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TECHNICAL NEWS

INDUSTRIAL SWITCHGEAR & AUTOMATION SPECIALISTS

Control voltages for contactors

Selecting the right control voltage is an important design criterion for contactor control circuits and the various issues are not always well understood. Directives to convert control circuits to Extra Low Voltage (ELV) (below 50 V) also expose some practical issues that need consideration. This discussion paper attempts to clarify the issues and offer suggestions for possible solutions.

Because of the increased coil current consumption at lower voltages and the resultant increased voltage drop in control circuit wires, reliable operation of contactors is often compromised. This is especially the case with larger contactors and where longer cable lengths are involved.

AS 60947.4.1 sets limits for reliable contactor operation. A contactor must pull-in reliably at 85 % of the nominal voltage which allows for a maximum volt drop of 15 % during the pick-up stage.

It is necessary to understand the nature of electro-magnetic contactor coil systems in order to fully appreciate the issues. From a practical design point, higher control voltages tend to be more reliable and have fewer operational issues than lower voltage control. On the other hand, lower voltages are considered safer.

FEATURING

- A C coil and magnet systems
- Control voltages
- Electronic contactors with built-in interfaces

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PLEASE CIRCULATE TO:

AC COIL AND MAGNET SYSTEMS

The standard contactor coil is mounted inside a magnet core and exhibits low impedance when the magnet is open. This gives the coil a high inrush current. As the magnet system closes under power from the coil, the impedance of the coil increases. This causes the coil current to reduce as the contactor closes.

The power consumption for pick-up and holding is normally expressed in VA and it is the same VA irrespective of the coil control voltage selected. It becomes obvious therefore that the lower the coil voltage, then the higher the current. The pick up phase is the most important time as the control voltage must be maintained to at least 85 % of nominal if the magnet is to close. Voltage drop in low voltage control circuits therefore becomes a major consideration as the higher inrush currents result in larger cable voltage drop. In some cases an increase of the control wires is required but this must be contained within practical limits.

Fig 1. *The graph demonstrates that for a 37 kW contactor, the inrush current is already over 8 A at 24 V yet only 0.8 A when a coil rated at 240 V is used. The VA is 200 for pick-up and 16 for holding.*

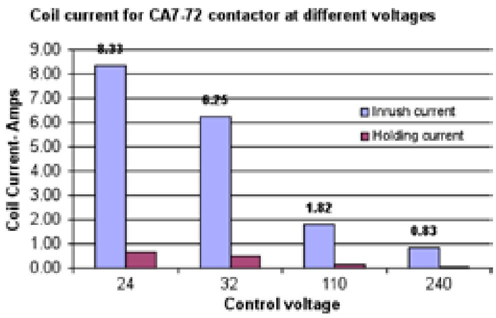
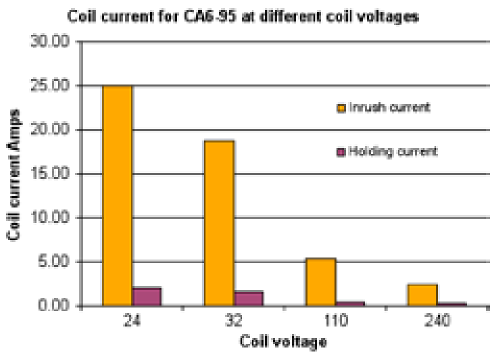


Fig 2. *Comparison graph for a 55 kW contactor shows that the inrush current is now 25 A at 24 V which is significant in terms of the control supply requirements. Again, the higher control voltages give more practical current levels.*



PICK UP VOLTAGES

In order that the coil has sufficient power to close the contactor, it will require the control voltage to be upheld and therefore voltage drop in the control circuit can be more an issue at lower voltages than higher voltages because the current is higher at lower voltages. In general, the specification of most contactors allows only a 15 % voltage drop in the coil circuit for reliable pick-up. Failure to maintain voltage can cause the contactor to 'chatter' or coil to overheat and fail due to low voltage.

Note: it is generally low coil voltages that cause coils to fail)

For 240 V then the minimum specified pick-up voltage is 204 V, while at 24 V the minimum is 20.4 V. That is a voltage drop of 3.6 V on 24 V coils and 36 V with 240 V coils.

Clearly, the lower the coil voltage, the greater the current consumption for both pick-up and holding. So what are the ramifications of low control voltage in a control circuit?

a) The cable size may need to be increased to ensure the voltage drop is minimised.

b) The cable route length may need to be minimised to reduce voltage drop.

c) Any control transformers need to be rated accordingly.

