Distant Control of Size 5 AC Contactors and Starters
Classes 8502 and 8536 Type SG, Class 8903 Type SX (Electrically Held)
Series B—Open Devices, Series C—Enclosed Devices

GENERAL THEORY

Mounting a contactor or starter a considerable distance from its control
device introduces problems not present when the distance is relatively short.
These problems are primarily due to the series impedance and shunt
capacitance of the control wires and their effect on contactor or starter
operation. Inherent characteristics of AC operated magnets make these two
problems important at different times, so they are treated separately here.

SERIES IMPEDANCE

Any coil current drawn through the series impedance of the control wires
causes a drop in the voltage available to the contactor or starter coil. The
largest drop occurs during inrush or pick up conditions, when coil current is
at its maximum. If the series impedance and the associated voltage drop are
large enough, the device may not pick up and seal properly.

NEMA standards require AC operated magnetic devices to perform
satisfactorily at 85% of the rated coil voltage. Allowing for a line voltage
fluctuation of 10% below the rated voltage, the voltage drop caused by the
series impedance effect of the control wires should not exceed 5%, to ensure
satisfactory operation of the circuit. The values shown in Table 3 on page 4
represent the maximum distance between the device and its control station
based on a maximum difference of 5% between the coil and source voltage
during inrush conditions. Values are for 60 Hz voltage sources only.

In addition to series impedance, the control circuit wires also exhibit a
distributed capacitance. The effect of this shunt capacitance is particularly
important when the contactor or starter circuit is opened and the device is to
drop out. If the control circuit components are arranged so that the control
wire shunt capacitance is in parallel with the stop button, limit switch, or other
disconnect means controlling the contactor or starter, a large enough amount
of capacitance can prevent the device from dropping out even though the
control circuit was opened. This is a very serious condition and must be
prevented. When determining whether the effects of the shunt capacitance
of the control wires are a consideration, refer to Figures 1 and 2.

If the control device is remote, and the control circuit components are
arranged so that the power source is adjacent to the device coil (see
Figure 1), the distributed wire capacitance is in parallel with the control device
(stop button) and must be considered. Under these conditions, you may
need to limit the length of the control wires so that the distributed capacitance
between the control wires does not exceed the maximum permissible value
for the control circuit to operate properly.

If the power source is adjacent to the control device (stop button), as shown
in Figure 2, opening the control device contact de-energizes the distributed
capacitance as well as the contactor or starter coil. The distributed wire
capacitance is not a consideration in determining the length of the control
wire run in this circumstance, since the capacitance does not prevent the
stop button from functioning. In such cases, the series impedance effect of
the control wires is the only limiting factor.

APPLICATION

In practical applications, system acceptability should not be determined
through trial and error. Even though the circuit may initially work properly,
changing conditions due to wear, aging, deteriorating insulation, humidity, or
other factors can cause the contactor or starter coil being controlled to fail to
pick up or drop out at some critical moment. For this reason, it is important to calculate the maximum allowable control distance that permits continued, reliable operation. When evaluating long runs of control wire, it may be difficult to determine the exact location of the wires, the thickness of the insulation, or other characteristics that can affect the shunt capacitance of the control wires throughout the entire run. This uncertainty requires that any calculation of the maximum length of a wire run be simplified.

Figure 3 shows a normal three-wire control scheme with the conduit and the source, hold, and coil wires shown in cross section. Both the conduit and L2 are properly grounded. To maintain the proper operation of the circuit, always assume the worst case (see Figure 4). The worst case occurs when:

- The conduit is filled with impure, conductive water due to condensation, flooding, or other accident.
- The conduit and/or L2 are ungrounded.
- The source wire (L1 to the stop station) is shorted at a termination point, or shorted to the conduit, due to the failure of the wire insulation.

These conditions can be present in the circuit without causing the control circuit fuse to blow.

Assuming these worst-case conditions and a dielectric constant of 8 for the wire insulation, it is possible to calculate the distributed capacitance per unit of length. Comparing this value to the maximum permissible capacitance determines the maximum control distance, as shown in Tables 2–3. The distance values given in the tables do not apply when using wire insulation with a higher dielectric constant or cable with a greater capacitance per unit of length. Consult your local Square D field office for assistance.

Based on the control circuit voltage and wire size, determine the maximum control distances due to series impedance and shunt capacitance (for two- or three-wire control) from Tables 1–3 as needed.

1. All installations are subject to the series impedance distance limitations of Table 3. See Figures 1 and 2 to determine whether the installation is also subject to the shunt capacitance distance limitations of Table 1 or 2. If the distributed wire capacitance is not in parallel with the stop button, shunt capacitance is not a consideration.

