Cell Voltage Monitoring System

Measurement & Control for Fuel Cells and Batteries

Introduction

The SMART CVMS (Cell Voltage Monitoring System) is designed specifically for the measurement and control of cascaded voltage sources such as stacks of batteries or fuel cells.

Due to its flexibility the CVMS is used in a variety of applications; all of these applications benefit from the compact size, robustness and reliability of the CVMS.

a) Development

Design engineers incorporate the CVMS into their test stands since they can mount it close to the fuel cell under test, thus avoiding long analog wiring with the risk of noise pick-up.

b) Evaluation and Qualification

Car manufacturers build the CVMS into their prototype vehicles in order to supervise against thresholds and to optimize the performance through longterm monitoring.

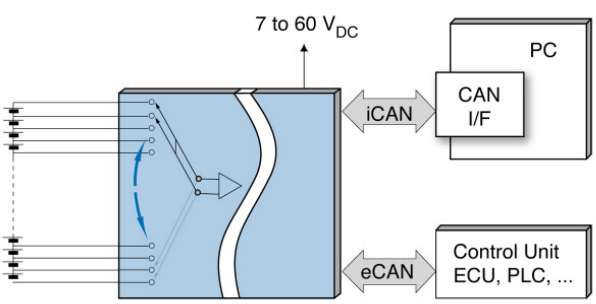
c) Series

In military applications the reliable stand-alone operation coupled with low power consumption are estimated.

CVMS Architecture

The core of the CVMS is the measurement module (CVMpro60-R3 or CVMpro90-R3). In the simplest application the measurement module is connected to a DC power supply (orange cable), the results are read via CAN bus (grey cable).

For PC operation the CAN-bus has to be converted into a typical PC-bus such as USB. For this task, a CAN-to-USB-interface (little black box) is offered. On the PC side 2 Windows software packages are provided: one for controlling the measurement module via C/C++ or via LabView programs, the other as graphical user interface.



Features and Benefits

	Features	Benefits
Input	60 or 90 channels, ±1.2V/ ±2.4V or ±4.8V, 12bit resolution, scan time 1ms/channel	Low volume per channel
Output	2 separate CAN buses	Parallel operation of control and analysis
Functions	Statistics, 2 alarms, detection of contact breaks, cell masking	Little postprocessing needed
Supply	7 to 60 V_{DC}, 6W	Connects to almost any supply
Environmental	-25℃ to +80℃, IP54	robust

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Performance

Inputs

The CVMS serves as universal measurement unit with up to 90 input channels. There are 2 different versions of measurement modules:

- the CVMpro60-R3 with up to 60 channels
- the CVMpro90-R3 with up to 90 channels

Both versions are available with 2 input voltage ranges:

- fuel cell versions with input voltage ranges of ±1.2V per channel (±2.4V per channel can be configured for measuring double cells)
- lithium-ion versions with input voltage ranges of ±4.8V per channel.

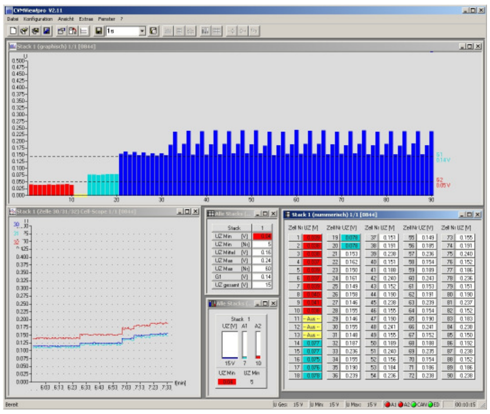
Outputs

The results are communicated as CAN messages and transmitted via two separate CAN buses.

The first CAN bus ("eCAN") typically acts as interface to the fuel cell control unit (FCCU). It just transmits 2 CAN messages: one for the specific configuration (e.g. of alarm thresholds) and one for the transfer of the condensed results (alarms, total voltage, lowest voltage).

The FCCU also drives the peripheral devices of the FC system (actuators like valves, switches, fans, etc), interfaces with the converters and communicates with other ECUs (e.g. in a vehicle network).

The second CAN bus ("iCAN") is used for setting and reading the result details (individual voltages) via 18 CAN messages. These messages can be used directly or transformed into higher level programming languages with additional software packages:



- a driver software which converts the CAN messages into an easier-to-use API (application programming interface). There are APIs for C/C++ programs and for LabView programs.
- a graphical user interface (see right picture) which displays all settings and results in graphical form thus allowing to operate the modules without the need of programming.

Since the analysis is normally performed with a PC, a suitable CAN-to-USB converter is available from SMART.

Functions

In order to facilitate control and monitoring applications, some useful functions are already implemented within the measurement module:

- real time comparison against 2 user-defined thresholds. Upon violation, flags on both CAN buses are set.
- detection of contact breaks: if the wiring between CVMS and fuel cell is interrupted, alarm flags are set.
- statistics: the sum of all individual cell voltages, the median value, the lowest voltage and the respective cell is calculated.
- cell masking: individual channels can be hided; they do not contribute to the above mentioned calculations and notifications.

