HEAVY MOVABLE STRUCTURES, INC.
FOURTEENTH BIENNIAL SYMPOSIUM

October 22 – 25, 2012

A Maintenance-Centered Approach to Movable Bridge Electrical System Design

Andrew Barthle, PE
Hardesty and Hanover, LLC

CARIBE ROYALE HOTEL
ORLANDO, FLORIDA

Biography

Andrew Barthle, PE, a native of South Florida, graduated with a bachelor of science degree in electrical engineering from Rensselaer Polytechnic Institute in Troy, New York in 2003. Since then, he worked for a year at the District Four office of the Florida Department of Transportation in Fort Lauderdale, Florida, with the balance of his professional career spent as an electrical engineer with Hardesty and Hanover.

Andrew has been the electrical engineer of record for several bridges including swing, bascule, and vertical lift rehabilitation and new construction projects in Florida, Louisiana, and South Carolina.

Abstract

Movable bridge control system design can be an intensely personal affair, fraught with heated emotions as proponents of various control and drive systems clash. The perennial relay versus PLC debate is a common example. We do not intend to demonstrate definitively that any one system is objectively better than the alternatives. Things are rarely so cut-and-dry in real life. Rather, we intend to demonstrate that expectations of the system's use and maintenance should weigh more heavily in its design than our engineer's intuition might initially dictate.

With that in mind, this paper aims to apply a fresh dose of unbiased technical rigor to the electrical system *big-picture* design process. We intend to spark a discussion, hopefully leading to the development of a framework of "best practices" to assist the bridge engineer in assessing the pros and cons of various system designs and their impacts on stakeholders.

Through the use of case studies, interviews, and other evidence, this paper will demonstrate that by designing and building a control and drive system tuned to the customer's needs and, most importantly, the customer's *capabilities*, the finished system may actually be safer, cheaper, and more reliable than it might initially seem on paper.

Introduction

This paper assumes an audience of people with some familiarity with movable bridge electrical system design. We will use some technical terms that only an electrical engineer would need to know, but in general anyone that has been paying attention to the big picture when designing a bridge or two, be they structural, mechanical, or electrical engineers, should have a pretty good idea what's going on.

Ultimately, we believe that everyone involved in bridge design and maintenance should have some input on the process; therefore this paper and presentation are written for general consumption within our industry.

Most of the examples are from experience in Florida, Louisiana, and South Carolina under various public and semi-private clients, along with some input from other engineers at our firm that work with yet more clients from other locales. In preparing this paper we tried to remain generic and unbiased, but a regional bent will none the less come through given the bulk of the author's experience.

A large part of the mission of HMS is "to provide forums for information interchange" leading to "improved safety and reliability [and] more cost effective utilization of public funds through improved design and maintenance practices." This paper will focus on *maintainability* as one of the electrical engineer's most important goals. In fact, we will argue that designing for ease of maintenance saves the client's (and, by extension, the public's) money and provides for a "better" system over the years.

The Ethical Basis and the Design Code Basis

> *"Engineers, in the fulfillment of their professional duties, shall… act for each employer or client as faithful agents or trustees."*
>
> *-NSPE Code of Ethics*

Though the laws and regulations vary across jurisdictions, there are a very few simple things engineers are supposed to strive for irrespective of the letter of the law. Rarely do we really need to split hairs. In the most general of terms, engineers must abide by a high standard of professional behavior that should be, in most cases, obvious to a reasonable person.

So we all know the basics of being a professional engineer. The argument here is that paying close attention to the client's needs, wants, and capabilities should be right there near the top of the list of professional behavior. According to the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers, Part I, Fundamental Canon, Item 4 "engineers, in the fulfillment of their professional duties, shall… act for each employer or client as faithful agents or trustees." This means that we are supposed to guard the client's resources in our decision making where it does not conflict with our obligations to the "safety, health, and welfare of the public" (Item 1 of the Fundamental Canon mentioned above).

Tending to our client's resources is a normal part of the design process. We try to keep costs low within the various requirements of codes, standards, guidelines, and policies. We calculate the lifecycle costs of various design options, in particular "big-ticket" items like span drive systems. Those calculations often consider general estimates of maintenance costs. But more nebulous concepts like the annoyance of maintaining an unfamiliar system or the cost of stocking parts for various types of systems is much harder to estimate. Worse, how does one calculate the cost of maintenance that is outright deferred due to tight budgets?

