The Power Sheet

Consultant Web Page

# VACUUM & SF6 COMPARISON

## INTRODUCTION

Medium voltage is defined as voltage above 1000 volts and below 100,000 volts. Two types of arc extinguishing technology are commonly used; vacuum interrupting and sulfur hexafluoride gas (SF6). In designing medium voltage distribution systems, voltage classes 5kV, 15kV, 27kV and 38kV are used and the following comparison applies to these voltage classes.

## ARC INTERRUPTION

Figure 1 shows a generic interrupting device comprised of a sealed enclosure, fixed contact , and a movable contact.

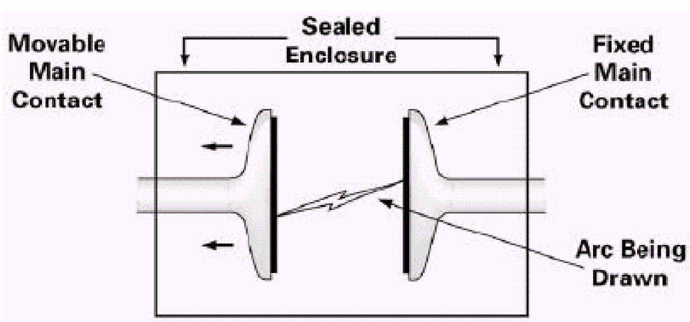


**Figure 1 - Arc Interrupter Schematic**

In normal operation, the two contacts within the interrupter are held together allowing current to pass through the breaker. When the breaker opens, the contacts part and an electric arc forms between the separated contacts. Arcs form because the medium between the parted contacts ionizes, meaning the particles become charged allowing the electricity to travel between the contacts. Further, the arc burns the metal surface of the contacts similar to an arc welder.

Figure 2 details AC sine wave current rising from zero current to full current then back to zero current. Lastly the electric arc dies and the contact surface ceases to vaporize.

At current zero, or slightly before, the arc is extinguished, and the breaker must prevent the arc from reigniting. Two concepts need explanation in preventing arc reignition: dielectric strength and transient recovery voltage.

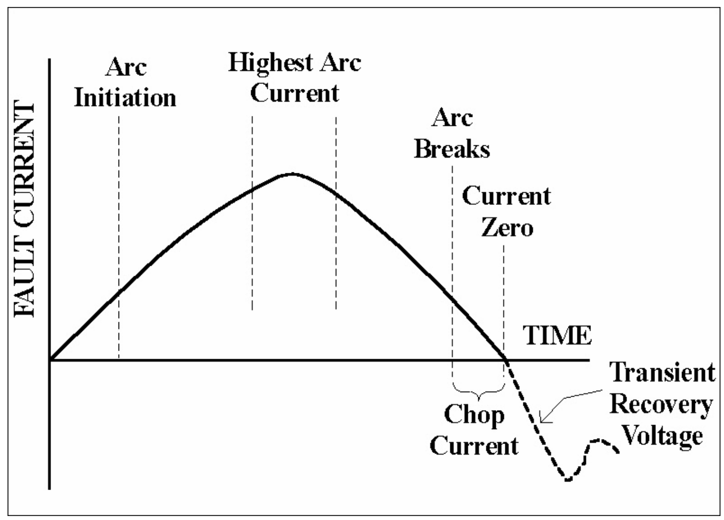


**Figure 2 - Arc Interruption Currents**

- **Dielectric Strength** is the maximum voltage that the interrupting medium (in this case vacuum or SF6) can withstand without breaking down
- **Transient Recovery Voltage** (TRV) is the voltage caused when the current suddenly drops off. The sudden drop-off of current shortly before current zero is called “chop current”. The effect of chop current is transient voltage of opposite polarity.

**Vacuum Interrupters are a Proved, Environmentally Safe Arc Interruption Technology**

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Whew, that's PHD complicated! So what does it really mean? Use the following analogy to illustrate transient recovery voltage. Think of a tug-of-war with two teams pulling a rope. Suddenly, the rope breaks. Does the rope passively fall to the ground? No, rather each end of rope flies uncontrolled in the direction of each pulling team before resting on the ground.

This uncontrolled action of the breaking rope is analogous to TRV and chop current is analogous to force that each tug-of-war team is pulling. Chop Current is the premature breaking of the electric arc before current zero, as shown in Figure 2. Therefore, the larger the chop current, the higher the TRV.

Why is TRV important? This is the most severe waveform that the interrupter has to withstand because it is unpredictable and may exceed the magnitude of the normally interrupted electric arc. In addition, interrupter medium cannot breakdown after the arc in first interrupted and allow the arc to reform. Meaning, the interrupting medium must have sufficient dielectic strength to prevent reignition of the arc after current zero.

