ABSTRACT

In an effort to improve system reliability in the southern end of their electrified territory, Amtrak recently undertook a program to investigate nuisance tripping of circuit breakers on Amtrak's new and rebuilt ac drive locomotives (the HHP-8, the High Speed Train set, and the AEM-7AC). Nuisance tripping of circuit breakers on these locomotives was interfering with train operations in the Washington Terminal. The findings concluded that, although the direct cause of the nuisance tripping was the new locomotive propulsion control system, a weakness in the Amtrak power system at the Washington Terminal was also a contributing factor.

The construction of a traction power substation in the Washington Terminal area to reduce system impedance and
voltage drop, thereby improving train performance was recommended. Construction of a 138 kV transmission line extension along the Amtrak Magruder Branch right-of-way from the existing Amtrak substation in Landover, MD was the recommended alternative for supplying power to the new substation.

Amtrak recently completed final design and engineering of the proposed substation and transmission line extension. This paper explains key project elements, coordination issues, innovative approaches as well as hurdles encountered during the design phase. Constructability and steps taken to minimize disruptions to service during construction are presented.

EXISTING CONDITIONS

Amtrak operates a single phase, 25 Hz transmission and distribution system to supply power to electric locomotives on the Northeast Corridor between New York City and Washington, DC. The power distribution system consists of a 138kV transmission system that feeds substations that are typically about 10 miles apart. At the substations, transformers change the voltage from 138 kV to 12 kV. The 12 kV is fed through circuit breakers, to the locomotives via the catenary system. Typically, catenary sections are fed from substations located at both ends of the section. The trolley section between Landover Substation and Union Station in Washington, DC, however, is an exception to the typical design of the electric system. Depicted in Figure 1, Union Station and the Ivy City Yard complex are fed from one end only via Switching Station 25A which is in turn fed from Landover substation in Maryland, approximately 7 miles away, via the catenary wires and two (2) 12 kV feeders (U1 & U2). Union Switching Station 25A is “not” a power supply station; it is simply a facility for accomplishing the complicated switching arrangements required at the Terminal Complex through the use of Master and Low Rupture breakers.

STATEMENT OF THE PROBLEM

Until 1995, Capital Substation provided two (2) 1250 kcmil 12 kV feeders to Switching Station 25A. Switching Station 25A, in turn, fed the south end of the trolley section between Union Station and Landover substation as well as feeding the tracks at Union Station and Ivy City Yard. Landover Substation fed the trolley section between
Union and Landover Substation from the north end and also provided a 12 kV feeder (25Y) to 25A. With this arrangement, Union Station was supplied with two independent 12 kV sources that in turn were fed from the Amtrak 138 kV system. The system between Union and Landover was, as all other sections of the Northeast Corridor still are, fed from either end by independent sources. The two 12 kV sources provided a better voltage profile at Union Station than the single 12 kV source from Landover. Two independent sources also enable contingency operation of the system as well as provide the ability to perform maintenance without having to restrict electrical operations in the Terminal area as is now required.

With the abandonment of Capital Substation, Switching Station 25A is now fed from one substation only, new feeder wires were required to reduce the impedance and provide additional capacity between Landover Substation and Union. The U1 feeder, which is a 795 kcmil ACSR (Aluminum Cable Steel Reinforced) conductor, was added to feed Switching Station 25A from Landover and the 25Y, which is a 400 kcmil copper conductor, was converted to the U2 feeder that also feeds 25A from Landover. The 25W feeder was added to feed Ivy City Yard from Switching Station 25A. So that, on balance, two (2) 1250-kcmil conductors that were two (2) miles in length, were replaced with one (1) 795-kcmil conductor that was seven (7) miles in length. The current carrying capacity of the 795-kcmil conductor and the 1250-kcmil cable are each approximately 900 amps. The present configuration reduced the capacity of the system by 900 amps. In addition, the impedance of the system was increased, as a two (2) mile parallel combination of cable was replaced with a single seven (7) mile conductor thus increasing the voltage drop between Landover and Union.

