MAENAD

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Model-based Analysis & Engineering of Novel Architectures for Dependable Electric Vehicles

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Authors

Editor	E-mail
Stefano Cerchio	stefano.cerchio@crf.it

Authors	E-mail
Sandra Torchiaro	sandra.torchiaro@crf.it
Dr. B. Rösel	birgit.roesel@continental-corporation.com
DeJiu Chen	chen@md.kth.se
Tahir Naseer	tnqu@md.kth.se
Frank Hagl	frank.hagl@continental-corporation.com
Henrik Lönn	henrik.lonn@volvo.com

The Consortium

Volvo Technology Corporation (S) Centro Ricerche Fiat (I)

Continental Automotive (D) Delphi/Mecel (S) 4S Group (I)

MetaCase (Fi) Pulse-AR (Fr) Systemite (SE) CEA LIST (F)

Kungliga Tekniska Högskolan (S) Technische Universität Berlin (D) University of Hull (GB)

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0.2	2010-12-07	Case study description EV demo added
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0.4	2010-12-20	Case study description for power regenerative braking (BbW) added
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		Evaluation Metrics chapter added
		Case study description EV demo: use cases added
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0.9.1	2011-02-08	Reviewing comments added
1.0	2011-02-08	Final

List of abbreviations

Table of terms and abbreviations used in this document

Abbreviation	Description
EVC	Electric Vehicle Controller
FEV	Fully Electric Vehicles
HVJB	High Voltage Junction Box
PE	Power Electronic

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1 Introduction

The aim of the Maenad project is to develop languages, methods and tools oriented to the design and development of Full Electric Vehicles.

The purpose of this document is to introduce a general description of the FEV related case studies which will be used during the project development to exercise the capability of the Maenad methodology and related tools and a preliminary description of the metrics that will be adopted to evaluate the effectiveness of the Maenad outcomes.

To ensure completeness and effectiveness of the analysis, three different case studies that pose significant challenge in terms of design complexity and model capability will be introduced. The applications include: power distribution and safe shut down mechanism, driving mode selector, intelligent dynamics for energy optimization, regenerative braking.

- Each case studies will address different aspects of the MAENAD methodology (EV development process, ISO 26262 safety analysis, language capability, modeling aspects, dependability methods, optimization algorithm…). Through these three case studies it will be possible to achieve the following project objectives (coming from the “Description of Work”):
- O4-1: Evaluation of ability to support ISO 26262 and other standards influencing FEV;
- O4-2: Evaluation of dependability & performance analyses;
- O4-3: Evaluation of optimization approaches;
- O4-4: Evaluation of suitability of overall methodology for FEV design.

The figure 1 shows how we can cover the above objectives through the proposed case studies.

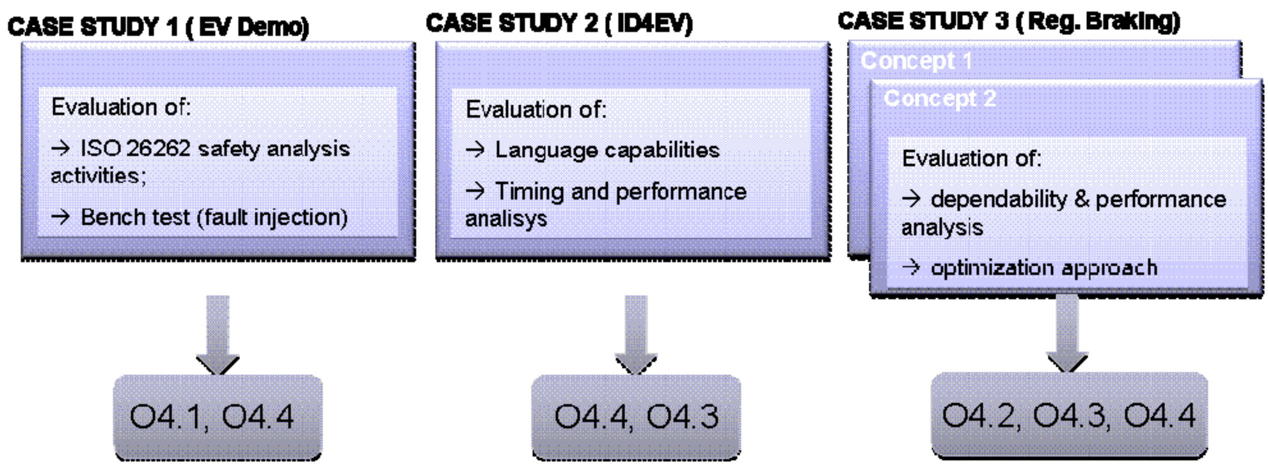

Figure 1 project objective vs case studies

In the deliverable the description of each case study will be provided. Moreover the evaluation metrics will be defined in a preliminary way.

2 Case studies description

Each case study has been described in terms of:

- Block diagram, to highlight the elements (sub-systems, components…), the interfaces and communication line of the case study;
- Functions description, to point out the main functions performed by each case study;
- Data Flow Diagram, to describe and analyse the flow of data internally, through the processes of the system under analysis, and externally, through the interfaces to external systems;
- SUSA (Sub-system Under Safety Analysis) table, that is a method typically used during safety analysis activity. In fact, the aim of the SUSA table, when we perform a safety analysis ISO 26262 compliant, is to highlight and to list the components/systems involved in the item (system or array of systems or a function to which ISO 26262 is applied [ISO FDIS 26262 – Part1]) under safety analysis, that is, everything inside the boundary, with inclusion of the interfaces. In general, each element of the list has not only to be identified in terms of name/description/etc., but it has to be classified in terms of development category as following:
    - Already existing, without modification: it is possible to inherit its safety classification from previous analysis or by "proven in use" evidence
    - Already existing, with modification: its involvement into the function has to be verified by means of proper impact analysis
    - New: its related safety activity shall be carried out without any tailoring of activity.

  However, in this deliverable the SUSA table has been used only to list and describe the components and the interface of each case study. We will update the SUSA table of the case study selected for evaluating the ability to support ISO 26262.
- Use Case description.

2.1 EV Demo

The EV Demo is a part of the EV Demo Car which is currently under development at Continental. The EV Demo Car shall demonstrate the car's entire potential set of features and functions. Furthermore the capability of Continental, as a leading automotive supplier, to provide a wide range of not only traditional but also innovative components and functions for an EV is a focus point to be demonstrated by means of this Demo Car.

The different systems in the car – tires, brakes and e-propulsion – have to be tightly integrated to achieve best efficiency. The HMI needs to reflect the special requirements of electric vehicles by displaying relevant information and support the user inputs.

The architecture and interfaces of the EV Demo Car system are defined in such a way that the components support best energy efficiency of the vehicle as well as to provide the required information to the driver. Thus the EV Demo Car shall represent a particularly well adapted platform to propose enhanced ergonomic-driven cockpit solutions facing the issues of always increasing complexity (see e.g. Continental's concept "Simplify your Drive"). This depends on the kind of function and on the safety relevance of the function/component.

The new concept of electric vehicle requires adapted system architecture and new system components to match the desired functionality. Not only the combustion engine is changed to electric propulsion but as well new additional functions have to be considered. The EV will be successful in the market if it is easy, simple, fun to drive and affordable in comparison to conventional combustion engines driven vehicles.

The costs issues shall also consider a comparison as complete as possible (environmental issues, inspection and workshop services, costs of operation, insurance, tax – also with respect to regional specificities –, etc…).

For the EV Demo as part of Maenad one of the newly developed components for the EV Demo Car will be a physical part of the demonstrator – the High Voltage Junction box.

The aim of the EV Demo is to show the power distribution and interlock concept as well as the Driving mode selection.

The following chapter gives an overview of the components and their interaction possibilities as set up for this demonstrator.

