SIEMENS

Ingenuity for life

Siemens Digital Industries Software

Driving engineering innovation for vehicle electrification

Using Simcenter to master the development complexity of electrified vehicles

Executive summary

The electrification race is on. Consumers are ready to adopt new mobility solutions that are cleaner, smarter and quieter. Modern megacities will promote smooth commutes while discouraging the circulation of noisy and polluting vehicles. Stricter environmental regulations will accelerate the need for electrifying the powertrain.

Contents

Abstract

Electrification reshapes vehicle engineering processes and methods. Market players feel the pressure to innovate while aiming at producing mass-market vehicles. The entire transportation industry needs to adapt and deliver solutions that offer optimal drive range, performance, life and in-vehicle experience at the lowest possible cost. The fierce competition requires adopting a real-time comprehensive digital twin framework that bridges virtual and physical engineering and preempts late technology defects or unexpected poor performance. Front-loading design and optimization using simulations from the early stages of prototype development limits costly design changes in later stages of product development and enables the virtual investigation of hundreds of possible architectures. Coupling simulation with physical testing methods at various stages of development permits advanced validation of the system even before it exists.

Coupling simulation with physical testing methods at various stages of development permits advanced validation of the system even before it exists.

This white paper addresses multiple aspects of the performance engineering of electrified vehicles:

- How the digital twin of hybrid and electric vehicles enable the virtual assessment and exploration of the various design options of e-powertrain components (batteries, motors and power electronics) to select the combinations that fit global system performance requirements
- How manufacturers can balance the performance attributes – noise, vibration and harshness (NVH), drivability, range, safety, aerodynamics and thermal and energy management – during the integration phase, and physically validate the components and architecture choices
- How integrated simulation and testing solutions help original equipment manufacturers (OEMs) and suppliers accelerate product design while simultaneously optimizing vehicle autonomy and other automotive megatrends

Electric vehicles become more attractive

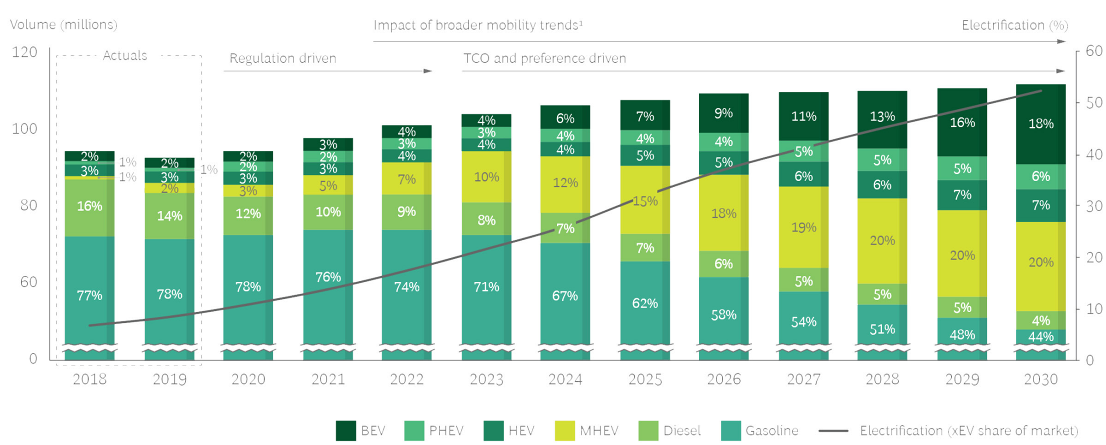
The transportation industry is responsible for 16 percent of global greenhouse gas emissions. Without vehicle electrification, the industry will not meet its objective to reduce carbon dioxide (CO2) emissions. Electric vehicles are ready for mass consumer adoption; it is no longer a technology for early adopters. Consumers are also more conscious of the global warning challenge and are willing to adopt electric vehicle technology to help lower greenhouse gas emissions

Despite the challenges of a health and economic crisis, and in some areas the absence of adequate infrastructure, the electrification trend is steadily growing. In the coming years, an increasing number of new vehicles will have some degree of hybridization or be fully battery-powered. According to recent surveys, 30 to 45 percent of vehicle buyers in the United States and Germany are now considering purchasing an electric vehicle for their next acquisition.

Some more contextual elements support this trend. Battery prices have decreased by about 80 percent since 2010, leading to a reduction in the manufacturing cost of hybrid and electric vehicles. The total cost of ownership has consequently decreased for consumers, as the battery packs account for over 50 percent of the total vehicle price. Those consumers also perceive electric-based platforms as being more robust than before. Overall, they are more likely to adopt a technology that could lower the total cost of vehicle ownership, contribute to reducing emissions and bring the same or even an increased level of comfort and driving pleasure. The spreading urbanization of populated areas also promotes electrification. Electric vehicles are particularly suitable for urban transportation as they are quieter and emit less harmful gases and particles.

Despite those benefits, obstacles remain that prevent the mass production and sales of electric vehicles. Manufacturers are still challenged to constantly improve the driving range, performance, safety, durability and design of their vehicles while lowering costs. They target improved vehicle performance, enhanced vehicle safety and reliability, a better product lifecycle management and reduced production costs, etc.

To achieve engineering objectives it is essential to have an innovative workflow for design and development and implement efficient simulation tools. This white paper introduces the framework, methodologies and tools required to deploy the digital twin concept and streamline the vehicle development process, from early requirements and architecture definition to validation and testing.



Global sales by 2030: a growing demand influenced by TCO and preference (Source BCG Analysis, 2020).

The challenges of electrification

Vehicle electrification is not the simple act of replacing the conventional combustion engine of a vehicle with an electric motor. Electric vehicles are complex machines with numerous design possibilities and many parameters to consider.

