Conext™ Core XC Series Inverter, 0G-XC-BB: Thermal Derating Application Note

AP-XC-089
Revision A

DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION, ARC FLASH, AND FIRE

This document is in addition to, and incorporates by reference, the relevant product manuals for Conect Core XC Series inverters. Before reviewing this document, you must read the relevant product manuals. Unless specified, information on safety, specifications, installation and operation is as shown in the primary documentation received with the product. Ensure you are familiar with that information before proceeding.

Failure to follow these instructions will result in death or serious injury.

Thermal Derating

PV inverters are designed to source the maximum available power from PV modules when they operate within their temperature specifications. In general, when the ambient temperature exceeds the optimum operating range, the inverter starts to reduce its output power. This feature is called "thermal derating".

Advantages of Thermal Derating

Thermal derating allows temperature management of the inverter's critical components while at the same time continuing to generate power. The sophisticated thermal derating algorithm is one of the safety and reliability features implemented on the Conect Core XC Series inverter. This algorithm makes sure that the temperature margins of critical components are never exceeded so that their expected lifetime can be reached. Since the inverter continues to generate power as long as it is able to manage its internal temperature, it can achieve a higher yield.

How Does Thermal Derating Work on the Conect Core XC Series Inverter?

The thermal derating algorithm uses the following inputs to define how much derating is required at any given time:

- The temperature of critical components on the inverter's power train.
- The output power.
- The ambient temperature.

All this information is required to know not only the external temperature of components, but also to model the internal temperature of some components. This allows the inverter to minimize its derating and still manage its internal temperature.

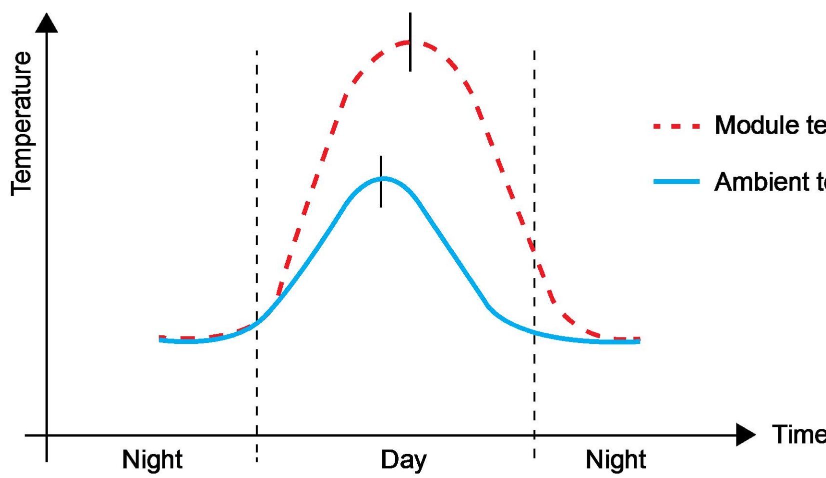
Is Thermal Derating Directly Linked to the Ambient Temperature?

Thermal derating definitely depends on the ambient temperature—the higher the ambient temperature the more difficult it will be for the inverter's cooling system to dissipate the heat produced during the conversion process. However, the relationship between ambient temperature and derating is complex and requires consideration of other effects such as module temperature, DC voltage, and conversion efficiency.

Relationship Between the Module Temperature and the Ambient Air Temperature

The module temperature and the ambient air temperature are not completely correlated. At sunrise, the modules and the ambient air have more or less the same temperature. However, when modules start to produce power, and since the solar power is not entirely converted into electricity, some heat is produced and accumulated by modules. This makes the module temperature increase faster than the ambient air temperature. As shown in *Figure 1*, module temperature can continue to increase for a short time even after the ambient air temperature starts to decline.

