ENGINEERING
TOMORROW

VACON 1000

Negative sequence compensation

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Head of Medium Voltage Drives Product Management

Three **business segments** geared for growth

Danfoss Power Solutions

#2 Market position

- 7,609 employees
- 28 factories in 13 countries
- 2.0bn EUR annual sales

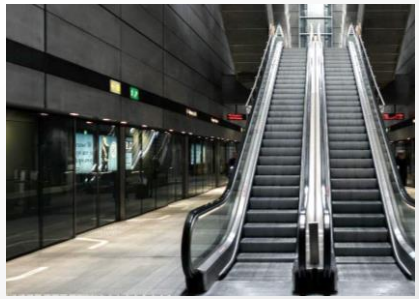
34%
of Group sales

Danfoss Climate Solutions

#2 Market position

- 10,530 employees
- 34 factories in 15 countries
- 2.5bn EUR annual sales

43%
of Group sales



Danfoss Drives

#2 Market position

- 4,438 employees
- 10 factories in 7 countries
- 1.4bn EUR annual sales

23%
of Group sales

Danfoss Drives business **in numbers**

Annual revenue
1.4bn
EUR

29m
drives delivered

40m
cars equipped with power modules

1000
partner companies

Global presence
100,50,10
Countries
Sales & service offices
Factories

First mover since
1968

2020 figures

Breadth and depth in **VLT® products**

Low-voltage drives up to 1.4 MW

				
VLT® Micro Drive FC 51	**VLT® Midi Drive FC 280**	**VLT® HVAC Basic Drive FC 101** Limited markets	**VLT® Automation Drive FC 360** Limited markets	**VLT® Lift Drive LD 302**
				
VLT® Refrigeration FC 103	**VLT® AutomationDrive FC 301/FC302**	**VLT® AQUA Drive FC 202**	**VLT® HVAC Drive FC 102**	**VLT® Low Harmonic Drive**
		Motor protection	**Brake resistors**	**Decentral drives up to 7.5 kW**
				
VLT® Advanced Harmonic Filter AHF 005 and AHF 010	**VLT® Advanced Active Filter AAF**	**VLT® Sine-wave Filter MCC 101** **VLT® dU/dt Filter MCC 102** **VLT® Common Mode Filter MCC 105**	**VLT® Brake Resistor MCE 101**	**VLT® Decentral Drive FCD 302**
	Motion drives and gear motors up to 7.5 kW		**Soft starters**	**Software**
				
VLT® DriveMotor FCP 106	**VLT® OneGearDrive®**	**VLT® Integrated Servo Drive ISD® 510 System**	**VLT® Soft Starters**	**VLT® Software**

Breadth and depth in **VACON® products**

Low-voltage drives up to 6.0 MW

				
VACON® 20	**VACON® 20 Cold Plate**	**VACON® 100 INDUSTRIAL**	**VACON® 100 FLOW**	**VACON® NXP Air Cooled**
				
VACON® NXC Air Cooled Enclosed Drives	**VACON® NXP Liquid Cooled Drive**	**VACON® NXP Liquid Cooled Enclosed Drive**	**VACON® NXP System Drive**	**VACON® NXP Common DC Bus**
			Harmonic products	**Decentral drives up to 37 kW**
				
VACON® NXP Liqued Cooled Common DC Bus	**VACON® NXP Grid Converter**	**VACON® NXP DC/DC Converter**	**VACON® NXC Low Harmonic**	**VACON® 20 X**
Medium-voltage drives				**Software**
				
VACON® 100 X	**VACON® 1000 Enclosed Drive**	**VACON® 3000 Enclosed Drive**	**VACON® 3000 Enclosed Drive**	**VACON® Software**

