Developing An Electric Vehicle Power Station Using Model Based System Engineering

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Abstract- *An electric vehicle power station, also known as an EV charging station or electric vehicle charging station, is a location where electric vehicles can be charged. These stations are equipped with charging infrastructure that can transfer electricity from the grid to an electric vehicle's battery. There are several types of electric vehicle charging stations, including Level 1, Level 2, and DC fast charging stations. Level 1 charging stations use a standard 120-volt outlet and can take up to 20 hours to fully charge an electric vehicle. Level 2 charging stations require a 240-volt outlet and can fully charge an electric vehicle in about 4-6 hours. DC fast charging stations, on the other hand, can charge an electric vehicle to 80% in 30 minutes or less. Electric vehicle power stations can be found in various locations, including public parking lots, rest areas, service stations, and private residences. They are an essential part of the infrastructure needed to support the widespread adoption of electric vehicles, as they provide a convenient and reliable way to recharge electric vehicles while on the go. This project we are developing an Electric Vehicle (EV) power station using Model-Based Systems Engineering (MBSE) approach. The development of an EV power station involves multiple disciplines, such as electrical engineering, mechanical engineering, and software engineering. MBSE provides an efficient approach to integrate these disciplines and manage the complexity of the system. The use of MBSE in the development of an EV power station results in a better understanding of the system, reduces development time and cost, and improves the overall quality of the system.*

Keywords- Electric vehicle power station, Level 1, Level 2, DC fast charging stations, widespread adoption of electric vehicles, Model-Based Systems Engineering (MBSE), reduces development time and cost, improves quality of the system, etc…

I. INTRODUCTION

Developing an electric vehicle power station using MBSE (Model-Based Systems Engineering) approach is a modern and innovative way of designing, building and managing power stations for electric vehicles. MBSE is a systematic approach that uses models and simulations to represent and analyze the behavior, functionality, and requirements of complex systems such as power stations. The primary goal of developing an electric vehicle power station using MBSE approach is to ensure that the station meets the requirements of the electric vehicle market and provides reliable and efficient power charging solutions. The process starts by creating a model of the system, which captures the different components, interfaces, and functions of the power station. The model is then used to simulate and analyze the behavior of the system under different scenarios and conditions. Using MBSE approach in developing an electric vehicle power station has several advantages. Firstly, it helps to ensure that the power station meets the specific needs and requirements of the electric vehicle market. This is achieved through a thorough analysis of the market trends, user needs, and technological advancements. Secondly, it enables the design and development of a more efficient and reliable power station, reducing the chances of failures and downtime. Finally, it allows for a more collaborative and iterative approach to design, involving all stakeholders and ensuring that the final product meets everyone's expectations. Developing an electric vehicle power station using MBSE approach is an innovative and effective way to meet the growing demand for electric vehicle charging solutions. It provides a comprehensive and integrated approach to design and development, ensuring that the power station is reliable, efficient, and meets the needs of the electric vehicle market. This project aims to showcase the benefits of MBSE software in developing complex systems, reducing error risks, saving time and resources, and enabling better collaboration between different stakeholders. Ultimately, this project could have a significant impact on the development of EV charging power stations and contribute to reducing greenhouse gas emissions, promoting sustainability, and creating a more sustainable future. This entire project is done using Catia magic systems of systems architect.

II. LITERATURE SURVEY

Design and Development of an Electric Vehicle Charging Station Based on Solar Energy" by R. O. Osorio, A. B.

Ramirez, and D. Sandoval. This paper presents a design for an electric vehicle charging station that uses solar energy to generate power. The paper presents a design for an electric vehicle charging station that uses solar energy to generate power. The authors note that electric vehicle use is growing, and with it, the need for charging infrastructure. They propose a charging station that can be powered by solar energy, reducing the reliance on traditional grid power and helping to address concerns about greenhouse gas emissions from vehicle use. The charging station design includes solar panels, batteries to store excess energy, and charging ports for electric vehicles. The authors describe the design process, including the selection of components and the calculation of energy requirements based on expected vehicle usage patterns. They also discuss the installation and testing of the charging station prototype. The authors note that the use of solar energy to power electric vehicle charging stations can have several advantages, including reduced dependence on fossil fuels, lower greenhouse gas emissions, and improved energy security. They also acknowledge that there are challenges to implementing solar-powered charging stations, such as the need for sufficient sunlight and the cost of solar panels and batteries.

