LITERATURE

ISOLATOR/SURGE PROTECTOR 118kA

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ELECTRICAL INDUSTRIES
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BACKGROUND

This addendum to "The Isolator/Surge Protector" describes the operation of the ISP in greater detail. It is assumed that the reader has already read the ISP Introduction for a general discussion of the features and characteristics.

To reiterate some of the ISP introduction material, the ISP blocks the flow of DC current and readily conducts AC current as long as the absolute value of the voltage across its terminals is less than a preselected voltage threshold level (12.5 or 20 volts) and the steady-state AC current is also within its rating. If either of these conditions are exceeded, the ISP momentarily transitions from its "blocking DC/conducting AC" mode to a virtual short circuit to both AC and DC. This transition is accomplished within 1 to 4 microseconds by the logic-controlled circuit turning ON thyristor T1 or T2 (depending on polarity). This protects the DC blocking/AC by-pass capacitor from failure due to excessive current. It also provides over-voltage protection between the two points to which the ISP is connected. Reference Figure 1 for a simplified diagram of the ISP showing all key circuit elements.

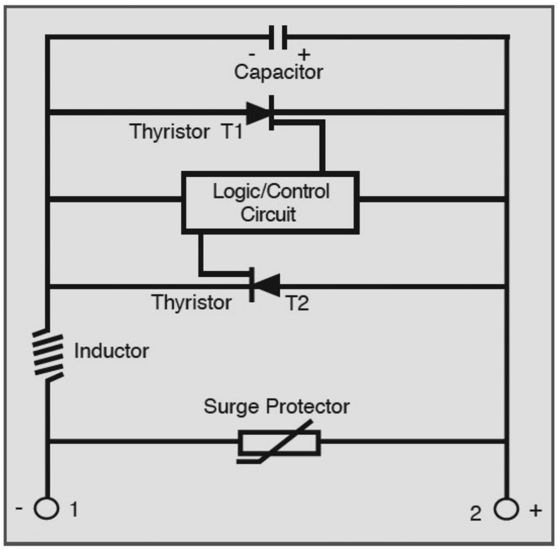

Figure 1: Isolator/Surge Protector Circuit

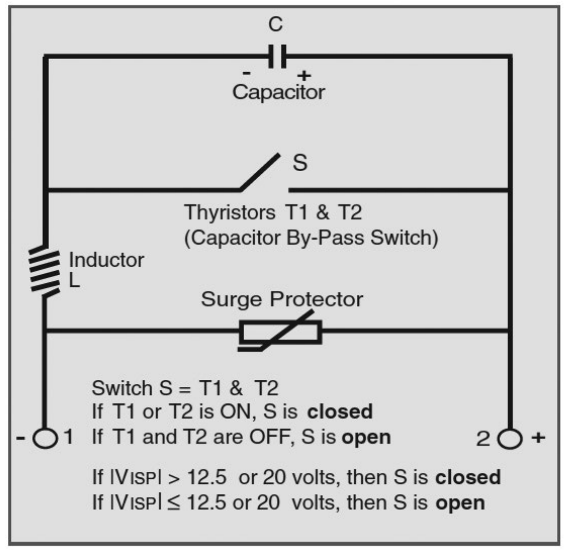

Figure 2: Simplified Isolator/Surge Protector

DURING DC CONDITIONS

The ISP appears as an open circuit to any DC voltage up to the 12.5 or 20 volt peak transition level selected. (However, it is recommended that 10 or 17 volts peak be considered the practical DC voltage blocking level because the DC current leakage level increases non-linearly above these levels until the actual transition level is reached.) When the absolute value of voltage across the ISP terminals attempts to exceed the voltage transition level selected, the logic-controlled circuit initiates turn-on of the thyristor T1 or T2, depending on polarity. The cathodic protection source is not usually sufficient to exceed the ISP threshold level, however, an external DC source, such as from a nearby rapid-transit system, can approach these levels of voltage.

See Figure 2. The only current that flows when T1 and T2 are OFF (switch S is open) is the DC leakage current through: (1) the capacitor C, (2) the logic controlled circuit, (3) the thyristors T1 and T2, and (4) the surge protector. The leakage current is nominally 0.25 milliamperes per volt or less, and is illustrated in Figure 3. Cathodic isolation is maintained through 10 volts DC when the 12.5 volt threshold level is selected, and through 17 volts when the 20 volt threshold level is selected.

