September 18-21, Predeal, ROMÂNIA

SIITME 2008

Conference proceedings

International Symposium for Design and Technology of Electronic Packaging

14th Edition, Predeal, România
Organized by
TRANSILVANIA University of Brasov

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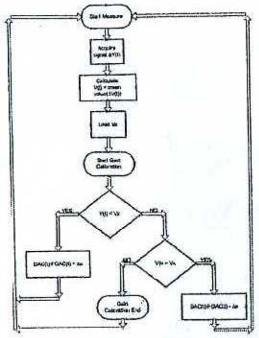

Fig. 5 Flow diagram of the AGC (Automatic Gain Control) Programme implemented with our digital loop

For the blood pressure channel we have used the commercial product Visomat® comfort 20/40 (UEBE-Germany) that is a fully automated upper arm blood pressure monitor that inflates the cuff automatically to the extent required for the individual user by real fuzzy logic. It was awarded with the quality seal of the German Hypertension Society and validated in clinical tests in accordance with DIN EN 1060/4 norms. We have designed a specific interface from the LCD display of the apparatus and we have serialized the data measured by the apparatus and also we have adapted the manual buttons at our designed serial interface by using our ATmega128 data acquisition system. Thus we have not affected the accuracy and functionality of the apparatus. We have implemented the wireless interface using LMX9838 module.

4. Conclusions and Future Developments

With our implementation we have fulfilled the requirements related to the precision and the sampling rates requested by a patient remote monitoring system. Our implementation ensures *accuracy*, *stability* and timely *availability* of portable remote patient monitor. By rational division of the system in subsystems, we have provided for each of them the *adequate power supply*. By choosing as required information flows, the *appropriate communication channels* between the subsystems of our BIOMED TEL system we have created the *premises* for the development of the *advanced and distributed processing software*, a mandatory step in order to reach a high precision and quality of patients' remote monitoring.

By organizing our distributed system on five tiers we have generated the possibility for the remote monitor to dynamically adapt and balance the processing power in order to satisfy the necessities to alarm, and act especially in case of emergency situations.

The two main objectives that we have reached: the acquisition of the ECG, ABPM, BGC, vibration and oximetry and the implementation of a new multimodal protocol for communication between PDHA and HS.

The future work will be focused on the processing of the acquired bio-signals and finding out the inter-correlation that are important for defining the hyperspace dimension for different kind of diseases and also the evolutionary algorithms that will provide the adaptation of BIOMED TEL monitor at the extremely large variety of situation that will meet in practice [10].

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Energy Management System Based on Supercapacitors used for Starting of Internal Combustion Engines of LDH1250 Locomotives and Charging their Batteries

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Abstract

The paper presents a new implementation of an energy management system that replaces the existing one on LDH 1250HP locomotive. Easley this system can be adapted for all kind of vehicles, hybrid or electric. The topology of the energy management system, the models considered for charging the batteries, the performance obtained for the start of Internal Combustion Engine are detailed into the paper. Using supercapacitors in the energetic circuit and a control system based on a microcontroller we successively switch on into the circuit of DC starting motor of ICE the voltage from supercapacitors and after from batteries. In order to avoid the discharging of batteries we designed and implemented an intelligent sensor that will detect the start of ICE and will switch off starting circuit ending the ICE start process. The current solutions use lead batteries which are supra-dimensioned in order to insure a reliable start of ICE and also to avoid the reduction of batteries life time. Using our new solution the inherent current spikes that appear during the starting process of ICE are strongly suppressed and the start of ICE became more reliable. Our solution was verified using a half of initial batteries capacity with excellent results.

1. Introduction

Nowadays the important changes of the climate at global level and depletion of fossil resources require from the human society a rapid and strong assembly of measures able to generate a drastically reduction of energy consumption. An important step towards this goal consists in the fuel consumption and engine pollutant reductions. Our application came to improve the actual locomotive starting system and to integrate all the functionalities related producing and using of electric energy, as an integrated system on locomotive.

Thus, that result is an increasing of overall efficiency of energetic processes that take place on vehicles [1].