"**An Overview of Electric Vehicle Charging Stations: Standards and Installations**" by T. Nagarajan, S. Sankar, and S. Suresh. This article provides an overview of the different standards and installation methods for electric vehicle charging stations. The article provides an overview of the different standards and installation methods for electric vehicle charging stations. The authors note that the development of electric vehicle infrastructure is crucial for the growth of the electric vehicle market and the reduction of greenhouse gas emissions. The article covers the different types of charging stations, including Level 1, Level 2, and Level 3, as well as the various charging standards, such as the CHAdeMO and CCS standards. The authors discuss the advantages and disadvantages of each type of charging station and standard. The article also covers the installation of electric vehicle charging stations, including the requirements for site selection, electrical supply, and safety considerations. The authors provide a detailed description of the installation process, from site preparation to commissioning, and discuss the challenges associated with installing charging stations, such as the need for permits and approvals. The authors conclude that the installation of electric vehicle charging stations is a complex process that requires careful planning and consideration of various factors, such as the location, electrical supply, and charging standards. They emphasize the need for standardization and interoperability in the electric vehicle charging infrastructure to ensure a seamless and efficient charging experience for electric vehicle owners

"**Design and Development of a Wireless Charging System for Electric Vehicles**" by H. Zhai, J. Zhang, and J. Lu. This paper presents a wireless charging system for electric vehicles that eliminates the need for physical connections between the vehicle and the charging station. The paper presents a design for a wireless charging system for electric vehicles, which eliminates the need for cables and connectors. The authors note that while cable-based charging is currently the most common method for electric vehicle charging, it can be inconvenient and pose safety risks. The wireless charging system uses magnetic induction to transfer energy from a charging pad on the ground to a receiver on the electric vehicle. The authors describe the design process, including the selection of components and the calculation of energy requirements based on the power consumption of the electric vehicle. The authors also discuss the installation and testing of the wireless charging system prototype. They note that the wireless charging system offers several advantages over cable-based charging, including convenience, safety, and reduced wear and tear on connectors.

"**Design of an Electric Vehicle Charging Station with Energy Storage**" by S. M. Munir, S. T. Islam, and S. A. Razzaq. This paper describes the design of an electric vehicle charging station that incorporates energy storage to improve efficiency and reduce costs. The paper presents a design for an electric vehicle charging station that includes energy storage to enable the integration of renewable energy sources. The authors note that electric vehicle use is growing, and with it, the need for charging infrastructure. They propose a charging station that can be powered by both renewable energy sources and traditional grid power, with excess energy stored in batteries for later use. The charging station design includes solar panels, wind turbines, batteries to store excess energy, and charging ports for electric vehicles. The authors describe the design process, including the selection of components and the calculation of energy requirements based on expected vehicle usage patterns and renewable energy generation. The authors also discuss the installation and testing of the charging station prototype. They note that the use of energy storage allows for more efficient use of renewable energy sources, reducing the need for traditional grid power and helping to address concerns about greenhouse gas emissions from vehicle use.

"**Modeling and Simulation of an Electric Vehicle Charging Station**" by Y. Zhang, Y. Wang, and H. Yan. This paper presents a modeling and simulation approach for an electric vehicle charging station that can be used to evaluate the performance of different charging strategies. The paper presents a modeling and simulation approach for an electric vehicle charging station to optimize charging efficiency and reduce charging time. The authors note that with the increasing use of electric vehicles, it is important to develop charging infrastructure that is efficient and effective. The authors propose a simulation model that takes into account the charging power, charging time, and battery capacity of electric vehicles. The simulation model is used to evaluate different charging scenarios, such as charging with a constant power level or varying power levels based on battery state of charge. The authors also discuss the implementation of the simulation model in a real-world charging station. They note that the simulation results were validated by comparing them with actual charging data.

"**Design and Optimization of a Fast Charging Station for Electric Vehicles**" by Y. Chen, Z. Zhu, and J. Zhang. This paper presents a design and optimization approach for a fast charging station for electric vehicles, with the goal of minimizing charging time while maximizing energy efficiency. The paper presents a design and optimization approach for a fast charging station for electric vehicles. The authors note that with the increasing popularity of electric vehicles, there is a growing need for fast charging infrastructure that can provide a quick and convenient charging experience for drivers. The authors propose a charging station design that includes multiple charging ports and a power distribution system that optimizes charging efficiency and reduces charging time. The optimization process involves considering factors such as the power output of the charging station, the number of charging ports, and the charging time required for different electric vehicle models. The authors also discuss the implementation of the fast charging station prototype and its performance in real-world testing. The authors acknowledge that there are challenges to implementing fast charging infrastructure, such as the need for high power output and the potential impact on the electrical grid. However, they note that the technology is improving and becoming more affordable, making it a promising option for electric vehicle charging infrastructure.

