SELECTING A SOLID STATE RELAY OR A SOLID STATE CONTACTOR FOR START/STOP CONTROL OF AN AC MOTOR

WHITE PAPER

Introduction

Solid State Relays (SSRs) and Solid State Contactors (SSCs) are ideally suited for controlling dynamic loads such as motors, particularly where frequent or multiple start/stop cycles are required in an application.

Proper selection of a Solid State Relay/Solid State Contactor to reliably start and stop a motor in each application requires an understanding of the demands placed on the Solid State Control by the motor and application.

Motor Control ratings in Horsepower (HP) or Kilowatt (KW) available on many Sensata | Crydom Solid State Relays and Contactors simplify the selection process, but Solid State Relays with only General Purpose Ratings can also be used to control motors.

This following discusses the process that can be followed to select the correct Solid State Relay for motor control in those situations where Horsepower (HP) or Kilowatt (KW) ratings of the Solid State Relay may not be known or available.

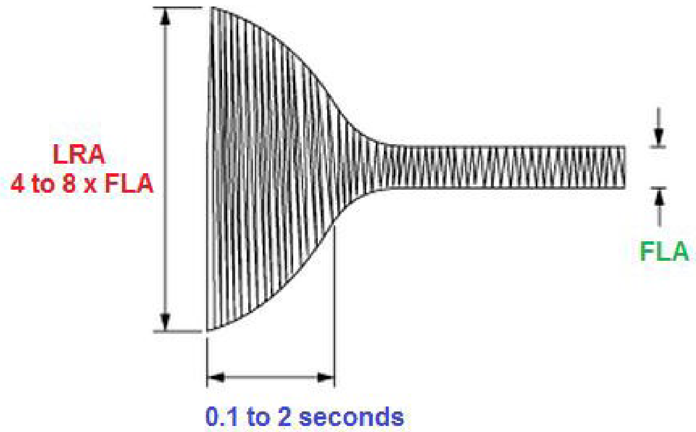
Note: Solid State Relays (SSRs) and Solid State Contactors (SSCs) are essentially if not exactly, the same functionally. The differentiation between them is that by definition a “contactor” must carry a motor control rating in HP or KW, whereas a similar Solid State Relay with a General Purpose rating may or may not carry a motor control rating as well. Aside from the evaluation (testing) process and the resulting approved ratings coordination, there is no difference between a Solid State Relay with and without a HP motor rating.

Full Load Current (FLA) and Locked Rotor Current (LRA)

In cases where no HP rating for the Solid State Relay is available, aside from correctly matching the operating and control voltages to the application, the next most important parameter to consider is the initial inrush current into the motor during the motor’s starting operation.

Motor actuation from a standing position will result in a high initial (or inrush) current drawn by the motor to overcome the combined inertial mass of the motor/load system. Larger inertial masses (motor/load) result in higher starting currents and longer duration.

Load current reaches its highest value immediately upon actuation as the motor starts from a stopped position and is limited only by the value of the motor’s winding resistance. This is a transitory condition that may last from several cycles to seconds depending on the nature of the mechanical load and application (spin up). This initial current is essentially equal to the current drawn by the motor if its rotor (shaft) was “locked” and could not rotate and therefore is generally known as Locked Rotor Current or LRA.



As the motor increases it rotational speed up to its operational rating, the current decreases to a value that corresponds to the horsepower being delivered to the load. The highest value current drawn in this state is the motor's Full Load Current or FLA.

The relationship between Full Load Current (FLA) and Locked Rotor Current (LRA) varies from motor to motor but generally falls within a known range. Once we know the steady-state current (or FLA) of a certain motor we have to consider that the starting inrush current (or LRA) can be 4 to 8 times the FLA value. Although the LRA may last for only a short period of time (from a few hundred milliseconds up to 2 seconds or more), the selected SSR needs to withstand these surge values "repetitively" based upon the start/stop frequency required in the application.

> **Note:** Solid State Relays and Solid State Contactors have no wear out mechanism, and as such, if properly selected based upon these criteria, will have a significantly longer life expectancy (>25 years in most cases) than similarly rated mechanical relays or contactors.

Fig. 1

Selecting SSRs/SSCs With a HP/KW Rating

Solid State Relays and Solid State Contactors that have been evaluated by a safety agency or regulatory body as "motor controllers" carry motor power ratings in Horsepower or HP, making the controller selection process for any given application simple because the HP rating is coordinated by UL or IEC standards with both LRA and FLA ratings.

Therefore, motor-rated Solid State Relays and Solid State Contactors are often preferred because the necessary coordination calculations have already been made and validated. These products are summarized in the Solid State Relays/Contactors for Motion Control flyer on the Sensata website.

One important advantage of specifying a motor control rated Solid State Relay or Solid State Contactor is that the agency approval process for the end application is greatly simplified, and further, the process associated with approval of the motor control (and associated costs) is complete.

Selecting SSRs/SSCs Without a HP/KW Rating

To use a standard Solid State Relay without HP or KW Motor rating to control the start/stop of a motor, engineers need to consider the motor nominal current value (FLA), inrush current value (LRA), and motor power factor (typically 0.1 to 0.9) to select the appropriate turn-on switching type (zero-crossing or random) and possible need for SSR transient protection to select an appropriate Solid State Relay.