2. When the shunt capacitance distance is greater than the series impedance distance, the series impedance distance is the limiting value. In this case, the shunt capacitance value does not appear in the table.

3. When shunt capacitance is a consideration as described in Step 1, and the shunt capacitance distance is less than the series impedance distance, the shunt capacitance distance is the limiting value.

Using one of the techniques shown in Figures 5–9 can often reduce the problems of series impedance and shunt capacitance caused by long runs of control wires, increasing the control distance of a contactor or starter.

Interposing AC Control Relay—Since the burden of a control relay coil is generally less than the burden of a contactor or starter coil, the contactor or starter’s control distance can often be increased by using an interposing control relay (if shunt capacitance does not become the limiting factor). The control relay, used to pick up the contactor or starter at line voltage, can be powered from line voltage or a control transformer (see Figures 5 and 6). For relay control distances, refer to Distant Control of Relays, Contactors, and Starters, data bulletin M-379. This bulletin is available from D-FAX (#1188) or www.squared.com. For more information, contact your Square D field office.
Interposing DC Control Relay—If shunt capacitance becomes the limiting factor, you can use an interposing DC control relay instead of an AC relay. If the voltage across the control wires is DC, the shunt capacitance cannot conduct and does not cause a problem (see Figure 7). Series impedance then becomes the limiting factor.

Interposing DC Control Relay and Solid State Amplifier—Using an interposing DC relay controlled by a solid state amplifier eliminates the problem of shunt capacitance, as well as greatly reducing the control circuit burden and therefore the effect of series impedance.

Mechanically Held Contactor or Relay—Provided that it has coil-clearing contacts, a mechanically held contactor or relay can be used instead of an interposing relay when the distance limiting problem is due to the shunt capacitance effect. (Ensure that the relay or contactor selected will work properly with coil clearing contacts.) Since the coil-clearing contacts are always located adjacent to the contactor coil, they are not shunted by the control wires’ capacitance (see Figure 8). Series impedance becomes the limiting factor. Contact your Square D field office for help in selecting the proper mechanically held device for your application (since the control distance depends upon the impedance of the latch and unlatch coils).

Discharging Shunt Capacitance—Figure 9 shows a circuit arrangement with an extra set of normally open contacts attached to the stop button. When the stop button is pressed, any current carried by the shunt capacitance is shorted to ground and bypasses the coil. When the stop button is released, the shunt capacitance again feeds the current to the starter coil, but it is very unlikely that the current value will be high enough for the coil to pick it up. IMPORTANT: Always ensure that pressing the stop button does not short L1 to ground due to arcing on the stop button contacts. For example, when using Class 9001 push buttons with a Type KA1 contact block, the arc may transfer. Instead, use a KA3 contact block for the stop button and a separate KA2 contact block to short the shunt capacitance to ground.

Resistance Sensitive Relays—The input sensitivity of resistance sensitive relays enables them to operate from substantially lower currents than standard electromechanical relays. They are often able to operate over greater distances than electromechanical relays. Contact your Square D field office for complete application details.

NOTE: Use two isolated contact blocks for this function.
**Maximum Control Distance**

Tables 1–3 show the maximum control distance in feet between the device and its control station. Calculations are based on two or three lengths of wire. Values represent the actual distance between the device and control station. Shunt capacitance distances are based on 110% of full source voltage and series impedance distances on a maximum difference of 5% between the coil and source voltage during inrush conditions. Values are for 60 Hz only.

### Table 1: Maximum control distance in feet due to Shunt Capacitance (3-wire control in water-filled conduit)

<table>
<thead>
<tr>
<th>Class</th>
<th>Type</th>
<th>Series</th>
<th>Poles</th>
<th>Coil Voltage @ 60 Hz</th>
<th>Copper Wire Gauge (AWG)</th>
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<td></td>
<td>Open</td>
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<td>#14</td>
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<tr>
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<td>B</td>
<td>C</td>
<td>All</td>
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</table>

* Distance for series impedance is shorter and is the limiting factor. See Table 3.

### Table 2: Maximum control distance in feet due to Shunt Capacitance (2-wire control in water-filled conduit)

<table>
<thead>
<tr>
<th>Class</th>
<th>Type</th>
<th>Series</th>
<th>Poles</th>
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<th>Copper Wire Gauge (AWG)</th>
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* Distance for series impedance is shorter and is the limiting factor. See Table 3.

### Table 3: Maximum control distance in feet due to Series Impedance

<table>
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<tr>
<th>Class</th>
<th>Type</th>
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<th>Coil Voltage @ 60 Hz</th>
<th>Copper Wire Gauge (AWG)</th>
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