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WIRELESS LOCAL STATION (WLS) FOR BRIDGE CONTROL

By
Claude Fontaine P.Eng
St. Lawrence Seaway Management Corporation

RENAISSANCE ORLANDO AT SEAWORLD
ORLANDO, FLORIDA

GUIDELINE FOR HMS SYMPOSIUM PAPERS

1.0 Introduction

The Wireless Local Station (WLS) has been implemented to improve the safety of the maintenance and inspection teams while they work (inspections, adjustments, troubleshooting) inside the bascule bridge machinery room while the bridge is in motion. Bascule bridge movements are performed remotely by the bridge operator in manual mode without visual contact with the workers. Also, the workers inside the machinery room of the moving bascule bridge didn't have access to an emergency stop button for his safety. Since the distance between the Operations Control Center (OCC) and the bridge is very long, on remotely operated bridges radio communications must go through the Ethernet network. Consequently, radio communications can then be interrupted on occasion and could cause dangerous situations when, for example, the worker asks the remote operator to stop the bridge while in motion. The implementation of the WLS has been modified to include a second WLS Authorization when we realized that the remote operators were not always available to operate and to provide continuous observation before and during the bridge movement when the bridge is in local mode (local control of the bridge).

2.0 Background

The St. Lawrence Seaway (the "Seaway") is a 3,700 km binational inland waterway stretching from Montreal to Lake Erie and comprising of 15 United States and Canadian locks and a series of canals connecting the world to the heartland of North America. The St. Lawrence Seaway is managed jointly by the Canadian St. Lawrence Seaway Management Corporation (SLSMC), and the Great Lakes St. Lawrence Seaway Development Corporation (GLS), part of the U.S. Department of Transportation (DOT).

Figure 1 - Geographical Area Associated with the St Lawrence Seaway System

Vessels are lifted a total of 168 meters (551 feet) as they transit the Seaway system. There are 13 Canadian locks, 2 U.S. locks and 19 movables bridges. There are 41 ports associated with the Seaway system. If all of the United States and Canadian Provinces that border the Seaway system were a single country it would represent one of the top 5 largest world economies.

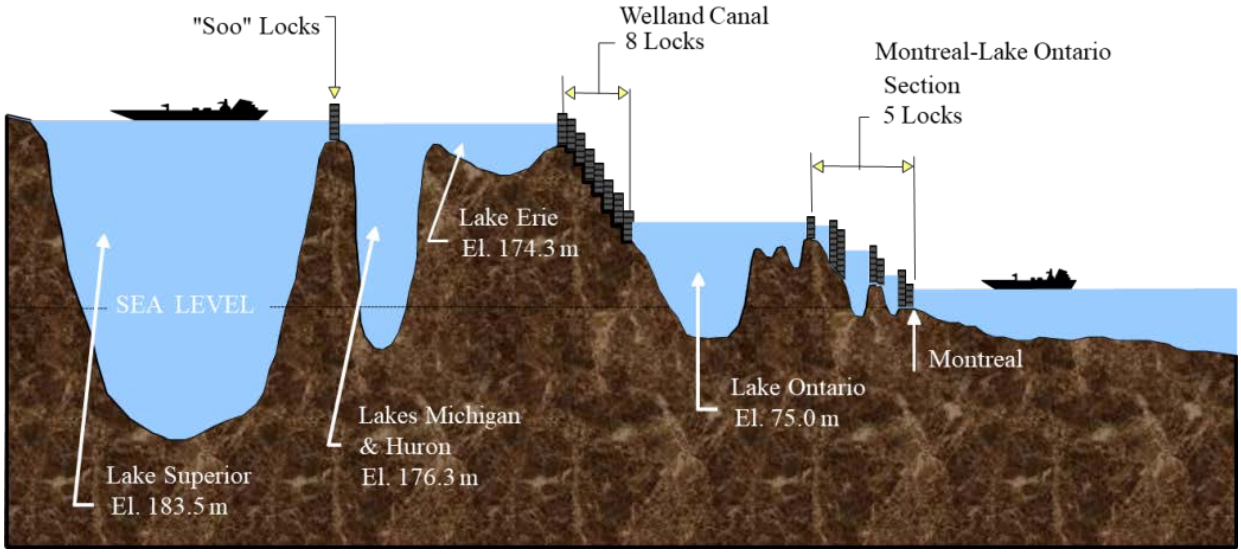

Figure 2 - The St Lawrence Seaway Profile

3.0 Bridges Control Considerations with Wireless Local Station (WLS)

Figure 3 - Wireless Local Station (WLS)

The main focus of this project was to find a solution to improve the safety of employees who want to execute maintenance and inspection while they are in a danger zone with moving equipment. To do this, we had to ensure that we have a reliable control system complying with applicable standards, implement training and working procedures.

3.1 Applicable Standards

The CSA Z432-04 standard (Safeguarding of machinery) was used to establish the base of our design. More precisely, the following articles of the Z432-04 standards have been used:

Danger zone

> "The zone around the machine (front, back, sides, top, and bottom) where a hazard is created by the motion of the machine components."