Whenever the DC voltage exceeds the voltage transition level selected, cathodic isolation is then interrupted until the transient condition which caused the ISP to transition to its shorted mode is past – after which the logic-controlled circuit assures that the ISP reverts to its "normal" mode of blocking DC/conducting AC. If the DC voltage remains above the voltage threshold level, the ISP will alternately transition between its blocking level and shorted mode every several seconds. A flashing red indicator on the cover of the ISP provides a visual indication when the voltage applied to the ISP is above its voltage threshold level (i.e., above the "B" code rating).

If the ISP was triggered into its ON mode by a DC voltage only, the subsequent voltage across the ISP terminals would be dictated solely by the impedance of the ON thyristor and the DC current available, a value that would typically be in the several volt range at most, even if hundreds of amperes of DC current were available.

DURING AC CONDITIONS

When an AC voltage is applied to the ISP, the current path is through the inductor L and capacitor C, for currents up to the steady-state AC current rating selected. Reference Figure 4.

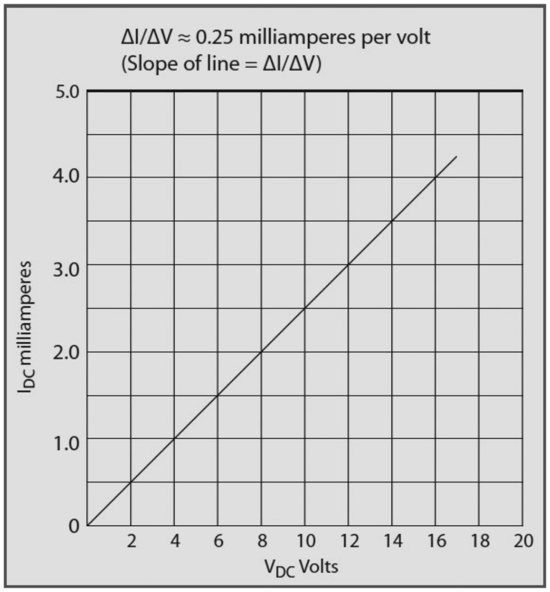

Figure 3: IDC Leakage Current vs. DC Voltage

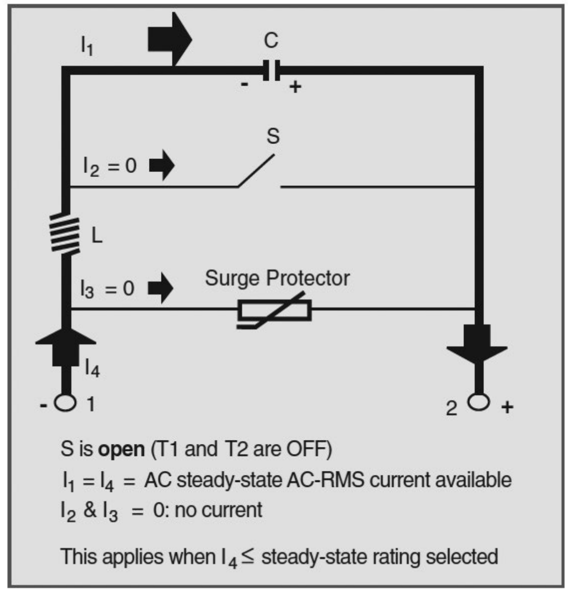

Figure 4: Primary Current Path When Blocking DC/Conducting AC

If the AC current exceeds the steady-state current rating, the logic-controlled circuit causes the ISP to transition to its “shorted” mode and capacitor C is discharged through closed switch S. If this were allowed to continue, capacitor C would be charged and discharged 120 times per second at 60 Hz, or 100 times per second at 50 Hz. If precautions were not taken, the resulting internal discharge current, which also flows through the equivalent series resistance of the capacitor, would cause excessive heating and failure of the capacitor. To prevent damage to the capacitor when the steady-state AC current is above rating, the logic-controlled circuit initiates a secondary triggering period of several seconds in duration, during which the thyristors (also known as SCRs or Silicon Controlled Rectifiers) are triggered ON at a very low voltage level. The power dissipation within the capacitor, which varies with the square of the voltage to which the capacitor is charged, is thereby reduced to a very low level, thus preventing failure of the capacitor.

