APPLICATION NOTE

String Sizing the PVS-500

DC-Coupled Energy Storage System

INTRODUCTION TO THE PVS-500

String sizing the Yaskawa Solectria Solar PVS-500 DC-Coupled Energy Storage System is different than the traditional 1:1 combiner-to-string-inverter pairing. The Solectria PVS-500 DC-Coupled Energy Storage System has the capability to handle a DC/AC ratio of 2.5 and comes with Solectria XGI 1500 inverters, a Heila Edge Plant Master Controller and a bi-directional Dynapower DPS 500 DC/DC converter. Having the energy storage and the PV array on the same inverter allows this DC-coupled system to store the excess PV production in batteries and discharge to the grid at select times and conditions to maximize the value of the system. The PVS-500 consists of 3 synchronized XGI 1500 string inverters that are fed by batteries and up to five PV remote combiner boxes through the Solectria DC Re-Combiner box (see Figure 1).

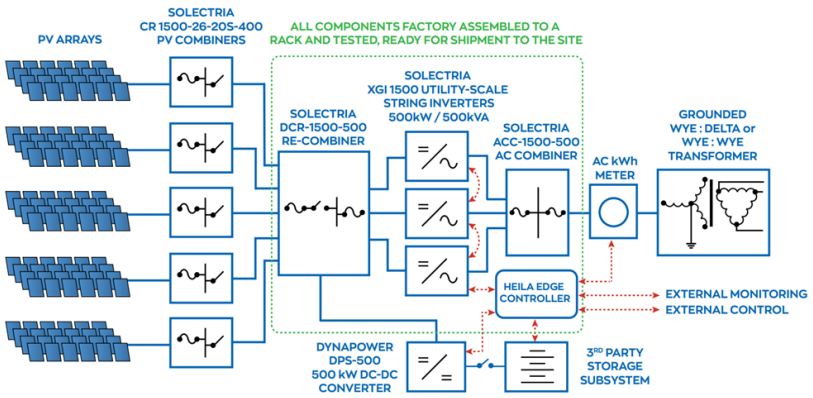

Figure 1 PVS-500 Schematic

During normal DC Coupled operation, the daily production (represented by a half sinusoid) can be split into three parts: inverter capacity (red), DC/DC converter capacity (blue) and power excess (cream). Assuming the inverter is able to output its full rated power unrestricted (red, up to the full inverter rating of 500kW), the DC/DC utilization ratio is the overloading of the DC/DC converter with array power that's left after the inverter output. An 80-149% DC/DC utilization would be ideal, however it depends on the use case. DC/DC utilization ratios greater than 100% are represented by the space above the blue area in Figure 2. This is now the excess power that is clipped, similarly to PV only systems with DC/AC ratios greater than 1.

