

**THE AMERICAN RAILWAY ENGINEERING AND  
MAINTENANCE OF WAY ASSOCIATION**

Committee 11 (Commuter and Intercity Rail), Subcommittee D6: Signal, Communication  
and Propulsion Considerations

Letter Ballot Number 11-11-09

Chapter 11, Part 6, Section 6.5

Proposal: Addition of Chapter material to the AREMA Manual for Railway Engineering

Reason: New material to be included in the Manual.

Not Yet Approved

## **CHAPTER 11, PART 6, SECTION 6.5 PROPULSION SYSTEMS**

The information and guidance provided with respect to Electric Traction Power aspects of Commuter Rail Systems is reference only, and the reader should review Chapter 33 of the AREMA Manual for additional information on Electric Traction Power for commuter rail applications.

### **6.5.1 General**

When commuter rail service is electrified, electric traction power is comprised of power supply from utility companies to substations with power distribution by means of an overhead catenary or 3<sup>rd</sup> rail system. However, some systems require a mix of commuter; freight or high speed trains and the traction power system would need to be designed to handle mixed use.

### **6.5.2 Traction Power System (1996)**

The general outline of the power supply system is found in Chapter 33 of the AREMA manual as well as the Canadian and European electrification standards.

### **6.5.3 Lines to be Electrified**

All tracks of electrified commuter routes should be electrified for train operation purposes. Where commuter trains run on other routes for access to passenger terminals, to maintenance facilities or for through running purposes, only assigned tracks and alternates need be considered for electrification. Route/track diagrams can be used to verify the choice of operating scenarios with all affected departmental personnel of the railroads involved.

### **6.5.4 Performance to be Achieved**

The electric traction power demand for commuter trains is considerably higher due to capacity and station starts. It is recommended that all or most substations have two transformers, providing sufficient capacity in reserve to enable all conceivable power demands to be met with only one transformer in service. The use of dual transformers, dual power supply sources and dual bus bars provides a high level of redundancy and ensures that the probability of total loss of supply is extremely small.

In addition to reliable operation and performance of substation equipment discussed above, it is important that the utility company power supply maintain a very high level of reliability. There should be two separate sources of incoming power supply, preferably direct from major high voltage supply grid circuits with proven high availability ratings.

The safe electrical operation of the traction power system requires safety standards for insulator creepage paths, air clearances and electrical switching arrangements. The

switching and feeding subassemblies should provide for fault detection and protection relay operation, including zone relays, which can distinguish between heavy load currents and fault currents, and can attain virtually instantaneous disconnection of electrical supply when a fault condition occurs. Additional information can be found in the Chapter 33 of the AREMA Manual and the Canadian and European electrification standards.

### **6.5.5 Sectionalizing Diagram**

The full extent of the catenary system and associated substation, switching station and paralleling station locations should be shown on an electrical sectioning diagram. The catenary system should include sufficient sectioning to facilitate isolation of electrical faults to individually controlled sections of the operational track system. Starting with the normal feeding configuration, a number of disconnect switches are used to energize all catenary sections with all normal and alternate feeding scenarios.

Some disconnect switches may need to be included for abnormal situations such as the temporary loss of power supply from a substation or main feeding point, or the inadvertent stranding of a train at a phase break. Disconnect switches for these situations are normally open and would only be closed when the abnormal situation occurs, after appropriate adjustment from the normal arrangements. Additional information concerning the principles and normal sectionalizing practices recommended for use are provided in Chapter 33 of the AREMA Manual and the Canadian and European electrification standards.

### **6.5.6 Substation and Feeding and Supply Locations**

The selection of substation locations is an iterative process involving a number of factors which sometimes conflict with each other. The nature of commuter rail route or network and the situation of routine high power demand zones create natural locations for preferred siting of substations. The high reliability requirements for utility power supply sources will usually restrict the number of alternative locations to a few choices. The availability of environmentally acceptable substation sites may further limit those choices, especially in urban or scenic areas. A provisional scheme for substation siting should be developed and verification procedures should be applied by implementing a series of computer studies. More than one scheme may need to be studied in difficult situations, involving the alternative types of feeding systems available for use, and providing alternative solutions for management review. Further information and details of recommended procedures are provided in Chapter 33 of the AREMA Manual and the Canadian and European electrification.

