Manage your Hybrid Power Energy to the Next Level

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***Abstract*— Studer-Innotec developed and launched an innovated 3-phase hybrid power inverter solution that can be used for either hybrid (grid-interactive) or hybrid off-grid inverter to manage different types of batteries, solar, and backup AC power sources such as a diesel generator, CHP power generator or small hydro power generator. The hybrid off-grid inverter is used to build advanced energy management systems with build-in solar charge controller and can be likewise AC-coupled with solar string inverters. The modular design allows parallel operation of several inverters and the use of multi battery units. The core management is done by a power flow dispatcher: A unique control algorithm at the power electronics level for quick reactions with 1ms synchronization between the units. A smart boost function helps to relieve the generator or public grid power by using the solar and battery energy available in priority and opening several energy strategies.**

Keywords: hybrid power inverter, power flow dispatcher, advanced energy management strategies, grid interactive, off-grid, modular design

I. Introduction

Hybrid energy systems or min-grids are increasingly used for the electrification of non-electrified areas, facilities or villages in African countries or other areas where electrification through grid extension is technically not feasible or too cost-intensive today. There are various technical requirements to be fulfilled by the hybrid energy systems and corresponding standards and legislation to be considered too. The complexity and requirements have increased in recent years as the systems must be able to make their contribution to energy and grid management. This means, besides the integration of different local sources such as conventional generators, solar, wind and hydro, also the stronger interactive cooperation with the local power grid to be available for grid support, as backup or also for reactive power compensation. These far-reaching energy management tasks are today often taken over by additional energy management systems, which can then control energy flows and grid variables with the help of communication interfaces to the essential components of a hybrid energy system.

The multifunctional and bidirectional hybrid inverters are the key for a smart, efficient, and smooth energy management system (EMS). This includes intelligent source and load management like disconnection of non-priority loads and frequency shifting and controlling. But state of the art Hybrid inverters coming with an integrated battery charger and connection in one simple have some limitations compared to dedicated off-grid battery inverters: one being the limited surge power or peak power output in the event of a grid shortage or blackout or cannot start or stop of a reserve power source like a generator. Also, some hybrid inverters do not have backup power capability, or the backup power is limited so only small or essential loads can be backed up in the event of a blackout.

II. The approach

An innovated 3-phase hybrid power inverter solution was developed that can be used for either hybrid (grid-interactive) or hybrid off-grid to manage different types of batteries, solar, and backup AC power sources such as a diesel generator or CHP power generator. The hybrid off-grid inverter is used to build advanced energy management systems with build-in solar charge controller and can be likewise AC-coupled with solar string inverters.

The core management is done by a power flow dispatcher: A unique control algorithm at the power electronics level for quick reactions with 1ms synchronization between the units. A smart boost function helps to relieve the generator or public grid power by using the solar and battery energy available in priority and opening several energy strategies. Further, the peak shaving and phase balancing functionalities in a 3-phase system as a potential future service for the grid bring advantages from the tariff negotiation and the addition contribute to the stability of the infrastructure.

The demand can vary along the day and night, season periods and other variables. The combination of two generators or one generator and the grid with different setups brings all the flexibility the usage requires for hybrid systems or mini grids. The unique AC flex interface allows to configure a second AC source or a second AC load with a swipe, with an integrated smart energy management simplifying complex installations. The AC-in flex second controlled loads by transfer excess of energy in system assets or secure the supply of critical loads with the battery backup to cover grid failures. The figure 1 depicts the internal architecture of the hybrid power inverter solution next3.

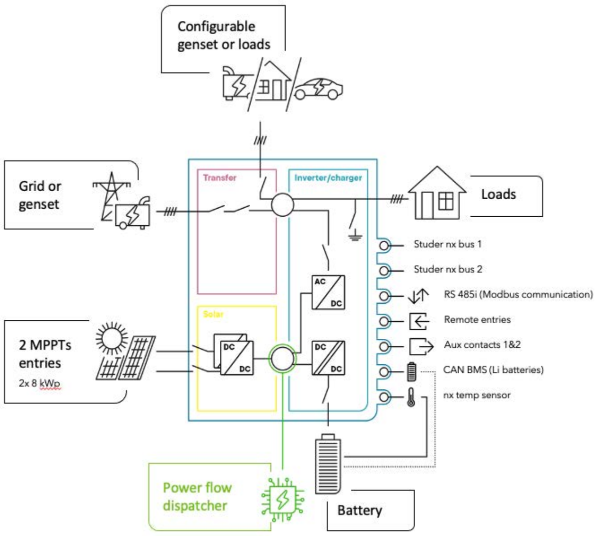

Figure 1: *Internal* architecture of the hybrid power inverter

III. ENERGY MANAGEMENT STRATEGY

The hybrid power inverter solution is designed always try to optimize the solar in the system. The energy management between all the converters and components of the energy system is done by the *Power Flow Dispatcher (PFD)* algorithm. This is at the core of the system.

