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Accelerating electrical systems design and analysis with VeSys

Executive summary

Electrical systems are constantly growing, whether in passenger cars, aircraft or heavy machinery. The growing size and complexity of these systems is driving up development costs and the likelihood of errors, potentially leading to even more cost or damaged brand reputation. New electrical systems and wiring harness engineering solutions implement automation, facilitate collaboration and accelerate verification to reduce design costs, shorten cycles and lower the risk of errors linked to the electrical system. To communicate the common practices in designing complex electrical systems, this whitepaper will walk through the design and review of a wiring harness for a small tractor using VeSys. With the capabilities offered in such a solution, vehicle manufacturers can meet the demands of product complexity and quality while going to market faster than ever.

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Introduction

Electrical networks are always growing, regardless of the industry or application. The increasing size of electrical networks can raise the cost of vehicle development two-fold due to the innate cost of the additional wiring and components and the time and resources required to design an ever more complex system. That complexity can spell even greater problems during revisions and re-designs. As there are more pathways and circuits, the likelihood of induced errors rises.

These errors can be incredibly costly as well. Errors in the electrical systems or wiring harness, or the integration of these systems into the vehicle can lead to incorrect functionality or, worse, danger to the customer. For instance, a failure in electro-mechanical co-design can cause the wiring harness to rub on mechanical components, creating an electrical short that inflates the airbags unexpectedly. In addition to the cost of identifying and recalling affected vehicles, the manufacturer may also be fined for such an error, costing additional money and hurting brand image.

In the attempt to address these issues, new E/E systems and wiring harness tools implement automation, facilitate collaboration and accelerate verification to reduce design costs, design cycles and risk of disaster scenarios linked to the electrical system. To communicate the common practices in designing complex electrical systems, this whitepaper will walk through the design and review of a wiring harness for a small tractor (figure 1).

Just as most electrical design work will be done on pre-existing harnesses, instead of a clean-sheet harness, the tractor wiring harness example in this paper is partially complete. To complete the wiring harness, an ancillary lighting circuit will need to be added to the tractor design and the added functionality will need to be verified.

Figure 1: A small tractor requires updates to its electrical system and wiring harness designs.

Adding functionality

Most often when designing an electrical system, whether for automotive, aerospace or heavy-industry, the engineers begin with pre-existing designs from previous vehicles. The design is more than likely being revised to meet a previously unmet condition or to add a new feature to the product. For the tractor, a brake light circuit needs to be added to the main lighting harness.

Before beginning modifications to the existing design data, the engineer can modify the look and feel of the wiring diagram to make it easier to read by changing colors, notations and filtering the display to show only relevant information. The 'style sets' feature in VeSys allows the engineer to make these changes without affecting any of the underlying design data. In this case, the engineer uses the style sets dialog box to change the display color of the devices to black, the connectors to purple, and to disable the names of individual wires to remove visual clutter. The tool can then apply these changes across the design all in one action.

The circuitry of the new brake light system is similar enough to the other lighting circuits that they can be reused. Copying the existing circuit components also captures the previous library part assignments and saves some design time (figure 2). It should be noted, copying a component and its library assignments also copies the physical values like resistance and wire gauge. In this example, the values are the same and are left as-is. Next, the engineer must add in a new switch to make this new circuit independent of the main light selector. The engineer can quickly drag and drop a switch from the symbols library, and then connect the new circuit by drawing wires in the diagram. The circuit is now complete, but the component names could be more meaningful.

