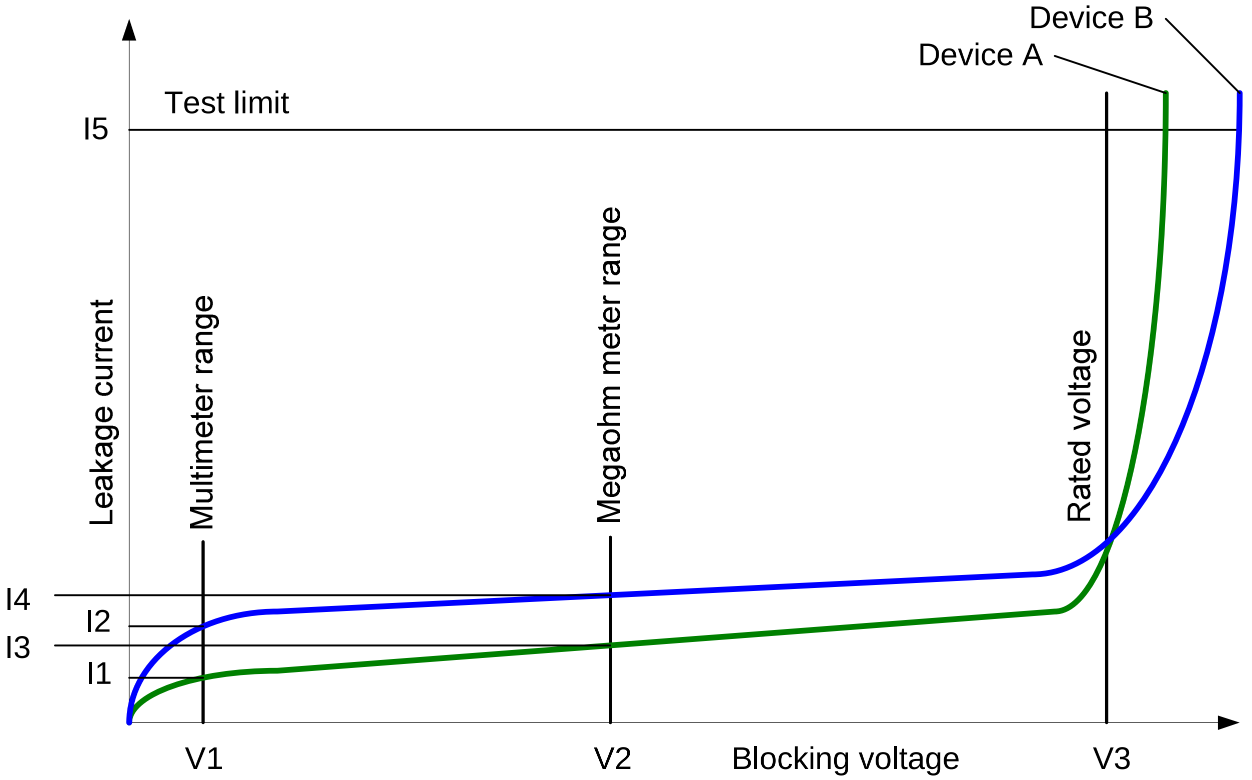
Power Semiconductors

Application note

Field measurements on High Power Press-Pack Semiconductors



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Application Note

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1 Introduction

All high power press-pack semiconductors from ABB are tested for their functionality and performance before leaving the factory and can be inserted in equipment without any further measurements. There are however occasions where a device needs to be field tested for fast, on-site verification following, for instance, a system fault. This application note gives hints and tips on for these measurements and guidelines on interpreting results.

It should be noted that only a few very basic electrical parameters can be verified by on-site electrical measurements of high power semiconductors. It is not possible to deduce data on expected or remaining component life-time from such results.

2 Measurements on components when not in service

In normal operation, components are measured using oscilloscopes. There may be cases however e.g. subsequent to a fault, where field tests are required on individual semiconductors prior to starting or restarting an equipment. Two basic cases will be considered: the devices have not yet been mounted in the equipment (and are therefore loose, on a bench) or the devices are correctly mounted but the equipment is not powered. Such field tests will normally be performed with fairly basic instrumentation such as a multi-meter rather than with the sophisticated and dedicated test gear with which the devices were tested at the manufacturer's out-going inspection in which full temperature, voltage and current limits were tested. In this paragraph we describe some of the common measurement methods used in the field and which conclusions can and cannot be drawn from them.