2.1.1 Block Diagram

The battery provides the high voltage to drive the FEV. The High Voltage Junction Box is distributing the energy to different consumers or providers. The main consumer is the drivetrain, consisting of power electronic and e-machine. But there are others as heater or compressor. These consumers are not part of this model. The energy is provided by a charger. There might be different chargers connected to the high voltage junction box. They are not modeled either.

The Electric Vehicle Controller is the main controller for many powertrain functions of an electric vehicle.

As an electric vehicle does not need gears for transmission there is no need for a transmission box. But the vehicle has to be able to change direction forward and backward.

Furthermore it has to be possible to bring the vehicle in a parking mode. That is why a Driving Mode Selector (PR(N)D) with at least 3 buttons is necessary. To accept a certain indication for a driving mode the brake signal and the actual speed have to be evaluated.

All these components and their interaction possibilities are described in the following two figures.

- **Error! Reference source not found.** shows an implementation with hard wired signals between EVC, HVJB and battery.
- **Error! Reference source not found.** shows another implementation of the same system with CAN connectors on all three components.

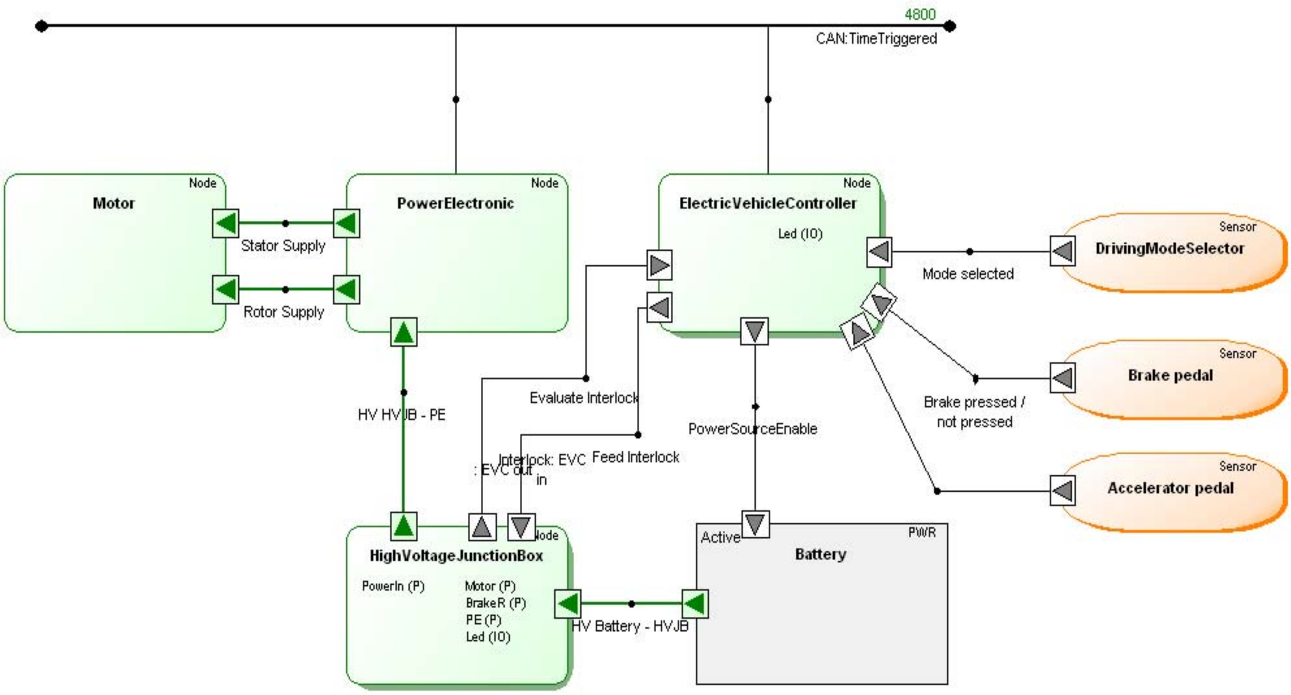

Figure 2: block diagram of the hardware of EV Demonstrator – version 1

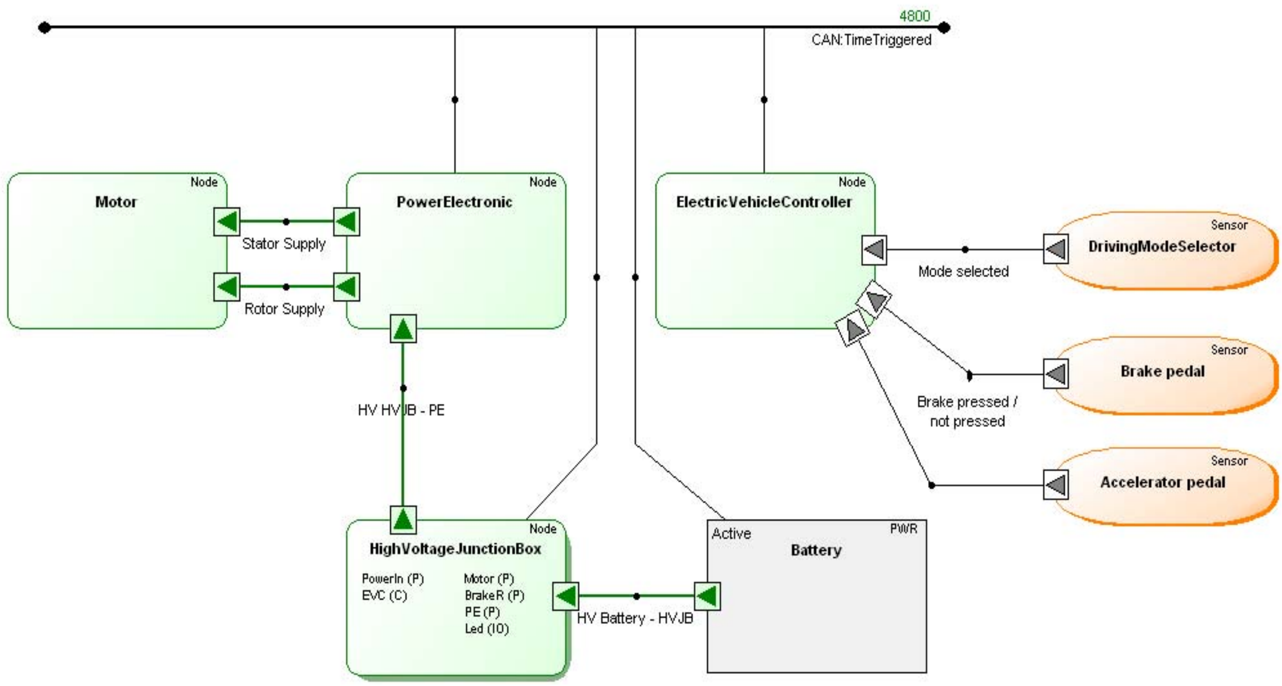

Figure 3: block diagram of the hardware of EV Demonstrator – version 2

2.1.2 Functions Description

It is necessary in electric vehicles to distribute high voltage through the vehicle. It has to be assured that no one touches high voltage unintentionally. Furthermore it is important to supervise the proper function of all high voltage connections. For this reason the interlock line is established. That is every high voltage connector has two additional contacts which are connected to each other as long as the connector is plugged in completely. As soon as one connector is released the interlock is opened. When this occurs the high voltage supply is disconnected immediately.

This function is required to assure that persons do not have contact to the high voltage under all circumstances. Maybe a connector is damaged after an accident. Then the high voltage supply has to be stopped to avoid any further damage of persons. It is dangerous to stop the emachine in case the interlock line was opened by mistake. If this happens during a takeover maneuver the vehicle will lose driving energy immediately (refer to **Error! Reference source not found.** for a data flow diagram).

