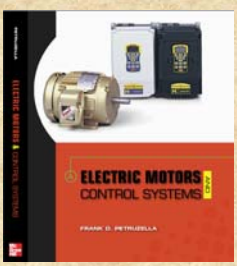


Chapter 6

Electric Motors

PART 2 Contactor Ratings, Enclosures, and Solid-State Types

NEMA RATINGS

National Electric Manufacturers Association (NEMA) and the International Electrotechnical Commission (IEC) maintain guidelines for contactors.

NEMA Contactor

The NEMA standard for contactors differs from that of the IEC and it is important to understand these differences.

IEC Contactor

A philosophy of the NEMA Standards is to provide electrical interchangeability among manufacturers for a given NEMA size.

60 Hz AC Contactor Standard NEMA Ratings

NEMA Size	Continuous Amps	Maximum HP				
		3ϕ			1ϕ	
		200 V	230 V	230/460 V	115 V	230 V
00	9	1½	1½	2	⅓	1
0	18	3	3	5	1	2
1	27	7½	7½	10	2	3
2	45	10	15	25	3	7½
3	90	25	30	50	—	—
4	135	40	50	100	—	—
5	270	75	100	200	—	—
6	540	150	200	400	—	—
7	810	—	300	600	—	—
8	1215	—	450	900	—	—
9	2250	—	800	1600	—	—

NEMA Size 1

NEMA Size 6

The continuous current rating and horsepower at the rated voltages categorize NEMA size ratings.

DC contactor NEMA ratings 600 volts max	
NEMA size	Continuous amps
1	25
2	50
3	100
4	150
5	300
6	600
7	900
8	1350
9	2500

- Because copper contacts are used on some contactors, the current rating for each size is an **8-hr open rating** -- the contactor must be operated at least once every 8 hr to prevent copper oxide from forming on the tips and causing excessive contact heating.
- For contactors with silver to silver-alloy contacts, the 8-hr rating is equivalent to a **continuous** rating.
- The NEMA current rating is for each main contact individually and not the contactor as a whole.

60 Hz AC contactor NEMA ratings 600 volts max	
NEMA size	Continuous amps
00	9
0	18
1	27
2	45
3	90
4	135
5	270
6	540
7	810
8	1215
9	2250

- A Size 00, 3-pole AC contactor rated at 9 A can be used for switching three separate 9 ampere loads simultaneously.
- Additional ratings for total horsepower are also listed.
- When selecting always ensure that the contactor ratings exceed that of the load to be controlled.

NEMA size 0

NEMA size 2

- NEMA contactor sizes are normally available in a variety of coil voltages.

60 Hz AC contactor NEMA ratings 600 volts max	
NEMA size	Continuous amps
00	9
0	18
1	27
2	45
3	90
4	135
5	270
6	540
7	810
8	1215
9	2250

EXAMPLE 6-1

Problem: Use the table to determine the NEMA size of an AC contactor required for a 480-V heating element load with a continuous current rating of 80 A.

Solution: According to the table, a size 2 contactor is rated for 45 A, while a size 3 is rated for 90 A. Since the load falls between these two values, the larger-size contactor must be used. The voltage requirement is satisfied because the controller can be used for all voltages up to 600 V.

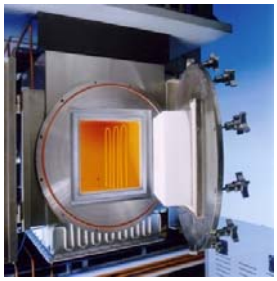
Magnetic contactors are also rated for the type of load to be utilized or actual applications.

HOT

Nonlinear loads such as tungsten lamps for lighting (large hot-to-cold resistance ratio- typically 10:1 or higher; current and voltage in phase).

COLD

Resistive loads such as heating elements for furnaces and ovens (constant resistance; current and voltage in phase).

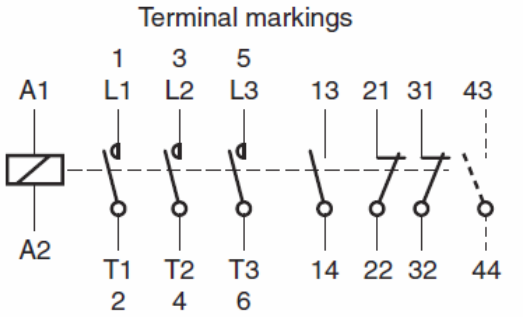


Inductive loads such as industrial motors and transformers (low initial resistance until the transformer becomes magnetized or the motor reaches full speed; current lags behind voltage).

