Future Hybrids

-Reduced cost and increased efficiency

May 14, 2014

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Kollmorgen HCV objectives

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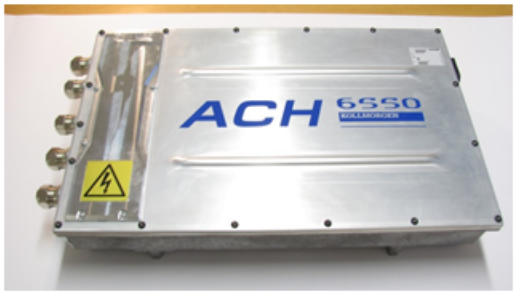
Main targets for Kollmorgen in the HCV Project

- Reduce Driveline component cost with 40%
  - Deliver a DC/DC converter in WP 4420 (600 / 28 VDC)
  - Deliver a Drive (Inverter) in WP 4420
- Participate in the specification of the components for the Hybrid driveline, WP4210
- Participate in creating simulation models for the components, WP4410
- Participate in the integration of the hybrid driveline, WP 4530

Main challenges for Kollmorgen and how they are solved

- Reduce cost with 40%
  - Topology with resonant DC/DC converter
    - Higher switching frequency
      - Smaller (lower cost) electromagnetic components

  - Use of multiple sourced standard components
    - High volume components (lower cost)



Hybrid components Beyond HCV

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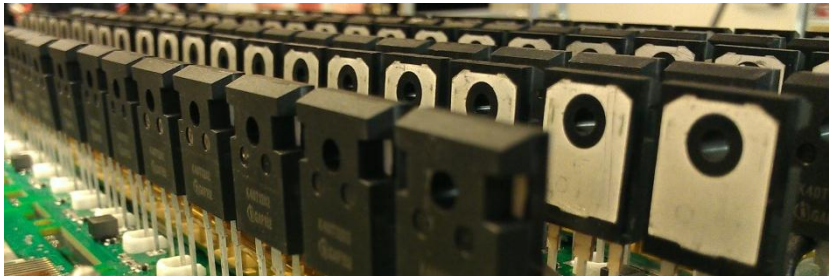
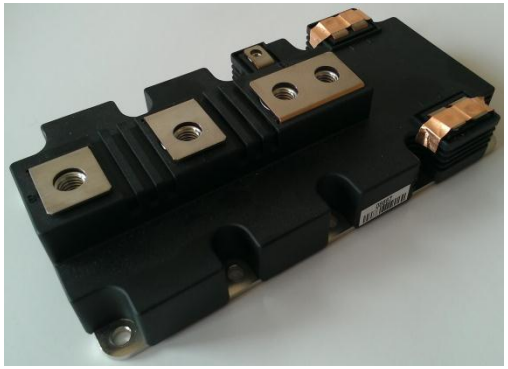
Parallel Discrete IGBT vs Modules

