Schneider Electric Battery-Based and Grid-Direct Inverters

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As interest in and deployment of ac-coupled PV systems has grown, Schneider Electric has directed product development and support resources toward these applications. Currently, many ac-coupled systems utilize equipment from multiple inverter manufacturers. This mix of products can create issues with system design, installation and operation and lead to warranty issues in some cases. Schneider Electric is one of two companies that designs and manufactures both utility-interactive grid-direct inverters and battery-based inverter/chargers for the North American solar market. Schneider Electric's solar inverters now feature the Conext product range name, followed by letter designations for the various models. The Conext TX is our newest generation of residential grid-direct inverters and replaces the GT inverter models. The Conext TX integrates with the Conext XW battery-based inverter/charger to create an ac-coupled system.

CONEXT INVERTER OPERATION

In residential or light commercial utility-interactive ac-coupled PV systems, all energy sources and loads are connected directly to the ac bus. This system design topology has benefits over dc-coupled systems in some applications. CONTINUED ON PAGE 88

In ac-coupled systems, the dc infrastructure is kept to a minimum by enabling higher voltage PV arrays (up to 600 Vdc). Higher voltage arrays minimize system material costs because smaller, lower-cost conductors, conduits and BOS components can be specified. These components are also more easily handled and installed in the field, which drives down installation labor cost.

Array-to-grid efficiency is improved in ac-coupled battery-based systems as well. In a utility-interactive ac-coupled system with battery backup, the array is connected directly to the utility grid through a grid-direct inverter. In a dc-coupled utility-interactive battery-based system, the array output is connected to the battery bank through a charge controller, which is then connected to the grid through an inverter/charger. The ac-coupled design approach increases system efficiency by removing a conversion step when the utility grid is present.

Grid-present operation. On Schneider Electric's Conext XW battery-based inverter/chargers, each of the two ac inputs is equipped with an input relay that closes only when the ac source is qualified and is within the parameters of the customer-adjustable voltage and frequency ranges. Closing the input relay connects the ac source directly to the inverter's ac-output terminals. In this Pass-Through mode, the XW essentially behaves like any other load as it charges the battery bank using its multi-stage algorithm. This charging feature helps deliver good battery performance and operational life. In ac-coupled systems, if the grid ac voltage and frequency are within limits per UL 1741 and CSA C22.2 No. 107.1, Schneider Electric's Conext TX grid-direct inverters synchronize with the utility-power reference and process power from the PV array. Local loads consume the energy from the PV array, including the XW charger as it charges the battery bank, and any excess is exported directly to the grid.

No-grid–present operation. The battery-based Conext XW inverter/charger continuously monitors the utility-input voltage and frequency. If the voltage or frequency moves outside the acceptable ranges—for example, during a power surge or outage—the XW opens its input relay, disconnecting all the inverters from the grid. As soon as the relay opens, the XW transfers from Charge mode to Invert mode to provide power to the critical loads terminated in the ac subpanel using energy stored in the battery. The grid-direct Conext TX inverter may detect the temporary loss of ac during this transfer and go off-line until it detects a stable ac output from the XW for a minimum of 5 minutes.

During utility failures, the XW serves as a voltage source for the grid-direct TX inverter, providing tightly controlled voltage and frequency on its ac output. The TX inverter qualifies and synchronizes with the ac-voltage reference provided by the XW just as it would if the utility grid was present. The XW's anti-islanding feature prevents the export of power from its AC1 connection during a utility outage, and the XW and the TX inverter continue to power backup loads. Any excess power from the TX inverter charges the battery bank in a Bulk Only mode.

SYSTEM REGULATION

When the Conext XW inverter/charger is in Invert mode, electrical current flows through it in either direction. If the Conext TX inverter is providing more power to the ac bus than the loads can consume, current flows back through the XW to charge the battery bank. Unlike in Charge mode, in Invert mode the XW does not regulate charging when power is flowing from its ac output to the battery. During brief grid failures, this is not a problem if the battery is sufficiently discharged. However, if the battery is fully charged and there is not enough load on the ac system, and if the TX inverter continues feeding power to the ac bus, the battery voltage could potentially rise until an overvoltage fault condition (*high batt cut out* setting) is reached. This causes the XW and the entire system to shut down, including the ac loads terminated at the subpanel, and could result in damage to the battery if *high batt cut out* is not set appropriately for the installed battery type.

To avoid this mishap, the Conext XW inverter/charger features integrated frequency-phase–shift protection for ac-coupled applications. This strategy varies the line frequency according to a predetermined pattern to prevent the grid-direct Conext TX inverter from overcharging the battery. The XW executes a pattern-generator algorithm that varies the line frequency in a linear manner to avoid overload. The frequency-generation function of the XW changes the ac-coupled grid frequency with a linear rate of change of 0.4 Hz/s. When the charge-bulk voltage is exceeded, the frequency decreases in a linear progression until the TX inverter drops off-line. While the XW and TX inverters are in AC-Coupling mode, the XW changes the frequency only when the *charge-bulk voltage* setting is exceeded. You can adjust this setting in the custom battery menu.

Once the battery voltage reaches its *charge-bulk voltage,* the Conext XW shifts its output frequency, causing the TX to disconnect and begin its 5-minute anti-islanding waiting period. No separate control wiring is required. During this period, the ac loads are powered from batteries via the XW only. When the 5-minute waiting period is complete, the TX reconnects to the XW's ac output and provides power for ac loads and recharging the battery. If the battery is fully charged and the ac critical loads are insufficient to absorb the PV array's ac output, the TX on-off cycle continues until the grid is restored and the system returns to normal operation.