CABLE VOLTAGE DROP

Using the CA7-72 contactor as an example with a 100M cable run:-

2.5 mm² cable:
Voltage drop = 12 V per 100 M @ 8.33 A

4 mm² cable:
Voltage drop = 7.4 V per 100 M @ 8.33 A

Increasing to 6 mm² control cable will not minimise the pick up voltage drop less than the required 3.6 V for this example. It is clear therefore that only short cable runs when using 24 V are possible as control wires greater than 4 mm² would be expensive and unwieldy.

At the higher 240 V one could even use 1 mm² cable and still only drop about 3 V (when the allowable voltage drop is 36 V). So it can be seen there is an advantage in using higher controls voltages.

SO WHICH CONTROL VOLTAGE?

It can be surmised that the control voltage should be as high as reasonably possible. This ensures that control currents and control cable sizes are kept to a minimum. The propensity to have unacceptably high voltage drop in control wires is minimised so that 85 % of volts can be maintained in the pick-up phase much easier.

110 V has been used in industry for many years and has proven to be an ideal level for control voltages with contactors. The control supply is derived from a separate isolation transformer and not directly sourced from the three phase network. This reduces the impact of mains disturbance affecting the control circuit components.

240 V has been the most popular because it can be sourced from the 3 phase network provided the neutral is available and negates the need for a transformer or separate power supply. Both 110 V and 240 V control voltages keep coil currents to manageable levels so that voltage drop is rarely an issue.

415 V control is used in a few cases where neutrals are not available and for cost reasons additional transformers are not considered. Not a favourite of the writer because two phases of the three phase supply are used and extra care must be taken in design. Also, many control circuit devices (contacts etc.) do not have 415 V ratings. It is most popular in simple enclosed starters with integrated controls not going outside the enclosure.

24 V (AC or DC)

Being ELV, this is used wherever safe operation is required and where accidental contact with maintenance personnel is likely. Because most contactors are switching 415 V motors circuits, the fact that the control voltage is low is only really advantageous where control wires need to be routed to external control stations. Alternatively, for fault finding and testing purposes, the main three phase power can be isolated and the control circuit worked on with relative safety. DC is ideal in many circumstances and allows interfacing with solid state controls and PLCs.

Given that 24 V is a safe voltage, it seems a logical choice but care must be taken to ensure the issues of control circuit currents and voltage drop are adequately addressed.

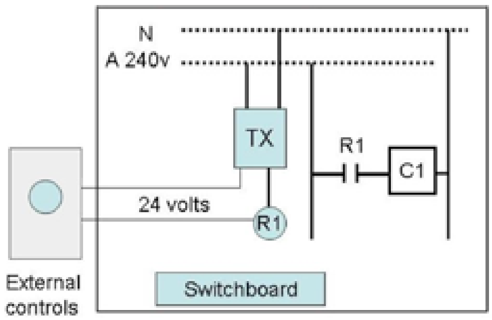
Using ELV control circuits with relay interfaces

One solution is to use ELV (e.g. 24 V) in the control circuit but use a higher voltage in for the actual contactor coil. The coil is then controlled via an interface or relay that is operated from 24 V (can be AC or DC).

The interface or small relay consumes a low VA and is therefore not affected by voltage drop. The interface relay ensures that all control wiring that is routed to remote control locations such as push button stations, are at 24 V but the contactor is not affected by any voltage drop.

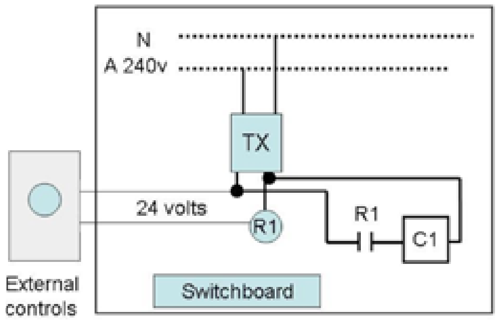
A contactor with a 240 V coil is ideal because 240 V is readily available from the standard three phase and neutral supply (415 / 240 V). The premise for this is that the coil and main power terminals are in close proximity in any case on the contactor (*please refer to fig 3*).

***Fig 3.** * 240 V contactor with 24 V interface relay*



Another option is to choose a contactor with 24 V coil but use a 24 V interface relay to switch it so that the high coil current is not routed over long cable runs to the external controls. The transformer or power supply must then be rated to handle the contactor inrush current (*please refer to fig 4*).

***Fig 4.** * 24 V contactor with 24 V interface relay*



Note: Some large contactors are not available with 24 V coils.

* The drawings are for demonstration only, circuit protection not included.

