
The Application Note is pertinent to the Mentor II / Quantum III Family

Inversion Faults in Regenerative DC Drives

This application note will try to describe what an inversion fault is, what it is caused by and how to minimize the risk of its occurrence.

An Inversion Fault is a fault in a regenerative DC drive (does not occur in a non-regenerative DC drive) whereby the current, which was being supplied back to the AC power line from the DC motor, is not properly commutated (or switched) to the next available AC power line.

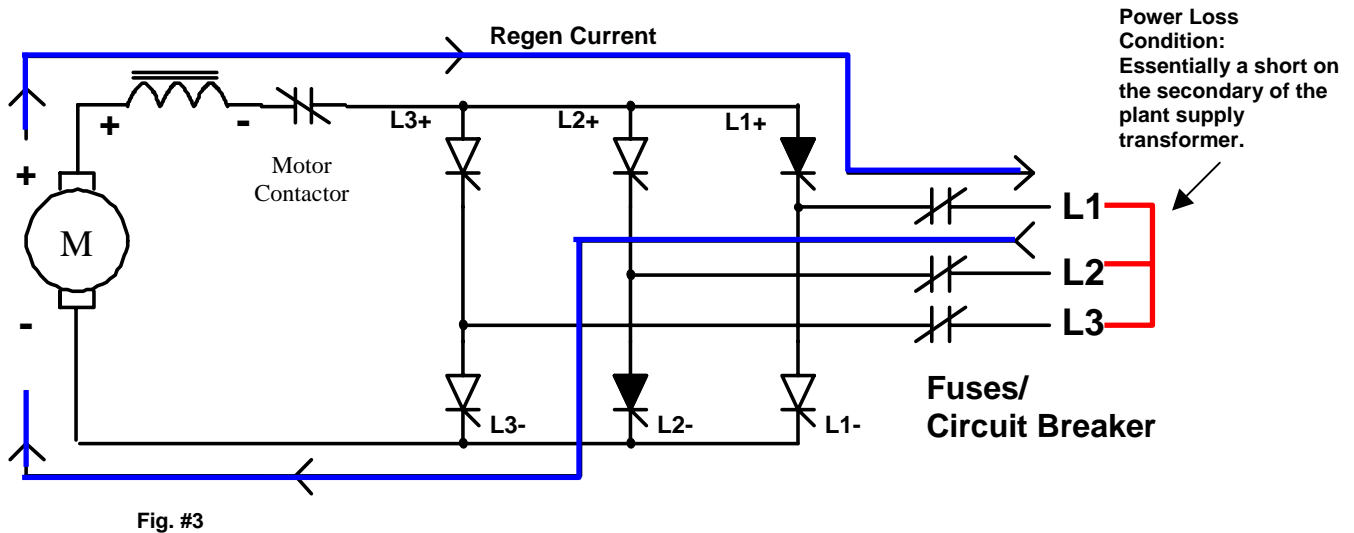
All SCR (silicon controlled rectifier) type dc motor drives whether they are non-regenerative (meaning single directional, two quadrant) or regenerative (meaning bi-directional, four quadrant) are known as line commutated converters. This means that they convert from one type voltage (ac) to another (dc) and count on the incoming three phase alternating line voltages to commutate the SCRs on and off. The SCRs can be turned on when there is a positive voltage across them (anode positive, cathode negative) and a gate pulse is applied to the gate connection of the SCR. Once current starts to flow, the device will not turn off until the current goes to zero even if the voltage across the device even goes negative (which it does toward the end of each conduction period). The device can be “forced” off during this time by gating on another SCR that has a more positive voltage across it. This actually forces the current to be reduced to zero in the conducting SCR and to increase it in the SCR that was just gated on. The only requirement is that all the current must be switched to the new SCR before the voltage across the “off going” SCR goes positive again. If this happens, the “off going” SCR will stay on and a drive fault will occur (this is known as a commutation fault). In a non-regenerative drive, this occurrence will merely cause a loss in output voltage. In a regenerative drive however, a severe over current condition can (and probably will) occur, which Drive Engineers have called an Inversion Fault.