"**Integration of Electric Vehicle Charging Stations with Renewable Energy Sources**" by R. Kandpal, A. Agarwal, and R. P. Sharma. This article discusses the integration of electric vehicle charging stations with renewable energy sources, such as solar and wind power, to reduce the reliance on traditional grid power. The paper provides an overview of the integration of electric vehicle charging stations with renewable energy sources, such as solar and wind power. The authors note that the integration of renewable energy sources can help to reduce greenhouse gas emissions and improve the sustainability of electric vehicle charging infrastructure. The authors review different approaches to integrating renewable energy sources with electric vehicle charging stations, including direct integration of solar or wind power, and integration with energy storage systems to manage the intermittency of renewable energy sources. The authors also discuss the technical and economic challenges associated with integrating renewable energy sources with electric vehicle charging infrastructure. They note that factors such as the variability of renewable energy sources, the availability of suitable locations for charging stations, and the cost of equipment and installation can all affect the feasibility of integration.

III. ROLE OF SYSML IN MBSE

Systems modelling language, or SysML, is a graphical modelling language used for model-based systems engineering (MBSE) applications. With the use of diagrams like requirements diagrams, use case diagrams, block definition diagrams, internal block diagram, activity diagrams, sequence diagrams, state machine diagrams, and parametric diagram among others, SysML diagrams, shown in Fig. 2, offers a standardised method for expressing complicated systems.

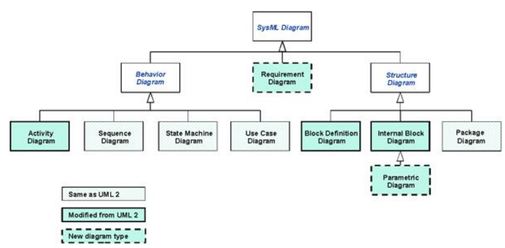

Fig. 2 SysML Diagrams

In MBSE, SysML is essential for creating a system model that encapsulates the needs, behaviour, structure, and interfaces of the system. Throughout the system's lifecycle, the SysML model serves as a blueprint for design, analysis, and verification.

Particularly, SysML enhances MBSE in the ways listed below:

1. Standardisation: SysML offers a standardised method of expressing systems, fostering uniformity, clarity, and stakeholder communication.
2. Modelling adaptability: SysML facilitates the modelling of a system's hardware and software components, allowing for a more thorough system model.
3. Management of needs: SysML provides modelling of system requirements, making it easier to connect requirements to design aspects.
4. Verification of the design: SysML models can be used to simulate and test the behaviour of the system, assisting in the early detection of design defects.

5. Communication and collaboration are made easier by the ability for team members and stakeholders to share SysML models.

In conclusion, SysML is a crucial tool in MBSE because it offers a standardised method for representing complex systems and makes it easier for stakeholders to collaborate and manage needs.

The four SysML pillars, which are shown in Fig. 3, are the fundamental ideas on which the language is built. They are as follows:

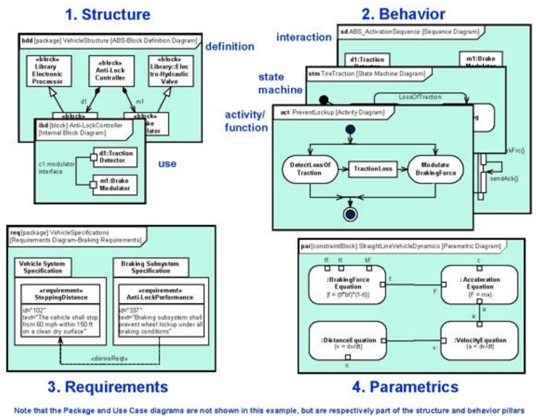

Fig. 3 Four Pillars of SysML

1. Structure: Blocks, pieces, ports, and connectors are just a few of the structural ideas offered by SysML to define a system's constituent parts and subsystems.
2. Behaviour: Using a range of diagrams, including activity diagrams, state machine diagrams, and sequence diagrams, SysML facilitates the modelling of system behaviour.
3. Requirements: SysML offers tools for managing and capturing system requirements, including attribution and tracability.
4. Parametrics: SysML provides the modelling of system constraints, equations, and other quantitative relationships through the use of parametric diagrams, allowing for the analysis and optimisation of system performance.

