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The Self Actuating Vacuum Interrupter (SAVI): A New Concept in Vacuum Interrupter Technology

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***Abstract*-This paper describes a new approach to the design of Vacuum Interrupters. Presently a Vacuum Interrupter (VI) is a component of electrical switchgear, which relies on an external mechanism to provide the movement of the contacts required for switching operation. The Self Actuating Vacuum Interrupter (SAVI) is a concept whereby the contact movement is performed by means of an internal mechanism within the Vacuum Interrupter. This gives a number of significant advantages over conventional designs including: removing the need for a bellows, eliminating the drive insulator and creating a switching device which has no external moving components. It is believed that these significant advantages will result in a new generation of switchgear which is no longer constrained by the conventional difficulties of an external mechanism. If a SAVI device is fitted with appropriate sensors and controls, such as Rogowski Coils, voltage sensors, CT, VT, Relay, etc. then it, in effect, becomes a single device circuit breaker.**

The SAVI concept is generally applicable to all applications where Vacuum Interrupters and switches are presently used and is fully scalable. In addition, the new concept will open up new possible solutions to applications which were previously extremely difficult or impracticable. In this paper we introduce the SAVI concept and show a number of designs of Vacuum Interrupters and Vacuum Circuit Breakers (VCB) which are designed around the new concept.

I. INTRODUCTION

The paper describes a radically new approach to the design of vacuum switchgear. The Self Actuating Vacuum Interrupter (SAVI) as shown in Figure 1, can, in combination with a control/protection relay unit, perform the functions of a classic vacuum circuit breaker. It can do this without the need for an external mechanism or cabinet, and if suitably encapsulated, without even the need for a substation building. It does this by incorporating the mechanism which provides movement of one contact within the body of the vacuum interrupter, thereby eliminating external moving parts and removing the need for the mechanism, drive insulator, and indeed most of the switchgear as presently conceived. In addition, protection sensors, Rogowski coils, etc., can be fitted to the SAVI in order to provide protection functions. As there are no external moving parts on the SAVI it is very easy to encapsulate to meet specific environmental conditions. Three SAVI can be fitted to a single control unit which will then operate in the same way as a normal three phase VCB. The SAVI principle is scalable and so SAVI could be used at any voltage rating met by existing or future vacuum switchgear.

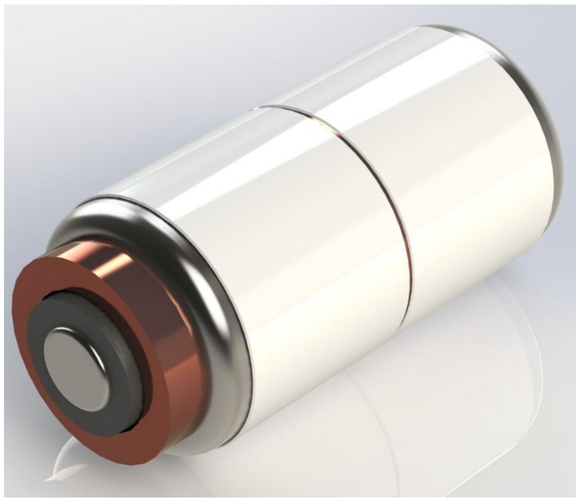

Figure 1: SAVI Prototype Design, 12kV;25kA;1250A

A. *Existing Technology*

Figure 2 shows a classic design of Vacuum Circuit Breaker with three vacuum interrupters mounted together on a truck to facilitate maintenance of the circuit breaker. A major function of the circuit breaker is to provide the necessary movement of the contacts within the vacuum interrupter in order to perform the switching duty, this function has dominated the design of circuit breakers of all types since they were first invented in the 19th century.

As shown in Figure 3 the key components of the drive mechanism are (A) the actuator, which may be spring, magnetic, or pneumatic, (B) the drive linkage which must not only transfer motion but also provide insulation between the high voltage circuit and the actuator which is normally at earth potential, and (C) the

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vacuum interrupter which incorporates a bellows to allow the breaker mechanism to perform its function of opening and closing the moving contact assembly. The essence of the SAVI concept is to incorporate this function within the body of the vacuum interrupter.

