10.0. VACUUM CIRCUIT BREAKERS

Learning objectives

The student should be able to:

1. Understand the terminology of vacuum replacement.
2. Understand the technology of vacuum replacement breakers.
3. Understand the difference between an OEM direct replacement and a retrofitted breaker.

10.1 Development of Vacuum Circuit breakers

If the contact system of the vacuum circuit breaker is judged by mechanical construction it is the simplest of the arc interrupting systems, it consists, in principle, of only a fixed and movable contact located in a vacuum vessel.

When the contacts are separated, the arc is supported by ionized metal vapor derived from the contacts instead of by ionized gas as in other forms of interrupter.

Initially the development of vacuum interruption seemed simple; however, it proved to be a difficult exercise in the switchgear world. Early work was originated in the USA as far back as 1926, and there was success at that time in interrupting small currents at voltages up to 40 kV, but the techniques did not exist to make it possible to build high power interrupters. It was not until 20 years later that the extensive research in the field of pure metals made further work in vacuum power interruption worthwhile. Development was recommenced in the early 1950s, but there were still many difficult problems to resolve. These included the necessity to remove completely the gas molecules absorbed in the metal of the components or attached as a thin layer on exposed surfaces, and the prevention of recontamination during assembly operations, requiring development of a number of elaborate processing techniques.

The first interrupters capable of really heavy short-circuit duty were built around 1960 by General Electric. A decade of intensive research and development was then necessary to convert the early prototypes into production designs, which

Required sustained confidence in the objectives. Both vacuum contractors and power circuit breakers then went into quantity production.

Vacuum interruption now offers the nearest approach so far achieved to the ideal circuit-breaker performance, in terms such as freedom from maintenance of the contact system for life, and consistency of interruption. However the maximum service voltage per interrupter is still restricted to the order of 36 kV, and although higher interruption voltage circuit breakers have been demonstrated as technically feasible, the economic problems associated with such assemblies have not yet been adequately solved in relation to the competition, more especially from SF_6 gas breakers.

Development of 11-15 kV distribution switchgear has taken place in two phases. In the 'first generation' switchgear, vacuum interrupters merely replaced conventional interrupters, the general form and arrangement of the switchgear being otherwise unchanged.

10.2 Roll In replacements: OEM breakers manufactured to replace older ACB's

10.2.1 GE's was the first manufacturer to offer direct "Roll in Replacement" breakers. This is the concept of an original manufacturer providing a replacement vacuum breaker for their older ACB's. These first generation vacuum circuit breakers were not economic, but they had the advantages that they could quickly modify existing air breakers to use vacuum interrupters, and thus service experience with vacuum interrupters was quickly gained without the delay and expense of designing complete new equipment. Figure 1 shows the Vacuum replacement breaker for a Magne-Blast. The original operating mechanism was used with the addition of a hydraulic dash pot for dampening the (Absorbing) the closing forces of the heavy Magne-Blast breaker. This was necessary because the contacts were only traveling less than an inch compared to the distance of almost 6" with ACB.

10.2.2 The new vacuum breakers have smaller operating mechanisms because they no longer need to move the contacts as far. Some first generation OEM replacement breakers used their 480 volt mechanisms to operate such as the ABB. Figure 2 shows the ABB Vacuum breaker with a K-Line type mechanism and Figure 3 is the K-Line 480 V Mechanism.

10.2.3 Westinghouse designed a direct replacement vacuum breaker for the DHP. This breaker is a direct roll in replacement. No modification is required for the switchboard. (See Figure 4 & 5)

10.3 Retro-fill and Retrofit Breakers

Is interchangeable term for converting an ACB to vacuum breaker, also referred to as “roll in vacuum replacements”.

- To vacuum retrofit is the process to change an ACB to vacuum breaker, the operating mechanism and contact structure is replaced but the interface with the cubicle is the same.
- Retrofill is what is being done to the cubicle the existing cubicle is being used to accommodate a new vacuum style breaker this could be a direct replacement retrofitted breaker or a new manufactured breaker.

The replacement vacuum breaker will be a complete unit and is racked directly into existing cubicle and connects to the existing primary bus and secondary controls. It could be manufactured using the existing truck and interface components or could be built from ground up with all new material. All the interface, racking and interlocks would be integrated into the new vacuum element. Figure 4 is a Siemens vacuum element on an ABB HK truck.

One of the problem areas with the vacuum retrofits is the MOC interface. The new breaker operating mechanism is smaller and sometimes can’t actuate the cubicle MOC.

