

WHITE PAPER

**Introduction to Off-Grid AC
Coupling Solution**

(EMEA)

Content

- 1 Background.....2
- 2 System Architecture.....2
 - 2.1 Supported equipment.....2
 - 2.2 System diagram.....3
- 3 Working Principle.....4
- 4 Off-Grid AC Coupling Installation.....5
 - 4.1 Frequency Shift Power Control.....5
 - 4.2 PV System Switch.....6
 - 4.3 PV System to APstorage Pairing.....7
- 5 Typical Scenarios.....10
- 6. Wiring Instruction.....11

1. Background

In real world PV projects, users often encounter accidents like sudden power outage, or unstable grid circumstance. Especially users have already has their own PV inverter system, thus connecting existing system to a PCS would be a cost-effective solution that allows users' emergency loads to keep running during any power outage without being to required to purchase the more expensive hybrid inverter.

However, not all PCS in the market supports to connect other inverters to its off-grid/gen port. To solve the problems above, APsystems provides the products covering from single-phase to three-phase that release the solution of PV system is working under off-grid condition.

This whitepaper introduces the implementation of our solution and related application scenarios.

2. System Architecture

2.1 Supported equipment

A "PV system working off-grid" solution is available on both ELS(single-phase) and ELT(three-phase) series, ELS is fully compatible with DS3/DS3D series product and ELT is fully compatible with QT2/QT2D/DS3/DS3D series product.

The PCS can control appointed APsystems microinverter series through frequency control, and it can also control other inverters through built-in relay.

Figure 1: ELS PCS with DS3/DS3D

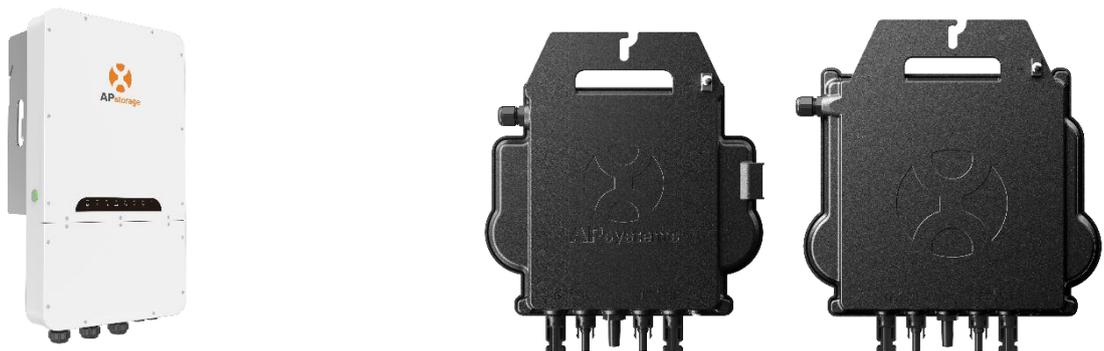
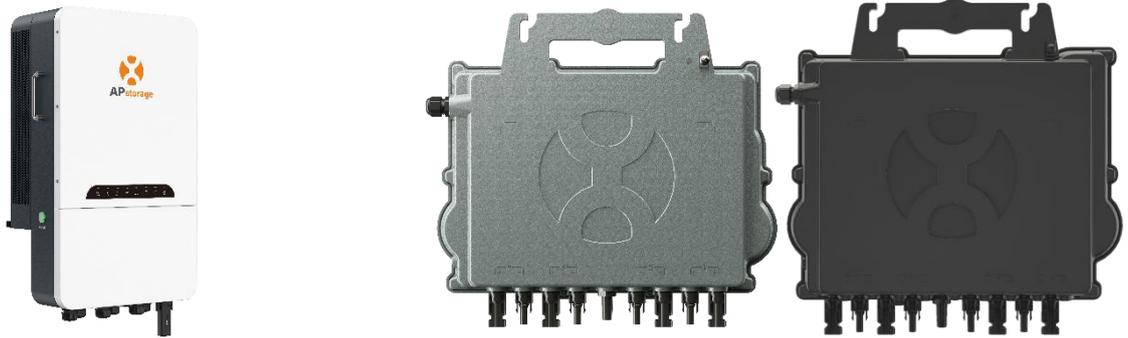


Figure 2: ELT PCS with QT2/QT2D



2.2 System Diagram

The PV System is divided into PV System 1 and PV System 2. PV System 1 is the photovoltaic system on the grid-tied side, and PV System 2 is the photovoltaic system on the off-grid side.

