APsystems
ALTENERGY POWER

White Paper 2025

Three-Phase AC Coupled Power Unbalance Control Solution

ELT-12

Three-phase solar and storage systems often face a critical challenge: power imbalance. This occurs when solar generation or home loads are uneven across the three phases, reducing efficiency, cutting into energy savings, and compromising system reliability.

This white paper introduces APsystem's solution: a smart, built-in Three-Phase Unbalance Control for the ELT-12 system. It explains how this intelligent feature automatically manages uneven power, unlocking higher solar generation, greater cost savings, and enhanced system stability for a wider range of home energy setups.

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Introduction

Three-Phase PV-ESS

A PV-ESS (Photovoltaic-Energy Storage System) is an integrated energy system that combines photovoltaic power generation units with energy storage units (typically battery storage systems) through advanced power conversion devices and energy management systems. The core concept is to utilize the charging and discharging functions of the energy storage unit, creating a controllable and stable "PV-Storage-Load" integrated unit. This overcomes the limitations of standalone PV systems, enabling efficient energy utilization and storage.

System Constitution

01

PV Array (PV Systems 1 & 2): PV modules, convert solar energy into DC power, serving as the system's power generation source.

02

Energy Storage Unit (Battery): The system's "energy warehouse," it stores excess power generated by the PV array and discharges it when needed. Currently, lithium-ion batteries are predominant.

03

Power Conversion System (PCS): This is the most critical and technologically advanced part of the system.

PV Inverter (e.g., QT2, DS3 from APsystems and PV modules from the third-party): Converts DC power from the PV array into AC power, supplying the load or feeding into the battery and grid via the storage converter.

Storage inverter (e.g., ELT-12): During charging, converts AC power from the grid or PV inverter into DC power to charge the battery. During discharging, converts DC power from the battery into AC power for the load. It facilitates energy interaction between the grid, battery, and load.

04

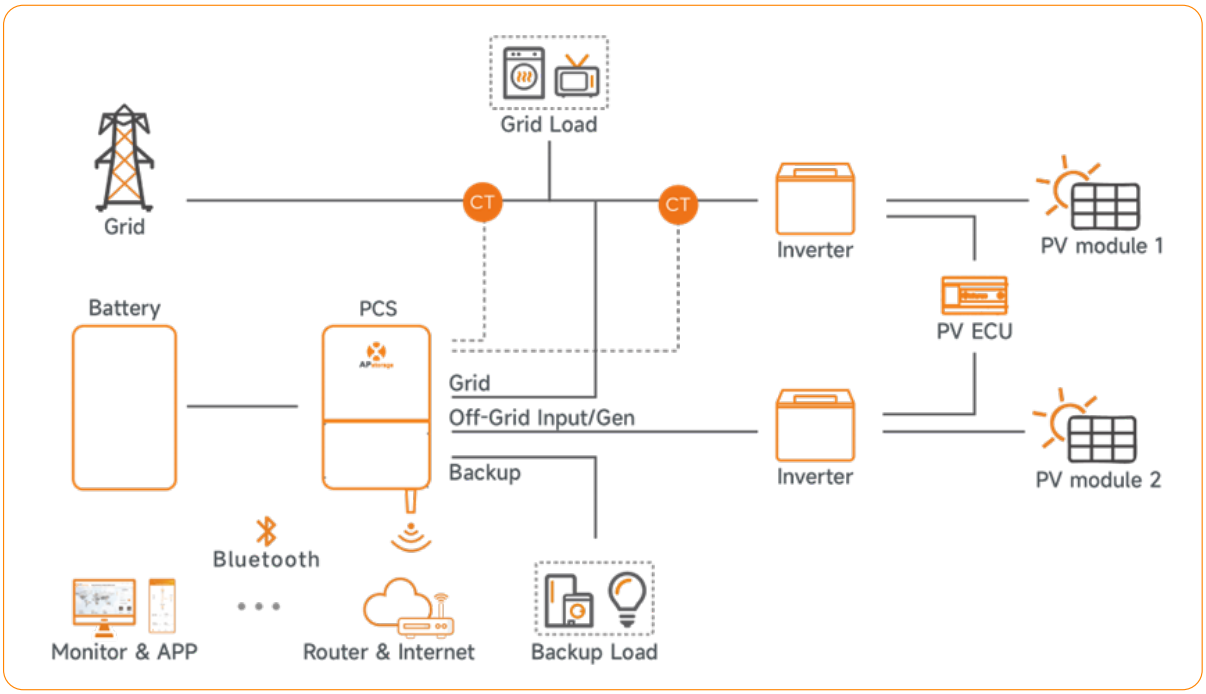
Energy Management System (EMS): The "brain" of the system. Based on data such as weather forecasts, load demand, and electricity price signals, it formulates optimal operation strategies for intelligent scheduling and control of system energy.

