Discover®

ENERGY STORAGE

OPzV Gel Tubular Plate Battery

Operating Manual

TUBULAR GEL OPzV
2V CELLS

REV C

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Overview

Certain 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 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 for any consequences arising out of the use of this material.

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Read instructions carefully and place them close to the battery.

Use protective glasses, gloves and clothing when working on batteries. Always make safe working practices a priority.

No smoking. Do not expose batteries to flames, or sparks, as it may cause an explosion.

Clothing contaminated by acid should be washed in water.

Batteries with this symbol can be recycled.

Risk of explosion and fire. CAUTION: Battery terminals and connector are always under voltage. Do not place tools or other metal objects on the battery. Avoid short circuits!

Electrolyte is highly corrosive.

Batteries and cells are heavy. Ensure secure installation! Use only suitable handling equipment and lifting gear.

Dangerous Voltage!

Do not mix with other industrial or household waste. Contact your servicing Discover® dealer for proper battery return and recycling!

1. Safety

1.1 Do's

- Do protect terminals from short circuit before, during, and after installation
- Do wear electrically insulated gloves
- Do use electrically insulated tools
- Do wear eye protection
- Do wear safety toe boots / shoes
- Do read user manual for battery handling instructions
- Do secure battery safely

1.2 Do Not's

- Do not operate or store battery outside of operating limits
- Do not short circuit battery
- Do not puncture battery
- Do not expose battery to flames, or incinerate
- Do not open battery case or dissemble battery
- Do not wear rings, watches, bracelets or necklaces when handling or working near battery
- Do not drop or crush battery
- Do not lift battery by the terminal cables
- Do not expose battery to water or other fluids
- Do not expose battery to direct sunlight
- Do not dispose of battery
- Do not connect with other types of batteries
- Do not expose battery to high temperatures

2. Delivery and Storage

2.1 Receiving Inspection

- Store the battery in a dry, clean, ventilated, cool and frost-free location.
- Do not expose the cells to direct sunlight as damage to the container and cover may occur.
- Do not stack pallets on top of each other. DO NOT store unpacked cells on sharp-edged supports. Storage on a pallet and wrapped in plastic material (shrink wrap) is permitted except in rooms where the temperature fluctuates significantly, or when high relative humidity can cause condensation under the plastic. With time this condensation can cause a whitish hydration on the terminals and current leakage leading to high self-discharge.
- Protect the batteries from any risk of electric shock from short- circuiting poles/terminals with conductive objects or from the building up of conductive dust.
- Maintain the same storage conditions for all batteries within the same batch. Batteries are normally supplied charged. Depending upon storage conditions, storage time may be limited. In order to prevent batteries from becoming over discharged during storage do not store them for more than 3 months at 20°C/68°F, 2 months at 25°C/80°F, or 1 month at 40°C/104°F before performing a re-fresh charge. Failure to observe these conditions may result in significantly reduced capacity and service life
- Record dates and conditions for all charges during storage.

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2.3 Unpacking and Handling

- Never lift cells by the terminal posts. Lifting cells heavier than 25 kg/55 lb should be made with lifting belts
- Never drag or roll the battery!
- The batteries are fully charged before shipment. Do not short circuit.
- Check for evidence of leakage. All cells with visible defects should be rejected

3. Installation and Commissioning Charge

3.1 Installation and Battery Room Design

- All electrical protective measures, devices, accommodation and ventilation of the battery installation area must be in accordance with all local rules and governmental regulations.
- The battery should be installed in a clean and dry area and protected against dropped items and dirt.
- Avoid placing the battery in a hot place or in direct sunlight.
- The location or arrangement of cells should result in no greater temperature difference than 3°C/5°F between cells within a connected string at any given time.
- Avoid conditions that result in spot heating or cooling, as temperature variations will cause electrical imbalances in the battery. For better cooling and temperature management ensure the installation allows for adequate air flow around each cell. Keep 10mm/0.5in distance between cells.
- The layout of the battery room or installation area must allow for easy access to the batteries. The recommended minimum distance between battery rows is 1.5 times the depth of the row.
- Racks or cabinets shall be located 100mm/4in from the wall.
- Be sure to provide adequate space and lighting for inspection, maintenance, testing, and cell replacement. Space should also be provided to allow the operation of lifting equipment and for taking measurements (cell voltage and temperature) during service.

