INTELLIGENT BATTERY CHARGING:
AN ALTERNATE SOLUTION TO YOUR BATTERY WOES

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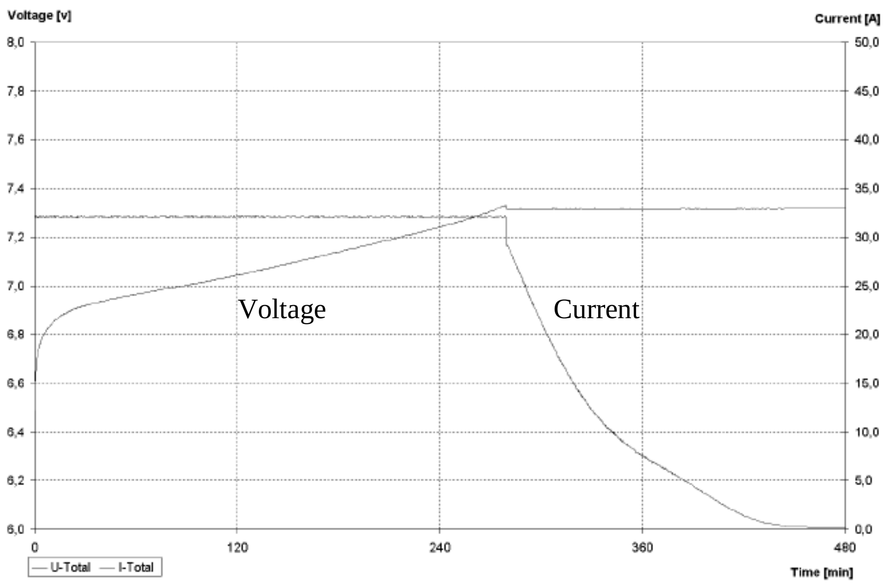
OVERVIEW

Batteries today in standby applications are typically charged with current limited constant voltage charging systems. This charging has two phases; the first is constant current, where the charger remains in current limit until the battery voltage reaches the set voltage limit of the charger, and the second is the constant voltage phase, where the current drops off and the battery voltage is held constant by the battery charger.

Constant Voltage Charging of 5 FNC Cells (Figure 1)



Many of these charging systems incorporate dual voltage outputs, float voltage and boost or equalize voltage. The float voltage is designed to provide sufficient overcharge to maintain the battery at 100% state of charge. The resulting float charge current (mA/100Ah) is responsible for water consumption and corrosion of the positive plate in lead acid systems. The float current increases with increased battery temperature and can contribute directly to the reduced life of lead acid systems. Alkaline battery systems (nickel cadmium, nickel metal hydride, etc.) do not have the internal corrosion issue, but their water consumption and life expectancy are directly correlated to increased operating temperatures.

The boost or equalize voltage is usually much higher and designed to return the battery to full state of charge in a short period of time after a discharge. This boost mode is typically initiated manually or automatically after loss of AC power. A battery will spend the majority of its life on float charge and only be in the boost mode after return of power after a power outage or other events resulting in discharge of the battery. In most cases, a battery is seldom used to its full design potential and the battery is never discharged completely. However, after these outages, when the battery is recharged on boost, either automatically or manually, it is charged for the same time period as if it were discharged completely. The result is significant overcharge of the battery resulting in excessive water loss, increase in internal battery temperature and general reduction in battery life.

The purpose of this paper is to present a simple, intelligent charging scheme that will help to reduce these effects of overcharge, grid corrosion, water consumption, higher internal cell temperatures and reduced life. In addition, advanced battery systems such as nickel metal hydride and lithium ion that require careful control of the charging algorithm (temperature, voltage) can be successfully charged and controlled using this general scheme.