05

Load and Grid Connection:

Load: Equipment within the system that consumes power, such as air conditioners, refrigerators, and lighting in a household.

Grid Connection: Manages the safe connection between the system and the public grid, including necessary circuit breakers and protection devices.



Note:

When selecting the APstorage ELT-12 PV-ESS, correctly match the energy storage system capacity and PV system capacity according to the home load capacity. When the PV system is connected to the off-grid side of the PCS, the PV power must be limited based on the storage system capacity.

- If APsystems inverters (QT2, QT2D, DS3, DS3D) are connected, PV power can support an extension of up to 1.25 times the storage system capacity.
- Especially, if APsystems single phase inverters are connected, ensure the power per phase does not exceed 1.25 × 4kW, and the total PV power does not exceed 1.25 times the storage system capacity.
- If inverters from other manufacturers are connected, only PV power equal or less to the storage system capacity can be connected.

Challenges

For the APstorage ELT-12 PV-ESS, the PV system can be either single-phase or three-phase. In both cases, power generation can become three-phase unbalanced (inconsistent power across phases) due to weather factors. Therefore, the input to the PV-ESS can be unbalanced. Similarly, loads can be single-phase or three-phase, leading to potentially unbalanced output from the PV-ESS. This system-wide unbalanced power input or output introduces several challenges:

- **System Instability:** Unbalanced input or output power affects the overall stability and reliability of the PV-ESS.
- **Reduced PV Generation under Export Power Control:** If the PV-ESS has export limit requirements, the PV output power is limited by the phase with the smallest load power, leading to decreased power generation from the PV system.
- **Decreased Self-Consumption Efficiency:** In systems operating under the self-consumption mode, if the three-phase PV-ESS has unbalanced input and output, the self-consumption efficiency of excess electricity decreases.

The APstorage R&D team has introduced a novel power distribution method deeply integrated with AC-coupled systems to enhance PV system power generation and the self-consumption ratio of the PV-ESS, thereby improving the system's economic viability.

Three-Phase AC Coupled Unbalance Control

Drawbacks of Solutions on Current Market

For a three-phase PV-ESS, its AC-coupled power control acts as the brain of the entire "PV-Storage-Load" unit and is a key technology determining system safety, reliability, and high-efficiency stability. Drawbacks of most current three-phase PV-ESS products on the market include:

01

Limited Flexibility: Most products can only interface with three-phase PV systems and cannot adapt to single-phase or unbalanced PV inputs. When the PV system generates unbalanced three-phase power due to weather, these systems cannot operate smoothly.

02

Low Efficiency: Lack of rational and effective power distribution strategies for the overall power conversion between PV, battery, grid, and load. This not only reduces PV power generation and utilization but also leads to increased electricity drawn from the grid, raising operational costs.

03

Safety Hazards: Unbalanced three-phase coupled power places higher demands on the equipment's carrying capacity, causing system instability. Without proper regulation and timely protection, significant safety risks arise, potentially leading to economic losses and serious safety incidents.

Advantages of APsystems Solution

Enabling the Three-Phase Unbalance function on the ELT-12 offers the following benefits:

- **Save electricity costs:** With the export limit function disabled, to maintain the balance of input and output in the three-phase AC coupling system, it is necessary to buy and sell electricity from the power grid at this time. However, the price difference in electricity trading will cause economic losses. After enabling the three-phase unbalance function, the three-phase AC coupling energy storage system can freely discharge each phase to the load without energy exchange with the power grid, reducing losses.

Examples:

Scenario	With grid, PV power is 0kW, battery charge/discharge power is 12 kW. The ELT-12 supplies loads of 1 kW, 2 kW, and 3 kW on phases A, B, and C respectively.	
Export Limit Function	Disabled	
Three-Phase Unbalance	Disabled	Enabled
Results	ELT-12 discharges 2kW per phase. Results in 1kW reverse power flow to the grid from Phase A, and 1kW drawn from the grid for Phase C..	ELT-12 discharges 1kW, 2kW, 3kW on phases A, B, C respectively, matching the load exactly.
Conclusion	Without the function, buying and selling electricity with the grid occurs. If the buy price exceeds the sell price, this causes economic loss. Enabling the function reduces energy exchange between the grid with the battery and load, making three-phase power distribution more efficient.	

Increased Power Generation: With export limit function enabled, the PV power of each phase cannot flow back to the grid. Therefore, the PV power will be limited by the minimum load power of the phase, which results in a significant waste of the PV power generation and its ability. However, after enabling the three-phase unbalance function, each phase of photovoltaic can provide power at its maximum capacity based on the load power and battery charging power.

