NOVEL PRESS PACK IGBT DEVICE AND SWITCH ASSEMBLY FOR PULSE MODULATORS

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Abstract

As the trend for Pulse Modulator applications nowadays is moving strongly into the direction of switch-on/-off devices, ABB has developed a new IGBT module which is designed to operate under specific pulsed power, non industrial standard conditions.
A press pack IGBT module will be presented which is optimized for pulsed power applications. The device has a collector-emitter voltage Vces of 4500V and is offering a chip set combination of 85% IGBT and 15% diode dies. The device has excellent current sharing between the individual chips, no wire bonding, and it will be shown that the advantages of the new design are high peak current at high dt/dt and high switching frequency as well as immunity to inhomogeneous clamping. The last is very important in case a large number of series devices are used, especially in applications where mechanical ruggedness is required, these devices are superior to conventional press pack IGBT's. A ready-to-use 20 kVdc / 4 kA switch assembly containing 7 pieces of the mentioned devices in series connection including cooling and driving circuit will be described.

I. INTRODUCTION

As IGBT technology based switch assemblies are ideal for modulators due to on and off switching capability, ABB decided to develop a high reliable press-pack IGBT module for use in series connection. The ABB IGBT Press Pack switching technology presented in this paper, was developed in 2002 and is now also available for 4.5 kV switching voltage which is more economical than the initial 2.5 kV switching devices. The device itself is based on ABB's HVDC Press Pack technology and is optimized for pulsed power applications. It shows superior mechanical ruggedness compared to conventional packages with bond wire connections and is designed for series stacking in high levels while being almost immune to misclamping. Every chip in the module has its own pressure contact (Belleville spring). This leads to equal clamping pressure on each chip and to excellent current sharing between the chips.

II. NOVEL PRESS PACK IGBT DEVICE

The technology of the novel press pack IGBT device for pulsed power applications is based on the standard ABB press pack (StakPak^{TM}) device, which is mainly used for High Voltage DC transmission systems (HVDC). The module described in this paper contains two (2) subassemblies. The chipset in those subassemblies is optimized for pulsed power applications by having more IGBT chips than diode chips inside (85% IGBT / 15% Diode) compared to the HVDC configuration which contains an IGBT / Diode ratio of 50% / 50%. This gives the module more switching power. The specification of the module is shown in table 1. below.

Specification 5SNA 1250K450300 (Device)	
Collector Emitter Voltage	4500 V
DC Collector current	1250 A
Max. repetitive turn on / off current	4000 A
Max. short circuit current	6000 A
Current Rise Rate (di/dt)	4000 A/us
Max. pulse repetition rate	3000 Hz

Table 1. Specification of the IGBT press pack device 5SNA 1250K450300.

ABB has a range of industrial type IGBT modules which are mainly used for energy conversion, motor drives and traction application. These modules are built-up with multiple chips in parallel connection and therefore the current sharing in the module is normally not designed for pulsed applications. In addition the chips have wire bonded connections which can be a reliability issue if used under pulsed stress conditions. In case of series connection, the wire bonded modules will have an open connection in case of failure and the switch will stop operating. To avoid this type of reliability problems, the solution for pulsed applications is to use press pack IGBT modules. Since 2002, ABB is producing so called StakPak^{TM} press pack IGBT devices [1] in high volume for High Voltage DC Transmission (HVDC) systems. These devices have a blocking voltage of 2.5 kV and can handle currents up to 4 kA. In 2011 the production for 4.5 kV press pack IGBT devices for pulsed power applications has started, based on the same press pin technology. The advantage of the ABB Press Pack construction is the unique mechanical construction which makes the devices very easy to stack without any

precautions for clamping force and pressure distribution over the individual chips. Every chip is covered by its own small Belleville spring and pressure can be added to the device until the housing frame of the device is taking the surplus clamping pressure, which means that over clamping is not possible. The design will allow flexibility to combine all required combinations of IGBT and Diode chips in the Sub-modules. Fig. 1 shows the construction of the 2.5kV version and Fig. 2 the sub-assemblies and device of the 4.5 kV version. All relevant parts like heat sinks and driver units are available.

