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Implementation of Drive Mode Feature for PHEV Vehicle using IBM Harmony Process

(SysML Modeling)

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Abstract— **In this paper SysML modeling of Terrain modes, hybrid modes and 4WD modes of Plug in hybrid electric vehicle are done using modern IBM harmony process. The work starts by working on the system level requirements and controllers such as Hybrid Control Processor (HCP), Body Control Module (BCM), Electronic Control Module (ECM) and Display (IPC).The next step of system functional analysis includes designing behavioural diagrams and the detailed analysis of system level requirements. In the final stage of IBM harmony process which is design synthesis process, design models are checked and verified before product development. The project involves studying the system using vehicle function documents, component functional technical specification documents and simulating all the drive modes in IBM Rational Rhapsody tool.**

Keywords— ***Design Synthesis, IBM Harmony Process, SysML Modeling, System Functional Analysis, IBM Rational Rhapsody***

I. INTRODUCTION

The Harmony process is a well-defined process supporting Model-Driven Development (MDD) environment. The process definition provides system engineer with a step-by-step guide on using the SysML in a way that allows seamless transition to subsequent system development. It is consists of three phases which are Requirement analysis, System functional analysis and Design synthesis. V diagram of harmony process is shown in figure 1. [1]

A. Requirement Analysis

The objective of the requirement analysis phase is to analyze the process inputs. Stakeholder requirements are translated into system requirements that define what system must do (Functional requirements) and how well it must perform (quality of service requirements).

This analysis starts with the analysis and optional refinement of the stakeholder requirements. Output of this phase is the stakeholder requirement specification.

B. System Functional Analysis

The aim of the system functional analysis is on the transformation of the functional system requirements into a coherent description of system functions (operations). The analysis is use case-based, i.e. each system-level use case that was identified in the previous requirements analysis phase is translated into an executable model.

C. Design Synthesis

The focus of the architectural design phase is on the allocation of functional requirements and non-functional requirements to an architectural structure. The architectural design is performed incrementally for each use case of an iteration by transforming from black-box view to white-box view also called as use case realization. The task flow of design synthesis is quite similar to the system functional analysis. In the design synthesis stage, all the requirements are checked and verified. We can see visual representation of verified requirements.

The SysML diagrams used in harmony process are shown in figure 2. These eight SysML diagrams are organized into three categories .These categories represent the requirement analysis, system functional analysis and design synthesis. [4]

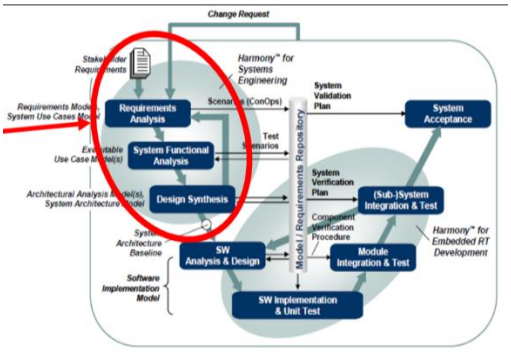

Figure 1. V diagram Of Harmony Process

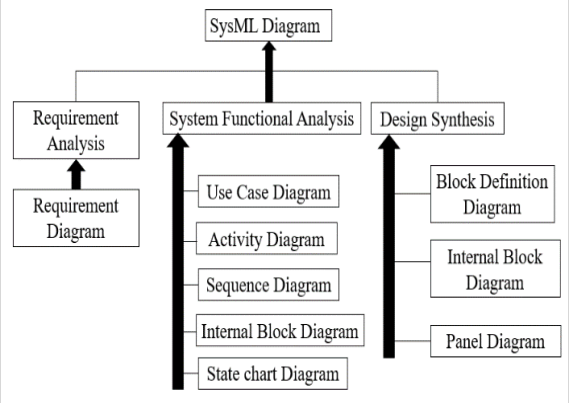

Figure 2. SysML Diagram

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II. SYSTEM DESCRIPTION

In this project drive modes for Plug In Hybrid Electric Vehicle are implemented which includes five terrain modes, three terrain modes and Four wheel drive modes. Also transition conditions of these modes are implemented.

A. Terrain modes

1) Auto Mode: The automatic mode is the default operating mode for the transmission. The transmission shall select auto mode on power up and remain in the same mode unless other mode is selected. It is available in both high and low transfer cases.