Examples:

Scenario	With grid, PV max power is 12kW, battery charge/discharge power is 12kW. Loads are 1kW, 2kW, 3kW on phases A, B, C.	
Export Limit Function	Enabled	
Three-Phase Unbalance	Disabled	Enabled
Results	PV supplies only 1kW per phase (limited by the smallest load phase). The ELT-12 discharges 1kW, 2kW to supply the remaining load on B and C phases.	PV supplies up to 3kW per phase priority to loads. Excess power (2kW from A, 1kW from B) charges the battery via the ELT-12.
Conclusion	Without the function, PV generation is capped by the smallest load phase, wasting potential and causing economic loss. Enabling the function allows each PV phase to generate freely, increasing total generation and self-consumption.	

Flexibility and Autonomy: Users can flexibly configure single-phase PV, three-phase PV, or unbalanced PV systems, alongside single-phase, three-phase, or unbalanced loads. The system fully adapts to all unbalanced scenarios, meeting diverse household energy needs. One ELT-12 unit suits various application scenarios.

Safety and Reliability: Three-phase AC coupling unbalance demands more from the equipment and system. The ELT-12 PV-ESS, through rational power allocation strategies and comprehensive protection measures, significantly reduces user risk and ensures stable, safe operation.

Simple Operation: Enabling the three-phase unbalance function requires no additional hardware or complex procedures. Users simply activate the function via the EMA Manager APP.

Implementation

Platform Setup and Preparation

Implementing the related functions requires the following setup:

· APstorage ELT-12 energy storage inverter

· Compatible energy storage battery

· Photovoltaic system

· APsystems ECU energy communicating device

· Household loads

· Mains grid connection

APP Downloading

Users need to download and use the EMA Manager APP to enable the Three-Phase Unbalance function. Search for the app in the APP Store or Google Play, or scan the QR code with your mobile browser. Alternatively, download via this link: http://q-r.to/1OrC

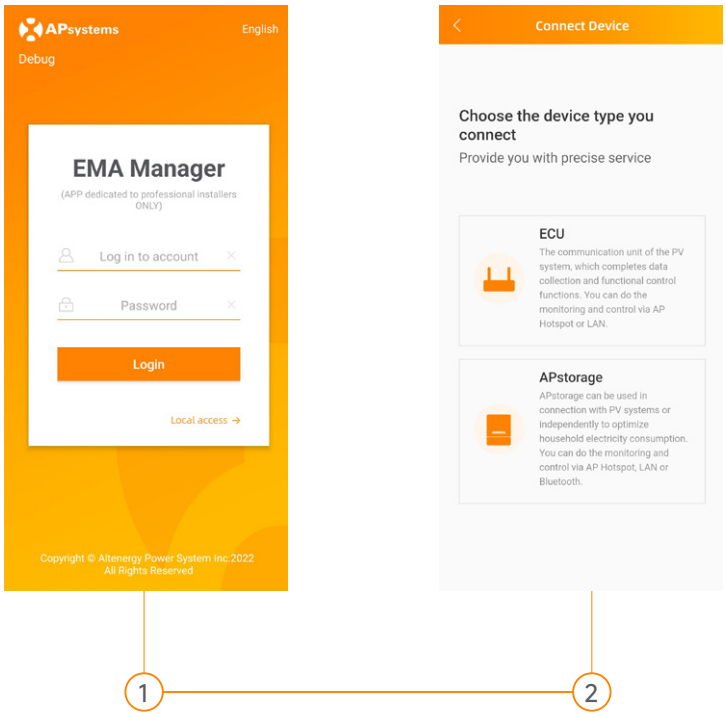
EMA Manager APP (Android)

EMA Manager APP (iOS)

