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High Voltage Circuit Breakers: SF6 vs. Vacuum

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Abstract. As important as finding new renewable and environmentally friendly sources of energy is the fact of transmitting and distributing this energy in the safest and most efficient way. In this field, High Voltage Circuit Breakers (HV CB), designed for operation of the electric network under normal conditions as well as for the interruption of faulted conditions, have played an important role in power systems over 100 years. However, research, development and improvement of the design of CBs have not stopped in our nowadays expanding grid.

The aim of this paper is to make a review of the existing different types of HV CB, comparing the most used one, SF6 CB, with the Vacuum CB, which has been developed and recently applied for HV, and could become the future environmental friendly HV CB.

Key words

Circuit Breaker (CB), Vacuum Circuit Breaker (VCB), Sulfurhexaflouride (SF6), Electric arc, Vacuum Arc.

1. Introduction

A Circuit Breaker is a switching device which can open or close a circuit in a small fraction of second. This is achieved due to its separable contacts. The closing and opening of the circuit allows to establish or to interrupt the circulation of current through the circuit under usual or unusual working conditions, such as short circuits.

The interruption process of the current in a CB, begins when the movable contacts start to separate. As a consequence, the contact area is reduced and the current density gets larger, until the energy causes the metal to begin vaporizing and an arc appears. In spite of the existence of a physical separation of the switching contacts, the established arc makes possible that the current continues flowing. The interruption of the circulating current will be achieved when the interrupting medium gets to turn the carrying arc plasma into an isolating medium. ([1]-[4])

In the beginning of the arc phenomena the main source of charged particles is the electrode vapour. However, as the contact separation increases, the ionization degree of the arc column is also influenced by the characteristics of the surrounding medium, except for Vacuum CBs.

Attending to the medium and the method used for the interruption of the current, CBs can be grouped in the following types:

- Air Magnetic Circuit Breakers
- Air Blast Circuit Breakers
- Oil Circuit Breakers
- Sulfurhexaflouride (SF6) Circuit Breakers
- Vacuum Circuit Breakers

Oil circuit breakers were the first CB type in the grid, due to its ability to interrupt large currents. The interruption process is based on the creation of hydrogen and acetylene gas bubble, as the oil decomposes as a result of the arc established between the switching contacts. The disadvantages of using oil as quenching media in circuit breakers, as flammability and a high maintenance cost, forced to search for different mediums of quenching. Air Blast and Magnetic Air circuit breakers were developed but did not sustain in the market due to some disadvantages, as the fact that they are bulky and cumbersome. In the middle of the century, and being considered as the new generation of CBs, SF6 and Vacuum CBs appeared.

SF6 CBs started quickly to replace oil and air CBs for HV applications, as most SF6 properties are superior to other interrupting mediums, such as its high dielectric strength or higher thermal conductivity. In contrast, Vacuum CBs started to spread in the Medium Voltage level up to rated voltages of around 36kV. ([1], [3])

Even though many CBs from the first generation, with oil or air as quenching medium, are still working, SF6 CB is undoubtedly the most common CB used nowadays for HV applications worldwide. But, it also has its limitations and disadvantages. Vacuum switching, widely used for medium voltage levels (5-38 kV), has emerged as an alternative for high voltage applications due to its environmental friendliness. Latest research on contact material composition, magnetic field application, insulation, multi-gap or long gap technology has lead to the development of various prototypes for higher voltage levels.

2. Comparison between SF6 and Vacuum CBs

In this section, SF6 and vacuum circuit breakers are compared considering different factors, as for example the dielectric strength and environmental effect.

According to the dielectric strength, SF6 has better behaviour than vacuum (Figure 1). That is why SF6 has generalized both as insulating and arc quenching medium. The use of SF6 makes possible to reduce the size of electric equipment and so the required space for installation. That is the reason why its most important use, about 50 % of the total, is as dielectric in electric devices, as CBs.

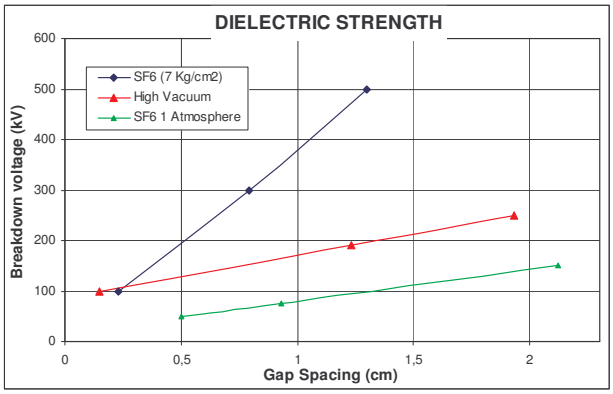

Figure 1. Dielectric strength of SF6 and Vacuum.

Besides, at normal conditions, SF6 is an inert, non-flammable, non-corrosive, odourless and non-toxic gas. However, at temperatures over 1000°C, SF6 decomposes to gases including S_2F_{10} which is highly toxic. Fortunately, the decomposition products recombine abruptly after arc extinction (when the temperature goes down). It could be said then, that SF6 would be the perfect quenching medium for a CB if it was not environmentally harmful.

SF6 has been labelled as one of the major global warming gases, since the 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change. The fact that SF6 is a special global warning contributory gas is based on its stable molecular composition, as it becomes indestructible for a long period of time, over 3200 years.

In Table I a comparison between several gases with regards to their lifetime years and their Global Warming Potential (GWP) is shown.

TABLE I. Global Warming Potential.

Compound	Lifetime Years	GWP
CO_2	50 - 200	1
CF_4	50.000	6.300
C_2F_6	10.000	12.500
SF_6	3.200	24.900
C_6F_{14}	3.200	6.800

In contrast, as in VCBs the quenching media is vacuum, there is no risk for the environment. In fact, they consist on an ordinary glass container and metallic components, that is, recyclable materials [5]. Vacuum brings it own advantages and disadvantages, which differ from those of SF6. Among the advantages of VCBs there can be highlighted its compact size and light weight. In addition, maintenance and inspection are easier, and there is no environmental damage. Besides, they have a long operation life, with very high number of operating cycles and a high dielectric resistance recovery after current zero. However, a main disadvantage is still the cost, as SF6 CBs are still cheaper.

3. Conclusion

The non stopping growing electric power grid demands increased performance and reliability, but also sustainability. Thus, it is important to continue developing new CB technology, more reliable, more capable, less costly, environmentally friendly, recyclable, and safe for humans. Vacuum is a medium with outstanding properties concerning short-circuit current control or dielectric strength recovery. The applications, today still mostly in medium voltage distribution networks, will potentially be widely spread to HV distribution networks, avoiding the environmental impact of SF6. But, it is necessary to introduce changes in the design and the materials used to ensure the proper working of VCB at higher voltage values.

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