

# A new generation of 6.5 KV IGBT modules for European interoperable rolling stock

François Lacôte  
16/04/2007

TRANSPORT |

**ALSTOM**

# Agenda

1st topic	The problem of interoperability	Page 3
2nd topic	Technical answers	Page 6
3rd topic	Validation tests	Page 12
4th topic	Commercial success	Page 17
5th topic	Conclusions	Page 22

# The problem of interoperability

## The “traditional” traction equipments are no more compliant to European interoperability

- The drives for traction in railway application have some specificities which impact strongly the design. At traditional requirements as :
  - Long life time, high reliability, severe environment, high performances and low life cycle cost
- We must now add emerging requirements as :
  - Increased performances, reduced weight, volume, and energy consumption,
  - Reduced impact on environment in use, when building and recycling.
- These requirements show clearly that the standard equipments are no more compliant and must be strongly up graded.

# Interoperable European products

## A complete range

### FREIGHT :

#### PRIMA 6000 :

A standard 6000 KW  
freight locomotive

Can work under :

1500 V DC

3000 V DC

25 KV 50 Hz

15 KV 16.67 Hz



# Interoperable European products

## A complete range

High speed passengers :

NEW PENDOLINO

A standard high speed  
tilting train

Can work up to 250 Km/h  
on standard tracks

Can work under :

3000 V DC

25 KV 50 Hz

15 KV 16.67 Hz



# Interoperable European products

## A complete range

Very high Speed  
passengers :

AGV :

The new high speed  
train with PM  
synchronous motors  
Can work up to 350  
Km/h

Can work under :

1500 V DC

3000 V DC

25 KV 50 Hz

15 KV 16.67 Hz



# Specifications

## Requirements for new products

- The same module family must cover :
  - The full range of power : EMU , HST , VHST , locomotive .
- The traction drive must be able to operate , with a low number of switchgears , under all standard voltages in Europe :
  - 1500 V DC , 3000 v DC , 25 KV 50 Hz , 15 KV 16,67 Hz
- Must be increased :
  - Reliability
  - Power density : more power in less weight & volume
- Must be decreased :
  - Acquisition cost
  - Life cycle cost
- Must be “environment friendly”:
  - No use of pollutant matters
  - Recyclable at end of life

# Technical answers

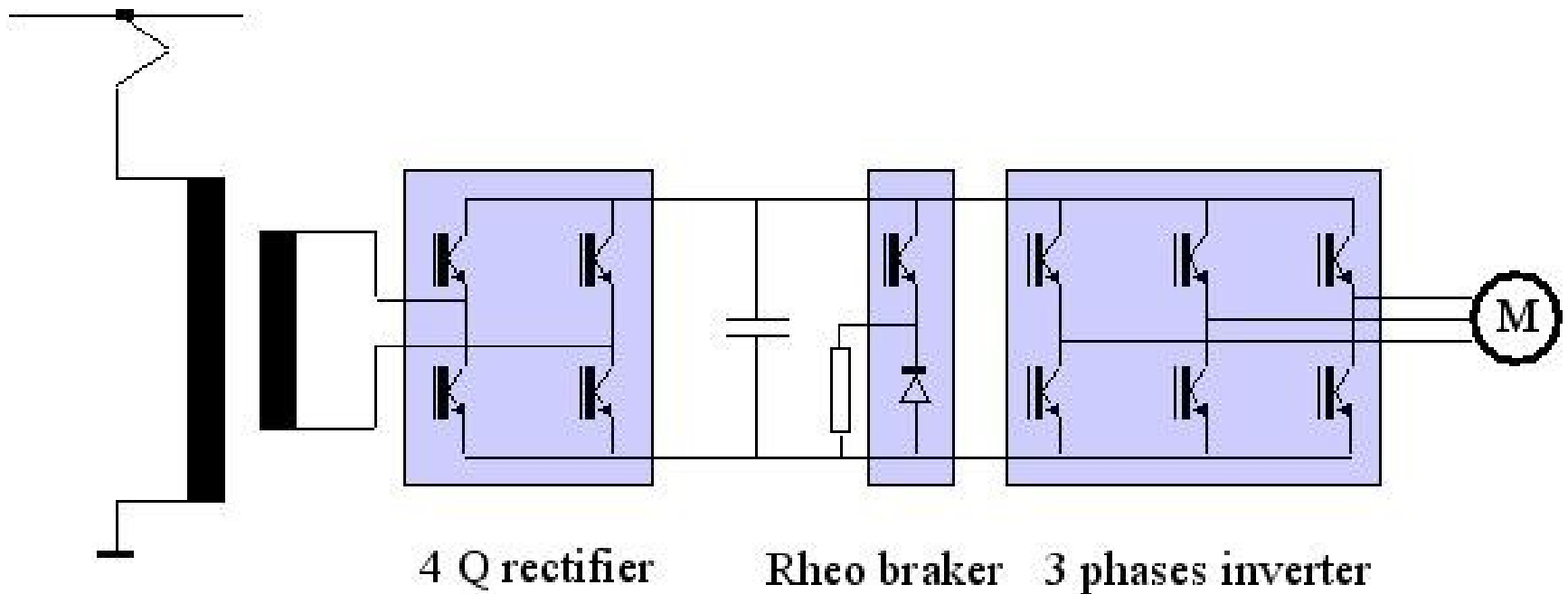
## Some major technical choices

- In order to minimize the number of switching devices, the choice of the dc link voltage is crucial. The optimal value has been determined and fixed at 3600 V dc. This high value gives other advantages :
  - **Weight saving** by reducing the power cables section
  - **Energy saving** by reducing the conduction losses.
- Optimal use of the up to date high power IGBT 6,5 KV , 800 A
  - More simple architecture : no chopper under 3 KV DC
- Use of main transformer secondary as a line inductor under DC voltage
  - No more extra inductor in transformer tank .
- High performance water cooling
  - To limit maximum temperature and thermal ripple
  - To avoid the drawbacks of air cooling
    - Huge ducts
    - Noise
    - Pollution of equipment ...
  - To save volume & weight