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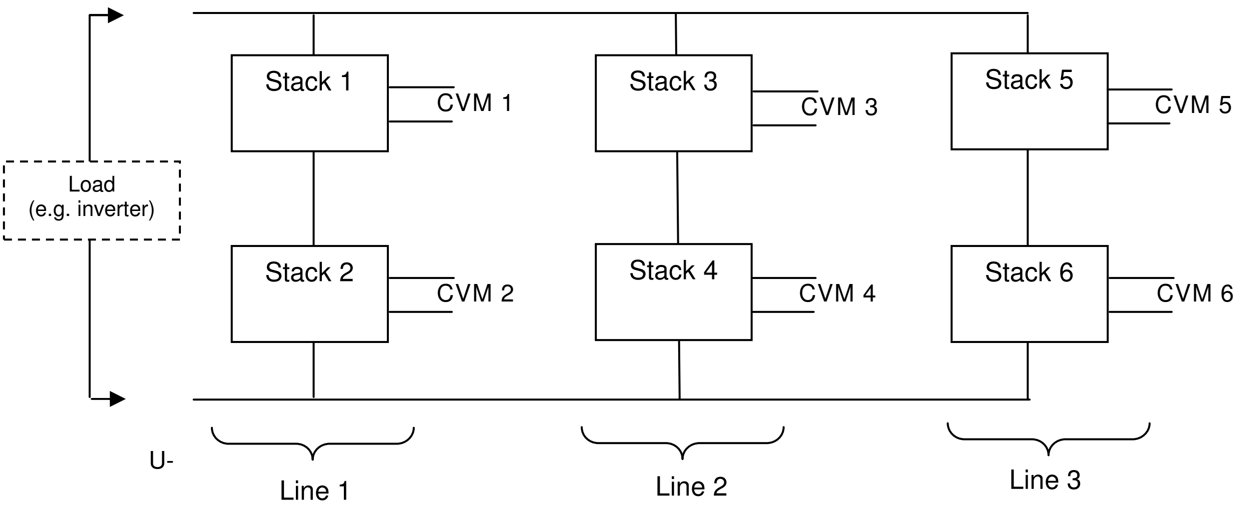
Example Fuel Cell Systems

System Structure

A typical high performance system consists of several fuel cell stacks which are cascaded in order to obtain higher output voltages. This serial configuration forms a line. Sometimes several lines even are connected parallel:



In such a system, not only the individual stack values are important but also the total values of all interconnected stacks.

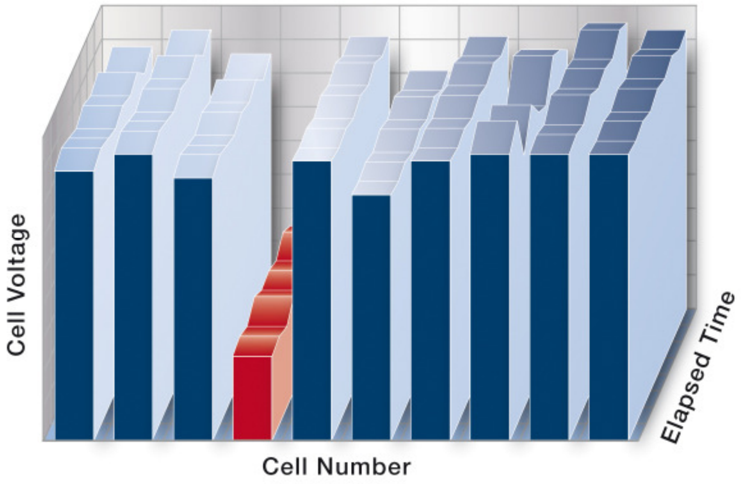
The CVMS reflects these requirements because it can be configured in rows and lines according to the actual system structure. Thus it reports also total system values.

Measurement Requirements

As different as the systems may be, they usually have a number of common objectives:

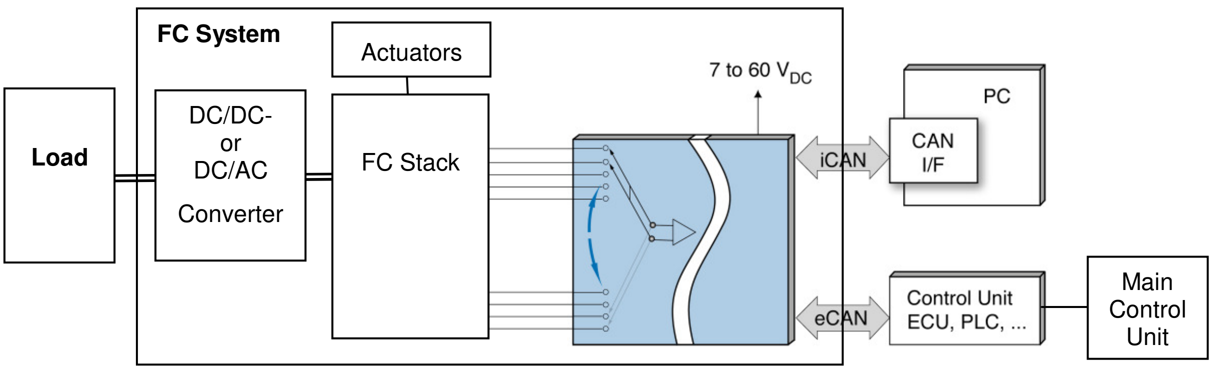
1. To ensure stable operation under changing conditions: Irrespective of environmental conditions (e.g. temperature) or load conditions (e.g. increased power off-take) the cell stack should be operated at a favourable working point.
2. To prevent malfunctions: Even in exceptional circumstances and fault situations, the system should be secure, e.g. by initiating contingency action.
3. Diagnosis: The ability to analyse a data pool is desirable for warranty claims, servicing and further optimisation.