For a full characterisation of high power semiconductors, dedicated production or laboratory equipment is required. Commercially available equipment for *field* measurements of high power semiconductors is not common but do exist such as portable testers available from *LemSys*, Geneva. For information about these products please visit www.lemsys.com.

2.1 Safety issues

For safety reasons, all high voltage measurements must be made by personnel trained and certified for working at the required voltage levels. The measurements must be made according to local, national and international safety laws and regulations.

For field verifications on devices *in situ* i.e. not in operation, voltage and/or current sources not used for the measurements (such as the main converter supply) must be disconnected and locked to prevent them from being re-connected during intervention. Paths in parallel with the device such as RC-snubber circuits, should be disconnected during the measurements to ensure that the semiconductor alone is measured. Disconnecting these additional components is especially important when measuring devices at high voltage. Semiconductor (instantaneous) voltage ratings are far higher than their working voltages. Thus, tests performed to the semiconductor's full rating could be damaging to auxiliary devices as snubber capacitors. Note that semiconductor voltage ratings are peak and not RMS values.

The measurement equipment must be designed for the prospective voltage and current levels. When in doubt, contact the equipment supplier to determine whether the equipment is suitable for its intended use.

2.2 Fault tracing using multi-meter or mega-ohm meter

Frequently, the only equipment available on site for measurements on high power semiconductors are multi-meters and sometimes mega-ohm meters, sometimes referred to as “Meggers”. These meters are general-purpose equipment and not designed for measurements on devices with non-linear characteristics such as those of high power semiconductors. Information on the condition of power semiconductors which can be obtained by this type of equipment is therefore very limited: it can basically only indicate whether the path between two connections to a device is open or short circuit. An open circuit between anode and cathode (or emitter and collector) for a press-pack device is a very unlikely condition. Practically the only possibility for an open circuit in a press-pack device would be a failed gate connection (gate-to-cathode or gate-to-emitter). Ohmic values read by such instruments give no information whatsoever with regards to leakage current or blocking voltage capability.
With exceptions, high power semiconductors from ABB have blocking voltages in the range of 1200 – 8500 V. Multi-meters measure resistance using a voltage in the range of 1.5 – 15 V and the displayed resistance value only gives an indication of the leakage current at *that voltage level*. Due to the device’s non-linear blocking characteristics - which vary from device to device due to manufacturing tolerances - it is not possible to draw conclusions from such low-voltage measurements with regards to the device’s capability at a rated voltage 100 times higher than the measurement voltage. Mega-ohm meters measure resistance at voltage levels of 500 – 1000 V which is closer to the semiconductor’s rated voltage but is still generally not high enough to draw other conclusions about the device’s status other than to say that the device can block the measurement voltage i.e. that it is “shorted” (*failed*) or “not-shorted-at-that-measurement-voltage” (*possibly, not failed*).

These measurements should be (and are, typically) made at room temperature. A hot device will have a comparatively high leakage current and depending on the scale of the mega-ohm meter, it can be difficult to distinguish between a shorted and a non-shorted device since the resistance value measured on a non-shorted device can also be quite low. This is because the leakage current of a silicon-based semiconductor doubles every eight degrees Celsius. At room temperature, the leakage current of a good (non-shorted) device is much lower and the distinction between shorted and non-shorted devices is clearer.