The engineer can quickly assign descriptive names and library parts to the new components, allowing much of the remaining definition phase to be sped up with automation. For example, the tool can automatically create the appropriate connectors based on library part

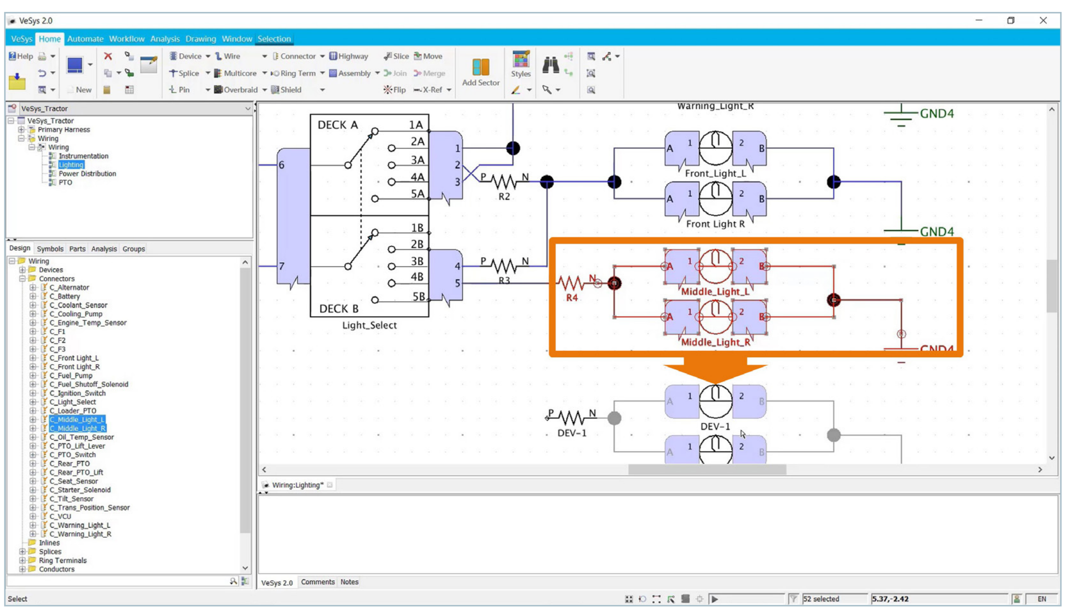

Figure 2: The engineer can reuse existing circuity to start designing the new brake light circuit. Copying circuitry also captures library part assignments from the copied components.

associations for the switch. The tool also designates the correct library part numbers for these connectors automatically to reduce human error and streamline design. The engineer then renames the connectors and the copied light circuitry so that the wiring paths are easier to understand further into the development cycle.

Before handing the design off to be reviewed, the intended functionality of the new circuit should be documented. For the tractor harness this is accomplished in a note (figure 3). Each of the light selector positions are labeled with their intended result. To eliminate any possible misunderstandings, the engineer can associate the note to the light selector switch and the other relevant objects in the design. For this design, the engineer associates the note to the light selector, each of the lights it controls, and the lighting diagram that contains the circuitry.

