Electrification of swing and bascule bridges with overhead conductor rails

Furrer+Frey system

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1. Introduction

Amtrak has in the Northend Electrification Project (NEP) electrified the New Haven to Boston line with a voltage of 25 kV. A fully-electrified service is now provided in the Northend Corridor from Washington to Boston. Tilting trains, called Acela (Acceleration, Elegance), have been ordered from Bombardier. They are very much similar to European high-speed trains like the TGV or ICE in terms of comfort and speed. The maximum speed which the trains will travel at will be 240 km/h. Between Old Saybrook and Mystic, the double track line passes over 5 movable bridges (3 bascule bridges and 2 swing bridges). This report will deal with the electrification of these bridges.

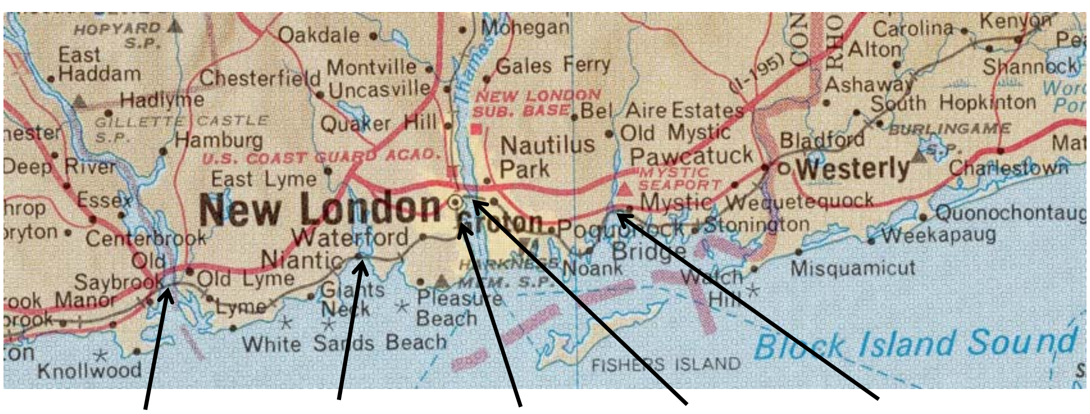

Figure 1: Location of bridges

2. Starting position

Amtrak has been pursuing the project for several years. After the first European/American Joint Venture (JV) failed, Balfour Beatty Construction and Massachusetts Electric Construction (BBC-MEC) took on the electrification project.

There remained the technical challenge of electrifying the movable bridges. A possible solution for this was to use Furrer+Frey’s overhead conductor rail system. BBC-MEC commissioned Furrer+Frey to provide the 5 bridges with conductor rails.

2.1 Performance criteria

The bridges are located on busy waterways with numerous leisure boat harbours; upstream of the Thames River Bridge there is a US Navy Base. River traffic has priority. In summer the bridges are normally open and are only closed when a train passes through.

The high volume of waterway traffic, resulted in the electrification system being designed to operate 50 times a day 365 days per year.

Other key requirements were:

- Passable with a speed of 145 km/h with raised pantographs
- Operable in temperatures ranging from -25°C to +40°C
- Capable of operating with a build up of ice 13 mm thick

2.2 Control and interlocking

Furrer+Frey and Balfour Beatty developed two different movable conductor rail systems:

- Longitudinal movement for the bascule bridges, driven by a Movable Catenary Unit (MCU)
- Vertical movement for the swing bridges, generated by a Rotary Overlap

Conductor rail units mounted on the MCU and Rotary Overlap are controlled by a specially designed electrification control panel. This control panel was integrated with the railroad signalling system and bridge control equipment such that the movable parts of the conductor rail and the earthing switch systems could be sequenced with bridge operations. The movable conductor rail sections are interlocked in such a way that the bridge can only be opened or closed if the conductor rail units are open and secure. The electrification control system can be operated in manual or automatic mode.

3. Solutions

The conductor rail system was selected due to its proven ability to meet the specified 145km/h speed requirement. Tests for Swiss Railways proved that the conductor rails are suitable for speeds up to approx. 160 km/h.

The transition element at the bridge ends was specially developed for this project. This new transition element which is patented by Furrer and Frey is called inline horn.