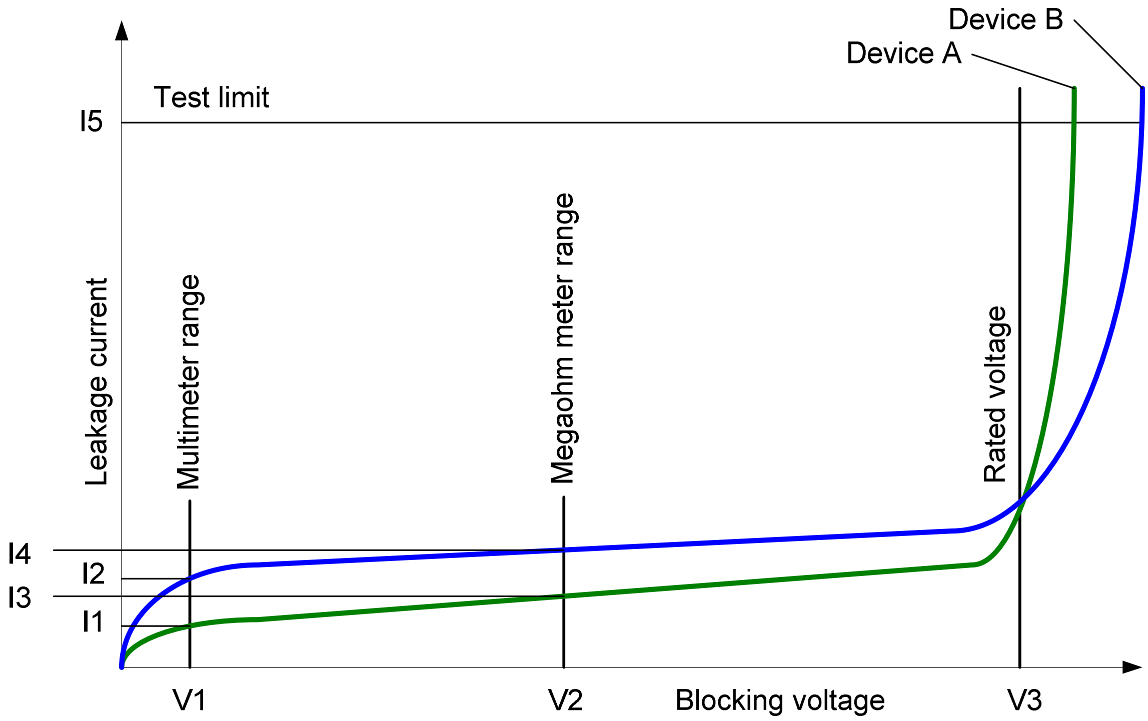

Figure 1: Comparison of blocking characteristics of two semiconductor devices of the same type.

To show why the resistance value is of little use and can lead to miss-interpretations, let us look at the example of Figure 1. In the figure we have drawn the blocking characteristic of two devices of the same type with blocking voltages of about 2000 V. Both have a leakage current at rated voltage V3 well below the manufacturing test limit I5 (normally the limit specified as I_{DRM} or I_{RRM} in the device data sheet) and have passed the out-going inspection of the manufacturer. At the test limit of I5, device B blocks a few more volts than device A.

When measuring resistance with a multi-meter using a source voltage V1 we will get a resistance value of V1/I1 for device A and V1/I2 for device B. Since I2 > I1 device B will show a lower resistance than device A. The only conclusion we can draw from this is that none of the devices are shorted. Device B has a lower resistance than device A but only at the voltage level used for the measurement. We cannot draw any conclusions whether the devices will block full voltage or not. To conclude this we need to measure at a voltage level of V3. As can be seen it is actually possible that the device with “lower resistance” in fact blocks more voltage at the rated test limit.

When measuring the two devices with a mega-ohm meter at voltage V2 the only additional information we obtain is that the devices can block the higher measurement voltage. Device B will still show a lower resistance than device A, since I4 > I3, but that does not give any additional information. Comparing the resistance values measured with the multi-meter with those obtained with the mega-ohm meter simply shows that the devices are non-linear. Only when measuring the leakage current level at V3, can we deduce whether the devices meet their blocking ratings.

Due to the internal design of high power press-pack semiconductor devices, a force must be applied during the measurements to ensure that the internal parts are properly contacted. Due to the internal design the devices may give a rattling noise when lightly shaken. This noise is harmless and does not mean that the device is broken. Excessive shaking may however harm the device and should be avoided. For voltage and/or resistance measurements, a force of at least 1 kN should be applied.

Most modern digital multi-meters have an integrated diode measurement function. When measuring high power semiconductor devices this function can be used to check the polarity of diodes but any other readings fall under the same limitations as the resistance measurement described earlier.

It must be noted that GTOs, IGCTs and IGBTs have blocking capabilities that depend on the gating conditions. These dependencies are shown in the device data sheets and should be consulted before performing measurements at high voltage to avoid misleading results or device failures.

Certain semiconductors such as asymmetric GTOs, have polarity-dependent blocking capabilities (reverse blocking is much lower than forward blocking capability). To avoid damage, tests must be performed with voltages corresponding to the polarity.

When measuring IGBTs, special care must be taken with regards to Electro- Static Discharge (ESD) at the gate terminal. IGCTs are supplied with gate drivers which should also be handled cautiously with regards to ESD.