Capacitive loads such as industrial capacitor for power-factor correction (low initial resistance unit capacitor charges; current lead voltage).

IEC RATINGS

IEC contactors, as compared to NEMA devices, generally are physically down sized to provide higher ratings in a smaller package.



On average, IEC devices are 30 to 70 percent smaller than their NEMA counterparts.

IEC contactors are not defined by standard sizes, instead, the rating indicates that a manufacturer or laboratory has evaluated the contactor to meet the requirements of a number of defined *applications*.

Allen Bradley

Square D

Siemens

With knowledge of the application you can choose the appropriate contactor by defining the correct utilization category. This makes it possible to reduce contactor size, and therefore cost.

The IEC rating system is broken down into different *utilization categories* that define the value of the current that the contactor must make, maintain, and break.

AC Categories

AC-1: This applies to all AC loads where the power factor is at least 0.95. These are primarily noninductive or slightly inductive loads.

AC-3: This category applies to squirrel cage motors where the breaking of the power contacts would occur while the motor is running. On closing, the contactor experiences an inrush, which is 5 to 8 times the nominal motor current, and at this instant, the voltage at the terminals is approximately 20% of the line voltage.

AC-4: This applies to the starting and breaking of a squirrel cage motor during an inch or plug reverse. On energization, the contactor closes on an inrush current approximately 5 to 8 times the nominal current. On de-energization, the contactor breaks the same magnitude of nominal current at a voltage that can be equal to the supply voltage.

DC Categories

DC-1: This applies to all DC loads where the time constant (L/R) is less than or equal to one millisecond. These are primarily noninductive or slightly inductive loads.

DC-2: This applies to the breaking of shunt motors while they are running.
On closing, the contactor makes the inrush current around 2.5 times the nominal rated current.

DC-3: This applies to the starting and breaking of a shunt motor during inching or plugging. The time constant shall be less than or equal to 2 milliseconds. On energization, the contactor sees current similar to that in Category DC-2. On de-energization, the contactor will break around 2.5 times the starting current at a voltage that may be higher than the line voltage. This would occur when the speed of the motor is low because the back e.m.f. is low.

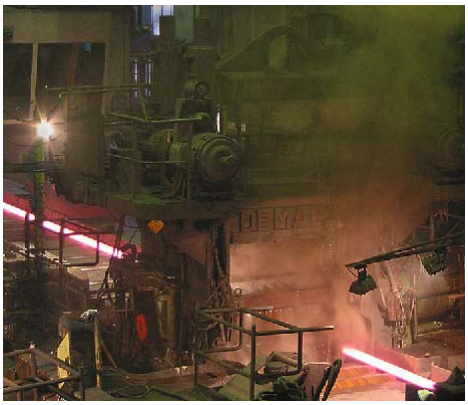
DC-5: This applies to the starting and breaking of a series motor during inching or plugging. The time constant being less than or equal to 7.5 milliseconds. On energization, the contactor sees about 2.5 times the nominal full load current. On de-energization, the contactor breaks the same amount of current at a voltage, which can be equal to the line voltage.

CONTACTOR ENCLOSURES

Enclosed magnetic contactors must be housed in an approved enclosure based on the environment in which they must operate to provide mechanical and electrical protection.

Severe environmental factors to be considered include:

- Exposure to damaging fumes.
- Operation in damp places.
- Exposure to excessive dust.
- Subject to vibration, shocks, and tilting.
- Subject to high ambient air temperature.



There are two general types of enclosures: *nonhazardous-location* and *hazardous-location* enclosures.

Nonhazardous--location enclosures are further subdivided into the following categories:

NEMA Type 1

General-purpose (least costly)

NEMA Type 4 & 4X

Watertight and Dusttight

NEMA Type 12

Provides a degree of protection from dripping liquids (non-corrosive), falling dirt and dust

NEMA Type 13

Oiltight

Hazardous-location enclosures are extremely costly, but they are necessary in some applications. Hazardous-location, explosion-proof enclosures involve forged or cast material and special seals with precision-fit tolerances. The explosion-proof enclosures are constructed so that an explosion inside will not escape the enclosure. Hazardous-location enclosures are classified into two categories:

- Gaseous vapors (acetylene, hydrogen, gasoline, etc.).
- Combustible dusts (metal dust, coal dust, grain dust, etc.).