Figure 1 Module temperature vs. ambient temperature

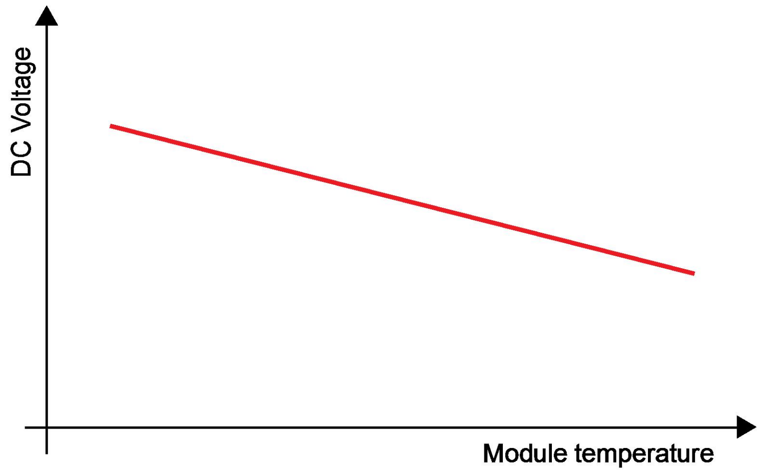


The temperature difference between the ambient air and the modules depends on the solar irradiance and other climatic factors like wind.

Relationship Between the DC Voltage and the Module Temperature

In photovoltaic module technology, when the module temperature increases, its DC output voltage decreases.

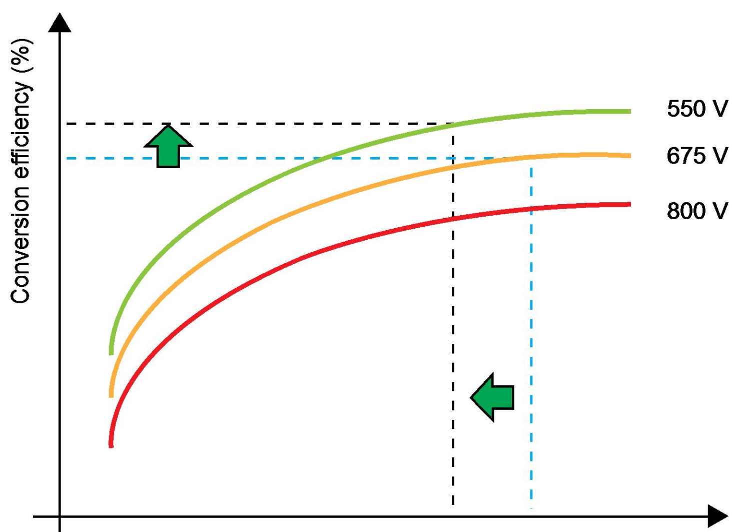
Figure 2 DC voltage vs. module temperature



Relationship Between the Conversion Efficiency and the DC Voltage

In addition to the previous relationships, the conversion efficiency of the inverter is also a function of the DC input voltage to the inverter. As far as Conect Core XC Series inverters are concerned, the lower the DC input voltage, the higher the conversion efficiency.

Figure 3 Conversion efficiency vs. power and DC voltage

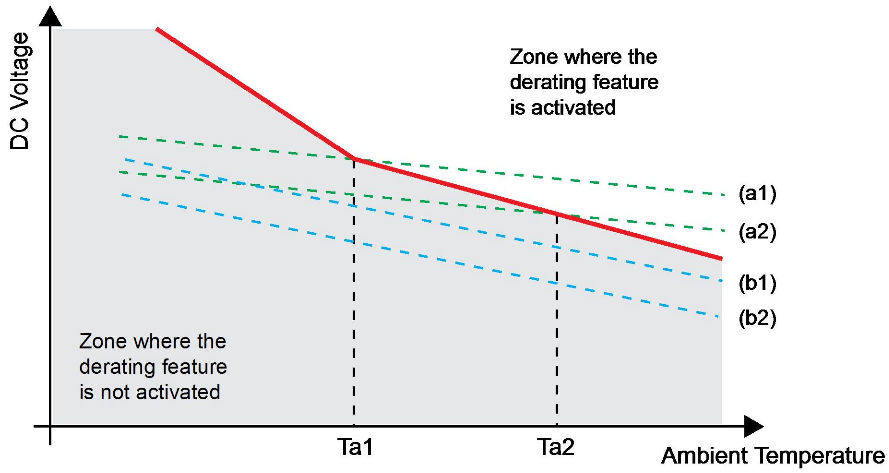


Consequences

The combination of these three relationships counterbalances the effect of the ambient temperature increase and results in the fact that the activation of the thermal derating feature does not depend only on the ambient temperature, but also on the DC voltage, which reflects the module temperature.