This reduction in current capacity and increase in impedance negatively affects the performance of the system at Union Station. With the large number of train movements in and out of the station as well as trains drawing hotel power in the station and Ivy City Yard, low voltages occur in the station and yard on a regular basis. Low voltages cause under-performance of trains and other equipment fed from the 12 kV system, which in turn, have an adverse effect on train operations that could possibly impact schedule. Low voltages on a regular basis over a long period of time can be very damaging to motors. Motors are a constant power load, so that a reduction in operating voltage results in higher motor currents, causing excessive motor heating and shortened motor life. Clear evidence of the instability of the system was the voltage fluctuations that were observed with the implementation of the Acela. The
voltage fluctuations were eliminated by a modification to the train’s software; however there are no assurances that there aren’t other problems, not as readily manifested as the voltage fluctuations. It is clear though, that the electrical system is inherently weak. To further strengthen the power system in this area, construction of a new substation in the vicinity of Ivy City and an extension of the existing 138 kV transmission line from Landover to Ivy City were recommended.

INITIAL STEP - FEASIBILITY STUDY

The initial step in strengthening the power system was to conduct a feasibility study and conceptual design for the proposed substation and transmission line extension. The study was required to develop the following concepts:

- A 138 kV transmission line from Landover Substation to the proposed new substation accommodating two single phase circuits;
- A new substation that will accommodate three 4500 kVA traction power transformers;
- Two 12 kV feeder circuits from the new substation to replace or tie into the existing U1 and U2 circuits to Union Switching Station Substation No. 25A; and
- Additional 12 kV circuits from the new substation as required to feed the Ivy City Complex.

Several items were investigated during the feasibility study with the most critical being:

- Project permitting requirements including identification of potential barriers to implementation or impediments to construction schedule and cost;
- Constructability issues involved with constructing the facilities around an active railroad included the implications on construction cost and schedule;
- Proposed substation sites and configurations; and
- Proposed transmission line routing and configurations including alternative materials and construction types.
Key issues pertaining to each of the above evaluation and selection criteria are explained in further detail below.

**Project Permitting and Regulatory Requirements**

Portions of the proposed project fall within the boundaries of the State of Maryland and the District of Columbia. In addition, the proposed transmission line crosses the navigable Anacostia River within the boundaries of the District of Columbia. There are numerous governmental entities in the District of Columbia and the State of Maryland, in addition to the Federal government, who could conceivably have jurisdiction over the project site. Results of investigations into regulatory and permitting agencies which impact the success and viability of the project are summarized below.

**Maryland Public Service Commission**

The Maryland Public Service Commission (PSC) regulates the construction of power generating facilities and aerial transmission lines of 69 kV and higher in the State of Maryland, according to the Public Utilities Companies Articles of the Annotated Code of Maryland. Electric companies planning to construct these facilities are required to apply for a *Certificate of Public Convenience and Necessity* (CPCN) as described in the Maryland Public Service Commission Regulations. Examination of the CPCN requirements and the Commission Regulations revealed that they appear to be applicable to electric utility companies who transmit and distribute power for public consumption, and therefore not to Amtrak.

**District of Columbia Public Service Commission**

The District of Columbia Public Service Commission (PSC) regulates the construction in the District of Columbia of power generating facilities, aerial and underground transmission lines of 69 kV and higher, and substations connected at 69 kV or higher, according to the Title 15 of the District of Columbia Municipal Regulations (DCMR) Chapter 21, *Provisions for Construction of Electric Plant*. According to 15 DCMR Chapter 21, paragraph 2100.1, “All electric corporations doing business in the District of Columbia shall obtain Commission permission and
approval before beginning the construction of any electric plant in the District of Columbia”. In addition, electric corporations planning to construct generation or transmission lines in excess of 69 kV are required to apply for a 
Certificate of Public Convenience and Necessity (CPCN). The District of Columbia PSC confirmed that Amtrak is not considered an “electric corporation”, and will not need to obtain a CPCN for this project as long as the power transmitted is not used for retail or wholesale purposes.

