Electrical/Electronic Components

Movable Bridge Control Systems: Simulation, Testing, Verification and Methods

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Introduction:

For years Engineers and Designers have struggled to find ways of proving out, testing and verifying their designs before they get built. They would start with simple circuits and build them into the final controls and operating systems. When these circuits (electrical and hydraulic) are connected together it is sometimes difficult to test and determine all the possible iterations, permutations, and possible failure modes. Validation of the design can sometimes overlook simple errors, backfeeds or "Gremlins". Remember Murphy?

Better Hammers Are Here:

Just like the carpenters digital stud finder, we now have better tools to help us design, validate and test with.

Bridge control systems are getting more complex and the need to build it to print, make it work the first time, and thoroughly test it before the it gets built is imperative.

We started our search over two years ago to find a tool that could be used to design, relay logic, PLC logic, Hydraulic logic, and control systems in there entirety. This tool had to be able to originate designs, import previous designs, and output tested, validated, and fully simulated designs into our CAD programs.

After reviewing several programs such as Electrical Designer Pro, EDSA, and The Constructor Pro, it was clear that Automation Studio was the tool of choice. In short, we can design electrical schematics, test, validate and simulate the entire bridge electrical, hydraulic, PLC, and relay control systems. Then in real-time or step time validate and fully understand every interaction and control node. An I/O box can be hooked up to the simulator computer to drive a bridge simulator system and control desk. To make it fully realistic the circuit components and their latencies are taken into account. For example, we know that control relay and solenoid operated directional valves take time to energize and de-energize. We also know that certain components have losses and inherent deficiencies, ie: pressure losses across valves, circuit reaction times to latch in relay logic functions, and so on. The dynamic values of most components can be set with this program in addition to setting the dynamic profile of the components.

A good example of this is the time it takes to latch in (or seal in) a switch function. The average control relay takes 10-50ms to fully actuate and pickup or drop out. Industrial relays, contactors and starters take longer (20-100ms). Then you have the delay times of other relays and components in the circuit. By the time you press the button and the circuit latched in can be 100 to 500ms. So, the operator hits the button, nothing happens, so he holds it till it latches. This is very typical.

Time Savers:

Once the basic electrical, PLC, and hydraulic circuits are modularized it becomes relativity easy to connect the "modules" together to make up the entire Bridge Control System.
We took some standard, proven and tested circuits and save them as "span locks", "traffic signals", "NA Drive", "recirc pump", and so on. When the circuit diagrams are loaded, a few inter-connections makes them work as a full system similar to the power of your CAD system.

Backfeeds and Gremlins:

A recent relay and PLC control system got confused when it was switch to PLC mode. It was difficult to determine that the PLC outputs that were driving the span locks "Pull" solenoid were also backfeeding the manual relay logic causing it to latch the control relay and forcing the "Pull" switch and indicator on. The simulation saved several hours in manual debugging the logic. The problem was quickly realized by observing the colored wires and relay contacts during the simulation in "Step Mode".
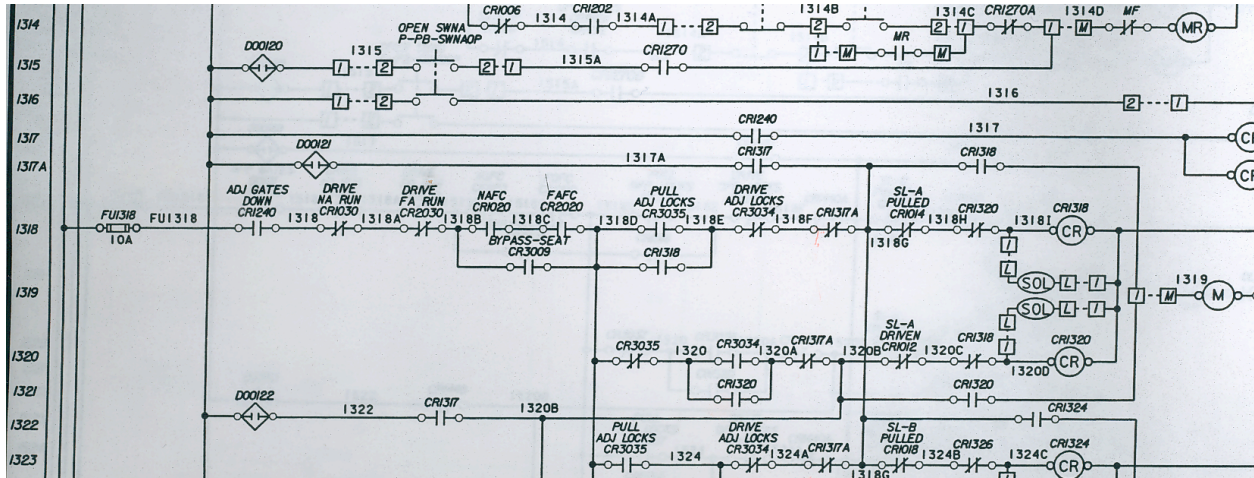

