Bridging the Gap between System and Component Design for Vehicle Electrification using Model Based Systems Engineering (MBSE)
Introduction
Speaker Introduction

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Tata Consultancy Services
IoT & Digital Engineering
Head of Centre of Excellence for FuSa, MBSE, Auto Electronics

- 20+ Years in Automotive Embedded Systems - (EV, ADAS, Body Electronics)
- INCOSE CAB representative for TCS
- SME-Functional safety, Functional Safety L2 Certified by TUV SUD
- Technical manager for BMS software, Project lead for modeling and simulation (E/E features)
- Tools Expertise – MBSE tool chains, SysML tools, Safety Analysis tool chain, Requirement Management, ALM tool chains

Neha Surjekar
Tata Consultancy Services
IoT & Digital Engineering
MBSE - Solution Lead, Auto Electronics Centre of Excellence

- 12+ Years experience in Automotive Embedded Systems
- Experience in MBSE (UML, SysML), ADAS, Body domain
- Member INCOSE, INCOSE India Chapter
- Tools Expertise - MBSE tool chains, SysML tools, Requirement Management, ALM tool chains
- Key member in deploying MBSE practices across various accounts
- Certified Scrum Master
TCS Automotive Experience Summary

TCS recognized as a Leader in ACES Automotive Engineering Services by Everest Group

11,000+ Engineers
Working in 15+ Countries
Spread across 50+ Customers

1000+ Electrical & Electronics Engineers
4000+ Vehicle & Powertrain Engineers
Challenges in Electric Vehicle Development
Automotive Trend - Vehicle Electrification – Challenges

- Handling inter-disciplinary teams
- Faster time to market
- No systematic method
- Increased complexity of vehicle features
- Field failures, Vehicle re-calls
Traditional Vehicle Electrification Development

Complex system design and development need complicated cross-functional interaction.
Bridging the Gaps through MBSE
Adaption of MBSE for Vehicle Electrification Development

System Engineering aims to ensure, the pieces work together to achieve the objective of the whole.
Motor Control System Development using MBSE

Vehicle Context

System Context *

* High level Representation of Motor torque control, not an exhaustive architecture
MBSE applied to Motor Control System Development

1. **Authoring System Requirements**
   - System Architecture & Req Allocation
   - Sys Req to Architecture Traceability
   - System Verification
   - End - End Traceability

2. **Authoring Sub Sys Requirements**
   - Defining Interfaces
   - Sub Sys Architecture & Req Allocation
   - Sub Sys Req to Arch traceability

3. **Component Requirements**
   - Authoring Software Requirements
   - SW Architecture & Req Allocation
   - Software Design & Implementation
   - Stakeholder Views
How MBSE helped
Benefits

- Reduction in time taken for adapting MBSE
- Seamless traceability:
  - EV Propulsion system requirements
  - Motor Control sub-system requirements
  - Motor, Motor control ECU detailed requirements, design
- Stakeholder views for OEM System team, TCS team, Suppliers
- Gaps between System and Component design Identified before implementation
- Classified and Precise Information exchange between OEM Team, TCS team, Suppliers
TCS in MBSE
TCS in MBSE

8+ Customer Engagements

INCOSE Working Group Contributor

10+ years of SysML Cross-industry Experience

System Requirement Decomposition & Maturation

System Architecture & Design

Simulation of System Functional behavior

Integration of System Engineering & Functional Safety

Expertise in Multiple Tools & Tool Chain Integration

ADAS  Body - Chassis  Infotainment  Powertrain  Electrification
Thank you

Contact : IoT.De@tcs.com
Specify System requirements consistent with Stakeholder requirements, functional boundaries, functions, constraints, critical performance measures.
System Architecture & Requirement Allocation

Identify system elements, interaction between them to satisfy the system requirements.

Establish "implements" relationship between architectural elements and requirements.
Identify system elements, interaction between them to satisfy the system requirements.
Establish “implements” relationship between architectural elements and requirements

