Benefits of Railroad Signal Software Simulation

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Abstract
Simulation of wayside signal software has been utilized since the 1990s. The ability to exercise vital signal programs through simulation has made signal installations safer, more efficient, and enhances understanding of design attributes. Simulation of signal software facilitates a comprehensive battery of tests in a controlled environment to discover program anomalies or operational inefficiencies resulting in less impact to operations. Simulators can provide a graphical representation of multiple programs allowing users to verify the desired operational behaviors and determine optimal results are achieved. The artifacts produced by simulation can be archived and directly associated with other project deliverables for future technical reference or troubleshooting. Simulation tools assist in removing the perceived mysteries of our microprocessor control systems expanding institutional knowledge. In this paper / presentation we will provide a current perspective on modern signal system simulation and provide examples of how it has improved the way we carry out signal design and testing at CSX.

Introduction
The implementation of microprocessor based railroad signal control systems has become more pervasive due to the requirements of Positive Train Control (PTC). CSX will have up to six times as many signal software programs when we have completed our wayside PTC installations as we do now. CSX has used simulation tools since 1996 to facilitate the initial installation of microprocessor based locations and to assist in managing the portfolio of programs over the life of the equipment.

The rail signal organizations will be tasked with managing an unprecedented quantity of wayside software because of PTC. The utility of hardware plans will substantially diminish when software is used in lieu of relays. Our challenge is to make certain we are equipped to provide the needed support so our people can quickly understand how the new systems function. Essentially we have to take the mystery out of what some perceive to be a “black box”.

Microprocessor based systems will be new to the preponderance of signal personnel tasked with maintaining the large volume of locations we are installing, both for PTC and for capacity projects. Understanding signal behavior, troubleshooting problems, and modifying the microprocessor based systems and the associated software programs will challenge the rail industry to quickly develop processes and tools necessary to meet
safety and operational requirements of the railroad. Simulation tools provide a long term solution to address many of these needs.

Capabilities of Simulation Tools

A well designed simulation tool can provide many benefits over the current manual approach to wayside program analysis. A simulation tool that is capable of graphically representing the locations (Figure 1) and archiving the results of testing is best for gaining the most benefit from simulating vital signal software. The most obvious use for a simulator is prior to the initial installation of a location or project, but the benefit will extend over the life of the installation if planned for early in the process.

Figure 1: Typical graphical representation containing multiple locations

A simulation tool is able to accurately depict the logic equations to the end user in a structure and format that can easily be understood. Ladder logic, Boolean statements, and relay logic are the more common representations with a simulator often allowing the user to switch between these representations. Individual variables and logic equations are shown with the appropriate logic states and actions. A simulator is able to logically represent multiple units within the same location and to link several locations together over a wide area, giving a full project view. Most importantly, a simulation tool must accurately simulate the logic to ensure valid results.

Figure 2: Typical Track Code Output Circuit
An additional benefit of a simulation tool is the ability to automate tedious user tasks. The capability to automate routine tests reduces user errors that can arise from the loss of situational awareness while performing mundane tasks. If the behaviors verified reside exclusively in the program logic, they can be fully tested via simulation. Some ideal candidates for this type of automation are color lamp downgrades along with many of the route based testing. However, a user must still thoroughly understand the relationship of program logic to all of the external I/O associated with the system in order to achieve the full benefits of simulation testing.

A simulator test routine (manual or automated) can incorporate certain executive and application rules that identify undesired or illegal conditions. Some of the items that may be detected are simultaneous vital codes, improper or imperfect signal aspects, and signal route conflicts. The simulator must make an anomaly clear to the user allowing proper and quick mitigation. Quality Assurance functionality is easily accomplished using a graphical interface to view the logic network structure. In addition variable assignments can easily be discerned in a simulated environment. A simulation tool can be used to enforce nomenclature standards and to detect programming errors or variation among different signal engineers.