Discrete transistors



Power Module

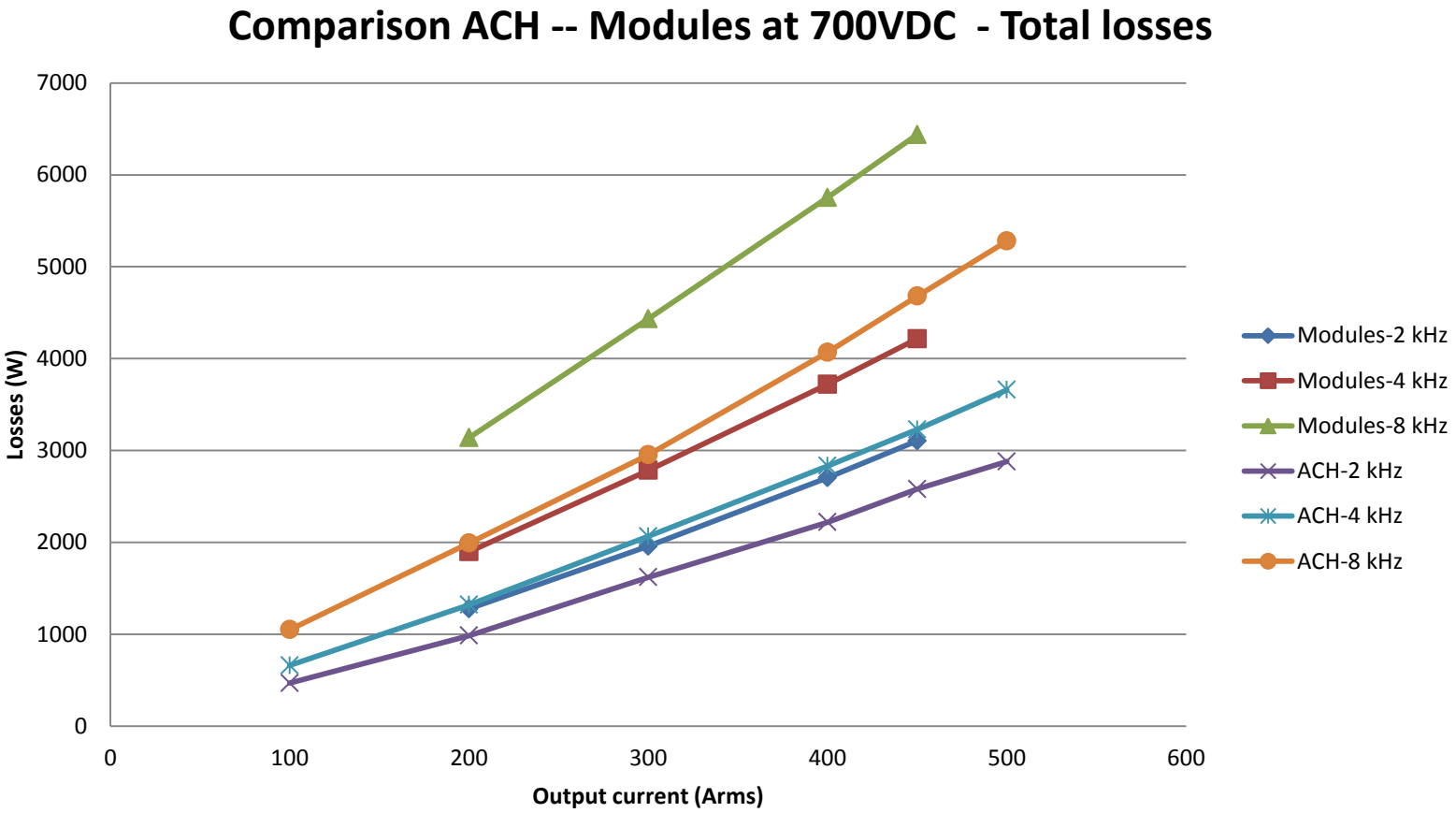


Paralleling of multiple discrete packages with on transistor each

One package with multiple transistors paralleled inside

Due to the shorter supply chain and larger production quantities the cost for a discrete power stage is approximately 50% of the cost for a module solution with the same current rating.

Modules Vs Discrete IGBT



Reduction in losses (W)	**200A**	**300A**	**400A**
2 kHz	293	337	483
4 kHz	577	719	888
8 kHz	1147	1480	1685

Assumptions

- 100kW Peak system-performance
- Duty cycle giving 50kW Continous
- 1% improvment of highly efficient system (95%➔96%)
- 50% of usage is braking and 50% is acceleration
- All losses in acceleration is waste
- 50% of losses in retardation/re-gen is waste

(When braking above Peak power, all losses are not waste)

Improved efficiency

- Acceleration

5% losses and 25kW cont ➔ (25/(1-0,05))-25 = 1,32kW losses
4% losses and 25kW cont ➔ (25/(1-0,04))-25 = 1,04kW losses
This gives 0,27kW less losses
If used in average 5000h/year this gives 1370kWh/year in less losses
With a diesel engin efficiency of 35% this means 3900kWh or 14000MJ
Energy content in diesel is about 37MJ/l
14000MJ=381l diesel/year

- Braking

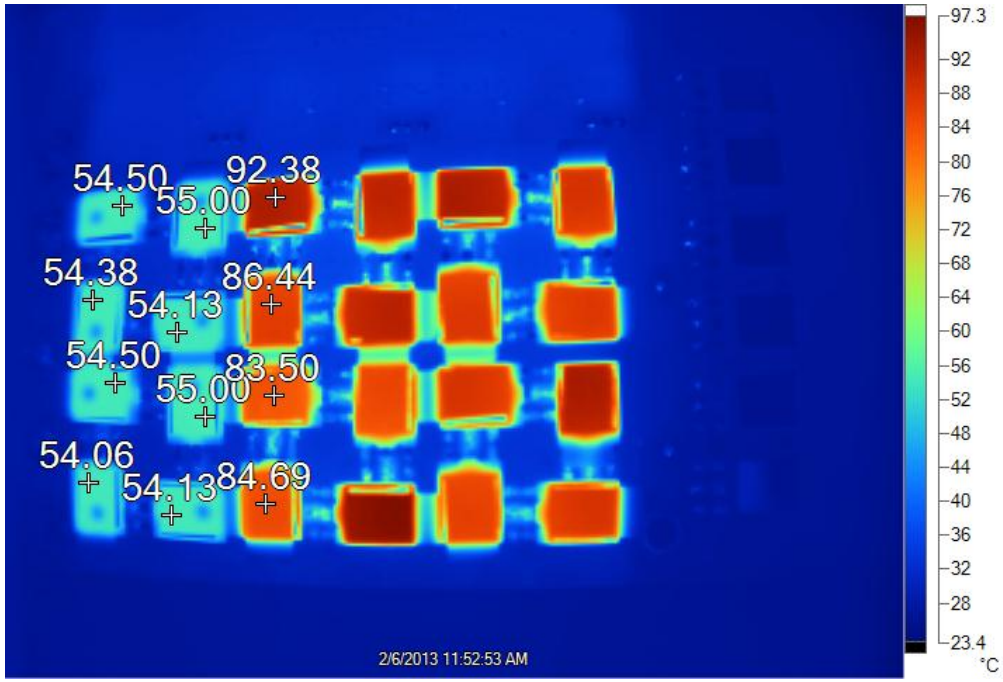
5% losses and 25kW cont ➔ (25/(1-0,05))-25 = 1,32kW losses
4% losses and 25kW cont ➔ (25/(1-0,04))-25 = 1,04kW losses
This gives 0,27kW less losses of which 50% is seen as waste ➔ 0,14kW
If used in average 5000h/year this gives 685kWh/year in less losses
With a diesel engin efficiency of 35% this means 1950kWh or 7000MJ
Energy content in diesel is about 37MJ/l
7000MJ=190l diesel/year

