GENERAL ORDER No. XXX-X

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PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

SAFETY RULES AND REGULATIONS GOVERNING
25 kV AC RAILROAD ELECTRIFICATION
FOR THE OPERATION OF HIGH SPEED TRAINS

Adopted Month Day, 201X
Effective Month Day, 201X
Decision XX

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FIGURES

TABLES

1 SCOPE

1.1 PURPOSE

The purpose of these rules is to establish uniform safety requirements governing the design, construction, operation and maintenance of 25 kV ac (alternating current) Overhead Contact Wire Electrification Systems, which are to be constructed under the California High Speed Train Project (CHSTP), for the operation of High Speed Trains (HSTs) in the State of California. The correct application of these rules will promote the safety and security of the general public and persons engaged in the construction, maintenance, and operation of the 25 kV electrified high speed railroad.

1.2 APPLICATION

These rules apply to the 25 kV Overhead Contact Systems that will provide power to the CHSTP electrified high speed railroad system within the jurisdiction of the California Public Utilities Commission. They apply to all such installations that are planned, acquired or constructed on or after the date of the issuance of this General Order.

1.3 ABBREVIATIONS

AISC	- American Institute of Steel Construction
AREMA	- American Railway Engineering and Maintenance of Way Association
CAC	- California Administrative Code
CHSTP	- California High Speed Train Project
CPUC	- California Public Utilities Commission
EN	- Euro Norm - European Standards
GO	- General Order
IEEE	- Institute of Electrical and Electronics Engineers
NESC	- National Electrical Safety Code
TSI	- Technical Specification for Interoperability of the Trans-European High Speed Rail System

1.4 REFERENCES

Document	*Revision*	*Title*
AISC Manual	N/A	Steel Construction Manual, 14th Edition
AREMA Manual	2010	AREMA “Manual for Railway Engineering” Chapter 33 Electrical Energy Utilization
EN 50119	2001	Electric Traction Overhead Contact Lines
EN 50122-1 Part 1	2011	Protective Provisions Relating to Electrical Safety and Earthing
CAC Title 8	N/A	Electric Safety Orders of the State of California
IEEE C2	2007	National Electrical Safety Code

IEEE 80	2000	Guide for Safety in AC Substation Grounding
IEEE 142	1991	Recommended Practice for Grounding of Industrial and Commercial Power Systems
CPUC GO No. 22-B	1959	Regulations Governing Reports of Accidents on Railroads
CPUC GO No. 26-D	1981	Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structure Parallel Tracks, Crossings of Public Roads, Highways and Streets
CPUC GO No. 95	2006	Rules for Overhead Electric Line Construction
CPUC GO No. 164-D	2007	Rules and Regulations Governing State Safety Oversight of Rail Fixed Guideway Systems
TSI Energy	2008	Technical Specifications for the Interoperability of Electrical Energy Subsystems

2 DEFINITIONS

2.1 AERIAL GROUND WIRE – see Static Wire

2.2 AGENCY

The railroad or other jurisdictional entity that is responsible for the operation and maintenance of the railroad.

2.3 AUTHORIZED PERSON

Any person, who has been authorized by the Agency to enter restricted areas of the property.

2.4 AUTOTRANSFORMER

Apparatus which helps boost the catenary voltage and reduce the running rail return current in the 2x25kV autotransformer feed configuration. It uses a single winding having three terminals. The intermediate terminal, located at the midpoint of the winding, is connected to the rail and the static wires, and the other two terminals are connected to the catenary and the negative feeder wires, respectively.

2.5 AUTOTRANSFORMER FEED SYSTEM

A traction power feeding system in which the main transformers and autotransformers are fitted with a single secondary winding having three terminals. The intermediate terminal is connected to the running rails/ground and the other two are connected one to the catenary conductors over the tracks and one to the parallel negative feeder(s).

2.6 BALANCE WEIGHT ANCHOR (BWA)

Catenary conductor tensioning equipment, comprising a pulley system and a weight, which is located at the termination points of the conductors, and which maintains essentially constant tension in the conductors in an auto-tensioned catenary system.

2.7 BARRIER

Equipment provided to prevent entry by an unauthorized person to a restricted area, structure or building, which also provides physical protection against direct contact with energized parts from non-normal directions of access.

2.8 BOND

An electrical connection from one conductive element to another for the purpose of maintaining a common electrical potential (equi-potential).

2.9 BONDING CONDUCTOR

A conductor for ensuring equi-potential bonding.

2.10 CATENARY SYSTEM

That part of an Overhead Contact System which comprises a Messenger Wire supporting a Contact Wire by means of a number of Hangers.

2.11 COLLECTOR HEAD

That part of the pantograph which runs under and in contact with, and collects current from the overhead contact wire or conductor rail.

2.12 CONTACT WIRE

A solid grooved, bare aerial, overhead electrical conductor of an Overhead Contact System that is suspended above the rail vehicles and which supplies the electrically powered vehicles with electrical energy through roof-mounted current collection equipment – pantographs - and with which the current collectors make direct electrical contact.

2.13 COUNTERPOISE

A buried wire or a configuration of wires constituting a low resistance grounding system or portion of a grounding system

2.14 CROSS BOND

An electrical bond that interconnects the running rails which, in signalized territory, must be connected through impedance bonds.

2.15 DE-ENERGIZED

A normally energized part or conductor that has been disconnected from all sources of electrical supply.

NOTE: this does **not** imply a grounded condition or ensure a safe state.

2.16 DIRECT CONTACT

Contact with energized parts.

2.17 DIRECT FEED SYSTEM

A traction power feeding system in which the transformers are fitted with a single secondary winding having two terminals. One terminal is connected to the running rails/ground and the other to the catenary conductors over the tracks.

2.18 DIRECT TRACTION SYSTEM GROUNDING

The direct connection between conductive parts and the traction system ground.

NOTE: Grounding via impedance bonds, required by reason of signaling system track circuit considerations, is considered to be direct grounding.

2.19 EFFECTIVELY GROUNDED

Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to limit the build-up of voltages to levels below which undue hazards to persons or to connected equipment may result.

2.20 ELECTRICAL CLEARANCES

a. Passing (Dynamic) Electrical Clearance is defined as the minimum permissible clearance distance between the messenger wire, contact wire, pantograph, or other live parts of either the vehicle or OCS and the grounded vehicle load gauge, overhead structure, or other adjacent fixed structure under dynamic operating conditions, such as during the short time it takes a train to pass or in adverse climatic conditions, such as temperature and/or wind and/or ice loading and/or conductor current heating, when the conductors are not stationary.
b. Static Electrical Clearance is defined as the minimum permissible clearance distance between live parts of either a vehicle pantograph or the OCS, when not subjected to the passage of an electrically powered vehicle equipped with a pantograph, and grounded (earthed) parts of either a vehicle or adjacent fixed structure, while the vehicle is stationary. Static clearances (not passing clearances) should be applied to the design of the OCS and maximum car profile (including any load) in stations, terminals and yards, or wherever vehicles may remain stationary for extended periods.
c. Safety Clearance is the distance in a straight line between a standing surface accessible to persons and energized parts that is necessary to prevent direct contact with energized parts, without the use of objects, as defined in EN 50122-1: 2011 Section 5.

2.21 ELECTRICAL SECTION

This is the entire section of the OCS which, during normal system operation, is powered from a substation (SS) feeder circuit breaker. The SS feed section is demarcated by the phase breaks of the supplying SS and by the phase breaks at the adjacent switching station (SWS) or line end. An electrical section may be subdivided into smaller elementary electrical sections.

2.22 ELEMENTARY ELECTRICAL SECTION
This is the smallest section of the OCS power distribution system that can be isolated from other sections or feeders to the system by means of disconnect switches and/or circuit breakers.

2.23 ELECTRIC SHOCK
The effect of an electric current passing through the human body.

2.24 ENERGIZED
Electrically connected to a source of potential difference, or electrically charged so as to have a potential significantly different from that of the ground in the immediate vicinity.

2.25 ENERGIZED PART
An energized part is a conductor or conductive part that is energized under normal service conditions, but does not include the running rails or parts connected to them. Energized parts include roof-mounted equipment on electric vehicles, such as pantographs, train-line conductors, and resistor units. The full length of insulators connected to energized parts shall be classified as energized when considering electrical clearance requirements.

2.26 ENTRANCE
A designated means or point of access to or egress from traction power facilities and/or trackside.

2.27 FAULT CONDITION
The presence of an unintended and undesirable conductive path in an electric power system.

2.28 FEEDER
A current-carrying electrical connection between the OCS and a traction power facility (substation, paralleling station or switching station). Also, an overhead conductor supported on the same structure as the OCS.

a. In an auto-transformer feed system, the feeder (often termed the negative feeder) is a paralleling conductor that is electrically separate from the catenary conductors over the tracks. This parallel (negative) feeder connects successive feeding points, and is connected, via a circuit breaker(s) and/or disconnect switch(es), to one terminal of a main power supply transformer or an auto-transformer in the traction power facilities. At these facilities, the other terminal of the main power supply transformer or auto-transformer is connected to a catenary section or sections, via circuit breakers or disconnect switches.
b. In a direct feed system or at other locations, the feeder is a paralleling conductor that can be connected at frequent intervals to the OCS to provide localized electrical reinforcement of the circuit by increasing the effective cross-sectional area of the electrical system in that section.

2.29 GROUNDED
Connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to limit the build-up of voltages to levels below that which may result in undue hazard to persons or connected equipment.

2.30 GROUNDING CONDUCTOR
A conductor that is used to connect equipment or wiring systems to a ground electrode or ground grid

2.31 HIGH VOLTAGE
A nominal voltage of 600 Volts or more

2.32 IMPEDANCE BOND
An electrical device located between the rails consisting of a coil with a center tap used to bridge insulated rail joints in order to prevent track circuit energy from bridging the

insulated joint while allowing the traction return current to bypass the insulated joint. The center tap can also be used to provide a connection from the rails to the static wire and/or traction power facilities for the traction return current.

2.33 INSULATED RAIL JOINT

A joint in the running rail used to prevent track circuit energy on one side of the joint from leaking to the other side of the joint.

2.34 LEAKAGE CURRENT

A current that flows to ground or to extraneous conductive parts in a circuit, following a path or paths other than the normal intended path, but which is not of sufficient magnitude to create a fault.

2.35 MESSENGER WIRE

In catenary construction, the OCS Messenger Wire is a longitudinal bare stranded conductor that physically supports the contact wire or wires either directly or indirectly by means of hangers or hanger clips and is electrically common with the contact wire(s).

2.36 NOMINAL VOLTAGE

Voltage by which an installation or part of an installation is designated.

NOTE: The operating voltage of the OCS may differ from the nominal voltage by a quantity within permitted tolerances as stated in Section 4.1.2.

2.37 NORMALLY NON-CURRENT-CARRYING PARTS

Metallic parts within the railroad right-of-way which do not normally carry load currents, return currents, or fault currents.

2.38 OCS POLE

Vertical structural element supporting the overhead contact system equipment, which provides physical support, registration and/or termination of the OCS conductors including ancillary wires or cables.

2.39 OVERHEAD CONDUCTOR RAIL

A rigid metallic conductor, which substitutes for the contact wire and is mounted on insulators under a fixed overhead structure.

2.40 OVERHEAD CONTACT SYSTEM (OCS)

An OCS is comprised of:

a. The aerial supply system that delivers 2x25 kV traction power from substations to pantographs of high-speed electric trains, comprising the catenary system messenger and contact wires, stitch wires and hangers, associated supports and structures (including poles, portals, headspans and their foundations), manual and/or motor operated isolators, insulators, phase breaks, conductor terminations and tensioning devices, downguys, and other overhead line hardware and fittings.
b. Portions of the Traction Power Return System consisting of the negative feeders and aerial static wires, and their associated connections and cabling.

2.41 PANTOGRAPH

Current collector apparatus consisting of spring-loaded hinged arms mounted on top of electrically powered rail vehicles that provides a sliding electrical contact and collects current from the contact wire of the overhead contact system. The pantograph is designed to follow changes in the vertical height and lateral offset of the contact wire or conductor rail, and to provide for essentially vertical movement of the pantograph collector head.

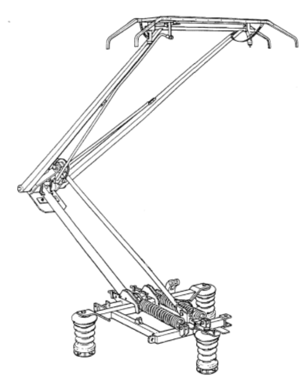


Figure 2-1 Typical Pantograph

2.42 PARALLELING STATION (PS)

An installation which helps boost the catenary voltage and reduce the running rail return current by means of the autotransformer feed configuration. The negative feeders and the catenary conductors are connected to the two outer terminals of the autotransformer winding at this location with the central terminal connected to the rail return system. The OCS sections can be connected in parallel at PS locations.

2.43 PAVED AREAS

In selected areas of maintenance facilities, yards and shops, the trackway may be paved to the upper level of the running rails to provide for the crossing of maintenance vehicles over the tracks and under the overhead conductors.

2.44 PHASE BREAK

An arrangement of insulators and grounded or non-energized wires or insulated overlaps, forming a neutral section, which is located between two sections of catenary that are fed from different phases or at different frequencies or voltages, under which a pantograph may pass without shorting or bridging the phases, frequencies or voltages.

