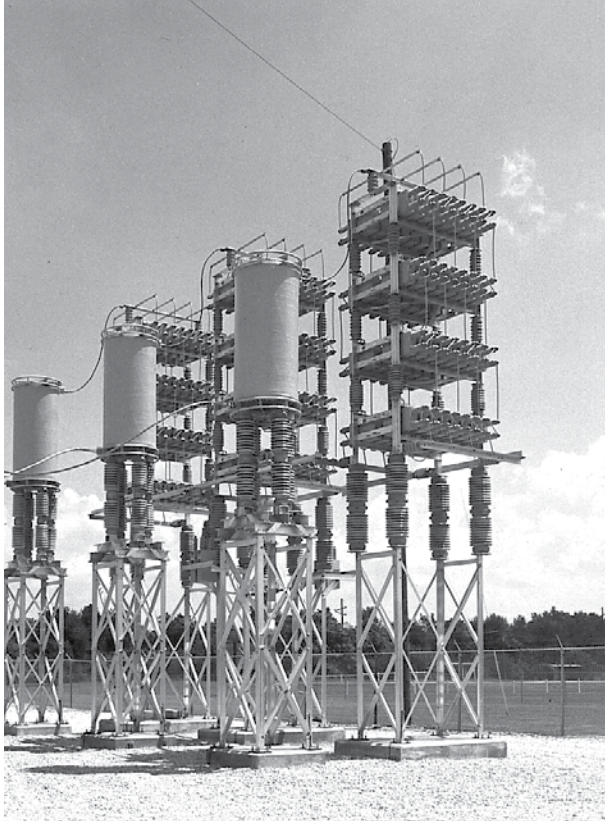


Fuseless capacitor banks



General

Eaton's fuseless capacitor banks, a Cooper Power™ series product, feature the latest capacitor technology, the standard-duty (SD), heavy-duty (HD), and extreme-duty (XD) all-film capacitors. The banks are designed to meet or exceed all applicable ANSI®, IEEE®, NEMA®, and IEC standards. The industry demand for more reliable and lower total life cycle cost (TLC) capacitor equipment has essentially made the fuseless capacitor bank the standard for substation applications at 34.5 kV and higher. Fuseless banks have been offered since the late 1980s and are not a new technology, but an application of an existing technology, the all-film capacitor introduced 1971. Fuseless capacitor banks offer the following advantages:

- Low initial and operating costs
- Low losses
- Small footprint
- Ease of unbalance protection
- Ease of installation and maintenance
- Increased protection against animal faults
- Increased reliability and availability
- Ideal for harmonic filters



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Description of operation

The SD, HD, and XD capacitors are constructed internally of smaller capacitors called elements arranged in series and parallel combinations to achieve the voltage and kvar rating of the unit. Figure 2 illustrates how the individual elements are arranged to form a complete capacitor unit. The elements are constructed of aluminum foil electrodes with a dielectric of electrical grade polypropylene. The SD, HD, and XD capacitors exhibit a benign, or safe, dielectric failure mode. It is this safe failure mode that is the key to applying the capacitor units without the need for additional fusing.

In the rare event the polypropylene dielectric fails, the energy in the resulting small arc punctures many layers of the thin film and foil within the element. The arc causes the film layers to recede allowing many layers of the aluminum foil electrodes to touch and weld together forming an extremely stable electrical joint. This welded aluminum electrical joint exhibits very low losses and is capable of carrying, indefinitely, without gassing or thermal degradation, the full capacitor unit rated current, and transient currents associated with normal operation. The result of a failed element is that an entire series section is shorted.

Figure 3 is a schematic of a fuseless capacitor bank connected in a grounded double wye configuration. A fuseless capacitor bank is constructed of one or more strings of series connected capacitor units. If one element within a capacitor unit fails, the series section in which it is located is completely shorted. The resulting increase in current through the capacitor unit is very small and thus the increase in voltage applied to the remaining series sections in the string is correspondingly very small. The safe failure mode of the SD, HD, and XD all-film capacitor units allow them to remain in service with shorted series sections.

Low cost

Fuseless capacitor banks have the lowest combination of initial and operating costs.

1. Fuseless banks require no fuses and have minimal structure and buswork thus minimizing land usage within and transportation costs to the substation.
2. Fuseless banks are easy to install due the low number of connections and the low current nature of the connections. This

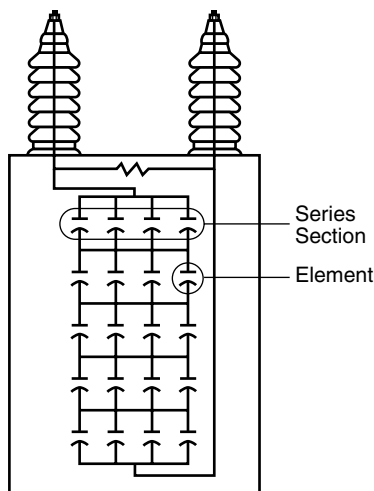


Figure 1. Typical capacitor internal schematic.

results in lower installation costs and allows the user to realize the economic benefits of the capacitor faster.

