Using MCA and MOP Ratings to Safely Connect Your Field Wired Air Conditioner

By Ted Eckert

Abstract

The minimum circuit ampacity (MCA) and maximum overcurrent protection (MOP) ratings provide guidance for safely connecting field-wired equipment to the building mains in North America. Understanding these ratings, and their relationship to each other, is critical to properly selecting wire and circuit breaker sizes.

Introduction

Minimum circuit ampacity (MCA) and maximum overcurrent protection (MOP) are necessary to correctly connect field wired equipment in North America. As their names indicate, the ratings will tell you the minimum wire size and maximum circuit breaker size allowed for the equipment. The North American operating voltages are lower than for the rest of the world, resulting in higher operating currents. These higher currents, along with a history of wood construction, have led to a greater awareness of the risks of overcurrents and fires in North America. The system of MCA and MOP was developed to reduce that fire risk. This system is not commonly used outside of North America and is not typically used with 230/400 V, 50 Hz equipment.

The calculations for the MCA and MOP are based on requirements of NFPA 70, the National Electrical Code (NEC) and CSA C22.1, the Canadian Electrical Code (CEC). The MCA is the minimum wire size needed to guarantee that the wiring will not overheat under all operating conditions for the life of the product. The MOP is the maximum allowable circuit breaker size that will properly disconnect power to the equipment under any anticipated fault condition.

The calculations for these numbers were fairly simple for years. However, the formulas are based on traditional equipment designs using AC motors and resistance heaters. The formulas assume that the motors will have a significant current surge at start-up and that the motor will draw more current as it ages. The formulas have not been changed to take into account new designs using variable frequency drives (VFDs), electronically speed controlled motors and DC motors. Products using these new motor technologies may have MCA and MOP ratings that seem counterintuitive.

Minimum Circuit Ampacity

The minimum circuit ampacity (MCA) is the minimum wire size required for a field wired product. It is chosen to guarantee that the wiring will not overheat under the expected operating conditions. The wire size takes into account the normal current draw, ageing of components and anticipated faults.

MCA calculation

The calculation of the MCA depends on the loads in the air conditioner. There are different calculations for direct expansion and chilled water units. For the calculations, the full load ampere (FLA) and rated load ampere (RLA) ratings of components are used. These ratings are based on the maximum anticipated current after ageing under any expected operating condition. These ratings will often be much higher than the normal operating current, especially for compressors. Only loads rated at least 1.0 ampere are used in the MCA calculation.

The MCA is calculated by adding 125% of the rating of the largest motor (normally the compressor) plus the rating of all of the other loads in the equipment that exceed one ampere. If the unit has electric heaters, 125% of the rating of the heaters is added into the calculation.

- For direct expansion units, the MCA is calculated by adding 125% of the rating of the largest motor (normally the compressor) plus the rating of all of the other loads in the equipment that exceed one ampere. If the unit has electric heaters, 125% of the rating of the heaters is added into the calculation.
- For chilled water units, the MCA is calculated as 125% of the sum of the ratings of all of the loads in the equipment over one ampere.

MCA interpretation

The MCA for air conditioners with a single compressor and electric reheat will be much higher than the normal operating current. Adding a second compressor will result in an MCA closer, but still much larger than, the normal operating current. Only the rating of one compressor is multiplied by 125% and the rating of the other compressor has no correction factor. The MCA for chilled water units will be more than the normal operating current, but it will not be significantly more.

The MCA should not be used to determine the normal operating current. It is only used for selecting wire sizes. The MCA is used in conjunction with the NEC or CEC to choose the proper size for field wiring connections.

Maximum Overcurrent Protection

The maximum overcurrent protection (MOP) is the maximum circuit breaker size required to properly protect the equipment under anticipated fault conditions. The MOP takes into account startup surges and component ageing.

MOP calculation

Unlike the MCA, the calculation of the MOP is less dependent on the types of loads in the air conditioner. The same calculation is used for direct expansion and chilled water units. As with the MCA, the full load ampere (FLA) and rated load ampere (RLA) ratings of components are used. As with the MCA, only loads rated at least 1.0 ampere are used in the calculation.

