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Source: next-gen-forum.com

NEXT GENERATION

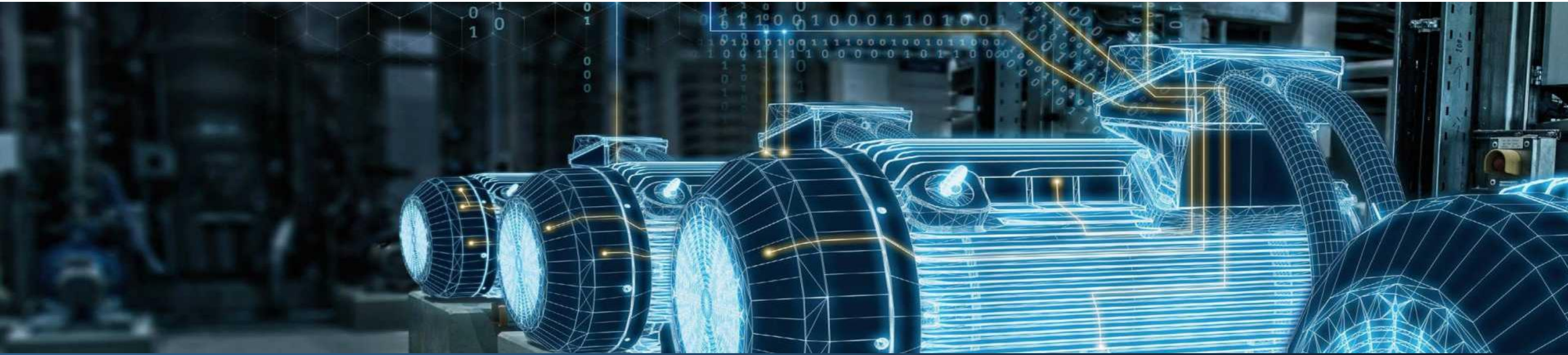
SiC/GaN 3-Φ Variable Speed Drive Systems

Johann W. Kolar et al.

Swiss Federal Institute of Technology (ETH) Zurich
Power Electronic Systems Laboratory
www.pes.ee.ethz.ch

Nov. 11, 2024

Source: SIEMENS



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CRERA

… "How to Handle a Double-Edged Sword"?

Johann W. Kolar | Jonas Huber

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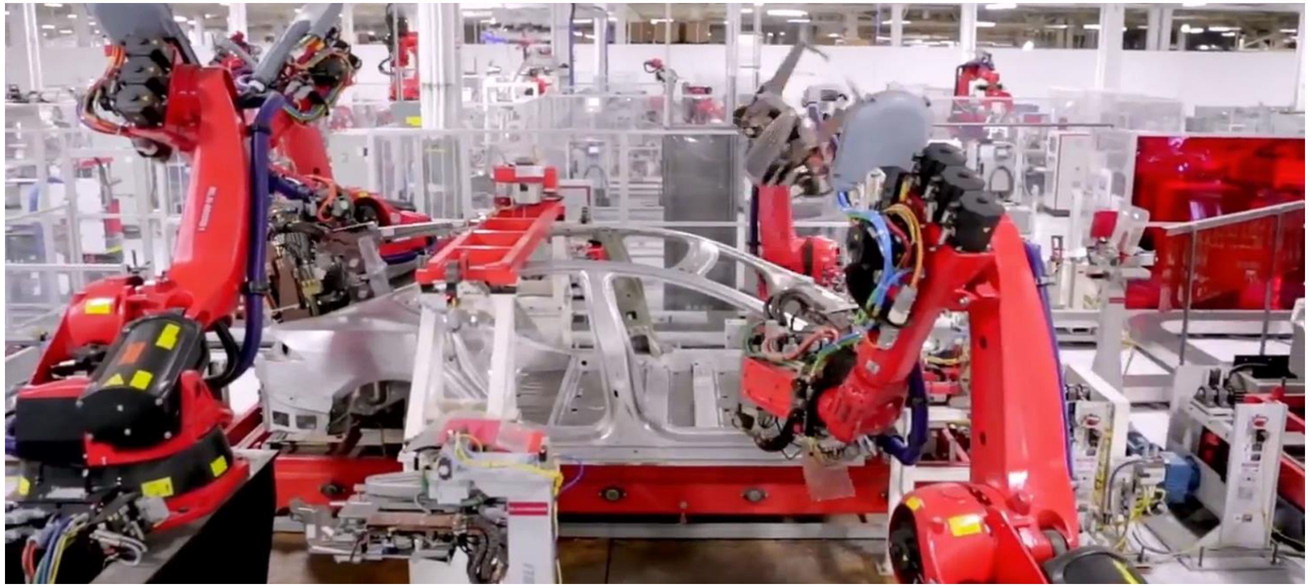
Power Electronic Systems Laboratory
www.pes.ee.ethz.ch

Nov. 11, 2024

Variable Speed Motor Drive (VSD) Systems

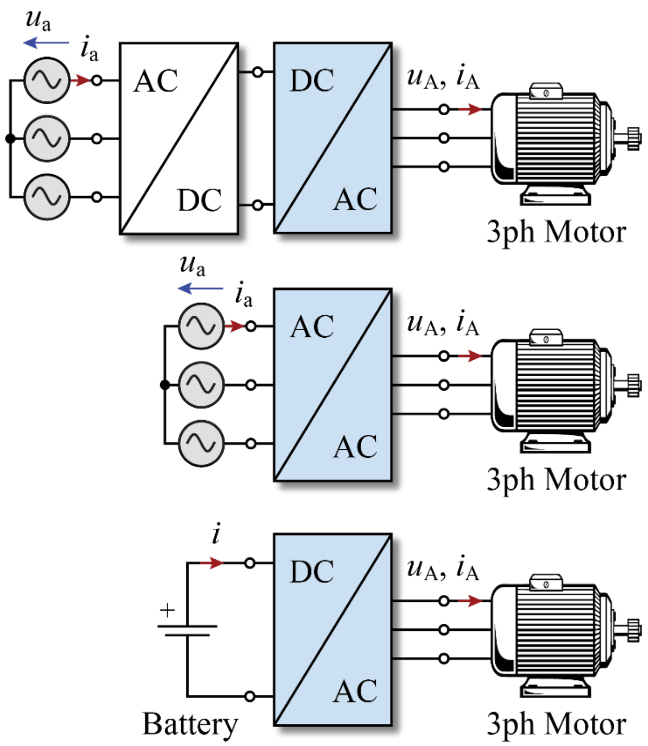
- *Industry Automation / Robotics*
- *Material Machining / Processing – Drilling, Milling, etc.*
- *Compressors / Pumps / Fans*
- *Transportation*
- *etc., etc.* .... *Everywhere !*

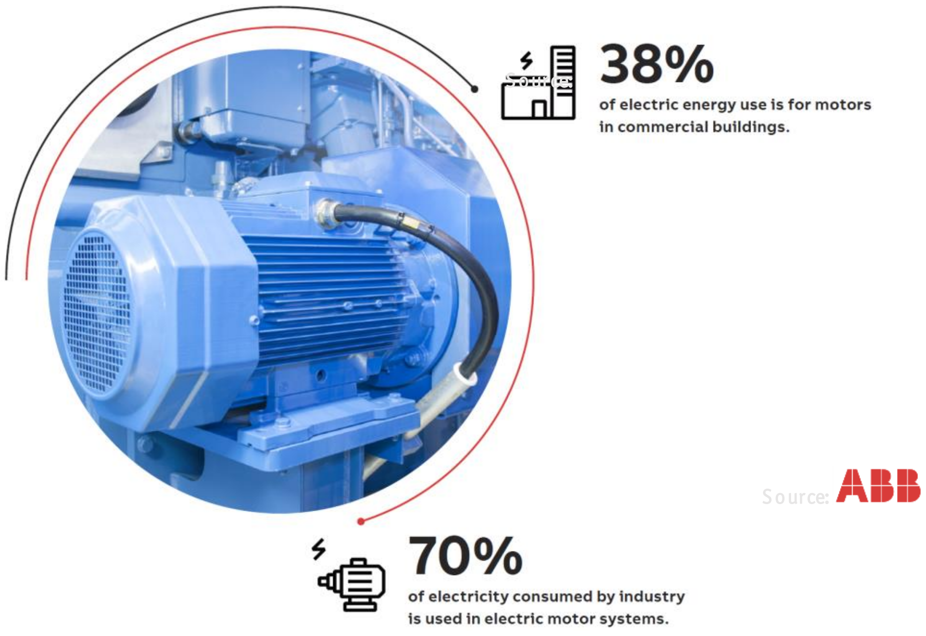


- *60...70 % of All Electric Energy Used in Industry Converted by VSDs*

Variable Speed Drives — State-of-the-Art 1/2

- *DC-Link Based AC/DC/AC OR Matrix-Type AC/AC Converters*
- *Battery OR Fuel-Cell Supply OR Common DC-Bus Concepts*





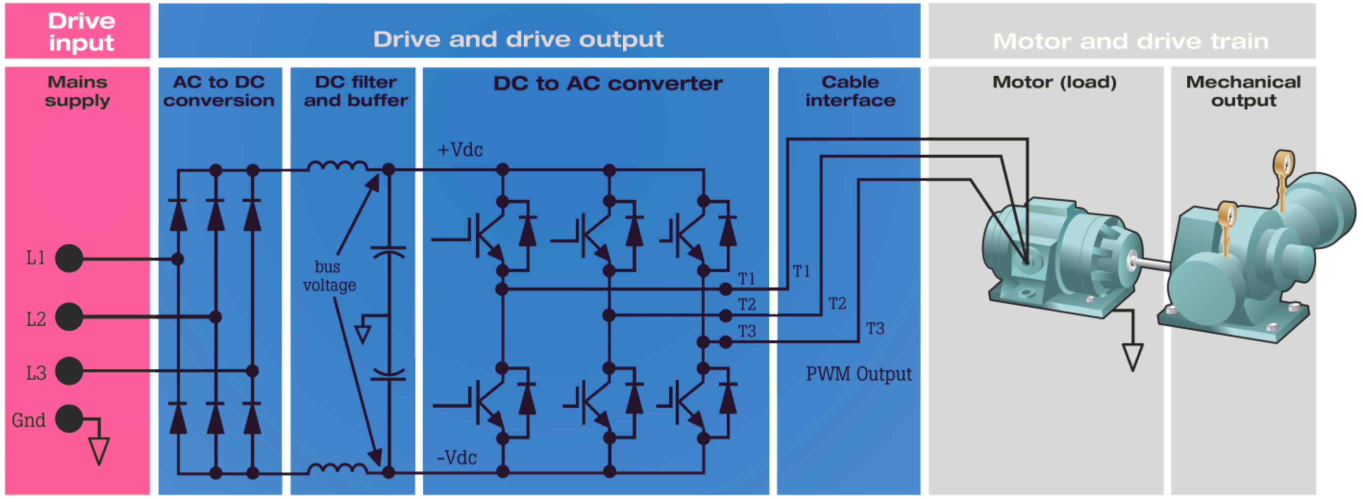
- *45% of World's Electricity Used for Motors in Buildings & Industrial Applications*

Variable Speed Drives — State-of-the-Art 2/2

- Mains Interface | 3-Φ PWM Inverter | Cable | Motor → All Separated
- PWM Output → Conducted & Radiated EMI / Reflections @ Motor Terminals / Bearing Currents

— Large Installation Space / $$$
— Shielded Motor Cables / Filters / $$$
— Special Types of Bearings / Grounding / $$$
— Complicated / Expert Installation / $$$

Source: FLUKE



- High Performance @ High Level of Complexity & High Costs (!)

SiC Low $R_{DS(on)}$ High-Voltage Devices

- *Higher Critical E-Field of SiC → Thinner Drift Layer*
- *Higher Maximum Junction Temperature $T_{j,max}$*

at 300 K	Si	GaAs	4H/6H-SiC	GaN
E_g (eV)	1.12	1.4	3.0-3.2	3.4
E_c (MV/cm)	0.25	0.3	2.2-2.5	3
μ_n (cm^2/Vs)	1350	8500	100-1000	1000
ε_r	11.9	13	10	9.5
v_{sat} (cm/s)	$1x10^7$	$1x10^7$	$2x10^7$	$3x10^7$
λ (W/cmK)	1.5	0.5	3 - 5	1.3

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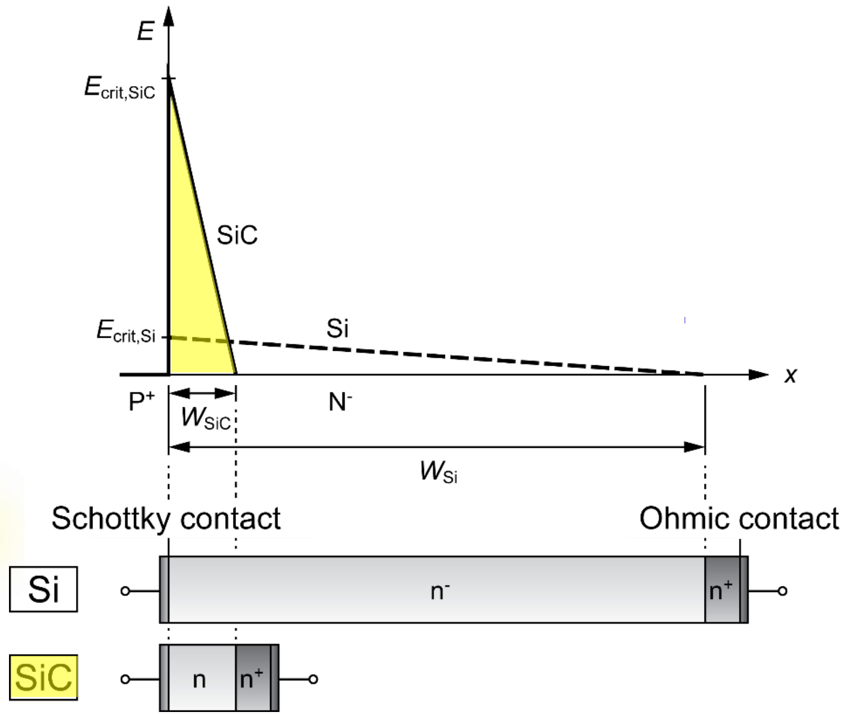
$$R^*_{on} = \frac{4V_B^2}{\varepsilon \mu_n E_C^3} \leftarrow$$

For 1kV:

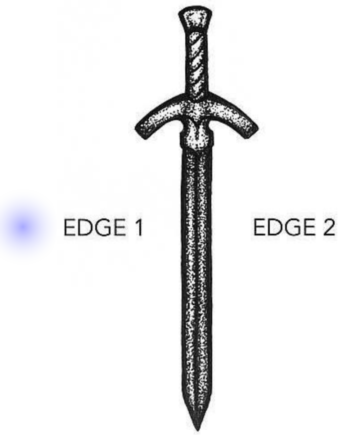
	Si	SiC
W (μm)	100	10
N_D (cm^{-3})	10^{14}	10^{16}

$$R^*_{on,SiC} \approx \frac{1}{300} R^*_{on,Si}$$



- *Massive Reduction of Relative On-Resistance → High Blocking Voltage Unipolar (!) Devices*