To assist in the Solid State Relay selection process, Table 1 below provides a simple and reasonably accurate rule-of-thumb method to coordinate HP/KW rating, FLA current rating, phases and load voltage.

The load current values in the Table 1 are typical and based upon industry average worst case motor ratings with motor efficiency ratings ranging from 20% for small type motors to 60% for larger type motors. Note: The values of load current in the table are FLA run currents of the motor and do not include the start-up surge currents (LRA). However, as discussed earlier in the text, FLA and LRA are coordinated with the HP ratings per the standards.

Motor Power		Full Load Amperes (FLA)								
		Single Phase				Three-phase				
HP	KW	115V	230V	400V	440V	115V	230V	400V	440V	550V
1/6	0.12	4	2	-	-	-	-	-	-	-
1/4	0.18	5.2	2.5	-	-	-	-	-	-	-
1/3	0.25	6.5	3.2	2	1.8	-	-	-	-	-
1/2	0.37	8	4.2	2.7	2.4	4	1.9	1.1	1	0.8
3/4	0.55	11.8	5.5	3.5	3.2	5.5	2.8	1.6	1.5	1
1	0.75	14	7	4.3	3.9	7	3.5	2.1	1.9	1.4
1 1/2	1.1	19	9.2	5.5	5	10.5	5.1	2.8	2.6	2
2	1.5	24	12.5	6.8	6.2	14	6.6	3.7	3.4	2.6
3	2.2	35	17	10	9	19	9.5	5	4.6	4
4	3	47	23	13	12	25	12.7	6.8	6.2	5.5
5 1/2	4	61	30	17	15.5	33	16.5	8.9	8.1	7
7 1/2	5.5	80	40	23	21	44	22	12	11	9
10	7.5	-	48	29	26	56	28	15	14	11
15	11	-	64	36	33	-	41	22	20	17
20	15	-	-	46	42	-	-	28	26	21

Table 1 – Relationship of HP/KW to FLA, phases and load voltage

For additional assistance in the Solid State Relay selection process, Table 2 provides Typical SSR motor rating (FLA) versus General Use ratings.

The Locked rotor value given in the Table 2 is the true measure of the Solid State Relay surge capability since this is the parameter that is tested and must comply with UL requirements. (The general procedure for UL testing is that the SSR must survive a test current of 6 times the full rating for 1 second. The test is repeated 50 times at a duty cycle of 1 second on, 9 seconds off, with a 0.45 power factor load).

SSR	Motor Load Amperes	
General Use Rating Amperes	Full Load Amperes FLA (Run)	Locked Rotor Amperes LRA (Start)
5	1	6
10	2	18
15	3	30
20	4	36
25	6	42
30	7	54
40	9	72
50	12	90
75	17	120
90	20	138
100	25	156
125	30	180

Table 2 – General Use rating current vs FLA/LRA

Note: Table 2 is representative of all UL-approved Sensata | Crydom SSRs and SSCs. Competitive products may not have similar performance and as a result do not necessarily comply with this “General use vs FLA/LRA value” conversion shown in the table.

A final point to be considered when selecting the appropriate Solid State Relay is the turn-on switching type of the Solid State Relay/Solid State Contactor's output. For motor control a "random turn-on" version is generally preferred (excluding certain motor applications with numerically high power factors >0.85) due to the high inductive nature of the load itself.

Zero voltage/zero crossing/zero turn-on (all refer to the same function) type outputs, which offer major advantages when controlling resistive loads (with or without significant inrush current), may be a disadvantage in cases with very low numerical power factor loads (typically <0.4).

Example Motor Control Use Cases

Example #1

- **Application**: A Customer would like to use a Crydom Series1 panel mount SSR (which is not Motor control rated) to start/stop a single phase AC motor rated 3 HP @ 230 VAC.
- **Solution**: From Table 1 we find that the FLA for a single phase 3 HP motor @ 230 VAC is 17 Amp; from Table 2 we find the SSR General Purpose output rating that corresponds to a 17 Amp FLA rating is 75 Amp. Consequently, the conclusion is that the customer can use a Crydom D2475- 10 SSR (75 A, 230 VAC, Random turn-on) to control the subject motor.

Example #2

- **Application**: A Customer wants to know if they can use the Crydom PF Series PCB mount SSR (which is 25A General Purpose rated SSR with no Motor Control rating) to start/stop a three-phase AC motor rated 2.2 KW @ 400 VAC.
- **Solution**: From Table 1 we find that the FLA for a three phase 2.2 KW motor @ 400 VAC is 5 Amp; from Table 2 we find the SSR General Purpose output rating that corresponds to a 5 Amp FLA is 25 Amp. Consequently, the answer is yes, the customer can use the Crydom PF series SSR because it is 25A General Purpose rated.

In conclusion, selection of Solid State Relays or Solid State Contactors that carry Motor Control Ratings is straight forward when the motor load HP or KW ratings are known. However, any Crydom General Purpose rated Solid State Relay can also be applied using a reasonably simple process.