2.45 PUBLIC AREA

Station free areas and paid areas, accessible to the general public.

2.46 QUALIFIED PERSON

In regard to traction electrification system equipment, an authorized person who has been trained in and has demonstrated adequate knowledge of the installation, construction, maintenance, and operation of the TES equipment and the hazards involved, including identification of and exposure to electric supply and communications lines and equipment in or near the workplace.

2.47 RAIL JOINT BOND

A conductor that ensures the electrical continuity of a running rail at an uninsulated, bolted rail joint

2.48 RAIL POTENTIAL

The voltage between running rails and ground occurring either under operating conditions, when the running rails are being utilized for carrying the traction return current, or under fault conditions.

2.49 RAIL RETURN SYSTEM

The combination of track structure, jumpers, impedance bonds, static and/or ground wires, grounds and cables each of which provides a part of the electrical return path from the wheel-sets of the traction units to the substations.

2.50 RAIL TO GROUND RESISTANCE

The electrical resistance between the running rails and the earth

2.51 RAILROAD OR RAILWAY ENVIRONMENT

The area immediately adjacent to the running rails generally referred to as the railroad or railway right-of-way, that is subject to the noise, vibration and air pressure of trains operating at high speed, and to the effects of the voltages, currents and electric and magnetic fields associated with a 25 kV ac TES.

2.52 REGENERATIVE BRAKING

A system in which the drive motors of the electric vehicles are converted to generators and provide dynamic braking of the vehicle, while at the same time returning power to the OCS that can be used by receptive vehicles on the system or can be returned to the utility at the traction power substations.

2.53 RESTRICTED AREA

An area for which a railroad agency has responsibility and to which access is permitted only to authorized persons.

2.54 RETURN CABLE
A conductor that forms part of the TES return circuit, and which connects the rest of the return circuit to the substation.

2.55 RIGHT OF WAY CLASSIFICATION
The Right-of-Way (ROW) classification for the CHSTP shall be Exclusive - a railroad or railway right-of-way without at-grade crossings, which is grade-separated or protected by a fence or substantial barrier, as appropriate to the location.

2.56 RUNNING RAILS
The steel rails on which the rail vehicles run and which, in an electrified system, form part of the traction return circuit. The running rails may also be used for signal system track circuits, in which case special measures must be implemented to permit joint use with electrification.

2.57 SCREEN
A barrier that prevents unintentional direct contact with energized parts but will not totally prevent direct contact by deliberate action.

2.58 SHORT CIRCUIT
An accidental or intentional conductive path between two or more conductive parts forcing the electrical potential differences between those conductive parts to be equal to or close to zero.

2.59 SHORT CIRCUIT CURRENT OR FAULT CURRENT
The electric current flowing through the short circuit or fault path.

2.60 STANDING SURFACE
Any point on a surface where persons may stand or walk.

2.61 STATIC WIRE (AERIAL GROUND WIRE)
A wire, usually installed aerially adjacent to or above the catenary conductors and negative feeders, that connects OCS supports collectively to ground or to the grounded running rails to protect people and installations in case of an electrical fault. In an ac electrification system, the Static Wire forms part of the traction power return circuit and is connected, via impedance bonds, to the running rails at periodic intervals and to the traction power facility ground grids. If mounted aerially, the static wire may also be used to protect the OCS against lightning strikes.

2.62 STEP VOLTAGE
The difference in surface potential experienced by a person bridging a distance of 3 feet 3 inches (1 m) with the feet, without contacting any grounded object.

2.63 STITCH WIRE
The stitch wire is a supplementary tensioned conductor that is attached to the messenger wire and positioned at the supports with hangers supporting the contact wire. The spring effect of the stitch wire and hanger arrangement enhances the elasticity of the catenary at the support and provides for a better match with the mid-span elasticity of the catenary, thereby providing improvement in the quality of the current collection.

2.64 STRAY CURRENT
A current which follows a path or paths other than the intended electrical path (see Leakage Current).

2.65 SUPPORTS
The structural elements that support the conductors and their associated line hardware and insulators in an OCS.

2.66 SURGE ARRESTER OR SURGE SUPPRESSOR

A protective device for limiting surge voltages on equipment by discharging or by-passing surge current; it limits the flow of power follow-on current to ground, and is capable of repeating these functions.

NOTE: Sometimes referred to as a Lightning Arrester.

2.67 SWITCHING STATION (SWS)

An installation at which electrical energy can be supplied to an adjacent, but normally separated electrical section during contingency power supply conditions. It also acts as a Paralleling Station.

2.68 TOUCH VOLTAGE

The potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure.

2.69 TRACK CIRCUIT

An electrical circuit which uses the track rails as the conductors between transmit and receive devices, the limits of which are often defined by the location of insulated joints. The primary purpose of the track circuit is to detect an occupancy or interruption. It may also be used to convey information.

2.70 TRACTION ELECTRIFICATION SYSTEM (TES)

An electrical power supply and distribution network used to provide energy for railroad rolling stock. The system may comprise:

a. Overhead contact system (OCS);
b. Return system, including the running rails, static (ground) wire, impedance bonds, negative feeders, return cables, and grounding/bonding interconnections;
c. Running rails of non-electric traction systems, which are in the vicinity of and conductively connected to the running rails of an electric traction system;
d. Electrical installations in the traction power facilities - substations, switching stations, paralleling stations - which are utilized for the supply and distribution of power to the OCS
e. Interfaces to the Supervisory Control and Data Acquisition (SCADA) System for monitoring and control of all TES subsystems.

2.71 TRACTION POWER SUBSTATION (SS)

An electrical installation where power is received at high voltage and is transformed to the voltage and characteristics required at the catenary and the negative feeders for the nominal 2x25 kV system, containing equipment such as transformers, circuit breakers and sectionalizing switches. It also includes the incoming HV lines from the power supply utility.

2.72 TRACTION POWER SUPPLY SYSTEM

The electrical power supply network used to provide energy to high-speed electric trains, which comprises three types of traction power facilities - substations (SS), switching stations (SWS) and paralleling stations (PS) - in addition to connections to the OCS and to the traction return system.

2.73 TRACTION RETURN CURRENT

The sum of the currents returning to the supply source (i.e., the substation)

2.74 TRACTION POWER RETURN SYSTEM

All conductors, including the grounding system for the electrified railway tracks, which form the intended path for the traction return current from the wheel-sets of the traction units to the substations under normal operating conditions and the total current under fault conditions. The conductors may be of the following types:

a. running rails;
b. impedance bonds;
c. static wires, and buried ground or return conductors;
d. rail and track bonds;
e. return cables, including all return circuit bonding and grounding interconnections;
f. earth

and as a consequence of the configuration of the autotransformer connections, the negative feeders.

2.75 TRACTION SYSTEM GROUND

The traction system ground consists of the running rails, the aerial static wires and all conductive parts connected thereto and which are solidly connected to ground.

2.76 TRACTION SYSTEM GROUNDING

Connection between non-energized metallic parts and the traction system ground

2.77 TUNNEL GROUND

The electrical interconnection of the reinforcing steel in reinforced concrete tunnels and, in the case of other modes of construction, the conductive interconnection of the metallic parts of the tunnel.

NOTE: In the case of single-phase ac traction systems, the tunnel ground is connected to the running rails and thus forms part of the traction system ground which may be supplemented by external ground connections to earth.

2.78 UPLIFT

The vertical distance by which the overhead contact system is raised during the passage of a pantograph

2.79 VOLTAGE-LIMITING DEVICE

A protective device which operates to prevent the permanent existence of a dangerously high step or touch voltage

3 SYSTEM DESCRIPTION

3.1 SYSTEM

3.1.1 The California High Speed Train Project (CHSTP) will use a 25 kV, 60 Hz, single phase ac (alternating current), Traction Electrification System (TES) to provide traction power to the electrically-hauled rolling stock, drawing power from an aerial overhead contact system, and travelling at speeds possibly as high as 250 mph (400 km/hr) in dedicated high speed corridors and up to 125 mph (200 km/hr) in shared use corridors. The TES comprises three primary elements

- the traction power supply system (TPS),
- the overhead contact system (OCS), and
- the rail return system,

which will be constructed along the length of the railroad right-of-way to provide power to the high speed electric vehicles.

3.1.2 The rules in this General Order define the functional safety requirements for the design, installation, operation and maintenance of the overhead contact and return systems, which include:

a. Catenary system messenger and contact wires, auxiliary wires, including associated supports and structures, isolators, insulators, terminations, phase breaks, downguys, and other overhead line hardware fittings
b. Negative feeders
c. Rail return system, including aerial static (ground) wires.

3.1.3 The traction power supply system comprising the traction power supply facilities – substations, switching stations and paralleling stations - will be constructed in accordance with the requirements and rules relevant to high voltage substation facilities. The rules identified in this General Order do not apply to those facilities. However, for completeness of the system description, information regarding the functional interfaces between those facilities and the OCS and the rail return system are included herein.

3.1.4 The following sections describe the typical railroad operations, followed by details of a typical TES and the major components that comprise the OCS and the rail return system and the traction power supply system.

3.2 OPERATIONS

3.2.1 The CHSTP will provide high-speed train service in the State of California connecting San Francisco and Sacramento in the north with Los Angeles and San Diego in the south. For much of the alignment, high speed trains will operate along dedicated track with stations that exclusively serve high speed train operations. There are also two segments (the Los Angeles to Anaheim and San Francisco to San Jose – the Metrolink and Caltrain corridors) where the California High Speed Rail (CHSR) line will operate within a shared right-of-way with conventional passenger railroad lines. Diesel or diesel-electric hauled trains are not precluded from and may share operations over the electrified lines in the shared-use corridors.

3.3 TRACTION ELECTRIFICATION SYSTEM (TES)

3.3.1 Electric traction power is supplied to the vehicles from the wayside power supply facilities through the catenary, which distributes the power through one or more wires. Hinged pantographs, which can accommodate variations in the contact wire height, are mounted on the vehicles and collect the traction power by running under and in contact with the contact wire. The negative feeders, running rails of each track, together with the static or ground wire(s), and earth ground are used as the electrical path for the traction power return.

3.3.2 An auto-transformer power supply system has been selected for the CHSTP – refer to Figure 3-1 for a simplified version of the feeding arrangements at a traction power supply substation. In this system, parallel negative feeders at a voltage of 25 kV to ground interconnect between the transformers in the main substations to autotransformers in the paralleling stations and switching stations to provide electrical reinforcement to the catenary system, which also operates at a voltage of 25 kV to ground leading to the common-use term of "2x25 kV" for this type of system. There is a 180 degree phase difference between the voltages of the parallel negative feeders and the catenary system, giving a 50 kV phase to phase voltage difference between these conductors.

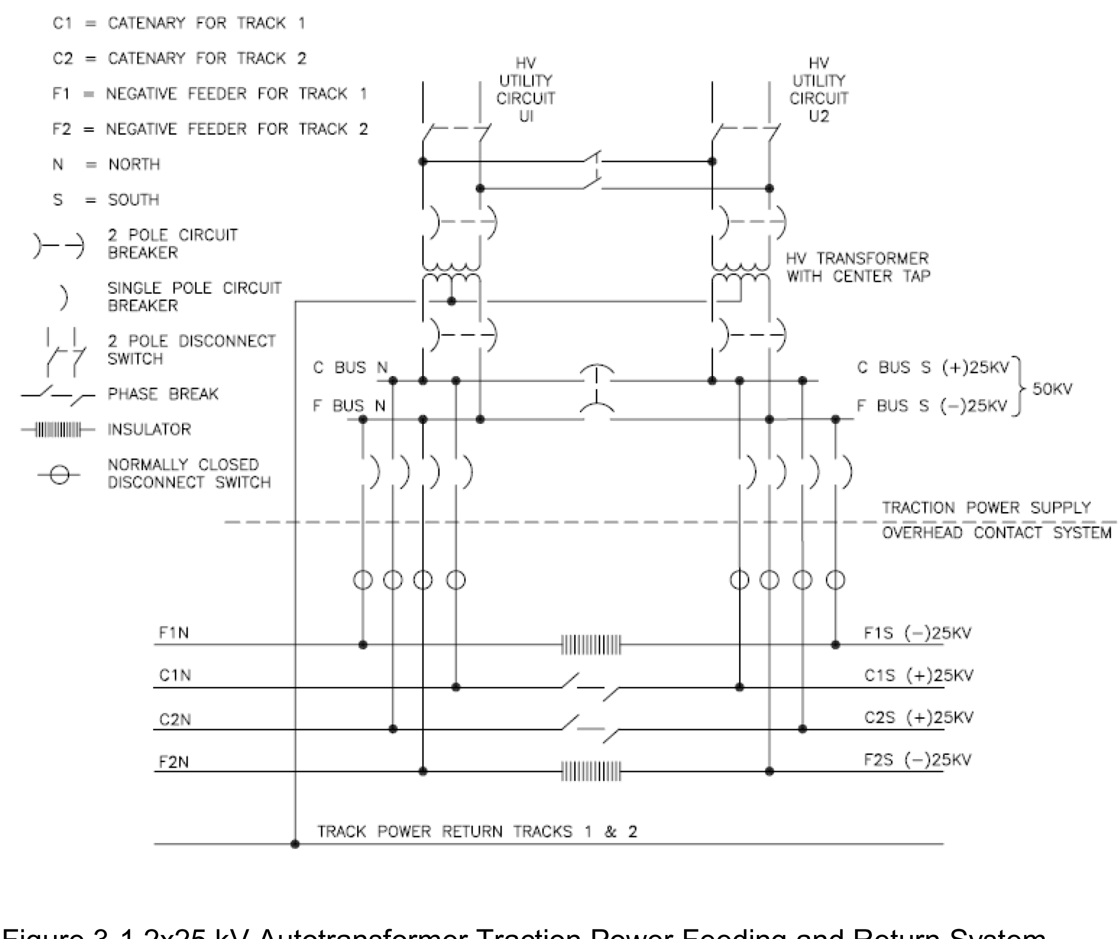


Figure 3-1 2x25 kV Autotransformer Traction Power Feeding and Return System
Static Wire and Ground Return omitted for clarity

The following three major elements comprise a 25 kV ac TES:

Traction Power Supply System
Catenary System and Parallel Negative Feeders
Rail Return System, including Aerial Static (Ground) Wires

3.3.3 Traction Power Supply System

Traction Power Substations (SS) transform utility power to the TES operating voltage, and supply the single phase 25 kV ac traction power to the catenary system and the negative feeders. To support the power distribution system, the traction power supply system also incorporates Switching Stations (SWS) and Paralleling Stations (PS). Major equipment in these facilities includes, but may not be limited to:

a. switchgear
b. transformers
c. interconnecting bus work
d. insulated cables and bare conductors
e. grounding and bonding systems
f. metering, relaying and control equipment, with inter-connection to one or more control centers.

