DISCOVER
ENERGY SYSTEMS

APPLICATION NOTE:

OPEN LOOP INTEGRATION WITH THE AES $LiFePO_4$ OR AES RACKMOUNT BATTERY

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1. SAFETY

1.1 AUDIENCE

Configuration, installations, service, and operating tasks should only be performed by qualified personnel in consultation with local utilities and/or authorized dealers. Qualified personnel should have training, knowledge, and experience in:

- Installing and configuring electrical equipment
- Applying applicable installation codes
- Analyzing and reducing hazards involved in performing electrical work
- Installing and configuring batteries

No responsibility is assumed by Discover Energy Systems for any consequences arising out of the use of this material.

1.2 MESSAGES AND WARNINGS

Before using the battery, read all instructions and cautionary markings on the unit and all appropriate sections of the owner's manual and this application note.

NOTICE
Important information regarding conditions that may result in damage to the equipment but not personal injury.

Read power conversion device manuals, for guidance on product features, functions, parameters, and how to use the product safely.

2. DOCUMENTATION

This Application Note provides information about the integration of Discover AES Lithium batteries in systems with open-loop communications.

Discover reference documents:

- AES 42-48-6650 Data Sheet
- AES $LiFePO_4$ 42-48-6650 Installation and Operation Manual
- AES RACKMOUNT48-48-5120 Data Sheet
- AES RACKMOUNT48-48-5120-H Data Sheet
- AES RACKMOUNT Installation and Operation Manual

Visit www.discoverenergysys.com for the most recent version of published documents.

2.1 TOOLS

Use the controller interface supplied with the power conversion device (charger or chargers) to configure the Open Loop settings for use with AES $LiFePO_4$ or AES RACKMOUNT Batteries.

To obtain historical data logs of an AES $LiFePO_4$ battery with cell data, please download and use AES Dashboard Software for 64-bit Windows 10 / 11 and connect the appropriate USB cable from the PC to the battery.

- AES Dashboard Software for 64-bit Windows 10 / 11.

To obtain historical data logs of an AES RACKMOUNT battery with cell data, please download the LYNK Access Software for 64-bit Windows 10 / 11 and connect the appropriate USB cable from the PC to the LYNK Communication Gateway and battery.

- LYNK ACCESS Software for 64-bit Windows 10 / 11.

Visit www.discoverenergysys.com for the most recent version of software.

DISCOVER ENERGY SYSTEMS

3. OVERVIEW

AES batteries must be set up to work with Power Conversion and Monitoring devices in either an Open Loop or Closed Loop configuration.

The charge and discharge settings in an Open Loop configuration are set up manually through the controller for the Power Conversion device at the time of installation. This compares to a Closed Loop configuration where charge and discharge settings are dynamically controlled by the BMS of the battery over a connection with the Power Conversion device's communication network.

NOTE
Closed Loop communication with a Power Conversion device network requires the use of an LYNK Gateway Communication device available from Discover Energy Systems. For details please refer to the LYNK Gateway Communication User Manual available from www.discoverenergysys.com website, or contact your Discover provider for assistance.

The Open Loop settings in this document are for AES $LiFePO_4$ and AES RACKMOUNT batteries in an off-grid application.

4. BATTERY OPERATING LIMITS

The BMS will open its internal relay and disconnect the battery from the system if any of these limits are exceeded. The battery should not be operated outside the maximum operating limits.

Table 4-1, Battery Operating Limits

Maximum Operating Limits	AES $LiFePO_4$	AES RACKMOUNT
	42-48-6650	48-48-5120 / 48-48-5120-H
Continuous Charge Current*	130 Adc	95 A
Continuous Discharge Current*	130 Adc	95 A
Peak Current (3 seconds)	300 Adc	218 A RMS
Operating Voltage (Min / Max)	44.8 V / 58.4 V	43.2 V / 58.4 V
Charge Temperature (Min / Max)	0°C / 45°C (32°F / 113°F)	4°C / 52°C (39.2°F / 125.6°F)
Discharge Temperature (Min / Max)	-20°C / 50°C (-4°F / 122°F)	-17°C / 52°C (1.4°F / 125.6°F)
Storage Temperature (Min / Max)	-20°C / 45°C (-4°F / 113°F)	-20°C / 55°C (-4°F / 131°F)

* The effects of AC Ripple must be taken into consideration when sizing and configuring your system.