Commutation faults can be caused by a variety of events:

- A. Loss of line voltage, which is probably the most common,
- B. A dip (or brown out) in the line voltage
- C. Excessive armature voltage
- D. Failure, or mal function of a gate circuit
- E. Poor power line quality (too soft with wide line notches)

For addition reading on Power Line Considerations (Hard Lines/ Soft Lines) click below:
http://www.emersonct.com/download_usa/techNotesMisc/PowerlineConsiderations.pdf

The next possible event is when the plant voltage goes to zero (power outage).



In this case, the motor is essentially shorted through the AC line connections. The current will build up to a level where the fuses / circuit breaker opens, when this happens, the same event will occur as described for figure #2 above.

The third possible event is where a commutation cycle is missed due to a “weak” gate pulse to the SCR, a “brown out” (dip in the line voltage) or too high of a motor voltage with respect to the line voltage level. In this case, the current will continue flow and begin to increase. If it reaches a level where the line fuses or circuit breaker opens, the scenario as described for figure #2 will occur. If the current does not reach this level (within approximately 2.77 milliseconds @ 60Hz), the next commutation cycle will begin gating the next SCR in the sequence causing a direct short across the motor will occur. Figures #4 through #6 below show this sequence.

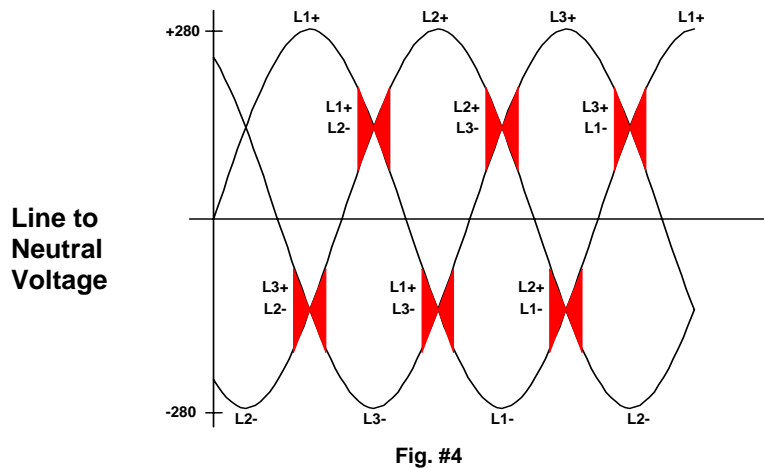


Figure #4 above shows the typical SCR firing sequence (areas in red) of a regenerative dc drive. From left to right, the SCR firing sequences would be as follows; L1+L2-, L1+L3-, L2+L3-, L2+L1-, L3+L1-, L3+L2- and would repeat the sequence all over again every line cycle. Each SCR conducts for two consecutive 60-degree (2.77 milliseconds @ 60Hz) periods. Once the SCR is gated on, it will stay on until the current flowing through the SCR goes to zero.

Figure #5 shows the conduction sequence L1+L2-.

