INFORMATION SUPPORT FOR MODELLING OF THE PROCESSES IN MOBILE ROBOTICS SYSTEM

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Abstract

The current crisis situations required immediate action of rescue equipment during the life-threatening operation conditions. In this case, a special robotic vehicles for operations in adverse conditions, finds its application. This type of vehicles uses embedded controller systems for the controlling processes during its operations. This paper presents methodology for design and simulation of the hybrid power sources for the electric propulsion system of the robotic vehicle and its critical states and processes.

Keywords: Vehicle information system, modelling, mobile robotics system, energy storage system.

1 Introduction

The contemporary demand for unmanned, ground, robotic vehicles or systems is largely driven by applications that inherently repeated, exacting, complicated and dangerous are. Mostly, these tasks includes search and rescue activities, fire-fighting, and military applications, agricultural works, intelligent transportation , scientific research in dangerous areas, mining of raw materials, waste management, etc.

1.1 Architecture of unmanned, ground, robotic vehicles

The software and hardware architecture of UGRV is well defined architecture, which allows efficient technical development and deployment of complete architectural systems. Furthermore, together with the software development environment and tool sets, their selection usually a key for programmatic decision is.

The complex information system of a modern autonomous UGRV complex is which can be seen in Figure 1.1. It has multiple interacting and independent subsystems, that the result behavior is a function of the individual subsystems behavior, and the interactions between them and on mutual communication with human supervisors. The research and development of such robust integration schemes represents the most significant technical solution for the practical deployment in the UGRV's.

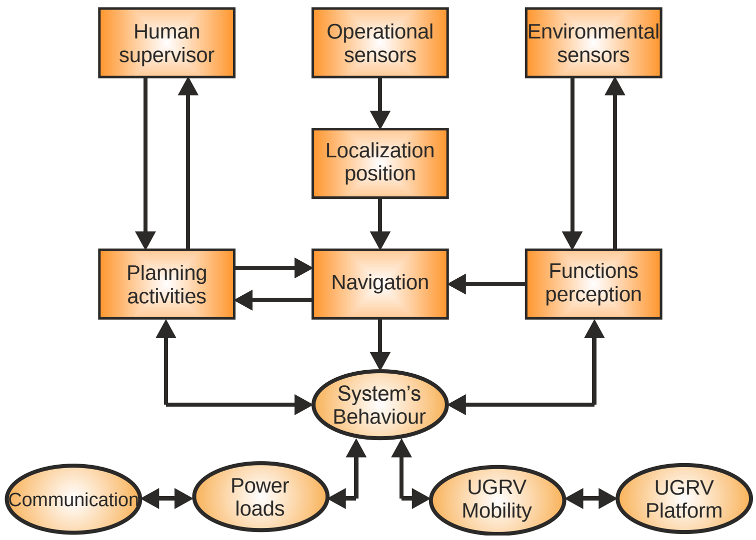

Fig.1.1 *Block scheme of Complex information system for an autonomous UGRV*

The complex information system is actually a function of a number of linked software and hardware elements processed by the experts, for example programmers, engineers and users. The significantly more complex networked systems are, either among themselves systems or with other technologies. Most commonly used are multiplicities of architectures, operating systems, data formats, programming languages and communications protocols, not to mention a multitude of hardware combinations. As the degree of autonomy increases, so it becomes increasingly difficult to predict the result state of the system. [1]

The key elements of any autonomous UGRV platform considered following functional components:

- **Propulsion systems** also are the key functional components of UGRV and they are typically designed around the tasks and missions likely to be undertaken. Designers must also take into account their signature, which can be acoustic, electromagnetic, infrared and visual.
- **Energy storage** and the rate at which it can be used, is key to any rescue mission of the UGRV. For small UGRV the energy systems typically are fully electric; larger UGRVs typically use fuel or hybrid-electrical systems and full electric systems.

Usage Monitoring Systems (UMS) and built in test equipment are often ignored in smaller UGRV, but they frequently used are for self-monitoring, diagnosis and remediation of systems or functional components in the larger ones. Of the functional elements identified, and others classify the areas of platform, energy storage, propulsion, UMS, payload, communications (and its management) and mobility as largely mature and existing in a deployable form.

2 Information system for the hybrid energy system control of the mobile robotics platform

The power management of the mobile robotics hybrid energy system contains two main elements:

- First, when power is demanded from the energy storage system, the control strategy must determine how many power (current) can be delivered from the battery system and how many can be delivered from the supercapacitor system during the dynamic loading process.
- Second, the control strategy must determine when and how fast the traction system should charge the supercapacitor system.