The result of thermal derating activation can be seen in *Figure 4*.

Figure 4 Zones where the derating feature is activated or not activated



The diagram above is separated into two areas:

- The area where the derating feature is activated
- The area where the derating feature is not activated

The separation line (in red) is given for the full output power, which assumes that solar modules are able to produce enough power within all the ambient temperature range. If they are not, the thermal derating feature would not be activated.

The dotted lines in *Figure 4 on page 4* represent case studies of two types of modules, (a) and (b), described in the table below.

Lowest temperature for the system design	Module	Module
0 °C	Case (a1): N modules per string	Case (b1): P modules per string
-10 °C	Case (a2): (N-1) modules per string	Case (b2): (P-1) modules per string

Case (a1): The DC voltage at the output of each string is represented by the curve (a1) and we can see that the derating feature will be activated from the ambient temperature Ta1.

Case (a2): The DC voltage at the output of each string is represented by the curve (a2) and we can see that the derating feature will be activated from the ambient temperature Ta2 which is higher than Ta1.

Cases (b1) and (b2): The DC voltage at the output of each string is represented by curves (b1) and (b2) and we can see that the derating feature will never be activated whatever the temperature.

How Often May Thermal Derating Take Place?

It is also important to understand how often thermal derating may take place and for how long. Both depend on the statistic distribution of ambient temperature at the site. The table below summarizes statistical information for some of the hottest places in the world[1] .

Location	Frequency of Hot Temperatures		
	Less than 2%	Less than 1%	Less than 0.4%
Jeddah, Saudi Arabia	38.4 °C	39.6 °C	40.9 °C
Riyadh, Saudi Arabia	42.9 °C	43.8 °C	44.2 °C
Abu Dhabi, UAE	40.2 °C	41.6 °C	43.0 °C
Dakhla, Egypt	40.7 °C	41.9 °C	43.0 °C
In-Salah, Algeria	44.7 °C	45.6 °C	46.5 °C
Bhuj, Gujarat, India	38.5 °C	39.7 °C	41.1 °C
Birdsville, QL, Australia	39.8 °C	41.1 °C	42.5 °C
Alice Springs, NWT, Australia	37.8 °C	38.9 °C	40.1 °C
Nellis AFB, NV, USA	37.4 °C	40.4 °C	41.8 °C

For example, the table above shows that Jeddah in Saudi Arabia only reaches temperatures higher than 38.4 °C less than two percent of the time and In-Salah in Algeria only reaches temperatures higher than 44.7 °C less than two percent of the time.

How Much Power is Lost When Derating is Activated?

The robust design and sophisticated derating algorithm of the Conect Core XC Series inverter results in a derating of 1.4% of the rated power per °C. Assuming operating conditions exist where derating starts at 50 °C, the inverter can still produce >90% of its rated output power at 55 °C.

Conclusion

The thermal derating algorithm on the Conect Core XC Series inverter has the following functions:

- Protects the critical components on its power train.
- Secures a lifespan that conforms to the PV power plant developers' expectations.
- Works during rare circumstances when the ambient temperature exceeds the inverter's optimum operating range.
- Optimizes the derating such that at maximum rated 55 °C the inverter can still produce >90% of its rated output power, for DC voltages up to 600VDC.

[1] Source: American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE), Climatic design conditions, www.ashrae-meteo.info.

