Smart Operation on Ground
Call for proposal
JTI-CS-2012-1-SGO-03-014

SOG Power Electronics with Energy Recycling System

PIECES JOINTES: *ENCLOSURES:* **Planches:** Sheets: **Annexes:** Appended documents:	**DIFFUSION:** *DISTRIBUTION:*

ETABLI PAR *WORKED OUT BY*			VERIFIE PAR *CHECKED OUT BY*			REFERENCE *REFERENCE*
NOM *NAME*	VISA *SIGNED*	DATE *DATE*	NOM *NAME*	VISA *SIGNED*	DATE *DATE*	**DR40763**
S. JABER	SJ	17 November 2011	A. SORIN	AS	17 November 2011	Issue 2

Issue N°	Issue date	Pages changed, added, deleted	Reason for document change
Issue 1 Draft	April, 2011	All	Creation
Issue 1	May 2011	All	First release
Issue 2	November 2011	All	

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1 Purpose

This document is a technical specification of the PEERS (Power Electronic with Energy Recycling System). The PEERS will be part of the Smart Operation on Ground System which allows the aircraft to move autonomously from the airport and without the use of the main engines.
There is 1 PEERS per aircraft.
One PEERS performs the drive of 2 taxiing actuator integrated on aircraft main landing gear (one per gear)

1.2 Terms and Acronyms

1.2.1 Terms

Shall: Sentences containing the word "Shall" are mandatory practices, which have to be followed without exception.

Should: Sentences containing the word "Should" are strongly recommended practices. A justification in a Preliminary Design Review (PDR) to the appropriate level in the hierarchy is needed if they are not followed.

Must: The word "Must" in the text is used for legislative or regulatory requirements (e.g. health and safety) and shall be complied with. It is not used to express a requirement.

Will: The word "Will" in the text denotes a provision or service or an intention in connection with a requirement.

May: Sentences containing the word "May" are guidelines; no justification is required if they are not followed.

1.2.2 Acronyms

A/C	_____	**A**ir**C**raft
ACSW	_____	**A**ctuator **C**ontrol **S**oft**W**are
BITE	_____	**B**uilt **I**n **T**est **E**quipment
DSO	_____	**DiS**crete **O**utput
I/O	_____	**I**nput / **O**utput
PMSW	_____	**P**ower **M**anagement **S**oft**W**are
SOG	_____	**S**mart **O**peration on **G**round
SOGCU	_____	**S**mart **O**peration on **G**round **C**ontrol **U**nit
TBC	_____	**T**o **B**e **C**onfirmed
TBD	_____	**T**o **B**e **D**efined
WA	_____	**W**heel **A**ctuator

1.3 Applicable / Referenced Documents

1.3.1 Applicable Documents

The following documents are applicable:

Reference	Issue	Title/Content
		ABD100.1.8E rev C

1.3.2 Referenced documents

The following documents are for reference only

Reference	Issue	Title/Content
		PTS SGO system_ME0839525_v1 Draft 7
		ARINC 429 Specification Part 1-17

2. GENERAL DESCRIPTION

The Power Electronic with Energy Collecting System is part of the Smart Operation on Ground system.
This system should be divided into two main parts :

- A Power Electronic Unit (PEU) which drives the wheel actuator motors
- A Power Supply Unit (PSU) which manages both power coming from the aircraft network and power provided to other aircraft systems

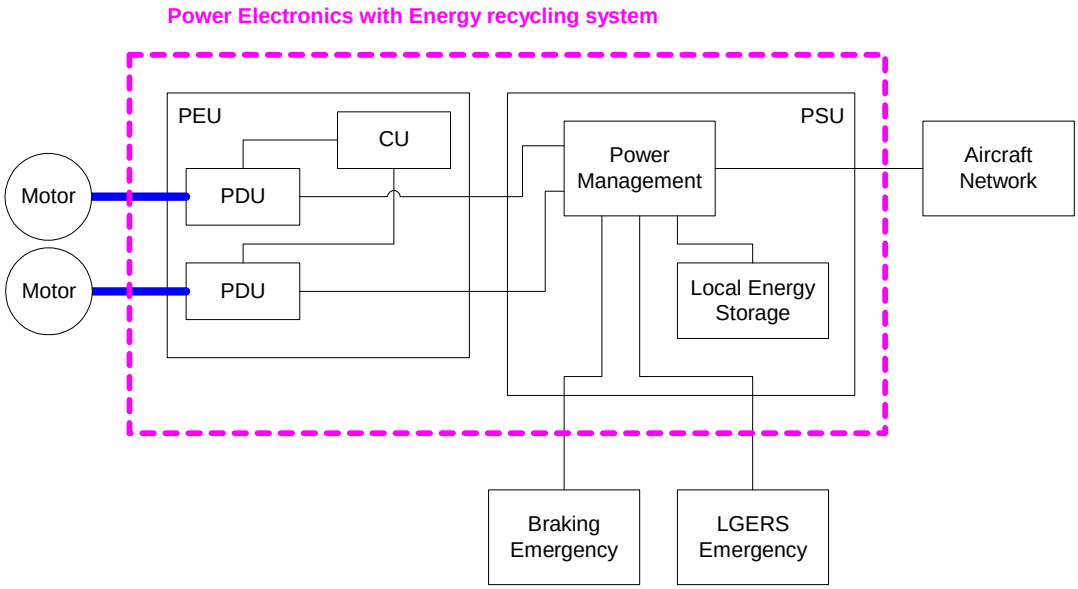


Figure 1: PEERS overview

The PEU interfaces with the SOG wheel Actuators. It is mainly composed of Power Drive Units (including inverters, filters, …) and a Control Unit (CU) which manages the wheel actuator sensors acquisition and which embedded the wheel actuator control laws. The Control Unit will also acquire orders coming from the high-level controller of the SOG system.

During acceleration phases, the PSU is providing power to the PEU in order to provide the needed motion torque to the aircraft thanks to the wheel actuators. This power may come from aircraft network or local energy storage device.

During braking phase, some regenerative power is transmitted from the Wheel Actuator Motors to the PEU and then, From the PEU to the PSU. Depending of the system status and configuration, the power may be :

- Stored in the local Energy storage device
- Transmitted to the aircraft network to supply other aircraft systems
- Burned in dedicated device (resistances, …)

During aircraft landing or landing gear Extension phases, the power embedded in the Local Energy Storage Device may be used to supply if needed the braking or the LGERS emergency systems.

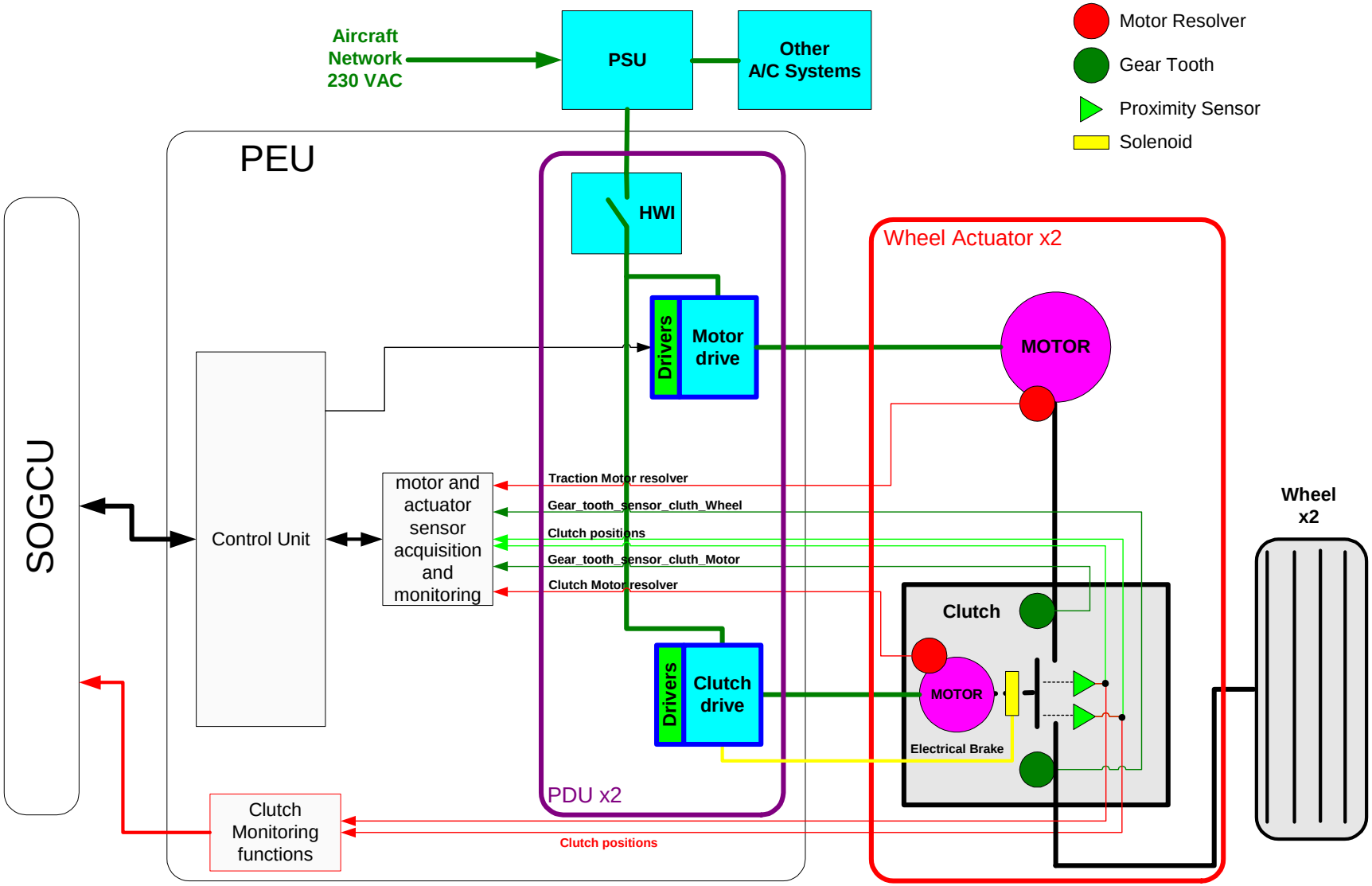


Figure 2: PEU and Wheel Actuator overview

Wheel actuators are interfacing with the PEU of the PEERS.
Wheel Actuators are mainly composed of:

- A traction Motor equipped with hall effect sensor (TBC) – This motor is providing the torque needed to move the aircraft
- A clutch which allows connection/disconnection of the wheel actuator to the wheel. It Includes:
  - A Clutch Motor with its resolver which drives a gear
  - 2 Gear Tooth sensors for synchronisation purpose
  - Proximity sensors to monitor clutch status
  - An electrical brake to maintain the clutch in connected position

During taxi phase, a torque demand is sent by the SOGCU to the PEU and the torque applied by the WAs versus the demanded input is controlled using a closed loop system.