3.2 Racks and Mechanical Stability

- Approved and insulated battery racks are recommended for proper installation. Calculations should be performed to ensure that floor loading capabilities are not exceeded. Seismic forces should also be considered.
- The installation should provide for adequate structural support and exposure to the minimum possible vibration.
- Discover® provides a variation of special designed OPzV 24VDC and 48VDC rack solutions. For more information please visit: discoverbattery.com/product-search

3.3 Cells in Parallel Strings

Discover® Tubular Gel cells may be connected in parallel to increase capacity, current capability and/or discharge durations. In the case of each parallel connected string, only use batteries of the same voltage, capacity, design and age.

The resistance and ampacity of the cables or connector bars in each string must be the same, e.g. same cross-section, same length and same conductor type (copper, aluminum). In addition, each string should be equipped with disconnect capabilities (circuit breakers) for maintenance and safety purposes.

Discover® recommends a maximum of four strings parallel, up to 10 strings is possible: If the following steps are fulfilled it is possible to have more strings in parallel without reducing battery life or cells getting out of balance if the following requirements are fulfilled:

- The same voltage drop must be realized from each string to the end connection (load and ground). This can be achieved by proper choice of cable lengths, cable diameters and arrangement for crosswise connection configurations
- The connector cables for positive and negative terminals of each battery string must have the same length
- It is a must that each string has a manually operated switching device that also automatically opens or breaks the circuit in the event of an over current (circuit breaker).
- Each string must have the same number of cells
- Each string must be exposed to the same heat or temperature potential.

- Always connect the individual series strings first and then check that the different strings are at the same potential before connecting them together on the bus.

Notes:

- The combined performance data of all of the cells will be realized at the end pole/terminal of each string.
- Battery life or reliability will not be negatively affected if this form of paralleling is done correctly.
- Parallel connection of strings with different capacities as well as different ages is possible (the age and capacity of the batteries within each string must be the same).
- The current during both discharge and charge will be split according to the capacity or age of the batteries respectively.

3.4 Cells in Series Strings

- Discover® Tubular Gel cells may be connected in series to increase system voltage.
- In the case of each series connected string, only use batteries of the same voltage, capacity, design and age.
- The resistance of the cables or connector bars in each string must be the same, e.g. same cross-section, same length and same conductor type (copper, aluminum).
- Each string should be equipped with disconnect capabilities (breakers) for maintenance and safety purposes.

3.5 Pre-installation Control

- Check cells for evidence of leakage.
- All cells with visible defects such as cracked jars or containers, loose terminal posts, or other unrecoverable problems shall be rejected.
- Before installation, in cases where the battery container is dirty, wipe with a dry anti-static cloth only.
- Carry out Open Circuit Voltage (OCV) measurements on each individual cell and check their compliance against the following variation and absolute voltage criteria:
    1. The OCV must not deviate from average more than ±0.025V for 2V cells
    2. The OCV must not be lower than 2.05 Vpc
    3. The OCV of a fully charged cell at 20°C/68°F should result between 2.12-2.15 Vpc
    4. Per 10% Depth of Discharge (DoD) the voltage is reduced by .015VPC

3.6 Electrical Connections

- Ensure that the cells are installed and connected in the correct polarity.
- Check that all contact surfaces are clean. If required, clean poles/terminals with a brass brush/pad.
- You may slightly lubricate terminal inserts and connections with silicone grease. Petroleum-based lubricants are not recommended.
- Tighten the terminal screws using a torque loading of 23 Nm or 17 Ft-lbs. Electrical connections between cells or cells on separate levels or racks should be made making sure to minimize mechanical strain on the battery poles/terminals.