XC680-XC-BB Derating

Figure 5 XC680-XC-BB maximum output power vs. ambient temperature

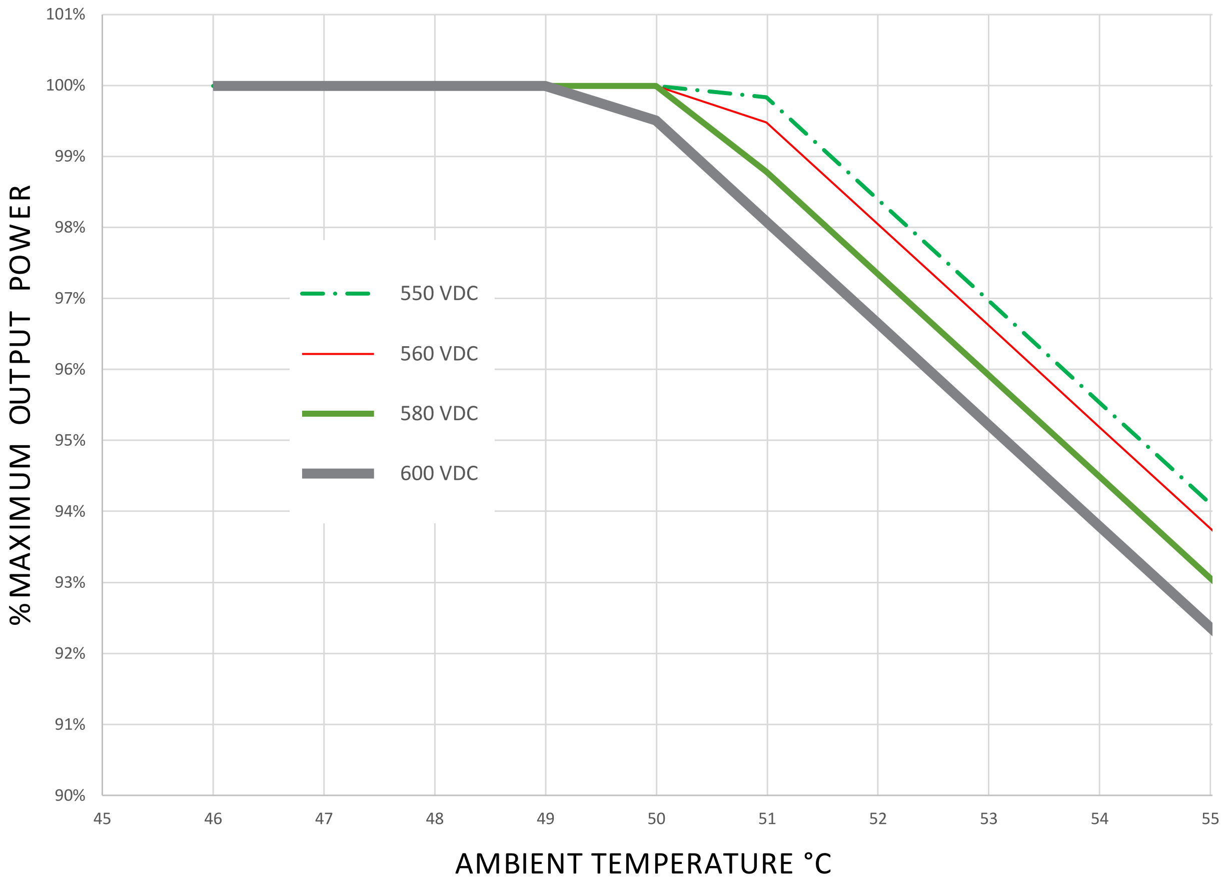


Table 1 XC680-XC-BB derating temperatures[1]

Input Voltage (VDC)	Derating Temperature (°C)
550	50
560	50
580	50
600	49

[1] DC voltages up to 600VDC are only provided based on real world scenarios where ambient conditions exist that meet or exceed 49°C. An ambient of 49°C is assumed to result in a corresponding array output voltage not exceeding 600VDC. (See Figure 2).