NOTICE
Intentional bypassing of BMS to operate battery outside maximum and minimum limits voids warranty.

NOTICE
Do not use or install a battery temperature sensor.

DISCOVER ENERGY SYSTEMS

5. MINIMUM BATTERY CAPACITY

Battery capacity must be sized correctly for the systems:

- Total charge power
- Total load discharge power
- Total load surge power

Using very large solar arrays with battery banks that are too small can exceed the operating limits of the battery to charge and possibly lead to the BMS triggering over-current protection. Battery capacity must be sized to accept the maximum charge current of the system, or the charging devices must be curtailed to charge below the operating limit of the installed batteries. This value is derived by adding together the charge capacities of all inverter/chargers and solar charge controllers in the system.
Additionally, battery peak capacity must be sized to support the surge requirements demanded by the load attached to the inverter. Match the sum of all inverter peak power values with the sum of all battery peak battery current values.

Table 5-1, Battery System Size

System Size	Peak Current Adc	Constant Current Adc	Rated Energy kWh
AES LiFePO$_4$ 42-48-6650			
1 Battery	300 Adc	130 Adc	6.650 kWh
2 Batteries	600 Adc	260 Adc	13.300 kWh
3 Batteries	900 Adc	390 Adc	19.950 kWh
4 Batteries	1200 Adc	520 Adc	26.600 kWh
5 Batteries	1500 Adc	650 Adc	33.250 kWh
AES RACKMOUNT 48-48-5120 / 48-48-5120-H			
1 Battery	218 Adc	95 Adc	5.120 kWh
2 Batteries	436 Adc	190 Adc	10.240 kWh
3 Batteries	654 Adc	285 Adc	15.360 kWh
4 Batteries	872 Adc	380 Adc	20.480 kWh
5 Batteries	1090 Adc	475 Adc	25.600 kWh
6 Batteries	1308 Adc	570 Adc	30.720 kWh

6. POWER CONVERSION DEVICE SETTINGS

The recommended settings for AES LiFePO$_4$ and AES RACKMOUNT batteries in an Open Loop configuration are as follows below. This section presumes familiarity with the control panel used to configure and monitor the power conversion device. Refer to the product manuals for the safe and correct operation of the power conversion device.

Table 6-1, Power Conversion Device Settings

Settings	42-48-6650	48-48-5120 / 48-48-5120-H
Inverter Settings		
Low Battery Cut Out Voltage Recommended [1]	48.0 V	48.0 V
Low Battery Cut Out Delay	5 seconds	5 seconds
Restart Voltage after LBCO	52.0 V	No automatic recovery
(1) The Low Battery Cut Out Voltage set point disconnects the load before the BMS enters low voltage protection.		

DISCOVER ENERGY SYSTEMS

Settings	42-48-6650	48-48-5120 / 48-48-5120-H
Charger Settings		
Bulk Voltage	55.2 V	55.2 V
Absorption Voltage	55.2 V	55.2 V
Absorption Voltage Time Limit [1]	1.0 < 3.0 Hr	1.0 < 3.0 Hr
Absorption Termination Current	2 A	2.5 A
Float Voltage	53.6 V	53.6 V
Equalization	Disabled	Disabled
Temperature Compensation	Disabled	Disabled
Charge Current per battery installed (Recommended < Maximum) [2]	Installed x (92 A < 130 A)	Installed x (70 A < 95 A)
MPPT Charge Controller Settings		
Bulk Voltage [3]	55.4 V	55.4 V
Absorption Voltage [3]	55.4 V	55.4 V
Absorption Voltage Time Limit [1]	1.0 < 3.0 Hr	1.0 < 3.0 Hr
Absorption Termination Current	2 A	2.5 A
Float Voltage	53.6 V	53.6 V
Equalization	Disabled	Disabled
Temperature Compensation	Disabled	Disabled
Charge Current per battery installed (Recommended < Maximum) [2]	Installed x (92 A < 130 A)	Installed x (70 A < 95 A)

(1) The recommended minimum is 1.0 hour. A longer period of time may be required for multiple batteries to achieve a smooth completion of charge.
(2) Set to a lower value if necessitated by the capacity of the charger.
(3) Set Charge Controller Bulk and Absorb targets at 0.2 V above the charger setpoints to favour solar charging.