DrivePro® Life Cycle Services

DrivePro® Site Assessment

DrivePro® Start-up

DrivePro® Extended Warranty

DrivePro® Spare Parts

DrivePro® Exchange

DrivePro® Preventive Maintenance

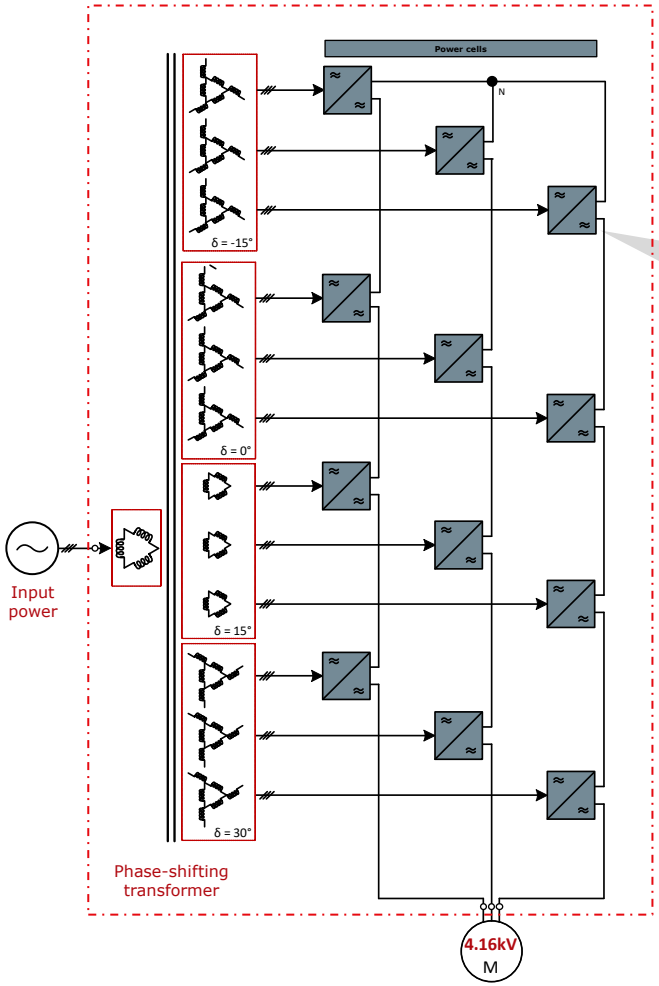
DrivePro® Upgrade

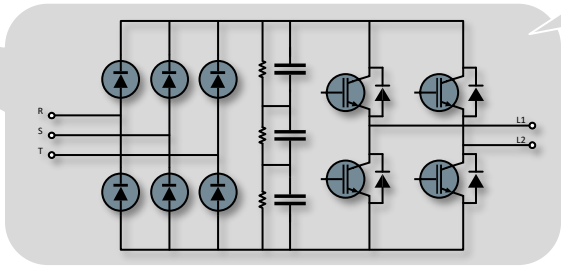
DrivePro® Remote Monitoring

DrivePro® Remote Expert Support

DrivePro® Retrofit

Multi-level Cascaded Inverter





- Modular design
- Series connected power cells
- Multi-level output voltage
- IGBT based power cell bypass (optional)
- N+1 redundant design (optional)
- System bypass (optional)

Stand-alone design structure

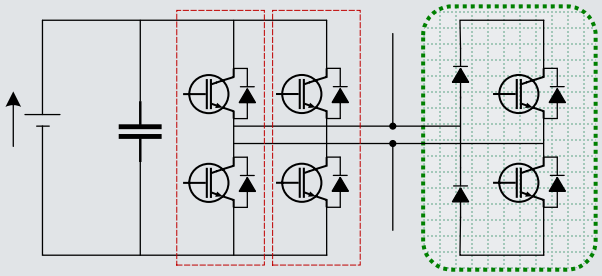
Bypass possibilities

Bypass type	Bypass device	Drive reactions
No cell bypass		Trip
Power cell bypass (+PPCB)	IGBT circuit	Continuous operation with voltage drop
Power cell redundancy (+PPCR)	As +PPCB, and additional power cell per phase	Continuous operation without voltage drop
System bypass Manual (+PMBP) Auto (+PABP) Synchronous (+PSBP)	 Manual disconnector Vacuum contactor Vacuum contactor	Possibility to transfer the load the grid, allowing DOL

VACON® 1000 **Power cell bypass** (+PPCB)

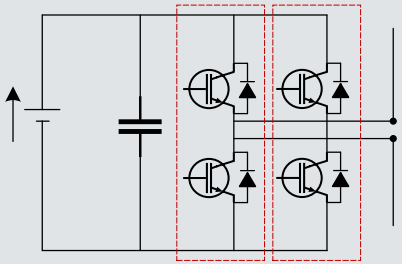
- Depends on power cell bypass availability
- IGBT type power cell bypass technology - **1ms bypass time**