2) Sports Mode: This mode provides enhanced vehicle dynamic performance and it is useful for providing a sportier driving feel. It is available only in 4 High state.

3) Snow Mode: This mode reduces launch torque to improve vehicle traction under winter driving conditions. It is available in both high and low cases.

4) Sand Mode: This mode provides enhanced vehicle traction on loose driving surface. It is available in both high and low cases.

5) Rock Mode: This mode will control the wheel torque for traversing highly uneven terrain. It is available only in low state. [2]

B. Four Wheel Drive Modes

1) 4 LOW Mode: It is useful for less speed and more torque.

2) 4 HIGH Mode: It is useful for more speed and less torque.

C. Hybrid Modes

1) Hybrid Mode: The aim of this mode is to increase fuel efficiency. While in this mode the vehicle will e-drive up to its capability. When its charging will get over it will switch on the fuel mode.

2) Electric Mode: In this mode electric motor will be used for propulsion.

3) ESave Mode: In this mode traction motor will be saved for the future use. It is basically charging state. [2]

The figure 3 showing all the three switches and their transition conditions. In this project we have implemented fourteen transition conditions of these three switches.

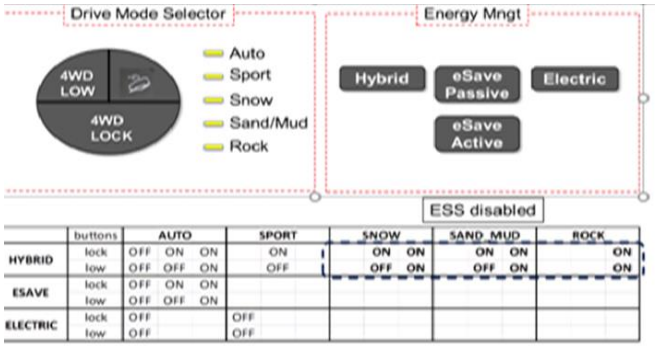

Figure 3. Switch Diagram

Table of Vehicle data specification is shown in figure 4.

Parameter	Range
Accelerator_Pedal_Position	0-100(%)
Transmission oil Temperature	-40 -150(°c)
Ambient Temperature	-40 -90(°c)
Vehicle speed	0-500(KMPH)
Wheel speed	0-500(KMPH)
Brake Pressure	0-200(bar)
Transfer Case Ratio	0-2.92
Axle Ratio	0-4
System voltage	0-15(V)
Brake Torque	0-12000Nm
Engine Idle speed	0-4000(RPM)
Engine speed	0-8000(rpm)

Figure 4. Vehicle Data Specification

III. SYSTEM MODELING

The project is implemented by using SysML modeling using IBM Rhapsody. This modeling method comprises some important phases that need to be followed to perform the modeling process.

A. Implementation of Requirement Analysis

In this phase all the requirements which are written into high level language are imported through gateway package into the project. Figure 5 shows requirement diagram.

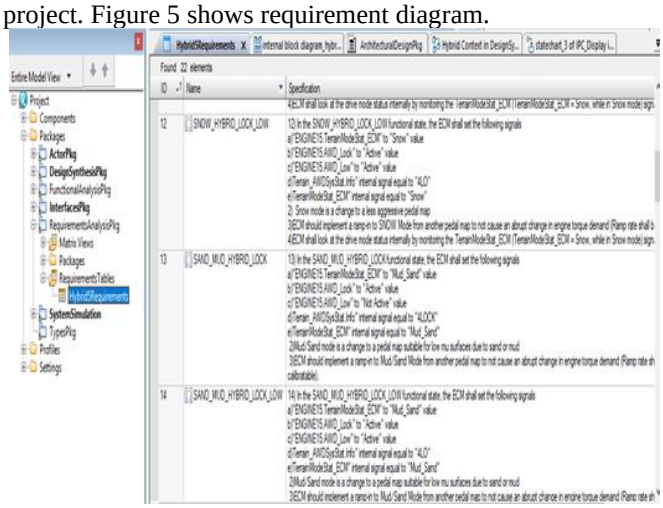

Figure 5. Requirement Diagram

B. Implementation of Functional Analysis

In this phase, Use case diagram is developed and based upon it activity, sequence, Internal block diagram and state chart diagrams are designed. In the use case diagram we have taken actors as switches, driver and controllers like BCM, HCP, and ECM. Figure 6 shows use case diagram. In use case diagram we have taken three use cases which are hybrid drive mode selection, Electric drive mode selection and Esave drive mode selection. In the system functional analysis we have to make all diagrams for each individual use case. We will see detailed analysis hybrid drive mode selection use case.