NOTE: The rules in this General Order do not cover the above facilities. These facilities are to be constructed, operated and maintained in accordance with the requirements of existing general order(s) or other code requirements of the State of California.

3.3.4 Catenary System and Parallel Negative Feeders

The Catenary System supplies power to the vehicles, and includes the aerial conductors, insulators, line hardware, support brackets, and support structures and their associated foundations. Mainline high speed systems generally utilize a Simple Catenary System, in which an energized and current carrying messenger wire (MW) supports a contact wire (CW) by means of in-span wire hangers. Some systems use a Compound Catenary System, in which a supplemental or auxiliary messenger wire is positioned between the main MW and the CW to provide additional current carrying capacity. In a compound catenary, in-span wire hangers from the main MW support the auxiliary MW, from which hangers support the CW. In both catenary styles, all conductors and hangers are energized and are part of the current carrying system.

The parallel negative feeders will normally be bare conductors mounted aerially on stand-off insulators on the OCS poles. In some restricted clearance locations, insulated cables may have to be substituted for the bare conductors.

a. For the high speed segments of the CHSTP, where trains will operate at over 125 mph, a typical configuration for the OCS could comprise an auto-tensioned (AT), stitched simple catenary, which consists of a MW supporting a level CW by means of hangers and a stitch wire at the support locations, - refer to Figure 3-2, which shows a single track pole and cantilever application.

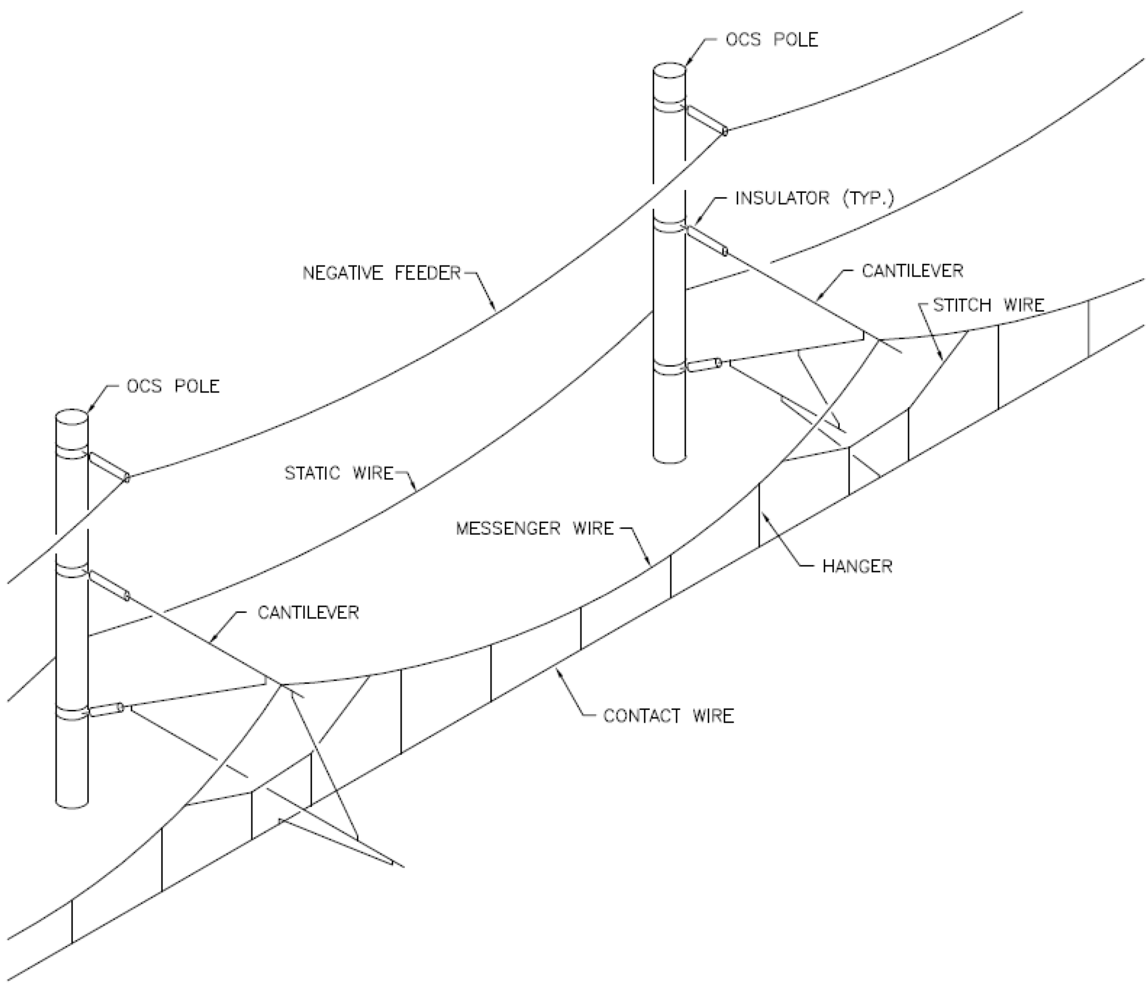


Figure 3-2 Stitched Simple Catenary OCS with Level Contact Wire

b. For high speed operations up to 125 mph, a typical configuration could be a simple catenary without a stitch wire, supporting either a level or pre-sagged CW. In a pre-sag arrangement, the mid-span CW height is lower than the CW height at the supports – refer to Figure 3-3, which shows a single track pole and cantilever application.

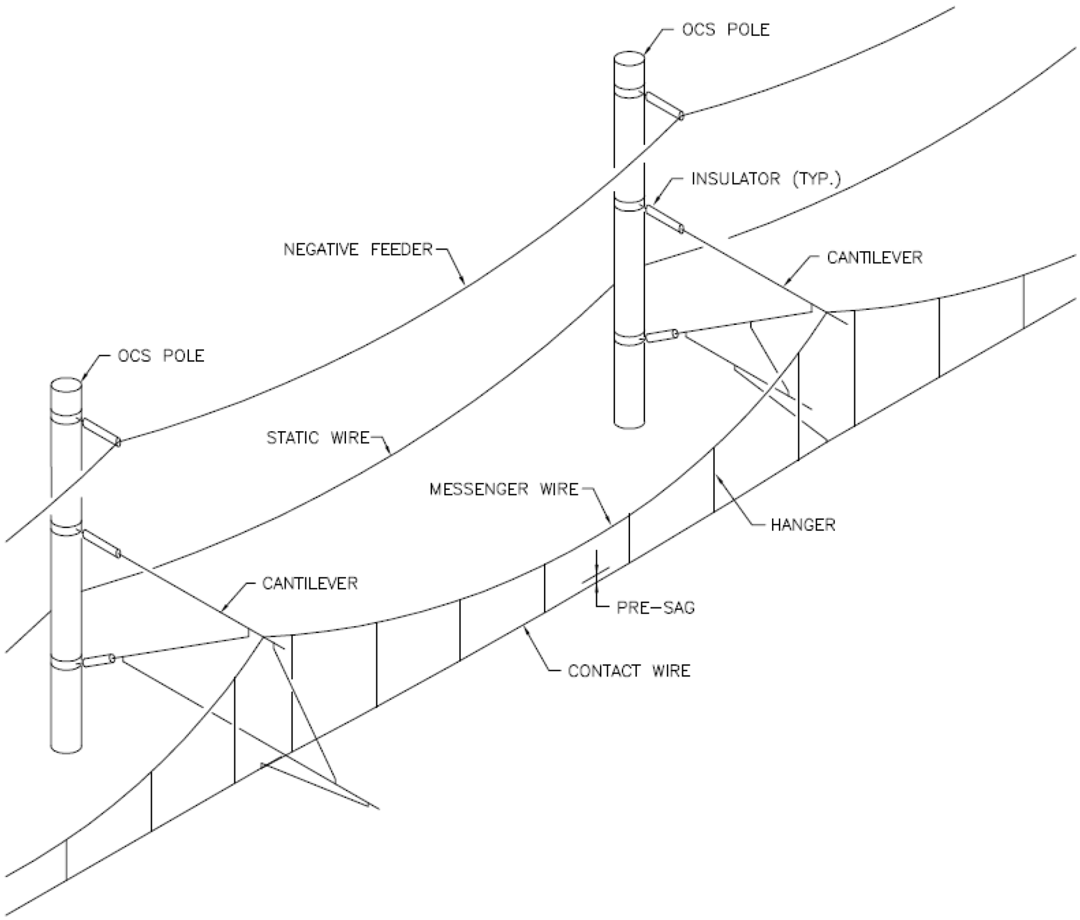


Figure 3-3 Simple Catenary OCS with Pre-Sagged Contact Wire

c. Simple AT catenary is usually tensioned by means of balance weight anchors (BWAs) located at the termination points of the conductors, often with different configurations dependent on system operating speed – refer to Figures 3-4 and 3-5.

For high speed operations over 125 mph, the messenger wire and contact wire are typically tensioned by means of separate, individual BWA units.

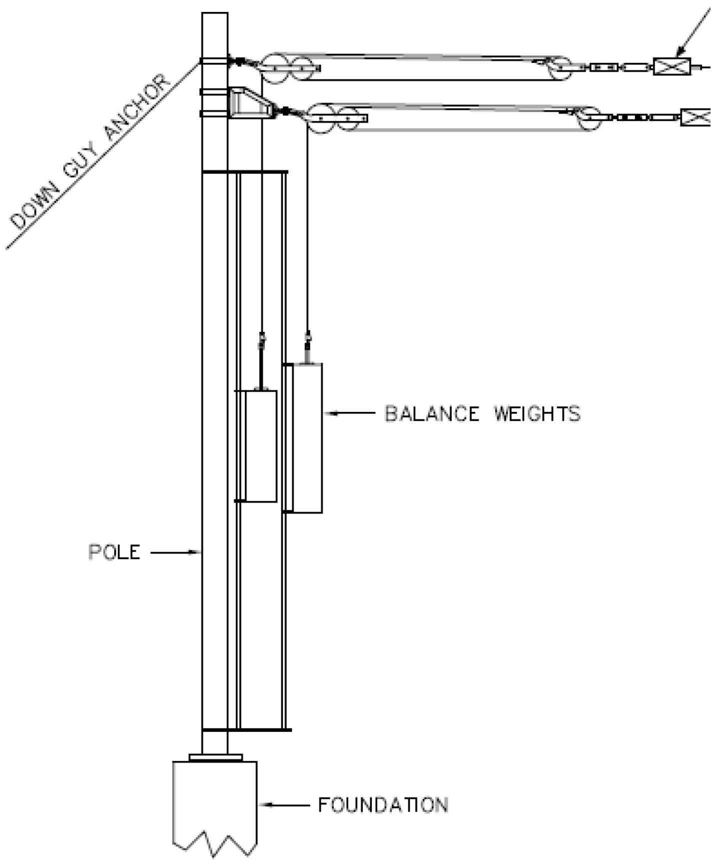


Figure 3-4 Typical Double Balance Weight Assembly for High Speed Operations at Speeds over 125 mph

For CHSTP operations up to 125 mph, the MW and CW could be terminated on a yoke plate, which connects both wires to a single BWA tensioning unit.

