DESIGN AND DEVELOPMENT OF A SIMPLIFIED MONITORING SYSTEM FOR EVs

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ABSTRACT

The Simplified Monitored System (SMS) is an electric vehicle data sensing, acquisition, logging, control and display system developed for electric vehicle fleet testing. A lower system cost is achieved by selecting suitable transducers and a reduced number of monitored parameters, that could satisfy the data needs of most interested groups, such as fleet operators, decision makers and industry. The simplicity in the installation procedure of the transducers is very important for easy retrofit and removal after the end of the testing period. The inherent reduction in hardware and data handling man-hours is also a very important factor for efficient fleet management. A user friendly “Data Administrator” software has also been developed, performing EV test programming, data retrieval and other functions between the SMS datalogger and a PC.

1. Introduction

The Simplified Monitoring System has been developed in the framework of the JOULE II project : “Programme for the Collaboration between CEU and National Programmes on Electric Vehicles in Europe”.
It has been designed with the following objectives:
a) reducing the cost of EV monitoring;
b) defining a limited but sufficient number of parameters to adequately characterize EV performance according to fleet’s assigned duty;
c) regulating and simplifying the installation on-board of data acquisition systems and related sensors;
d) developing a common format for data collection, analysis and presentation.

1.1. SMS Description

The SMS is made up of a box (SMS Unit) consisting of the CPU card, the Power Supply card, a Back Plane card and the sensors. Figure 1, presents the internal architecture of the SMS unit. The SMS does not intervene with the electric power circuits of the vehicle and its visual aesthetics. The installation procedure of the monitoring system and sensors is considered to be simple and non-intrusive. The “Data Administrator” software is menu driven and programmer friendly, operating in a windows environment.
The prototype datalogger developed by CRES, is based on the Motorola microcontroller MC68HC11F1. The maximum of its resources are : 8 analog inputs, 8 digital inputs, 8 digital outputs and 3 PWM inputs/outputs. The software-controlled power-saving modes make the MC68HC11 family especially attractive for automotive and battery-driven applications.

2. SMS Concept Presentation

At the beginning of the project, a group of EV specialists and demonstration fleet testing organizations, among the participants, has come to a consensus that a reduced number of parameters could satisfy the data needs of most interested groups (fleet operators, decision makers and industry) and agreed upon the fundamental parameters to be measured, as well as the technical specifications of the SMS. The SMS was developed based on these specifications, to simplify and reduce the system cost as well as the installation procedure.
The CPU card, is a removable card, where a testing program and the collected data are saved. When the CPU card is plugged into the SMS unit, it reads the DIP-switch combination (up to 255 combinations), thus allowing demonstration and testing fleet operators to differentiate between EVs being monitored. This may also allow one SMS unit to be used for spot checks on many vehicles (if necessary) or to identify different spot check trials.
Therefore, one SMS unit is installed in each EV being tested, while one SMS unit is permanently located in the control room, where the CPU cards of the various EVs are programmed and later unloaded of their collected data by qualified personnel. The EV user is not involved in anyway with the SMS and data handling. He is responsible to be present at predetermined appointment, when a qualified person will remove the CPU card from the vehicle and load a fresh one. This procedure does not take more than 10 minutes. The output file provided by the SMS is in ASCII format, ready for use with all the popular data analysis programs.
The EV fleet tests could be of short duration, collecting several hours of raw data in the SMS Flash RAM or of longer duration, weeks to months, collecting this time information of the vehicle’s usage profile. The long tests are in the form of histograms being stored in the Static RAM of the SMS.
The aim is to obtain a degree of accuracy of the measured parameters in the range of 1% to 2% for the full scale range and sometimes 5% for calculated parameters. The 8 bit A/D conversion of the microcontroller provides a maximum resolution of 1/256th of the measured range (0.4% resolution).
By measuring the speed at a high sampling rate (i.e. a few times per second), the amount of collected data and storage device cost are certainly increased. On the other hand, we avoid the cost of other expensive sensors (such as : accelerometers, ...) and the associated installation and calibration procedures.