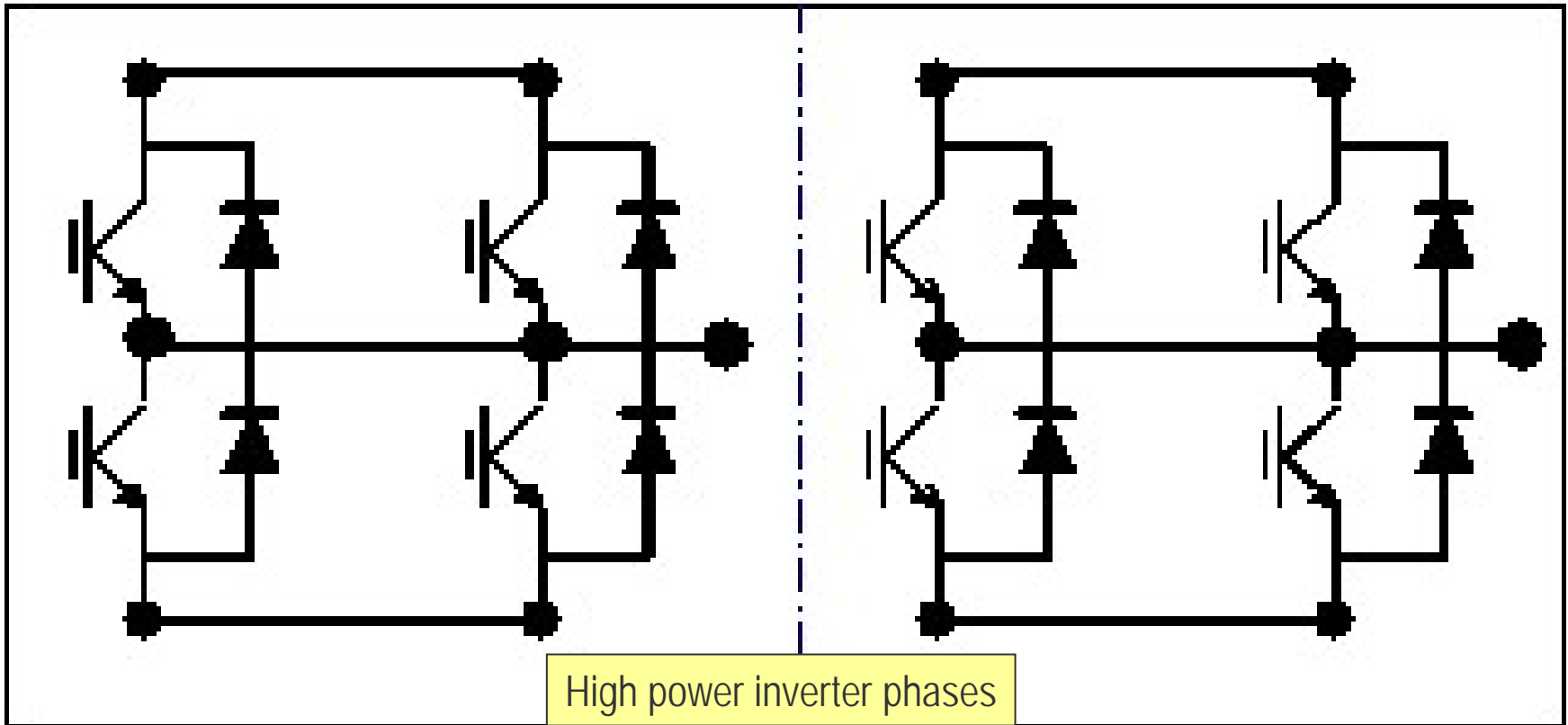
# Range definition

## Module functionality adaptation by internal wiring



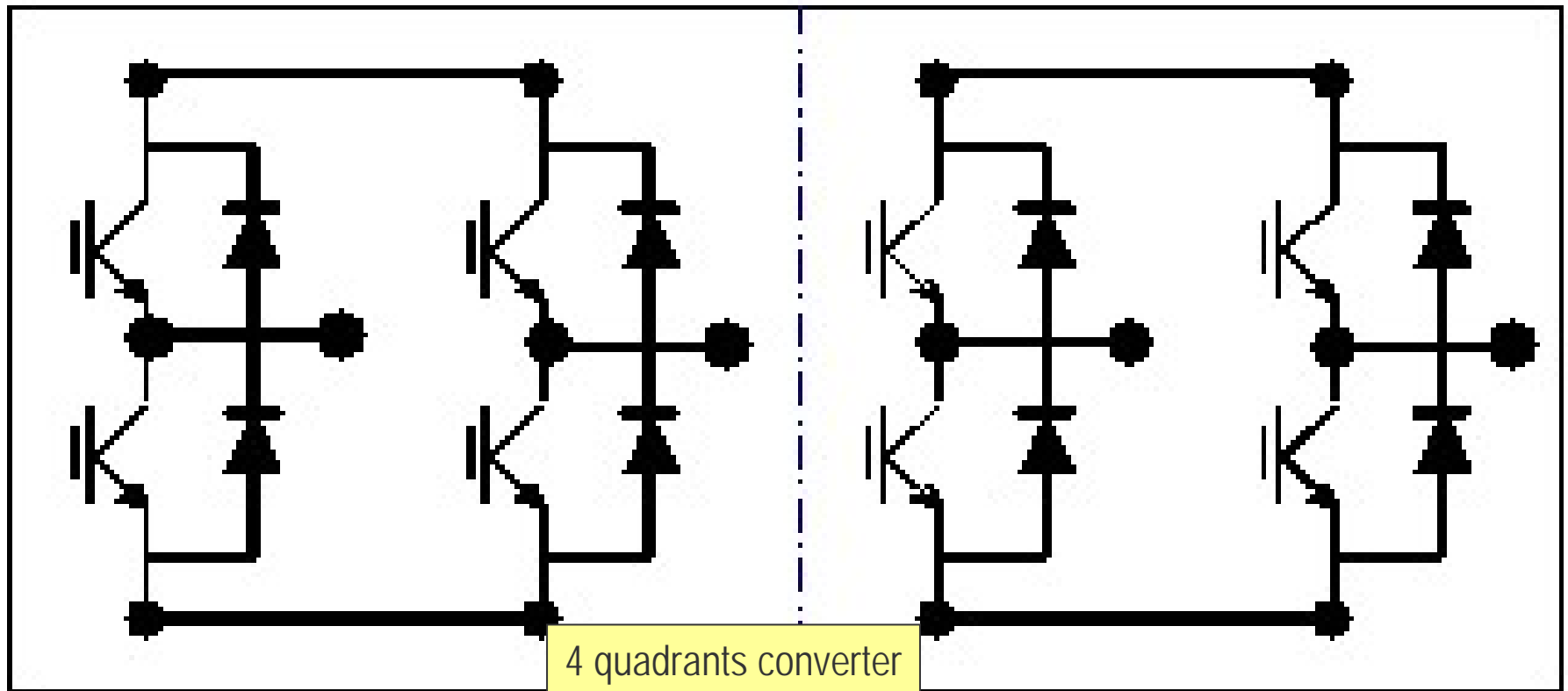
# Range definition

## Module functionality adaptation by internal wiring



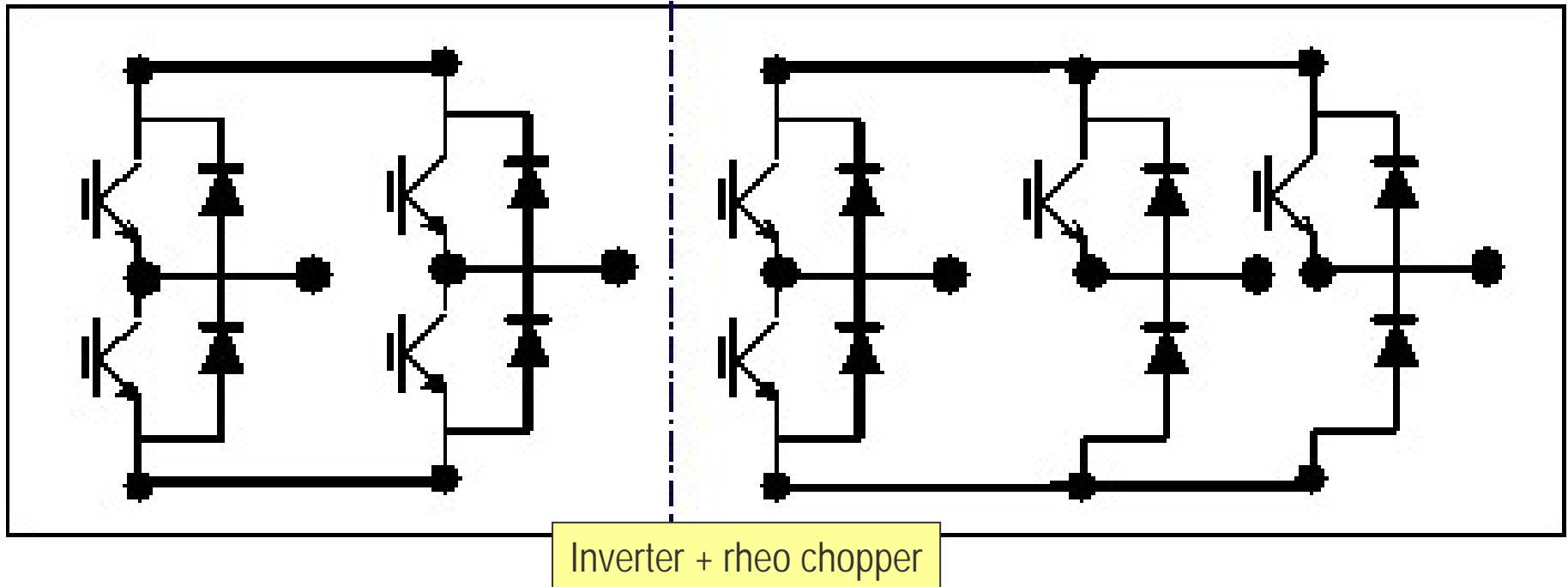
# Range definition

## Module functionality adaptation by internal wiring



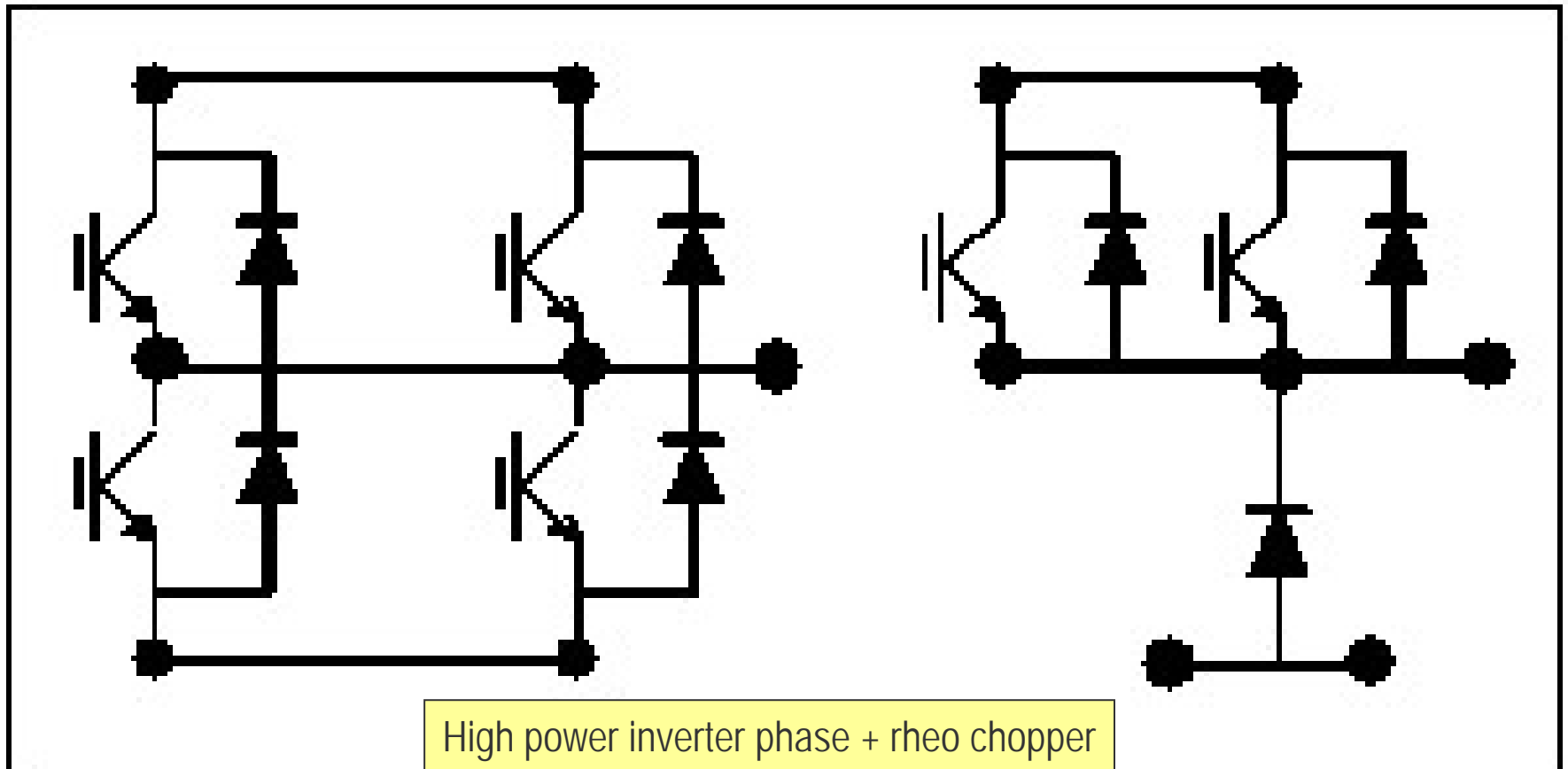
# Range definition

## Module functionality adaptation by internal wiring



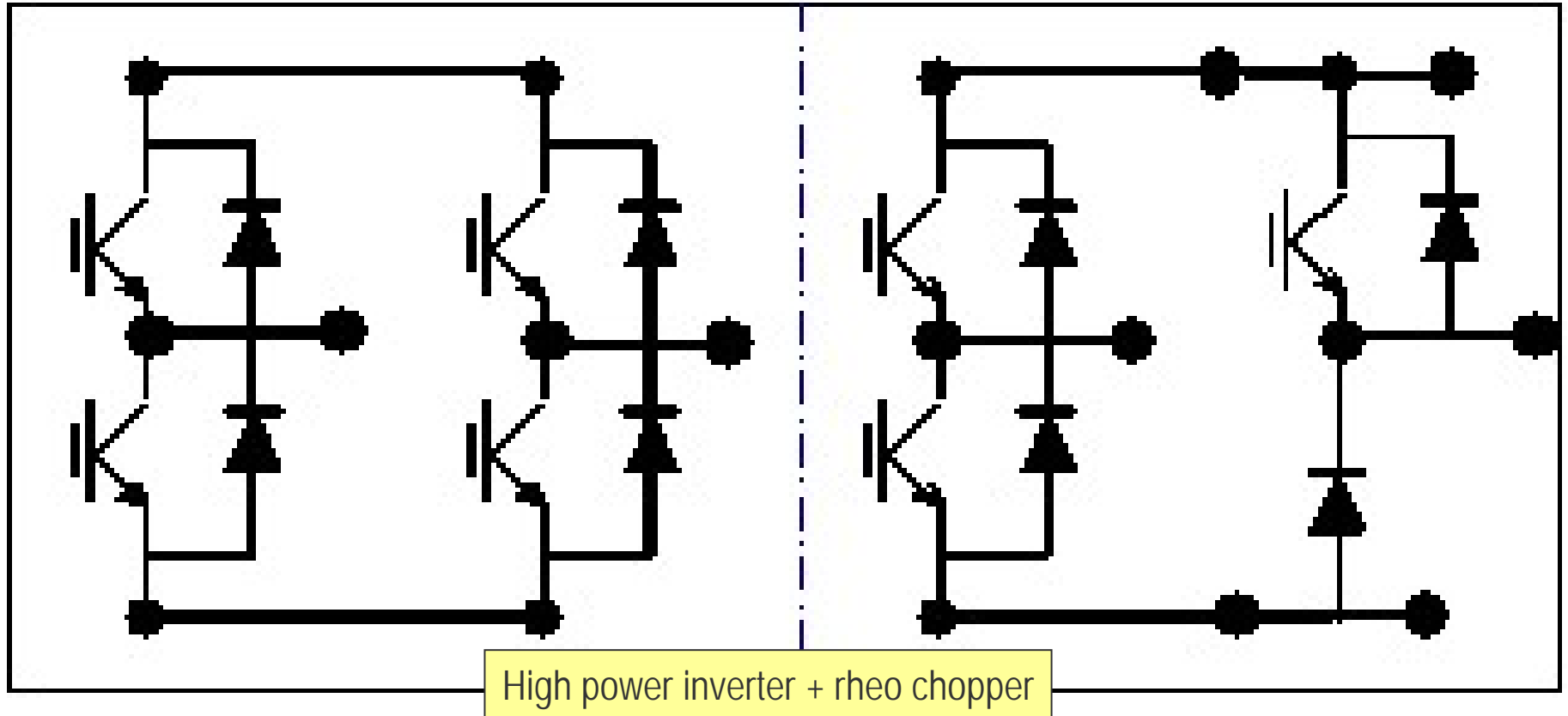