3. Fuseless banks have no fuse I^2R losses resulting in lowest operating costs and longest capacitor life.
4. Field maintenance is reduced as periodic capacitance measurements are not required and defective capacitor units are easily located by a few capacitance measurements. Further, nuisance fuse operations are eliminated that result in unnecessary alarm and trip conditions.

Losses

A fuseless capacitor bank has approximately 40% to 50% fewer losses than those of a comparable internally fused capacitor bank and approximately the same or slightly lower losses than that of a comparable externally fused capacitor bank using expulsion fuses. This can result in significant annual power savings. Any comparison between fuseless and internally fused banks should include the effect of losses on the operating costs.

Also, fuseless capacitors operate at a significantly lower internal temperature rise than internally fused capacitors. The cooler operating conditions of the all-film fuseless capacitor not only means lower energy consumption, but also indicate greater reliability and longer useful operating life of the dielectric system.

A capacitor is an electrochemical device that has no moving parts and, in performing its useful function, is acted upon by temperature and electrical stress. The combinations of electrical stress and temperature stress drive the mechanism by which capacitors wear out and come to the end of usefulness. The result of capacitor wear-out is always dielectric breakdown and failure. Thus, low operating temperatures are important since the chemical reaction of the wear-out mechanism will occur at a slower rate resulting in long useful dielectric life.

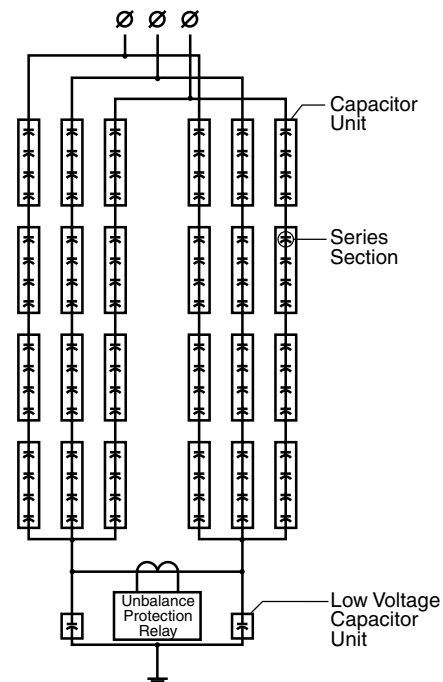


Figure 2. Typical fuseless bank schematic.

Small footprint

Fuseless banks are ideal in applications where installation space is limited. There is no requirement for extra clearance for fuse expulsion gasses or for a minimum number of parallel-connected capacitor units. Fuseless banks are ideal for indoor applications.

Capacitor Bank Protection

Fuseless capacitor banks have two modes of protection:

1. The primary mode is the stable short circuit of a failed element. A capacitor unit may operate indefinitely with a shorted series section as long as the overvoltage on the remaining series sections is within allowable limits.
2. The secondary mode of protection is affected with protective relays. Protective relaying increases bank availability by warning personnel of potential problems in the bank and by removing the bank from service before severe damage occurs.

Overcurrent and overvoltage protection of a fuseless capacitor bank is affected in a manner identical to fused banks. Unbalance protection for a fuseless capacitor bank is very simple as failed elements result in the shorting of entire series sections. This allows for greater sensitivity in failure detection than a comparable internally fused bank.

The design of the protective relaying begins with bank design. Eaton's Cooper Power series Edison® Idea™ protective relay platforms are the state-of-the-art in microprocessor based relays for capacitor bank protection. With these relays, all capacitor bank protection, control, communications and monitoring needs can be economically met.

Installation and maintenance

Fuseless capacitor banks are easy to install. Most of the interconnections between capacitors are factory assembled so fewer electrical connections are required during installation.

Fuseless capacitor banks utilize simple and efficient unbalance detection methods. The capacitors used in fuseless banks are designed with a small number of large capacitor elements. Therefore, element failures provide sufficient impedance change such that they can be detected by simple relaying schemes.

Eaton's fuseless capacitor banks are virtually maintenance free. Periodic measurements of capacitance are not required for all but the very largest banks with unbalance detection schemes susceptible to ambiguous indication. However all capacitor banks should be, at least, visually inspected periodically. See *Service Information S230-30-4, Fuseless Block Bank Installation Instructions*, for recommended maintenance items.

Locating capacitor units with shorted series sections in a fuseless capacitor bank requires some capacitance measurements. However, these measurements are few and relatively easy. The measurements may be taken with a simple low voltage meter.

Reliability and Availability

The following features of fuseless capacitor banks from Eaton maximize the reliability and availability of your capacitor bank installations.

1. **Animal Protection:** Optional protective caps for the capacitor unit bushing terminals and protective tubing for the interconnecting wire are available to minimize exposed live parts thus reducing the potential for external flashover due to birds or other animals.
2. **No Fuses:** Spurious fuse operations and the i^2R losses associated with the fuses are eliminated in fuseless capacitor banks. With no internal fuses heating the dielectric, fuseless capacitor units have the longest dielectric life.