These four pillars work together to make it possible to build a complete system model that encapsulates a system's structure, behaviour, needs, and parametric relationships. This paradigm helps system stakeholders communicate and work together while acting as a potent tool for system design, analysis, and optimisation.

SysML Tool

Dassault Systèmes created the software suite CATIA MAGIC (Modelling and Generation of Integrated Components), shown in Fig. 4, which includes the Systems of Systems Architect (SoS Architect) tool for model-based systems engineering (MBSE) using SysML. Using a modular and hierarchical approach, SoS Architect is a tool for creating and analysing complex systems of systems.

Fig. 4 CATIA Magic Systems of Systems Architect Icon

SoS Architect supports the four pillars of SysML, enabling the modeling of system structure, behavior, requirements, and parametric relationships. The tool provides a rich set of graphical modeling capabilities, including block diagrams, internal block diagrams, activity diagrams, sequence diagrams, state machine diagrams, and parametric diagrams.

One or more of SoS Architect's salient characteristics is:

1. Hierarchical modeling: Using SoS Architect, complex systems can be modelled hierarchically, including the division of system components into smaller parts and the assignment of requirements and restrictions to different system elements.

2. Management of system requirements: SoS Architect supports managing system requirements, including managing requirement modifications and tracing requirements to system components.

3. Analyses and simulation: SoS Architect enables trade studies and optimisation analyses as well as simulation and analysis of system behaviour and performance.

4. Collaboration: Collaboration is supported by SoS Architect, which enables system stakeholders to share system models and data as well as track changes and comments.

Overall, SoS Architect is an effective tool for MBSE utilising SysML that enables the development of detailed system models that accurately depict the structure, behaviour, specifications, and parametric linkages of complex systems of systems.

SysML Implementation

Every model in SysML starts with the package diagram. A SysML package diagram is a specific sort of diagram that demonstrates the hierarchy and connections between SysML packages. Blocks, interfaces, and diagrams are just a few examples of the SysML elements that can be contained in packages and used to organise related elements.

The organisation of packages in a SysML model is represented visually by the package diagram. Packages are shown as rectangles in a package diagram, and the relationships between them are shown as lines linking the rectangles. The diagram enables the modelling of complicated systems with several degrees of hierarchy by including packages at various levels of abstraction. The package diagram for the bricklaying robot is shown in the Fig. 5.

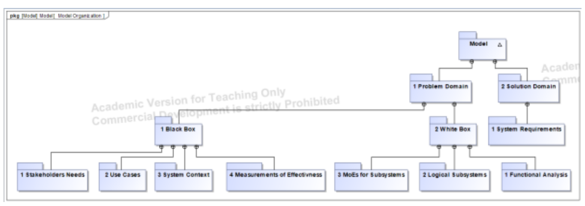

Fig. 5 Package diagram

The package diagram shows two main sections, which are Problem domain and Solution Domain. The whole systems model is contained inside the package diagram.

Problem Domain

The problem domain in SysML for the use of model-based systems engineering (MBSE) to support a bricklaying system in construction automation could be defined as follows:

1. System requirements: The problem domain begins with defining the system requirements, including performance, safety, and regulatory requirements.
2. Analysis of the construction process: The construction process must be analyzed to understand the requirements for the bricklaying system. This includes analyzing the bricklaying process, the materials used, and the environment in which the system will operate.
3. Identification of system components: The next step is to identify the components of the bricklaying system, including the bricklaying robot, the bricks, the mortar, and any sensors or controllers.
4. Definition of system interfaces: The interfaces between system components must be defined, including the inputs and outputs for each component.
5. Modeling of system behavior: SysML can be used to model the behavior of the system, including the sequence of actions taken by the robot to lay bricks, and the conditions under which the robot must operate.
6. Modeling of system structure: SysML can also be used to model the structure of the system, including the physical layout of the components and the connections between them.
7. Identification of system requirements and constraints: The requirements and constraints for the system components must be identified and allocated to the appropriate components.
8. Optimization and trade-off analysis: SysML can be used to perform trade-off analyses and optimization studies to identify the best design choices for the system.

a. Stakeholder Requirements Diagram

A requirement diagram in MBSE (Model-Based Systems Engineering) is a graphical representation of the system requirements and their relationships with each other. It is a type of UML (Unified Modeling Language) diagram that is used to capture and communicate the requirements of a system. The main purpose of a requirement diagram is to provide a high-level view of the system requirements, and to show how they relate to each other. The diagram typically consists of a set of nodes and relationships, with each node representing a requirement, and each relationship representing a dependency or relationship between requirements. This can help to identify potential conflicts or ambiguities in the requirements, and can help to ensure that the system is designed to meet all of the necessary requirements. It can also serve as a communication tool between different members of the development team, as well as between the development team and stakeholders.

