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Novel voltage control for C&I storage enabling seamless transition between grid-connected and island operation

If a battery storage system has the ability to form and operate local grids in addition to grid-connected operation, the increased resilience, robustness and safety provide the operator with decisive advantages. These include, the seamless continued operation of their systems in the event of a utility grid failure.

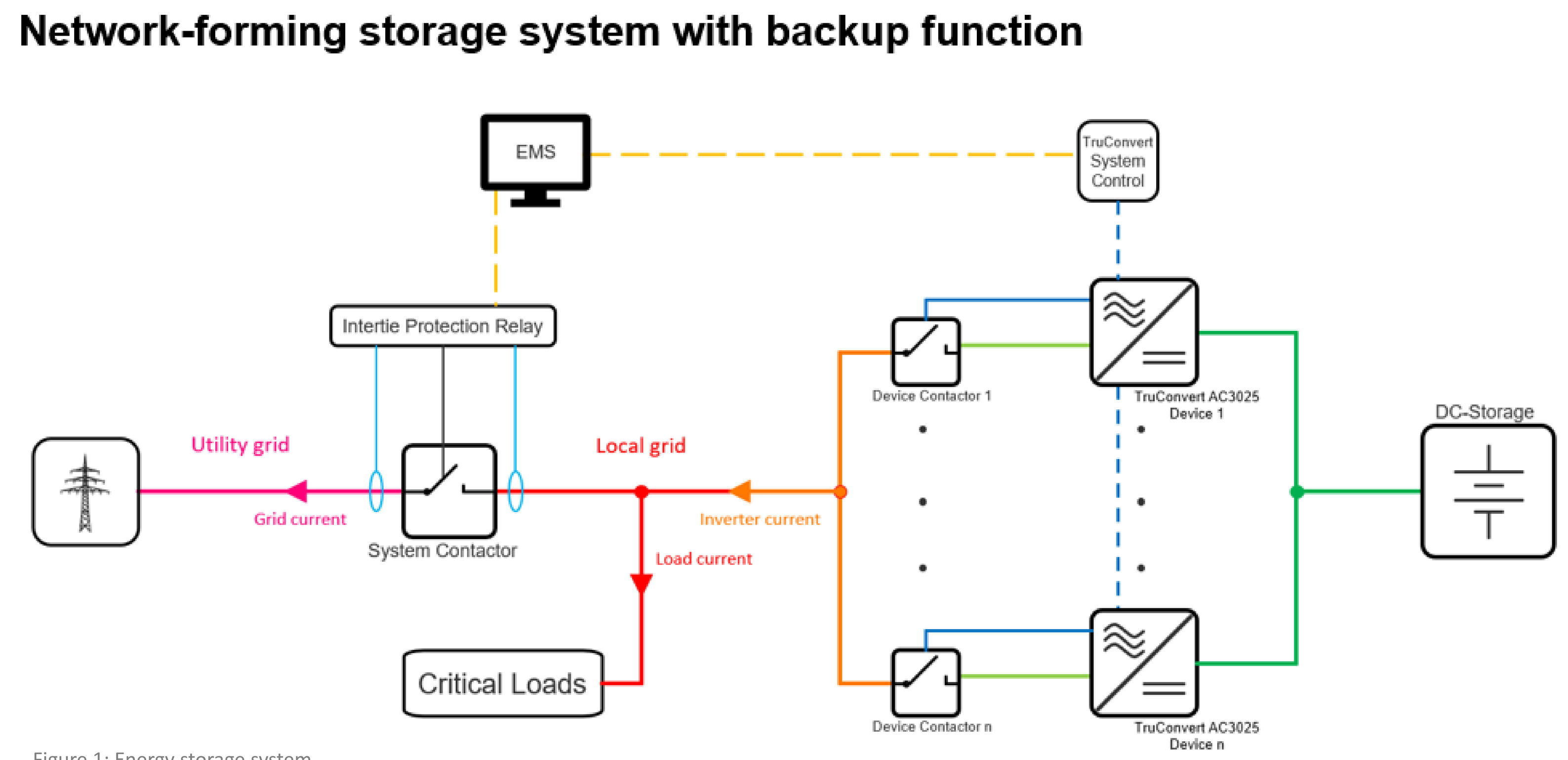

Figure 1: Energy storage system

Figure 1 depicts an energy storage system capable of connecting to or disconnecting from a utility grid through a system contactor. **Critical loads** are integrated into the local grid, ensuring **seamless operation** during a **utility grid failure** or a **black-start scenario** when the system contactor is open.