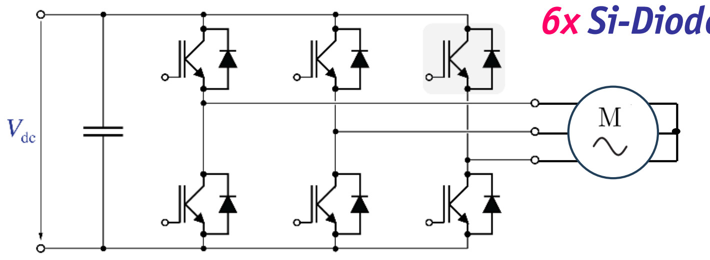
Advantages



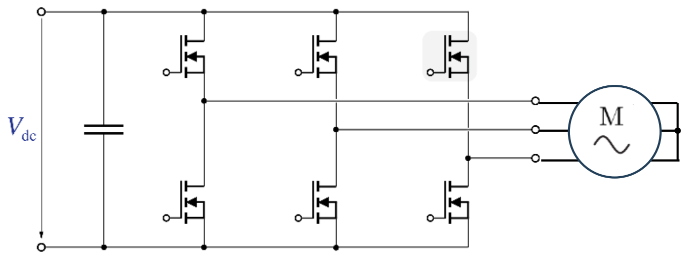
Si vs. SiC

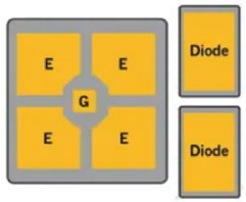
- *Si-IGBT / Diode* → *Const. On-State Voltage, Turn-Off Tail Current & Diode Reverse Recovery Current*
- *SiC-MOSFET* → *Loss Reduction @ Part Load BUT Higher R_{th}*

6x Si-IGBT
6x Si-Diode



6x SiC-MOSFET





Source: ATZ elektronik

1200V 100A
Die Size: 98.8mm² + 39.4mm²

Source: Infineon

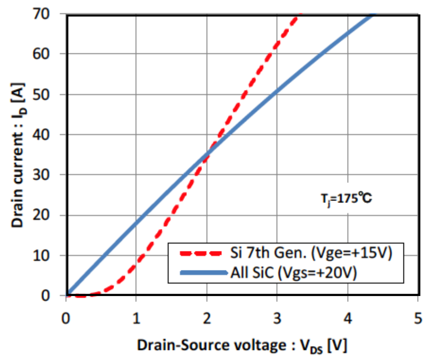
1200V 100A
Die Size: 25.6mm²

Source: Cree

- *Space Saving of >30% on Module Level (!)*

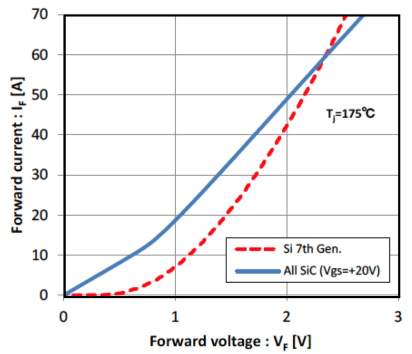
Si vs. SiC Conduction Behavior

- *Si-IGBT → Const. On-State Voltage Drop / Rel. Low Switching Speed*
- *SiC-MOSFETs → Resistive On-State Behavior / Factor 10 Higher Sw. Speed*

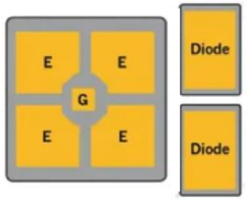


Source: Fuji Electric

Forward



Reverse



1200V 100A
Die Size: 98.8mm² + 39.4mm²

Source: Infineon

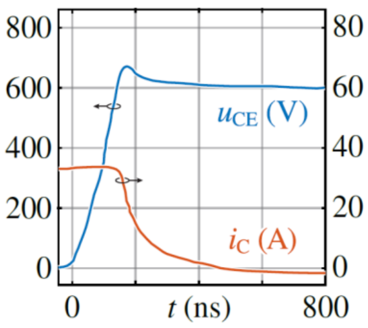
1200V 100A
Die Size: 25.6mm²

Source: Cree

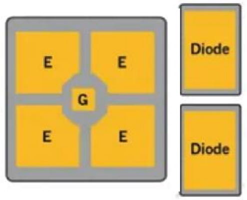
- *SiC MOSFETS Facilitate Higher Part Load Efficiency*

Si vs. SiC Switching Behavior

- *Si-IGBT* → *Const. On-State Voltage Drop / Rel. Low Switching Speed*
- *SiC-MOSFETs* → *Resistive On-State Behavior / Factor 10 Higher Sw. Speed*

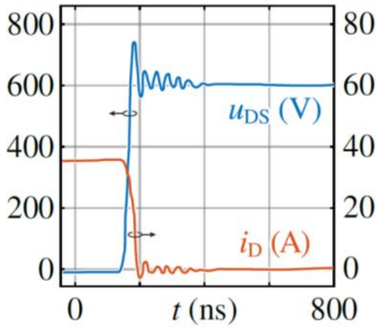


Source: Fuji Electric



1200V 100A
Die Size: 98.8 mm² + 39.4 mm²

Source: Infineon

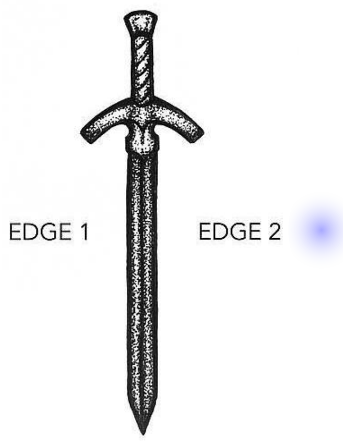


1200V 100A
Die Size: 25.6 mm²

Source: Cree

- *High di/dt & dv/dt* → *Challenges in Packaging / EMI / Motor Insulation / Bearing Currents*

Challenges



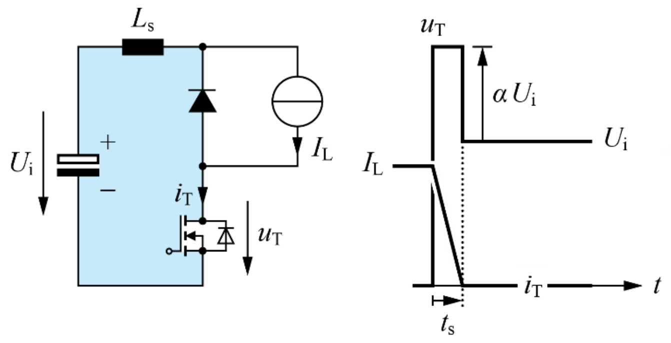
Low Commutation Loop Inductance

$$L\frac{di}{dt} = u$$

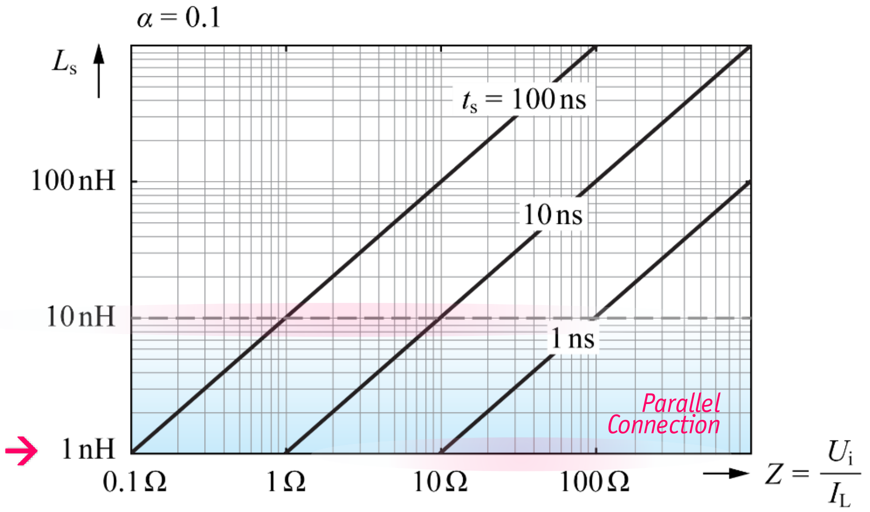
- *High di/dt Switching Transition*
- *Commutation Loop Inductance L_s*
- *Allowed L_s Directly Related to Switching Time t_s* →

$$L_s \le \frac{\alpha U_i}{\frac{I_L}{t_s}} = \alpha t_s \frac{U_i}{I_L}$$

Z



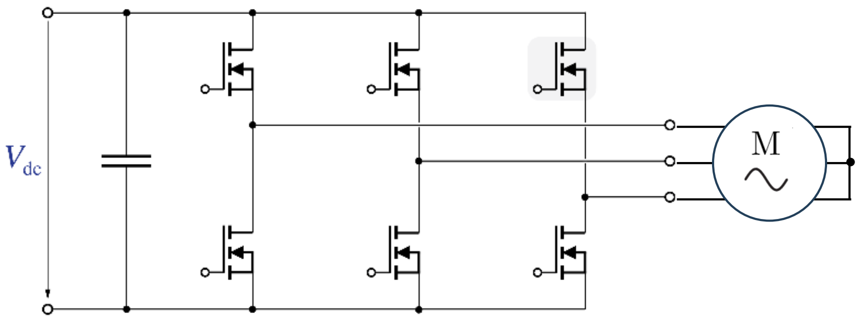
→



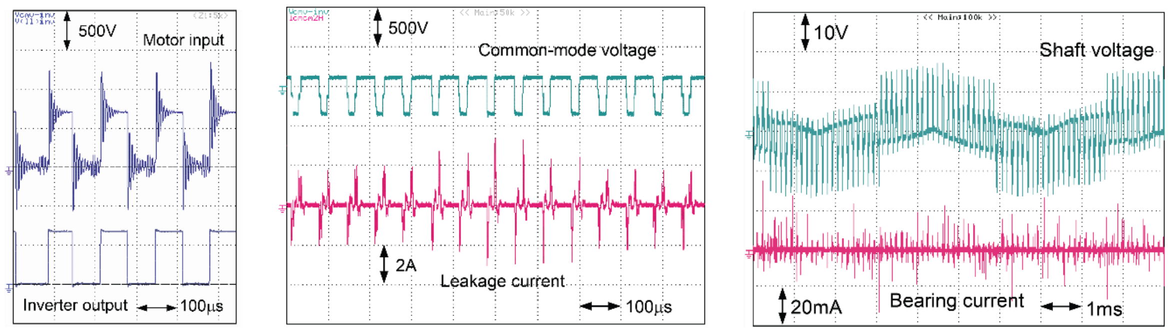
- *Advanced Packaging & Parallel Interleaving for Partitioning of Large Currents (Z-Matching)*

Surge Voltage Reflections & CM Currents

- *High dv/dt / Short Rise Times of Inverter DM & CM Output Voltage Pulses*
- *Reflections @ Motor Terminals → High Insulation Stress*
- *CM Leakage Current → Radiated Emissions & Bearing Currents*



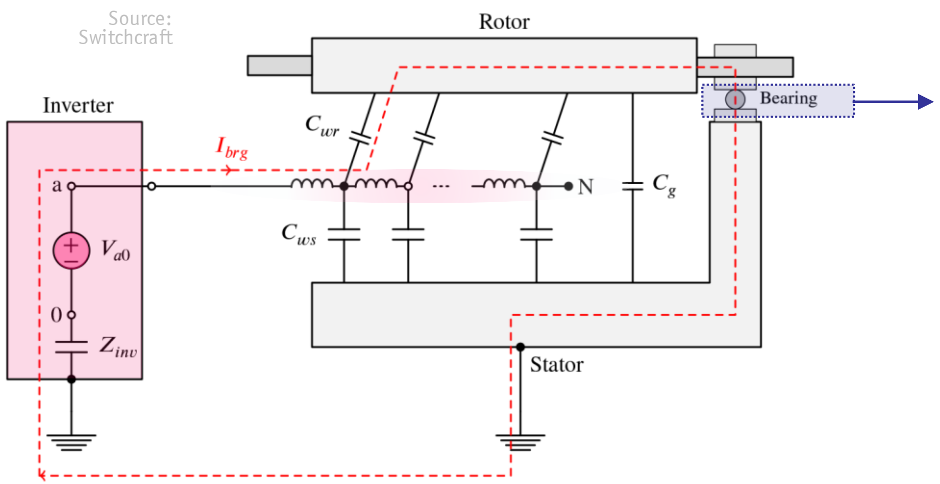
Source: YASKAWA

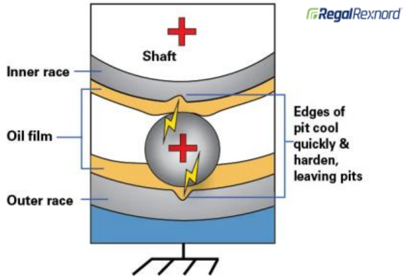


- *Motor Surge Voltage | CM Leakage Current | Bearing Current*

Motor Bearing Currents

- *Switching Frequency CM Inverter Output Voltage → Motor Shaft Voltage*
- *Electrical Discharge Machining ("EDM") in the Bearing*



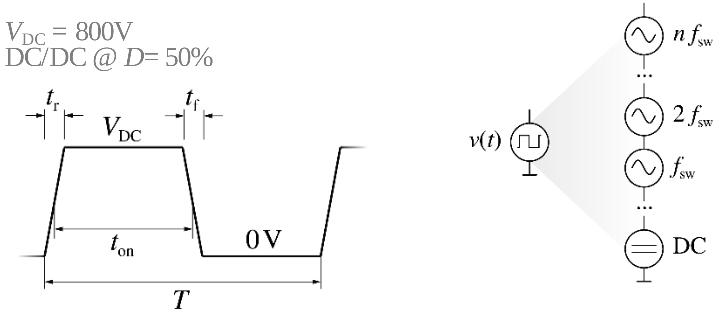


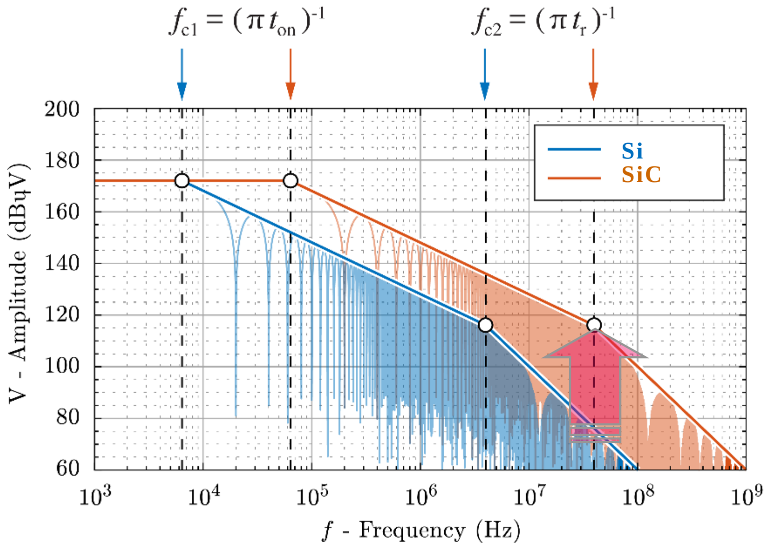
→ *Cond. Grease / Ceram. Bearings / Shaft Grndg Brushes / dv/dt-Filter OR Full-Sinewave Filters*

Conducted & Radiated EMI Emissions

- *Higher dv/dt* → *Factor 10*
- *Higher Switching Frequencies* → *Factor 10*
- *EMI Envelope Shifted to Higher Frequencies*

f_S= 10 kHz & 5 kV/us for (Si IGBT)
f_S= 100 kHz & 50 kV/us for (SiC MOSFET)





- *Higher Influence of Filter Component Parasitics & Couplings* → *Advanced Design*