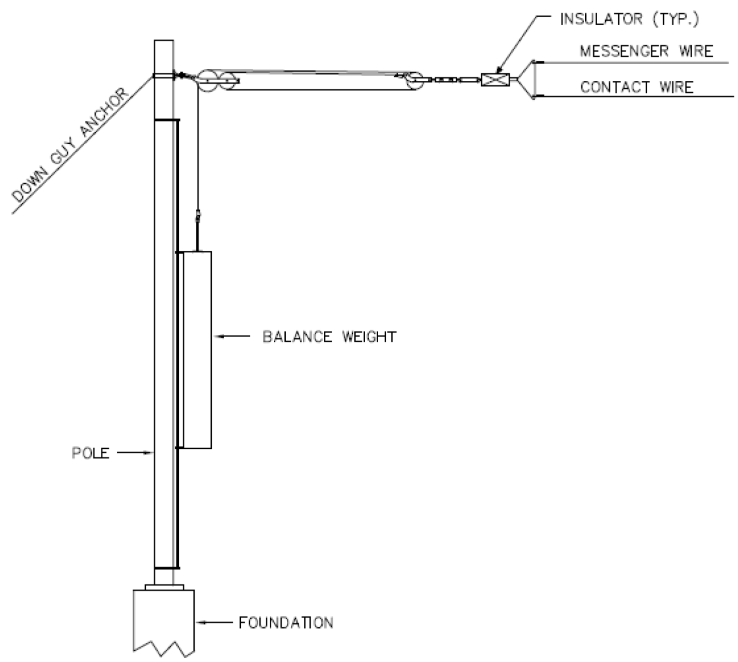


Figure 3-5 Typical Single Balance Weight Assembly with Yoke Plate for Conductor Terminations for Operations at Speeds up to 125 mph

With both of these auto-tensioning arrangements, essentially constant conductor tensions are maintained throughout a large temperature range. Variations on the typical arrangements shown above or other tensioning devices or methods may also be employed, if appropriate. Regardless of the auto-tensioning method employed, constant wire heights, clearances and safety factors must be assured under the full range of environmental and operating conditions.

d. At end-of-line mainline passenger terminals and in yards and shops, where operating speeds are very slow, an AT or fixed termination (FT) simple two-wire catenary system with hanger lengths adjusted to provide for a level CW could be used. Alternatively, at these locations an AT or FT Single Contact Wire OCS may be selected – refer to Figure 3-6, which shows a single track pole and cantilever application.

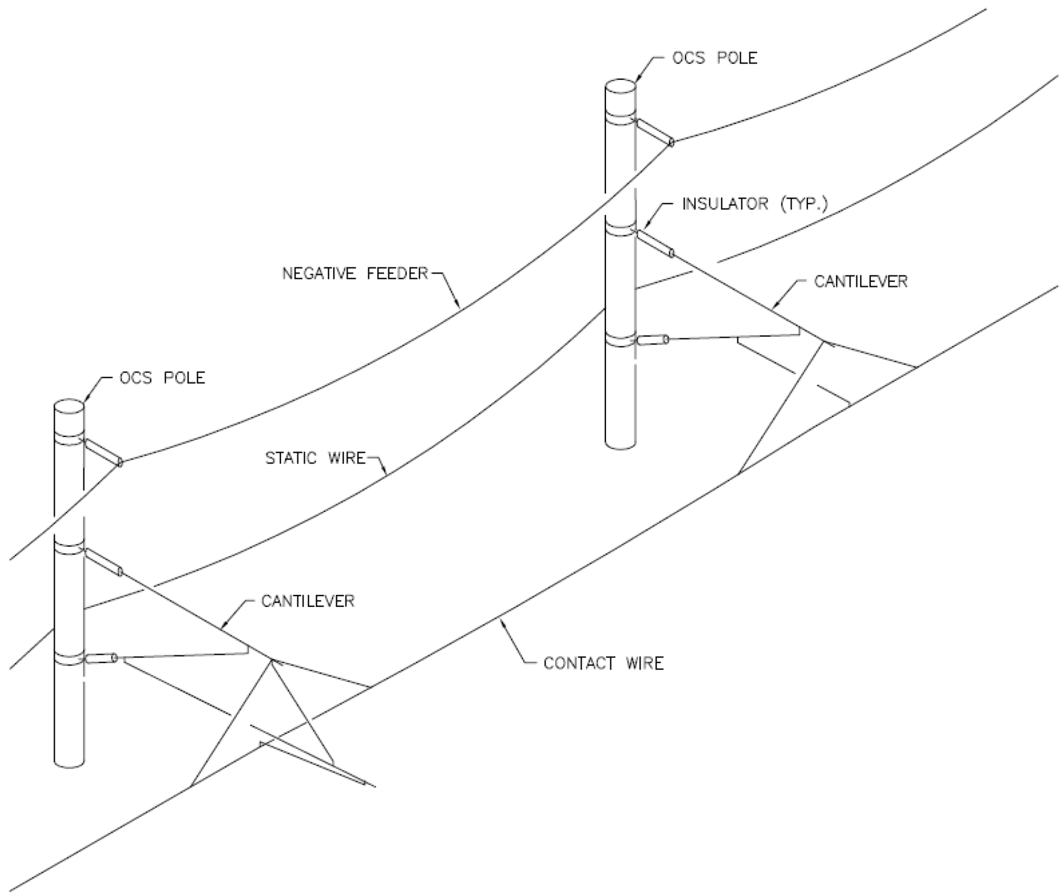


Figure 3-6 Single Contact Wire OCS

With FT systems, the conductor tensions vary with temperature. As a consequence of those tension variations, the wire heights will vary and changes in clearances must be carefully addressed.

3.3.5 Rail Return System and Traction Power Return System

The Rail Return System comprises the running rails, impedance bonds, static or ground wires, return cables, and the earth, which provide a part of the electrically continuous return path for the traction currents.

The Traction Power Return System, through which the whole traction current is returned from the wheel-sets of the traction units to the substations, comprises the Rail Return System together with the Negative Feeders.

3.3.6 Functional Characteristic of the Parallel Negative Feeders in the Traction Power Return System

When a train is operating between any two adjacent autotransformers, the whole traction return current flows through the rail return system within the bounds of these two autotransformers, as shown below in Figure 3-7. However, these autotransformers 'force' a major portion of the traction return current to flow into the negative feeders in the sections remote from the train operating section, thereby minimizing the flow of return current in the rails in these remote sections. This is a safety related benefit of the autotransformer feed system, the other benefit being reduced electro-magnetic interference produced by this system, due to the opposing current flows, by comparison with that produced by the direct feed system.

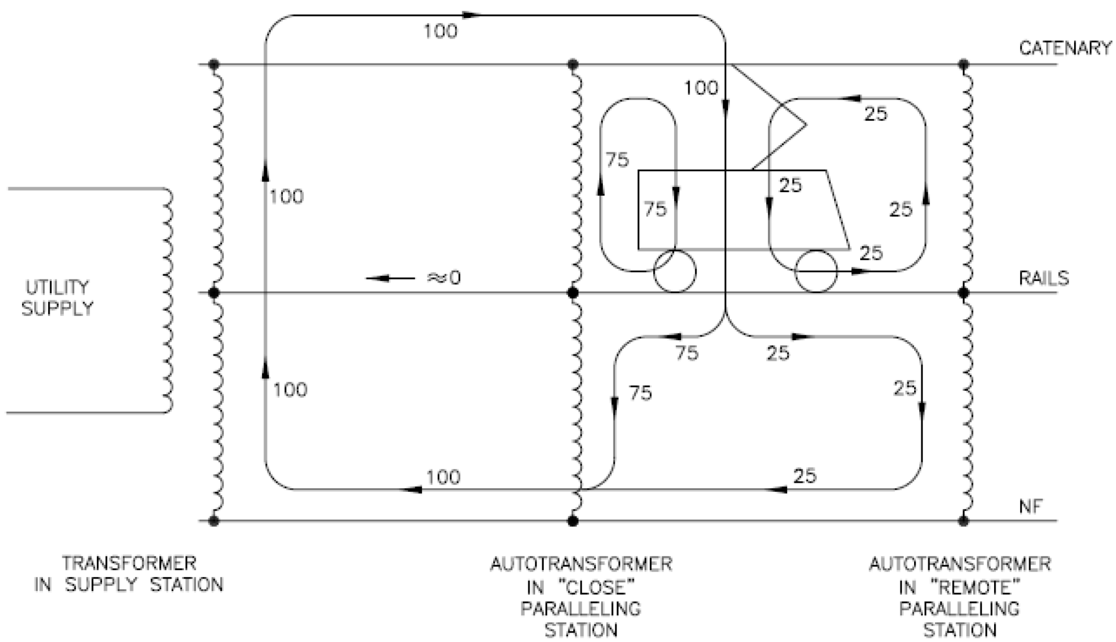


Figure 3-7 Typical Proportional Current Distribution in a 2x25 kV Autotransformer System for a Train Current of 200 Amps

It is recognized that Figure 3-7 is a simplified diagram and is not an accurate representation of all current flows, since portions of the return current flow from the train location back to the substation via the static wires and earth, and that a portion also remains in the track rails.

4 PERFORMANCE REQUIREMENTS

4.1 OPERATING VOLTAGE REQUIREMENTS

4.1.1 The Traction Electrification System (TES) must provide for rail operations under a wide variation of voltages for two main reasons:

a. Heavy power draw by the rail vehicles causes significant dips in voltage levels. Low voltage levels impact vehicle performance, so a recommended minimum level must be established.
b. Regenerative braking by electrically powered rail vehicles causes increases in voltage levels, so a recommended maximum level must be established.

4.1.2 The operating voltages, detailed below, establish the limits for which safety clearances and values at the 25 kV level shall apply:

a. Nominal Voltage	25 kV	
b. Maximum Voltage	30 kV	[+ 20% of Nominal]
c. Minimum Voltage	17.5 kV	[- 30% of Nominal]

4.2 ENVIRONMENTAL PARAMETERS - CLIMATIC AND GEOGRAPHIC CONDITIONS

4.2.1 The TES shall be designed to operate safely and satisfactorily within the anticipated environmental conditions. The required clearances and other safety parameters shall be maintained at all times and under all conditions. The following factors, any or all of which may have a significant impact on performance and safety issues, shall be taken into consideration:

a. Ambient temperature range
b. Permissible conductor operating temperature range
c. Permissible equipment operating temperature range
d. Wind variations and wind loading effects
e. Ice loading
f. Seismic zone
g. Humidity
h. Atmospheric pollution
i. Lightning (Isokeraunic levels)
j. Elevation
k. Soil conditions
l. Soil resistivity.

4.2.2 Conductor Temperatures

The conductor system of the TES shall operate safely and satisfactorily considering the probable variations in conductor temperature due to:

a. Ambient Temperature
b. Solar Radiation
c. Current Heating
d. Wind Cooling.
e. Condition of the conductor surfaces – new, heavily oxidized, etc.
f. Permissible contact wire wear

4.2.3 Vehicle performance variations subject the conductors to rapidly changing current values over a wide range as a consequence of frequent acceleration and deceleration cycles.

High conductor temperatures may result in increased wire sags and directly influence clearance values, particularly with fixed termination OCS arrangements, but less so with auto-tensioned systems. Safety issues associated with increased wire sags must be addressed thoroughly.

4.2.4 Wind and Ice Loading

a. There are significant variations in seasonal and climatic conditions and resultant loading conditions in the different regions of North America. Reference should be made to the National Electrical Safety Code (NESC) Section 25 Loadings and Section 26 Strength Requirements, which address these issues in detail.
b. The conditions of temperature and loading specified in Table 4-1 shall be used, as a minimum, for determining the strength required for all aerial, tensioned conductors in the TES and for determining consequent sag variations and lateral displacements to establish the clearances from those conductors. More stringent conditions may be used, if deemed appropriate. The use of modified conditions or modified loading districts may be authorized by the Commission upon application and presentation of data from US weather records or other authenticated climatological data which, in the opinion of the Commission, justifies such change.
c. The NESC has established three different Loading Districts - Heavy, Medium and Light – and has defined combined loading criteria. Basic wind speeds are also detailed in the NESC, together with hurricane zones and Special Wind Regions.

Table 4-1 Combined Loading Criteria

Factor	Heavy Loading District	Medium Loading District	Light Loading District	Extreme Wind Loading
Radial Thickness of Ice (inches)	0.50	0.25	0	0
Horizontal Wind Pressure (lb/ft^2)	4	4	9	Refer to NESC
Temperature (^{o}F)	0	+15	+30	+60
High Temperature for Sag Computations (^{o}F)	+130	+130	+130	NA

d. The effects of Extreme Wind Loading on OCS support structures of less than 60 feet in height must be investigated, as detailed in the NESC. The effects of Extreme Wind Loading on the total system, including conductors, must be investigated if any portion of the OCS structures or the supported facilities is located at more than 60 feet above ground level, as detailed in the NESC Section 25.
e. Table 4-1 summarizes the minimum required general requirements, but designers shall investigate local conditions and review NESC Sections 25 and 26 in their entirety to determine the specific values and criteria that shall be applied for each segment of the high speed rail project in California.
f. In calculating permissible conductor tensions, the approach defined in EN 50119 shall be adopted and the additional arbitrary “Load Constants, detailed in NESC Table 251-1 shall not be used.