3. FUNCTIONAL DESCRIPTION

3.1 PEERS High Level Functions

[SCD-PEERS-001]
The PEERS **shall** drive SOG Wheel Actuator Traction Motors

[SCD-PEERS-002]
The PEERS **shall** drive SOG WA Clutch Motor to ensure Wheel Actuator connection to its associated wheel

[SCD-PEERS-003]
The PEERS **shall** drive SOG WA Clutch Motor to ensure Wheel Actuator disconnection from its associated wheel

[SCD-PEERS-004]
The PEERS **shall** monitor each SOG Wheel Actuator status

[SCD-PEERS-005]
The PEERS **shall** monitor each SOG Wheel Actuator clutch position

[SCD-PEERS-006]
The PEERS **shall** acquire orders coming from SOGCU

[SCD-PEERS-007]
The PEERS **shall** provide its status to the SOGCU

[SCD-PEERS-008]
The PEERS **shall** store regenerative power into Local Energy Storage Device (LESD)

[SCD-PEERS-009]
The PEERS **shall** provide power from LESD to Braking and Landing Gear Extension Systems

[SCD-PEERS-010]
The PEERS **shall** convert regenerative power coming from WA into suitable electrical power for A/C network

3.2 PEU Functions

[SCD-PEERS-011]
The PEU Shall be able to drive the traction motor in four quadrant Mode

[SCD-PEERS-012]
The PEU Shall be able to drive the clutch motor in four quadrant Mode

[SCD-PEERS-013]
The PEU Shall be able to control the activation/deactivation of the clutch electrical brake

[SCD-PEERS-014]
The PEU **shall** provide sensors power supplies and Filtering / acquisitions

[SCD-PEERS-015]
The PEU **shall** provide protections against reverse polarities

[SCD-PEERS-016]
The PEU **shall** provide inrush current limiters

[SCD-PEERS-017]
The PEU **shall** provide Power-Fail detection

[SCD-PEERS-018]
The PEU **shall** provide monitorings

[SCD-PEERS-019]
The PEU **shall** provide I/Os discretes acquisitions (analog functions)

[SCD-PEERS-020]
The PEU **shall** provide 2 Hosts for the ACSW in charge of actuator control

[SCD-PEERS-021]
The PEU **shall** provide two segregated (fault isolation) ARINC429 bus interfaces

[SCD-PEERS-022]
The PEU **shall** provide 2 power stages which supply the three phases of the associated traction motors by applying the transformed PWM signals to the inverter's power switches.

[SCD-PEERS-023]
The PEU **shall** provide 2 power stages which supply the three phases of the associated clutch motors by applying the transformed PWM signals to the inverter's power switches.

[SCD-PEERS-024]
The PEU **shall** provide current sensing module to measure the motors phase currents in order to manage the motor currents and to protect inverters

[SCD-PEERS-025]
The PEU **shall** provide lightning and EMC filtering modules that provide protections against lightning threats, ESD, HIRF, EMI/RFI and implement a thorough segregation to avoid fault/Failure propagation.

3.3 PEU Functions

[SCD-PEERS-026]
The PSU **shall** provide the following functions:

[SCD-PEERS-027]
The PSU **shall** provide sensors power supplies and Filtering / acquisitions

[SCD-PEERS-028]
The PSU **shall** provide protections against reverse polarities

[SCD-PEERS-029]
The PSU **shall** provide inrush current limiters

[SCD-PEERS-030]
The PSU **shall** provide back up power supply for transparency during power cuts

[SCD-PEERS-031]
The PSU **shall** provide Power-Fail detection to manage power cuts

[SCD-PEERS-032]
The PSU **shall** provide monitorings

[SCD-PEERS-033]
The PSU **shall** provide I/Os discretes acquisitions (analog functions)

[SCD-PEERS-034]
The PSU **shall** provide 1 Host for the PMSW in charge of actuator control

[SCD-PEERS-035]
The PSU **shall** provide two segregated (fault isolation) ARINC429 bus interfaces

[SCD-PEERS-036]
The PSU **shall** provide the supplies for all PEERS parts

[SCD-PEERS-037]
The PSU **shall** provide a reversible power stage to convert 230 VAC into HVDC and HVDC into 230 VAC (aircraft network)

[SCD-PEERS-038]
The PSU **shall** provide a reversible local energy storage unit

[SCD-PEERS-039]
The PSU **shall** provide crow-bar to avoid any un-requested power regeneration on the aircraft power electrical system

[SCD-PEERS-040]
The PSU **shall** provide power switches for hardware interlocking controlled by power management software

[SCD-PEERS-041]
The PSU **shall** provide protection on HVDC bus and on 230 VAC supply bus

[SCD-PEERS-042]
The PSU **shall** provide lightning and EMC filtering modules that provide protections against lightning threats, ESD, HIRF, EMI/RFI and implement a thorough segregation to avoid fault/Failure propagation.

4. MODES

4.1 Functional operating modes

4.1.1 OFF mode:

PSU:

- Power unit is unpowered
- Monitoring is unpowered
- Control unit is unpowered

PEU:

- Power unit(s) are unpowered
- Monitoring is unpowered
- Control unit is unpowered
- Transmissions (clutch) are disengaged

4.1.2 Standby mode:

PSU:

- Power unit is powered
- Monitoring is powered
- Control unit is powered

PEU:

- Power unit(s) are unpowered
- Monitoring is unpowered
- Control unit is unpowered
- Transmissions (clutch) are disengaged

4.1.3 Ready mode:

PSU:

- Power unit is powered
- Monitoring is powered
- Control unit is powered

PEU:

- Power unit(s) are powered
- Monitoring is powered
- Control unit is powered
- Transmissions (clutch) are engaged

[SCD-PEERS-043]
In case of ready mode acquisition, the PEU **shall** not drive the traction motor

[SCD-PEERS-044]
In case of ready mode acquisition, the PEU **shall** drive the clutch motor

[SCD-PEERS-045]
While in ready mode, the PEU **shall** be able to perform a free wheel mode for WA motor rotation speed varying from -44 to 193 rpm

4.1.4 Active mode:

PSU:

- Power unit is powered
- Monitoring is powered
- Control unit is powered

PEU:

- Power unit(s) are powered
- Monitoring is powered
- Control unit is powered
- Transmissions (clutch) are engaged

[SCD-PEERS-046]
In the active the PEU **shall** acquire the "torque request" orders coming from the SOGCU

[SCD-PEERS-047]
In the active mode, the PEU **shall** keep connected each wheel actuators to its associated wheel

[SCD-PEERS-048]
In the active mode, the PEU **shall** drive the traction motor

4.2 Mode Transitions

[SCD-PEERS-049]
In case of power loss (28 VDC or 230 VAC) at PEERS level, the PEU **shall** command the disconnection of the WA transmission

[SCD-PEERS-050]
The PEERS **shall** be able to switch from OFF mode to standby Mode with a wake up command from SOGCU.

[SCD-PEERS-051]
Upon a Standby mode acquisition, the PSU **shall** verify the validity of its PMSW (monitoring & control) before becoming operational.

[SCD-PEERS-052]
Upon a ready mode acquisition, the PSU **shall** detect known incompatibilities of its PMSW (monitoring & control) before becoming operational.

[SCD-PEERS-053]
Upon a ready mode acquisition, the PEU **shall** verify the validity of its ACSW (monitoring & control) before becoming operational.

[SCD-PEERS-054]
Upon a ready mode acquisition, the PEU **shall** detect known incompatibilities of its ACSW (monitoring & control) before becoming operational.

5. PERFORMANCES

5.1.1 General performances

[SCD-PEERS-055]
The PEERS **shall** be able to perform during 10 min (TBC) the working point {175 rpm; 1820 N.m } (TBC)

[SCD-PEERS-056]
The PEERS **shall** be able to perform during 10 min (TBC) the working point {131 rpm ; 3178 N.m}

[SCD-PEERS-057]
The power stages functions **shall** be active within 1 s (TBC)

[SCD-PEERS-058]
The PEU **shall** drive the WA motor within 1.5 second following a torque request order sent by the SOGCU

[SCD-PEERS-059]
The output torque accuracy of WA/PEU **shall** not be less than:

- ±10% of the commanded value (proportional)
- or not less than ±5% of the maximum torque value (absolute)

[SCD-PEERS-060]
The PEERS **shall** be able to perform a power step of TBD for wheel speed varying from -44 rpm to +193 rpm

5.1.2 Duty cycles

[SCD-PEERS-061]
The PEU **shall** be capable of performing the torque versus speed cycles defined in APPENDIX A (taxi-out and taxi-in) 8 times per day (TBC)

5.1.3 Efficiency

[SCD-PEERS-062]
The PEERS efficiency **shall** be better than 0,95% at max speed, nominal torque {175 rpm ; 1820 N.m}

5.1.4 Local Energy Storage Device

[SCD-PEERS-090]
The LESD **shall** be designed to ensure the storage of an amount of energy of 100 000 J.

