DC/AC inverter oversizing ratio – what is the optimal ratio for Australian solar farms?

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Background & Aim

DC/AC ratio, also known as inverter oversizing ratio, is a common design metric when designing both small and large scale solar photovoltaic (PV) systems. It is defined as the ratio of the DC output power of a PV array, which is equal to the sum of each PV module's rated output under Standard Test Conditions (STC), to the total inverter AC output capacity. For example, a solar PV array of 13 MW combined STC output power (also commonly referred to in the non-SI unit MWp) connected to a 10 MW AC inverter system has a DC/AC ratio of 1.30.

Oversizing inverters (that is systems with a DC/AC ratio >1.00) is common practice in both Australia and worldwide, as solar PV modules rarely operate at their STC performance when not under controlled conditions. Variable cell temperature, variable irradiance, soiling, wiring losses, mismatch and degradation from age all cause a reduction in solar PV module performance below its STC value. This reduction means an inverter with AC output capacity less than the array's combined STC output power can often be used with little to no impact to yield (power generated per year).

In Australia, to be eligible for government incentives, solar PV arrays below 100 kWp must have a DC/AC ratio no greater than 1.33[1]. However, for array sizes beyond 100 kWp, there is limited guidance other than requiring adherence to manufacturer's written instructions (which may state a maximum DC power or DC/AC ratio).

The aim of this paper is to identify an 'optimal' DC/AC ratio for large Australian solar farms by:

- Completing software simulations of solar farms with high DC/AC ratios to compare performance; and
- Investigating the Australian grid-connection regulatory requirements and the associated impact on DC/AC ratio.

Software Simulations – Yield Estimates

As an input to the economic optimisation, solar farm yield estimates were completed using the Helioscope software package. Estimates were completed for each combination of the variables in Table I below.

Table I. Variables considered as part of solar farm yield estimates

Variable	Range
DC/AC Ratio	1.00 – 2.20 in steps of 0.10
Solar Farm Latitude / Location	South Victoria (-38° lat) South NSW (-35° lat) North NSW (-30° lat) Mid SA (-32° lat) South WA (-32° lat) South QLD (-27° lat) North QLD (-20° lat)

[1] See *Clean Energy Council: Grid-connected solar PV systems, design guidelines for accredited installers* – Section 9.4 "Array peak power – inverter sizing".

Mounting System	Fixed tilt Single Axis Tracking East-West high density[2]

Losses from DC cabling were ignored, on the assumption that facilities with higher DC/AC ratios would use larger DC cables to offset the increase in DC cable loss.

Across all estimates:

- For each type of mounting system, the same location and solar irradiance data were used;
- The same array azimuth was used for all assessments;
- The same mono-facial solar PV module was used for all assessments;
- The 'fixed tilt' mounting system was tilted towards north at an angle matching that of the latitude of the location;
- The same central inverter was used for all assessments.

The results of the above simulations follow a similar profile to that of Figure 1, with power generated per year by the solar farm initially increasing linearly with DC/AC ratio, then flattening at higher ratios.

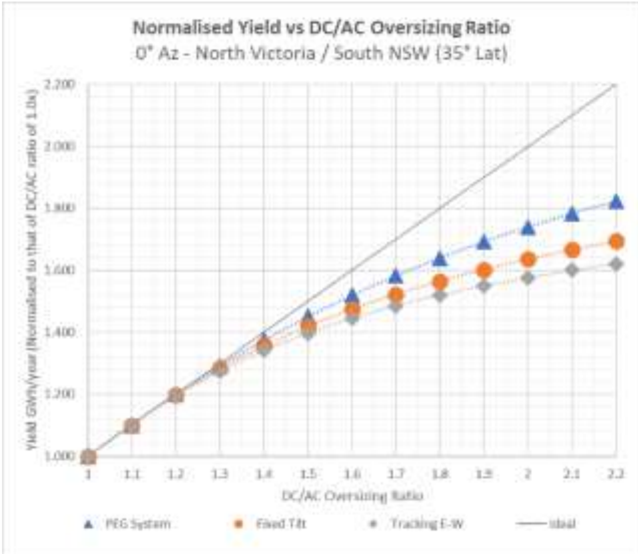

Figure 1. Solar farm yield becomes non-linear at high DC/AC ratios

Solar Farm Capital Cost & DC/AC Ratio

Increasing the DC/AC ratio of a solar farm does not always result in an equivalent scaling of the solar farm capital cost[3].

For example, consider a proposed fixed tilt 10 MW AC solar farm with an DC/AC ratio of 1.00 (10 MWp) and an indicative capital cost of $20 million. Increasing the DC/AC ratio to 1.30 (13 MWp) would increase the capital cost of the project, but the increase would be likely less than $26 million as there has been no increase in the cost of inverters or high voltage plant. For sake of the example, we will state the revised nominal cost is $24.8 million.

If this solar farm was in South NSW (Figure 1), compared to the example with a DC/AC ratio of 1.00, the higher ratio solar farm would yield 28% more energy per year whilst only costing 24% additional capital. This presents an economic benefit for the project which (subject to available capital) may provide a better rate of return.