Since, given the wide differences between each bridge and owner, a rigorous calculation of these and other hidden costs is exceptionally difficult if not impossible to perform, we argue that the best substitute is then the judgment of the client, in particular those who maintain the bridge on a daily basis. In most if not all cases it turns out that the client's preferences are not arbitrary, but are rather based on years of practical, hands-on experience.

AASHTO recognizes this, at least with respect to the control system. In Section 8 of the AASHTO LRFD Bridge Design Specifications, our core set of guidelines, the commentary in the control system selection section recommends that the engineer to consider factors relating to the maintenance of the system. Specifically C8.4.2.2 states that "relay logic is highly reliable and possibly preferred for bridges where the level of maintenance may be limited." Similarly, the following paragraph of commentary, C8.4.2.3, notes that "… the technical demands of servicing PLC systems should be considered along with an evaluation of the owner's means of acquiring the technically trained personnel needed to perform PLC maintenance and troubleshooting."

Our Core Argument

We propose that a similar approach should be applied to far more of the electrical system beyond the simple PLC versus relay decision. The Florida Department of Transportation's Structures Design Guidelines for movable bridges hint in this direction: Section 8.1.1(B), Applicability, directs engineers to "incorporate design and operational features… which can be operated and maintained by the Department's forces," and to "maintain consistency of configuration, when feasible, for movable bridges throughout the State." Furthermore, an *entire section* of the document, 8.9, is devoted exclusively to maintainability with the goal of making bridges that are easier to repair, thereby making them *more likely* to be repaired in a timely manner.

So how do we decide when to use our engineering judgment and when to defer to the judgment of a maintenance person? First off, as engineers we are ultimately responsible for the design. Everything we do is based on our engineering judgment. So it is a false choice to consider it an either-or kind of decision. Rather, we simply need to seek some more detailed information from the client about how the bridge will be maintained and consider that heavily in our decision making process. In almost all cases clients do not ask for things that are outright unsafe or are otherwise unwise. They may ask us to design things that we wouldn't do ourselves given no direction, but the outcome is virtually always acceptable.

What we are saying is that, in cases where there is room for argument among reasonable engineers as to whether one system is better than another, the truth is often that the benefits of one system versus another are relatively small. Furthermore, those benefits are often easily canceled out by some practical effect of daily operation. For example, a reasonable engineer can say that a PLC is “better” than a bunch of relays strung together like Christmas tree lights in a box, but a maintenance person can tell you that they just have neither the time nor the money to learn how to program a PLC.

This is not the first HMS paper to note the importance of maintainability in electrical system design. In an article called *Factors to Consider when Developing an Electrical System Design Philosophy for a Movable Bridge Project* by Mitchell Wisniewski and Anthony Bartello of HNTB Corporation for the eighth HMS symposium in 2000, “Maintenance and Operation” is one of six factors to consider. Heading up the section is the following sentence: “The experience and level of competency of the bridge operators and bridge maintenance personnel is an important factor to consider in movable bridge electrical system design.” The authors specifically point to consistency between bridges and familiarity by maintenance staff as major factors. We recommend that the audience read this paper at their leisure for some other interesting observations. Notably, the authors mention this: “New technology, such as a PLC based control system rather than a relay based control system, may be totally unfamiliar to maintenance personnel and may require significant education which the maintenance personnel may not be interested in participating in.” Again this focuses on the PLC versus relay debate, but we feel that the concept should be applied to many more decisions.

Case Studies

At this point the audience tends to get a little incredulous with the whole argument. So let us take a look at a few examples. In most cases we have left out the specifics of the bridges, engineers, and maintenance forces to keep this whole effort neutral and unbiased.

PLCs versus Relays

Since it seems to be such a fun subject for everyone to talk about, from writers of the design codes to maintenance electricians, we shall begin with several examples of the PLC versus relay question. We have two major clients that are steadfastly opposed to the use of PLCs on movable bridges. In one case, the decision was made at a fairly high level that movable bridges should be maintainable with tools you can get at Sears. Though this is clearly a case of comic hyperbole used to get the point across, it is still pretty clear that a PLC is out of the question. Just about any bridge electrician can take a screwdriver to a hefty machine-tool relay and fix most problems, at least until they can go get a new part. In the other case, the client’s consultant manager deferred the decision on control system configuration to the maintenance staff, whose experience with bridges is very extensive, but experience with PLCs is thin and has, unfortunately, been largely negative.