**DC Department of Public Works**

The District of Columbia Construction Codes Supplement (1999) contains regulations applicable to the construction of aerial transmission and distribution lines in the District of Columbia. Paragraph 2710.2 of this Supplement prohibits the installation of “overhead lines” within the boundaries of a large portion of the District that includes Union Station. Upon superimposing these boundaries on a map, it was determined that the project site is outside of the prohibited area (the boundary line crosses the Amtrak main line at the western end of the Wedge Yard) and therefore overhead extension of the 138 kV lines is not prohibited by this supplement.

**Wetlands and Waterways**

The United States Army Corps of Engineers (USACE) administers the regulatory program defined by Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act for Maryland and the District of Columbia (Maryland and the District subsequently review and certify the USACE findings). Section 10 prohibits the obstruction or alteration of navigable waters of the United States without a permit from the USACE. Section 404 prohibits the discharge of certain materials into the waters of the United States without a permit from the USACE. A permit request under Section 404 requires State certification of compliance with other sections of the Clean Water Act, which must be obtained from Maryland and the District of Columbia for this project. Results of investigations into permitting requirements of the USACE, Maryland and the District of Columbia are summarized below:

1. A tidal wetland permit will be required for an aerial transmission line across the Anacostia River per Section 10 of the Rivers and Harbors Act. This would be a Nationwide Wetland Permit (NWP) that should be
grant under a Section 10, NWP-12 (Utility Line Activities) permit.

2. The normal 25 ft. wetland buffer zone required by the USACE should apply to the site (no expanded buffer zones are expected). No impacts are expected within the District of Columbia.

3. As long as the project creates no direct impacts to the non-tidal wetlands or wetlands buffers, no non-tidal wetland permits will be required. Therefore, project final design should attempt as much as possible to avoid construction in these areas. This includes test boring activities and construction access roads. If work in one or more of these areas is unavoidable, the project should qualify under a Maryland State Programmatic General Permit as a Category I, Activity 17 (Install supports for overhead power lines: less than ½ acre of non-tidal wetland impacts).

4. If construction access or other construction requirements in Maryland should require the cutting of trees, Maryland Forest Conservation Law impacts would be expected. This could require a Forest Stand Delineation and Forest Conservation Plan, or Forest Conservation Exemption. For this reason, removal of trees should be avoided where possible.

DC Department of Health

The Watershed Protection Division of the Bureau of Environmental Quality, which is part of the DC Department of Health, Environmental Health Administration, regulates storm water management and sediment and erosion control for all construction sites. A permit for the substation and transmission line construction within the District of Columbia will need to be obtained from the Sediment and Storm Water Technical Services Branch. An erosion and sediment control plan will need to be prepared as part of the permit process. A storm water management plan will also need to be prepared since both substation site alternatives exceed the 5,000 square foot regulatory cutoff.

MD Department of the Environment

The Maryland Department of the Environment (DOE) regulates storm water management and sediment and erosion control for all construction sites in the State. The MD DOE must approve erosion and sediment control plans, and
stormwater management plans, for all construction projects that will disturb more than 5,000 square feet or excavate more than 100 cubic yards of soil.

**Construction Considerations**

Construction of the Ivy City facility is unique from a typical power substation and transmission line engineering project in that all work needs to be implemented while working around an active railroad and while maintained uninterrupted service to that railroad. Several factors unique to the construction of this project were considered and evaluated for each alternative. Key points addressed included:

1. **Limited Vehicle and Equipment Access.** Bounded by wooded areas, wetlands, and state roadways, there is very restricted vehicle and equipment access along the proposed transmission line route. Certain areas of the proposed alignment are assessable by rail only, requiring temporary access roads for the construction of the new extension. Requirements for temporary access should be addressed.

2. **Presence of Wetlands.** As noted, the proposed transmission route is bordered by wetlands for small portions of its routing. To facilitate project permitting requirements, impacts on these wetlands must be minimized. Impacts of each transmission alternative on the wetlands should be assessed and mitigated where appropriate.

