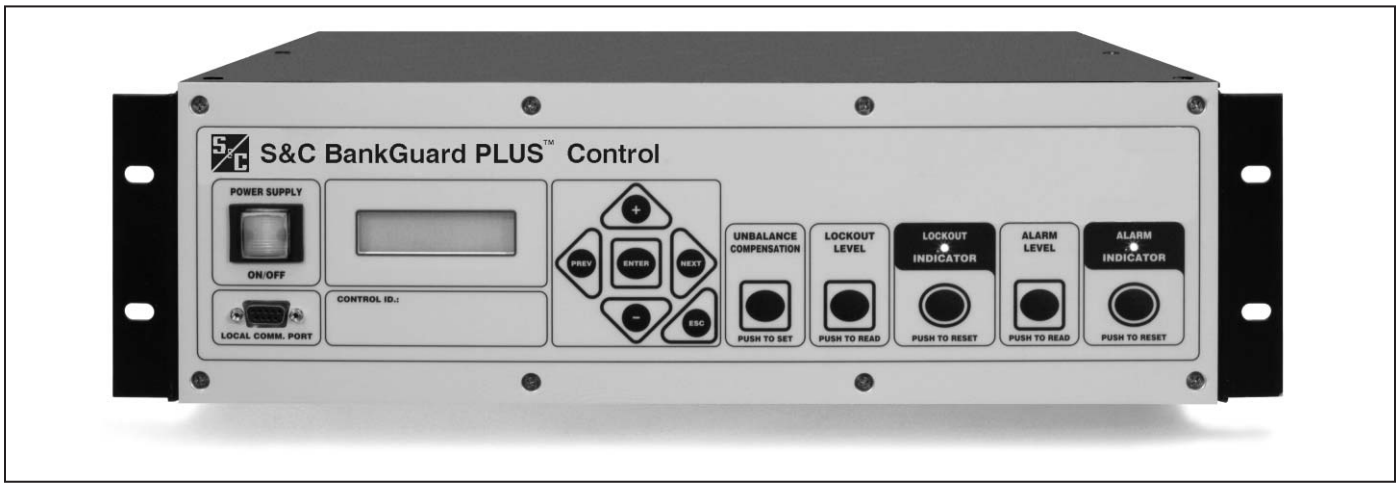
S&C BankGuard PLUS™ Controls for Substation Capacitor Banks and Shunt Reactors



BankGuard PLUS Control.

These new S&C controls utilize flexible and reliable microprocessor technology to:

- Protect substation shunt capacitor banks from overvoltage stress.
- Protect shunt reactors from turn-to-turn faults.

Substation Capacitor Banks Need Sophisticated Overvoltage Protection

Medium- to large-sized wye-connected shunt capacitor banks commonly utilize twofold protection against short circuits. Individual capacitor units are protected by fuse links that clear internal faults, reducing the probability of case ruptures. And the bank—plus the system—is protected against major faults by the bank protective device, such as power fuses or an S&C Circuit-Switcher.

But when a fuse link operates to isolate a failed capacitor unit, the voltage across remaining units in the same series group increases. This increased voltage can overstress and shorten the life of the other good capacitor units in the group. As subsequent units fail, their isolation leads to still further voltage increases on remaining units. The result is an accelerating cascade of overvoltages that destroys good capacitor units.

This phenomenon is addressed in IEEE Standard 18-1992, "IEEE Standard for Shunt Power Capacitors." The standard specifies a curve which indicates permissible capacitor-unit operating time at varying per-unit multiples of the capacitor nameplate voltage rating. See Figure 1. (The standard further states that capacitors shall be capable of continuous operation to at least 110% of rated voltage, including harmonics. Most capacitor manufacturers publish similar data, which may permit higher working voltages.) When the voltage applied to the surviving capacitor units exceeds the manufacturer's maximum recommended working voltage (or in the absence of a recommendation, the IEEE data), the entire bank should be removed from service.

BankGuard PLUS includes these features:

- ***Microprocessor-based control***
- ***Interchangeable with S&C Types UP, GP, and UPR Automatic Control Devices***
- ***Expanded timer ranges***
- ***Previously optional features are now standard***
- ***SCADA communication port***
- ***Fast, easy, and precise setup***
- ***Setup via computer or faceplate keypad***
- ***User-friendly faceplate includes tactile-feedback switches, standard two-line LCD***
- ***Full range of safety features***

Thus, large-sized capacitor banks need a third form of protection: A sophisticated control device having the sensitivity to detect isolation of the first failed unit in a capacitor bank—and alarm upon isolation of that unit, to enable the user to replace it before additional failures occur—but with the discrimination to disregard system and inherent bank unbalances and spurious transients, as well as harmonics.