### **6.5.7 Catenary System – General Description**

A catenary system provides the means of distribution of electrical power to moving railroad trains. All new catenary systems consist of a constant tensioned contact wire supported by one or more messenger wires which are in turn supported by brackets or

cross span assemblies on adjacent poles. Some older catenary systems have variable tensions with fixed wire dead ends. Detailed descriptions, definitions, standards and concepts relating to catenary systems are provided in Chapter 33 of the AREMA Manual and the Canadian and European electrification.

#### **6.5.8 Car Clearance Gage**

See Chapter 33 of the AREMA Manual and the Canadian and European electrification for information and guidelines on locomotive and car clearance gages, subject to potential super elevation, sway, tilt and bounce allowances relevant to electric train operations. In addition Chapter 28 of the AREMA manual has standard freight car clearances used in North America.

#### **6.5.9 Electrical and Mechanical Clearances**

See Chapter 33 of the AREMA Manual and the Canadian and European electrification for information and guidelines on electrical and mechanical clearances.

#### **6.5.10 Contact Wire Height**

The range of contact wire height on existing systems is normally controlled by the minimum height of overhead bridges and structures, together with the maximum height of contact wire necessary to comply with high wire clearance requirements at highway grade crossings or other facilities.

#### **6.5.11 Safety Considerations**

The use of high level platforms may generate additional electrical clearance safety considerations and compliance with the National Electrical Safety Code or equivalent National Code is required.

All overpasses and other overhead structures on electrified commuter rail routes will require the use of safety barriers in all areas of feasible pedestrian access. Barriers should be at least 6 feet 6 inches (1.98 m) high, should extend at least 10 feet (3.05 m) longitudinally from the nearest catenary, and should include features preventing any side access around the end of a barrier. The material usually selected is rigid aluminum sheeting, which should not include any protrusions providing feasible footholds for climbing access.

Grounded safety screens, barriers and anti-climbing guards should be included in the design of signals and other railway facilities and features within 10 feet of a catenary system, and the use of fencing or safety cages should be considered to prevent vandalism or unauthorized access when required by specific circumstances.

#### **6.5.12 Electrical Characteristics**

The electrical characteristics for Commuter Rail typically include sufficient power supply system capacity for sustained acceleration from station stops or from in-route delays up to the high operating speeds required. The electrical current demand for each train is substantially higher than for other types of passenger trains, due to the high drag coefficient at high-speed and the current drawn by onboard facilities. The use of motive power utilizing regenerative power capability may also be considered, subject to load limitation, traffic levels and potential for future growth, over-voltage prevention and harmonic content limitations.

#### **6.5.13 Grounding and Bonding**

The grounding system must prevent any risk of an unsafe condition occurring either within the electric traction system, at stations, or in the immediate surroundings along the right of way. The electric traction and signaling systems both require the use of appropriate bonding connections, circuits or other devices at project-specific spacings to ensure the fail-safe operations of trains and supporting infrastructure. Compliance with step-and-touch protection standards should be given high priority in all areas accessible to passengers and other non-railroad personnel.

#### **6.5.14 Catenary Safety Design**

The catenary industry applies local engineering and construction procedures to their relevant extent, together with appropriate input from overseas railroads. This composite design basis should be monitored to verify that all technical, operational and environmental safety requirements are adequately provided for, to the satisfaction of the appropriate regulatory organization. The following are some of the key requirements to be considered when an overhead electric catenary system is required for an electrified rail project.

#### **6.5.15 Conductor Parameters**

The conductors for an overhead catenary system consist normally of a contact wire supported by hangers from one or more messenger wires. The conductor tensions at each operating and non-operating limiting condition have to be reviewed to verify that adequate safety factors are provided. The recommended minimum safety factors for electrified rail projects are 2.5 on messenger wire tensions and 2.0 on contact wire tensions, relative to ultimate conductor breaking loads throughout the lifespan of the wire.

#### **6.5.16 System Features and Arrangements**

The operational performance requirements for commuter rail projects make it essential to incorporate some form of automatic tensioning into the catenary system. This feature compensates for temperature changes and maintains a constant high mechanical tension in the catenary conductors to facilitate optimum current collection performance. The need for automatic tensioning creates a number of special system features and

arrangements. These include catenary overlaps between individual tension lengths of catenary, typically spaced as needed at up to a maximum of about one mile (1.6 km), dependent upon the system design selected.