Inverter Output Filters

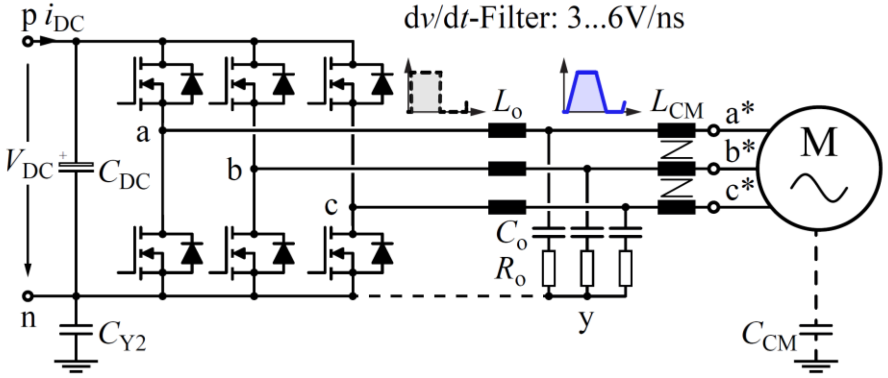
dv/dt-Filters
Full-Sinewave Filters

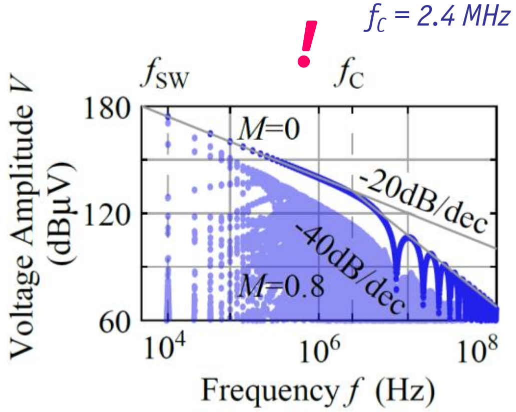
dv/dt-Limitation

Passive | Hybrid | Active dv/dt-Limitation

- *Passive* – *Damped LC-Filter* $f_C > f_S$
- *Hybrid* – *Undamped LC-Filter & Multi-Step Sw. Transition*
- *Active* – *Gate-Drive Based Shaping of Sw. Transients*

f_{sw} = 16 kHz
$t_R = t_F$ = 130 ns
f_C = 2.4 MHz

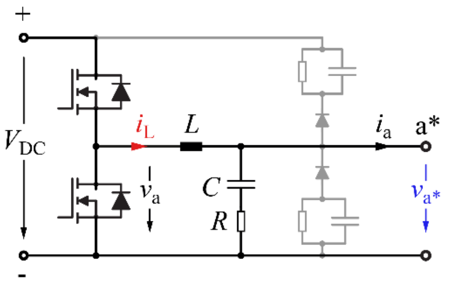


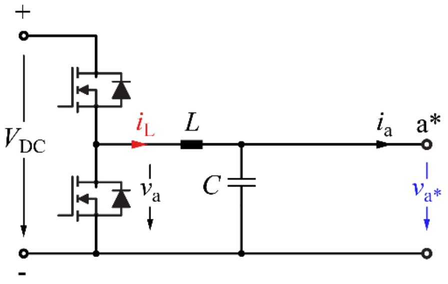


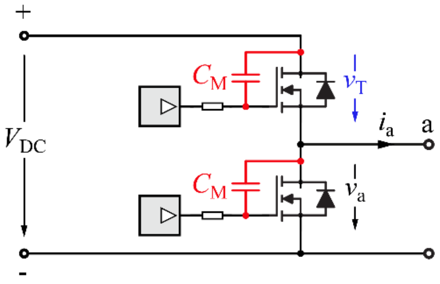
- *Connection to DC-Minus & CM Inductor* → *Limit CM Curr. Spikes / EMI / Bearing Currents*

Comparison of dv/dt-Filtering Techniques

- **Passive Concept**
  1. LCR-Filter
  2. Clamped LC-Filter
- **Hybrid Concept ($3f_{sw}$)**
  1. LC-Filter
  2. Multi-Step Switching
- **Active Concept**
  1. Miller Capacitor
  2. Gate Current Control

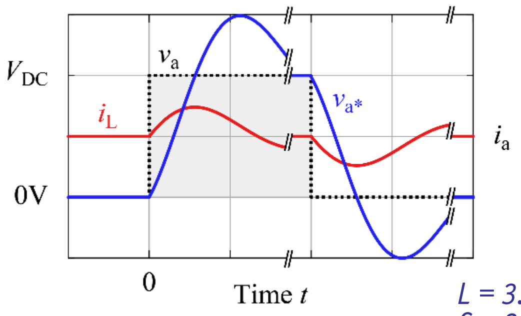




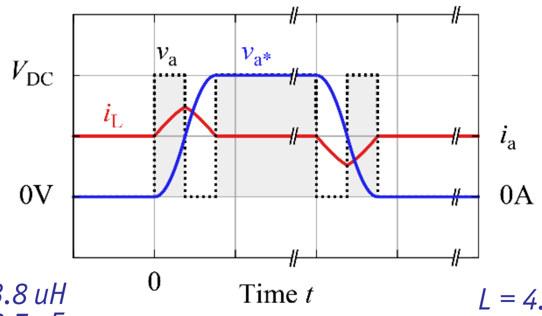


- **Output Voltage Waveforms — V_{DC} = 800 V, P_{out} = 10 kW, 6 kV/us**

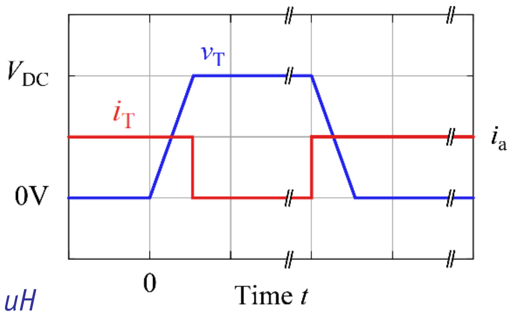
1200V SiC / 16 mΩ
C_M = 120 pF



L = 3.8 uH
C = 2.7 nF
R = 19 Ω

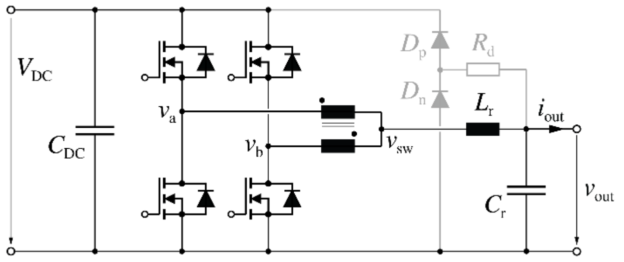


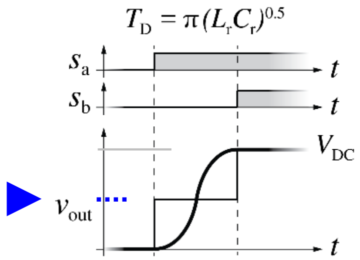
L = 4.1 uH
C = 1.3 nF



Multi-Bridge-Leg dv/dt-Limitation

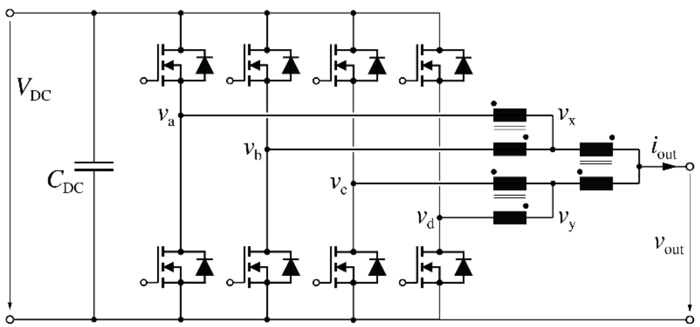
- *2-Step Switching / Resonant Transition (Hybrid dv/dt-Filter)*

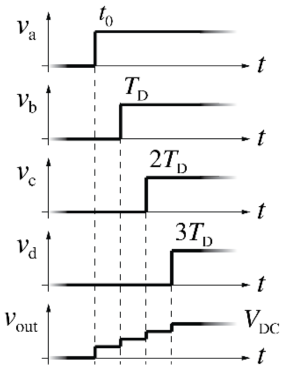




Source: J. Ertl et al.
PCIM Europe 2018

- *Staggered Sw. Parallel Bridge-Legs → Non-Resonant Multi-Step Transition*





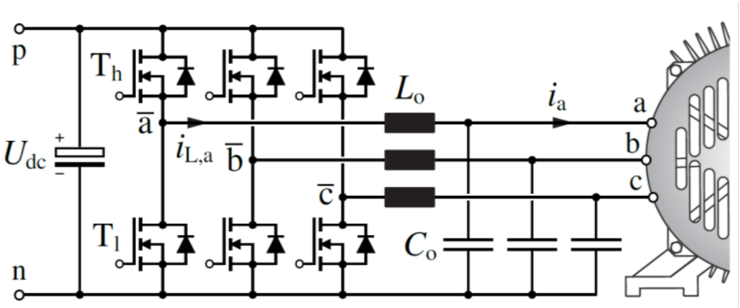
Source: J. Ertl et al.
PCIM Europe 2017

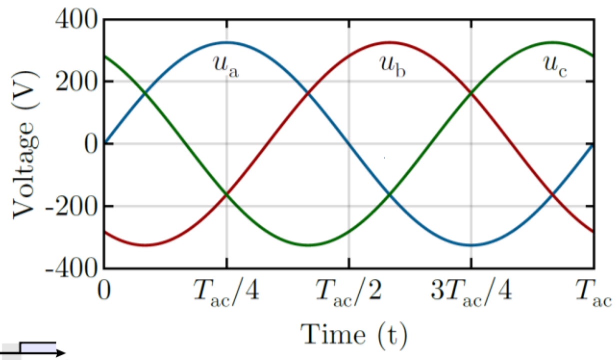
- *Adv. for High Power / High Output Curr. Syst. Employing Parallel Bridge-Legs & Local Comm. Caps*

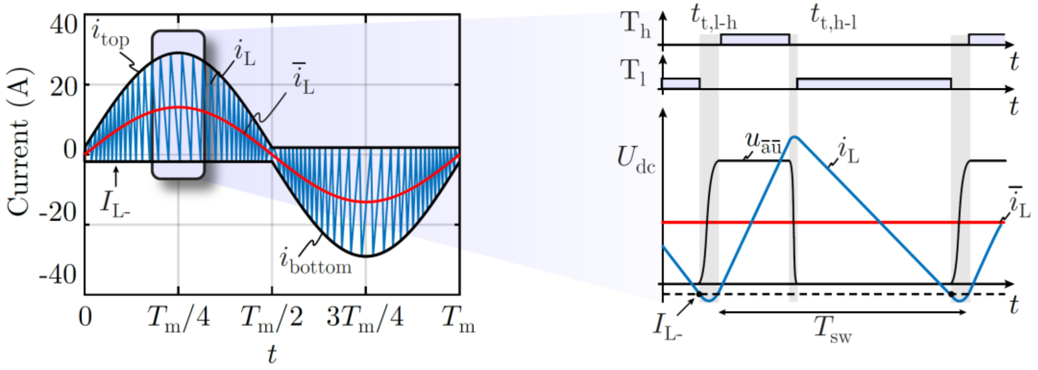
Triangular Current Mode (TCM)
ZVS Operation

Full-Sinewave Filter & ZVS Operation

- *Purely Sinusoidal Output Voltage (DM & CM Filtering)*
- *High Sw. Frequency & TCM → Low Filter Inductor Volume*
- *ZVS of Inverter Bridge-Legs*





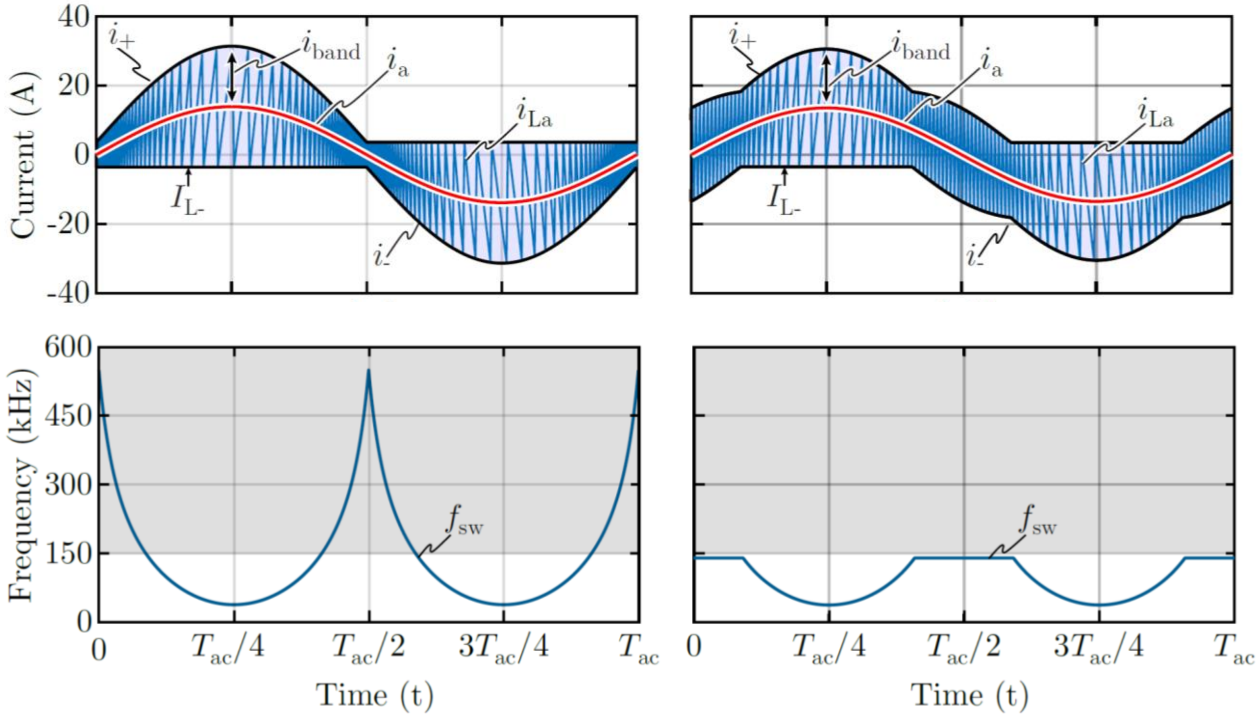


NFO Sinus

- *Only 33% Increase of Transistor Conduction Losses Compared to CCM (!)*
- *Very Wide Switching Frequency Variation*