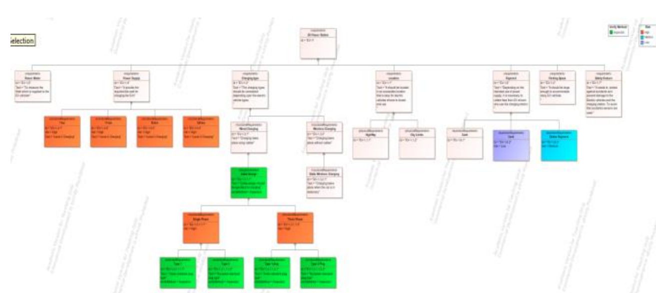
Fig. 6 Stakeholder Requirements Diagram

b. Use Case Diagram

In MBSE (Model-Based Systems Engineering), a use case diagram is a type of UML (Unified Modeling Language) diagram that is used to model the interactions between a system and its external actors. It is a high-level diagram that provides an overview of the system's functionality from the user's perspective. A use case diagram typically consists of a set of actors, use cases, and relationships between them. The actors represent the external entities that interact with the system, such as users, other systems, or hardware devices. By creating a use case diagram, engineers can get a high-level view of the system's functionality and the interactions between the system and its external actors. It can also serve as a communication tool between the development team and stakeholders, helping to ensure that everyone has a clear understanding of the system's requirements and functionality.

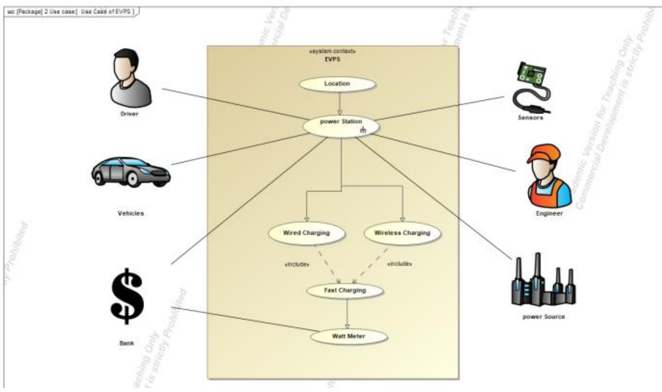

Fig. 7 Use Case Diagram

c. *Activity Diagram*

In MBSE (Model-Based Systems Engineering), an activity diagram is a type of UML (Unified Modeling Language) diagram that is used to model the flow of activities or actions within a system or process. It provides a visual representation of the steps involved in a process or activity, and the relationships between those steps. An activity diagram typically consists of a set of nodes and edges, with each node representing an action or activity, and each edge representing a transition between two nodes. The nodes and edges are connected to form a flowchart-like diagram that shows the sequence of activities and the conditions or events that trigger each activity. By creating an activity diagram, engineers can get a detailed view of the process or activity being modeled, and can identify potential issues or inefficiencies in the process. It can also help to ensure that all necessary steps and conditions are included in the process, and can serve as a communication tool between the development team and stakeholders, helping to ensure that everyone has a clear understanding of the process being modeled.