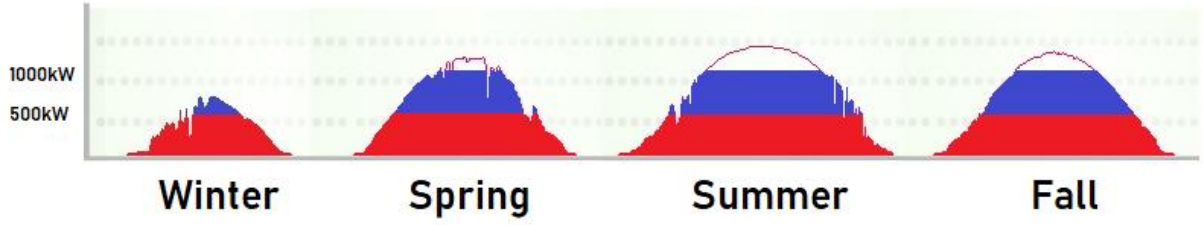

Figure 2 Performance of System with DC/AC Ratio 2.5 Through the Seasons

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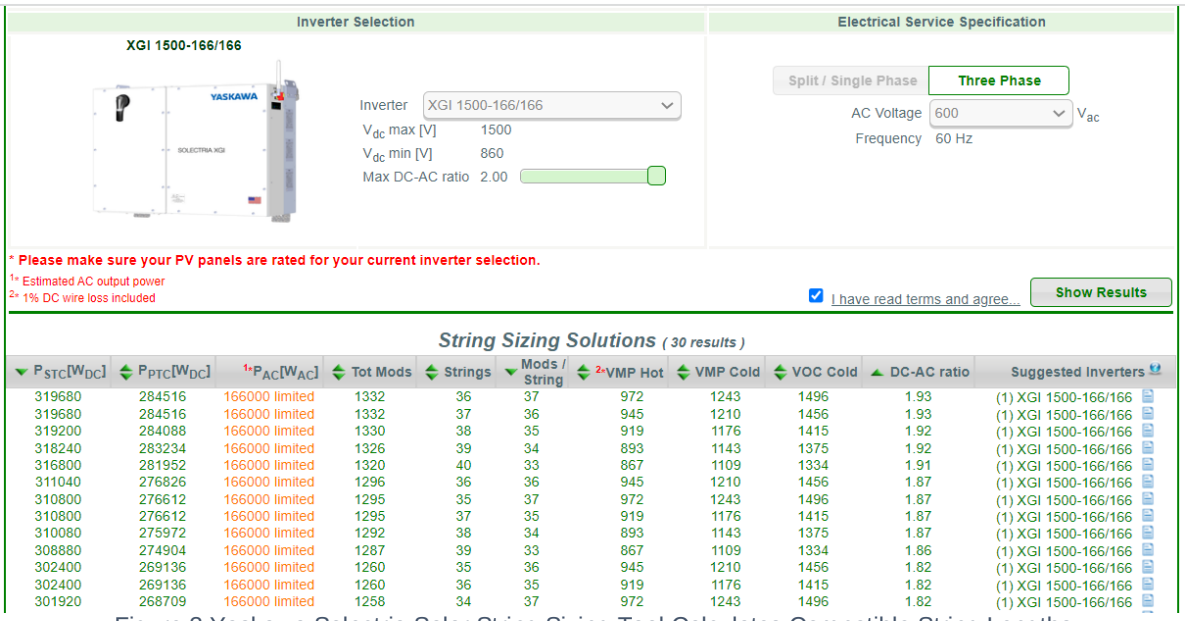
STRING SIZING THE PVS-500 DC COUPLED SOLUTION

String sizing the PVS-500 is similar to any other system with a single MPPT zone. All of the strings must be the same length and, depending on the desired DC/AC ratio, normally 3-5 PV combiner boxes may be utilized.

String sizing may be calculated by hand in the same manner as conducted for a traditional string inverter, or by using the Yaskawa Solectria Solar String Sizing Tool to determine acceptable string lengths (see Figure 3).



PSTC[WDC]	PPTC[WDC]	1*PAC[WAC]	Tot Mods	Strings	Mods / String	2*VMP Hot	VMP Cold	VOC Cold	DC-AC ratio	Suggested Inverters
319680	284516	166000 limited	1332	36	37	972	1243	1496	1.93	(1) XGI 1500-166/166
319680	284516	166000 limited	1332	37	36	945	1210	1456	1.93	(1) XGI 1500-166/166
319200	284088	166000 limited	1330	38	35	919	1176	1415	1.92	(1) XGI 1500-166/166
318240	283234	166000 limited	1326	39	34	893	1143	1375	1.92	(1) XGI 1500-166/166
316800	281952	166000 limited	1320	40	33	867	1109	1334	1.91	(1) XGI 1500-166/166
311040	276826	166000 limited	1296	36	36	945	1210	1456	1.87	(1) XGI 1500-166/166
310800	276612	166000 limited	1295	35	37	972	1243	1496	1.87	(1) XGI 1500-166/166
310800	276612	166000 limited	1295	37	35	919	1176	1415	1.87	(1) XGI 1500-166/166
310080	275972	166000 limited	1292	38	34	893	1143	1375	1.87	(1) XGI 1500-166/166
308880	274904	166000 limited	1287	39	33	867	1109	1334	1.86	(1) XGI 1500-166/166
302400	269136	166000 limited	1260	35	36	945	1210	1456	1.82	(1) XGI 1500-166/166
302400	269136	166000 limited	1260	36	35	919	1176	1415	1.82	(1) XGI 1500-166/166
301920	268709	166000 limited	1258	34	37	972	1243	1496	1.82	(1) XGI 1500-166/166

