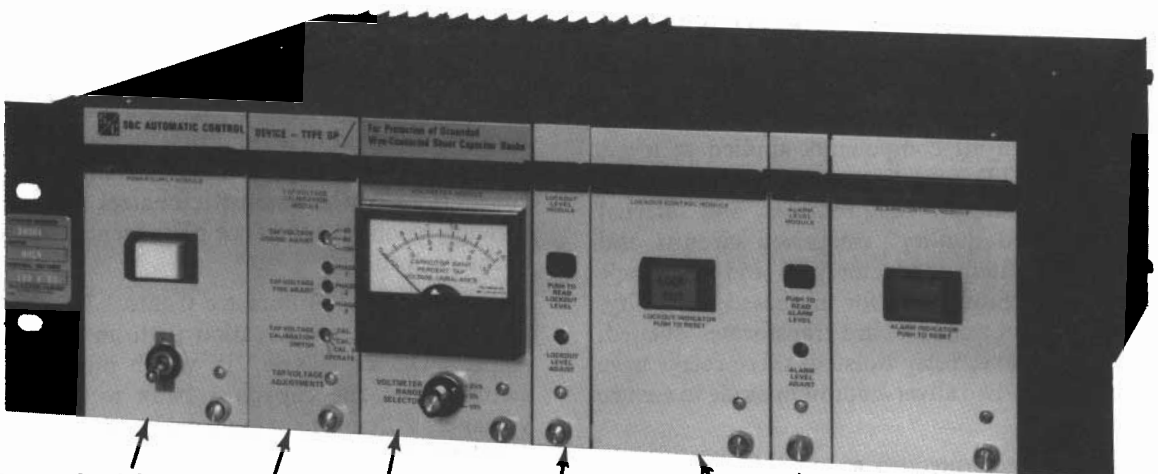
INSTRUCTIONS

For Installation and Operation

INTRODUCTION

CAUTION: The equipment covered by this publication must be selected for a specific application and it must be installed, operated, and maintained by qualified persons who are thoroughly trained and who understand any hazards that may be involved. This publication is written only for such qualified persons and is not intended to be a substitute for adequate training and experience in safety procedures for this type of equipment.

The S&C Automatic Control Device—Type GP provides protection of *grounded*, wye-connected shunt capacitor banks consisting of two or more series groups per phase. It is a solid-state electronic control device of modular construction which detects the loss of individual capacitor units. See Figure 1. As successive individual capacitor units in a series 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 Type GP Automatic Control Device—which isolates and locks out the entire bank when a predetermined overvoltage occurs.



Power Supply Module

Tap-Voltage Calibration Module provides adjustment means to null out difference between phase-tap voltages under normal bank conditions (all capacitor units sound and energized)

Voltmeter Module permits direct reading of tap-voltage percent unbalance and, when the push-to-read button on the alarm or lockout level module is pressed, the alarm and lockout-level settings, respectively

Lockout Level Module responds to loss of critical number of capacitor units and, after a short time delay, provides a signal to the lockout control module

Lockout Control Module accepts signals from lockout level module or gross overvoltage circuit, and initiates tripping of the capacitor-bank switching device to lock out the capacitor bank—as denoted by a lighted indicator

Alarm Module Set (optional) consists of Alarm Level Module and Alarm Control Module:

Alarm Level Module responds to loss of a lesser number of capacitor units than that corresponding to the lockout-level setting and, after a short time delay, provides an alarm signal to the alarm control module

Alarm Control Module accepts signal from alarm level module and provides local alarm indication—denoted by a lighted indicator, as well as closure of remote-alarm contacts

Figure 1. S&C Automatic Control Device—Type GP.

Supersedes Instruction Sheet 531-505 dated 9-16-85

INTRODUCTION — Continued

The Type GP Automatic Control Device incorporates a *gross overvoltage* circuit which functionally bypasses the lockout-level and timing-control circuits and initiates isolation of the capacitor bank in the event of a flashover of series groups within the capacitor bank. This circuit is activated, after a field-adjustable short-time delay, when the tap-voltage percent unbalance exceeds a field-adjustable level.

An optional plug-in alarm module set (catalog number suffix "-H") may be furnished to provide an alarm signal upon loss of a lesser number of capacitor units than that corresponding to the lockout-level setting. For many capacitor banks it is quite feasible to activate the alarm upon loss of a single capacitor unit—a decided advantage since replacement of the failed capacitor unit can be accomplished at a convenient, planned time.

The Type GP Automatic Control Device, with the precision, flexibility, and compactness of solid-state electronics, offers matchless design features and proven circuits that withstand the rigors of power equipment application.

The Type GP Automatic Control Device utilizes plug-in modules featuring glass-reinforced epoxy circuit boards, with all components applied at levels well below MIL-STD guidelines to minimize component stress, power-supply requirements, and internal heating. "Enhanced quality" integrated circuits and gold-over-nickel plated connector pins and receptacle contacts are used throughout, for increased reliability. Voltage-sensing input circuits are transformer isolated, and output circuits are relay isolated; these relays have contacts of gold-flashed silver-cadmium oxide to ensure long service life.

Metal-oxide surge protectors at critical points in the control circuits provide the optimum in surge protection. S&C's unique surge-control techniques have been field proven through years of successful application in hostile utility-substation environments. The capability of every S&C electronic device to withstand voltage surges is confirmed by two factory quality-check tests: The ANSI Surge Withstand Capability Test (ANSI Standard C37.90a, 1974); plus a much more severe (5-kv, 3.75-joule) capacitive-discharge test specially developed by S&C to duplicate or exceed voltage surges measured in EHV power substations. The specified surges are applied at all terminals of the device. Additional factory tests include a dielectric test; screening procedures with the device energized—including vibration, temperature-cycling, and maximum-operating-temperature tests; and functional tests (both before and after the screening tests).

The Type GP Automatic Control Device is suitable for mounting in a standard 19-inch relay rack. External control-wiring connections are made to numbered terminal strips at the rear of the device. See Figure 2. 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 (catalog number suffix "-L" or "-M") is available.

The Type GP Automatic Control Device may be furnished in a weatherproof enclosure suitable for mounting on a substation structure. In this instance, a prewired, auxiliary, front-access, covered terminal strip is provided, in addition to a space heater suitable for 120-volt ac or 240-volt ac operation. The space heater is controlled by a nonadjustable 90°F thermostat. Factory-installed fuses and fuse blocks for the control source and for the space heater are included. External connections to the automatic control device are made through a conduit-entrance plate located at the bottom of the enclosure.

The Type GP Automatic Control Device may also be furnished in combination with an S&C Automatic Control Device—Type VR, which provides automatic switching of the capacitor bank to regulate system voltage. When this combination is furnished in a weatherproof enclosure, an additional auxiliary, front-access, covered terminal strip is provided, as are additional fuses and fuse blocks. See Figure 3. All necessary interconnections are prewired. Further, if the combination is furnished for 125-volt dc control-source voltage (catalog number suffix "-B"), the weatherproof enclosure is supplied with an exhaust fan controlled by a nonadjustable 120°F thermostat. Refer to S&C Instruction Sheet 531-515 for details on the Type VR Automatic Control Device.

