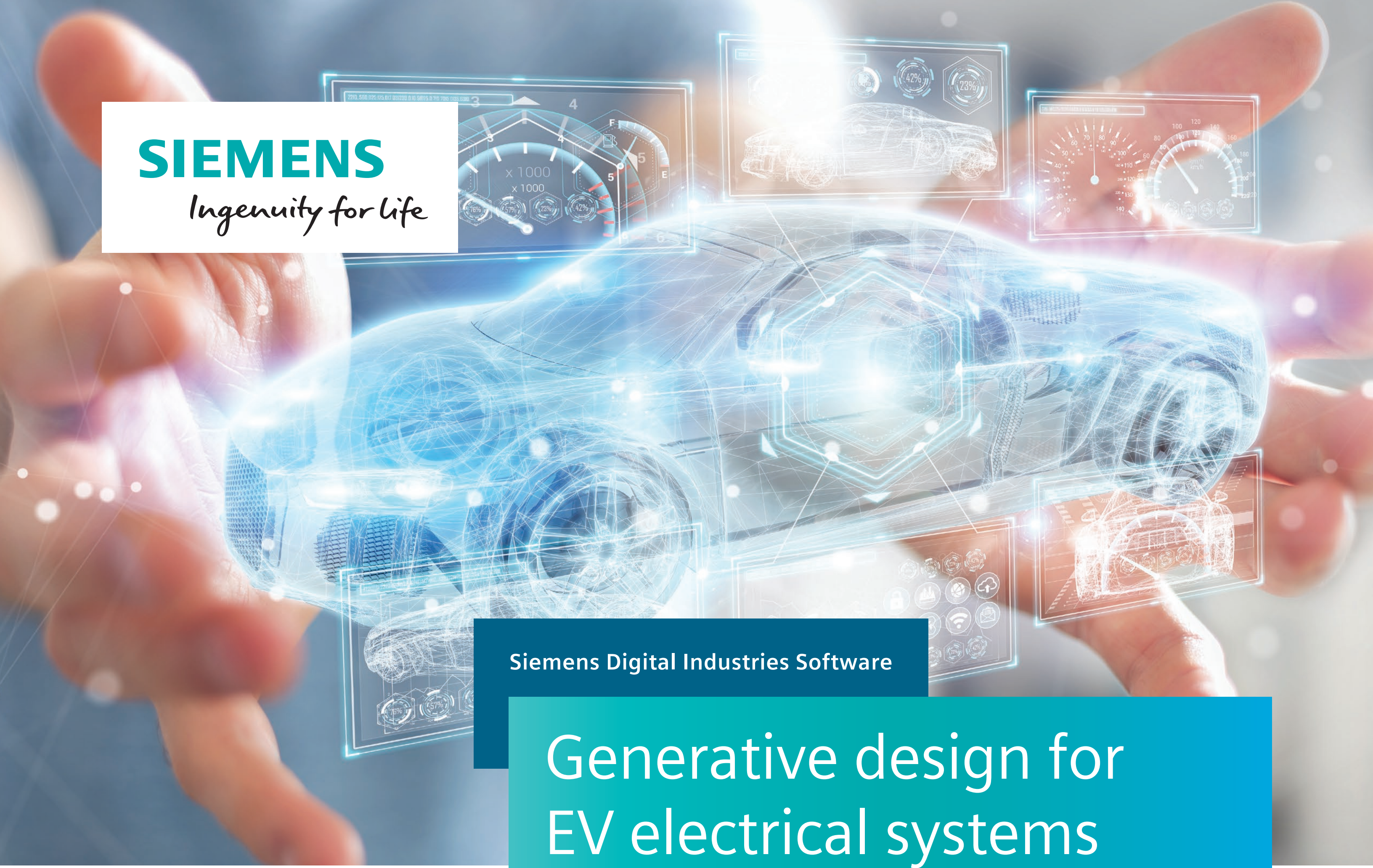

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Generative design for EV electrical systems

Executive summary

Electric vehicles (EVs) are popularly held as the future of personal mobility and transportation. New electric car manufacturers are flooding the market while established OEMs divert more investment to electric vehicle programs in an attempt to stay ahead. Automotive electrical and electronic systems are becoming more complex, and the complexity is beginning to strain conventional design methods. Generative design will be a key enabler for new and established automotive companies as they develop all-electric vehicle platforms.

