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The purpose of the Workshop was to collect the available information on interrupting and switching performance with state-of-the-art of alternatives to SF6 and then to evaluate their interrupting capabilities in comparison with SF6 in order to decide whether any new actions are required in CIGRE, besides the recently published SF6 paper in 2014 [1].

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Abstract

CIGRE Study Committee A3 held a Workshop on SF_6 alternatives jointly with Current Zero Club (CZC) on Monday, 22 August 2016 during the 2016 Paris session. Sixty experts attended. The purpose of this Workshop was to collect the available information on interrupting and switching performance with state-of-the-art of alternatives to SF_6 and then to evaluate their interrupting capabilities in comparison with SF_6 in order to decide whether any new actions are required in CIGRE, besides the recently published SF_6 paper in 2014 [1]. After opening remarks by the chairs of SC A3 and CZC, the results of the latest investigation conducted by the CIG members were presented. Five manufacturers then presented developments and on-going pilot projects with SF_6 alternatives. The amount of information presently available to make comparisons of the main properties and of the switching performance to SF_6 is very limited and is often only from a single source. The most promising new gases are perfluorketones and perfluoronitriles. Due to the high boiling point of these gases, in HV applications mixtures with CO_2 are used. For MV insulation perfluoroketones are mixed with air, but also other combinations might be possible. The dielectric and switching performance of the mixtures, with mixing ratios that are acceptable for the environment, are comparable to the dielectric that of SF_6. Minor design changes or de-rating of switchgear are therefore necessary. The new gases decompose under the influence of arcing but do not contribute $HeSF_5$. Physical differences between the gas mixtures are mainly in the boiling point and the GWP.

Introduction

SF_6 is widely used in electric power transmission and distribution systems, as for example in gas insulated switchgear (GIS), circuit breakers (CB) and load break switches. It combines unique electrical insulation and arc interruption capabilities [1]. However, it is also a very strong greenhouse gas with a global warming potential (GWP) of 23500 times that of carbon dioxide. Its use and its use and release are regulated with further restrictions being discussed. Consequently, the search for alternative gases for use in power applications has been ongoing since about two decades ago [1]-[4]. This paper briefly reviews the status of the present solutions, with a focus on switching applications. This review is mainly based on the most recent literature available from some manufacturers. No independent confirmation is available. Since vacuum switching technology is a separate ongoing activity [5], it is not included in the present review.

Search for alternative gases

An intensified search for alternative gases started about two decades ago [1]-[4] after the Kyoto protocol was agreed in 1997 and gained increased focus in the last 10 years [6]-[7]-[8]-[9]-[10]-[11]-[12]-[13]-[14]. The following important requirements for alternative gases were identified:

- Low global warming potential (GWP) and zero ozone depletion (ODP) potential
- Low toxicity and non-flammability
- High dielectric strength, arc quenching capability and heat dissipation property
- Stability and material compatibility
- Availability on market

From various studies of gases of natural origin, CO_2 is the most promising arc quenching gas [7]-[16], possibly enhanced by performance by some additives [11]. However the switching and dielectric performance of CO_2 are both below those of SF_6 [16]-[15]. Other interesting gases were identified to be fluorinated gases like CF_4 perfluoroketones (e.g. C_4F_7O) and perfluoronitriles (e.g. C_4F_7N [6]-[12]-[13]-[14]-[16]-[17]. Taking all the requirements into account, the most promising candidates at present appeared to be the C3 perfluoroketone ($CF_3CO(CF)CF_3$, or C3-PFK) [18] and the new C5 perfluoroimide (CF_3CF_2CN or C4-PFN) [19]. The dielectric performance of pure gases typically scales with the boiling point, i.e. gases with high dielectric strength usually also have a high boiling point [9]. For C3-PFK and C4-PFN, the boiling point at 0.1 MPa are 26.9°C and -4.7°C, respectively. Thus, for application in switchgear, where a sufficiently low boiling point is needed for the gas to prevent condensation, the advantage of a buffer gas is needed. CO_2 is selected for this role in HV due to its good arc quenching capability. In MV application air is also reported as the buffer gas in combination with C3-PFK for insulation purposes [20]-[21]. The concentration of C3-PFK and C4-PFN, and by this the performance of the mixtures, will depend on the minimum operating temperature requirement of