The inline horn ensures that overlapping conductor rail sections are positioned as close as possible to the centre of the track thus avoiding lateral excitation of the pantograph. Electrical connection of the conductor rail sections was achieved by newly developed, ice and current-resistant contact that was fixed to the inline horns.

<u>Passive electrical connector - MCU</u>

(operating position)

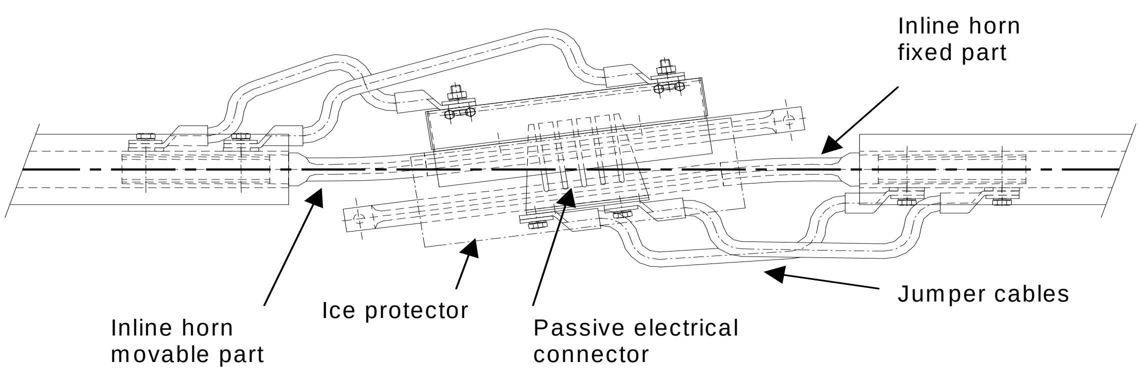

Figure 2: Passive electrical connector with inline horn used on bascule bridges longitudinal movements

3.1 Transition from catenary system to conductor rail

The catenary system, comprised of contact wire and messenger wire each measuring 150 mm² and each with a tension of 19.6 kN, has to be terminated to the bridge portal.

The contact wire runs directly into the conductor rail profile which is designed as a transition end section (patented by Furrer and Frey) at the catenary - conductor rail system interface. The transition end section is used to ensure a gradual equalization of stiffness between the catenary system and the conductor rail. This ensures smooth running of the pantograph and facilitates good current collection. In addition it prevents fatigue fractures of the contact wire at this interface.

3.2 Swing bridges

The swing bridges traverse the Shaw's Cove River and Mystic River and bear the names of these rivers. The bridges are laid out symmetrically on a centre pier and rotate on a vertical axis. With the railroad signals set at red, rotary actuators drive the rotary overlap open. The movable rail joints in the railway track open and the swing span locking bar retracts, the bridge rotates by 90° and opens the waterway for river traffic.

The transition from catenary system to conductor rail is located at the fixed bridge heads. The Rotary Overlaps are located at both ends of the swing span conductor rail. These motor-operated Rotary Overlaps allow enough space in open position to move past the transition end section on the bridge head. Inline horns guarantee the mechanical and electrical transition.

