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KEEP YOUR CABLES COOL

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The year 2000 edition of the Wiring Rules or AS/NZS3000:2000 has introduced a different approach to the selection of devices for the protection of cables against over currents and short circuits. This change allows a more flexible selection process but at the same time can make the topic very confusing to many people in the industry. For most applications however the selection process is quite simple.

Cable/Device Rating

For electrical equipment it is the temperature reached while carrying current that determines its basic or thermal current rating. There are two main areas of concern. The first is the temperature of the insulation in contact with the conductors and the second is the performance of any electrical joints at elevated temperatures. For both areas there is no set temperature at which failure will occur, rather a limit is set where the rate of deterioration is considered acceptable.

The installation method will determine the temperature reached at any particular current. In the case of cables, Australian standard AS/ANZ3008.1 sets out ratings for cables in typical installations. As the heat loss from the cable is restricted the current rating is reduced.

The basic requirements

The objective of the Wiring Rules is to prevent damage to the conductor and its insulation. Three operating conditions are considered. These are the circuit operating under normal load conditions, overload conditions and fault conditions.

Normal Load

The requirement is straight forward. The circuit load (or calculated maximum demand) must be smaller or equal to the cable rating and the cable rating must be smaller or equal to the circuit breaker rating. If a fuse is used as the protective device then the cables can only be used to 90 % of their rating. In most applications meeting this requirement also satisfies overload and fault conditions.

IN THIS ISSUE

Table 1

Cable I^2t values and withstand currents

Cable size. Sq mm	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120
$I^2t \times 10^{-6}$ (K=111)	0.012	0.028	0.077	0.20	0.44	1.2	3.2	7.7	15.1	15.1	60	111	177
5 sec withstand. Amps	49.6	74.5	124	199	298	496	794	1,241	1,737	1,737	3,475	4,761	5,957
0.1 sec withstand Amps	351	527	878	1,404	2,106	3,510	5,616	8,775	12,285	12,285	24,571	33,346	42,122

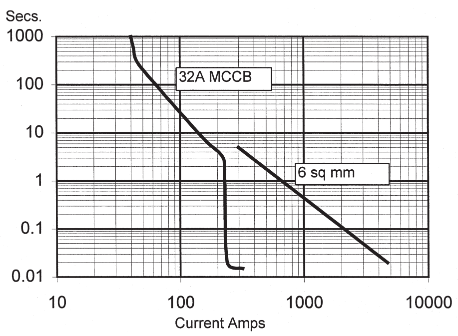
Overload

Overloads can occur as a normal part of the circuit operation. The starting of a motor is a typical example. Currents around eight times the motor running current can exist during the starting cycle. As this type of overload is short term it will not normally heat the cables to a degree that will cause damage.

In the case of a long term overload it is expected that the cable will overheat to some extent before the protective device operates. Fuses and circuit breakers require some degree of overload before they will operate. For circuit breakers they may require up to 1.45 times rated current to trip while fuses are permitted to go to 1.6 times before they operate. To accommodate this difference the Wiring Rules now require a 90 % derating for cables protected by fuses. This is to limit the maximum possible overloading to the same level as a circuit breaker ie. 1.45/1.6 = 0.9. While overloads can cause excessive cable temperatures, the damage to insulation also depends on the time it is at elevated temperatures. Protection of the cables is therefore not perfect but is considered to be an economical solution for the minimum requirement. Electronic overload sensing can provide tighter trip levels with operation at currents equal to 105 % of nominal setting in some relays. These are normally applied only on circuits of 400 A and higher.

Figure 1

Cable withstand compared to MCCB tripping characteristic



Fault Conditions

Fault conditions can arise due to failure of the cable insulation or a fault within connected apparatus. The current that flows is determined by the maximum fault prospective at the protective device, the length of cable in circuit and the impedance of the fault itself.

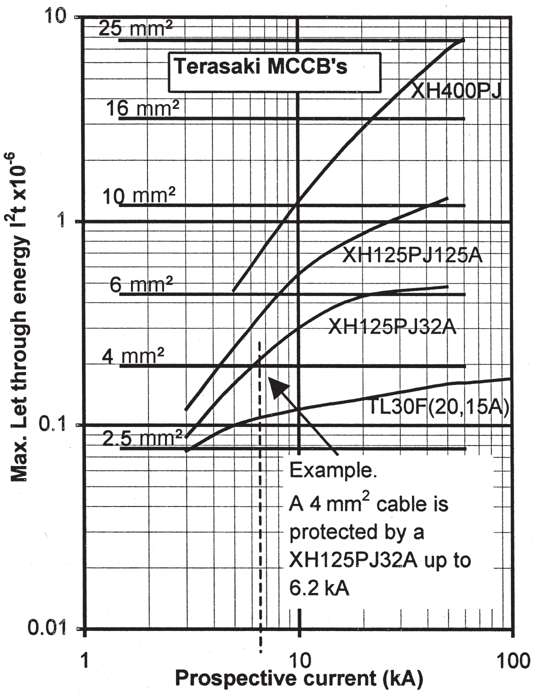
The protective device is required to limit the maximum temperature reached by the cable to within admissible limits. The highest temperature is not necessarily reached when the fault current is at the maximum possible fault level. This is because of the characteristics of the protective device.

