AVID CONTROLS

Application Note

Control Impacts of Upgrading from DELTA to AEI Modules in MV3000 Renewable Energy Converters

Application Note Title:	Control Impacts of Upgrading from DELTA to AEI Modules in MV3000 Renewable Energy Converters
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Approvals

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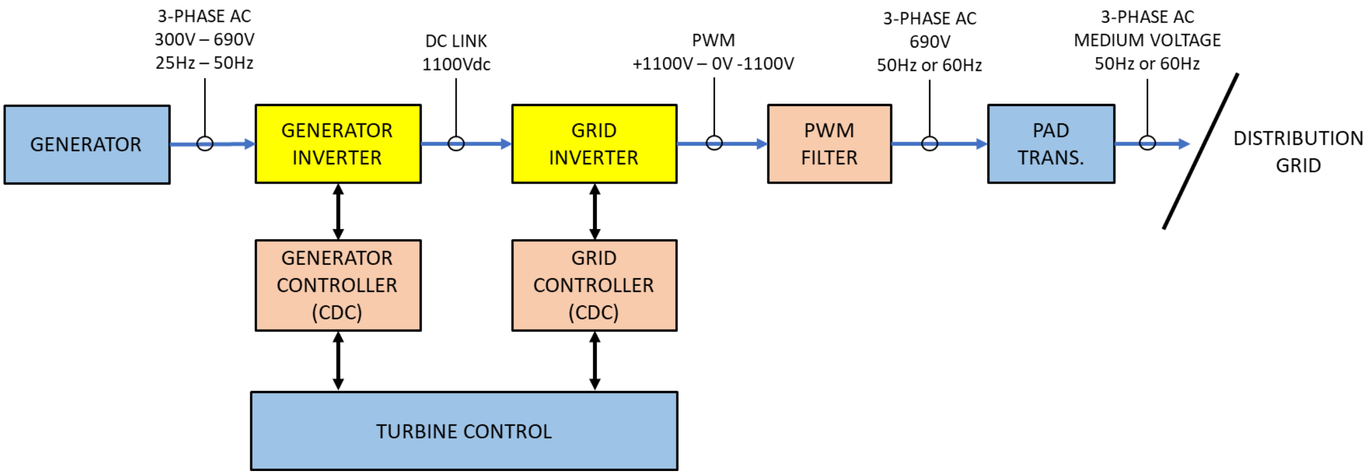
1. Overview

- Several renewable energy operators who have upgraded turbines from DELTA modules to Avid Extreme Converters have asked similar questions regarding the impact of this upgrade on control performance of the converters – particularly questioning if there are any impacts on grid compliance or fault ridethrough capabilities.
- *The straightforward answer is that there are no impacts on control performance that might affect grid compliance or fault ridethrough resulting from upgrading from DELTA modules to AEIs.*
- The document does not directly address the issue of grid compliance – this is beyond Avid's expertise and responsibility – it provides explanation for the italicized summary in the previous bullet.

2. MV3000 Converter Overview



Items that are not part of the converter.

Converter items that are not changed when upgrading.

Converter items that are changed when upgrading.

- The generator and grid inverters are each constituted of parallel DELTA or AEI modules in the following configurations:

Turbine Rating	DELTA Configuration	AEI Configuration
2.3MW	3 x 800A MVDL800	3 x 900A AEI900L configured for 800A scaling
Re-power >2.3MW	N/A	3 x 900A AEI900L
3.6MW	4 x 1000A MVDL1000	4 x 1000A AEI1000L

- The GRID controller is a DSP-equipped CDC, while the GENERATOR controller is a base-model CDC without the DSP enhancement.

- The PWM filter is a large three-phase inductor combined with a three-pole L-C-R trap filter tuned to the harmonics of the 2.5kHz PWM used by the grid controller.

- All the preceding statements apply whether the MV3000 contains DELTA or AEI inverters.