When PCS is in off-grid mode, the off-grid energy storage system consists of Battery, PCS, Transformer, Backup Load and PV System 2. PCS and PV System 2 forms an AC-coupled Microgrid.

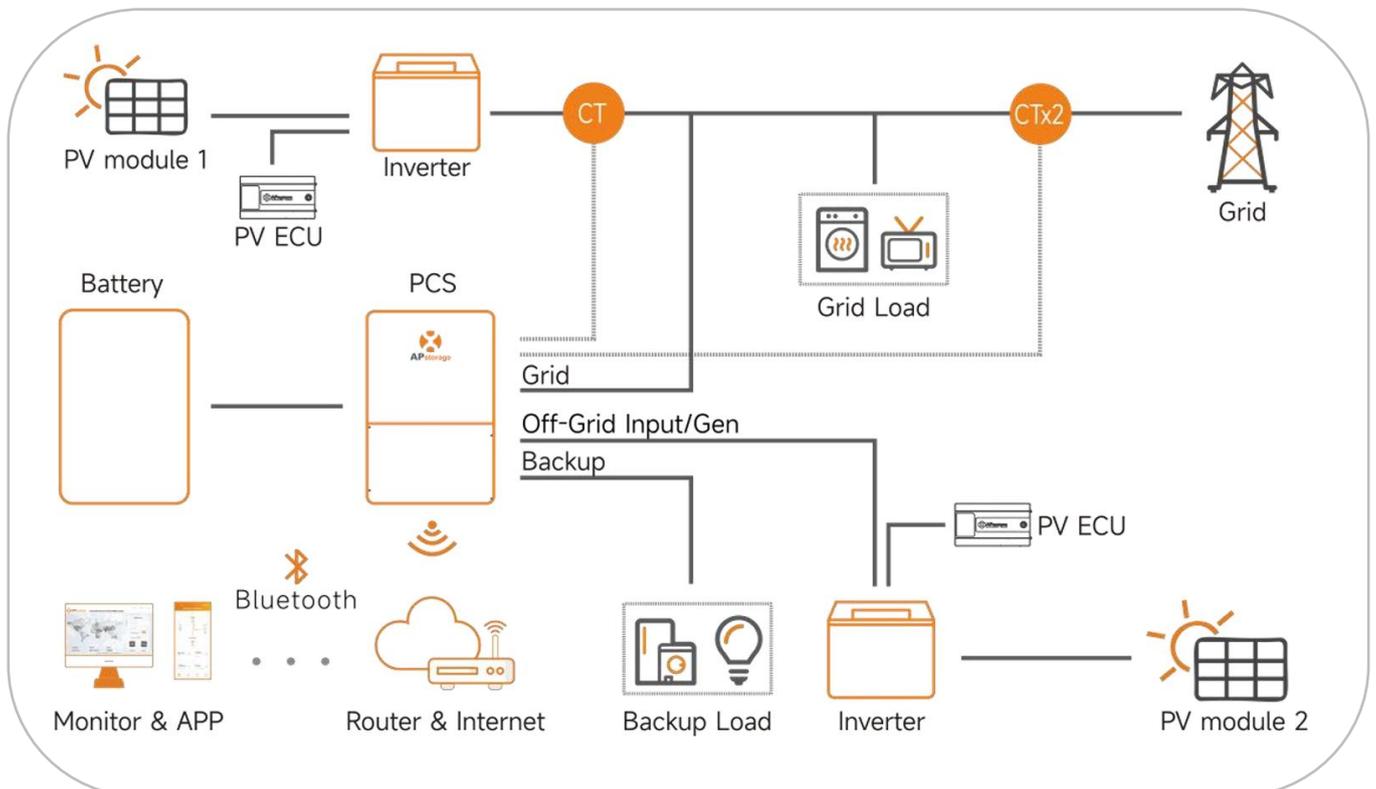


Figure 3 Schematic of the APStorage Energy Storage System

APsystems PCS not only can work under on-grid situation, but also off-grid situation, when PV system connects to the off-grid port on PCS, it works during the grid power outage (temporary and permanent off-grid situation) as well.