# Range definition

## Module functionality adaptation by internal wiring



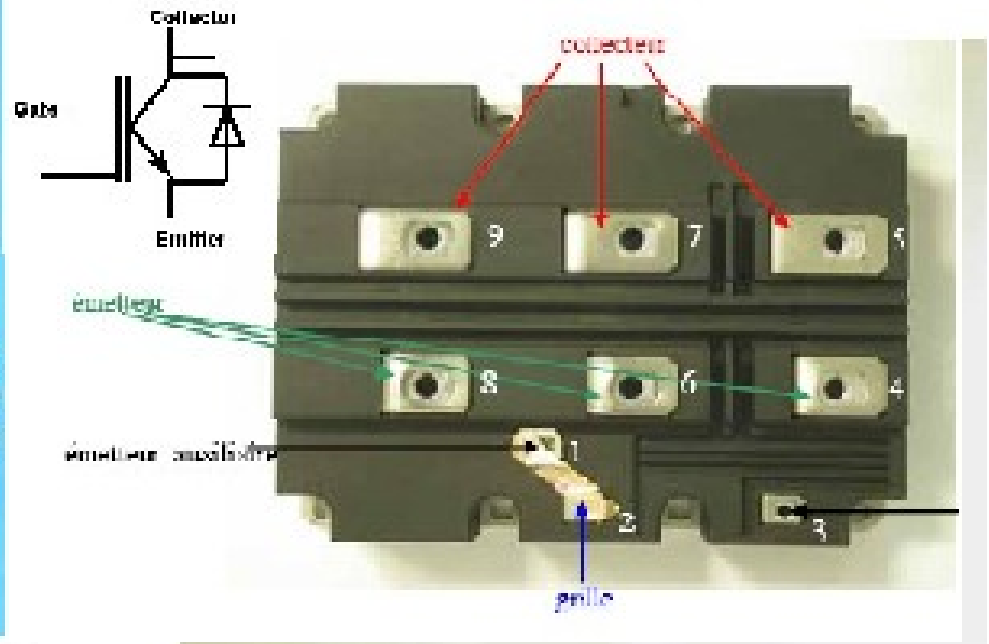
# Range definition

## Module functionality adaptation by internal wiring



# Semi conductor technology

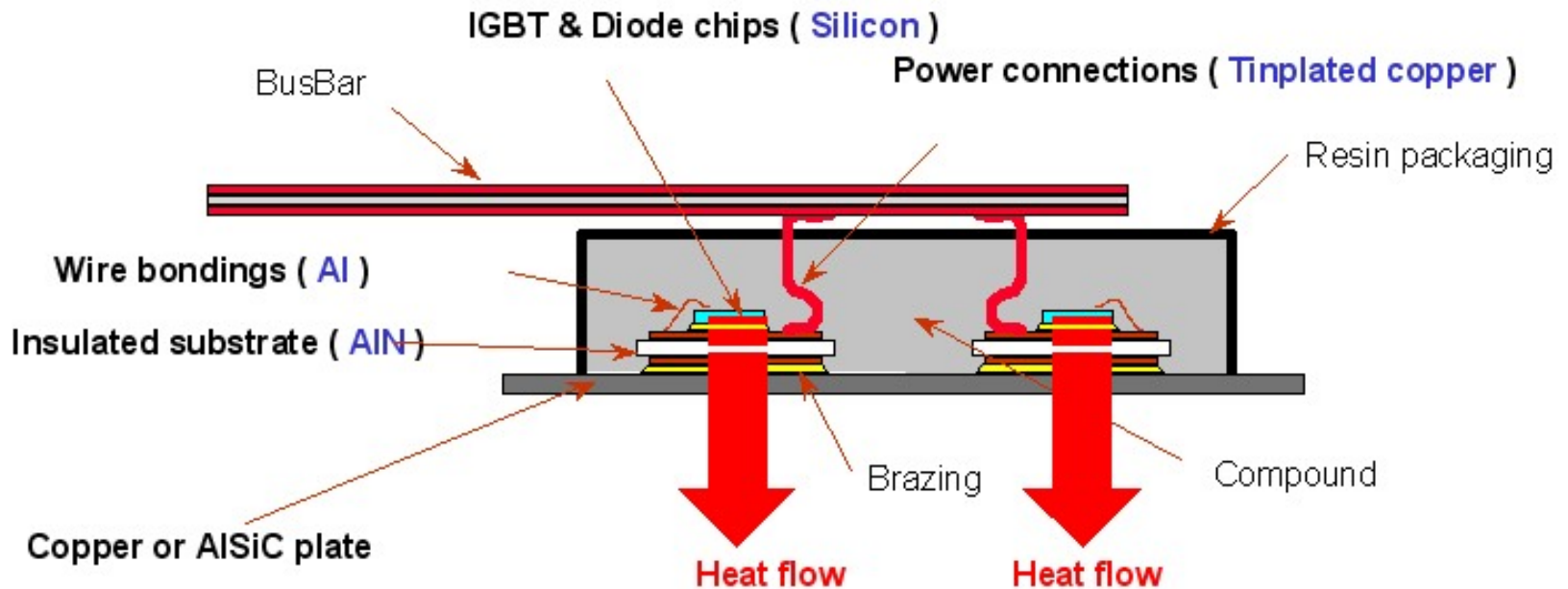
## The last up to date IGBT technology



# Semi conductor technology

## The last up to date IGBT technology

The power switch : a 6500 V, 600 A IGBT housed in a 190x140 mm insulated package.





