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Dynamic response analysis on a 9 kW VRFB test facility

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An industrial-scale Vanadium redox flow battery test facility (IS-VRFB) is operating at the Electrochemical Energy Storage and Conversion Laboratory of University of Padua aiming to explore the technological developments from VRFB laboratory test-beds to grid scale VRFB systems. The 40-cell 600-cm^2 active-area stack and two 550-L tanks provide a power of 9 kW and an energy of 27 kWh. An AC/DC bidirectional static converter that controlled by the battery management system (BMS) provides the electric power conditioning during charge and discharge with currents up to 75 A and a variable passive load allows high-current discharges up to 600 A. The plant is fully instrumented with electrical and thermo-fluid dynamic probes and the in-house LabVIEW-based BMS provides acquisition, processing and control functions. Since VRFBs are capable of fast response times and can provide fast grid services, such as frequency regulation, it is quite important characterizing their transient behavior. Nerveless, extensive experimental campaigns for investigating the fast response of a large-scale VRFB systems, are largely missing, especially in term of fast time-domain analysis. This abstract is an early contribution in such regard, in view of real large-scale applications of the VRFB technology. Two different time intervals involving different phenomena occurring in the cell have been analyzed. Initially, the first 20 ms after battery powering were acquired using an oscilloscope with a sample rate of 2 GHz. Secondly, the first 120 s were explored by means of the BMS acquisition system a sampling rate of 0.8 Hz. In order to widely explore the fast response capability, different conditions were examined by varying state of charge (*SOC*), flow rate (*Q*), and current (*I*). The oscilloscope analyses revealed a "peak transient" time interval during which both current and voltage undergo large variations, up to 50%. During this interval, lasting few milliseconds, no reliable current and voltage value can be provided by the battery. In the longer timescale, different behaviors occurred depending on the *Q*, *SOC*, and *I*. The higher *Q* and *SOC,* the shorter the transient before a steady-state condition was achieved, with both current and voltage constant in time (Fig.1a). Preliminary analysis demonstrated the suitability of the model of Fig.1b to predict the stack dynamic response. Modelling resorted to experimental data obtained from a multichannel Electrochemical Impedance Spectroscopy (EIS) analyzer, tailored for IS-VRFB and capable of operating in the range 0-20 kHz with bias currents up to 400 A.

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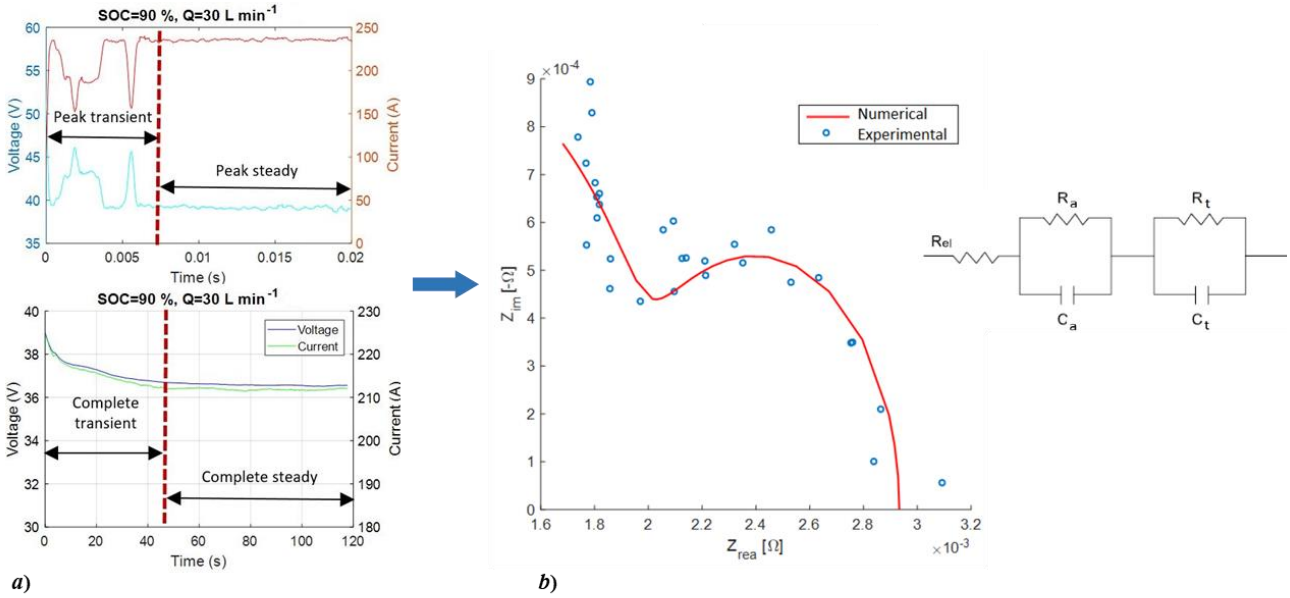

Fig. 1. a) Current and voltage trend over time in 0−20 ms and 0−120 s time range at SOC=90%, Q=30 L min^{-1}. b) Nyquist diagram of 12-th cell in the range 1–20.000 Hz and cell equivalent electric circuit as numerical model.