Micro-Inverters vs. DC Optimisers

Why do we need module level electronics?

In many ways the rapid uptake of PV in Australia over the last decade has caused the city-based PV installer a problem: many of the easy, large area, unobstructed, north-facing roofs have already been used. Often this leaves us with "sub-optimal" installation options involving small areas where only 1-4 modules will fit, roof areas that face in multiple orientations – thus precluding the use of a simple string inverter – and roofs with transient or even permanent shading. Other issues include customers wanting to expand old systems, typically with modules in the 165-190Wp range which are expensive and hard (if not impossible) to source matching modules for. Simultaneously, we have seen a tightening of standards and an increase in awareness of potential safety issues around unprotected LV DC cabling, resulting in the need to provide additional mechanical protection for the cables inside buildings via the use of HD conduit or, in non-domestic installations, ducts or cable trays with lids. The mandatory use of rooftop isolators on PV systems has also seen its own set of issues with multiple recalls of faulty DC isolators over the last few years.

Key benefits of DC Optimisers and Micro-Inverters

Both DC optimisers and micro inverters provide potential solutions to the problems faced by the average Australian Installer. These technologies provide a higher degree of sophistication to the PV system:

- Allow for mismatch between modules (within limits, typically ±25%) – this includes mix and match module types, manufacturing defects, and manufacturer's tolerances.
- Visibility of individual modules for monitoring, fault-finding and potentially warranty purposes.
- Reduces the impact of shading without placing heavy loads on the module bypass diodes. The reduction varies on a case by case basis, with manufacturers of both products often claiming up to 25% improvements in energy yield in specific cases – general independent testing tends to show 5% to 10% improvement in system yield compared to a typical string-type inverter.
- Allow for modules to be mounted at varying tilts and orientations in the same string without matching issues by implementing an independent Maximum Power Point Tracker for every module rather than the per string MPPT that a string inverter would be restricted to.

Typical wiring configurations

A typical grid-connect PV system will be wired as described by Figure 1. Figures 2 to 4 shows the wiring configuration when DC optimisers or micro inverters are used. These figures are displayed on the following page.