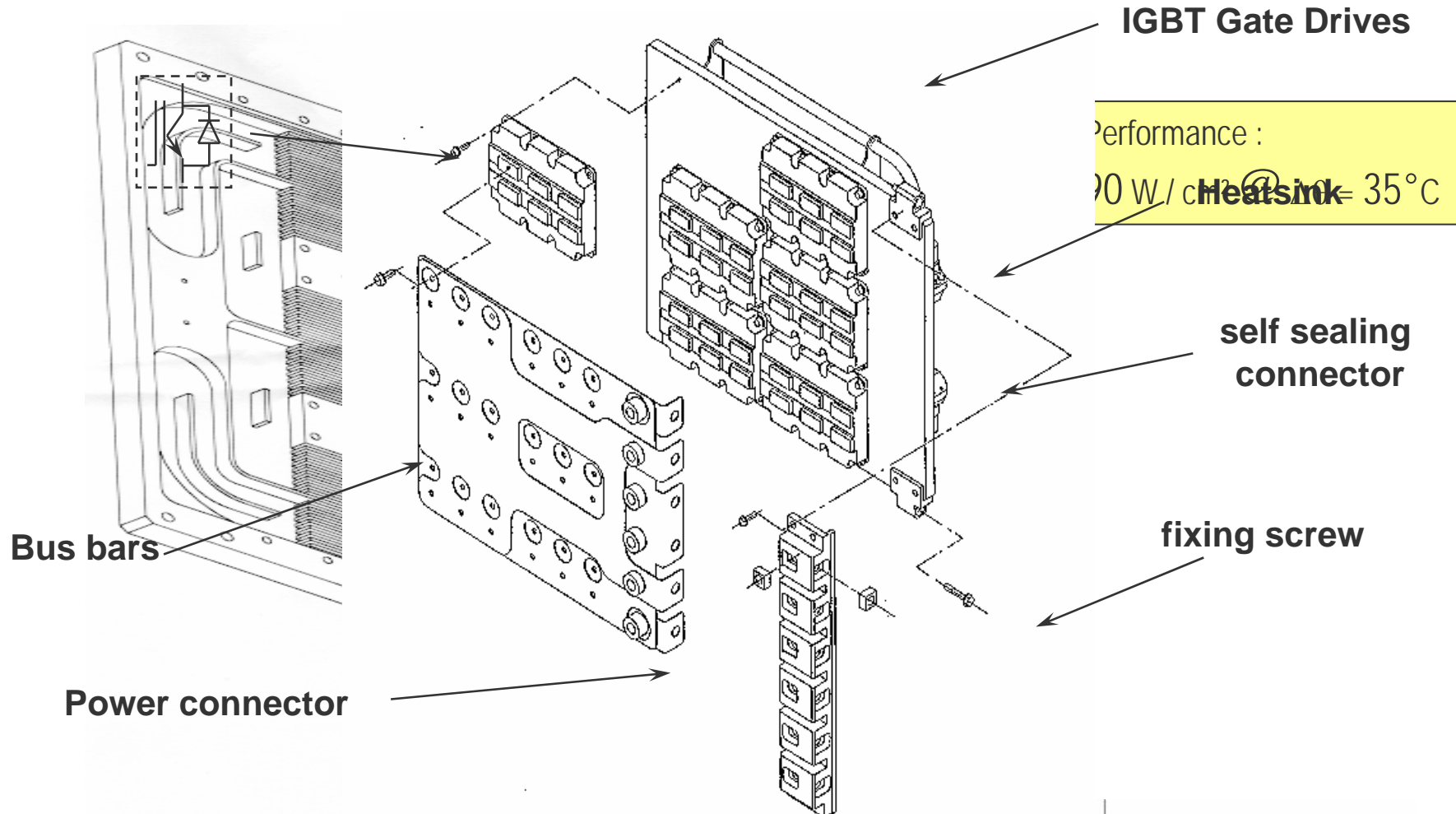
# Standard & custom components

## Standardization at component level

- To cover the complete range of electric schemes and power applications some part are strictly standard :
  - Water plate, mechanical frame, phase connectors, low voltage connectors, gate drive units.
- But, to obtain the different power schemes, it is unavoidable to accept customised parts :
  - IGBT 6,5 KV 600 A for all, except for the chopper packs, using a 400 A one
  - Power supply bus bar (2 different parts),
  - Phase bus bars, to adapt the electric scheme ( 8 different parts).