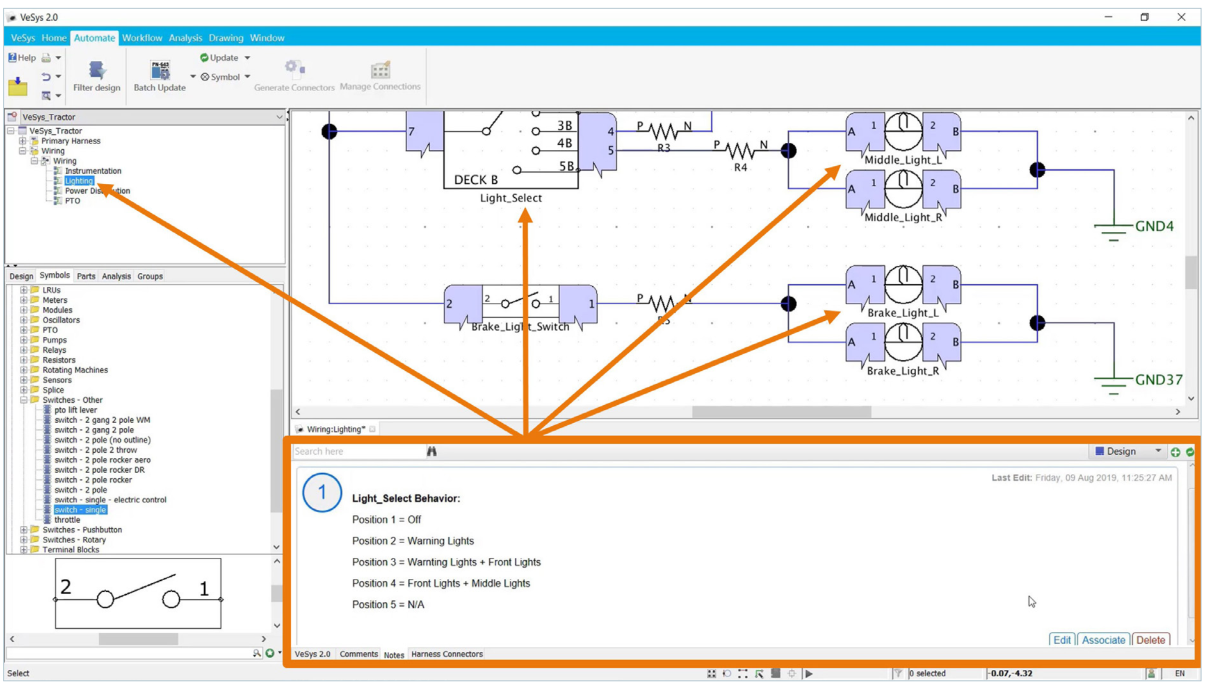

Figure 3: The engineer creates a note describing the inteneded functionality of the light selector switch.

Qualitative design review

With a completed wiring design, the next step is to test whether the circuits meet the original design intent. This first level of analysis is best completed through qualitative review. Conducting a qualitative review of the circuit does not take into account any of the physical properties or restrictions of the circuit. The physical attributes of the circuit will be verified in the next phase during more detailed design review. Instead, this review is meant to verify the logic of the circuits is accurate and all the proper connections have been made within the design.

For the tractor lighting example, both the light selector circuit and the brake light circuit must be verified before the design is passed on to the next step. The engineer performing verification can easily reference the intended behavior of the circuit using the associated parts list defined by the design engineer in the previous step. This ensures that the behavior being verified is connected to the correct circuit logic.

Qualitative review demonstrates basic circuit behavior by highlighting components in various colors to indicate various states. Beginning analysis, the diagram will update to show the flow of current through the relevant circuit and wiring designs. This method of qualitative review, with different colors indicating various states for components in the diagram, allows engineers to quickly verify basic circuit functionality. Qualitative review can also indicate design issues during early circuit design. It is critical to catch these errors as early as possible, where they are the easiest to detect and the cheapest to correct.

For example, during review of the tractor brake light circuit, the engineer cycles through the positions of the light selector switch to verify its behavior against the note left by the designer. In each position the components change from cyan to green to indicate current flow in the design (figure 4). Comparing to the intended circuit behavior, the engineer discovers incorrect behavior in the light selector switch such that it is directing power to incorrect lights in two positions. Investigating further, the engineer finds that a pair of wires need to be swapped, and leaves a note for the designer to make this change.

Qualitative review provides rapid analysis of circuit behavior at the right level of detail for early verification. Component properties, current values and other physical characteristics are important for verification, but can be encumbering during early design reviews. Qualitative review provides intuitive real-time feedback on the basic connectivity and behavior of circuit designs. Engineers can use this real-time feedback to quickly discern and correct issues.