**Limitations of Simulation Tools**

It is essential before incorporating simulation tools into a test process to have a thorough understanding of the capabilities and limitations of a simulator. This can be done by instituting a level of redundancy in certain portions of the test process until all questions regarding the accuracy of the simulation results have been satisfied. Documentation of results done in conjunction with a simulator is essential to remove any ambiguity associated with individual aberrations.

Use of a simulation tool is optimized when operated by a skilled and knowledgeable user. Improper design or programming may not be identified through simulation alone. A simulator is generally capable of exercising the internal logic and illustrating the states of outputs. Thorough testing will require manually changing states of inputs that are external to the program logic and observing the output states to fully satisfy a test plan.

Even if a program satisfies all simulation testing there is a risk that problems can still occur in the field. Inputs or outputs in the field could be wired improperly, resulting in undesired results or critical failures. Such behaviors can only be discovered in the actual field devices.

As an example, a simulator will not accurately reflect all executive functionality. This means that PCB reset commands and communication link statuses are among some of the actions handled by the physical vital unit only. A complete understanding of behaviors residing in the vital unit is a key to incorporating simulation tools into your test plan. Simulation of vital software can never exonerate a test person from using the proper amount of due diligence to perform appropriate field testing with the production equipment.
Incorporating Simulation into the Test Process

A simulator should only be part of a carefully considered all-inclusive test plan. A simulation tool in the hands of an experienced user will lead to a more efficient use of resources and will reduce risk in the operating environment. It is important to comprehensively understand the capabilities and limitations of simulation in order to achieve optimal results. There are a multitude of reasons to utilize simulation testing, with safety being at the top of the list.

One of the main benefits of simulation testing is limiting test time in the operating environment, which minimizes personal and operational safety risks. All simulation testing can be done in a controlled atmosphere. A simulator will be able to perform the preponderance of test procedures that reside exclusively within the vital logic application without the need for additional equipment beyond a computer. Some testing can be performed more efficiently with a simulator than what can be done in the field. Cab control circuits and parallel route operations are a couple of examples where simulation testing is more effective. When doing simulator testing it is important that the test requirements be defined in advance with all results documented for future reference during a final cutover.

In order to achieve the most benefits from a simulation tool it is important to create a menu of tests that may be partially completed or fully accomplished within the simulation process. Route integrity testing, signal aspects, signal downgrades, cab initiation, and FRA Locking tests are examples of what might be done with a simulator. Simulation also provides an opportunity to examine the program structure, logic syntax, and requirements to design standards. Local Panel interfaces and dispatch system operation may be exercised.

A thorough test process should contain specific requirements for entering and exiting each phase of the test process. In addition all results must be documented, including errors discovered while testing. This information is useful to determine that your simulation methodology is effective in achieving the needed results.

Incorporating Simulation Tools into the Management Process

PTC will change the architecture and requirements of the nation’s rail signal systems for a long time to come. The large scale and accelerated pace of PTC necessitates substantial modifications to our present processes and how we support our signal infrastructures. We must think beyond just implementation and make certain we are equipped to manage our systems over the product life cycle. At the conclusion of PTC CSX will have about six times as many wayside software programs installed as we did prior to PTC.

Much of our wayside equipment that was replaced for PTC was legacy analog (relay-based) systems, many of them over 50 years old. Employees were able to look at a set of circuit plans and diagnose a problem by observing relays in most cases. We were endowed with sufficient subject matter experts indicative of a mature system.
Transitioning to PTC, along with large quantities of new wayside systems, requires rethinking how these systems are managed. Our biggest challenge will be to educate our organization on the requirements of microprocessor systems. A signal simulator assists in educating new engineers and allows them to become productive rapidly even before fully mastering signal engineering.