A complete control strategy consists of a power flow management strategy and algorithms for battery system and the supercapacitor management strategy in terms of safety and dependability of the mobile robotics platform.

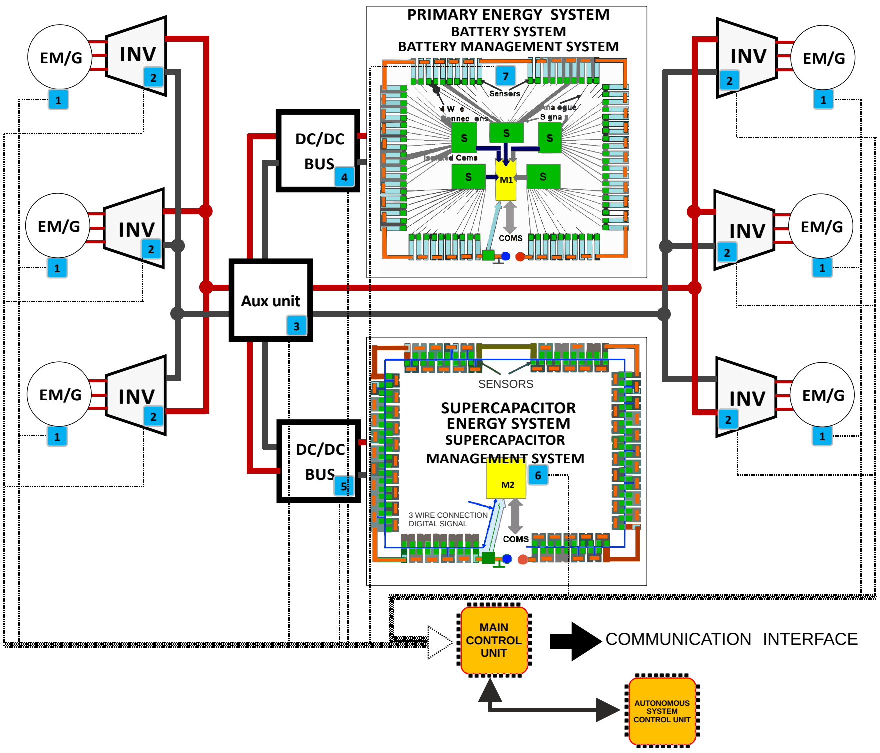

Fig. 2.1 Topological model of complex information system connected with mechatronic systems and hybrid energy system of the mobile robotics vehicle.

Where: EM/G – Electric Motor / Generator, INV – Invertor, Aux unit – Auxiliary unit, DC/DC Bus – Supervisory DC/DC power control unit of electric energy source, S – Supervisory control of the battery management unit, M1 - embedded control unit of the battery management system, M2 - embedded control unit of the supercapacitor management system, MAIN CONTROL UNIT – main electronic control unit

On Fig 2.1 is shown information and communication systems with sensor subsystem which is implemented to the mobile robotics system and this communication system – interface is interconnected with main control system Mobile robotics systems contain these sensor systems:

1. Sensors for monitoring of the electric motors/generators: electric voltage sensors, electric current sensors, angular velocity sensors, temperature sensors.
2. Invertor sensors: electric voltage sensors, electric current sensors, temperature sensors.
3. Auxiliary unit sensors: electric voltage sensors, electric current sensors.
4. DC/DC bus sensors of the battery system: electric voltage sensors, electric current sensors, on/off sensor of the power relays.
5. DC/DC bus sensors of the supercapacitor system: electric voltage sensors, electric current sensors, on/off sensor of the power relays.
6. Supercapacitor control unit with sensors: electric voltage sensors, electric current sensors, temperature sensors.
7. Supercapacitor control unit with sensors: electric voltage sensors, electric current sensors.

2.1 Information system of the discharging and charging of the hybrid energy system

Part of the information system is based on the primary energy source that, a rechargeable battery system is. Rechargeable battery system provides a stable supply of energy and power during the dynamic movement of the mobile robotics platform. Supercapacitor system is a secondary electric source, which is designed to power supply the electric traction system.

The proposed control algorithm has implemented limit values of the control parameters. These parameters will be applied for the connecting of the each energy system (battery system, supercapacitor system) to the traction system.