One of the most important measured variables is the output voltage, measured either as the total voltage of a stack or as single-cell measurements. Although it is far easier to measure the total voltage, single voltage measurements (or group voltage measurements) allow us to draw a number of conclusions (see the chart):



1. From the distribution of single measurements relative to one another we can infer the medium supply and initiate system management actions accordingly (e.g. cell purging).
2. Only a single-cell measurement can indicate whether a cell falls below / rises above a critical voltage level, and where the cell is, so as to perform a safey shutdown.
3. Time-resolved measurement indicate trends. Statistical analyses enhance the quality of maintenance interval or service life projections.

Solution with CVMS



The CVMS measurement module is connected to the individual cells of the fuel cell stack. Two input modes can be selected: one cell per channel (input voltage range ±1.2V) or 2 cells per channel (input voltage range ±2.4V). The results are transmitted via CAN buses.

In a test stand application, the iCAN is connected to a CAN-USB interface card for communication with the PC; the eCAN is left open.

In a control application, the eCAN is connected to the FCCU which incorporates the algorithm and drives the peripheral components of the fuel cell system, mostly via digital outputs.

SMART

Example Battery Management System for Li-Ion Batteries

Requirements

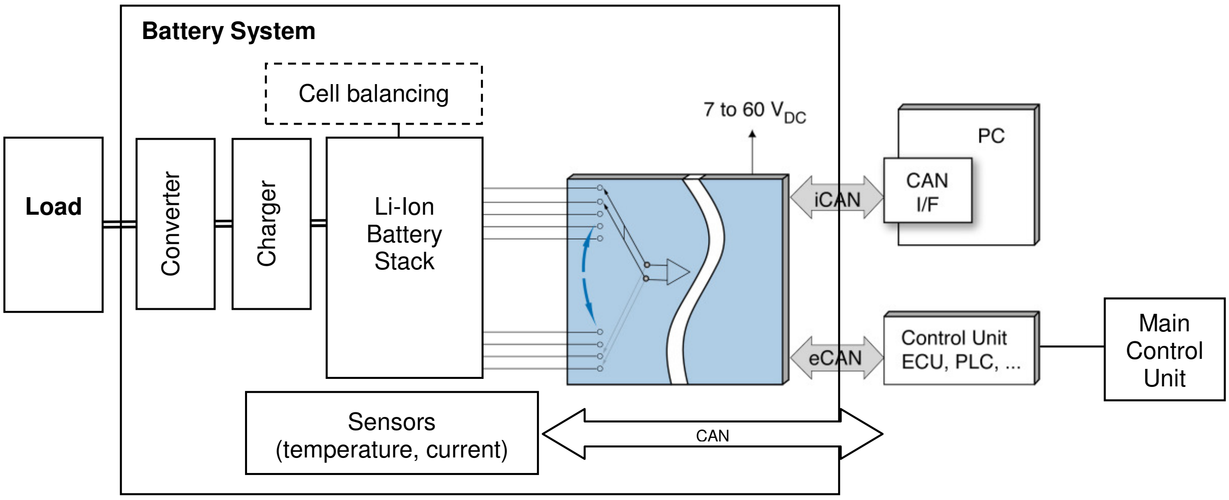
Many modern batteries use Li-Ion technology which offers high energy per volume and wide charging/discharging ranges at good lifetimes. Reliable and longlasting operation requires precise monitoring and control of each battery cell. Typical tasks for such a battery management system (BMS) are:

- Safety: protection against overcharging, undercharging, short-circuit, overtemperature
- Charge control: charge algorithms, supervision of decharging
- Monitoring of operational states: state-of-charge, state-of-health, state-of-function
- Temperature management: monitoring of temperatures, control of cooling
- Cell balancing: keeping all cells in equal condition
- Data logging: data recording, diagnostic functions
- Communication: with the vehicle network

In order to fullfill all of these requirements, precise measurements of the following parameters are necessary:

- all individual cell voltages
- several temperatures
- the battery current

Solution with CVM



The CVMS can be used for development and prototyping of the different operation algorithms. The measurement module is connected to the battery stack and monitors the cell voltages. The results are transmitted to the PC which runs the software simulation of the BMS. Additional sensors (temperature, current) are interconnected via the same CAN-bus.

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