Dimensioning Thermal Circuit Breakers for Equipment

Factors that need to be considered when selecting rated currents of circuit breakers

Thermal circuit breakers for equipment (CBE) protect motors and transformers against electrical overloading. The trip release of a breaker takes place with the deflection of a bi-metal. This deflection is in turn dependent on heat caused by the level of current flowing through the bimetal. The typical time-current characteristic of a thermal circuit breaker is a result of the thermal delay of the bimetal.



Thermal circuit breakers for equipment have the advantage that they are insensitive to inrush currents that occur when switching on motors and transformers. However, dimensioning of the rated current is not only determined from the rated current of the load. Other parameters such as in-rush current, overloading capacity, operating duty and ambient temperature should also be taken into consideration.
Numerous types of loads, especially motors, can be temporarily operated with an overload. So as to avoid an unwanted trip release of the circuit breaker in cases such as these, the rated current can be selected more generously. However, the motor data sheet and/or the overloading capacity of the load to be protected must also be taken into consideration here. This overloading capacity is in turn heavily dependent on the operating duty. In many applications, the operating duty, and thus also the current resulting from the load, is not constant. Alongside other factors, the heat rise caused by the load, and thus the deflection of the circuit breaker bimetal, is dependent on how the load current develops, the switching frequency and/or how often an overload occurs.

Circular saw

With a circular saw for example (figure 1), the motor is started via the closure of breaker and runs under no-load conditions for a short period of time, that is, the machine is not physically loaded. During the run-up time the load current is extremely high, but only for a very short period. The bimetal is heated rapidly with this, but is too slow to trip out the breaker. It cools down again when the motor runs under no-load conditions, that is, with only a small fraction of its rated load. During sawing the operating current increases again. The level of current flow is dependent with this on various factors such as the type of wood being cut, thickness and hardness of the wood, and on the speed at which the wood is being fed to the circular saw blade. With a hand-operated saw, a number of these factors are not constant, that is, they vary during the operation. The load current generally drops back to no-load conditions after a few seconds of operation when the motor and bimetal can cool down again. With fluctuating loads such as this, the bimetal should only trip out the breaker when the machine is subjected to an overload for too long or when the motor is blocked.

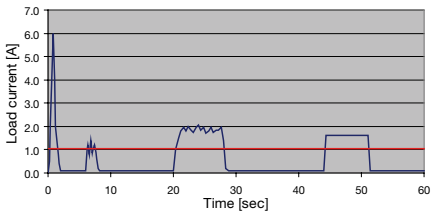

Figure 1: Circular saw

Feeder

Dimensioning of the rated current of the circuit breaker is critical with applications where the motor is switched on frequently and then only turned off for short periods. If the motor with an automatic feed installation (figure 2) is switched on every 10 seconds for six seconds, only four seconds remain for cooling. With high frequency duty cycles such as these, the bimetal is heated further with each duty cycle to a point where it trips out the breaker. It would be better for the motor to be switched on and off less frequently but with longer operating times, leading also in turn to longer cooling periods.

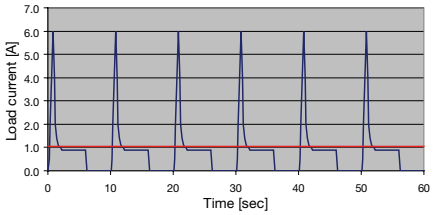

Figure 2: Feeder

Ventilator

It is far simpler to determine the bimetal rated current with a constant load. A ventilator fan (figure 3) that is operated for many hours at a constant load also has a constant load current. A fault occurrence can be thus protected against with relative accuracy. However, with an application such as this, the in-rush current should also be taken into consideration so as to ensure that this does not lead to nuisance tripping of the breaker.

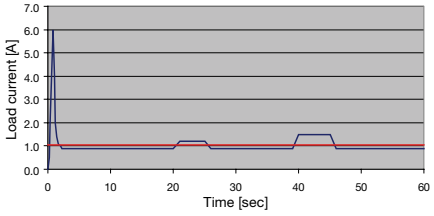

Figure 3: Ventilator

Garden shredder

In any event it is worthwhile deliberating how well and how secure a load needs to be protected: the better the protection, the higher the probability of unwanted and unnecessary trip disconnections. It is precisely with applications having irregular loadings, such as a garden shredder (figure 4), that the determination of the rated current becomes difficult.

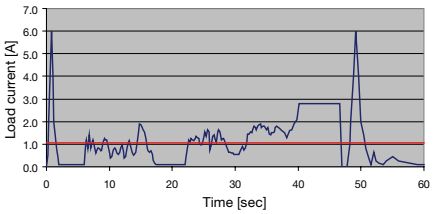

Figure 4: Garden shredder

Ambient Conditions

The most important factor that has a direct influence on the trip characteristic of the circuit breaker is the ambient temperature. The trip characteristic is stipulated to an extent by the international standards IEC 60934, UL 1077 and CSA C22.2 235 with which calibration takes place at 23 °C. But if the breaker is subjected in an application to an ambient temperature of 60 °C, the bimetal is deflected quite strongly from the onset before any load current flow. The breaker will then trip out too early when only operated with just the normal rated current. For applications where the CBE is subjected to a considerably different ambient temperature than 23 °C, the rated current selected must be corrected. The appropriate correction values can be found in the relative product data sheets.

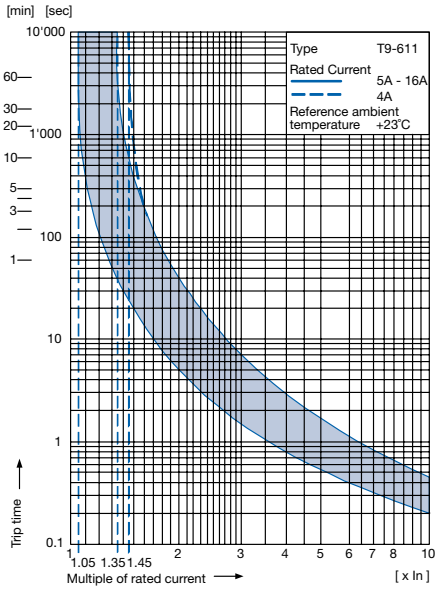

Figure 5: Tripping characteristic circuit breaker T9

Conclusion

With the selection of the rated current, the switch-on and start-up characteristics of the load need to be considered so that the breaker does not trip unnecessarily. On the other hand, the trip release characteristic should lie as close as possible to the characteristic of the load so that the breaker not only protects the load safely but that it also does not give rise to nuisance tripping. The best approach is to use trip characteristic curve of the appropriate breaker (figure 5). The maximum in-rush current under normal operating conditions must lie below the bimetal characteristic in both duration and size, otherwise a trip release will occur with switch-on. Circuit breakers for equipment are calibrated so that with a constant 105% of rated current they will not trip for at least one hour. With a constant 132% of rated current, they must have tripped after one hour at the latest. Dependent on the overload capacity, the bimetal rated current can now be selected as close as possible to, slightly below or above, the rated value of the load. With critical operating duty modes having frequent starts, large load fluctuations or increased ambient temperatures, it is recommended that tests be carried out with the rated current selected under practical conditions.

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Albert Bürgler
Product Manager CBE
SCHURTER AG
Werkhofstr. 8-12
6002 Lucerne
albert.buergler@schurter.ch
www.schurter.com

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