With power cell bypass



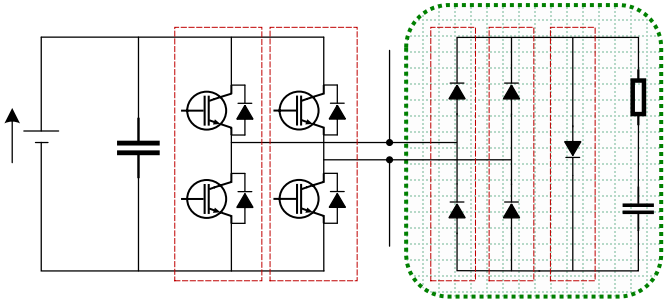
PCU-A_HA-xxx-006+PPCB

Without power cell bypass

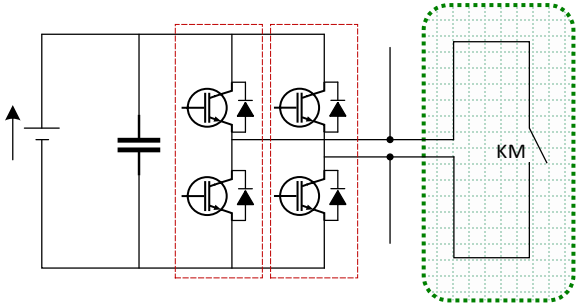


PCU-A_HA-xxx-006

Power cell bypass comparison



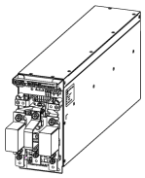
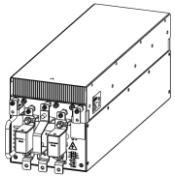
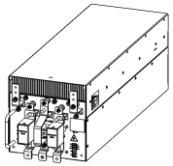
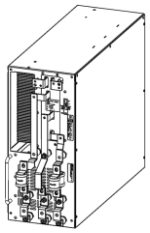
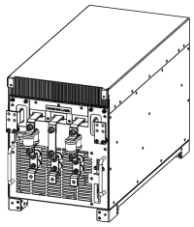
SCR bypass (electronic type)



Contactor bypass (mechanical type)

Method of bypass	Contactor bypass	SCR bypass	IGBT bypass
Type of bypass	Mechanical	Electronic	Electronic
Reacting time	Slow	Fast	Fast
Reliability	Low	Mid	High
Remark	Easy to be polluted by dust	Low dV/dt endurance	High dV/dt endurance