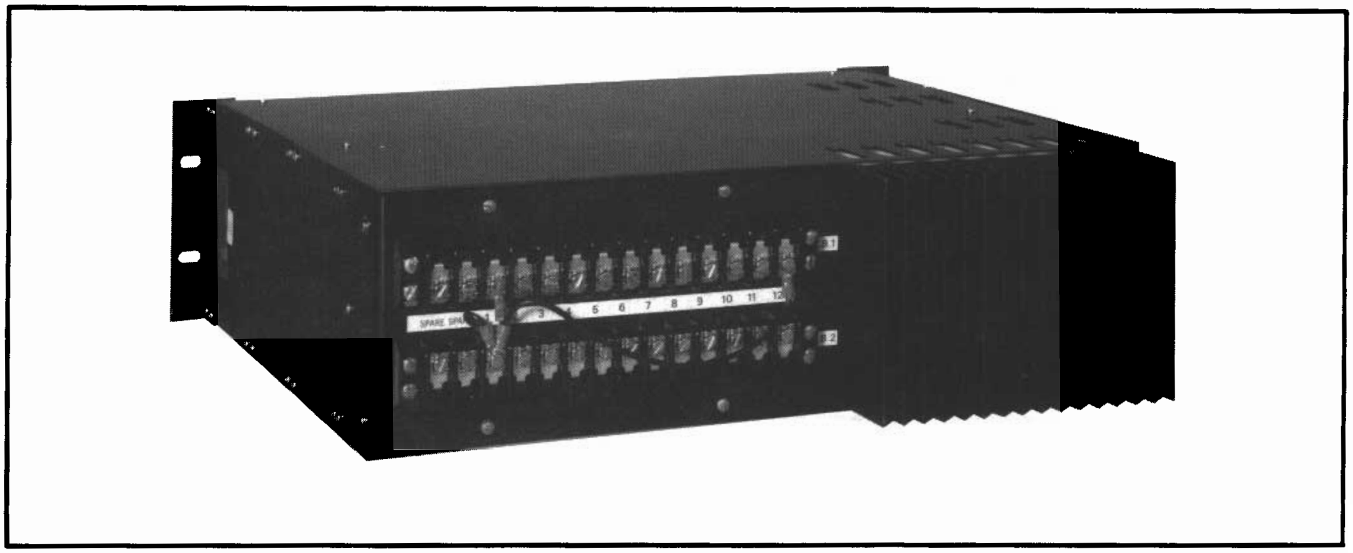


Figure 2. Terminal strips for external control-wiring connections.

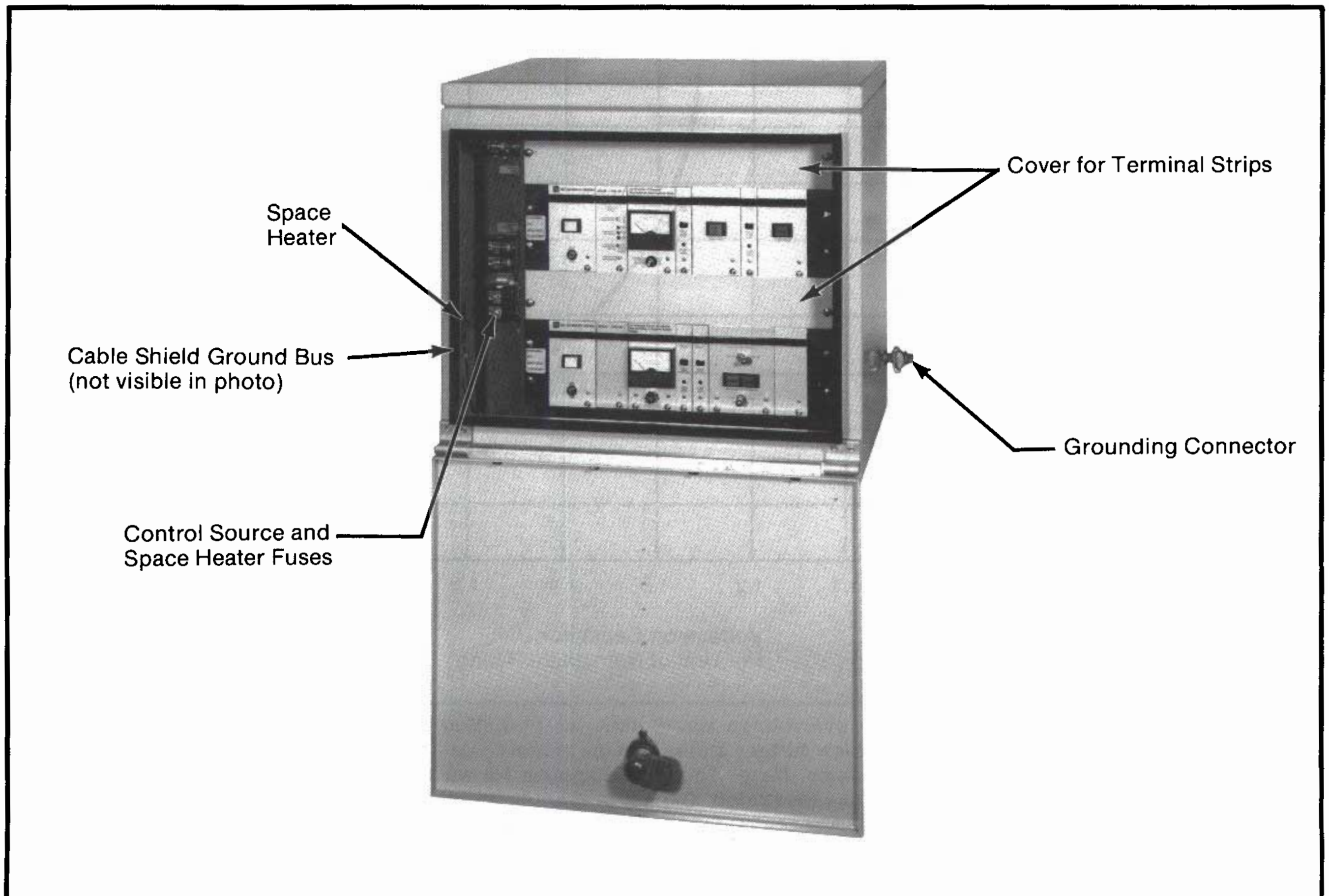


Figure 3. S&C Automatic Control Device—Type GP/VR mounted in weatherproof enclosure.

FUNCTIONAL PERFORMANCE

As failing capacitor units are successively isolated from the same series group by their associated fuses, the voltage applied to the surviving capacitor units in the group increases in discrete steps. Figure 4 indicates permissible capacitor-unit operating time at varying per-unit multiples of capacitor nameplate voltage rating, according to ANSI/IEEE Standard 18-1980, which further states that capacitors shall be capable of continuous operation up to 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 such a recommendation, the ANSI/IEEE data), the entire bank should be removed from service.