The majority of vehicles use the lead-acid (L-A) batteries as power supplies for starting the ICE engine and after that, the starting process provides the electric energy necessary on vehicles. The starting process is critical because requests from batteries important peaks of power that induce an over-dimensioning of the batteries and also affects its life time. The possible damages produced due to starting shocks are difficult to be evaluated and as consequence these facts induce an important reduction of the system's reliability.

The evolution in the domain of nano-technologies has determined important improvements of the parameters of the super capacitors that become more appropriate to fulfill the requirements related to the maximum current, power and energy density. Thus appears as mandatory to introduce on vehicles a management of energy system and applications inclusive for those related to starting of ICE and other transitory processes [2].

Combined solutions, L-A batteries and super capacitors, appear to be the optimum compromise in terms of energy economy, materials, size and cost (including maintenance costs) [1]. While for batteries, starting becomes difficult at low temperatures, by using the combined solution, the battery will be protected and this fact significantly improves ICE starting. By providing intelligent and adaptive switching of the electric starter, energy source between supercapacitor and battery, the characteristic response of the system can be optimized in starting phase and also in the charging phase of batteries [3].

Resuming, the most important demands addressed to locomotive are starting system reliability and availability, low weight, cost and fuel consumption as well as the current tendency of increasing the battery life time due to appropriate operation [2], [4]. Our energy management system optimally satisfy all these necessities.

2. STRUCTURAL AND FUNCTIONAL DESCRIPTION OF THE NEW ENERGY MANAGEMENT SYSTEM

The energy management system can be considered from two sides: informational and energetic. The informational part includes three microcontrollers specialized to solve specific tasks such as: to control the starting process of ICE (1) by controlling the charging of the super capacitor at the beginning of the process and after that under the control of locomotive driver (0) to manage the starting process of ICE by switching on successively the supercapacitors and respectively the batteries in the DC starting motor circuit. During this process the controller will monitor the current and voltage on the DC starting circuit (14).

Also it will adapt the delays between commutation of different power supplies in DC motor circuit function of starting conditions (voltage level on batteries and State of Charge (SoC) of it, ambient temperature and temperature of cooling water of ICE, oil pressure realized by pumps inside ICE).

Synchronously with the switch on of the batteries in the DC starting circuit the system will monitor the rotation speed of ICE (1) and also the oil pressure created at the level of locomotive speed regulator. Those actions are made in order to detect when is reached the stable regime for the ICE and to switch off the batteries in circuit of DC starting motor and to end the starting process, so obtaining an optimal ICE start control.

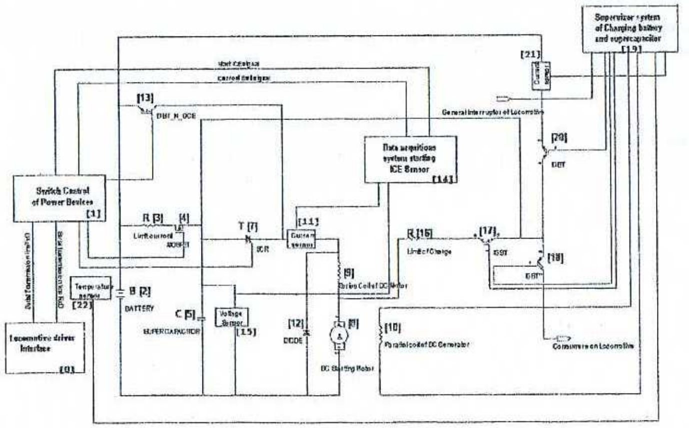

Fig. 1 Schematics of whole energy management system used for prototype LDH1250HP locomotive

In **Fig. 1** we have shown the schematic of whole management system. Between the microcontroller systems (0), (1) and (14) we have developed a specific protocol based on a serial asynchronous bus implemented with optical fibers in order to be immune at all electro-magnetic disturbances. This bus offers the support for transferring the information between pending elements and it is in accordance with their specific time constants.

When the ICE of locomotive is active (running) the role of energy management system is changed, respectively it will coordinate the charging process of the batteries. Using the Coulomb method [5], [6] the microcontroller measures with accuracy all the currents that are related with the batteries system.

