



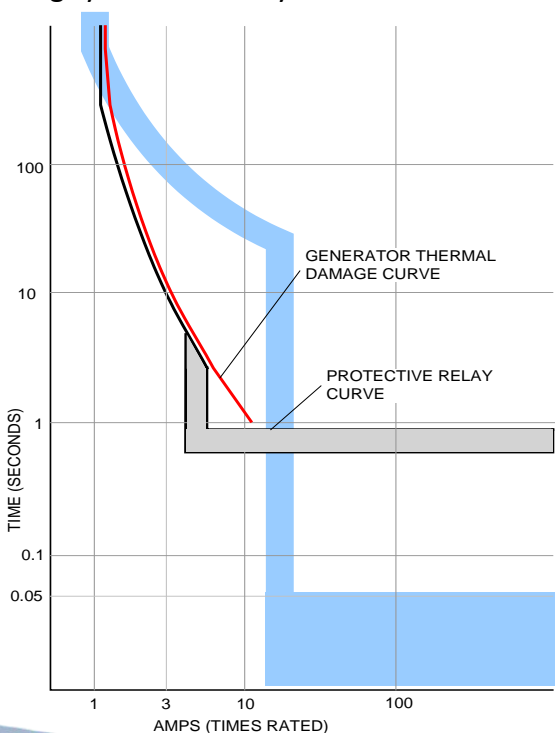
**Understanding the Importance of Alternator Protection:**

Grid powered distribution systems use various forms of over current and short circuit protection to prevent a wide range of conditions, most notably the loss of life. However, due to the alternator’s unique characteristics, extra attention must be emphasized.

To that point, as with other electrical conductors, alternator windings operate with a positive correlation between temperature and load levels. Meaning that as one increases, so true to the other. This is significant in the fact that over load conditions will produce higher temperatures that will cause thermal stress and ultimately insulation failure. It only takes a single over load to dramatically reduce the effective life of the alternator even if there is no immediate failure.

It would seem that since higher alternator temperatures are a precursor to impending damage, a preventative method for detecting this damage would simply be fitting the alternator with temperature sensing devices across the winding. Then after fitting the windings, set a predetermined temperature value at any of the thermocouple, and that would represent the damage point. Unfortunately, this process is flawed as the response and monitoring characteristics of such devices are not suitable. Even though the devices could report before the damage became too severe, the machine itself could be damaged while operating under the condition just before the damage point value. This is including but not limited to rotor damage which can occur on unbalanced faults.

**Alternator damage due to over loads can be defined as the alternators capability to resist damage during over current conditions.** By testing the alternators under short circuit conditions estimates can be formed. The alternator’s damage curve, as it is called, takes the results of the testing of current flows and temperature inside the machine, while pairing that with the characteristics of the insulation system used in a specific machine and provides an evaluation of the possible failure point, but does in no way clearly define the specific machine’s exact failure point. This provides a starting point, but needs to be used in conjunction with protective device operating curves. Doing so will ensure optimum system protection at acceptable levels while offering system reliability.



A misconception that commonly arises is that the alternator's main circuit breaker protects the alternator from a short circuit event. This is untrue as the main output breaker protects the cabling and provides a convenient disconnect. The reason for this is that the trip curve for the industry standard thermal magnetic breaker does not work in conjunction with the alternator’s damage curve. In order to provide generator protection, then a solid state circuit breaker with full adjustments (LSI, Long / Short Time and Instantaneous) is required to work in conjunction with the alternator’s damage curve.



However, since the alternator damage curve generally follows an  $I^2t$  characteristic, any circuit breaker that does not operate within that curve shape throughout the overload operating range of the alternator will find it difficult or impossible to adequately protect the alternator. This can be seen in the Figure located to the left as an example situation where an alternator is being “protected” by a circuit breaker that isn’t operating within its curve shape

**In this situation, no protection can be provided at all as for nearly any overload condition, the breaker operation curve lies to the right of the thermal damage curve of the alternator.** Therefore, how can the circuit break provide protection when the thermal damage curve cannot meet the requirements for the breakers tripping point.

In the event of a short circuit, the overcurrent devices within the Emergency Power Supply Systems (EPSS) will selectively trip the circuit overcurrent devices. This is achieved through the coordination of the alternator’s damage curve and the specific protective device. During the most critical applications, that electrical system coordination is required and can protect the device.