NOTE: If the wireless signal in the area where the PCS is weak, it is necessary to add a Wi-Fi signal booster at a suitable place between the router and PCS.
In a Storage System with APstorage PCS, the battery is one of the key components. Therefore, it is necessary to keep the installation environment well ventilated, please refer to Battery user manual.

3. Working Principle

In the off-grid mode, the off-grid port of the PCS provides stable alternating current through the battery, simulating the voltage and frequency of the grid (such as 220V/50Hz). At this time, the PCS acts as a "virtual grid" and provides the reference signals necessary for the grid-connected inverter to operate.

Key points:

- **Voltage/frequency generation:** PCS utilizes the DC from the energy storage battery and generates stable sinusoidal AC through the internal inverter circuit.
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- **Synchronous control:** After the on-grid inverter detects the voltage and frequency provided by the PCS, it synchronizes with them through the phase-locked loop (PLL) technology and enters the power generation state.
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- **Power matching:** The PCS adjusts the output power in real time, balancing the power generation of the on-grid inverter with the load demand, and maintaining the stability of the system.

Importance:

- **To perform export control:** Through frequency shift or relay to control the output power of the PV system that at the off-grid port, to prevent the extra power flows back to the PCS, thereby, to improve the stability of the whole system.
- **To prevent the battery overcharging:** If the power generated by PV system that at the off-grid port exceeds the sum of the load demand and the upper limit of off-grid charging battery SOC,, it may cause the battery to overcharge, resulting in protection shutdown or damage.

4. Off-Grid AC Coupling Installation

4.1 Frequency Shift Power Control

If the PV inverter is connected to the off-grid side of the PCS in the system, the PCS must be able to limit its output power. This limitation is necessary when the battery of the PCS is fully charged and the available power of the photovoltaic system exceeds the power demand of the connected load. In order to prevent the battery from overcharging, the PCS uses the measured the photovoltaic power and the requested charging power from battery to adjust the frequency of the microgrid, and the photovoltaic inverter adjusts the output power by detecting the change of the frequency of the microgrid.

The Frequency shift power control is enabled by default on PCS. At the same time, it is necessary to ensure that the PV System 2 is correctly connected to the Production CTs, the over-frequency load reduction function is enabled in PV system2, and is set according to the APstorage over-frequency load reduction parameter setting table.