Vehicle electrification encompasses full-electric or battery-electric cars. It also includes all hybrid electric variants, such as mild hybrids and plug-in hybrids. The hybrid electric vehicle (xEV) refers to all types of electrified vehicles, from the mild hybrid to the fully electric battery-powered version. To make things even more complex, some electrification challenges are common to all xEVs, while others are specific to a certain type of vehicle, like plug-in hybrids.

What are the challenges of xEVs? For full-electric vehicles, range anxiety remains the main barrier to consumers adopting the technology. Battery range has tremendously improved over the past decade, yet range anxiety persists. Other concerns about vehicle performance, safety, durability and cost remain prominent amont consumers. Manufacturers of hybrid-electric vehicles must manage the power transmission and energy transfer within the vehicle. On top of that, they need to address the same performance issues as with any other vehicle such as driving dynamics, NVH quality, durability and many more.

Manufacturers of xEVs need to balance all these parameters in the earliest stages of design and front-load decisions in this phase. There is no magic formula for optimal design and there are almost as many design variants as there are manufacturers.

Mastering complexity over the entire development cycle

Another challenge that is common to all vehicle manufacturers is the need to shorten the time-to-market. Front-loading essential design and development decisions and validating them earlier in the process is critical to bringing innovative products to market sooner rather than later. At every stage of design and development, from concept to testing and final validation, the digital twin helps assess and balance performance criteria and meet the right decisions as early as possible.

Opting for a design

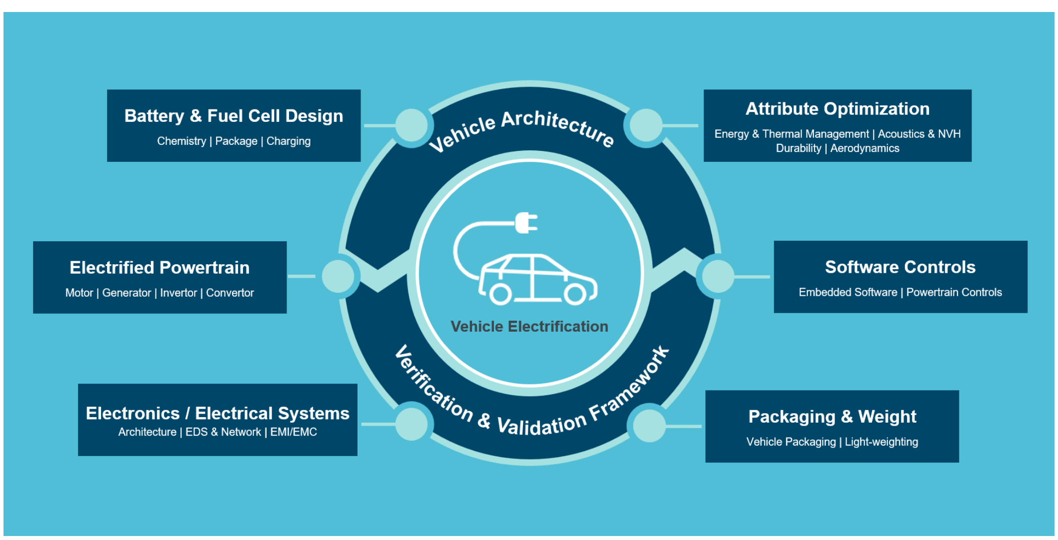
There are two general trends for electrified vehicle design. Traditional automakers often start from their conventional platforms and adjust them to the needs of electric propulsion. Startups and newcomers to the transportation industry opt for designing from scratch, creating a new vehicle without any preconception. When it comes to conceiving a completely new platform, China leads the race with hundreds of companies registered as new energy vehicle manufacturers.

Native platforms usually offer a greater range but come at a higher cost. Adapted platforms are cheaper to develop but those builds require radical tradeoffs to solve range anxiety issues. The Nissan LEAF is a good example of such a tradeoff. The 2011 LEAF version had a range of 117 kilometers (km) on a full battery charge. By comparison, the 2017 version offered a range increase of 55 kilometers up to 172 km, enough to comfort worried customers. To achieve this range increase, the Nissan engineers put the LEAF driveline on a serious diet, drastically reducing weight. They also added a battery pack and some comfort elements, consequently increasing the vehicle's overall weight. The net result was a vehicle that weighed slightly more in 2017 than it did earlier on.

Developing proper packaging and reducing weight provides part of the answer to the problem, but that is not easy to achieve.

Setting the requirements

OEMs are still considering a variety of possible designs and have not converged on a common standard, platform or proven vehicle architecture. Established OEMs will mostly re-use existing vehicle platforms and work towards integrating more or less electrification. New market players build their architecture from scratch. Both strategies pose challenges for vehicle architecture and driving configuration.



Addressing the challenge of innovation while managing the complexity of mechatronic system development.