Figure 3 Yaskawa Solectria Solar String Sizing Tool Calculates Compatible String Lengths

Iterate through a combination of string lengths and number of strings that results close to the desired DC/AC ratio or total number of modules. Note that the DC Re-Combiner has 5 positions, each with a 400A fuse and disconnect, for a maximum of 5 input PV combiner boxes.

The maximum current per PV input, I_{max}, is listed in the DCR manual at 305 A (Table 1.). There are two methods of calculating maximum current (Imax) in NEC 690.8(A)(1)(a), one being Isc x 1.25.

$$I_{max} < 305\ A$$

Table 1 Re-Combiner maximum PV currents

		DCR-1500-500	DCR-1500-250
Maximum Current Rating of each PV Input (Source) Circuit *[Calculated per NEC 690.8(A)(1)]*	Indiv Circuit Max Current	305 A	305 A

Once the string length and number of strings are determined, identify an appropriate remote combiner box (3rd party or Yaskawa Solectria Solar) and calculate the maximum current for the

sub-array per combiner box. Then populate the combiner boxes as evenly as possible up to the maximum current, until all strings are used.

EXAMPLE

PVS-500
1MW DC STC
500kW AC
Hanwha Q CELLS Q. PEAK DUO XL-G11.3BFG 570 (Bifacial Gain 10%)
Mounting: Ground
Low Temp: -14ºC
High Temp: 30ºC

1. FIND STRING LENGTH OPTIONS

Perform the string sizing calculations either by hand, with an analysis tool or by using the Yaskawa Solectria Solar string sizing tool.