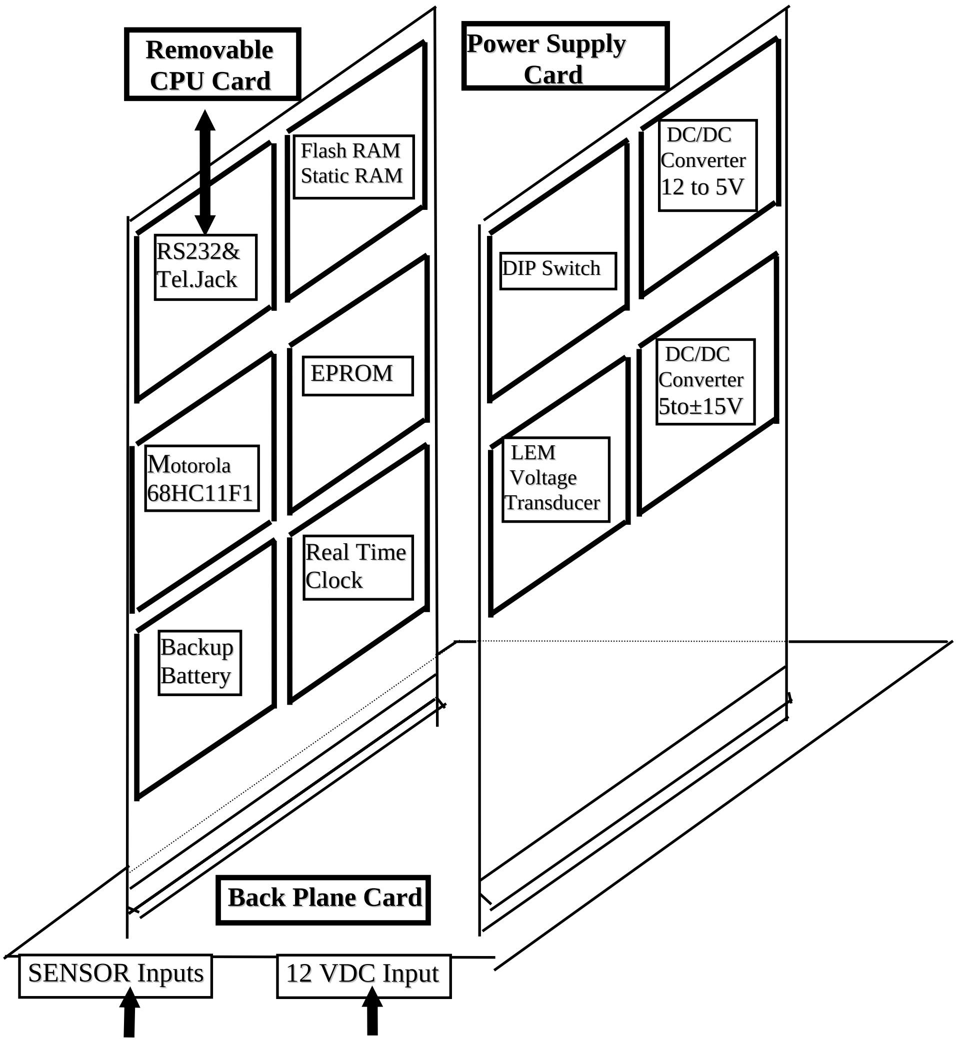

Figure 1. Internal architecture of the SMS unit

The energy received from the grid can be also measured by instantaneous response the Hall effect sensors, being proposed, to monitor the voltage and current of the traction batteries (considering a fixed charger efficiency). This way, the power transducer cost can be avoided as well as the problems due to the voltage and current waveforms encountered in the charging and driving systems of the electric vehicles. On the other hand, the complexity of the installation is increased if we are to use the same sensor for the driving and charging phase. Care must be taken regarding the accuracy of the measurement during the low current charging phase (typically 5 to 30 DC Amps) compared to the high current measurements during the driving phase (typically 5 to 400 DC Amps).