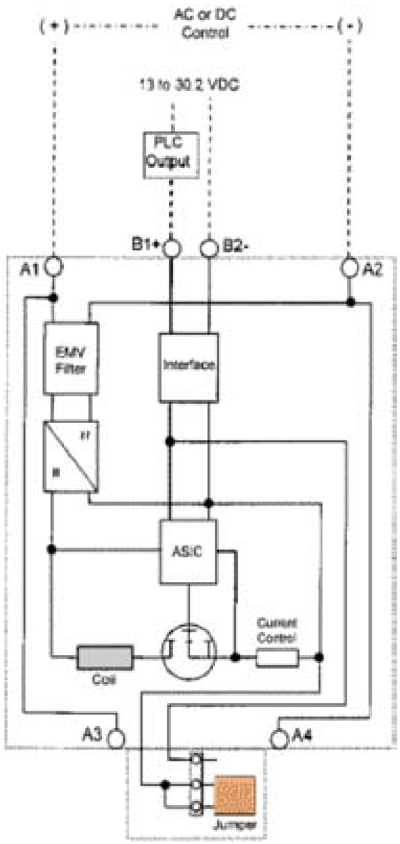
Fig 5. CA 6 contactor with built-in interface

ELECTRONIC CONTACTORS WITH BUILT-IN INTERFACES

Contactors such as the Sprecher + Schuh CA 6 range incorporate an electronic coil circuit that optimises the pick up currents and holding currents. The result is a reduction in coil VA even at lower control voltages. This in itself is an advantage and may assist to solve the problems associated with maintaining the voltage during pick-up. However, the inclusion of a built in 24 V DC interface provides an alternative solution similar to that described before.

The selectable built-in electronic interface allows control of the 240 V control circuit using an optic-coupled interface that operates at 24 V DC. In this case, the coil terminals are supplied with the normal control voltage permanently and the switching is performed via the interface at a few milliamps directly from 24 V DC control circuits or PLC outputs.

Fig 6. Control circuit of a CA 6 contactor



In addition to 240 V coil circuits, the CA 6 range can also be supplied with alternative coil voltages including, in some cases, 24 V DC. However, the control supply must be capable of delivering the inrush current of the main coil while the actual interface control is at a few milliamps.

Having defined pick-up and drop-out levels the coil magnet system is chatter proof which results in high contact security with less chance of unwanted contact wear and welding. The electronic control also reduces the heat contribution in the panel so there are a number of advantages.

Low current 24 V DC coil design reduces power consumption

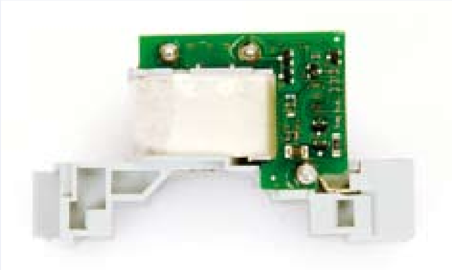
A new design of magnet systems in smaller DC operated contactors together with compact electronic circuits has allowed the construction of low current consumption DC contactors with a number of advantages. First, the holding power consumption has been reduced to only 1.5 Watts and although there is still an in-rush current, it is less than one third of its AC counterpart. Another advantage is that the coil circuit is 'chatter proof' as it will only attempt to pick up when there is sufficient voltage and will drop out when the voltage level gets too low.

This new CA 7-E contactor has the same physical dimensions of its AC counterpart, which is both a cost and space saving feature. It is available for contactor sizes up to 22 kW.

In practise the contactor will pick-up at 15 V and drop out at 7 V. Overall, this improves the reliability of the control circuit and negates any problems with low voltage chatter and the associated coil failure.

Comparison of Standard DC verses Electronic DC contactor

Standard DC coil



CA7E electronic coil system

CONTROL TRANSFORMER SELECTION

When selecting control transformers for contactor and control circuits, allowance must be made for the inrush current of the largest contactors. This ensures the transformer voltage does not sag during the pick-up stage.

A 'rule of thumb' is as follows: -

The VA rating of the transformer = the sum of pick-up VA of the largest simultaneously switched contactors plus the sum of the holding VA of all other contactors, plus any other loads.

Example:

A control circuit has 10 x 24 V AC contactors of which 1 and 2 can be switched at the same time. Contactors 3 - 10 are energised at random but all 10 may be energised at the same time. There are no other loads.

Contactor 1
Inrush power = 300 VA (Holding power is 20 VA)

Contactor 2
Inrush power = 200 VA (Holding power is 15 VA)

Contactors 3-10
Inrush power = 130 VA (Holding power is 10 VA)

VA of transformer = 300 + 200 + (8 x 10) = 580 VA

A 600 VA transformer would be adequate.

In closing, while this edition of technical news does not address all the issues of control voltage selection for contactors, it does demonstrate some important thought processes that must be considered in circuit design.

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