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ELIMINATING SUBMARINE CABLE USE IN MOVABLE BRIDGE ELECTRICAL SYSTEMS

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ELECTRICAL/ELECTRONIC SYSTEMS

Eliminating Submarine Cable Use in Movable Bridge Electrical Systems

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Abstract:

Submarine cables have traditionally been used to carry power and control signals across the navigable channel to reliably connect equipment on both sides of the channel. There are a variety of reasons why alternatives to submarine cables may be desirable.

A bridge electrical system can be designed without the use of submarine cables.

The disadvantages of any alternative or combination of alternatives must be considered as well as the potential advantages. Redundant backup systems should be included as well. An example of a movable bridge electrical system designed without submarine cables is the new Chelsea Street Bridge which is a vertical lift bridge which will replace the existing Chelsea Street Bridge owned and operated by the City of Boston. The Chelsea Street Bridge will be installed with electrical service on both sides of the channel and a small number of extra flexible cables drooped from the towers to the movable span. These cables will include optical fibers for control, video and audio communication and a small number of copper conductors for backup control.

Introduction:

A traditional means of carrying power, communication and control signals across the navigable channel spanned by any type of movable bridge has been through the use of one or more submarine cables. These cables are typically installed through trenching, plowing or jetting or by laying on the top of the waterway bottom. While these cables are a simple and familiar method of connecting the two sides of the channel together, there may be circumstances in which use of an alternative to submarine cables could be desirable or even necessary.

I have explored alternatives to the use of submarine cables during the design of an electrical system for the new Chelsea Street Bridge. The new Chelsea Street Bridge will be a vertical lift with a 450 foot long movable span. This bridge will replace the existing Chelsea Street Bridge owned and operated by the City of Boston. Submarine cables will not be installed on the new bridge because dredging of the navigable channel is planned to follow the installation of the new bridge electrical system.

There are a variety of reasons to consider alternatives to submarine cables on other bridges. The disadvantages of any alternative or combination of alternatives must be considered as well as the potential advantages. I am presenting some of my findings on these alternatives in this paper to inform the reader of these possibilities.

Reasons for Alternatives to Submarine Cables:

Effects of Submarine Cable Installation on the Environment - Submarine cables are typically installed into the bottom of the waterway through means such as jetting, plowing or trenching. These methods can temporarily resuspend hazardous materials which had settled at the bottom of the waterway back into the water where they can become an increased danger to plant and marine animal life. The associated environmental permitting process can be lengthy or prohibitive. Federal, state and local requirements must be observed during the permitting process.

Even if hazardous material is not a factor, the physical disruption to the waterway during cable installation may be a concern for the fishing industry and recreational and commercial boaters.

Effects of the Environment on Submarine Cables - Submarine cables are subject to damage from misplaced boat anchors, dredging efforts and the natural degradation due to exposure to the marine environment. These factors decrease the lift of the cables necessitating replacement. Especially if left on the top of the waterway bottom rather than under it, cables can be damaged by water current induced motion and abrasion against rocks.

Conflicting Installations or Work - The installation of bridge submarine cables can be hindered or restricted by prior installation of utility cables and pipes which may still be active. The installation can also be impacted by future utility installations or dredging.

Product Ordering and Installation Concerns - Submarine cables are expensive to procure and expensive to install. Lead times for cable orders can also be long. Delays for the purchase of new cable can be especially troublesome if service must be quickly restored after a cable failure due to wear or damage.

Important Considerations in Selecting an Alternative:

Cost - The cost of the alternative must be considered and weighed against other alternatives as well as the cost of proceeding with the installation of submarine cables. This cost does not only include the cost of purchasing and installing the alternative system hardware but in integrating the hardware into a functional system and maintaining it as well.

Maintainability - A very important issue to consider is whether the new system will be maintained by the existing maintenance personnel and whether these personnel will be willing and able to acquire any additional training and education that may be needed to keep the new system in working order. If maintenance will be provided by an outside organization, is that organization located nearby with a work force that can respond as quickly as necessary to keep the bridge operational?

Reliability - Modern armored submarine cables have a reputation for being rugged and able to provide reliable service. Concerns about the lifespan of alternatives as well as dependable operational characteristics should be considered. A backup system should always be considered but this is especially true when reliability of a system is a concern.

Safety - Safety is the most important consideration. We must ensure that bridge equipment will not start operating by itself causing personal injury or structural and/or mechanical damage. If our Emergency Stop function is not hardwired to all bridge equipment, there must be a 100% fail safe alternative installed in its place.