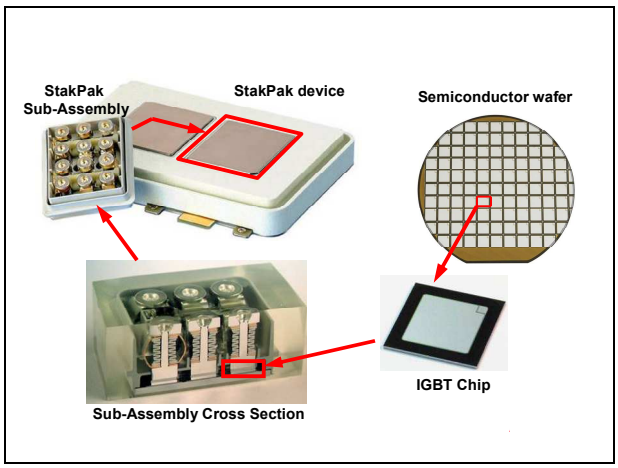

Figure 1: Detail of basic construction of the 2.5kV Press Pack IGBT

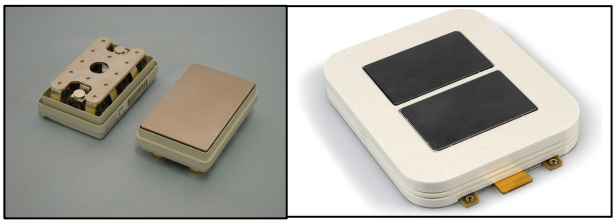

Figure 2. Left: Sub-Assemblies with 4.5kVdies
Right: 4.5kV Press Pack Device 5SNA 1250K450300

III. TEST RESULTS

The devices are tested under standard conditions and also under specific pulsed power conditions. One of the tests was during a period of 117h duration under modulator application conditions. No change in behavior or thermal runaway was noticed. The test was performed with several devices under the same conditions: Vdc=3kV, tp=7.0µs, f=100Hz, Ic=4.2kA.

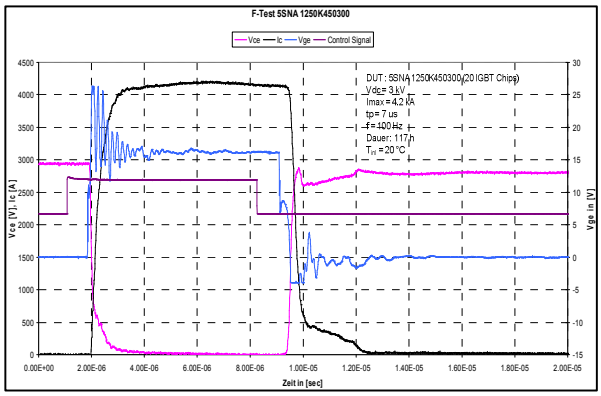

Figure 3. Test Results of 5SNA 1250K450300 under specific conditions.

IV. PRESS PACK IGBT SWITCH ASSEMBLY

ABB is in the position to supply complete IGBT press pack switch assemblies up to 45 kVdc charge voltage. The assemblies are based on the previous described press pack module in the two (2) subassemblies version. The switch presented in this paper is a ready to use switch for 20kV DC charge voltage. The switch is built up with 7 devices, each blocking 4.5kV. For reliability reasons, which are mainly cosmic ray conditions, the maximum applied voltage per device level is reduced to approx. 2.8kVdc.

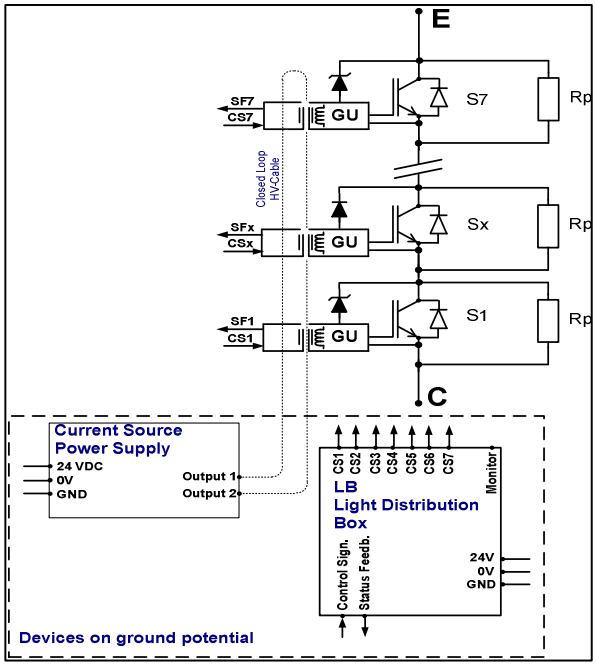

Figure 4. Circuit diagram of 40 kVdc IGBT Press Pack Assembly (P/N 5SVI 071711E02)

The design of the switch is modular and can, according to the required charge voltage, vary in the quantity of device levels (e.g. a charge voltage of 6 kV DC requires 4 devices in series; a charge voltage of 45 kV DC requires 16 devices in series). The complete switch assembly is built up from IGBT press pack devices, the corresponding gate unit, active clamp, and sharing resistors as well as water cooled heat sinks, auxiliary power supply, isolated clamping system and light distribution box.