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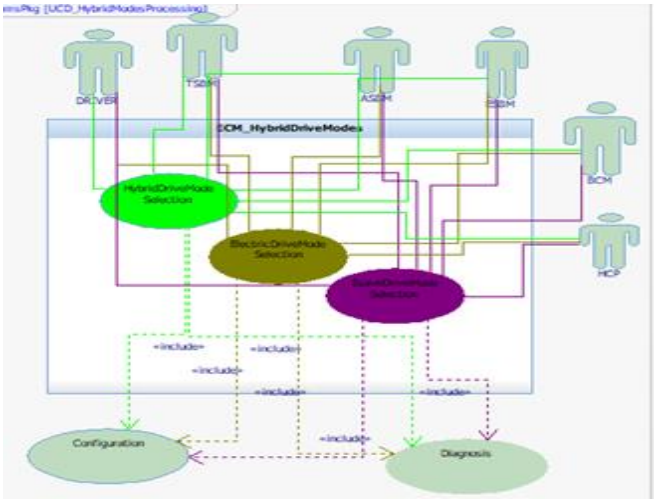

Figure 6. Use Case Diagram

Activity diagram represents workflow consists of sub activities of execution joined by connectors and actor pins. It is shown in figure 7.

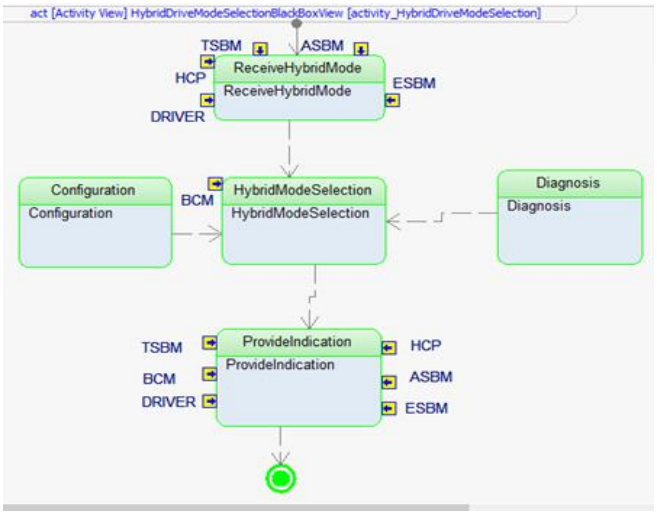

Figure 7. Black-box Activity Diagram

Sequence diagram elaborate on requirements specified in use cases and activity diagrams. It shows how actors and blocks collaborate in some behavior. It describes one or more scenarios through use case. It is shown in figure 8.

Figure 8.Black-box Sequence Diagram

All the diagrams in the system functional analysis are called as “black-box diagrams”. The internal block diagram represents interconnection and interface between the parts of a block by using ports and interface blocks. It refers to the communication and flow of items between the block. Figure 9 shows the internal block diagram for the system.

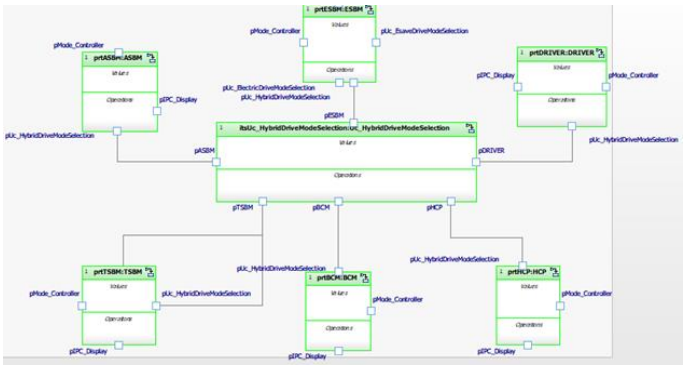

Figure 9. Back-box Internal Block Diagram

The state chart diagram specifies the sequence of events that an object goes through during its lifeline in response to the event. Each block contains state machines according to the requirement and Cpp or C programming logic is developed. The purpose of the state chart diagram is to trigger the states, to perform the action while entering and exiting the states, to generate the event and to accept an event upon execution of the mode. State machine diagram is shown below in figure 10.[8]