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Introduction

Electric vehicles are popularly held as the future of personal mobility and transportation. New electric car manufacturers are flooding the market while established OEMs divert more investment to electric vehicle programs in an attempt to stay ahead. All of these manufacturers will face significant challenges during development. Automotive electrical and electronic systems are becoming more complex, and that is making the task of designing today's cars much more difficult. Infotainment, comfort and convenience features, and even safety- and mission-critical systems such as steering and throttle control are accomplished through electrically powered computers, actuators and sensors.

Electric vehicles will only further increase this challenge as every system in the car will be electrically powered. As more systems are added, a higher load will be placed on the batteries powering the vehicle. This includes incredibly high voltage transmission lines that will bring power to the electric motor driving the car. These lines require additional design guidelines to ensure they are bundled and routed appropriately. To succeed, EV manufacturers will need to integrate all of these features into a safe, reliable and high quality package.

To add to this challenge, electric vehicles require extensive testing and validation to ensure safety while maximizing the drive range and performance of the vehicle. Manufacturers will need to incorporate the lessons learned through simulated and real-world testing into their electric vehicle designs to remain competitive.

Many expect electric vehicles to take over as the primary mode of personal transportation and mobility in the future.

From hybrid to hull electric

The ramp to all electric vehicles presents significant challenges for the engineers tasked with their design. Critically, the engineers must optimize the charging and discharging of the battery packs to maximize the drive range and performance of the vehicle. In addition, engineers must balance the supply of electrical power between the engine and the litany of safety, comfort and convenience features that have become commonplace in modern vehicles. Systems such as in-vehicle infotainment (IVI) and the instrument cluster, climate control and advanced driver assistance systems (ADAS), all place a load on the battery.

Hybrid electric and plug-in hybrid electric vehicles use a combination of internal combustion and electric powertrains to maximize drive range, fuel efficiency and performance (figure 1). Most hybrid electric vehicles can be driven completely by either the internal combustion engine (ICE), or the electric motor, or by a combination. The ICE can also create electric energy and charge the batteries, much like it would in a traditional vehicle. This combination of energy sources gives hybrid electric and plug-in hybrid electric vehicles tremendous flexibility in how energy is created to power various systems.

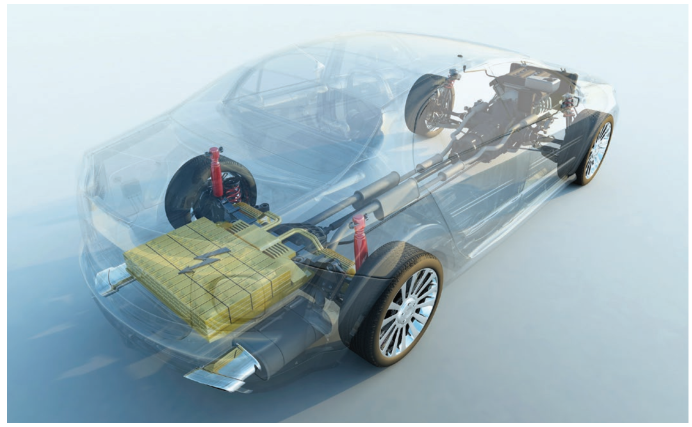

Figure 1. Hybrid electric vehicles have both electric and traditional powertrains to power various systems within the vehicle.

All-electric vehicles do not have the support of a supplemental source of power such as an ICE. All the power the vehicle needs is supplied by the energy stored in the batteries. As a result, the number and sophistication of the electronic features on an electric vehicle has a direct effect on the drive range and performance of the vehicle. ADAS systems often incorporate cameras, radar and ultrasonic sensors to enable lane departure warning systems, automatic braking and more. These systems are a constant drain on the battery as they are always active.

To enhance the efficiency of the electrical and electronic systems, and thus drive range, engineers will need to perform architecture and tradeoff analyses to investigate architectural proposals. The tradeoff analyses for an EV will need to account for hundreds of components and millions of signals while optimizing function locations, network latency, error rates and more. In addition, engineers will need to manage the high voltage lines that carry power to the electric motor, or motors. These lines often require special design guidelines regarding routing and bundling that must be taken into account.