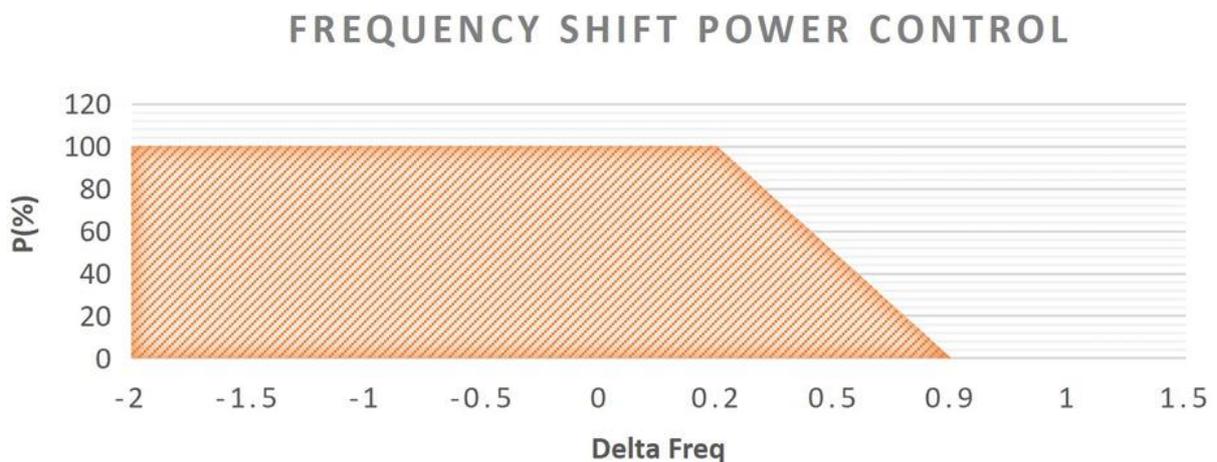


Figure 4 Example PV Inverter Function showing Power vs Delta Frequency

In the graph above, the horizontal axis is variation of the frequency, 0 is the rated frequency. The vertical axis represents the percentage of the current power to the rated power. The photovoltaic power changes with the microgrid frequency controlled by the PCS.



NOTE: The frequency change curve shown in Figure 2 is only for display purposes. The specific parameters of the photovoltaic inverter and PCS are set according to the local certification standards and APstorage over-frequency load reduction parameter setting table.

4.2 PV System Switch

If the PV inverter cannot effectively adjust the output Power through Frequency Shift Power Control, we propose the PV System Switch solution. Through the PV System Switch, we can disable the photovoltaic inverter to prevent the battery from being fully charged and the photovoltaic Situations where power cannot be stopped.

- **For ELS-5K**, We can replace the PV System 2 Breaker with an externally controllable PV contactor , together with the backup relay inside the PCS, controls the off-grid energy storage PV system:
 - **For ELT-12**, We can control off-grid energy storage photovoltaic systems by opening and closing GEN relays
- A) Backup relay inside the PCS: when the Battery SOC is lower than the lower limit of Backup SOC protection, the PCS stops supplying power to the load to ensure that the battery does not enter a state of power loss. When there is enough solar power to meet the starting conditions of PV System 2, PV System 2 charges the battery through the PCS.
- B) When the battery SOC is greater than Backup SOC limit, Backup Loads can be enabled.
- C) PV contactor: when the battery SOC is greater than the upper limit of off-grid charging SOC, PCS will disconnect the photovoltaic inverter to prevent battery overcharging and ensure the normal operation of Backup Load.
- D) When the battery SOC is lower than the upper limit of off-grid charging SOC recovery, PCS will wake up PV System 2 which will supply power to the energy storage system.

4.3 PV System to APstorage Pairing

1. Determine the maximum single load power rating (kW) to be backed up and select the absolute minimum number of PCS units required to meet the requirements of 2017 NEC 690.10->710.15(A).
2. Calculate the required energy storage capacity (kWh) based on the backup load estimate for the user-defined time period, capacity and the minimum number of batteries required.
3. Calculate the maximum power of the photovoltaic system connected to the PCS.



NOTE: the number is different if the PV inverter has Frequency Curtailment and/or not. If the total power of the photovoltaic system is greater than the maximum power, the excess power is connected to the grid side.

4.3.1 PV system for ELT-12 backup

When use ELT (Three-phase PCS), the off-grid function demonstrates fully compatible with APsystems’ QT2/QT2D/DS3/DS3D microinverters. Alternatively, users have the option to select third-party inverters. Nevertheless, it is important that users take into account the power limitations to ensure the stable and efficient operation of the system.

The maximum power of the photovoltaic system for storage system backup ELT-12			
Solar Inverters Used	# of APbattery - 51.2V/10.24kWh	Maximum Off-grid Output Power kWac	Maximum Off-grid PV Size kWac
APsystems Inverters QT2/QT2D/DS3/DS3D	1	6.14	7.67
APsystems Inverters QT2/QT2D/DS3/DS3D	2	12	15
Others	1	6.14	6.14
Others	2	12	12

4.3.2 PV system for ELS-5K backup

When use ELS (Single-phase PCS), the off-grid function demonstrates fully compatible with APsystems' DS3/DS3D microinverters. Alternatively, users have the option to select third-party inverters. Nevertheless, it is important that users take into account the power limitations to ensure the stable and efficient operation of the system.