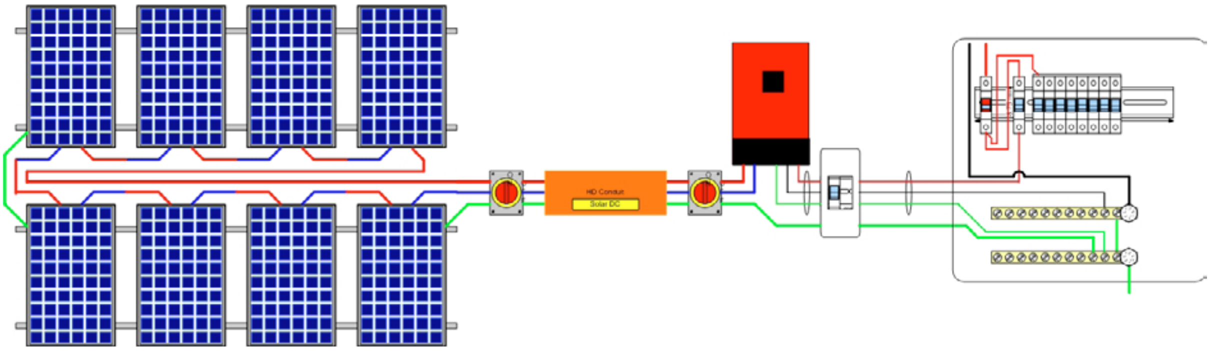

Fig.1 Standard string inverter configuration

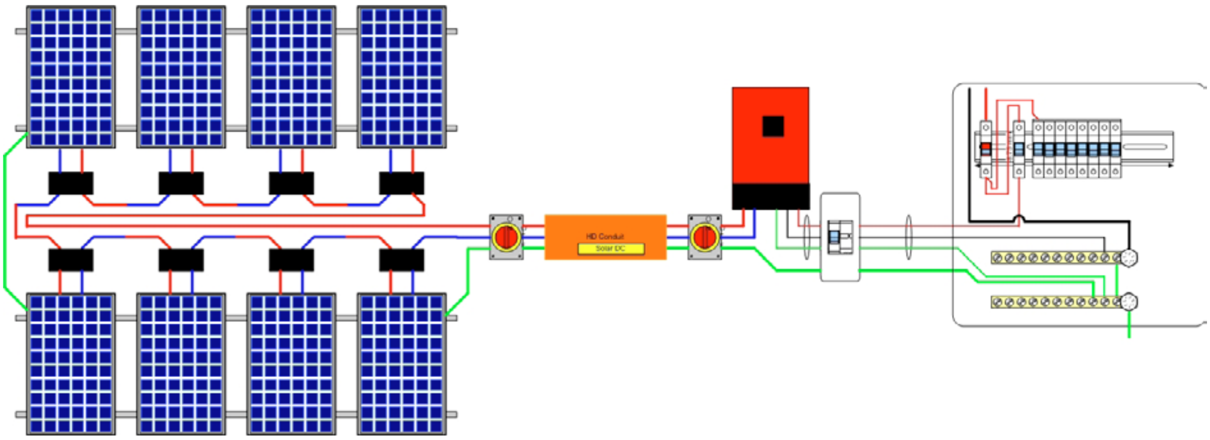

Fig.2 Typical DC optimiser configuration

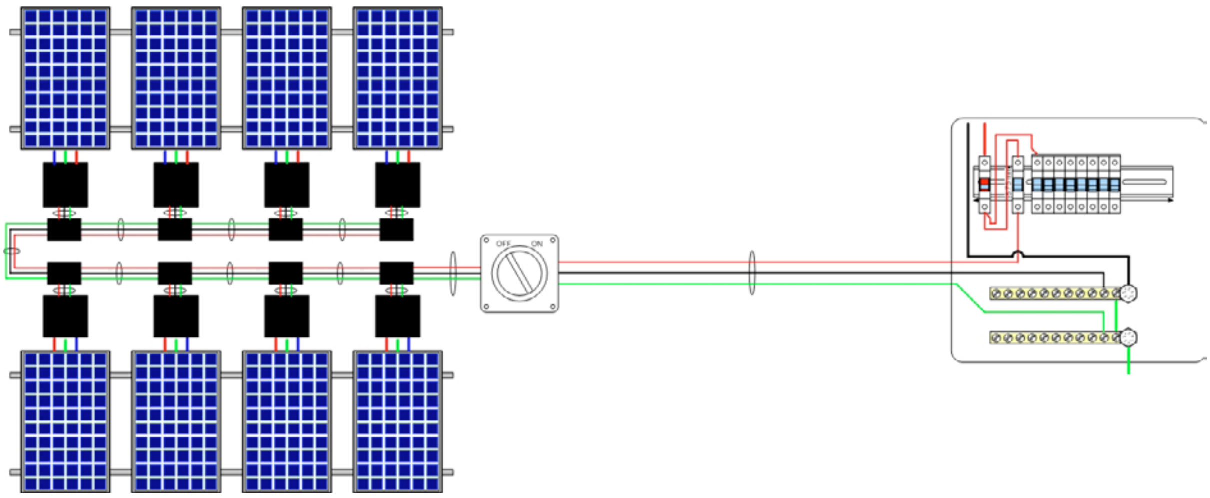

Fig.3 Typical micro inverter configuration with plug-in trunk cable

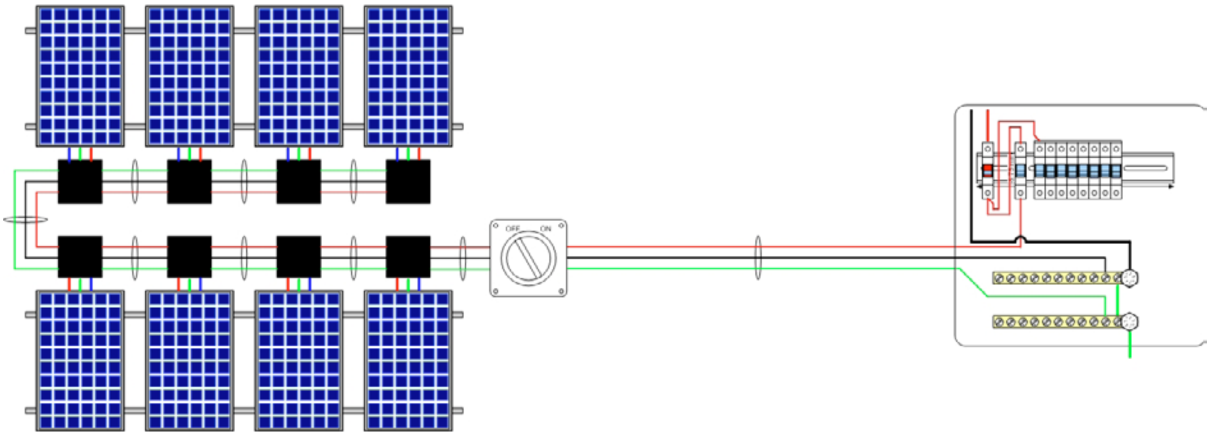

Fig.4 Typical micro inverter configuration where the micro inverters have AC fly leads prewire

Differences between DC Optimisers and Micro Inverters

The following sections compare the two technologies to typical string inverter setup

Savings in hardware/labour:

DC Optimisers

- Design time potentially reduced as the need to match tilt/orientation and avoid shade with modules is alleviated. String-to-inverter matching calculations are still required as well as module-to-DC-optimiser matching checks.

Micro Inverters

- Design time potentially reduced as the need to match tilt/orientation and avoid shade with modules is alleviated. Only module-to-micro-inverter matching checks required.
- DC rated isolators and cable can be replaced with AC rated isolators and cable (typically cheaper and more readily available).
- No string inverter to be purchased or installed.
- No requirement to run the array cable in HD conduit within the building structure with labelling at 2m intervals.
- Some manufacturers allow for equipotential bonding of the module frames and racking via the micro inverter earth connection without the need to run a dedicated bonding earth (subject to lightning risk analysis).

Winner – micro inverters

Extra hardware needed on the roof:

- DC Optimisers – typically 1 or 2 modules per optimiser. With some systems a minimum number of DC optimisers are required to power up the string inverter.
- Micro Inverters – typically 1 module per micro inverter although some manufacturers provide for 2 or even 4 modules per micro inverter.

