New electro-magnetic contactor with wide control voltage range

Electromagnetic contactors are simple switching devices for low-voltage and medium-voltage applications, including the remote control of electrical machines. Despite the advantage of their simple design, contactors can only be used within narrow control voltage and operating temperature ranges. To overcome this limitation, ABB Control has developed a new generation of electromagnetic contactors that makes use of application-specific integrated circuit (ASIC) technology. The new contactors are designed for a wide control range and can be used with both AC and DC. By reducing power consumption, they also allow a saving in costs. Their field-bus connection capability further supports the current trend in the automation sector towards distributed intelligence and system interoperability.

Contactors are simple, robust and very versatile control elements with a wide range of uses in the electricity distribution and automation sector. ABB Control manufactures three-pole and four-pole contactors with current ratings from a few amperes to 750 A. One application of such contactors is shown in **1**. The circuit is for a simple, direct on-line drive system consisting of low-voltage (< 1kV) power line, switch-fuse, contactor, overload relay and motor. The switch-fuse, which acts as an interrupter, not only ensures safety but also gives visual assurance of the circuit's interruption. In addition, it provides overload and short-circuit protection whenever the current exceeds a certain value for a given period of time. The contactor makes or breaks the motor current by means of remote control. The overload relay monitors the motor current, activating the contactor if there is a risk of the motor overheating.

2 shows the basic parts of an electromagnetic contactor. When voltage is applied to the coil terminals, a current flows through the coil to create a magnetic field which exerts a force on the moving magnet. If the current is sufficiently high, the force will compress the spring and pull the contacts together.

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Limitations of conventional contactors

Restricted control voltage range

A problem with conventional contactor types is their limited control voltage range, which is necessary to ensure reliable operation. On the one hand the voltage has to be high enough to guarantee that the contacts close properly. On the other, a voltage which is too high will cause the closing contacts to bounce and generate extra heat, thereby damaging the coil winding insulation. In either case, contactor lifetime is reduced.

According to the international standards, a contactor must close within 85 to 110 % of the rated control voltage. However, problems could arise, for example, when an installation uses a common power supply network for the control circuits and motors. When the coil is energized and the contacts close, the motor inrush current will cause a voltage drop on the power line if either the power transformer or the cables are undersized. A contactor supplied with power by the same network could experience a voltage drop sufficiently large to momentarily reopen the contacts.

Such a situation is hazardous and could result in unpredictable behaviour or even serious damage to the equipment. Another possibility is contact welding. This can occur when the contacts reclose before the breaking sequence has finished and the arc still has enough energy to weld the contacts together. In such cases, the contacts stay closed and no longer respond to remote control.

Restricted operating temperature range

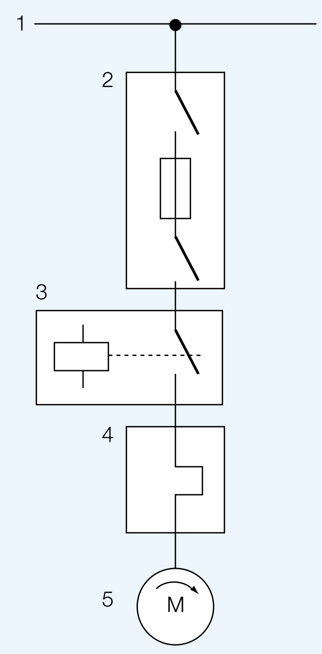
Another problem with conventional contactors is that the operating temperature range is limited. This is because the resistance of the copper used in the coil windings of machines increases with temperature, causing the coil current to decrease, and with it the magnetic force that pulls the contacts together.

AC versus DC coil supply

A coil supplied with AC current loses its magnetic force at each zero crossing. The problem is solved by adding a fixed winding to the magnetic core to ensure that the magnetic field remains the same even if the current temporarily drops to zero. Nevertheless, an AC coil supply still has one distinct advantage: as the magnet air gap becomes smaller the coil inductance increases significantly, automatically reducing current consumption and power dissipation.