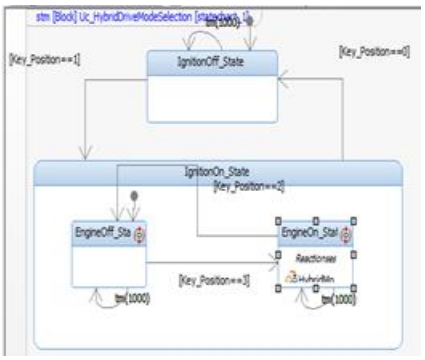

Figure 10.Black-box State Diagram

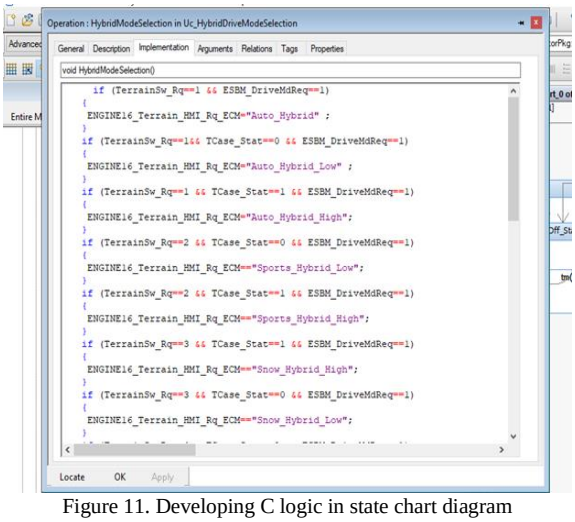

Figure 11. Developing C logic in state chart diagram

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As shown in figure 11, C logic is developed for Hybrid Drive Mode Selection use case. The function of this code will be called in corresponding block of Internal Block Diagram. According to this logic system will behave. All the functions which are used in this logic are declared as a value properties in the system functional analysis package.

C. Implementation of Design Synthesis

In this phase, all diagrams of each use case in system functional are merged to verify their result. Block definition diagram is made to made basic blocks of the system. It is shown in figure 12. And according to block definition diagram all sub activities in black box activity diagram are segregated in those blocks. After formation of block definition diagram, White –box activity, sequence, IBD and state chart diagrams will be generated using swim lanes. They are shown in figures 13, 14, 15 respectively. In the figure 13 of white box activity diagram we can see all the sub activities are separated for mode controller block and IPC block. Mode controller will perform the activities of selection and receiving of hybrid mode. IPC block will perform indication activity. In the white-box sequence diagram blocks in the block definition diagram will get added. In figure 15, State chart diagrams of all three use cases are merged.

Then the whole modeling project is built to check the errors. After successful building of the project, we get error free system and we get validation of all the requirements.