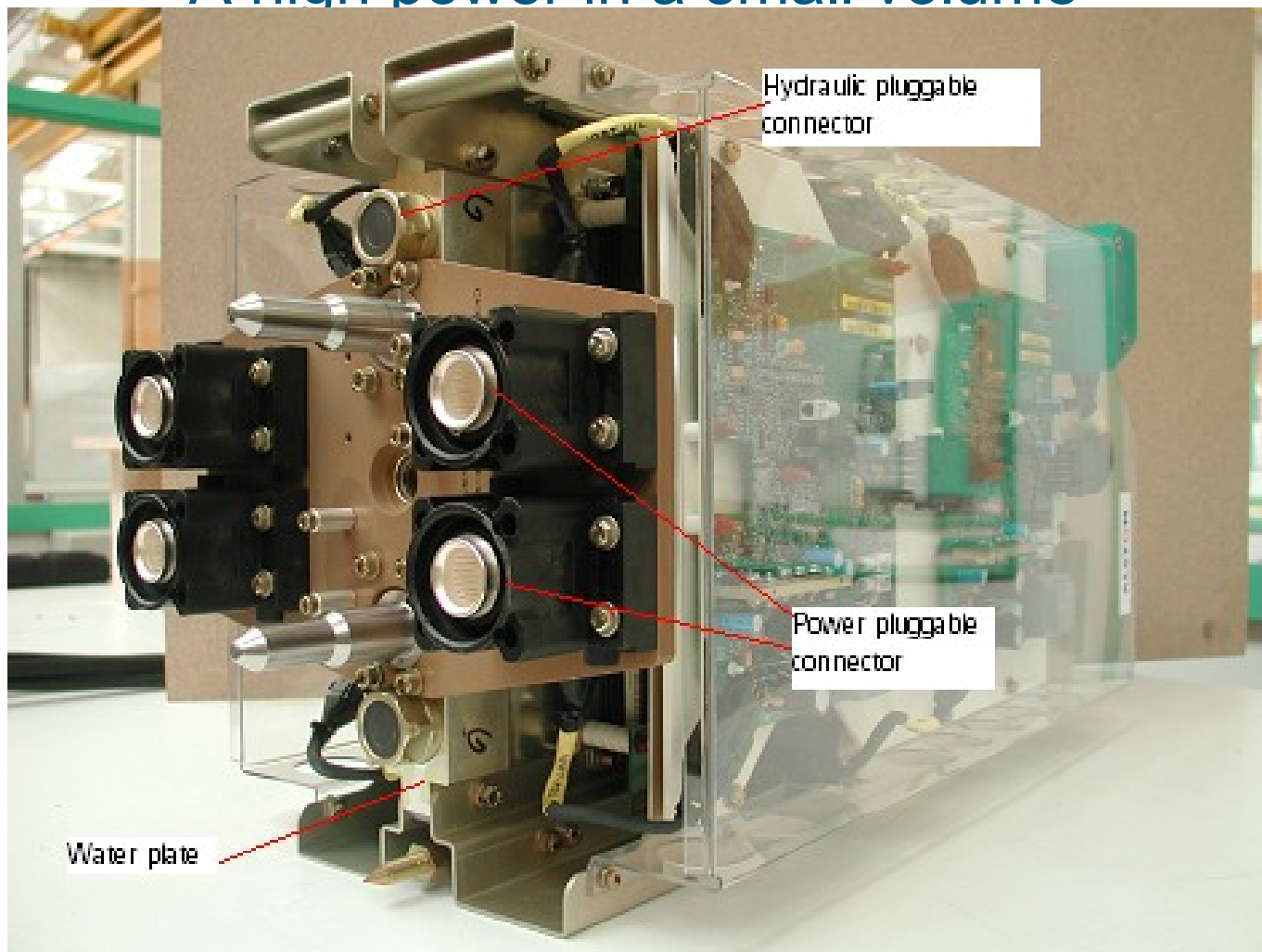
# Cooling technology

## A simple assembly



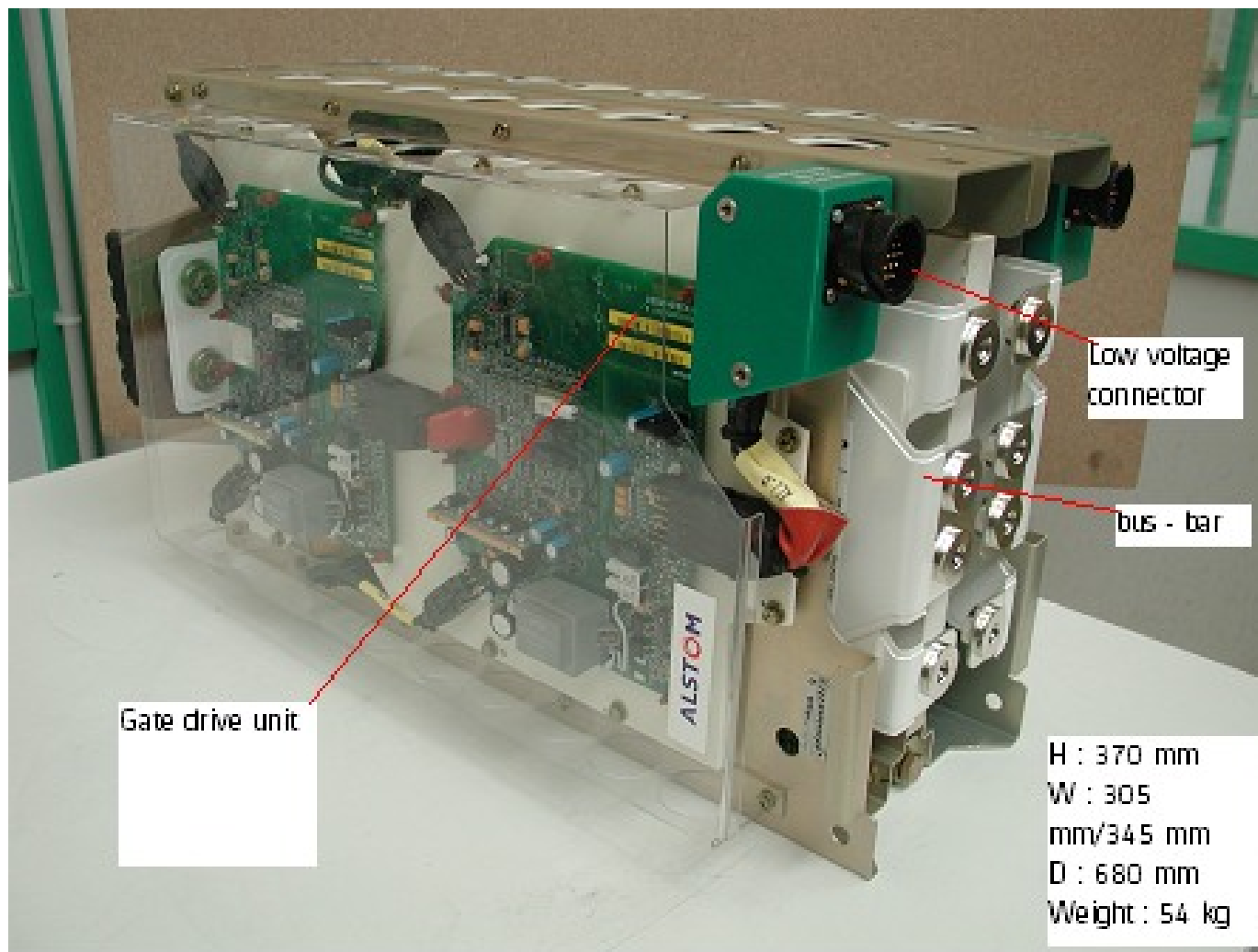
# The standard module

## A high power in a small volume



# The standard module

A high power in a small volume



# The standard module

A high power in a small volume

Bus bar connexions  
between modules

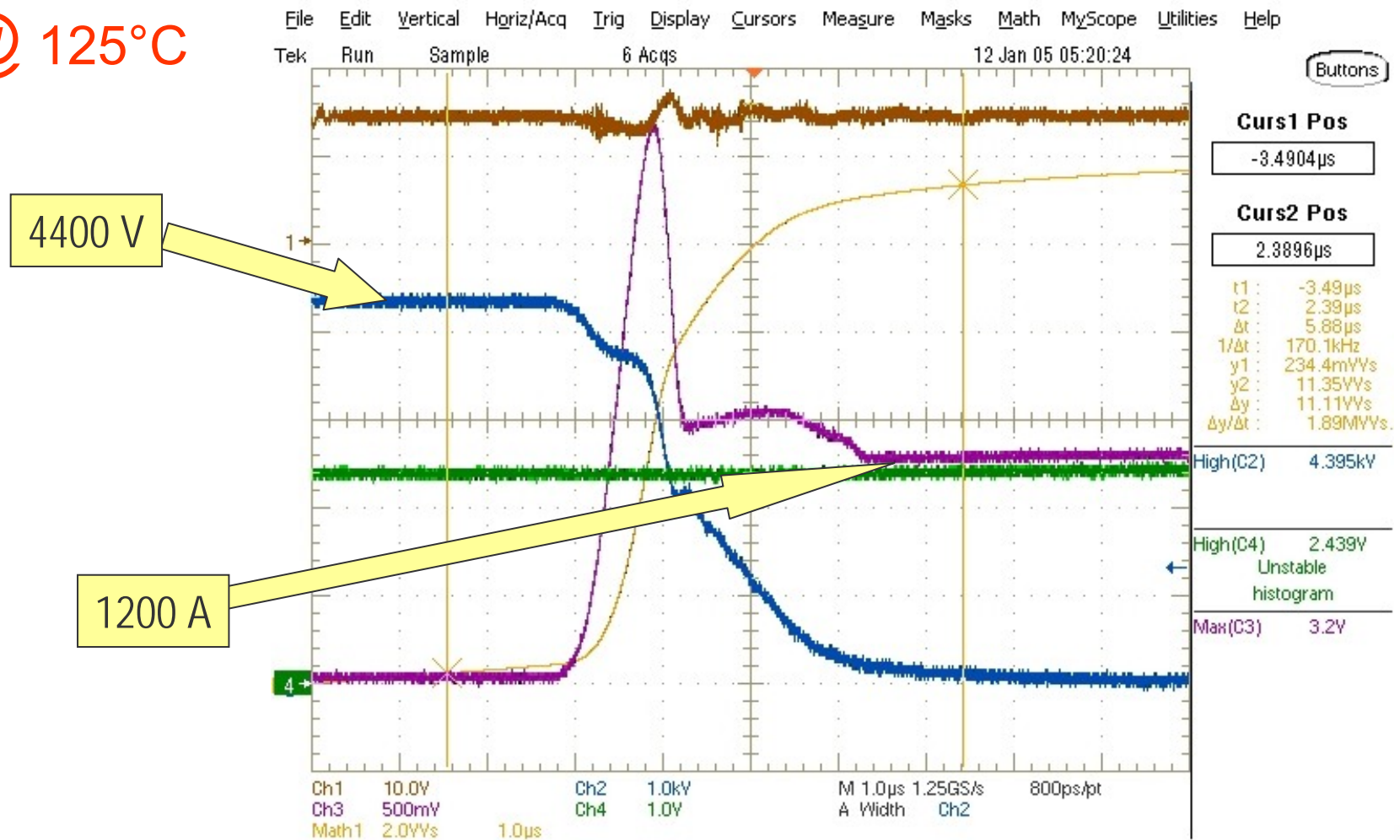