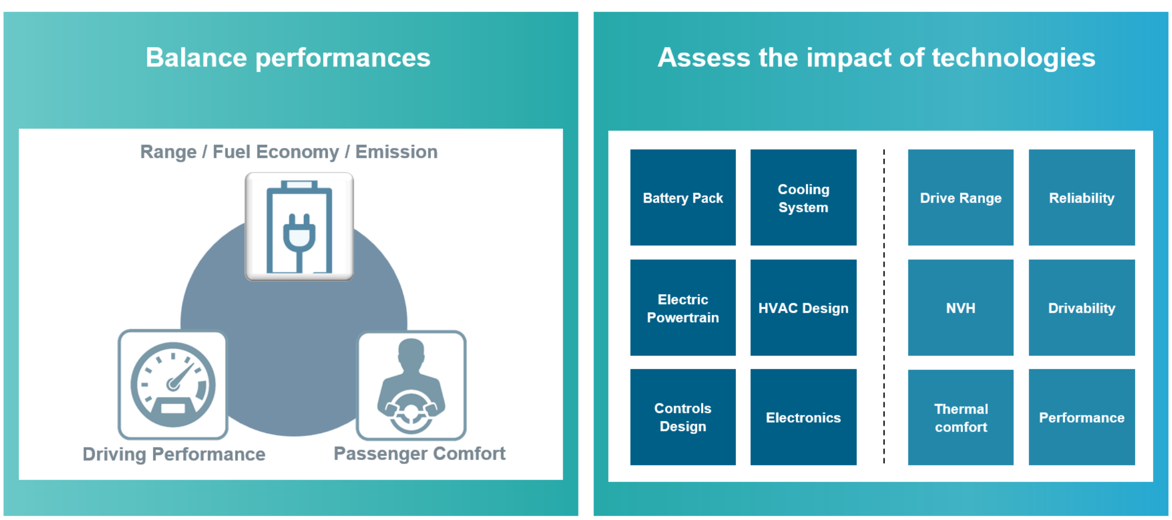
Selecting the right architecture design is all about making a compromise, getting the right performance targets that are set by the consumers' expectations, the governmental regulations and the operating environment. Engineers need to optimize for metrics quantified in their targets while conforming to the laws of physics and the constraints of the boundary conditions. In this stage of design, computer-aided engineering (CAE) technology and simulation tools help designers efficiently solve this type of problem.

From the concept phase on, engineers need to set the right targets and expectations to design an architecture that is compatible with the objectives. How many electric motors does the vehicle require? What is the ideal size for the battery pack(s)? All these considerations need to take the vehicle's targeted market and usage into account. The architecture of a small urban car fundamentally differs from the one of a fun, sporty vehicle, or of a big family sedan that is used to travel over long distances. The same vehicle will consume energy and dissipate heat differently on the iced tracks of Sweden compared to the sunny roads of Italy.

A system simulation approach gives system architects early insight into the behavior of the vehicle. With system simulation, engineers build up a complete vehicle based on simple but still physics-based lumped models. The objective is to virtually evaluate technologies and balance high-level performance attributes (such as performance, range, energy efficiency, operability) in a multitude of driving scenarios, such as scenarios that comply with the Worldwide Harmonized Light Vehicles Test Procedures (WLTP) or the Environmental Protection Agency (EPA) Urban Dynamometer Driving Schedule (HD-UDDS) regulation cycles.

Architecture-driven simulation significantly reduces the time and effort needed to integrate systems by defining simulation architectures in a tool-neutral format. It transforms system simulation models originating from multiple authoring applications, including 3D simulation or even test-based models, into modular and re-usable assets for easy configuration, variant evaluation and multi-attribute balancing of the target vehicle from the early design stages.

With Simcenter™ System Architect software, engineers take an architecture-driven simulation approach to accelerate system design. The platform helps system architects and project engineers rapidly create heterogeneous system simulation architectures and seamlessly evaluate performance. Engineers can collaborate more effectively by using a common modeling language that interfaces with various software. In this way, they can quickly create complex co-simulation models and accelerate the design cycle by avoiding numerical errors. Additionally, the simulation models are traceable and re-usable for different types of analyses, including requirements analysis or what-if analysis, to reduce modeling effort.



Selecting the right technologies to meet target performance levels while balancing conflicting attributes.

Balancing efforts with multi-attribute optimization

When system architects have envisioned the vehicle's architecture, the project team still needs to ensure this vehicle will meet regulations as well as targets for vehicle performance and comfort. The target vehicle needs to meet the performance requirements in many ways: speed, driving range, quality and comfort. Some of these targets' requirements are conflicting: a weight reduction is essential to increase the driving range but can come at the expense of the durability of vehicle parts. If not designed carefully, lightweight components are more prone to failure over time.

The ideal vehicle successfully meets defined performance levels for attributes such as driving range, driving performance, passenger comfort and durability. For hybrid vehicles, fuel economy and emission reduction are also essential.

Engineers must validate an optimal design of the battery pack, electric powertrain, electronic controls, cooling system, heating, ventilation and air conditioning (HVAC) design and the vehicle's electronics against the performance attributes of driving range, NVH comfort, thermal comfort, reliability, drivability and driving performance. Performing this multi-attribute balancing in the early stage of development helps optimize designs and remove the need for late-stage troubleshooting.

Simcenter, which is part of the Xcelerator™ portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, helps answer design questions that matter at the vehicle, motor, engine, transmission and thermal integration levels. It offers the required modeling capacity to simulate all critical electric subsystems. Whether dealing with battery sizing or electric machine design, the project teams benefit from efficient modeling workflows that support the engineering efforts from the architecture creation to its integration, including all design details. Simcenter Amesim™ software offers a state-of-the-art multilevel modeling capability for all the critical subsystems (electric machine, battery and transmission). It helps deliver an optimal design in terms of energy efficiency, performance and drivability.

Exploring designs with generative engineering

An excellent way to evaluate the system architecture and design variants is to create simple models and use them to run several driving scenarios.

One possible scenario evaluates the overall energy flow in the various subsystems over a target drive cycle. A similar scenario could also be used to evaluate the drivability performance of the target vehicle taking the effects of the tip-in/tip-out into account. Using simple 1D vehicle models allows us to realistically gauge the comfort level, even at this early stage.