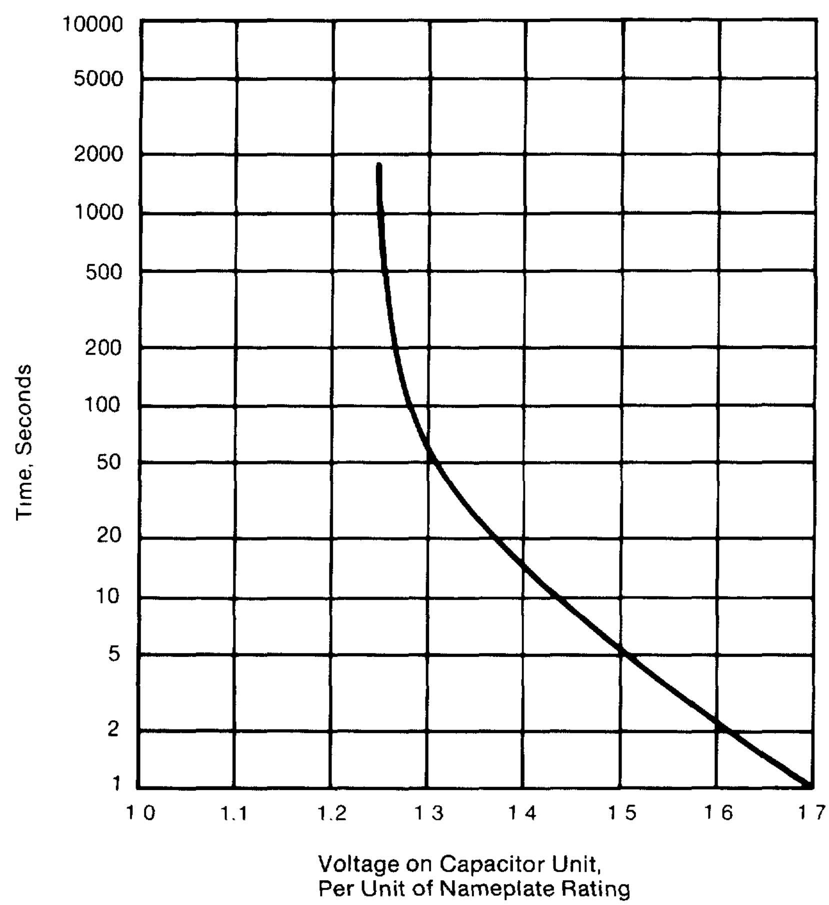


Figure 4. Capacitor-unit power-frequency overvoltage versus time, as permitted by ANSI/IEEE Standard 18-1980, "IEEE Standard for Shunt Power Capacitors," which further states that capacitors shall be capable of continuous operation up to 110% of rated voltage, including harmonics. Note: This curve applies for up to 300 applications of power-frequency overvoltages of the magnitudes and durations illustrated. Capacitor manufacturers may publish different recommendations applicable to their particular units.

The Type GP Automatic Control Device utilizes a tap-voltage calibration module which develops the phasor sum of the intermediate tap-point voltages on the three phase legs and provides a nullifying phasor that eliminates the effects of inherent capacitor-bank unbalance (resulting from manufacturing-tolerance variations among capacitor units in the bank) and fixed system voltage unbalance. 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 module of the Type GP Automatic Control Device.

A field-adjustable 4- to 30-second§ time delay is incorporated in the lockout level module, to assure operation of the fuse associated with the last-failing capacitor unit before providing a signal to the lockout control module to initiate tripping of the capacitor-bank switching device.

A gross overvoltage circuit responds to faults within the bank producing a tap-voltage percent unbalance in excess of a field-adjustable level of 5 to 20% by initiating isolation and lockout of the capacitor bank after a field-adjustable time delay of 0.5 to 5 seconds.⊕

The Type GP Automatic Control Device may be furnished with an optional alarm module set, which provides an alarm signal upon the loss of a lesser number of capacitor units than that corresponding to the lockout-level setting. The alarm module set, further, responds to loss of control power to the Type GP Automatic Control Device and provides an alarm signal. The 4- to 30-second§ time delay incorporated in the lockout level module is also utilized here to avoid false alarms due to transient disturbances.

The Type GP Automatic Control Device also incorporates an auxiliary relay (33X) which is actuated through a "b" contact of the capacitor-bank switch-operator auxiliary switch. This auxiliary relay prevents nuisance lockouts of the automatic control device (as well as nuisance activation of the alarm circuit in installations which include the optional alarm module set) resulting from excessive tap-voltage percent unbalance being induced during periods when the capacitor bank has been routinely de-energized.

The intermediate tap point for each phase of the capacitor bank should be located as follows:

- For capacitor banks having an even number of series groups per phase, the number of series groups between the tap point and ground should equal the number of series groups between the tap point and the line.
- For capacitor banks having an odd number of series groups per phase, the number of series groups between the tap point and ground should be one less than the number of series groups between the tap point and the line.

Each Type GP Automatic Control Device installation requires the use of three S&C 30-Volt-Ampere Potential Devices equipped with a factory-adjusted calibration device (contained within the base of the potential device), specified by adding the suffix "-T" to the catalog number of the potential device. The potential devices used should have a system voltage rating at least equal to the voltage appearing between the intermediate tap points and ground multiplied by $\sqrt{3}$.

Note: Since S&C Potential Devices are not of instrument-class accuracy, their performance in intermediate-tap-point voltage-monitoring applications on very-large-sized grounded, wye-connected shunt capacitor banks may not be entirely satisfactory, especially if it is desired to obtain an alarm signal upon the loss of a single capacitor unit. Specifically, this alarm signal setting on banks consisting of more than 150 capacitor units or more than 5 series groups per phase (often the case where system voltage is higher than 138 kv) may possibly lead to nuisance alarms under severe rainfall conditions. In cases where such false operations are of especial concern, higher-accuracy devices such as voltage transformers or capacitor-coupled voltage transformers are recommended. The minimum system voltage rating of these devices is derived by calculating the voltage appearing between the intermediate tap points and ground and multiplying this value by $\sqrt{3}$.

§ Factory-set at 10 seconds.

⊕ Factory-set at 12%, for a time delay of 2 seconds.

General Installation Requirements

To prevent damage to the Type GP Automatic Control Device in the event that surges which exceed factory-tested levels are encountered, S&C's control-circuit fusing recommendations must be followed. The required fuse blocks and fuses are furnished with the control device. If frequent surges in excess of factory-tested levels are anticipated, S&C should be advised as to the severity of the surges so that special recommendations can be made.

The following steps are recommended to ensure that the control device is not subjected to surges in excess of the level defined in ANSI Standard C37.90a:

1. Adequate shielding should be provided for control-circuit wiring. Refer to the interconnection diagram furnished.
2. For installations involving two or more grounded-wye capacitor banks in the same station, their neutrals should preferably be interconnected and grounded at a single point only. Additionally, it may be desirable to equip the capacitor-bank switching devices with pre-insertion resistors, or to provide current-limiting reactors, for reduction of inrush current and transient voltage disturbances.

In designing the installation, consideration should be given to provision of adequate ventilation for the control device to limit the temperature adjacent to the unit to 160°F maximum. This is particularly important in instances where the control device is installed in a cabinet or where several control devices are installed in close proximity to each other.

Making the Connections

The Type GP Automatic Control Device is equipped with numbered terminal strips for external control-wiring connections at the rear of the device. See Figure 2. Using the connection drawing in the instruction manual furnished with the device, make the following external connections:

1. Control source (48 volts dc, 125 volts dc, 120 volts 60 hertz, or 240 volts 60 hertz, as appropriate).
2. Output terminals of three S&C 30-Volt-Ampere Potential Devices equipped with factory-adjusted calibration device, catalog number suffix "-T."★ The potential devices should have a system voltage rating at least equal to the voltage appearing between the intermediate tap points and ground multiplied by $\sqrt{3}$.
3. Opening circuit of the switch operator.
4. Closing circuit of the switch operator.
5. "b" contact of switch-operator auxiliary switch. This contact should be set to open near the fully closed position of the capacitor-bank switching device.
6. Station ground.
7. Space heater source, where applicable (120 volts ac or 240 volts ac).
8. Alarm circuit (optional).

Connecting circuits from the voltage-monitoring devices to the Type GP Automatic Control Device must be free of variable loads, variable voltage drops, and ground loops so that the voltages monitored accurately represent the magnitude and phase angle of the bus and tap voltages. Some possible errors affecting unbalance compensation are:

- Unbalanced or variable loading of the voltage-monitoring devices. (Station-service transformers are thus not suitable sources for this purpose.)
- Control-wiring voltage drops between the voltage-monitoring devices and the automatic control device. (For example, a 1-ampere current flowing through 1000 feet of number 10 AWG wire will result in a 1-volt drop in the voltage-level signal, which may be sufficient to produce undesirable performance of the protection scheme.) Adequately sized dedicated connecting circuits between the voltage-monitoring devices and the automatic control device will minimize voltage drops.
- Induced voltages in control wiring. Proper shielding is important.
- Ground loops caused by differences in voltage between the grounding points of tap-point voltage-monitoring devices and those of phase-to-ground voltage-monitoring devices. Preferably, the secondaries of all the voltage-sensing devices should be grounded at one point—at the control house, as per proposed ANSI C57.13.3, "Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases."