Frequency-Bounded TCM → B-TCM

- *Very Wide Switching Frequency Variation of TCM → B-TCM*



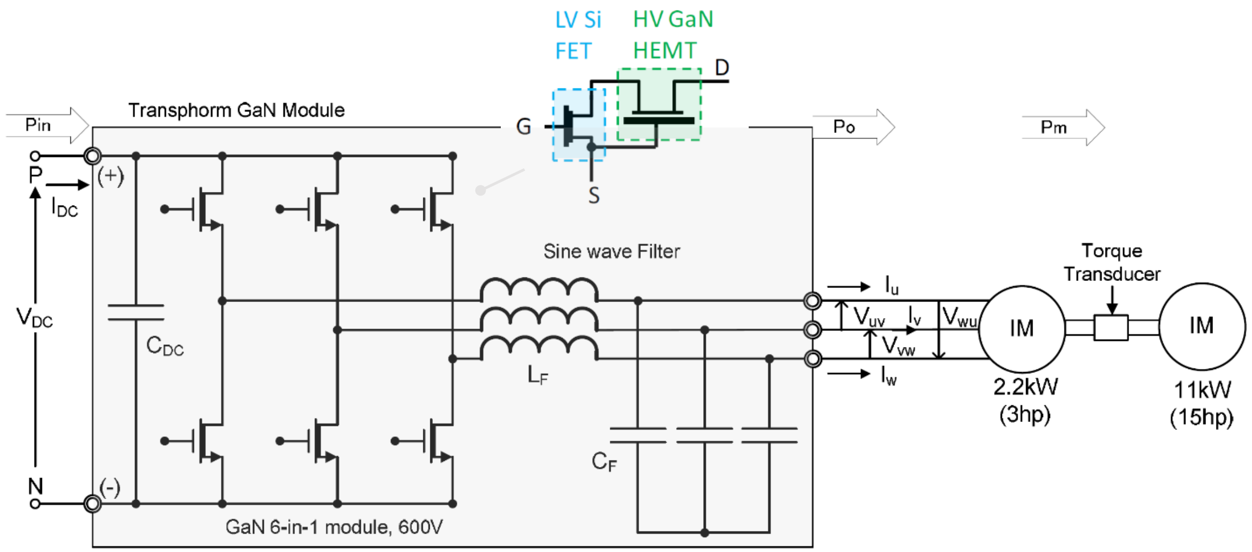
- *TCM → B-TCM — 10% Further Increase of Transistor Conduction Losses*

Continuous Current Mode (CCM) Operation

3-Φ 650V GaN Inverter System (1)

Source: YASKAWA

- *Transphorm 650 V Normally-On GaN HEMT/30V Si-MOSFET Cascode 6-in-1 Power Module*
- *Sinewave LC Output Filter — Corner Frequency f_C= 34 kHz (f_{sw}= 100 kHz)*
- *No Freewheeling Diodes*

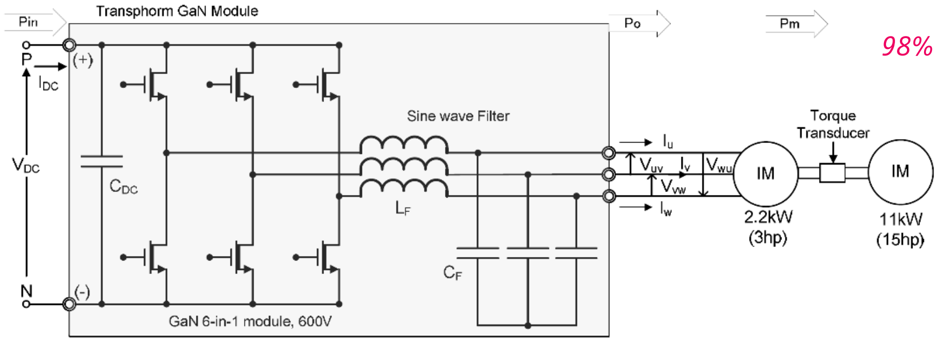


→ *Comparison to Si-IGBT Drive Systems*

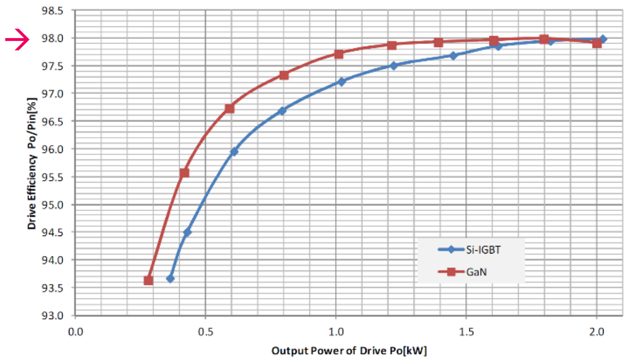
3-Φ 650V GaN Inverter System (2)

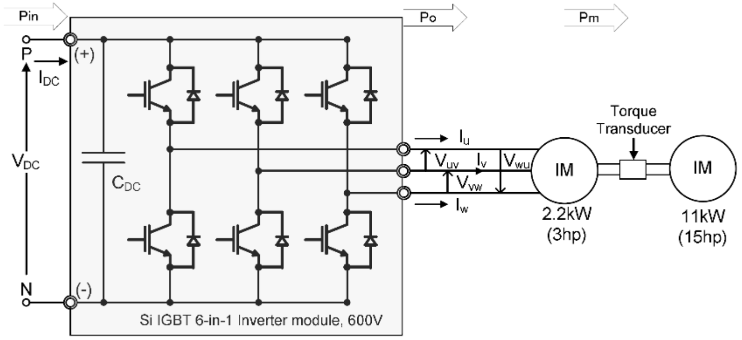
Source: YASKAWA

- *Comparison of GaN Inverter w/ LC-Filter to Si-IGBT System (No Filter, f_{sw}=15 kHz)*
- *Measurement of Inverter Stage & Overall Drive Losses @ 60 Hz*

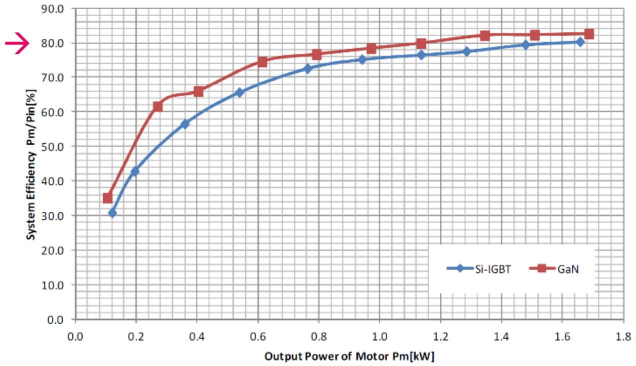


98% →





80% →

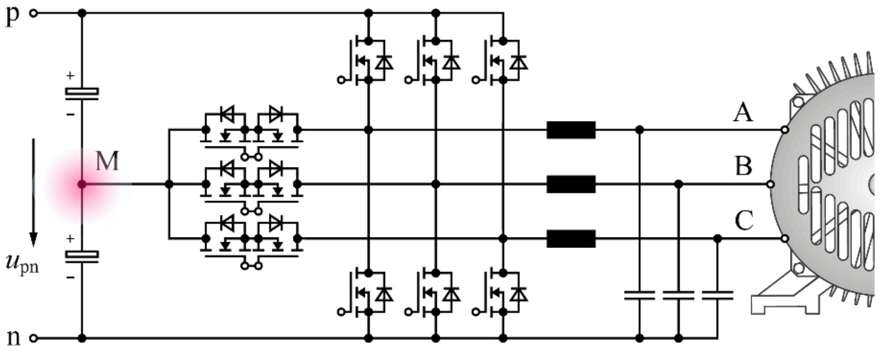


→ *2% Higher Efficiency of GaN System Despite LC-Filter (Saving in Motor Losses) !*

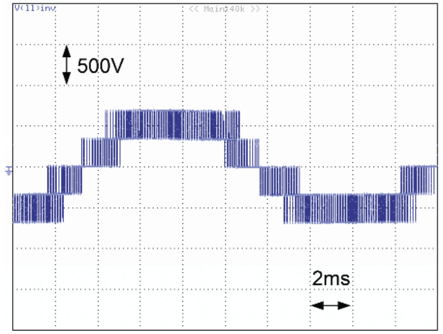
Multi-Level / Multi-Cell Converters & Modularity

3-Level T-Type Inverter (1)

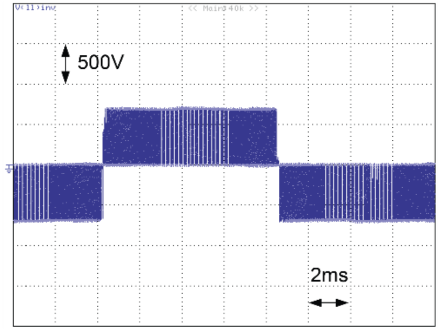
- *Higher Number of Bridge-Leg Output Voltage Levels / Lower DM & CM Voltage Steps*
- *Neutral Point Clamped | Flying Capacitor | T-Type Bridge-Leg Topologies*



Motor Line-to-Line Voltage



3-Level Bridge-Leg

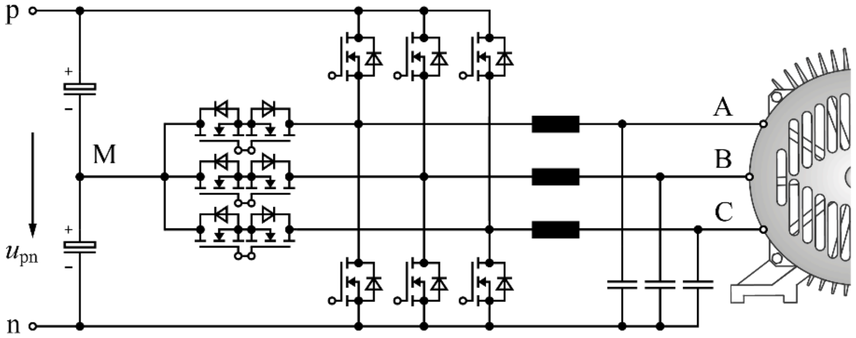


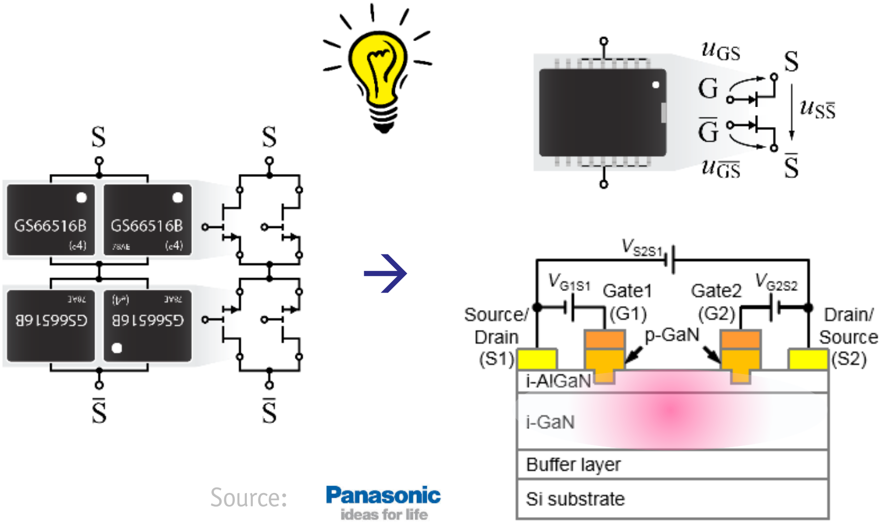
2-Level Bridge-Leg

- *More Complicated Bridge-Leg Structure*
- *On-State-Losses of Series-Connected Switches*

3-Level T-Type Inverter (2)

- *3-Level T-Type Inverter — 3-Level Phase Voltage / 5-Level Line-to-Line Voltage*
- *Lower DM & CM Voltage Steps Compared to 2-Level Converter*



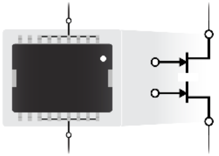


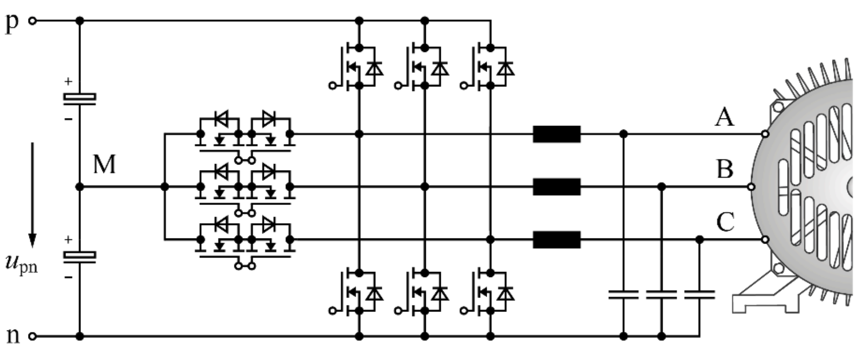
Source: Panasonic ideas for life

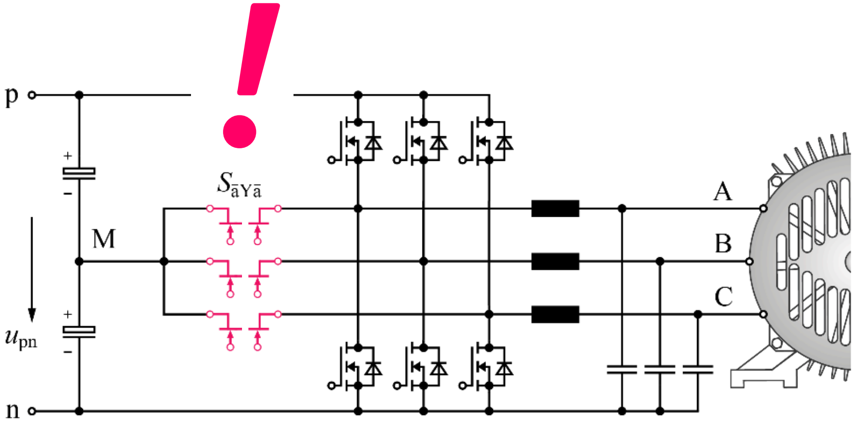
- *Full-Sinewave DC-Link Referenced LC-Filter — Elimination of DM & CM Sw. Frequ. Voltage Harmonics*
- *T-Type Topology Ensures Low Conduction Losses — Adv. Application of M-BDSs (!)*

3-Level T-Type Inverter (3)

- *3-Level T-Type Inverter — 3-Level Phase Voltage / 5-Level Line-to-Line Voltage*
- *Lower DM & CM Voltage Steps Compared to 2-Level Converter*





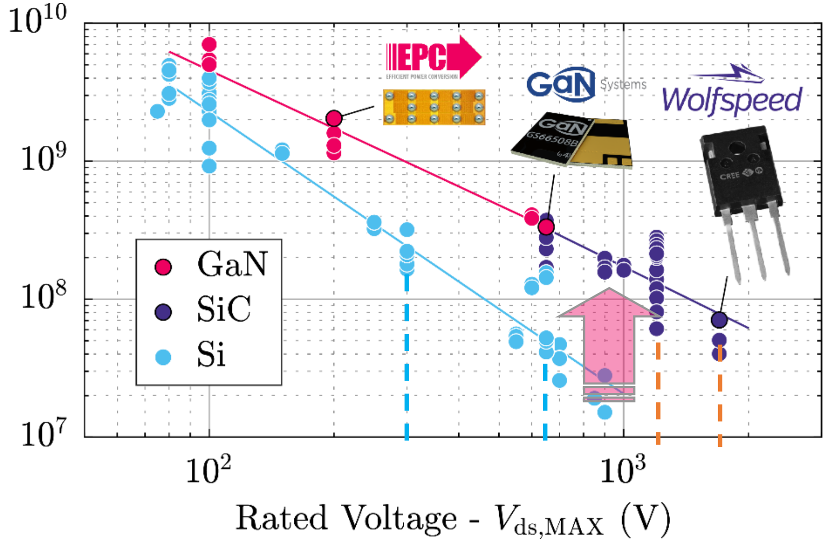


- *Full-Sinewave DC-Link Referenced LC-Filter — Elimination of DM & CM Sw. Frequ. Voltage Harmonics*
- *T-Type Topology Ensures Low Conduction Losses — Adv. Application of M-BDSs (!)*

SiC/GaN Figure-of-Merit

- *Figure-of-Merit (FOM) Quantifies Conduction & Switching Properties*
- *FOM Identifies Max. Achievable Efficiency @ Given Sw. Frequ.*

