

Relay Settings for a Motor with Power Factor Correction Capacitor

Application and Setting Guide



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1. Scope

The present document discusses the effect of power factor (pf) correction of 3-phase asynchronous motors on the settings of motor protection relays. The calculation of the corrected rated current of the motor, and the corrected start-up current of the motor are described by means of an example.

This document only deals with the correction made by installing a capacitor in parallel with the motor. Other types of power factor correction are not discussed.

The rules given in this document are applicable for all motor protection relays, like SPAM 150 C, REM 610, REX 521, REM 541/543/545, REF 541/543/545 and REF542plus.

KEYWORDS: motor protection, power factor correction, compensation.

2. Introduction

Power factor (pf, $\cos\phi$) is the ratio of the actual power ("real power") to the apparent power. The value of the power factor is always less than or equal to 1. Light bulbs and resistance heaters, for example, draw pure resistive current (i.e. $\text{pf} = 1$) from the network, but most other loads tend to draw current with a time lag (i.e. phase shift).

As well know, the power factor of an asynchronous 3-phase motor is inductive and typically within the range 0.8 ... 0.9. A low power factor means waste of electrical energy. Further it reduces the distribution capacity of the power system by increasing the current flow and causing voltage drops.

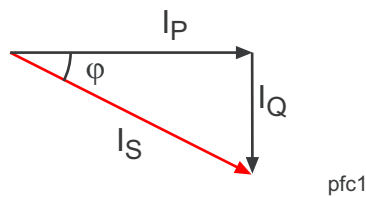


Fig. 2.-1 Uncorrected motor current. I_S , I_P and I_Q are the apparent, actual and inductive current, respectively.

For correcting the inductive current (I_Q) of the motor, a capacitor producing capacitive current (I_{QC}) is used.

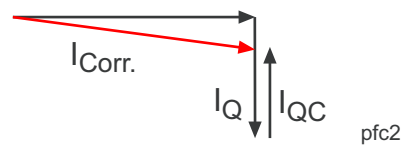


Fig. 2.-2 Corrected motor current ($I_{\text{Corr.}}$).

This document only deals with the correction made by installing a capacitor in parallel with the motor, as shown in Fig. 2.-3. The current measured by the motor protection relay is the corrected motor current and thus the relay settings must be adjusted to take account of the degree of correction.

Irrespective of whether the correction capacitor is connected before the relay measuring point, or a centralized correction capacitor (connected directly to the busbar) is used, the relay will measure pure motor current. In these cases the correction does not affect the relay settings.

Relay Settings for a Motor with Power Factor Correction Capacitor

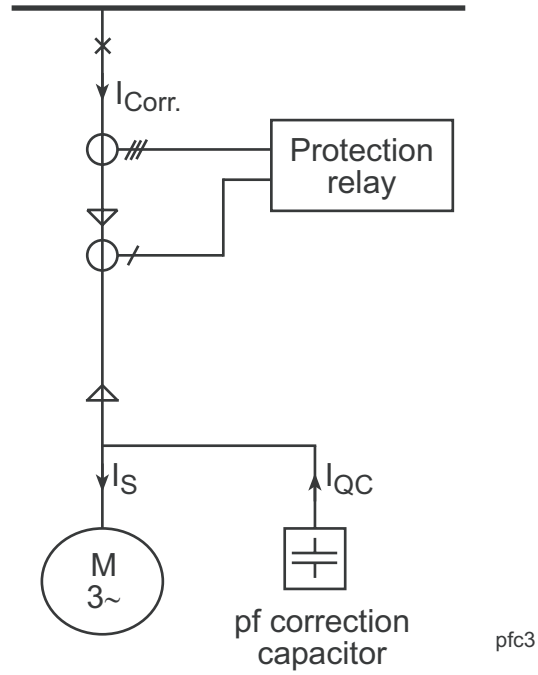


Fig. 2.-3 Power factor correction capacitor in parallel with a motor.

3. Technical implementations

3.1. Corrected motor rated current

The capacitive current (I_{QC}) of the capacitor compensates for the inductive current of the motor (I_Q). As a result, the corrected motor current is smaller than the rated current of the motor. The motor protection settings must be based on the corrected motor current, otherwise the motor will be under-protected.

When the reactive power of the capacitor, network voltage, motor rated current and power factor ($\cos\phi$) are known the corrected current can be calculated.

$$I_{QC} = \frac{Q_c}{\sqrt{3} \times U} \quad (1)$$

$$I_P = I_S \times \cos\phi \quad (2)$$

$$I_Q = I_S \times \sin(\arccos\phi) = \sqrt{I_S^2 - I_P^2} \quad (3)$$

$$I_{C\text{corr.}} = \sqrt{I_P^2 + (I_Q - I_C)^2} \quad (4)$$

Where:

$\cos\phi$ = motor power factor at rated load

I_{QC} = capacitive compensation current (current through the capacitor)

$I_{C\text{corr.}}$ = corrected motor current (current measured by the relay)

I_S = motor rated current

I_P = motor active (effective) current

I_Q = motor reactive current

Q_C = reactive power of the p.f. correction capacitor

U = network voltage

Example. $Q_C = 220 \text{ kW}$, $U = 6.6 \text{ kV}$, motor rated current $I_S = 68 \text{ A}$ and $\cos\phi = 0.85$.

$$I_{QC} = \frac{220 \text{ kW}}{\sqrt{3} \times 6.6 \text{ kV}} = 19.2 \text{ A}$$

$$I_P = 68 \text{ A} \times 0.85 = 57.8 \text{ A}$$

$$I_Q = \sqrt{(68 \text{ A})^2 - (57.8 \text{ A})^2} = 35.8 \text{ A}$$

$$I_{C\text{corr.}} = \sqrt{(57.8 \text{ A})^2 + (35.8 \text{ A} - 19.2 \text{ A})^2} = 60.1 \text{ A}$$

In the protection relay setting calculations, the value 60.1 A should be used as the motor rated current instead of 68 A.

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3.2.

Corrected motor start current

Should the power factor at start be known, the equations 2-4 can be used for calculating the corrected start current of the motor.

Example. $U = 6.6$ kV, $I_S = 68$ A and $\cos\varphi = 0.85$. Motor start current is $7.8 \times I_S = 530.4$ A and $\cos\varphi = 0.15$. From the previous calculations we know $I_{QC} = 19.2$ A and $I_{Corr.} = 60.1$ A.

$$I_{PStart} = 530.4A \times 0.15 = 79.6A$$

$$I_{QStart} = \sqrt{(530.4A)^2 - (79.6)^2} = 524.4A$$

$$I_{Corr.Start} = \sqrt{(79.6A)^2 + (524.4A - 19.2A)^2} = 511.4A$$

Often the power factor at start is not known. Then, the active current at start can be assumed to be the same as in the rated situation (i.e. $I_{PStart} \approx I_P$)

$$I_{QStart} = \sqrt{(530.4A)^2 - (57.8A)^2} = 527.2A$$

$$I_{Corr.Start} = \sqrt{(57.8A)^2 + (527.2A - 19.2A)^2} = 511.3A$$

As a result, the power factor correction reduces the start-up current, but in the relay setting calculation, the relay should be set according to the ratio of the starting current and the corrected rated current. I.e. the relay is set for a starting current = $511.4A / 60.1A = 8.51$ times the rated current, instead of 7.8 times.

The actual start current of the motor may be reduced because of the reduced phase voltage during the motor start, owing to a weak power system and/or long motor feeder cables. At the same time, the motor start time will increase. From the protection relay point of view, the relay can be set either on the basis of the calculations done with the full voltage, or on the basis of the actually measured start current and time.



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