Today the back-up power applications are more critical than ever. It is due to this critical nature that the desire to protect the system against relatively rare failure modes has increased. As generator control systems today have become more powerful; manufacturers have been able to supply the necessary coordinated short circuit or over load This is increasingly important as alternators must be protected from the effects of short circuit conditions and overcurrent. Having the appropriate protection is all the National Electric Code (NEC) requires however, this protection cannot be chosen at random and must be carefully chosen utilizing the specific generators full capabilities and limitations.

Protection for the generator set can come in many forms. AKSA gen-set control systems have a comprehensive control of monitoring generator output and protect the alternator for over current, short circuit, earth fault and negative sequence current.

### **Over Current Protection:**

The high current shutdown / electrical trip alarm combines a simple warning trip level with a functioning IDMT curve for thermal protection.

AKSA gen-set controllers have an immediate warning feature which generates a warning alarm as soon as the trip level is reached. The alarm will automatically reset once the generator loading current falls below the trip level.

AKSA gen-set controllers monitor the generator output and begin following the IDMT curve as soon as the trip level is passed. If the trip is surpassed for an excess amount of time the IDMT alarm triggers (Shutdown or Electrical trip as selected as action)

- High current shutdown is a latching alarm and stops the generator set.
- High current electrical trip is a latching alarm and removes the generator from load by tripping the breaker, before stopping the generator set after off load cooling timer.



The higher the overload, the faster the trip. The speed of the trip is dependent upon the fixed formula:

$$T = t / ((I_A / I_T) - 1)^2$$

Where:  $T$  is the tripping time in seconds  
 $I_A$  is the actual current of the most highly loaded line  
 $I_T$  is the delayed over current trip point  
 $t$  is the time multiplier setting and also represents the tripping time in seconds at twice full load (when  $I_A / I_T = 2$ )

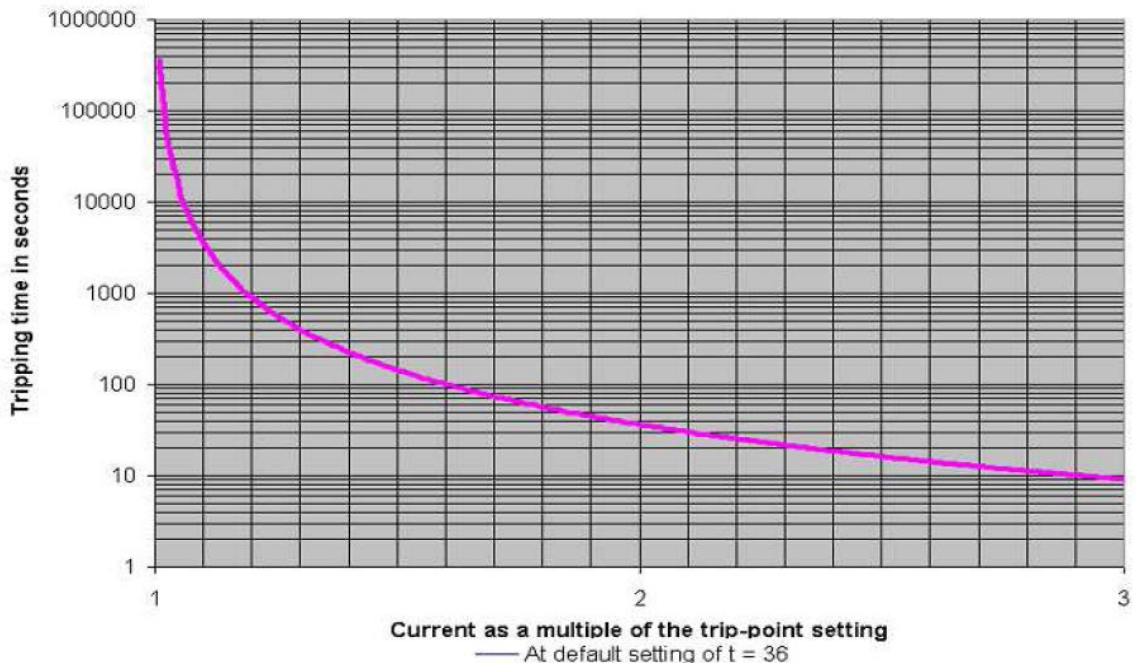
Factory settings for the IDMT Alarm when used on a brushless alternator are as follows:

### Overcurrent Alarm

Immediate Warning	<input checked="" type="checkbox"/>	
IDMT Alarm	<input checked="" type="checkbox"/>	
Trip	<input style="width: 40px;" type="text" value="100"/> %	$I_T$ (Trip Setting) <span style="margin-left: 100px;">500 A</span>
Time Multiplier	<input style="width: 40px;" type="text" value="36"/>	$t$ (Time Multiplier Setting)
Action	<input type="text" value="Electrical Trip"/>	

These settings provide for normal running of the generator up to 100% full load. If full load is surpassed, the immediate warning alarm is triggered, the generator set continues to run. The effect of an overload on the generator is that the alternator windings begin to overheat; the aim of the IDMT alarm is to prevent the windings being overloaded (heated) too much. The amount of time that the generator set can be safely overloaded is governed by how high the overload condition is.

With typical settings as above, the tripping curve is followed as shown below.





This configuration ensures the alternator is protected whereby 110% overload is permitted for 1 hour and power system is ensured of 300% fault current for breaker coordination for 9 seconds. If the generator load reduces, the control system then follows a cooling curve. This means that a second overload condition may trip much sooner than the first as the controller knows if the windings have not cooled sufficiently.

**Short Circuit & Earth Fault Protection:**

Each AKSA gen-set has a suitable rated 'Earth Fault CT'. The control system measures Earth fault and is configured to generate a specified alarm condition (shutdown or electrical trip) when the specified level has been surpassed.

Short circuit alarm operates the same way as the Earth Fault, using the same curve formula but typical uses a lower value for K (time multiplier) to give a faster acting trip.

The control systems follow the IDMT curve. If the trip is surpassed for an excess amount of time the alarms triggers.

The higher the Short Circuit / Earth Fault, the faster the trip. The speed of the trip is dependent upon the fixed formula:

$$T = K \times 0.14 / ((I / I_s)^{0.02} - 1)$$

Where: T is the tripping time in seconds (accurate to ±5% or ±50ms, whichever is the greater)

K is the time multiplier setting

I is the actual earth current measured

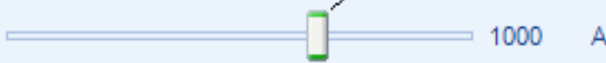
I<sub>s</sub> is the trip setting value

Factory settings for the IDMT Alarm when used on a brushless alternator are as follows:

**Short Circuit**

Enabled

Action  **I<sub>s</sub> (Trip Setting)**


Trip  %  1000 A

Time Multiplier  **K (Time Multiplier Setting)**

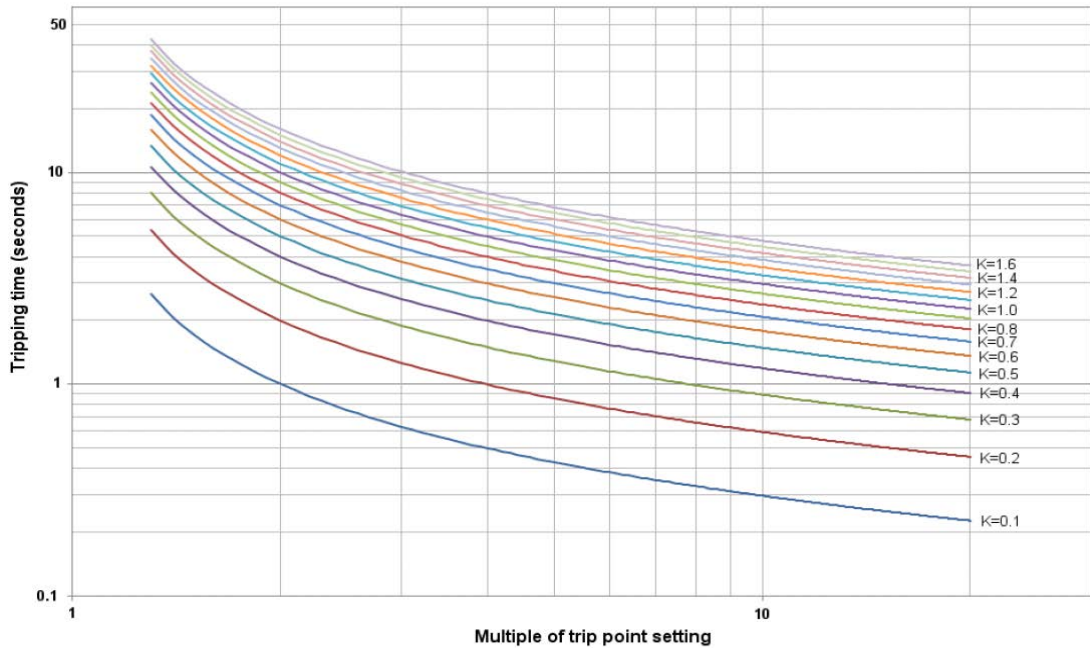
**Earth Fault**

Enable

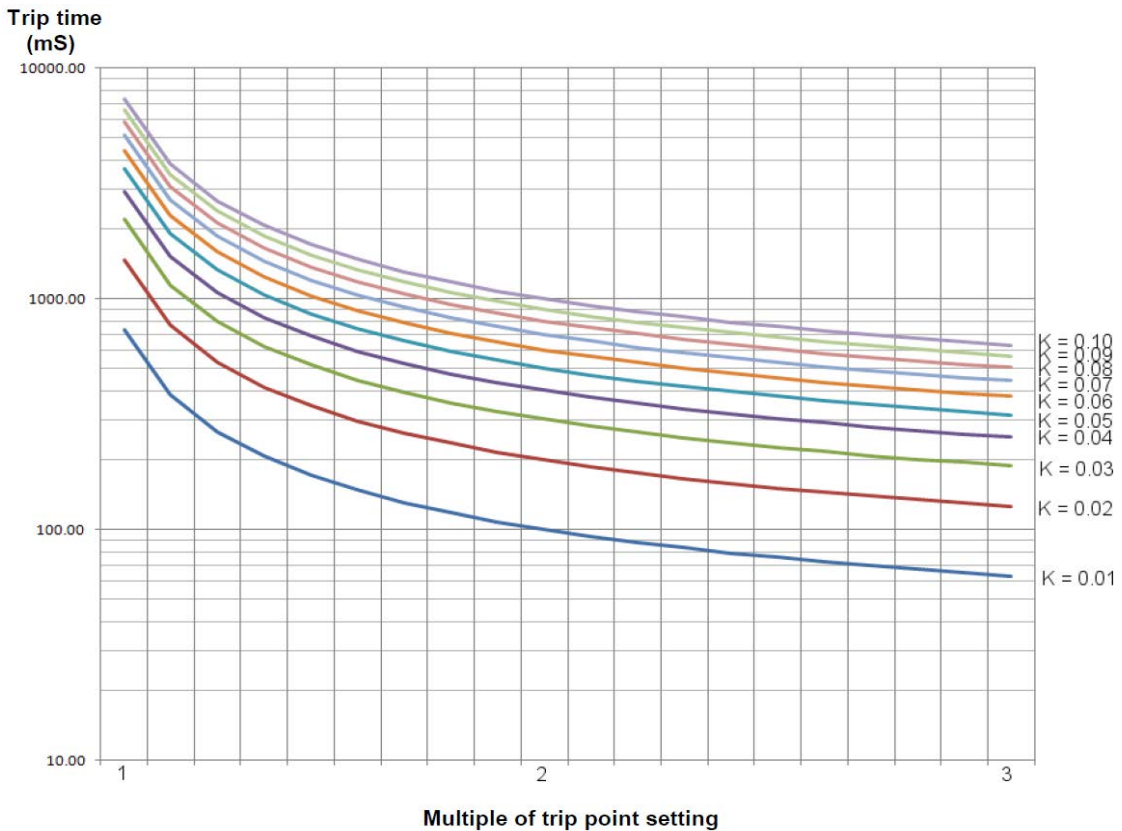
Action  **I<sub>s</sub> (Trip Setting)**

Trip Level  %  50.0 A

Time Multiplier  **K (Time Multiplier Setting)**



Note: AKSA factory setting is time multiplier (K) = 0.4



Note: AKSA factory setting is time multiplier (K) = 0.01