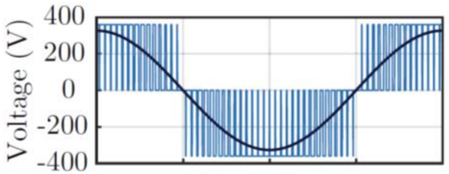
$$\mathrm{FOM} = \frac{1}{R_{\mathrm{ds,on}} Q_{\mathrm{oss}}}$$

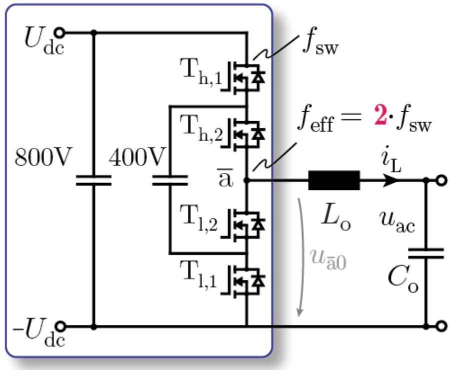


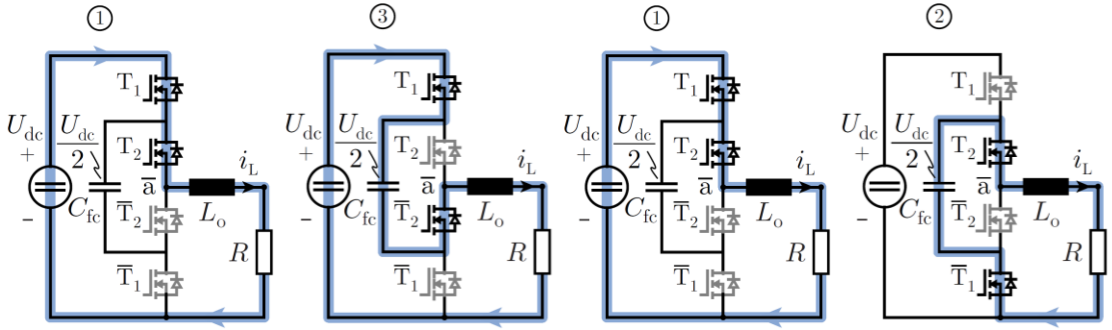
- *Advantage of LV over HV Power Semiconductors →*
- *Advantage of Multi-Level over 2-Level Converter Topologies*

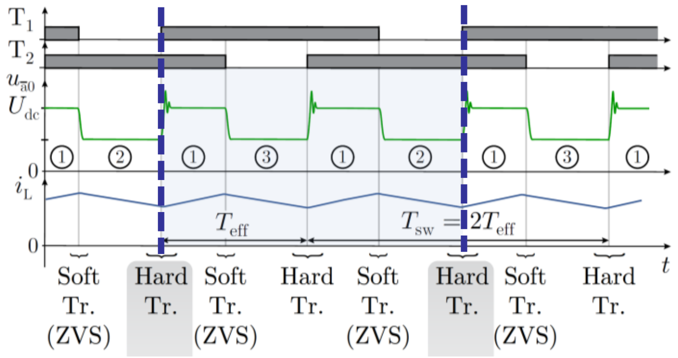
3-Level Flying Capacitor (FC) Converter

- *3-Level Flying Cap. (FC) Converter → No Connection to DC-Midpoint*
- *Involves All Switches in Voltage Generation → Eff. Doubles Device Sw. Frequency*









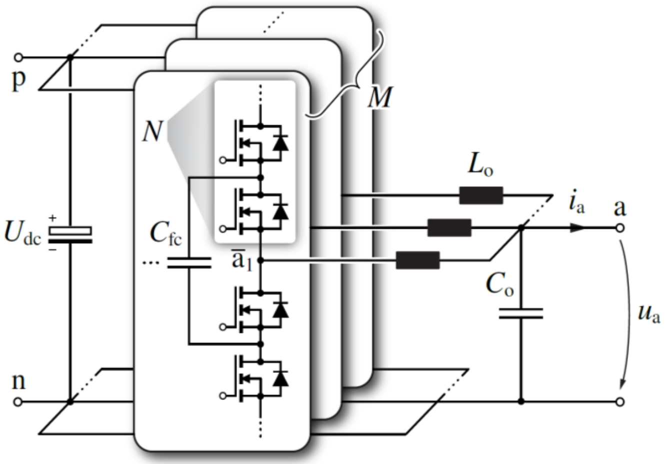
- *FC Voltage Balancing Possible also for DC Output (!)*

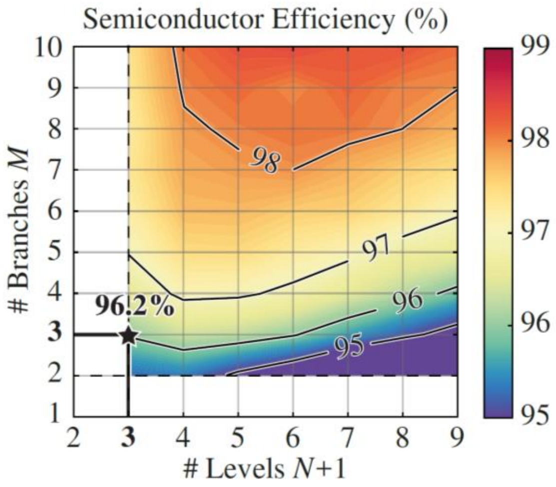
4.8MHz GaN Half-Bridge Phase Module

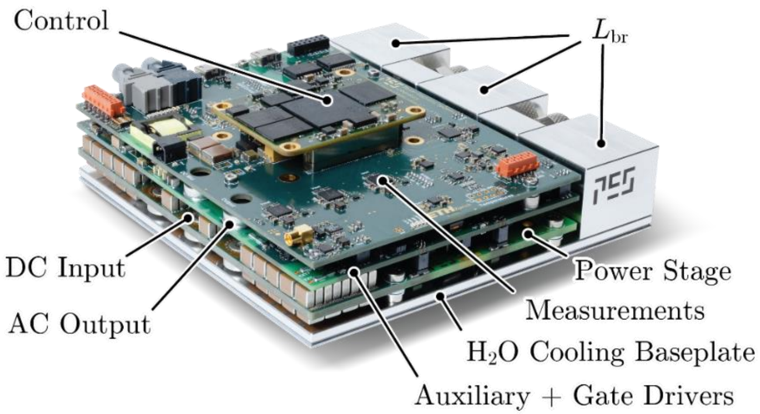
- *Combination of Series & Parallel Interleaving*

— *600 V GaN Power Semiconductors, f_{sw} = 800 kHz*
— *Volume of ≈180 cm^3 (incl. Control etc.)*
— *H_2O Cooling Through Baseplate*

★ *25 kW/dm^3*





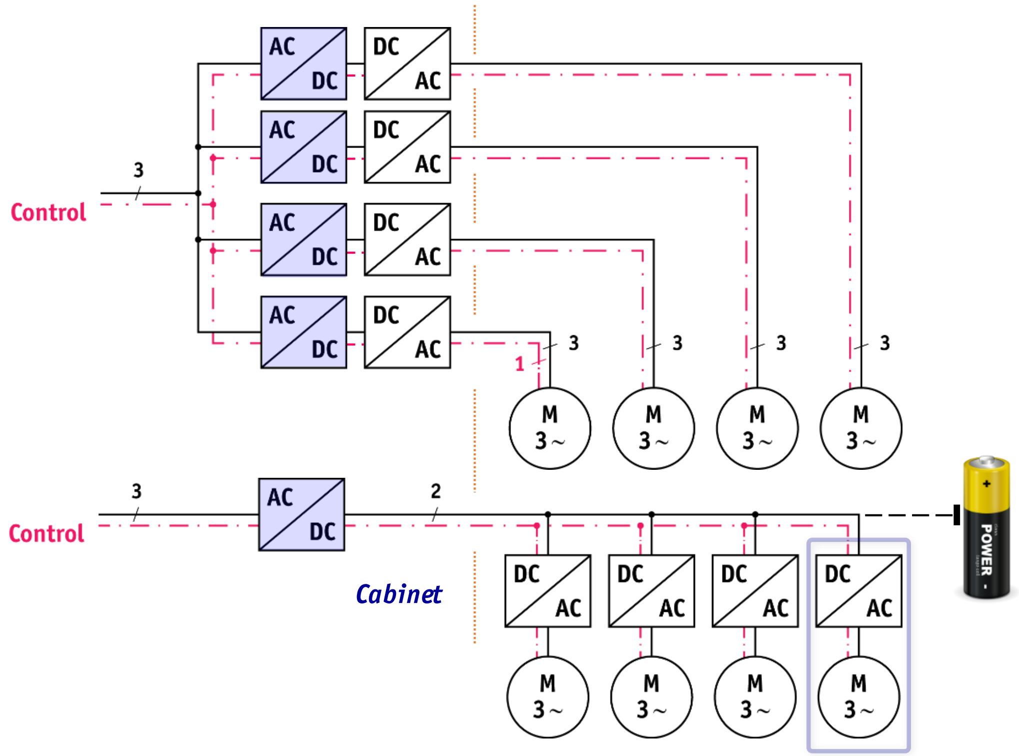


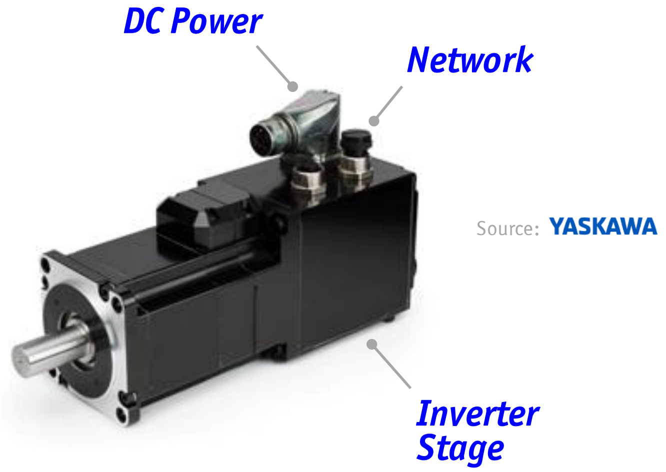
- *Operation @ f_{out} = 100 kHz / $f_{sw,eff}$ = 4.8 MHz, 10 kW, U_{dc} = 800 V*

Motor-Integrated Inverter Systems

Multi-Axis Drive Systems

- *Common DC-Bus — Single AC/DC Converter / Smaller Cabinet*
- *Motor Integration of DC/AC Stage — Massive Saving in Cabling Effort / Simplified Installation*

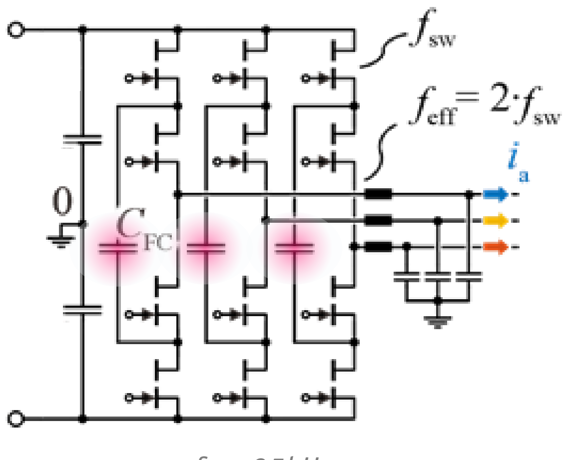




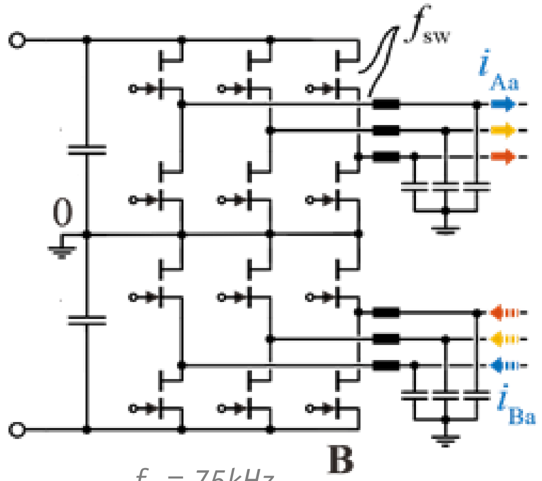
- *Facilitates DC-Bus Energy Buffer*
- *Direct Energy Exchange @ DC-Bus / Higher Efficiency / Unidir. Front-End*

Motor Integrated Inverter Stage

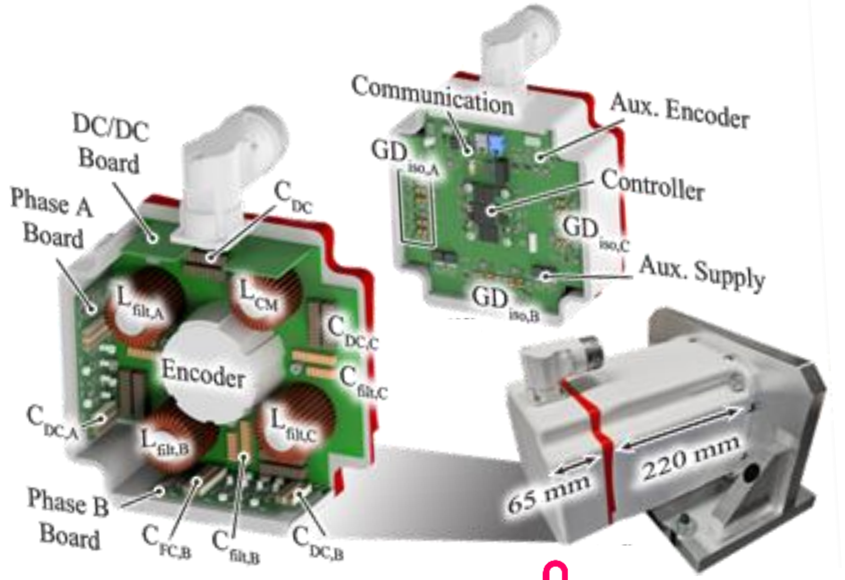
- *Comparative Evaluation of ML-Inverter Concepts*
- *2x 2-Level Stacked 650V GaN | 3-Level 650V GaN | 7-Level 200V Si Inverter*
- *Design for 800V DC-Link / 7.5kW / 99% Efficiency / 3s 3x T_N Overload*



f_{sw} = 35kHz



f_{sw} = 75kHz



90° C

- *7-Level FC Inverter — Large PCB Area Requirement & High Complexity*
- *2x 2-Level Inverter — No Flying Capacitors & CM Cancellation / Low L_{CM} Volume*
- *3-Level FC Inverter — Best Overall Trade-Off (Complexity / PCB Area / Volume of Full-Sinewave Filter etc.)*

