Siemens Digital Industries Software

The impact of vehicle electrification on electrical system design

Automotive

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The impact of vehicle electrification

Introduction

Electrical distribution systems (EDS) are designed within a broader multi-domain context. Given the accelerating trends of vehicle electrification and autonomy, carmakers and suppliers are evaluating their EDS processes and tools with renewed scrutiny. And it's not just established industry players demanding more from EDS vendors. At a recent count there are approximately 300 companies developing electric cars and light trucks, with nearly 100 companies having announced autonomous drive programs. Many of these companies are new entrants to the automotive industry and are working to disrupt the status quo.

Autonomy and electrification are demanding significant changes to electrical and electronic architectures within vehicles. This is due in part to the introduction of high voltages, increased safety considerations and significant weight reductions needed to maximise vehicle range from electrification, and 'fail operational' designs, hugely increased data network loading and virtual validation requirements from autonomy. The race to electrified self-driving cars is on.

In this article I'll look at some of the implications of autonomy and electrification, and then have a deeper dive into the technical implications of high voltage electrification on how electrical systems are designed.

Growth in electrical content

Conventional wisdom has it that over the last decade or two, the global auto industry has undergone waves of disruption, each larger than the last. First was the rise of China as a major vehicle market (now the world's largest in terms of both demand and supply), second was the introduction of mainstream hybrid-electric vehicles, last was the rise of autonomy and mobility services.

The images below show why it's autonomy that ultimately looms largest in terms of EDS impact. First, on the left, is a picture of the low-voltage harness of the Chevy Bolt EV, introduced to much acclaim in 2016, in-part because of its nearly-400 km-to-a-charge range. Now consider the second image, at right, which is the autonomous version of the Bolt, not currently a production vehicle. At a glance, autonomy's impact on EDS is obvious. In fact as part of a GM investor presentation in November 2017, the company described the addition of 40 new sensors and a 40 percent increase in new hardware content compared to the non-autonomous version [1].

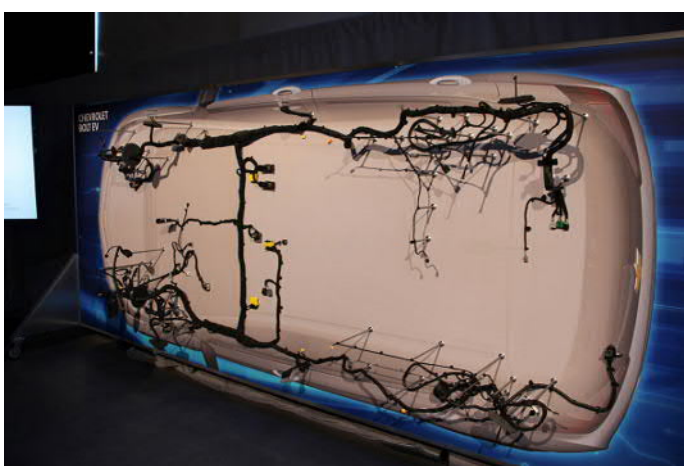

Figure 1. Low-voltage harness for Chevy Bolt EV. Image courtesy Sam-Abuelsamid, http://sam.abuelsamid.com.

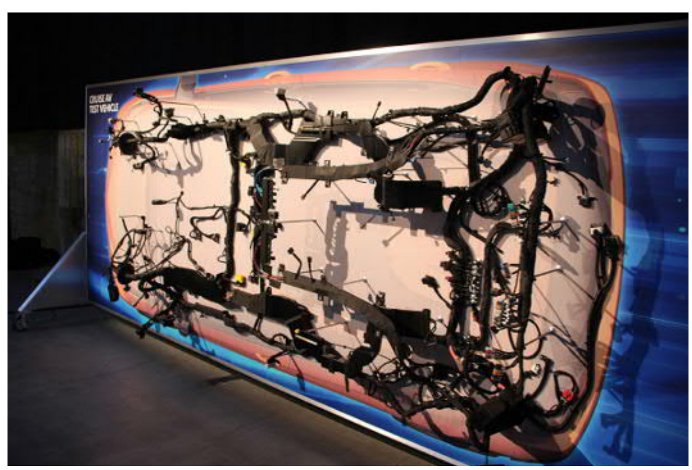

Figure 2: Harness for autonomous Bolt. Image courtesy Sam Abuelsamid, http://sam.abuelsamid.com.

Figure 3: Evidence for electric vehicle momentum, including free charging stations, is apparent in cities around the world.