[SCD-PEERS-063]
The LESD **shall** be designed to provide power for the following duty cycles:

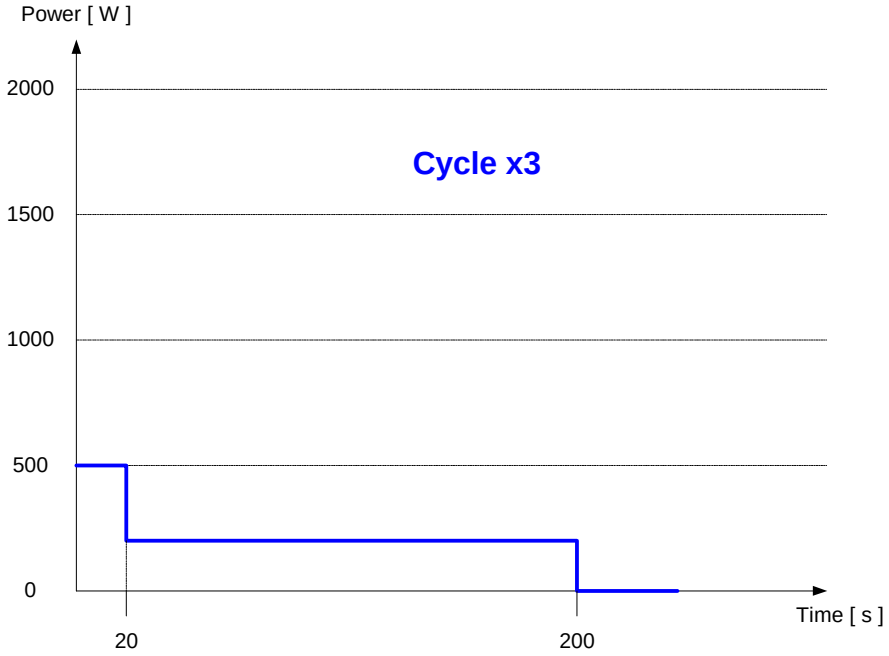


Figure 3: LESD Duty cycle A

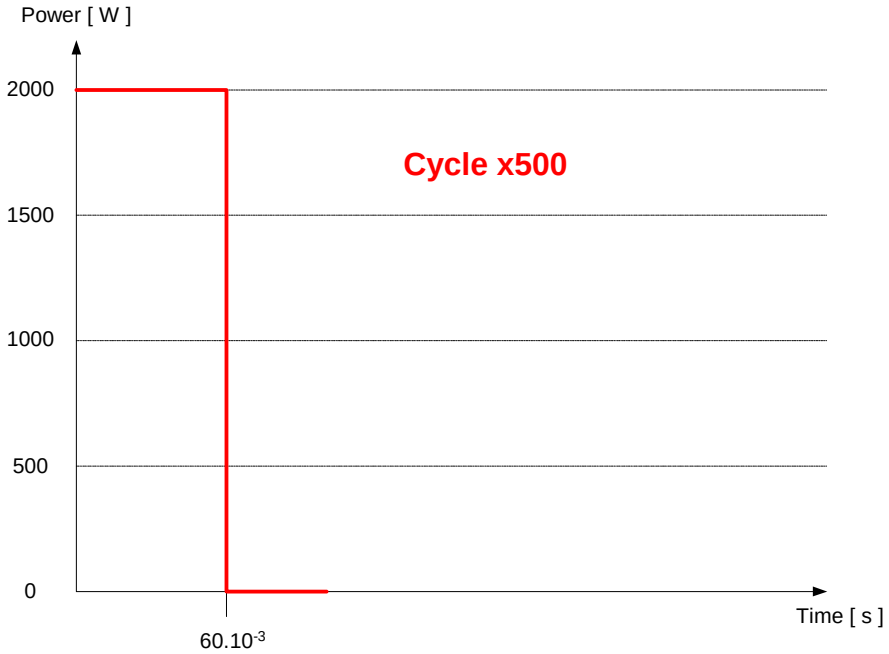


Figure 4: LESD Duty cycle B

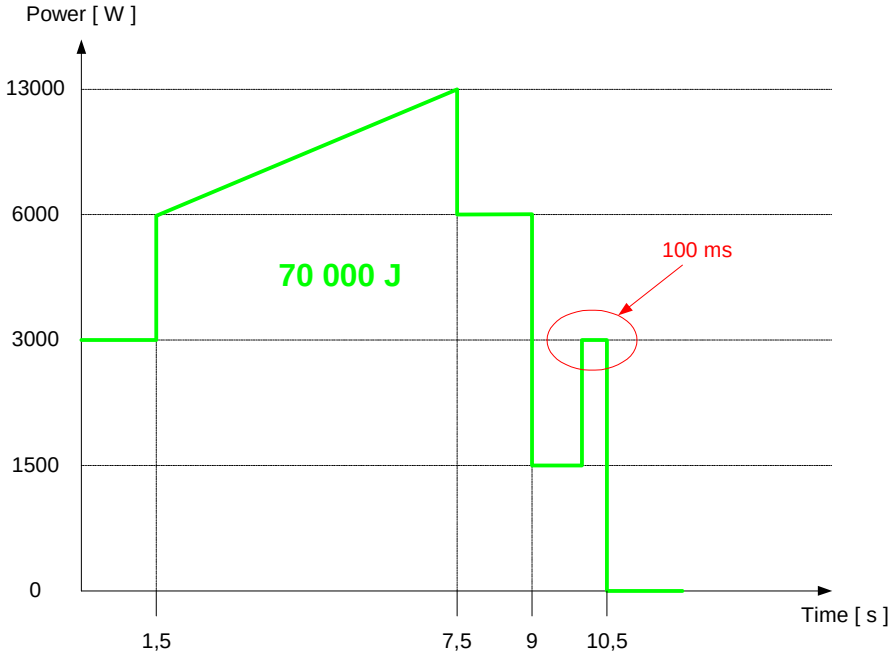


Figure 5: LESD Duty cycle C

6. ARCHITECTURE & PHYSICAL REQUIREMENTS

6.1 Architecture

[SCD-PEERS-064]
A modular design for the PEERS **shall** be achieved.

[SCD-PEERS-065]
The PEU and PSU **shall** have independent packaging.

[SCD-PEERS-066]
The PEU **shall** be composed at least of the following hardware devices:

- Electro-mechanical clutch control devices
- Power stages
- Currents sensing module
- Supply module
- Input/Output interfaces
- Monitorings
- EMH Protections
- Miscellaneous internal protections
- Actuator control device

[SCD-PEERS-067]
The PSU **shall** be composed at least of the following hardware devices:

- Supply module
- Regenerative dissipation module
- Power stages
- Supply module
- Input/Output interfaces
- Monitorings
- EMH Protections
- Miscellaneous internal protections
- Power management device

[SCD-PEERS-068]
PEERS equipment **shall** meet the general design and verification requirements of the ABD1001.8

6.2 Dielectric and Insulation requirements

[SCD-PEERS-069]
PEERS equipment **shall** meet the dielectric and insulation requirements of the ABD1001.8

6.3 Grounding and bonding

[SCD-PEERS-070]
Bonding and grounding **shall** comply with Airbus requirements ABD100 1.8.1

[SCD-PEERS-071]
Power Returns **shall** be electrically isolated from case ground within the PEERS according to ABD100 1.8.1 for insulation requirements.

[SCD-PEERS-072]
Case grounds **shall** be used to conduct fault current only and not used as a normal current return path; except for EMI filters, which may be connected to current return and chassis.

[SCD-PEERS-073]
Analog circuits except 230 VAC **shall** have wired returns.

[SCD-PEERS-074]
Digital, analog, or discrete electronic circuits housed in PEERS **should** have a reference ground to case.

[SCD-PEERS-075]
Equipment interfacing with shielded ships wiring **shall** have electrical connectors with an electrically conductive finish to enable the shielding to be grounded to the chassis.

6.4 Filtering

[SCD-PEERS-076]
The PEERS **shall** be designed to function properly with wirings defined in appendix B considering the following additional tolerances:

- +/- 20% on electrical characteristics
- +/- 20% on wiring length

6.5 Weight

[SCD-PEERS-077]
The PEU weight **shall** be less than 60 kg (TBC)

[SCD-PEERS-078]
The PSU weight **shall** be less than 40 kg (TBC)

6.6 Volume

[SCD-PEERS-079]
The PEU **shall** be TBD Liters as a maximum

6.7 Electrical connections

[SCD-PEERS-080]
Connectors **shall** be compliant with DO160

6.8 Heat Dissipation – cooling and ventilation

[SCD-PEERS-081]
The PEERS **shall** manage the heat dissipation by forced convection (air or fluid)

[SCD-PEERS-082]
The PEERS cooling system **shall** allow PEERS temperature to decrease under acceptable level within 20 minutes following a taxi In Cycle.

[SCD-PEERS-083]
The PEERS **shall** operate normally within the following ground envelope TBC (refer to Figure 6, red curve).