TruConvert inverters connect to the DC storage system and the local grid through device contactors. An **energy management system** (EMS) coordinates grid connections, utilizing an intertie protection relay and the system contactor.

The **protection relay** monitors electrical data on both **utility and local grids** at the system contactor, allowing for **disconnection from the utility grid under impermissible conditions while maintaining** power to critical loads via TruConvert inverters.

When transitioning the local grid from island mode to utility grid connection, the protection relay ensures **synchronization** by releasing control of the system contactor only when measured data align within specified tolerance ranges.

This synchronization is facilitated by **setting frequency/voltage setpoints for islanding inverters** through the energy management system.

The following figures (Figure 2-8) show voltage and current waveforms that occur when disconnecting and re-connecting a local grid and a utility grid. In the case described, the 3-phase local grid (3 phases + neutral conductor) is loaded with critical loads of 10 kW per phase. The graphs show the utility and local grid voltage (load voltage), the utility and load current (consumer convention) and the current supplied by the storage system (inverter current) for each phase.

Disconnection from the supply network

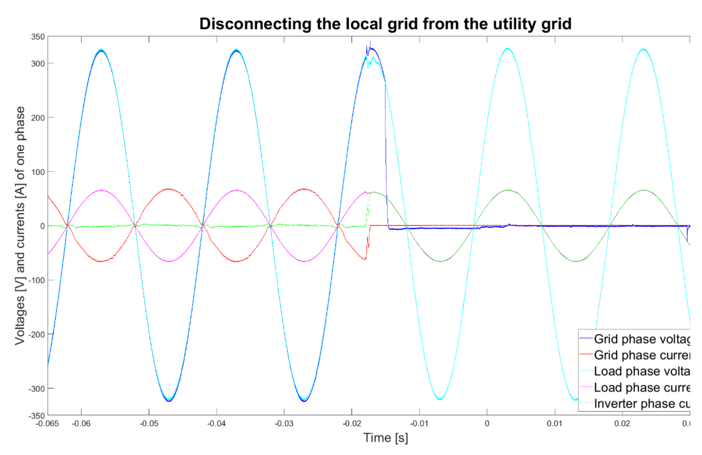

Figure 2

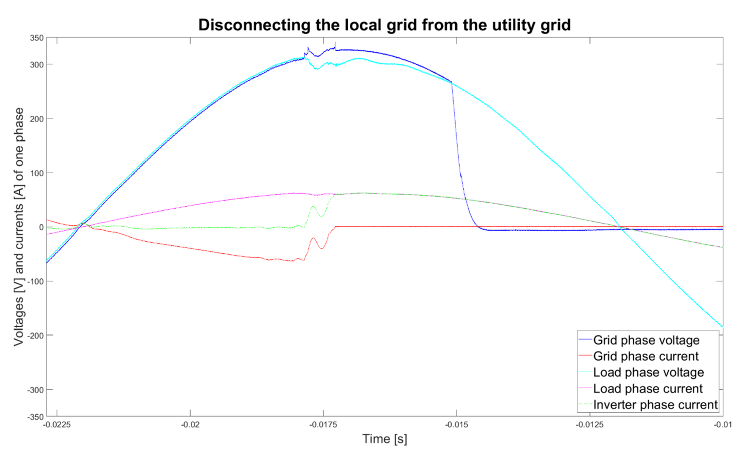

Figure 3

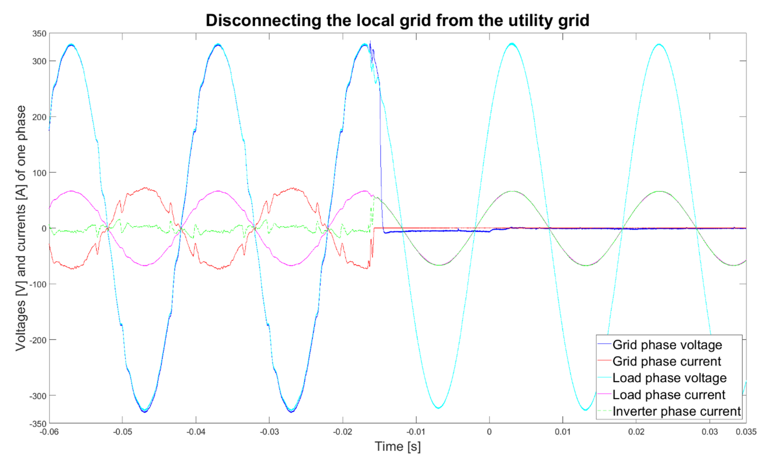

Figure 4

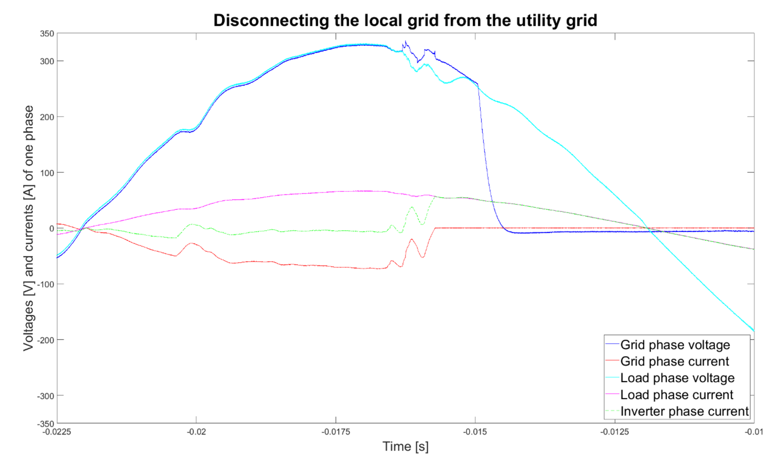

Figure 5

Figure 2 displays voltage and current waveforms during the local grid's disconnection from the utility grid. The storage system's inverters seamlessly take over the load current, as shown in the magnified moment in Figure 3. Notably, the voltage curve of the local grid remains largely unaffected. In the connected state, the load current is entirely supplied by the utility grid, resulting in almost zero current from the storage system, given an ideal sinusoidal voltage curve (Figures 2 and 3).

However, under more practical conditions (Figures 4 and 5), even in adverse grid situations, disconnecting from the utility grid ensures uninterrupted operation for critical loads.