Wired Alternatives:

Multiple Utility Services (one per side of the channel) - This option will allow use of local utility supplied electric service for powering of bridge machinery without any submarine cable to carry power from one side of the channel to the other. This works well for single or dual leaf bascules and tower drive vertical lift bridges. It can be implemented on a swing bridge if a utility bridge is built to carry the service conduit above water level to the center pier. Use of such a utility bridge would limit navigation to a channel on only one side of the center pier. This strategy can be implemented on a span drive vertical lift bridge only in conjunction with an option such as droop cables (described below) to carry power from one or both towers to the movable span.

Droop Cables - Extra flexible cables may be drooped between stationary and movable structures to carry power, communication and control signals. These cables may consist of optical fiber and/or copper. Multiplexing of signals can help minimize the number of conductors. Using this option, the emergency stop function may be hardwired to keep this element of the system simple. The use of droop cables is especially useful for single and dual leaf bascules where the electrical machinery moves with the bascule span and on the span or tower drive vertical lift bridges. It is also useful on a swing bridge in conjunction with a generator and/or direct engine drive alternative as described under "Wireless Alternatives", below.

Aerial Cables - Most often used between towers on vertical lift bridges, implementation on other bridge types would require construction of foundations and towers to anchor the cables. The towers and/or the cables themselves may be determined to be aesthetically objectionable and may present a hazard to air traffic. Construction of foundations for aerial cable towers can result in waterway disruption. Aerial cables may consist of optical fiber and/or copper. Multiplexing of signals can help minimize the number of conductors.

Directional Drilling - Directional drilling involves the use of a global positioning system (GPS) to guide a drill bit which tunnels below the waterway. Generally expensive, it allows circumventing any environmental concerns because use of this technology does not interfere with the waterway or and sediment on the bottom of the waterway. During drilling, bentonite clay or a polymer material is usually used during drilling to keep the drilled shaft open. After drilling, a polyethylene duct is usually pulled through the drilled shaft. Optical and/or copper cable may be pulled through the duct. Multiplexing of signals can help minimize the number of conductors. Adequate space must be provided on both sides of the channel for setting up the directional drilling equipment. The process of drilling the shaft using the GPS guidance is extremely accurate. This method may be implemented anywhere and for any type of bridge as long as enough room is available for the equipment.

Hardwired Cables Run Across The Movable Span Terminated In Quick Connectors - This option consists of wiring power and/or control across the movable span to the equipment on the opposite side of the channel. This wiring would be terminated in weather proof connectors which would be disconnected by bridge operation personnel after operating traffic signals, gates and locks but before opening the span. This works because during the time that the movable span is not fully closed, no other piece of bridge equipment needs to be operated (or needs to change state as in the case of a red traffic light). Circuitry must be provided on each side of the channel (with separate utility power or battery power) to maintain traffic lights and gate arm lights during the span operation. This method is especially useful for power and/or control wiring on single leaf bascules but may also be used for control wiring on dual leaf bascules, swing bridges (with control from the movable span) and on span drive vertical lift bridges (with generator and/or direct engine drive and control from the movable span).

Dual Systems - A single or dual leaf bascule can be equipped with a separate control house, control equipment, and electrical service on each side of the channel. One operator per side would operate all electrical equipment (including the movable leaf) on their side of the channel. Backup power can be provided with separate generators on each side of the channel. Operator salaries need to be weighed against the savings in submarine cable costs but this option may be especially useful for single or dual leaf bascule bridges with limited use or where circumstances don't allow the use of other options.

Telephone Lines - Wired telephone lines can be used for control of equipment on single and dual leaf bascules. This is typically done with leased line phone service with associated monthly charges.

Wireless Alternatives:

General - Advances in technology in the communications field have provided a variety of low cost, safe and reliable means of wireless control. Wireless control alternatives are in use for safe operation of diesel locomotives, cranes and hoists, ship loaders and people movers. Equipped with redundant safety circuits and "watchdog relay" hardware and/or software which immediately shuts down operation of the system upon loss of communication, it is not necessary to connect the emergency stop circuitry on one side of the channel with that on the other with a piece of wire.

Wireless technologies provide a variety of significant advantages when compared to submarine cables:

- Wireless technologies present no disruption to waterways.
- Wireless communication equipment can be located in areas where protected from damage.
- The installation of wireless communications equipment allows flexibility which virtually eliminates the concern for conflict with other installations.
- Wireless communications equipment is readily available and can be procured and installed quickly.