CONTROLLING BATTERY CHARGING

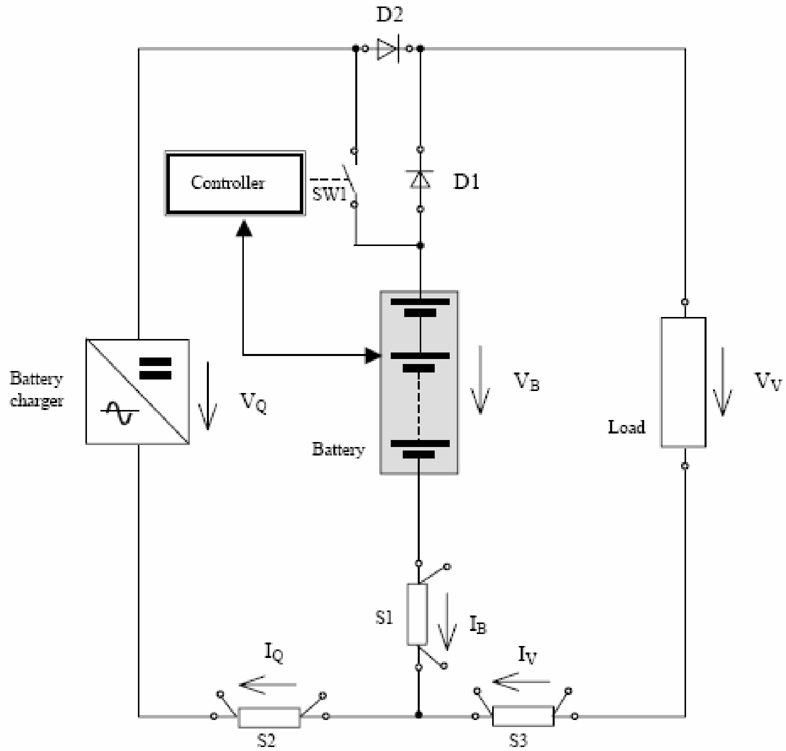
Today, advances in electronics and programmable circuits provide us with the ability to design circuits with the custom capabilities to do almost anything. But often the cost of design of this customization for the average user is prohibitive. In this paper, it will be demonstrated that, with the use of a standard off the shelf constant voltage battery charger and a separate configurable monitoring and controlling device, it is possible to reduce these detrimental effects of battery charging. The result is reduced water consumption and extended battery life.

A simple circuit was developed to test the function of the controller with the battery charger. The monitoring function of the controller was used to collect the test data and monitor the testing. In order to demonstrate the concept, two tests were devised. One test, which simulated an application using a high rate battery to complete the normal sequence (trip / close / spring recharge) of a medium voltage switchgear followed by a recharge based on a pre-determined final state of charge of the battery, and a second test using the same load sequence with several trip/close cycles before recharge from a lower, preset state of charge. This is a limited test and only tests a few of the control parameters of the controller, but clearly demonstrates the potential for the use of multiple control parameters in a charging scenario.

Battery Controller and Monitor, Figure 2

The basic circuit used for the testing is shown below in Figure 3. A brief description of the equipment used is included in the Legend.

Basic Circuit Diagram, Figure 3



LEGEND:

Battery: 10 cells FNC 602 HR
Battery Charger: SCR single voltage output, current limit 7 Amps
Controller: Hoppecke BCMU
Load: constant current, variable
S1: battery shunt (current I_B measurement)
S2: charger output shunt (current I_Q measurement)
S3: load shunt (current I_V measurement)
D1: blocking diode (voltage drop 0.75VDC)
D2: dropping diode (voltage drop 0.78VDC)
SW1: switch

The battery is a fiber nickel cadmium (FNC) high rate cell.

Battery charger used is a basic silicone controlled rectifier (SCR) constant voltage with current limited output. Includes dual voltage output for float voltage and boost (equalize) voltage and standard analog controls.

The monitor / controller used has the following characteristics:

- Inputs
  - 2 Voltage inputs (0 – 160VDC)
  - 1 Current input (0 – 9999A as mV)
  - 3 Temperature (digital inputs) –55 deg C to +125 deg C
  - 2 digital inputs (0V to 24VDC)
  - 2 Amp hour inputs
    - Main counter 0 – 100% SOC
    - Overcharge counter >100%

- Data Logging
  - 0.1 sec to 10 sec sampling frequency for input data (2 Mb storage)
  - Summary data (12 month storage)
- Outputs
  - 5 relay switches controlled by inputs, input differentials or time

TEST 1

Test Conditions:

Charger output
V (nominal) = 16.0 VDC
I (nominal) = 7.0 Amps

Load Profile
L1 = 10 Amps for 10 minutes
L2 = 5 Amps for 10 minutes
L0 = Rest for 1 hour
Repeat sequence 3 times