As the Electric Vehicle Controller is the main controller for many powertrain functions of an electric vehicle it provides the information to feed the interlock line to the HVJB. For the ‘hard wired version’ this is done by a dedicated signal on the connection *Feed interlock* between EVC and HVJB (refer to **Error! Reference source not found.**). Thus is this version the EVC is the beginning of the interlock line. Furthermore the EVC is then the endpoint of the interlock line – connection *Evaluate interlock* between HVJB and EVC. In the EVC the evaluation of the status of the interlock line is done. As a result of this evaluation the EVC may decide to shut down the high voltage which is done with the connection *PowerSourceEnable* and to stop the torque request from the Powerelectronic (refer to **Error! Reference source not found.**).

With the ‘CAN based version’ the EVC sends a CAN message to the HVJB to start to feed the interlock line. That is the interlock line physically begins and ends in the HVJB. Thus the HVJB has to send a status of the actual interlock line to the EVC where the evaluation of the interlock line is done as in the hardwired version. Again, if the result of the evaluation is to shut down the high voltage, an appropriate message has to be sent to the battery – in this version by CAN. Furthermore the torque request from the Powerelectronic has to be stopped as well.

As an electric vehicle does not need more gears for transmission there is no need for a transmission box. But the vehicle has to be able to change direction forward and backward electrically. Furthermore is has to be possible to bring the vehicle in a parking mode. That is why at least 3 buttons are necessary to indicate the drivers wish to the EVC:

- Normal driving (forward direction) – D
- Backward driving – R
- Parking mode (no energy provided to the emachine) – P.

A logic has to be established to be sure that there is no accident due to unintended change of motion

Normal driving (D)

A status change from P to D will only be accepted when vehicle speed is below 5 km/h and brake pedal is pressed.

A status change from R to D will only be accepted when vehicle speed is below 5 km/h.

Backward driving (R)

A status change to R will not be accepted above 6 km/h forward speed.

Parking mode (P)

For any change from P to another status brake pedal has to be pressed.

P will be engaged as soon as vehicle speed is below 6km/h. A status change to P will not be accepted above 6 km/h forward speed. In this case no more drive torque is commanded by the accelerator pedal. As soon as the vehicle speed decreases below 6 km/h the parking mode is activated.

2.1.3 Data Flow Diagram

The data flow diagram describes the functional behavior of the EV Demo. The diagram given in **Error! Reference source not found.** is valid for both physical versions.

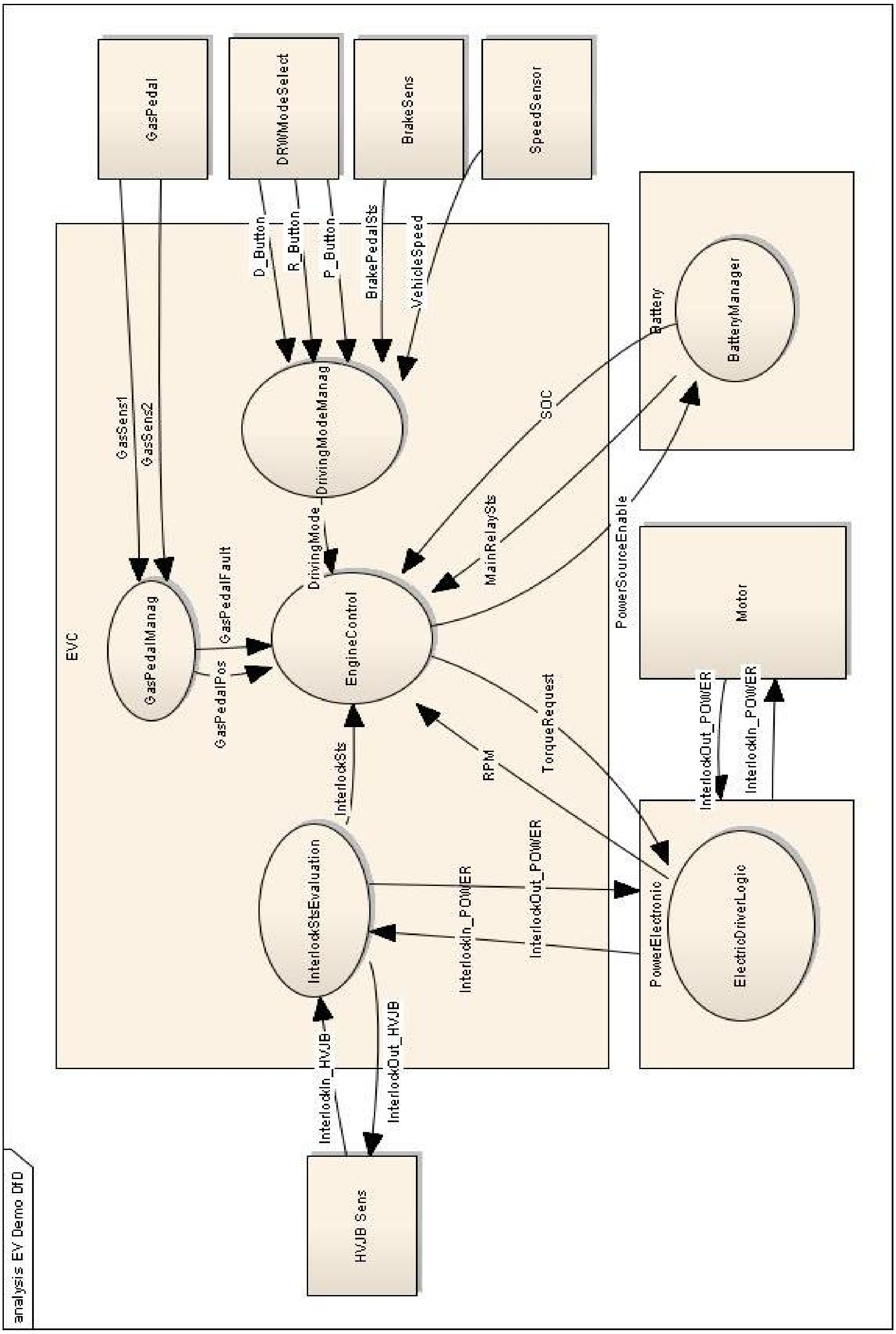

Figure 4: EV Demo data flow diagram

2.1.4 SUSA Table

SUSA (Sub-system Under Safety Analysis) table is typically used during safety analysis activity. The aim of a SUSA table is to highlight and to list the components/systems involved in the item under safety analysis, that is, everything inside the boundary, with inclusion of the interfaces. In general, each element of the list has not only to be identified in terms of name/description/etc., but it has to be classified in terms of development category as following:

Element				
ID	Component	Function		Type
		VF Link	Description	
01.001	Electric Vehicle Controller	Interlock	Disconnecting high voltage supply	Involved
01.002	Power Electronic	Interlock	Disconnecting high voltage supply	Interface
01.003	Motor	Interlock	Disconnecting high voltage supply	Interface
01.004	Battery	Interlock	Disconnecting high voltage supply	Interface
01.005	HVJB	Interlock	Disconnecting high voltage supply	Involved
01.006	Driving Mode Selector	Driving mode selection	Selecting the driving mode	Involved
01.007	Brake Pedal	Driving mode selection	Selecting the driving mode	Involved
01.008	Accelerator sensor	Driving mode selection	Selecting the driving mode	Interface
01.009	CAN		CAN network	Involved

Figure 5: EV Demo SUSA table

2.1.5 Use Cases

The use cases presented in this chapter cover the interlock function as well as the driving mode selection of the EV demo.

UC1: Maintenance Operation

Precondition: Vehicle in parking mode for maintenance operation

Operator opens the HVJB cover. The interlock is opened and thus the battery stops providing energy automatically

UC2: Connector fault during driving operation

Precondition: Vehicle running (in any manoeuvre scenario). A fault condition that implies a disconnection of any high voltage connector in the system occurs

EVC detect the failure through the HVJBInterlockIn Line.

EVC set torque request to 0 to the power electronics.