6.2.1.9.10.2

> "A stop control device shall be placed near each start control device. Where the start/stop function is performed by means of a hold-to-run control, a separate stop control device shall be provided if a risk can result from the hold-to-run control device failing to deliver a stop command when released."

6.2.1.9.10.3

> "Controls shall be located outside the danger zones, except for certain controls, such as emergency stop or teach pendant, where, of necessity, they are located within a danger zone."

6.2.1.9.10.4

> "Whenever possible, control devices and control stations shall be located so that the operator has direct visibility of the working area or hazard zone, in particular, when safe operation depends on direct permanent control by the operator."

6.2.1.9.12.1

> "Where, for setting, teaching, process changeover, fault-finding, cleaning, or maintenance of machinery, a guard has to be displaced or removed and/or a protective device has to be neutralized, and where it is necessary for the purpose of these operations for the machinery to be put in operation, safety of the operator shall be achieved, where practicable, using a manual control mode that simultaneously:
>
> (a) disables the automatic control mode (this implies, among others, that no hazardous operation may result from any sensor changing its state);
> (b) permits operation of the hazardous elements only by triggering an enabling device, a hold-to-run control device, or a two-hand control device; and
> (c) permits operation of the hazardous elements only in enhanced safety conditions (e.g., reduced speed, reduced energy/force, step-by-step — e.g., with a limited movement control device)."

6.2.1.9.12.2

"The manual control mode shall be associated with one or more of the following measures:

(a) restriction of access to the danger zone as far as possible;
(b) emergency stop control within immediate reach of the operator; or
(c) portable control unit (teach pendant) and/or local control (allowing sight of the controlled elements)."

6.2.1.13

Limiting exposure to hazards through location of setting and maintenance points outside of danger zones

"The need to access danger zones shall be minimized by locating maintenance, lubrication, and setting points outside these zones, thereby limiting exposure to hazards."

7.15 Access for adjustment, lubrication, and maintenance

7.15.1

"Machinery shall be designed to enable all routine adjustments, lubrication, and maintenance to be carried out without removing safeguards and without extensive dismantling of machinery components. Ideally, lubrication and routine maintenance facilities shall be incorporated outside the hazardous area, wherever practicable."

7.15.4

"During maintenance, if it is necessary to reach into the danger zone around moving parts, which would otherwise be out of reach, either the machine shall be powered down and locked out or all the moving parts shall be guarded against possible contact."

14 Maintenance

14.1 Access to machinery for maintenance

"Machinery should be designed to enable all routine adjustments, lubrication, and maintenance to be carried out without removing the guard or disabling a safety device, and without extensive dismantling of machinery components. Lubrication and routine maintenance facilities should be incorporated outside the danger zone or such activities shall be subject to lockout procedures.

To facilitate cleaning and maintenance work without causing interference to adjacent machinery, any platforms, means of access, or lifting suspension points should be "built-in."

3.2 Wireless Local Station (WLS) Selection

According to the CSA Z432-04 Standard, the pendant station with the following requirements is allowed to operate de machinery inside or close a danger zone:

1. Hold-to-run control device (jog control)
2. Emergency stop button available
3. Reduced speed of equipment
4. Visual contact to see the controlled elements
5. Blocking of all other control devices

We have decided the following requirements for the WLS in our applications:

1. Select a wireless local station (WLS) instead of a wired pendant station to improve the mobility and to reduce risk of accidents of the users.
2. Have the possibility to program different control button on the WLS to select different equipment with the same local wireless control for lock applications and to be able to activate the siren of the bridge.
3. Have relay outputs for PLC interface.
4. Have an integrated, Category 4 (redundant with control supervision) for the emergency stop.
5. Have no less than 50 m of operating range.
6. Have no less than 15 hours of battery autonomy.
7. Have a secure communication system and protocol.
8. Make the selection of different technologies for the WLS, do a test bench to check them and make a test on the bridge with the selected unit to validate the results (range, reliability, ergonomics, safety features, communication security etc.).

Here are the principal specifications of the selected WLS, model XARSK12D12W (including: (1) ZART12D, (1) ZARB12H, (1) ZARC01, (1) ZARC02 and (1) TCSMCNAM3M002P) of the company Schneider Electric:

1. Maximum radio range: 100 m (328’) minimum without obstacles and 50 m (164’) minimum with obstacles.
2. Communication frequency and power: 2.4 GHz Bluetooth, Category 1, low energy (10 mW).
3. Private communication protocol with automatic change of 7 channels (hopping) every 15 msec randomly among the 40 available channels.
4. Safety Integrity Level (Controller): SIL 3 (mean failure probability of $\geq$ 10-4 to <10-3).
5. 30 hours of autonomy in intense service operation with 15 minutes recharge time.
6. Base: Twelve (12) relays + two (2) safety relays.
7. WLS: Six (6) configurable motion push-button and 6 configurable auxiliary push-button, one (1) integrated emergency stop, Category 4 (redundant with control supervision).