Generator Power and/or a Direct Drive Engine for Span Operation - This option consists of installing a generator and/or a direct drive engine so as to eliminate the need for power wiring to cross the channel. It is because of this lack of need to cross the channel with wiring that I have categorized this as a "wireless" option. This option is especially useful for the swing span where navigation must be allowed on both sides of the center pier. In conjunction with a droop cable, the generator and/or engine could be mounted on the center pier rather than suspended on the structure above the center pier. The weight of fuel and the generator and/or engine must be considered in the structural design. If a direct drive engine is provided in addition to the generator, one can act as a backup to the other.

This option is also applicable to the span drive vertical lift bridge.

On swing bridges, this option would be used along with multiple utility services (or additional generators) for operation of bridge equipment mounted on the approaches.

Magnetically Activated Switches - Magnetically activated switches can provide a simple option for use on a single leaf bascule or swing bridge. Mounted on the rest pier with corresponding electromagnetic actuators mounted on the movable span, signals could be passed for control of gates and traffic signals prior to opening the movable span. Opening the span would separate the switches from the actuators preventing use during the opening. As there is no need to operate any equipment mounted on the approaches while the span is open, this is not a problem.

Infrared - Infrared communication technology is considered to be the fastest but the least reliable. There are four (4) types of infrared communication technologies. The line of site technology is easily interrupted by obstacles. The scatter and reflective technology is inexpensive and can provide fairly reliable communication with some possibility of interruption due to weather conditions. The broadband optical telepoint technology is reliable but costs significantly more than other infrared technologies.

Laser Light - Laser light can be used to provide reliable communication over long distances. This communication technology is more sensitive than the infrared technology and is limited to line of site usage.

Obstacles such as boats can interrupt the signal. As there is no need, however, to operate any bridge equipment while the boat is passing, this may not be a critical flaw.

Radio - Radio has evolved into a very safe and reliable means of control. Of the various radio technologies, the Spread Spectrum technology has the reputation of being the most reliable and the most popular. This technology was originally developed for military usage for communications which required reliability and security. At least one manufacturer offers radio interface hardware that can be directly installed into a PLC (programmable logic controller) rack.

Conclusion:

Movable bridge electrical systems can be successfully installed and operated without submarine cables. The various technologies described above have a history of successful implementations in applications where security, reliability and safety are important. These technologies are equally applicable to movable bridge applications.

The electrical system developed for the Chelsea Street Bridge, used a relatively conservative approach to a system without submarine cables. The Chelsea Street Bridge will be installed with separate electrical services on both sides of the channel. Video, intercom and control signals will be multiplexed and transferred across redundant droop cables using highly flexible fiber optic cables. Backup control utilizing an auxiliary drive motor was provided with redundant flexible copper cables. The combining of the two approaches (fiber optics and copper) allowed for a great reduction in the amount of cabling required across the span.

The unique characteristics and requirements of any specific application must be considered in choosing an alternative to submarine cables. Some options are limited to or are particularly suited for use on specific movable bridge types. Combining of options can be valuable in that the drawbacks of one option can be balanced by the strengths of another. For some applications, the best choice may be a combination of options or a temporary use of one or more options.

CONTROL APPLICATIONS

Movable Bridge Type vs. Submarine Cable Alternative Type

	DROOP CABLE	AERIAL CABLE	DIRECTIONAL DRILLING	QUICK CONNECTOR	DUAL SYSTEMS	TELEPHONE	MAGENTIC SWITCHES	WIRELESS
VERTICAL LIFT - SPAN DRIVE	A S		A S-1	A	A	A S-1	A	A S
VERTICAL LIFT - TOWER DRIVE	A S	A S	A S	A	A S-3	A S	A	A S
SWING - 1 NAVIGABLE CHANNEL		A	A S	A	A	A S	A	A S
SWING - 2 NAVIGABLE CHANNELS		A	A S	A	A	A S-2	A	A S
BASCULE - SINGLE LEAF	S	A	A S-1	A	A S	A S	A	A S
BASCULE - DUAL LEAF	S	A	A S-1	A	A S	A S	A	A S

KEY:

- **A - Approach equipment (gates and signals).**
- **S - Span drive equipment.**
- **1 - Requires droop cable in conjunction.**
- **2 - Requires directional drilling in conjunction.**
- **3 - Requires droop cable or wireless option in conjunction.**

Note: Chart above depicts potential applicability of various approaches to various movable bridge types.