EVC shut down the battery through the signal PowerSourceEnable.

EVC check the shutdown execution through the signal MainRelaySts.

UC3: Backward driving inhibition

Precondition: Vehicle speed above 6 km/h

Driver presses the Backward driving button. The backward driving mode is forbidden.

UC4: Normal Driving Selection

Precondition: Vehicle in parking mode. Vehicle speed is below 5 km/h.

Driver presses the normal driving button and the brake pedal. The D gear mode is enabled.

UC5: Parking mode Selection

Precondition: Vehicle speed above 6 km/h

Driver presses parking mode button and brake pedal. A status change to P will not be accepted above 6 km/h forward speed. In this case no more drive torque is commanded by the accelerator pedal. As soon as the vehicle speed decreases below 6 km/h the parking mode is activated.

UC6: Parking mode Selection

Precondition: Vehicle speed below 6 km/h

Driver presses parking mode button and brake pedal. Parking mode is engaged.

2.2 ID4EV

The purpose of the ID4EV (intelligent dynamics for electrical vehicles) project, which is co-funded by the European Commission, is to develop vehicle components and systems that satisfy the distinct requirements of fully electric vehicles. Both central electric drivetrains and wheel hub drivetrains with their unique driving comfort challenges fall within the scope of the project. Continental Engineering Services is leading the consortium; the other partners are fka, Renault, ZF Friedrichshafen, Chalmers University of Technology, Applus IDIADA,TNO and ICOOR.

The consortium has set high goals focusing on driving safety, comfort and energy efficiency. The objective is to offer the drivers of future fully electric vehicles products with the highest levels of safety, comfort and usability, leading to greater customer acceptance and, thus, quick and widespread market penetration.

Within the WP5 of the ID4EV project – intelligent networking – the goal is to identify and control the driving modes of an electric vehicle. This includes the already existing system modes of a vehicle, as well as to be defined driving profiles for an electric vehicle and a power and energy management. This includes the ability to act in critical range situations by finding charging spots along the road, or switching off consumer systems or putting them in a more energy efficient mode. A HMI concept to support these concepts also is in the scope of the WP5. A special focus on the ID4EV models lies on dynamic models as the interaction with the driver, the mode management and other algorithms contributing to the energy mode management as the range calculation and navigation services.

The modeling of ID4EV-WP5 was done in SysML. Modelica will be used for simulation and virtual integration purposes. Due to the close connection between EAST-ADL and SysML, especially structural elements of SysML can be mapped on EAST-ADL. Any missing expressiveness in EAST-ADL will be evaluated for assessing the language (see chapter 3). The advantages of relating an EAST-ADL and SysML model are:

- Deepening and extending of the SysML/EAST-ADL mapping (especially for dynamic elements).
- Deepening and extending of the SysML/EAST-ADL mapping (especially for dynamic elements).
- Modelica simulations can be made available to EAST-ADL models.
- Constraint checking and thus verification and validation can be based on dynamic model.
- This also opens the perspective to verify timing constraints (TADL) of EAST-ADL on base of dynamic models and simulations.
- Also the perspective of fault injection and FMEAs on base of model simulations is given this way.
- Feature models for electrical vehicles can be defined.
- Safety and Timing models can be added to the SysML model this way.
- The variability concepts of EAST-ADL and SysML/Modelica can be aligned.

2.2.1 Block Diagram

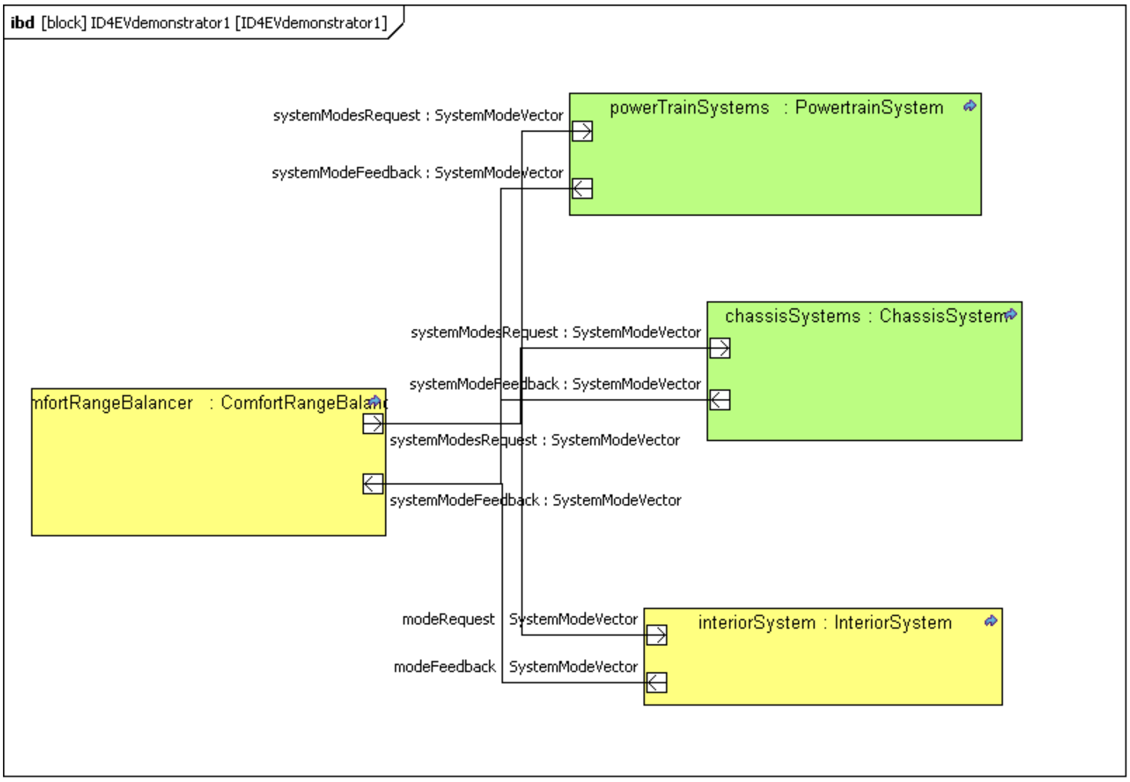

Figure 6 – ID4EV block diagram

The mode management for the driving profiles and the energy management of the electrical vehicle is done by the Comfort Range Balancer (CRB). The diagram from above shows the collaboration of the CRB with other systems of the vehicle. The systems itself are grouped in a hierarchy, with the interior system, the chassis systems and the power train system at the top level of a hierarchy. The SW of “ConfortRangeBalancer” and “InteriorSystem” blocks in the diagram is developed in the context of the ID4EV – WP5; only configurations (modes) for systems are defined in “ChassisSystem” and “PowerTrainSystem” blocks. A system vector is a set of modes (one mode for each system), which represents an operating mode of the vehicle. Between the CRB and other systems a mode request and a mode Feedback vector is exchanged. The CRB can be seen as a global mode management, where the global mode management does not have means to really enforce a mode, but depends on and tracks the feedback of single systems.

The global modes are either representing driving modes of the electric vehicle (Travel, FUN…) or energy modes of single systems, which allow to reduce the energy consumption of the vehicle in critical range situations.

