Waqas Arshad and Colleagues, Corporate Research, ABB, 16.04.2014

High MW Converters
Role of SiC

Power and productivity
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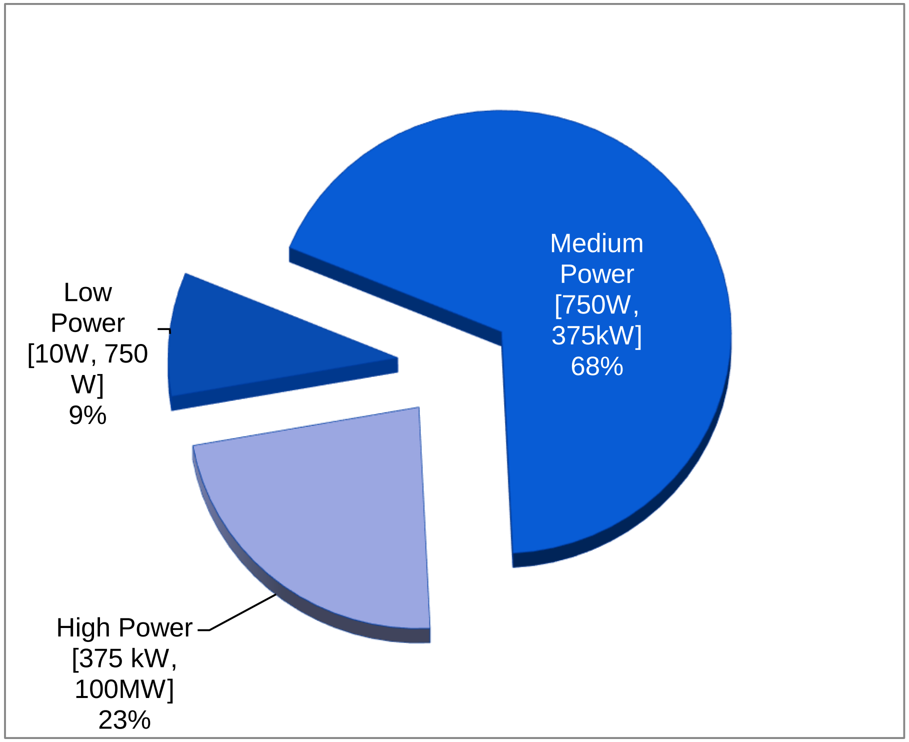
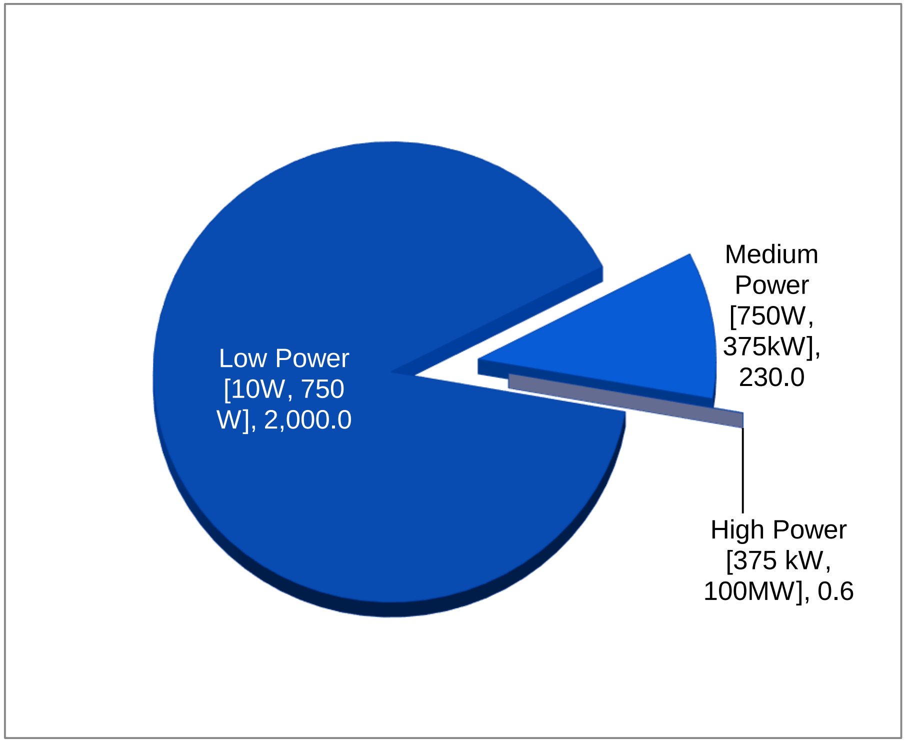
Global Population of Electrical Motors