7. CHARGING

Each electrical system will have different characteristics and balance-of-system components. Charger settings may require modifications to optimize system performance.

NOTICE

- Exceeding the Peak Current, or continually exceeding the Max Charge Current (1 hour), Max Discharge Current (1 hour), Max Continuous Charge Current, or Max Continuous Discharge Current, of all the batteries in the system will lead to triggering the battery's BMS over-temperature protection quicker, resulting in disconnection of all batteries in the system.
- Disconnection will result in a voltage spike (Load Dump), which may damage any component electrically attached to the battery system.

NOTICE
• Always confirm that the charging device cannot produce transient spikes that exceed the published terminal voltage limits for the battery. • Always confirm the charging curve meets the battery's charging requirement. • Never charge a visibly damaged or frozen battery. • If the battery is stored in a cold environment, it may become frozen and may not accept a charge. Be aware of the supported Charge Temperature range (refer to the battery manual's Environmental Specifications) and recharge before it approaches 0% SOC.

7.1 Operation

The BMS prevents battery operation outside of specified operating conditions. Understand each of these protections and how to set up the system accordingly. Refer to battery documentation for Protections Specifications.

NOTICE
Intentional bypassing of the BMS to operate the battery outside maximum and minimum limits voids the warranty.

7.2 When to Charge the Battery

- **Opportunity charging is OK.** Charging the battery after every use will not reduce its cycle life.
- **Partial State-of-Charge is OK.** If the battery SOC is greater than 10% at the end of discharge, it does not require an immediate charge. However, do not continually leave the battery in a partial state of charge as that will reduce its performance as battery cells become unbalanced.

  Every 4 cycles, fully charge the battery so the inverter-charger reaches the charge termination criteria. This ensures the battery cells are balanced and that each battery cell is fully charged.
- **Charge if below 10% SOC.** If the battery has been discharged below 10% SOC, it must be charged within 24 hours to avoid permanent damage to the battery. Otherwise, irreversible damage to the battery cells will occur in a very short period of time.
- **Low charge current extends life.** Charging at 50% of nominal current or lower helps extend the battery cycle life
- **Charge within the proper temperature range.** Ensure that charging is within the charge temperatures specified in the battery manual's Environmental Specifications.

NOTICE
• The battery must be charged within 24 hours if discharged below 10% SOC. Otherwise, irreversible damage to the battery cells will occur in a very short period of time and void the warranty. • Do not continually leave the battery in a partial state of charge as that will unbalance the battery cells. Fully charge the battery every 4 cycles so each battery cell is fully charged. If the end of charge criteria is not regularly performed, multiple balancing charges may be required to fully charge each battery cell.   o To perform a balancing charge, reduce charge termination to 100 mA and maintain 54.4 V for 10 hours.

7.2.1 Bulk Charge

NOTICE
Do not charge using a lead-acid charging profile. Charging using a lead-acid profile will void the warranty.

Bulk phase. The Bulk Charge is the first phase of the charging process, called the constant current phase. This phase is when the charger's maximum current is directed to the battery until reaching the desired voltage. The Bulk phase will recharge the battery to approximately 90-95% SOC.

A single-stage charge may be appropriate if the charging source is a generator or other charge source that is inefficient at low output current. A single-stage charge will only complete the Bulk phase portion of the charge curve. This method should return the battery to 90-95% SOC. Refer to Table 6-1, for charging parameters.

7.2.2 Absorption Charge

Absorption phase. The second phase of the charging process is Absorption Charge, also called the constant voltage phase. In this phase, the charger reduces current accordingly to maintain the desired voltage.

Refer to Table 6-1, for charging parameters.