Figure 1 – After Isolation Relays and Simulation

Building the Models and Simulation:

Automation Studio allows the designer to build the electrical and hydraulic schematics using simple drawing drag & drop tools and then debug and run the simulations:
Figure 2 below shows the main simulation screen that contains the Control Desk, Span Locks, Traffic and Sidewalk Gates, Electrical and Hydraulic Control Panels, and the Hydraulic Power Unit. All the logic and components are simulated and connected together via drawing modules.
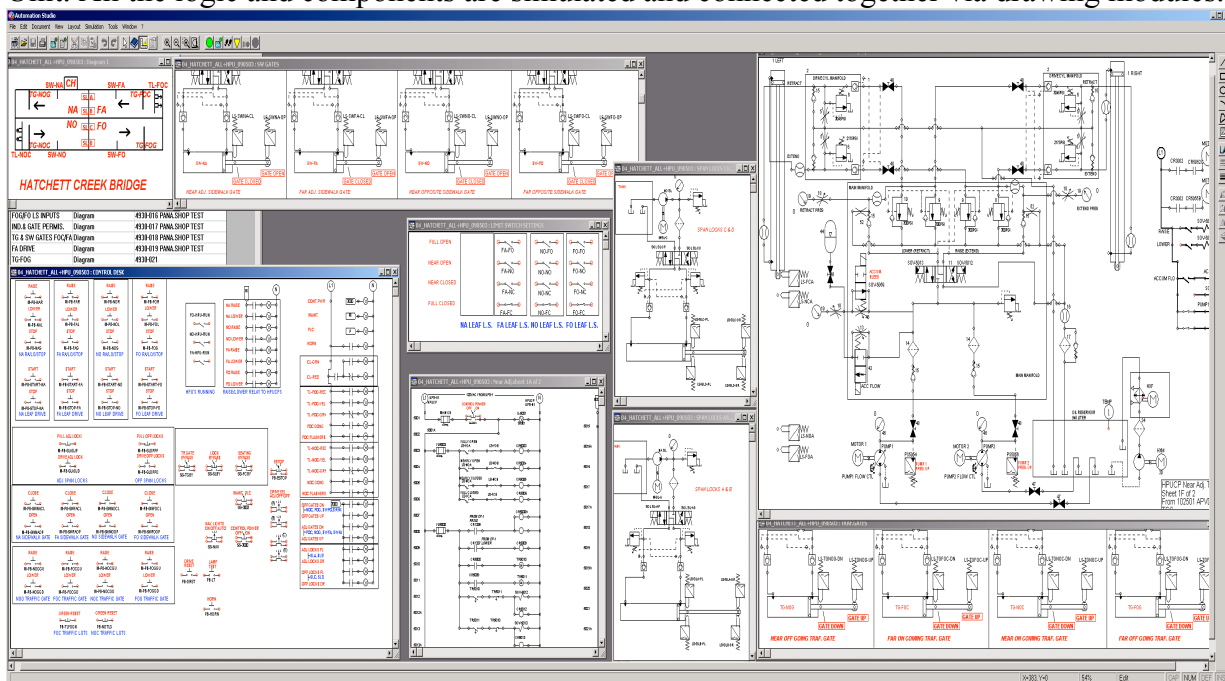

