ABB LinPak: smart design for efficient converters

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ABB LinPak: smart design for efficient converters

Module concept and EM Design
Design and Manufacturing
Applications
Outlook
LinPak IGBT modules
Setting the standard for the next generation power module

- **Low inductive**
  module inductance 10 nH, ready for fast chip-sets and future SiC solutions

- **Flexible**
  one module for different current ratings, easy paralleling with one driver

- **Highest current density**
  compact inverter design

- **Integrated thermistor**
  keep the temperature under control

- **Multiple source**
  Open standard – no license fee for the outline

- **150°C (3.3kV) and 175°C (1.7kV) operation**

1700V, 2 x 1000A
3300V, 2 x 450A
How an idea evolves into a standard
LinPak has a history and drives the future

First advanced thoughts and discussions on a phase-leg IGBT module with traction proof high reliability, low inductance and appropriate power connections.

October 2014: ABB and Hitachi present for the first time a product-concept based on 90 x 140mm²

PCIM’15: ABB presents a prototype stack with 4 LinPak modules in parallel. Outline changed to 100x140mm² as a result of customer feedbacks.

Autumn 2015: Final outline and pin-out of the LinPak is frozen.

Spring 2017: LinPak is fully qualified. First bulk order received for traction converters and deliveries of modules has started.
## Comparison in the inverter

**HiPak versus LinPak**

<table>
<thead>
<tr>
<th></th>
<th>2 HiPak (1.7 kV / 3600A)</th>
<th>4 LinPak (1.7 kV / 4000A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module inductance</td>
<td>16nH (2 x 8nH)</td>
<td>2.5nH (10nH for a single module)</td>
</tr>
<tr>
<td>Bus-bar inductance</td>
<td>10nH</td>
<td>1.5nH</td>
</tr>
<tr>
<td>Capacitor inductance</td>
<td>1.5nH</td>
<td>1.5nH</td>
</tr>
<tr>
<td>Total (module including DC-link)</td>
<td>27.5nH</td>
<td>5.5nH (22nH for a single module)</td>
</tr>
<tr>
<td>$L_o \cdot I_C$ (3600A)</td>
<td>99 $\mu$Vs</td>
<td>19.8$\mu$Vs</td>
</tr>
<tr>
<td>Overvoltage $@ t_f = 0.12\mu s$ (1700V SPT++)</td>
<td>825V 100%</td>
<td>165V 20%</td>
</tr>
</tbody>
</table>
For fast Si chip-sets and SiC devices a balanced gate emitter coupling is crucial.

LinPak: Electromagnetic Layout
Coupling Inductance

LinPak internal layout

Gate Emitter Coupling

\[ V_{GE,x} = V_{GE} + L_x \frac{dl}{dt} \]

- \( V_{GE,x} \): Effective gate-emitter-voltage at IGBT \( x \)
- \( V_{GE} \): Externally applied gate-emitter voltage
- \( L_x \): Coupling inductance
- \( \frac{dl}{dt} \): Current transition

EM improvement in the development

High side IGBTs
Low Side IGBTs

1st prototype
Improved design
LinPak EM layout
Impact on IGBT turn on behavior

Similar switching speed of bottom and top switch
Balanced GE-coupling
- Homogenous current sharing during switching
Counter coupling trade-off
- Limit short-circuit oscillations, but still allow fast switching
LinPak Assembly
Design for Automation and Manufacturing

Housing assembly with integrated terminals, nuts, sealings and gateprint (PCB)
- Reduced number of components for assembly
- Fewer process steps
- Faster production
- Easy for automated manufacturing

HiPak 1 vs. LinPak Components

<table>
<thead>
<tr>
<th></th>
<th>HiPak 1</th>
<th>LinPak</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual parts</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>total parts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LinPak Assembly
Particle free ultra sonic welding

LinPak IGBT modules

Easy paralleling (e.g. 1700V)

- One directional internal current flow from dc to phase
- Paralleling with minimal derating

- 2x4000A, 400 x 140mm²
- 2x3000A 300 x 140mm²
- 2x2000A 200 x 140mm²
- 2x1000A 100 x 140mm²

One directional internal current flow from dc to phase
Paralleling with minimal de-rating
LinPak IGBT modules
Easy paralleling (e.g. 1700V)

Homogenous switching behavior in parallel operation
Traction package for regional trains

Next generation traction converter platform

Country: CH, DE
Operator: SOB, SBB, BLS, GoAhead, Abellio
Category: EMU FLIRT
Scope of supply: Transformer Traction converter
Key data: 3000 – 3700 kW per train
Deliveries: Since 2018

Customer need
- Highest efficiency
- 100 % roof-mounted traction package
- Higher traction and auxiliary power

ABB solution
- High efficient converter with innovative topology
- Next generation power semiconductors
- Most efficient traction transformer
- New high-performance control system with TRDP (train real time data protocol)
- High power density

Customer benefits
- Up to 25 % improvement of overall traction chain efficiency
- Increase of passenger capacity
SiC - LinPak
Technology drivers

Full-SiC technology drivers built and tested with special substrate for homogenous switching: 1200V, 2 x 500A
Lowest switching losses and low over-voltage
1700V, 2* 1100A available as engineering sample
3300V technology drivers in evaluation
LinPak
Comparison LV to HV package

LV LinPak
- Low-inductive strip-line DC-connection

HV LinPak
- Temperature sensor
- Interrupted strip-line: increased DC-link inductance
  Electro magnetic field emission