Why System and Inherent Capacitor-Bank Unbalance Compensation Is Essential

In larger-sized capacitor banks, extraneous voltages can introduce significant errors in—or even overpower—the voltage signal created by loss of individual capacitor units. For example, a fixed error voltage may be present due to capacitor-bank inherent unbalance resulting from manufacturing-tolerance variations among individual capacitor units, or due to system-voltage unbalance resulting from nontransposition of overhead lines. A variable error voltage may also be present due to system load unbalance resulting from changing load conditions, although this error voltage is usually only significant in very-large-sized, transmission-voltage-level capacitor banks. Compensation for these extraneous voltages is thus crucial to ensure proper operation of the capacitor-bank control device.

Capacitor-bank inherent unbalance can usually be minimized through costly and time-consuming measurement and relocation of capacitor units. The effect of fixed system voltage unbalance is not as readily remedied. A capacitor-bank control device should thus be conveniently adjustable to compensate for both of these sources of extraneous voltage, so that it has the capability to detect and respond to a single faulted capacitor unit.

Voltage Relays and Neutral Current Relays Are Inadequate

Capacitor protection schemes assembled from general-purpose relays provide only marginal performance.

On ungrounded, wye-connected shunt capacitor banks, voltage relays are sometimes used for sensing isolation of capacitor units. See Figure 2. But this protection method has some severe limitations. The associated voltage trans-

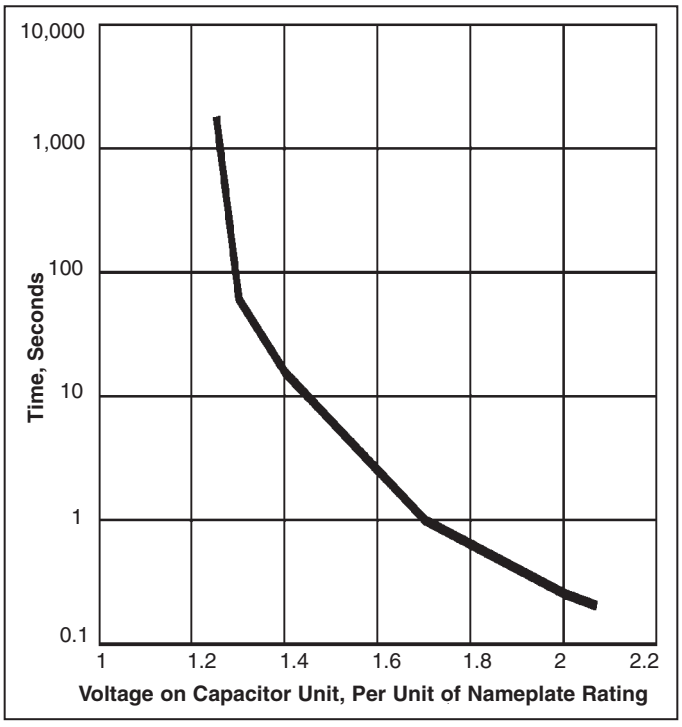


Figure 1. Capacitor-unit power-frequency overvoltage versus time, as permitted by IEEE Standard 18-1992. This curve applies for up to 300 applications of power-frequency overvoltages of the magnitudes and durations indicated.

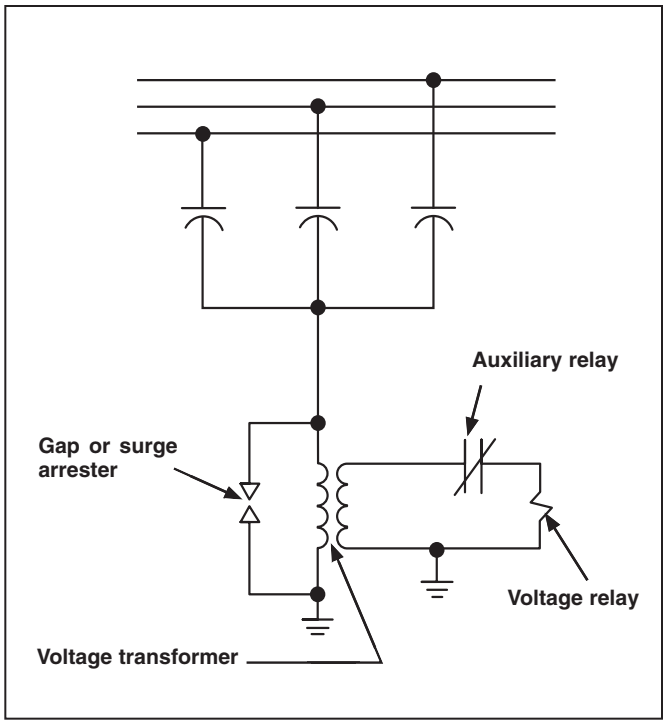


Figure 2. Voltage relay method on ungrounded, wye-connected shunt capacitor banks.