TERMINAL TORQUE
23 Nm / 17 ft-lbs

- For systems where the total battery voltage is measured at the controller, use oversized cables between the controller and the battery to minimize the voltage drop.
- Check the battery's total voltage. It should match the number of cells connected in series. If the measurement is not as expected, recheck the connections for proper polarity.
- The installer of the battery is responsible for conformity to local electrical standards.
- For future identification, apply individual cell numbers in sequence starting from one end of the series string. Also apply identification letters or numbers for the parallel strings.
- Only connect the battery to the DC power supply after ensuring that the polarity is correct, the charger is switched off, and the load is disconnected.

3.7 Instrumentation

- For large installations consider using permanent instrumentation for measurements and alarms. These include voltmeters, amperemeters, Ah counters, high and low voltage indicators, ground fault detector(s) and temperature sensor(s) for the battery and the ambient air.
- For smaller installations, use portable test equipment. The battery temperature sensors shall be fixed on the cell side wall or negative pole/terminal.
- The use of monitoring and recording systems is mandatory in "Hybrid" systems.

3.8 Commissioning Charge

The initial charge is very important for the future battery operation and the battery's service life. It is performed as a "Commissioning Charge" as listed in paragraph 4.2.1. Keep records in the battery's logbook. Discover Commissioning Logs are online available at discoverbattery.com/en/resources/

4. Operations

STAND ALONE SYSTEMS

In "Stand-alone" systems, the renewable source (e.g. PV array) is the only charging source available for the battery. In some systems, an external source - like a diesel generator - can be used but this is not within the basic design principle of a stand- alone system. (e.g. the source is engaged only intermittently and manually by the user in order to serve excessive loads or to maintain the batteries). Two types of charger controllers can be used:

On-Off PV controllers:

- The controller interrupts the charging current from the PV array (off state) when the battery voltage reaches the high regulation point and re-connects when the voltage drops to the low regulation point.

Constant Voltage type:

Once the battery voltage reaches the regulation point, the controller limits the charging current to keep the voltage constant at this level as long as there is enough power available from the renewable source. Two sub types may be defined here:

- One voltage step controllers: There is only one voltage regulation point.
- Two voltage steps controllers: There are two voltage regulation points. Initially the controller maintains an elevated voltage to recharge the battery fast (absorption stage) then, after a certain time or other criteria, it steps back to a lower voltage to prevent unnecessary overcharging (floating stage).

HYBRID SYSTEMS

In "Hybrid" systems, the renewable source size is most often smaller than the application load. There is always an independent source available - diesel or grid – to recharge the battery in every cycle. The same independent source can also be engaged, either automatically at regular intervals or manually when required to maintain the battery with balance charges. Only Constant Voltage controllers (usually with two voltage steps) shall be used.

4.1 Discharging

No restriction on the discharge current up to the maximum allowable is required as long as the connections are properly sized and the battery temperature stays within the allowable limits. The Maximum Daily Depth of Discharge per cycle (MDDoD) is:

- Stand-alone: 30% of the batteries C10 nominal capacity rating
- Hybrid systems: 50% of the batteries C10 nominal capacity rating

Standard RE warranty is reduced on system designs that exceed the MDDoD. The Maximum allowable Depth of Discharge (MDoD) is 80% of the batteries temperature compensated C10 nominal capacity at any given discharge rate.

OVER-DISCHARGE PROTECTION

Maximum Depth of Discharge (MDoD) limits should not be managed solely based on Ah-counters (counting the ampere- hours into and out of the battery). Monitoring the battery voltage against the low- voltage disconnect setting (LVD) should always be included.

- The system designer or installer shall adjust and confirm the LVD settings based on the actual conditions of the system.
- For systems where the voltage is measured at the controller and not on the battery, the voltage drop on the connections to the battery shall be considered.
- For mission critical systems with the load directly connected on the battery, an alarm or other method of user feedback must be included to provide information about the battery status when DoD exceeds the design limits

Reference LVD / I10	20% DOD	2.05 Vpc
	50% DOD	1.97 Vpc
	80% DOD	1.91 Vpc

4.2 Charging

The most common type of charging method can be grouped into three phases: bulk, absorption, and float charge. An additional balance phase can be performed on a routine maintenance-as-required basis.