Relay SW1 control conditions
OPEN if SOC is <98%
CLOSE if SOC is >100.25%

Start conditions
Battery at 95% SOC

Diode D1: 0.75 V

V_Q = charger voltage I_Q = charger current
V_B = battery voltage I_B = battery current
V_V = load voltage I_V = load current

TEST 1 COMMENTS

Section A: The battery initial state of charge (SOC) is 95%, SW1 is closed, the diode D1 is bypassed, and the battery is charged up to 100.25% SOC. During the application of L1, the battery does not receive any current from the battery charger and is discharged. During L2, the battery has 3 Amps available for recharge, and during L0 (rest), the battery is fully recharged. Figure 1-1 shows the battery, charger and load voltages during this period. Figure 1-2 shows the available current to recharge the battery during this period and Figure 1-3 shows the state of charge of the battery. Note that the battery is discharged initially below 94% SOC before available current allows recharge to the set point of 100.25% SOC.

Section B: The switch SW1 is open and diode D1 prevents charging of the battery. The load sequence begins again and the battery is discharged during L1 and the charger again picks up the load during the application of L2. Since SW1 is open, the battery voltage is depressed, while the charger voltage output remains constant supplying the load. Note that in Figure 1-3, the state of charge is reset to 100% when the discharge step L1 is initiated. This prevents inaccurate SOC readings after several cycle applications. Before the end of Section B, the load L1 is again applied and, in Figure 1-3, we see the state of charge drop below the SW1 setting of 98%. At this point, SW1 is closed and charging begins again.

Section C: In the final section, the battery is recharged and we see a repeat of the conditions in Section A.