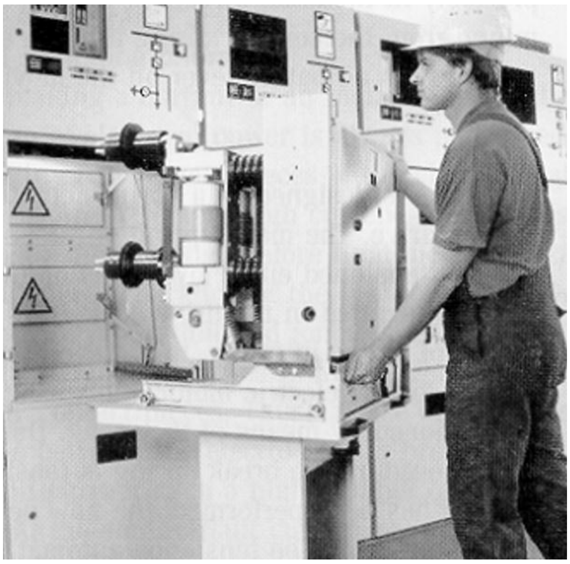

Figure 2: Classic indoor VCB design (courtesy AEG)

Today it is quite common for the mechanism of a vacuum circuit breaker to be based on a permanent magnetic actuator which uses the field of a magnet to hold the moving contact in the open or closed position [1]. In classic circuit breakers it is normal for one large actuator to operate three vacuum interrupters simultaneously, although designs do exist which use one magnetic actuator per interrupter [2].

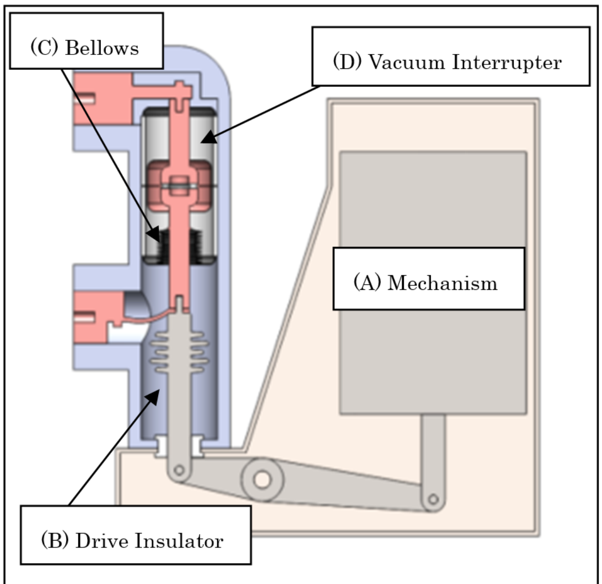

Figure 3: Classic indoor VCB design schematic

II. Discussion

A. The Concept

A classic vacuum interrupter is shown in Figure 4, this has the normal insulators, arc control, internal shields, and a bellows on the moving contact stem to allow it to open and close when driven by the circuit breaker mechanism. These have been developed for many years, but retain these same key features [3].

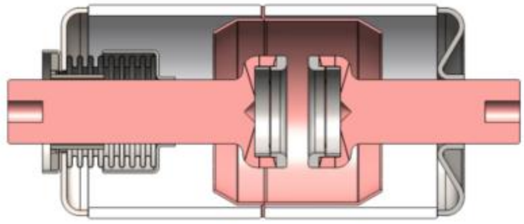

Figure 4: Classic Vacuum Interrupter

The SAVI version shown in Figure 5 is identical to the classic vacuum interrupter as far as insulator, arc control and shielding is concerned, but instead of the bellows and moving contact stem, there is a permanent magnetic actuator fitted within the interrupter, together with a guide and flexible conductors.

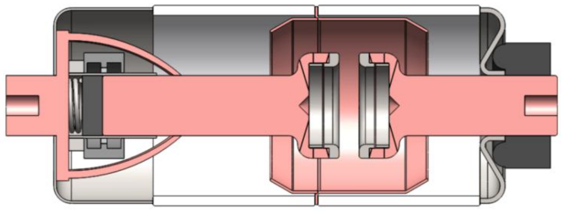

Figure 5: SAVI Prototype Design, open

The interrupter operates by means of signals sent from the control unit to the coil inside the actuator, this makes the contact move to the open position (Figure 5) by overcoming the effect of the permanent magnet. To close the contacts, the field in the coil is reversed (Figure 6).

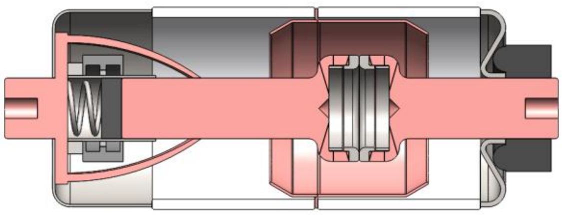

Figure 6: SAVI Prototype Design, closed

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B. Two Variants

The concept includes two main variants. The first variant shown in figures 5 & 6 has the entire magnetic actuator contained within the vacuum envelope. This gives a very compact design, with simple external circuit connections, but significantly complicates the vacuum interrupter design as it is necessary to include the permanent magnet system within the vacuum envelope and also to make electrical connections through the vacuum wall for the operating coil.