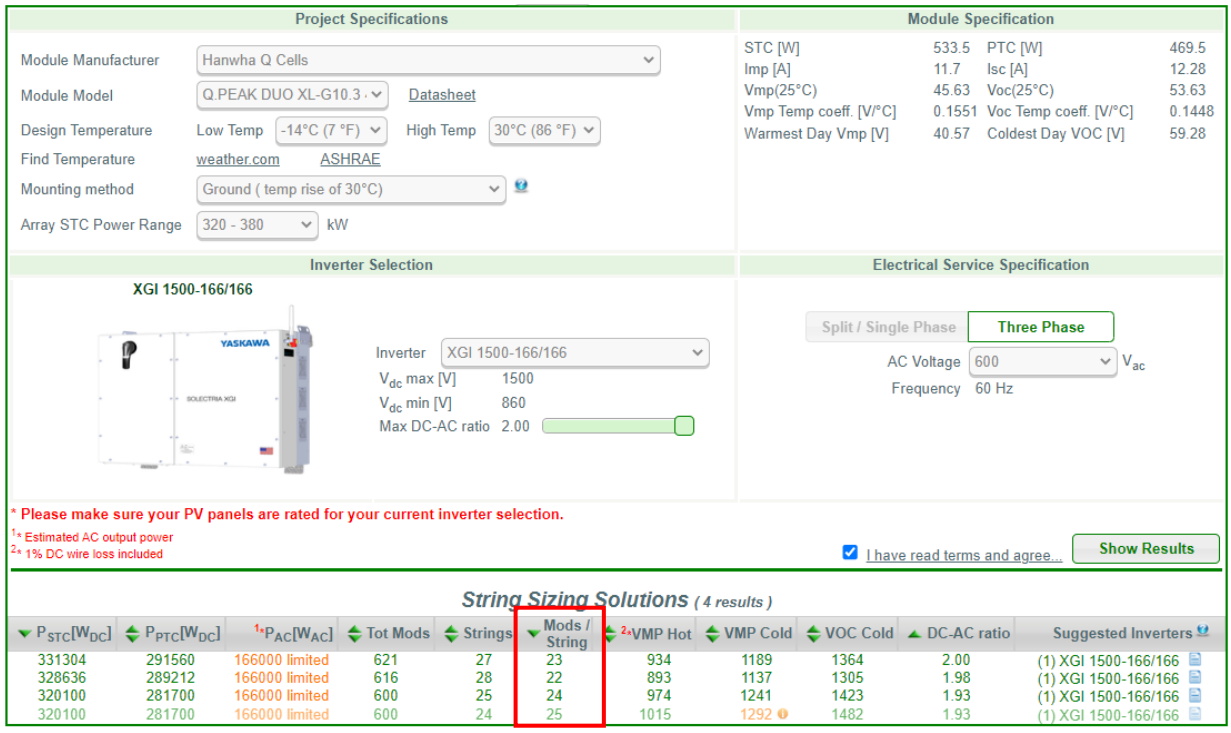


Figure 4 String Sizing Tool Results

After using the string sizing tool, some acceptable string length choices are

- 22 Mods/String,
- 23 Mods/String,
- 24 Mods/String, and
- 25 Mods/String.

The option of 25 modules per string has a warning because the VMP cold is 1292Vdc and is above the MPPT range of 1250Vdc, which means some derating would occur when above the 1250V MPPT upper limit:

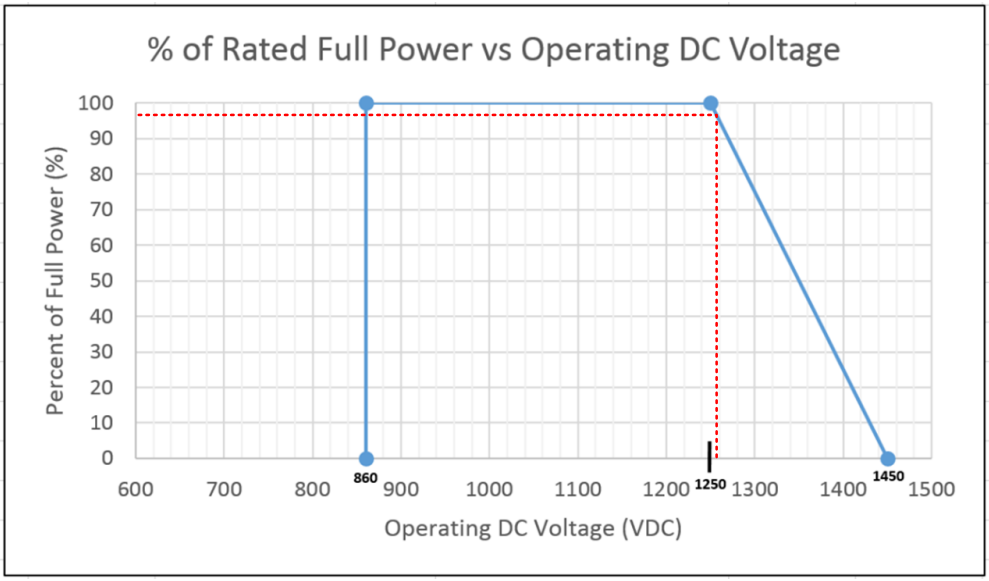


Figure 5 XGI 1500-166 inverter Derating with DC Voltage (XGI 1500 Manual)

However, it is 42 volts above the MPPT upper limit and for the location of this example, this would very likely be infrequent. In addition, as the modules begin to age and degrade, the module voltage will also begin to drop over time.

2. ITERATE TO FIND ACCEPTABLE ARRAY CONFIGURATION

Iterate through the different configurations of string length and number of strings to get the desired array power or number of modules but within the PV Input (Source) Circuit max current of the Re-Combiner. In order to simplify the analysis, the maximum string length of 25 modules was chosen.