# *Validation tests*

# Electric validations

IGBT Switch "on"  
@ 125°C

## Switching behaviour

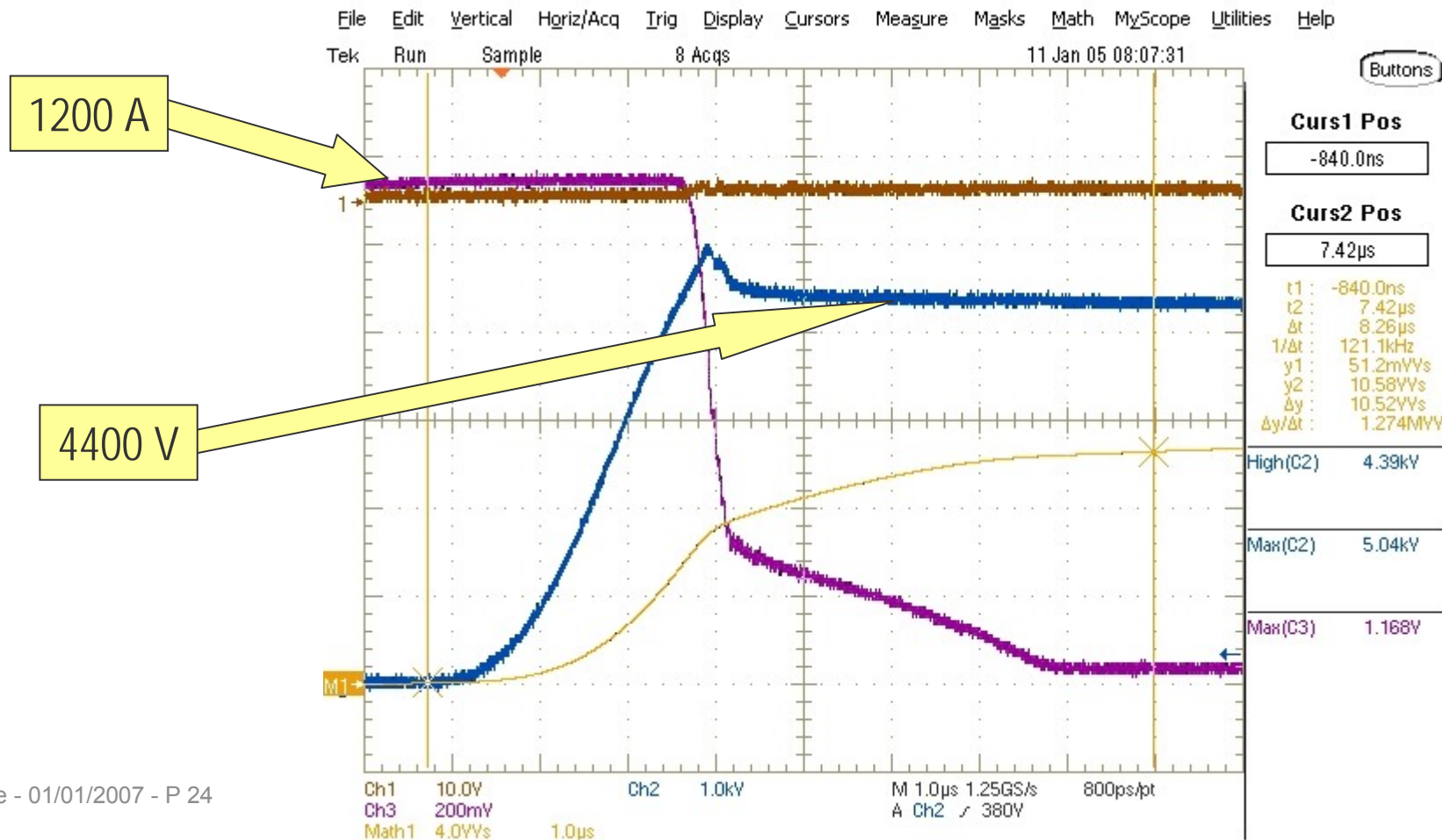




# Electric validations

IGBT Switch “off”  
@ 125°C

Switching behaviour



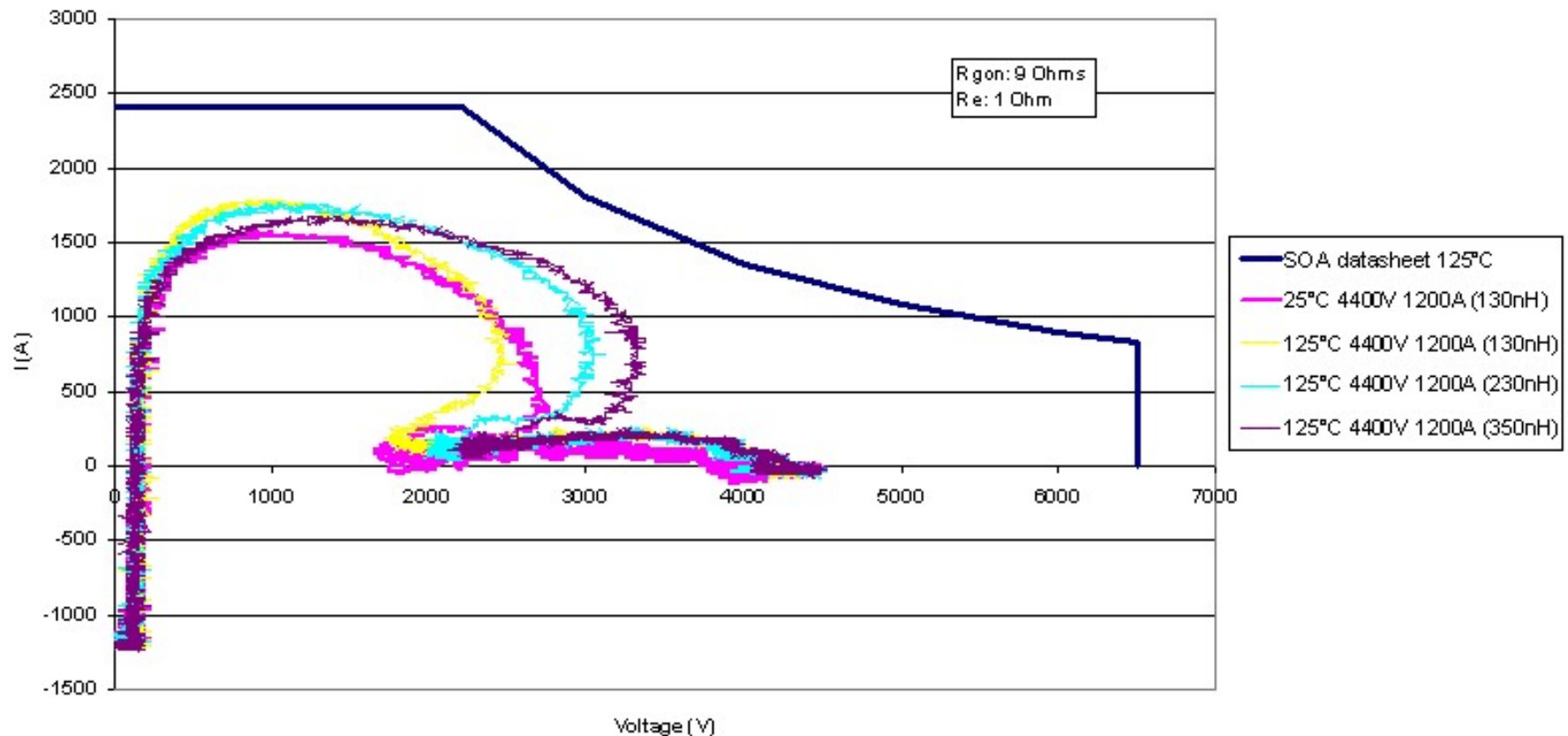


# Electric validations

Diode switching “off” under  
Various conditions of  
temperature and stray inductance