Some form of overrun protection should be provided wherever passenger trains are routed past facing connections with diverging non-electrified track. This will prevent safety and operational problems in the event of a raised pantograph being inadvertently routed onto the diverging track, with resultant potential teardown of overcrossing feeder, static, communications or signaling cables and wires. Overrun protection can be provided by adding short sections of catenary to guide diverging pantographs beyond overcrossing obstructions, or by raising or rerouting such obstructions beyond the maximum pantograph reach and sway.

#### **6.5.17 System Sub-Assemblies**

The automatic tensioning system has to cater for temperatures ranging from minimum ambient to maximum operating temperature, which includes provision for solar heating and peak levels of electrical load heating. The pulley/balance weight tensioning assemblies (or spring tensioners used where space is very restricted) can be fitted with inertial stops to hold the tensioning assemblies if sudden breakage of conductor occurs. Temperature stops can be provided to operate below a defined wire temperature, typically 20 degrees F. (-7 degrees C.) to restrict the amount of catenary system sag that would otherwise occur when heavy icing conditions are encountered, and to reduce the need for severe speed restrictions at such times.

#### **6.5.18 Poles and Foundations**

An additional consideration concerns the minimum and normal pole clearances from adjacent tracks. Where feasible, especially when applied to new construction, the normal clearance should be at least 14 feet (4.27 m) to provide for passage of a train with one or more derailed vehicles which are in the process of making an emergency stop, or experiencing a progressive derailment. Trackside features including catenary poles and foundations can be set back sufficiently to permit such passage without sideswipe contact and increased risk of injury to passengers and crew. The choice of pole design can include consideration of likely impact scenarios involving commuter trains to minimize the danger to passengers and crew. Features to be evaluated should include the style, ductility and break-away elements of poles considered for use.

#### **6.5.19 Catenary System Installation Design**

The catenary system selection and design process should consider how installation of the selected system can be undertaken in accordance with safe working practices and in compliance with OSHA and local regulatory requirements.

#### **6.5.20 Installation Procedures**

The design process should take full advantage of feedback from prior construction experience, and should avoid construction staging configurations that involve partly constructed system supports, conductors or other features which are structurally weak or incapable of withstanding severe weather conditions. If construction work has to be undertaken on an existing operating railroad, the catenary installation plan should be conceptually developed as a number of individual work stages, most requiring relatively brief on-track time and incorporating a maximum amount of advance subassembly work under more controllable conditions at a construction depot.

#### **6.5.21 Shop Drawings**

Wherever detailed design of material is part of a procurement contract scope of work, or where proprietary materials are being supplied, the contractor should be required to submit detailed shop drawings. These should illustrate the design, function, means of manufacture and specification appropriate to the specific item, and should give reference to the originating conceptual design or assembly drawing.

#### **6.5.22 Catenary Maintenance Manuals and Procedures**

Overhead catenary systems are typically designed to have a service life of at least 30 years, ranging up to 50 years in many instances. Systems are intended to be maintenance free, but the typical harsh railroad environment requires that effective preventive maintenance procedures be adopted. The use of specialized custom-built hardware also requires provision of supplier maintenance manuals, specifying necessary routine inspection activities.

#### **6.5.23 System Maintenance**

An overhead catenary system and its component items should be subjected to a number of prescribed periodic inspections to verify system functions and to check for component wear, misadjustments or faults. Correct functioning of automatic constant tensioning systems is of particular importance, and routine checks of termination assemblies should be carried out at regular intervals.

A dedicated maintenance team should be established at a strategic location, equipped with purpose-built hi-rail and wire train vehicles sufficient to carry out both routine maintenance and emergency repair tasks.

#### **6.5.24 Maintenance Standards**

Maintenance standards for electric traction systems should either be established as part of the design and installation basis, or be included in supplier documentation packages approved during procurement of equipment, hardware assemblies or components. Many maintenance standards will be identical or similar to construction acceptance standards and tolerances; a few may include additional tolerance or performance

nonconformance provisions not available to the original supplier or installation contractor.

The maintenance standards for catenary systems on commuter train routes require close conformance with contact wire heights and gradients to avoid high vertical acceleration of pantograph head assemblies, high contact forces or momentary loss of electrical supply to the locomotive. Some maintenance standards involve two or more levels of tolerance or other conformance parameters, which facilitate continuing operation on a degraded basis, that could include lower acceleration rates or lower maximum speeds, similar to track classification standards.