The Bulk charge accounts for charging the battery from anywhere between 0% up to 80% state of charge. The absorption phase charges the battery from 80% to nearly 100% state of charge. Lastly, a float charge supplies a controlled voltage and amperage to bring the battery to a complete full charge.
For specific charge programming instructions, please refer to the documents provided by the charger manufacturer.

The battery temperature must be monitored during charge. It should never exceed 45°C/113°F. If the upper temperature limits are reached, the charge shall be interrupted or the charge voltage should be reduced to float voltage for a period of time sufficient enough to allow the battery to cool down. Operation can continue once the temperature stabilizes below 45°C/113°F.

Depending on the charger type and charging characteristic curve, alternating currents flow through the battery during charging and are superimposed onto the charging direct current. These alternating currents (AC ripple current) must not exceed 1A per 100 Ah of C10 nominal capacity.

4.2.1 Commissioning Charge

Batteries lose charge while in transit or during storage. For this reason, a refresh charge should be given before putting the battery into service. The charge voltage should be set for 12 hours at constant voltage with current limitations as listed below. The battery should be considered fully charge when individual cell voltages have not risen for a period of 4 hours. The surface temperature must not exceed 40°C (104°F).

Constant Voltage	2.35 V/Cell at 20°C/(68°F)
Current Limit	15A per 100Ah C10 rating
Time Limitation	Max. 12 hrs

Temperature Compensation	
0°C	2.45 Vpc
10°C	2.40 Vpc
20°C	2.35 Vpc
30°C	2.32 Vpc
35°C	2.30 Vpc

During commission, measure the cell voltage of the cells and after commissioning, measure the cell voltage and surface temperature of each cell and log this data. Discover Commissioning Logs are online available at discoverbattery.com/en/resources/

4.2.2 IU Charging

- The charge voltage should be set as shown in the table below multiplied number of cells in series.
- The battery should be considered fully charged when the individual cell voltages have not risen for a period of 4 hours and the inverter/charger adjust to float voltage. The absorption phase should not last more than 10 hours.

Bulk/Absorption	Voltage limit: 2.35 V/Cell at 20°C/(68°F)
	Constant current limit: 20A per 100Ah C10 rating
Float	Constant voltage limit: 2.25 V/Cell at 20°C/(68°F)

4.2.3 IUI Charging

Use an I-U-I or I charger that can charge the battery with constant current at elevated voltages greater than 2.50VPC to 2.80VPC. Charge with IU characteristic as described above. An additional balance phase is followed after the absorption phase in IUI characteristic. Keep the charging current at 1.2A per 100Ah nominal battery capacity C10 as soon as the

current has dropped to this value during absorption phase and limit the voltage to 2.65V per Cell. The balance phase should last max 1-4 hours. The battery should be considered fully charged when the individual cell voltages have not risen for a period of 1 hours or the inverter/charger adjust to float voltage.

Bulk/Absorption	Voltage limit: 2.35 V/Cell at 20°C/(68°F)
	Constant current limit: 20A per 100Ah C10 rating
Balance	Voltage limit: 2.65 V/Cell at 20°C/(68°F)
	Constant current limit: 1.2 per 100Ah C10 rating
	Time limit: 1-4 hours
Float	Constant voltage limit: 2.25 V/Cell at 20°C/(68°F)

4.2.4 Charging with a Solar Charge Controller

The charge voltage should be set as shown in the table below multiplied number of cells in series.

On-Off Controller	High Disconnect Voltage: 2.40V/Cell at 20°C/(68°F)
	Low Restart Voltage: 2.25 V/Cell at 20°C/(68°F)
Constant Voltage Controller - One Step	Regulation Voltage:2.35V/Cell at 20°C/(68°F)
	Time limit: max 24 hours
Constant Voltage Controller - Two Step	Bulk/Absorption Voltage 2.40 V/Cell at 20°C/(68°F)
	Float Voltage: 2.25 V/Cell at 20°C/(68°F)

In Stand-alone systems, the renewable source shall be sufficiently oversized against the application load in order to avoid excessive cycling beyond design limits which may limit the battery's life expectancy.

