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World's Leading Solar Controllers & Inverters

Retrofitting Backup Power to a String Inverter System

Overview –
The vast majority of grid tie PV systems are useless when grid failures occur. They shut down at the very time that the electricity generated on site is most needed. This does not need to be the case. There are a number of ways to ensure that a PV array does not become stranded during utility outages, the common thread between them all is that they utilize energy storage, additional inverters and a variety of different power electronics depending on the system design[1].

System Types –
Each of the systems outlined below will achieve the goals of providing secure AC power during utility outages. The systems all utilize existing onsite PV for recharging batteries and powering daytime loads.

Battery Based Grid Tie Systems [2] have a long and proven history. Some of the very first residential grid tie systems in North America were battery based and more than twenty years later many are still going strong. However these systems are more complex, less efficient, and more expensive. They are generally not a good choice unless the utility connected customer wants the "off grid" experience.

Micro Grids[3] are AC Coupled PV systems that are designed to operate in stand-alone mode or utility interactive mode. These systems integrate a battery-based inverter/charger that takes over controlling the grid-tie inverters when utility failures occur. They are very efficient, represent the current "state of the art" technology and are the most costly choice for most emergency power applications.

AC Coupled Back Up Power Systems[4] utilize a battery-based inverter/charger to "fool" the GT inverter to "thinking" that is still connected to the grid by supplying it with a AC signal[5]. Once the GT inverter "qualifies" the AC signal (five minutes) it starts producing power from the array, which is sent to the AC charger input of the battery based inverter/charger. The power is used to power daytime loads and recharge the batteries. AC Micro inverters are also used in AC coupling applications. The principle is generally the same as with the larger string inverters although they offer somewhat more design flexibility due to their more modular nature.

Almost all retrofitted AC Coupled systems represent a series of design compromises[6]. Systems must be designed so backup inverter and battery bank can handle the entire output of the grid tie inverter plus a safety margin. This results in system designs that are often unnecessarily large for the intended purpose of providing a limited amount of back up power during utility failures.

Another casualty of this design approach is the quality of battery charge control during power outages. These systems often use a single stage approach that turns the GT inverter off when battery voltage reaches a

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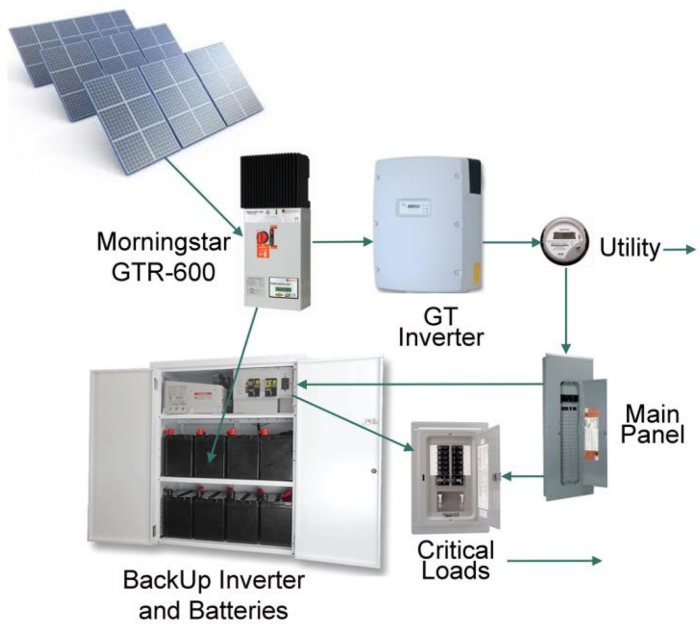
[1] SMA offers a "secure power" feature that puts out up to 15 amps AC during utility interruptions however the output varies with the available solar resource. Because the output of these inverters is not stable and they don't provide power at night they are not addressed in this article.
[2] Examples include the Schneider XW series, and Outback GTFX modes.
[3] Examples include the SMA Sunny Island series.
[4] Examples include Outback Radian and some Magnum inverters
[5] The reason that PV arrays become stranded during utility outages is that the Grid Tie inverter cannot operate and process power without an AC reference voltage from the utility. They are designed this way to prevent them from "islanding" which is a term which refers to sending power onto a shutdown utility grid. It is an important safety protection for utility workers.
[6] The exception is retrofitting a Sunny Island to an existing SMA grid tie system. This solution is very effective as the inverters are designed to communicate with each other. It is also, in most cases, the most costly option.

predetermined level. Battery voltage is allowed to drop until a "reconnect" threshold is reached at which time the GT inverter is turned back on. After a five minute qualifying period the GT inverter begins supplying AC power for use by local loads and the battery charger. This single-stage method of charging may reduce the state of charge at the end of the day by as much as 20%. Sadly the AC Coupled system enters the second day of an extended power outage with a battery of diminished capacity.