★ Alternately, three voltage transformers or capacitor-coupled voltage transformers having a minimum system voltage rating at least equal to the voltage appearing between the intermediate tap points and ground multiplied by $\sqrt{3}$. See note on page 5.

Two methods of establishing the capacitor-bank lockout level are given on this and succeeding pages—one utilizing graphs and one utilizing formulas. Both methods are predicated on location of the intermediate tap points as described under FUNCTIONAL PERFORMANCE, on page 5.

In both methods, sets of values of % U—the tap-voltage percent unbalance—are derived for increasing values of F—the number of individual capacitor units isolated from the same series group. The sets of values of % U so derived are valid for isolation of capacitor units in any series group of a capacitor bank having an *even* number of series groups per phase.

The sets of values of % U so derived are also valid for isolation of capacitor units in any series group located *between the tap point and the line* when the total number of series groups per phase is *odd*. However, if the total number of series groups per phase is odd, the sets of values of % U so derived are valid for isolation of capacitor units in any series group located *between the tap point and ground* only after applying the following adjustment factor:

$$\frac{S+1}{S-1} = \text{Adjustment factor to be applied to derived sets of values of \% U}$$

where S = Number of series groups per phase

Determine Incremental Capacitor-Unit Overvoltage and Tap-Voltage Percent Unbalance Due to Loss of Successive Capacitor Units—Graphical Method

Step-by-step Procedures

1. Collect installation data, including:
   a. Highest anticipated continuous system line-to-neutral voltage, kv
   b. Nameplate capacitor-unit rating, kv
   c. Number of series groups per phase — S
   d. Number of capacitor units in parallel per series group — P.
2. Using the graph, Figure 5, read per-unit values of V_O—the voltage applied to surviving capacitor units—for a series of steps corresponding to increasing values of F—the number of capacitor units isolated—up to and including F_C—the step for which V_O, when corrected as described directly below, equals or exceeds the capacitor manufacturer's recommended maximum working voltage (generally 1.1 per unit). The step corresponding to F_C will hereafter be referred to as the "critical step."
3. If the capacitor units are operated at other than rated voltage, correct the values of V_O read in (2) above by multiplying by the ratio of the "normal" (highest anticipated) applied voltage (all capacitor units operating) to the nameplate voltage rating of the capacitor units.
4. Using the graph, Figure 6, read values of % U—the tap-voltage percent unbalance—for the same series of steps corresponding to increasing values of F up to and including F_C.
5. Determine the desired lockout level—the midpoint between % U for F_C, the critical step, and % U for F_{C-1}. (For capacitor banks having an odd number of series groups per phase, alternate values of % U computed by application of the appropriate adjustment factor must be considered as well, and a lockout level selected which will provide the best overall response.)

Using the Graphical Method—First Example

1. Installation Data
   a. Highest anticipated continuous system line-to-ground voltage, kv 20
   b. Nameplate capacitor-unit rating, kv 9.96
   c. Number of series groups per phase 2
   d. Number of capacitor units in parallel per series group 10
2. For F = 1, enter the graph, Figure 5, at 10 on the horizontal scale (1/10 = 10% of capacitor units isolated from a series group). Follow up to a point corre-

ESTABLISHING THE SETTINGS — Continued

sponding to 2 series groups per phase (curve labeled "S = 2") and read V_O = 1.053 per unit on the vertical scale.

For F = 2, in like manner, enter the graph, Figure 5, at 20 on the horizontal scale (2/10 = 20% of capacitor units isolated from the same series group). Follow up to a point corresponding to 2 series groups per phase (curve labeled "S = 2") and read V_O = 1.11 per unit on the vertical scale. Obviously, F = 2 is the critical step, F_C, if it is desired to limit V_O to 1.1 per unit or less.

3. With an anticipated system line-to-ground voltage of 20 kv and with 2 series groups per phase, the capacitor units are operated at 10 kv. Therefore:

For F = 1,

$$V_O = \frac{1.053 \text{ X } 10 \text{ kv}}{9.96 \text{ kv}} = 1.057 \text{ per unit}$$

For F = 2,

$$V_O = \frac{1.11 \text{ X } 10 \text{ kv}}{9.96 \text{ kv}} = 1.114 \text{ per unit}$$

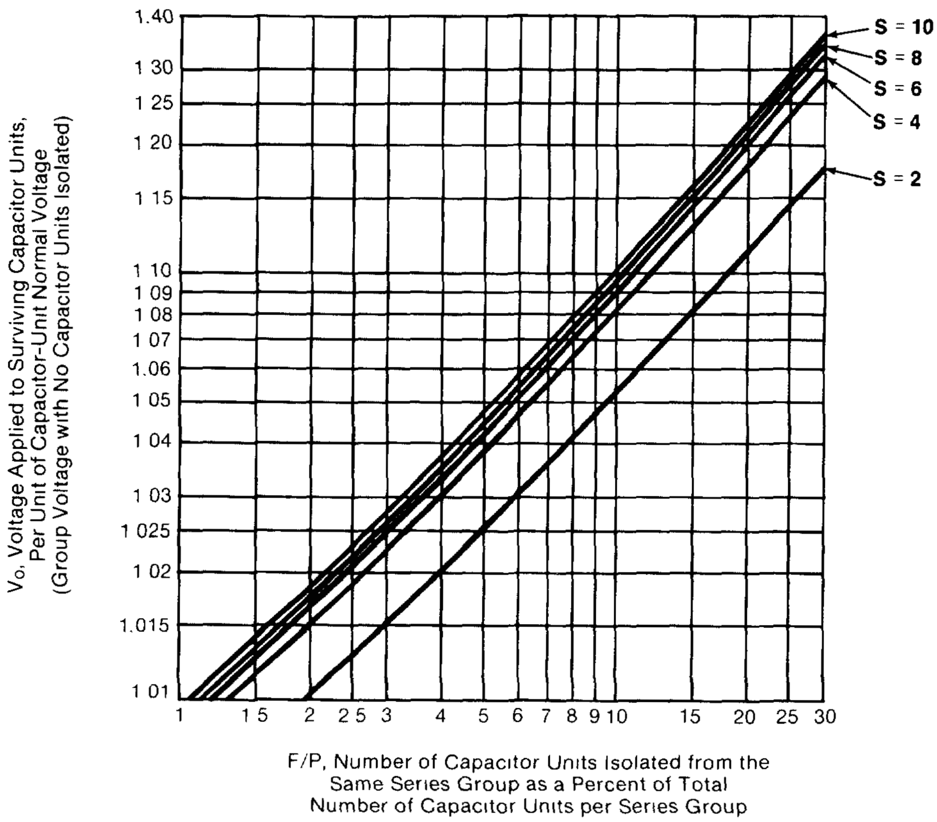


Figure 5. Per-unit voltage applied to surviving capacitor units in a series group versus percentage of capacitor units isolated from the same series group.

4. For F = 1, enter the graph, Figure 6, at 10 on the horizontal scale (1/10 = 10% of capacitor units isolated from a series group). Follow up to a point corresponding to 2 series groups per phase (curve labeled "S = 2") and read % U = 5.2% on the horizontal scale.

   For F = 2, in like manner, enter the graph, Figure 6, at 20 on the horizontal scale (2/10 = 20% of capacitor units isolated from the same series group). Follow up to a point corresponding to 2 series groups per phase (curve labeled "S = 2") and read % U = 11% on the vertical scale.