Still, autonomy, especially full Level 4/5 mostly hands-off driving, remains a number of years away. Despite ample marketing noise and news coverage, most expect autonomy to enter a well-known "trough of disillusionment" as described by Gartner. Indeed of late, self-driving stories have seemed to focus on more modest applications like shuttles operating at relatively low speeds in geo-fenced areas.

This is not the case when it comes to electrification, which if anything is accelerating, thus impacting product development times as well, including the work of EDS design teams. Companies large and small, and all levels of government, from the national- to the village-level, continue to declare their electrification plans. A lot of this rush to market and consequent pressure on product development times is now driven by fear of being left behind rather than by trying to be a first mover. As a result of this activity, design organizations need processes and tools that allow them to respond rapidly to change. Old interactive processes are inadequate to move as quickly as is now needed, which is leading organizations to invest in high levels of design automation and virtual validation.

So what will the some of the specific implications of high-voltage electrification be on EDS designers and what characteristics will they need from their design tools?

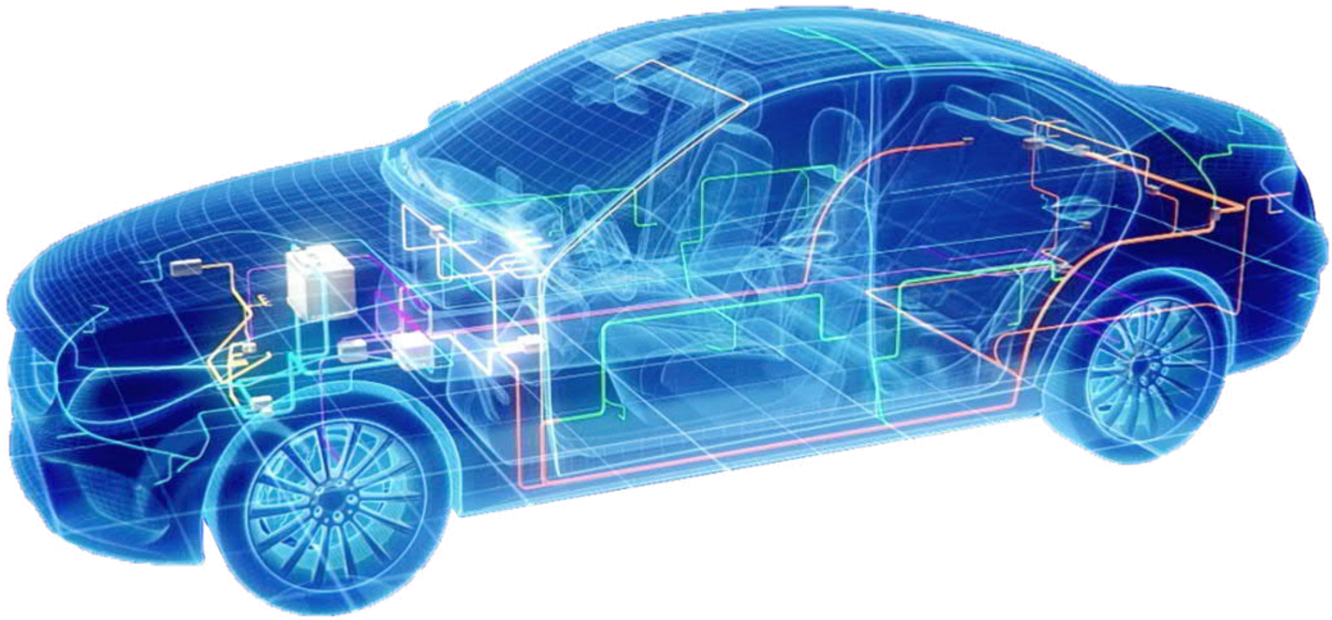

Figure 4: Mounting harness complexity spurs the need for design tools, like Siemens Digital Industries Software's Capital suite, for managing a long list of design rules and checks. Capital automatically generates circuits to optimize length and routing, and to check for circuit completeness.

Multi-domain design and safety

Electric vehicles require a greater focus on true multi-domain system level design. A simple example is regenerative braking. The addition of high power electric motors, power electronics and high-capacity battery storage means that braking systems now have to consider the dynamics of high-power electronics, motor characteristics, battery electrical safety as well as cell chemistry to understand and manage the capturing of braking energy. It is no longer only rejected as heat via the friction brakes, but can also be converted into useful energy again via storage in the battery. The design of this system requires a new level of close integration between mechanical, electrical and thermal domains. It becomes necessary to have true multi-domain data exchange between engineering software tools to inform the system design from an early concept stage. At the most progressive automotive OEMs, thermal, electrical and mechanical designers work increasingly closely together when designing HV electric powertrains, as each of their 'independent' decisions significantly impacts the others. (See the Siemens Digital Industries Software whitepaper "Automotive ECAD-MCAD Co-Design Leads to First-Pass Success.")