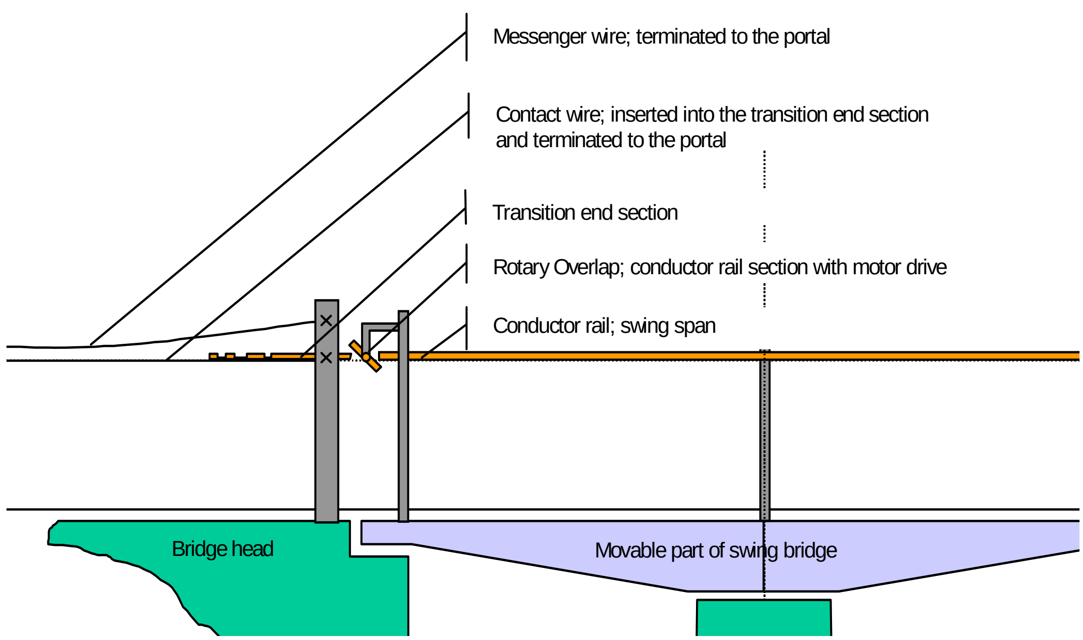

Figure 3: Swing bridge with Rotary Overlap in open position

3.3 Bascule bridges

The bascule bridges traverse the Connecticut River, Niantic River and Thames River and are also named after the rivers over which they cross. The bridges have a long, projecting lifting unit which is balanced with the aid of a counterweight. When the bridge opens, the counterweight moves down to track level.

The bridges open and close via interlocked segmental wheels at Niantic and Connecticut and rack and pinion at Thames. Maintaining balance of the bascule span is very complicated, since the centre of gravity is always changing.

The steel construction for the mounting of the conductor rail increases the weight of the bascule span and moves the centre of gravity. In order to maintain the bascule span in balance throughout the construction period additional counterweight was installed and the state of balance checked at the end of each shift. As the bascule span opens, the counter weight swings down towards the bridge deck, the conductor rail must be retracted to provide clearance for this counterweight motion.

Retraction of the conductor rail is achieved by a specially designed mobile unit called a Movable Catenary Unit (MCU). The MCU for Connecticut and Niantic River Bridges comprises of a portal structure which moves on running rails mounted on bearer beams set between bridge piers. Due to constraints of the bridge geometry at Thames River the conductor rail is mounted to an MCU which is suspended from the bridge structure. In all cases the MCU is driven by a winch mechanism using variable speed drive units.

The length of conductor rail on the MCU measures 15 m for Connecticut River, 11 m for Niantic River and 22 m for Thames River. The MCU is equipped with hingeable support arrangements, on which the conductor rail can be moved out of alignment with the centre of track. The movement is controlled using locking plate/opener and guide rollers in such a way that the movable conductor rail moves along past the fixed conductor rail. Interlocks in the control system prevent the bascule span opening until the MCU is fully retracted. When the bridge is closed the MCU conductor rail unit is folded back to the centre of the track using the same mechanism.

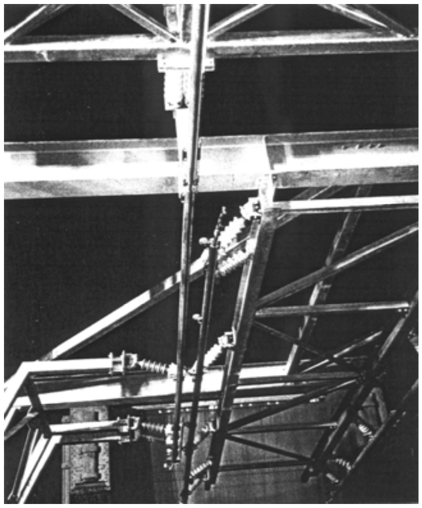

Figure 4: Horizontally movable conductor rail in open position

The Thames River Bridge is a Strauss Heel Trunnion bascule in which the bascule span motion is more complicated than that of the Connecticut and Niantic bascule bridges which are of the Scherzer Rolling lift bascule type. At Thames the conductor rail unit had to be split into two movable sections, an MCU and Pivoting Catenary Unit (PCU).