During over-current conditions, the ISP is protected against failure at current significantly above its steady-state AC current rating, but it is not blocking DC. Any time the ISP is being operated above its steady-state AC current rating or the DC voltage is above the switching threshold level, a red indicator mounted on the cover of the ISP will flash intermittently as a warning. (This indicator is provided with the non-submersible enclosure only.)

Figure 5 illustrates the predominant current flow path through an ISP when subject to excessive steady-state AC or AC fault current.

The ISP model should be selected so that under the highest steady-state AC current expected it is in its cathodic isolation (OFF) mode (i.e. neither T1 or T2 is in the ON state).

Whenever AC voltage is present (such as induced AC) one must determine the maximum steady-state AC current available. (This current is the maximum steady-state AC current that would flow through a “short circuit” between the cathodically protected structure and the grounding system for the ISP.) Then a model of the ISP should be selected that will provide cathodic isolation while carrying that value of current. ISP models are available where cathodic isolation will be obtained with steady-state AC current levels up to 90 amperes at 60 Hz or 75 amperes at 50 Hz. When DC voltage is present (particularly excessive stray DC), the steady-state AC current allowed may have to be reduced from these maximum values, as is shown in Figures 3 through 6 in the catalog section, “The Isolator/Surge Protector.” If the ISP is triggered ON due to AC, the voltage across the ISP terminals is dictated by the magnitude of the AC current flowing through the impedance of the “ON” thyristor and the voltage developed across an air-core inductor within the ISP. The voltage across the inductor is the dominant factor at high values of fault current.

The voltage due to AC that can be developed between the two points to which an ISP is connected will only be of significance when very high levels of fault current are involved. Figure 6 illustrates the voltage developed across a typical ISP for all values of 60 Hz steady-state and fault current. Similar results would be obtained at 50 Hz.

DURING LIGHTNING SURGE CONDITIONS

Under lightning (or switching transient) surge conditions, where the input current has a very fast rise time, the conduction path through the ISP is different than for AC conditions. (Lightning is characterized by a 8 x 20 microsecond waveform, which takes 8 microseconds to reach crest value and 20 microseconds to decay to one-half of crest value.) See Figure 7 below.

When the ISP is exposed to a lightning surge, the voltage developed across the inductor L instantly rises to a value that places the surge protector (metal oxide varistor) into conduction, enabling the surge protector to carry the bulk of the

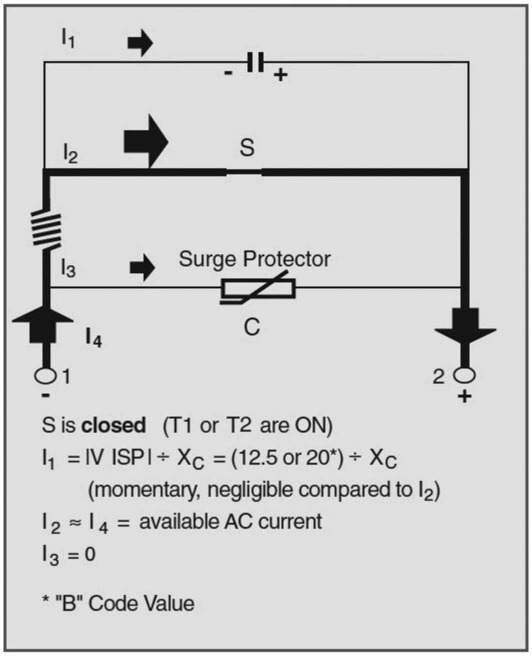

Figure 5: Primary Current Path Under AC Fault Conditions or Steady-State AC Current Above Rating