To go one step beyond and evaluate uncommon architectures, the ones that would not immediately come to mind, engineers can choose to rely on generative engineering. Generative engineering automatically creates and evaluates thousands of them. It lets the artificial intelligence (AI) compute the architecture, combining the different components of the car in myriad variants. It allows us to evaluate many more architectures according to a wide number of predefined scenarios, including some that a human brain may not have considered. But generative engineering goes beyond thinking out-of-the-box; it filters and cleans the platform combinations, ultimately delivering only the ones that match the requirements. Generative engineering allows for deep architecture exploration using functional system modeling. This method is usually easier for nonexpert users as the choice of the level of complexity of the model is made automatically. The outcome permits them to make an informed decision on the rough size of the components and how they connect.

Deepening insights with 3D simulation and test

Whether using generative engineering tools or simpler system simulation models, engineers can already configure the target vehicle according to a variety of performance metrics and requirements. Some system characteristics, however, will require a deeper level of information to be properly evaluated. The tip-in/tip-out behavior of the transmission is easily detected using a system simulation model but identifying potential torsional vibration issues will require an additional layer of information, such as the gears inertia. Therefore, to get deeper insight into the torsional dynamics of the transmission system, the engineer will create a 3D simulation model.

Interestingly, simulation engineers do not need to create the full 3D models of all the car components. Co-simulation is a technique by which 3D simulation models connect to simple system simulation models. Depending on the component under scrutiny, engineers can choose to model a certain part in full 3D while leaving other elements of the system as 1D models.

Equally so, as some components are difficult to model in either 1D or 3D, testing remains an important tool, even in the early stages of development. By characterizing predecessor components using dedicated testing, modeling approaches can be validated at detailed levels. And for those components that are re-used from other vehicles, test-based characterization is often the most accurate way to create a component model.

One of the objectives of creating the vehicle's architecture is to identify and map the target requirements and cascade those down to the level of the subsystems and components. Since many components are designed by suppliers, the relationship between the suppliers and the OEMs is critical when it comes to optimizing the performance of the part. On one hand, OEMs need to set the right requirements for the parts and clearly communicate them to the suppliers. On the other hand, they need tools to integrate the components into the full system before the vehicle exists in order to preempt integration issues. Integrating test and simulation is an excellent way to address potential integration issues before the vehicle is built.

Testing and validating designs

The seamless integration of testing and simulation methods helps front load the testing and validation of designs. By validating the design and performance of components within the framework of the digital twin, engineers get an understanding of the component's behavior when integrated into the full system. They preempt potential integration issues and avoid costly late-stage troubleshooting actions. The same goes for validating control software and mechanisms when early-stage virtual testing of the control unit helps verify and validate the behavior before a physical prototype is built.

Designing the electrified powertrain

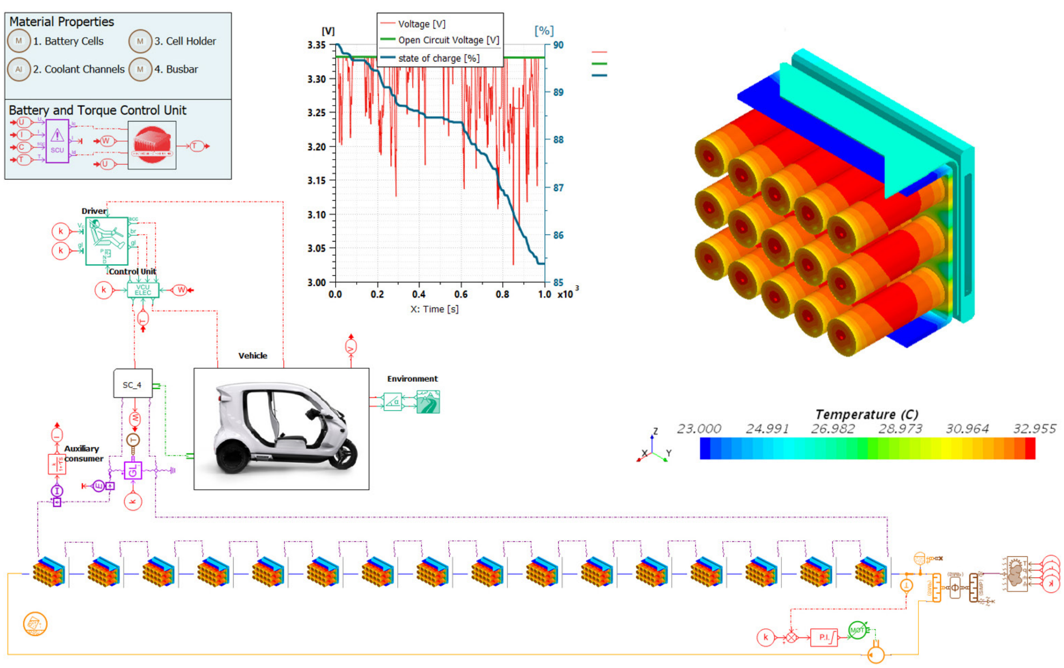
The electric powertrain is the heart and soul of the electric vehicle. Manufacturers will have to ensure the e-vehicle meets the expectation of consumers, not only in terms of energy and monetary savings but also for driving pleasure and comfort. On top of that, they deal with problems previously unheard of, such as battery quality, size, weight and lifetime.

Optimizing the battery pack

The design of the battery cell and pack is a good example of the importance of the OEM-supplier relationship. Traditionally, battery design and performance optimization have been the responsibility of dedicated suppliers. Established manufacturers of internal combustion engine (ICE) vehicles are sourcing from third parties most of the components needed to electrify their platforms. Newcomers and dedicated e-car companies sometimes design, develop and manufacture a larger part of the electrical components. The Chinese OEM BYD is, to date, the sole carmaker to manufacture almost all its e-components. However, the industry is witnessing a trend in which OEMs tend to gradually outsource less and less of the electrical motor and battery design tasks.