The maximum temperature reached by a cable under short term fault conditions is determined by, the initial temperature, the current flowing and the time it flows. For times less than five seconds the heat produced by the fault current is all applied to raising the cable temperature as there is very little heat loss to the surrounds. This gives rise to the term I^2t. The heat produced is proportional to the current squared multiplied by the time it flows. How much heat a cable can withstand is determined by its temperature before the fault and the peak temperature permitted for the type of insulation. AS/ANZ3008.1 provides the information to perform the calculation. *Table 1* gives the calculated I^2t values for a typical cable condition.

The cable I^2t or energy withstand needs to be compared to the protective device's energy let through which is required to be equal to or less than the cable's energy withstand. Only the range from the current required to cause operation in five seconds to the maximum fault current of the installation needs to be considered. The information on let through energy is provided in two ways. For times down to 0.1 seconds the devices time current curve is used. At any point on the curve read the operating time and multiply it by the corresponding current squared for that point. The resulting let through is then compared with the cable withstand energy. A better means of checking is to plot the cables withstand time current curve on the same graph as the device time current curve. This is done by selecting a time, dividing the I^2t value by it and taking the square root of result to give the current corresponding to the selected time. In *Figure 1* the cable withstand has been

Figure 2

Cable I^2t withstand compared to circuit breaker let-through I^2t.



plotted on a circuit breaker time current curve. It can be seen from this that the circuit breaker will trip before the cable's maximum withstand has been reached.

For a circuit breaker the current at which the instantaneous trip operates at is less than the current at which contact lift occurs. As the current is increased contact lift and tripping of the mechanism occur at close to the same time. This contact lift modifies the actual current flowing and the time current curve is not accurate for comparing with the cable withstand curve. If the cable withstand curve crosses the circuit breaker time current curve in the very short time region then it may be necessary to refer to the circuit breakers I^2t curve. An example is shown in *Figure 2*. To use this curve the I^2t value is determined for the maximum fault level of the installation and this is compared with the cable withstand I^2t.

It can be seen that in most cases compliance is proven with the time current curve alone as the cable withstand curve does not cross at currents equal to or below the installation maximum fault level.

Circuit breaker type tests

Circuit breakers are required to pass a range of tests to prove short circuit and overload performance. To perform these tests the connecting cable is specified by the test standard and the tests effectively prove not only the circuit breaker performance but also that the cable was protected. In *Table 2* the test conductor's sizes are listed against the typical circuit breaker ratings. These sizes can be used without further consideration.

Separation of protection

The Wiring Rules permit the separation of the required short circuit protection and the device used for overload protection. A typical application is a motor installation where the motor protection overload is near the motor and a circuit breaker has been installed up-stream to provide short circuit protection.

As the motor is the only load on the circuit the overload protection can be at the load end of the cable being protected. The short circuit protection device in this case is typically a circuit breaker with a rating of double the motor full load current. The question is, can the cables from the circuit breaker be sized according to the motor load or do they need to be larger? To consider this the combined characteristics need to be examined as shown in *Figure 3*. In addition to the cable being protected the overload device must also be protected or co-ordinated with the short circuit device.

A very important point to remember is that we now have not just a cable but a small installation comprising of a circuit breaker, cable and overload device which will include a contactor. With this arrangement the actual fault current that will flow can be greatly reduced by the impedance of these devices. Testing becomes the only practical way of determining the performance and for motor starters this is covered by AS3947.4 in what is known as Type 2 short circuit co-ordination. The cable sizes

Figure 3

Combined operation of 100 A MCCB and 50 A thermal motion overload provide full protection to 16² mm cable

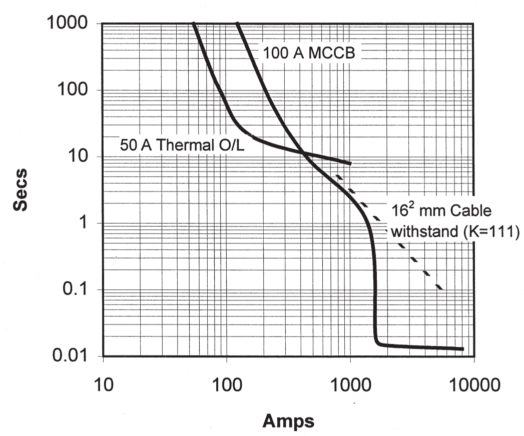


Table 2

Standard cable sizes for circuit breaker testing

Sq mm	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120
Amps	6	12	20	25	32	50	63	80	100	125	160	200	250

and lengths are specified in the standard. The cable sizes versus current rating are the same as for short circuit tests on circuit breakers alone so *Table 2* applies based on the rating of the overload not the short circuit protection.

Conclusion

The new Wiring Rules allow greater flexibility by moving to specify what is required to be achieved rather than specifying how it is done. Unfortunately this has created a lot of confusion but when examined closely the changes in most cases do not alter current practice.

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