2.2.2 Functions Description

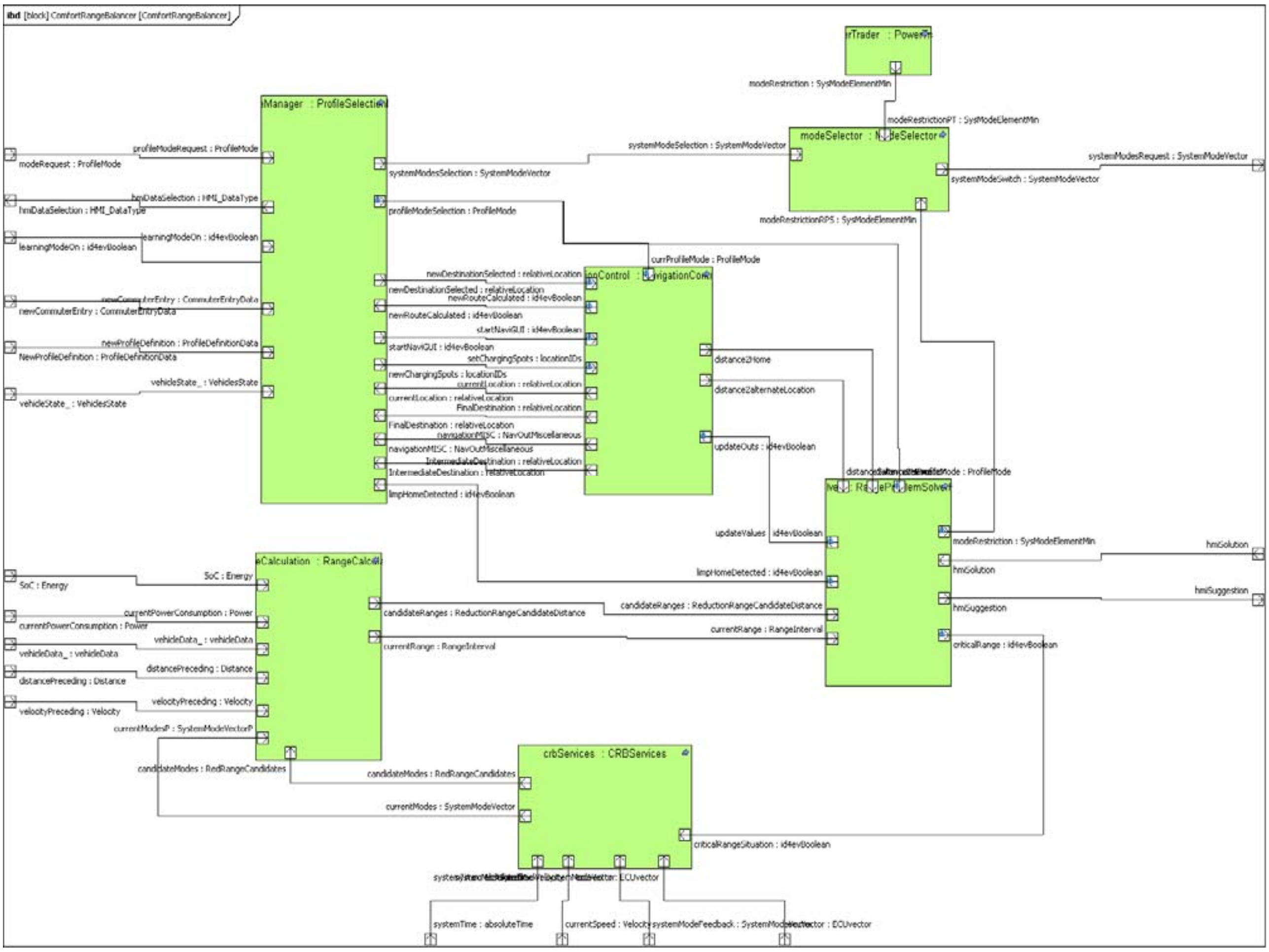

Figure 7 – ID4EV functions description

The Comfort Range Balancer (CRB) is the core of the driving profile and energy mode management. It collaborates with the energy consumer systems, and systems which are affected by the driving mode as well as with the HMI of the electric vehicle. The CRB consists of the following modules or components:

Profile Selection Logic: A logic which controls the driving profile of the electrical vehicle. A vector of system modes is defined for each driving profile, in order to put the vehicle in an appropriate configuration for a selected profile.

Range Problem Solver: The range problem solver acts in critical range situations. The critical range situation has to be detected, and possible more energy efficient successor from the available current modes are identified, and possible solutions are presented to the driver. The driver has then the possibility to make a final decision.

Range Calculation: On base of main characteristics, the remaining range for a vehicle is calculated on base of the SOC (State of Charge) of the battery. The history (driver characteristics) and also future events (traffic situation) can be relevant for the range calculation. Also the energy savings and range improvements, when switching to another mode, are calculated.

Navigation Services: Here as services required by the navigation systems are collected. This information is relevant for the realization of the driving profiles as well as for appropriate decisions on the critical range management the range calculation. The navigation system must be able to access and edit EV charging spots in an internal or external database.

CrbServices: This is some central logic, which is aware of the current modes, in which the systems of a vehicle are operating. Also the defined modes of each system, their dependencies and their power consumption characteristics are defined in the module. In addition some global values of the system are provided to the modules of the CRB.

Power Trader: Similar to the range problem solver, with a focus on the power consumption instead of the energy consumption.

Mode Selector: A small logic, which acts as a filter on selected driving mode in order to enforce mode restrictions, enforced by the Range Problem Solver or Power Trader.

2.2.3 Data Flow Diagram

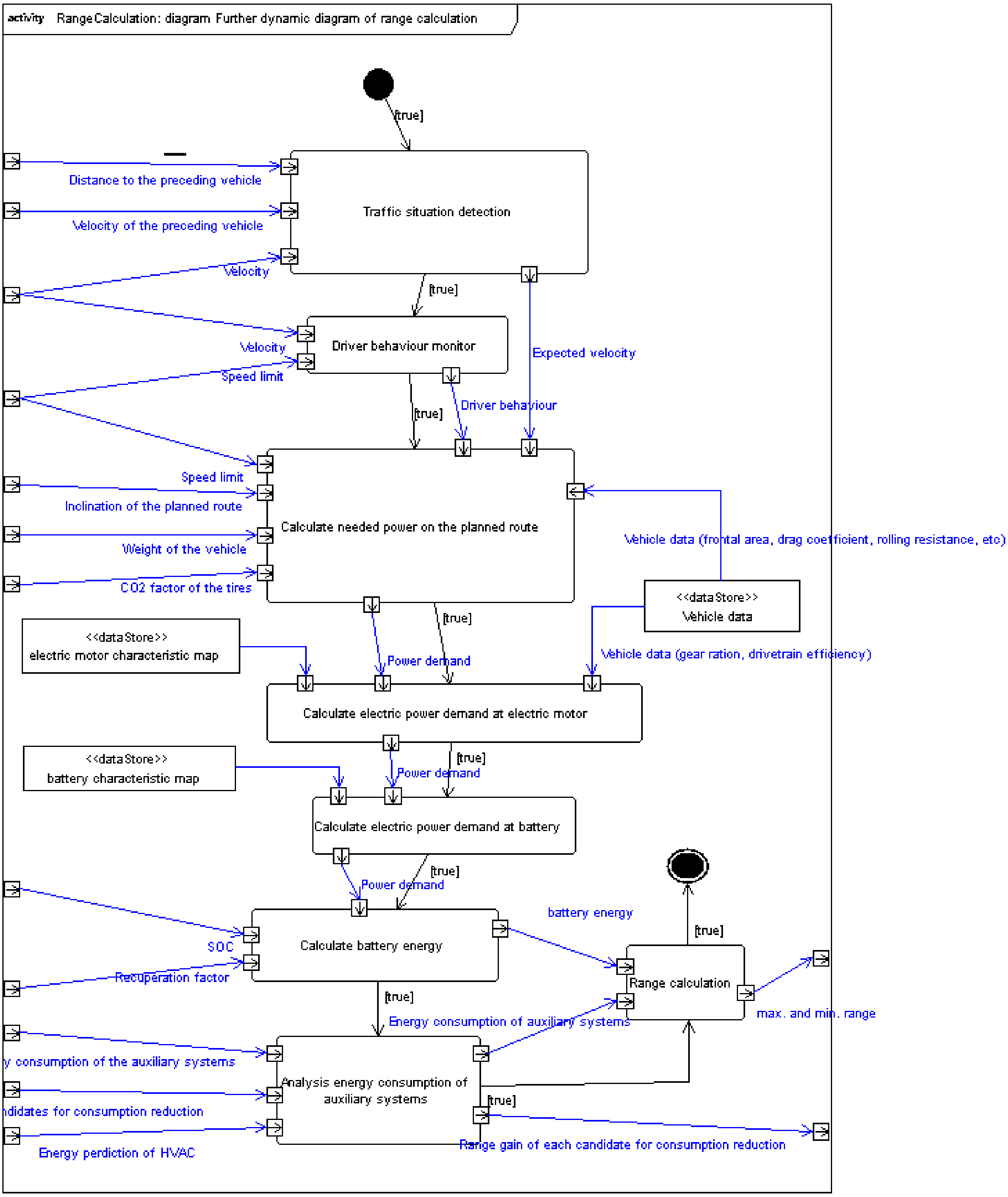

Figure 8 – ID4EV dataflow diagram

One of the main goals of the ID4EV project was to model the dynamic behaviour of the vehicle. With the help of Modelica language, the execution of the model shall be made possible. Dynamic diagrams are given in the following context:

- description of the Interaction concept on an operational level
- state diagram for the mode logic on design level
- activity diagrams for all modules on design level, including all the main actions of the modules and the data flows going through the module.

All diagrams can be seen in the model and HTML documentation.

The diagram from above shows the activity diagram of the range calculation, including all data flow going through the range calculation. The algorithm is still under development and may be updated later. It already shows the main actions of the range calculation and their data flows, connecting the actions to the environment and among each other:

- Analysis energy consumption of auxiliary systems
- Calculate battery energy
- Calculate electric power demand at battery
- Calculate electric power demand at electric motor
- Calculate needed power on the planned route
- Driver behaviour monitoring
- Range calculation
- Traffic situation detection

2.2.4 Use Case Table

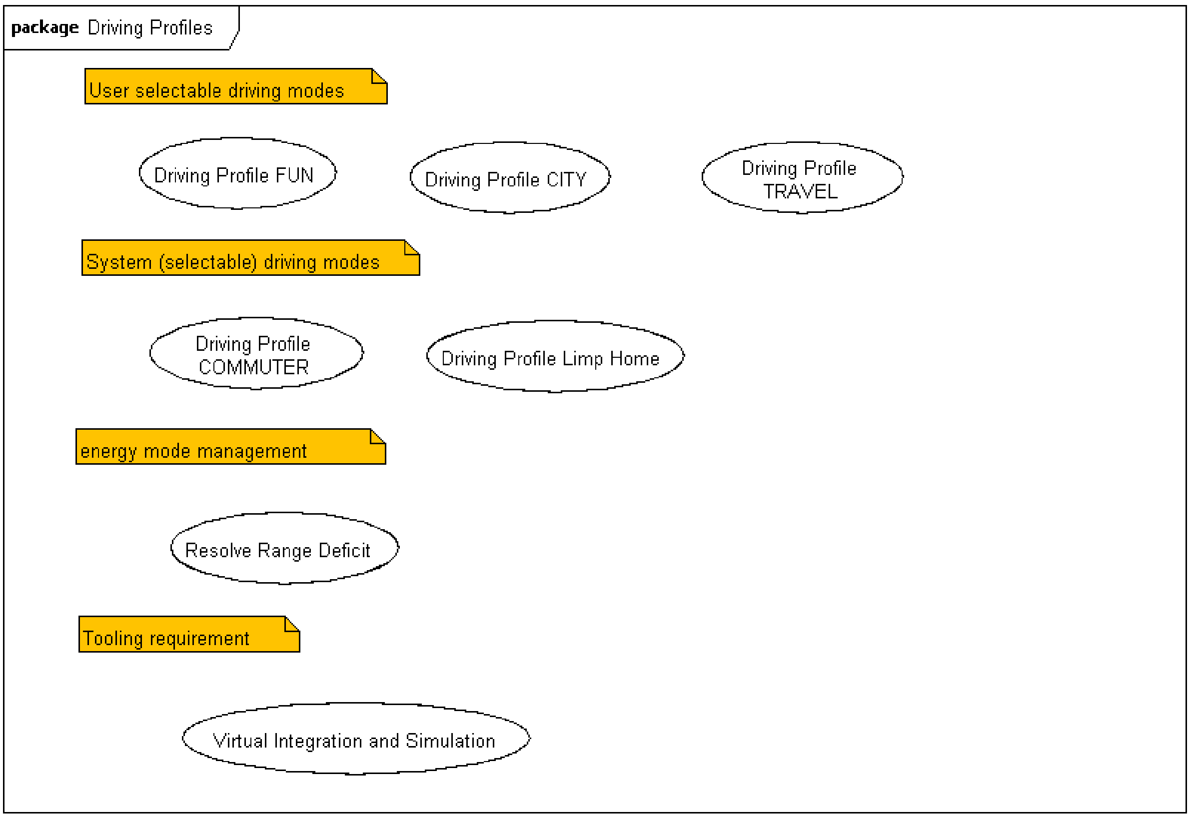

Figure 9 – ID4EV use cases

Use Cases of ID4EV – intelligent Networking and MAENAD:

UC1: selection of Driving Profile Travel

Precondition: the vehicle is started.

User select the driving destination. The range to the selected destination can exceed the driving range of the loaded vehicle

UC2: selection of Driving Profile CITY

Precondition: No destination is selected when starting the vehicle

User select the driving profile CITY. The vehicle continuously tracks the distance to HOME and available charging spots.

UC3: selection of Driving Profile CITY

Precondition: None

User select the driving profile FUN. This mode offers a further possibility to optionally enter a destination, no destination or to find charging spots along the road.

UC4: selection of Driving Profile COMMUTER

Precondition: None

User select the driving profile COMMUTER. The vehicle automatically detects a recurring trip and changes to the commuter profile. The selection for the time being is only based on timing information.

UC5: selection of Driving Profile LIMP HOME

Precondition: system detect that the next available charging spot can only be reached in a very energy efficient configuration of the vehicle systems.

The vehicle automatically switch to this mode if the precondition is satisfied.

UC6: selection of Driving Profile Resolve Range Deficit

Precondition: system detect that the driving range left, is lower than the driving range to a selected destination or HOME.

Solutions are suggested and presented to the driver, so that the range deficit disappears.

2.3 Regenerative Brake

This case study, built up from previous studies in ATESST, ATESST2, TIMMO projects and a physical implementation at VTEC, aims to provide a basis for the validation and demonstration of all EAST-ADL features relevant to MAENAD. Along with architecture modeling and related tool support, emphasis will be placed on the language enhancement through MAENAD for quality analysis, verification and validation. In particular, the following features will be explicitly evaluated:

I. modeling and analysis of *behaviors for requirements, architectural design, timing and dependability analysis*;

II. modeling for supporting ISO 2262 through representing safety goals, functional and technical safety concept and their formalization;

III. automated *test-case generation, test system modeling, and support for fault injection*;

IV. integration of compositional *variability* models and *design-space specification*;

V. modeling and analysis of physical dynamics with multiple levels of abstraction;

VI. modeling and analysis of selected part of the electrical architecture.

The target system for the case study is the Brake-by-Wire (BBW) system in the context of a full electrical vehicle (FEV). Based on *regenerative braking*, the kinetic energy produced by braking is converted to electrical energy and stored in capacitor or/and battery. It is expected that a hardware implementation is pursued for the base brake functionality excluding regeneration. The model shall also be seen as the brake system representation of the common EV demonstrator.

