Submitted by the experts from
Special Interest Group EMB (EBSIG)

Informal document **GRVA-17-19**
17th GRVA, 25-29 September 2023
Provisional agenda item 8(b)

Status Report:
Special Interest Group on Electrical Braking

Monitoring the Electrical Energy in an Electrical Braking System

Terms of Reference

A. Energy supply and brake transmission architectures.

1. Identify design principles for the energy supply.
2. Identify the brake transmission arrangements that may be recognised by UN Regulations Nos. 13 and 13-H.
3. Develop recommendations for the methodology of measuring/monitoring the value of energy available in a reserve of energy suitable for use in identifying critical energy thresholds.
4. Identify the safety critical elements of electromechanical braking systems that will require monitoring for fault/failure and the generation of warning signals.

B. Based upon understanding from the above, and building upon GRVA Informal Document GRVA-15-17;

1. Develop proposals to amend UN Regulation No.13,
2. Develop proposals to amend UN Regulation 13H, and
3. Make recommendations regarding the application of the electrical system safety principles with respect to other UN Regulations, esp. UN Regulation No. 79.

Meeting Schedule

Special Interest Group Meetings.

1. 12-13 July 2023 - Brussels
2. 22-24 August 2023 - Paris
3. 10-12 October 2023 - Brussels
4. 7-9 November 2023 - Paris
5. 12-14 December 2023 - Paris
6. 9-11 January 2024 – Berlin

All meetings are held “in-person” with virtual attendance also possible.

Sub-group Meetings: Arranged on an ad-hoc basis.

Delivery Schedule

January 2024:
Informal papers to GRVA setting out proposals to amend UN Regulation 13 and 13H.

May 2024
Formal proposals to GRVA to amend UN Regulations 13 and 13H.

November 2024;
Subject to agreement by GRVA, Working Party 29 to consider the proposals for adoption.

September 2025:
Entry into force on the common commencement date.

Principles for GRVA Opinion / Agreement

How the reserves of electrical energy will be monitored.

- These new brake systems will rely on the availability of electrical energy to deliver the required braking effort.
- It is necessary to know, at all times, that there is sufficient energy available for the braking task.
- Electrical energy cannot be measured in the same way that hydraulic/pneumatic pressure can.

Dedicated energy reserves.

- Currently, the reserves of energy required for braking have to be “dedicated reserves”, i.e., the reserve of energy is for use by the brakes only.
- It is envisaged that future electrical braking systems will use the traction battery as an energy reserve for the braking system, i.e., the energy reserve would not be dedicated to the braking system.

Tasks given by EBSIG to the specialist sub-group

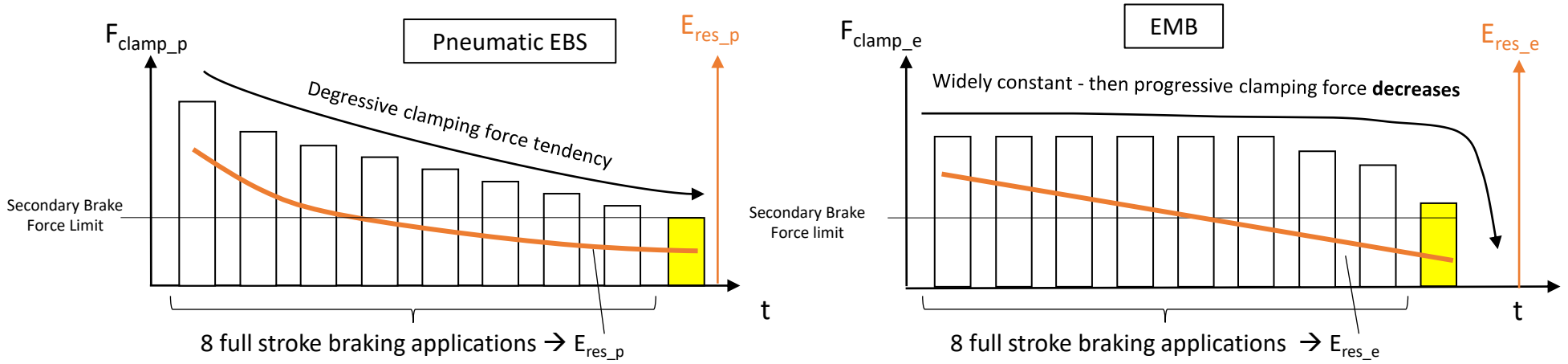
Provide confidence that technology is able to do the following:

1. Measure and/or monitor in real time the energy available in the reserve in all operating conditions and over the lifetime (high temperatures, ageing, …).