FIGURE 1-1 Voltage Plot

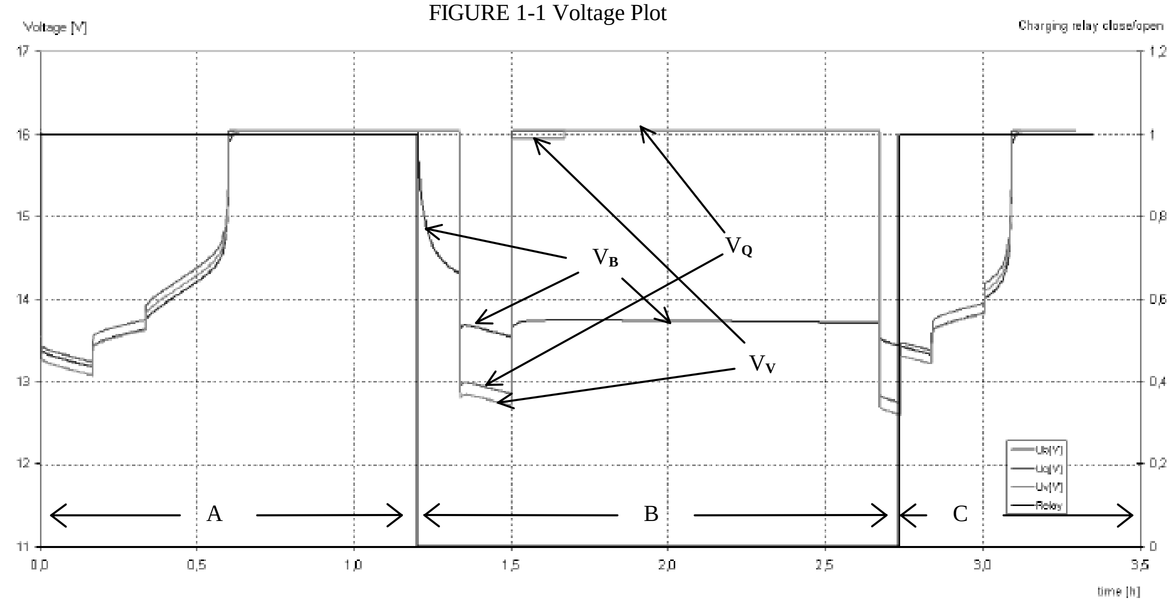


FIGURE 1-2 Current Plot

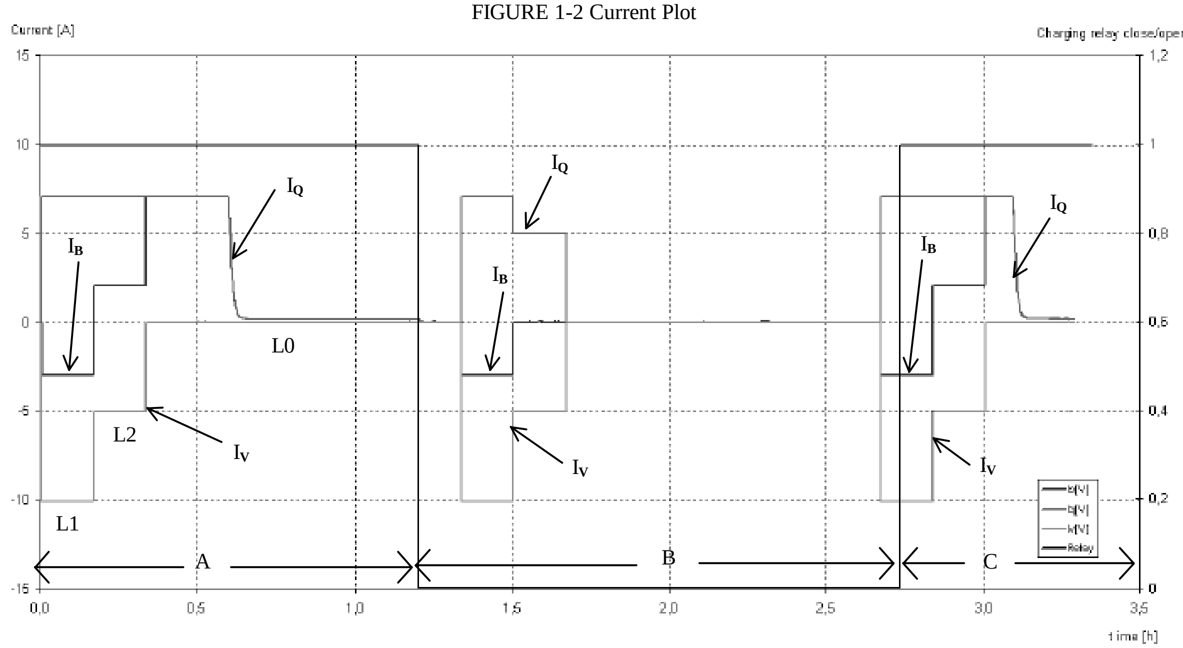
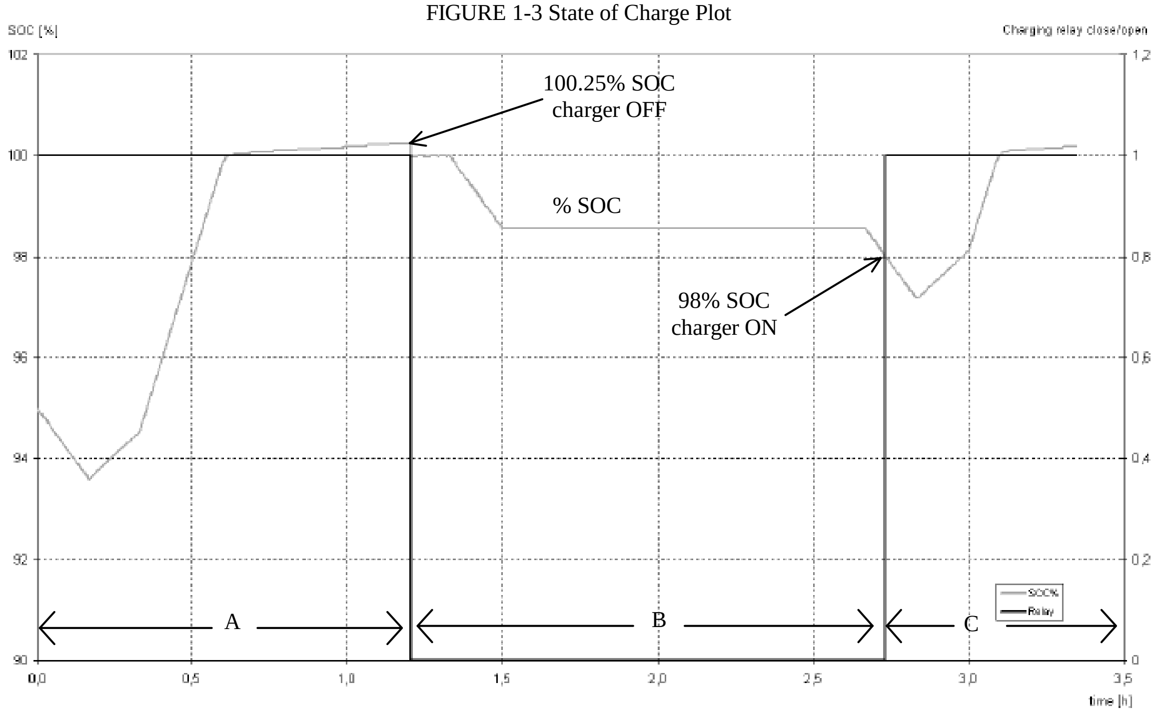