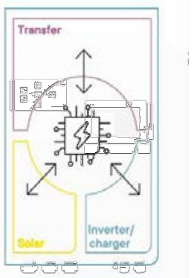

Figure 2: ***Power Flow Dispatcher*** *algorithm*

One of the targets during the development was simplifyng the use of the product to be transparent to most of the end-user. Four standard energy strategies are implemented and can be selected during the configuration process in the wizard with only two questions to answer:

Is grid feeding allowed? This question is asked only if you have selected “grid” as connection to AC-source. If you selected “genset”, the grid feeding is forbidden.

Is battery used for solar self-consumption optimization? In this operation mode the battery is used daily as energy buffer. Solar energy recharges the battery and is used during the night.

The 4 cases description, defined by those two questions are:

• Use of battery for **solar self-consumption optimization** until a state of charge (SOC) for back-up. During the night, the battery is discharged until the given SOC level. Under the defined SOC level, a reserve is left in case of blackout. The default level is 20% to use 80% of the battery as buffer for lithium batteries and 50% for lead acid batteries. During the day, when the solar power is produced, that energy is used to supply the AC loads, charge the battery and inject the excess energy to the grid, if applicable. Battery is loaded up to the SOC for grid feeding level. SOC for grid feeding is 100% by default but it can be modified.

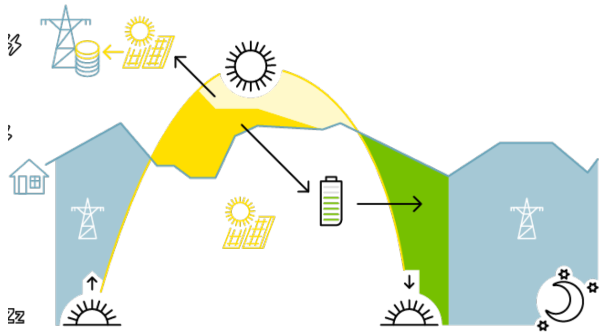

Figure 3: ***Grid connected installation*** *with grid feeding allowed and use of battery for* ***self-consumption optimization****:*

• **Full grid feeding**: In this situation, the battery is kept full to be ready in case of blackout. The SOC for back-up is 100%. All the solar power produced supply the loads and the excess is injected to the grid.

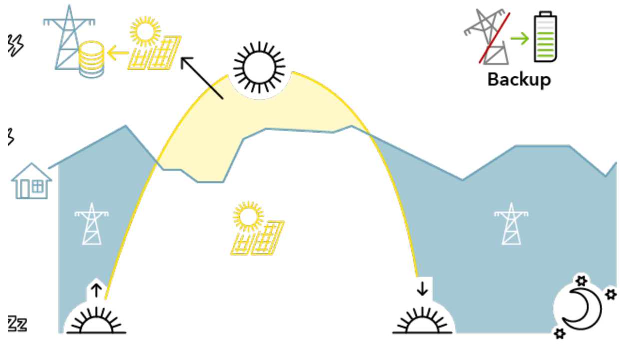

Figure 4: ***Grid connected installation with full grid feeding****; the battery is not cycled (kept for backup only):*

• **Solar priority with zero export**. The solar power is used to charge the battery and to supply the loads but is never sent back to the AC-source. In that mode the grid-feeding is not allowed. The battery is used as buffer. When there is more solar than loads, the excess will charge the battery. When the loads are higher than the production, the energy is taken first from the battery. Only when it is at the lower threshold (SOC for Backup) the grid or a available generator will be used. Like that, there is still some energy left in the battery to run some loads when a blackout happens, or the start of a generator is not required. When the battery is full and the load is small, the MPPTs will reduce the production, causing some solar energy to be lost.