## VACUUM INTERRUPTING

A vacuum interrupter consists of two contacts encased in an evacuated envelope. The operating principle is that an electric arc needs a medium to ionize for travel from one parted contact to the other. Removing this medium eliminates an ionization path for the electric arc.

The primary parts of a vacuum interrupter are: one fixed contact, one movable contact, a ceramic enclosure, and a stainless steel bellows as detailed in Figure 3.

The manufacture of vacuum interrupters is relatively simple. An automated process welds the ceramic enclosure to the fixed contact ***in a vacuum.*** Next a stainless steel, accordion like bellows is welded to the ceramic enclosure and the movable contact, again ***in a vacuum.***

The reason for an accordion bellows is to allow the movable contact to separate from the fixed contact. This stainless steel bellows will not compromise the vacuum within the enclosure. Further note that travel of the movable contact is approximately **½ inch**.

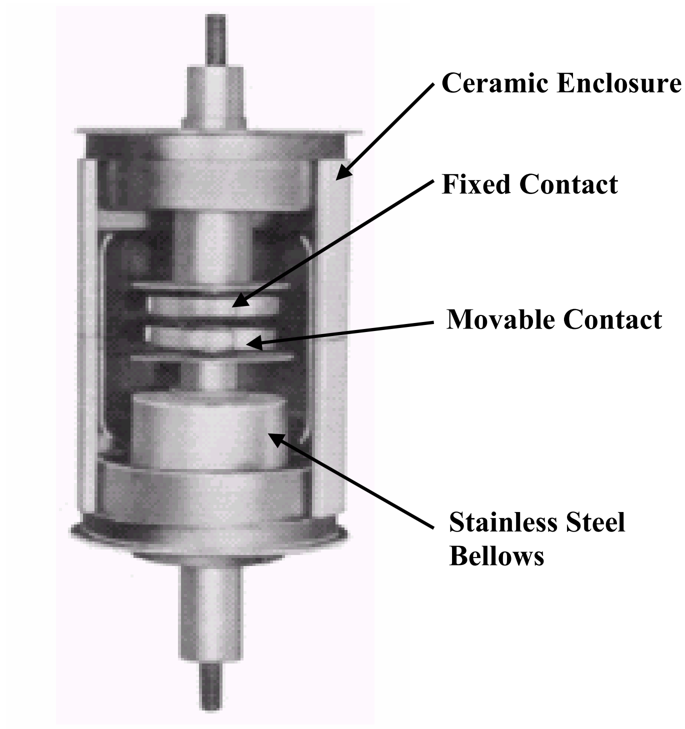


**Figure 3 - Vacuum Interrupter Components**

## SF6 INTERRUPTING

SF6 interrupting technology has excellent dielectric properties and complex manufacturing techniques makes this technology popular, especially outside the United States.

The concept of operation is similar to vacuum interruption: contacts are separated in a medium in which ionization does not occur. In this case, the medium is SF6.

The components of an SF6 interrupter is similar to a vacuum interrupter and consists of: a fixed contact, a movable contact, within a metal envelope.

The difference is in the manufacturing process of SF6 interrupters. This interrupter is assembled using rubber "O" rings to seal the movable contact, rather than an impervious stainless steel bellows used in a vacuum interrupter. The interrupter then is injected, under pressure, with the SF6 gas.

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## ENVIRONMENTAL CONCERNS

Vacuum, obviously, is a benign medium and presents no environmental concerns.

SF6 is classified as a floral carbon similar to the refrigerants used in air conditioning systems and refrigerators. As most persons are aware, chemicals classified as refrigerants are regulated in the U.S. by the Environmental Protection Agency (EPA). Simply stated, SF 6 is an ozone depleting gas, or greenhouse gas, and currently is attracting international restrictions.

Because of this classification, SF6 carries the following issues:

- Special care for disposal as SF6 byproducts are considered hazardous waste and require special, regulated disposal
- SF6 is a potent greenhouse gas labeled as contributing to global warming
- Byproducts formed by electric arcing in SF6 are toxic and present safety concerns to maintenance personnel
- SF6 has 3 times the global warming potential than CFC-12 (CFC-12 is commonly used in refrigerator and automobile air conditioning systems)
- SF6 is attracting regulation that add cost and complexity to facilities

In addition, SF6 is included in the Kyoto Treaty. This international treaty, currently not adopted by the U.S., regulates compounds classified as "ozone depleting". SF6 is regulated by this treaty. Should the U.S. ever adopt the Kyoto Treaty, SF6 will be heavily regulated resulting not only increasing maintenance costs by requiring yearly inventory and penalties for release of SF6 gas, but the cost of SF6 most likely will skyrocket.