Single-line diagram of a simple drive system **1**

1 *Low-voltage system*
2 *Fuse-switch*
3 *Contactor*
4 *Overload relay*
5 *Motor*



When the supply is DC, the current is defined by the resistance alone, being independent of the coil inductance. Special DC magnets are used for small contactors, while for large contactors the high pull-in current is reduced either by connecting a resistor in series or by switching to a second coil winding when the contacts close.

Thus, the advantage of the AC supply is the automatic reduction in power dissipation that occurs during the contact-holding phase, while DC has the advantage of a constant magnetic force and silent operation. The two types of supply require magnetic systems which, besides being different, are not interchangeable.

Overcoming the restrictions of conventional contactors

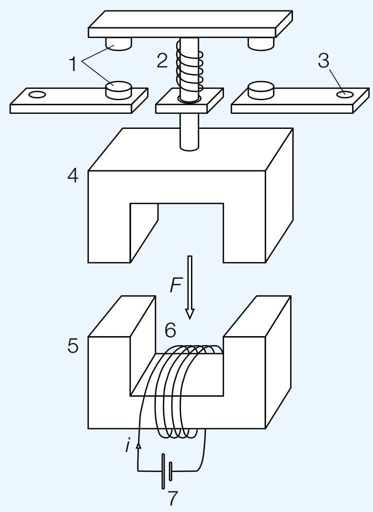
Coil interface for controlling the current

The problem of limited control voltage and temperature ranges can be solved by feeding the coil with regulated DC current. To this end, ABB Control has developed a coil interface in the form of an electronic unit that supplies the coil with an optimum current as long as sufficient power is available **3**. A PWM[1] regulation circuit controls an FET[2] switch that feeds the coil with current from a rectifier. A key benefit of the rectification is that the contactor can be operated with both an AC and a DC supply.

Controlled pull-in

To control the movement of the magnet during pull-in and at the same time minimize power consumption, the contactor

[1] PWM = Pulse width modulation
[2] FET = Field effect transistor



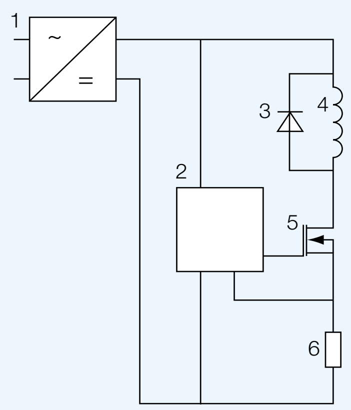
Main parts of an electromagnetic contactor **2**

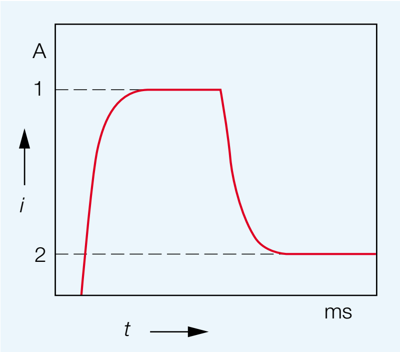
1 *Contacts*
2 *Spring*
3 *Connection terminal*
4 *Moving magnetic core*
5 *Fixed magnetic core*
6 *Coil*
7 *Remote control voltage*