former must have a voltage rating equal to the actual system voltage, in order to withstand the short-term overvoltages experienced during routine capacitor bank switching and during faults. Such a transformer, however, provides inherently poor sensitivity to isolation of a single capacitor unit because of its high turns ratio. Further, to alarm upon isolation of a single capacitor unit—to enable the user to replace the failed capacitor unit before additional failures occur—a second voltage relay is required. This method may also lack a harmonic filter, as is required to prevent sensing errors due to system harmonic voltages. And, this method provides no compensation for system or inherent capacitor bank unbalances, which can be quite significant in larger-sized capacitor banks and can cause false operations (resulting in lockout of the capacitor bank or, conversely, no operation when one is necessary).

On grounded, wye-connected shunt capacitor banks, neutral-current and voltage relays are sometimes used for sensing isolation of capacitor units. See Figures 3 and 4, respectively. But again, these techniques have some significant limitations.

In the neutral-current relay scheme, the current transformer associated with the neutral current relay must have a high ratio in order to withstand the momentary charging currents flowing between neutral and ground during routine capacitor-bank switching and during faults. Such a transformer provides inherently poor sensitivity to isolation of a single capacitor unit. A high-ohmic-value burden resistance is also required so that the neutral current relay can withstand these charging currents. Further, to alarm upon isolation of a single capacitor unit, a second relay must be furnished. This method too lacks a harmonic filter, as is necessary to prevent sensing errors due to system harmonic voltages. And again, this method provides no compensation for system or inherent capacitor bank unbalance.

The voltage relay method, on the other hand, provides excellent sensitivity in grounded capacitor bank applications. But it also has some significant drawbacks: A second relay is required to alarm upon isolation of a single capacitor unit. This method also lacks a harmonic filter, as is necessary to prevent sensing errors due to system harmonic voltages. And, once again, this method provides no compensation for system or inherent capacitor unit unbalance which can cause false operations.

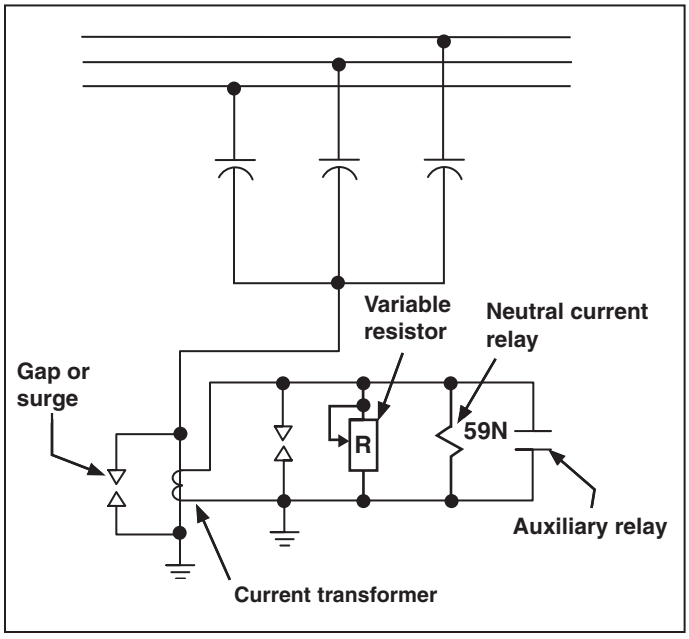


Figure 3. Neutral-current relay method on grounded, wye-connected shunt capacitor banks.

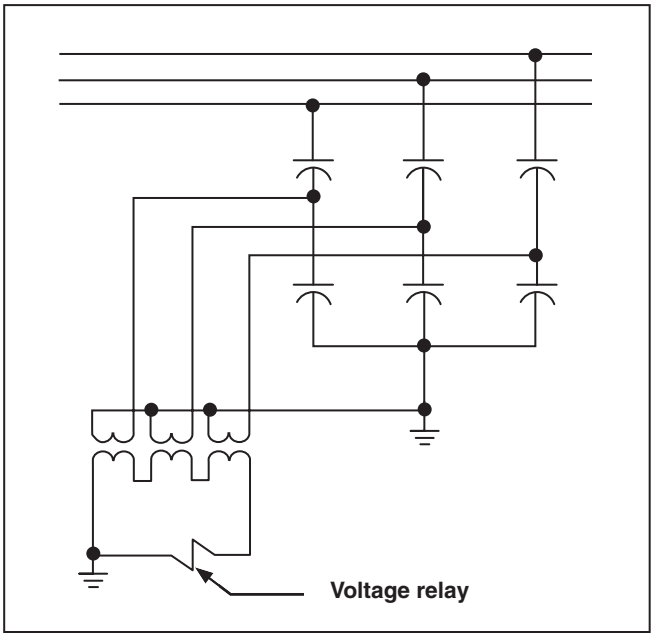


Figure 4. Voltage relay method on grounded, wye-connected shunt capacitor banks.