The second variant shown in Figures 7 & 8, has the magnetic circuit external to the vacuum wall, with the magnetic field acting through the end cap material.

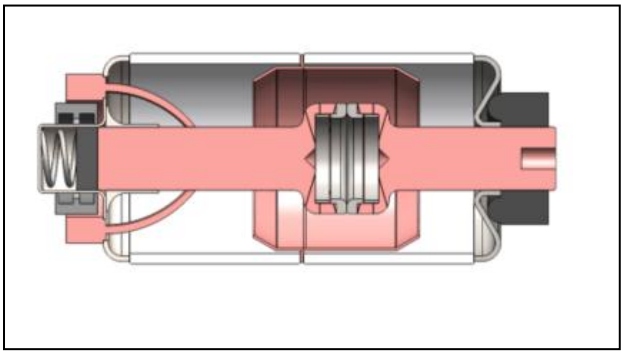

Figure 7 SAVI Prototype Design II, closed

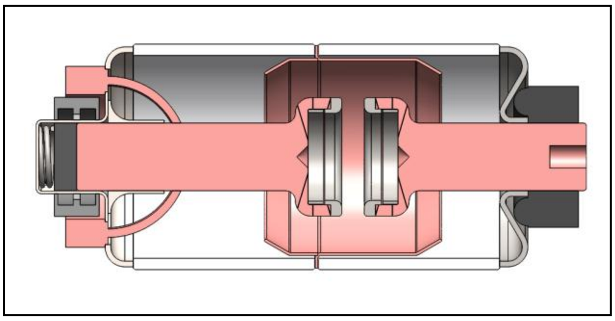

Figure 8 SAVI Prototype Design II, open

This allows us to build the VI without the magnetic actuator magnet or coil (Figure 9), and for these to be added after the VI is sealed off, together with a combined Rogowski coil and voltage sensor if required (shown on the right hand stem in Figure 9). This significantly simplifies manufacture and allows us to use normal vacuum interrupter manufacturing techniques. In this concept once the external components have been fitted the whole device could, for example, be encapsulated in insulating material. This in turn leads to interesting new possibilities for circuit breakers and switchgear.

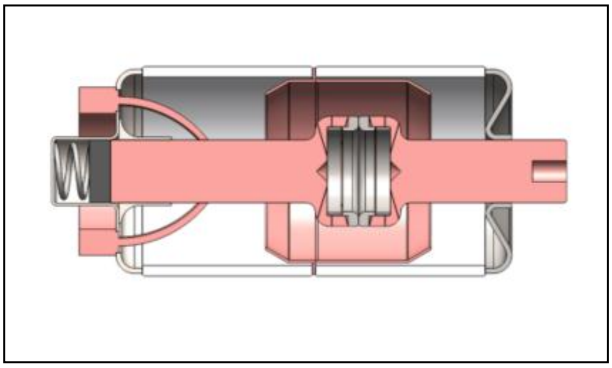

Figure 9 SAVI Prototype Design II, as sealed off

C. Applications

The SAVI concept is not restricted to a particular voltage class or application of circuit breaker. As long as a classic VCB can be used, so may a SAVI version. Thus the concept is equally applicable at low voltage as well as high voltage. It should also be suitable for all switchgear and control-gear applications, indoor and outdoor. Indeed, it is possible that new applications – such as subsea oil and gas production platforms - may be opened up by this concept as difficult environmental conditions such as very high pressures underwater are no longer a problem in the absence of a bellows and external movement.

Figure 10 shows the SAVI interrupter fitted to a circuit breaker truck. This would perform the same functions as that shown in Figure 3, but in a significantly smaller size, and at lower cost, as the large mechanism and drive insulator are longer needed.