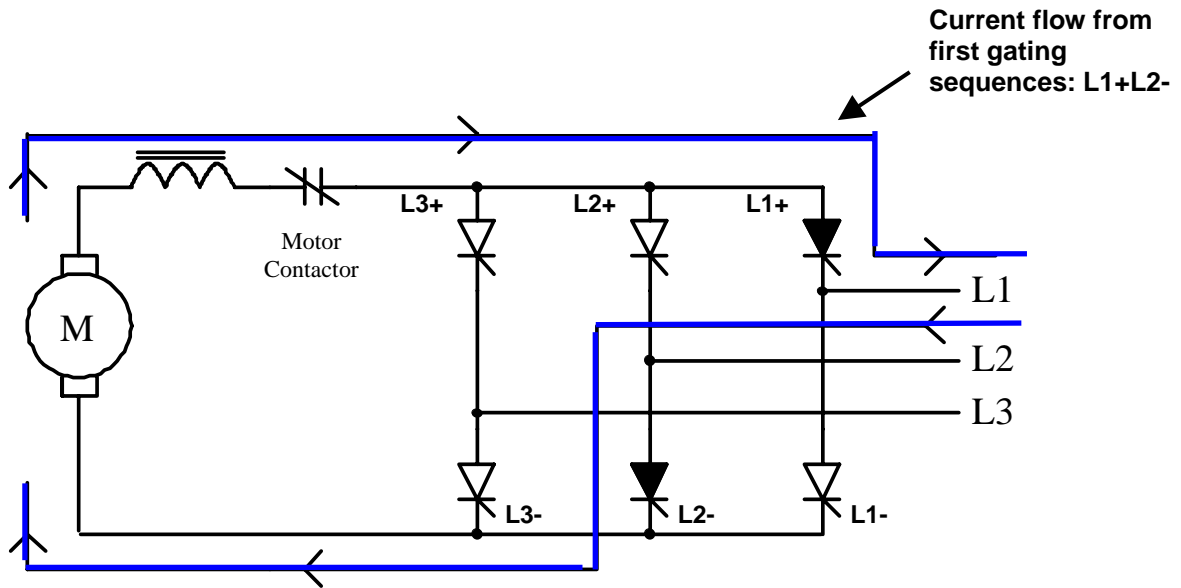


Fig. #5

Figure #6 below shows a missed gating sequence (designated by dark blue colored items).

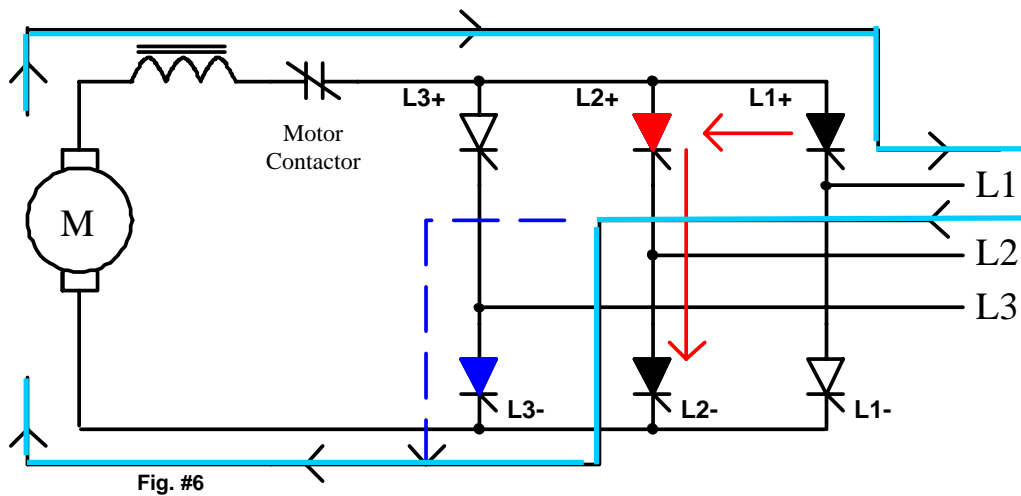


Fig. #6

When the gating of L3- failed, the current continues to flow through L1+ and L2-. The next firing sequence is L2+L3-, since SCR L2- is still conducting, when SCR L2+ fires there will be a direct short across the motor. Very high current will flow from the motor through the contactor and the SCRs. If the motor contactor tries to open, it will create a severe arc and most likely damage the contactor (shown by the path in red).

Minimizing the risk of Inversion Faults

1. One of the most common reasons for an Inversion Fault is excessive armature voltage.
 - The rule for this is that the **MAXIMUM armature voltage** should be limited to 1.05 times the **LOWEST line voltage** the drive will operate on. This calculates out to:

For 480vac line – 504vdc armature voltage max.
For 240vac line – 250vdc armature voltage max.

In Mentor II and Quantum III drives this is set by parameter #3.15

If tachometer feedback is used, armature voltage cannot be ignored or assumed to be correct.

- If the drive has a field current regulator, set the field current such that the armature voltage is within 1.05 times the lowest line voltage when the motor is running at the motors base speed.
 - If the drive has a voltage supply for the motor field, the maximum armature voltage should not exceed the maximum armature voltages given above when the motor is running at maximum speed and when the motor is cold.
 - If field weakening is used, the armature voltage at base speed should be about 10-20 volts less than the maximum armature voltages given above. When running at the maximum extended speed, the armature voltage should not exceed the maximum armature voltages given above.
2. A poor quality line voltage can cause Inversion Faults.
 - If there are many DC Drives on the same power lines, line notches created by one drive can affect another drive. To enhance reliability, each drive should be on its own isolation transformer or at a minimum have a 1½% to 5% line reactor.