3. SMS Hardware

The SMS is based on the Motorola MC68HC11 F1 microcontroller driven by a 8 MHz crystal oscillator, making use of 2 analog inputs with 8 bit A/D resolution, 2 digital inputs and 1 PWM input (see Table 1).
A DIP switch set is mounted on the Power Supply card, identifying the EV on which it was installed. The sample rate is user definable, on a per channel basis, up to 5 Hz (it could be increased if necessary), controlled by a test program downloaded from a computer (Data Administrator Software).

3.1. Memory resources of SMS

- For the operational software: an EPROM is used for onboard S/W needs, sensor and onboard data manipulation.
- For data collection: Static RAM 128 Kb for Histogram generation and 2 Mb Flash RAM for raw data collection

A Static RAM module is being used for “unlimited” write/erase cycles and a Flash RAM with a minimum of 100.000 write/erase cycles. Regarding the selection of memory, the advantages of the Flash RAM are : its lower cost per Kb and high availability, versus its limited write/erase cycle life. If the SMS is to be used for a large volume of raw data collection,

the Flash RAM should be used. For on board data manipulation (histograms, averaging over longer times than the sampling rate,...) static RAM should be used because of the large number of write/erase operations being performed during data collection.
The real time clock and static RAM are being backed up by a rechargeable Ni-Cd battery placed on the CPU card. It provides power when the card is removed from the SMS unit, or when the unit is off. When fully charged, the backup battery could support them for more than one month.

Table 1. SMS Specifications

FEATURES	SPECIFICATIONS
External Communication	RS232 & Telephone Jack (for optional data transmission by cellular phone)
Power Supply Source	7 - 40 VDC (Max Power consumption 30W)
Input/Output Channels of MC68HC11F1 being used: Analog inputs Digital inputs PWM input	 2 (8 bit resolution) - Input range: 0 - 5V, - Conversion type: Successive approaches, - Sampling period: at least 16μs per input 2 (0-5V) 1 Counter input
Memory	- Static RAM 128 Kb for Histogram generation - 2 Mb Flash RAM for raw data collection - EPROM for the operational software (backed up by a battery with 1 month power autonomy)
Real Time Clock	Real time clock on the CPU card, registering time with the measurements in the stored data files (backed up by a battery with 1 month power autonomy)
Sampling Period	0,2 sec to 24 hrs (selected by the user).
Operation Environment	Inside a vehicle, -20 to 70°C
LCD & Keyboard (optional)	- Display of the measured value of each input channel. - A basic keyboard of 4 keys to choose between input channels
Data File Output	ASCII format (to download data) that can be used with commercial spreadsheets
Sensors (provided with SMS)	-LEM Hall effect transducers for Current and Voltage -Digital Thermometers for Temp. -Electro-Optic coupler on the speedometer cable (4 pulses per revolution)

3.2. Signal conditioning hardware

According to the sensors being used and the operating environment, signal conditioning hardware is included, for signal noise reduction, as well as filtering and transient protection.

4. MEASURED PARAMETERS

The sensors being proposed are able to measure at least the following quantities (see Table 2), with an accuracy in the range of 1% to 2% of the full scale range and sometimes 5% for calculated parameters.

Table 2. Measured and calculated parameters

MEASURED QUANTITIES	CALCULATED QUANTITIES
Speed In km traveled / hour (depending on sensor and vehicle - meters traveled per speedometer cable turn) -The sampling rate and sensor selection should be such as to provide the possibility to deduce with an adequate degree of accuracy the distance and the rate of change of speed with time.	- Distance - Acceleration / deceleration
DC current -Driving cycle - Charging cycle: ± 0.4% of full scale range delivered by the battery assembly to the electric motor and vice versa during regenerative braking	- Energy received from the grid, assuming a fixed efficiency and cosφ for the charger being used. - Energy delivered to the controller/ Electric motor - Energy delivered to the batteries by regenerative braking

DC voltage -Driving and Charging cycle: ± 0.4% of full scale range	
Traction battery box Temperature Ambient Temperature	± 0.5 °C >>
Absolute (Real) time	- Service related data
Electric Motor ON Heater ON	- Service and other related data - Auxiliary energy used
	QUANTITIES POTENTIALLY DEDUCED AFTER ELABORATE DATA ANALYSIS
	- Battery efficiency - Controller/Electric motor/power train efficiency - Energy consumption, AC and DC - Inclination at every point of the trail

The above suggested parameters may also be adequate to provide the approximate Lead-acid battery capacity, through an appropriate model, as well as the energy consumption of the vehicle, this remains to be studied in future work.