Tie – the minimum number of DC optimisers is a manufacturer specific issue that can be avoided by choosing a different product if desired.

Extra power cabling needed:

- DC Optimisers – typically none, modules plug into DC optimisers and DC optimisers are series connected with pre-existing fly leads, in a daisy chain fashion, to form strings in the same way as typical module interconnection. String length will depend on the string inverter DC maximum input voltage, and these strings are then paralleled together as usual.
- Micro Inverters – manufacturer dependent, either:

a) none; modules plug into micro inverters and micro inverters are parallel connected with pre-existing fly leads, in a daisy chain fashion, to form a branch circuit. The number of modules per branch circuit will depend on the current carrying capacity of the AC 'string' cables, and these branches are then paralleled together; or,

b) trunk cable; modules plug into micro inverters and micro inverters are parallel connected by plugging into a proprietary trunk cable to form a branch circuit. The number of modules per branch circuit will depend on the current carrying capacity of the AC 'string' cables, and these branches are then paralleled together.

Tie – the proprietary trunk cable is a manufacturer specific issue that can be avoided by choosing a different product if desired.

Safety issues:

In operation:

- DC Optimisers – when operating output is still LV DC to the string inverter, issues around unprotected supply cables still exist with potential for sustained DC arcs if the array cables are damaged.
- Micro Inverters – output is LV AC direct to the switchboard, damage to the array cable will cause the AC circuit breaker to trip and de-energise the system.

Winner – micro inverters right now, although DC optimisers with arc fault detection are available in overseas markets and will no doubt soon be available in Australia.