3. Functions of the Controllers and Inverters

3.1 Functions of the GRID controller

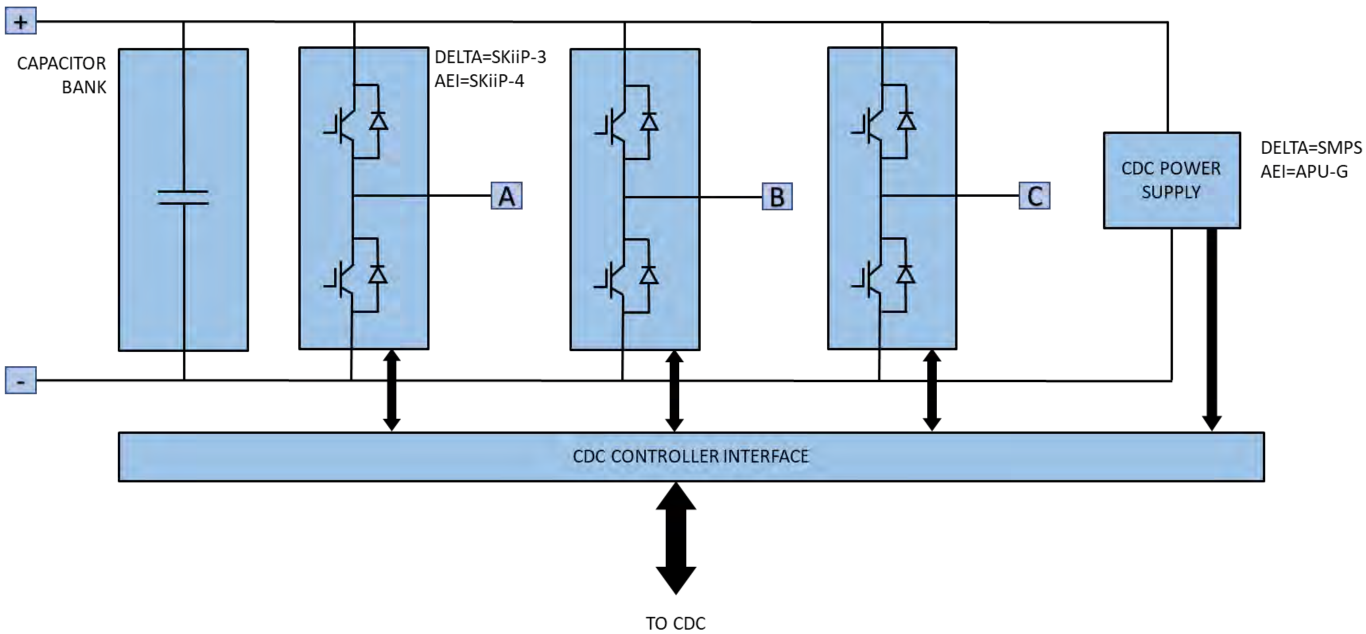
- Communication with turbine controller
- Generation of PWM signals to the inverter
- Ensure that parallel module in the inverter share load current equally
- Grid synchronization
- Control of grid kW (via control of in-phase current)
- Control of grid kVAR (via control of quadrature current)
- Control of grid-loss ridethrough (by kW and kVAR adjustment)
- Control of asymmetrical grid-loss ridethrough (by control of negative sequence current)
- Minimization of generated harmonic and non-harmonic distortion to the grid by accurate PWM generation

These functions together constitute a grid-compliant converter controller.

3.2 Functions of the GENERATOR Controller

- Communication with turbine controller
- Generation of PWM signals to the inverter
- Ensure that parallel module in the inverter share load current equally
- Control of generator magnetizing flux
- Control of generator torque
- Torque multiplied by generator speed controls the power flow into the DC link
- The control of power flow into the DC link controls the DC link voltage to the operating 1100V DC