% of Total Motor Energy



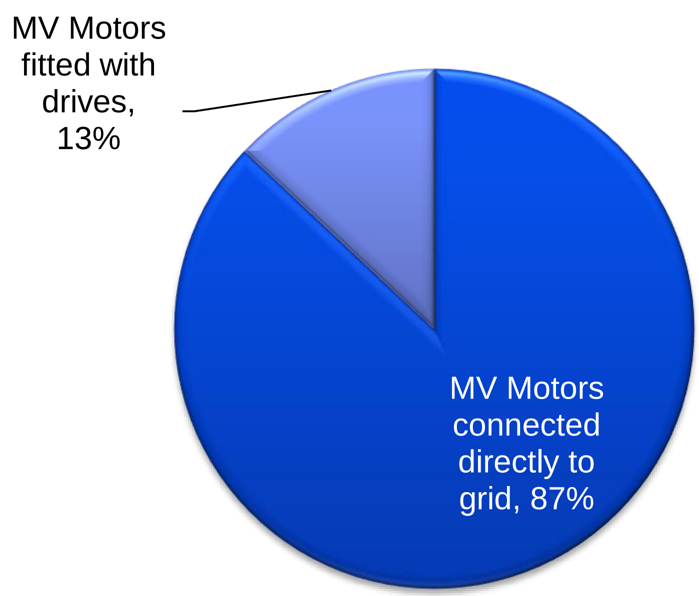
Total Stock (millions of pieces)



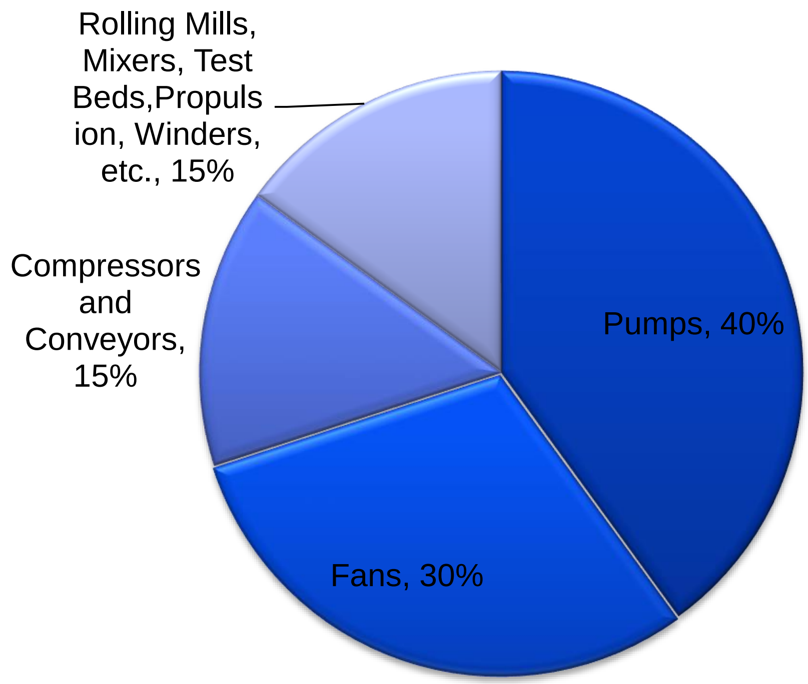
- **High-power motors are 0.027% of the stock and consume 23% of energy**