Battery design requires dedicated engineering knowledge and skill sets. Car manufacturers have little to no experience in that engineering field and rely heavily on third-party suppliers to provide them with a battery pack that meets their requirements. Recently, new players have entered this market segment, while some OEMs are aiming to develop more e-components in-house. The only way to fill in the expertise gap is to rely on software that provides the insights, knowledge and tools that replace the supplier's expertise.

There are multiple cell chemistries available for electric storage technology. Today, selecting specific chemistry depends mostly on the target application. Every choice implies a tradeoff of performance versus lifetime versus costs, etc.



A multi-physics, multi-level approach to design the most appropriate energy storage system balancing key attributes like range, reliability, size, weight, and lifetime.

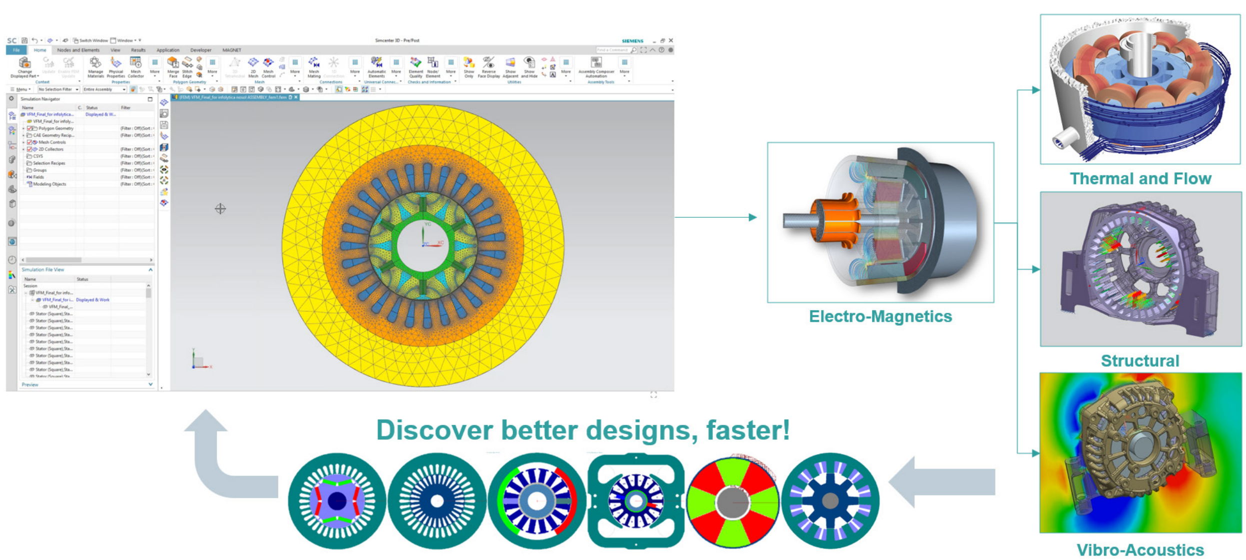
Once a cell technology is selected, many technical issues remain, such as the sizing of the full battery pack, the thermal management of the pack, the impact of aging batteries on the systems' performance and managing the battery's lifetime.

Model-based systems engineering (MBSE) offers scalable solutions for tiered collaboration between suppliers and OEMs. In the early stage, the designer (usually the supplier) selects the cell chemistry and presizes the battery cells. He or she can rely on tools such as Simcenter STAR-CCM+™ software to understand the microstructures electrochemistry and to study in 3D the effect of the electrode morphology on the electrochemical performance. This tool is particularly useful for material manufacturers and cell designers. At the cell level, Simcenter Battery Design Studio™ software offers the unique capability of letting the cell designer build a comprehensive digital twin of the cell configuration with high fidelity. This design can then be coupled with a performance model to virtually test the cell in various conditions, like over many drive cycles, with pulses, etc.

At the level of the battery pack, the engineers need to design the cooling system, optimize the thermal management, assess the impact of aging as well as validate the integration into the electrified driveline and verify the controls strategies. To study the packs and modules, the Simcenter STAR-CCM+ battery simulation capability lets designers build and analyze the complexity of a pack and its thermal management system. Simcenter STAR-CCM+ battery simulation helps the user understand the highly coupled behavior of the packs' electrical performance and the surrounding thermal environment, whether the pack is actively or passively cooled (with liquid or air). A system simulation software like Simcenter Amesim allows the integration team to investigate the impact of cell chemistry or design change on battery aging, simulating thousands of driving cycles during several calendar years. Finally, to study a full system, the co-simulation between Simcenter Amesim and Simcenter STAR-CCM+ Battery Simulation brings even more realism into the driving cycles applied to the pack.

With thousands of engineers working on the integration of the cell within the pack and vehicle, the teams need to be able to seamlessly connect and exchange models. Some engineers may use computational fluid dynamics (CFD) software to design a thermal management system project that optimizes battery performance.

Simultaneously, some system simulation specialists will focus on sizing the pack, designing a cooling subsystem or optimizing a control strategy while virtually assessing the energy performance of the electrochemical storage systems when integrated into the full hybrid or battery electric vehicle. Simcenter Amesim offers a scalable and flexible platform to precisely perform such analyses. It also combines with a battery identification tool that allows the characterization of existing battery packs from dedicated battery testing. The Simcenter solutions also allow the automated export of the cell-equivalent empirical model from Simcenter Amesim to its multi-physics solution in Simcenter STAR-CCM+. Engineers can focus on their domain expertise, such as thermal management, while considering the relevant and accurate component behavior and the system's boundary conditions.



Evaluate different e-machine topologies and simulate their performance, from initial system-level sizing to high fidelity detailed engineering models in an integrated environment.

Siemens' battery modeling solution offers a set of software and features that provide simulation capability. The multidomain, multi-physics and multilevel modeling approach makes the engineering teams, both at the OEM and on the suppliers' side, stronger and more agile in their digitalization process.