Power cells details

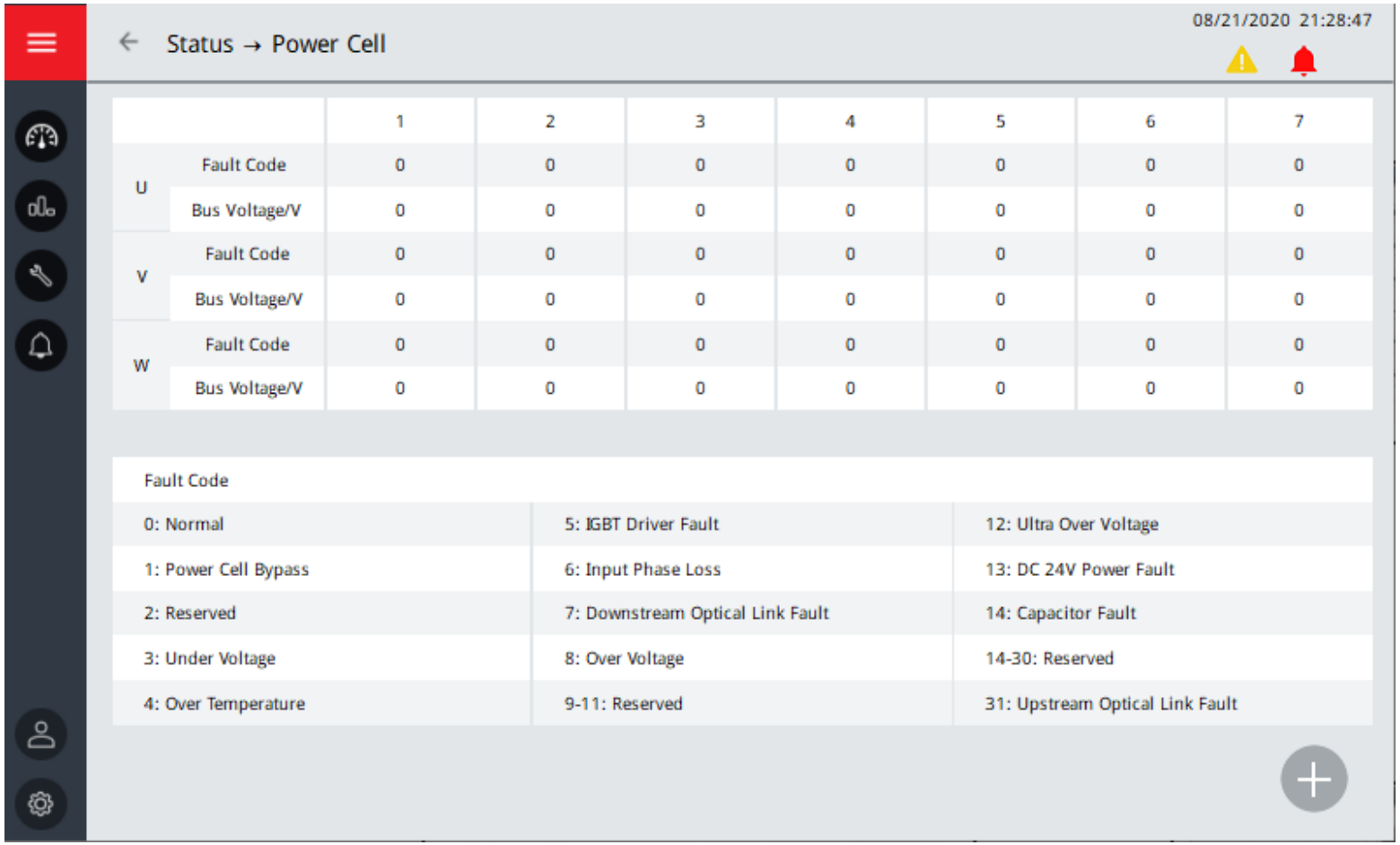






Type PCU-A2_LA-_ _ _-006 Dimensions	036 050 070	100 140	180 215	250 305 350	438 560 680
Height [in]	8.6	8.3	8.3	21.9	18.6
Width [in]	4.4	6.5	7.5	9.7	14
Depth [in]	22.5	24.6	26.6	30.2	33.5
Weight [lb]	46.3 | 48.6 | 50.8	70.6 | 72.8	88.2 | 92.6	187.4	242.6 | 264.6 | 286.7
Current [A]	36 | 50 | 70	100 | 140	180 | 215	250 | 305 | 350	438 | 560 | 680

Stand-alone

Line-up

Power Cells Monitoring
HMI Operation Interface



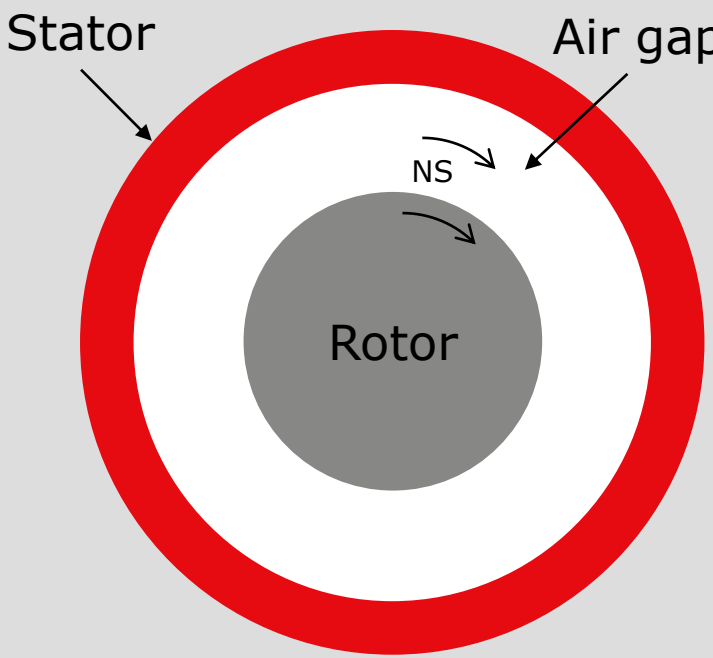
		1	2	3	4	5	6	7
U	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0
V	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0
W	Fault Code	0	0	0	0	0	0	0
	Bus Voltage/V	0	0	0	0	0	0	0

Fault Code		
0: Normal	5: IGBT Driver Fault	12: Ultra Over Voltage
1: Power Cell Bypass	6: Input Phase Loss	13: DC 24V Power Fault
2: Reserved	7: Downstream Optical Link Fault	14: Capacitor Fault
3: Under Voltage	8: Over Voltage	14-30: Reserved
4: Over Temperature	9-11: Reserved	31: Upstream Optical Link Fault

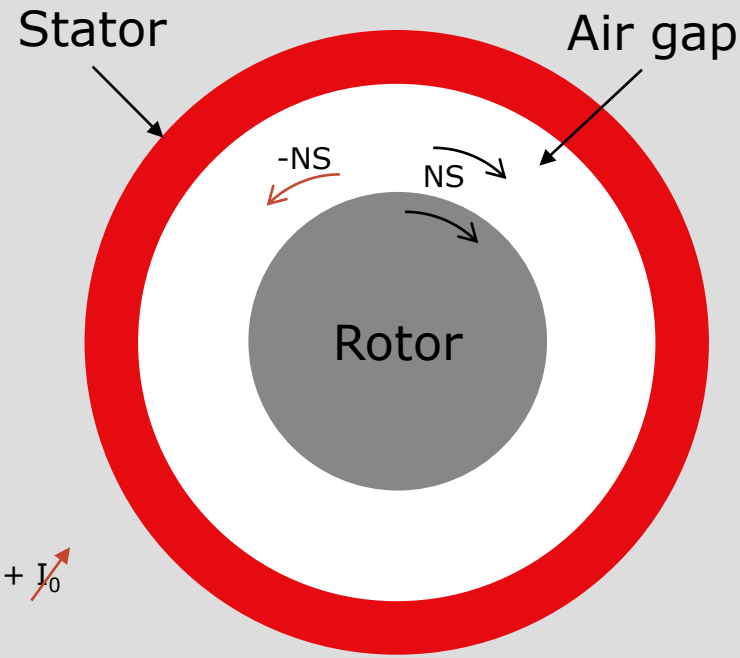
Unbalanced supply

- Balanced supply voltage
- Unbalanced supply voltage

AC motor cross-sectional view



NS = Synchronous speed



$I = I_1 + I_2 + I_0$

Where:

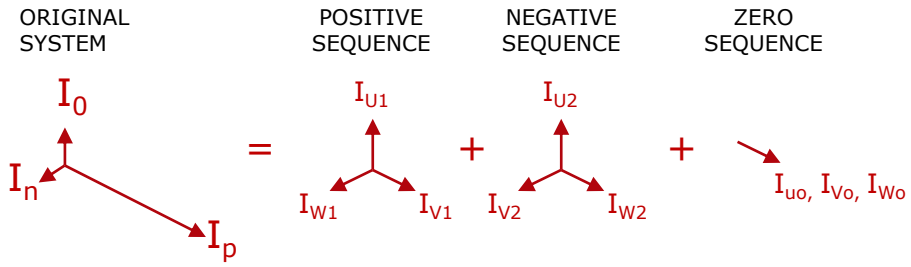
I_1 = positive sequence

I_2 = negative sequence

I_0 = zero sequence (only present if ground fault)

Negative Sequence Compensation
Description

- When the modulation ratio is above the maximum modulation ratio parameter, the drive output speed is decreased automatically after power cell bypass occurs, namely bypass derating. Therefore, the actual motor speed becomes lower than the specified speed.
- When the modulation ratio is lower than the maximum modulation ratio, bypass derating is finished.
- The operating thresholds of negative sequence compensation are:
  - Minimum operating power factor for negative sequence compensation
  - Minimum operating speed for negative sequence compensation
- When the power factor or output speed is below the thresholds, the drive works in symmetrical bypass mode.



Symmetrical components: positive-, negative- and zero-sequence

Negative Sequence Compensation
Limitations

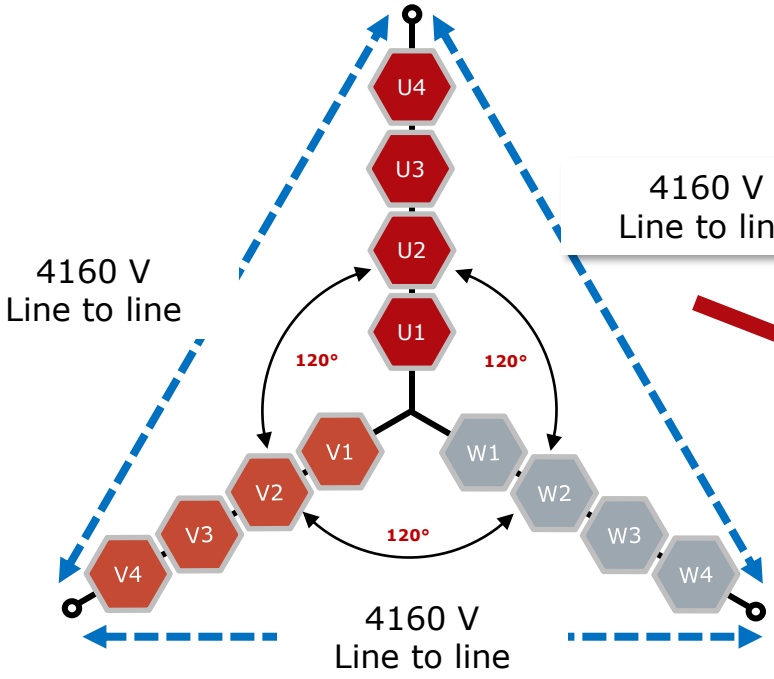
Motor output voltage	Motor voltage with one power cell bypassed [%]	Motor voltage with two power cells bypassed in different phase [%]	Max qty of power cell bypassed [qty]	Lowest output voltage when max qty is bypassed [%]	How many power cells from the same phase can be bypassed
2300 V (9 cells)	84.4	72.6	3	64.1	1
2400 V (9 cells)	80.5	69.2	3	61.2	1
3000 V (9 cells)	91.4	78.6	3	69.4	1
3300 V (9 cells)	82.8	71.2	3	62.9	1
4000 V (12 cells)	87.5	79.1	3	72.1	1
4160 V (12 cells)	84.3	76.2	3	69.4	1
6000 V (15 cells)	86	79.7	6	55.6	2
6300 V (18 cells)	93.2	87.6	6	66	2
6600 V (18 cells)	88.8	83.5	6	62.9	2
6900 V (18 cells)	90.5	85.1	6	64.1	2
10000 V (24 cells)	84.7	80.9	9	55.3	3
11000 V (27 cells)	87.4	84	9	60.6	3