For more information and on Line Reactors click on the link below:
http://www.emersonct.com/download_usa/appNotes/CTAN132.pdf

For more information and on Isolation XFMR's click on the link below:
http://www.emersonct.com/download_usa/appNotes/CTAN144.pdf
 - The service to the drive should be a high enough KVA rating for the drive size. Too "soft" of a line can cause inversion faults. A reasonable rating of the service would be one that can supply a short circuit current of 20 times the input current rating of the drive but less than 66 times.
 3. Do not "kill" the circuit breaker or power feed to the drive while the drive is running. If it is regenerating at the time it will cause an Inversion Fault. Command the drive to stop and wait until the motor is stopped first.

Installations where Power Outages are common

There are installations where power outages are common due to bad weather conditions such as lightening storms or where power quality is generally poor. In these situations, the drive system must be designed to “tolerate” inversion faults or change to another technology such as a regenerative AC drive system since they are not subject to inversion faults. Some general guidelines to designing systems that must “survive” inversion faults are given below.

1. Use Mentor II with a contactor rated for this type duty. Typically these externally mounted contactors have bi-directional magnetic blowouts. These contactors will withstand many faults but will eventually fail due to arcing of the contacts. Some examples are:
 - Joslyn Clark Type 5DP series
 - ABB Type EFLG series
2. Use a high-speed semiconductor type armature fuse and line fuses sized for the specific motor being used.

Recommended fuse types:

- Gould Shawmut Type A70P (for armature), A50P (for line)
- Bussmann FWP (for armature), FWH (for line)

