SCHAFFLER

Power Electronics for the Railway Industry

Battery Charging – the Scientific Way

Date

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Introduction

Battery charging of large expensive batteries is more complex than meets the eye. Most inexpensive battery charger simply choose a charging voltage higher than the open circuit voltage but slightly lower than the gassing voltage. This does not give optimum performance of the batteries and reduces their effective life.

Problem Statement

Batteries are very often badly treat mainly because of the lack of knowledge about the nature of batteries. The most important result is short battery life.

Most battery chargers do not discriminate between battery charging and Standing Load that the battery charger is required to provide simultaneous power. Usually the standing load takes preference and the batteries take whatever is produced at the output of the battery charger.

This is what happens:

Constant current charging without voltage limiting, high cell voltages are possible which lead to grid corrosion and gassing.

Previous Options

Batteries are often charged at a constant voltage regardless of the battery condition. In some instances, only a transformer – rectifier with a limiting inductor produces the charge to the batteries. Little consideration is given to Equalise Charging This treatment will severely reduce the life of the battery.

SCHAFFLER Solution

The best way to charge lead acid batteries is to follow the algorithm of Constant Current (I), followed by Constant Voltage (U) and finally Constant Current (I) charging curves. This is commonly referred to the **IUI** algorithm.

Constant current charging provides the fastest way of returning charge to the battery and provides cell-to-cell equalisation. This is desirable when there are a number of cells in series as it tends to eliminate charge imbalance in the battery. Charge is delivered equally to all cells independently of charging voltage for each cell. However, without voltage limiting, high cell voltages are possible which lead to grid corrosion and gassing.

Constant voltage region provides for a more conservative approach to charging the battery. This mode of voltage charging will reduce the risk of grid corrosion and gassing at the expense of recharge time.   The major downside to constant voltage

charging is that cell-to-cell charge equalisation is not likely. Saturation levels differ between cells and series strings will therefore float at different voltages unless individually charged. There is some levelling of cell voltages over time since gassing and corrosion will force higher cell voltages down and lower cell voltages will be forced up to maintain the string voltage. This however results in an increase in the float current with battery age.

Constant current charge near the end of the charge cycle is an effective way of providing cell-to-cell equalisation. The finishing current should be moderate so that charge and recombination reactions can remain near equilibrium to minimise the net gas generated. A typical value for the finishing current is 5A per 100Ah capacity (C_{20} rate).

Schaffler Battery Charger

The MiniCSU2 has the facility to perform IUI charging regime. The finishing current is set by equalise current limit which is generally lower than the float current limit. When the battery reaches float voltage the battery charging current will decrease exponentially until it reaches the equalise current at which point constant current charging resumes at the equalise current limit. Equalisation current parameter **Bllim Vb>Vfl** should be set at the C_{20} rate to maximise cell-to-cell equalisation but limit the cell voltage above float in order to minimise the risk of gassing and grid corrosion. Low equalisation currents will extend the constant voltage region and therefore increase the charge time.

For faster charge times during equalisation, higher charging currents may be used with the equalise voltage programmed in accordance with battery manufacturer recommendations. Note that charging currents above the C_{10} rate have reduced efficiency and state of charge calculation may not reflect the battery capacity.

For further information on charging of VRLA Batteries the reader is referred to chapter 9 of *Valve-Regulated Lead-Acid Batteries*, edited by Rand, Moseley, Garche and Parker; Copyright 2004 Elsevier.

