HITACHI ABB

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High-quality power semiconductor modules now support lower voltages

Hitachi ABB Power Grids Semiconductor is well known for its high reliability power semiconductors that support medium and high voltage applications, including IGBT power semiconductors used in the main traction chain of rail rolling stock, press-pack devices used in HVDC[1] or other T&D[2] applications, and various power semiconductors used in industrial applications such as medium voltage drives. Building on its experience of high-performance, high-reliability devices for voltages above 3.3 kV, Hitachi ABB Power Grids is now expanding its product portfolio to lower voltages. This whitepaper examines the use of power semiconductors in a low voltage drive with the general architecture shown below:

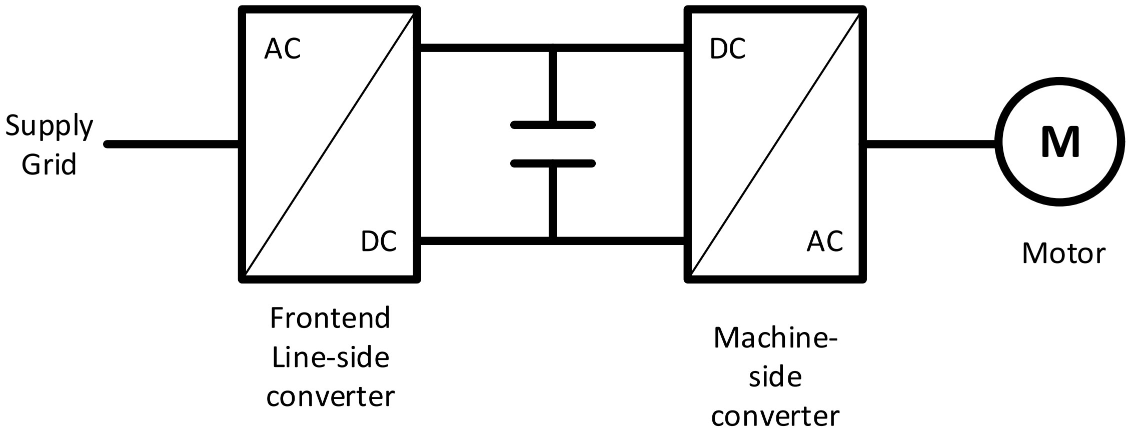

Figure 1: General architecture of a low voltage drive

The Frontend, also called line-side converter, converts an AC voltage to DC and supplies it to the DC-Link. Depending on the operating scheme, diodes, thyristors or even IGBTs might be used for this application. Typically products such as Hitachi ABB Power Grids Semiconductors' 60Pak diode and thyristor modules might be used because they feature industry-standard housings and very low losses together with the highest operating temperatures. This allows these devices to deliver the highest performance under load cycling, high thermal utilization, increased overload capability and many more benefits.

The 60Pak product family has press-force construction, where the assembly is pressed by the main spring to the baseplate (cooler), instead of a soldered connection. This construction produces a better performance, particularly improved reliability over the device's lifetime.

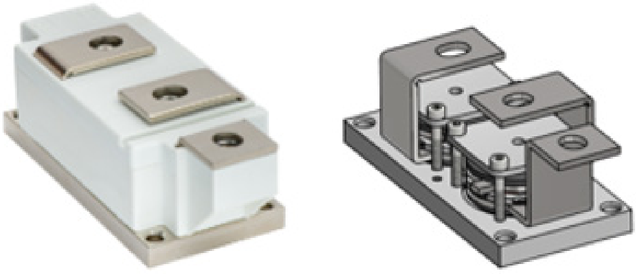

Figure 2: 60Pak Bipolar module

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[1] HVDC = High Voltage Direct Current distribution