3.3 Functions of the Inverters



3.3.1 Summary

Function	DELTA	AEI	Notes
Capacitor Bank	MVDL800 & AEI900L 36 x 2900uF 450V Electrolytic Capacitors MVDL1000 & AEI1000L 36 x 4200uF 450V Electrolytic Capacitors		The exact same capacitors and laminated busbar are used in the AEI and DELTA
IGBT On-State Voltage TYP [MAX]	2.43V [3.19V]	1.94V [2.14V]	All at maximum recommended temperature and 1400A current See explanation below
DIODE On-State Voltage TYP [MAX]	1.95V [2.10V]	1.75V [2.02]	
IGBT PWM Distortion. TYP (Ton – Toff)	0.0µs	0.1µs	See explanation below
Current Feedback to CDC	+/-10V = 2500A Derived from SKiiP module		SKiiP signal buffered using precision diff. amp. circuit in both DELTA and AEI
DC Link Feedback to CDC	0 – 10V for entire operating range of DC link		Identical feedback circuit used (implemented on SMPS for DELTA and on the AEI unit itself)
Power Supply to CDC	DC link powered SMPS	DC link powered APU-G or AC powered APU-E/F	See explanation below

3.3.2 Voltage Ratings

- The capacitor bank in the AEI and DELTA are identical – having a continuous operating voltage up to 1300VDC and surge rating of 1430V.

- The SKiiP-3 has a maximum operating voltage of 1200V, the SKiiP-4 has a maximum operating voltage of 1300V. Both devices use 1700V IGBT and DIODE chips.

- The DELTA SMPS module has a maximum instantaneous operating voltage of 1262V and continuous of 1172V. The APU-G module is rated at 1500V continuous.

3.3.3 Voltage Distortion

- An ideal inverter would connect each of its three phase outputs to either the DC+ or DC- value instantaneously when commanded to do so by the CDC.

- Real inverters differ from this behavior in the following ways:
  1. There is a small voltage drop across the IGBT or DIODE element when conducting – so the outputs don't quite reach DC+ or DC-.

  2. There are small delays in switching from when the CDC command is issued to when the actual voltage output switches.

- The first error (conduction loss) is small (around 2V in 1100V in our case) and is very similar between the DELTA and AEI (SKiiP-3 and SKiiP-4). The SKiiP-4 is slightly better.

- The second imperfection only induces voltage error if there is a difference between turn-on and turn-off delays (called "skew"). In the case of the SKiiP-4, the typical skew is 0.1µs in a PWM period of 400µs – i.e. negligible.

- These errors – specifically the difference between SKiiP-3 and SKiiP-4 - are negligible in themselves. Their effect is further diminished by the fact that the CDC controllers (both GENERATOR and GRID) *operate in high-bandwidth closed-loop current control mode* – hence these (already negligible) errors are fully compensated by the current controllers.

3.3.4 CDC Power

- For DELTA modules, power for the SKiiP modules and CDC is derived from a bolt-on Switch Mode Power Supply (SMPS). One is used for each DELTA and the SMPS on DELTA position 1 is also used to power the CDC. The SMPS module derives its power from the DC link. The SMPS mounted on DELTA 1 also provides the DC link voltage feedback for the CDC.

- For AEI modules, the typical arrangement is to use an Auxiliary Power Supply Type G (APU-G) for each AEI module. The APU-G derives power from the DC link, so the operation of the converter utilizing AEIs powered with APU-G is identical to using DELTAs with the GEPC SMPS module.

- AEI-based systems may optionally use an arrangement of AC-powered auxiliary power units (APU-E and APU-F) along with a custom control-power transformer (CPT). With this arrangement, the CDC and other diagnostic capabilities of the AEI modules are available prior to energizing the DC link.

- To continue to meet grid tolerance requirements, the CPT provides 170Vac to the APUs, which in turn can operate continuously from 90Vac to 270Vac. This means that auxiliary power to the AEIs and CDCs will be maintained continuously for grid voltages from 360V to 830V (saturation limit of the CPT).

- To handle total grid loss, a buffer is provided in each APU that will maintain power to the AEIs and CDCs for 1s.

4. Revision History

Rev.	Date	Author(s)	Changes
00	Oct 31 2022	Gary Pace	Document created from template AQS-AAN-REV_00