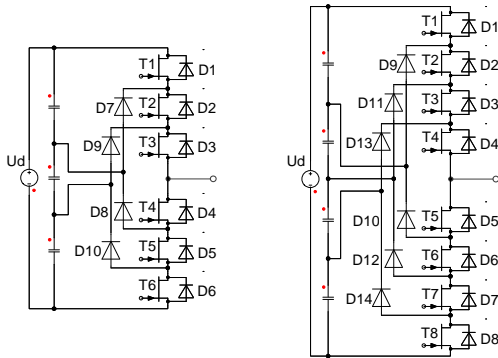


Multilevel inverter with active clamping diodes for energy efficiency improvement

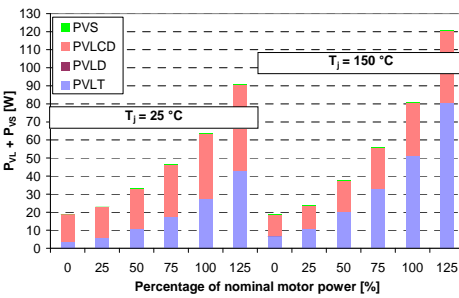
Prof. Dr.-Ing. Rudolf Mecke

Neutral-point-clamped multilevel inverter

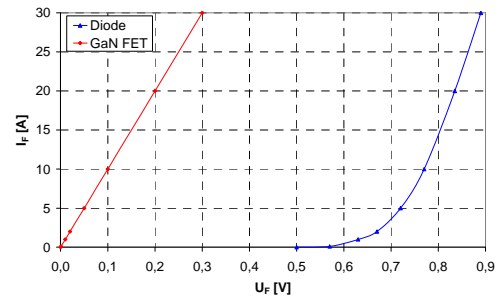
Bridge legs of 4L and 5L NPC inverter



Conduction losses of GaN FETs and Clamping diodes of 5L NPC inverter

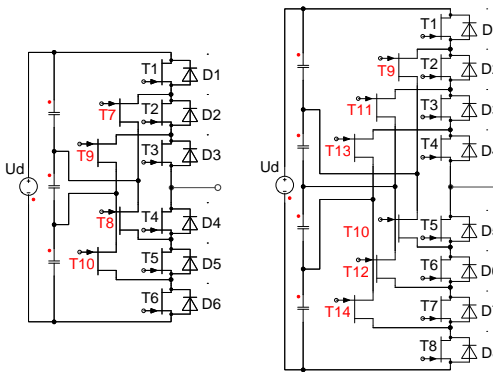


Forward characteristics of clamping diode and active clamping switch

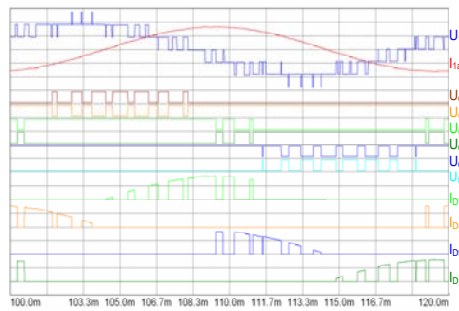


Multilevel inverter with active clamping switches

Bridge legs with active clamping switches



Control signals of main switches and clamping diode currents of 4L

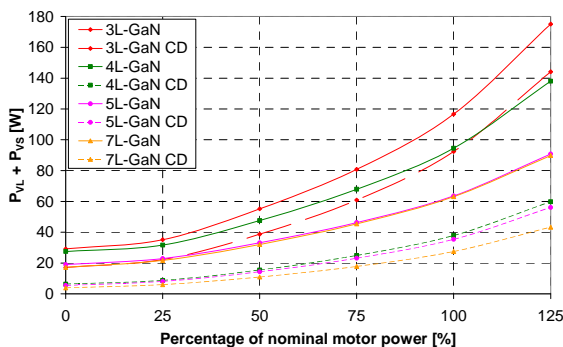


Control signals for active clamping switches

	Clamping Switches	Control signals
Three-level	S5 and S6	$U_{GS2} \cdot U_{GS3}$
Four-level	S7 and S8 S9 and S10	$U_{GS2} \cdot U_{GS4}$ $U_{GS3} \cdot U_{GS5}$
Five-level	S9 and S10 S11 and S12 S13 and S14	$U_{GS2} \cdot U_{GS5}$ $U_{GS3} \cdot U_{GS6}$ $U_{GS4} \cdot U_{GS7}$
Seven-level	S13 and S14 S15 and S16 S17 and S18 S19 and S20 S21 and S22	$U_{GS2} \cdot U_{GS7}$ $U_{GS3} \cdot U_{GS8}$ $U_{GS4} \cdot U_{GS9}$ $U_{GS5} \cdot U_{GS10}$ $U_{GS6} \cdot U_{GS11}$

Energy efficiency improvement

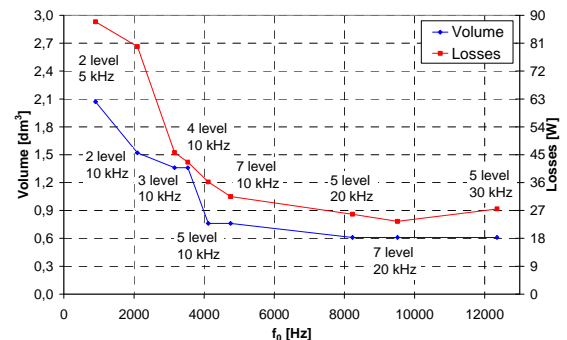
Conduction and switching losses with active clamping switches (CD)



Three-phase inverter output filter (motor filter)



Volume and losses for various inverter levels and switching frequencies



Results:

- Wide-bandgap power semiconductors (SiC MOSFETs, GaN FETs) available for multilevel inverters with 560 to 750 V DC link voltages
- They have hardly any switching losses, so high switching frequencies of several 100 kHz are possible
- The majority of inverter losses are caused by the threshold voltage of the clamping diodes
- Replacement of clamping diodes by active switches (SiC MOSFETs, GaN FETs), only the low on-resistance acts in forward direction
- Freewheeling paths have to be actively switched, control signals for clamping switches generated from main switches by logic operations
- Active clamping switches have significant potential to reduce semiconductor losses, but requires reverse blocking capability
- Reduction of size, weight and losses of motor filter: 70 % weight, 73 % losses for seven-level inverter with 20 kHz switching frequency