BankGuard PLUS Control is the Answer

The S&C BankGuard PLUS Control has the sensitivity to detect the first faulted unit in a capacitor bank—but with the discrimination to disregard system and bank unbalance and spurious transients. This compact microprocessor-based device overcomes the inadequacies of voltage relays and neutral current relays. It utilizes rugged construction for quick setup and simple software-selectable options, and offers design features and proven logic that withstand the rigors of power equipment application.

Protection of Ungrounded Capacitor Banks

The BankGuard PLUS provides protection of *ungrounded*, wye-connected shunt capacitor banks. See Figure 5. As successive individual capacitor units in a group of a capacitor bank are isolated from the bank by their respective fuses, the surviving capacitor units in the group are protected against cascading voltage overstress by automatic switching—initiated by the BankGuard PLUS—which isolates and locks out the entire bank when a predetermined neutral-to-ground voltage is exceeded.

The BankGuard PLUS detects the capacitor-bank neutral-to-ground voltage, as monitored by an S&C 15-Volt-Ampere Potential Device having a system voltage rating as indicated in the following table. A digital filter attenuates harmonics and noise. Since predictable discrete increases in capacitor-bank neutral-to-ground voltage result from the isolation of successive capacitor units, a specific value may be selected for the lockout level setting of the BankGuard PLUS.

A field-adjustable 0.2- to 30-second time delay is incorporated in the lockout level logic, to assure operation of the fuse associated with the failing capacitor unit before the lockout contacts are activated to initiate tripping of the capacitor-bank switching device. In this way, the failed capacitor unit can be readily located.

System voltage rating of 15-Volt-Ampere Potential Device

Nominal Source Voltage, kV	15-VA Potential-Device System Voltage Rating, kV, Nominal
below 23	23
23	23
34.5	23
46	23
69	34.5
115	69
138	69
161	138

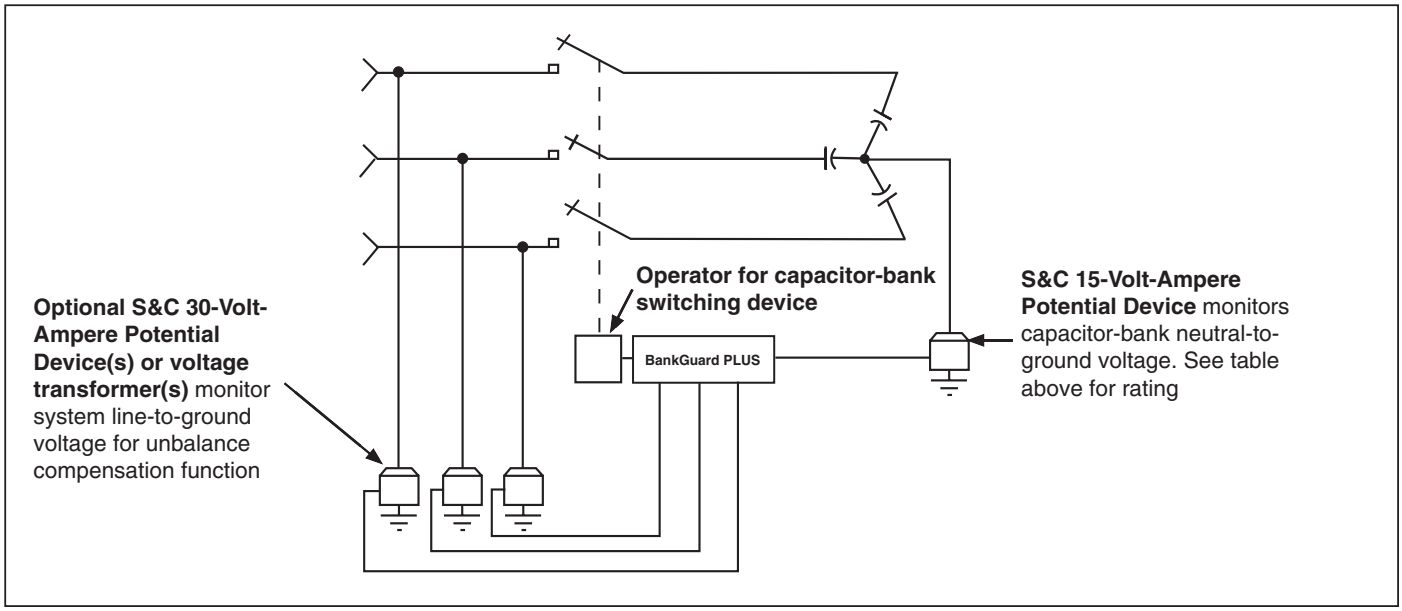


Figure 5. System diagram of BankGuard PLUS for protection of ungrounded shunt capacitor banks.