Specification: 5SVI 071711E02 (Switch Assembly)	
Max. charge voltage	20 kV DC
Turn on / off current	4.2 kA
Max. short circuit current	6.0 kA
Current Rise Rate (di/dt)	4 kA/us
Pulse repetition rate	100 Hz
Pulse width	7.0 µs
Quantity of devices in series	7 pcs
Cooling	De-Ionized Water
Clamping system	Alu, glass fiber epoxy
Clamping force	40 kN
IGBT devices	5SNA 1250K450300
Overall dimensions (mm)	H=590 W=260 D=400

Table 2. Specification of the ABB IGBT press pack switch assembly

The gate unit is special designed to operate under pulsed power conditions. To reach the isolation between the device levels it is powered through a current source power supply using a HV cable to energize the inductive coupling of the gate unit. The gate unit is optically triggered by a light distribution box. Each gate unit has an optical feedback which indicates the condition of the gate unit, the current source power supply and the IGBT device. The gate unit is EMV proof through a metal shield.

Figure 5. 5SNA 1250K450300 with gate unit and clamp resistors

The water cooled heat sink is made of Nickel plated Aluminium for this application. If it should be required in the application, it is also possible to have a version with stainless steel water channels inside. The power supply feeds the gate units with 25 kHz / 4A through an inductive coupling with a HV cable, which is also the isolation between the 7 gate-unit levels. The anode and cathode of the switch assembly are isolated by glass fibre epoxy rods of the clamping system. The clamping force of 40kN is applied between the base plate and the cross bar by using Belleville springs to apply the force. Due to the high clamping force applied to the stack, it is very stable and can be mounted in any position. To trigger all the device levels of the stack assembly simultaneously, a light distribution box is used. The light distribution box for this application, has 1 optical trigger input and 7 + 1 optical outputs, 1 for each gate unit plug and 1 for monitoring reasons. An optical status feedback is available in order to monitor the function of the box. The separate light distribution box and the built-in current source power supply need auxiliary power of 24 Vdc.

Figure 6. Water Cooled Press Pack IGBT Switch assembly 20kVDC with current source power supply. (P/N 5SVI 071711E02)

V. APPLICATIONS

This type of solid state switches is mainly used for pulse modulators in particle accelerators, free electron lasers, radar power supplies and medical applications.

Therefore the reliability of the switch is extremely important. The switch design in combination with the described IGBT press pack module, guarantees a very long lifetime under the given conditions. ABB has extensive experience and several 10-thousands of devices for High Voltage DC transmission (HVDC) with the same press pack technology successfully in the field since more than 8 years. The new 4.5kV press pack technology has been successfully tested and qualified under the strict ABB standards. Since 2010 type tests are done on device and switch level. Full qualification will be finished by mid 2011 and from that time the device or switch will be commercially available.

VI. CONCLUSION

It has been shown that it is possible to reach a highly reliable IGBT solution for pulsed applications- The reason to use the Press Pack IGBT solution was to avoid wire bonding in the series connected modules. The wire bonding can age very fast in pulsed applications. The ABB press pack technology has a very good reliability due to its individual Belleville spring press contact for each chip, which guarantees good pressure distribution, excellent current sharing and a short circuit failure mode. The device with its rectangular frame is made for series stacking and is almost immune to misclamping. The ABB group has now the technology to build high repetitive on/off switches for pulsed power applications with an outstanding reliability. The product for pulsed applications is based on mass production series for HVDC applications.

VII. REFERENCES

[1] A.Welleman, R. Leutwyler, “Solutions with solid state switches for pulse modulators”, Pulse Modulator Conference PMC2008, Las Vegas, NV, May 2008.

Re-Print of presentation made at the 18th IEEE Pulsed Power Conference, Chicago, IL, June 2011