Negative Sequence Compensation
Limitations

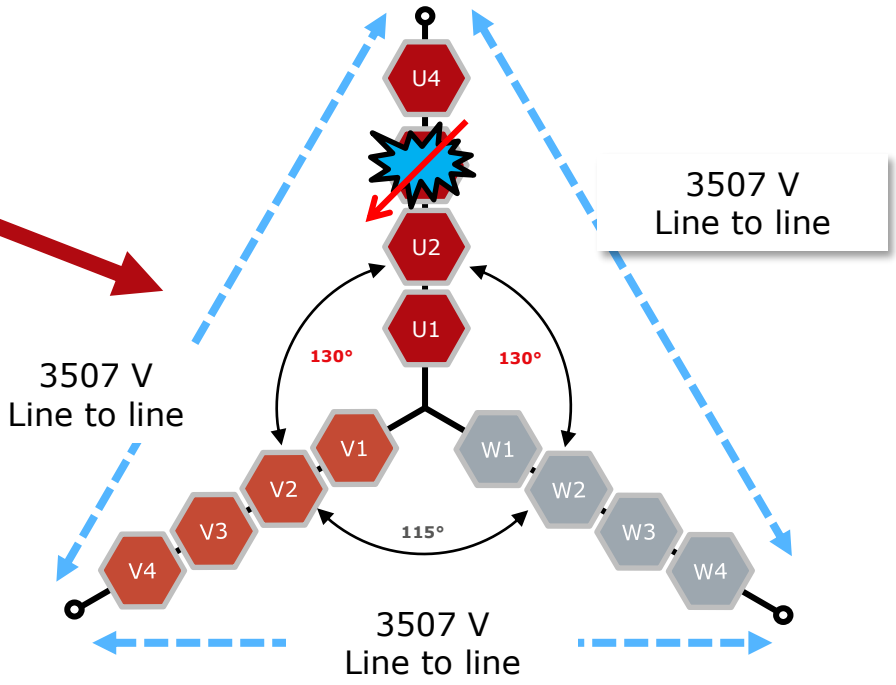
Motor output voltage	Motor voltage with one power cell bypassed [%]	Motor voltage with two power cells bypassed in different phase [%]	Max qty of power cell bypassed [qty]	Lowest output voltage when max qty is bypassed [%]	How many power cells from the same phase can be bypassed per phase
2300 V (9 cells)	84.4	72.6	3	64.1	1
2400 V (9 cells)	80.5	69.2	3	61.2	1
3000 V (9 cells)	91.4	78.6	3	69.4	1
3300 V (9 cells)	82.8	71.2	3	62.9	1
4000 V (12 cells)	87.5	79.1	3	72.1	1
4160 V (12 cells)	**84.3 (3507 V)**	**76.2 (3170V)**	**3**	**69.4 (2887 V)**	**1**
6000 V (15 cells)	86	79.7	6	55.6	2
6300 V (18 cells)	93.2	87.6	6	66	2
6600 V (18 cells)	88.8	83.5	6	62.9	2
6900 V (18 cells)	90.5	85.1	6	64.1	2
10000 V (24 cells)	84.7	80.9	9	55.3	3
11000 V (27 cells)	87.4	84	9	60.6	3

Negative Sequence Compensation

Power cell bypass (+PPCB)