The maximum power of the photovoltaic system for storage system backup ELS-5K			
Solar Inverters Used	# of APbattery - 48V/5.76kWh	Maximum Off-grid Output Power kWac	Maximum Off-grid PV Size kWac
DS3&DS3D Series	1	2.5	3.12
DS3&DS3D Series	2	5	6.25
Others	1	2.5	2.5
Others	2	5	5

4.3.3 Calculation examples

- Step 1: Figure out Battery Max Charge Power.
- Step 2: Figure out PCS Charge Power.
- Step 3: Take the smaller number.
- Step 4: Multiply by 1.25 (If using Frequency Power Control)

Examples Calculation of Off-grid Solar:

Configuration A: 1 ELS-5K+1 APbattery-48V/5.76kWh

Calculation progress:

1. Battery Power = 2.5kW
2. PCS Power =5kW
3. Battery Power is smaller than PCS Power
4. Off-grid PV power is 2.5kW
 $2.5kW * 1.25 = 3.125kW$ of Off-grid PV

Configuration B: 1 ELT-12+2 APbattery-51.2V/10.24kWh

Calculation progress:

1. Battery Power = 12.28kW
2. PCS Power = 12kW
3. PCS Power is smaller than Battery Power
4. Other Off-grid PV power is 12kW
 APsystems Off-grid PV power is 15kW

How to use EMA App to set Frequency Shift Power Control and PV System Switch

If your PV inverter supports Frequency Shift Power Control, you can use Frequency Shift Power Control and PV System Switch at the same time to ensure stable system operation.

If using Frequency Shift Power Control,

- A) It is necessary to confirm that your photovoltaic inverter supports the Frequency Shift Power Control function. According to your country, set the photovoltaic inverter and PCS according to the local APstorage over-frequency load reduction parameter setting table, and follow the wiring instructions.



NOTE: If you need to use Frequency Shift Power Control and PV System Switch at the same time, please consult the technical supports.

- B) Connect to PCS through EMA Manager. For the operation process of APP connection, see Chapter 4 of APstorage Sea Family ELS Series PCS Installation & User Manual;
- C) Find Frequency Shift Power Control through EMA Manager, and it will run automatically after opening. (APP with pictures)

If using PV System Switch,

- A) It is necessary to confirm that your system equipment is wired according to the wiring instructions in Chapter 1.2.2;
- B) Connect to PCS through EMA Manager. For the operation process of APP connection, see Chapter 4 of APstorage Sea Family ELS Series PCS Installation & User Manual;
- C) Find the PV System Switch through EMA Manager, and the function will run automatically after opening. (APP with pictures)