Figure 2 – The Main Simulation Screen

For example, the Span Lock module contains the electrical schematics, the Traffic Signals module and so on.
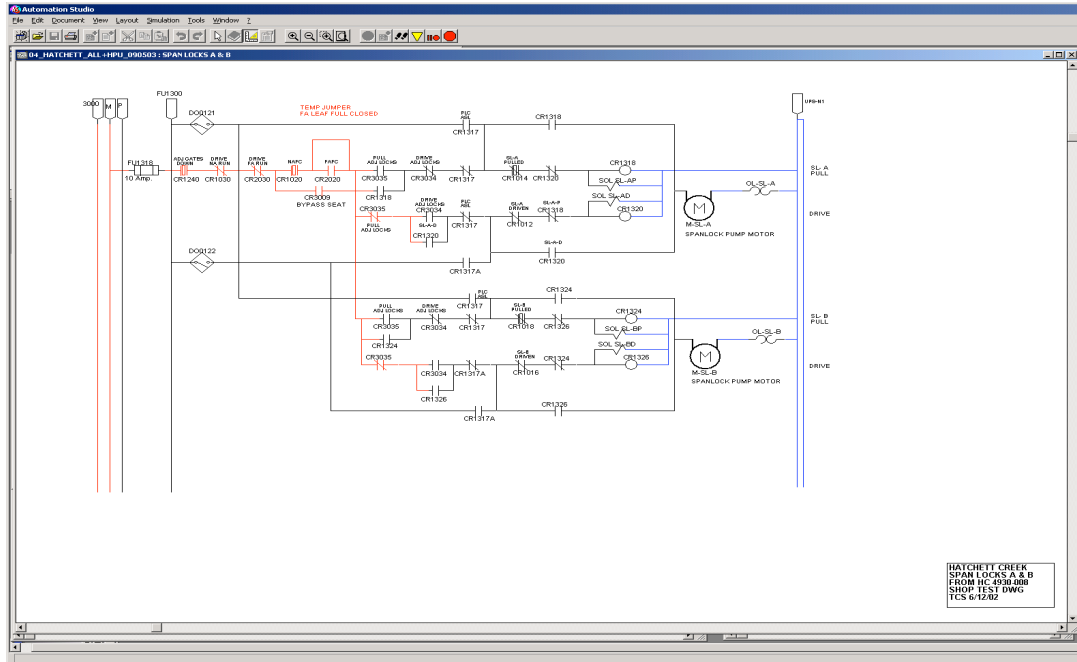

Figure 3 – Span Lock Circuit during Simulation

The next Figure shows the entire system running the simulation. This shows the Traffic Signals Red, Gates down, Span Locks Pulled, and ready to start the hydraulic drives.
Notice the red lines on the schematics show devices that are active and energized.
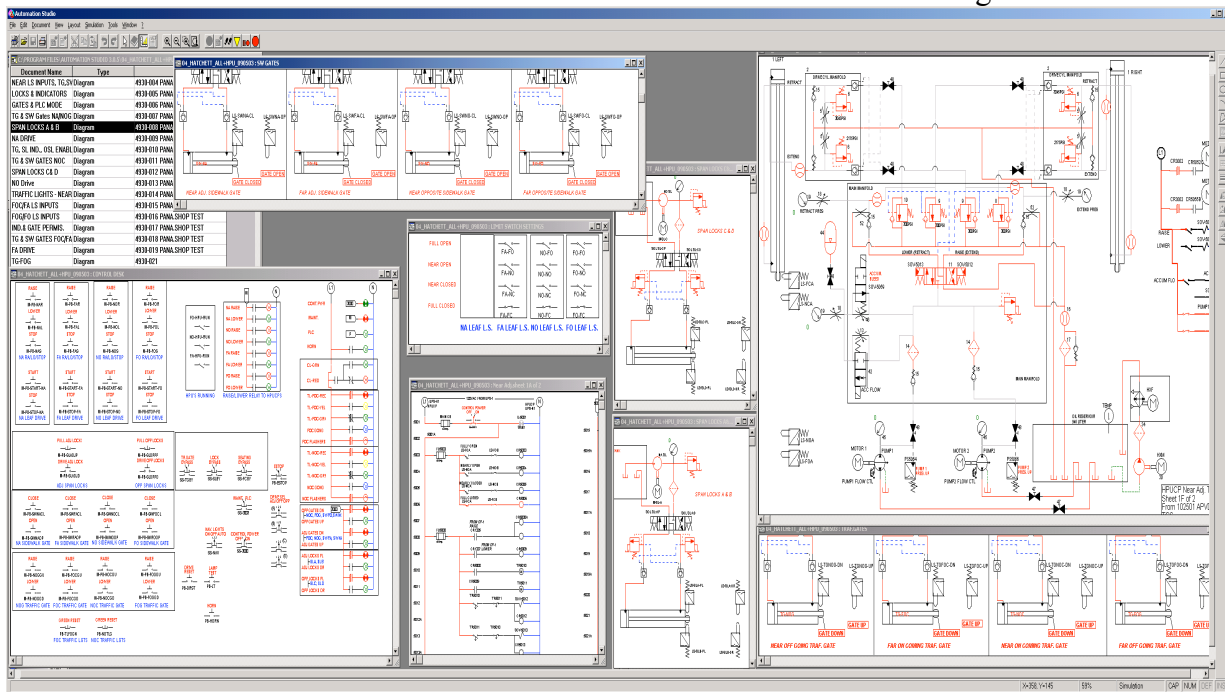

