Application Note

Fuses and Cable Sizing

MCD 3000

Protection of SCRs - Semiconductor fuses

■ Overview

SCRs or Thyristors are used extensively throughout industry. Over many years they have proven to be very reliable and robust. They contain no moving parts and so do not suffer from the wear and tear experienced by many electromechanical components used in industry. However, there are a number of conditions that will shorten the SCR life and ultimately lead to failure. There are also conditions that can cause catastrophic failure.

Failure of an SCR usually results in the SCR becoming a short circuit (conductive in both directions) but occasionally an SCR can fail in a way that prevents it from conducting in either direction.

■ What is an SCR?

An SCR (Silicon Controlled Rectifier) is a semiconductor based component which blocks current flow in both directions but can allow current to be conducted in one direction only. When an SCR is in blocking mode it behaves as an open circuit. When it is in conduction mode it behaves as a rectifier. The SCR is naturally in its blocking mode and needs to be “gated” ON to be forward conducting. The “turn ON” instruction is by means of a current pulse into the gate of the SCR. This gate pulse must be high enough to properly control the SCR. A low gate current will only turn on a portion of the SCR wafer and can result in localised damage to the device. Once the SCR is in conduction mode it will stay conducting until the current passing through it falls below the holding current of the SCR. In an AC environment it will turn OFF (commutate) at the end of each current cycle.

■ DesignConsiderations

The SCR dissipates heat while conducting current. This heat must be transferred away from the junction (Silicon) of the SCR to prevent it from overheating. A heatsink is employed to dissipate the heat generated by the SCR. This should be selected to minimise the temperature rise of the SCR junction. It is very important that the junction temperature does not exceed the maximum operating temperature of the device. This temperature T_j is typically 125 degrees C. If the junction temperature exceeds the maximum, degradation will occur resulting in a reduction in the useful life of the device. The power dissipated varies considerably from device to device depending on the size (rating) and manufacturer. Exchanging similar devices from different manufacturers can lead to major problems if the power dissipations do not match.

SCRs have a rated maximum RMS current and a rated maximum average current at a particular case temperature. The RMS current reflects the ability of the device to carry current and can be determined by the terminations as well as the silicon wafer. The average current reflects the junction temperature and power dissipation of the device.

There are two voltage ratings given to SCRs. The forward blocking voltage and the reverse blocking voltage. With phase controlled SCRs these are usually very similar. If a voltage in excess of these ratings is applied to the SCR failure can occur. Sometimes if an excessive forward voltage is applied the SCR will “overhead trigger” due to a zenering action between the anode and gate. This phenomenon will not damage the device provided the rate of rise of current (di/dt) is restricted. (This is the case with an induction motor load) An overvoltage breakdown is often around the outside of the SCR silicon wafer and can be easily recognised.

The SCR can suffer catastrophic failure by passing excessive current in a short time. The rating covering this is the I^2t rating and is based on a one half-cycle interval. This is the maximum energy let through of the device. A half cycle energy greater than this value will cause the device to fail.

SCRs can also be damaged by excessive rate of rise of voltage (dv/dt) across them. This can occur without exceeding the voltage rating of the device.

■ SCR Protection

Voltage related protection of an SCR is achieved by using shunt components across the SCR and optionally across the supply. For a three phase supply SCRs are selected for a voltage rating of 2.5 to 3 x the nominal supply voltage to give some immunity to transient voltages. RC Snubber circuits across the SCR help to minimise the rate of change of voltage (dv/dt) and will also help to reduce the magnitude of transient voltages. Metal Oxide Varistors (MOVs) can also be connected across the SCR and supply to provide over voltage protection but an exploded MOV is worse than a failed SCR.

Temperature sensors can provide overtemperature protection but to be fully effective the junction temperature of the SCR needs to be measured.

A semiconductor fuse can only provide short circuit protection.

Semiconductor Fuses

HRC semiconductor fuses are designed for the protection of semiconductor devices. They are not, as sometimes perceived, made of a semiconductor material. The semiconductor fuse contains a series of silver elements that are designed to limit the energy flow under fault conditions. These are sometimes referred to as energy limiting fuses.