Total savings of ~570l diesel/year

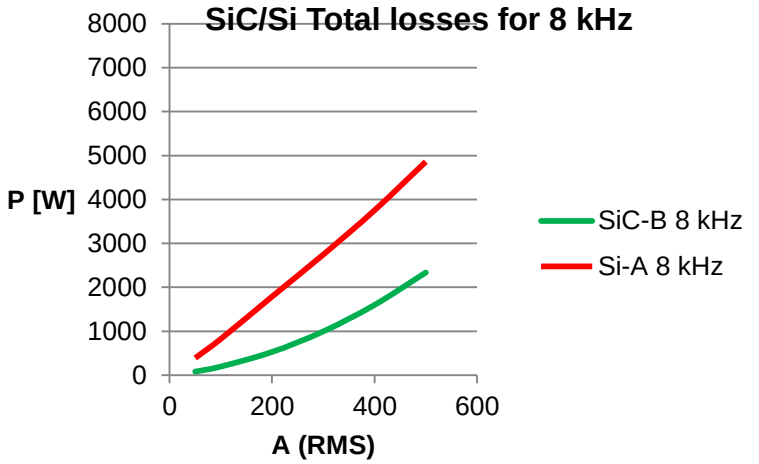
SiC Power transistors

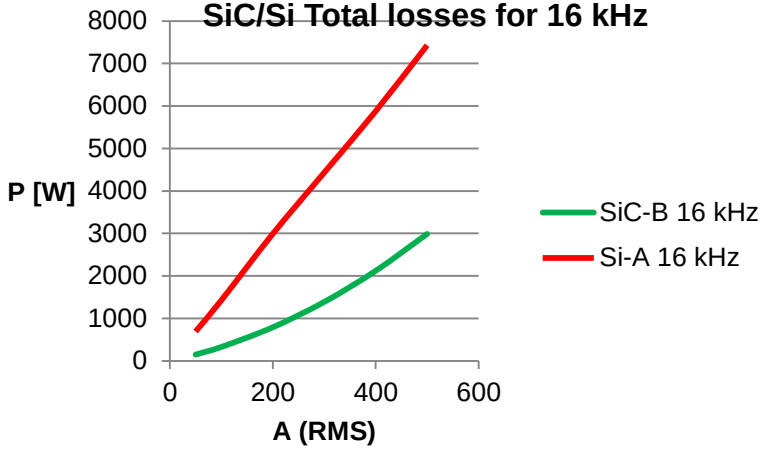
Losses in electronics show up as heat

Thermal imaging measurements below shows the result when running 60Arms at 600VDC and 7.6 kHz in air for a few seconds



SiC MOSFETs are the eight devices to the left, the other 16 devices are the Si-IGBTs





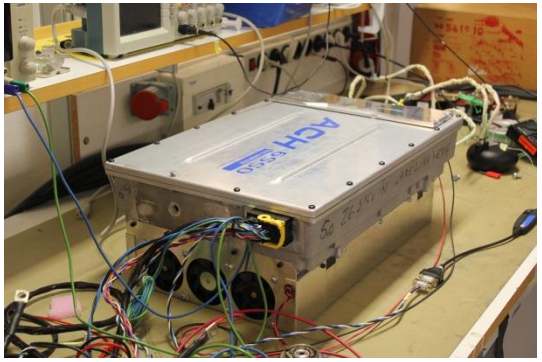
System level benefits

System benefits

• Lower switching losses → Higher system efficiency

• Higher → Lower demand on cooling → Simpler heat sink or even air cooling instead of WEG cooling

• Increased frequency of operation -> Smaller passive components like inductors and transformers



ACH 6550 SiC, Complete inverter assembled. DC/AC converter, Air cooled, 750 VDC, 400 ARMS peak

ACH 6550 Si, DC/AC converter, WEG cooled, 750 VDC, 550 ARMS peak