Understanding Equalization

Introduction

Equalization is a specific cycle when re-charging a lead-acid battery. See *Understanding Battery Charging* for more theory. The general parameters for performing equalization are provided herein. Specific values will vary by battery technology, e.g., flooded or sealed, and by the specific manufacturing technology; therefore, specification limits provided by the manufacturer must be carefully reviewed.

Terms and Definitions

absorb charge: The second phase during the battery recharging cycle where the voltage is fixed at the bulk/absorb limit and the charging current decreases to an arbitrarily low limit.

ampere-hour (amp-hour; AH): A measure of current over time, used to measure battery capacity and state of charge.

battery capacity: The total maximum charge, expressed in ampere-hours that can be withdrawn from battery under a specific set of operating conditions including discharge rate, temperature, state of charge, age, and cutoff voltage.

charge rate: The current applied to a battery to restore its available capacity, specified in relation to total battery capacity.

NOTE A C/20 charge rate is 1/20th of the total battery capacity measured in amp-hours, e.g., if the capacity were 100 amp-hours, a C/20 would be 5 amps taking at least 20 hours of bulk charging to recharge.

depth-of-discharge (DOD): The ampere-hours removed from a fully charged battery, expressed as a percentage of rated capacity.

discharge rate: The current removed from a battery measured in amps.

equalization: When required, the process of restoring all cells in a lead-acid battery to an equal state-of-charge, typically for a duration longer than normal recharging.

intrinsic battery voltage: The open circuit voltage of a fully charged battery after the gassing within the electrolyte from the charging operation has stopped and the resulting polarization of the battery plates has dissipated.

NOTE Sometimes called the battery rest voltage.

self-discharge: The tendency of all batteries to lose energy to internal chemical reactions within the cell.

state-of-charge (SOC): The ampere-hours remaining in a battery, expressed as a percentage of rated capacity.

sulfation: The formation of lead-sulfate crystals on the plates of a lead-acid battery, which decreases battery capacity by impeding the opportunity for chemical reaction within a cell, typically caused by leaving the battery in a discharged state for long periods of time.

NOTE An equalization is often performed to mitigate sulfation.

usable battery capacity: The number of amp-hours that are available for use on an ongoing basis.

NOTE The usable battery capacity at a given discharge rate is typically 50% of the maximum battery capacity at that discharge rate. The usable battery capacity is measured from the intrinsic battery voltage level to the minimum recommended battery voltage level, while the maximum capacity is measured from the intrinsic battery voltage level to the minimum allowed battery voltage.

Operation

In order to properly recharge the batteries (see figure 1), one must use the battery specific recommended settings (available from the manufacturer). Sometimes this is not always possible, e.g., the bulk/absorb timer on many charge controllers does not allow the batteries to fully meet the desired recharge time during a short winter day. If batteries cannot be regularly charged for the full bulk & absorb cycle, then a quarterly (or monthly) equalization charge may be appropriate, assuming the battery manufacturer allows equalization charging, e.g., some sealed battery manufacturers do not recommend a separate equalization cycle.

The bulk/absorb settings for voltage and current for the normal recharge are the same settings used for equalization; however, the durations may vary, e.g., when performing an equalization with a generator after a normal, but incomplete renewable energy recharge cycle. Essentially, when doing a normal recharge as set by the charge controller or inverter, the cycle is called bulk & absorb; when doing a recharge specifically to address issues such as sulfation or extended float charging, the cycle is called equalization.

Lead-acid batteries require up to 5% more ampere-hours to recharge to the intrinsic battery voltage than the ampere-hours used when discharging; this efficiency loss is integrated in the recharge cycle. A good practice is to over-charge flooded batteries by 2% each day and 5% once per week above the nominal usable battery capacity. This is accomplished by keeping the battery at the absorb voltage until the number of excess ampere-hours has been transferred to the battery. For example, if the battery bank is rated at 400 ampere-hours and a 2% overcharge is required, maintain the absorb voltage after reaching the normal low trickle charge until an additional 8 ampere-hours are transferred, e.g., less than 1 hour with a generator or renewable energy system providing 10 amperes. Regular equalization is a critical component for flooded batteries in an off-grid system. The renewable energy system and battery bank should be sized so that a typical daily DOD is < 15% (e.g., at night for a photovoltaic system) and external

recharging should start is the SOC is < 30% (note a recharge must occur before SOC reaches 50% or 100% DOD of usable battery capacity).