The energy requirement during dynamic loading is expressed by the equation:

$$E_{net} = \left[\int_{t=0}^{t=n} (P_{discharging\ batt} + P_{discharging\ sc})\, dt + \int_{t=0}^{t=n} (P_{charging\ batt} + P_{charging\ sc})\, dt\right] \tag{2.1}$$

Where: E_{net} - energy required / generated by electric traction system, $P_{discharging\ batt}$ - required power from rechargeable battery systems for the traction system, $P_{discharging\ sc}$ - the required power from supercapacitor system for traction system, $P_{charging\ sc}$ - regenerative power, power delivering to the supercapacitor system from traction system during regenerative braking, $P_{charging\ batt}$ – regenerative power, power delivering to the rechargeable battery system from traction system during regenerative braking, t – time step, n-total time of the UGRV movement

Via equation (2.1), the main algorithm for hybrid energy sources management designed is. Main control algorithm of the hybrid energy sources task is to define, when the hybrid electric energy system will be used for demanded power (current) delivered into the electric traction propulsion system. Designed control algorithm of the hybrid energy management on the Fig. 2.2 shown is.

In the control algorithm the variable parameter (I_{limit}) implemented is. The variable parameter is the decision parameter for controlling the energy requirements and control energy delivering from specific energy source in the critical states.

Hybrid energy system for the initial value of the voltage designed is. During the critical processes, such as limit value of the current during discharging process and limit value of the current during charging process, the algorithm of the control management of the hybrid energy system by the power limit value for electric current requirements defined is.

This algorithm principle defines, that the required output current and the output power of the traction electric motor/generator for this case equivalent values is.

The proposed control algorithm with the control units is complex decision control system that manages the hybrid electric system. The control management is based on the conditions described by the equation (2.2) and equation (2.3) the control algorithm operates simultaneously with the equation (2.1). If the conditions are accepted, the power distribution system (DC/DC bus) will be connected to the supercapacitor system. If the conditions are not accepted, the power distribution system (DC/DC bus) will be connected to the rechargeable battery system.

$$I_{MOTOR}\,(A) > I_{LIMIT}\,(A) \tag{2.2}$$

$$E_{net}\ (P_{MOTOR})(kW) > P_{LIMIT}\ (kW) \qquad (2.3)$$

Where: I_{MOTOR} - requirement of the current or generating of the current by electric power traction system, I_{LIMIT}- set the value of the limit parameter required for power distribution systems during discharging battery energy system, E_{net} – energy requirement (or generating) by electric power traction system, P_{motor} - Required (or generating) traction power, P_{lim} - limit value for required (or generating) power flow distribution performance of the energy system.

For the dynamic simulation analysis of the mobile robotics platform, the value *Ilim* can be modified and set for next optimization options. By defining the parameters of the rechargeable battery system sufficient is. Supercapacitor system can be connected to the energy circuit and the traction system at the starting electric current requirement, until its falls to lower limit value of the state of charge.

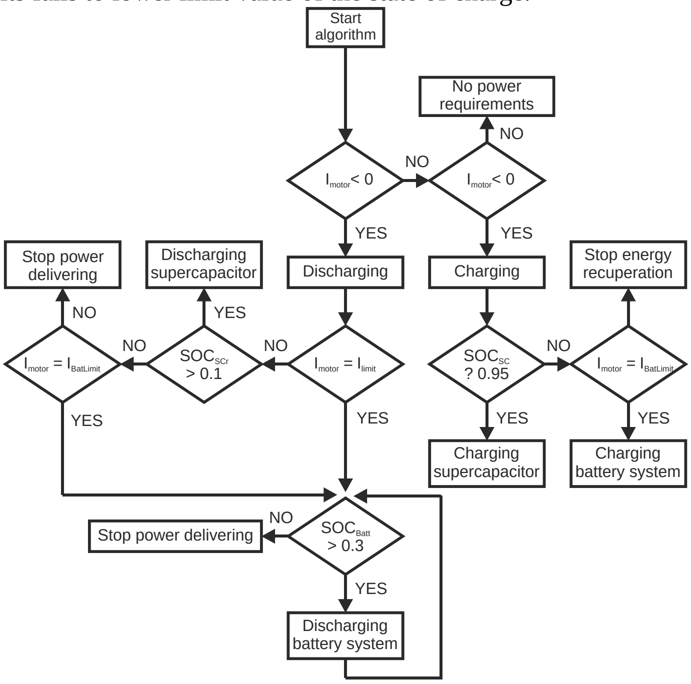

***Fig.2.2** Block diagram of the designed information system operational algorithm during discharging/charging of the battery system with supercapacitor system in hybrid energy system of the mobile robotics platform*

2.2 Information system operational algorithm implemented for the energy management system of the mobile robotics platform

Information system algorithm of the control unit for the current (power) control (redirecting), when electric motors /generators works in the electric motoring mode or the electric motor works in the generating mode.

```
function [Ich,Idis]= splitter1(Imot)
if Imot > 0
   Ich = Imot;
   Idis = 0;
elseif Imot < 0
   Ich = 0;
   Idis = Imot;
else
  Ich = 0;
  Idis = 0;
end
```