5. Typical Scenarios

Scenario 1: PV-Storage microgrid system

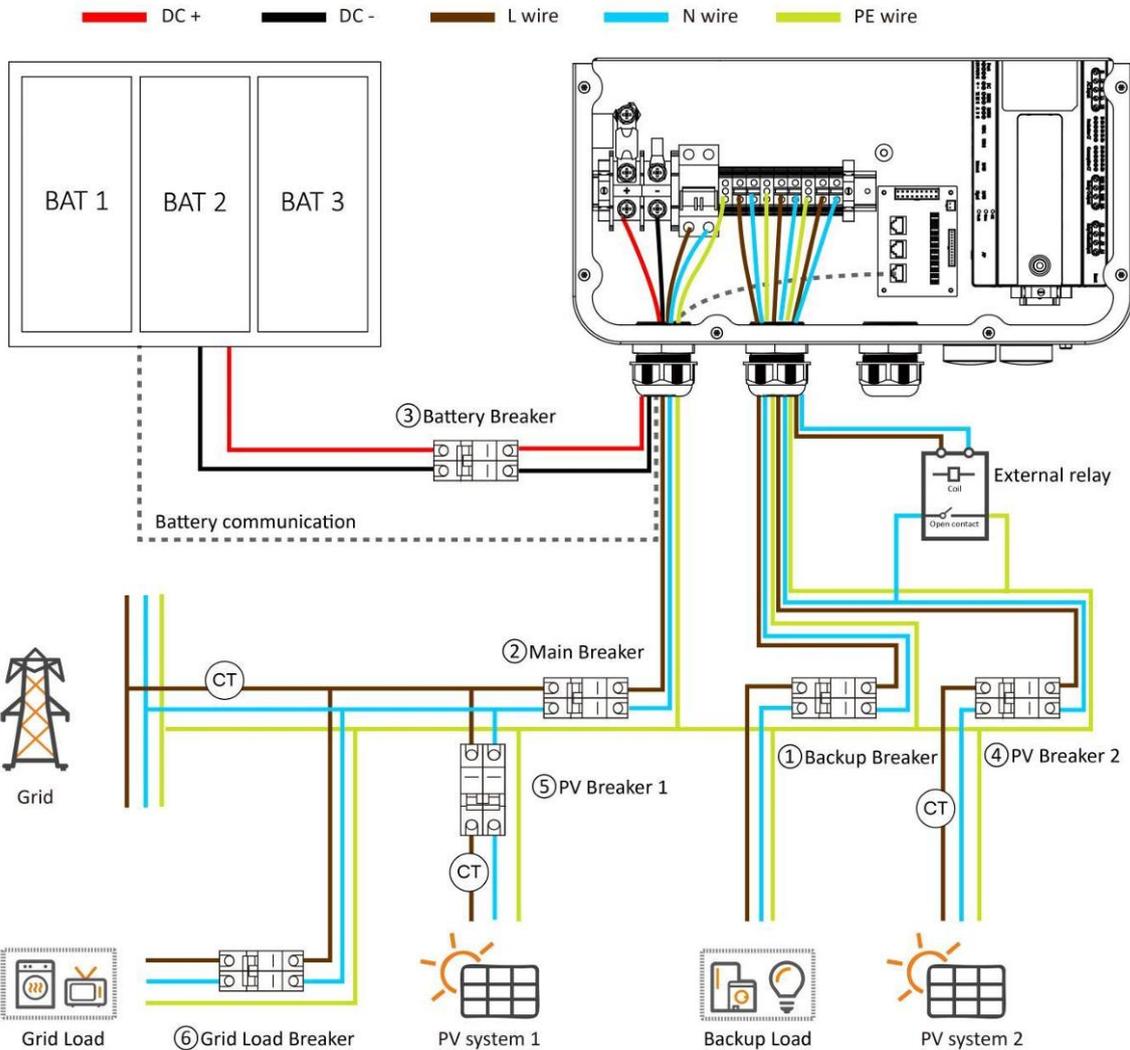
The photovoltaic-storage microgrid integrates photovoltaic power generation, energy storage systems and local loads. It can operate in parallel with the grid or switch to off-grid mode for independent power supply in case of grid failure. It is suitable for remote areas or households without grid coverage, ensuring continuous power supply for critical loads.

Scenario 2: Pure off-grid system

Since APsystems' PCS can start up in an environment without a power grid, this solution is also applicable to scenarios such as islands and mountainous areas where there is no power grid coverage. It relies on photovoltaic power and energy storage for independent power supply.