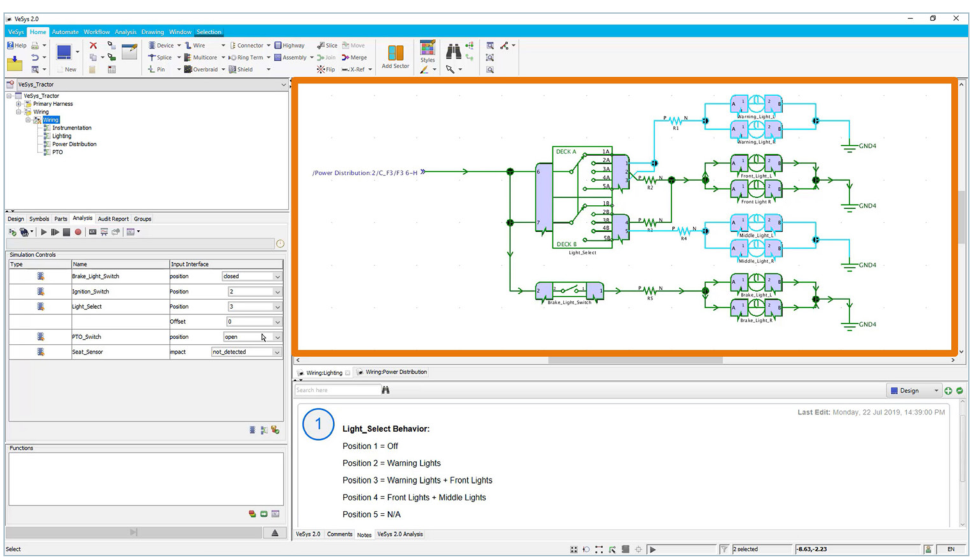

Figure 4: Qualitative review provides real-time feedback on basic circuit logic and connectivity, enabling early verification of circuit behavior.

Design revisions and circuit analysis

After accepting and making any necessary wiring changes to the harness issued from the qualitative review, the next stage of development is analyzing the circuits with physical restraints. The process of analyzing the circuits physically is accomplished through numeric analysis, which takes into account cross-sectional area of wires being simulated along with any other physical values like resistance and capacitance. Once numeric analysis is turned on, the engineer can quickly view additional detail about each component in the diagram.

Hovering over a component will reveal relevant properties (figure 5). For a wire these include rated and maximum current, the current applied to the wire, voltage, resistance, cross-sectional area, length, and temperature. The information displayed depends on the analysis model associated to the component. For instance, the displayed properties of a light will include a 'lit' condition, displaying whether or not the light has been turned on. While qualitative analysis can only indicate if the light is receiving power, numeric analysis can determine if the light is receiving enough power to function properly.

Numeric analysis enables the system to understand what is physically happening in the wires and electrical components. If a component fails due to high current or if the harness shorts, errors will display in the log pointing to the components in question. Components don't need to fail to throw errors either. The system can also identify configurations that exceed recommended operating conditions.