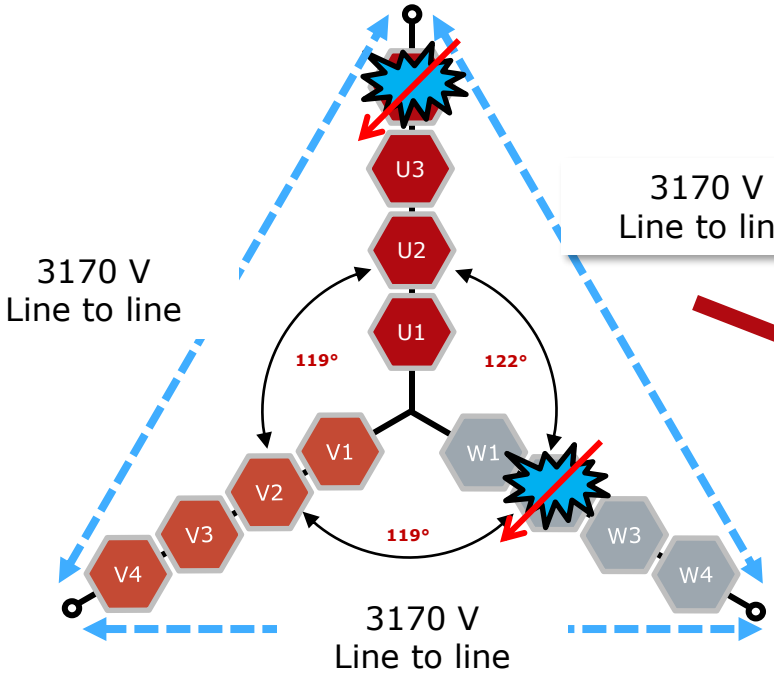


4.16 kV, normal operation

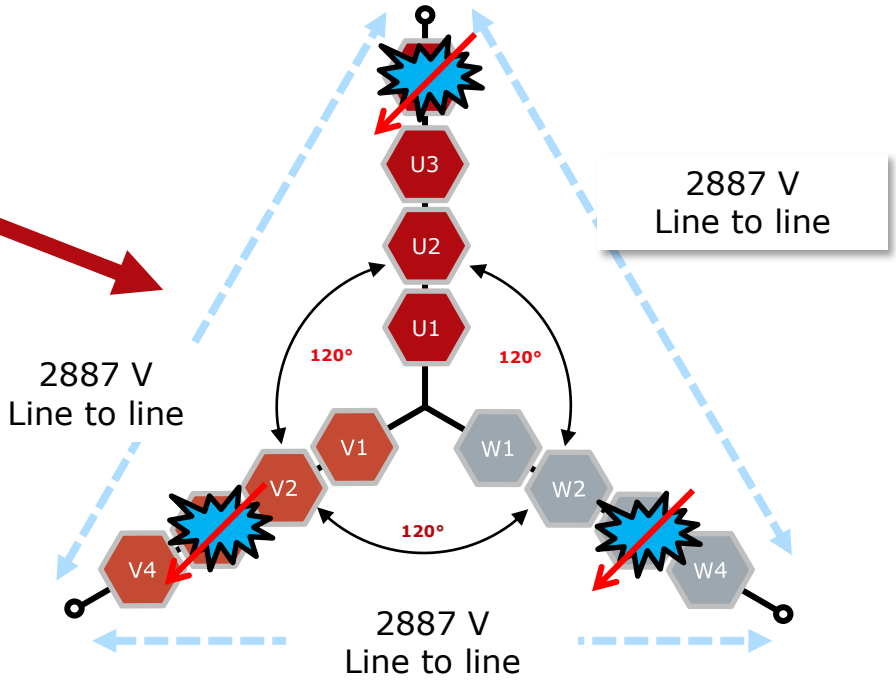


4.16 kV, with one power cell faulty and bypassed

Negative Sequence Compensation
Power cell bypass (+PPCB)



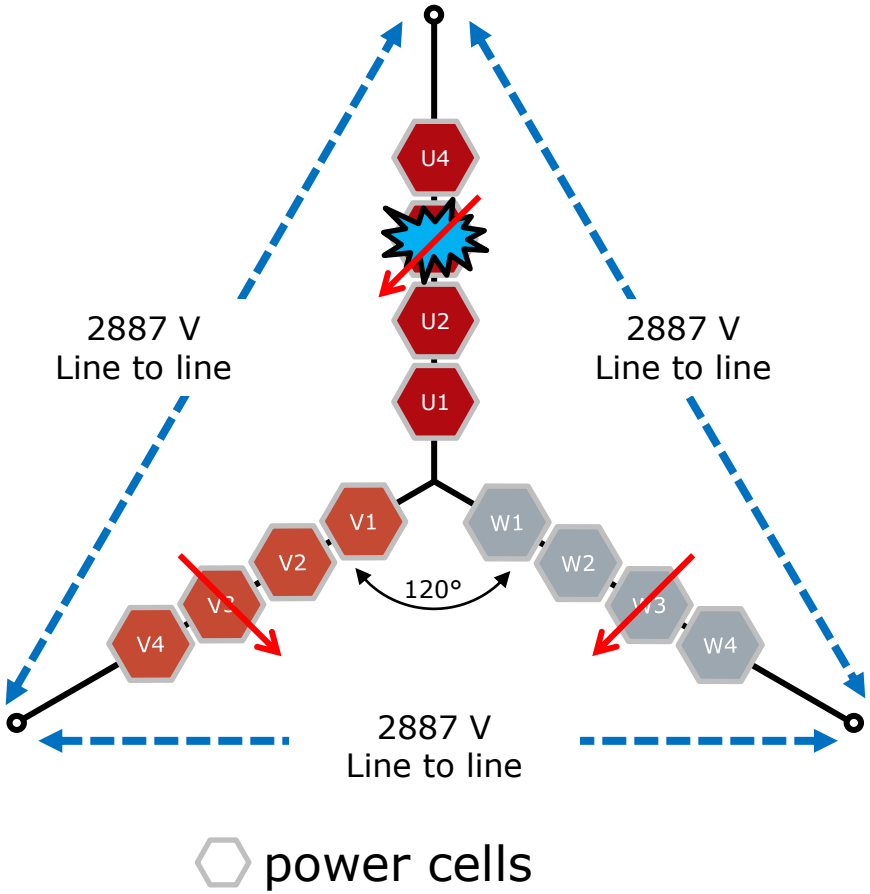
4.16 kV, with two power cell faulty and bypassed