[2] T&D = Transmission and Distribution

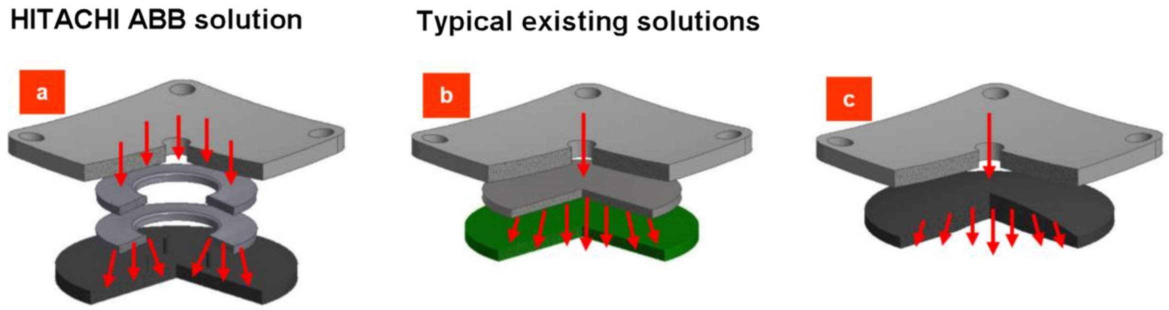
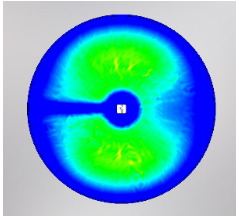
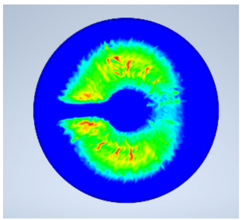
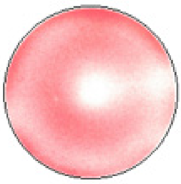
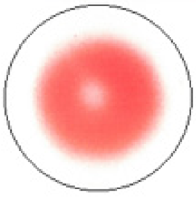


Figure 3:
a) dual spring construction
b) ceramic + metal force spreader
c) only plastic force spreader

The dual spring clamping system helps to achieve perfect IOL[3] performance, longer lifetime and enhanced resistance to temperature changes. The dual spring system consists of the main square spring on the top and pair of auxiliary springs. This unique setup enables close to ideal efficiency in a well-known hockey puck housing. In the pictures above you can see the force distribution of the two-spring system compared with ceramic + metal and plastic insulator force spreaders.

Figure 4:
Comparison of standard force distribution with dual spring force distribution

	Dual spring force distribution	Standard force distribution
Stress		
Test		

The modules passed the reliability tests shown below:

Storage at high temperature t = 1000h, Tc = 125°C ✓	High temperature reverse bias t = 1000h, Tc = 125°C, $V_{AC(peak)} = 2/3\ V_{RRM}$ ✓	
Storage at low temperature t = 500h, Tc = -40°C ✓	High humidity, high temperature reverse bias t = 1000h, 85% RH ✓	
Thermal cycling load (intermittent operating life, power cycling) N ≥ 20 000 cycles, $\Delta T_j = 80°C$ ✓	Verification of maximum module ratings $T_j = T_{jmax} = 160°C$ ✓	
Change of temperature Tc = -40°C / 160°C ✓	Shock and vibration (mounted modules and in transport box) ✓	Partial discharge Qpd < 10 pC ✓

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[3] IOL = Intermittent Operational Life

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The results show that this approach to module design brings the performance and reliability associated with Hitachi ABB Power Grids Semiconductors' medium and high-voltage devices to lower voltages.
For the active front end or the machine-side converter that connects the DC-link to the motor, LoPak modules are a common choice. These LoPak modules are now also available with pre-applied TIM[4], helping to increase reliability over the drive's lifetime.
The heat generated by the power losses during the operation of IGBT switches must be removed from the chip to prevent the junction temperatures of the chips rising beyond maximum allowable limits. Heat is transferred through the module to a heat sink, with the interface between the module baseplate and the heat sink typically having the highest thermal resistance and therefore contributing most strongly to the overall module thermal resistance.

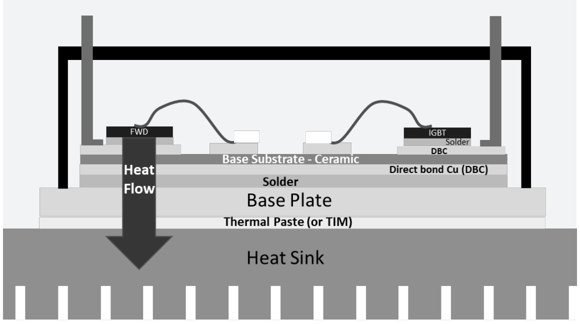

Figure 5: Heat flow pathway through module and layer contributions

Layer	Contribution to thermal resistance
Baseplate to terminal material (thermal paste)	50%
Device	3%
Solder	6%
Base substrate - ceramic	33%
Base substrate - DBC	3%
Baseplate	5%

Heat conducting paste is applied manually using stencil printing, leading to high variability in the amount of material applied and non-uniformity of its application across the interface area. The paste also remains viscous after application.