In line with the above example, a basic cost-optimisation has been completed for each combination of the variables in Table I. To facilitate this optimisation, we will introduce a ratio A, defining it as the proportion of the total solar farm capital spend which varies with the DC/AC ratio of a solar farm. In the previous example, the ratio A was assumed to be 0.80, meaning $16 million of the $20

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[2] Such as 5B's MAVERICK or Jurchen Technology's PEG system

[3] For example, the costs associated with the number of inverters, HV equipment and grid connection costs do not scale with DC/AC ratio, whereas the costs associated with modules, DC cabling, mounting system and land does scale with increasing DC/AC ratio.

million initial capital cost directly varies with the DC/AC ratio. Therefore, an increase to a DC/AC ratio of 1.30 increased the price to $(16 \times 1.30 + 4) =$ \$24.8 million.

Detailed solar farm capital costs are typically commercially sensitive and, combined with the variable costs for local site conditions, prevents the presentation of the most common Australian solar farm A ratio. Project experience by the author has indicated an approximate A ratio of 0.70 for small (<10 MW AC) solar farms within South-East Australia at the time of writing, however the A ratio for each proposed solar farm should be calculated independently as part of a project's concept design stage with assistance from an early works contractor or engineering consultant.

For each combination of the variables in Table I, the A ratio has been used to calculate a normalised solar farm cost, normalised by the cost of the same solar farm with a DC/AC ratio of 1.00 (similar to the example above.) This normalised solar farm cost, divided by the solar farm yield (again normalised to the DC/AC ratio of 1.00), gives a final solar farm revenue (assuming fixed price for each unit of power generated) as per the below.

$$\mathrm{R}_{\mathrm{Norm},\delta=1.00} = \frac{A\delta + (1 - A)}{y_{\mathrm{Norm},\delta=1.00}}$$

Where:

- R is the revenue from the solar farm;
- δ is the DC/AC ratio;
- A is the proportion of the solar farm capital cost which varies with DC/AC ratio;
- y is the solar farm's annual yield;
- The subscript $_{\mathrm{Norm},\delta=1.00}$ means the associated value is normalised by the result for a DC/AC ratio of 1.00.

Results

When the results from the Helioscope software simulations were inputted into this basic economic model with varying A ratios, a maximum (optimal) normalised revenue can be observed. An example of such results can be seen in Figure 2.

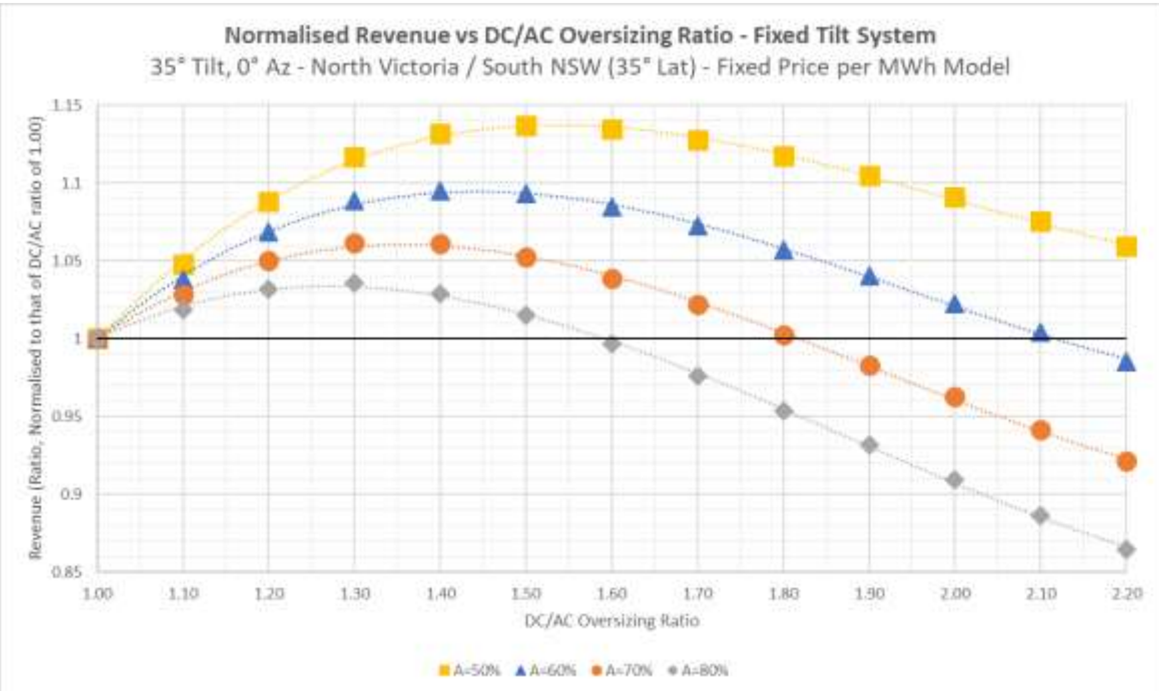

Figure 2. Normalised Revenue vs DC/AC ratio (Fixed Axis System, South NSW) for A ratio between 0.50 and 0.80.

The maximum value of each revenue curve as per Figure 2 for A ratio between 0.50 to 0.80 inclusive has been summarised in Table II through Table V below.

Table II. A = 0.50, approximate optimal DC/AC ratio

Location	Latitude	High Density East/West	Fixed Tilt	Single Axis Tracking
South Victoria	-38°	2.00	1.65	1.55
South NSW	-35°	1.70	1.50	1.45
North NSW	-30°	1.70	1.45	1.40
Mid SA	-32°	Will be provided in full submission		
South WA	-32°			
South QLD	-27°			
North QLD	-20°			

Tables/results for A = 0.60, 0.70, 0.80 in full paper submission.

Restrictions for Grid-Connection

Assessment vs S5.2.5.1 of the NER in full paper submission.