4.1. Operation phases

In figure 2, the proposed SMS installation layout is presented, in order to determine the suggested parameters during the 2 phases of EV operation, the charging phase and the driving phase.

Charging phase : the voltage and current is measured by the Hall effect sensors and thus the energy delivered to the traction batteries by the grid is determined. At the same time, the driving battery assembly and ambient temperatures are being monitored, assuming a fixed efficiency and cosφ for the charger being used.

Driving phase : the speed, the driving battery assembly and ambient temperatures, the voltage and current provided by the traction batteries to the controller/Electric motor combination and vice versa during regenerative braking, as well as the two operation states (Motor ON, Heater ON) could be monitored.

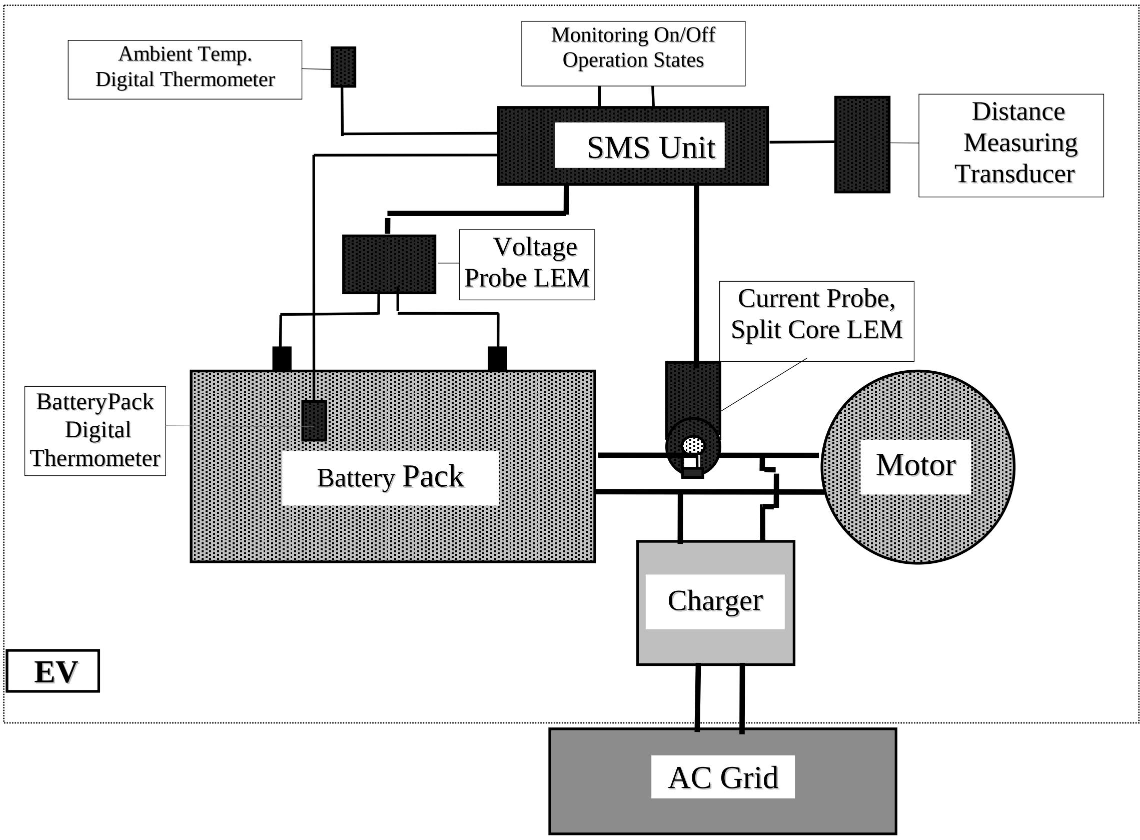

Figure 2. General Layout of EV Mounted SMS

Any other auxiliary electric consumption can be estimated from previous acquired experience and/or via a manual logging procedure during the vehicle operation.