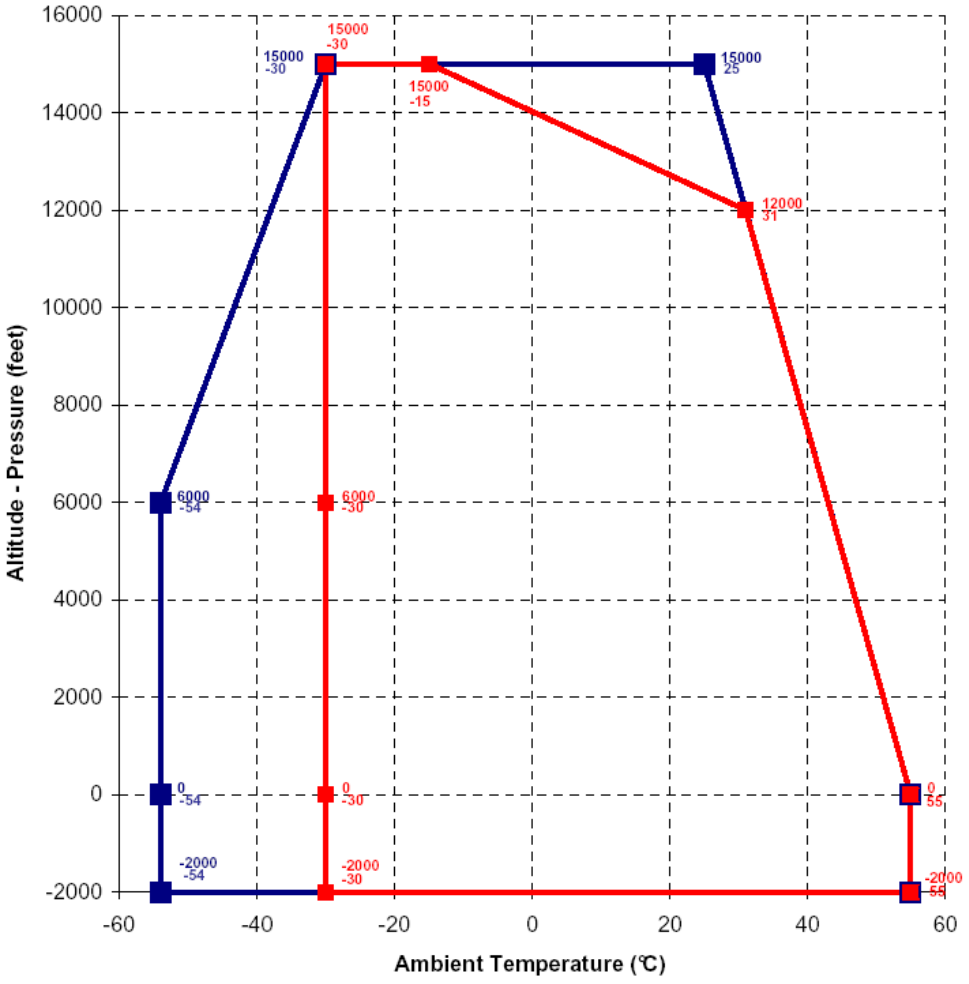


Figure 6 : Preliminary Ground Starting envelope

7. INTERFACES

7.1 Mechanical interfaces

[SCD-PEERS-084]
Drawing **shall** clearly show location, size and tolerance values of all interfaces.

Mechanical interfaces will be jointly defined during plateau phase

7.2 Electrical interfaces

[SCD-PEERS-085]
The PEERS system **shall** be able to acquire or send signals defined in appendix C.

8. MONITORINGS AND TESTS

[SCD-PEERS-086]
The PEU **shall** monitor each motor speed

[SCD-PEERS-087]
If the motor speed is above 12500 rpm then the PEU **shall** disconnect the corresponding wheel until its speed decrease below 12000 rpm

[SCD-PEERS-088]
The low power supply and the monitoring functions of the PEU **shall** be active within 2 s TBC

[SCD-PEERS-089]
The PEU **shall** send a "Ready" or "fault" status to the SOGCU within 2 seconds after the reception of the "stand-by" order

[SCD-PEERS-091]
An independent status "ready/fault" **shall** be sent to the SOGCU by the PEU for each wheel actuator

[SCD-PEERS-092]
The PEU **shall** implement BITE in accordance with ABD0100.1.4.

[SCD-PEERS-093]
Monitoring of the PEERS **shall** be performed continuously when the SOG system is powered. Monitoring list to be identified

[SCD-PEERS-094]
When the PEERS has a known incompatible software configuration (ACSW or PMSW), the PEERS **shall** inhibit power stages.

[SCD-PEERS-095]
The PEERS **shall** detect software/hardware incompatibility and report the fault in order to generate a bus message report that **shall** be sent on SOGCU ARINC429 bus

9. ENVIRONMENTAL REQUIREMENTS

[SCD-PEERS-096]
The PEU **shall** meet all performance requirements without physical or electrical degradation during and after exposure to relevant environmental conditions according to DO160D and Airbus's standards / specifications, throughout its service life (see applicable category for RTCA DO160 are provided in the following table).
Results of inspection at the end of qualification tests shall be reported in the Qualification test report.

Section	Test	Category
Section 4	Temperature and altitude	A3
Section 5	Temperature variation	B
Section 6	Humidity	A
Section 7	Operational Shocks and Crash Safety	A
Section 8	Vibration	R Level C&C1
Section 9	Explosive Atmosphere	E
Section 10	Waterproofness	Y
Section 13	Fungus resistance	F
Section 15	Magnetic Effect	C
Section 17	Voltage spike	A
Section 18	Audio frequency conducted susceptibilty - Power Inputs	R
Section 19	Induced signal susceptibility	C
Section 20	Radio frequency susceptibility (radiated and conducted)	W
Section 21	Emission of Radio frequency energy	L
Section 22	Lightning direct effects	A3J33
Section 25	Electrostatic discharge	A
Section 26	Fire, flammability	C

[SCD-PEERS-097]
The PEU equipment **shall** operate normally from -15°C to +70°C ambient temperature.

[SCD-PEERS-098]
The PEU **shall** operate normally after exposure to a temperature of – 55°C.

[SCD-PEERS-099]
The PEU **shall** comply with the Protection Against Fluid Retention Requirements contained in ABD0100.1.7, Section 6.10. List of contaminant to be defined

[SCD-PEERS-100]
Environmental tests of the PEU **shall** be performed using actual WAs for loading.

10. SAFETY REQUIREMENTS

[SCD-PEERS-101]
The PEU **shall** contribute to the compliance of the SOG system to System Particular Risks Analysis Requirements

[SCD-PEERS-102]
In CWAe of PEU or SOG System failure, the PEU **shall** not degrade any other A/C capabilities

[SCD-PEERS-103]
A failure in PEU **shall** not impact 28VDC availability

[SCD-PEERS-104]
A failure in PEU **shall** not damage any other component of the SOG system

[SCD-PEERS-105]
A failure in PEU **shall** not damage equipment located close to the PEU

[SCD-PEERS-106]
A failure in PEU **shall** not lead to fire ignition

11. MAINTAINABILITY REQUIREMENTS

[SCD-PEERS-107]
No maintenance task for the PEU **should** use tooling not currently considered standard for the Airbus single-aisle family of aircraft.

[SCD-PEERS-108]
Maintenance activity on PEU **shall** not compromise ground or flight safety.

[SCD-PEERS-109]
All PEU components weighing more than 25kg **shall** be designed to allow installation and removal using Airbus-standard ground tooling.

[SCD-PEERS-110]
The PEU **shall** provide a simple means to discharge or disconnect any stored energy devices within the system prior to any maintenance.

[SCD-PEERS-111]
All potential sources of personnel injury or equipment damage in the PEU **shall** be clearly indicated by a warning label.

[SCD-PEERS-112]
List of maintenance tasks to be identified.
Minor task **shall** be achieved within TBD min
Major task **shall** be achieved within 6 hours (TBC)

[SCD-PEERS-113]
The PEU **shall** communicate Maintenance information to the SOGCU

[SCD-PEERS-114]
The PEU **shall** communicate PEU & PSU key data to the SOGCU

12. TRL4 DEMONSTRATION TESTS

[SCD-PEERS-115]
The adequate tests **shall** be performed in laboratory environment in order to demonstrate the following capabilities of the actuator:

- the conformity to the present specification regarding the functional aspects (control/command, clutch operations),
- the conformity to the present specification regarding the weight requirement,
- the conformity to the present specification regarding the performance requirements (Torque vs speed capacity, efficiency),
- the conformity to the present specification regarding the thermal cycle requirement,
- the conformity to the present specification regarding the endurance requirement (10% of full life),
- the conformity to the actuator definition dossier.