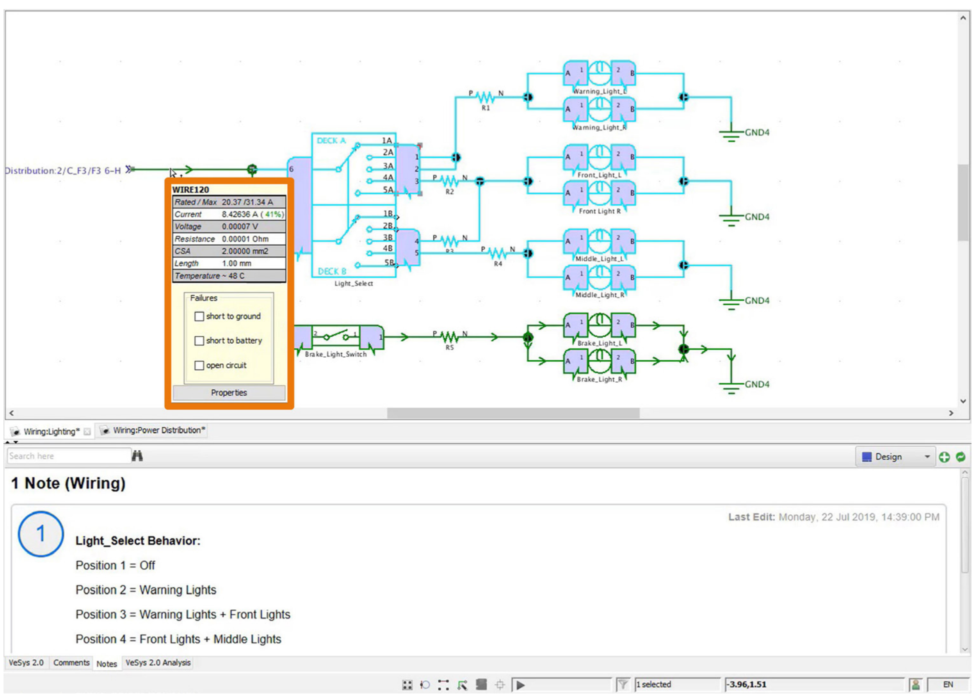

Figure 5: Numeric analysis considers physical properties of components. These details can be viewed by hovering over any component in the design.

Using numeric analysis, then engineer can identify more specific problems with the tractor brake light circuit. For instance, when powering multiple light groups, the resulting current causes a fuse to blow in the power distribution diagram. Returning to the power distribution diagram, the fuse in question has changed yellow, indicating it has failed (figure 6). The engineer hovers over the fuse to gain more information such as the fuse rating, the current at which it blew, and even a suggested rating for the fuse. In this case, the engineer replaces the 10 amp fuse with one rated at 30 amps. When replacing the component, VeSys can automatically refine the available parts from the library to display only two-sided fuses that fit in the pre-defined connector, making the replacement simple.

Numeric analysis provides another level of detail for design review and verification. By considering physical properties of components and the circuit design, engineers can begin testing the circuit in simulated operational conditions to uncover problems such as overcurrent, overheating, insufficient power and more. As with qualitative review, numeric analysis helps engineers to identify these problems while they are still relatively easy and inexpensive to resolve.

The circuit diagram for the tractor brake light has now been updated and analyzed to confirm its functionality. The next step is to pass this diagram to the wiring harness engineers.

