Fuzzy Logic-Based Estimation of State-Of-Health of Portable Defibrillator Batteries

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Abstract

It is critical to know the condition of batteries in portable external defibrillator batteries to minimize the number of extra batteries that need to be carried with the devices, to ensure that the battery packs are fully utilized, and in the worst case, to prevent failure of the device. Conventional measurement of battery state-of-charge (SOC)/state-of-health (SOH) is obtained through a coulomb counting technique that offers rather limited accuracy. In the present project, we have used a combination of electrochemical impedance spectroscopy (EIS) and fuzzy logic data analysis to estimate, to within a few percent accuracy, the SOH of portable defibrillator batteries.

Galvanostatic EIS measurements were made on sealed lead acid battery packs used in the Medtronic Physio-Control Lifepak 500™ external defibrillator unit over a frequency range of 1Hz to 10 kHz using a Solartron 1280 B combined potentiostat/galvanostat and frequency response analyzer (FRA). The test procedure comprised the following steps:

1) EIS measurement over the frequency range of 1 Hz – 10kHz.
2) Constant current discharge at 1 A for 5 minutes.
3) Constant current discharge at 7 A for 10 seconds.
4) Rest at open circuit for 1 minute.
5) EIS measurement.
6) Repeat steps 2-5 until end-of-discharge is reached (1.75 V/cell).

Clearly good separation can be seen between the different curves at different SOC's.

Measurements were made on a total of four battery packs. As a battery pack was cycled, the number of 7A pulses that the battery could deliver decreased from an initial maximum of 20 pulses.

Figure 1a shows the magnitude of the impedance for cycle 9 at different battery SOC's while Fig. 1b shows the phase angle of the impedance for the same SOCs and cycle.

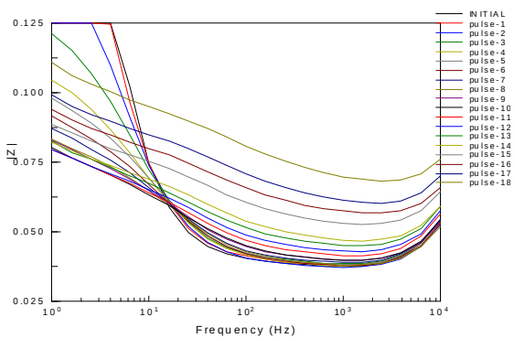

Fig. 1a. EIS, Magnitude of the Impedance |Z| *vs.* frequency at various SOCs. Medtronics/Physio-Control, 2.5 Ah, 8 V, Lead Acid, cycle 9.

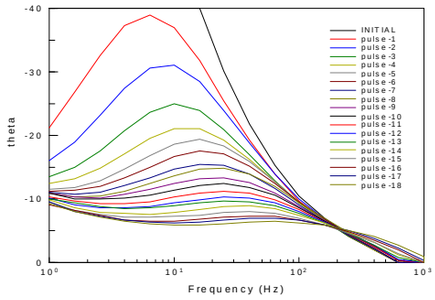

Fig. 1b. EIS, Magnitude of the Impedance |Z| *vs.* frequency at various SOCs. Medtronics/Physio-Control, 2.5 Ah, 8 V, Lead Acid, cycle 9.

A 3- input, 1-output fuzzy system was developed using custom algorithms to implement the Standard Additive Model (SAM) to predict the number of pulses that could be obtained from the battery. The resulting model was able to accurately predict (within ± 1 pulse for batteries used to develop the model and within ± 2 pulses for batteries not used to develop the model), the number of pulses that could be obtained from the battery packs (see Fig. 2).

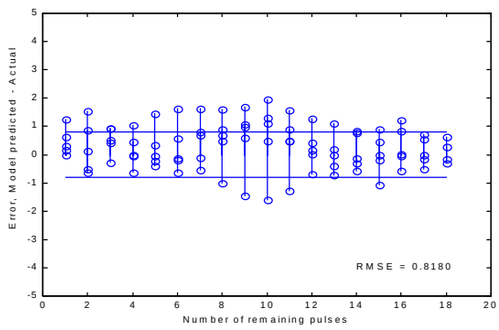

Fig. 2. Fuzzy Logic Model, # of remaining pulses – Error. Medtronics/Physio-Control, 2.5 Ah, 8 V, Lead Acid – Testing Data, Battery 0008.

In conclusion, we have developed an accurate means of determining the SOC and SOH of portable defibrillator battery packs.