NEMA Type 7 & 9

Indoor Hazardous Locations

The IEC provides a system for specifying the enclosures of electrical equipment on the basis of the degree of protection provided by the enclosure. For this reason, IEC enclosure classification designations *cannot be exactly equated* with NEMA.

NEMA Enclosure Type Number	IEC Enclosure Designation
1	IP10
2	IP11
3	IP54
3R	IP14
3S	IP54
4 and 4X	IP56
5	IP52
6 and 6P	IP67
12 and 12K	IP52
13	IP54

SOLID-STATE CONTACTOR

Solid-state switching **refers to interruption of power by nonmechanical electronic means.**

Single-Pole Contactor

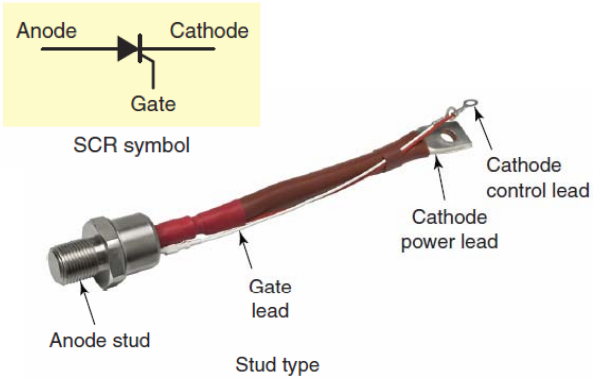
Three-Pole Contactor

A solid-state electronic contactor is absolutely silent, and its contacts never wear out. Static contactors are recommended in applications that require a high switching frequency.

Solid-state switch

The most common high-power switching semiconductor used in solid-state contactors is the Silicon Controlled Rectifier (SCR).

An SCR is a three terminal semiconductor device that acts like the power contact of a magnetic contactor.

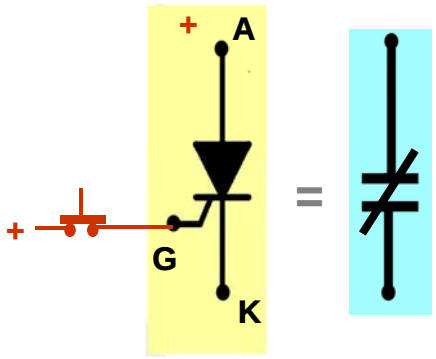


A gate signal, instead of an electromagnetic coil, is used to turn the device *on* allowing current to pass from cathode to anode.

The heat generated by the SCR must be dissipated, thus, all contactors have some means to cool the SCR's. Typically an aluminum heatsink, with fins to increase the surface area, is used to dissipate this energy to air.

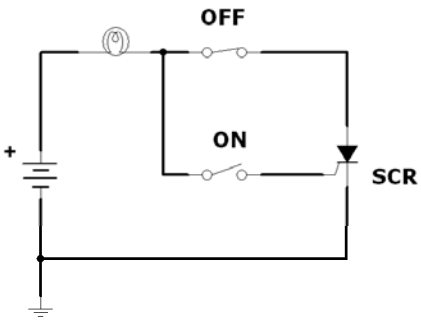
SCRs Installed Within An Electronic Module

- The SCR, like a contact, is in either the ON state (closed contact) or the OFF state (open contact).
- SCRs are normally-off switches that can be triggered on by a small current pulse into the gate electrode.