4.2.5 Exposure Effects

a. Railroads pass through sheltered, normal and exposed areas. Across-track wind speeds in deep cuts, dense forests and urban areas are generally less than normal. For urban areas, it is recommended that local experience with wind gusting be investigated. Railroads located on high embankments or viaducts or in flat exposed areas can be subjected to abnormally high wind conditions and should be investigated fully.
b. Wind speed criteria shall be adjusted by the factors (f) listed in Table 4-2, which have been derived from those found in the American Railway Engineering and Maintenance of Way Association (AREMA) "Manual for Railway Engineering" Chapter 33 Table 33-4-3. Alternatively, the requirements detailed in the NESC should also be reviewed, since the NESC provides further - possibly more detailed - recommendations based on topography, exposure and gust response factors.

Table 4-2 Wind Speed Exposure Factors (f)

Wind Speed Type	Sheltered Areas	Exposed Areas
Operating Wind Speed	0.80	1.25
Design Wind Speed	0.80	1.50

4.2.6 Seismic

In accordance with NESC Rule 250A4, the structural capacity provided by meeting the loading and strength requirements of Sections 25 and 26 will provide sufficient capability to resist earthquake and ground motions.

4.2.7 Atmospheric Conditions

a. High humidity can present operational and safety issues with medium and high voltage switchgear, and shall be evaluated on a project-specific basis. In areas of high atmospheric pollution, such as industrial locations or salt-laden atmospheres, insulation levels may have to be increased.
b. The frequency and number of thunder storm days (isokeraunic level), and the probability of lightning strikes on the TES shall be determined. Where the probability is high, in addition to any measures, such as surge arresters or other equipment, that may be implemented to protect the overhead lines and fixed installations, appropriate measures shall be implemented to provide protection for authorized personnel and the public.

4.2.8 Elevation (Altitude) Compensation

In accordance with NESC Section 44, clearance values, particularly approach distances for maintenance workers, shall be increased for systems operating at elevations higher than 3,000 feet – refer to Table 5-3.

4.2.9 Soil Conditions and Soil Resistivity

a. Soil strengths and types vary along most railroad rights-of-way from poor quality compacted fill to high grade bedrock. OCS pole footings, equipment foundations, and power facility ground grids shall be designed based on detailed geotechnical investigations derived on a project- and location-specific basis.
b. Soil resistivity tests shall be performed during the geotechnical investigations to permit the development of safe pole grounding and ground mat designs that satisfy the Rules in Section 6 of this General Order.

5 25 KV CLEARANCES AND PROTECTION AGAINST ELECTRIC SHOCK

5.1 GENERAL

Protection against electric shock shall be achieved by:

a. establishing adequate safety clearances that will minimize the possibility of direct contact with energized parts, and/or
b. erecting suitable barriers or screens to prevent direct contact, and/or
c. installing appropriate signs warning of the potential dangers.

5.2 OVERHEAD CONTACT LINE ZONE AND PANTOGRAPH ZONE

5.2.1 Structures and equipment may accidentally come into contact with a live broken contact line, or with the live parts of a broken or de-wired pantograph or energized fragments. Figure 5-1 has been derived from EN 50122-1: 2011 Figure 1 and, for the CHSTP, defines the zone inside which such contact is considered probable, but whose limits are unlikely to be exceeded by a broken overhead contact line or damaged energized pantograph or fragments thereof.
NOTE: The damaged pantograph may be live even though it is not in contact with the overhead line, because it is inter-connected with other energized pantographs or because the train is in regenerative braking mode,.

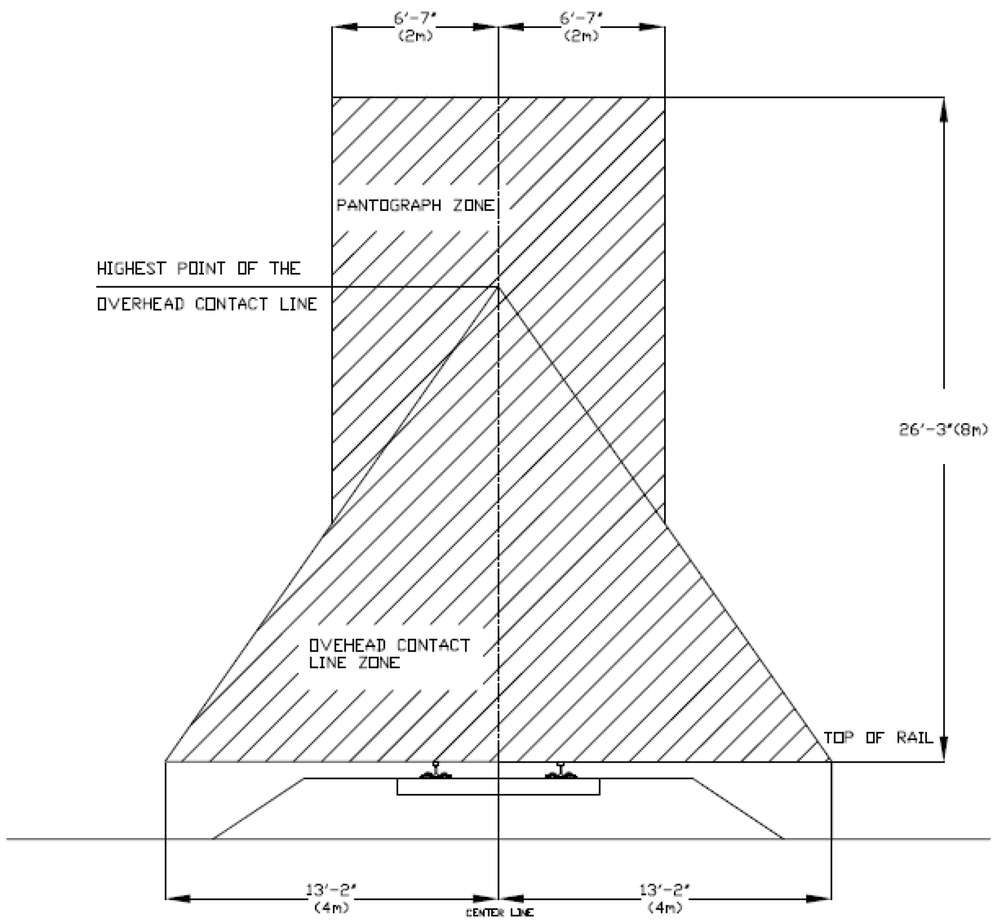


Figure 5-1 Overhead Contact Line Zone and Pantograph Zone
(derived from EN 50122-1: 2011 Figure 1)

5.2.2 The limits of the overhead contact line zone below top of rail extend vertically down to the earth surface, except where the tracks are located on a viaduct where it extends to the viaduct deck. In the case of out-of-running OCS conductors, the overhead contact line zone shall be extended accordingly.

5.3 PROTECTION BY SAFETY CLEARANCES

5.3.1 The minimum unconstrained clearances from energized parts to generally accessible areas (no barriers, screens or other physical restrictions to movement) for 25 kV systems have been derived from EN 50122-1: 2011 Figure 4 and values required for high speed operations in California are shown in Figure 5-2 for (a) public areas and (b) restricted areas. The values shown are based on touching in a straight line without the use of tools or other objects and shall be achieved under all climatic and loading conditions. These requirements include clearances from standing surfaces, used by people, to accessible live parts on the outside of vehicles as well as to live parts of the OCS.

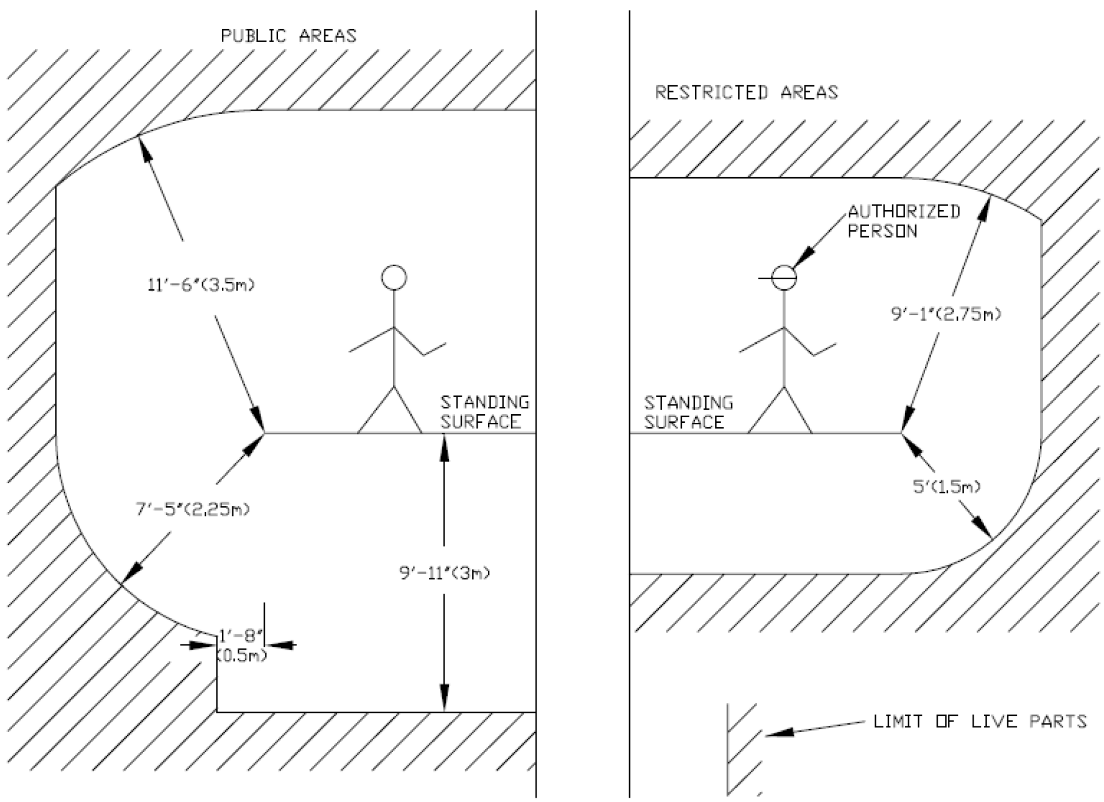


Figure 5-2 Minimum Required Safety Clearances – Unconstrained Access
(derived from EN 50122-1: 2011 Figure 4)

5.3.2 The standing surface indicated in Figure 5-2 does not provide protection against contact with live parts located below or to the side. However, dependent on its construction, this surface may meet the requirements detailed below regarding barriers and screens, in which case the lower clearance values appropriate to the type of barrier may be adopted.

5.3.3 Energized parts of the OCS shall be limited to the electrified tracks and adjacent areas that are necessary for support, tensioning and positioning of the OCS. Placing OCS energized parts over safety walkways shall be avoided where practicable.

5.3.4 Safe working clearances and approach distances for qualified employees shall be developed by the Agency in accordance with Rule 8.1.

5.4 PROTECTION BY BARRIERS AND SCREENS – PUBLIC AREAS

5.4.1 The requirements for protective screening and barriers for standing surfaces in public areas for protection against direct contact with adjacent live parts on the outside of vehicles or adjacent live parts of an overhead contact line system for nominal system voltages up to 25 kV ac to ground are based on the requirements of EN 50122-1. Where clearances are less than specified in Figure 5-2, the protection shall be of solid barrier construction for standing surfaces above live parts on the outside of vehicles or above live parts of an overhead contact line system. For other situations, as depicted in Figure 5-3, the following sections should be referenced.

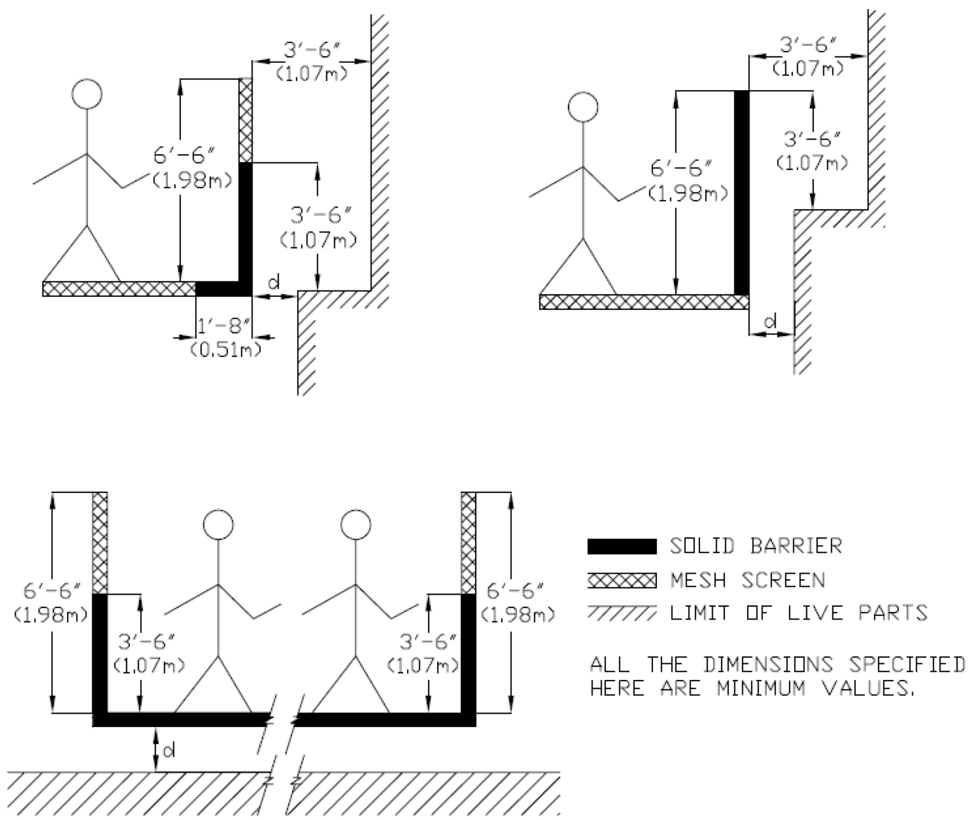


Figure 5-3 Clearance Requirements from Protective Screens and Barriers for Standing Surfaces in Public Areas (based on EN 50122-1: 2011 Figure 7)

5.4.2 The minimum requirements for clearances from barriers and screens to live parts in public areas of the CHSTP are shown in Figure 5-3 and can be summarized as:

a. where the energized parts are located below the standing surface, protection of the standing surface shall be by means of a solid barrier,
b. the minimum height of the protective barrier – solid or a combination of solid plus mesh screen, as shown - shall be 6’- 6” (1980 mm),
c. barriers of greater height may be required in areas where vandalism is prevalent,
d. the value for dimension “d” between the protective screenings & barriers and live, parts shown in Figure 5-3 shall be determined from Table 5-2,
e. as recommended in EN 50122-1 Clause 5.3.1, where buckling or warping of solid barriers is likely, 1¼ inches (30 mm) shall be added to dimension “d”, and where mesh screens are used, 4 inches (100 mm) shall be added.