5. In this example, the desired tap-voltage unbalance lockout level is the midpoint between the value of % U for F = 1, and the value of % U for F = 2, or

$$\frac{5.2\% + 11\%}{2} = 8.1\%$$

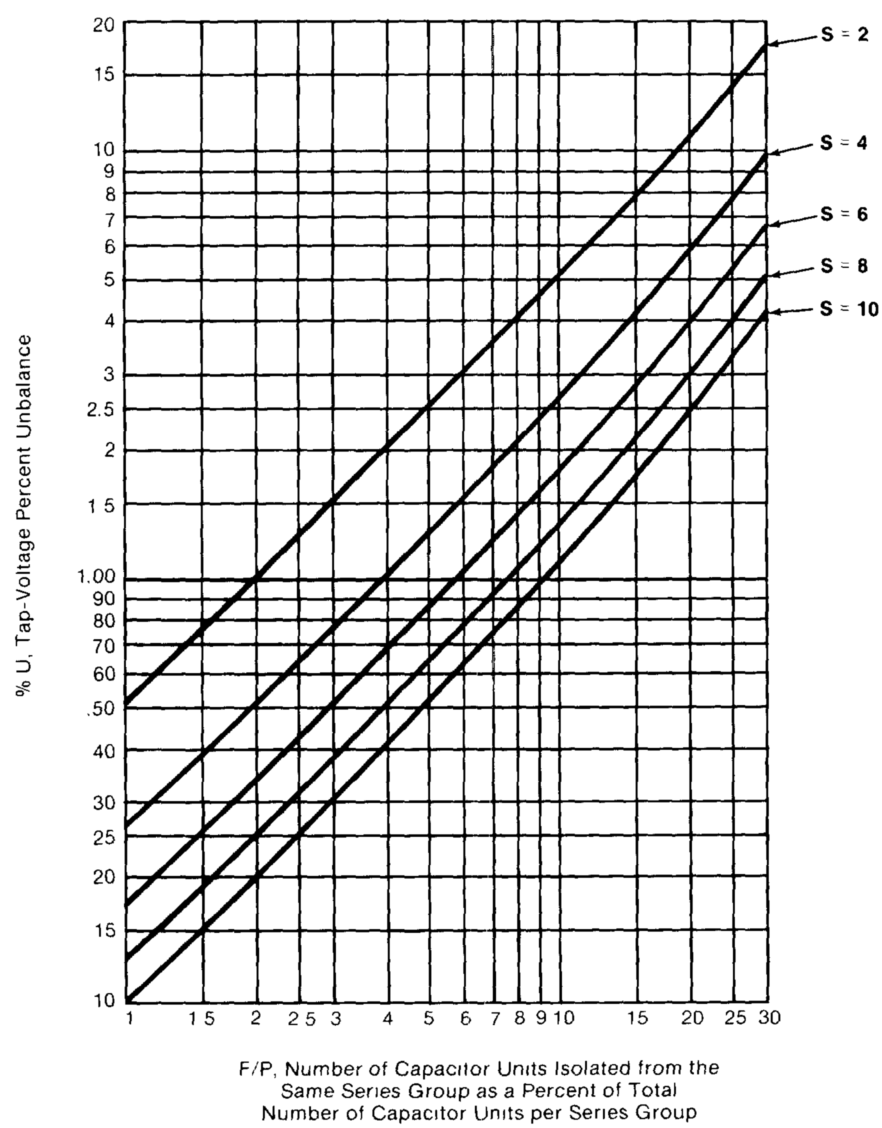


Figure 6. Tap-voltage percent unbalance versus percentage of capacitor units isolated from the same series group.

Using the Graphical Method—Second Example

1. Installation Data
   a. Highest anticipated continuous system line-to-ground voltage, kv 139.44
   b. Nameplate capacitor-unit rating, kv 19.92
   c. Number of series groups per phase 7
   d. Number of capacitor units in parallel per series group 12
2. For F = 1, enter the graph, Figure 5, at 8.33 on the horizontal scale (1/12 = 8.33% of capacitor units isolated from a series group). Follow up to a point corresponding to 7 series groups per phase (interpolate between curves labeled "S = 6" and "S = 8") and read V_O = 1.076 per unit on the vertical scale.

   For F = 2, in like manner, enter the graph, Figure 5, at 16.67 on the horizontal scale (2/12 = 16.67% of capacitor units isolated from the same series group). Follow up to a point corresponding to 7 series groups per phase and read V_O = 1.17 per unit on the vertical scale. Obviously, F = 2 is the critical step, F_C, if it is desired to limit V_O to 1.1 per unit or less.
3. With an anticipated system line-to-ground voltage of 139.44 kv and with 7 series groups per phase, the capacitor units are operated at 19.92 kv, their rated voltage. Therefore, no correction factor need be applied to the values read in (2) above.
4. For F = 1, enter the graph, Figure 6, at 8.33 on the horizontal scale (1/12 = 8.33% of capacitor units isolated from a series group). Follow up to a point corresponding to 7 series groups per phase (interpolate between curves labeled "S = 6" and "S = 8") and read % U = 1.3% on the vertical scale.

   For F = 2, in like manner, enter the graph, Figure 6, at 16.67 on the horizontal scale (2/12 = 16.67% of capacitor units isolated from the same series group). Follow up to a point corresponding to 7 series groups per phase and read % U = 2.8% on the vertical scale.
5. Since the number of series groups per phase in this example is odd, compute alternate values of % U by using the adjustment factor (7 + 1)/(7 − 1) = 1.33 which applies for isolation of capacitor units in a series group located between the tap point and ground. See page 7.

   For F = 1,

   % U = 1.3% X 1.33 = 1.7%

   For F = 2,

   % U = 2.8% X 1.33 = 3.7%

In this example, the desired tap-voltage unbalance lockout level is the midpoint between the *higher* value of % U for F = 1, and the *lower* value of % U for F = 2, or

$$\frac{1.7\% + 2.8\%}{2} = 2.25\%$$

Determine Incremental Capacitor-Unit Overvoltage and Tap-Voltage Percent Unbalance Due to Loss of Successive Capacitor Units—Formula Method

Step-by-step Procedures

1. Collect installation data, including:
   a. Highest anticipated continuous system line-to-ground voltage
   b. Nameplate capacitor-unit rating, volts
   c. Number of series groups per phase
   d. Number of capacitor units in parallel per series group.
2. Calculate per-unit values of V_O—the voltage applied to surviving capacitor units—for a series of steps

corresponding to increasing values of F—the number of capacitor units isolated—up to and including F_C—the step for which V_O equals or exceeds the capacitor manufacturer's recommended maximum working voltage (generally 1.1 per unit). The step corresponding to F_C will hereafter be referred to as the "critical step." Use the formulas:

$$V_O \text{ (volts)} = \frac{P\,(V_{L\text{-}G})}{S\,(P-F)+F}$$

$$V_O \text{ (per unit)} = \frac{V_O \text{ (Volts)}}{\text{Nameplate voltage rating of capacitor units}}$$

where $V_{L\text{-}G}$ = Highest anticipated continuous system line-to-ground voltage

S = Number of series groups per phase

P = Number of capacitor units in parallel per series group

F = Number of capacitor units isolated from bank (and from the same series group)

3. For each value of F used in (2) above, calculate the tap-voltage percent unbalance, % U. Use the formula:

$$\%\,U = \frac{100F}{S\,(P-F)+F}$$

where S, P, and F are defined as in (2) above, and % U = tap-voltage percent unbalance.

4. Determine the lockout level by calculating the midpoint between % U for F_C, the critical step, and % U for F_{C-1}. (For capacitor banks having an odd number of series groups per phase, alternate values of % U computed by application of the appropriate adjustment factor must be considered as well, and a lockout level selected which will provide the best overall response.)