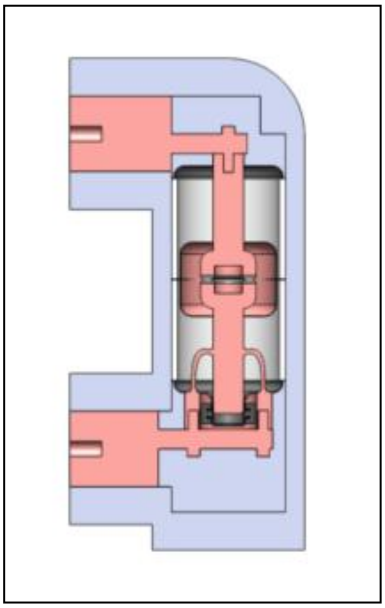

Figure 10: SAVI indoor circuit breaker concept

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For outdoor switchgear the benefits are also significant. Figure 11 shows a classic pole mounted recloser incorporating a mechanism and drive insulator. Figure 12 shows the same switchgear but using a SAVI interrupter design. The benefits are obvious.

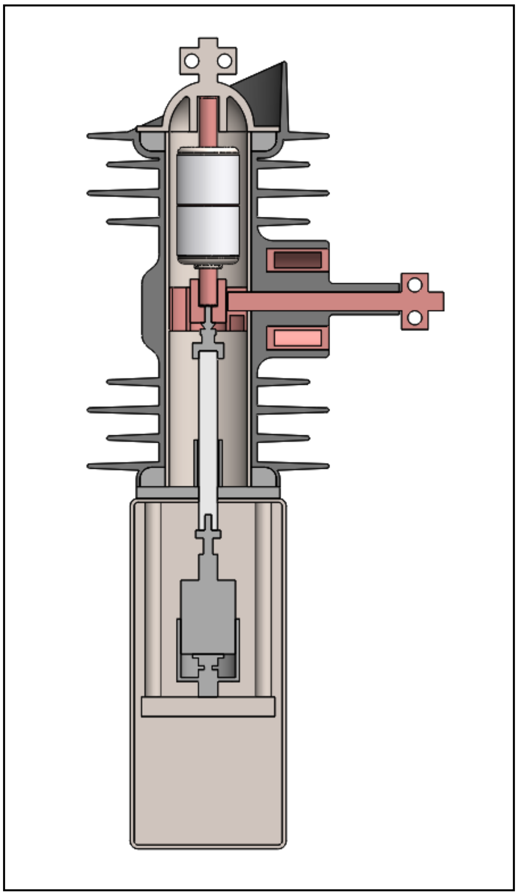

Figure 11: Classic outdoor circuit breaker

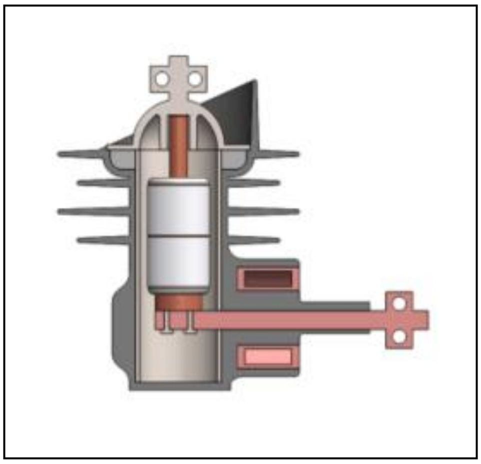

Figure 12: SAVI outdoor circuit breaker concept

Present circuit breaker designers are limited by the thinking of the past century, which in turn was constrained by the requirement to have a mechanism which could move contacts physically in order to perform a switching function. However once this constraint is removed by the SAVI concept then other, previously un-thought of, designs and solutions may be created. An example of this thinking is shown in Figure 13. This is a concept where the SAVI interrupter is connected to underground cables in the form of a cable joint. This would allow the switching function to be performed underground without the need for a substation. The only installation required above ground would be a small control cabinet.

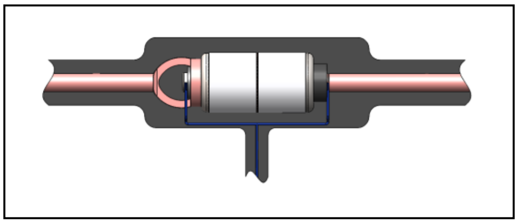

Figure 13: SAVI underground concept?

CONCLUSIONS

The SAVI concept is a significant step in VI design and makes the possibility of a “single device circuit breaker” feasible and cost effective. Much of the classic circuit breaker, and indeed the substation itself, is simply no longer needed. We believe that this new concept will result in a significant rethinking of not only the circuit breakers, but also how the electrical distribution supply networks themselves are designed and configured. Whether or not SAVI represents a paradigm shift in circuit breaker design, with the majority of future VCB designed like this, only time will tell.

ACKNOWLEDGEMENTS

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