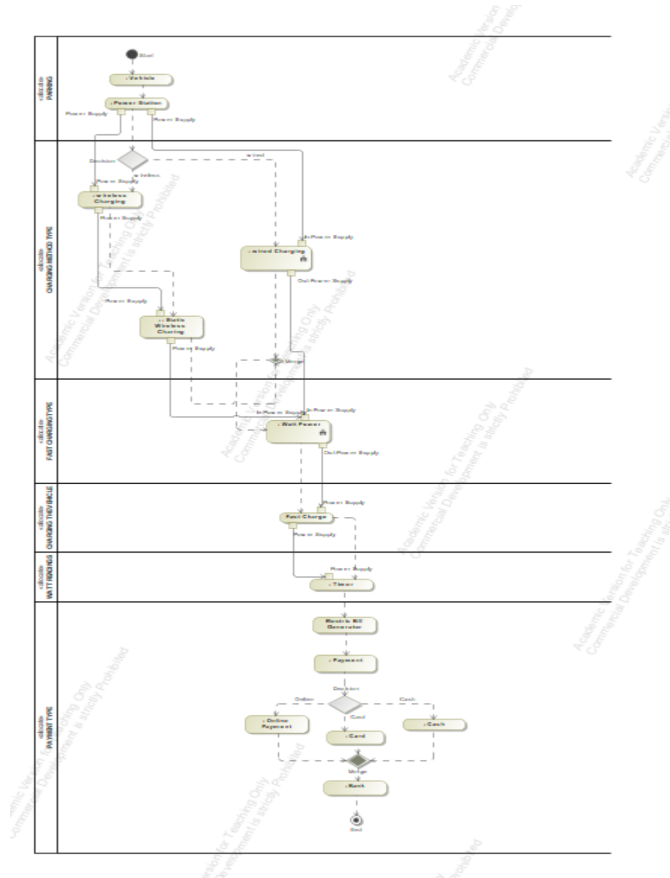

Fig. 8 Activity Diagram

d.Block Definition Diagram

In MBSE (Model-Based Systems Engineering), a block definition diagram (BDD) is a type of SysML (Systems Modeling Language) diagram that is used to model the structure or composition of a system or process. It provides a high-level view of the system or process, showing the major components or blocks and their relationships to one another. A BDD typically consists of a set of blocks or components, with each block representing a major system or process component. The blocks are connected by relationships, which show how the blocks are related to one another and how they interact with one another. By creating a BDD, engineers can get a high-level view of the structure or composition of the system or process being modeled, and can identify potential issues or inefficiencies in the system design. It can also help to ensure that all necessary components or blocks are included in the system design, and can serve as a communication tool between the development team and stakeholders, helping to ensure that everyone has a clear understanding of the system composition being modeled.

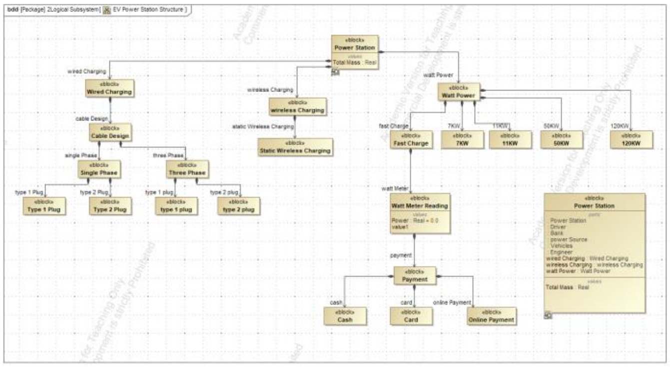

Fig. 10 Block Definition Diagram.

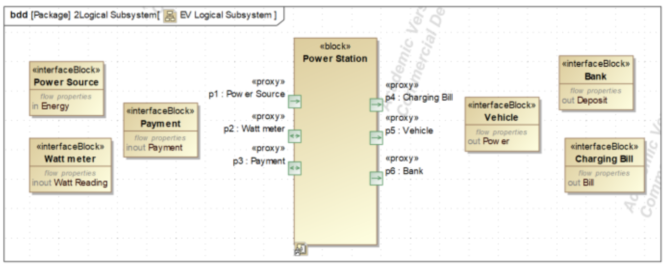

Fig. 11 Block Definition Diagram.

e. Internal Block Diagram

In MBSE (Model-Based Systems Engineering), an internal block diagram (IBD) is a type of SysML (Systems Modeling Language) diagram that is used to model the internal structure of a system or process. It provides a detailed view of the system or process components and their interrelationships, showing how the system or process works together as a whole. An IBD typically consists of a set of blocks or components, with each block representing a major system or process component. The blocks are connected by relationships, which show how the blocks are related to one another and how they interact with one another. Additionally, an IBD includes ports, which represent the inputs and outputs of each block. By creating an IBD, engineers can get a detailed view of the internal structure of the system or process being modeled, and can identify potential issues or inefficiencies in the system design. It can also help to ensure that all necessary components or blocks are included in the system design, and can serve as a communication tool between the development team and stakeholders, helping to ensure that everyone has a clear understanding of the system structure being modeled.