Using the Formula Method—First Example

1. Installation Data
   a. Highest anticipated continuous system line-to-ground voltage 20,000
   b. Nameplate capacitor-unit rating, volts 9,960
   c. Number of series groups per phase 2
   d. Number of capacitor units in parallel per series group 10

2. For F = 1,

$$V_O \text{ (volts)} = \frac{(10)(20{,}000)}{2(10-1)+1} = 10{,}526 \text{ volts}$$

$$V_O \text{ (per unit)} = \frac{10{,}526}{9{,}960} = 1.0568 \text{ per unit (or 5.68\% overvoltage)}$$

For F = 2,

$$V_O \text{ (volts)} = \frac{(10)(20{,}000)}{2\,(10-2)+2} = 11{,}111 \text{ volts}$$

$$V_O \text{ (per unit)} = \frac{11{,}111}{9{,}960} = 1.1156 \text{ per unit (or 11.56\% overvoltage)}$$

Obviously, F = 2 is the critical step, F_C, if it is desired to limit V_O to 1.1 per unit or less.

3. For F = 1,

$$\%\,U = \frac{(100)(1)}{2\,(10-1)+1} = 5.26\%$$

For F = 2,

$$\%\,U = \frac{(100)(2)}{2\,(10-2)+2} = 11.11\%$$

4. In this example, the desired tap-voltage unbalance lockout level is the midpoint between the value of % U for F = 1, and the value of % U for F = 2, or

$$\frac{5.26\% + 11.11\%}{2} = 8.19\%$$

Using the Formula Method—Second Example

1. Installation Data
   a. Highest anticipated continuous system line-to-ground voltage 139,440
   b. Nameplate capacitor-unit rating, volts . . 19,920
   c. Number of series groups per phase 7
   d. Number of capacitor units in parallel per series group 12

2. For F = 1,

$$V_O \text{ (volts)} = \frac{(12)(139{,}440)}{7(12-1)+1} = 21{,}452 \text{ volts}$$

$$V_O \text{ (per unit)} = \frac{21{,}452}{19{,}920} = 1.0769 \text{ per unit (or 7.69\% overvoltage)}$$

For F = 2,

$$V_O \text{ (volts)} = \frac{(12)(139{,}440)}{7\,(12-2)+2} = 23{,}240 \text{ volts}$$

$$V_O \text{ (per unit)} = \frac{23{,}240}{19{,}920} = 1.1667 \text{ per unit (or 16.67\% overvoltage)}$$

Obviously, F = 2 is the critical step, F_C, if it is desired to limit V_O to 1.1 per unit or less.

3. For F = 1,

$$\%\,U = \frac{(100)(1)}{7\,(12-1)+1} = 1.28\%$$

For F = 2,

$$\%\,U = \frac{(100)(2)}{7\,(12-2)+2} = 2.78\%$$

4. Since the number of series groups per phase in this example is odd, compute alternate values of % U by using the adjustment factor (7+1)/(7−1) = 1.33 which applies for isolation of capacitor units in a series group located between the tap point and ground. See page 7.

For F = 1,

$$\%\,U = 1.28\% \times 1.33 = 1.70\%$$

For F = 2,

$$\%\,U = 2.78\% \times 1.33 = 3.70\%$$

In this example, the desired tap-voltage unbalance lockout level is the midpoint between the *higher* value of % U for F = 1, and the *lower* value of % U for F = 2, or

$$\frac{1.70\% + 2.78\%}{2} = 2.24\%$$

Gross Overvoltage Circuit

Calculate the tap-voltage percent unbalance, % U, resulting from a fault within the capacitor bank which would short out an entire series group. Use the formula:

$$\%\,U = \frac{100}{S-1}$$

where S = Number of series groups per phase

For the first example given under "Determine Incremental Capacitor-Unit Overvoltage and Tap-Voltage Percent Unbalance Due to Loss of Successive Capacitor Units—Formula Method," the desired gross overvoltage lockout level is the midpoint between the value of % U for F = 2—11.11%—and the value of % U resulting from shorting out a series group—$\frac{100}{2-1}$ = 100%, or

$$\frac{11.11\% + 100\%}{2} = 55.56\%$$

However, the maximum setting for the gross overvoltage circuit is 20%. Hence the gross overvoltage circuit should be set for the 20% level.

For the second example given under "Determine Incremental Capacitor-Unit Overvoltage and Tap-Voltage Percent Unbalance Due to Loss of Successive Capacitor Units—Formula Method," the desired gross overvoltage lockout level is the midpoint between the *higher* value of % U for F = 2—3.70%—and the value of % U resulting from shorting out a series group—$\frac{100}{7-1}$ = 16.67%, or

$$\frac{3.70\% + 16.67\%}{2} = 10.19\%$$

Step 1

Place the on-off toggle switch on the power supply module in the *on* position. The presence of control-source voltage will be signified by a lighted indicator.

If an alarm indicator or lockout indicator lamp should light, press the appropriate button to reset the circuit.

Step 2

Choose the appropriate scale for the voltmeter by setting its meter range selector so that the predetermined lockout level will fall in the upper half of the voltmeter scale. Thus, for the examples given under the "Formula Method" on pages 11 and 12, the 10% scale should be selected to accommodate the lockout level of 8.19%, and the 2½% scale should be selected to accommodate the lockout level of 2.24%, respectively.

Step 3

Adjust the lockout level by pressing the "push-to-read lockout level" button on the lockout level module while turning the "lockout level adjust" screw to attain the required voltmeter reading.

Step 4

If the optional alarm module set is furnished: Adjust the alarm level by pressing the "push-to-read alarm level" button on the alarm level module while turning the "alarm level adjust" screw to attain the required voltmeter reading. Choose the appropriate meter range as noted in Step 2.

The alarm level setting should be approximately half of the value of tap-voltage percent unbalance resulting from the isolation of one capacitor unit (the *lower* value, if the number of series groups is odd). Thus, for the examples given under the "Formula Method" on pages 11 and 12, the alarm level settings should be 5.26%/2 = 2.63%, and 1.28%/2 = .64%, respectively.

Activation of the alarm circuit upon isolation of one capacitor unit enables the user to choose either to continue operating the capacitor bank—deferring replacement of the failed unit until a convenient time—or to replace the failed unit sooner, thus minimizing the time that surviving capacitor units are exposed to overvoltage and thereby reducing the likelihood that marginal units will fail prematurely.

Step 5

Record, for future reference, the lockout-level and alarm-level settings arrived at in the preceding steps, as indicated on the voltmeter. Note also the voltmeter range selected.

Step 6

Adjust the gross overvoltage circuit percent unbalance level by setting the 5-20% single-turn potentiometer located on the lockout control module printed circuit board for the required value. For the example given under "Gross Overvoltage Circuit" on page 12, the gross overvoltage settings should be 20% and 10.2%, respectively.

• Refer to footnote under SPECIFICATIONS, on page 18, regarding level settings of less than 1%.

LOCKOUT-TIMER ADJUSTMENTS

An important consideration in the application of the Type GP Automatic Control Device is that of coordinating capacitor-bank isolation and lockout with operation of the individual capacitor-unit fuses. It is undesirable for the control to initiate lockout before the fuse for the last-failing capacitor unit has had sufficient time to operate. If the fuse does not operate there will not be any indication as to which capacitor unit was in the process of failing. Generally, coordination will be achieved provided:

1. The lockout and alarm levels are set as described in the foregoing example,
2. The lockout time delay is adequate, and
3. A fusing ratio of 1.25 or less is used for individual capacitor-unit fuses.

Step 7

If other than the factory-set lockout time delay is desired (see SPECIFICATIONS, page 18), set the 4-30 second single-turn potentiometer, located on the lockout level module printed circuit board, for the desired value. The scale on the potentiometer is accurate to ±20%.