EQUIPMENT, DESIGN, INSTALLATION AND OPERATION

Schneider Electric's Conext XW inverter/chargers and TX inverters have been developed to CONTINUED ON PAGE 90

provide a fully integrated ac-coupled system. However, in some applications, ac-coupled systems can be more complex than their dc-coupled counterparts, and integrators tend to have less experience with ac-coupled systems. Here I address specific equipment specifications and use of Conext inverters in ac-coupled systems, as well as general design details that you should consider related to ac-coupled system architectures.

Grid-direct inverter compatibility. Schneider Electric has developed and tested the integration of its Conext XW and TX products in ac-coupled systems. Although this architecture may work with UL 1741/CSA 107.1-01–compliant inverters from other manufacturers, Schneider Electric has not tested these products in ac-coupled systems, so support for systems that integrate other vendors' products with Conext inverters may be limited.

Stand-alone, off-grid systems. To maximize battery performance and life, the Conext XW– and TX–based ac-coupling architecture is intended for utility-interactive systems connected to a dependable utility grid. Schneider Electric does not recommend or support its ac-coupled system architecture for use in stand-alone, off-grid applications.

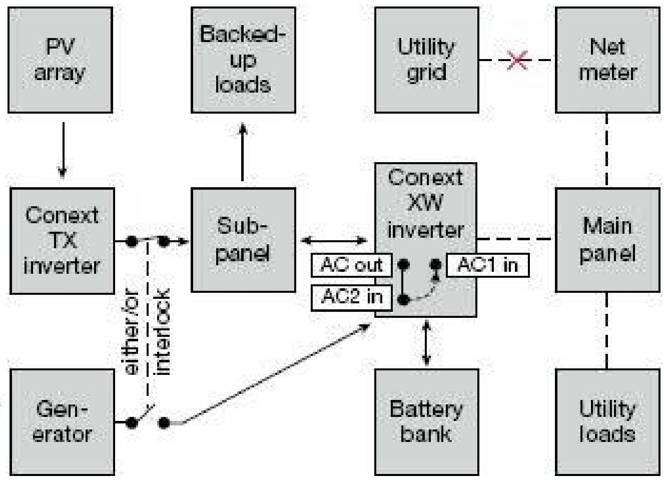
Power ratings for single Conext XW installations. The battery-based XW inverter power rating should match or exceed the grid-direct TX inverter power rating. Accordingly, the XW 6048 (6.0 kW/48 Vdc) is compatible with a single TX 5.0 (5.0 kW) or TX 3.8 (3.8 kW) inverter, or with one or two TX 2.8 inverters (2.8 kW each, 5.6 kW total). The XW 4548 (4.5 kW/48 Vdc) and XW 4024 (4.0 kW/24 Vdc) are compatible with a single TX 3.8 or TX 2.8 inverter.

Power ratings for parallel Conext XW installations. In applications that utilize multiple XW inverter/chargers configured in parallel, the total TX inverter power rating should not exceed the power rating of a single XW inverter deployed in the system. For example, while two TX 2.8 inverters can be connected to a single XW 6048, a stacked pair of XW 6048s would also be limited to two TX 2.8 inverters.

Conext XW firmware. To prevent battery damage in ac-coupled applications, XW inverter/chargers should be updated to the latest firmware that includes the ac-coupling feature. At present, XW-specific firmware (version 1.07) is available for each North American XW model and can be downloaded at schneider-electric.com/conextxw.

Conext XW ac qualification period. The XW and TX products are fully compliant with UL and CSA anti-islanding standards. However, for ac-coupled applications, the XW inverter/charger's *ac-qualification* CONTINUED ON PAGE 92

Figure 4 When a backup ac generator is included in an ac-coupled system that uses Schneider Electric's Conext TX grid-direct and XW battery-based inverters, the manufacturers recommends the installation of an "either-or" interlock switch to prevent the unintended back-feeding of current from the TX inverter to the generator.



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period default setting of 10 seconds must be adjusted to 300 seconds.

Backup generators. Schneider Electric's ac-coupled system has not been tested with a generator providing the ac reference for TX inverters. If the system includes a backup generator, I recommend installing an "either-or" interlock switch to prevent unintended back-feeding of current from the TX inverter to the generator (see Figure 4).

System metering. In ac-coupled applications, the power metering on the Conext XW may not work reliably when the inverter/charger is in Voltage-Source Invert mode and power is flowing back into the batteries.

Terminating ac circuits. The designated Conext XW and TX ac outputs are typically connected in the critical-loads subpanel. Each TX inverter requires its own ac breaker in the subpanel, which is connected to the output of the XW inverter/charger. Although there is space to add breakers for the TX inverters directly into the XW power distribution panel, it is more straightforward to install the TX inverter breakers in the ac subpanel.

Critical load and battery-bank sizing. Critical loads that are terminated in the ac subpanel should be selected based on the customer's essential safety and lifestyle requirements during utility failures. It is not practical to back up all of a home's loads. The battery bank should be sized to power the critical loads for a specific time period and to avoid completely discharging the battery bank during utility outages. An occasional 50%–60% maximum discharge may be appropriate. When specifying battery bank Ah capacity for ac-coupled systems, the designer should consider potential excess current that the TX inverter produces while it is powering the critical loads in relation to the battery manufacturer's charge-current recommendations.

Alternatives to ac coupling. If array-to-battery distance is the primary design driver for an ac-coupled system, you should weigh the potential cost and operational benefits of utilizing a dc-coupled system architecture with a higher voltage dc-charge controller. Schneider Electric manufactures charge controllers rated at 150 Vdc (XW-MPPT60-150) and 600 Vdc (XW-MPPT80-600).