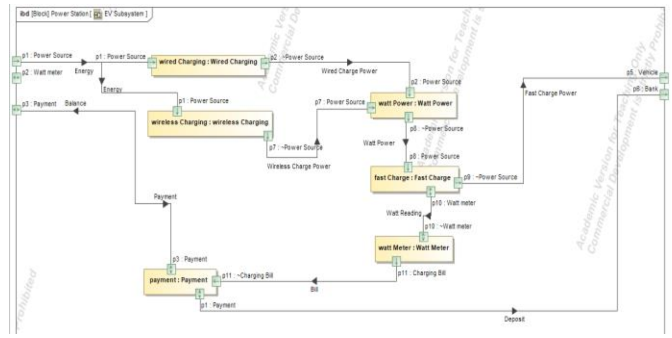

Fig. 12 Internal Block Diagram

Solution Domain

The solution domain in SysML is refinement of problem domain to support the design process with accurate required data. Generally, the solution domain consist of requirements, structure, behaviour and parametric of system, sub-system, and component level.

a. System Requirements Diagram

The system requirements for any system may consist of the followings,

functional requirements,
non-functional requirements,
physical requirements,
interface requirements,
performance requirements,
design constraints, and
verification requirements.

The above requirements must be satisfied with the design and development process of the system during the downstream engineering. The illustration of a SysML system requirements of developing an electric vehicles power stations using model based system engineeringhown in Fig. 13.

The system requirements developed for bricklaying robot shows five design requirements to satisfy during development and testing phase. Designers can guarantee that the system satisfies the needs and expectations of its stakeholders and that it can be checked and validated to satisfy those criteria by expressing these requirements in SysML.

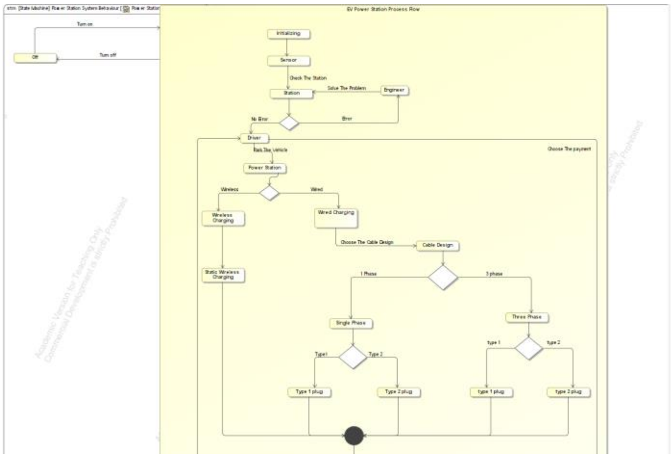

Fig. 13 System Requirements Diagram

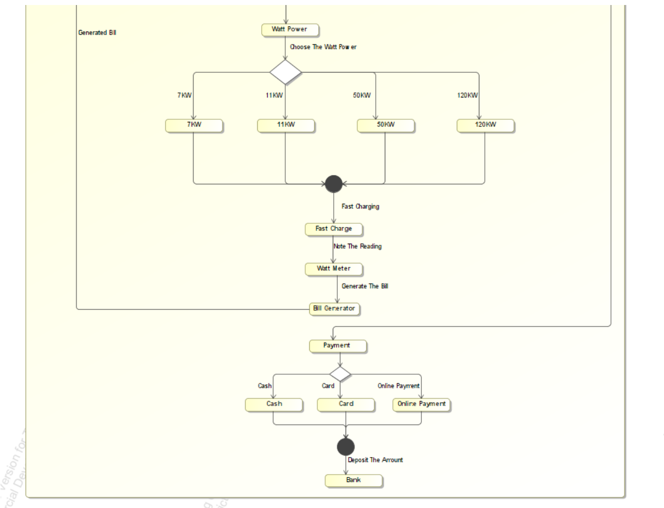

Fig. 14 State Machine Diagram

b. Parametric Diagram

In MBSE (Model-Based Systems Engineering), a parametric diagram is a type of SysML (Systems Modeling Language) diagram that is used to model the relationships between system or process parameters. It provides a visual representation of the interdependent variables that affect the behavior of the system or process being modeled. A parametric diagram typically consists of a set of variables, with each variable representing a different parameter that affects the system or process behavior. The variables are connected by relationships, which represent the mathematical or logical equations that describe the behavior of the system or process. By creating a parametric diagram, engineers can get a detailed view of the interdependent variables that affect the behavior of the system or process being modeled, and can identify potential issues or inefficiencies in the system design. It can also help to ensure that all necessary parameters are included in the system design, and can serve as a communication tool between the development team and stakeholders, helping to ensure that everyone has a clear understanding of the system behavior being modeled.