3.4 Electrical contacts

Submarine cables laid under the federal channel maintain continuity of catenary system on both sides of the bridge. Therefore the catenary system is supplied with power even when the bridge is open.

The conductor rail on the bridge is supplied with power from one side by using the passive electrical connectors on the inline horns. (Figure 5).

Due to the insulated overlap at the end of the bascule span, current flow will occur through the submarine cables: hence the passive electrical connections are not required to disconnect under electrical load. The passive electrical connectors are composed of contacting interlocking copper elements and are directly connected to the conductor rail with two jumper cables (Figure 2).

These contacts are laid out vertically on the inline horns on the swing bridges, horizontally on the bascule bridges.

The contacts and the motion were tested in the climatic chamber under the influence of temperature changes and freezing conditions (see Section 4).

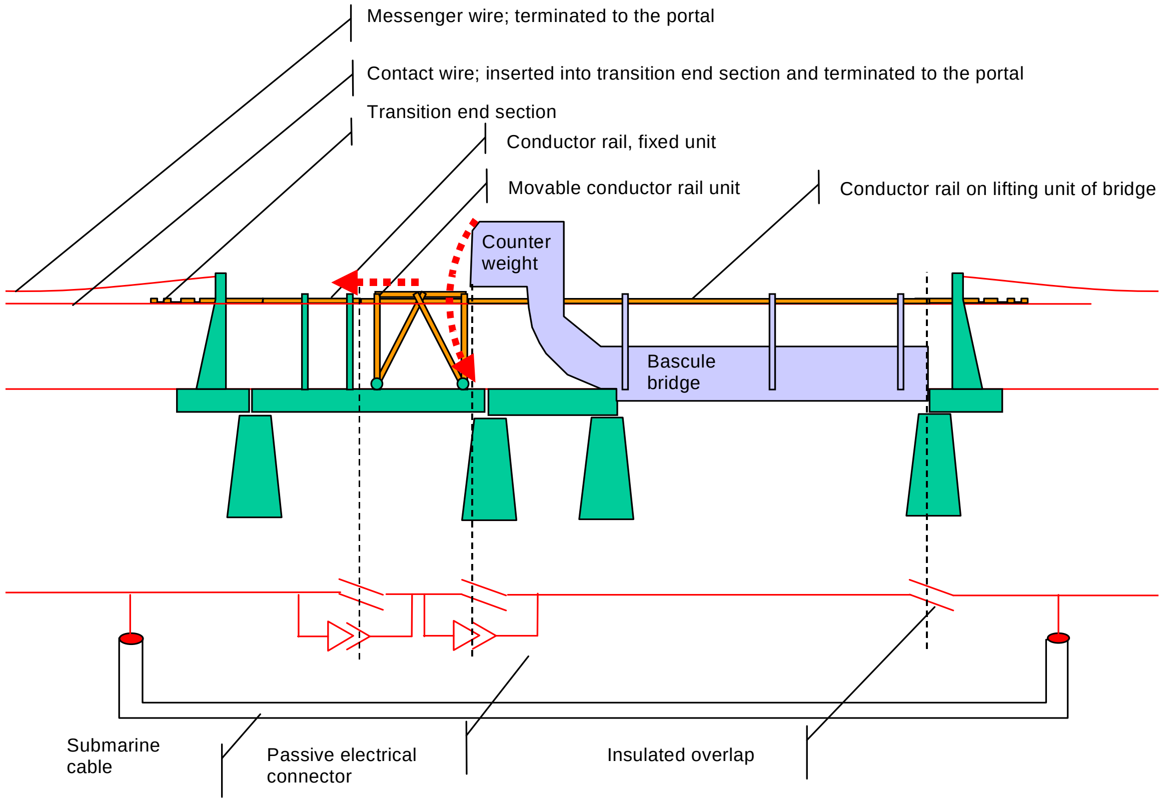

Figure 5: Schematic diagram of the conductor rail system on a bascule bridge

3.5 Earthing of the conductor rail on the bascule bridges

When a bascule bridge is open the conductor rail under the counterweight is approximately 0.50 m above the bridge deck. In this position it is accessible, even through the conductor rail is insolated from supply voltage, it needs to be earthed for safety reasons. The conductor rail for each track has an earthing switch, the operation of the earthing switch being sequenced with the opening and closing of the bascule span. Motion of the bascule span is detected by an inclinometer, which controls the earthing switch operation.