3. **Working around an Operating Railroad.** A key difference between this proposed transmission line extension and an average utility transmission line is that this extension is to be constructed along an operating railroad. Train traffic will be present continuously during the construction of the line. Impacts of short construction windows, track outage requirements, and overall safety during construction need to be addressed. Knowledge of railroad operating parameters should be included in developing estimates of construction cost and schedule. Construction windows available for track occupancy have been estimated at four (4) hours per night.

4. **Presence of U1, U2, and Catenary Feeders.** The presence of the existing energized overhead conductors will greatly increase the difficulty in constructing any overhead transmission line. With limited opportunities for de-energization, applicable safety clearance must be maintained during erection of poles and stringing of conductors. Preliminary assumptions are that at least one of the 12 kV supply conductors, U1 or U2, must be in service at all times in order to provide an adequate source of power to Ivy City and Union Station.
Substation Location

The Ivy City complex has several locations that may prove suitable for a 138-12 kV substation. Shown in Figure 2, these locations include adjacent to New York Avenue, south of the existing mainline tracks, in the vicinity of the "Wedge Yard" at the southwest end, and adjacent to the Commissary building at the northeast end. Summary findings of each potential location are presented below.

New York Avenue Site (Option 1)

This site identified is on the south side of the main line tracks opposite Ivy City Yard, west of the 9th Street road bridge. The site is a narrow strip of land which runs along the existing mainlines and is bounded by the OCS structures on the north side and the Amtrak property line on the south side. The site is approximately 68 feet wide. The along track space available is approximately 350 ft and is bounded on the east side by the railroad access gate and on the west side by an existing signal and communication hut.

Due to the site geometry, location and the amount of equipment required to be installed in the substation, it has been necessary to split the substation into two compounds. The first compound towards the east of the location contains all the 138 kV equipment and provides a location for the transmission line circuits to be terminated. The second compound, located to the west of the first, is situated such that the guy wires and span wires for the adjacent OCS and signaling structure do not have to be relocated. This compound contains the 12 kV equipment and supplies traction power to the overhead contact system. The splitting of the substation into two compounds requires the use of a cabled 12 kV connections between the locations. The primary reason for the division of the site into two distinct, fenced compounds is the present location of the existing OCS (and originally signaling) structure E-727 and its associated guy wires.

Advantages of this proposed site include:
• Site location is in line with the proposed location of the transmission line extension. No transmission line track crossing will be necessary.

• Site is on the east side of 9th Street Bridge; therefore the transmission line does not have to go under or over this obstacle.

• A site access road is already present, and the road does not cross any tracks.

• Being adjacent to New York Avenue it is anticipated that a utility power supply will be readily available for substation auxiliary 60 Hz power.

Disadvantages of this proposed site include:

• It will be necessary to verify that the Amtrak property line is as shown on the topographical and valuation maps during detailed design to confirm that the required space is available.

• The land in the vicinity of the proposed compounds is currently banked with approximately a 10 ft rise across the proposed location for the 12 kV compound. This may require the installation of a retaining wall or regrading of the embankment. This requirement should be determined during detailed design after detailed survey data is available.

• Numerous internal Amtrak entities are interested in the site for potential storage track or siding configurations. Track expansions may jeopardize availability of the site for ancillary uses.

**Wedge Yard Site (Option 2)**

This site is located at the east end of the existing Wedge Yard storage area. In an effort to minimize the encroachment of a new substation into this storage area, the new substation would be located at the extreme east end of the storage yard making the site triangular in shape. The site is bounded by the Amtrak main lines on the south side, by the B&O/CSX railroad tracks on the north and east sides, and by an existing fence within the storage area on the west side. It should be noted that this site is on the west side of the 9th Street road bridge.
The Wedge Yard site is sufficiently large to include all the required substation equipment within one compound. However, due to the site location being on the west side of the 9th Street Bridge, it is necessary route the 138 kV transmission circuits over or under the bridge. Due to the proximity of the identified site to the bridge it will be impractical to route the transmission line over the bridge. Consequently, in the conceptual design the transmission line is terminated within a small compound at the location identified in Option 1 and then cabled under the 9th Street Bridge to the Wedge Yard location.