International Energy Agency, 2011

MV Drives Market



Adoption Rate of MV Drives

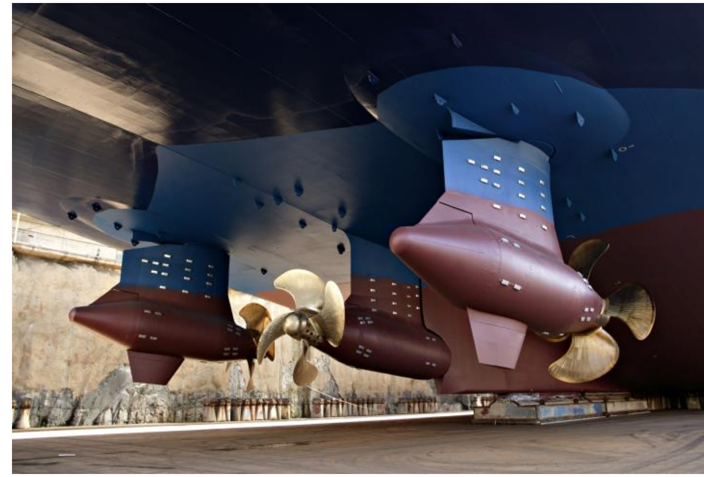


Equipment used with MV Drives

- **Only 13% of MV motors are fed by a drive (2011)**

Frost & Sullivan Research Service, 08.02.11

MV Drives
Challenges



MV Drives operating regime

- MV semiconductors => high losses =>limits switching frequency & power throughput & grid harmonics
- MV => high energy => limits size of passives=> shorter time constant =>dynamic operation, requires fast action

Challenges in MV Drives

- Low switching frequency => low control bandwidth => difficult to meet control objectives
- High losses => Limits power throughput

Achieving High Power by Increasing the Voltage

Disadvantages	Advantages
High dv/dt ➢ More complex insulation concept	Smaller cross-sectional area of cable ➢ Cost-effective drive setup
Less familiarity of plant electricians and drive service personnel with medium voltage levels.	Circuit breakers of lower current rating
	Lower rms current, lower conduction losses ➢ Higher efficiency

Medium Voltage Variable Frequency Drive

<u>Design Hardware</u>

- MV supply
- Main feeder breaker
- Input transformer
- Rectifier (active, diode bridge)
- Dc-link
- Power converter
- Cabling
- 3-ph MV motor
- Cooling Unit
- Enclosure / Mechanical Parts
- Auxiliary Power
- Control Unit
- Input filter
- Output sine wave filter
- EMC filter