XC630-XC-BB Derating

Figure 6 XC630-XC-BB maximum output power vs. ambient temperature

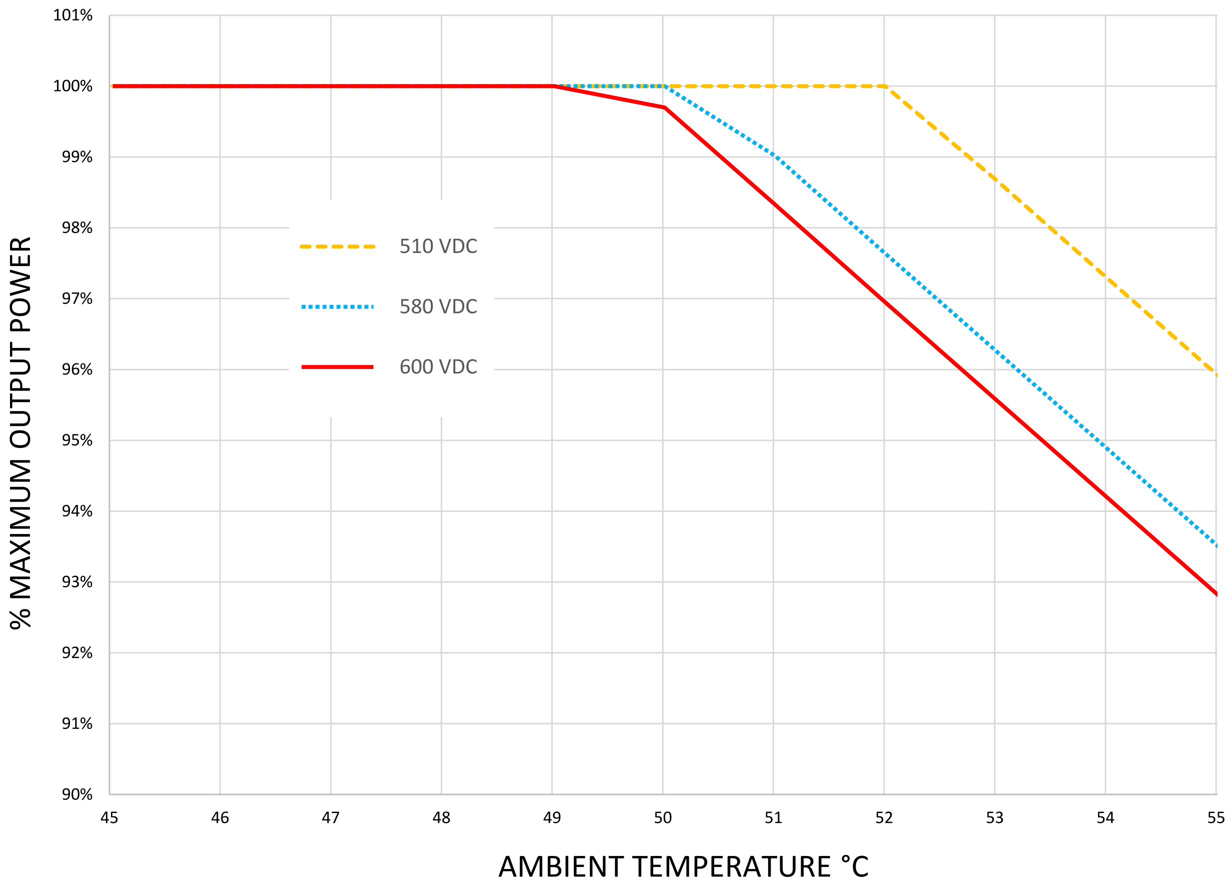


Table 2 XC630-XC-BB derating temperatures[2]

Input Voltage (VDC)	Derating Temperature (°C)
510	52
580	50
600	49

[2] DC voltages up to 600VDC are only provided based on real world scenarios where ambient conditions exist that meet or exceed 49°C. An ambient of 49°C is assumed to result in a corresponding array output voltage not exceeding 600VDC. (See Figure 2).