2.3 Control of the gate path on thyristors and GTOs

Since the maximum allowed voltages gate-to-cathode is 10 – 15 V for thyristors and 15- 20 V (reverse) for GTOs, gate-cathode voltage measurements should not be made with mega-ohm meters due to the risk of destroying the device. When using other instruments such as multi-meters, always ensure that the measurement source voltages are within the device voltage rating. Since the gate-cathode path is also non-linear, the observations from the paragraph above apply here also.

As mentioned earlier, gate-cathode measurements can reveal an open circuit. This could be the case of a broken gate wire either externally or internally. Such faults can be detected using the diode function of multi-meter: a value of about 0.6 V in one direction and a high resistance in the other normally means that the gate path is in order. A very high ohmic value or open circuit in both directions indicates a broken gate wire.
IGBTs have isolated gates so an open-circuit measurement cannot distinguish between a “good” or a “failed open” gate-emitter path. Furthermore because of the risk of damage through ESD, this kind of field measurement should be avoided.

3 Notes on measurements on equipment in operation

Certain semiconductor measurements can only be done when the equipment in which the device is installed, is operating. On example is tracing the source of spurious device triggering, which normally requires equipment operation. These measurements need special care since the voltage and current levels are generally very dangerous.

3.1 Safety issues

Measurements on high power semiconductor devices are dangerous. For safety reasons, all measurements on high power semiconductor devices must be made by personnel trained and certified for working at the corresponding voltage levels. The measurements must be made at conditions meeting local, national and international safety laws and regulations.

The main converter supply must be disconnected and locked whenever changes to the measurement circuit are made.

The measurement equipment must be designed for the prospective voltage and current levels. When in doubt, contact the equipment supplier to determine whether the equipment is suitable for its intended use.

Measurements should be performed with a disconnected main circuit wherever possible.

3.2 Current measurements

It is preferable to make galvanically isolated current measurements i.e. current measurements that do not require the display instrumentation (e.g. oscilloscope) to be at high voltage (or “live”). There are several current sensors which allow this provided their isolation ratings are higher than the prospective test voltages. This should be verified by against the specifications of the considered sensors prior to connection. Typically IGBTs and IGCTs produce fast transients requiring current transducers with good dynamic performance but this may also be required when searching for sources of spurious triggering in Thyristor circuits. Pearson current transducers (www.pearsonelectronics.com) and Rogowski coils (www.pemuk.com) are normally used for fast transient measurements. For slower transients and DC current measurements, Hall-effect sensors (www.abb.com/lowvoltage) can be used.

Since high power semiconductors can switch very high currents and voltage within very short times, Electro-Magnetic Interference (EMI) at the measurement points can be intense, strongly perturbing the measurement results. Precautions must be taken to minimise this interference for the test results to be meaningful. Precautions include careful measurement planning of sensors and display instruments positioning, routing of measurement cables to avoid or cancel induced signals, grounding and eventually also filtering.
Since thyristors and GTOs are current controlled, fault tracing in the gate circuit should be made with measurements of the current and not the voltage. In many cases current probes supplied by the main oscilloscope manufacturers such as *Tektronix* (www.tektronix.com) or *LeCroy* (www.lecroy.com) are sufficient for the purpose of fault tracing.
When looking for causes of spurious triggering in Thyristor circuits, it must be remembered that pulses of less than 1 A and of duration shorter than 1 µs are enough to trigger a thyristor and therefore the sensors or probes must be selected to detect such fast transients. Thus instrumentation bandwidth must be determined from the manufacturer’s specification and for safety reasons, the rated isolation voltage verified prior to any measurements.

3.3 Voltage measurements

It is more difficult to find instruments for galvanically isolated voltage measurements. Fibre optic connected and Hall-effect sensors are available but tend to be expensive and of limited bandwidth. High voltage probes (www.tektronix.com or www.lecroy.com) for direct measurements are generally deemed better. Since these, however, are directly connected to high voltage, safety considerations require a sound grounding and isolation level analysis before starting measurements.

Probes for measurements on high voltage semiconductors need to be calibrated at high voltage to ensure that the transient response, especially with high dv/dt, is correct. It is not normally enough to calibrate them using the calibration output of the oscilloscope due to the low voltage level. Suitable calibrators are not common but can be obtained from pmk (www.pmk-gmhb.com).

4 Additional notes

4.1 Technical support

For further information please contact:

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