5. SMS DATA ADMINISTRATOR SOFTWARE

5.1. Introduction

SMS Data Administrator (SMSDA) is a menu driven software, developed at CRES, that provides user friendly communication between a PC and the SMS datalogger. The physical arrangement is shown below at Figure 3.

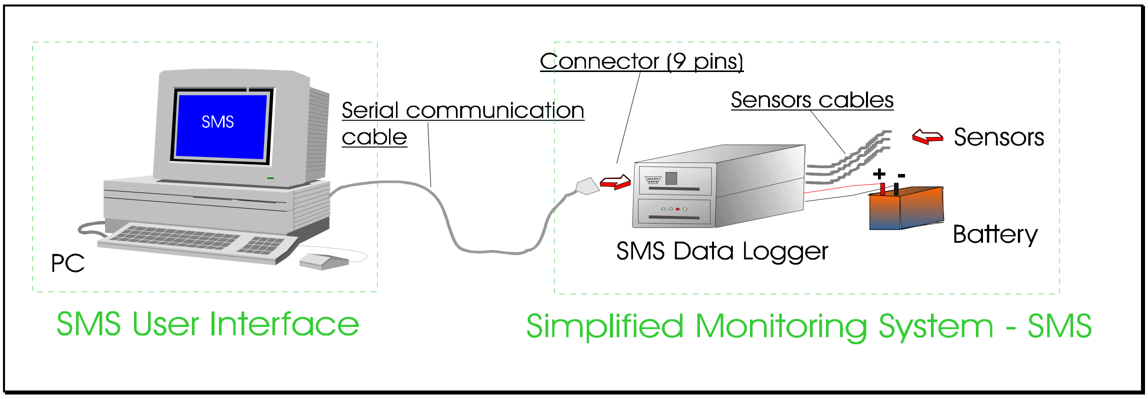

Figure 3. PC and SMS physical arrangement

The SMSDA is installed in the PC, providing the SMS User Interface platform. The communication with the SMS datalogger is made through a cable link. The SMSDA user could store the SMS data in a diskette or in the PC's hard disk, creating a data file that can be easily handled by spreadsheet software.

5.2 Hardware Requirements

The SMSDA is based on the Microsoft Windows operating system and it has been proved to work properly under WFW 3.11 and Windows 95.
It requires a screen resolution up to 800x600 and the screen's color resolution should not be less than 65535 (High color mode - 16 bit). The PC should also have a serial port available to communicate with the SMS datalogger.

5.3. SMSDA Software Overview

The SMSDA main MENU appears in Figure 4 and provides 7 options.