2. Compare that measured value with the known threshold value required to meet the specific performances required by the regulations. Note: The known value means the value identified by the manufacturer to fulfil the specific requirements of the regulation.

3. To be able to generate the warning to the driver in real time in accordance with the known threshold value.

Actuating force and energy level degradations of the reserve in a capacity test of EBS vs. EMB



- The actuating force of pneumatic brakes gradually degrades with each application, since the actuating force is directly proportional to the reserve's pressure level, i.e., with the energy level of the reserve.
  ➔ **Pressure level of the reserve well represents the energy state of the brake system.**

- The actuating force of EMBs is approximately constant till a critical discharge level, where the rated power output of the energy reserve cannot be anymore provided. After this a reduction of brake performance occurs, since the power output capability of the reserve depends on its energy level.
  ➔ **Both, the energy level and power output capability, shall be monitored.**

Comparison of pneumatic braking system and an electrical braking system

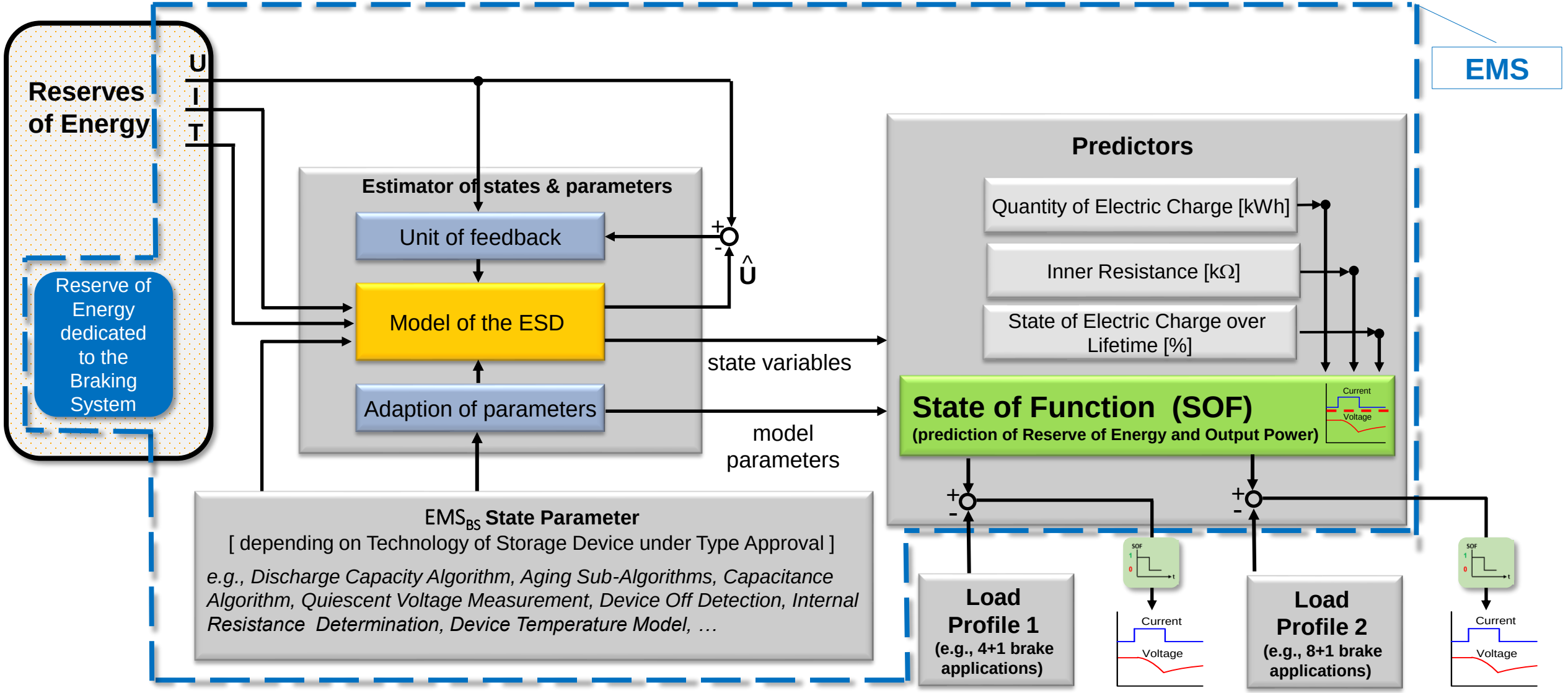
Pneumatic Braking Systems (PBS)

- The reserve of energy **can be** monitored and measured at any time (by direct means e.g., a pressure gauge).
- The reserve of energy is direct proportional to the actuating force of the actuators.
- The actuating force may change in response to multiple full-stroke brake applications.