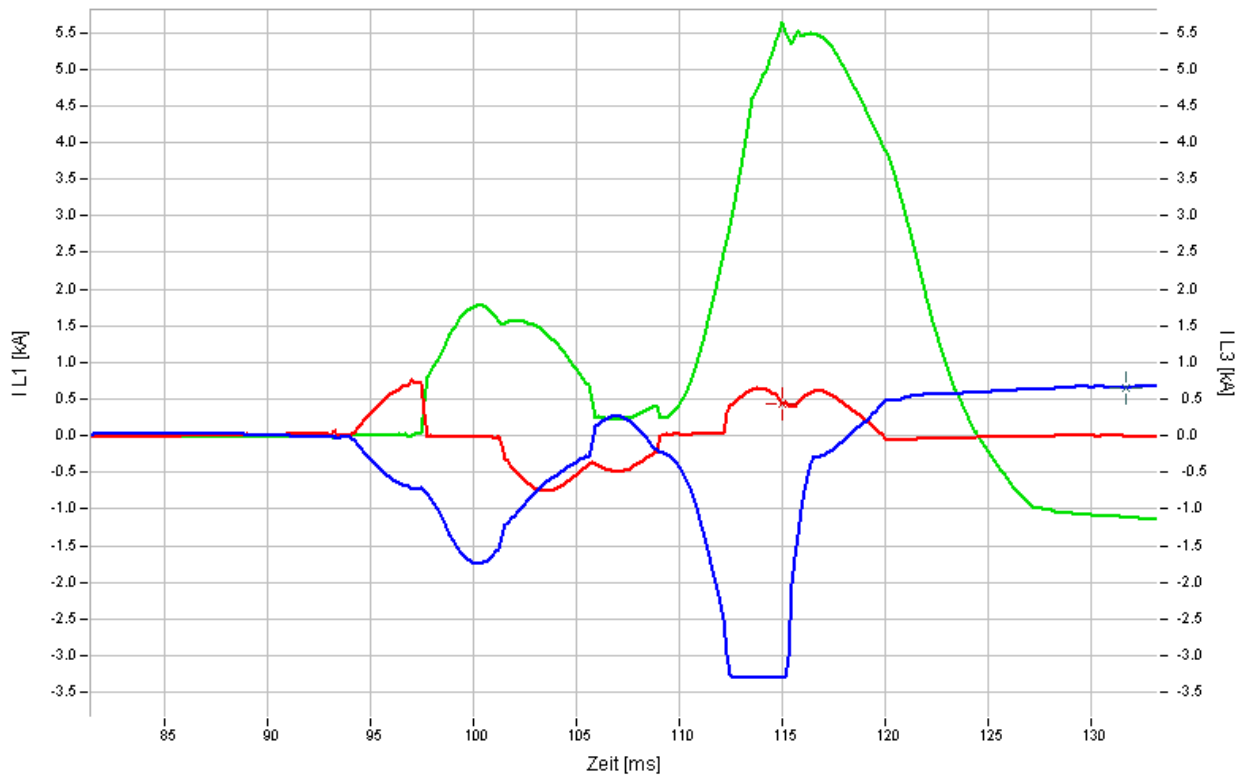
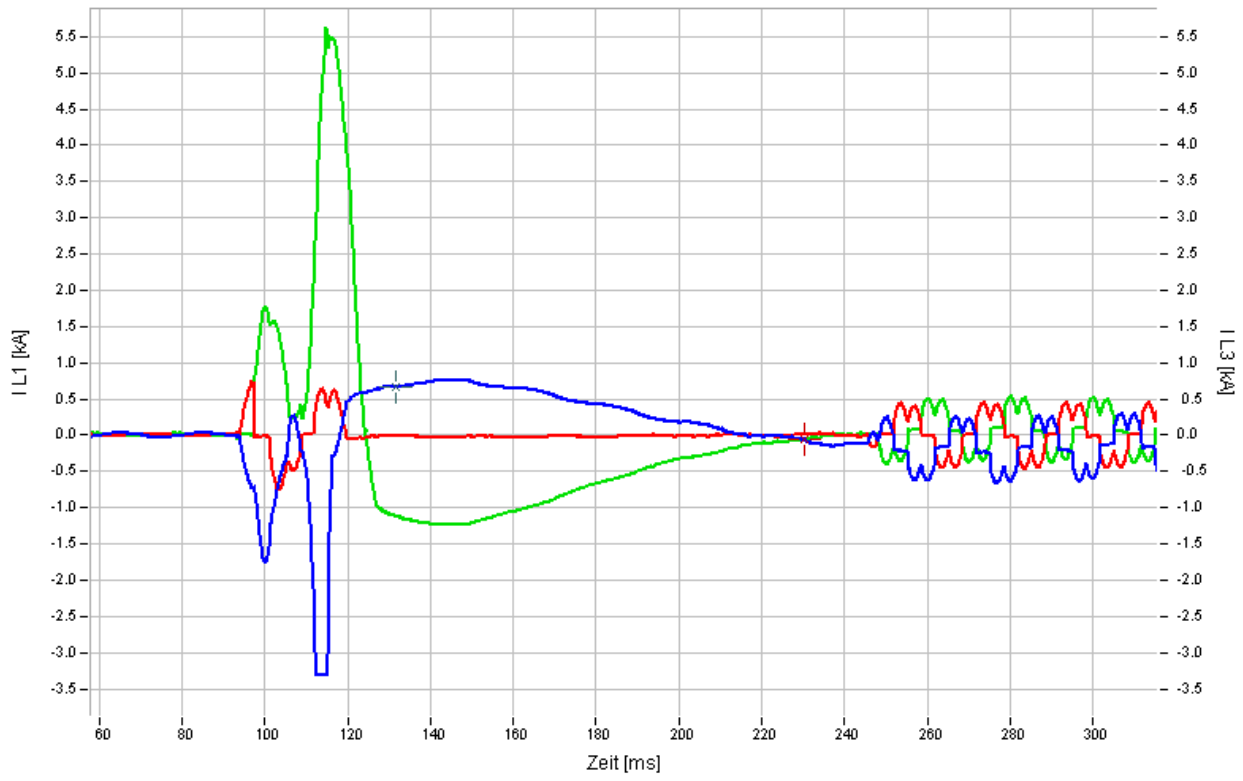
Applications prone to Inversion faults