Vacuum, being completely inert, does not carry any of these issues. In addition, the arc interrupting performance is not compromised, if not better.

## SYSTEM RELIABLITY

Cutler-Hammer vacuum interrupters are designed and manufactured for a life-time seal. Vacuum interrupter are manufactured where the movable contact is brazed to the ceramic envelope using a stainless steel bellows. The bellows allows movement of the contact without compromising the vacuum within the metal envelope.

All vacuum interrupters are factory tested before installation into breakers. Further, the breakers are again tested before shipment for field installation.

Interrupters that are in field service have a leak rate of only ***8 parts per million.*** Experience shows that a vacuum interrupter in service for more that 5 years without and vacuum loss will never leak.

Vacuum interrupters require movable contact travel of approximately ½" therefore making the open/close mechanical mechanism of the breakers simple and requiring less mechanical energy to quickly open/close.

In contrast, SF6 breakers require a more complex open/close breaker mechanism. This added complexity is due to greater travel needed to separate the contacts and the added energy needed for quick separation.

Here lies a significant reliability difference between vacuum breakers and SF6 breakers: the **breaker mechanisms are more complex in SF6 breakers**. A typical SF6 breaker mechanism (depending on the design) has 30% more mechanical parts than a vacuum beaker. This difference offers a significant reliability advantage for vacuum breaker technology.

**Typically, medium voltage breakers failure is due to mechanical mechanism malfunction rather than failure of the interrupter itself.**

## SUMMARY

Vacuum technology offers the following advantage:

✓ **No regulatory issues – In contrast, SF6 is classified as a greenhouse gas**

✓ **No toxic byproducts when the gas breaks down – SF6 requires special disposal of byproducts**

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- ✓ **High reliability – fewer than 8 parts per million fail in the field**
- ✓ **Time proved technology – Vacuum technology was introduced in the late 1960's**
- ✓ **High mechanical reliability – SF6 breakers need a mechanically complex open/close mechanism introducing significantly more system failures**

## CUTLER-HAMMER MEDIUM VOLTAGE ASSEMBLIES

Cutler-Hammer has been manufacturing medium voltage switchgear for over 50 years previously under the Westinghouse brand name. Figure 4 is two high, 15kV class medium voltage assembly.

In addition, Cutler-Hammer internally manufactures all components needed in the assembly of medium voltage switchgear including: the vacuum interrupter itself, the breaker assembly, and the switchgear. The plant is located in Greenwood, SC.

An important design feature of Cutler-Hammer medium voltage switchgear is the connection between the vacuum interrupter and the breaker internal bus. This connection needs to be flexible to accommodate the movement of the contact within the interrupter.

Cutler-Hammer uses a "V" shaped coupling for connection, as shown in Figure 5. This method provides a non-sliding, positive connection while allowing for needed contact movement. The V-Flex connector is a Cutler-Hammer exclusive and has the advantage of providing a large current carrying area greatly reducing the possibility of hot spots caused by high current flow through a small area.

Other manufacturers use bonded flexible cable, a sliding mechanism, or compression connected metal plate to allow for contact movement. These methods have proved less reliable than the Cutler-Hammer V-Flex design.

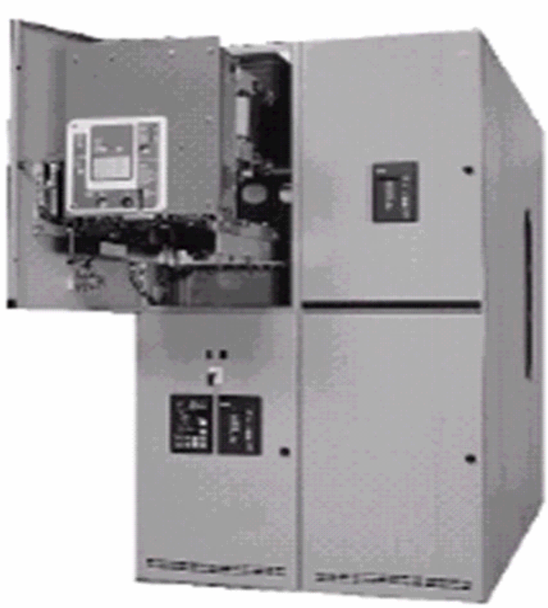

**Figure 4 - Two High Medium Voltage Assembly**

**Figure 5 - V-Flex Connection**