Advantages of this proposed site include:

- The substation equipment is contained within one compound.
- The Wedge Yard is a currently a flat piece of land and therefore would not required the installation of a retaining wall.

Disadvantages of this proposed site include:

- Amtrak has not yet been able to not confirm that this land is available for use for a traction substation (there may be other uses planned for this location).
- The routing required for the 138 kV underground cables must traverse B&O/CSX property. The conceptual design shows the cable route being between the tracks on B&O property as a consequence for avoiding the bridge footing and attempting to provide, as far as possible, straight runs which would be a necessity for high voltage cable installation.
- The installation of a high voltage duct bank and manhole between tracks will require multiple Amtrak and CSX track outages and will require the installation of sheeting which will be costly and time consuming.
- Access to the site requires vehicular crossing of yard tracks.
- An additional compound is required to provide the transition between aerial 138 kV transmission and underground 138 kV transmission.
Commissary Site (Option 3)

This site identified is located east of the existing Commissary building in the northeast corner of the Ivy City complex. The site is a relatively level parcel and is bounded by the commissary on the west, the property lines on the north and east, and existing storage tracks on the south. There is a substantial grade change between the proposed site and the adjacent storage tracks, making it unsuitable for use as future train storage without major grading operations. Present use of the site is limited to storage and lay down of construction materials. The site is approximately 30,000 square feet (0.69 acres) in area and provides adequate room for the proposed construction. The site is serviced by an existing paved access road that runs along the northern edge of Amtrak’s property. The Commissary site is sufficiently large to include all the required substation equipment within one compound.

Advantages of this proposed site include:

- Site is easily accessible by an existing access road, and the road does not cross any tracks.
- Site is isolated from existing yard operations enabling uninterrupted and facilitated construction.
- Amtrak has indicated that this land is available for use and that there are currently no plans for any other development at this location.
- The site is relatively flat and level, not requiring any retaining structures and limiting the amount of civil construction required to create useable space.

Disadvantages of this proposed site include:

- The routing required for the 138 kV and 12 kV circuits must traverse B&O/CSX property and multiple yard tracks.
- Proposed location is not located along the existing mainline or yard tracks and as such requires additional lengths of 138 kV and 12 kV circuits in order to provide proper feeding arrangements.
Transmission Line Alternatives

As stated earlier, the existing 138 kV transmission line which provides power to Landover substation must be extended along the Magruder Branch to the new substation site to provide a 25 Hz power source to the new substation. Extension of this existing transmission line, which currently branches off the mainline at Milepost 129.32, would be approximately five (5) miles in overall length as shown in Figure 3. All construction would be confined to Amtrak’s existing right of way. Various transmission line alternatives with respect to structure type, composition, line routing and overall configurations were investigated with the findings presented below.

In evaluating alternatives, an analysis was undertaken to determine which type of structure and footing will be best suited to the project. Various types of structures were investigated including wood poles, steel H-frames, steel poles on foundations, and steel monopoles. Items that were considered in the evaluation include:

- Initial construction cost;
- Life-cycle cost, including maintenance and painting requirements;
- Strength and serviceability;
- Ease of construction; and
- Effect on construction schedule.

Extension of Existing OCS Structures

The existing OCS support structures along the Magruder Branch are predominantly two-track cantilever type supports. The existing single pole guyed structures currently support both of the mainline track catenary systems, rail return conductors, and signal conductors. In 1994, two new 12 kV feeders, U1 and U2, were strung along the existing pole line from Landover to Ivy City in an effort to strengthen the power system in that area. Supporting the new 25 kV transmission circuits on the existing structures in a similar manner was analyzed as an alternative.
Although the alternative of supporting the extended transmission circuits on the existing structures initially appeared attractive, it was dismissed from consideration at an early stage for the following key reasons:

1. The existing catenary structures are the original structures, and may be due for replacement. Significant strengthening of the existing structures would be required to support the additional circuits while maintaining the OCS at the proper heights and offsets. Deflections of the existing structures due to the increased wind loadings on the transmission line(s) pose the potential of creating unacceptable deflections of the contact wire. Maintaining independence of the new transmission line from the poles will extend the service life of the existing structures and preserve the integrity of the existing OCS.