Step 8

Adjust the gross overvoltage circuit time delay by setting the 0.5-5 second single-turn potentiometer, located on the lockout control module printed circuit board, for the desired value. The scale on the potentiometer is accurate to ±20%.

The gross overvoltage circuit time delay should be a minimum of 0.5 second‡ *plus* the elapsed time between energization of the capacitor-bank switching device opening circuit and closing of the switching device "b" contact (which is coincident with mechanical parting of the disconnect blades, if an S&C Circuit-Switcher is furnished).

For example, if the capacitor-bank switching device is a 230-kv S&C Circuit-Switcher, the minimum gross overvoltage circuit time delay setting should be 0.5 second plus 0.6 second, or 1.1 seconds total. The elapsed time between energization of the opening circuit and mechanical parting of the disconnect blades can be approximated as 40% of the maximum operating time of the particular S&C Circuit-Switcher used.

Step 9

Record, for future reference, the time-delay settings selected in Steps 7 and 8.

‡ Required to prevent gross overvoltage lockout due to transient system voltage.

Step 10

The tap-voltage calibration module must be pre-calibrated prior to initial energization of the capacitor bank, using the following procedure.

1. Temporarily disconnect, from the terminals at the rear of the Type GP Automatic Control Device, the external connections to the three voltage-monitoring devices.
2. Make up the external single-phase voltage source connections to the "Phase 1" terminals of the tap-voltage calibration module, as indicated in Figure 7. Adjust the variable transformer to simulate the output of the "Phase 1" voltage-monitoring device as follows.

$$V_T = \frac{S_T\,(V_{L\text{-}G})}{S(N_T)}$$

where $V_{L\text{-}G}$ = Highest anticipated continuous system line-to-ground voltage

N_T = Voltage ratio of tap-point voltage-monitoring device

S = Number of series groups per phase

S_T = Number of series groups per phase between the tap point and ground

3. Perform Steps 13 through 16, below.
4. Relocate the variable-transformer output connections to the "Phase 2" terminals of the tap-voltage calibration module and perform Steps 17 and 18, below.
5. Finally, relocate the variable-transformer output connections to the "Phase 3" terminals of the tap-voltage calibration module and perform Steps 19 and 20, below.
6. Disconnect the external, single-phase voltage source connections and reconnect the three voltage-monitoring devices. Be sure to observe polarities of the voltage-monitoring devices.

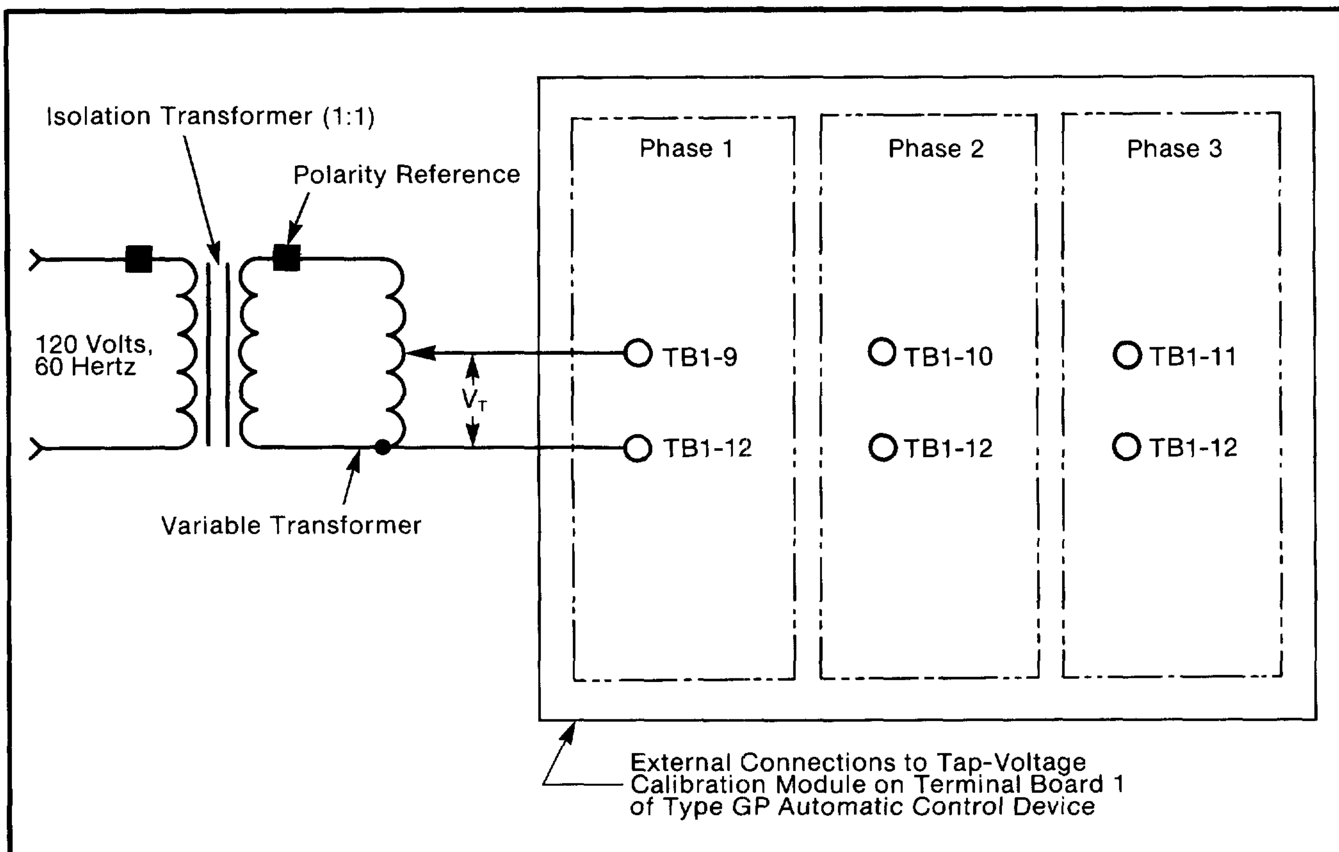


Figure 7. Connections to tap-voltage calibration module, for pre-calibrating module prior to initial energization of capacitor bank. See Step 10.

FINAL ADJUSTMENT OF TAP-VOLTAGE CALIBRATION MODULE

Step 11

Close the capacitor-bank switching device to energize the capacitor bank.

Verify that no capacitor units have been isolated from the capacitor bank (check for blown fuses). It is necessary to adjust the tap-voltage calibration module, as described in the following steps, to attain minimum voltmeter readings.

Step 12

Remove the lockout control module to prevent inadvertent automatic lockout during final adjustment of the tap-voltage calibration module.

Step 13

Turn the voltmeter range selector on the voltmeter module to the "10%" position.

Step 14

Turn the tap-voltage calibration switch on the tap-voltage calibration module to the "Cal. 1" position.

Step 15

Turn the tap-voltage coarse-adjust switch on the tap-voltage calibration module to the appropriate position: "60," "80," or "100," in order to obtain an intermediate tap-point voltage percent unbalance reading in excess of 8%. (The "60" position covers a tap-voltage range of 60 to 80 volts, the "80" position covers a tap-voltage range of 70 to 110 volts, and the "100" position covers a tap-voltage range of 100 to 140 volts.)

Step 16

Turn the "Phase 1" tap-voltage fine-adjust potentiometer screw on the tap-voltage calibration module counterclockwise to obtain a meter reading of 8%.

Step 17

Turn the tap-voltage calibration switch on the tap-voltage calibration module to the "Cal. 2" position.

Step 18

Turn the "Phase 2" tap-voltage fine-adjust potentiometer screw on the tap-voltage calibration module counterclockwise to obtain a meter reading of 8%.

Step 19

Turn the tap-voltage calibration switch on the tap-voltage calibration module to the "Cal. 3" position.

