INNOVATIVE TRACTION ELECTRIFICATION DESIGN FOR THE PORTLAND STREETCAR LOOP PROJECT

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ABSTRACT:

The $148M 3.3 mile Portland Streetcar Loop Project extends from the Pearl District, across the existing Broadway Bridge, to serve the eastern half of the Portland Central City.

The project alignment includes 28 new streetcar stops and crosses the TriMet MAX Light Rail alignment at two locations. At the Broadway Bridge, the streetcar is grade separated above the MAX Yellow Line tracks. At Holiday Street the streetcar crosses the MAX Blue Line at Grand Ave and MLK Jr. Blvd locations.

Five (5) 300KW traction power substations (TPSSs) are required per loadflow simulation. To reduce project costs, two (2) streetcar TPSSs were eliminated by interconnecting the streetcar OCS with light rail OCS near the two crossings. Interconnection of the two system rails is also required.

A cost saving of $1M was realized due to the elimination of two streetcar TPSSs. Several benefits to TriMet light rail system are also realized due to the interconnection: a) redundant feed between the MAX Yellow and Blue Lines; b) better load sharing; c) higher dc system voltage and; d) lower rail voltage rise.

At the time it was built in 1911, the 1,613 ft Broadway bridge was the world longest double-leaf bascule bridge. Overhead conductor rails (OCR) designed by Furrer + Frey for lift bridge applications are installed on the bridge. OCR offers several advantages including no messenger wire required, no contact wire tension, and simplified maintenance. The OCR attached to the opening span is required to be de-energized and grounded during bridge opening to ensure safe operation. The controls and sectionalizing operation are accomplished through power contactors controlled by PLC.

This paper discusses the streetcar traction electrification system including TPSS protection & controls, interconnection and interfacing with TriMet light rail system, and the Broadway bridge PLC control system.

PORTLAND STREETCAR SYSTEM DESCRIPTION

The Portland streetcars run on two lines, the North South (NS) Line and the Central Loop (CL) Line.

The first, the NS Line, is a 4-mile one-way route from Legacy Good Samaritan Hospital at NW 23rd Avenue, on Lovejoy and Northrup, through the Pearl District and on 10th and 11th Avenues to SW Mill and SW Market Streets, Portland State University Urban Center, SW Harrison Street, RiverPlace, OHSU, the Aerial Tram and to a terminus at SW Lowell & Bond at the South Waterfront District.

The second, the CL Line, is a 4.5-mile one way route from SW Market along 10th and 11th to the Pearl District, across the Broadway Bridge, along Broadway, Weidler, 7th, MLK and Grand to the Rose Quarter, Lloyd District, Convention Center, Central Eastside and OMSI. A map of the Portland Streetcar system is included in the Appendix.

TRACTION POWER SUPPLY SYSTEM

Power to the streetcars is supplied from 300KW prefabricated traction power substations (TPSS) located approximately 0.5 miles along the streetcar alignment. Each TPSS receives incoming power from the electric utility company at either 480VAC or 208VAC, three phase. The transformer-rectifier unit rated for heavy duty traction applications utilizes 6-pulse rectification to produce a nominal dc output voltage of 825Vdc at rated load. This dc system voltage was selected for compatibility with TriMet MAX light rail dc system voltage.

TPSS single-line diagram is included in the Appendix.
A computer loadflow simulation was performed and it was confirmed that five (5) 300kW traction power substations are required for the Eastside Loop extension.

The TriMet MAX Light Rail has three traction power substations in the vicinity of the Portland Streetcar Loop Extension alignment:

- The Rose Quarter TPSS feeds both the MAX Yellow line and the Blue line,
- The Graham TPSS feeds the MAX Yellow line only
- The Lloyd TPSS feeds the MAX Blue line only.

It was decided to interconnect the light rail traction power supply system with the streetcar system to power a portion of the streetcar loop project.

Two (2) streetcar traction power substations were eliminated. A cost saving of about $1M was realized for the Portland streetcar loop project.

**LIGHT RAIL - STREETCAR INTERCONNECTION PLAN**

The Portland Streetcar Loop Extension alignment crosses the TriMet MAX Light Rail alignment at two locations. At the Broadway Bridge, the Portland Streetcar Loop Extension is grade separated above the TriMet MAX Light Rail Yellow line tracks. At Holiday Street, track crossings will be installed at Grand Ave and at MLK Jr. Blvd. where the Portland Streetcar Loop Extension alignment crosses the TriMet MAX Light Rail Blue line at grade. Non-bridging section insulators, and insulated rail joints will be installed at these locations.

Interconnection of the streetcar and light rail OCS system was accomplished using two (2) interconnection station (ICS). Each ICS includes a dc feeder breaker furnished with overcurrent and rate-of-rise protection (device 150/176), and automatic reclosing circuit (device 182/183). ICS single line diagram is included in the Appendix.

Each ICS is also configured to receive transfer trip signals from the adjacent TriMet MAX TPSSs. This will allow TriMet to transfer trip the dc breaker at each ICS to disconnect the streetcar system in case there is a fault on the TriMet system.

The dc breaker at each ICS does not send transfer trip signals to adjacent TriMet TPSSs and does not trip TriMet dc breakers.

Rail bonds are provided between the TriMet MAX light rail and the streetcar system to complete the negative return circuits.