Gross overvoltage logic is employed, which bypasses the lockout level and timing-control logic, to initiate isolation and lockout of the capacitor bank in the event of a flashover of series groups within the capacitor bank. This logic is activated, after a field-adjustable time delay of 0.2 to 5 seconds, by such faults producing a capacitor bank neutral-to-ground voltage in excess of a field-adjustable level of 1000 to 5000 volts.

The BankGuard PLUS includes an alarm function, which provides an alarm signal upon the loss of fewer capacitor units than that corresponding to the lockout level setting. For many capacitor banks it is practical to activate the alarm at the loss of a single capacitor unit. This is a decided advantage since replacement of the failed capacitor unit can be accomplished at a convenient, planned time, instead of on an urgent basis during a lockout resulting from subsequent failure of capacitor units. The alarm function logic, further, responds to loss of control power to the BankGuard PLUS and provides an alarm signal. The 0.2- to 30-second time delay incorporated in the lockout level logic is also utilized here to avoid false alarms due to transient disturbances.

The BankGuard PLUS incorporates a digital input which is actuated through a contact of the capacitor-bank switch-operator auxiliary switch. This digital input prevents nuisance operation of the BankGuard PLUS alarm or lockout functions resulting from neutral-to-ground voltages of several kilovolts being induced during periods when the capacitor bank has been routinely de-energized.

The BankGuard PLUS includes an unbalance compensation function. This capability may be used, with the addition of a fully rated S&C 30-Volt Ampere Potential Device(s) or voltage transformer(s) connected to the station bus, to detect and compensate for the error voltage appearing between the capacitor bank neutral and ground. Error voltage can be caused by system voltage unbalance and/or inherent capacitor bank unbalance resulting from manufacturing-tolerance variations among capacitor units in the bank. Such error voltage can otherwise cause false operations resulting in lockout of the capacitor bank, or conversely, no operation when one is necessary.

If capacitor-unit manufacturing tolerance variations are of specific concern, a single potential device or voltage transformer is required. If system voltage unbalance is also of concern, three potential devices or voltage transformers are required.

Protection of Grounded Capacitor Banks

The BankGuard PLUS provides protection of *grounded*, wye-connected shunt capacitor banks, consisting of two or more series groups per phase, by detecting the loss of individual capacitor units. See Figure 6. As successive individual capacitor units in a group of a capacitor bank are isolated from the bank by their respective fuses, the surviving capacitor units in the group are protected against cascading voltage overstress by automatic switching—initiated by the BankGuard PLUS—which isolates and locks out the entire bank when a predetermined overvoltage occurs.