2. Construction on the existing catenary support structures would require that both the U1 and U2 feeders be temporarily taken out of service.

3. The existing U1 and U2 circuits take up the last of the available space on the existing catenary support structures (and the available structural capacity as well). The original support structures were burdened above initial stress levels in 1994 when these two conductors were installed on new pole extensions. The additional loadings due to U1 and U2 pushed the existing structures to their limits. Installation of additional cables would require additional extensions require complete retrofit and strengthening of the existing poles, or additional structures, which would be quite costly. New pole extensions would also require additional extensive guying to maintain the deflections of the poles within acceptable values.

**Construction of a Wood Pole Line**

Construction of a transmission line supported on wood poles, independent from the existing OCS support structures, was investigated. The pole line would be installed on the opposite side of the tracks from the OCS structures, with pole spacing coincident with the OCS supports. Construction would utilize standard utility type support arrangements where the circuits are suspended from wood cross arms with suspension insulators. Relative to extension of the existing structures, construction of the wood pole line would be relatively inexpensive and create minimal construction impacts. Poles could be easily set in the ground during the limited work windows, with conductor stringing occurring during limited single track outages. Construction equipment requirements would also
be less demanding, with smaller equipment typically required. Since construction of the pole line would occur opposite the existing OCS supports, impacts on the existing U1 and U2 conductors would be minimized.

Although the construction of an independent wood pole line met several of the selection criteria, it was eliminated from further consideration for the following reasons:

1. Due to the inherent structural capacity of wood poles, maximum span lengths between poles would be limited, requiring a significant number of poles to be installed. Pole spacing would coincide with OCS structure spacing, with spans approximately 200’ to 250’ long. An increase in the overall number of poles required directly corresponds to a higher probability of construction impacts concerning track and power outages.

2. The wood poles would be unable to support any additional future OCS pull-off loadings or high radial and wind loadings without extensive back-guying of the poles. In most instances there is insufficient right-of-way width to install these guys as the right-of-way is pinched between CSX and New York Avenue.

3. At several overhead bridges, 110’ tall poles would be required to span over the roadway while maintaining the minimum allowable clearances. These large poles would most likely be steel, requiring different types of installation equipment to be mobilized for their erection. Mobilization costs could be minimized by utilizing uniform construction methods throughout the corridor.

4. As evidenced by many local utilities currently converting from wood poles to steel poles for transmission and distribution purposes, the maintenance and life cycle costs of wood are greater than that of equivalent steel construction

Construction of a Tubular Steel Pole Line

Construction of an independent transmission line supported on tubular steel poles was considered and evaluated. The construction of the new pole line would mostly resemble that installed by Northeast Utilities along the Metro North right of way in Connecticut. The pole line would utilize steel davit arm construction with polymer type suspension insulators. Pole heights would range from 75’-0” to 115’-0” depending on there use and location along the route.
Where possible, poles would be installed opposite from and located at every other catenary support structure, using maximum 550’ span lengths. Locating poles directly adjacent to the catenary structures will allow the OCS structures to be utilized as reference locations for installation of the poles during construction, as well as provide a reference location for future reference. According to Amtrak’s Standards, for new construction, overhead transmission poles shall be constructed not less than 18’-0” from the centerline of the nearest track. Where required to be installed on the same side of the tracks as the existing OCS supports, due to inadequate right of way width, etc. the pole will require a greater offset to provide adequate clearance to the existing U1 feeder.

SELECTED ALTERNATIVES

After review of each alternative, the following were selected and progressed into final design.