Electrical braking system (EMB)

- The reserve of energy **cannot** be monitored and measured at any time directly.
- The actuating force depends directly on the output power [KW] of the reserve of energy, but not on the content of the reserve of energy [kWh] itself.
- It is necessary to observe multiple signals (e.g., voltage, current, temperature) to assess the available output power of the reserve of energy.
- The actuating force does not depend directly on the number of full stroke applications but will be almost constant until as critical discharge level of the reserve of energy is reached.

“Energy Management System (EMS) used by the Braking System - 1”



“Energy Management System (EMS) used by the Braking System - 2”

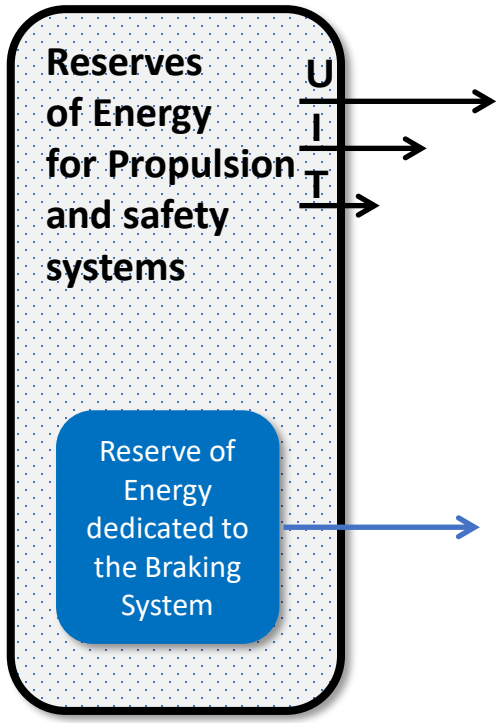
1. EMS will use multiple signals (voltage, current, temperature) and models (or observers) to “know”, in real time, that the reserve of energy and output power is sufficient to guarantee the specified braking performance.

2. State of Function (SOF) continuously determines if the reserve of energy, and the necessary output power, are greater than the thresholds at which the regulations require the activation of the brake warning signals.

3. SOF is based on predictions of
    - State of Health (Ageing)
    - State of Charge
    - Inner Resistance

4. SOF based predictions serve for providing safety warning triggers for
    - Insufficient brake performance (red waring light)
    - Replacement of energy reserve due to degradation (yellow warning light)

Energy reserve as part of, e.g., the traction battery.



Traction Battery

- The traction battery may also function as the energy reserve, and energy supply, for the braking system.
- The dedicated braking system energy reserve, required by R13/R13H, would be ensured by protection devices that isolate other electrical consumers, including the traction motors, at critical energy levels.

Scenarios to prove the concept of the EMS based on an example of a lead-acid battery

Example:

Scenario	Physical effect on the battery	EMS-Control Action	Warning
Low temperature e.g., the vehicle is parked outside during a cold night	**Increased internal resistance (Ri)** – In combination with internal resistance increase due to battery aging, low temperature is problematic for battery's power delivery capability	EMS-Control continuously measures voltage (U), current (I) and temperature (T). Because of low temperature the "predictor of Ri" will exceed the threshold. – EMS-Control reports *"State of function critical, due to insufficient Power Delivery Capability".* – **SOF Warning issued** during vehicle startup – Previous warnings to the driver due to battery aging are technically possible and recommended. Other control strategies are possible	**Yes** – The power supply for the 8+1 brake applications cannot be is ensured**.**

Summary

- Monitoring and Measuring the energy of an electrical braking system is possible by using an *“Energy Management System (EMS)”*

- EMS can deduce, via the State of Function (SOF), that an Electrical Storage Device´s performance can meet the braking demands during application by an assessment of the available reserve of energy and available output power.

- EMB compares the measured value of SOF with the known threshold value of SOF required to meet the specific performance of the braking system. The known threshold of SOF is defined by the vehicle manufacturer and confirmed as part of the approval process.

- A traction battery may also serve as an energy storage device for the braking system. Protection devices will be used to ensure that energy is available to the braking system.

Three questions to GRVA

Is GRVA content that :

1. The level of energy available in the energy reserves of an electrical braking system cannot be monitored and measured as is the case with pneumatic braking systems?

2. Will an energy management system that deduces the energy in the reserves based on, for example, charging rates, temperature, usage history, current, and voltage, be acceptable?

3. Will it be acceptable to use an energy reserve that is available to several vehicle systems as an energy storage device for the braking system – the dedicated portion of energy for the braking system being ensured by, for example, electrical switches?