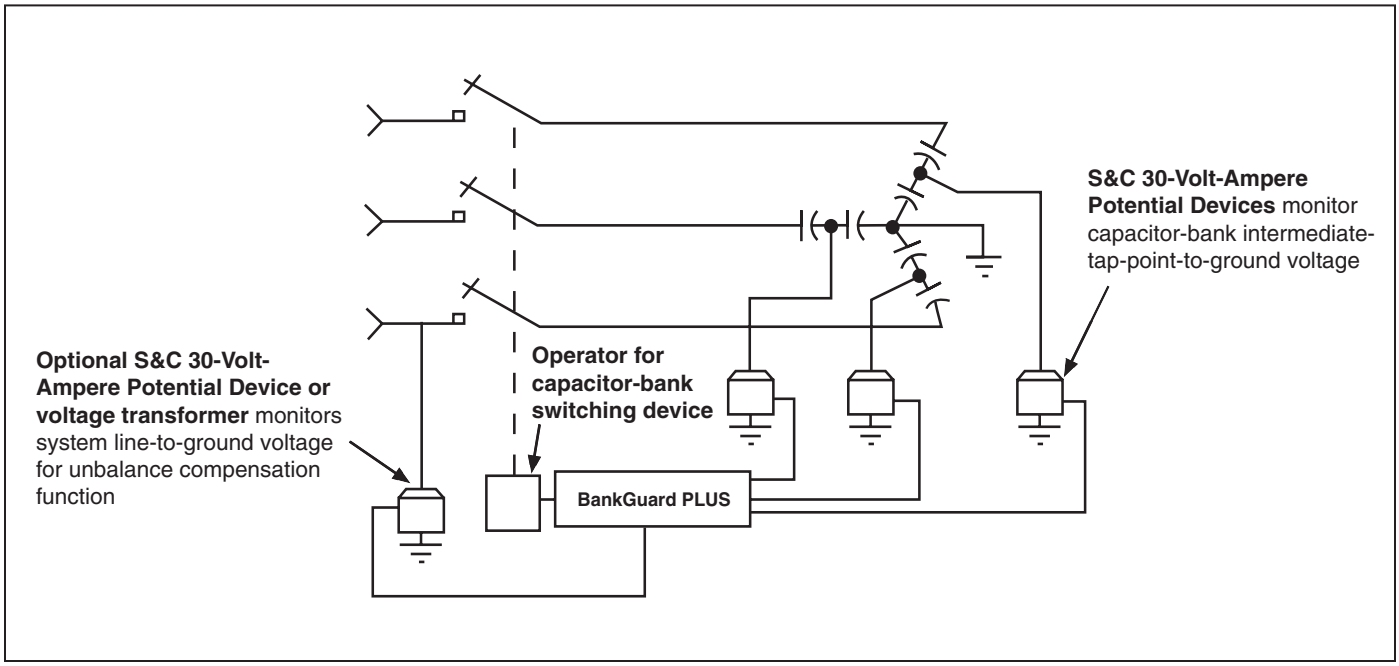


Figure 6. System diagram of BankGuard PLUS for protection of grounded shunt capacitor banks.

The BankGuard PLUS utilizes tap-voltage calibration logic which develops the phasor sum of the intermediate tap-point voltages on the three phase legs, as monitored by S&C 30 Volt-Ampere Potential Devices, and provides an adjustment means for eliminating the effects of inherent capacitor bank unbalance resulting from manufacturing-tolerance variations among capacitor units in the bank. Each potential device should have a system voltage rating at least equal to the voltage appearing between the intermediate tap points and ground multiplied by the square root of 3.

A digital filter is employed to attenuate harmonics and noise. Since predictable discrete increases in tap-voltage percent unbalance result from the isolation of successive capacitor units, a specific value may be selected for adjusting the lockout level setting of the BankGuard PLUS.

A field-adjustable 0.2- to 30-second time delay is incorporated in the lockout level logic, to assure operation of the fuse associated with the failing capacitor unit before the lockout contacts are activated to initiate tripping of the capacitor- bank switching device. In this way, the failed capacitor unit can be readily located.

Gross overvoltage and alarm functions are standard and operate in the same manner as described for the ungrounded bank application.

The BankGuard PLUS includes an unbalance compensation function. This capability may be used, with the addition of a fully rated S&C 30-Volt Ampere Potential Device or voltage transformer connected to the station bus, to detect and compensate for capacitor bank unbalance resulting from manufacturing-tolerance variations among capacitor units in the bank. Such error voltage can otherwise cause false operations resulting in lockout of the capacitor bank, or conversely, no operation when one is necessary.

Protection of Ungrounded Shunt Reactors

The BankGuard PLUS provides protection of *ungrounded*, wye-connected shunt reactors—either three-phase reactors or three-phase banks of single-phase reactors—by detecting turn-to-turn faults in the windings of these shunt reactors, the most common mode of reactor failure. See Figure 7.

The BankGuard PLUS utilizes an analog input which detects the reactor neutral-to-ground voltage, as monitored by an S&C 15 Volt-Ampere Potential Device. A digital filter is employed to attenuate harmonics and noise. When a turn-to-turn fault occurs in one of the phase windings, the shunt reactor is protected from further damage by automatic switching—initiated by the BankGuard PLUS—which isolates and locks out the shunt reactor when the predetermined neutral-to-ground voltage value set in the lockout function is exceeded.

A field-adjustable 0.2- to 30-second time delay is incorporated in the lockout level logic, to assure that transient disturbances will not initiate a nuisance reactor isolation.

Gross overvoltage logic is employed, which bypasses the lockout level and timing-control logic, to initiate isolation and lockout of the reactor in the event of a fault which open-circuits an entire phase winding. This logic is activated, after a field-adjustable time delay of 0.2 to 5 seconds, by such faults producing a reactor neutral-to-ground voltage in excess of a field-adjustable level of 1000 to 5000 volts.

The BankGuard PLUS includes an unbalance compensation function. This capability may be used, with the addition of a fully rated S&C 30 Volt-Ampere Potential Device(s) or voltage transformer(s) connected to the station bus, to detect and compensate for the error voltage appearing between the reactor neutral and ground. Error voltage can be caused by system voltage unbalance and/or inherent reactor unbalance resulting from manufacturing-tolerance variations among the phase windings. Such error voltage can otherwise cause false operations resulting in lockout of the reactor or, conversely, no operation when one is required.