4.2.5 Float Charge/Operation (Stand-by use)

The following is characteristic for this operating mode:

- Consumers, direct current source and battery are connected in parallel
- The charge voltage is the operating voltage of the battery and the system voltage at the same time
- The direct current source is not able to supply the maximum load current at all times. The current intermittently exceeds the nominal current of the direct current source. During this period the battery supplies power.

Float charging is used to keep the batteries in a fully charged state after IU or IUI characteristic. The charge voltage should be set at (see table below) multiplied number of cells in series

Float	Constant voltage limit: 2.25 V/Cell at 20°C/(68°F)
	Constant current limit: 20A per 100Ah C10 rating

4.2.6 Balancing charge

To avoid permanent capacity loss and acid stratification in cycling operation the goal is to achieve a complete recharge (100% SoC) after every discharge. Capacity loss and acid stratification will threaten the battery's state of health.

In Stand-alone Systems this is not always possible as in Stand- alone applications where the RE source depends on the weather conditions causing the load to exceed the designed limitations.

For Hybrid Systems with diesel generators/grid the charging source is always available but the boost charging time is restricted to favor a more efficient utilization of the diesel.

The less complete the daily recharge is, the more frequently a balance charge will be required to protect the battery from sulphation and lagging cells. When short charging times are used then balance charges are required at frequent intervals, preferably every month.

Balance charges are also required after incidents of excessive stress for the battery (deep discharges with inadequate charges) or when the individual cell voltages show excessive deviation from the average (lagging cells and sulphation problems). Should the voltage in individual cells deviate from the average value more than the following limits, perform a balance charge. Balance charge is generally required when the total spread between cells is greater than 0.04V under float charge conditions.

Perform the balance charge as follows:

1. Balance charge voltage is 2.35-2.4 Vpc for a maximum duration of 48 hours. The charge current must not be higher than 20 A per 100 Ah nominal capacity.
2. If the maximum temperature exceeds 45 °C, terminate the charging process or switch to float charge to allow the temperature to drop.
3. The end of the balance charge is reached if the current has decreased to a value lower than 5A per 100Ah C10 rating

4.3 Temperature Limits

The battery is designed to perform optimally at temperatures between 15-30°C. At lower temperatures the battery capacity is lower and at elevated temperatures the life is reduced. A maximum ambient operating temperature of 45°C/113°F must not be exceeded.

Sub-zero temperatures may cause electrolyte freezing and irreversible damage with increasing depth of discharge (DoD). The minimum safe temperature versus the cell depth of discharge:

Depth of Discharge (DoD)	<20%	20% – 40%	40% - 60%	60% - 80%
Freezing point	-40°C / -40°F	-30°C / -22°F	-20°C / -4°F	-15°C / 5°F

4.4 Charge Current Limits

Charging current in general should not exceed 30A/100Ah C10 rating.

5. Battery Maintenance

VISUAL INSPECTION AND CLEANING INSTRUCTIONS

Check for any visible defects such as cracked jars, loose terminal posts and oxidized connectors. To avoid leakage currents and the associated risk of fire, keep the battery dry and clean. Clean with clear water. Do not use any solvents or detergents. Avoid electrostatic charges. Discover Maintenance Logs are online available at discoverbattery.com/en/resources/

BI-ANNUAL MAINTENANCE

- Check/record Battery voltage
- Deviation testing of cell voltages (deviations signal short circuit)
- Deviation testing of cell temperatures (deviations signal imbalance cells)
- Check if balanced charge is applied
- Confirm daily DoD per cell
- Confirm max DoD per cell does not exceed the allowed limit
- Confirm charging factor is within acceptable limits
- Confirm that charge settings correspond to recommendations

ANNUAL MAINTENANCE

- Further to the bi-annual maintenance, do the following:
- Check/record Battery voltage
- Deviation testing of cell voltage (deviations signal imbalance cells)
- Deviation testing of cell temperatures (deviations signal short circuit)
- Check/record if connectors are firmly tightened.
- Inspect/record the racks for corrosion or loss of integrity
- Check/record if ventilation is sufficient.
- Check/record battery room temperature

6. Faults

Should faults be detected in the battery or the charging device, contact your servicing dealer immediately. Keeping records of all measured data will simplify fault detection and corrective action. A service contract with your servicing Discover® dealer will help to detect faults in time.