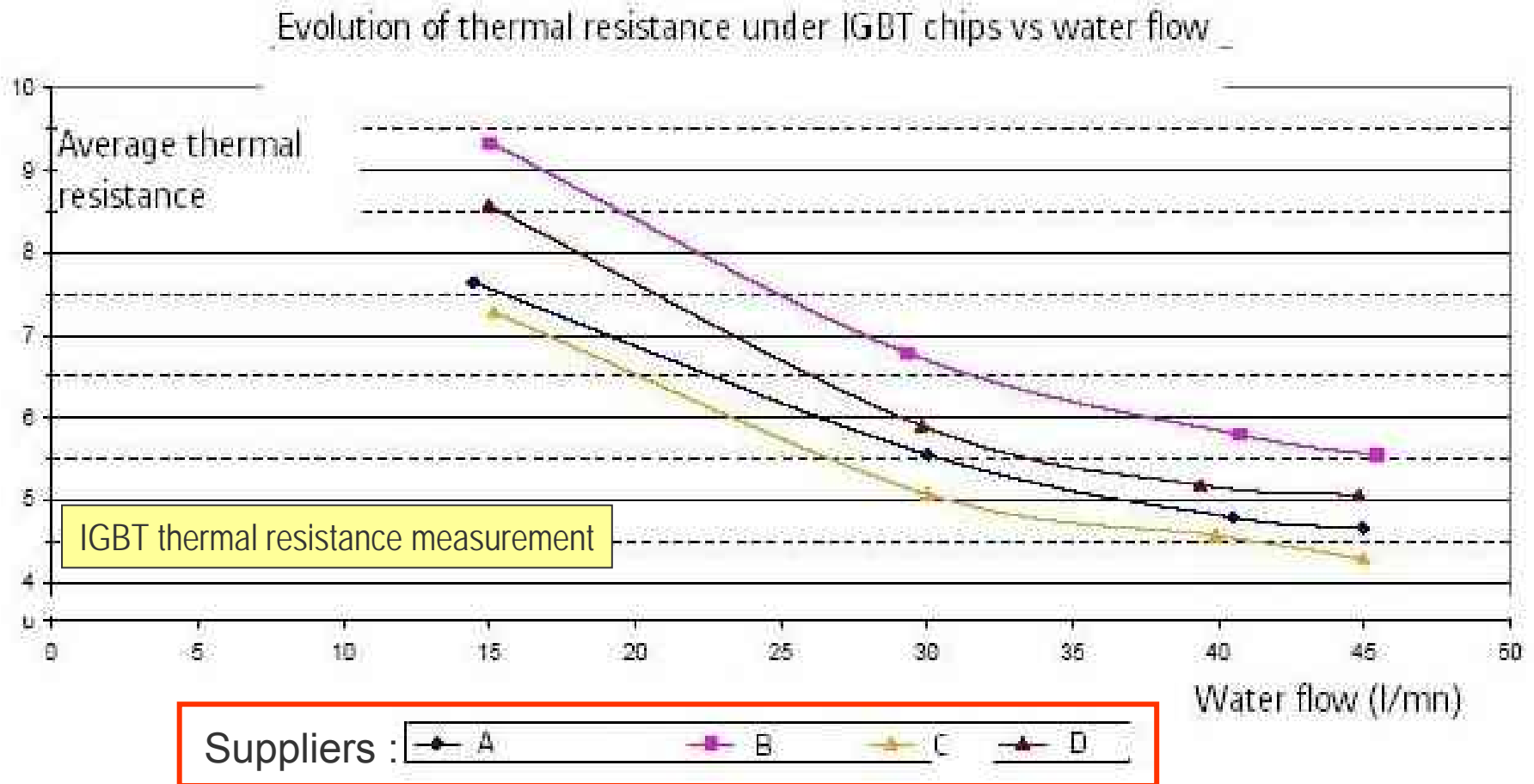
Switching behaviour

SOA Curves



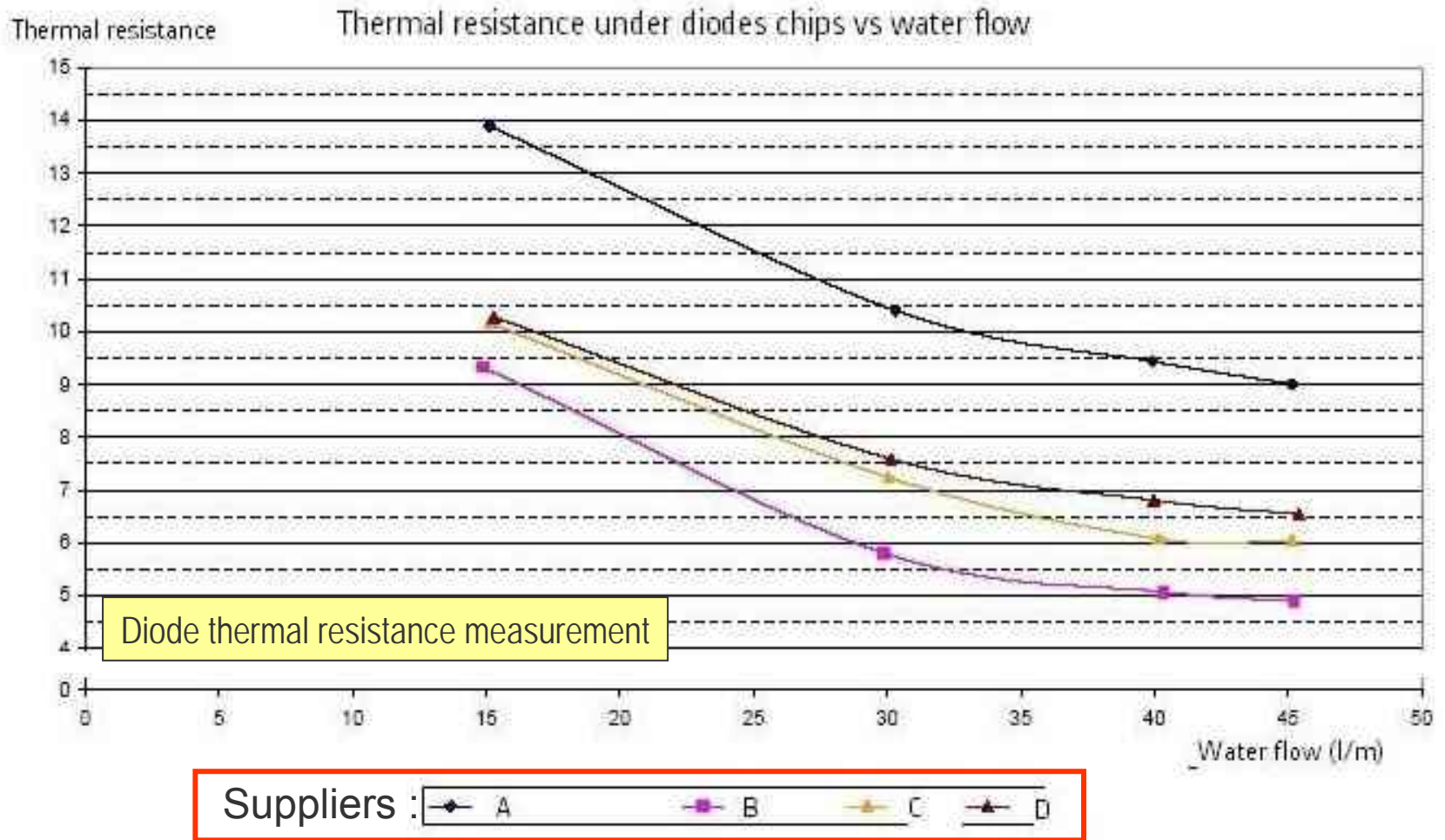
# Thermal validations

A huge dispersion of thermal characteristics between suppliers



# Thermal validations

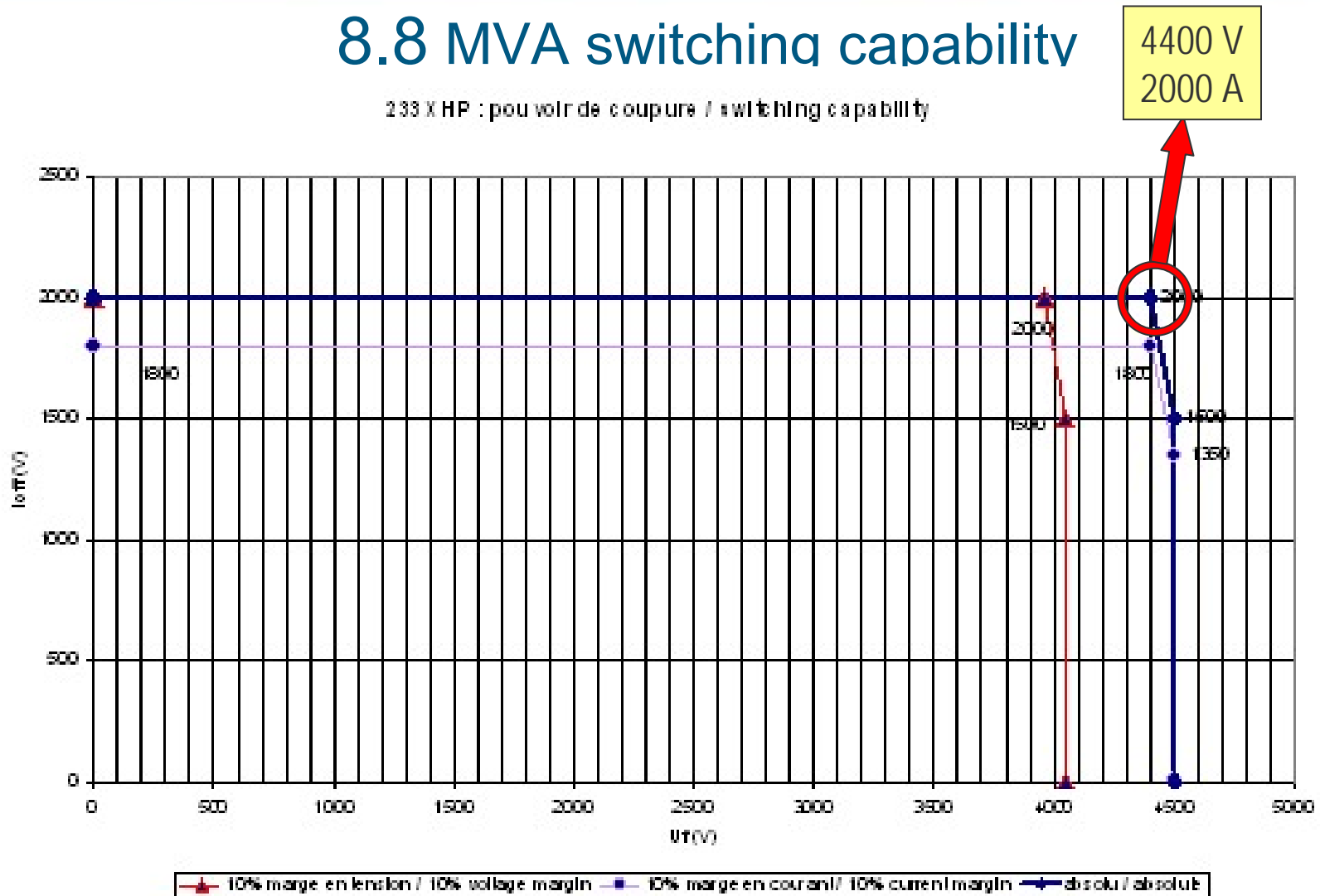
## A huge dispersion of thermal characteristics between suppliers