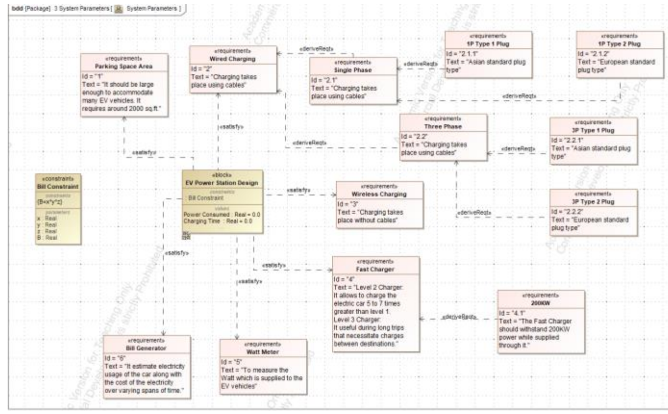

Fig. 16 System Parameters Diagram

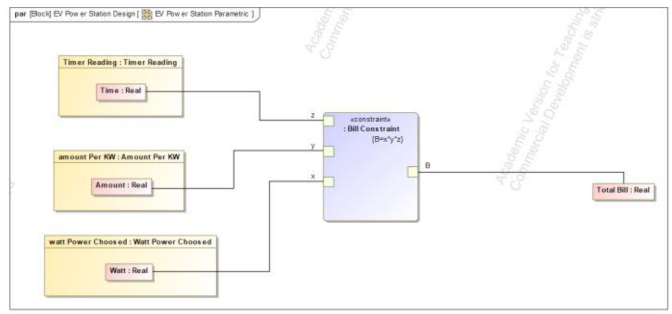

Fig. 17 Parametric Diagram

IV. RESULT & DISCUSSION

SysML is a useful tool for creating and analysing complicated systems, like the bricklaying system in construction automation, as it is a language for model-based systems engineering (MBSE). We can express the numerous facets of the system, such as its functional needs, physical components, and behaviour, in a straightforward and organised manner by utilising SysML to generate multiple models and diagrams.

The ability to model the many requirements of the system using various sorts of diagrams, such as use case diagrams, activity diagrams, and sequence diagrams, is one of the main benefits of utilising SysML for the design of the by electric vehicle power station system. These diagrams offer a clear overview of the system's operation, the various interactions between its parts, and the movement of information and control throughout the system.

Additionally, SysML offers the capability to model the physical structure of the system using block definition diagrams and internal block diagrams, allowing us to represent the various system components, their properties, and the relationships between them.

The ability to use state machine diagrams and parametric diagrams to model the behaviour of the system is another crucial component of the SysML implementation for the electeic vehicle power station. While parametric diagrams offer a means to examine the interactions between the many parameters and constraints of the system, state machine diagrams assist in modelling the system's various states and transitions. These diagrams aid in ensuring that the bricklaying system satisfies the necessary performance standards and functions well in various environmental settings.

Overall, the SysML implementation for the building automation bricklaying system offers a potent tool for developing, deconstructing, and optimising the system. We can better comprehend the system's functionality, physical makeup, and behaviour by using SysML to model its various components. This will allow us to decide on the system's design and operation.

V. CONCLUSION

In conclusion Developing an electric vehicle power station using MBSE (Model-Based Systems Engineering) approach is a modern and innovative way of designing, building, and managing power stations for electric vehicles. The use of this approach ensures that the power station meets the specific needs and requirements of the electric vehicle market, providing reliable and efficient charging solutions. The benefits of using MBSE approach in developing an electric vehicle power station include a more efficient and reliable power station, reduced chances of failures and downtime, and a collaborative and iterative approach to design involving all stakeholders. Furthermore, this approach enables a thorough analysis of the market trends, user needs, and technological advancements, ensuring that the final product meets everyone's expectations. As the demand for electric vehicles continues to increase, the need for reliable and efficient charging solutions also grows. Developing an electric vehicle power station using MBSE approach is a step towards meeting this demand, providing a comprehensive and integrated approach to design and development. Ultimately, this approach can help accelerate the adoption of electric vehicles, reducing carbon emissions and promoting a sustainable future.

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