Sealed batteries generally do not need equalization in off-grid systems, since the renewable energy recharging process uses the same settings as would be used for equalization. If the batteries are not fully charged by the renewable energy system, then the generator based battery charger will be using the equalization settings to recharge the batteries. In battery backed-up on-grid systems, sealed batteries may require quarterly equalization (if so allowed by the manufacturer), if there are no grid outages, e.g., the batteries are only seeing a float charge (to recover the normal self-discharge losses).

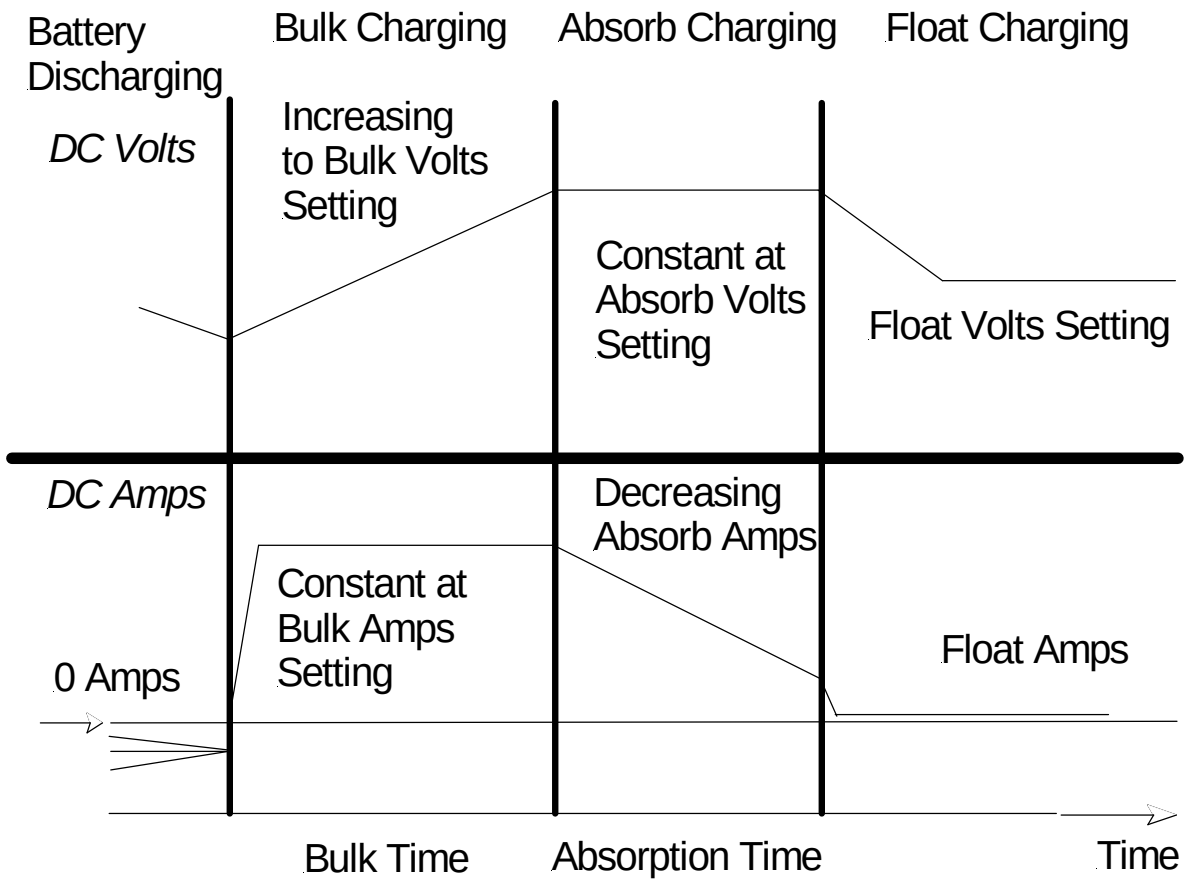

Figure 1 Battery Charging Stages