When asked why the relay preference, the maintenance supervisor gave several reasons:

- For one, there is no one on staff with PLC experience. If this client were to receive a PLC operated bridge, they would either have to hire someone for which they have no budget, outsource the PLC work (for which they also have no budget), or just cross their fingers and hope it never fails before the next rehabilitation project.
- Secondly, again due to limited budgets, repairs need to be cheap. So a failed relay is cheaper than a failed PLC card.
- Thirdly, given the nature of competitive bidding and various rules against sole-sourcing, it cannot be guaranteed that the same PLC equipment will be used from one bridge to the next, resulting in a large and expensive stock of spare parts.
- Finally, obsolescence is a serious concern. Again due to tight budgets, this client's bridges do not get electrical maintenance when the money could be spent on structural improvements that affect the public more directly. Even if a particular relay style is outdated, the maintenance staff have the skill and experience to replace it with a new, equivalent part. This cannot be done quite so easily with PLCs.

This owner has therefore made a conscious decision to direct engineers to design PLC-free systems.

On the other hand, we have two clients that explicitly *prefer* PLCs (with touch screens, no less) for bridge operation. They have found them to be reliable and user friendly from the bridge tender's perspective. Notably, these owners do not have significant PLC experience in-house. However, they have good relationships with control system fabricators and have been able to work out in at least one case an effective on-call type arrangement where most PLC problems can get fixed quickly and inexpensively. We should also note that one of the owners mentioned here did not have PLCs with touch screens until fairly recently. The concept was proposed by one of our competitors, was accepted by the owner, and has now become the de-facto standard for that client.

This serves to demonstrate that our judgment and guidance as engineers is key, and that ultimately decisions like this need to be part of a clear process in which the client is involved from the start. When this happens, the client is happy and things go well.

Rotary Cam, Proximity, and Snap-Action Limit Switches

Let us diverge from the more contentious area of the control system to less controversial subjects. One simple example from personal experience had to do with a rotary cam limit switch assembly used for span position indication. It turned out that the client's maintenance forces as a general rule did not like rotary cam assemblies. They found them "fiddly" and at times inaccurate, irrespective of how well the gear train may have been designed. Not long after construction completed, the client gave us a friendly "heads-up" that they would replace the rotary cam switches with discrete limit switches one-by-one as they failed. During design we had not explicitly conferred with the client as to whether the rotary cam limit switch assembly would be acceptable and they did not comment on it in the plans. In this case the result was luckily only a fairly small amount of wasted money. And we are still on good terms with the client because of our general focus on their needs otherwise.

Similarly, some clients prefer proximity switches, some hate them. In our experience it's almost always a matter pure preference. Of course there are cases where certain types of proximity switches cannot drive certain PLC or relay control system inputs, and that is the perfect example of where we should most definitely provide our guidance to the client.

Conduit Embedment

At times there can be disagreement between different administrative units within one client. In this case the engineer needs to test out his or her skills as mediator as well. One of our major clients has a general policy at the highest level that nearly all conduit should be surface-mounted or hung. This is to facilitate future replacement and repair in-kind. Additionally, with respect to the main incoming service or feeder conductors, they can be kept well away from the traveling public beneath the approach spans.

On the other hand, within the same client, the entirely opposing opinion is held by personnel in a local unit. In this case the belief is that embedding the main incoming service or feeder protects it from corrosion, is more aesthetically pleasing, and serves to reduce maintenance by eliminating hangers which must be inspected from time to time.

In truth, both people have valid, reasonable points. Luckily they both reached an agreement and provided us with our direction explicitly. For us, either outcome would have been a safe, acceptable alternative. This usually is the case. However, if one option is clearly beneficial to the client or the public, we must of course give voice to that point of view in the course of our fiduciary duties.