Substation Location and Configuration

For reasons stated earlier, Option 3, the Commissary site, was selected as the preferred option for the substation construction. The substation will be supplied with 138 kV, single phase, 25 Hz power via Amtrak’s existing transmission system which is presently terminated at Sub 24 in Landover. The transmission line will be extended from Sub 24 to the new location with provisions for two (2) single phase 138 kV transmission circuits (discussed later). The proposed substation is designed to accommodate three (3) 4500 KVA, 138 kV/12 kV traction power transformers and is arranged to provide traction power to the Union Station/Ivy City Yard complex, utilizing Sub 25A, via circuit breakers/switchgear and feeders that provide increased operational flexibility over existing conditions. Two circuits are designated to feed the mainline tracks #1 and #2, and the Ivy City Yard complex is fed directly from the proposed new substation rather than being routed through Sub 25A. Shown in Figure 4, a non-standard Amtrak equipment arrangement was utilized in order to provide the most efficient use of the substation site as well as provide the most operational flexibility and opportunity for future expansion. Major elements of the substation include:

- 138 kV motorized disconnect switches (with and without grounding blades);
• 4.5 MVA 138-12 kV, 25 Hz single phase oil filled traction power transformers complete with oil containment and fire separation walls;

• 12 kV motorized disconnect switches – single and double pole;

• 12 kV 25 Hz circuit breakers - single and double pole;

• 12 kV cabling between transformers and the 12 kV circuit breakers including terminations;

• Traction return and transmission line static wires conductors and connections;

• Disconnect switch support steelwork, gantries and foundations; and

• Control building containing low voltage ac and dc distribution equipment and controls, battery charger and batteries, protection relay panels complete with all required protection relays, control boards, annunciator, SCADA RTU, HVAC equipment, interior lights and terminal cabinets.

Transmission Line

An independent steel pole transmission line was selected to support the twin 138 kV circuits required to provide high voltage power to the Ivy City substation site. The pole line extends along the north side of the right of way from Structure E632 until it traverses to the south side at its new terminus at Ivy City. Although there are existing underground utilities on this side of the corridor (fiber optic, C&S cables, and storm drainage), the structures have been spotted on this side of the right-of-way to minimize impacts with the existing catenary structures and also minimize construction impacts on existing conductors U1 and U2. Existing utilities were located during the design stage, and will also be verified by test pits during installation of any new poles.

Construction impacts of the steel pole line have been minimized paying attention to the physical and environmental characteristics of the project area, as well as being cognizant of Amtrak operating parameters. Wetlands mitigation has been obtained by placing poles outside of the preliminary wetlands boundaries and buffer zones. In addition, during excavation of pole foundations, it is envisioned that hay bales and silt fences will be utilized on the field side of the excavation to protect any existing wetlands.
Poles have also been placed where there construction will have the least impact on the existing U1, U2 and catenary feeders. In most instances, the new transmission line conductors will be constructed on a new pole line on the opposite side of the existing poles as shown in Figure 5. Installation of the conductors in these locations will enable all existing feeders to remain in service. In areas where the new poles are placed on the same side as the existing catenary structures, the new poles have been offset away from the tracks enough so that only U1, which is suspended off the rear of the OCS structures, needs to be taken out of service during conductor stringing.

Physical properties and characteristics of the steel pole line alternative are summarized as follows.

1. **Ruling Span Length.** Since the structures were spotted primarily to coincide with the existing OCS supports, span length was regulated to be a multiple of the existing OCS span lengths within the project area. The ruling span used for determination of conductor tensions was 542’. Longer spans were not feasible due to their requirement for larger diameter, taller poles. Smaller span lengths were used in the first curve east of Ivy City to minimize the line angles and corresponding radial loads due to the transmission loadings. The 542’ ruling span was also chosen to minimize the amount of mid span sag, allowing a more reasonable 75’ normal pole length to be utilized while still maintaining adequate electrical clearance to ground.