Despite these challenges, electric drive is a burgeoning market. There are almost 350 companies known to be developing electric vehicles, and that number continues to increase. Some of these are major automotive manufacturers seeking to stay ahead of the coming industry disruption, but most are startups or companies from other industries seeking to enter a traditionally impenetrable market. These companies lack industry-specific experience and the engineering resources to brute force their way through the complexities of electric vehicle design. Even the major automotive OEMs will face problems that their legacy design flows are ill-equipped to handle.

This will be true especially as companies move their electric vehicle projects from research, development and one-off prototyping into full-scale production. The electrical and electronic systems will need to be optimized for cost, weight and power consumption while adhering to the stringent safety requirements prevalent in the automotive industry. To compete, these companies will need a new design methodology that enables young engineers to design accurate and optimized systems, which can only be done by capturing the experience and knowledge of veteran engineers. They will need generative design.

Generative design and engineering

Generative design takes system definitions and requirements as input and generates architectural proposals for the logic, software, hardware and networks of the electrical and electronic systems using rules-based automation (figure 2). These rules capture the knowledge and experience of the veteran engineers to guide younger engineers throughout the design. Capturing this IP helps companies to develop both vehicle architectures and new generations of engineers as they learn and implement existing company knowledge.

A generative design flow begins with functional models. A functional model represents the functionality of the electrical system to be implemented, without specifying how it should be implemented. It accounts for aspects such as communication networks, power sources and components. These models may be captured in a variety of formats such as spreadsheets, SysML files and MS Visio diagrams.

Design teams then normalize these various functional models into a unified format within their electrical systems design environment, such as Capital. Once normalized, the engineers can generate potential architectures for the E/E system logic, networks, hardware and software. Valuable company IP is integrated automatically into these proposals through the design rules that govern proposal generation. At this stage, the electrical engineers can rapidly generate, assess and compare multiple architectural proposals, optimizing the design from the initial solutions presented.

From the selected architectural proposal, the engineers can extract discreet logical systems to generate platform-level network designs and the electrical distribution system (EDS). With this in place, the team can synthesize wire harness designs for each subsystem, generate manufacturing aids and bills-of-process costs, publish electrical service data and generate VIN-specific service documentation.