Figure 4 – Traffic Signals Red, Gates Down, Span Locks Pulled

Applying Testing Methods and Techniques Used in Product Industries:

A lot of product industry engineering and manufacturing experience has taught me to TEST, TEST, TEST it as a COMPLETE system. To many times we have tested the HPUCP (for example) at one shop test (at on facility) and the control desk and control panel(s) at another time and shop. Then the only time they come together is at the Bridge site.

This strategy almost never worked at product related manufacturers. Chrysler and Cadillac Motors (for example) tried to build and test the early Engine Control Modules (ECM) at their module manufacture without wiring them into the "complete system". They failed EMC testing, were unpredictable and non-repeatable. Engines would go wide open throttle or stall for no apparent reason.

If we think of a movable bridge as a complex manufactured "Product" and apply similar modern "Systems Testing" methods, the "system" will have much better chance of being (as we say in computer land) "Plug-and-Play" instead of "Plug-and-Pray".

Here are a few proven methods and techniques that can help:
- Test all system components individually prior to staging them as a complete system.
- Test all control system components together at one location. Stage items in a factory floor prototype layout configuration.
- Every component of the control system should be interconnected. ie: drive system, control panels, control desk, MCC, inclinometer, etc.
- Where loads are not available (ie: the Bridge leaf), provide practical simulators. Dynamic based simulators are always better.
- Include all I/O sensors and output devices including VSDs, Hydraulic Power Units, etc.
- Use a developed test plan that tries hard to "break it" and find detailed problems. The test plan should include all possible checks for failure modes. All primary and backup systems should be tested.
- Remove components and force failures to determine safe conditions. Pull a CPU card or remove a critical control component and watch the system react.
- Use data loggers with range and limit settings and "burn-in" the system. Do repeated operations.
- Allow plenty of time to exercise every unit and component in the entire system. On a complex bridge system using unproven components, allow 3 to 4 weeks for testing.
- Obviously, adjust and fix any problems, then "re-test".
- Document, Document, Document. The more information that is provided to the end maintenance groups, the higher the chance of long-term success of the system.

Conclusion:

Movable Bridge control systems can be complex, but if the systems are not highly integrated and fully simulated and tested prior to installation, the end results can be unreliable, unpredictable and extremely time consuming to get it all working properly in the bridge site environment.

Even if the bridge system is conventional, simple and "old designs", they can and should be simulated, tested and highly documented.

Biography:

Tom Smelker has been in the electrical, electronics systems and component industry since the early 70's. He graduated with a BS Degree and two associates degrees from Ferris State University. He holds a patent on LCD Display PWM control which the technology is currently used in Compaq and HP Laptops to save power and increase brightness, and credits over 18 major electrical and electronics inventions in automotive and electronics product related industries. He was the Lead Designer of the entire electrical and electronics system for the 1996 Dodge Viper Coupe and later became the electrical/electronics department manager before leaving Chrysler Motors for better weather. He was also the Lead Designer for the 1985 Cadillac Allante' which has 19 computers on board. He invented the distributed lighting system and wrote the software for that vehicle. He was also involved in several factory floor automation programs involving robots, PLCs, and intercommunications. He then became the Design Manager for Baker Electronics after developing several computer-based hardware and software products for FAA certified In-Flight Entertainment systems. As a member of IEEE and SAE, he was on the standards committee for the development of the OBD II (On Board Diagnostics) system that assembly plants and mechanics use today to debug your vehicle electrical system.

He has been involved in movable bridge power and control systems with E.C. Driver for about three years. As a member of the electrical/mechanical team he has designed new and replacement electrical power and control systems for over 12 bridges. His experience, ranges from inspection to construction and startup assistance.

He lives in the Palmetto, Fl area with his wife and enjoys writing and playing music, computers, and riding his motorcycle. He is always fascinated with the different electrical system methodologies used on movable bridges.