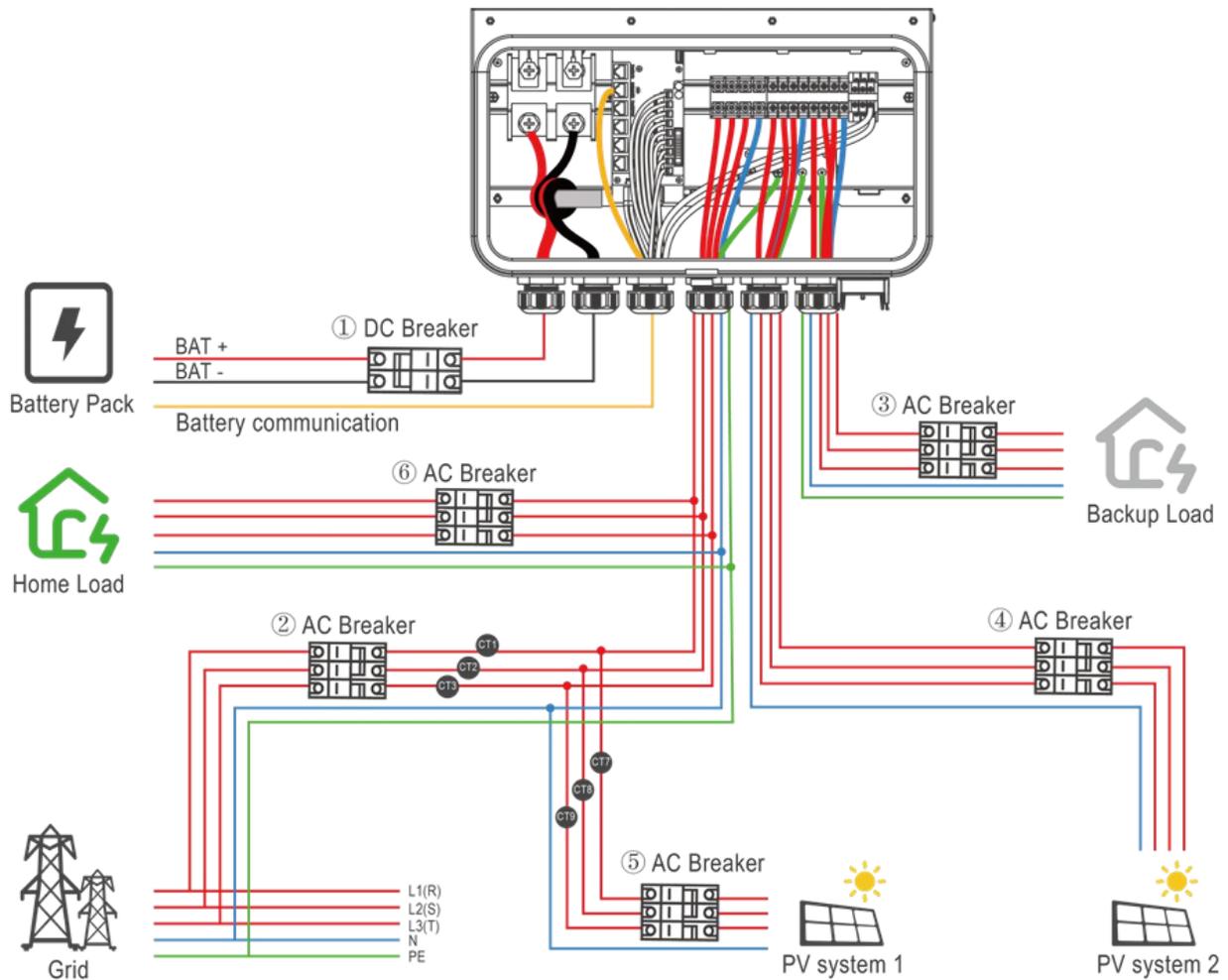
6. Wiring Instruction

ELS-5K PCS (EMEA Version)



- ① Back up Breaker: 32A AC Breaker
- ② Main Breaker :63A AC Breaker
- ③ Battery Breaker: 125A DC Breaker
- ④ PV Breaker 2: 32A AC Breaker

ELT-12 PCS (EMEA Version)



- ① DC Breaker for battery: 300A DC breaker
- ② AC Breaker for Grid : 63A AC Breaker
- ③ AC Breaker for PV system 2: 32A AC Breaker
- ④ AC Breaker for Load: 32A AC Breaker
- ⑤ AC Breaker for PV system 1: Depends on PV system1
- ⑥ AC Breaker for home load: Depends on household Loads