Asset Management

It is important to consider the fact that many bridges are maintained by asset management companies. Moreover, these asset management companies have values that can, at times, be at odds to those of the owner. This raises an interesting question. If we are supposed to consider maintenance so carefully in design, but the maintenance company isn't our client, does that not put us at odds with our duties as a "faithful agent or trustee" for our client?

Indeed it would appear so. But the solution is, in fact, not at all contrary to the main thrust of this paper. The real focus here is to involve the client in the decision making process. In this case, we would ask our client the same questions we might normally ask, and the client can (and in our experience often does) refer us to someone at the asset management company for answers. Of course we confer with the client on any conclusions before moving forward.

In fact, in the cases where our designs will ultimately be maintained by an asset management firm, bridge owners have shown a greater interest in influencing certain design decisions in order that they may eliminate contentious issues that arise in the course of their oversight of the asset management firms.

Considerations for Design-Build Projects

The design-build process can also put strains on the maintenance-focused design of an electrical system. As noted in the NSPE Code of Ethics, after the public at large, our allegiance as engineers is to our client. In this case that is the contractor. By the time we have made it deep enough into the design phase to start making the difficult decisions, it is typically too late to make substantial changes to the design to address various maintenance considerations. Therefore we recommend two things:

- First, through open dialogue, try to uncover as many issues as possible as early as possible in the pre-bid phases of the project. This is good practice anyway in that it can give the team an advantage in any technical scoring that may occur. Furthermore, for the more expensive items, the client may wish to add the conclusions drawn from such discussions to the project requirements for all to bid on.
- Second, once the project is well underway, consider addressing the client’s maintenance considerations where they will not increase the cost of construction in time or money. Examples include certain configurations of interlocks and bypasses.

Even with design-build projects where our client and the owner are different entities, there are ways to maintain our maintenance focus.

What About Innovation?

Can’t all this deference to old-hat stymie innovation? Yes, it can. Innovation is at least implied in HMS’s mission statement. Innovation is part of what we are all here to do. But innovation for innovation’s sake serves no particular purpose. Innovation to solve a specific problem does. And even then, expensive innovation to solve a cheap problem can result in more harm than good.

But then how does progress ever get made if we don’t try new things? That is a good question, too. Unfortunately, in most cases it is not our place to experiment. That is, unless our client directs us to try something new, we’re actually breaking one of our major ethical obligations as codified by the NSPE and quoted in the beginning of this paper. But I think innovation has in general become a little too much of a hot topic. Innovation for innovation's sake gives our clients no extra value. And our clients usually won’t knowingly sign up to do others' research and development, particularly in these days of tight budgets. Innovation does not make the world go around. It moves it forward, but not around.

As noted above in the successful case of introducing a client to touch screens and PLCs, we do not want to give the impression that we think that innovation is never a good thing. It simply needs to be done in close coordination with the client. And we need to apply our knowledge as engineers from the angle of a maintaining agency to hone in on more optimal solutions

Summary and Conclusions

Our code of ethics as laid out by the NSPE directs us to consider very highly our clients' resources. In serving as "faithful agents or trustees," we must, in effect, pretend that we are the direct employees of our clients. Imagine the direction your decisions would take in such a circumstance and place those conclusions high on your list of pros and cons as you work out the details of your electrical system design. In most cases we can simply ask the client directly for their opinion on various questions. Our clients are savvy individuals and, though their *breadth* of experience may in some cases not match that of an experienced consultant's, their *depth* of knowledge is almost certainly more profound. That is, consultants often design electrical systems for numerous clients across the country and even the world, but our clients deal with bridges on a daily basis, from birth to death, in sickness and in health. It is therefore no surprise that we can learn a great deal from them, and them from us.

Ultimately the concepts described in this paper are by no means earth-shattering or particularly controversial. In fact, they are things we all do to some extent every time we design a new bridge electrical system. However, I can say for myself there is *always* room for improvement, as should any engineer of any experience level. That is why we have these conferences every two years and share our new discoveries and ideas.

Hopefully this paper can help push the consideration of maintenance practices in electrical system design one or two steps higher up on the list. But in any case, most importantly we wish for this paper to trigger an ongoing discussion within the industry, and not just in the electrical subspecialty, but in mechanical and perhaps even structural system design. Open discussion of ideas like this will ensure that only the best ideas survive, while the weaker ones ultimately fall into obscurity.