# Guaranteed performance

## 8.8 MVA switching capability

233 X HP : pouvoir de coupure / switching capability



# *Commercial success*

# 3 KV regional trains for Spain

Simple scheme : no input chopper





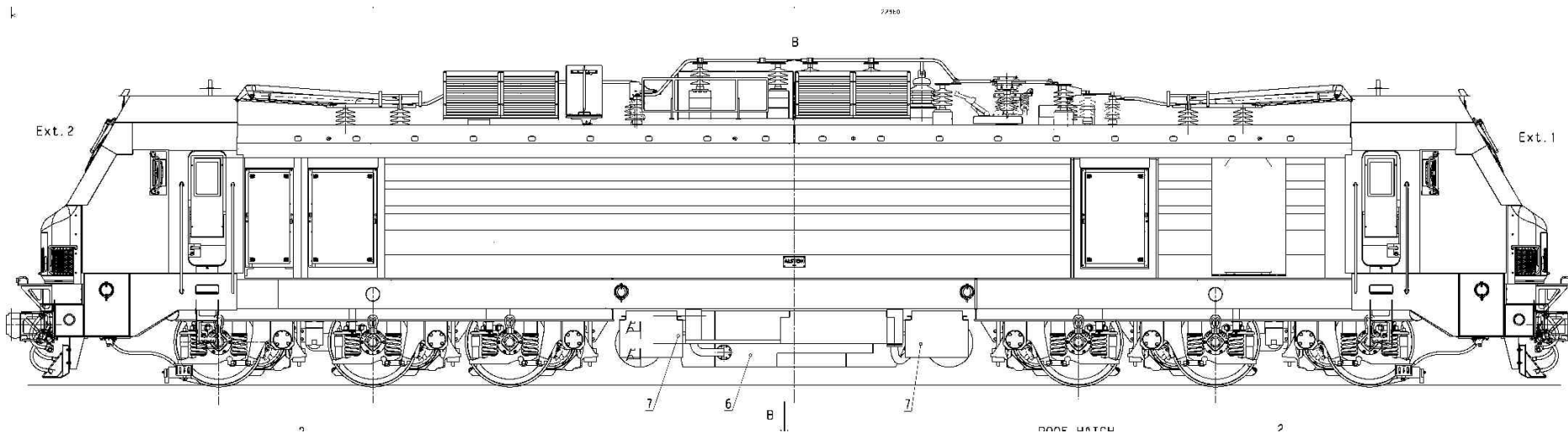
# 250 Km/h EMU's for Chinese railways

25 KV 50 Hz 5500 KW



# 25 KV 50 Hz 9600 KW locomotive for Chinese railways

The most powerful Co Co locomotive in the world



22.83 m 144 T



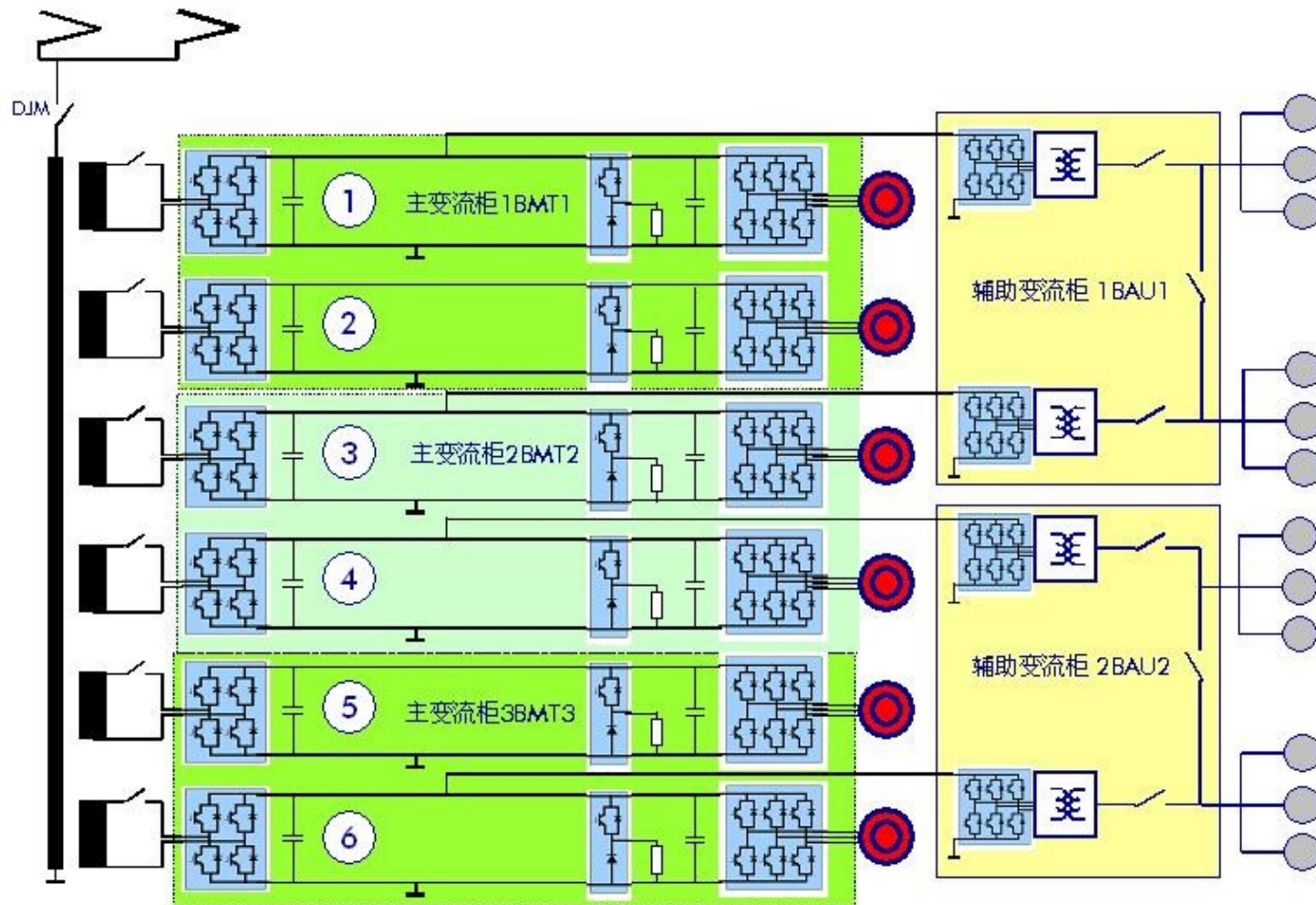
# 25 KV 50 Hz 9600 KW locomotive for Chinese railways

The most powerful Co Co locomotive in the world



# 25 KV 50 Hz 9600 KW locomotive for Chinese railways

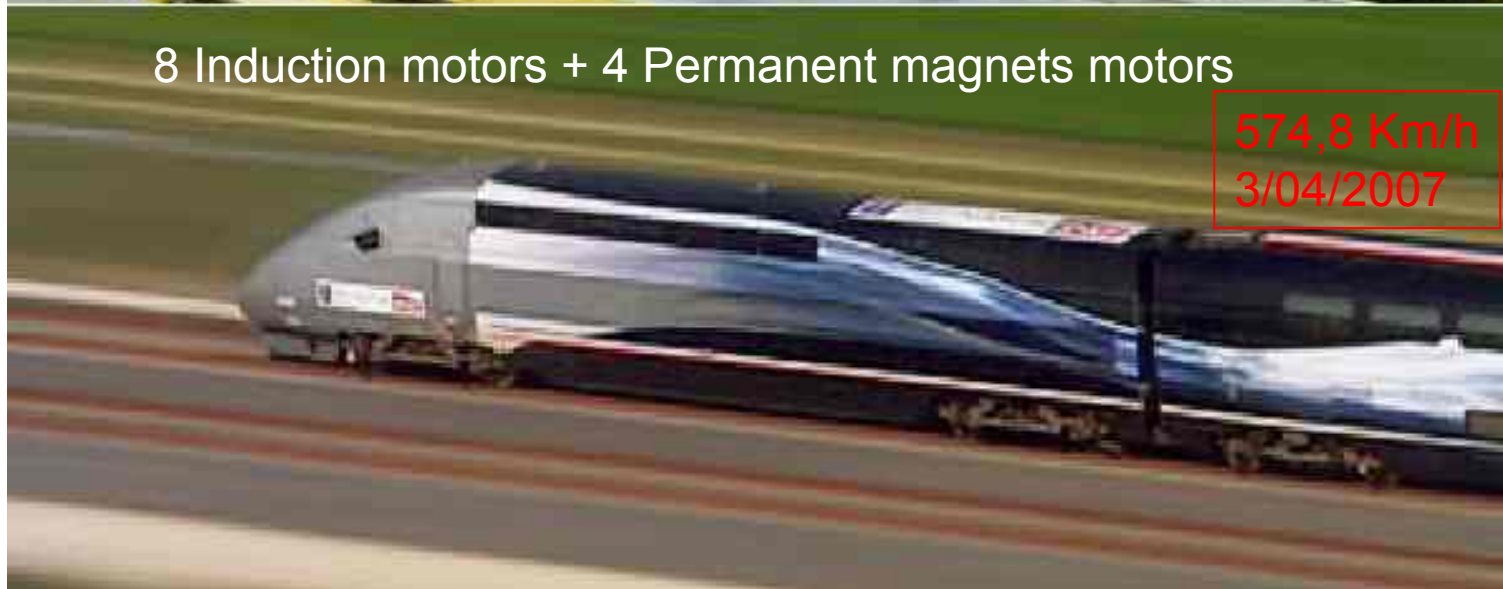
The most powerful Co Co locomotive in the world



# An other form of validation



8 Induction motors + 4 Permanent magnets motors



# Conclusions

- For the customer, a traction system built with a low number of different standard sub assemblies manufactured in big series is a warranty of a full validated product and service proven in many different applications.
  - In addition to the quality performance, it is also the insurance to have always the lowest price. The low number of different modules simplifies the service and maintenance actions.
- In an other hand, it generate for the customer money savings by reducing the stock of spare parts.
- The tests on track in very severe conditions have shown a good behaviour and comfortable design margins witch is an indication of reliability and life duration.

Thank you for attention

[www.alstom.com](http://www.alstom.com)

**ALSTOM**