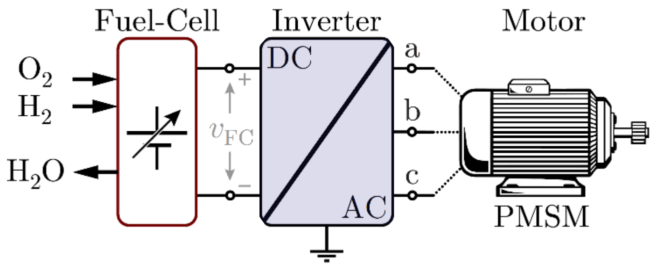
Buck-Boost Functionality

Motivation

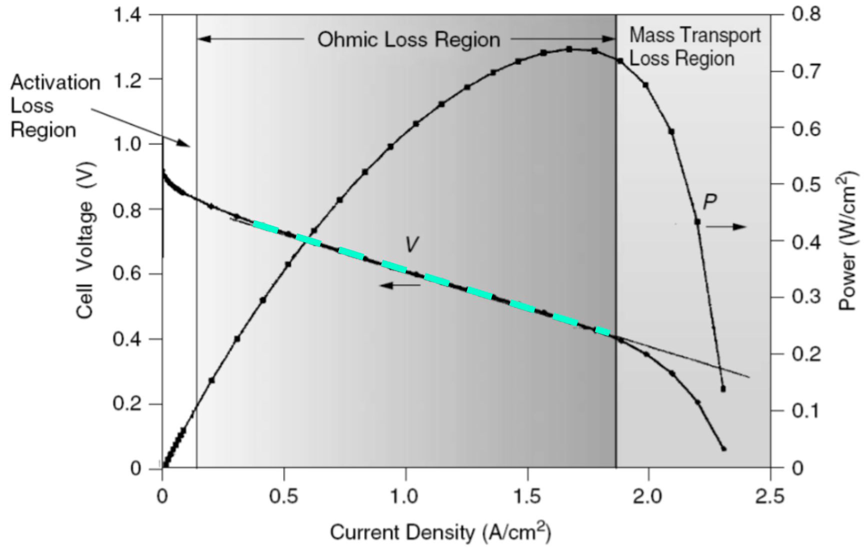
- *General / Wide Applicability*

— *Adaption to Load-Dependent Battery | Fuel Cell Supply Voltage*
— *Operation in Wide Output Voltage / Wide Motor Speed Range*

Source: magazine.fev.com



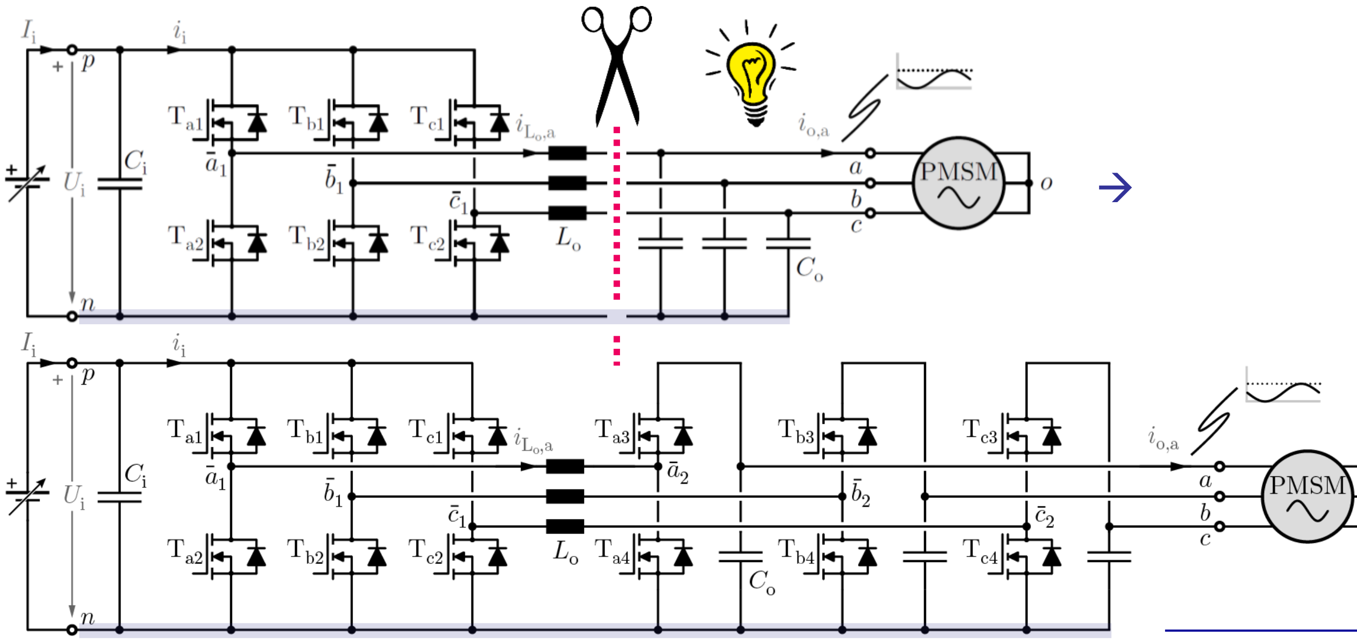
Source: www.chegg.com



- *Full-Sinewave Filtered Motor Supply Voltage*
- *LC Output Filter Inductor Advantageously Utilized as Buck-Boost-Inductor*

Buck-Boost «Y–Inverter»

- *Generation of AC-Voltages Using Unipolar Bridge-Legs*



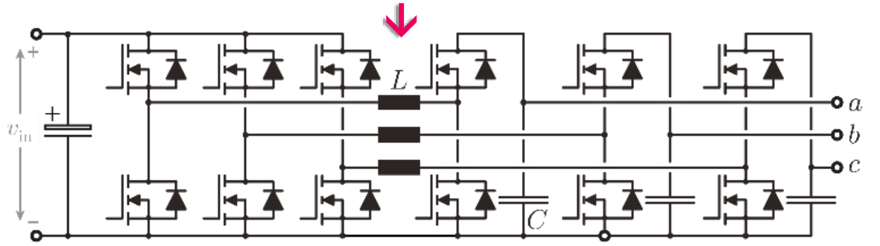
→

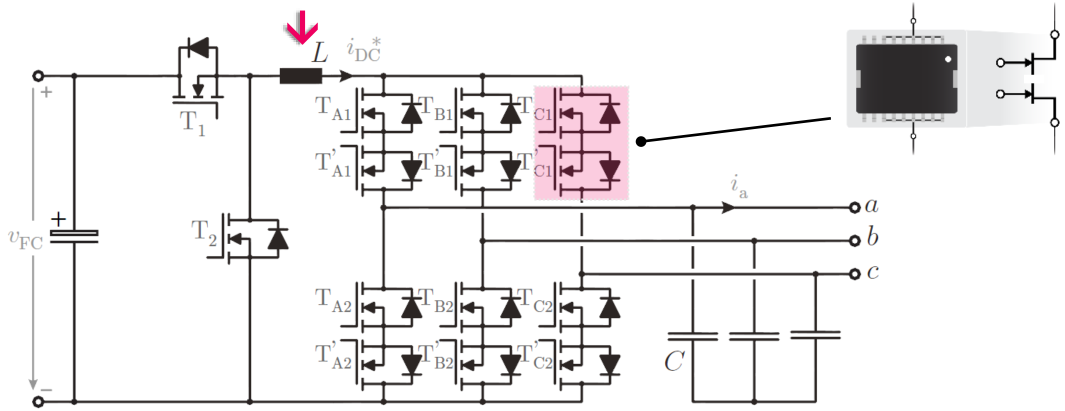
"Y-Inverter"

- *Switch-Mode Operation of Buck OR Boost Stage* → *Quasi Single-Stage Energy Conversion (!)*
- *3-Φ Continuous Sinusoidal Output / Low EMI* → *No Shielded Cables / No Motor Insul. Stress*

3-Φ Current Source Inverter (CSI) Topology

- *Y-Inverter → Phase Modules w/ Buck-Stage | Current Link | Boost-Stage*
- *3-Φ CSI → Buck-Stage V→I Converter | Current DC-Link DC/AC-Stage*

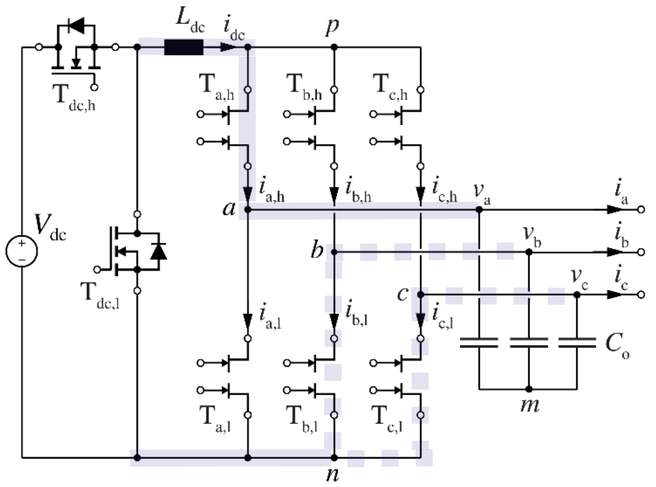


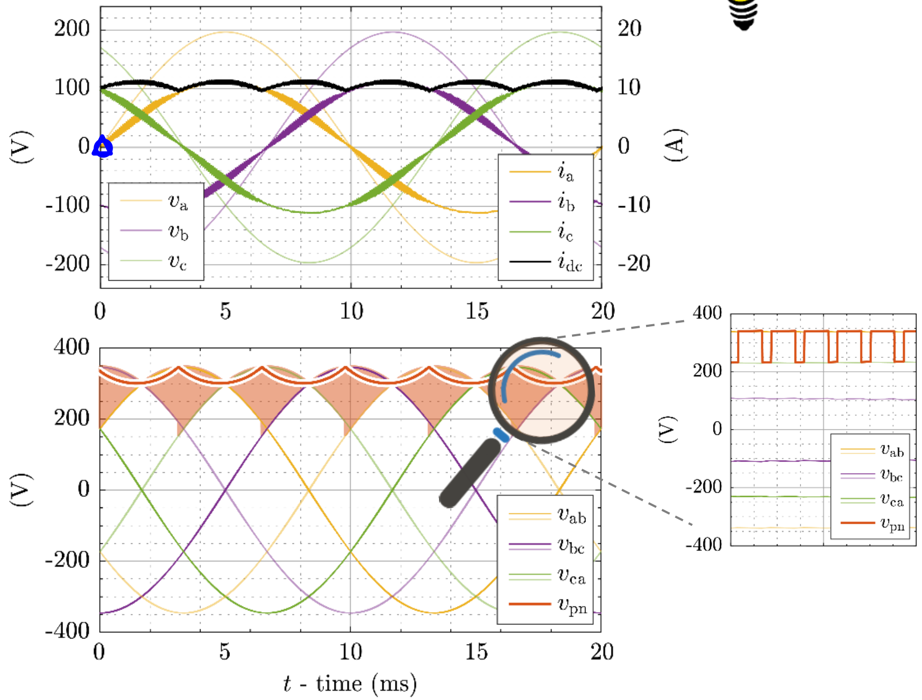


- *Single Inductive Component*
- *Positive DC-Side Voltage for Both Directions of Power Flow → Future Utilization of M-BDSs*

3-Φ Buck-Boost CSI Modulation

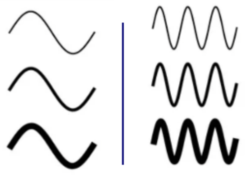
- *"Synergetic" Control of Buck-Stage & CSI Stage*
- *6-Pulse-Shaping of DC Current by Buck-Stage → Allows Clamping of One CSI-Phase*





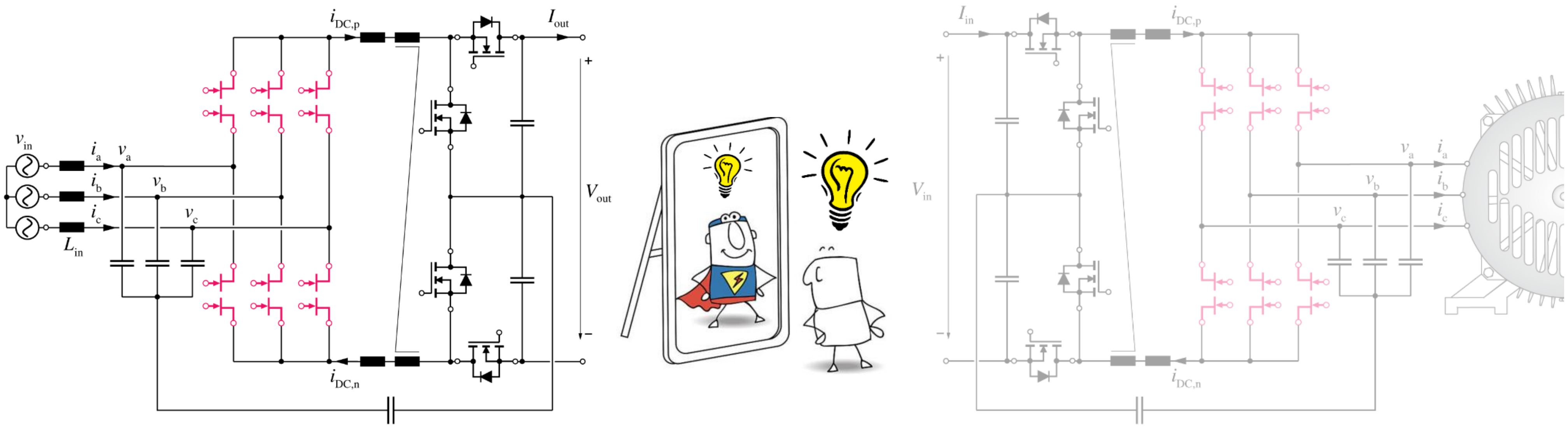
- *Switching of Only 2 of 3 Phase Legs (2/3 Mode) → Significant Reduction of Sw. Losses*

3-Φ AC/AC Conversion



Derivation of 3-Φ Current Source AC/AC Converter (1)

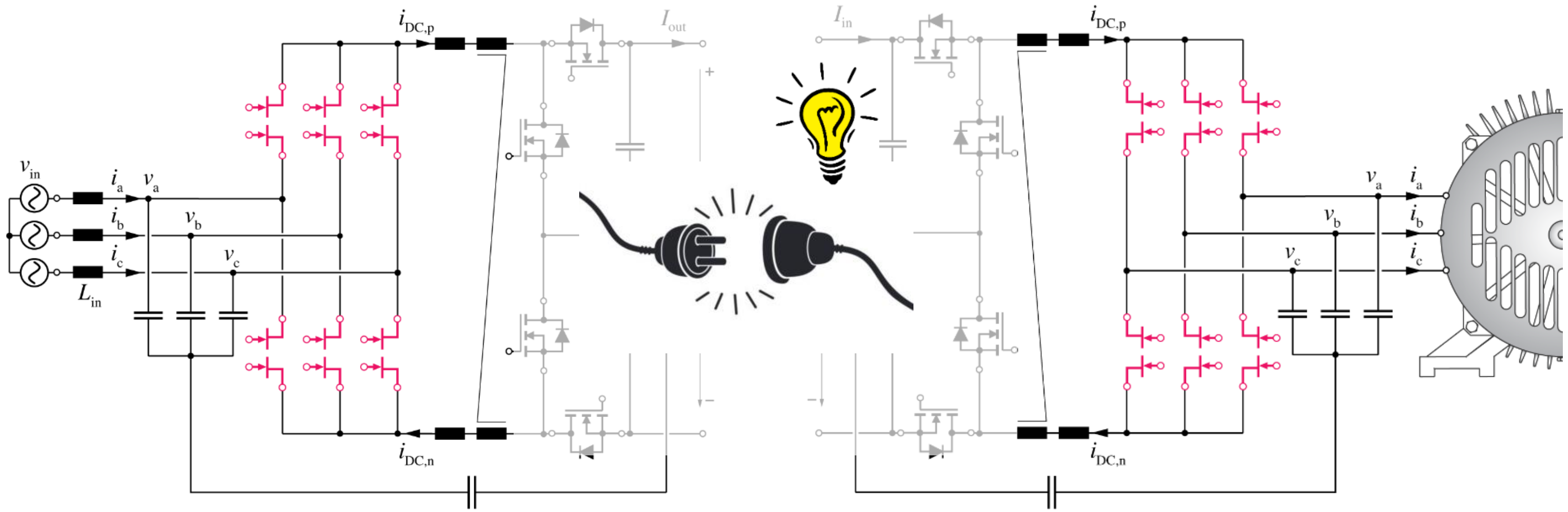
- *Derivation Based on Bidir. Buck-Boost Current Source Inverter (CSI) → Buck-Boost PFC Rectifier (CSR)*
- *Lower # of Ind. Components Compared to Boost-Buck Rectifier Approach*