FIGURE 1-3 State of Charge Plot



TEST 2

Test Conditions:

Charger output

V (nominal) = 18.0 VDC

I (nominal) = 7.0 Amps

Load Profile

L1 = 10 Amps for 10 minutes

L2 = 5 Amps for 10 minutes

L0 = Rest for 10 minutes

Repeat sequence 3 times

Relay SW1 control conditions

OPEN if SOC is <95%

CLOSE if SOC is >100.5%

Start conditions

Battery at 100% SOC

Diode D1: 0.75 V

Diode D2: 0.78 V

V_Q = charger voltage	I_Q = charger current
V_B = battery voltage	I_B = battery current
V_V = load voltage	I_V = load current

TEST 2 COMMENTS

In Test 2, there is a voltage dropping diode D2 included in the circuit. This simulates a voltage drop between the charger and the loads.

Section A: The battery initial state of charge (SOC) is 100%, SW1 is open, the diode D1 is in place, and the battery is not being charged. During the application of L1, the battery does not receive any current from the battery charger and is discharged. During L2, the load receives all its current from the battery charger. Figure 2-1 shows the battery, charger and load voltages during this period; note that the load voltage is lower than the charger output voltage due to the dropping diode D2. Figure 2-2 shows the current taken from the battery during this period, and Figure 2-3 shows the state of charge of the battery. Here, the battery SOC continues to decline during Section A.

Section B: The battery SOC drops below the SW1 set point of 95% (Figure 2-3). SW1 is closed and diode D1 is bypassed and allows charging of the battery. The load sequence continues, and the battery is discharged during L1, and the charger picks up the load during the application of L2 while allowing 3 Amps current to recharge the battery. Since SW1 is closed, the battery and load voltages are depressed, while the charger voltage output remains constant. Note that in Figure 2-3, the state of charge is increased during this section to the set point of 100.5%