3. **Low Maintenance:** Periodic maintenance is minimized. The unbalance detection schemes used for internal fused banks, typically, cannot detect the first or second internal fuse operation and thus are susceptible to fuse operations distributing themselves throughout the bank and maintaining a level of unbalance undetectable by the unbalance relaying scheme. This is known as ambiguous indication. Because of this, internally fused banks require periodic maintenance to locate partially failed capacitor units.

The unbalance detection schemes used for fuseless banks, typically, will detect the first series section short. This allows for maintenance to be scheduled at the owner's convenience and eliminates the possibility of dielectric failures distributing through the bank undetected. Therefore, periodic maintenance to locate partially failed units is not required. Fuseless banks are virtually maintenance free.

4. **Ease of Maintenance:** Locating a partially failed capacitor unit in a fuseless bank is very easy, especially when compared to internally fused banks. A readily available, low voltage capacitance meter is used to isolate the string containing the faulted capacitor unit. From there, individual unit capacitance measurements are made to locate the faulty capacitor. Determining if an individual fuseless capacitor unit is faulty is also very easily accomplished. A partially failed fuseless capacitor unit will typically have a capacitance that is > 11% higher than its original capacitance and thus is easily detectable with a simple, low voltage, hand held capacitance meter.

The location of a partially failed internally fused capacitor unit requires a capacitance measurement of every capacitor unit. However, this is not a simple capacitance measurement because the decrease in capacitance of a typical internally fused capacitor unit with an operated fuse is only 1 to 2%. To properly identify a partially failed internally fused capacitor unit, its capacitance measurement must be correctly for temperature and compared to previously recorded values.

Fuseless capacitor units are typically 20% smaller and lighter than a comparable internally fused capacitor unit thus making their handling easier.

5. **Simplicity:** Fuseless capacitor banks from Eaton are the "keep it simple solution" to your capacitor banks needs. Unbalance relaying and maintenance are simplified and useful life is extended. Also, fuseless capacitor units typically have 1/4 to 1/3 the number of elements and about 1/5 the number of internal connection points of an internally fused capacitor unit. The simplicity of fuseless capacitor units equates to greater reliability.

Harmonic filters

Fuseless capacitor banks are an ideal choice for application in harmonic filters for the following reasons:

1. The change in capacitance as a result of a dielectric failure is small thus the tuning of the bank changes very little.
2. The capacitance of fused capacitor banks decreases as fuses operate shifting the tuning point of the filter to a higher frequency. This may move a parallel resonance to a frequency with a harmonic content and thus result in an unacceptable voltage distortion. For this reason, harmonic filters using fused capacitors are typically tuned below the frequency to be filtered.

The shorting of a series section in a fuseless capacitor bank increases its capacitance thus shifting the tuning point of the filter to a lower frequency. This typically moves the parallel resonance away from frequencies with a harmonic content and allows harmonic filters to safely be tuned close to the desired frequency for optimal performance.

3. Harmonic filters are often subject to large dynamic overvoltages due to switching of the filters or other components such as furnace transformers. These overvoltages often exceed the capability of the fusing in the event of a dielectric failure during the overvoltage. This is not an issue with fuseless banks because of the safe failure mode of the all-film capacitor. In addition, the string configuration of fuseless banks inherently minimizes the parallel energy discharge, which can result in the failure of external and/or internal fusing systems.

Accessories

The following accessories can be provided with the capacitor banks:

1. Protection and control equipment including instrument transformers
2. Isolating or grounding switches
3. Switching devices/circuit breakers
4. Interlocks
5. Arresters
6. Elevating structures
7. Reactors for current-limiting and/or filtering
8. Power Fuses
9. Capacitance meters
10. Capacitor removal/installation devices

Ordering information

When ordering fuseless capacitor banks, or when requesting proposals, specify:

1. Voltage
 - A. Nominal and maximum voltage at which bank will be operated
 - B. Capacitor bank rated voltage
 - C. System BIL
 - D. Creepage requirements
2. kvar
 - A. Desired three-phase kvar at nominal system voltage
3. System frequency
4. Available fault current at bank
5. Bank construction
 - A. Connection (delta, grounded wye, ungrounded wye, etc.)
 - B. Configuration (single wye, double wye, "H," etc.)
 - C. Elevated or non-elevated — if elevated, specify height
 - D. Limiting dimensions, if any, in bank height, width, or length
 - E. Desired unbalance protection scheme
6. Type of Duty Expected
 - A. Isolated or paralleled bank
(If paralleled, how many other banks, what kvar sizes, how close?)
 - B. Expected number of switching operations daily
7. Options with applicable ratings (Refer to accessories listed in this bulletin.)
8. Any unusual operating conditions (i.e. high altitudes, extreme temperatures, heavy pollution)
9. Applicable standards to which the equipment is to be manufactured and tested

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