A necessary and indeed primary aspect of the electrical system design for high voltages is to ensure there are safety mechanisms to prevent electrocution (driven by good professional engineering practice and also to satisfy section 5 of UN ECE Reg 100). A High Voltage Interlock Loop (HVIL) is introduced to the design of high voltage electric vehicles to provide electrical safety when, for example, high-voltage connectors are removed as part of vehicle fault finding or correction. It is preferable to verify the HVIL protection at the design stage. It is necessary to confirm that no high-voltage connectors and components have been accidently omitted from the HVIL circuit design. In addition, we need to confirm that the circuit offers the required protection when continuity is broken and that circuit sensing happens at the correct points within that circuit to locate faults expediently. This is a key part of the overall vehicle electrical safety and fault detection strategy. Using Siemens Digital Industries Software's Capital tools, it's possible for a company to generate a set of design rules and checks that support the auto-generation of the HVIL circuit to optimise length, routing and so on, and also to check for circuit completeness.

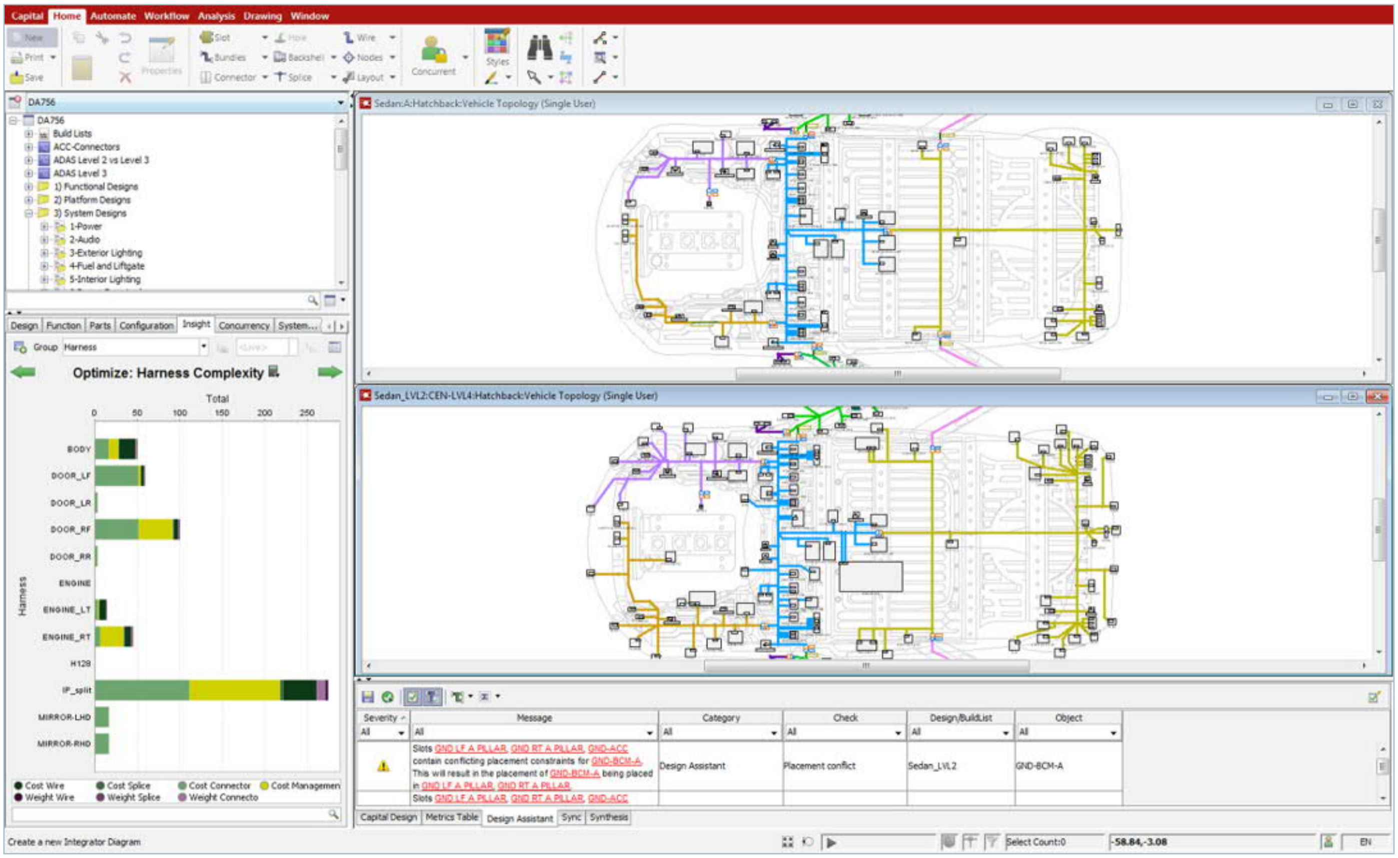

Figure 5: Siemens Digital Industries Software Capital UI for defining electrical systems and network domains.

Other consideration: Heat, weight and vehicle start-up / shutdown

Localized heating of connectors is an issue which would be better supported with tools that are integrated between mechanical, thermal and electrical domains. A related design consideration is ultra-high power DC charging systems (150-350kW+), which require careful thermal analysis of the vehicle-side charger mating connector, and HV cabling to the battery. It's also beneficial to be able to analyse the total thermal losses in the HV system to contribute to range estimations and to ensure suitable thermal clearances for HV cables are maintained.

Ensuring the as-designed HV electrical system is isolated at the design stage saves later re-design and potential physical rework. Embedding design rule checks in electrical system design software enables this checking to be automated leading to a much higher level of confidence in the design at an early stage.

Optimizing packaging and weight requires deep integration between electrical and mechanical design tools. This is a key concern for electric vehicles. For example a like-for-like comparison between a 2017 VW Golf SE gasoline vs e-Golf shows a 32 percent unladen weight increase in the electrified version. And the picture gets even more stark when autonomous packages are added to the mix. A recent paper by researchers at the University of Michigan and Ford suggested that large autonomous systems might actually increase net energy consumption of self-driving electric vehicles, despite the vehicles' ability to optimise the driving profile [2].

