SITE AC DESIGN GUIDELINES

The purpose of this application note is to outline in general terms the Engineering Best Practices considerations

AC Breaker Rating: Circuit Breakers must be derated for ambient temperature to prevent nuisance tripping in high outside air temperatures (OSAT). The ambient temperature is the temperature inside the circuit breaker enclosure is not the same as the OSAT. The temperature rise above OSAT will depend on the color, the solar orientation and the heat from the circuit breakers and power conductors. Temperature rise of 28°C was recorded at one typical site in Florida in July. The enclosures with largest surface areas facing East and West tend to have the highest solar heat gain in the evening and thus the highest temperature rise. The table below is derate values from a family of MCCB products. The breakers should never be operated above 70°C and the terminals are typically rated at 75°C. Using the 90°C NEC Ampacity for wire sizing will also raise the temperature inside the AC enclosure.

For the example in Florida, the temperature inside the enclosure was 60°C. The worst case derate would be 81%. Thus, for a 60kW inverter the breaker should be 125A with the temperature derate.

60,000 ÷ (480 x 1.73 x A x B)

Where **A** = 80% rated Breaker = 0.80 (80%) or 1.00 (100%)

B = Temperature derate = 1.00 – 0.81

NOTE: The NEC allow the calculation to be rounded to the nearest whole number (NEC220.5.B)

Without the temperature derate the Circuit Breaker would be 100A. There are a couple of design options that can be used to control the circuit breaker rating. While some of these options may increase the cost of the circuit breaker, they may reduce the cost of wire, conduit and life cycle maintenance.

1. Maintain an enclosure temperature that only requires a 90% derate instead of the 81% used in this example. This can be done with active or passive cooling and azimuth orientation of the enclosure.
2. Use Electronic Trip Breakers, which often have a higher temperature tolerance.
3. Use 100% rated circuit breakers. This will set the “A” variable in the equation above to 1.00 – lowering the size of the breaker and the associated wire and conduit.

Circuit breakers for plant protection								
At 40 °C	100%	100%	100%	100%	100%	100%	100%	100%
At 50 °C	96%	92%	96%	94%	96%	91%	91%	91%
At 55 °C	93%	87%	94%	90%	93%	86%	85%	85%
At 60 °C	91%	83%	92%	87%	90%	82%	81%	81%
At 70 °C	86%	73%	88%	80%	84%	70%	70%	70%

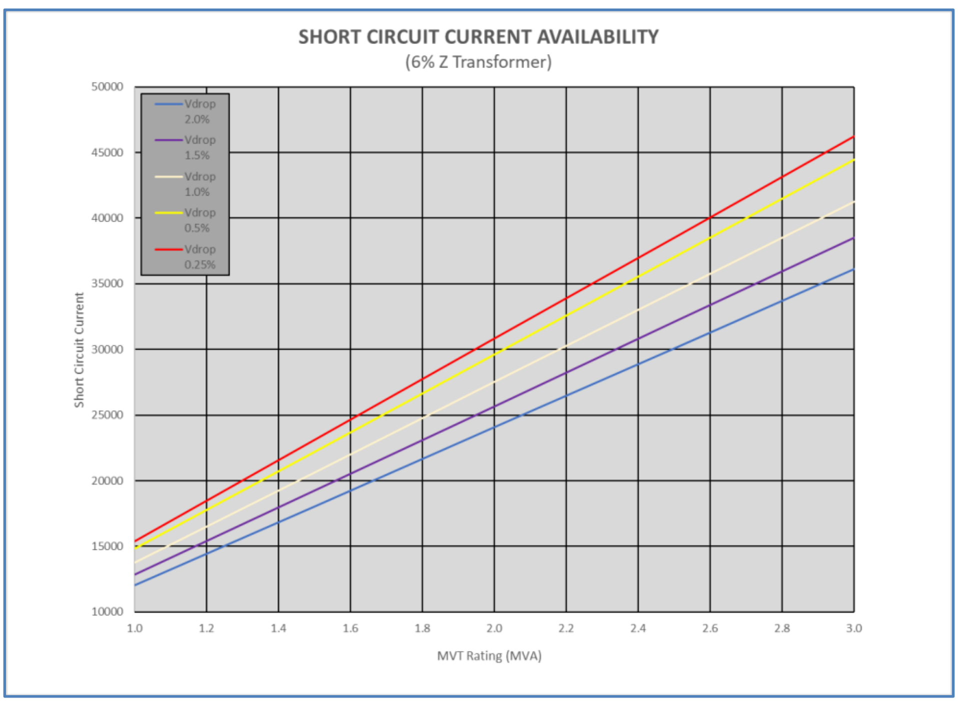
SITE AC DESIGN GUIDELINES

AC Breaker Rating (Interrupt Current Rating): Another important circuit breaker design factor is Interrupt Current rating. The breaker must be rated for the maximum fault current that is possible in the circuit. The interrupt current rating of the circuit breaker is based on the available short circuit current at the input to the inverter. As the Step-Up Transformer increases in KVA capacity, the Available Short Circuit Current increases. As the voltage drop from the transformer to the inverter increases, the Available Short Circuit Current decreases. The graph below illustrates the point.