4.16 kV, with three power cell faulty and bypassed

Symmetrical bypass mode

Power cell bypass (+PPCB)



- When the power factor or output speed is below the thresholds, the drive operatess in symmetrical bypass mode

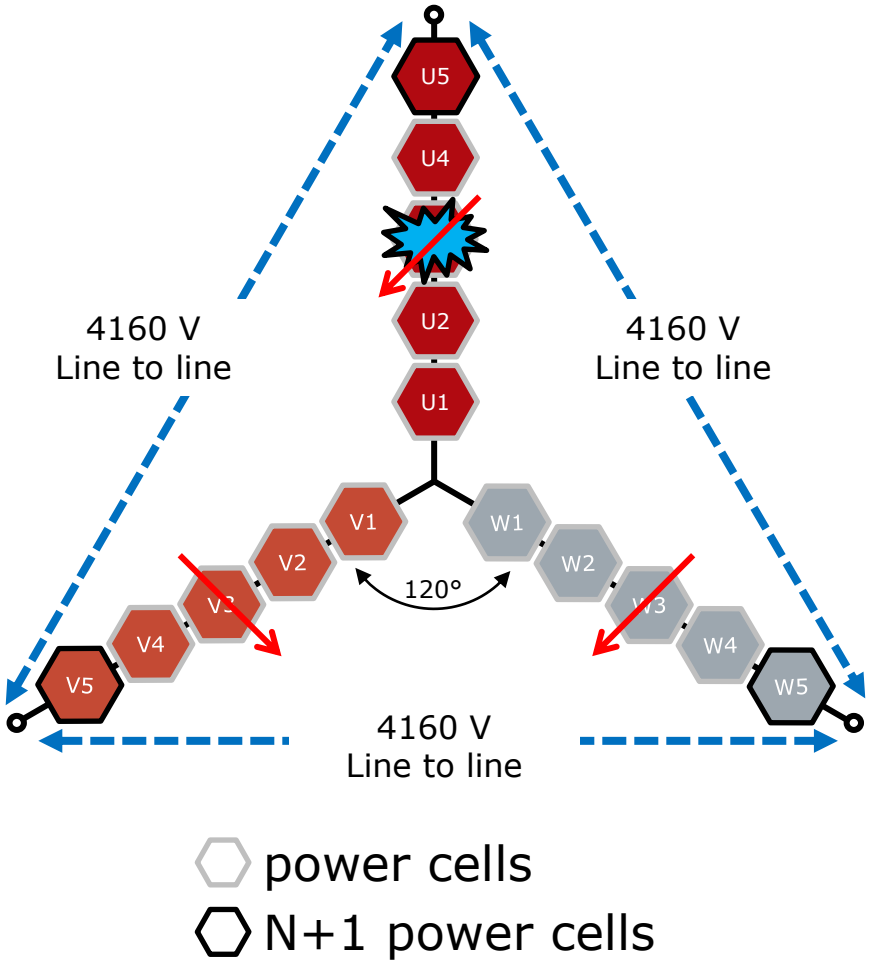
Maximum output power

Output Power 100%

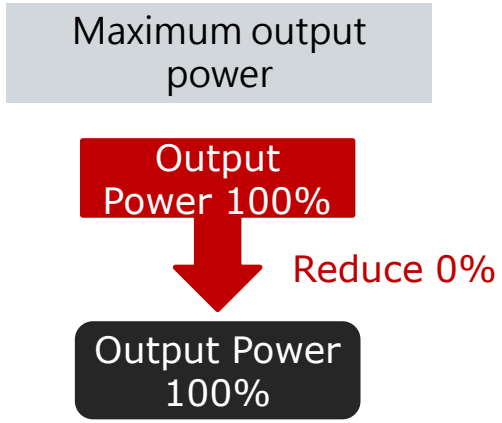
Reduce ~25%

Output Power ~75%

Power cell redundancy (+PPCR)



- Implement one more power cell in each phase
- When power cell bypass function is on, the MVD can still output 100% power without power de-rating
- The output voltage is equally distributed to each power cell before and after power cell bypass



Unbalanced supply consequences

- Induction motors
  - 5% unbalance can cause the reduction in the motor power by 25%
    - even if the induction motor continues to get the rated current before unbalancing.
    - This reduced electrical power of the induction motor attributes to heating in the rotor.
  - The unbalance present in the VFD output by 3% can increase the rotor heating by approximately 20%.

- The VFD will balance the output voltage to reduce losses in the motor
- The VFD will provide proper protection against the unbalanced currents in induction motors

Your **best supplier**

THE AC DRIVES PARTNER WHO SHARES YOUR GOALS

First mover
in mass production of drives

Financially robust

Global presence

World leader
for installed base

#1

Equip differently
with the motor and fieldbus of your choice

Simplified purchasing

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