Toolbox used - System Composer
Establish and maintain traceability between System Requirements and System Architecture elements
End to End traceability can be maintained. System<->Sub System<-> Software and component requirements
<table>
<thead>
<tr>
<th>Sub-System Requirement</th>
<th>System Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub_Sys_1.1.4 Actuated Torque Production</td>
<td>Sys_1.4 Regenerative braking</td>
</tr>
<tr>
<td>Sub_Sys_1.1.6 Inverter’s DC Voltage Monitoring</td>
<td>Sys_2.1 Evaluate and send drive for ESC</td>
</tr>
<tr>
<td>Sub_Sys_1.1.7 Inverter temperature monitoring</td>
<td>Sys_2.2 Monitor the accelerator pedal</td>
</tr>
<tr>
<td>Sub_Sys_1.1.8 Inverter output current monitoring</td>
<td>Sys_2.3 Receive motor control info</td>
</tr>
<tr>
<td>Sub_Sys_1.1.5 Inverter output current monitoring</td>
<td>Sys_2.4 Acquire motor speeds information</td>
</tr>
<tr>
<td>Sub_Sys_1.2.1 Sensor fault isolation</td>
<td>Sys_2.5 Monitor EPCU</td>
</tr>
<tr>
<td>Sub_Sys_1.2.2 Sensor redundancy</td>
<td>Sys_2.6 Monitor the BSM</td>
</tr>
<tr>
<td>Sub_Sys_1.2.3 Sensor data validation</td>
<td>Sys_2.7 Evaluate the brake warning</td>
</tr>
<tr>
<td>Sub_Sys_1.2.4 Sensor bias calibration</td>
<td>Sys_2.8 Monitor the park brake status</td>
</tr>
<tr>
<td>Sub_Sys_1.2.5 Sensor data fusion</td>
<td>Sys_2.9 Send mode command to Motor Co</td>
</tr>
</tbody>
</table>

Toolbox used - Simulink Requirements
## Simulink Requirements vs Simulink Requirements

### Sub - System Requirement

**Software Requirement**

- Software_1.1.4.1 Get Phase current
- Software_1.1.4.2 Get angular velocity
- Software_1.1.4.3 Get DC link voltage
- Software_1.1.4.4 Generate stator dq voltage
- Software_1.1.4.5 Send PWM signal

### Simulink Requirements Toolbox used - Simulink Requirements

- Motor control System Requirements
- SubSystem_V1
- Motor control System Requirements
- Software_V1

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**Toolbox used - Simulink Requirements**

- Motor control System Requirements
- SubSystem_V1
- Motor control System Requirements
- Software_V1
Sub System requirements Authoring

Derive Sub system requirements from System requirements. Requirement writing guidelines help to author quality requirements.
Defining Interfaces
Perform interface definition for defining the required interface and understanding of architecture.
Defined interfaces are represented using data dictionary
Sub System Architecture & Requirement Allocation

Establish allocation relationship between architectural elements and requirements
Define the stereotype and apply it on sub-system elements like block and connection. Trace sub-system elements to system elements.
Toolbox used - System Composer
Establish allocation relationship between architectural elements and requirements
Sub System Requirement to Architecture Traceability

Toolbox used - Simulink Requirements
Component Requirements

Toolbox used - Simulink Requirements
### Software Requirements

<table>
<thead>
<tr>
<th>Index</th>
<th>ID</th>
<th>Summary</th>
<th>Type</th>
<th>Implemented</th>
<th>TypeOfReq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Software_1.1.4.1</td>
<td>Get Phase current</td>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Software_1.1.4.2</td>
<td>Get angular velocity</td>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Software_1.1.4.3</td>
<td>Get DC link voltage</td>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Software_1.1.4.4</td>
<td>Generate stator dq voltage</td>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Software_1.1.4.5</td>
<td>Send PWM signal</td>
<td>Functional</td>
<td></td>
<td></td>
</tr>
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**Requirement: Software_1.1.4.4**

**Details**
- **Type:** Functional
- **Index:** 4
- **Custom ID:** Software_1.1.4.4
- **Summary:** Generate stator dq voltage

Current control module shall generate stator dq voltage based on torque request, phase current, angular velocity and DC voltage.

**Keywords:**

**Revision Information:**

**Custom Attributes**

**Links**
- Derived from: Sub_Sys_1_1_4 Actuated Torque Production
- Implemented by: Drive_Controller

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**Toolbox used - Simulink Requirements**
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Software Design and Implementation
Stakeholder views

OEM Perspective

Apply stereotypes to see the System views which can help OEM to explain system from their perspective.

Tier 1 Supplier Perspective

Generate the sub system view to share precise information with the Tier 1 Supplier.

Motor Vendor Perspective

Generate the component view to share with the vendor.

Motor Specifications

Share the generated component specification along with the requirements with the vendor.
Apply stereotypes to see the System views which can help OEMs to explain system from their perspective
Generate the sub system view to share precise information with the Tier1 Supplier
Generate the component view to share with the vendors
1 Produce torque

Requirement Type: Functional
ID: Component_1.1.1

Description:
Motor shall produce torque based on Phase current provided by Inverter

Links
Artifact: Vehicle_Architecture_0902.xlsx

<table>
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<tr>
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2 Equipped with motor position sensor

Requirement Type: Functional
ID: Component_1.1.2

Description:
Motor shall be equipped with motor position sensor

Links
Artifact: Vehicle_Architecture_0902.xlsx

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3 Torque production range

Share the generated component specification along with the requirements with the vendor