Standard HRC fuses are generally constructed with copper elements and are designed to provide long term over current protection for cables. These are not energy limiting. The energy let through under fault conditions is a function of the fault current capacity of the supply.

Circuit breakers are designed to provide long term over current protection to cables and circuits. They can be fitted with magnetic trip devices to provide an instantaneous trip on severe overload. The fault current flows through the circuit breaker until it opens. Even if it opens in half a cycle (10ms) there is no control over the energy that flows through the SCR and there is no guaranteed protection.

Semiconductor Fuse Selection

Semiconductor fuses are rated for continuous current, pre-arc I^2t and total clearing I^2t for a range of supply voltages. As the voltage is increased, the I^2t also increases. SCRs have a maximum energy let through rating (I^2t) for 10 ms. The total clearing I^2t of the fuse at the applied line voltage must be less than the rated I^2t of the SCR.

It is also important to ensure that the load current curve is less than the rated current curve of the selected fuse. Sometimes it is necessary to parallel connect semiconductor fuses to achieve a current rating high enough for the load. In these cases parallel connected fuses must be identical. The I^2t of parallel connected fuses increases by the square of the number of fuses. For two parallel fuses the effective current rating is doubled and the I^2t is multiplied by 4. For three parallel fuses the effective current rating is trebled and the I^2t is multiplied by 9.

For soft starter applications allow a margin on the motor start current curve as seen by the fuses to ensure long term reliability. This is necessary due to the "shape factor" of the current waveform during start. We suggest a factor of at least 33% (multiply by 1.33) be applied to the expected motor start current.

Example.

Select semiconductor fuses for an MCD3030. Assume a 460VAC supply, a motor full load current of 60 amps, and a start current ratio of 350% for a 20 second duration.

The MCD3000 Operators Instruction Manual lists the I^2t of an MCD3030 SCR device as 15,000. Select a fuse with a total clearing I^2t less than this value from the table 1 below. Note that the selected fuses in the shaded area must be multiplied by the factor obtained from table 2.

Table1

Square Body – DIN 43 653

660V (IEC/U.L.) 10-400A

Electrical Characteristics						Ordering Information					Curves
Size	Rated Current RMS-Amps	I^2t (A^2 Sec) Pre-arc	I^2t (A^2 Sec) Clearing at 660V	Watts Loss	Protection Class	-U/80 Without Indicator	-/80 Visual Indicator	-T/80 Type T Indicator for Micro	Carton Qty.	Carton Weight (kg)	See Page or (BIF #)
000	10	3.8	25.5	3.0	gR	170M1308	170M1358	170M1408	10	1.34	page 60 (17056310)
	16	7.2	48	5.5	gR	170M1309	170M1359	170M1409			
	20	11.5	78	7	gR	170M1310	170M1360	170M1410			
	25	19	130	9	gR	170M1311	170M1361	170M1411			
	32	40	270	10	gR	170M1312	170M1362	170M1412			
	40	69	460	12	gR	170M1313	170M1363	170M1413			
	50	115	770	15	gR	170M1314	170M1364	170M1414			
	63	215	1450	16	gR	170M1315	170M1365	170M1415			
	80	380	2550	19	aR	170M1316	170M1366	170M1416			
	100	695	4650	24	aR	170M1317	170M1367	170M1417			
	125	1200	8500	28	aR	170M1318	170M1368	170M1418			
	160	2300	16000	32	aR	170M1319	170M1369	170M1419			
	200	4200	28000	37	aR	170M1320	170M1370	170M1420			
	250	7750	51500	42	aR	170M1321	170M1371	170M1421			
	315	12000	80500	52	aR	170M1322	170M1372	170M1422			

The total clearing I²t listed is for a voltage of 660VAC. Use table 2 below to find a multiplying factor for the total clearing I²t at 460VAC. In this case the multiplying factor is 0.70. After applying this factor you will see that all fuses in the shaded area of table 1 have a total clearing I²t rating less than the SCR (ie, 16000x0.70 = 11200 I²t). These fuses are therefore suitable for protection of the SCR from short circuit currents. You must also select a fuse that is capable of carrying the motor start current.