Designing the e-motor

The design of an electric machine is a century-old technology. Every industry masters the technology and most OEMs develop their own electric motors (or in the case of hybrid vehicles, the electric motors and the components that permit the energy transfer).

The challenge for the engineers is to evaluate and validate the performance of components in the context of the full system. Tradeoff decisions need to be made based on objectives, constraints and applications of the e-machine.

Engineers will have to decide on the drivetrain topology and drive cycle-based sizing, the motors' efficiency and its power density as well as its speed range. They will have to design for fault tolerance and robustness, incorporating manufacturing tolerances, and take NVH performance and thermal management into account. Eventually, they need to optimize the e-powertrain for cost and performance, while considering its aging behavior.

The engineering process for the electric motor uses system simulation models to define the operating envelope of the motor under realistic vehicle operating conditions. After that, using Simcenter SPEED™ software and Motorsolve™ software for rapid motor simulations helps the user search for a design that meets electromagnetic and thermal finite elements analytics (FEA) performance. Using Simcenter 3D electromagnetics, the engineering team analyses the final design to ensure it meets the electromagnetic performance targets. Further analyses in Simcenter 3D and Simcenter STAR-CCM+ help confirm the design's NVH is compliant and the cooling system is optimized to be effective at peak operating conditions. Physical tests ultimately confirm the performance. Simcenter offers a complete and bespoke solution for motor design, development and testing.

Developing the gearbox

An electric driveline is not complete without the transmission. This could be a simple single-stage gearbox in the case of a pure electric vehicle, or a complex system with multiple planetary gears and an automatic or automated gearbox in the case of a hybrid vehicle. The point is this subsystem is often under high loads and needs to be designed with durability, drivability and even with NVH in mind.

System simulation tools such as Simcenter Amesim are excellent for modeling the rotational and thus the torsional aspects of the driveline to study the drivability aspects. The 3D simulation enables the user to analyze the gear and bearing loads to evaluate strength, durability and NVH.

Specifically on the 3D simulation side, this has always been a computationally costly exercise using mostly nonlinear FE codes. Simcenter 3D Transmission Builder software alleviates many of these issues by enabling engineers to rapidly create gear trains and their bearings. It also applies a patented methodology to the calculations that facilitate much faster computing. This gives the designers and engineers more time, for example, to optimize the gear profiles and minimize gear whine under high load.

Developing and integrating the e-components

The main components of the electric drive for automotive applications are the electric motor and driveline, the power converter, the power supply and the lines connecting the components. Simulation engineers will need to model and analyze each component individually as well as integrate those models in a subsystem view. The modeling of some components requires expert-oriented software, which includes model templates and a material database. It provides significant analytical computation capabilities together with a design space exploration functionality to explore a multitude of possible configurations.

When conceiving the components that make up an e-powertrain, the risk is designing in silos. Individual components might meet the target requirements, but they will eventually need to meet the requirements at the full e-powertrain and full vehicle level. Components that were designed to meet the requirements may turn out to contribute to excess electromagnetic emissions when integrated into the e-powertrain ecosystem. Each component acts as a path for electromagnetic emissions, even though the power converter is known to be the main source. Therefore, all the components of the drive system must be analyzed as being either a source or a path within the car's electrical system. Simulation domain experts can perform an FEA-based electromagnetics simulation to understand the transfer of electromagnetic radiation. Connecting the analysis at the component level and performing it with a dedicated expert software with the analysis at the system level brings tremendous added value.

Another example of the cornerstone value of a suite of compatible expert software is the thermal design of the vehicle. The e-motor is one of the largest producers of heat in an electric vehicle, and if this heat isn't dissipated properly it results in poor performance and decreased reliability. A better thermal design exploits the seamless connection between Motorsolve, the Siemens software for motor design, and Simcenter Flomaster™ software, the thermal simulation software at the system level. This powerful combination allows for a more accurate simulation of the motor's thermal performance and its effects on the overall thermal system design. This helps achieve significant time and cost reduction in the design phase.

Optimizing electrical systems

Optimizing electrical systems is obviously an essential step in electric vehicle development. Engineers need to conceive and design the electric wiring harness so it is optimized to convey the required energy while minimizing complexity and potential interference. The position of the harness and the potential movements of the cables need to be considered so cables do not become unnecessarily long or run the risk of getting disconnected or even simply pinched. A model-based system engineering approach helps you understand and address the relationship between the various systems and optimize the packaging of the wire harness.

Adopting this approach today is essential as electrical systems become more and more complex. The trends towards a higher level of driving automation leads to a huge increase in the systems' complexity. Adding driver assistance functionalities means adding more electrical components, wires and interfaces, consequently adding weight and increasing the risk of electromagnetic interference.

Electromagnetic interference (EMI) occurs when electrical components are positioned near one another. The effects of this interference should be carefully monitored and avoided if possible. EMI is subject to strict regulations to avert potential safety issues. Electromagnetic compatibility (EMC) and EMI are terms that are typically used together with their particularities. When a system is compliant with EMC requirements, it means the system is functioning properly within its electromagnetic environment: The system is sufficiently immune to electromagnetic influences, both from outside or originating from the system itself. In addition, EMC also refers to the influence a system can have on its surroundings. Electronics systems are supposed to keep the electromagnetic interference to other electronic systems below the targeted level.

On one hand, Siemens has a framework that allows a multi-domain collaboration between the software environments of Capital™ software, NX™ software and Teamcenter® software, leading to a dynamic collaboration between the electrical and mechanical environments. Using Active Workspace facilitates collaboration and lets engineers manage multi-domain data in Teamcenter.