The Coulomb is the unit of electrical charge corresponding to one ampere-second. In practice we use the ampere-hour unit (Ah) closer to the level of charge stored and provided by LA batteries. SoC is defined as the percentage of the full capacity of a battery that is still available for further discharge [7]. For example the method developed by Christianson & all named: Open Circuit Voltage (OCV) is based on measuring with high accuracy of V_{bat} and the internal resistance R at a measured current I.

$$OCV = V_{bat} + I \cdot R \tag{1}$$

In case of LA batteries the dependency between the OCV and the SoC is quasi linear and combining this method with the Coulomb method that is based on integration of current absorbed or provided by batteries with corresponding sign we can know at any moment the SoC of batteries with a good accuracy.

$$Q(t) = \frac{1}{R}\int_0^t i(\tau)\cdot d\tau \tag{2}$$

Our microcontroller will store the values corresponding at the maximum charge stored on batteries and thus we will know the real SoC on base of above mentioned relationships. For measuring the Electro Motive Force (EMF) we used the *„voltage relaxation"* methods that measure the battery voltage will relax to the EMF value after current interruption. This may take a long time, especially when a battery is almost empty, at low temperatures and after a high discharge current rate [8], [9]. Before mounting the batteries on the locomotive a LUT with the EMF values for different level of SoC was complete result of initial measurements. For calculate the actual value of SoC we use the interpolation formula:

$$SoC = SoC_l + \frac{EMF - V_l}{V_h - V_l}\cdot(SoC_h - SoC_l) \tag{3}$$

Where V_h and V_l represent two values, the limits of interval stored initially in the LUT that includes the specific characteristic of battery. Measuring the present EMF value we calculate by linear interpolation the value of SoC. In this sense in schematic we introduced the following switchers: (17) that insulate the generator in order to determine with high precision the voltage generated, (18) that represent the main switcher for the electrical services provided on locomotive. In this circuit we have introduced a high precision current sensor. The circuit switch (20) play the role to insulate the battery in order to measure and monitor with high accuracy the voltage, the relaxation time and implicitly its State of Charge (SoC). The sampling rate for SoC is very low (between 5 to 60 min periods) and adapted at the values of it and stored in a look up table (LUT).

We mention that the measurement of SoC is also mandatory at the initial moment when turning on the locomotive in order to preset the charging current for supercapacitors, necessary to prepare the conditions for the starting of locomotive ICE.

3. IMPLEMENTATION OF THE NEW ENERGY MANAGEMENT SYSTEM

In the implementation phase of this new system we have used LA batteries - 150Ah/110V, that means half capacity of the initial of batteries that had have - 360Ah/110V. We have used 3 super capacitors each12 F/110V connected in parallel. These supercapacitors are stacked Electric Double Layer Capacitors (EDLC) with aqueous electrolyte each of them with 20mΩ Equivalent Series Resistance (ESR). The domain of its temperature is situated between -50°C to +80°C and the weight of each of them is around 40 kg. The size is: 23 cm diameter, the length is 42cm, and the energy stored on each of them is 72KJ. This kind of stacked EDLC doesn't require any additional balancing system for the elementary cells, being compact and resisting at a mechanical stress (sinusoidal acceleration of 5g) more than 10.000 hours. The cyclability of this stacked EDLC exceeds 500,000 charging - discharging cycles. The total resistance of connection wires between stacked EDLC and starting motor had around 10-15mΩ. For the charging of supercapacitors we have used as switching device (4) a CMOS transistors (82A/150V); and for discharging of it on DC series motor we have used (7)-SCR a thyristor 4000A/1200V from EUPEC. The switching device (13) is an IGBT at 600A/1200V from POWEREX and this apply controlled by (1) the voltage from battery on DC series motor in the second phase of the starting process of ICE. For the rotation speed sensor we have used the existing tacho-generator that provides the real speed of ICE.

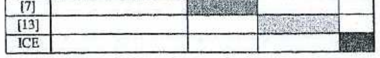

Fig. 2 The sequence in time (X axis) is controlled by system (1)

In Figure 2 we have shown the control sequence implemented by the control power switching system (1). The systems (0), (1), (14) and (19) use single board computers (SBC) based on Atmega128 microcontrollers and the link between SBC is implemented using iLink devices and fiber optics.

4. Experimental Results

In the figure below it is shown the prototype of the starting system. For the measures we have used Hall sensors for voltage and current the accuracy of it it's 0,2%.