Table 2

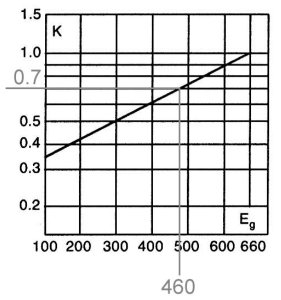
Square Body – DIN 43 653

660V (IEC/U.L.)

Electrical Characteristics

Total Clearing I²t

The total clearing I²t at rated voltage and at power factor of 15% are given in the electrical characteristics. For other voltages, the clearing I²t is found by multiplying by correction factor, K, given as a function of applied working voltage, E_g, (RMS).



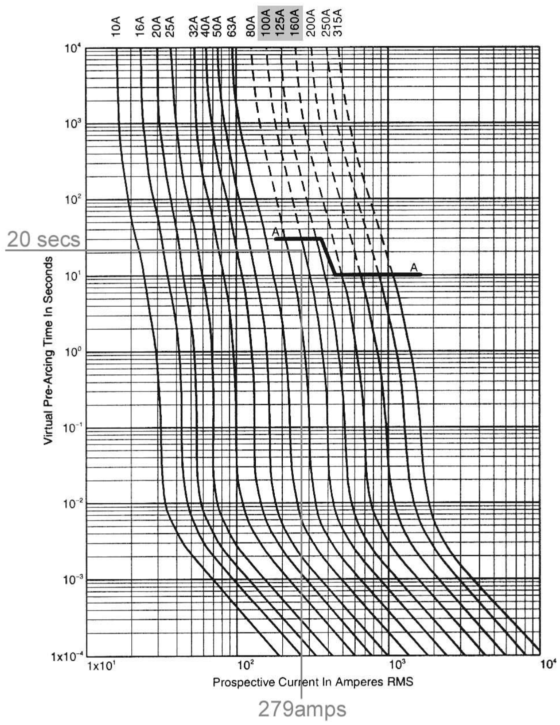
Now use the graph below to select a fuse based on the motor starting current. The starting current is 350% of 60 amps multiplied by a factor of 1.33. This equals 279 amps. The motor start duration is 20 seconds.

Square Body

Curves

Size 000: 660V (10-315)A

Time-Current Curve



From the intersection of the above lines you can see that anything above a 100amp rated fuse is capable of carrying the motor start current for 20 seconds. You could use a 100, 125 or 160amp semiconductor fuse (1per phase) for the MCD3030 on this application.

MCD 3000 Cable Sizes

Control Wiring Sizes

Input Voltage	AWG	mm²
All models	30-12	0.75-4

Power Wiring Sizes

Power cabling used for connection to MCD3000 soft starters must be terminated with cable lugs that can be attached to the MCD3000 input and output bus bar terminals.
This method of termination imposes no specific limitations on the minimum or maximum cable size suitable for connection to the MCD3000.

Minimum cable size for connection to any MCD3000 model is the minimum cable size appropriate for supply of the current required by the connected motor.
Maximum cable size for connection to any MCD3000 model is set by the following factors:

- availability of terminal lugs that will interface between the power cable and the MCD3000 bus bar terminals.
- physical space within the MCD3000 to place and gland the power cables.

Given the variability of the factors determining minimum and maximum cable sizes for any individual MCD3000 model the following list of cable sizes should be used as a guide only.

Input Voltage	AWG	mm²
MCD-3007	#14-#4/0	2.5-120
MCD-3015	#14-#4/0	2.5-120
MCD-3018	#14-#4/0	2.5-120
MCD-3022	#14-#4/0	2.5-120
MCD-3030	#14-#4/0	2.5-120
MCD-3037	#14-#4/0	2.5-120
MCD-3045	#14-#4/0	2.5-120
MCD-3055	#14-#4/0	2.5-120
MCD-3075	#8-250	10-150
MCD-3090	#8-250	10-150
MCD-3110	#8-250	10-150
MCD-3132	#8-300	10-185
MCD-3185	#6-600	16-400
MCD-3220	#6-600	16-400
MCD-3300	#6-600	16-400
MCD-3315	#6-600	16-400
MCD-3400	#6-600	16-400
MCD-3500	#6-600	16-400
MCD-3600	#4-800	25-630
MCD-3700	#4-800	25-630
MCD-3800	#4-800	25-630

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