On the other hand, the Simcenter portfolio offers a complete set of solutions for the electromagnetic simulation of low-frequency electromagnetics and high-frequency electromagnetics, as well as for the calculation of the EMC/EMI output parameters at the vehicle level based on the components' input parameters.

Integrating components and subsystems into the full vehicle

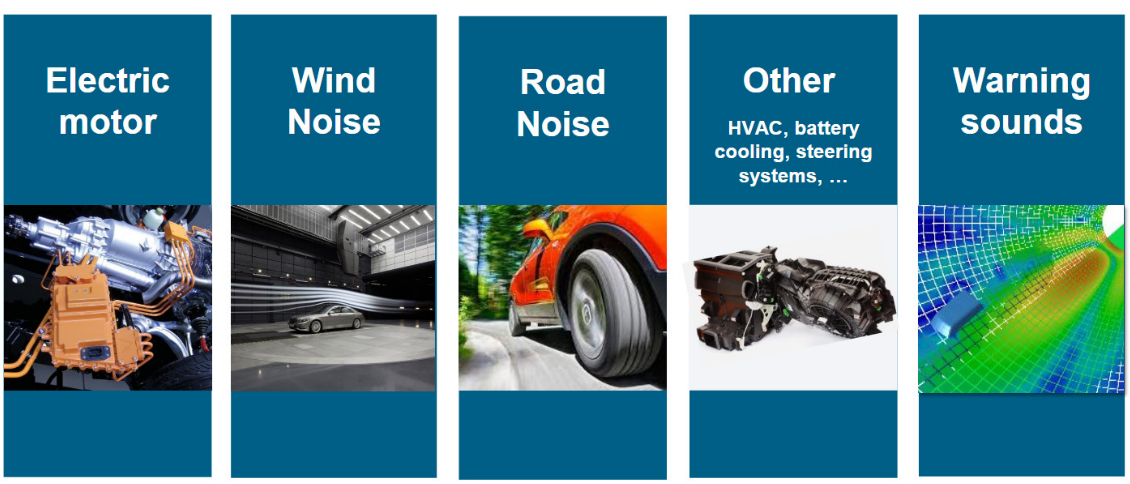
An electric car may use a different type of motion system, but it remains a passenger vehicle. Passengers will have the same or even higher expectations for their vehicles. They will expect a comfortable, fun and pleasant experience. They will want to enjoy the ride but minimize the costs of ownership. The carmakers must optimize the vehicles for all relevant characteristics and implement multi-attribute performance engineering, just as they would do for a regular combustion engine vehicle, to achieve a harmonious design. Creating a realistic and comprehensive digital twin of the vehicle helps optimize and achieve the expected performance levels for all key attributes throughout the development process.

Addressing NVH issues differently

Manufacturers of low noise-emission vehicles still encounter NVH issues. First, electric vehicles may be quiet, but they are not silent. E-motors produce unpleasant high-frequency tones, which is also true for the gearbox in the form of a whine. The noise of the auxiliaries, such as the electrical motors of the wiper and the automatic windows, becomes noticeably annoying. The traditional source-transfer-receiver concept as applied in transfer path analysis (TPA) helps to analyze how all these noise sources contribute to the noise inside the cabin. Since their early conception in the 1980s, these methods have evolved to integrate not only 3D simulation models but also a 1D simulation that is useful when dealing with rotational systems. Lately, newly introduced tools have been able to be used to create full vehicle models from simulated or bench-characterized passive and active components. These tools are used to efficiently create virtual prototype vehicle models that allow a fast analysis of multiple options for each of the auxiliary systems.

Wind and road noise are not masked by the engine noise anymore and also become appallingly audible as the prime sources of cabin noise. Wind noise is the largest contributor to overall noise and probably the most difficult to master. To optimize the acoustic comfort inside the vehicle's cabin, the engineers can rely on wind tunnel testing, an empirical method that computes the information received from multiple microphones to understand the perception of wind noise inside the cabin. A smart combination of instrumentation, testing hardware and software allows us to reliably correlate a wind noise source to the corresponding audible effect inside the cabin.

Also, in some situations, electric vehicles need to generate sound. The European Commission regulations stipulate that electric vehicles must implement a pedestrian warning known as the acoustic vehicle alerting system



Deliver superior NVH and acoustic performance in terms of road and wind noise as well as the electric drive, auxiliaries and cooling systems.

(AVAS) to prevent accidents in populated areas. Active sound design is a technology that is used to develop AVAS sounds. These sounds should be loud and remarkable enough to alert pedestrians, but pleasant enough and not too intrusive so as to burden the environment/generate noise pollution. Finally, as there is no constraint with the type of sound that is added, many manufacturers seize the opportunity to create a sound signature for their brand or models. Brand sound design links to both interior and exterior design and can even relate to the engineering of the sound system inside the vehicle. Simcenter Testlab™ Sound Designer software supports the engineering of brand sounds and soundscapes.

Trading durability for weight reduction: a reasonable choice

Another example of a seemingly unsolvable problem is the tradeoff between weight reduction and durability. Weight reduction is critical for an e-vehicle to increase the driving range. At the same time, it could result in erroneous design decisions when lighter components are selected and integrated into a vehicle at the expense of durability. Consumers today carefully assess the total cost of ownership of a vehicle and will reject vehicles that have a poor reputation for durability. Therefore, the durability performance of the parts and the full system cannot be neglected, and the digital twin should integrate and analyze all characteristics to properly assess and validate the durability behavior.

Increasing range by reducing drag

Next to weight reduction, a key factor in increasing the driving range of the electric vehicle is reducing the aerodynamic drag. Simcenter Star-CCM+ helps you to assess design variants and minimize aerodynamic energy losses while other attributes are related to fluid dynamics such as cooling optimization, handling of the dynamic drive, or even water and dirt management for the windows and sensors.