7.2.3 Equalization Charge

⚠ CAUTION
FIRE AND BURN HAZARD Do not perform an equalization charge on the lithium battery. **Failure to follow these instructions can result in minor to moderate injury.**

Do not equalize charge the lithium battery. Equalization charging is intended only for lead-acid batteries. An equalization charge is a purposeful overcharge that targets a voltage above the standard charge voltage to remove sulphate crystals that form on lead-acid plates over time.

7.2.4 Float Charge

Float phase. Float charge, the third phase of charging, is optional. During this stage, the battery is maintained at 100% SOC for extended periods, counteracting any self-discharge or parasitic loads.

Not necessary. Float charging is not required. Refer to Table 6-1 for float parameters, if required.

NOTE
Charging at 50% of nominal current or lower will extend the battery cycle life.

8. CALIBRATION AND VERIFICATION OF THE CHARGER SET POINTS FOR AES $LiFePO_4$ and AES RACKMOUNT BATTERIES IN OPEN LOOP SYSTEMS

NOTICE

The accuracy of voltage and current regulation varies between power electronic vendors and across models. Verify the output of a charge cycle against the expected settings to confirm the performance of the power electronics with battery data logs exported using either AES Dashboard or LYNK ACCESS Software.

After completing the initial configuration of the charging sources (inverter/charger and charge controllers), validate and confirm that the set charge points actually match the voltage at the battery terminals during a charge cycle.

There are many reasons why the voltage at the battery terminals may not match the Bulk, Absorb and Float settings. Common reasons include resistance, poor connections, differing cable lengths, etc. However, the leading cause is that voltage regulation, particularly with older power electronics, is not very precise.

Output voltage variances that may have been acceptable for lead-acid batteries will no longer fall within the tolerances required for proper charging and maintenance of a lithium battery. To reduce the risk of premature failure due to improper charging, take the following steps to ensure that the system is configured properly.

1. Confirm the charger(s) target VDC has been set to 55.2 VDC for Bulk and Absorb stages and that the Float target is set to 53.6 VDC.
2. Allow the system to run a complete daily cycle or, at least one full charge/discharge cycle.
3. After a full cycle, pull the data logs using AES Dashboard Software for 64-bit Windows 10 / 11 or LYNK ACCESS Software for 64-bit Windows 10 / 11 from at least one of the batteries.
4. Review the charge voltages from the data set by following these steps:
   a. Under “System Amps” (Column M) identify the positive numbers that indicate energy going into the battery and “charging”.
   b. Highlight the “Terminal Voltage [mV]” readings in Column P associated with charging current. Convert these from mV to volts by dividing by 1000.
5. Determine the average terminal voltage during charging and compare it with the programmed voltage set point.
   a. If the terminal voltage reading from the battery data log is below the 55.2 V target for Bulk and Absorb stages, increase the setting on the charger(s) to compensate by the amount they differ (typically not more than 1.2 VDC).
   b. If the terminal voltage reading from the battery data log is above the 55.2 V target for Bulk and Absorb stages, decrease the setting on the charger(s) to compensate by the amount they differ (typically not more than 0.5 VDC).
6. Use the same process as Step 4 above, to calibrate the Float voltage parameters. The data required to calibrate the Float stage will be found at the end of the charge cycle once the SOC (%) field nears or is equal to, 100% SOC. The Float voltage target should be 53.6 VDC.
7. If changes had to be made to calibrate output, run the system for another day, or at least for a charge and discharge cycle, then pull that day’s data log and start the verification process again from Step 3.

NOTE

- It is better to round up on calibration set points and be slightly over the recommended charging targets for Bulk, Absorb, and Float than slightly under.
- Calibrating and charging Discover lithium batteries properly will ensure warranty compliance, maximize expected service life, and optimize battery capacity.

9. GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

BMS	Battery Management System
Closed Loop	The battery management system is communication charge configurations to the power conversion devices
DOD	Depth of Discharge
Open Loop System	There is no communication between the battery management system and the power conversion devices. Also known as a drop-in lead-acid replacement system.
SOC	State of Charge
VPC	Volts per Cell