The MOP is calculated as 225% of the rating of the largest motor plus the sum of all other loads over one ampere. The rating of the largest motor is multiplied by 2.25 regardless of whether it is a compressor, fan or pump. If this number does not match the standard rating of North American circuit breakers, it is rounded down to the next lower standard rating.

There are a number of exceptions to the calculation, but the most common exception is when the calculated MOP is less than the calculated MCA. In this case, the MOP is normally adjusted up to the next higher standard circuit breaker rating above the MCA.

MOP interpretation

The MOP for direct expansion units will often be very high. For air conditioners with a single compressor, the MOP could be significantly larger than the MCA. This is normal and acceptable as the chosen circuit breaker will provide the correct protection. The MOP must be high enough to avoid nuisance tripping of the circuit breaker. Lowering the MOP could cause nuisance tripping, which can encourage bypassing the circuit breaker to improve up-time.

The MOP for chilled water units will not normally exceed the MCA as much as the MOP for direct expansion units. In particular, chilled water units with many small loads instead of one large load will have a fairly low MOP. Again, this is normal and it will provide proper protection without the risk of nuisance tripping of the circuit breaker.

The Effect of Modern Technology on the Ratings

Modern motor loads, such as variable frequency drives (VFDs) and electronically speed controlled fans, have an adverse effect on the MCA and MOP ratings. Air conditioner designs with redundant components can further skew the ratings.

VFDs normally have soft start circuitry. The MCA and MOP calculations assume start-up current surges which are minimized by the VFD. Further, the VFD will often have built-in overload protection and torque control which will keep the motor from drawing significantly more current as it ages. Some fans have built-in electronic speed control which has the same features. The MCA and MOP calculations do not take this into account and the result is often ratings larger than actually necessary.

The use of redundant components can further skew the MCA and MOP ratings. A chilled water unit with multiple fans will not have one predominating load. The MOP will apply a correction factor to only one load in the unit, but the MCA applies a correction factor to all of the loads. As a result, the MCA and MOP ratings will be very close.

Should the MOP Always Be Larger than the MCA?

The normal rules for calculating the MOP require it to be larger than the MCA. It is a very unusual situation to have an MOP less than the MCA. In this case, the MOP would indicate that the equipment is not designed to draw more than a specified current, but the MCA indicates that the equipment must have wiring sized for a higher current.

The InRow RP chilled water units are examples of where the MOP is smaller than the MCA. These air conditioners have three identical fans, three identical heaters, a humidifier and a condensate pump. There is no one predominating load. The MOP calculation takes 225% of the rating of one component plus the ratings of the other seven. However, the MCA is calculated as 125% of the rating of all of the components. The result is an MCA larger than the MOP.

This is one case where the MOP should not be increased to exceed the MCA. The InRow RP fans have electronic speed control; the air conditioner does not have a significant start-up current surge. The heaters cannot start up until the fans are running, further decreasing the start-up current. Increasing the MOP to account for the current surge is unnecessary and would result in less protection from faults. The MCA is considerably higher than the normal operating current, but the NEC, CEC and Underwriters Laboratories regulations make no provision for adjusting the MCA. Exceptions to the rules exist only for adjusting the MOP, not the MCA. In this case, the MOP must remain small enough to disconnect the air conditioner under fault conditions without risking tripping other circuit breakers in the power distribution system, thereby shutting down additional loads in the data center.

Sample Calculation

Some sample calculations of the minimum circuit ampacity and maximum overcurrent protection for two hypothetical air conditioners can help illustrate how the ratings can vary based on the design of the equipment.

Traditional air cooled computer room conditioner

We can look at the basic calculations for an air conditioner with two compressors, two fans, electric reheat and a humidifier.