FIGURE 2-1 Voltage Plot

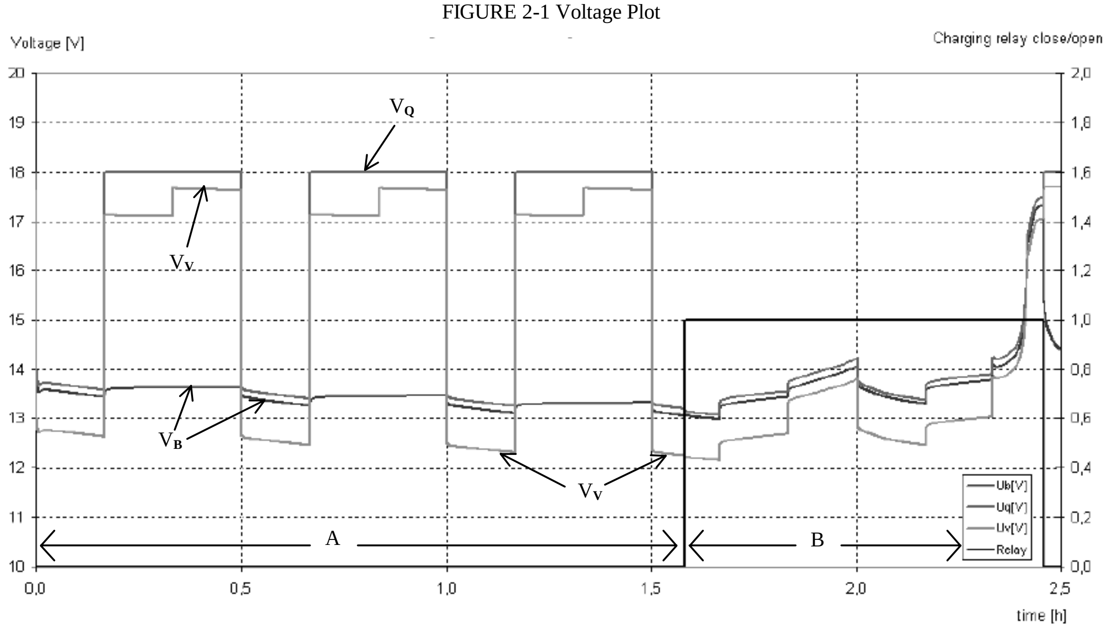


FIGURE 2-2 Current Plot

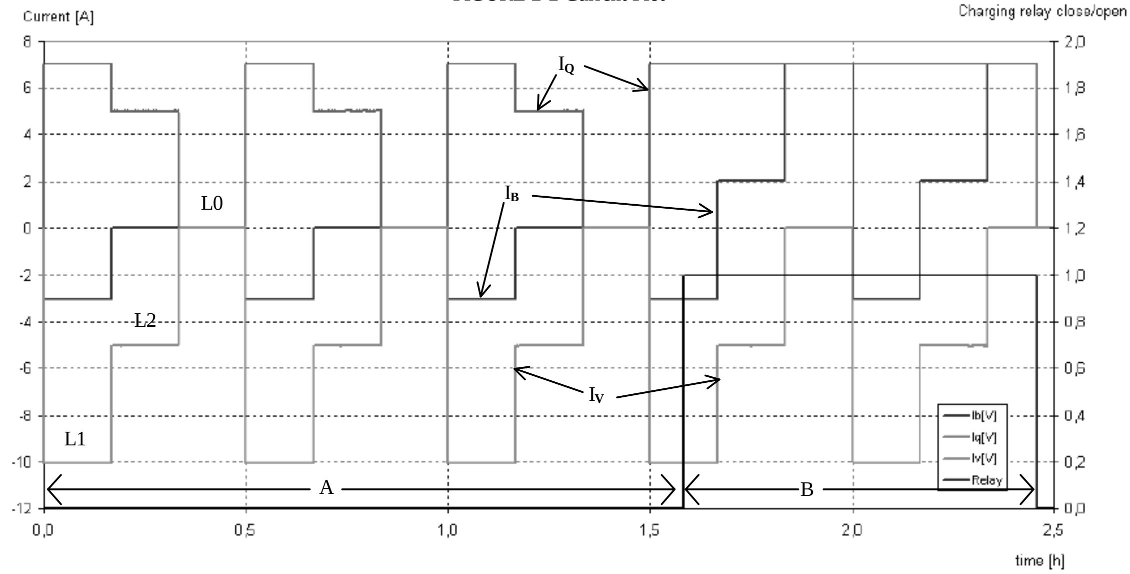
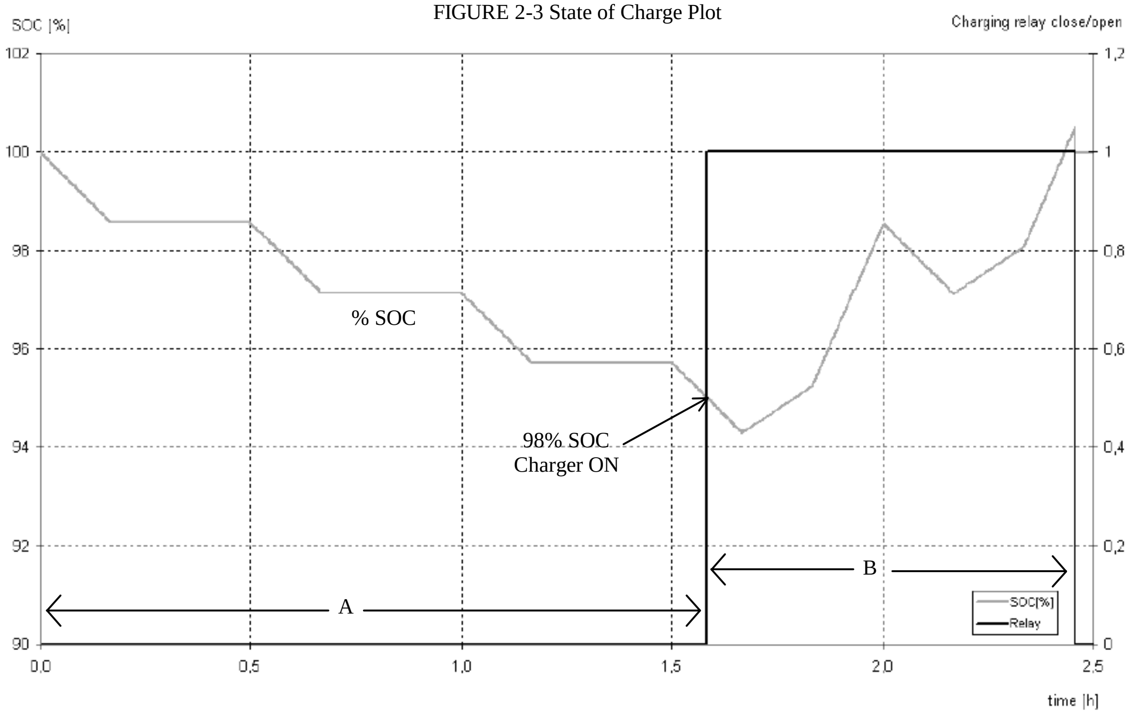