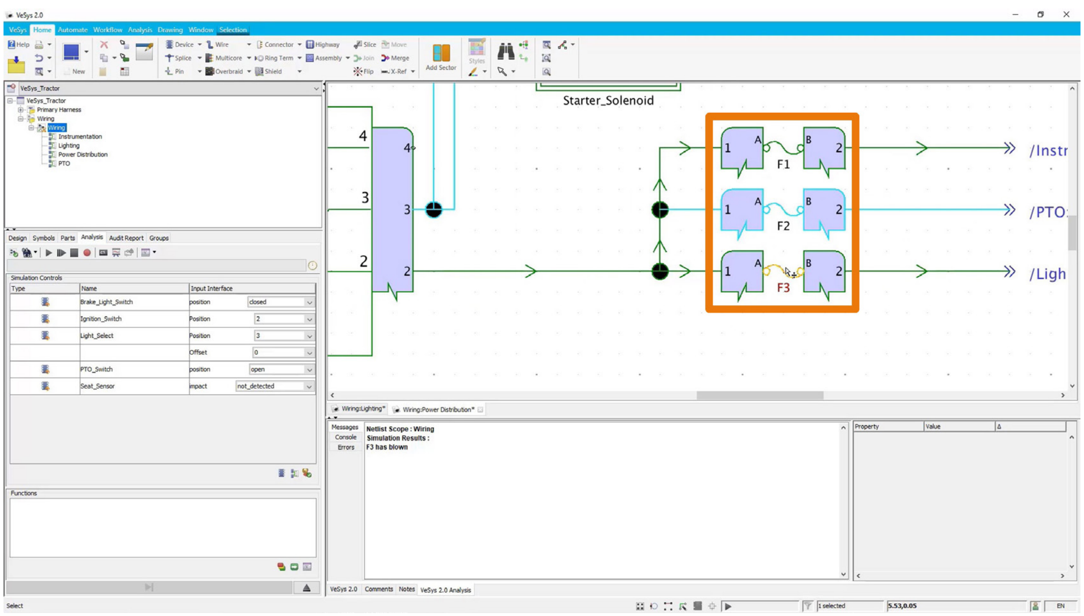

Figure 6: A fuse has turned yellow to indicate that it has blown.

Design synchronization and diagram exporting

Traditionally, transferring design information between teams or engineering domains was an inconvenient or even arduous task. Handoffs between various teams required exporting large files of design data, changes and more which had to be imported and reorganized by downstream or cross-domain teams to fit their needs. Now, modern E/E and wiring harness engineering solutions, such as VeSys, can synchronize design data between abstraction levels and even engineering domains directly, automating much of the process. Such synchronization eliminates significant manual work, both accelerating design cycles and eliminating errors from manual data re-entry.

In the tractor example, the engineer can now synchronize the updated circuit designs with the wiring harness. After synchronization, the wiring harness diagram will automatically update with the added components including connectors, switches and even necessary splices (figure 7). Next, the engineer must simply move these components to the correct location in the harness diagram.

With the new components placed, the engineer can manipulate the topology of the harness as needed. The harness topology in VeSys can be changed easily by using the grab handles on each component to move them around. In this example, the engineer adds a bend to the left and right brake light bundles, and moves them further away from the main harness. Reapplying the diagram styling will automatically re-orient the connectors.

These harness diagrams also contain multiple tables that automatically update as changes are made and synchronized in the design. These include a from-to connectivity table, a table showing all the connectors in the design, and wiring tables for each connector. All of these tables are configurable to display a wide range of information,

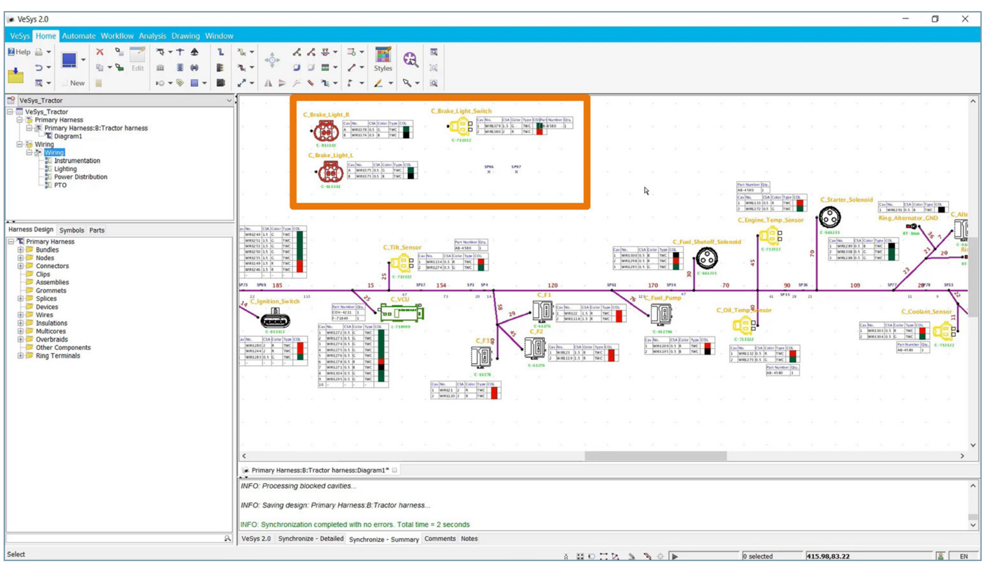

Figure 7: After synchronization, the wiring harness design automatically updates with added components.

such as part numbers for wires and terminals. After configuring a table, the engineer can apply this styling across the whole diagram to update all tables that were changed.