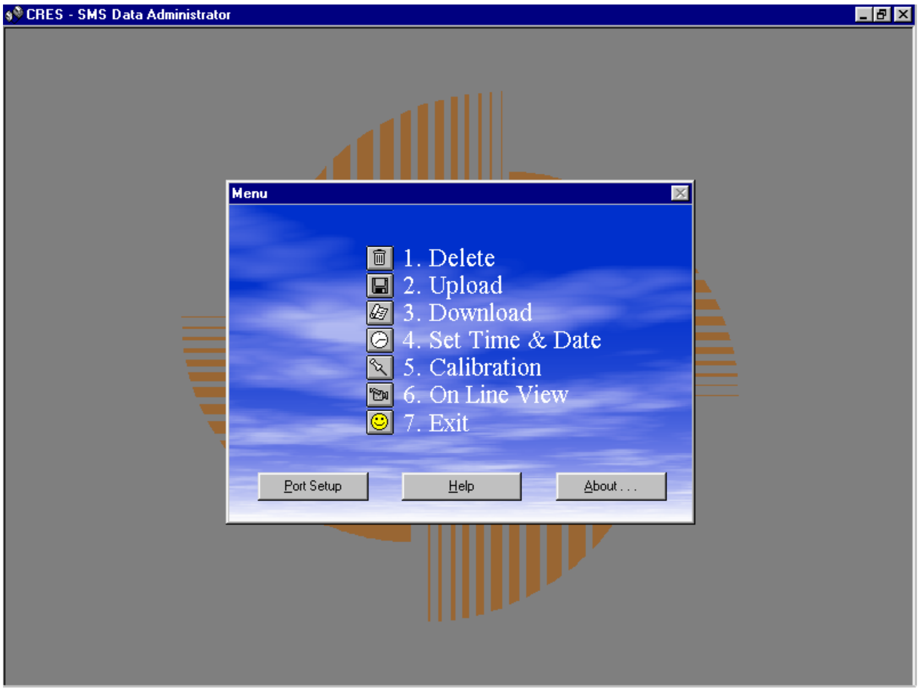

Figure 4. Main SMS Data Administrator MENU
Each option represents a function and it is activated by two different ways. You can either select an option by its number (keyboard) or by pressing the button next to the option (mouse).
The available options are :

1. Delete: It deletes the data collected in SMS memory.
2. Upload: A data file is created in the PC, where the collected data by the SMS are saved.
3. Download: It defines a number of parameters concerning to the SMS data logger operations.
4. Set Time & Date: It checks the date and time kept by the SMS internal clock. The user can also adjust the time kept by the internal clock with the time and date of the test.
5. Calibration: It applies correction values to the data being uploaded from the SMS to the PC.
6. On Line View: It displays the measured parameters.
7. Exit: It exits the communication program.

On the main MENU the user has also the option to select the communication port (Port Setup button) of the PC being used.

6. SMS Prototype Construction

CRES has constructed 3 SMS prototypes. One prototype with the previously presented sensors was sent to IBERDROLA, a Spanish Electric Utility, to install in one of its electric vehicles and test its performance. A second one was sent to Vrije University of Brussels (ETEC Dept. at VUB) for the same reason, while a third one was kept at CRES for testing and further improvements according to the comments received from the other two project partners.

The SMS installation time on the FIAT Panda is 15 minutes, not including the time that would have taken to install, for the first time, the speed sensor. The procedure for the speed sensor installation, by a professional, takes less than 2 hours. Figure 5 presents the traction battery voltage, current and speed for a period of about 31 seconds. The data was collected by CRES mounting the SMS unit on the Panda Elettra, before it was sent to IBERDROLA.