Appearance	Paste	TIM
Color	White or grey	Grey
Base material	Silicone fluid with filler	Phase change material with filler
Consistancy @ room temperature	Viscous	Hard
Thermal conductivity (W/mK)	0.8 - 3.0	5.2

Comparison of materials used between base plate and heat sink

The amount of thermal material applied and its application pattern, however, significantly impact the thermal resistance of the interface. The pattern design of the TIM takes into account the locations of highest heat generation and the intentional baseplate bending of the module, while ensuring the best possible metal-to-metal contact is made between the module baseplate and the heat sink. The TIM comes in a paste form and is applied using automatic stencil printing during module fabrication. It remains solid at room temperature, reducing the potential for damage to the print pattern by accidental contact and making module handling and installation easier for the customer.

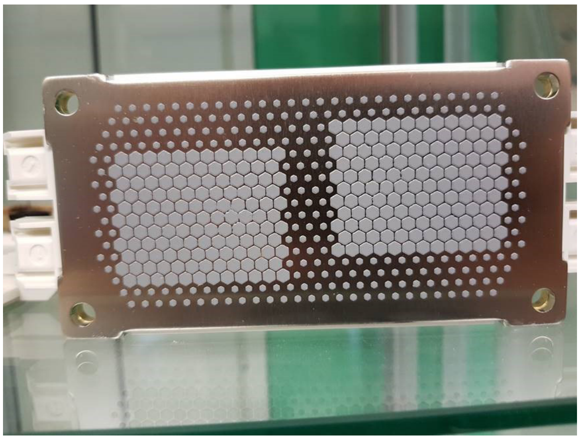

Figure 6: Baseplate bottom surface with TIM applied

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[4] TIM = Thermal Interface Material

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The better thermal stability of TIM compared to heat conductive pastes can be seen during power cycling, a standard test to simulate the degradation of the module over its lifetime by thermo-mechanical stress. The test was run for 9,400 cycles, in line with the JESD51-14 specification, using the maximum allowable junction temperature of 150°C, with a total cycle time of 120 seconds ($t_{on} = t_{off} = 60s$).
The results of this testing showed:

- A 7 percent improvement in the average thermal resistance for the entire pathway from the IGBT junctions to ambient when the TIM is used instead of heat conductive pastes
- An 11 percent improvement in the average thermal resistance from the case to ambient when the TIM is used instead of heat conductive pastes

Thermal resistance, average over 9400 cycles	Paste	TIM	Improvement
Junction to ambient (K/kW)	114.8	106.7	7.1%
Case to ambient (K/kW)	73.9	65.9	10.8%

Performance of TIM compared to heat conductive paste

The impact of using the TIM rather than the heat conductive paste can be seen by looking at data from the test for the partial thermal resistance from the case to the heat sink (where the TIM is located) and for the entire path between the transistor junction and the heat sink. While the initial thermal conductivity of pre-applied TIM is comparable with the heat conductive paste, the modules using TIM show no increase in thermal resistance with cycling, while those using the heat conductive paste show increasing thermal resistance during the test.

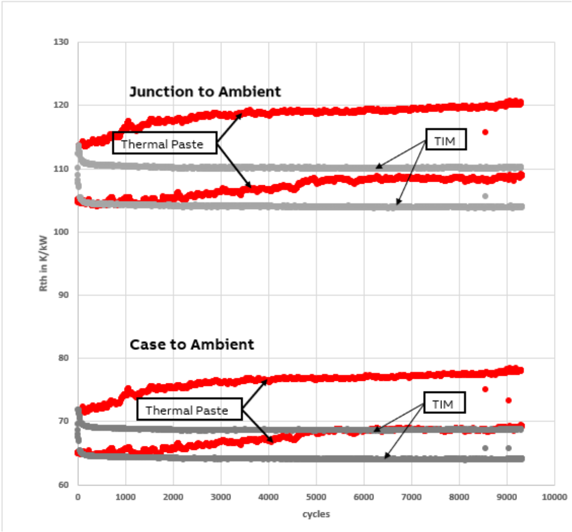

Figure 7: Comparison of TIM and heat conductive paste stability

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