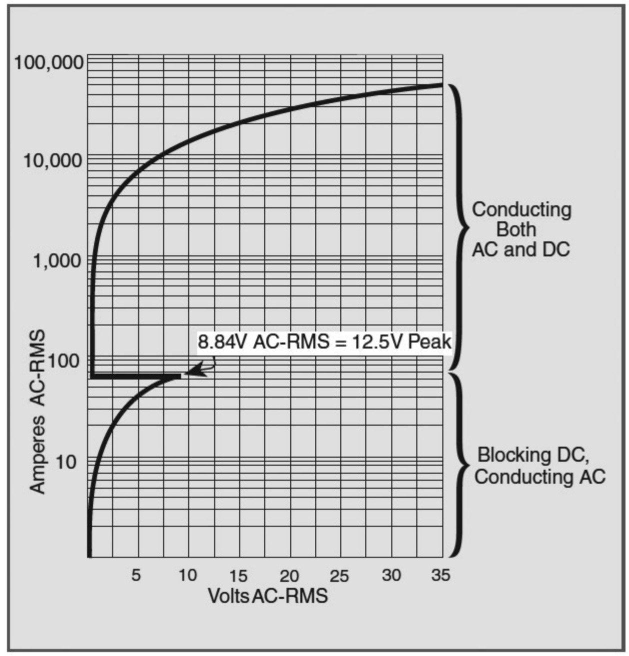

Figure 6: Voltage Across ISP Terminals vs. AC Current (Steady-State and Fault Current) Shown: ISP with D code = 60, B Code = 12.5

current. Since the peak voltage across the thyristor also rapidly exceeds the threshold level, thyristor T1 or T2 (depending on polarity) is also put into conduction. However, the impedance of the current path through the thyristor is now much higher because the inductor is in series with this path. Whereas the impedance of the inductor was not a significant factor under AC or DC conditions, it is important and necessary under lightning surge current conditions. The impedance of the inductor allows only a small fraction of the surge current through the ISP to be carried by the thyristors, thereby preventing failure of the thyristors due to excessive rate of change of current. Most of the current chooses the lower impedance path through the surge protector.

If the ISP was triggered into its ON or "shorted" mode by lightning (or other similar waveform with a very fast rate of rise of current), the voltage directly across the terminals of the ISP is dictated by the breakdown voltage of the internal metal oxide varistor (MOV), a value in the 300 to 700 volt range depending on the magnitude of lightning surge current available.

The voltage due to lightning that can be developed between the two points to which the ISP is connected is dictated to a much greater extent by lead length than it is by the internal characteristics of the MOV used inside of the ISP for lightning protection. For a lightning surge, leads can develop from 1 to 3 kV per foot (approximately 3 to 10 kV per meter) of lead length due to L di/dt effect. Therefore, if an ISP (or any other protective device, for that matter) were connected with two 1.5 foot (457 mm) leads, the voltage developed between the two connection points could be: 2 x 1.5 x 3000 V/ft = 9000 volts, solely due to lead inductance. Therefore, it is imperative that the leads be kept as short as possible whenever an ISP is to be used to provide lightning over-voltage protection between the two points to which the leads are connected.

A key factor regarding the ISP is that it is strictly a current-rated device. Under abnormal system conditions (e.g., AC power fault or lightning surge) where an external source may attempt to impose a high voltage across the device, it instantly reverts to its short circuit mode; therefore, it never has to withstand high voltages. For this reason, the ISP has only current ratings.

THE LOGIC-CONTROLLED CIRCUIT

The most important part of the ISP is the logic-controlled circuit. This circuit determines exactly when the high current capacity thyristors should be turned "on," and following the transient event, it assures that the ISP is transitioned back to its normal mode of blocking DC/conducting AC. This assures that the thyristors can not be permanently stuck in an ON condition by the cathodic protection voltage source or an external DC voltage source. The logic-controlled circuit, as with the entire ISP, is autonomous and does not require an auxiliary source of electrical power. It captures and stores the necessary power from any event that causes the voltage across, or the current through, the ISP terminals to reach the threshold level. Power is stored for a sufficient period of time for the logic-controlled circuit to deal with any foreseeable event.

Thyristors, when turned ON, remain ON until the current decreases below the "minimum holding current," a value typically a fraction of an ampere. Therefore, the DC source used for cathodic protection (or an external stray DC source) could keep a thyristor in the ON state indefinitely if precautions were not taken to prevent this; hence one main reason for the logic-controlled circuit.

Another key function of the logic-controlled circuit is to assure that after the ISP is forced back to its "normal" or OFF mode following a transient, that it in fact remains in this mode. Any

DC circuit with inductance is susceptible to a "pumped up" voltage across its terminals when current flow from the circuit is interrupted. This is due to energy stored in the inductance between the ISP and the external DC voltage source. This stored inductive energy can generate a voltage across the ISP terminals many times its normal steady-state DC value, which could re-trigger the ISP into conduction.