On the next frame can be seen an algorithm of the control unit for discharging current management between the battery system and supercapacitor system, with limit control management for discharging current of the battery system.

```
function [Isc,Ibatt]= splitter2(Idis,I_limit)
if abs(Idis) <= I_limit
    Iaku = Idis;
    Isc = 0;
else
    Ibatt= - I_limit;
    Isc = Idis + I_limit;
end
```

On the next frame can be seen an algorithm of the control unit for the management of the discharging current. When state of charge of the supercapacitor is 0% and then the battery system discharging is.

```
function [Iscout,Idisbatt] = splitter3(Isc,SOCsc)
if SOCsc > 0.10
   Iscout = Isc;
   Idisbatt = 0;
else
   Iscout = 0;
   Idisbatt= Isc;
end
```

On the next frame can be seen an algorithm of the control unit for control management of the regenerative current, which can be redirected to the rechargeable battery system if state of charge of the supercapacitor system, will be 95%.

```
function [Iscchargingout,Ichargingbatt] = splitter4(Ich,SOCsc)
if SOCsc < 0.95
   Iscchargingout = Ich;
   Ichargingbatt = 0;
else
    Iscchargingout = 0;
    Ichargingbatt = Ich;
end
```

On the next frame can be seen an algorithm of the control unit for limit value of the battery charging current.

```
function Charging_current_batt = splitter(Ichargingbatt,Max_charge_batt)
if Ichargingbatt <= Max_charge_batt
            Charging_current_batt = Ichargingbatt;
else
            Charging_current_batt = Max_charge_batt;
end
```

3 Case study and the simulation results

Simulation results for the proposed hybrid energy system are obtained using MATLAB/Simulink and "SimPowerSystems" based software packages by implementing the detailed mathematical and electrical models of the main components of the mobile robotics platform.

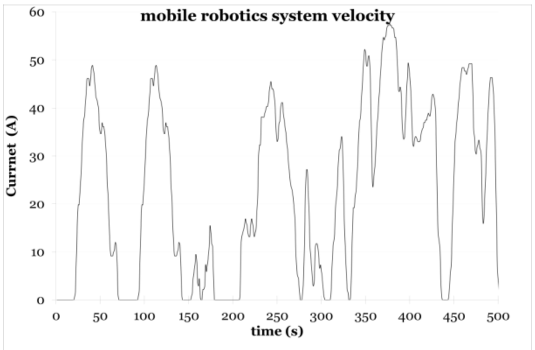

Fig. 3.1 *Representative drive cycle for simulation of the mobile robotics system*

For simulating and searching critical states of the hybrid energy system of the mobile robotics system was chosen representative drive cycle. This representative drive cycle is showed in Fig. 3.1. The Fig. 3.2 describes the state of charge of the battery and supercapacitor system during a chosen driving cycle.

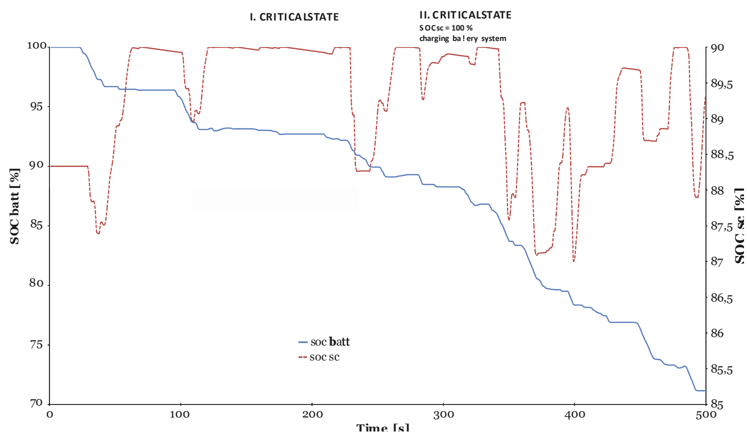

Fig. 3.2 *Time response of the battery system and supercapacitor system state of charge*

4 Conclusion

Information system of energy management system of the hybrid electric system has been designed, implemented and tested for mobile robotics system by uses of computer simulations.

Computer simulations of a mobile robotics system reveal reliable results of the proposed system in terms of energy saving and critical states. The proposed Information system algorithm and methodology allow an improvement of the function of the autonomy in a basic critical processes and states with decreasing of the performances of the propulsion system but increasing energy saving of the hybrid energy system.

The designed methodology and the case study results confirm that the proposed Information system of the energy management system is effective for the wide spectrum of the critical processes control in the mobile robotics system.

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