5.4.3 The length of the protective screening and/or barrier on structures that cross over an electrified railroad, and which protect publicly accessible standing surfaces, shall extend laterally beyond the live parts of an overhead contact line by at least 10 feet (3050 mm) on each side. In the case of energized conductors not being used for current collection (e.g., line feeders, reinforcing feeders, out of running overhead contact lines), the barrier shall extend for a width of at least 10 feet (3050 mm) on each side of the conductor, with the proviso that movement due to dynamic and thermal effects has been taken into account.

5.5 PROTECTION BY BARRIERS AND SCREENS – RESTRICTED AREAS

5.5.1 The requirements for clearances from protective screening and barriers for standing surfaces in restricted areas, shown in Figure 5-4, for protection against direct contact with adjacent live parts on the outside of vehicles or adjacent live parts of an overhead contact line system, operating at nominal voltages up to 25 kV ac to earth, are based on EN 50122-1: 2011. Where clearances are less than specified in Figure 5-2, the protection shall be of solid barrier construction for standing surfaces above live parts on the outside of vehicles or above live parts of an overhead contact line system. For other situations, as depicted in Figure 5-4, the following sections should be referenced.

5.5.2 The length of the solid barrier, protecting the standing surface, shall correspond to the pantograph zone and shall extend beyond the live parts of an overhead contact line by at least 1’- 8” (510 mm). In the case of energized conductors not being used for current collection (e.g., line feeders, reinforcing feeders, out of running overhead contact lines), the barrier shall extend for a width of at least 1’- 8” (510 mm) on each side of the conductor, with the proviso that movement due to dynamic and thermal effects shall be taken into account.

5.5.3 The minimum requirements for clearances from barriers and screens to live parts in restricted areas of the CHSTP are shown in Figure 5-4 and can be summarized as:
a. where the energized parts are located below the standing surface, protection of the standing surface shall be by means of a solid barrier,
b. the minimum height of the protective barrier – solid or a combination of solid plus mesh screen, as shown - shall be 6’- 6” (1980 mm),
c. barriers of greater height may be required in areas where vandalism is prevalent,
d. the value for dimension “d” between the protective screenings & barriers and live, parts shown in Figure 5-4 shall be determined from Table 5-2,

e. as recommended in EN 50122-1 Clause 5.3.1, where buckling or warping of solid barriers is likely, 1¼ inches (30 mm) shall be added to dimension "d", and where mesh screens are used, 4 inches (100 mm) shall be added.

5.5.4 The height "h" of the protective screening and barrier shall be such that a clearance of 5 feet (1530 mm) to energized parts is maintained from the top of the protective screening and barrier (see Figure 5-4).

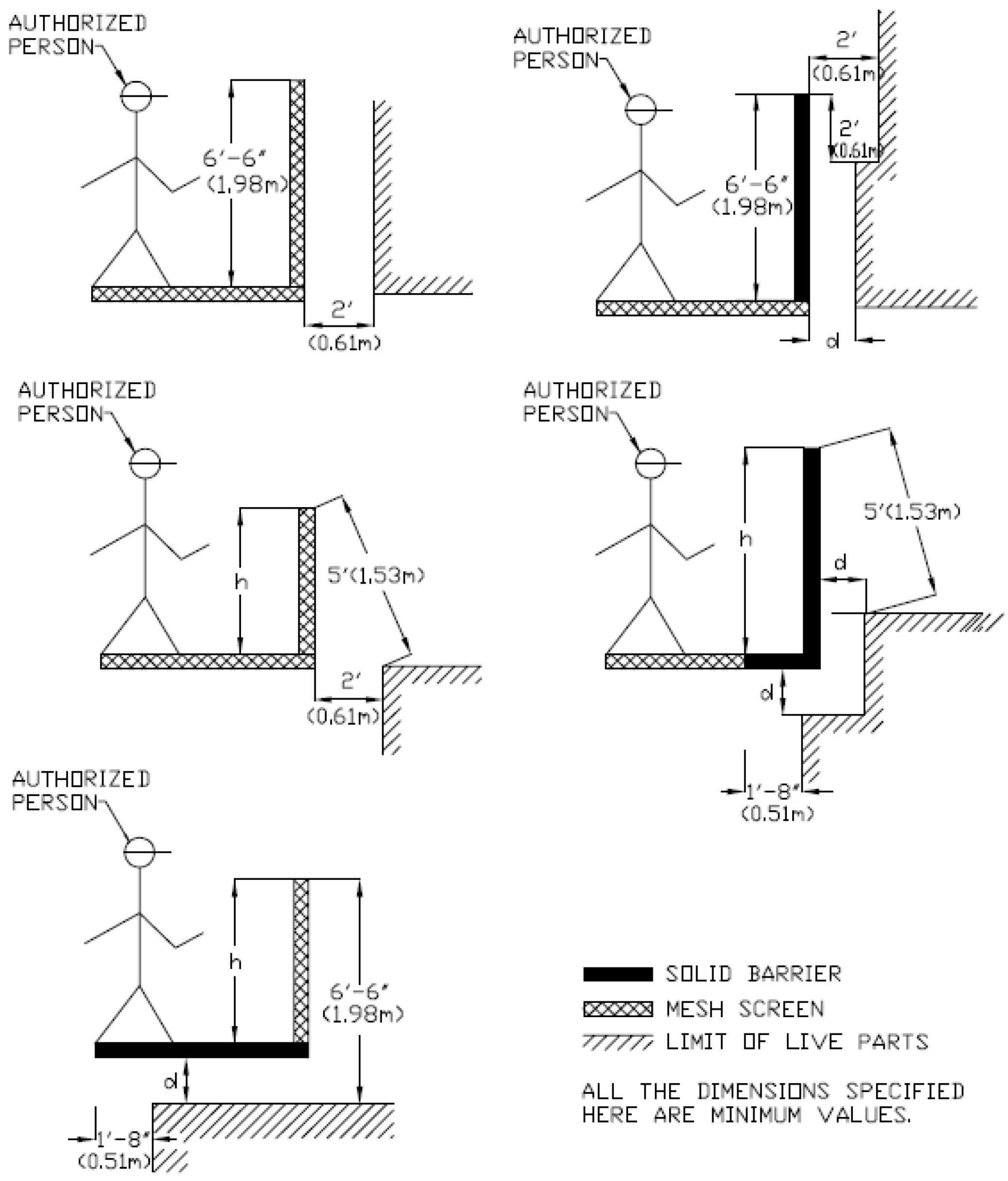


Figure 5-4 Clearance Requirements from Protective Screenings and Barriers for Standing Surfaces in Restricted Areas (based on EN 50122-1: 2011 Figure 9 & 11)

5.5.5 The height of the side protective screenings and barriers should correspond to the height of any necessary safety railing but should have a minimum height of 3’- 6” (1070 mm).

5.5.6 Safe working clearances for qualified employees shall be developed by the Agency in accordance with Rule 8.1.

5.6 GENERAL REQUIREMENTS FOR PROTECTIVE BARRIERS AND SCREENS

5.6.1 Protection barriers or screens shall be of sufficient strength and shall be supported rigidly and securely enough to prevent them from being displaced or dangerously deflected by a person slipping or falling against them.

5.6.2 Barriers and screens shall be permanently fixed, and shall be removable only with tools. Barriers in public areas shall employ non-removable, captive fasteners.

5.6.3 Barriers shall be of solid construction and be fabricated from either conductive or non-conductive materials.

a. Non-conductive barriers shall be surrounded by a grounded, bare conductor that is inter-connected with the traction system ground, preferably at not less than two locations.
b. Conductive barriers shall be bonded and grounded by inter-connection with the traction system ground, preferably at not less than two locations.

5.6.4 Screens shall be of conductive, open mesh materials and grounded by inter-connection with the traction system ground, preferably at not less than two locations. Non-conductive mesh or plastic-coated metal mesh shall not be used.

5.6.5 Conductive mesh screens shall be constructed such that a cylinder, greater than ½ in. (13 mm) in diameter, cannot be pushed through the mesh. Mesh screen construction shall be such that required clearances to energized parts are maintained.

5.6.6 The style of barrier to be employed is dependent upon type of standing surface and its proximity to the energized parts, and whether the surface provides for public or restricted access, as detailed above.

5.6.7 The size of the barrier or screen shall be such that energized parts cannot be touched in a straight line by persons on a standing surface.

5.6.8 The design of the protective screens and barriers shall minimize the loading on existing structures and any adverse visual impact.

5.6.9 The metallic part of the overhead bridge screening and barriers shall be bonded to static wires. All other metallic items on the overhead bridge, within a lateral distance of 10 feet (3.05 m) from any energized and uninsulated equipment passing below the structure, shall be directly or indirectly bonded to static wire.

5.7 PROTECTION AGAINST CLIMBING

5.7.1 Where there is public access or trespass is likely, anti-climbing protection shall be provided at buildings and other structures supporting energized parts of the OCS. The anti-climbing protection should include signs warning of the dangers of high voltage.

5.7.2 Access to fixed ladders, particularly at signal poles and signal gantries, and the means of access to any roof or other place, which could allow non-authorized persons to approach energized parts, shall be secured or otherwise protected.

5.8 CLEARANCES FOR UTILITY LINES CROSSING OVER ELECTRIFIED RAILROADS

5.8.1 The minimum clearance for overhead power, communications or other utility lines, which are not part of the TES, shall be in accordance with CPUC General Order No. 95 Rule 38 Table 2 and shall be measured from the highest energized point on the TES.

5.8.2 Utility lines crossing the high speed railway, shall comply with the requirements of CPUC General Order No. 95 with regard to the conductor suspension arrangements and strength of the structures immediately adjacent to the crossing point.

5.9 CLEARANCES ABOVE PAVED AREAS IN MAINTENANCE FACILITIES AND YARDS

5.9.1 In the CHSTP maintenance facilities, yards and workshops, paving that matches the elevation of the upper surface of the running rails may be required, so that maintenance vehicles and pedestrians can cross the tracks under the overhead contact line.

5.9.2 In accordance with NESC Rule 232C1, the normal clearance of the lowest energized part of the OCS above paved areas in CHSTP maintenance facilities, yards and workshops, under the worst conditions of temperature and loading, shall be as shown in Table 5-1. Warning signs shall be provided, as detailed in Rule 5.11.2.

5.9.3 At pedestrian and vehicle crossings in maintenance facilities or yards where vehicles over 8 feet high are prohibited, a restricted clearance may be permitted, and the minimum height of energized parts of the OCS above the crossing surface, under all conditions of temperature and loading, shall be as shown in Table 5-1. Warning signs shall be provided, as detailed in Rule 5.11.2.

Table 5-1 Clearances above Track Crossings in Paved Areas of Maintenance Facilities, Yards and Workshops – derived from NESC Rule 232C1a

Normal Clearance	20 ft. 4 in.	6.20 m
Restricted Clearance	18 ft. 4 in.	5.59 m

5.10 ELECTRICAL CLEARANCES TO RAIL VEHICLES AND STRUCTURES

5.10.1 Clearances are classified as either Static or Passing.

Static Clearance is the physical air clearance between energized parts of a vehicle or OCS, when not subjected to dynamic conditions or climatic influences or pantograph pressure, and an adjacent fixed structure or the grounded parts of a vehicle, while the vehicle is stationary.
Passing or Dynamic Clearance is the physical air clearance between energized parts of either the vehicle or OCS and the grounded vehicle or adjacent fixed structure under dynamic operating conditions and exists only during the passage of the train, or when the OCS is affected by extreme climatic conditions, such as wind and/or ice loading.

5.10.2 Electrical clearances, shown in Table 5-2 and depicted in Fig 5-5, from energized parts to grounded parts of rail vehicles or structures are categorized as normal and minimum. Where the OCS is to be installed at elevations greater than 3,000 ft (900 m), the clearances shall be increased in accordance with the Altitude Correction Factors ($_A$), detailed in NESC Rule 441A4b(3) and Table 441-5 and shown in Table 5-3.