F *Force acting on the moving magnet*
i *Coil current*

Interface for the supply of regulated DC to the contactor coil **3**

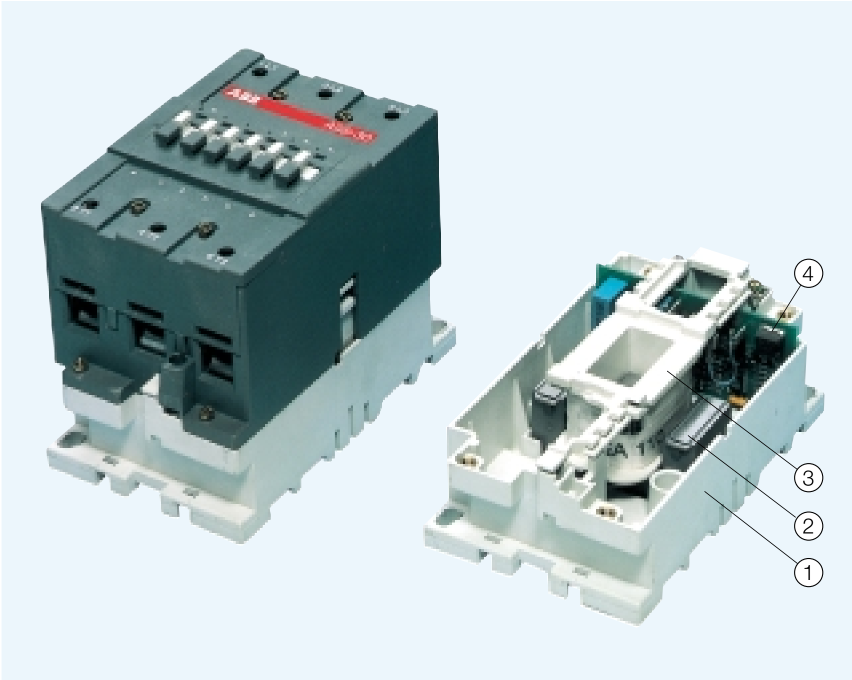
1 *Rectifier*
2 *ASIC*
3 *Freewheeling diode*
4 *Magnet coil*
5 *FET switch*
6 *Coil current sensing resistor*





Current characteristic of the new electromagnetic contactor during the closing operation **4**

i *Current* 1 *Closing current*
t *Time* 2 *Holding current*



The new contactor, on the right with the casing removed **5**

1 *Base* 3 *Magnet coil*
2 *Magnet* 4 *PC board*

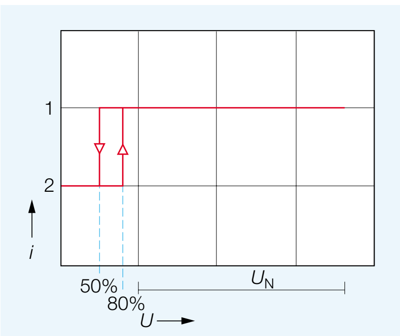
operates in two phases: pull-in and hold. When an AC supply is used, the pull-in action is delayed until the supply voltage has risen to a sufficiently high level.

During pull-in, the coil current is regulated to ensure that its value is high enough to guarantee proper closing of the contacts. When the contacts close, the current is reduced to a fraction of the pull-in current. This very low current is sufficient to hold the contacts together **4**.

Coil current regulation over the control voltage range **6**

i *Coil current*
U *Control voltage*
U_N *Nominal voltage range*
80 % *80 % of lower voltage value*
50 % *50 % of lower voltage value*

1 *Contactor closed*
2 *Contactor open*



Functions are controlled and monitored by an ASIC

To provide the required functionality with a small-size contactor that meets all of the power dissipation requirements at a competitive price, it was necessary to develop an application-specific integrated circuit, or ASIC. Together with several discrete components (resistors and capacitors), the ASIC controls the following functions:

- Control voltage monitoring
- Control of pull-in and holding
- Coil current regulation
- Magnet position monitoring

The ASIC, which was designed by ABB Corporate Research in Oslo, is based on CMOS technology. The ASIC chip has an area of 10 mm² and features both analogue functions (eg, reference voltages and comparators) and digital functions.