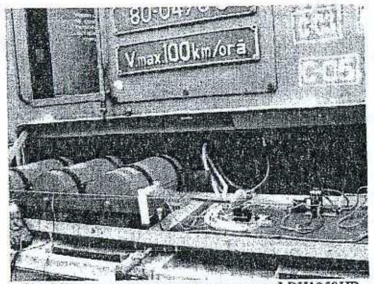

Fig. 3 The energy management system on LDH1250HP locomotive (system 1, 14,19)

The variation of the voltage along the starting process (X axis represents the time, Y axis represents the voltage variation) is shown in Figure 4. We want to emphasize that the voltage variation on battery for the prototype was reduced more than three times, that means an important improvement of life time battery comparing with the initial situation. (the upper line represents the initial record and the bottom line represents the prototype record).

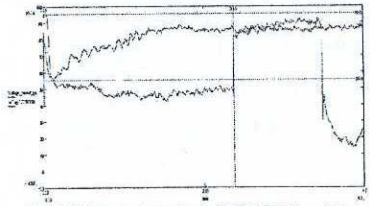

Fig. 4 Voltage variation for the LDH1250HP, and the prototype LDH1250 endowed with the new energy management system

As we have shown in **Fig. 4** in less than 200ms practically the ICE engine reaching the "ralenti" rotation speed. The necessity to continue to supply de DC starting motor is due on the existing speed regulator that need a longer time to reach a stable regime of ICE.

In **Fig. 5** we have shown the variation of current along the same starting process. (X axis represents the time, Y axis represents the current variation). It is obvious that the current variation in the two situations (initial and on the new prototype) is similar, the difference was made only by commutation of battery that improve the premise of starting process of ICE.

Comparing the initial situation with the new one it is shown in figure 4, figure 5 the main parameters (voltage variation and current variation) recorded for the same locomotive in above mentioned conditions. The blue line represents the initial situation and the red line the behavior of new prototype for each parameter. We want to mention that the energy management system was endowed with a new firmware that allow to automatically adapt the switching between supplies, supercaps and batteries, in function of following factors: temperature and oil pressure inside the ICE.

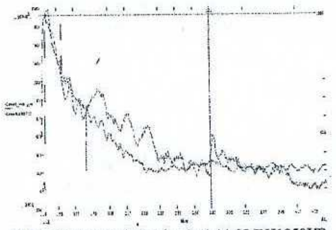

Fig. 5 Current variation for the initial LDH1250HP locomotive and the prototype LDH1250HP

A more significant for future development is the variation for short term of the Equivalent Series Resistance (ESR) of power supplies. In **Fig. 6** we have shown this variation in a graph where on X axis represents the time and on Y axis – using a logarithmic scale- we have represented the ESR in booth the two cases: initial locomotive (blue line) and the new prototype (red line).

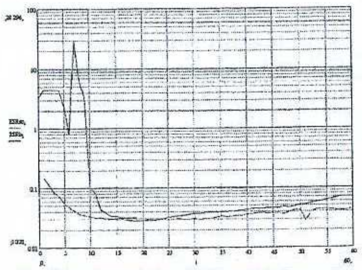

Fig. 6 Short time variation of ESR on initial locomotive and prototype in the first 600ms after begining of the start process.

5. Conclusions

The new energy management system designed for vehicles and used for locomotive presents some very interesting features:

- can assure a reliable starting process of the ICE in a large domain of temperature from -30°C to +60 °C because the transfer for short term of power to the DC starting engine is assured in quite similar electrical condition by the supercaps controlled by our new energy management system (see **Fig. 6**)).
- Using the supercaps as temporary buffer of energy provided by generator on locomotive allow us to use a very precise algorithm for the charging system of batteries integrated into the energy management system.
- The reliability and also the availability of the whole locomotive is increased as a result of a better functioning conditions assured by the batteries. More that, we have demonstrated by testing the prototype that the size of the batteries for the same locomotive was reduced at more than the half of initial ones;
- The fuel consumption is reduce due to the possibility that appears to switch off for any dead time the ICE of locomotive based on the very high availability of the new starting system created by us.
- The integration of all electrical services under the same control system offers new possibilities related to the optimization in the future of functionality and also the energy efficiency of vehicles.

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