4. Tests on the prototype

All new components that were developed had to be tested for operability in accordance with specifications. The required of the system to operate within a temperature range of between -25°C and +40°C and the requirement of serviceability when there is 13 mm of ice accretion, made it necessary to perform operating tests under simulated conditions in a climatic chamber. A suitable location was found at the Swiss Army base in Spiez, which was made available for a fortnight.

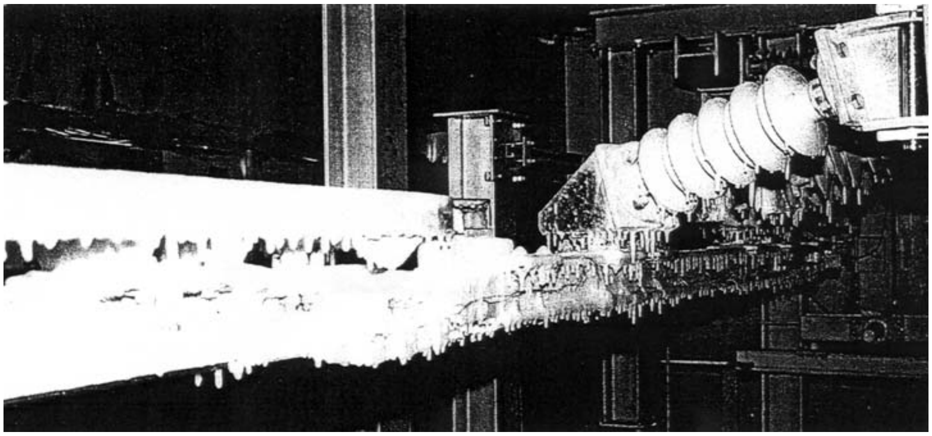

Figure 6: Horizontally movable conductor rail with ice accretion

The horizontally movable conductor rail of the bascule bridges and the vertically movable conductor rail of the swing bridges were erected on a test frame made of steel beams. The requirement was the trouble-free attainment of the end position at 3000 motion cycles and at various temperatures (-20°C, +20°C and +40°C). Both specimens fulfilled the requirements, in the case of the swinging conductor rail over 5000 cycles were actually completed.

5. Choice of materials

When the materials were being chosen, account was taken of the local climatic conditions such as ice, frequent high levels of relative humidity, storms, sea water and frequent temperature fluctuations. The conductor rail is an extrusion moulded from a high-grade aluminium alloy, hingeable components and current connectors are made of bronze and the insulators are composed of a GRP rod with silicon sheds. The steel constructions are hot dip galvanised, other components use stainless, electropolished steel.

6. Experience

The conductor rail system was energized and commissioned at the end of 1999. Since January 28 2000 an electrified revenue services has been operating.

7. On-site training

Through out the construction period Furrer+Frey provided on site support supervising the rigid conductor rail assembly crew as well as training Amtrak's operating personnel.

As part of the training program Furrer+Frey set up in the USA the model used for the tests in the climatic chamber and drew up various lesson plans for the training personnel and the workers under instruction.

8. Outlook

In nearly all the cases where movable overhead lines are required, Furrer+Frey can come up with a tried and tested solution. In addition to vehicle workshops and locomotive depots these solutions can include fire doors in tunnels or overhead lines around cranes in container terminals.

Negotiations are currently taking place on equipping other bridges between New Haven and New York. At this point thanks must go to the Balfour Beatty Construction and Massachusetts Electric Construction Joint Venture for their excellent co-operation, in particular Mr Paul Stubbings and Mr Roger D. Wilson of Balfour Beatty Construction who contributed to this remarkable solution.

References:

Stromschienenoberleitungen

eb 92 (1994) Issue 9, pages 249-259

Zulassung einer Stromschienenoberleitung durch das EBA

eb 94 (1996) Issue 11, pages 325-327

Stromschienenoberleitung in der Fahrzeuginstandhaltungshalle Erfurt

eb 98 (2000), Issue 1-2, pages 58-62

Electric charge

New Civil Engineer (January 21, 1999), pages 22 - 25