Managing thermal design at the system and full-vehicle level

There are some aspects specific to electric vehicles. Thermal management, for example, is even more critical for electric vehicles than conventional engine vehicles. Beyond the problem of battery and powertrain cooling, which need to be carefully addressed, engineers will have to solve new issues related to the day-to-day use of the car. Consider the issue of in-cabin heating and ventilation. Without a combustion engine, there is no big heat generator inside the car anymore. The battery needs to be kept within a narrow temperature window in order to ensure longevity, which is a challenge in cold or hot climates where there is also an immediate need for the passenger compartment to be cooled down or heated up at the same time. How fast and well will the windshield defrost in winter? Those seemingly trivial questions need to be answered to ensure a pleasant passenger experience.

Simcenter enables you to take a holistic approach to thermal management and combines system simulation with 3D simulation solutions and testing to ensure that no question is left unanswered when it comes to heat dissipation and thermal management.

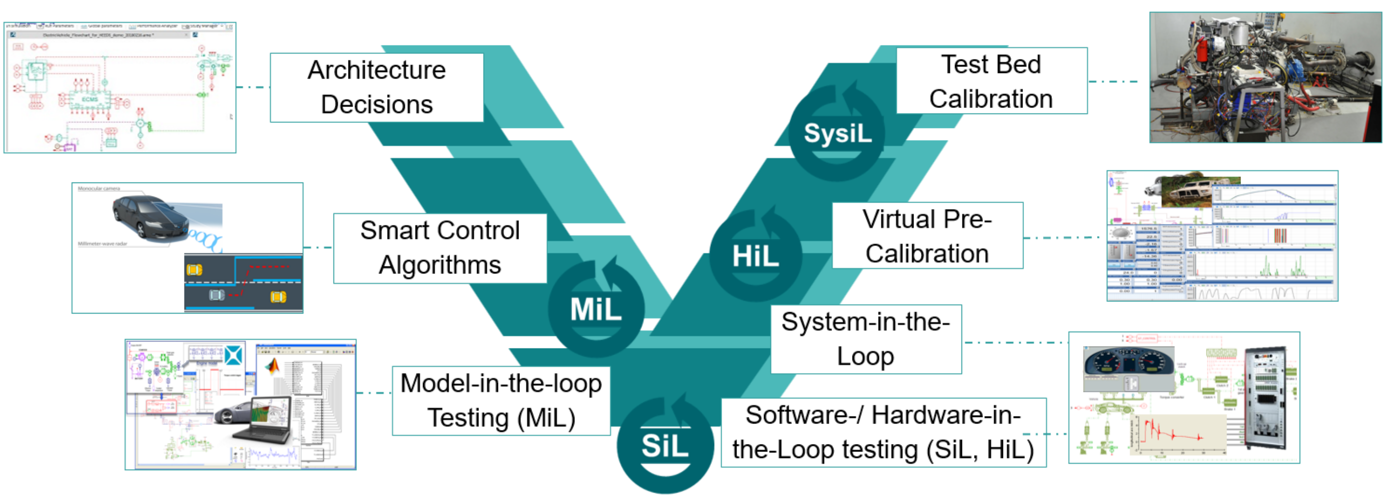
Balancing, balancing and balancing again

All these performance attributes and many more need to be analyzed against each other and other essential performance criteria such as energy efficiency and safety. The Simcenter software and hardware suite contains the generalist and expert tools that help electric vehicle manufacturers nurture and refine the car’s comprehensive digital twin from the earliest stage of development to the final testing phase. Simcenter helps optimize the vehicle’s performance in terms of thermal management, drivability, driving dynamics, integrated safety, NVH, acoustics, durability, electromagnetic emissions and more. All these attributes need to be optimized not only according to the set target metrics, but also in the context of the subsystem and full system behavior. This holistic approach is what makes the digital twin methodology effective.

Relying on physics simulation to support controls V&V

Engineering the software and controls of a vehicle is more critical today than ever. Siemens helps control and software engineering departments to develop and validate best-in-class mechatronic systems by supporting MBSE, an approach integrating simulation and test. The MBSE approach helps you make the best choices, starting from capturing the requirements and selecting the architecture over the early design of the control algorithm and the development of the embedded code to verification, validation (V&V) and calibration of the electronic control unit (ECU) and the full system. MBSE rolls out a concurrent mechanical, software and electric/electronic (E/E) hardware design process and replaces expensive and time-consuming physical tests with early virtual evaluation, improving the quality of the final product and reducing development time and cost.

Developing control systems, which include battery management, motor control and cooling systems for the driveline and HVAC and many others, all go through a design cycle that involves the control strategy design, software implementation and calibration of the parameters. This requires not just controls design and implementation software with tools like Matlab Simulink, but also system simulation to support model-in-the-loop (MiL), system-in-the-loop (SiL) and hardware-in-the-loop (HiL) testing for which accurate plant models need to be created. Simcenter Amesim is an excellent tool to create these plant models, supporting each of the development steps with system models to run in a closed loop with the controls from desktop MiL and SiL to real-time HiL simulations.



Frontload hybrid and electric vehicle controls development and calibration with multi-level simulation.

Conclusion

Regardless of the stage of the development process or the engineering discipline, integration is key. The examples in this white paper have shown that to be successful, manufacturers must always keep in mind the entire vehicle. The only way to achieve a proper balance of all requirements and avoid late-stage troubleshooting is to generate a realistic and comrehensive digital twin of the car, one that accurately describes its properties, characteristics and attributes even before it physically exists. Simcenter provides a suite of software and hardware that makes the digital twin real and lets engineers take a virtual ride in the car before it is built.

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. The Xcelerator portfolio helps companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

siemens.com/software

82717-C4 12/20 A