If reactor phase-winding manufacturing tolerance variations are of specific concern, a single potential device or voltage transformer is required. If system voltage unbalance is also of concern, three potential devices or voltage transformers are required.

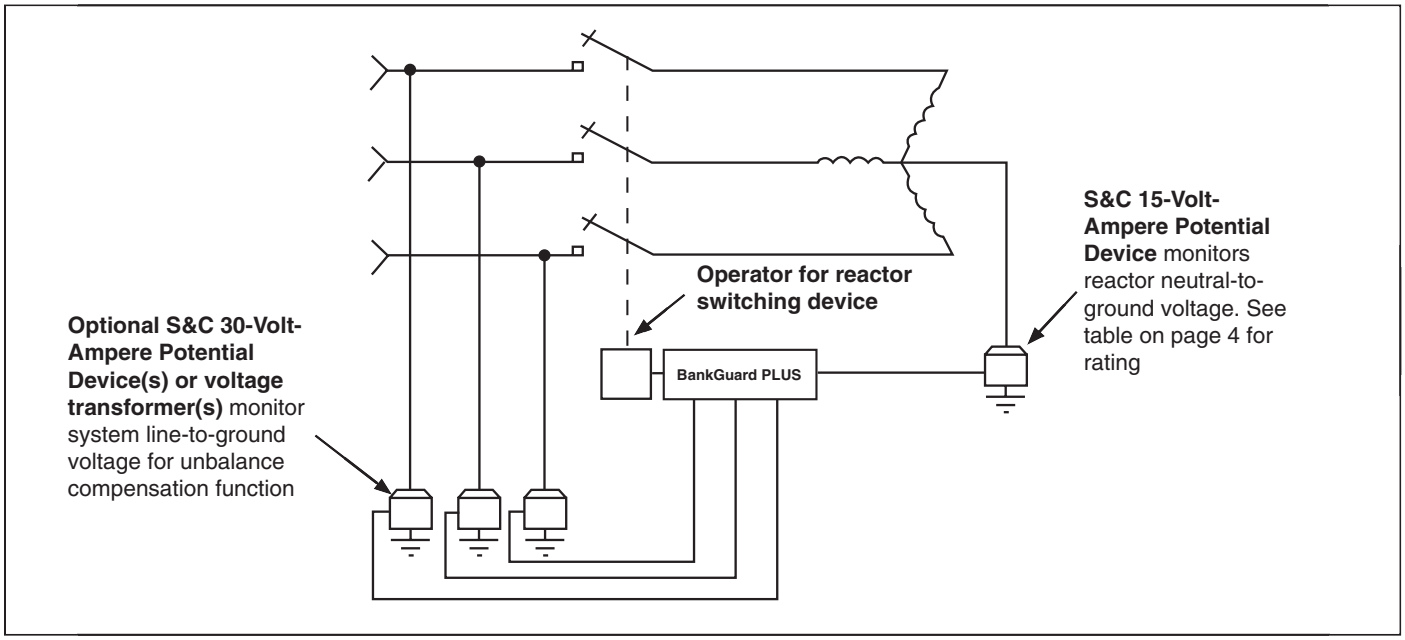


Figure 7. System diagram of BankGuard PLUS for protection of ungrounded shunt reactors.

SPECIFICATIONS

Neutral-to-Ground Voltage Input Circuit

- Normal Operating Voltage Range: 0 to 150 volts
- Frequency Range: 50/60 Hz
- Burden: less than 0.1 VA

Unbalance Compensation Input Circuit

- Voltage Range: 10 to 150 volts, 3 phase
- Frequency Range: 50/60 Hz
- Burden: less than 0.1 VA

Lockout Level

- **Level Detector**
  Adjustment Range: 0 to 2000 volts
  Accuracy: ± 1% of range
- **Time Delay to Initiate Lockout**
  Factory Setting: 10 seconds
  Adjustment Range: 0.2 to 30 seconds

Alarm

- **Level Detector**
  Adjustment Range: 0 to 2000 volts
  Accuracy: ± 1% of range
- **Time Delay to Initiate Alarm**
  Factory Setting: 10 seconds
  Adjustment Range: 0.2 to 30 seconds

Gross Overvoltage Circuit

- **Level Detector**
  Adjustment Range: 1000 to 5000 volts
  Accuracy: ± 1% of range
- **Time Delay to Initiate Lockout**
  Factory Setting: 2 seconds
  Adjustment Range: 0.2 to 5 seconds

Output-Relay Contact Ratings

- 16 A at 250 Vac
- 0.5 A at 125 Vdc
- 16 A at 24 Vdc

An interposing relay is required if these ratings will be exceeded

Control Power Requirements

- 48–250 Vdc
- 100–240 Vac, 50 or 60 Hz

Environmental Specifications

- Temperature: -40 C to +70 C
- Humidity: 0-95% (non-condensing)

Enclosure

- 17.13″ w × 14.68″ d × 5.25″ h (plus mounting bracket)
  19″ rack mount
- Painted Aluminum
- Weight (nominal): 11 lbs.