- Fault current at the LV side of the MV Transformer. Usually the MV side is assumed to be connected to a zero-impedance grid. Thus, the short circuit current is totally determined by the Zero Impedance of the transformer, 6% Maximum in this requirement. As an example, a 3MVA, 6% transformer at 600VAC would have a short-circuit current of

  3,000,000 ÷ (600 x 1.73 x 0.06) = 48,170A Minimum
- Inverters that are located in the array have a significant addition impedance (voltage drop) which will lower the fault current in the circuit. In an array using string inverters, the ac distribution is divided in to as many circuits as inverters, so the calculation is much more complex than the example given below. A 3MVA 6% transformer with a 2% voltage-drop to the inverter will have a short circuit current of:

  3,000,000 ÷ [(600 x 1.73) x (6% + 2%)] = 36,127A Minimum
- This example assumes all inverters are collocated and grouped in the array. This gives a very conservative estimation as illustrated by the next detailed example below yields 24.2kA instead of 36.1kA from the example above.



Application Note: ACGRID
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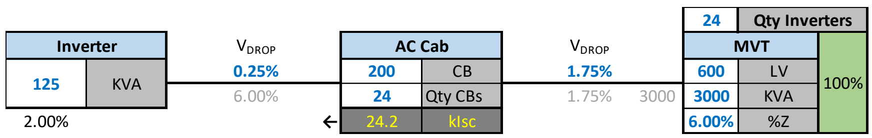
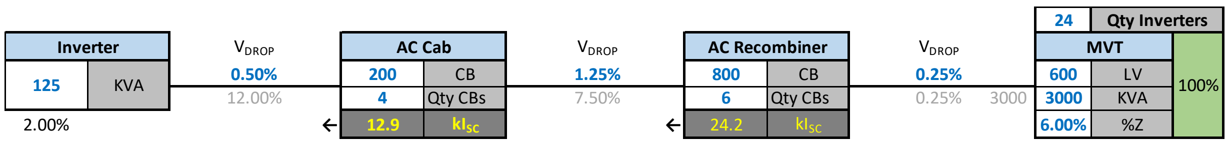
SITE AC DESIGN GUIDELINES

AC Breaker Rating (Interrupt Current Rating): The example below is a detailed example with different distributed architectures each have an effective 2% voltage-drop from the MVT to the Inverter.



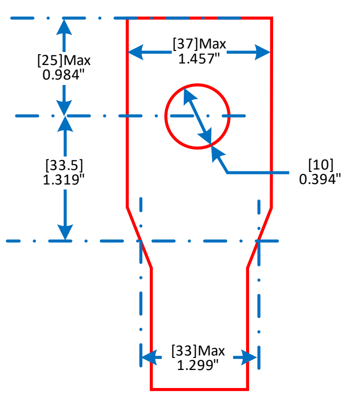


AC Power Conductor Size: The AC terminations in the CPS inverters are rated for 90°C. This will allow use of the 90°C wire ampacity from the NEC Table 310.15(B)(16) for 30°C ambient in conjunction with the temperature correction factors from NEC Table 310.15(B)(2)(a). The termination temperature rating at the circuit breaker end of the circuit may be 75°C – thus the ampacity must be based on 75°C.

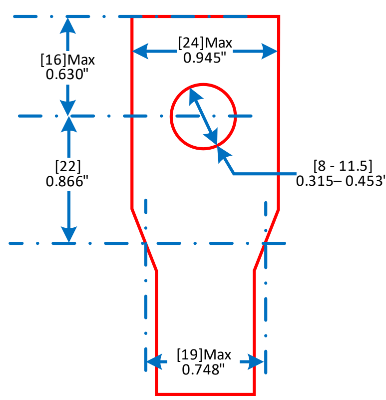
The temperature in the wire box will be higher than the OSAT due to solar loading and the heat generated by the fuses. CPS recommends using a 10°C rise in the wire box above the design OSAT for determining the correct wire size. The temperature corrected ampacity of the wire must be greater than or equal to the circuit breaker size determined in the section above **(AC Breaker Size)**.

Other considerations in determining the wire gauge is the allowable voltage drop and the physical dimensions of the AC Termination Block. The figure below represents the lug dimensions compatible with the inverter AC terminal block.

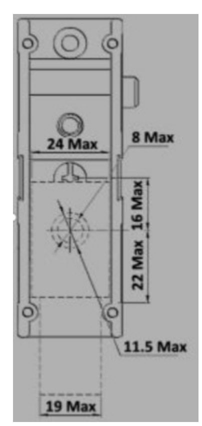
The uninsulated barrel of the lug protruding more than 1/2-inch from the terminal block should be insulated with tubing.



100/125kW Inverter Lug Dimensions



50/60kW Inverter Lug Dimensions



50/60kW Inverter Terminal Block Dimensions

SITE AC DESIGN GUIDELINES

AC Power Ground Conductors: The ground terminations are rated for 90ºC. The size of the conductor is determined by NEC Section 250. CPS recommends a PE or Circuit ground for Floating AC circuits.

Inverter	Wire Range	AL/Cu
100kW/125kW	#12 – 1/0	AL/Cu
50kW/60kW	#14 - #2	AL/Cu
25kW/36kW	#14 - #4	AL/Cu

Equipment Ground: Both the Inverter and Wire Box enclosures MUST be bonded to ground for personnel safety. This bonding conductor should be visible to the operator for safety assurance. This connection to ground is different from the circuit ground in the section above that is designed to provide a consistent low impedance path for fault current. The equipment ground bond connection is located on the wire box. It is critical that the bolted connection between the wire box and inverter power head enclosure be properly and securely maintained to ensure operator safety.

AC Power Conduits: Conduit size is determined by NEC. CPS recommends a Flex conduit to reduce mechanical stress on the inverter. The conduit must be water tight to maintain the NEMA-4X rating. The conduit should be metal to provide the best containment of any thermal event that may occur. Conduit ends in the wire box must be sealed to prevent moist air ingress. Elimination of water ingress is absolutely essential for eliminating moisture induced failures in the wire box.