#### **6.5.25 Periodic Tests**

Part of the preventive maintenance program recommended for commuter rail routes should be a series of performance tests applied both to the power supply equipment and to the overhead catenary power distribution system. Power supply equipment testing can routinely include one or more operations of circuit breakers and disconnects which have no recorded operations within a defined period, typically one year.

Catenary system performance testing can routinely include one or more pantograph operation video recording along each main track of the commuter route. One video should be taken at or close to the maximum operating speeds along the entire route. If any degradation of pantograph performance is identified, a second video should be taken through route sections of interest or concern, with train speeds controlled to match the design balancing speeds through each curve. Direct comparison and joint evaluation of the two videos should help to establish the cause of any performance degradation, which typically could be related to track misadjustment, vehicle suspension misadjustment, pantograph frame joint deficiencies, catenary system misadjustment or any combination of deficiencies.

A permanent maintenance history log should be maintained for each power supply facility and for each electrical catenary section. This log could highlight any long term recurrence of deficient conditions, and help to develop corrective actions for implementation prior to system or equipment failure occurrences.

#### **6.5.26 Safety During Electrical Fault**

Electrical faults are caused by one or more factors, including inadvertent faults caused by wild animals and birds, insulation failures in power supply and catenary systems, or equipment failures on board locomotives or other motive power vehicles. All interconnected, energized equipment and systems have to be fully bonded throughout to prevent any possibility of floating electrical potential remaining in conductors, wires or equipment components when the traction power system is de-energized.

All non-energized metallic and other electrical conductive items including support poles and frames, line side fencing, station metalwork and all other such items within the

traction power system electrical zone of influence should be effectively grounded. Metal components should be bonded together and all assemblies and isolated items should be connected to a ground wire system, a ground grid or to grounding rods, in accordance with NESC requirements and electrification industry practice.

Circuit breaker and relay systems installed at power supply substations and switching stations provide protection against electrical faults. Each circuit breaker provides connection of electrical power from an energized bus bar to an individual region or track-specific section of the catenary system. The occurrence of an electrical fault would be detected by relays which cause the circuit breaker to open within a few milliseconds. Since many faults are transient in nature, most circuit breakers should be set to reclose automatically within a few seconds to restore power to the section. If the fault persists, the circuit breaker will lock open until the fault is investigated and repaired. Special distance zone type relays should be used to differentiate between high traction power loads and actual faults.

The circuit breakers for catenary sections at yards, station platforms and other areas where passengers or railroad personnel are routinely present should not reclose onto a fault, but instead should lock out immediately for on-site investigation of the fault cause and affects.

#### **6.5.27 Safety During Switching Operations**

The switching of electrical power is carried out in accordance with prescribed procedures by authorized personnel at an electrification system control center that would usually control an entire route or region. The procedures used should include some form of interlock or logic data-based system to prevent simultaneous supply of power to a section from more than one source, phase or substation, particularly when alternate feed arrangements have to be implemented while a fault is being investigated and rectified.

Safety measures adopted include siting of all switching equipment in high security situations, compounds or buildings, with intrusion detection systems connected to the control center for all facilities which are normally unattended.

#### **6.5.28 Safety During Maintenance Operations**

Maintenance of traction power supply and catenary system facilities should be preplanned for implementation during light traffic periods or during short overnight system shutdowns. All access and work activities should be in accordance with prescribed procedures that prevent any approach within specified limitations until all power has been disconnected and permanent or temporary grounds have been installed at either or both sides of the access area. Any circuit breakers or disconnects that could be inadvertently closed and reenergize the area of access should be locked open and tagged by the person responsible. The tags should not be removed until all personnel have been accounted for as being outside the specified access limitations and maintenance grounds have been removed or disconnected, and the tags should

only be removed by the person who initially placed them. The remote operation of circuit breakers and disconnects may require supplementary safety procedures to achieve safety of personnel and equipment.

Safety during specific maintenance activity requires that all personnel should clearly understand and acknowledge the limits of temporary access, and should be fully trained, regularly certified and checked in respect of their knowledge and familiarity with maintenance procedures and activities being undertaken.

#### **6.5.29 Pollution/Contamination**

Past experience on railroad electrification projects included the need for mitigation of industrial air pollution and contamination. Most harmful forms of air pollution have now been eliminated, but some benign contamination still exists in unique local circumstances. Such contamination may occur naturally and its presence should be recognized by incorporation of appropriate design features, treatments or materials. One typical example is the presence of high salt concentrations in moist onshore winds at route sections along stretches of sea or ocean coastline.