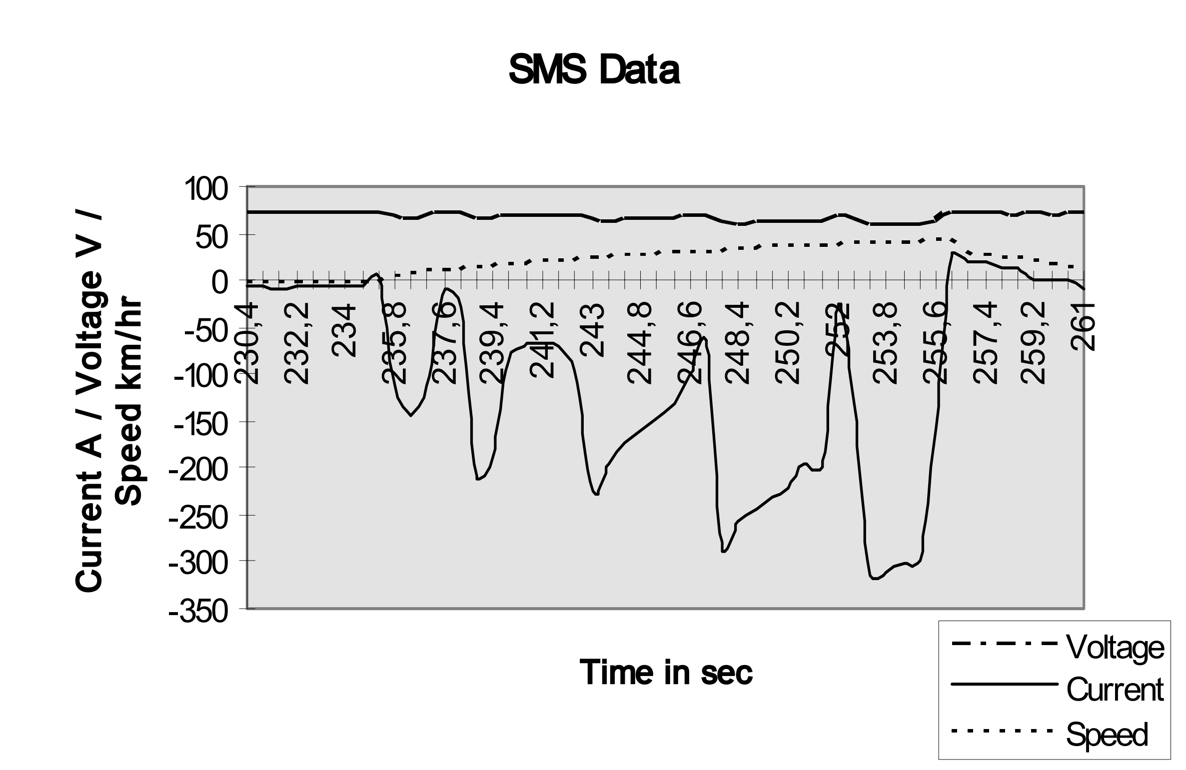

Figure 5. SMS data. Sampling time for Voltage and Current 200 msec, Speed 600 msec.

Figure 6 displays the longitudinal vehicle axis acceleration/deceleration values, as they are derived from the speed recorded data (averaging over 3 consecutive samples) by the SMS. We have concluded that the 4-blade rotor, being used in the speed sensor, has to replaced with one with at least 16 blades in order to improve the acceleration/deceleration resolution, deduced from the speed raw data, especially at low speeds.

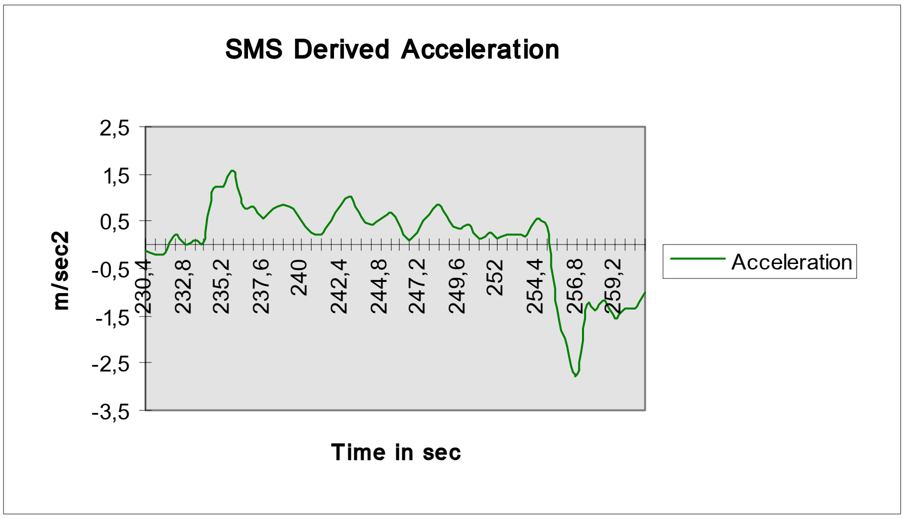

Figure 6. SMS derived acceleration/deceleration measurements

The distance traveled during the previous test was calculated, from the SMS raw data, to be 7.52 km. The distance recorded on the instrument panel of the Panda, for the same trip, was 7.4 km. That makes a difference of 1.6%, measuring from the same speedometer cable. Although such a mechanical vehicle instrument does not give an accuracy better than 5%, it gives a measure of comparison.

7. Conclusions

The design, realization and testing of the SMS will support the fleet testing work and clarify the advantages and drawbacks related to the reduced number of parameters selected to be measured, the technical adequacy of the SMS design, as well as the installation and use of such systems on electric vehicles. The first tests at CRES have shown that the SMS operation is satisfactory. At this time, the SMS is being tested by IBERDROLA and VUB and we are awaiting for their comments and results to complete the on-going validation procedure.

Acknowledgments

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Especially, we would like to thank G. Baliouskas for his efforts and contribution for the joined development of the SMS Data Administrator Software.