2. **Design Tension.** A design tension of 4,869 lbs. at 60°F was used in the determination of preliminary load calculation and structure sizing. This tension was selected to minimize conductor sag and corresponding pole height. Also, using this tension provides a conductor tension at minimum average temperature that is approximately 20% of its rated strength of 19,500 lbs. According to industry recommendations, experimental evidence has shown that limiting conductor tensions to these values eliminates wind-borne and Aoelian vibration in short to medium spans. A design tension of 3,800 lbs. was utilized for the 9/16” diameter Copperweld static wire.

3. **Conductor Clearances.** The conductor clearances used in the final design were the more stringent of those contained in Amtrak standards or the National Electric Safety Code (NESC). To accommodate the clearance requirements, pole heights range from a minimum of 75’-0” to a maximum height of 115’-0”. The increased length poles are required at crossings with overhead bridges and at locations where the proposed poles are located on the same side of the right of way as the existing OCS structures.
4. **Conductor Loadings.** Four distinct loading cases were evaluated for each different height pole. Resultant base moments, including wind loads on the structures and all applicable NESC overload factors, were determined in order to develop preliminary pole sections to be used in development of an estimate of probable construction costs. Pole types were classified as light, medium, or heavy depending on the magnitudes of the resultant base moments.

5. **Pole Details.** The design of the steel pole line utilizes 12-sided (dodecagonal) tapered steel poles ranging from 24 to 30 inches in diameter. Poles will be galvanized to provide protection against the elements and minimize the amount of required maintenance. Where pole lengths greater than 60’-0” are required, poles will be constructed in sections connected by an overlapping slip joint. Pole taper shall be uniform throughout the length of the pole and range in value from 0.75 to 0.40 inches per foot measured as a change in diameter.

6. **Pole Footings.** Drilled piers will be utilized as the preferred foundation for all pole installations. The concrete footings range in diameter from 3’-6” to 5’-0” and vary in depth from 14’-6” to 18’-6”. Diameters and embedment depths were analyzed to limit pole top deflection due to footing rotation to 1’-0”. Minimizing pole deflection will minimize the additional P-delta moments to be considered in the design of the poles.

**NEXT STEPS**

Final design of the substation and transmission line project has been completed and will be bid in late 2008 or early 2009. The anticipated construction duration is estimated between one and two years, with a summer of 2010 targeted completion date. Once completed, the south end of Amtrak’s systems will be strengthened to eliminate voltage fluctuations and increased impedances thereby eliminating nuisance tripping of vehicles, and also provide overall increased redundancy in the event of future system outages.
Figure 1 – 138 kV; 25 Hz Traction Power Operating Diagram

Figure 2 – Alternate Substation Site Locations

Figure 3 – Proposed Transmission Line Routing

Figure 4 – Commissary Site Equipment Arrangement

Figure 5 – Proposed Transmission Line Arrangement
U1 FEEDER - 1/C 795 MCM ACSR (900AMP CONT.)
U2 FEEDER - 1/C 400 MCM COPPER FROM LANDOVER
TO MP 133.96, 1/C 795 ACSR FROM
MP 133.92 TO UNION (APPROX. 730AMP CONT.)
12-SIDED TUBULAR POLE (# RANGES FROM 20.62" TO 34.04" AT THE BASE AND 9.10" TO 10.40" AT THE TOP)

TYPE 1181 POLYMER SUSPENSION INSULATOR, TYP.

STEEL DAVIT ARM, TYP.

EXISTING U1 12KV FEEDER WIRE

EXISTING U2 12KV FEEDER WIRE (TBR BY CONTRACTOR)

EXISTING 12KV 25HZ Catenary Wires

EXISTING Catenary Pole (With Pole Extension)

GUY WIRE

GROUND/Grade Level

EXISTING GUY ANCHOR FOUNDATION

EXISTING CATENARY POLE FOUNDATION

CONCRETE PIER DEPTH VARIES (3'-9" TO 5'-0")

10'-4" TRACK 1 10'-4" TRACK 2

12'-5 3/4" (PER AEO-1)

18'-0"

12'-0"

2502 2503

EXISTING RAIL RETURN CONDUCTOR

SIGNAL CONDUCTORS

4'-6"

9'-0"

75'-3"

58'-0"

44'-0"