2.3.1 Block Diagram

Error! Reference source not found. provides a schematic view of the logical design of the regenerative braking system. As braking systems in conventional vehicles, the *boundary* of this braking system to the plant and drivers consists of the following interfaces:

1. Measured brake pedal position through Brake Pedal Sensor;
2. Measured vehicle longitudinal velocity through Vehicle Speed Sensor;
3. Measured angular velocity of each wheel through Wheel Speed Sensor;
4. Controlled brake torque on each wheel through Brake Actuator (this actuator affects the rotation force by means of brake disc);
5. Controlled brake torque on each wheel through Power Converter (this actuator affects the rotation force by means of electrical motor).

To support regenerative braking, additional interfaces to the system boundary have been identified. These include

6. Measured motor load on each wheel in terms of electrical current through the Load Current Sensor.
7. Controlled power regeneration with braking through the Power Converter actuator (this actuator enables or disables the conversion from kinetic energy of braking to electrical energy stored in the capacitors).
8. Measured battery charging status through Battery DoD Sensor (the charging status is defined through Depth of Discharge (DOD), referring to the fraction of power can be withdrawn from a battery).
9. Measured battery voltage through Battery Voltage Sensor.
10. Measured capacitor voltage through Capacitor Voltage Sensor.

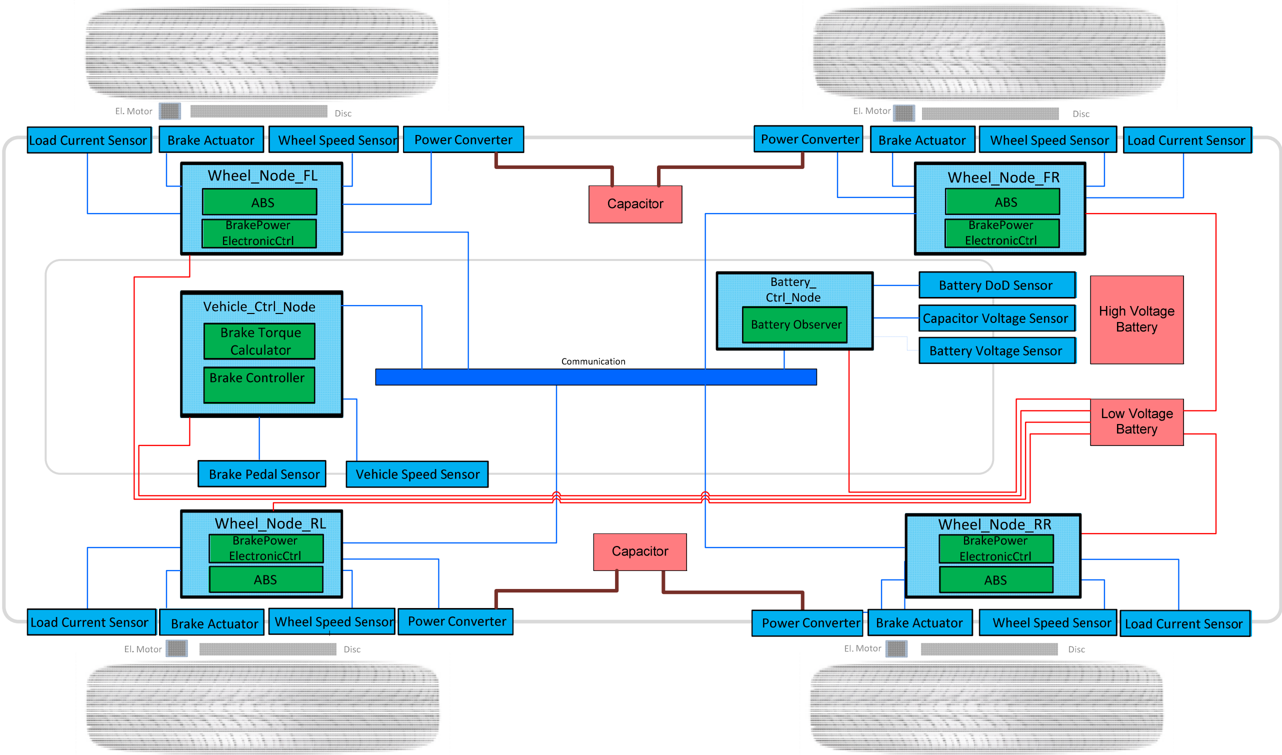

Figure 10: Block diagram showing the logical design of the BbW Demonstrator.

The Brake-by-Wire (BBW) system has a communication network for distributing signals of sensed status data and control requests for vehicle braking as well as power regeneration. For example, the observed battery and capacitor status information is fed to the BrakePowerElectronicCtrl function on each wheel for regulating the charge of capacitors. Other design details concerning the control of battery charge/discharge can be based on the design described in Sec 2.1. For example, the capacitors and high voltage battery can be connected to a high voltage junction box where a control function decides the charging based on current battery and capacitor status.

2.3.2 Functions Description

In the case system, we assume that braking is controlled by the vehicle driver.

- When a brake pedal displacement is detected, the brake torque calculator computes the driver requested torque and sends the value to the vehicle brake controller function.
- The vehicle brake controller then decides the required torque on each wheel. Each of the required wheel torque values is sent together with the sensed vehicle velocity to the ABS function on respective wheel.
- Based on the received torque request, current vehicle velocity and wheel angular velocity, an ABS function decides appropriate braking force on wheel.

Compared to conventional braking where the needed braking force is completely realized by the electromagnetic brake actuator (which is connected to the brake disc), the regenerative braking allows a fraction or whole of the needed braking force to be realized by electrical motor. To this end, the local power electronic control function of each wheel receives the observed battery and capacitor status for determining the maximum possible braking torque to be offered by the electrical motor. It informs the ABS function about current brake torque by electrical motor based on the measured motor load current. With such information, the ABS function commands the local

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power electronic control function (which is connected to the power converter for transferring energy from an electrical motor to a capacitor) and the electromagnetic brake actuator (which is connected to the brake disc) for realizing the requested braking force. The converted braking power is first stored in capacitors. Depending on the status of battery and capacitor, the power stored in the capacitors can be used either to recharge the battery or to directly drive the motors for acceleration or deceleration.

2.3.3 Data Flow Diagram

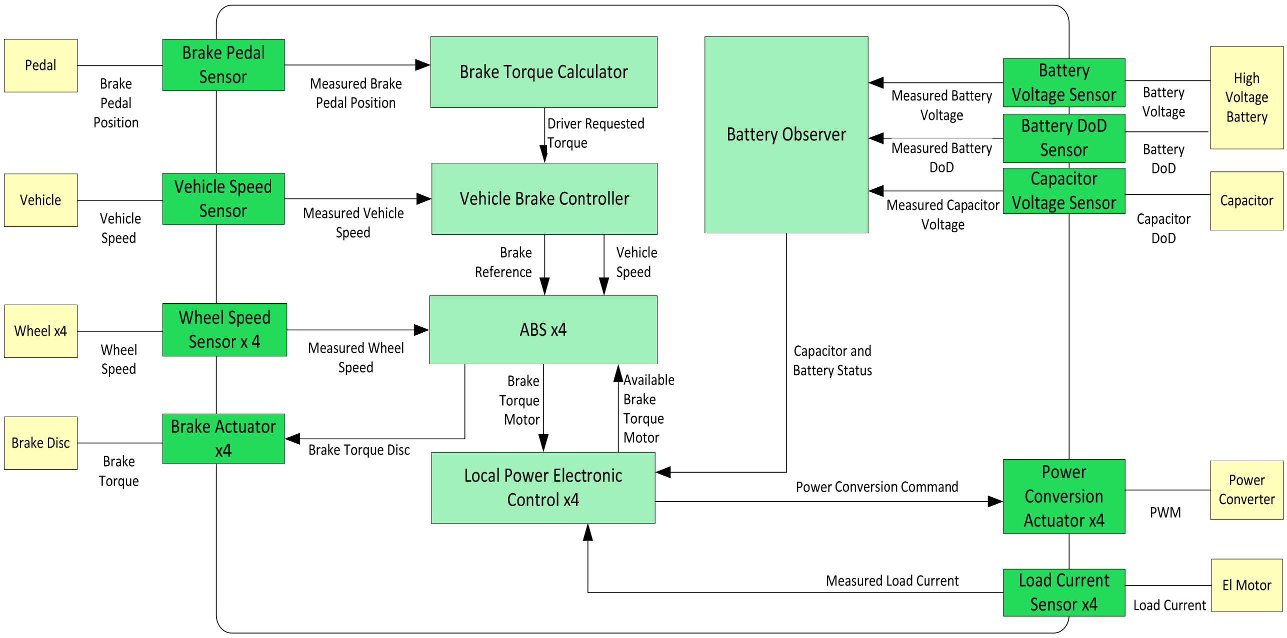

Figure 11: diagram showing the functional design of the BbW Demonstrator.