With the electrical distribution system as the third heaviest system in a vehicle (after the chassis and powertrain), reducing EDS mass makes a vital contribution to overall vehicle weight targets. Managing the physical size and mass needed to conduct high currents is one of the more significant challenges in designing EV connectors and cables. One example that OEMs are considering is in removing and/or reducing HV cable shielding to optimize weight and packaging. An obvious implication of this is the need to manage electro-magnetic interference via integrations with tools to analyse high and low frequency emissions from sources such as HV cables, the battery management system and power electronics. Coupled with this is the requirement to evaluate and optimise cable and harness routing, meaning design teams need tools that are tightly integrated with 3D CAD (e.g. Capital and NX).

Finally, analysing the optimal startup/shutdown sequencing of the HV system is now an important consideration. An example is supporting the analysis of the HV electrical system capacitance to calculate the correct timing for the system to self-check for welded HV contactors (all electric vehicles run this test on either startup and/or shutdown of the HV system). It is normally a functional safety-driven mitigation action. Also critical is confirming that only the required components in the HV system are woken for the specific vehicle mode (e.g. charging mode vs. driving mode).

Siemens Digital Industries Software's Capital product portfolio, which supports the electrical systems and network domains, is an example of how we can transform design capabilities across organizations. Using a model-based design paradigm, Capital can define system architectures and then, using in-built metrics and design rule checks, compare and contrast multiple potential architectures to ensure the platform design meets the original intent. The tools can then automatically integrate the electrical systems to be incorporated into a representative topological layout of that vehicle. Systems devices are automatically placed and interconnected, and the entire wiring system is automatically generated using rules and constraints embedded by the company into the software. The result is design tasks that took months can now be achieved in hours or days and, critically, the designs can be verified as they are created. Data can be reused across vehicle programs and in the downstream processes of manufacturing and service.

Forward-looking automotive manufacturers and suppliers are adopting these approaches to give them an 'unfair advantage' in this increasingly competitive world. It will enable them to take a lead when dealing with the interwoven technical and business challenges they face on a daily basis.

For more information

- siemens.com/software
- Dan Scott, "Growing up – the automotive electrical distribution system (EDS) maturity landscape," on-demand webinar[3]
- Walden C. Rhines, "Discontinuities in Automotive EE Design," IESF conference keynote (video)[4]

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