- *AC/DC Buck Stage Distributes DC-Link Current to Mains Phases — Sinusoidal Inp. Current*
- *Synergetic Control/Modulation of Rectifier Stage & DC/DC Stage for Min. Sw. Losses*

Derivation of 3-Φ Current Source AC/AC Converter (2)

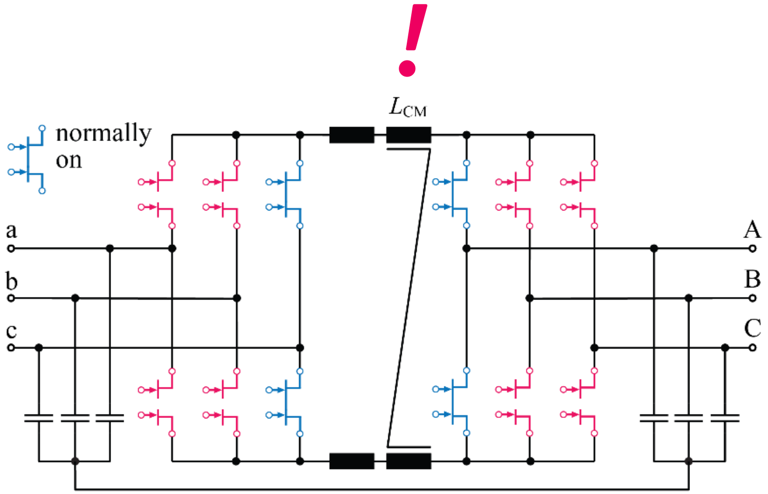
- *DC-Side Coupling of Buck-Boost Current DC-Link PFC Rectifier & Inverter — AC/DC/AC*
- *Full-Sinewave Filtering @ Input & Output w/ Single Magnetic Component*



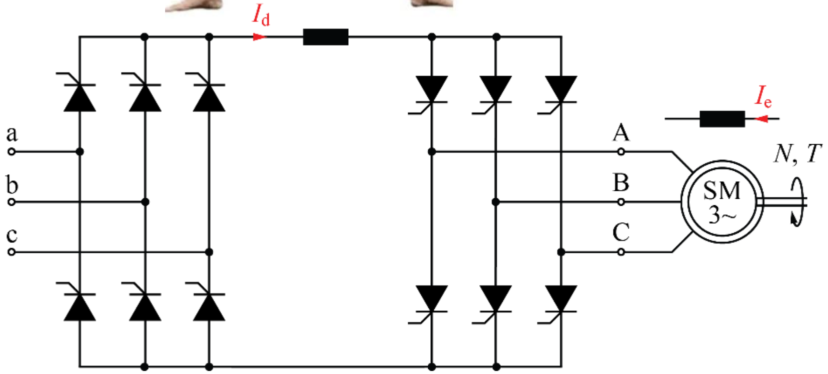
- *Bipolar Blocking / Unidir. Switches | Unidir. DC-Link Current Sufficient for Bidir. Power Conversion*
- *Modulation-Based Inversion of DC-Link Voltage Polarity → Inv. of Power Flow Direction*

3-Φ Current Source AC/AC Converter

- *Sinusoidal Motor Voltage Achieved w/ Single Ind. Component*
- *Unidir. Valves Sufficient for Bidir. Power Conversion*
- *M-BDSs — Synchronous Rectification*



Source: www.mb-drive-services.com

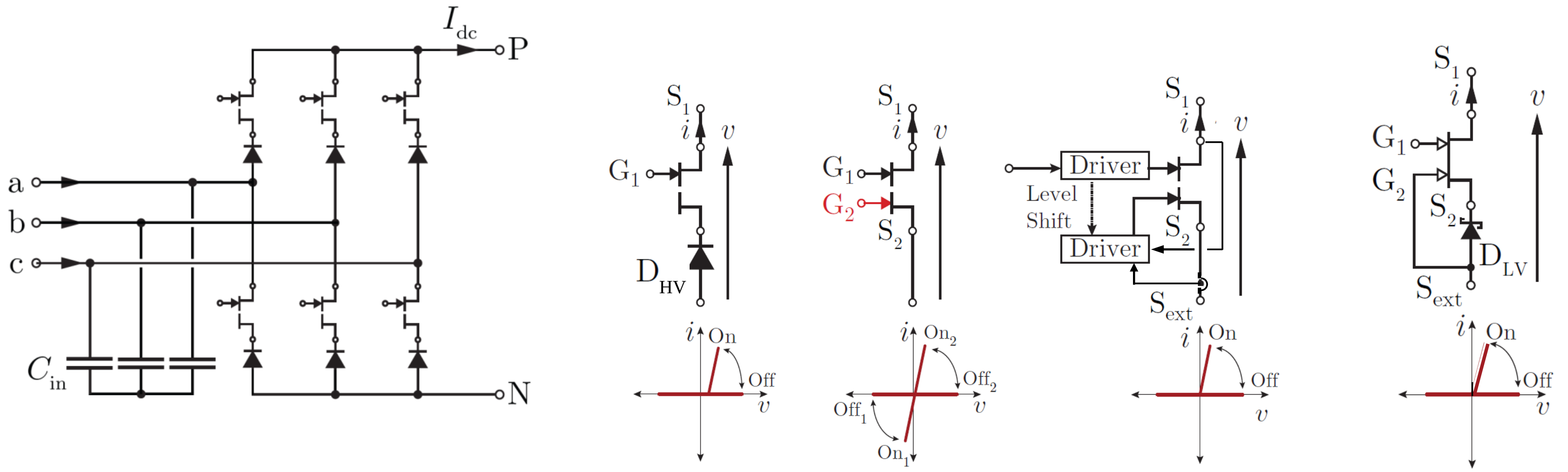


- *Relation to High-Power Thyristor-Based Medium-Voltage Synchr. Machine Variable Speed Drives*

Remark Self Reverse-Blocking M-BDS-Concept (1)

- *Bidir. Curr. DC-Link Converters — Unidir. I_{dc} & Bipolar U_{dc} OR Bidir. I_{dc} & Unipolar U_{dc}*

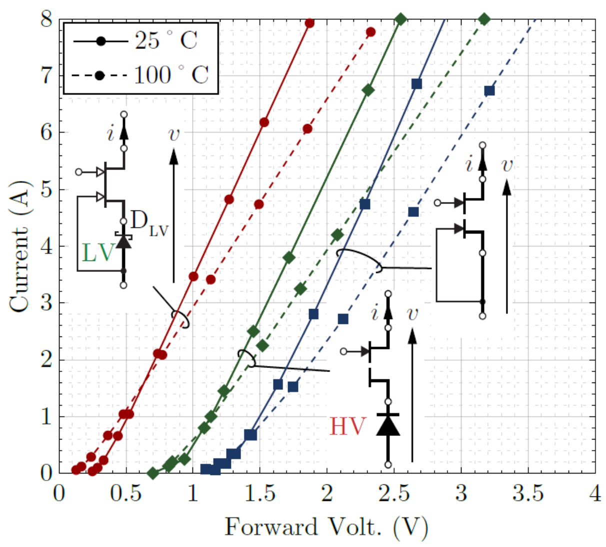
• *HV Switch + HV Diode*	*HV Diode Characteristic / High Cond. Losses*
• *M-BDS*	*Ohmic Cond. Char. BUT 2 External Gate Signals / 2 Gate Drivers*
• *"Self-Switching"*	*Ohmic Cond. Char. BUT High Local Complexity (Sensing)*



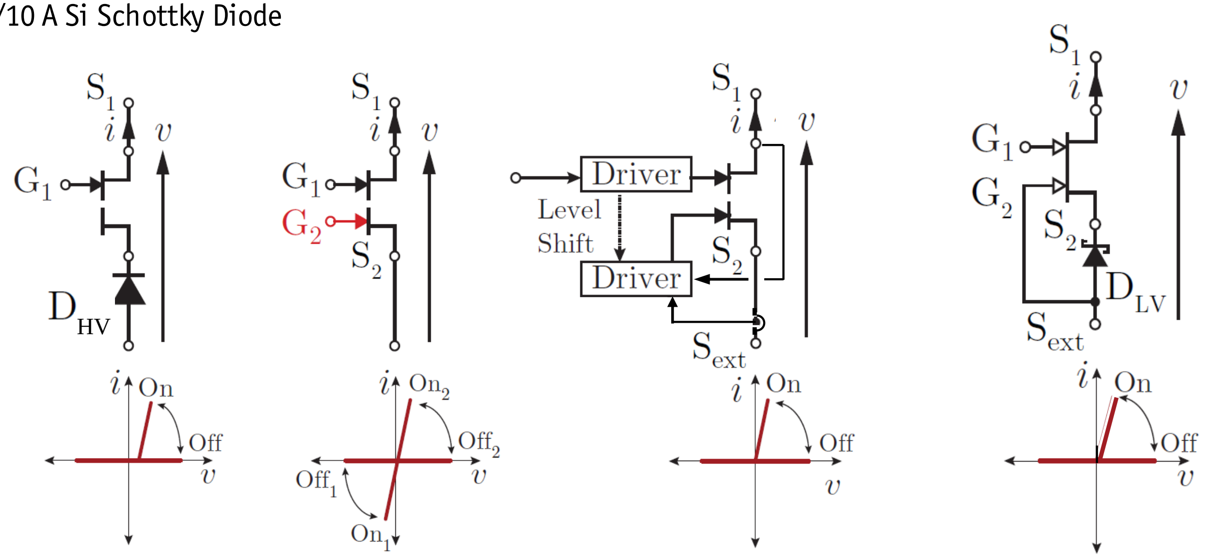
- *SRB-MBDS* *Quasi-Ohmic Cond. Char. (Cascode w/ LV Si Schottky Diode) & 1 External Gate*

Remark Self Reverse-Blocking M-BDS-Concept (2)

- *Bidir. Curr. DC-Link Converters — Unidir. I_{dc} & Bipolar U_{dc} OR Bidir. I_{dc} & Unipolar U_{dc}*
  - *HV Switch + HV Diode* — *HV Diode Characteristic / High Cond. Losses*
  - *M-BDS* — *Ohmic Cond. Char. BUT 2 External Gate Signals / 2 Gate Drivers*
  - *"Self-Switching"* — *Ohmic Cond. Char. BUT High Local Complexity (Sensing)*



600 V 190 mΩ GaN M-BDS
40 V/10 A Si Schottky Diode



- *SRB-MBDS* — *Quasi-Ohmic Cond. Char. (Cascode w/ LV Si Schottky Diode) & 1 External Gate*

Source: www.reuts.com

DUALITY

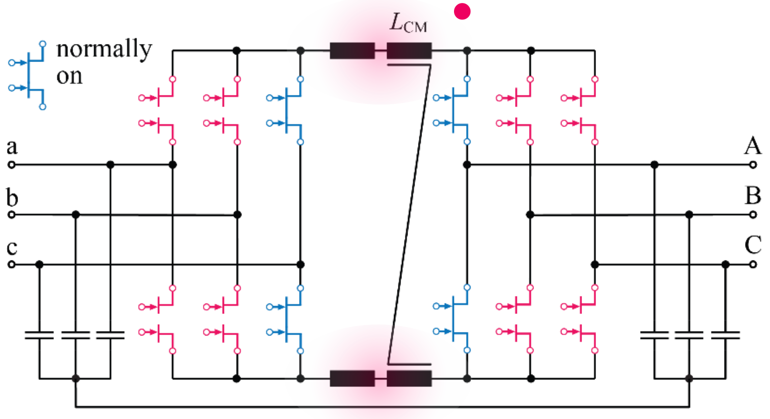
■ ***Current DC-Link Topology***

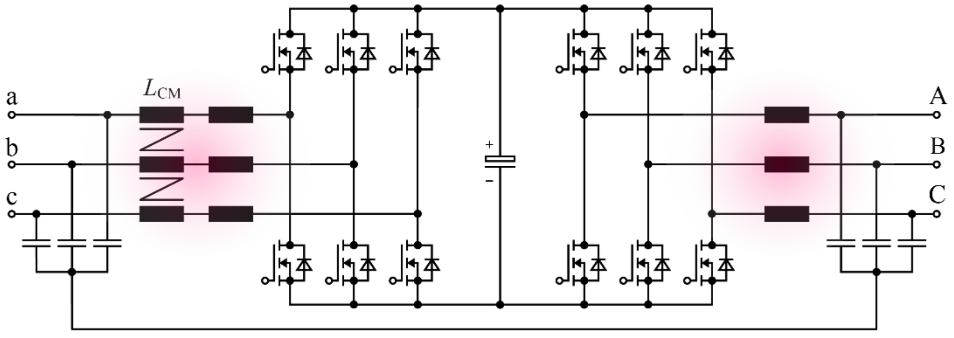
- *Application of M-BDSs*
- *Complex 4-Step Commutation OR SRB-MBDSs*
- *Low Filter Volume*

■ ***Voltage DC-Link Topology***

- *Standard Bridge-Legs*
- *Low-Complexity Commutation*
- *Defined Semiconductor Voltage Stress*
- *Facilitates DC-Link Energy Storage*

!