2.3.4 SUSA Table

Element				
ID	**Component**	**Function**		**Type**
		VF Link	**Description**	
01.001	Brake Pedal Sensor	Braking	Measuring brake pedal position	Involved
01.002	Vehicle Speed Sensor	Braking	Measuring vehicle longitudinal velocity	Involved
01.003	Wheel Speed Sensor x4	Braking	Measuring angular velocity of each wheel	Involved
01.004	Brake Torque Calculator	Braking	Computeing driver required torque	Involved
01.005	Brake Controller	Braking	Computing required torque on each wheel	Involved
01.006	ABS Controller x4	Braking	Computing reqired braking toque through braking dic and electrical motor for a wheel	Involved
01.007	Local Power Electronic Control Function x4	Braking	Computing the maximum possible braking torque by electrical motor and power conversion behavior.	Involved
01.008	Brake Actuator x4	Braking	Controlling brake torque through brake disc	Involved
01.009/ 02.001	Power Conversion Actuator x4	Braking	Controlling brake torque through electrical motor	Involved
02.001/ 01.009	Power Conversion Actuator x4	BPR (Braking Power Regeneration)	Controlling power regeneration with braking through electrical motor	Involved
02.002	Load Current Sensor x4	BPR, Braking	Measuring motor load on each wheel in terms of electrical stream.	Involved
02.003	Battery DoD Sensor	BPR, Braking	Measuring battery charging status	Involved
02.004	Battery Voltage Sensor	BPR, Braking	Measuring battery voltage	Involved
02.005	Capacitor Voltage Sensor	BPR, Braking	Measuring capacitor voltage	Involved
02.006	Battery Observer	BPR. Braking	Computing battery and capacitor status	Involved
03.001	Communication Bus	BPR, Braking	CAN network	Interface
04.001	Low Voltage Battery	BPR, Braking	Power supply for electronic devices	Interface
05.001	High Voltage Battery	BPR, Braking	Power supply for electrical motors.	Interface
06.001	Capacitor	BPR, Braking	Temporary storage of electrical charge.	Interface

2.3.5 Use Cases

UC1: Engage brake until minor retardation occurs

Precondition: Vehicle Speed is non-zero

Driver engages the brakes smoothly. Within 50 ms, there is a noticeable deceleration. The deceleration is proportional to the degree of engagement.

UC2: Engage brake until normal retardation but no wheel lock occurs

Precondition: Vehicle Speed is non-zero

Driver engages the brakes distinctively. Within 50 ms, there is a considerable deceleration. The deceleration is proportional to the degree of engagement.

UC3: Engage brake to a degree that wheel lock occurs

Precondition: Vehicle Speed is non-zero

Driver engages the brakes firmly (sufficient intensity to cause the wheels to lock). Within 50 ms, there is a noticeable deceleration. The deceleration is proportional to the degree of engagement. When the wheel locks, it is immediately released and a pulsating deceleration is experienced.

3 Preliminary Evaluation Metrics

This deliverable has introduced a description of the FEV related case studies that will be used to evaluate the effectiveness and practicability of the overall Maenad concepts that will be developed during the project.

These case studies, provided by various partners, represent different application examples with the goal to supply an example system able to address and exercise the whole aspects of the methodology.

One of the goals of WP6 in the context of Maenad project is also the assessment of the results of the different WPs against project objectives.

This chapter introduces a general description of the criteria and evaluation metrics that will be adopted as guidelines to evaluate the various project outcomes.

In principle, evaluation criteria fall down in two main categories:

- project centric: to what extent Maenad's languages, models and tools reflects the engineering scenario and needs related to the design and development of a Full Electric Vehicle
- Product centric: impact of the developed methodologies on the development of a Full Electric Vehicle.

Evaluation metrics	Description
Support for EV design	
Coverage of the relevant standards and regulations.	It is foreseen that FEV standards and regulation will affect the EAST-ADL modelling language on which Maenad project is based. Requirements introduced by FEV regulation will be implemented as new properties and attributes on the modelling elements of the language, or as guidelines and modelling patterns using existing constructs. Possible evaluation could be based on qualitative estimation about the completeness of the modelling language against the requirements coming from FEV regulation analysis
Support for ISO 26262	
Ability to support design of safety related embedded system.	Maenad project plans to further improve modelling and analysis support of EAST-ADL language for the development of safety related embedded system according to ISO 26262. This goal impact the methodology definition, enhancement of modelling and analysis support (e.g ASIL decomposition), allocation and traceability of safety requirements. The application of the functional safety assessment procedure, defined directly in ISO26262- Part2 to a specific case study, will guarantee the effectiveness of Maenad approach, supported by EAST-ADL language in compliance with the standard .

Modelling	
Integration capability with external tools	Interoperability and integration of Maenad outcomes and modelling language with external tools is a key issue to have a widespread acceptance in automotive industry, due to the existence within OEMs and supplier of consolidated procedures and methods based on well established toolchain. Maenad plan and is working to establish concrete link with the major development environment in the market (e.g. simulink, modelica,…) to take also advantage of the simulation and analysis capability that they provide. Link is established through model transformation approach, or inserting explicit reference on the Maenad functions element to external model. Possible evaluation metrics could be based on qualitative estimation about the effectiveness of model transformation (to what extend the original model could be automatically exported to other environment).
Support for neutral data exchange format - Tools interoperability	To enable support by tools vendor for the EAST-ADL modelling language, a neutral exchange format of the meta-model shall be specified in order to provide means for the different platform to implement basic import-export capability and to make possible interoperability between the tools starting from a common basis. A schema for an XML based exchange format, EAXML is automatically generated from the EAST-ADL meta-model. New versions will be generated as the metamodel is enhanced to support the new requirements related to the Maenad project. Effectiveness and scalability of EAXML exchange will be evaluated by exchanging models between different development environment provided by tool vendors involved in the Maenad Project
Optimization	
Automated exploration of design spaces for design solutions	One of the goal of the MAENAD project is the development of model-based engineering methods and tool for optimal design of FEV. This will be achieved through the development of tools for automated exploration of different architectural configurations, starting from quality attributes (dependability, performance) and cost, to support the designer to identify the best possible trade-off. Effectiveness of optimization tools and plug-in will be evaluated by means of a quality review of the results obtained applying the MAENAD approach on two variants of the proposed case studies.

Throughout the project, the successful design of the case studies applying Maenad methodology and tools will be considered as a fundamental metrics to evaluate Maenad results against the project objective.

During the first part of the project, requirements, needs and use cases have also been collected and assigned to work packages.

Requirements are derived from the project challenges and project objectives, which are defined in the Description of Work. So the fulfillment of those requirements guarantees the achievement of project objectives and will be used as an additional evaluation metrics during the assessment activities.

At current status of the project, the collected requirements are partially not suitable for a direct evaluation of the project outcomes. Part of them are expressed at an high level of abstraction, or are related to the compliance with FEV standards.

During the project development, those requirements will be analyzed and refined during WP2 activities and a better understanding about their impact on methodology and language will be achieved.

The goal of the WP6 assessment activity will be the evaluation of requirements coverage.