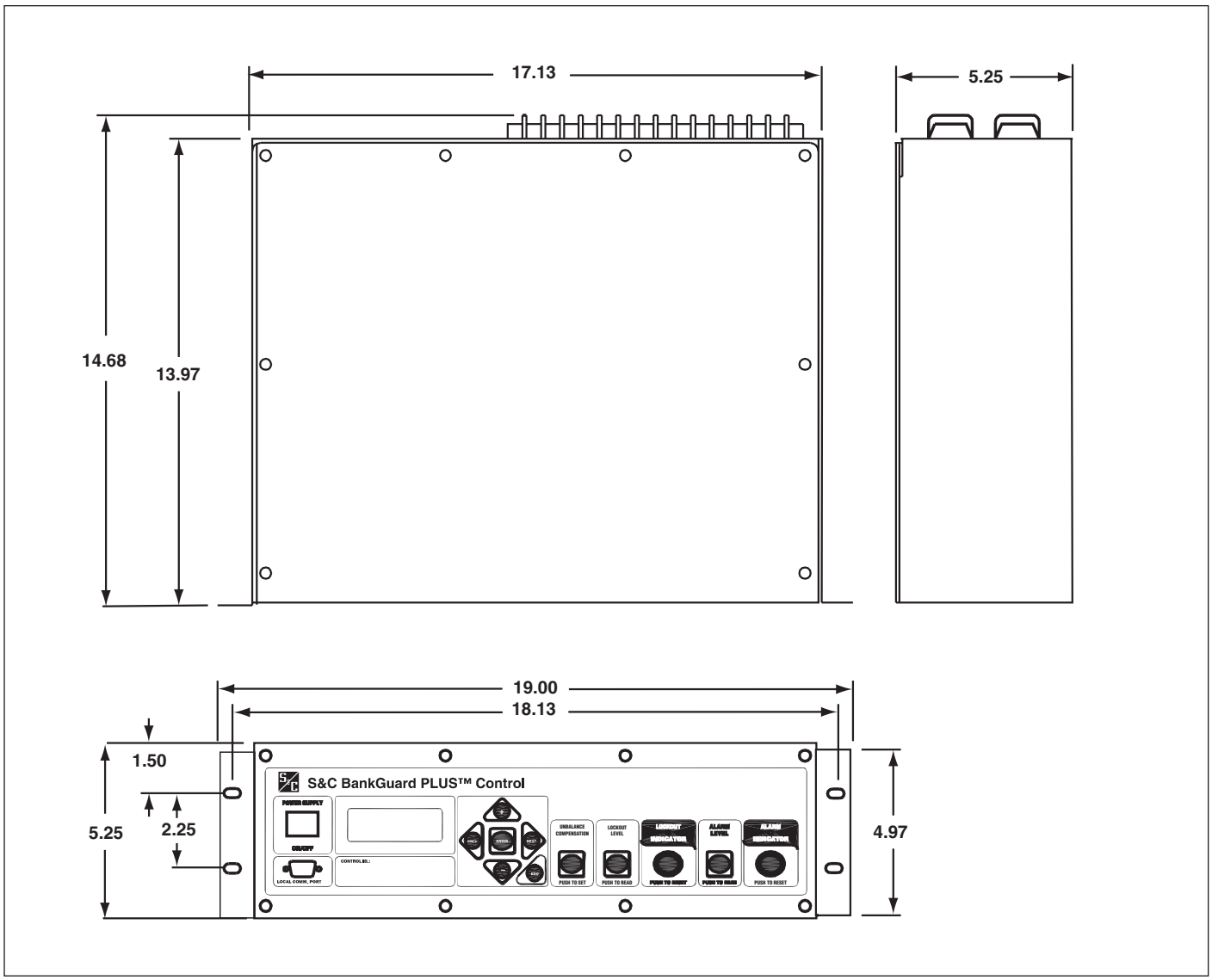


Figure 8. BankGuard PLUS dimensions, in inches.

BankGuard PLUS Installation

BankGuard PLUS Controls are suitable for mounting in a standard 19-inch relay rack. See Figure 8. External control wiring connections are made to numbered terminal strips at the rear of the device. Customer-installed fuses and fuse blocks for the control source are provided. For flush mounting of the control device on switchboards, control consoles, or other enclosures, an optional mounting bezel is available.

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