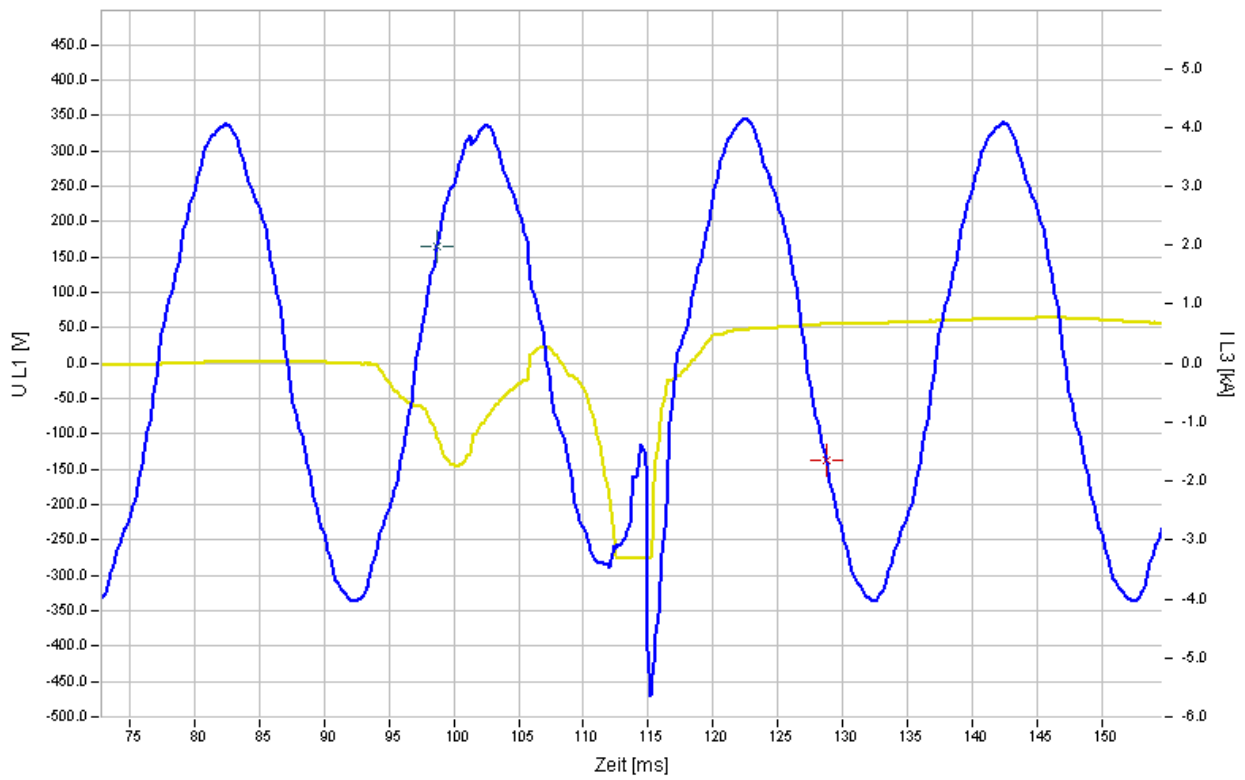
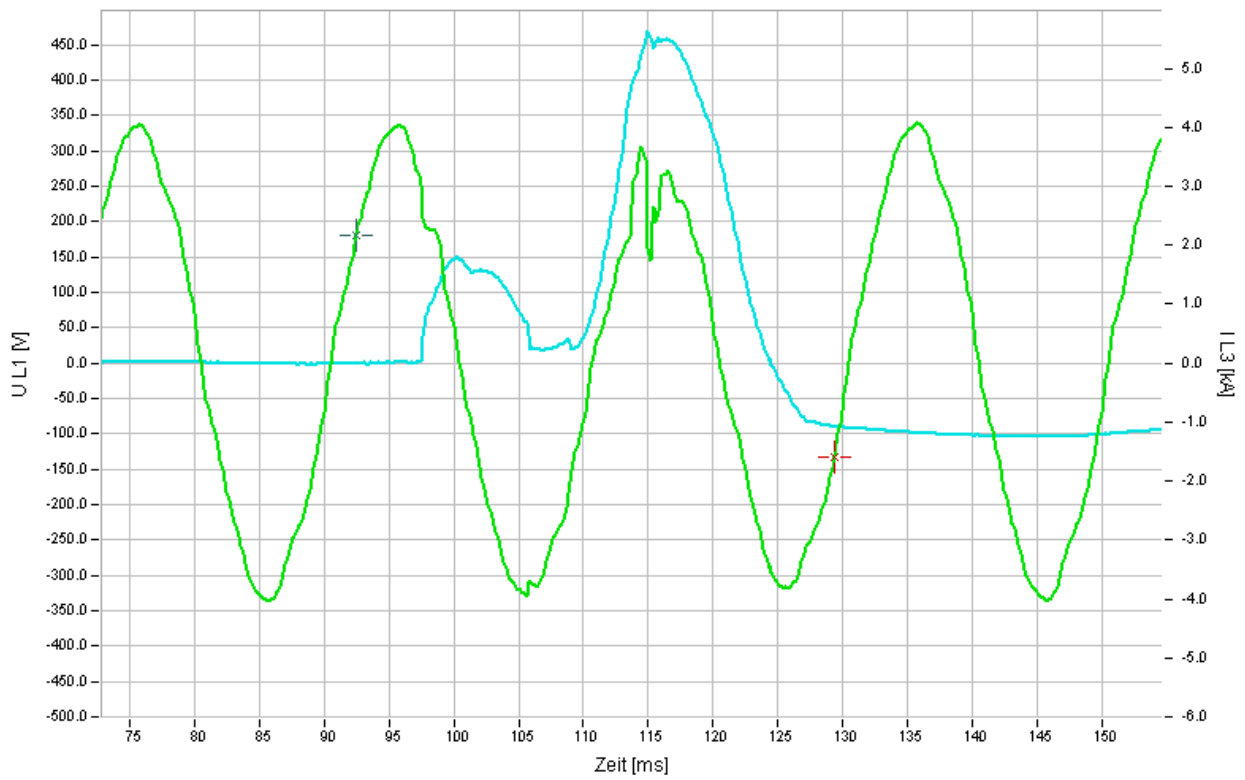
In general, the most common applications that are prone to Inversion faults are those that have high inertia loads connected to the motor armature. These systems store large amounts of energy in the rotating mass (fly-wheel inertia) and typically utilize a regenerative drive to stop the motor in a short time. Examples of such systems would be Metal Stamping Presses, Centrifuges and Amusement Rides.