**TriMet Interconnect Station (ICS) at Holladay Street between 7th Avenue & Grand Avenue**

In addition to provide significant cost saving to the Eastside streetcar Loop project, TriMet MAX light rail system also gains a number of benefits from the interconnections including:

- Redundant feed between the MAX Yellow line and Blue line traction power systems
- Load sharing between the TriMet Lloyd and Graham TPSS.
- Reducing voltage drop and power losses on the TriMet MAX Light Rail traction power system due to the additional parallel conductors.
- Lowering rail voltage rise due to the additional rail cross sectional area.
OVERHEAD CONTACT SYSTEM (OCS)

The Eastside streetcar loop utilizes a single contact wire fixed termination OCS system. The contact wire size is 300kcmil. Two levels of electrical insulation are provided between contact wire and an OCS pole or other grounded structure. One level of insulation is at the contact support, and the second level is adjacent to a structure.

BROADWAY BRIDGE OVERHEAD CONTACT SYSTEM

The Broadway Bridge structure totals 1,613 feet in length and consists of three westerly approach Pennsylvania-Petit Through truss spans of 270 feet, 286 feet and 297 feet, a 278-foot double-leaf Rall bascule main channel draw span, and one Pennsylvania-Petit Through truss of 297 feet and one Warren Through truss of 185 feet on the eastern approach.

Built in 1911, the Portland Broadway Bridge was the world longest double-leaf bascule bridge at the time. The bascule spans are supported, and guided by rall wheels. As the span hinges upward, it also rolls back. The weight of each lift span is balanced by a counterweight (~1,250 tons), which is located above the roadway.

The Broadway Bridge posed significant design challenges for the overhead contact system.

The minimum allowed contact wire height is 16'-0", and the distance from top-of-rail to bottom of truss is 17'-0". The 1-foot total space available is insufficient for a conventional single contact wire fixed termination system. At high temperatures wire sag will result in a height less than 16 feet, unless span lengths are reduced.

The bridge is supported solely by the rall wheels, which results in the bridge closing in a variety of locations due to the influences of temperature, wind and friction on the rall wheels. The contact wire overlaps will have to allow for these variables.

When the lift spans are raised, the balance weights lower to within several feet of the deck. This requires the overhead contact wire to be moved out of their path. To ensure personnel safety, the movable sections of the overhead contact wire will have to be de-energized and grounded.

These design challenges has led to the selection of the overhead conductor rail system (OCR) for the Broadway Bridge. The OCR is designed and manufactured by Furrer + Frey. It consists of an extruded conductor rail into which a
standard size contact wire is clamped. The OCR is suspended from gliding supports provided with insulators. The point of transition from the conventional overhead contact wire to the overhead conductor rail is equipped with a transition bar, contact wire anchoring bar and endpoint anchor.

The OCS at the Broadway Bridge has one level of insulation between the conductor rail and the grounded structures above the conductor rail to prevent flashover.

This system has several benefits as compared to conventional overhead contact system. The conductor rail provides additional current carrying capacity, which means no messenger wire and/or parallel feeder is required. Also, the contact wire is not tensioned, which allows significantly greater wear (80% wear) before wire replacement is required.

The OCS on the Broadway Bridge is sectionalized into four electrical sections by section insulators installed in the OCS:

- The eastern lift span will be sectionalized from the western lift span by insulating runners installed in the OCS at the toe of the lift spans.
- The approach span at the east end and the eastern lift span is powered from the TriMet interconnection station (ICS) located near NE Interstate Avenue.
- The approach span at the west end and the western lift span is powered from an existing streetcar TPSS.
- The lift spans are sectionalized from the approach spans and controlled so that the OCS on the lift spans is automatically de-energized and grounded when the bridge opens.

A copy of the sectionalizing diagram is included in the Appendix.

A movable cable carrier system was installed to provide a positive and negative traction power cable connection between the east approach span and the east lift span and between the west approach span and the west lift span.

To move the OCS out of the path of the counterweights, two sections at each counterweight location are rotated to a vertical position, using electric motors. The position of the movable sections is controlled by an encoder and its control system, an Allen-Bradley PowerFlex 70 Variable Frequency AC Drive.

Energizing, de-energizing and grounding the movable sections are accomplished by the use of DC power contactors controlled by the bridge PLC. Electrical interlock is provided to prevent grounding an energized line. When the bridge tender initiates a bridge open command, the DC power contactor opens to disconnect power to the movable sections, and the motorized grounding switches are closed. This enables the movable sections to rotate open, and only after they are in the fully open position can the bridge lift mechanism be engaged.

Bridge PLC control block diagram is included in the Appendix.
BIOGRAPHICAL SKETCHES

Kinh D. Pham, P.E. is the Managing Principal and a Senior Project Manager with Elcon Associates, Inc., Consulting Engineers, in Portland, Oregon. He has worked on various transit projects including heavy rail, light rail, streetcar, electric trolleybus, and monorail projects since 1981. Kinh is Elcon principal-in-charge for the Streetcar Loop Project.

He is a registered professional engineer in Oregon and nine other states. A senior member of IEEE, Kinh earned his BSEE and BS Mathematics degrees with honors from Portland State University (PSU), an MSEE degree from the University of Portland and did his doctoral studies at PSU. He has co-authored a text book and authored/co-authored a number of papers in rail traction electrification.

Kai Looijenga is currently a senior systems engineer with the Tri-County Metropolitan Transportation (TriMet) District. He has been working at the agency since 1987 and has held various positions as Journeyman Technician, Training Supervisor, and Systems Engineer.

Kai was responsible for coordinating all the design interfaces and the interconnection system design of the MAX light rail and Portland Streetcar Loop project. Kai was TriMet traction electrification engineer for the Interstate MAX and South Corridor I-205 extensions. He is currently working as a senior systems engineer for the TriMet Portland to Milwaukie Light Rail Extension scheduled for revenue operation in 2015.
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APPENDIX

- Portland Streetcar System Map
- Broadway Bridge Plan & Elevation
- Traction Power Substation Single-line Diagram
- Interconnection Station (ICS) Single-line Diagram
- Sectionalizing Schematics
- Bridge PLC Control Block Diagram