The logic-controlled circuit includes a sub-circuit which provides a means for dissipating the stored inductive energy to prevent retriggering of the ISP. After this inductive energy is dissipated, the DC voltage will return to its normal steady-state value. The logic-controlled circuit then automatically deactivates and goes dormant until the next triggering event occurs. The logic-controlled circuit distinguishes between rising voltages which are due to stored inductive energy that should be dissipated, and voltages due to "outside" influences (such as a lightning surge or AC fault) where the ISP must be triggered ON to prevent any damage to the ISP itself and to limit the voltage between the two points between which the ISP is connected. Thus, the logic-controlled circuit has ability to distinguish between situations that require grounding versus situations that require isolation. This ensures proper functioning under the wide variety of field conditions which may be encountered.

The original logic-controlled circuit provided all of the above functions described, but did not protect an ISP from failure if the steady-state AC current were continually above rating. A design revision to this circuit (noted on the ISP nameplate by a "Rev. #" in model number position G) includes several new features described as follows:

- Prevention of overheating of the capacitor due to repeated retriggering if the ISP is being operated above its steady-state ratings.
- Protection of the capacitor from excessive AC current that can occur below the absolute voltage threshold level of the ISP (applies when the 20 volt threshold level is selected).
- Provision for activating a flashing red warning indicator whenever the ISP is being repeatedly retriggered (due to application above steady-state rating).

The Isolator/Surge Protector is the only product which provides DC isolation and AC grounding/coupling with logic-controlled circuitry: the key to proper functioning under all foreseeable field operating conditions.