13. DELIVERABLES

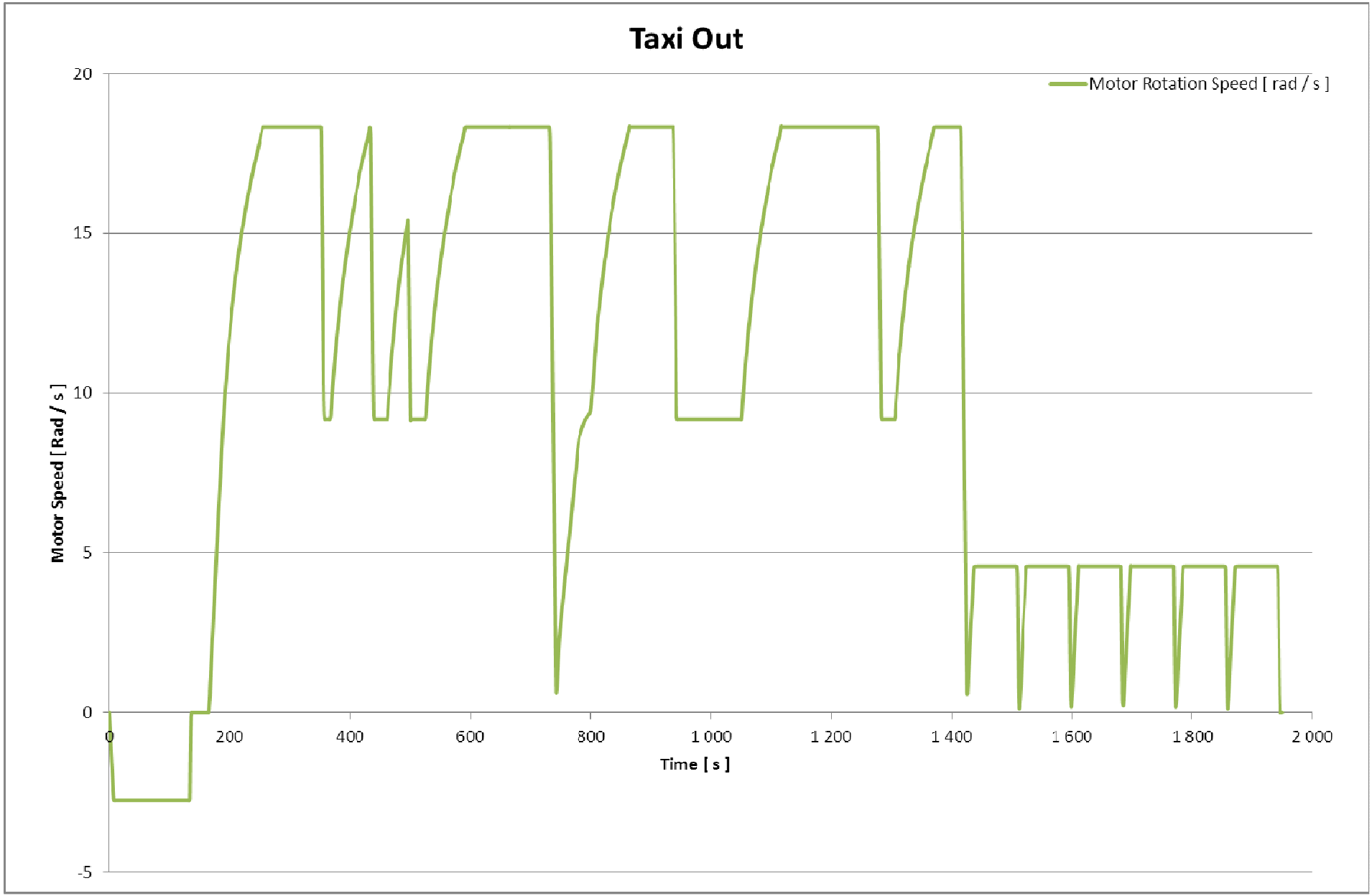
[SCD-PEERS-116]
The following documentation **shall** be delivered:

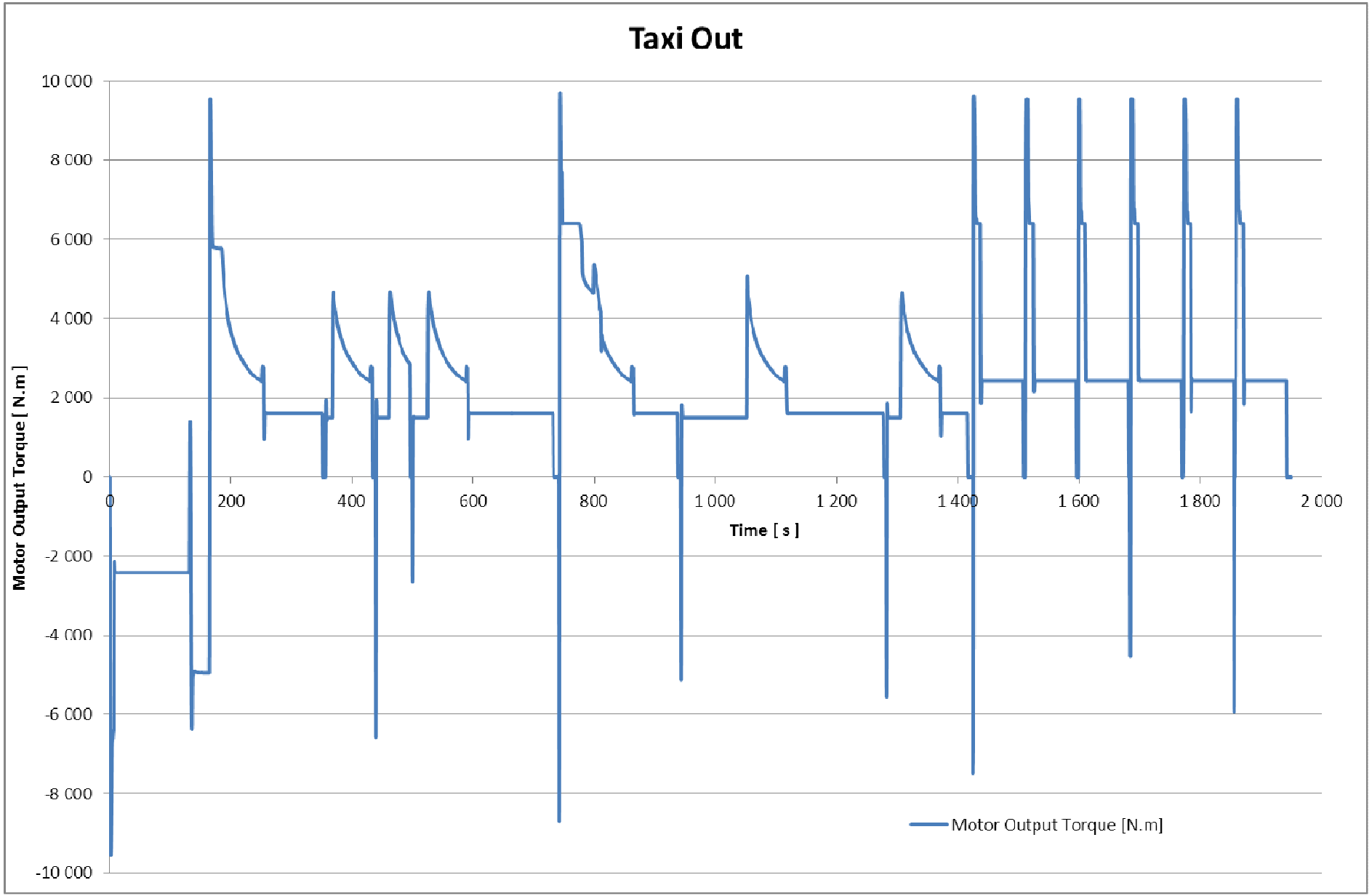
- specification conformity matrix,
- ATP (Acceptance Test procedure),
- ATR (Acceptance Test Report)
- PJD (Definition Justification Plan),
- DJD (Definition Justification Dossier),
- Tests programs,
- Tests reports.

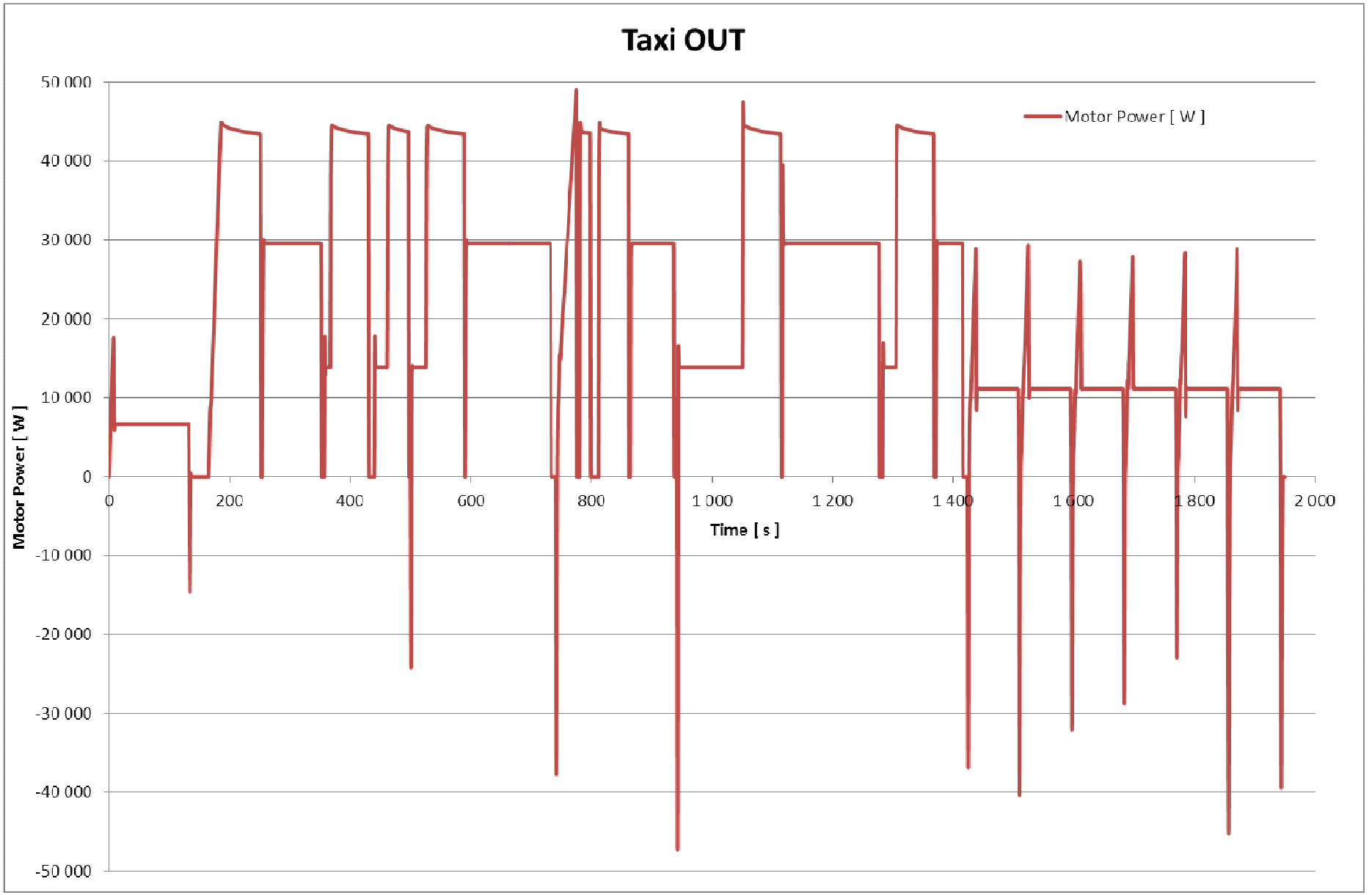
[SCD-PEERS-117]
Two actuator prototypes **shall** be manufactured:

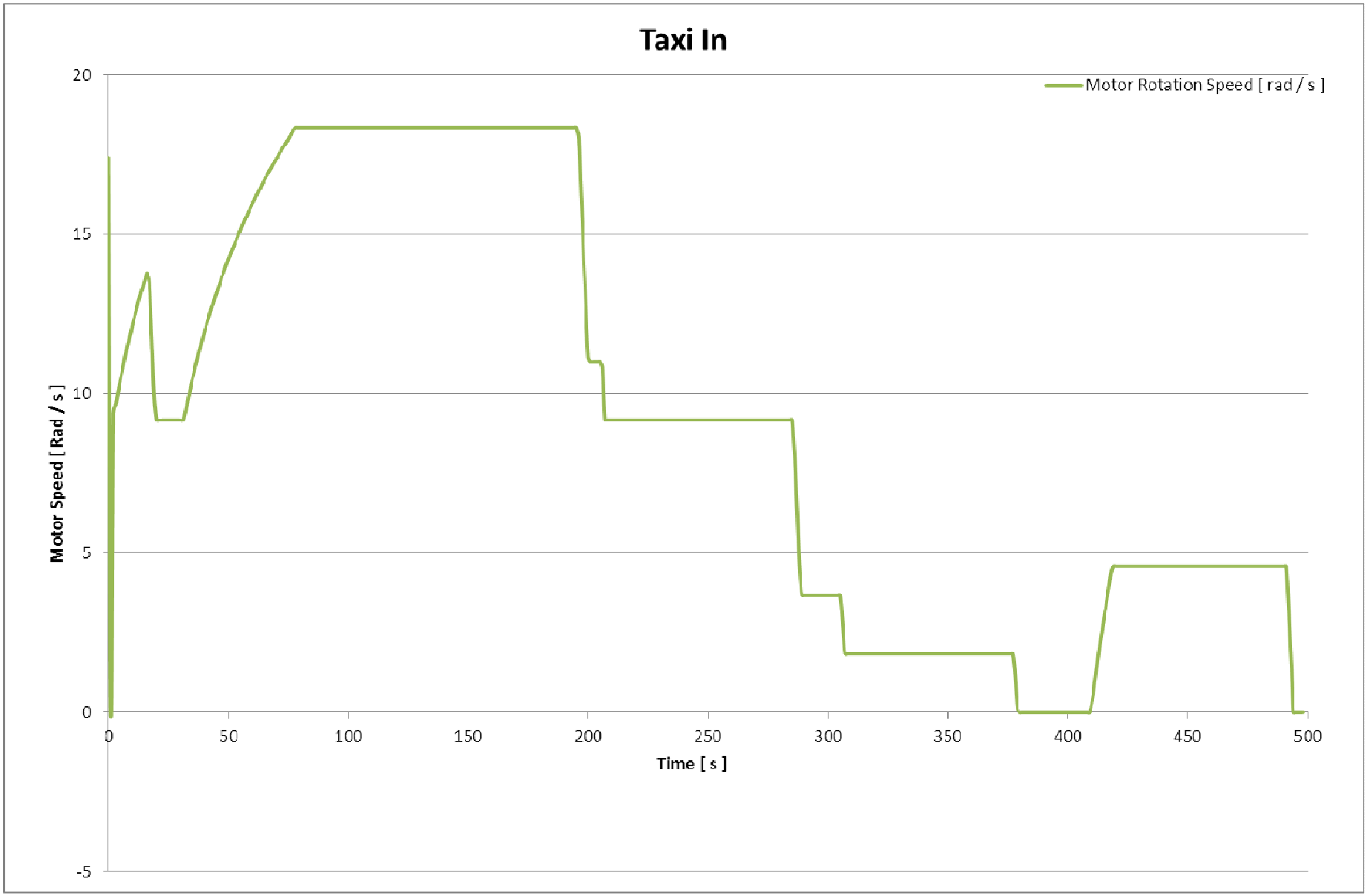
- one for the TRL4 demonstration,
- one for the system integration tests.