XC540-XC-BB Derating

Figure 7 XC540-XC-BB maximum output power vs. ambient temperature

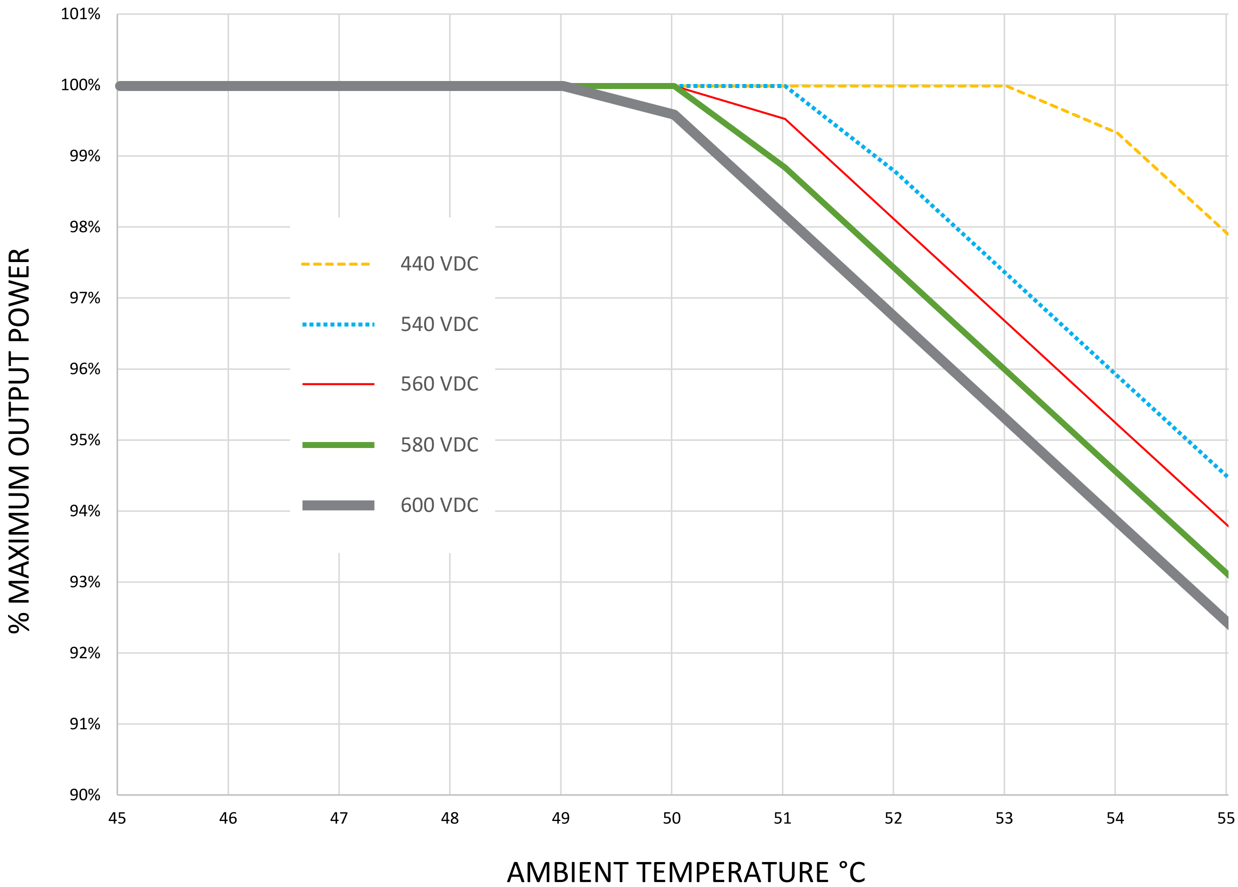


Table 3 XC540-XC-BB derating temperatures[3]

Input Voltage (VDC)	Derating Temperature (°C)
440	53
540	51
560	50
580	50
600	49

[3] DC voltages up to 600VDC are only provided based on real world scenarios where ambient conditions exist that meet or exceed 49°C. An ambient of 49°C is assumed to result in a corresponding array output voltage not exceeding 600VDC. (See Figure 2).

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Contact Information

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