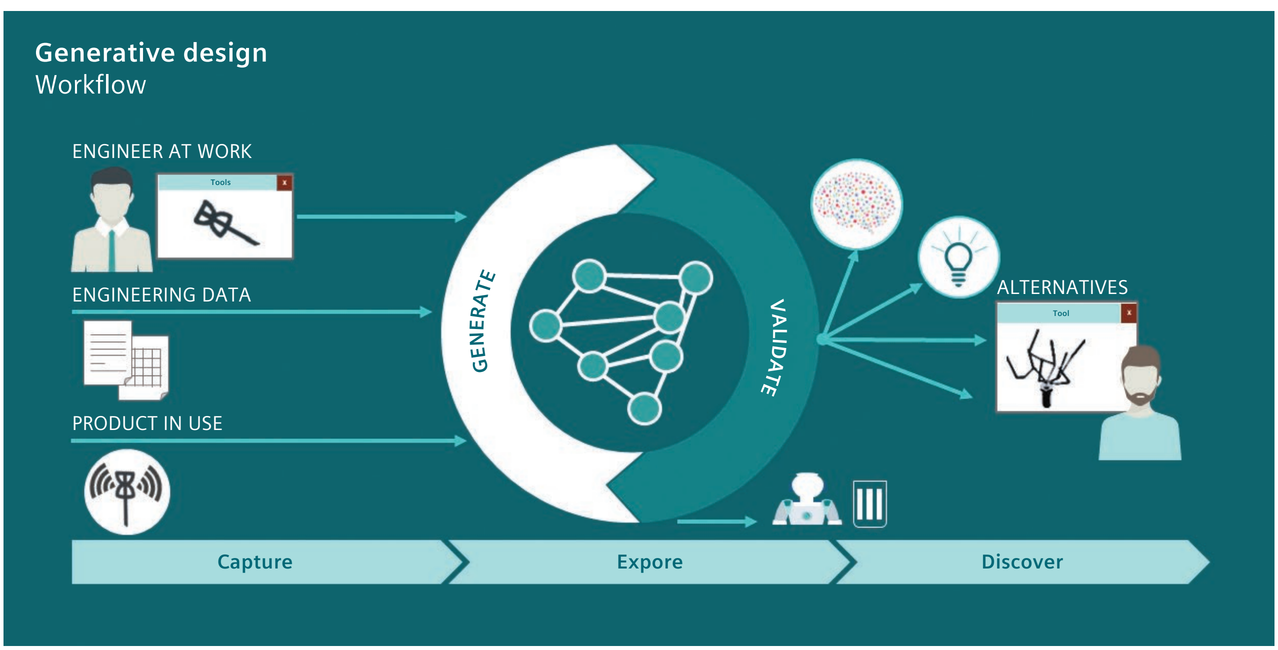

Figure 2. Generative design uses rules-based automation to generate proposals for the logic, software, hardware and networks of the E/E system.

Why generative?

The increasing electrical and electronic content of modern vehicles is already pushing current design methods to their limits, yet the complexity of automotive systems will only continue to grow in the future. Fully electric cars will contain incredibly complicated electrical and electronic systems. The drivetrain and critical systems alone will require a sophisticated system of computers, sensors and actuators to manage battery charge and discharge, control systems and the electric motors. What's more, future electric vehicles will contain dozens of sensors, hundreds of ECUs, and miles of wiring to gather, process and transmit the data required for advanced features. Engineers developing these vehicles will also need to balance performance requirements against power consumption, physical space constraints, weight and thermal considerations.

Generative design empowers automotive engineers to tackle the challenges of electrical and electronic systems design for electric vehicles. It employs rules-based automation for rapid design synthesis, enables engineers to design in the context of a full vehicle platform, and tightly integrates various design domains to ensure data continuity.

Firstly, employing automation throughout the process will help design teams manage design complexity without increasing time-to-market. Automation helps engineers focus on the most critical aspects of the design and verification of the functionality of the E/E system and reduces errors from manual data entry. This empowers engineers to focus more of their time on applying their creativity and ingenuity to creating the next generation of automotive technology breakthroughs. Automation also applies company IP to the generated proposals through design rules, increasing the accuracy and quality of the designs.

Next, designing in the full platform context helps engineers to understanding the way signals, wires and other components are implemented across the entire vehicle platform, thereby reducing errors at interfaces or due to the intricacy of the harness. This design flow also enables teams to re-use validated data across vehicle platforms to improve quality and reduce development costs.

Finally, a tightly integrated environment enables the electrical engineers to share data with engineers and tools in other domains, such as mechanical or PCB design. The interactions between the electrical, mechanical and software components of a vehicle are increasing. Seamless synchronization of data between these domains improves the integration of them into a single system.

Data continuity

Generative design creates a continuous thread of data from the initial system definition and requirements to full-scale production and service. The same data feeds each stage of the generative design flow so that nothing is lost between design stages or design domains. This continuous thread of data keeps all engineering team members up to date and working with the most current data while also ensuring that designs are meeting various requirements for functionality, safety, weight and so forth (figure 3).

Built-in design rules enable engineers to check designs for flaws automatically, flaws that can easily be lost in the sheer complexity of an electric vehicle. These design rule checks can catch unterminated wire ends, inconsistencies in graphical and physical bundle lengths, and check for current loads on wires, generated heat and other faults. Again, generative design employs company IP through these design rule checks to catch design flaws that have caused trouble in the past or that new engineers may not think to check.