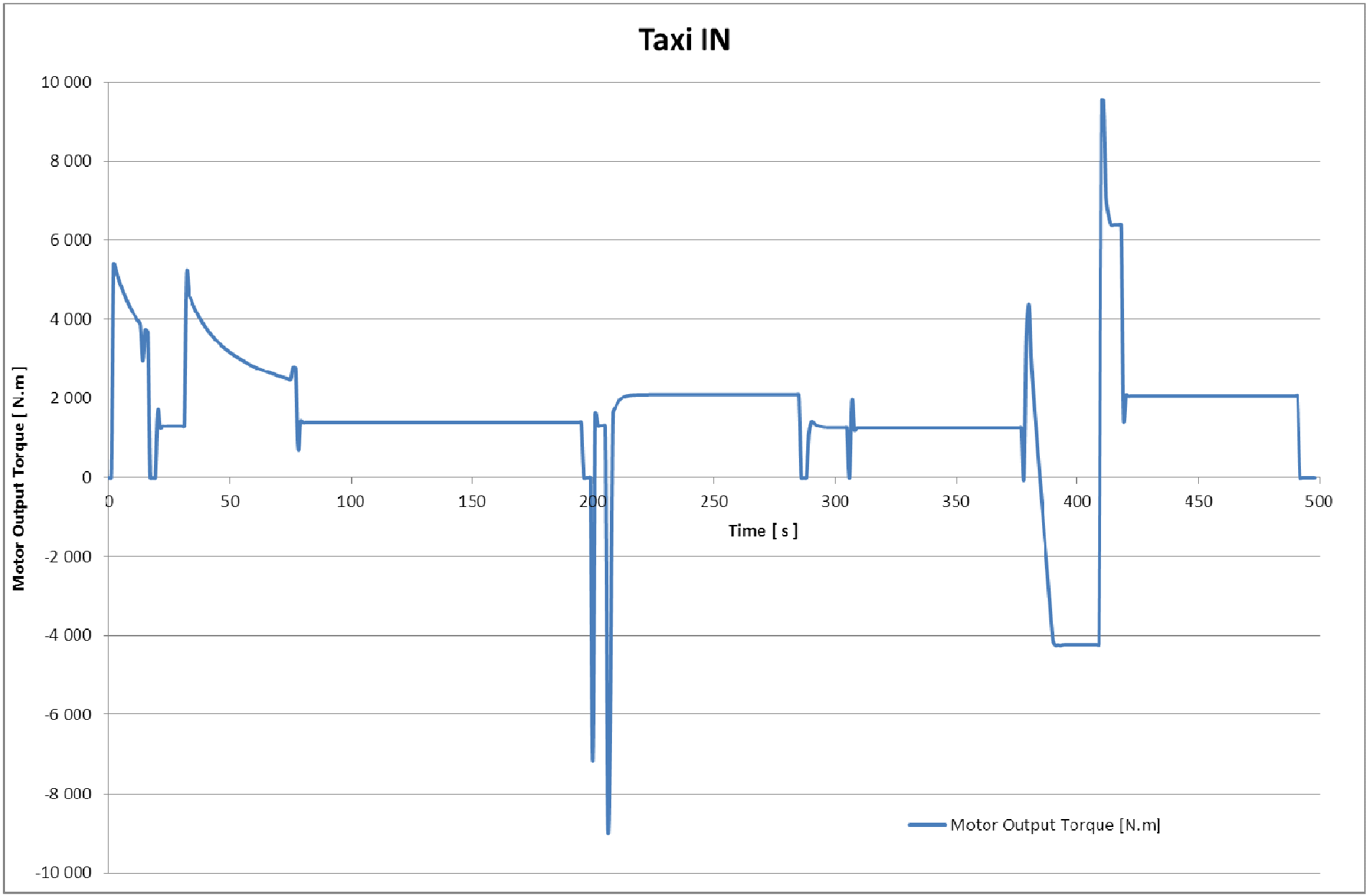
APPENDIX A: Duty Cycle

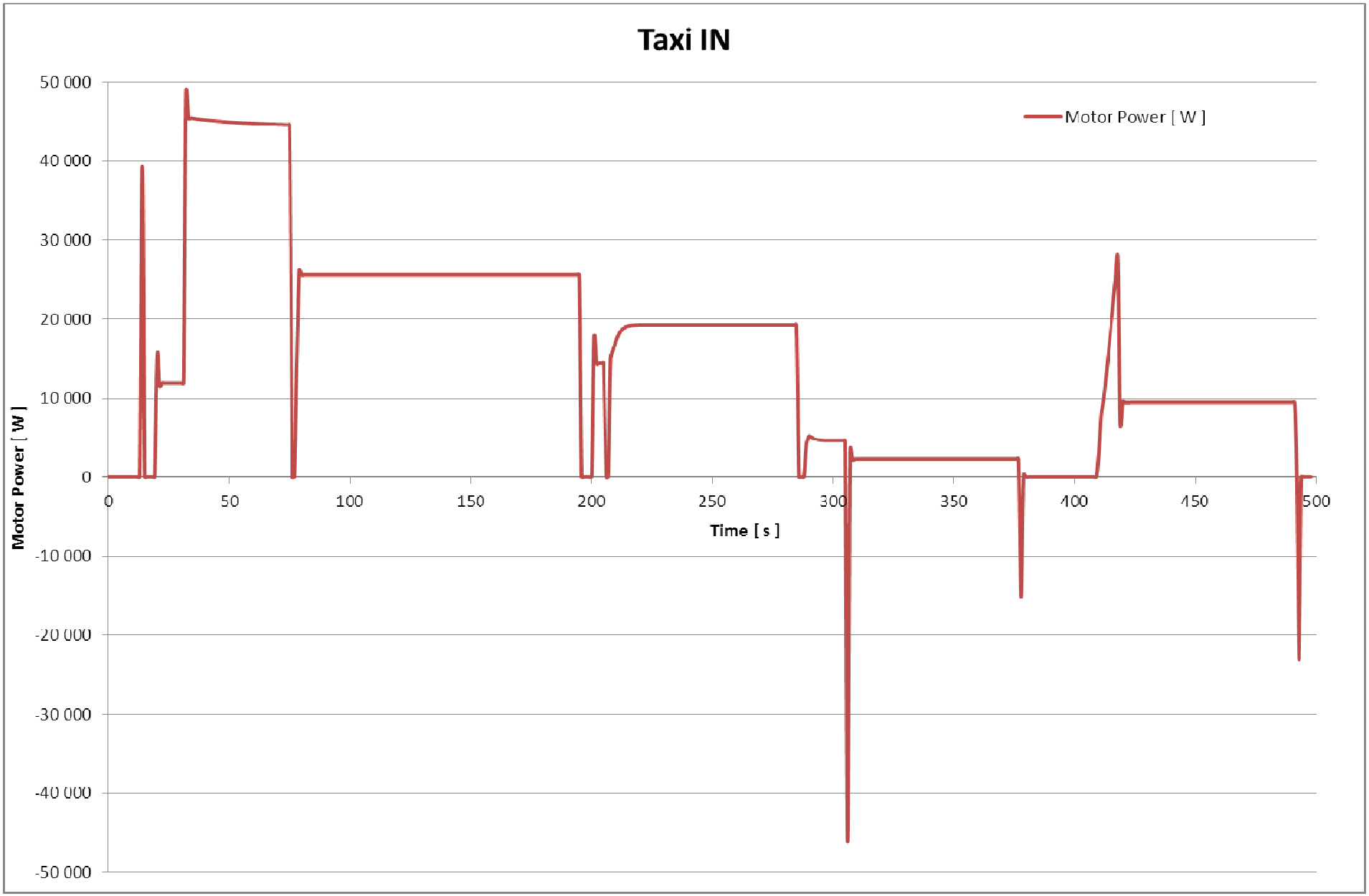












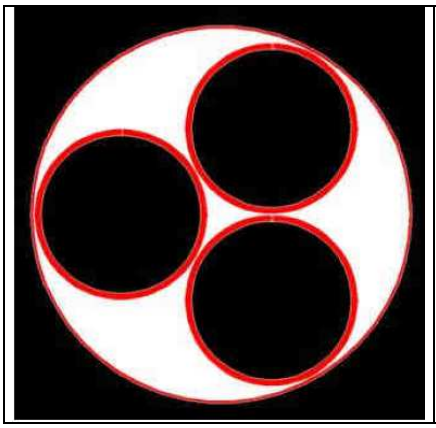
APPENDIX B: Wiring description

N°	Description	Length [m]	Wire number	Voltage	Material	Gauge	Shield
1-A	Phase 1 between PEU & Left MLG Disconnection	11.5	3	+/- 270 VDC	Aluminium	4	Yes
1-B	Phase 2 between PEU & Left MLG Disconnection	11.5	3	+/- 270 VDC	Aluminium	4	Yes
1-C	Phase 3 between PEU & Left MLG Disconnection	11.5	3	+/- 270 VDC	Aluminium	4	Yes
2-A	Phase 1 between Left MLG Disconnection & Left WA	4.5	3	+/- 270 VDC	Copper	6	Yes
2-B	Phase 2 between Left MLG Disconnection & Left WA	4.5	3	+/- 270 VDC	Copper	6	Yes
2-C	Phase 3 between Left MLG Disconnection & Left WA	4.5	3	+/- 270 VDC	Copper	6	Yes

N°	Description	Length [m]	Wire number	Voltage	Material	Gauge	Shield
3-A	Phase 1 between PEU & Right MLG Disconnection	6.5	3	+/- 270 VDC	Aluminium	4	Yes
3-B	Phase 2 between PEU & Right MLG Disconnection	6.5	3	+/- 270 VDC	Aluminium	4	Yes
3-C	Phase 3 between PEU & Right MLG Disconnection	6.5	3	+/- 270 VDC	Aluminium	4	Yes
4-A	Phase 1 between Right MLG Disconnection & Right WA	4.5	3	+/- 270 VDC	Copper	6	Yes
4-B	Phase 2 between Right MLG Disconnection & Right WA	4.5	3	+/- 270 VDC	Copper	6	Yes
4-C	Phase 3 between Right MLG Disconnection & Right WA	4.5	3	+/- 270 VDC	Copper	6	Yes

Preliminary features of wires are given in the following table:

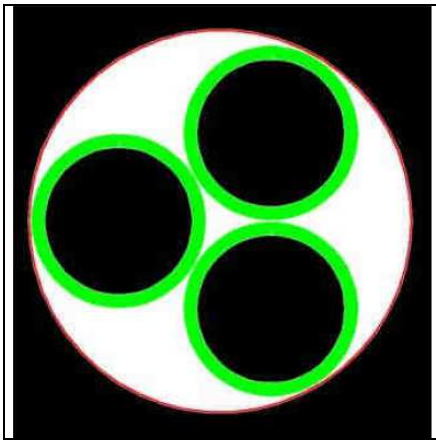
Copper Harness
3 wires DR6, with PTFE, copper shielding



$$C = \begin{pmatrix} 178 & 70 & 70 \\ 70 & 178 & 70 \\ 70 & 70 & 178 \end{pmatrix} pF/m$$

$$L = \begin{pmatrix} 59 & 16 & 16 \\ 16 & 59 & 16 \\ 16 & 16 & 59 \end{pmatrix} nH/m$$

Aluminum Harness
3 wires YV4, with PTFE, copper shielding



$$C = \begin{pmatrix} 248 & 77 & 77 \\ 77 & 248 & 77 \\ 77 & 77 & 248 \end{pmatrix} pF/m$$

$$L = \begin{pmatrix} 85 & 19 & 19 \\ 19 & 85 & 19 \\ 19 & 19 & 85 \end{pmatrix} nH/m$$

APPENDIX C: Preliminary Motors features

Motor Characteristics	
Kt (peak) (N.m/A)	36
L (mH)	20
R (Ohm) at 20 °C	0.768
Imax (Amps)	276 A (for peak torque)
Imax (Amps)	450 A (for maximum converter rating)
Number of Pole	42

Note: Values may be updated accordingly to progress made on wheel actuator design