FIGURE 2-3 State of Charge Plot



CONCLUSIONS

Further testing of all functions of the controller are ongoing. But, by the application of these simple tests, it can be seen that it is possible to use a standard battery charging system with an external controlling device and simple circuits to limit the charging of a battery. This test allows charging based on state of charge, but other custom applications using combined or individual control parameters can be used to provide more detailed charge control of a battery system.

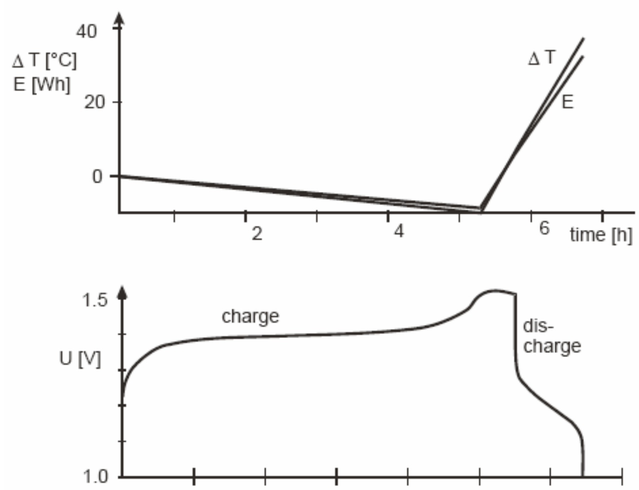
As an example, it would be possible to set the following combined control conditions:

Charge ON if battery SOC is <95%
Charger OFF if battery SOC is >100.5%
Charger OFF/ON based on ambient temperature*
Charger OFF/ON based on battery temperature*
Charger OFF/ON based on differential temperature between ambient and battery*

* *These parameters could be used to prevent thermal runaway of a battery or terminate charging when the maximum recommended operating temperature of the battery is exceeded.*

The controller was originally designed to control charging of advanced batteries, such as nickel metal hydride where there is a steep rise in the battery temperature as the voltage rises near the end of charge (Figure 4). Here, the control parameter (battery temperature) is used to limit charging to the battery.

Constant current charge of sealed NiMH batteries showing thermal characteristics during charging.
Figure 4



There will be applications where a charge controller may not achieve an appreciable improvement in maintenance or life of a battery; however, the safety aspect of a high temperature disconnect to protect a site from thermal runaway or battery damage may justify the use of such a system. The addition of a standard modem line makes remote monitoring and controlling of a system possible and allows for downloading up-to-date information on any site installation, including the possibility of remote load testing.

Overall, the advantages of using such a device with a standard battery charger seem to be a benefit to any type of battery system.

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