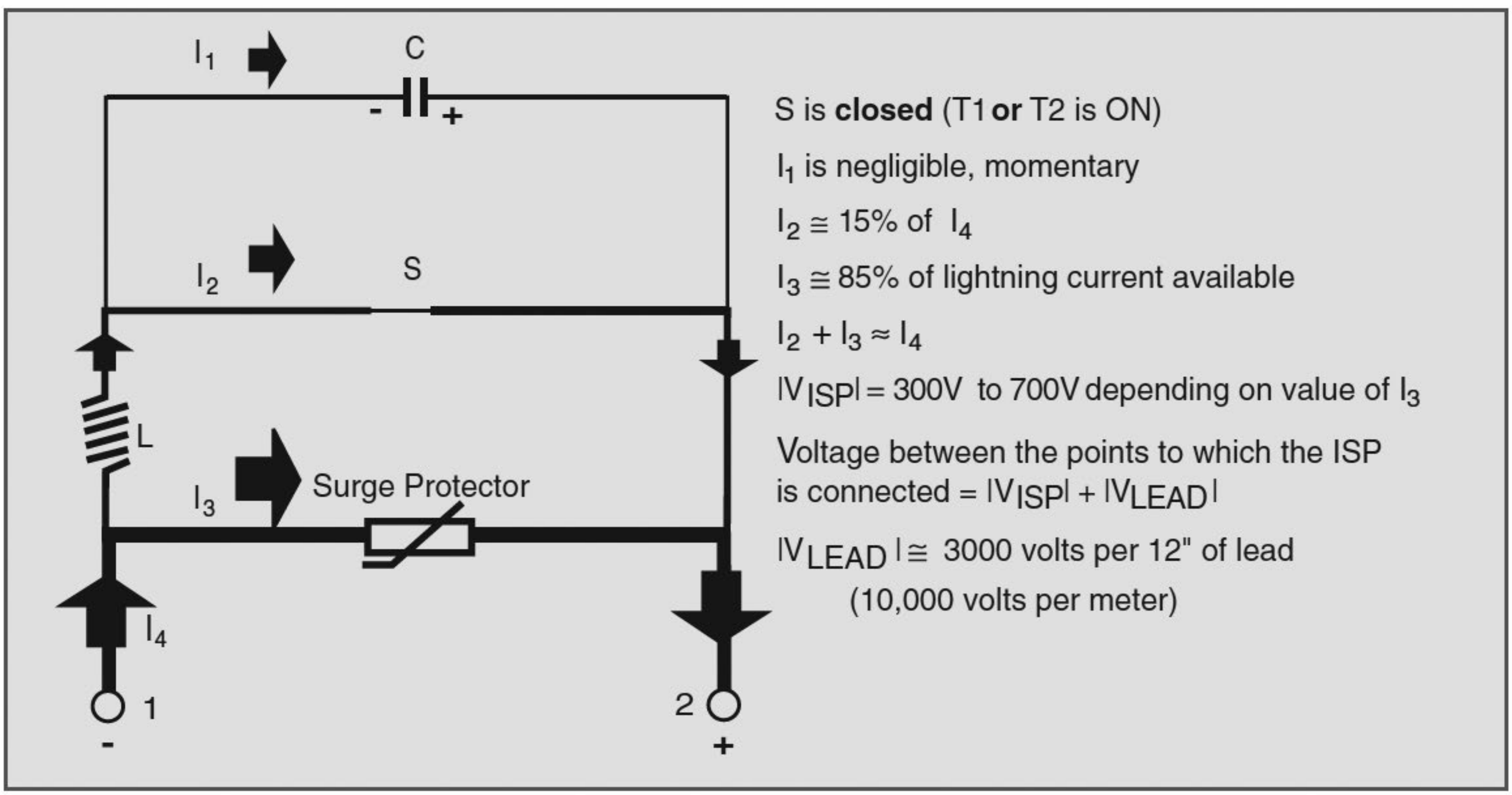

Figure 7: Primary Current Path Under Lightning Conditions

ADDENDUM

General

The Isolator/Surge Protector (ISP) is a solid-state, logic-controlled device which provides DC isolation and AC grounding/coupling of cathodically protected systems, usually underground power cable systems. The system on which this product is installed should be compatible with the product ratings checked below.

Note: For more information on the ISP product, please view the full ISP Technical Literature.

Ratings

The code letters in the following ratings tables refer to the model number position. See product nameplate.

Ambient Operating Temperature

-40° F to +150° F

(-40° C to +65° C)

Typical Model Structure

ISP-A-B-C-D-E-F

Lightning Current Rating (8 x 20 waveform)	
"A" Code	**Peak Amperes**
75	75,000
Note: 8 x 20 micro-second waveform	

Voltage Blocking Rating	
"B" Code	Volts Peak
12.5	12.5
20 (Alternate)	20

AC Fault Current Ratings (Amps AC-RMS Symmetrical)				
60 Hz "C" Code Cycles				
1	3	10	30	60
118kA	96kA	75kA	54kA	40kA

Steady-State Current Ratings (Amps AC-RMS Symmetrical)	
60 Hz "D" Code	**Amperes**
120	120

If there is DC voltage across the ISP that is above normal cathodic protection voltages, the steady-state current must be derated from the above values as illustrated in the ISP technical literature.

Enclosure	
"E" Code	Type
NS	Non-Submersible

The enclosure is made of 14 gauge (0.0747" thick) #304 series stainless steel and is rated NEMA 4X. It is rain-tight and suitable for outdoor application.

Four hole NEMA terminals are furnished as standard equipment.

The enclosure is isolated from the both terminals as furnished. The enclosure should be grounded externally to the positive terminal, and the positive terminal should be connected to electrical system ground.

ISPs with the 118kA designation manufactured after March 15, 2015 have construction and dimensions as shown in drawing #100070, attached. This repackaged design has the same footprint, uses the same mounting hole locations, and has identical internal construction as all previous ISPs furnished in this rating. The unit is sealed, and features an externally mounted Test Point.

FACTORY STANDARD OPTIONS

Model Code "F"

TP = Test Point. This ISP is furnished with a multi-pin connector through which the unit can be comprehensively tested in-situ with a field tester available for rent from Dairyland Electrical Industries.

Rev4 = Rev. 4 of logic/control circuit (current version).

40 = Maximum allowable dc current that can be flowing through the ISP when in its conducting mode and still enable the device to be automatically reset back to its normal mode after a fault condition.

L = Red LED indicator that will flash about once per second only if the dc voltage is above the voltage blocking level (i.e., about 12.5 volts) or if the steady state ac current is above the steady state rating for this model (i.e., above 120A). Should either of these conditions occur, consult DEI. Under normal operating conditions this LED should always be off.