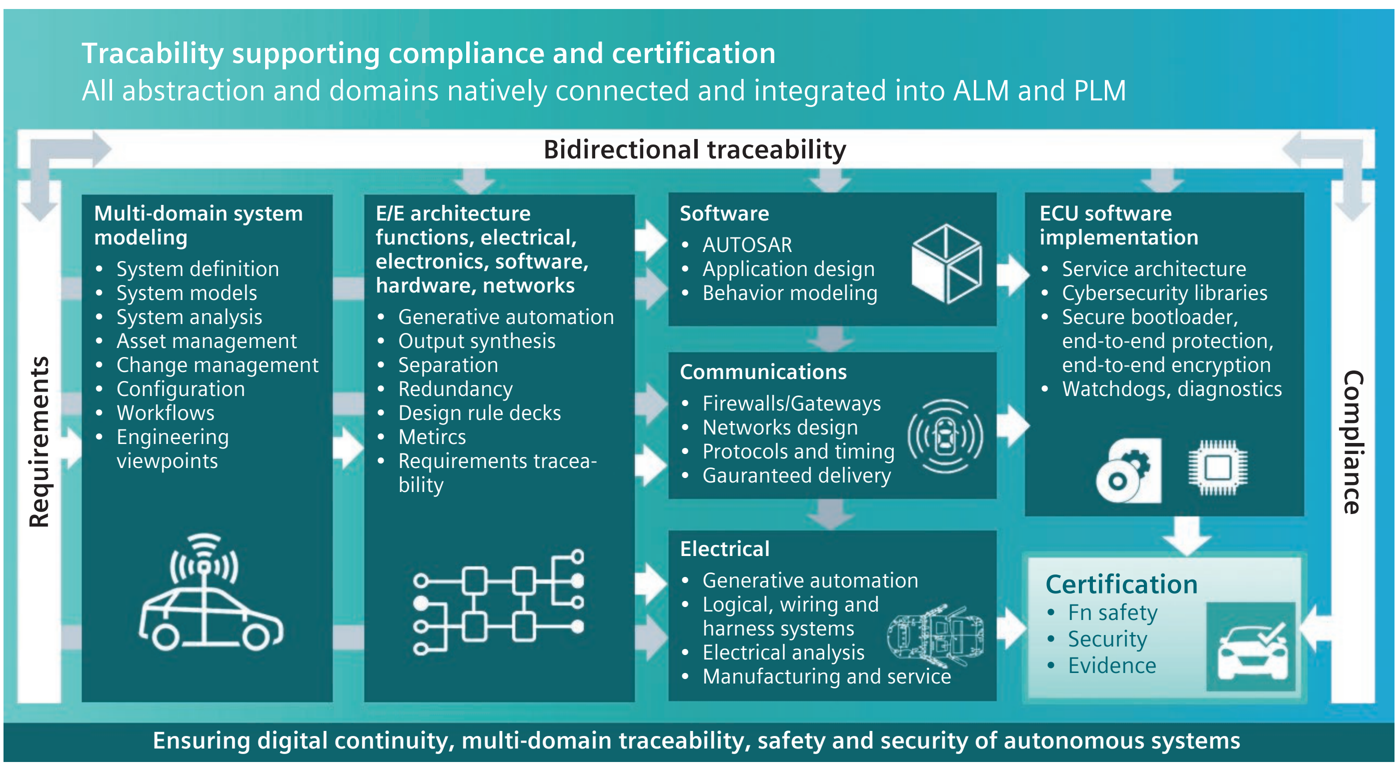

Figure 3. Generative design ensures data continuity from initial system definitions through production and after-sales for full traceability and compliance with requirements.

Additionally, data continuity enhances the engineer's ability to analyze the impact of design changes. Traditional design methodologies struggle to quantify the knock-on effects of design changes. Each change affects the rest of the system, and the second- and third-order effects can be very difficult to predict. Migrating an ECU to a new location or network in the architecture may affect performance elsewhere in the system. This change in behavior may cascade, invalidating any number of subsystems.

Data continuity ensures that projects have a single data source, providing a clear picture of the myriad inter-domain and inter-system interactions. As changes are made to the design, they can be examined with detailed impact analysis that will inform the engineer of issues the change may cause in other domains. For instance, moving or removing an ECU could be assessed for its impact on network timing, signal integrity, or physical clearance and collision issues. As a result, changes are made knowing their full impact on the system.

Electrifying the drive

Generative design will be a key enabler for new and established automotive companies as they develop all-electric vehicle platforms. The ability to generate electrical system architectures automatically enables early exploration and optimization of designs while embedding company IP into the design flow. Additionally, a singular source of data promotes consistency between domains, design re-use, and enhances the analysis of change impact. Finally, tight integrations between the electrical domains and with mechanical and PLM tools streamlines the entire design flow from conception through production.

The significant complexity inherent in electric vehicle design will continue to push the tools and methodologies used by automotive engineers. This is especially true in the electrical and electronic systems domains as they come to dominate the operation of a vehicle's safety-critical systems and amenities. The winners in this disruptive technology will be those companies that can most effectively integrate the advanced technologies required for all-electric powertrains into a package that is reliable, safe and attractive to consumers, and then get those technologies to market quickly and with a high level of quality.

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