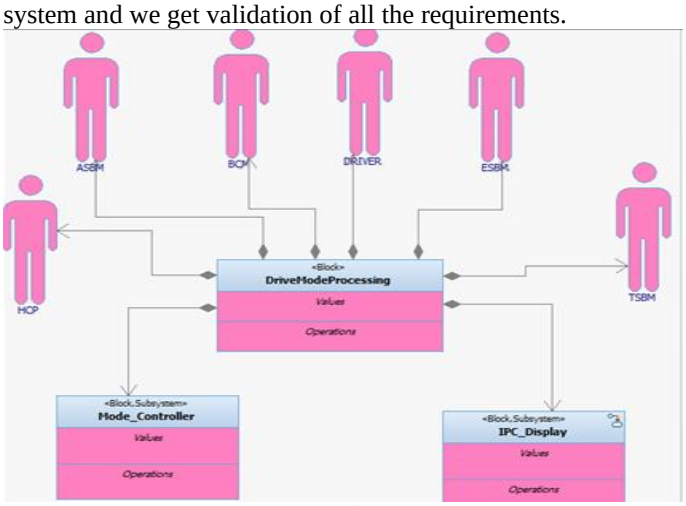

Figure 12. Block Definition Diagram

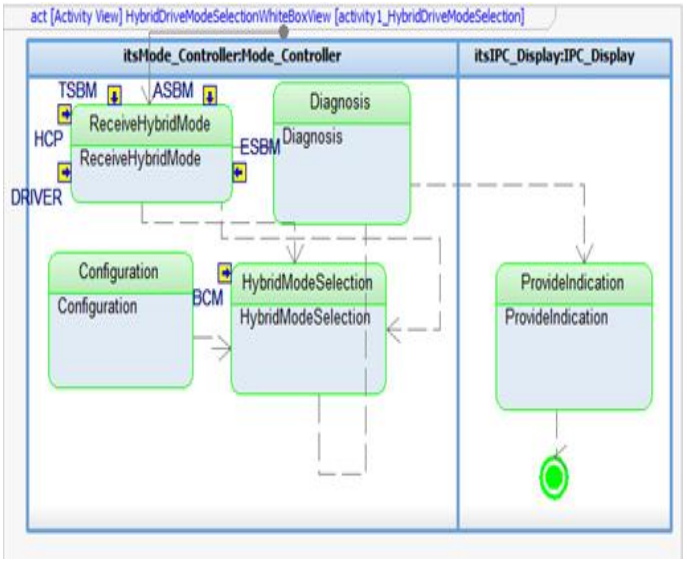

Figure 13. White-box Activity Diagram

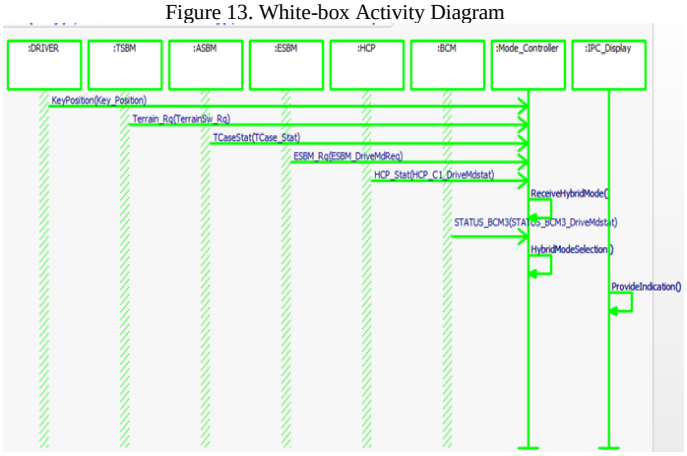

Figure 14. White-box Sequence Diagram

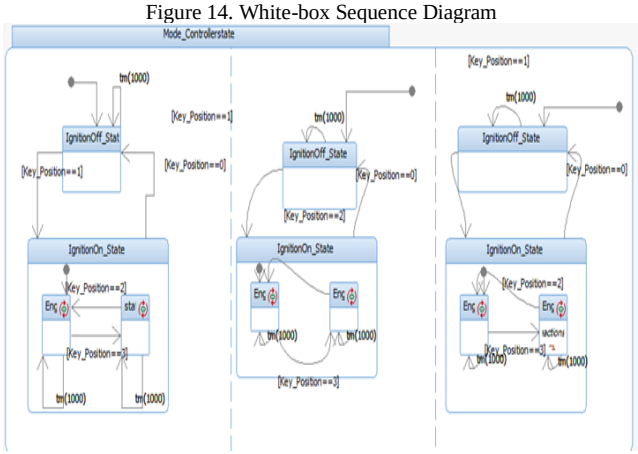

Figure 15. White-box State Diagram

IV. CONCLUSION

SysML modeling allows us to identify interactions, the flow of data between parts of the system. The Harmony process is a general systems development process that, while emphasizing the real-time and embedded software development aspects, includes the steps to produce general-purpose software and systems. The Harmony process has been used effectively on very small one to three person projects as well as large teams consisting of hundreds of team members.

Traditional method of modeling has not any specific work flow but Harmony process has the disciplined approach. It provides

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a project template to guide workers through the development and delivery of a product. Engineers can work simultaneously in the harmony process hence it is not time consuming as traditional method. More data can be added in the harmony project even after many years of its release because it has a standard pattern of developing and understood globally.

In the traditional method, after developing entire project, project is built. Hence it was time consuming and hectic. IBM Harmony process has improved re usability, stability and maintainability. It has decreased number of defects as compared to the traditional method.

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