Table 2 Example Analysis of Possible String Configurations with 1MW STC Goal

	Mods/ string	# Total Strings for 1 MW STC	# Strings for Max Individual Current	Number of Combiner Boxes	Combiner Box with Most Strings	Array STC	Array PTC	# of Modules
# Strings Rounding Up	25	75	20	4	19.0	1000.3	880.3	1875
# Strings Rounding Down	25	74	19	4	19.0	987.0	868.6	1850

Twenty five modules per string and 75 strings total was chosen as the best option to meet the 1MW DC STC target.

3. SPECIFY REMOTE COMBINER BOXES AND LAYOUT

Yaskawa Solectria Solar provides optional remote combiner boxes (not required, 3rd party combiners are acceptable) with fuse ratings from 20A-32A and with 16, 20, 24, or 28 positions. The module has an Isc of 12.28A and requires a 20A fuse.

The system total maximum current, I_{max}, would be 1,151.25 A, using the NEC 690.8(A)(1)(a)(1) method (Isc x 1.25). For the proposed array size, the DC Re-Combiner needs to be evaluated for the minimum number of remote combiners so as to not exceed the maximum PV Input (Source) Circuit max current allowable of 305 A.

$$\frac{1{,}151.25\ A}{5\ Combiners} = 230.25\ \text{A per circuit}\ \checkmark$$

$$\frac{1{,}151.25\ A}{4\ Combiners} = 287.8\ \text{A per circuit}\ \checkmark$$

$$\frac{1{,}151.25\ A}{3\ Combiners} = 383.8\ \text{A per circuit}\ \mathbf{X}$$

Four or five remote combiner boxes should be used, with a number of strings per combiner box in the range of 15-19 strings. Distributing the strings evenly between four combiners would result in an average of 18.75 strings per combiner. Four CR1500-20P-20S-400 remote combiner boxes could be considered.

This would provide a total of 80 positions and enough positions to combine the 75 strings and be below the max current per individual circuit.

Distribute the strings evenly between the combiners and ensure that the max current output does not exceed the individual circuit maximum. This example project distributed the strings with 19 strings for three combiner boxes and one at 18 strings. The worst case would be 19 strings in the single combiner box. Calculate to ensure this is below the maximum PV Input (Source) Circuit max current allowable per Table 1.

$$12.25 * 1.25 * 19 = 290.9\ \text{A per circuit} < 305\ \text{A max}\ \checkmark$$

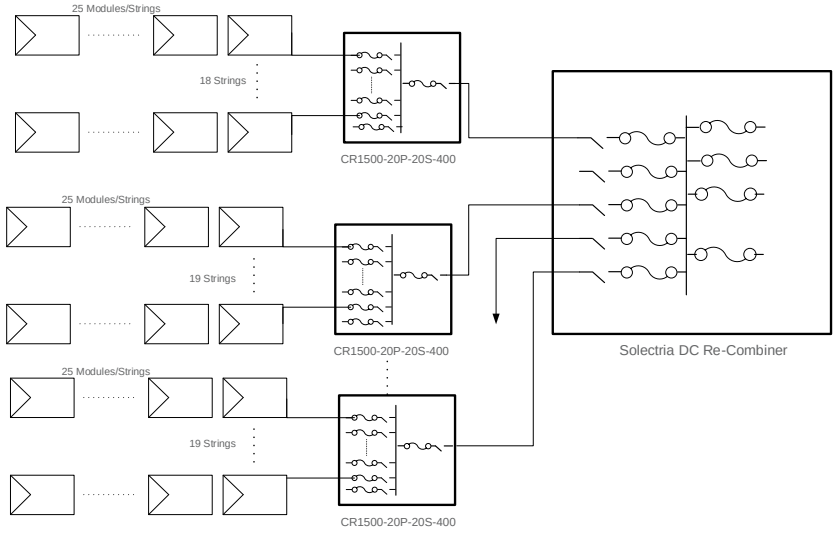


Figure 6 Remote Combiner Configuration

4. RESULTS

Results show a 1000.3 kW DC STC PV array with 25 modules per string and 75 strings total distributed among four CR1500-20P-20S-400 combiner boxes.