Table 1 *– Traditional air conditioner*

Load	Rating	MCA Correction Factor	MCA Rating	MOP Correction Factor	MOP Rating
Compressor 1	34.3	125%	42.9	225%	77.2
Compressor 2	34.3	100%	34.3	100%	45.7
Fan Motor 1	13.4	100%	13.4	100%	13.4
Fan Motor 2	10.0	100%	10.0	100%	13.4
Fan Motor 3	10.0	100%	10.0	100%	13.4
Heater 1	25.0	125%	31.2	100%	34.2
Heater 2	12.5	100%	12.5	100%	17.1
Humidifier	12.0	0%	0	0%	0
Total	-	-	154.3	-	182.4 (175)

In this example, the correction factor for the humidifier is zero. The heater and humidifier do not run at the same time, so only one is used in the calculations. The heater rating is used because it is higher than the humidifier rating. This gives us the MCA result of 154.3. The MOP calculation comes to 182.4 amperes, which is not a standard size. The next lower size is 175 A which is used as the listed MOP.

Electronic speed technology equipped chilled water air conditioner

This example is for a Chilled Water unit that has electronic speed control for the fans. It has six electrical loads rated over 1.0 amperes; three fans, two heaters, and a humidifier.

***Table 3** – Electronically speed controlled AC calculations*

Load	Rating	MCA Correction Factor	MCA Rating	MOP Correction Factor	MOP Rating
Fan 1	3.5	125%	4.4	225%	7.9
Fan 2	3.5	125%	4.4	100%	3.0
Fan 3	3.5	125%	4.4	100%	3.0
Heater 1	9.2	125%	11.5	100%	9.2
Heater 2	4.6	125%	5.8	100%	4.6
Humidifier	7.0	125%	8.8	100%	7.0
Total	-	-	39.1	-	35.7 (35)

In this example we are assuming operating modes where the humidifier and reheat can be on at the same time. These modes would occur only when there is a low cooling demand, resulting in the fans running at low speed and with minimal electric reheating of the air. As such, the current due to the fans and heaters would be much lower than the rated values.

The calculations result in a number for the MOP does not equal a standard circuit breaker size. It is lowered to the next standard rating of 35 amperes. Normally, the MOP would be increased to the next standard size above the MCA which would be 40 amperes.

However, the MCA formulas assume that all devices are operating at their maximum power concurrently. Deviation from the formula is not allowed. The actual maximum current consumption would be 30.3 amperes and would occur when the fans and heaters are running at full capacity and the humidifier is off. 30.3 would become the MCA rating which would be less than the calculated MOP of 35 amperes. As a result, increasing the MOP to 40 amperes is unnecessary and could even lead to fault conditions that would not open the overcurrent protection. The MOP remains at 35 amperes to provide maximum safety with minimal risk of nuisance tripping of the circuit breakers.

Cord and Plug Connected Products

Products with a cord and plug connection will not have an MCA or MOP listed on the label. They will have a single current rating listed instead. The MCA and MOP are unnecessary for products supplied with a cord and plug. North American plugs and receptacles have unique configurations for each voltage and current combination. A product supplied with a given plug will only be able to be connected to the correct mating receptacle. The NEC and CEC have specific requirements for the wire size and overcurrent protections for each type of receptacle. All of the necessary calculations have been performed and are incorporated into the NEC and CEC requirements for the installation of receptacles. No additional calculations need to be performed based on motors and other loads within the plug connected equipment.

Conclusions

The minimum circuit ampacity and maximum overcurrent protection ratings are important for properly connecting field wired air conditioners. The MOP may be significantly greater than the MCA or it may even be less than the MCA. However, these ratings are based on standard calculation. The ratings for any particular air conditioner are reviewed by the test laboratory, such as Underwriters Laboratories, that has tested and approved the air conditioner.

About the Author:

Ted Eckert is a Regulatory Compliance Engineer for APC. He is responsible for ensuring the safety of APC's cooling products. Ted received a Bachelor's degree in Electrical Engineering from Washington University in 1988, is a charter member of IEEE Product Safety Engineering Society and is a NARTE Certified Product Safety Engineer.