POWER APPLICATIONS

Movable Bridge Type vs. Submarine Cable Alternative Type

	DUAL ELECTRIC SERVICE	DROOP CABLE	AERIAL CABLE	DIRECTIONAL DRILLING	DIRECT DRIVE OR GENERATOR
VERTICAL LIFT - SPAN DRIVE	A S-1	A S	A S-1	A S-1	S
VERTICAL LIFT - TOWER DRIVE	A S	A S	A S	A S	S
SWING - 1 NAVIGABLE CHANNEL	A S-2		A S-3	A S	S
SWING - 2 NAVIGABLE CHANNELS	A		A S-3	A S	S
BASCULE - SINGLE LEAF	A S	S	A S	A S	S
BASCULE - DUAL LEAF	A S	S	A S	A S	S

KEY:
- **A - Approach equipment (gates and signals).**
- **S - Span drive equipment.**
- **1 - Requires droop cable in conjunction.**
- **2 - Requires conduit along walkway to center pier (span opens in only one direction) or slip ring assembly at center of span.**
- **3 - Requires slip ring assembly at center of span.**

Note: Chart above depicts potential applicability of various approaches to various movable bridge types.

COMMUNICATION (INTERCOM, CCTV, PLC, ETC.) APPLICATIONS

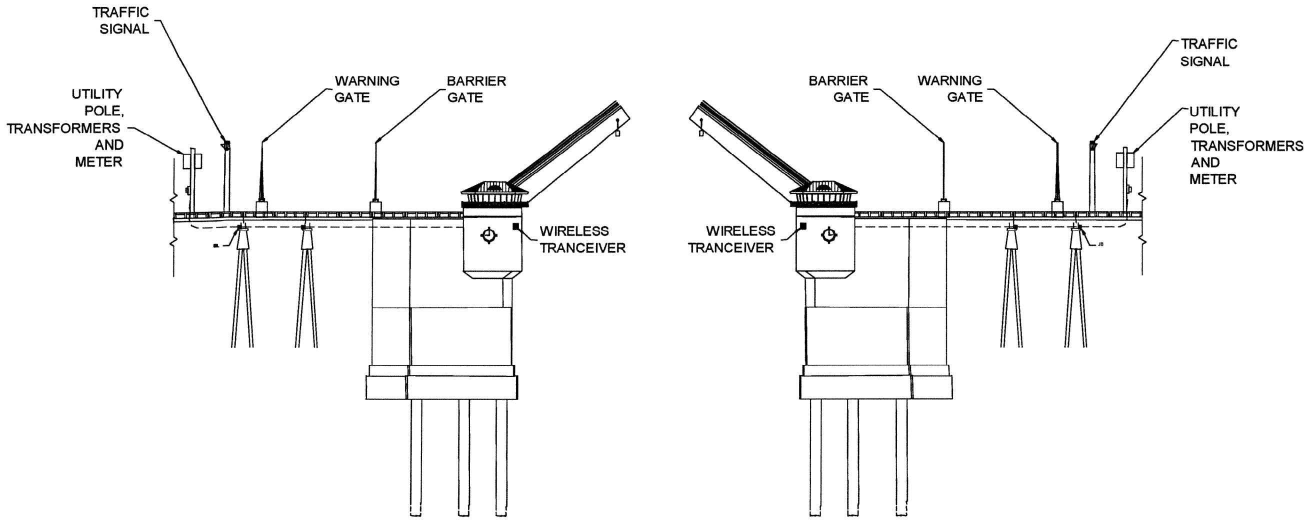
Movable Bridge Type vs. Submarine Cable Alternative Type

	DROOP CABLE	AERIAL CABLE	DIRECTIONAL DRILLING	QUICK CONNECTOR	DUAL SYSTEMS	TELEPHONE	MAGENTIC SWITCHES	WIRELESS
VERTICAL LIFT - SPAN DRIVE	X		X-1					X
VERTICAL LIFT - TOWER DRIVE	X	X	X					X
SWING - 1 NAVIGABLE CHANNEL		X-2	X					X
SWING - 2 NAVIGABLE CHANNELS		X-2	X					X
BASCULE - SINGLE LEAF		X	X					X
BASCULE - DUAL LEAF		X	X					X

KEY:

- **1 - Requires droop cable in conjunction.**
- **2 - Requires slip ring assembly at center of span.**

Note: Chart above depicts potential applicability of various approaches to various movable bridge types.



NO SUBMARINE CABLES – EXAMPLE
DUAL BASCULE – ELEVATION
Not to scale

NOTES:

1. DUAL INCOMING ELECTRICAL SERVICES. EACH SERVICE SERVES EQUIPMENT ON THE SAME SIDE OF THE CHANNEL.

2. GENERATOR ON EACH SIDE OF THE CHANNEL (IN CONTROL HOUSE) FOR BACKUP POWER.

3. MOTOR CONTROL EQUIPMENT ON EACH SIDE OF THE CHANNEL SERVING BRIDGE EQUIPMENT ON THAT SIDE.

4. NO SUBMARINE CABLE.