Hardware plans will be of minimum use and manually analyzing individual logic statements on paper will not be conducive to managing large systems. Incorporating simulation tools into test and maintenance processes will build the internal expertise needed over the life of a signal network. Simulation incorporated into the initial installation process provides the substantial benefits described earlier, but the ultimate benefit is the ability to manage a portfolio of vital software over the entire life of a signal network. A simulation tool produces files that can be retained and associated with individual locations or larger geographic areas. Incorporating the simulation files into a configuration management system will ensure easy access for managing an entire signal network. In addition errors may occur during normal operations that quickly need to identified and resolved. A simulation tool can simplify and speed up the process of tracking down the error, resulting in reduced downtime.

**Conclusion**

Signal systems have served the rail industry for over a century, delivering a safe and efficient product. PTC has accelerated the transition to microprocessor based systems. This necessitates a comprehensive analysis of what is needed to successfully manage a more integrated network and to build the institutional knowledge required to achieve desired performance. Traditional hardware plans or manually interpreting software behavior will not work on the scale we are encountering. A robust simulation tool, coupled with the appropriate execution strategy, will put us on the right path to successfully face the challenge ahead. Are we prepared to meet the challenge?
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Introduction

- PTC speeding transition away from relay-based systems
- Need to manage significant portfolio of software programs
- Need tools to:
  - Understand signal system behaviors
  - Troubleshoot problems and adherence to requirements
  - Help modify software programs

CSX Experience with Simulation Tools

- CSX began using simulation tools in 1996
- We mirror best practices of IT and software firms by creating a development environment to troubleshoot and verify program behaviors
- Incorporating software simulation has allowed us to instill defined processes where a less experienced employee can be utilized to perform testing
- Simulators have allowed us to manage a portfolio of programs over product life
- 80% of our software discrepancies are discovered during simulation

Capabilities of Simulation Tools

- Location Graphical Representation
  - Signal Aspect
  - PTC Code
  - Directional Stick
  - Track Codes

- Project View
  - Simulate entire project
  - Exercise use case scenarios for multiple locations
  - Simulate location communication
  - Transmission of track codes

Capabilities of Simulation Tools

- Logic Equation Display
Capabilities of Simulation Tools

Automation

- Automate tedious tasks
- Reduce user errors
- Automate simulation tests
  - Lamp downgrades
  - Route-based testing
  - Cab control circuits
  - Parallel routes
- User is still accountable for checking results

Quality Assurance

- Detect illegal conditions
  - Simultaneous multiple vital codes
  - Improper aspects
  - Signal route conflicts
- Enforce nomenclature
- Detect design and programming errors

Limitations of Simulation Tools

- Improper design may not be found through simulation alone
- Skilled and knowledgeable user needed for thorough testing
- Does not test potential field issues
  - Wiring
  - Executive functionality
  - Reset commands
  - Communication link statuses
- Field testing is still required

Incorporating Simulation Tools into the Test Process

- Must be only part of an all-inclusive test plan
- Can make testing more efficient and limit operating environment risk
  - Simulation testing is done in a controlled environment
  - Limit test time required in the field
  - Minimize personal and operational safety risks
  - Test of the vital logic needs no equipment beyond a PC
  - Program structure, logic syntax and satisfaction of design standards can be examined easily
  - Test traceability needs to be documented and saved
    - Able to review what was done and by whom

- Some tests can be completed partially or wholly in a simulator
  - Route integrity testing
  - Signal aspects & downgrades
  - FRA locking tests
- Local panel interfaces and dispatch system operation can be exercised

Incorporating Simulation Tools into Management Process

- PTC necessitates process and support changes
- Need to manage systems over entire life cycle
- Need to be able to manage all installed software
- No longer able to just look at circuit plans or observe relays to troubleshoot
- Need a way to educate new engineers on microprocessor systems
- Simulation tool creates files that can be saved and retained for each location
  - Speeds up troubleshooting time
Example

Incorrect lamp equation
Corrected lamp equation

Incorrect PTC equation
Corrected PTC equation

Example

Conclusion

• PTC has accelerated transition to microprocessor based systems
• Traditional hardware plans or manually interpreting software behavior will not work on the scale we are encountering
• A robust simulation tool, coupled with the appropriate execution strategy, will put us on the right path to successfully face the challenge ahead