5.10.3 The designated normal clearances shall be adopted at all other locations, wherever practicable.

5.10.4 Where it can be demonstrated that it is not practicable to provide normal clearances, adoption of the minimum clearances shall be permissible. However, prior to their adoption, the following factors require further evaluation:

a. fault current resulting from a breakdown of the electrical clearance.
b. vulnerability of the OCS and railroad infrastructure to damage should a breakdown of the electrical clearance occur.
c. consequences for the safety of persons should a breakdown of the electrical clearance occur.
d. application and maintenance of tolerances of the OCS and railroad infrastructure.
e. economic and technical considerations.

Table 5-2 25 kV ac Electrical Clearances

Atmospheric Condition	Normal Clearance		Minimum Clearance	
	Static (C_A)	Passing/ Dynamic (P_A)	Static (C_A)	Passing/ Dynamic (P_A)
Non-Polluted	10½ " (270 mm) *	8 " (205 mm) *	8 " (205 mm) *	6 " (155 mm) *
Polluted	12½ " (320 mm) **	10 " (255 mm) **	10 " (255 mm) **	8 " (205 mm) **

*: These clearance values are as stated in AREMA Table 33-2-4 (2010)
**: For polluted atmospheres, 2" has been added as stated in AREMA Table 33-2-4 (2010)

The minimum clearance from bare energized ancillary conductors (the 25 kV negative feeders) to grounded structures under worst case conditions in non-polluted areas is specified in the AREMA Manual Chapter 33 Table 33-2-2 to be 10.5" (270 mm) and 12.5" (320 mm) in polluted locations. These values shall be adopted for the project.

In a 2x25 kV ac system, there is a 180^o phase difference between parts common to the energized negative feeder and parts common to the energized catenary system. The minimum clearance between these elements shall be as stipulated in Table 10 of EN

50119: 2001, which is 21½” (540 mm) under static conditions or 12” (305 mm) under worst case dynamic conditions.

Table 5-3 Altitude Correction Factors ($_A$) to be Applied to Clearances

Altitude (ft)	Altitude (m)	Correction Factor
3,000	900	1.00
4,000	1,200	1.02
5,000	1,500	1.05
6,000	1,800	1.08
7,000	2,100	1.11
8,000	2,400	1.14
9,000	2,700	1.17
10,000	3,000	1.20

5.10.5 Enhanced clearances or other protective measures shall be provided at locations where there is a high probability of incidents due to birds, animals, icicles or vandalism, or for particularly vulnerable structures. Regardless, the maximum practicable value of electrical clearance shall be provided at all locations.

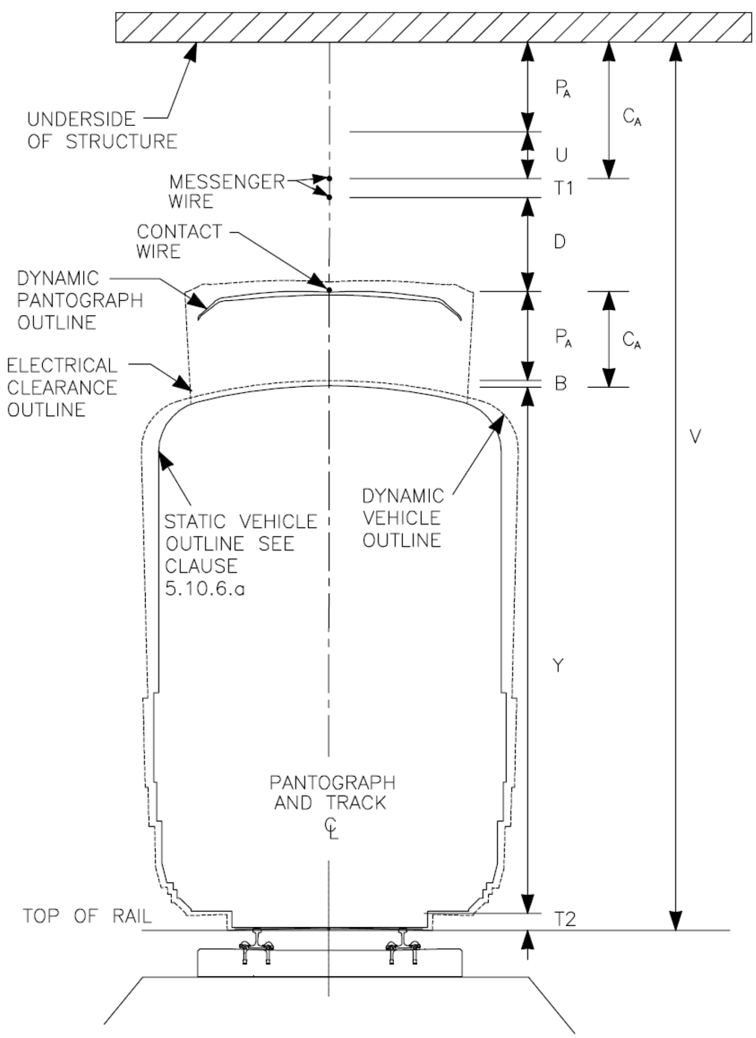
5.10.6 Structural Clearance Envelope

In determining the minimum vertical and lateral clearance envelope at fixed structures, including OCS support structures and signal bridges, the following factors shall be assessed, as shown in Figure 5-5:

a. The static vehicle outline shall be based on the size of the high speed rail vehicles or, in shared-use corridors, the maximum permitted vehicle size, if larger, which shall be based on the Association of American Railroads (AAR) Plate Gauge applicable to the track section being electrified for high speed operations in the shared-use corridor.
b. The dynamic vehicle outline shall take into consideration the dynamic swept envelope, track position and maintenance tolerances, including railhead side wear, and the effects of vertical and horizontal curvature, including track super-elevation.
c. The position of energized parts on the rail vehicles, including the dynamic pantograph envelope, allowing for pantograph carbon wear and dynamic movements and deflections of the pantograph frame, and vehicle construction and maintenance tolerances. The pantograph envelope shall include an allowance for chording effects, if the pantograph is offset longitudinally on the vehicle from a truck centerline.
d. The position and size of energized parts of the OCS allowing for installation and maintenance tolerances, uplift and other dynamic movements, including those due to wind, temperature and loading conditions.
e. For lateral clearances of OCS support structures refer to General Order No. 26-D Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structure Parallel Tracks, Crossings of Public Roads, Highways and Streets, Rule 3.7, Rule 3.16 and Rule 3.20.

5.10.7 Clearances to Vegetation

a. Based on the requirements stipulated in EN 50122-1: 2011 Clause 5.2.6, trackside vegetation shall be managed, such that there is no overhanging vegetation and that a minimum clearance of 8'- 3" (2.5 m) is maintained between the vegetation and energized parts of the OCS at all times and under all climatic conditions.
b. In addition, the operating right-of-way shall be cleared of all vegetation that could:
    1) constitute a fire hazard or other threat to safety.
    2) obstruct a vehicle or train operator's visibility of signs, signals, or the track ahead.
    3) interfere with employees in performing normal trackside duties.
    4) obstruct emergency walkways.
c. Vegetation at traction power facilities shall be managed to eliminate overhanging branches or ground level growth that could cause equipment damage by falling or creating a short circuit path.



V - Total Vertical Clearance Required for Electrification
P_A - Passing (Dynamic) Electrical Clearance – see **Note** below
U - Catenary Uplift
T1 - Catenary Construction Tolerance
D - Catenary Depth
B - Vehicle Bounce
Y - Static Vehicle Load Height
T2 - Track Maintenance Tolerance
C_A - Static Electrical Clearance

Note: the diagram depicts the dynamic condition. For static situations, the Static Electrical Clearance (C_A) – refer to Table 5-3 - shall be not less than P_A+U or P_A+B

($_A$) - At higher elevations, Static and Passing Electrical Clearances shall be adjusted using the appropriate Altitude Correction Factor derived from Table 5-4.

Figure 5-5 Vertical Structural Clearance Envelope – based on AREMA Figure 33-2-3 and Figure 33-2-4

5.11 SIGNAGE

5.11.1 At locations where there is a risk of persons coming within the clearances specified in Section 5, in spite of all other control measures, “High Voltage” warning sign(s) shall be posted.

5.11.2 Permanent High Voltage warning signs shall be:

a. displayed in conspicuous places at all entrances to locations containing exposed current carrying parts.
b. located on all enclosures that provide access to conductors, equipment, and apparatus that are energized at high voltage.
c. displayed at anti-climbing locations.
d. displayed at pedestrian and maintenance vehicle crossings in CHSTP maintenance facilities and yards.

5.11.3 The warning signs shall be posted in a consistent manner throughout the electrified route and shall be clearly visible to persons on or near the electrified lines.

6 GROUNDING AND BONDING

6.1 GENERAL

6.1.1 For ac traction systems, grounding is the preferred method for protecting equipment against electrical system faults and for providing safety for employees and the general public. Adequate bonding shall be designed and installed throughout the entire electrified system to provide proper return circuits for the traction power currents and fault currents, with grounding connections as detailed below.

6.1.2 The design of a 25 kV, 60 Hz, ac TES includes traction return circuits as the preferred method for conducting the return current under both operating and short circuit or fault conditions. All exposed normally non-current-carrying metallic parts, liable to become energized from the TES under short circuit or fault conditions, shall be directly connected to the traction return circuits. If it is determined that the normally non-current-carrying metallic parts cannot be directly connected to the traction return circuits, then an alternative method, such as counterpoise grounding or voltage limiting devices, shall be used.

6.1.3 Since the 25 kV traction power system utilizes "earth" as part of the return circuit, an electrical safety analysis shall be undertaken to assess which metallic parts need to be grounded and bonded, and the appropriate methodology for implementation. This grounding and bonding analysis must be applied to all current-carrying elements that lie within the sphere of influence of the TP Return system, which would include third party utility and adjacent railroad systems. Where those third party utility or railroad system elements are affected, protective measures must be installed, as detailed under Rule 6.5.

6.2 TRACTION POWER FACILITIES

6.2.1 The design of traction power facilities [i.e., substations, paralleling stations, switching stations] shall incorporate grounding and bonding designs that are compliant with the latest revision of IEEE 80 Guide for Safety in AC Substation Grounding.

6.2.2 The grounding design at traction power facilities shall ensure the maximum permissible potentials in Rule 6.6 are not exceeded and, without exception, the resistance to ground shall not exceed 5 ohms.

6.3 RUNNING RAILS

6.3.1 The running rails provide the primary return circuit for the traction power supply and fault currents. When insulated rail joints are used to define the limits of track circuits in a signaling system, the insulated joints must be by-passed by impedance bonds in order to provide a continuous return circuit for the traction power supply and short circuit or fault currents. The location of the impedance bonds and the type of connections must be fully coordinated with the signal system design.

6.3.2 To take advantage of all of the running rails in multi-track areas, the running rails of adjacent tracks should be cross-connected as often as the signaling system will allow. In addition, at each of the cross-bond locations, a connection should also be made between the rails or impedance bonds and the adjacent aerial static wire or counterpoise. Interconnecting the rails with the aerial static wires or counterpoise will minimize the potential rise of the running rails during normal and fault conditions, and also minimize voltage drop and leakage current in the return circuit under normal operations. The location of the impedance bonds and the type of connections must be fully coordinated with the signal system design.

6.4 OVERHEAD CONTACT SYSTEM SUPPORT STRUCTURES AND METALLIC COMPONENTS

6.4.1 General Requirements

a. Specific metallic items associated with the OCS shall be grounded by a direct connection to an aerial static wire. All OCS poles and support structures shall be interconnected by an aerial static wire. Multi-track structures supporting more than one OCS shall be interconnected to two separate aerial static wires.
b. All OCS attachment brackets at overhead bridges, tunnels and center sections of OCS phase breaks shall be connected to the aerial static wire in at least two locations.
c. Connections shall be made periodically between each aerial static wire and the running rails. The spacing of these interconnections must be coordinated with the operating requirements of the signaling system. Each aerial static wire shall also be connected to the ground bus of each traction power facility providing power to the OCS.
d. The grounding design shall ensure the maximum permissible potentials in Rule 6.6 are not exceeded and, without exception, the resistance to ground shall not exceed 25 ohms.

6.4.2 Additional Requirements Within Railroad Passenger Station Limits

a. To provide uniform ground potential at station platforms (to protect passengers from unsafe potentials), all metallic structures and miscellaneous metallic items located on passenger station platforms, including any OCS poles, that lie within 8 feet (2.44 m) from the platform edge shall be isolated from the static wire and grounded by a direct connection to a dedicated counterpoise that covers the entire platform length and may extend beyond the platform ends.
b. One end of the counterpoise shall be connected to the running rails either directly or via an impedance bond outside the limits of the station platform. The connections shall be made in such a manner as to avoid the possibility of interference with broken rail detection and to adhere to other requirements of the signaling system.
c. The grounding design shall ensure the maximum permissible potentials in Rule 6.6 are not exceeded and, without exception, the resistance to ground shall not exceed 5 ohms.