User-benefits of the new contactor

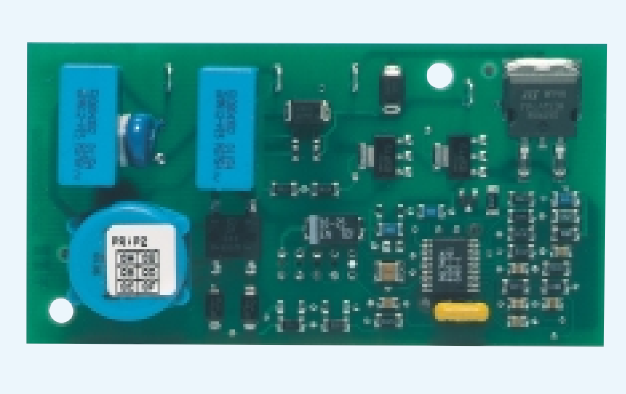
Wider control voltage range and improved voltage fluctuation tolerance

The operating voltage range of the new contactor **5** with coil interface is shown in **6**. It closes at 80 % of the nominal voltage and remains closed until the control voltage drops below 50 %. The maximum voltage that is allowed is typically 250 % of the nominal value.

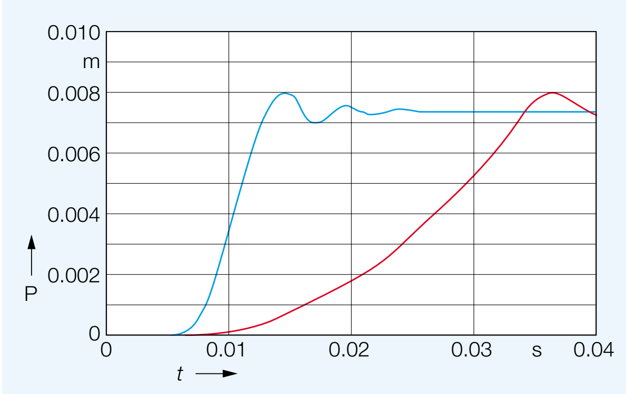
The coil interface power monitor **7** allows one half-period loss of power without contactor turn-off. Power line disturbances are therefore filtered out by this function. The lower limit, at 50 % of the nominal voltage, permits large voltage drops caused by motor inrush currents. The coil interface ensures that the contactor stays closed.

Power saving

A conventional contactor with a current rating of 100 A consumes about 8 W of power in AC operation. Thanks to the coil interface, power consumption with



PC board with electronic components for controlling and monitoring the contactor 7



Magnet position for the closing sequence with a conventional contactor and the new contactor 8

Blue *Conventional contactor* P *Position*
Red *New contactor* t *Time*

the new contactor generation is reduced to 3 W. The power reduction with the larger contactors is even better. This translates into a considerable saving in energy costs. Another important benefit of the reduced power dissipation is that less heat is generated inside the switchgear cabinets.

Longer lifetime

Controlled closing of the contacts significantly reduces contact bouncing, allowing a larger number of operations for the contactor.

A lifetime test with repeated on/off operations has shown very promising results. At a point where normal contactors start to show signs of damage, the new contactors still looked unused. 8 compares the magnet positions for a conventional contactor with that of a new one during the closing sequence. The motion of the new contactor is significantly slower, and at the point where the contacts strike the speed is only half that with the conventional contactor.

Reduced transients

When the power supply to a coil is cut off, the changing current causes voltage transients of several kV to be induced at the coil terminals. The contactor withstands these transients, but they may still disturb or damage other electrical components. To overcome this problem, especially when contactors are installed in sensitive environments, it is necessary to add surge arresters or some other kind of overvoltage protection.

The new contactor uses a freewheeling diode for the PWM regulation of the coil current. This diode conducts the coil current whenever the FET switch is in the off state. When the contactor is turned off, the diode short circuits the coil, with the result that all the energy stored in the electromagnetic field is dissipated in the coil winding. Thus, there is no need for any extra external protection.

Reduced noise level

The new contactor with regulated DC supply is considerably quieter than conventional contactors with coils powered by AC. In the latter case, a characteristic hum is emitted due to the AC supply harmonics.

Simplified system solutions for field-bus connections

Market analyses point to a considerable growth potential for field-bus systems in the automation sector. In such systems, electrical components are connected to the bus to form a network with distributed intelligence. This presumes control inputs and diagnostic outputs at the numerous component locations. The coil interface has been prepared for interoperability in this area by fitting it with inputs for on/off control and outputs that provide information about the coil control voltage condition and contact position.

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