Re-synchronization and connection to the supply network

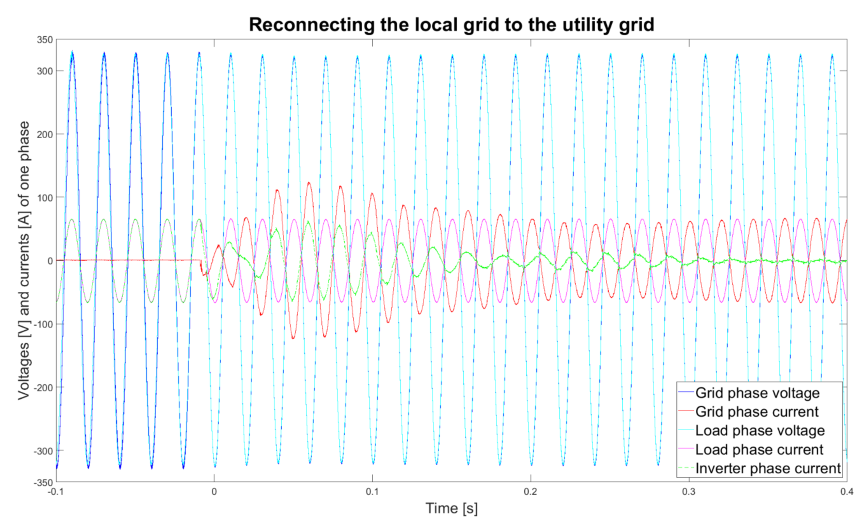

Figure 6

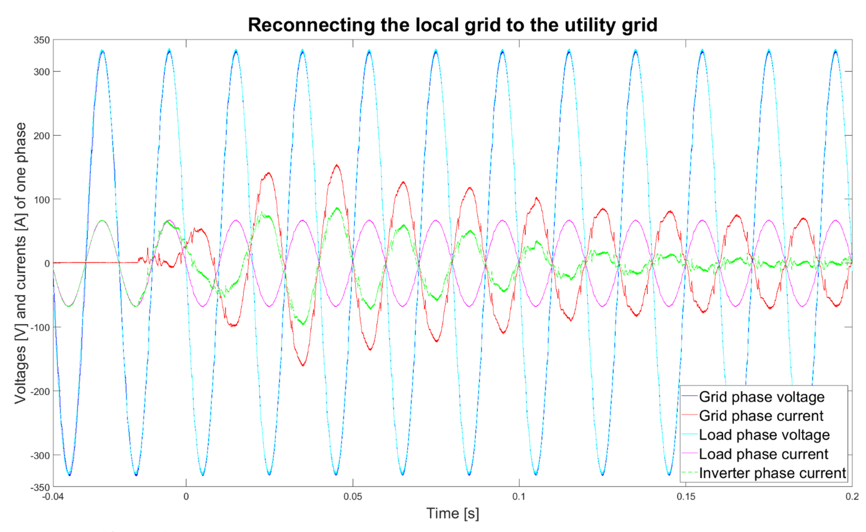

Figure 7

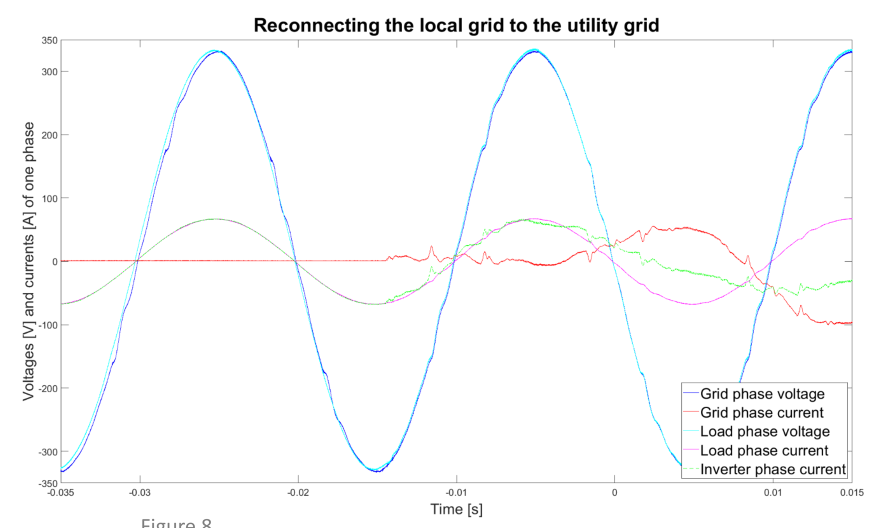

Figure 8

Figure 6 illustrates voltage and current waveforms during the connection of a loaded local grid to the utility grid. When disconnected, the storage system's inverters provide the load current. Synchronization between the local and utility grids is essential for the intertie protection relay to release control of the system contactor. Despite synchronization, equalization processes occur between the two grids during connection, determined by the output impedances of the voltage sources. However, the voltage and load current of the local grid remain largely unaffected during the connection process. After approximately 10 to 15 grid periods, the load current is entirely supplied by the utility grid, reducing the storage system's current to zero.

Similar to the disconnection process, the inverter current in the connected state is determined by the utility grid's power quality, reaching zero with an ideally sinusoidal voltage (as in Fig. 6). Figure 7 depicts the connection process to a utility grid with harmonic distortions, resulting in a non-zero inverter current post-connection. This current supports the grid, but the load current remains mostly unaffected.

The detailed curve of the connection event in Figure 8 reveals the transition from the originally sinusoidal local grid voltage to a utility grid with harmonics, influencing the load current curve to a lesser extent but still present.

The use of TRUMPF Hüttinger TruConvert inverters in battery storage systems enables not only grid-parallel operation but also the creation and operation of local grids. The basic grid-forming properties provide the operator with decisive advantages through increased resilience, robustness and safety. In addition to inherent improvements in grid quality and the provision of virtual inertia, seamless disconnection and reconnection between the local and utility grid can be achieved, enabling seamless operation of critical assets in the event of a utility grid outage.

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