6.4.3 Requirements When the 25 kV ac TES is Located Adjacent to a dc TES

a. Where a 25 kV ac TES is located adjacent to a dc TES, special grounding arrangements may be necessary to avoid interaction of the two systems and to mitigate the corrosion effect of any dc leakage or stray currents on the 25 kV ac TES components.

b. The static wire in the area affected by dc stray currents shall be electrically insulated from the OCS poles by supporting the static wire on insulators.
c. The OCS poles shall be grounded through inter-connection of the pole, anchor bolts and steel reinforcement of the concrete foundation so that the ground resistance of individual poles is kept low, and does not exceed 25 Ω. Where the ground resistance of individual OCS poles exceeds 25 Ω, individual ground rods or other grounding solutions shall be applied.
d. Fault conditions shall be evaluated and grounding designs developed such that unsafe touch potentials are not created.
e. Additionally, close coordination shall be maintained with any adjacent dc track authority so that a high level of insulation is maintained between the dc system rails and ground to minimize dc stray current leakage.

6.4.4 Requirements where CHSTP passenger platforms and maintenance or emergency walkways are located adjacent to dc system tracks
a. Further coordination will be needed with the dc system operator where CHSTP passenger platforms and maintenance or emergency walkways are located adjacent to dc system tracks.
b. If inadmissible touch/accessible voltages could occur between the rail and ground, the use of voltage-limiting devices, such as non-permanent rail to ground connections, should be installed to control touch potential during an ac fault condition and also to limit the uncontrolled dc stray current.

6.4.5 Coordination with Train Control and Signal Systems
All of the above measures need to be coordinated with the train control and signal systems design so that the integrity of the train control/signal system is not compromised.

6.5 WAYSIDE NORMALLY NON-CURRENT-CARRYING METALLIC PARTS

6.5.1 General Requirements

a. At concrete or masonry overhead structures, where the structure above energized OCS conductors or feeders lies within the Overhead Contact Line Zone and Pantograph Zone (Figure 5-1), metallic flash plates shall be installed above the conductors to capture any flash-overs or short circuit faults.
b. Flash plates and overhead bridge barriers/screens shall be grounded by a direct connection to the aerial static wire in at least two locations.
c. Utilities crossing over, or paralleling in close proximity to, the electrified ROW, such as pipelines or conduits, may require the installation of insulated joints or couplings and shall be grounded and bonded so as to prevent potential rises and TES current flow. The method of grounding shall be coordinated with the relevant local utility company.
d. All other normally non-current–carrying metallic parts [e.g., wayside equipment enclosures, structures and fences] shall be permanently and effectively grounded.
e. The grounding design shall ensure the maximum permissible potentials in Rule 6.6 are not exceeded and, without exception, the resistance to ground shall not exceed 25 ohms.
f. Signal equipment shall be separately grounded and fully coordinated with the signal system design.

6.5.2 Additional Requirements Within Railroad Passenger Station Limits

a. All normally non-current-carrying metallic parts [e.g., overhead walkway structures and canopies] within railroad passenger station limits and that lie within 8 feet (2.44 m) of platform edge shall be connected to the counterpoise, subject to the adopted grounding methodology, to ensure all normally non-current-carrying metallic parts are at equi-potential.

b. The grounding design shall ensure the maximum permissible potentials in Rule 6.6 are not exceeded and, without exception, the resistance to ground shall not exceed 5 ohms.

6.6 MAXIMUM PERMISSIBLE POTENTIALS

6.6.1 Potentials in traction power facilities shall be governed by the requirements of IEEE 80, Guide for Safety in AC Substation Grounding.

6.6.2 Potentials of running rails and normally non-current-carrying metallic parts shall be controlled to ensure safety. Table 6-1, which has been derived from EN 50122-1 Clause 9.2.2, is included as a guide, pending development of an equivalent American standard.

a. The EN 50122-1 requirements provide values for maximum permissible touch voltages for short time conditions of less than 0.5 seconds and also for long term conditions (refer to Table 6-1) under all power supply feeding conditions.

b. These requirements also indicate that, for permanent conditions for time intervals greater than 300 seconds, the maximum touch potentials should not exceed 60 V RMS under all power supply feeding conditions, except in maintenance shops and similar locations where the limit should be 25 V RMS.

Table 6-1 Maximum Permissible Touch Voltages as a function of Time

Time - seconds	Voltage – volts	Time - seconds	Voltage – volts
0.02	865	0.6	180
0.05	835	< 0.7	155
0.1	785	0.7	90
0.2	645	0.8	80
0.3	480	1	75
0.4	295	300	65
0.5	220	>300	60

Note: This table is based on EN 50122-1: 2011 Table 4

7 STRENGTH REQUIREMENTS

7.1 OVERHEAD CONTACT SYSTEMS [OCS] ENERGIZED AT 25 KV 60 HZ

7.1.1 The design process for the OCS requires that due consideration be given to calculating the maximum load that can be applied to the component parts of the OCS and its support structures. Data that must be considered when determining the maximum design load include, but are not limited to:

- tensions applied to the OCS conductors, feeders, headspan assembly wires, down guys, span guys, balance weight support arrangements, brackets and conductor terminations.
- the effect of maximum and minimum temperatures on the applied tensions.
- the effect of maximum wind speed and other climatic conditions on the OCS conductors and structures supporting the OCS.
- the effect of ice coating on the OCS and support structures, as detailed in NESC Section 25 and 26.

7.1.2 The environmental and loading conditions detailed in Section 4 shall be determined for each project-specific location or area, and the grade of construction for OCS support structures for the high speed electrified railroad, operating at 25 kV nominal voltage, 30 kV normal maximum, shall be Grade ‘B’ as defined in the NESC. The structures shall be designed in accordance with the requirements of NESC Section 26.

7.1.3 Foundations shall be designed on a location-specific basis and shall be capable of meeting the structural loading requirements, with the structural dimensions being dependent on:

a. Loads on the poles due to the OCS conductors and support arrangements, plus feeder and static wires, and insulators, and, where applicable, tensioning equipment, mid-point anchor ties, disconnect switches, and all other necessary equipment
b. Wind loads on the poles and associated OCS equipment
c. Ground condition and type
d. Seismic loads
e. The requirements of train operations at the applicable speed.

7.1.4 The design of OCS foundations, including cast-in-place concrete foundations, driven pile foundations, and those for direct embedment poles, shall be in accordance with established civil and structural engineering practices, ASTM, AISC, and ACI standards, other applicable codes, and proven foundation engineering and anchoring methods.

7.1.5 The design of OCS steel structures, poles, wall brackets, and bridge abd tunnel support arrangements shall conform to the AISC code, including relevant seismic requirements.

7.1.6 In calculating the strength of the OCS conductors, supporting structures, span wires, backbones, etc., there shall be no requirement to allow for the application of additional vertical loads on cross-arms or conductors to allow for the support of a lineman.

7.2 MINIMUM SAFETY FACTORS

7.2.1 OCS Conductors

The requirements defined in Section 5 of EN 50119: 2001 shall be used to determine the maximum permissible tensions for all aerial OCS conductors, based on the environmental and loading conditions detailed in Section 4 of this General Order. The maximum allowable Contact Wire wear shall not exceed *30%*, in accordance with current US practice – AREMA Table 33-4-11.

7.2.2 OCS Hardware

OCS conductor terminations, fasteners, insulators and other hardware shall be designed, installed and maintained to withstand the maximum load that can be applied to a single component, multiplied by the safety factors shown in Table 7-1.

Table 7-1 Minimum Safety Factors for OCS Hardware

Element of Overhead Contact System	Minimum Safety Factor
Conductor terminations, splices and fasteners (except tie wires)	2.0
Down guys, span guys, headspans, balance weight support wires and their terminations	2.5
Glass, porcelain and synthetic insulators	3.0
Pins, shackles, swivels, hinges, brackets, castings, and attachments	2.0

8 SAFE WORKING PRACTICES

8.1 GENERAL

8.1.1 The Agency shall:

a. develop and maintain formal safety rules, procedures and safe working practices pertaining to the operation and maintenance of the complete TES, including safe approach and working distances for qualified personnel, to which all parties working on or adjacent to the electrified railroad shall adhere.

b. provide all employees authorized to work on the TES with the appropriate first aid equipment, personnel protective equipment and protective devices.

c. require all employees and third parties working on or adjacent to the electrified railroad to be trained in the application of the safety rules, emergency procedures and safe working practices, and appropriate first aid practices, and periodically provide refresher training.

d. require that first aid equipment, personnel protective equipment and protective devices are periodically inspected to ensure they are in safe working condition.

e. maintain formal records to ensure employees and require that third parties working on or adjacent to the electrified railroad comply with the prescribed safety rules, procedures and safe working practices; and to ensure their first aid equipment, personnel protective equipment and protective devices are in safe working condition. Formal records shall be kept on file for a minimum of four (4) prior calendar years.

f. comply with:

1) the rules pertaining to the operation of electric supply lines and equipment, as prescribed in the latest version of the NESC, and
2) the latest version of Title 8, Electrical Safety Orders, California Administrative Code.

8.2 FAULT LOCATION AND ISOLATION

8.2.1 To provide for rapid fault detection and isolation, a relay protection system shall be installed and the entire TES shall be remotely supervised, controlled and operated from one or more control centers that will be in communication with the various electric utility control centers.

8.2.2 The relay protection scheme shall:

a. Protect the TES equipment within traction power facilities, and the catenary and the negative feeders against short-circuit faults, overloading and subcomponent failures

b. Include fault location and discrimination capabilities, including automatic circuit breaker reclosing for catenary and negative feeder circuits, as well as manual, local and remote re-closure management

c. Provide proper coordination and selectivity for rapid fault clearance to the affected area of the system only, preventing as much as possible the loss of power to the healthy sections of the TES

d. Adequately discriminate between short-term high loads and fault conditions

8.2.3 High-voltage relay protection equipment on the primary side of the traction power substations shall be coordinated with the respective electric power utility companies.

8.3 PRINCIPLE FOR ACHIEVING SAFE ISOLATION

An effective safe isolation procedure (i.e., lock-out / tag-out, or red-tag procedure) shall be established to ensure that the equipment on the load side of a circuit breaker or disconnect switch, or a portion of the 25 kV ac OCS, cannot be re-energized accidentally or deliberately.

8.4 PRINCIPLE FOR WORKING ON THE TES

Work on the TES shall only be permitted after implementation of the safe isolation procedure. For testing purposes, work on energized parts shall only be undertaken by or under the supervision of a qualified person.

8.5 ACCESS TO ENERGIZED PARTS AND TRACTION POWER FACILITIES

a. Energized parts, other than rails or rail connected equipment installed or maintained as part of the TES, shall be located with sufficient clearance or enclosed so as to prevent accidental contact by persons or objects.
b. All traction power facilities, OCS disconnect switches, and other enclosures shall be kept securely locked at all times to prevent unauthorized access or operation.
c. Access to traction power facilities and enclosures containing energized parts shall be limited to qualified persons, and to authorized persons under the supervision of a qualified person.

9 REPORTING REQUIREMENTS

9.1 PLANS AND SPECIFICATIONS
All plans, drawings, specifications and other engineering documents shall be prepared under the responsible charge of a qualified professional engineer, registered in the State of California, and each plan shall show the name and branch of engineering of the responsible engineer, and must be available for inspection.

9.2 TES INSPECTIONS AND RECORDS
The Agency shall adopt and follow a TES maintenance and inspection program. Records of the TES maintenance and inspection activity, including any defects or deviations from the adopted standards or changes to the as-installed records shall be kept on file for a minimum of four (4) prior calendar years.

9.3 INCIDENT REPORTING AND INVESTIGATION

9.3.1 In the event of an incident meeting the criteria described below, the Agency shall notify the Commission and the Governor's Office of Emergency Services per the following guidelines.

a. If the Agency is notified of the incident during its normal working hours, the report should be made as soon as practicable but no longer than 2 hours after the Agency is aware of the incident and its personnel are on the scene.
b. If the Agency is notified of the incident outside of its normal working hours, the report should be made as soon as practicable but no longer than 4 hours after the Agency is aware of the incident and its personnel are on the scene.

9.3.2 Reportable incidents are classified as those which:

a. Result in fatality or serious injury and are attributable or allegedly attributable to the Agency's TES.
b. Are the subject of significant public attention or media coverage and are attributable or allegedly attributable to the Agency's TES.
c. Include damage to property of the Agency or others estimated to exceed $50,000 that are attributable or allegedly attributable to Agency's TES.

9.3.3 Not later than 30 days from the end of the month in which the reportable incident occurred, the Agency shall submit to the CPUC a written account of the incident which includes a detailed description of the nature of the incident, its cause and estimated damage. The report shall include a description of the Agency's response to the incident and measures the Agency took to repair facilities and/or remedy any related problems on the TES which may have contributed to the incident.

9.3.4 Each Agency shall establish procedures for investigating all reportable incidents for the purpose of determining the causes of the incident and minimizing the possibility of a recurrence.

9.4 ACCESS BY COMMISSION REPRESENTATIVES
Representatives of the Commission shall be allowed to enter upon the property for the purpose of determining compliance with Commission rules, conducting tests, and inspecting records. Commission's representatives entering the property shall have appropriate training or be accompanied by appropriately qualified Agency personnel.