Now that synchronization of the wiring and harness designs is complete, the engineer can select the appropriate wire and cavity component part numbers for the harness design and generate wire lengths. Automation capabilities within modern solutions make part selection fast and easy by pulling the appropriate part numbers for each wire in the design from the library definition. The cavity component part numbers can also be defined automatically, or on a case by case basis by the engineer. Lastly, wire lengths can be generated automatically for reporting purposes.

Finally, the engineer can generate reporting and documentation directly from the harness design data. First, the engineer can generate a preconfigured bill-of-materials report that pulls information from the design into an organized and easy-to-read report (figure 8). Alternatively, the engineer can build custom reports as needed directly within E/E systems engineering solution. In this example, the engineer creates a simple from-to connectivity report for the wires, including wire names and part numbers. Custom report formats can be saved and reused in future designs. The generated wiring harness reports and documentation can be used to help guide harness manufacturing, or as reference for future designs. As with synchronization, the potential for human-induced errors is eliminated by pulling data directly from the wiring harness design.

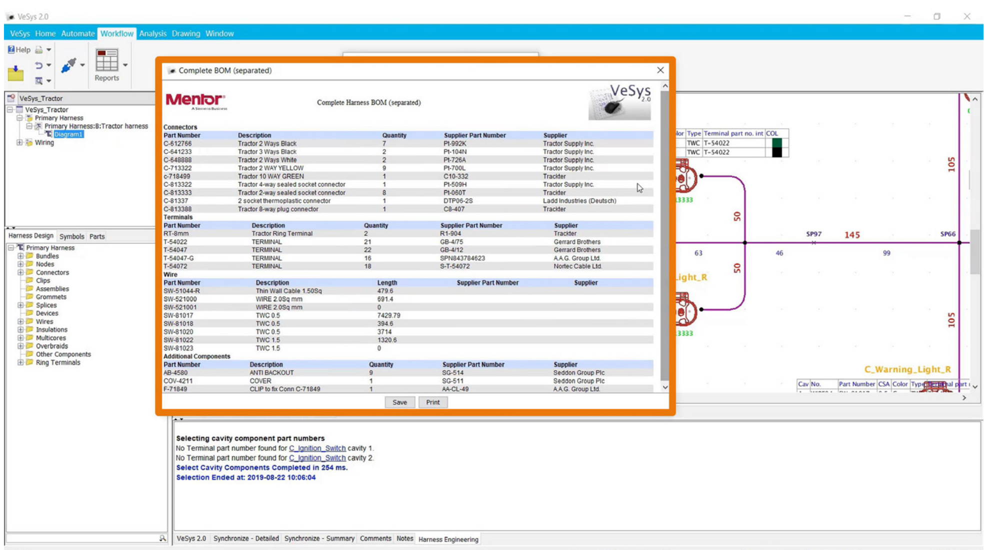

Figure 8: Custom and pre-configured reports, such as this BoM, can be generated within the design environment using design data directly.

Conclusion

The complexity of today's electrical systems is higher than ever before. The ability to work with these systems with accuracy and efficiency is key to producing high quality products on constantly shrinking design cycles. Traditional methods that rely on manual engineering work and data sharing will not suffice for today's complex products, much less the advanced vehicles of tomorrow. Companies will need to adopt new solutions to meet these challenges.

VeSys provides design and analysis functionality that helps engineers deliver rapid, 'right-first-time' error free electrical and harness designs. Through automation, analysis and a plethora of time saving features, the tool allows teams to focus their energy where it counts: innovation. Furthermore, a robust digital thread ensures that designs are traceable throughout the development flow, from requirements and definitions to the manufacturing of the wiring harness. With such capabilities, vehicle manufacturers can meet the demands of product complexity and quality while going to market faster than ever.

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