research investigation focused on examining how the presence of oxygen gas impacts the dielectric breakdown voltage and self-recovery attributes of the HFO1336Mzz(E)/CO_2 gas mixture. Different concentrations of oxygen ranging from 2-10% were added to the gas mixture under alternating current (AC) test conditions. The novelty of this work is that the insulation properties of HFO1336Mzz(E)/CO_2 are first investigated under the influence of oxygen as a ternary mixture. The results captured will serve as the basis for further investigation and an important reference for the proposed gas engineering applications.