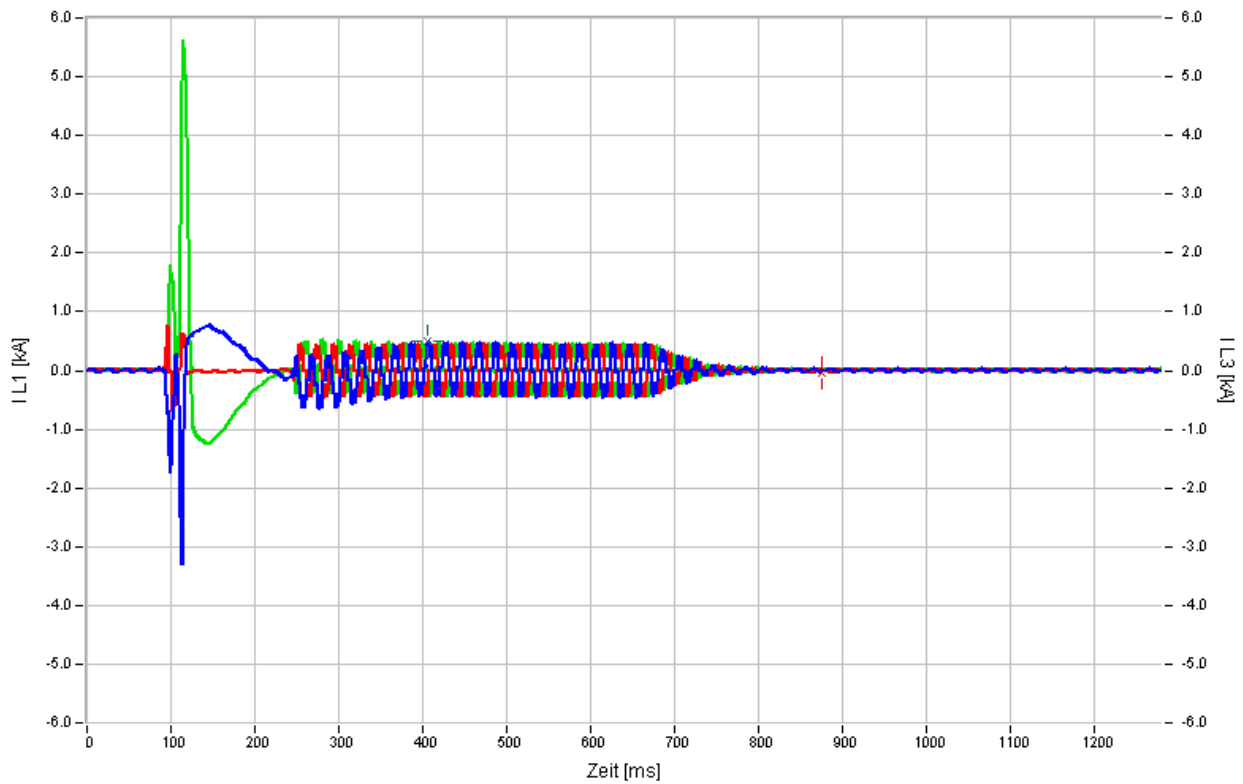
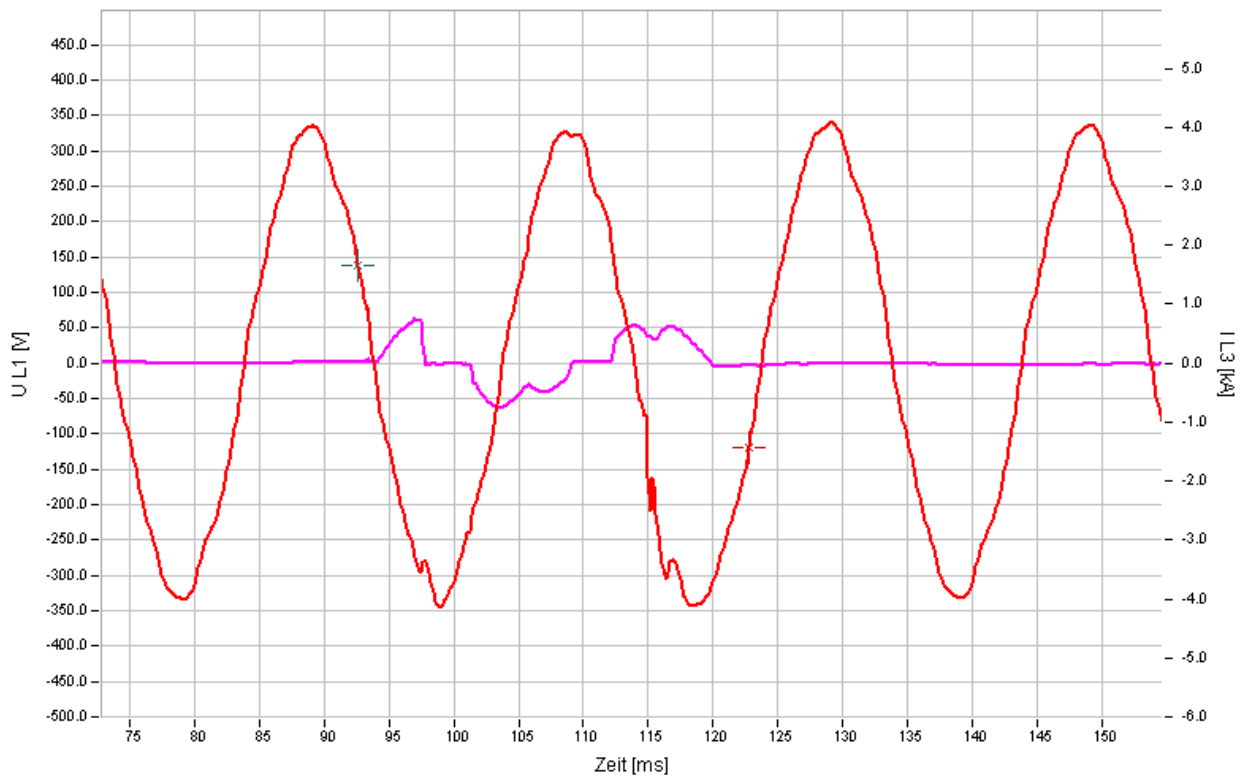
Below are some actual graphs from a chart recorder that was monitoring supply line conditions when an inversion fault occurred on a motor test stand.

These graphs have been supplied courtesy of **Lothar Baehr, CT Hennef Germany.**

Measured Variable	EH	Plot
U L1	[V]	*****
U L2	[V]	*****
U L3	[V]	*****
I L1	[kA]	*****
I L2	[kA]	*****
I L3	[kA]	*****







Questions: Ask the author ??

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