Step 20

Turn the "Phase 3" tap-voltage fine-adjust potentiometer screw counterclockwise to attain a meter reading of 8%.

Step 21

Turn the tap-voltage calibration switch on the tap-voltage calibration module to the "Operate" position.

Step 22

Turn the voltmeter range selector on the voltmeter module to the desired scale.

Step 23

To complete the adjustments, turn the "Phase 2" and "Phase 3" tap-voltage fine-adjust potentiometer screws to attain a minimum reading of the voltmeter.

Step 24

Replace the lockout control module.

Step 25

Record, for future reference, the minimum voltmeter readings for each phase, arrived at in Steps 13 through 23. Note also the voltmeter scale ranges utilized.

VERIFICATION OF CALCULATED LOCKOUT AND ALARM LEVELS

Lockout level can be checked as follows:

Step 26

Verify that no capacitor units have been isolated from the bank.

Step 27

De-energize the capacitor bank by opening the capacitor-bank switching device. Then ground the bank, observing established operating procedures and safety precautions. Isolate the number of capacitor units—all in the same series group—previously determined as required to lock out the bank, by removing their respective fuses. (In instances where the number of series groups per phase is odd, a lesser number of capacitor units will need to be isolated from a given series group located between the tap point and ground than from a given series group located between the tap point and the line.)

Step 28

Remove the temporary grounds, re-energize the bank, and record the voltmeter reading. If the voltmeter deflection exceeds the lockout-level value, an automatic switching operation will occur to isolate the entire capacitor bank after the timer completes its cycle—as indicated by the "Lockout Indicator" lamp. In any event, de-energize the bank by opening the capacitor-bank switching device as soon as the voltmeter reading has been obtained, to avoid shortening the life of the capacitor units. Verify that no other capacitor units have been isolated.

Note: Following automatic lockout of the capacitor bank, the bank can be returned to service *only after pressing* the "Lockout Indicator" button. This permits closing of the capacitor-bank switching device.

Step 29

De-energize and ground the capacitor bank, observing established operating procedures and safety precautions. Reconnect the fuses which were previously removed to isolate the capacitor units.

Step 30

Repeat Steps 26 through 29 for each of the remaining phase legs of the capacitor bank.

Step 31

To check the alarm level value (if the optional alarm module set is included), proceed in the same manner described in Steps 26 through 30 with regard to checking the lockout-level value.

MAINTENANCE

No routine maintenance is recommended for the Type GP Automatic Control Device other than an occasional exercising (about once per year) to verify that it is operational. This can be done by temporarily adjusting the lockout level downward until lockout of the capacitor bank occurs.

At installations utilizing an S&C Circuit-Switcher as the capacitor-bank switching device, the associated S&C Switch Operator, Type CS-1A or Type CS-2A, may be conveniently decoupled from the Circuit-Switcher. This capability makes it possible to check out the Type GP Automatic Control Device and control circuit without actually switching the capacitor bank.

It is advisable, for the first few days after start-up, to compare day-to-day voltmeter readings with those recorded in Step 25, following completion of adjustments to the tap-voltage calibration module. It is possible for changes to occur due to irregularities in the voltage-monitoring devices or to aberrations (developing faults) in the capacitor units themselves. When it has been determined that the tap voltages are remaining constant, voltmeter readings may be compared at convenient intervals. If a small increase in percent voltage unbalance is then observed, it can be an indication of a failing capacitor unit.

Use the "push-to-read" buttons on the appropriate modules to occasionally check the alarm level (if applicable) and lockout level—as indicated on the voltmeter—against the settings recorded in Step 5.

In the event that capacitor units are replaced for any reason, some readjustment of the tap-voltage calibration module may be required.

Finally, it may be prudent to confirm that the time-delay settings, as recorded in Step 9, have not been altered.

SPECIFICATIONS

Automatic Control Device

Catalog Number Suffix	Control-Source Voltage		Current
	Nominal	Operating Range	
A	48 v dc	38.5—56 v dc	1 amp
B	125 v dc	100—140 v dc	1 amp
D	120 v, 60 hz	102—132 v, 60 hz	½ amp
E	240 v, 60 hz	204—264 v, 60 hz	¼ amp

Operating Temperature Range

Ambient adjacent to device ...... −40°F to + 160°F

Tap-Voltage Input Circuit

Normal operating voltage range .. 60 to 140 v, 60 hertz
Frequency range .... 60 ± 0.3 hertz§
Burden .... 1 va maximum

Tap-Voltage-Percent-Unbalance Voltmeter

Accuracy .... ± 2% of full-scale reading
Ranges 0-2½%, 0-5%, 0-10%

Lockout Level Module

Level Detector
- Adjustment range .... 0 to 10%♦
- Accuracy .... ± 1% of setting‡

Time Delay—To Initiate Lockout
- Factory setting .... 10 seconds
- Adjustment range .... 4 to 30 seconds
- Accuracy .... ± 3% of setting‡

Optional Alarm Module Set

Level Detector
- Adjustment range .... 0 to 10%♦
- Accuracy .... ± 1% of setting‡

Time Delay—To Initiate Alarm★
- Factory setting .... 10 seconds
- Adjustment range .... 4 to 30 seconds
- Accuracy .... ± 3% of setting‡

Gross Overvoltage Circuit

Level Detector
- Adjustment range .... 5 to 20%
- Accuracy .... ± 5% of setting‡

Time Delay—To Initiate Lockout
- Factory setting .... 2 seconds
- Adjustment range .... 0.5 to 5 seconds
- Accuracy .... ± 5% of setting‡

§ For 50-hertz applications, refer to the nearest S&C Sales Office.

♦ Level settings of less than 1% may result in nuisance alarm and tripping operations due to uncompensated errors. For example, variations in bank capacitance due to aging and normal day-to-day temperature excursions or variations in the ratio between voltage sensed by the voltage-monitoring device and the voltage appearing at the terminals of the Type GP Automatic Control Device may produce uncompensated unbalance errors.

‡ For any combination of control-source voltage and ambient temperature within specified range.

★ Utilizing lockout level module time delay.

S&C ELECTRIC COMPANY • Chicago
S&C ELECTRIC CANADA LTD. • Rexdale

Output-Relay Contact Ratings

Current Carrying
Continuous . . . . 10 amperes
1-Second . . . . 50 amperes
Interrupting . . . . 1.0 ampere at 48 v dc,
0.5 ampere at 125 v dc,
10 amperes at 120 v, 60 hz,
or 5 amperes at 240 v, 60 hz

Approximate Shipping Weight

Type GP Automatic Control Device only . . . . . 26 lbs.
Type GP Automatic Control Device in
Weatherproof Enclosure . . . . 186 lbs.
Type GP/VR Automatic Control Device in
Weatherproof Enclosure . . . . 212 lbs.

Options

Options which have been included with the Type GP Automatic Control Device are signified by the addition of one or more suffixes to the catalog number of the control device, as indicated in the following table:

Item	Suffix Added to Automatic Control Device Catalog Number
Plug-in alarm module set, consisting of one alarm level module and one alarm control module. Provides an alarm signal upon loss of a lesser number of capacitor units than that corresponding to the lock-out-level setting.	-H
Mounting bezel for flush mounting of Type GP Automatic Control Device.	-L
Mounting bezel for flush mounting of Type GP/VR Automatic Control Device.	-M
Card extender for Type GP Automatic Control Device. Permits positioning of any module for test. Required for field calibration.	-N
Card extender kit for Type GP/VR Automatic Control Device. Permits positioning of any module for test. Required for field calibration.	-P

Accessories

Item	Catalog Number
Detailed instruction manual for Type GP Automatic Control Device	RD-3358
Detailed instruction manual for Type GP/VR Automatic Control Device	RD-3359