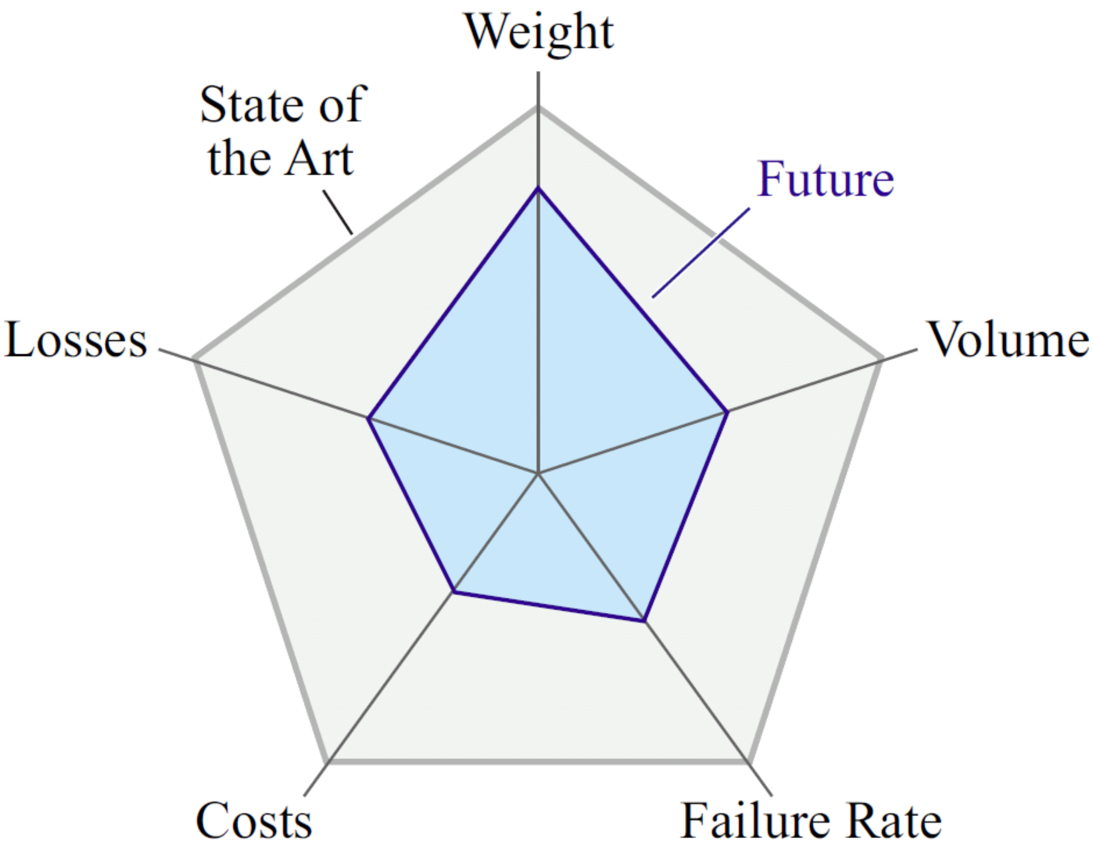
<u>Design and Performance Criteria</u>

- Cost
- Failure Rate / Reliability / Availability
- Efficiency
- Power Density and Weight
- Power Losses vs. Output Voltage and Current Harmonics
- Torque pulsations
- Motor control
- Voltage fluctuations
- Acoustical noise
- Power factor issues
- Operation with long cables
  - High dv/dt, reflected waves
- Common-Mode voltage
  - Stress on motor, especially in operation without transformer

Design and Performance Criteria of MV Drives
A Reduced Set of Criteria

- Cost
- Failure Rate / Reliability / Availability

- Efficiency
- Power Density and Weight
- Power Losses



"Performance Trends and Limitations of Power Electronic Systems"
J. W. Kolar, J. Biela, T. Friedli, U. Badstuebner, CIPS 2010