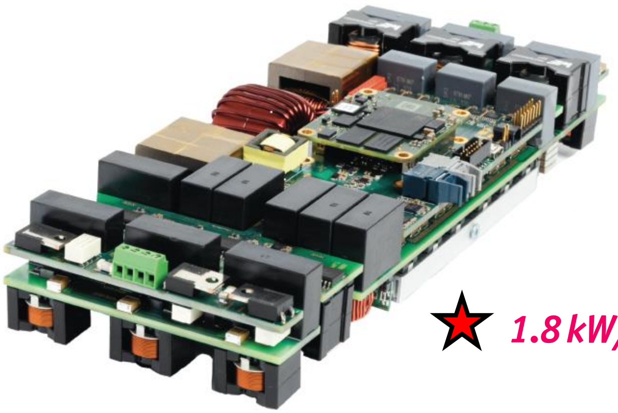
- *Challenging Overvoltage Protection*
- *Limited Control Dynamics*

- *High Input / Output Filter Volume*

DUALITY

■ *Current DC-Link Topology*

- *Application of M-BDSs*
- *Complex 4-Step Commutation*
- *Low Filter Volume*



★ *1.8 kW/dm³*

■ *Voltage DC-Link Topology*

- *Standard Bridge-Legs*
- *Low-Complexity Commutation*
- *Defined Semiconductor Voltage Stress*
- *Facilitates DC-Link Energy Storage*

★ *1.7 kW/dm³*

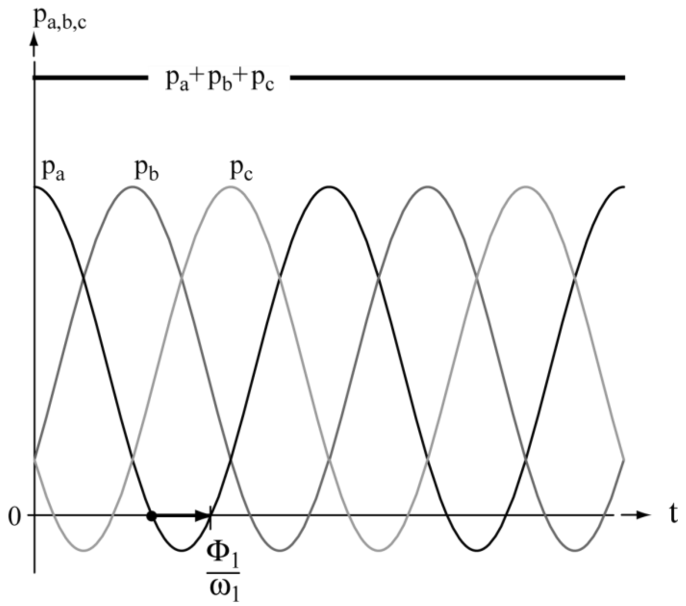
■ *All-600 V-GaN AC-AC VSDs / 1.4 kW, 200 V L-L / Full EMI Filter (Grid & Motor) / 97% Nominal Eff.*

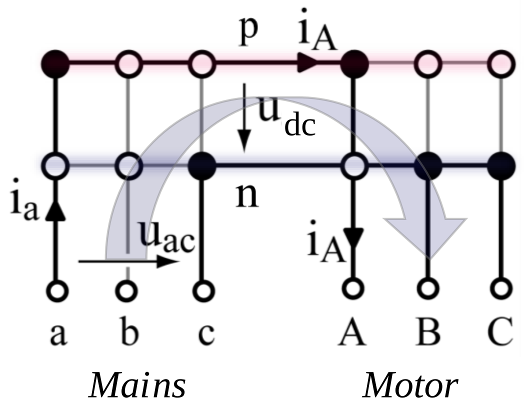
3-Φ AC/AC Matrix Converter

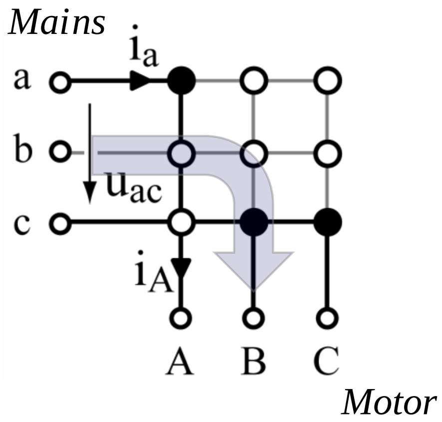
$$\left\{\begin{matrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 1 \end{matrix}\right\}$$

Indirect & Direct 3-Φ AC/AC Matrix Converter

- *Constant 3-Φ Instantaneous Power Flow → No Low-Frequ. DC-Link Power Pulsation Buffer Requirement (!)*
- *Indirect AC/DC—DC/AC OR Direct AC/AC Power Conversion → IMC OR DMC*
- *DMC → Switch Matrix w/ Bipolar Voltage Blocking & Current Carrying Devices*





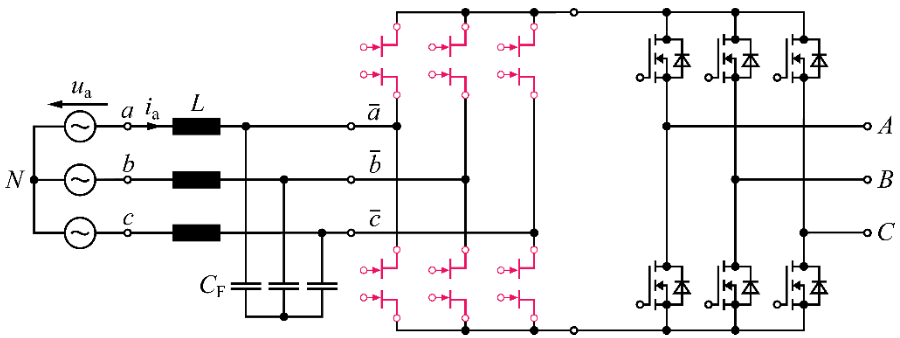


- *Input-Side Cap. / Output-Side Motor Ind. → Operation Limited to Buck-Type (Step-Down) Conversion*

3-Φ AC/AC *Matrix* Converter Comparison

Indirect Matrix Converter (IMC)

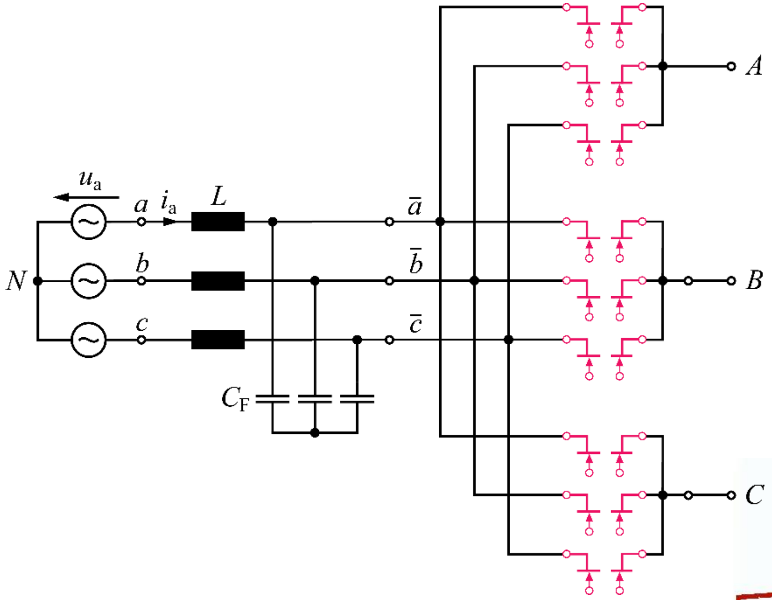
- *GaN M-BDS AC/DC Front-End*
- *ZCS Commutation of AC/DC Stage @ i_{DC}=0*
- *No 4-Step Commutation*



- *Higher # of Switches Compared to DMC*
- *Lower Cond. Losses @ Low Output Voltage*
- *Thermally Critical @ f_{out} → 0*

Direct Matrix Converter (CMC)

- *4-Step Commutation*
- *Exclusive Use of GaN M-BDSs*

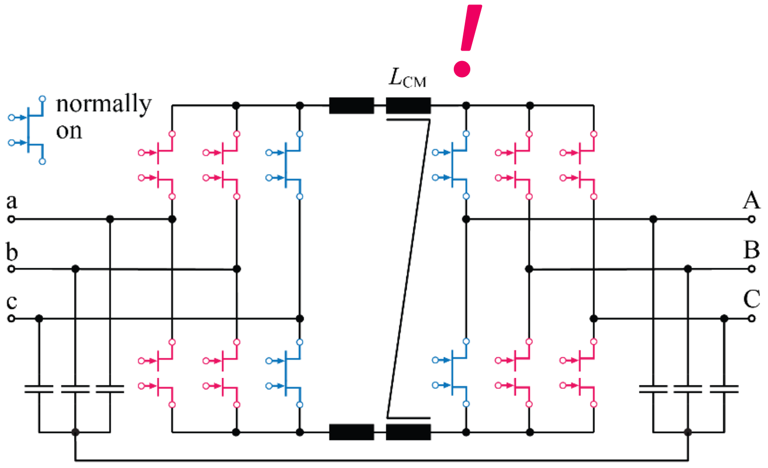


- *Thermally Critical @ $f_{out} \approx f_{in}$*

3-Φ Current DC-Link vs. Matrix AC/AC Converter

Current DC-Link Topology

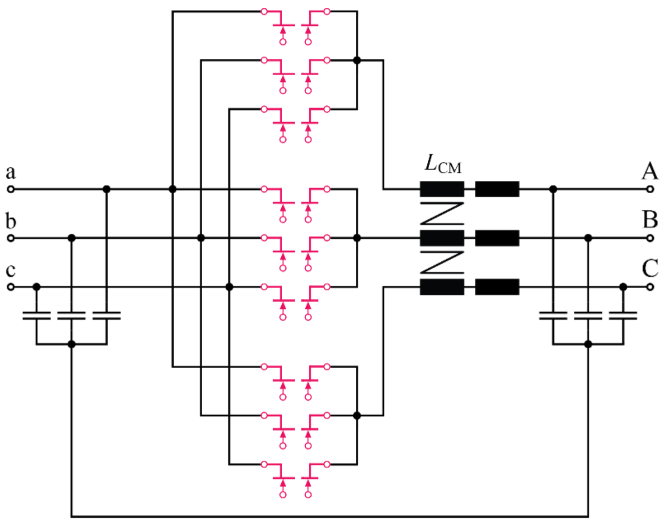
- Application of M-BDSs | 12 Switches
- 4-Step Commutation
- Buck-Boost Functionality
- Low Filter Volume



- Challenging Overvoltage Protection

Direct Matrix Converter

- Application of M-BDSs | 9 Switches
- 4-Step Commutation
- Complex Space Vector Modulation
- Limited to Buck-Operation (!)



- Challenging Overvoltage Protection

Outlook

Summary

- **Future Need for „SWISS Knife"-Type Inverter Systems**

— Wide Input / Output Voltage Range
— Continuous / Sinusoidal Output Voltage
— Electromagnetically „Quiet" - No Shielded Cables
— "Plug & Play" / Non-Expert Installation
— SMART Motors / Cognitive VSDs
— On-Line Monitoring / Industry 4.0

Source: UK Outdoor Store

- **Enabling Technologies**

— SiC / GaN
— Advanced (Multi-Level) Topologies
— "Synergetic" Control
— Monolithic Bidirectional GaN
— Integration of Switches / Gate Drives / Sensing / Monitoring
— Adv. Modeling / Simulation / Optimization
— Machine Learning / AI

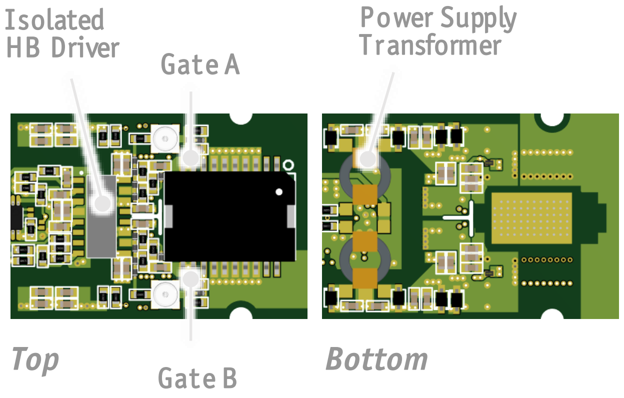
- **System Level →** Distributed DC Bus Systems, Integration of Storage, etc.

Monolithic 3D-Integration

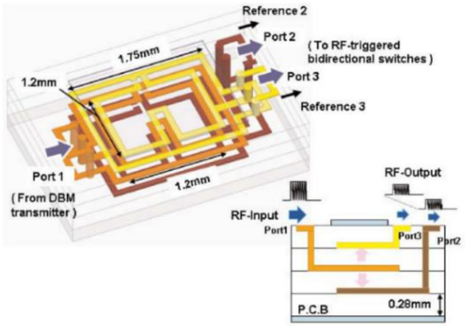
Source: Panasonic ISSCC 2014

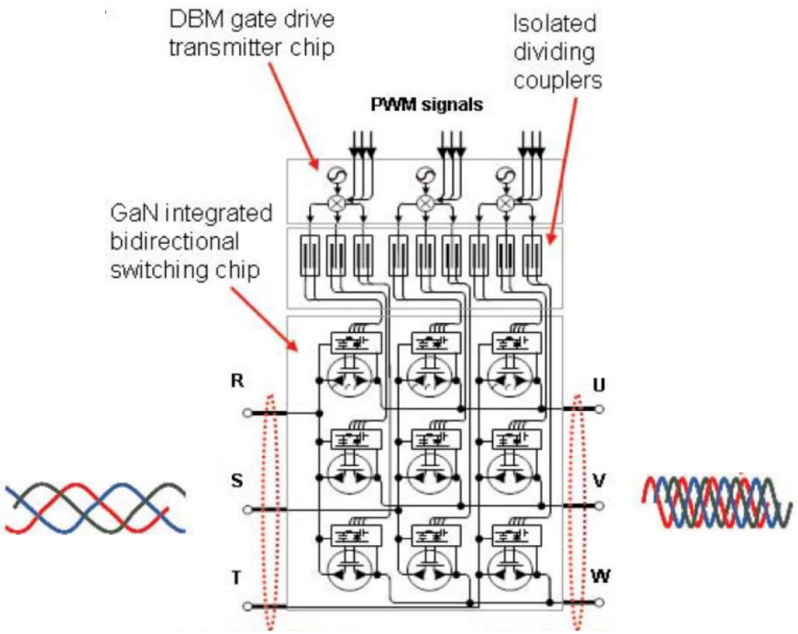
- *M-BDS GaN 3x3 Matrix Converter with Drive-By-Microwave (DBM) Technology*

  – *9 Dual-Gate GaN AC-Switches / 4-Step Commutation*
  – *DBM Gate Drive Transmitter Chip & Isolating Couplers*
  – *Ultra Compact → 25 x 18 mm^2 (600 V, 10 A – 5 kW Motor)*



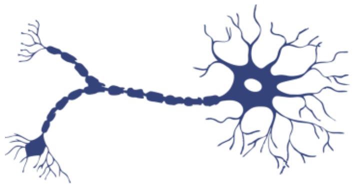
5.0GHz Isolated (5 kV$_{DC}$) Dividing Coupler





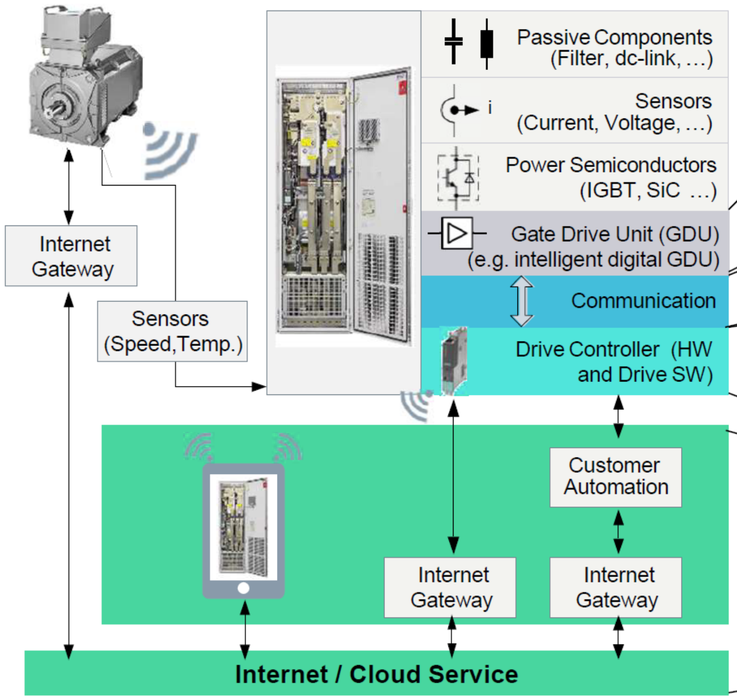
- *Massive Space Saving Compared to Discrete Realization (!)*

Smart Converter Concept



■ *Utilize High Computing Power & Network Effects in the Cloud → "Cognitive" Power Electronics*

Source: Dr. R. Sommer SIEMENS



Intelligent Gate Drive Unit
- Semiconductor protection (overcurrent, overvoltage, …)
- Collecting and preprocessing of sensor data (current, voltage, temperature, …)
- Semiconductor specific condition monitoring functions

Communication
- Communication protocol instead of on/off signals

Drive Controller
- Observer based condition monitoring functions
- Predictive maintenance functions
- Data Processing and data compression
- Communication to customer automation and/or internet

Internet / Cloud
- Service and commissioning tools
- Algorithms for „Big Data" analysis
- Smart documentation (e.g. video to support service)
- …

- *Sensing & Computing on Component Level | Converter Level | System Level | Application Level*

Thank you!

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