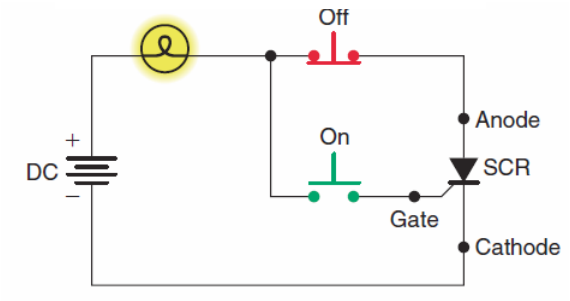


Puck type SCR

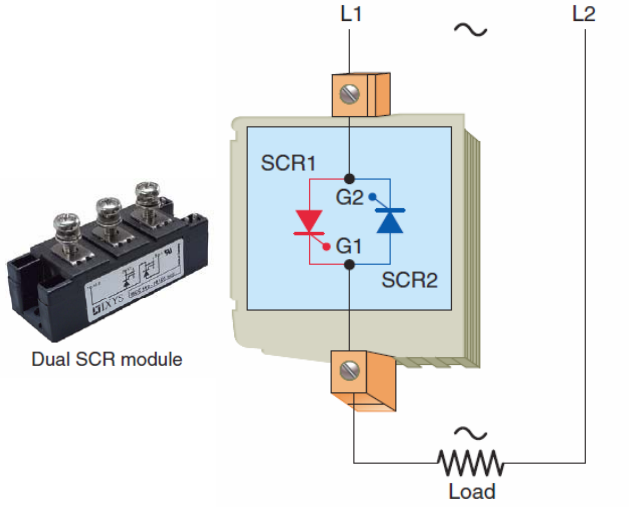
- Once turned ON the SCR stays ON even when the gate signal is removed.



SCR Operation And Test Circuit

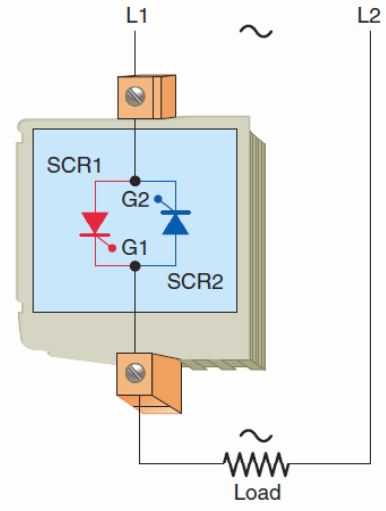


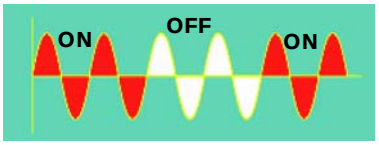
Since an SCR passes current in one direction only, two SCRs are necessary to switch single-phase AC power.



Dual SCR module

The two SCRs are connected in inverse-parallel: one to pass current during the positive half cycle and the other during the negative half cycle.

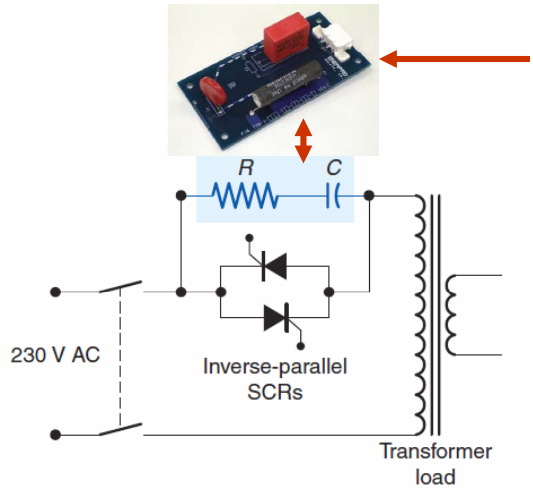




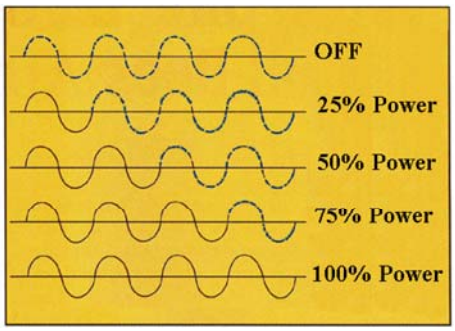
- **Being a rectifier, two SCR devices in inverse parallel are needed to control AC power to the load**

- **Half the current is carried by each SCR.**
- **AC current flows through the resistive load R when gates G1 and G2 are fired at 00 and 180°, of the input respectively.**

Inductive loads **are seen as problems areas in solid-state AC contactor control due to the fact that they could falsely turn-on an SCR.**



- For this reason, when driving an inductive load a ***snubber network*** is used to improve the switching behavior of the SCR.
- The resistor and capacitor wired in series with each other and placed in parallel the SCRs suppresses any rapid rise in voltage across the SCR.



- By electrically switching an SCR on at the AC sine wave **zero crossing point**, it remains on through the half cycle of the sine wave and turns off at the next zero crossing.
- Known as ***zero-fired control*** no current is switched under load.

Zero-Fired SCR Power Controller