Below is an example of a IUI charge when recovering from deep discharge.
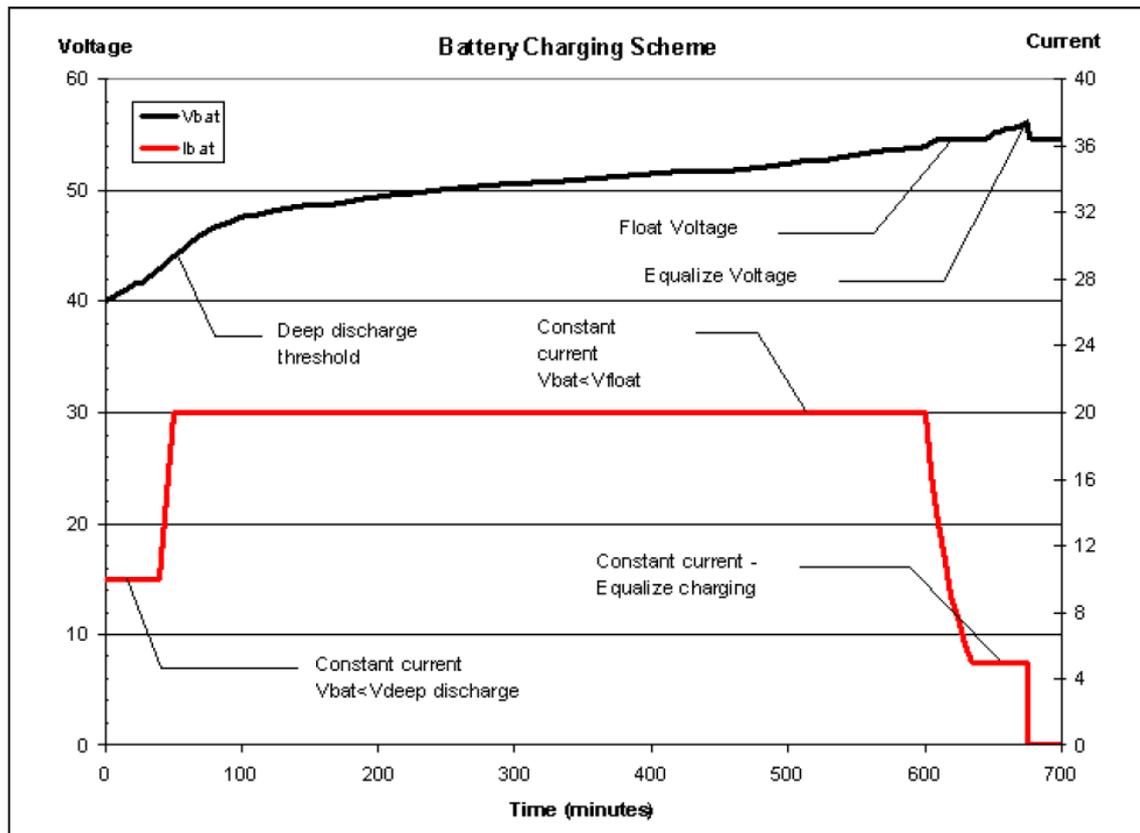
The graph is for a 48V battery, but the same applies for 72 and 280V batteries. As controlled current and voltage charging is provided, there is no requirement for a timer function - the battery will naturally terminate certain modes of charging once a state of charge (SOC) is reached.

Cross Reference Terminology

To cross reference to the more conventional terms, the charging curve is as follow:

Bulk Phase - (Our term is **Constant Current Float Region Charging**): Battery charging current held constant at Blimit (Vbat < Vfloat), which is programmable and usually set to C10 rate.

End of Bulk Phase - (Our term is constant **Float Voltage Region**): Battery voltage held constant at Vfloat. The battery charging current naturally decays at an exponential rate toward zero. Time to get to this region is dependent on the battery depth of discharge when recharging was commenced, not a preset timer.

Gassing Phase - (Our term is **Constant Current Equalise Region Charging**): If the Equalise mode is enabled, then the charger will initiate this phase once the battery charging current when in the above **Float Voltage Region** has decayed to the **Equalise Charging Current Limit** (programmable and usually set to 50% of the limit in the "Bulk Phase"). The battery charging current is held constant at Blimit (Vbat > Vfloat) until the Equalise Voltage is reached. The maximum battery voltage is limited to the programmed value of the Equalise Voltage, and the Equalise or "Gassing Phase" is terminated when either the battery charging current decays to

below the minimum Equalise End Current or the maximum time limit / duration is reached.

Battery Over temperature: If a battery temperature sensor is used and the battery overheats during charging, then an over temperature condition will be detected and the charging current limit will be reduced to zero until the battery cools down.

Battery Ready Phase - (Alternate term for return to Float Voltage): At the end of the Equalise phase, the charger reduces the bus set point voltage back to the programmed Float voltage and the battery voltage naturally decays from the higher equalize /gassing voltage back to the lower float voltage of a fully charged battery.

The Equalise or "Gassing" phase is automatically initiated by one of the following stimuli: The battery voltage fell below the programmed "**Equalise Start Voltage**", the charge extracted from the battery (as measured by the controller remaining capacity meter) exceeded a threshold value (e.g 20Ah withdrawn), or the operator Manually starts Equalise.

The charging times are NOT recorded by the charger, but the State of Charge is recorded (as long as the controller is always powered up off the battery bus). If the controller stays alive while the batteries and system are being used away from the AC sources, then the controller will know EXACTLY how much charge was extracted from the batteries (Ah) and will update the "remaining capacity" meter both during the discharge and the recharge.

Summary

The understanding of the chemistry of batteries and their behaviour to charging is of paramount importance to the life of the batteries. It is essential that an intelligent battery charger be used to prolong the life of large battery banks.