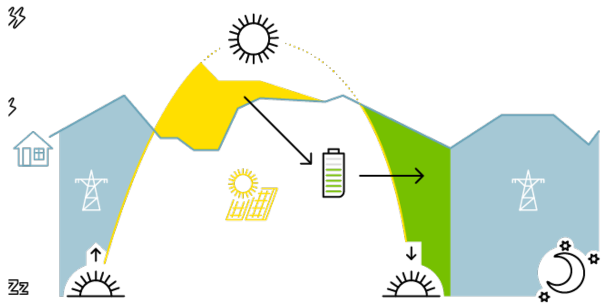

Figure 5: ***Solar priority without grid feeding: zero export solar backup***

• **Off-grid or weak grid:** AC-source is a genset or a grid where the injection is forbidden. The battery is charged to the maximum as soon as the AC source is present ensuring to have energy available in the next blackout event.

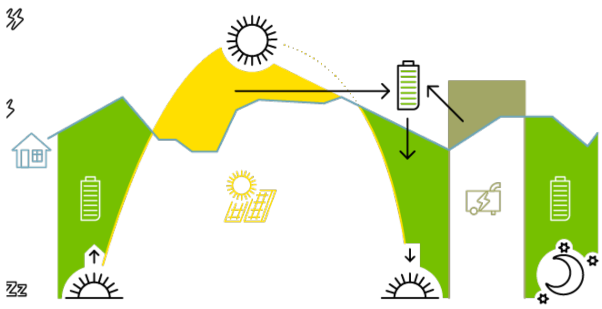

Figure 6: ***Off-Grid installation (back feeding on genset is forbidden!)***

IV. The State of Charge Indication (SOC)

The determination of the SOC is used to manage the energy availability in the system. If the **SOC for backup** is set to 100%, the battery will be fully charged with the AC-source (when available) with a target voltage following the cycle (for lead acid: absorption, floating, or with the voltage given by the battery management system (BMS). If the SOC for backup is lower than 100% the charging may stop before reaching the target voltage of the cycle. Voltage limits of the battery cycles are always used as boundaries in any cases. SOC for backup is modified in the battery configuration menu and can be changed at any time.

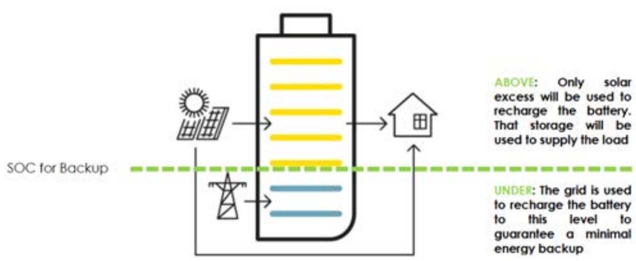

Figure 7: Principal usage of the battery storage

If the SOC for backup is lower than 100% the charging may stop before reaching the target voltage of the cycle. Voltage limits of the battery cycles are always used as boundaries in any cases.

The principle of the **SOC for grid feeding** following a different approach. If the SOC is higher than a defined threshold, the battery is discharged in the grid (if grid available and grid feeding allowed). After some time, the SOC will be at the setting value and there will be no grid feeding from the battery anymore.

The SOC for grid feeding can be used for buffering peak solar production when grid feeding power is limited. Discharging the battery voluntarily for tests by a manual change of the parameter or keep the battery at a lower SOC than 100% without losing the energy production. If the SOC for grid feeding is 100%, the battery voltage is maintained at the target voltage of the cycle (for example absorption voltage).

When discharging the battery, the low boundary for voltage will be limited to undervoltage level +2% higher. That means the battery will go down to the SOC you adjusted but keeping that minimum voltage to reduce the discharging current. The SOC for grid feeding must be set higher than the SOC for backup.

V. Conclusion

Hybrid systems and mini grids for rural electrification are since various years a central subject at Studer Innotec. The innovated next3 hybrid power inverter solution with its future features for multi-units and the powerful Power Flow Dispatcher (PFD) function are the base of the future of residential mini-grids and hybrid energy solutions for off-grid and on-grid applications. The advanced hybrid inverter solution complies a wide range of energy data to build an energy management model usable for advanced energy management strategies. The handling of the diverse energy management tasks by the all-in-one hybrid power inverter solution makes the additional integration of an energy management controller unnecessary. The hybrid power inverter next3 complies with the European grid codes.