APP Operation

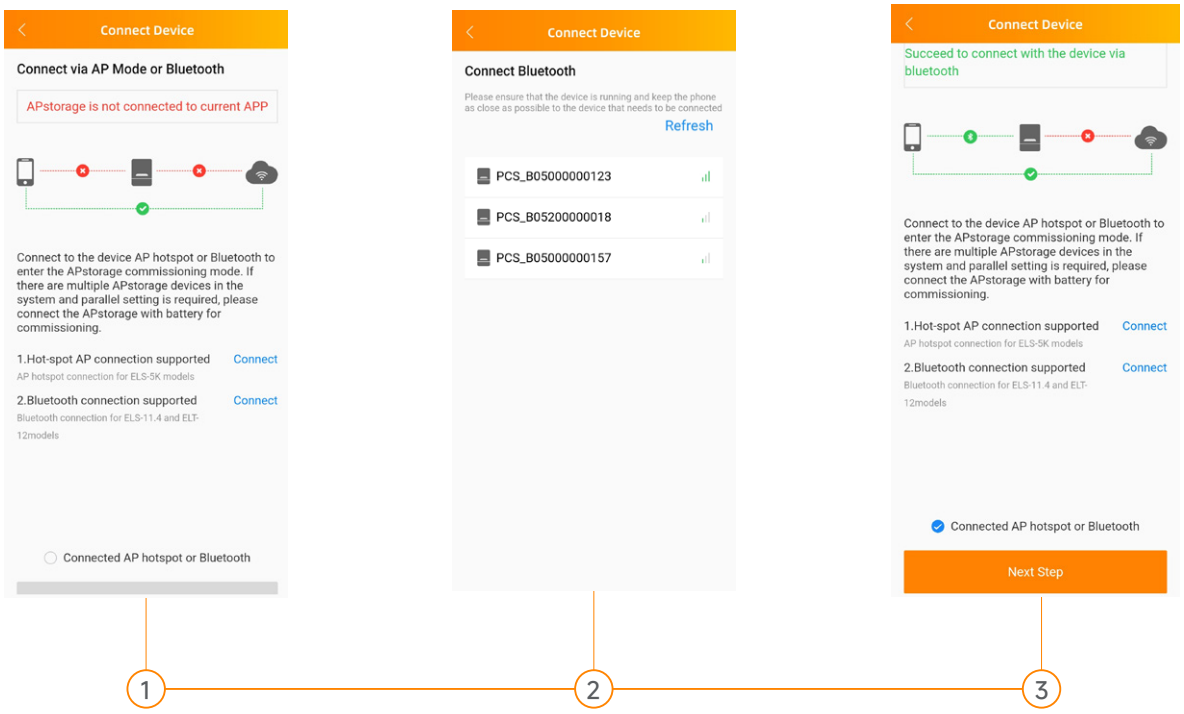
① *Local Access & Connect Device:*

Open the APP, tap "Local Access" then tap to connect to the "APstorage" device.



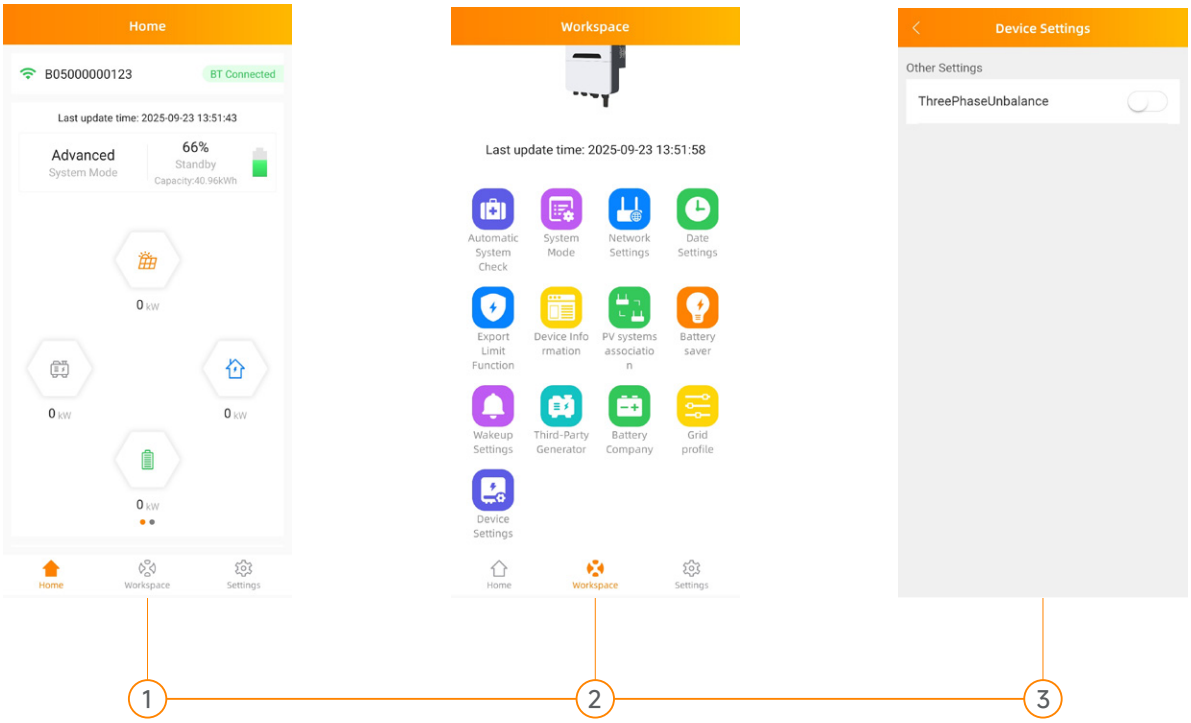
② *Bluetooth Connection:*

Tap "Connect" of "Bluetooth connection supported" -> Select the corresponding PCS ID, check the box for "Connected AP hotspot or Bluetooth" and tap "Next Step".



② ***Enable the Function:***

On the home page, tap the "Workspace" at the bottom. Find "Device Settings" tap into it, and toggle the "Three-Phase Unbalance" switch ON. The function is now successfully enabled.



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