Benefits of SiC to Drives
Si vs SiC

For LV Drives

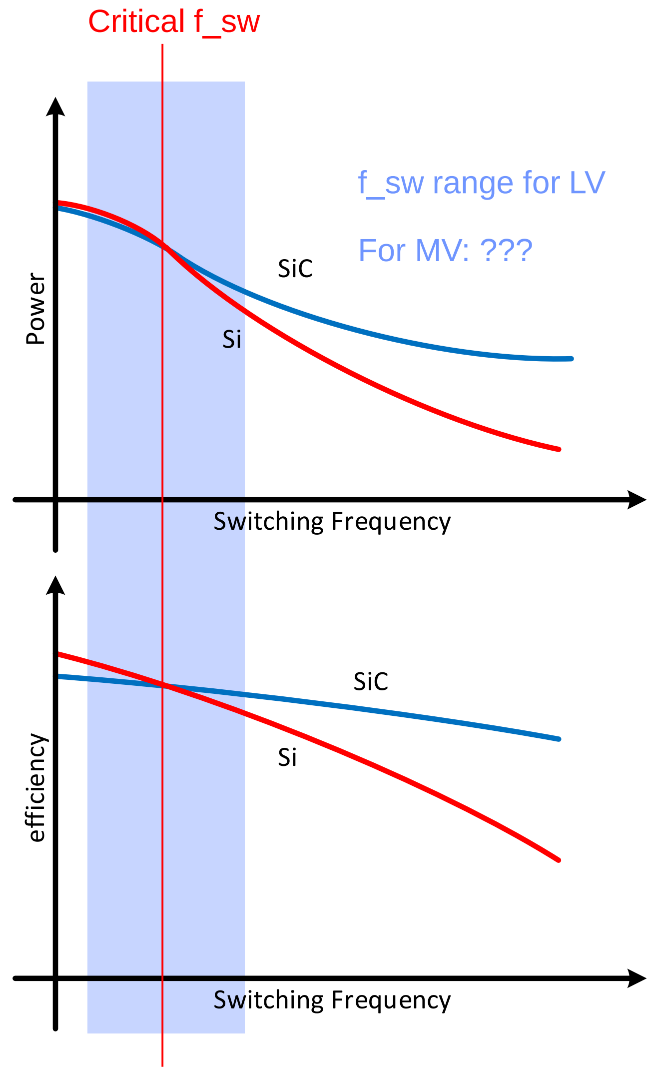
- SiC switching losses very flat with switching frequency :
  - Higher output power compared to Si at f_sw = const.
- Crossover point above critical switching frequency (LV)
  - Si: P_losses = P_cond + P_sw
    (40%) (60%)
  -
  - SiC: P_losses=P_cond + P_sw
    (60%) (40%)

For MV Drives

•SiC Diode technology brings a definite benefit in reducing the turn-on switching losses of the semiconductor switch.

•We see the hybrid Si+SiC power modules as a promising entry point for SiC in MW applications, but limited by the Si operating temperature

•Full SiC modules show an additional reduction in losses compared to hybrid technology, but are limited mainly by their low current rating & over voltages due to the fast unipolar SiC switch



Benefits of SiC to MV Drives
Demands on SiC devices

- Higher voltages
  - Multi-level CHB (Si) ----> 2L or 3L SiC
  - Simpler topology -> no multi-winding transformer (?)
  - Better reliability (device count)
  - Lower foot print
  - Lower weight
  - Higher power density
  - Regeneration -→ energy saving
  - DC link -→ interconnecting several motors
  - ….efficiency (?)

- Higher f_sw
  - Active rectifiers
    - Easier control
    - Smaller passives
    - Less current distortion => power density
  - Power inverters
    - Easier control
    - f_sw 50% higher => L_filter 50% smaller
    - Less current distortion => power density

- Requirements
  - 1-2kHz loss parity with 200Hz Si
  - 100Amps (or more)
  - 5 kV (or more)

- Challenges
  - Motor insulation
  - EMC filter design
  - Module performance/ reliability

Wide Bandgap Power Devices in Megawatt Applications
ABB Summary

SiC (R&D demands)

Power modules – reduced parasitic inductances, suitable for high switching transients

Topologies – take full advantage of SiC device properties

Layout (mechanical integration) – targeting higher blocking voltage . This would require larger insulation distances while having to keep the parasitic inductances low to avoid fast switching over voltages.

Passive components – filters, magnetics, capacitors need to be optimized to fully benefit from the SiC performance

Gate Drives – fast transients combined with high voltage and expected paralleling of many semiconductor devices. New protection schemes needed?

Control algorithms – faster switching frequencies

Cooling – higher temperature operation combined with higher current densities and increased integration require innovative cooling technologies

Reliability – at system level, reliability has to be assessed in order to understand the critical failure mechanisms and sources of stress when incorporating novel SiC technologies

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