Interestingly a number of pre engineered AC Coupled system designs utilize Morningstar controllers to improve the effectiveness of battery charging management. In string inverter applications Morningstar TriStar diversion controllers are utilized to "burn off" energy to keep the battery voltage below the threshold that turns off the GT inverter. In micro inverter systems the Morningstar Relay Driver is utilized to control groups of micro inverters. When demand for current decreases the micro inverters are turned off in groups. By doing so decreasing amounts of the available PV energy can be supplied to the batteries to support their requirements. When demand increases the Morningstar Relay Driver reconnects the AC signal to the micro inverters that are turned off. After the five-minute qualifying period they begin to contribute to the load and charging again.

DC Coupled Back Up Power Systems[7] divert the output of the PV array away from the GT inverter to a MPPT Charge Controller to convert the PV array string voltage to battery voltage (usually 48 Vdc). They operate independently of the GT inverter and as such the connected battery based inverter/charger or UPS system can be sized to the customers needs. This design approach often results in a simpler system that can be installed at a lower initial cost.



DC coupled systems, by their very nature, put more power back into the batteries during a power failure. The MPPT controller utilizes 4-Stage voltage regulation to fully recharge the batteries during the solar day (providing sufficient solar resource is available). This is a very important advantage if the power outage extends beyond a few hours and into the evening hours because batteries in a DC coupled system will end the first and subsequent days of a power outage at a higher state of charge.

An additional advantage of this system is that it can accept an "oversized" PV array without harm to the controller. During sunny conditions the controller simply "ignores" input power that is in excess to its capabilities or requirements.

During cloudy weather the controller can harvest energy from the entire array and as such the likelihood of achieving a full charge is greatly increased.

The inherent design flexibility of a DC coupled system allows the inclusion of back up power into one leg of a three-phase PV array. The design paradigm also allows DC installation on sub-arrays in large systems. DC coupling can also be used as an effective way to increase the DC charging capacity of an AC coupled system. With increased DC charging capacity the entire output of the GT inverter can be passed through the back up inverter to support loads. Additionally the effective capacity of the installed battery is "increased" because the DC coupled part of the system completes a full charge cycle when sufficient solar resource is available.

Summary –

Each of the types of system outlined above met the objective of automatically providing a measureable and somewhat predictable amount of back up power during utility power outages. They also had distinct

[7] Examples include the Morningstar integrated Transfer Switch/600Vdc MPPT Charge Controller.

advantages and disadvantages. Full-time battery based GT systems and micro grids are most suitable for applications where the grid will be used as a secondary source of power and a place to 'bank' excess power. These systems, especially the micro grids, are often designed so that the vast majority of the power is generated and consumed on the customer's side of the meter.

Both forms of dedicated GT PV back up power (AC and DC Coupled) have advantages and disadvantages. In general the AC Coupled system is the best choice for very small systems where the GT inverter is 3 kW of less. AC coupled systems also are an excellent choice where there are very high demands for power delivery on the first day of a power outage or where the combined capacity of the battery inverter and the GT inverter will be called upon during the solar day. DC Coupled systems are superior in most other residential and light commercial applications largely due to their simplicity and flexibility with respect to inverter and battery bank choice.

The table below highlights some of the advantages and disadvantages of both types of systems.

AC Coupled

Advantages	Disadvantages
✓ The backup inverter(s) and batteries must be sized to accommodate the full output of the existing grid-tied inverter.	✓ Crude on/off overcharge protection does not fully recharge the batteries during power outages, which can result in diminished capacity during long duration outages.
✓ Can combine the output of the solar array and the back up inverter to support loads during a power outage (day time only).	✓ Often requires additional control relays.
✓ Well-understood application with kitted solutions.	

Morningstar DC Coupled

Advantages	Disadvantages
✓ Back up system inverter and battery bank sizing completely independent from the grid tie inverter. Can be sized to suit customers' needs and budget.	✓ Greater number of components to install in some installations only.
✓ Uses 4-Stage charge voltage regulation to attain 100% SOC when sufficient solar resource is available.	✓ Manual switch operation.
✓ Can handle oversized PV inputs with no harm to controller, which allows for greater energy harvest on cloudy days.	
✓ Offers a simple way to provide single phase back up power on three phase systems.	
✓ Lowest total cost for entry-level systems.	
✓ Can be installed in sub-array wiring for large arrays.	
✓ Additional units can be installed in parallel for increased battery charging/load support capacity.	

Conclusion –

DC coupling makes the most sense for most GT applications that require battery back up capabilities. The advantages far outweigh the disadvantages and the Morningstar DC Coupled system offers the lowest cost and best performance for comparably sized GT systems.