In shutdown:

- DC Optimisers – when Solar Supply Main Switch is turned off in switchboard the string inverter shuts down, depending on the manufacturer the DC array voltage may drop to ELV levels until the inverter is reconnected or it may stay at LV DC levels. A communications based "rapid shutdown" facility is common however this generally requires an extra cable to the rooftop.
- Micro Inverters – when Solar Supply Main Switch is turned off in the switchboard, all the micro inverters will turn off (anti-islanding) thus reducing the entire array to individual, ELV DC modules.

Winner – micro inverters unless the "rapid shutdown" facility is implemented on the DC optimisers chosen.

Long term reliability:

At the system level:

- DC Optimisers – single point failure of the string inverter results in total loss of output. Failure of an individual DC optimiser does not typically compromise the entire system instead only resulting in the loss of that DC optimiser's output.
- Micro Inverters – failure of any individual micro inverter only results in the loss of that micro inverter output.

Winner – micro inverters due to no single point failure.

At the module electronics level:

- DC Optimisers – less components in the harsh rooftop environment so theoretically a longer mean time between failures.
- Micro Inverters – more components in the harsh rooftop environment so theoretically a shorter mean time between failures.

Tie, leaning towards micro inverters – theoretically DC optimisers should be more reliable than micro inverters. However, at the end of the day if a product fails in service the customer is going to expect you, the installer, to make good. I compared the warranty offerings of several DC optimiser and micro inverter manufacturers in Australia. While the long term limited warranties varied from 10 or 12 to 25 years for parts and workmanship of the equipment, only one manufacturer (micro inverter) backed their product to the hilt by offering a service rebate for an installer to go to site and change out a faulty product during the warranty period. Even then, the rebate offered is the same as that offered for swapping a standard string inverter at ground level and is unlikely to cover the actual costs involved in a rooftop change out.

Economics - Does system size matter?

Interestingly, yes it does. Two basic case studies were generated, where one system is domestic scale and the other system commercial scale. Both sites are connected to 3 phase electric power, have single storey access, corrugated metal roof, facing north and pitched at 22 degrees with no shade.

The two systems were then costed using current list pricing from a major solar wholesaler for micro inverter and DC optimisers. The micro inverter and

DC optimiser manufacturers chosen were generally considered in the industry to be among the market leaders for their products. All other equipment was kept identical (i.e. PV modules, mounting rails, etc. except where design requirements or Australian Standards permitted differences). Typical labour rates were applied after consultation with a number of local installers and a $38.00 STC's were taken into account.

Results:

Domestic scale system

- DC optimisers system installed out of pocket cost of $13116.94 including GST
- Micro inverters installed out of pocket cost of $10967.89 including GST

Winner = micro inverters - primarily due to reduced parts and labour costs through not having DC isolators, cable or HD conduit.

Commercial scale system

- DC optimisers system installed out of pocket cost of $162,258.86 including GST
- Micro inverters installed out of pocket cost of $202364.96 including GST

Winner = DC optimisers - mostly due to the option with this manufacturer to have 2 modules per DC optimiser.

It would be fair to say that in either case, changing the product manufacturer to another in the marketplace would modify the results, possibly even reverse them so a direct cost comparison like this is of less value than one might think. Likewise, no attempt was made to access discounted rates for large quantities of equipment.

Conclusion

There is no clear winner in this debate. Choosing the optimum equipment solution for any individual installation remains, as always, up to the system designer; who needs to balance customer expectations, Australian Standards, costs and site requirements. Changing equipment manufacturers has an enormous effect on features and costs in both technology types.

My personal opinion is that micro inverters tend to be superior in the domestic market place due to their reduced installation requirements (no string inverter, no DC isolators, no DC cables, no HD conduit in the building, possible to equipotentially bond via the micro inverter earth conductor) and potentially higher level of safety in that any damage to the array cable will cause an AC circuit breaker to trip and thus shut down the system.

In the commercial space the differentiation is harder but based on the particular manufacturers used in the case studies for this article I would choose the DC optimiser option. If different equipment manufacturers were selected the outcome could well be micro inverters.

GSES welcomes feedback on technical papers and other resources available on www.gses.com.au, please contact GSES by email at info@gses.com.au or by telephone on 1300 265 525.