7. Testing

Check that the battery is fully charged, before testing new batteries. Ensure that a sufficient commissioning charge has been applied and the battery is fully charged.

PERFORMING CAPACITY TEST

Necessary tools:

- Suitable test load
- Voltmeter
- Stopwatch
- Battery logbook to record measurements

1. Fully charge the battery system
2. Make sure that all connections are clean, tightened and non-corroded
3. Interrupt the connection between the battery system, the charger and all consumers
4. Prepare an adjustable load that you can connect to the battery system
5. Prepare the voltmeter to test the voltage of the battery cells and battery system
6. Connect the test load and the voltmeter. The load must correspond to the nominal capacity test rate. Simultaneously start a time measurement.
7. Check connectors for excessive heating
8. Keep the test load current constant and measure the voltage of the battery system in regular time intervals.
9. Log the discharge time once the permitted minimum voltage is reached
10. Calculate the capacity of the battery system using following formula:

$$\text{Capacity (\% at 20°C)} = \frac{T_a}{T_s} \times 100$$

T_a = actual discharge time until the permitted minimum voltage is reached
T_s = theoretical discharge time until the permitted minimum voltage is reached

11. Reconnect the battery system as originally connected and perform a fully charge

The recommended practice is to replace the battery if its capacity is below 80%. Following the test, it is necessary to review the battery sizing to determine whether the remaining capacity is sufficient for the battery to perform the intended function. Additional characteristics such as abnormality of cell temperature and cell voltage are often requiring complete battery or cell replacements. Individual cell voltages should not deviate more than 0.15 VPC from the average voltage of all the cells in the group.

8. Storage

If lead acid batteries are to be taken out of operation for extended periods of time, they must be placed fully charged in a dry, frost-free room. To avoid damage, perform periodical balance charging or permanent float charging.

9. Transport

Be sure that all cells are protected against short-circuit. Be sure to document and transport all cells or batteries according to local department of transportation rules and regulations.

10. Recycling

Discover's lead acid batteries are recyclable products. All Discover Factory Warehouses and servicing dealers are qualified to accept and handle all used lead acid batteries. Contact Discover® or your servicing dealer for details.

11. Definitions and Abbreviations

- Ampacity: The allowable current-carrying capacity of a conductor measured in amps. Ampacity is the current, in Amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.
- Battery Capacity: The power a battery can deliver from full charge at standard temperature, and at a specified (usually C10) discharge rate.
- Circuit Breaker: Is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.
- DoD: Depth of Discharge or how deeply the battery has been dis-charged. Like the fuel gauge of your car, DoD is the measure of how much fuel you have used.
- I10: The constant current (I) discharge rate that can be maintain for 10 hours (10).
- MDDoD: Maximum Daily Depth of Discharge allowable
- MDoD: Maximum allowable Depth of Discharge
- OCV: Open Circuit Voltage: The voltage across the cell or battery terminals with no load applied. The maximum possible voltage across a PV array, module, or cell with no load.
- SoC: State of Charge or how much energy is still available to be discharged. Like the fuel gauge of your car, SoC is the measure of how much gas you have left.
- V: The unit of measure for voltage. Voltage is the electrical pressure which forces the current to flow in a conductor such as a wire.
- VPC: Volts per Cell. The voltage of each individual cell, each cell in a block or each cell in a battery. The system voltage of your battery is the sum of the individual volts per cell.
- 100AH C10: Battery has a capacity (C)of 100 amp hours (AH) when rated at the 10 hour (C10) rate.