3.3 Control Requirement

To improve the safety of the users and to prevent any confusion when using the WLS, we decided the following requirement for the control strategies:

1. Create a bridge local mode on the HMI to allow local bridge control and prevent the operator of the Operation Control Center (OCC) to take the control back of the bridge while the WLS is in operation.
2. Replace the existing wired local station with the WLS since the user was not able to see all the danger zones when operating the bridge.
3. Use two (2) WLS for each bridge to operate the bridge when the bridge is in local mode.
    a. One of the two WLS is used to operate the bridge inside or close to the danger zone (WLS Operation).
    b. The other one (WLS Authorization) is used to authorize the movement of the bridge out of the danger zone by confirming everything surrounding the bridge is secured for bridge operation.
    c. Both WLS are using a start sequence.
        i. WLS “Operation” initiate a bridge command (raise or lower) otherwise, the start sequence is aborted.
        ii. WLS “Authorization” have 10 sec. to initiate the same bridge command otherwise, the start sequence is aborted.
4. Attach a unique coded security key to each WLS with a small crimped stainless-steel cable.
    a. The coded security key of each WLS (Operation and Authorization) needs to be retrieved (WLS system “ON”) from the corresponding receptacle to activate the WLS system when the bridge is in local mode.
    b. The coded security key insures that nobody can deactivate the WLS system while it is in operation and the remote operator cannot take back the control of the bridge.
    c. A local light, located on the WLS console, indicate the bridge is in local mode (local control activation instead of remote control) “steady illuminated light” and when the WLS is activated “Blinking light”.

Figure 4 - Wireless Local Station (WLS) console

5. Use a double activation (press two buttons at the same time) to activate the raising/lowering command of the bridge to prevent any accidental movement.
6. Each controller is connected to the bridge PLC inputs for raise/lower commands, siren command and alarm activation.
7. The bridge operator is not always available to continuously observe hazards around the bridge before and during bridge movement in local mode. For this reason, we have used a second WLS "Authorization" with a controlled sequence.

3.4 Installation and Configuration

The following lessons learned represent major installation problem that we had with the WLS:

1. Position the antenna to have the best coverage possible with fewer obstacles.
2. Use the WLS with liquid crystal display since led display has bad visibility in direct sunlight.
3. Program the WLS to have unique control equipment.
4. Activate the emergency stop when the WLS is not synchronized, is not in start mode or is out of range. The security key will bypass the emergency stop contacts when the WLS is not in service.
5. Identify permanently the WLS to avoid any operation confusion.
6. Install a cleaning kit in every WLS panel.
7. Install a work platform as well as grab handles inside the bascule bridges machinery room to avoid stepping on the motors and to make work safe at all times.

3.5 Implementation

A risk analysis has been performed in order to establish a working procedure to guide work with the use of WLS to protect persons from injury and damage to structures resulting from the use of wireless local stations. The risk analysis and the working procedure shall be complete before the deployment of the WLS system.

The following recommendation has been established after the risk analysis:

1. Each WLS user must have a mobile radio in their possession to ensure communications with the various stakeholders.
2. Wearing fitted clothing is mandatory to avoid being caught in moving machinery.
3. Have visual contact at all times with the controlled equipment.
4. During mechanical work or lubrication on equipment, the lockout procedure is applicable and recommended. The emergency stop button on the WLS is not sufficient to guarantee the zero energy of the equipment.
5. Stay out of the path of moving equipment at all times.
6. The “Authorization” and “Operation” WLS user must never be used simultaneously by the same person, in any way.
7. Use only the “Operation” WLS to operate the bridge, never the “Authorization” WLS.
8. The person with the "Authorization" WLS must position himself in order to have a good overview of the danger zone before authorizing the movement of the bridge since the person with the "Operation" WLS must remain focused on the maneuvers and the work to be done.

3.6 WLS Bridges Control Advantages and Disadvantages

Advantages

1. Better security for maintenance and inspection team:

    a. Two (2) WLS to remote control the bascule bridges with local observer (WLS Authorization) for bridge control.
    b. Starting sequence improves the safety and prevents confusion in the bridge control direction.
    c. Visual contact to see the controlled elements.
    d. Hold-to-run control device (jog control).
    e. Emergency stop buttons and siren control available on each WLS.
    f. Starting sequence improves the safety and prevents confusion in the bridge control direction.
    g. Reduced speed of equipment.
    h. Blocking of all other control devices.
    i. No radio transmission interruption during remote control in manual mode done by the operator.
    j. Safety coded key attached to each WLS.

2. Less waiting time by the maintenance and inspection teams to have remote equipment control.
3. Reduce maintenance and inspection time.
4. Training station available for bench test, short and complete training.
5. The WLS is safer than having the operator control the bridge with no visual contact and full interaction with the maintenance and inspection team.
6. The WLS are cost effective, efficient, reliable and safe.

Disadvantages

1. Need two persons to operate the bridge locally.