10.4 Vacuum Circuit Breaker Operation and Maintenance

As with air circuit breakers, the reliability of vacuum circuit breakers is contingent upon its unfailing performance, preventive maintenance and testing is required to maintain safe operation.

10.4.1 Contact Wear:

Vacuum interrupter contacts wear principally because of the erosion caused by arcing but normally only to a negligible degree by no-load operation. In most interrupters the erosion rate is not a constant but increases with increasing current. The best commercial interrupters will interrupt their full short-circuit current some hundreds of times, and will give many thousands of operations on normal full load current.

1. When provided, the contact wears and gap indicators should be measured and compared with manufacturer’s specifications. Most breaker manufacturers provide go/nogo tools or the breakers have permanent marks or gages which are used to indicate wear.

10.4.2 Vacuum bottle integrity tests:

AC or DC Hipot testing should be performed across the open contacts in strict accordance with manufacturer's recommended test voltage. The test equipment should have a full wave rectification.

10.4.3 Other testing:

All other testing such as insulation testing, micro-ohm tests and timing should be performed to circuit breakers and compared to acceptance criteria. Any mechanical adjustments should also be verified and compared to the manufactures

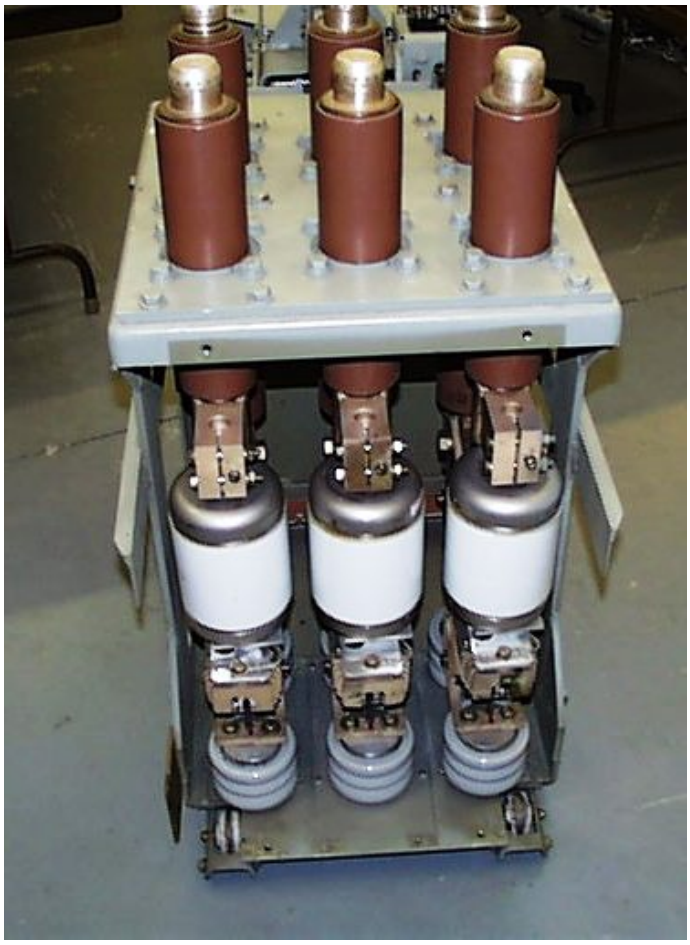

Figure 10-1 GE Magne-Blast replacement

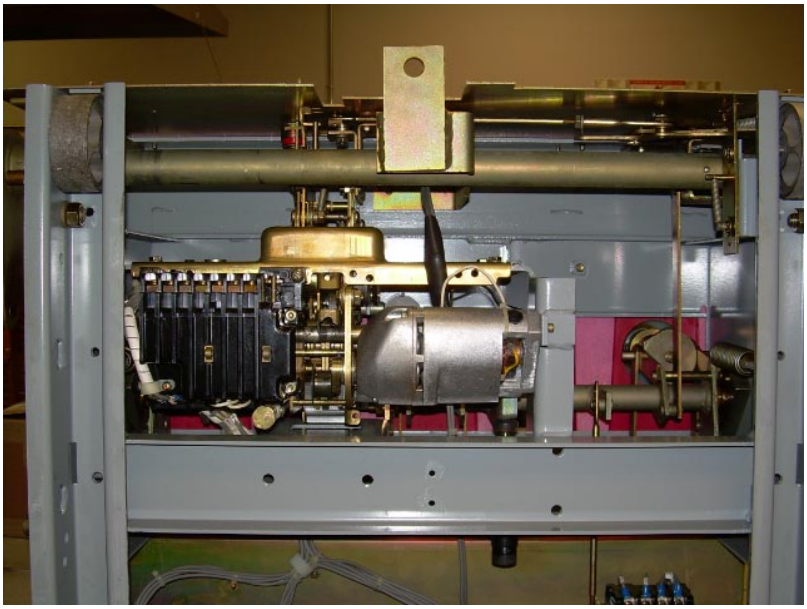

Figure 10-2 ABB HK Vacuum replacement

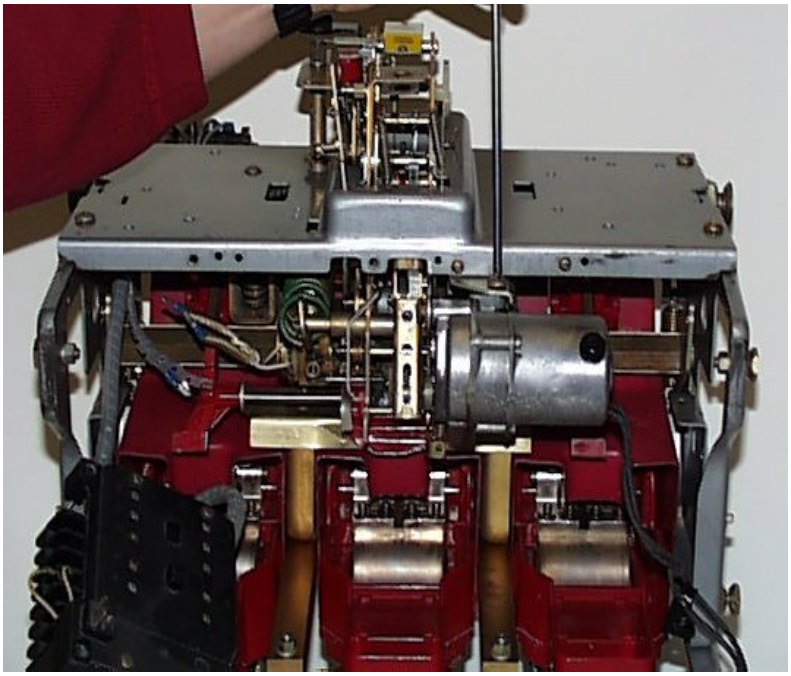

Figure 10-3 ABB 480 Volt breaker mechanisms

Figure 10-4 Siemens element used to retrofit an ABB HK Breaker

New 4160 breaker front panel

Operating mechanisms behind protective cover

Figure 10-5 DHP Vacuum replacement

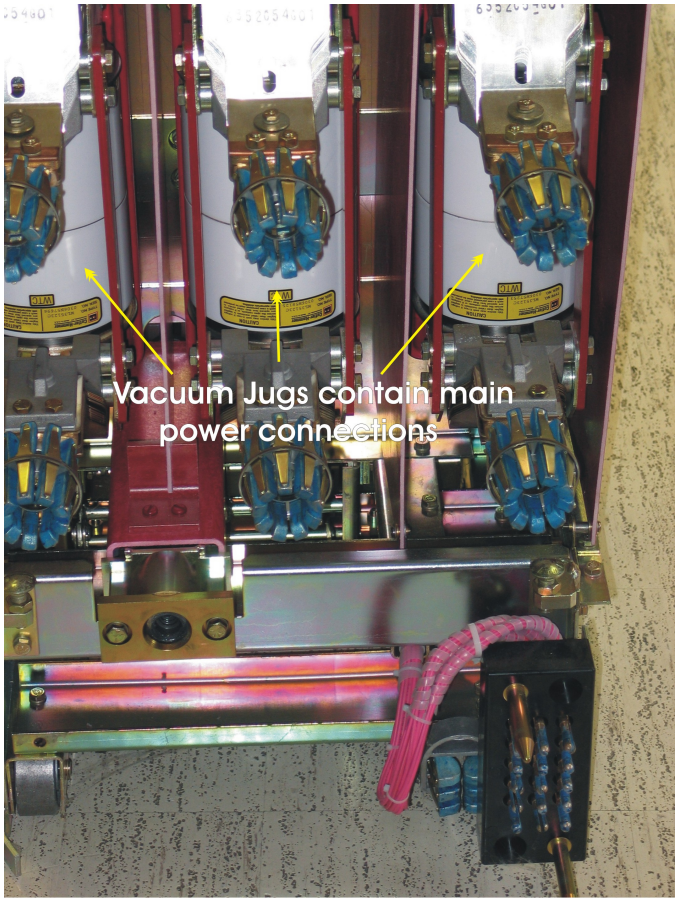

Figure 10-6 DHP Roll in vacuum replacement