APPENDIX D: Preliminary Interfaces

	SOG : parameters function PEU												
				data definition						affectation HW			
	from/to	data name	data description and interest	type (bool, real, int)	encoding (nb of bit)	required accuracy	Refresh	Input	Output	DSI	DSO	A429 RX	A429 TX
ACTUATOR WHEEL 1	SOGCU	TORQ_1	Torque to be commanded on traction motor	real	tbd		5 ms	x				x	
		CMD_STBY_1	Standby order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_READY_1	Ready order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_ACTIVE_1	Active order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_CLUTCH_VAL_1	Clutch validation order	bool	tbd	-	20 ms	x		1			
		CMD_PS_ACT_1	Power Supply activation order	bool	tbd	-	20 ms	x		1			
		CMD_PS_VAL_1	Power Supply validation order	bool	tbd	-	20 ms	x		1			
		ACT_SPEED_1	Actuator speed	real	tbd	tbd	5 ms		x				x
		MOT_SPEED_1	Traction motor speed	real	tbd	tbd	5 ms		x				x
		MOT_ANG_POS_1	Traction motor angular position	real	tbd	tbd	5 ms		x				x
		STAT_CLUTCH_A_1	This status provide the clutch position	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_B_1	This status provide the clutch position	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_A_MON_1	This status provide the clutch position for monitoring	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_B_MON_1	This status provide the clutch position for monitoring	bool	tbd	-	20 ms		x		1		
		STAT_POWER_INPUT_OK_MOT_1	This status is true when power is stable and available for traction motor drive	bool	tbd	-	20 ms		x				x
		STAT_POWER_INPUT_OK_CL_1	This status is true when power is stable and available for clutch motor drive	bool	tbd	-	20 ms		x				x
		STAT_MOTOR_CONTROL_1	This status is true when traction motor is controlled	bool	tbd	-	20 ms		x				x
		STAT_ACT_MINOR_FAULT_1	This status is true when a minor fault is detected on actuator path (degraded)	bool	tbd	-	20 ms		x				x
		STAT_ACT_CRITICAL_FAULT_1	This status is true when a minor critical is detected on actuator path (failed, jammed…)	bool	tbd	-	20 ms		x				x
	TRACTION MOTOR DEVICE	VBUS	Power supply voltage at Motor drive input	real	12 bits			x					
		POS_RES	Traction Motor resolver position	real	12 bits			x					
		IA_MOT	Traction Motor phase current A	real	12 bits			x					
		IB_MOT	Traction Motor phase current B	real	12 bits			x					
		IC_MOT	Traction Motor phase current C	real	12 bits			x					
		TM_PWM_MN	Order to control traction motor	real					x				
		TM_A_MOT	Order to control traction motor	real	12 bits				x				
		TM_B_MOT	Order to control traction motor	real	12 bits				x				
		TM_C_MOT	Order to control traction motor	real	12 bits				x				
		B_HZ_MOT	Order to control traction motor	bool					x				
	CLUTCH DEVICE (Provision)	VBUS	Power supply voltage at Motor drive input	real	12 bits			x					
		B_HA	Hall sensors A of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_HB	Hall sensors B of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_HC	Hall sensors C of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_GR1_CH1	Gear tooth sensor of the wheel gear	bool	tbd	-		x					
		B_GR1_CH2	Gear tooth sensor of the wheel gear	bool	tbd	-		x					
		B_GR2_CH1	Gear tooth sensor of the clutch gear	bool	tbd	-		x					
		B_GR2_CH2	Gear tooth sensor of the clutch gear	bool	tbd	-		x					
		B_SWH_ENG	Proximity switch of the clutch for engaged position	bool	tbd	-		x					
		B_SWH_DISENG	Proximity switch of the clutch for disengaged position	bool	tbd	-		x					
		B_SOL_PWR	Order to supply the solenoide to maintain the clutch is position	bool	tbd	-			x				
		IA_CLH	Clutch Motor phase current A	real	12 bits	tbd		x					
		IB_CLH	Clutch Motor phase current B	real	12 bits	tbd		x					
		IC_CLH	Clutch Motor phase current C	real	12 bits	tbd		x					
		TM_PWM_CLH	Order to control Clutch motor	real	tbd				x				
		TM_A_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		TM_B_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		TM_C_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		B_HZ_A_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_B_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_C_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_CLH	Order to control Clutch motor	bool	tbd				x				

TBD

	SOG : parameters function PEU												
				data definition						affectation HW			
	from/to	data name	data description and interest	type (bool, real, int)	encoding (nb of bit)	required accuracy	Refresh	Input	Output	DSI	DSO	A429 RX	A429 TX
ACTUATOR WHEEL 2	SOGCU	TORQ_1	Torque to be commanded on traction motor	real	tbd		5 ms	x				x	
		CMD_STBY_1	Standby order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_READY_1	Ready order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_ACTIVE_1	Active order for actuator control	bool	tbd	-	20 ms	x		1			
		CMD_CLUTCH_VAL_1	Clutch validation order	bool	tbd	-	20 ms	x		1			
		CMD_PS_ACT_1	Power Supply activation order	bool	tbd	-	20 ms	x		1			
		CMD_PS_VAL_1	Power Supply validation order	bool	tbd	-	20 ms	x		1			
		ACT_SPEED_1	Actuator speed	real	tbd	tbd	5 ms		x				x
		MOT_SPEED_1	Traction motor speed	real	tbd	tbd	5 ms		x				x
		MOT_ANG_POS_1	Traction motor angular position	real	tbd	tbd	5 ms		x				x
		STAT_CLUTCH_A_1	This status provide the clutch position	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_B_1	This status provide the clutch position	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_A_MON_1	This status provide the clutch position for monitoring	bool	tbd	-	20 ms		x		1		
		STAT_CLUTCH_B_MON_1	This status provide the clutch position for monitoring	bool	tbd	-	20 ms		x		1		
		STAT_POWER_INPUT_OK_MOT_1	This status is true when power is stable and available for traction motor drive	bool	tbd	-	20 ms		x				x
		STAT_POWER_INPUT_OK_CL_1	This status is true when power is stable and available for clutch motor drive	bool	tbd	-	20 ms		x				x
		STAT_MOTOR_CONTROL_1	This status is true when traction motor is controlled	bool	tbd	-	20 ms		x				x
		STAT_ACT_MINOR_FAULT_1	This status is true when a minor fault is detected on actuator path (degraded)	bool	tbd	-	20 ms		x				x
		STAT_ACT_CRITICAL_FAULT_1	This status is true when a minor critical is detected on actuator path (failed, jammed…)	bool	tbd	-	20 ms		x				x
	TRACTION MOTOR DEVICE	VBUS	Power supply voltage at Motor drive input	real	12 bits			x					
		POS_RES	Traction Motor resolver position	real	12 bits			x					
		IA_MOT	Traction Motor phase current A	real	12 bits			x					
		IB_MOT	Traction Motor phase current B	real	12 bits			x					
		IC_MOT	Traction Motor phase current C	real	12 bits			x					
		TM_PWM_MN	Order to control traction motor	real					x				
		TM_A_MOT	Order to control traction motor	real	12 bits				x				
		TM_B_MOT	Order to control traction motor	real	12 bits				x				
		TM_C_MOT	Order to control traction motor	real	12 bits				x				
		B_HZ_MOT	Order to control traction motor	bool					x				
	CLUTCH DEVICE (Provision)	VBUS	Power supply voltage at Motor drive input	real	12 bits			x					
		B_HA	Hall sensors A of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_HB	Hall sensors B of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_HC	Hall sensors C of the brushless motor for Clutch motion control	bool	tbd	-		x					
		B_GR1_CH1	Gear tooth sensor of the wheel gear	bool	tbd	-		x					
		B_GR1_CH2	Gear tooth sensor of the wheel gear	bool	tbd	-		x					
		B_GR2_CH1	Gear tooth sensor of the clutch gear	bool	tbd	-		x					
		B_GR2_CH2	Gear tooth sensor of the clutch gear	bool	tbd	-		x					
		B_SWH_ENG	Proximity switch of the clutch for engaged position	bool	tbd	-		x					
		B_SWH_DISENG	Proximity switch of the clutch for disengaged position	bool	tbd	-		x					
		B_SOL_PWR	Order to supply the solenoide to maintain the clutch is position	bool	tbd	-			x				
		IA_CLH	Clutch Motor phase current A	real	12 bits	tbd		x					
		IB_CLH	Clutch Motor phase current B	real	12 bits	tbd		x					
		IC_CLH	Clutch Motor phase current C	real	12 bits	tbd		x					
		TM_PWM_CLH	Order to control Clutch motor	real	tbd				x				
		TM_A_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		TM_B_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		TM_C_CLH	Order to control Clutch motor	real	12 bits	tbd			x				
		B_HZ_A_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_B_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_C_CLH	Order to control Clutch motor	bool	tbd				x				
		B_HZ_CLH	Order to control Clutch motor	bool	tbd				x				

TBD

	SOG : parameters function PEU													
				data definition						affectation HW			
	from/to	data name	data description and interest	type (bool, real, int)	encoding (nb of bit)	required accuracy	Refresh	Input	Output	DSI	DSO	A429 RX	A429 TX
PEU	SOGCU	CMD_BITE_GENERAL	BITE order autotest PEU after PEU power up	bool	tbd	-	20 ms	x		1			
		STAT_BITE_GENERAL_RUN	this status is true while autotest is ordered and running	bool	tbd	-	20 ms		x				x
		STAT_BITE_GENERAL_DONE	this status becomes true when autotest is realized and finished	bool	tbd	-	20 ms		x				x
		STAT_BITE_GENERAL_OK	this status becomes true if autotest result is OK	bool	tbd	-	20 ms		x				x
		STAT_BITE_GENERAL_FAULT	this status becomes true if autotest result is KO	bool	tbd	-	20 ms		x				x
		STAT_INITIAL_POWER_UP	this status is true if PEU initial power up is OK	bool	tbd	-	20 ms		x				x
		PEU_TEMP	PEU internal temperature	real	tbd	tbd	80 ms		x				x
		MOTOR_TEMP	Traction motor temperature	real	tbd	tbd	80 ms		x				x
		CLUTCH_TEMP	clutch motor temperature	real	tbd	tbd	80 ms		x				x
		PEU_POSITION	This data is used for determining PEU position (Left, Right)	bool	tbd	-	20 ms		x				x
		PEU_VALIDITY	This data is used to monitor PEU validity	bool	tbd	-	20 ms		x		1		

	SOG : parameters function PEU												
			data definition						affectation HW			
	from/to	data name	data description and interest	type (bool, real, int)	encoding (nb of bit)	required accuracy	Refresh	Input	Output	DSI	DSO	A429 RX	A429 TX
Global	N/A (servitudes)	PIN_PROG_POS_1	to select module position	bool	tbd	-	N/A	x		1			
	N/A (servitudes)	PIN_PROG_POS_2	to select module position	bool	tbd	-	N/A	x		1			
	N/A (servitudes)	PIN_PROG_POS_3	to select module position	bool	tbd	-	N/A	x		1			
	N/A (servitudes)	PIN_PROG_POS_4	to select module position	bool	tbd	-	N/A	x		1			
	N/A (servitudes)	28 VDC	module power supply	-	N/A	tbd	N/A	x					
	N/A (servitudes)	230 VAC PHASE 1	module high power supply	-	N/A	tbd	N/A	x					
	N/A (servitudes)	230 VAC PHASE 2	module high power supply	-	N/A	tbd	N/A	x					
	N/A (servitudes)	230 VAC PHASE 3	module high power supply	-	N/A	tbd	N/A	x					

									TOTAL	17	9	1	2
										DSI	DSO	A429 RX	A429 TX