TRANSIT

RAPID TRANSIT SYSTEM EXTENSIONS
COMPENDIUM OF DESIGN CRITERIA

VOLUME VII
SYSTEM EQUIPMENT DESIGN CRITERIA

CHAPTER 1
TRACTION POWER EQUIPMENT DESIGN CRITERIA

INTERIM RELEASE
REV 1

OCTOBER 30, 2008

PROGRAM MANAGEMENT CONSULTANT

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MIAMI-DADE COUNTY TRANSIT

VOLUME VII – SYSTEM EQUIPMENT

CHAPTER 1 – TRACTION POWER EQUIPMENT DESIGN CRITERIA

REVISION 1

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DOCUMENT REVISION RECORD

ISSUE NO.	DATE	REVISION DESCRIPTIONS
0	5-3-07	Interim Release
1	10-30-08	Revisions to incorporate MIC-EH design specifications that have been adopted by MDT.

ISSUE NO.	SECTIONS CHANGED
1	Table of Contents – (pagination changes due to TABLE 2 formatting)
	1.2.2 Traction Power Substations - Location and Rating - TABLE 2 (grammar and formatting corrections)
	1.2.6.18 Traction Power Substations - Substation Equipment - DC Circuit Breakers

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VOLUME VII – SYSTEM EQUIPMENT

CHAPTER 1 – TRACTION POWER EQUIPMENT DESIGN CRITERIA

REVISION 1

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1.1 INTRODUCTION

1.1.1 SCOPE

The scope of the design criteria for the Traction Power Equipment shall include:

A. The criteria for establishing the parameters and design methodology of the electrification system to satisfy the Vehicle power requirements as well as those of all other Systems requiring electrical power.

B. The criteria for establishing the design of the substations including transformers, rectifiers, ac and dc switchgear and controls, etc., that will be required to supply power to the wayside contact rail system.

C. The criteria for establishing the electrical supervisory control interface functions required for supervising and controlling the performance of the traction power equipment vital to the continuous operation of the transit system.

Refer to these and other related Design criteria:

- Volume II - Station Design Criteria, Chapter 4 "Electrical Design Criteria"
- Volume II - Station Design Criteria, Chapter 5, "Mechanical Design Criteria"
- Volume III - Guideway Design Criteria, Chapter 4 “Electrical Design Criteria”,
- Volume VII - System Equipment Criteria Chapter 3 – “Traction Power Installation Hardware”

- Volume VII - System Equipment Criteria Chapter 7 – “Communications System”

1.1.2 SYSTEM DESCRIPTION

The Traction Power Equipment includes all the equipment and subsystems from the point of receiving power from the Utility Company (Florida Power and Light Company) to the point of supplying that power to the contact rail for supply to the transit vehicles. It also provides primary power supply to other transit (non-vehicle) loads including passenger stations, maintenance facilities and the test track building. The Traction Power Equipment consists of all the equipment in the Traction Power Substations, Gap Tie Stations, and that local equipment required to provide Supervisory Control over the entire Traction Power System. Related cabling and conduits are covered in Volume VII - System Equipment Criteria Chapter 3 – “Traction Power Installation Hardware”.

1.1.3 CODES, STANDARDS AND REGULATIONS

Wherever applicable, the Traction Power Equipment design shall conform to all Federal, State and local laws, codes and regulations and shall be in accordance with the latest MDT adopted editions of the codes and standards listed hereunder:

- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- American National Standards Institute (ANSI)
- National Electrical Manufacturer's Association (NEMA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Insulated Cable Engineers Association (ICEA)

- Occupational Safety and Health Act (OSHA)
- American Society for Testing and Materials (ASTM)
- Underwriter's Laboratories Inc. (UL)
- National Fire Protection Association (NFPA)
- Florida Building Code
- Metropolitan Dade County Fire Prevention and Safety Code

The current MDT adopted version of codes, standards and regulations shall apply, unless otherwise directed, all addenda, interim supplements, revisions and ordinances by the respective code body shall also apply. Where conflicts exist between these requirements, the more stringent requirements shall take precedence, unless otherwise directed by MDT.

Definitions that are specifically applicable to dc traction power, ac power and local supervisory control functions will conform to the following standards, unless otherwise stated in this section:

- IEEE 100, "The IEEE Standard Dictionary of Electrical and Electronics Terms"
- ANSI C34.2, "Practices and Requirements for Semiconductor Power Rectifiers"
- ANSI C37.14, "Standards for Low-Voltage dc Power Circuit Breakers used in Enclosures"
- ANSI C37.20.2 "IEEE Standard for Metal Clad and Station Type Cubicle Switchgear".
- ANSI C37.100, "Definitions for Power Switchgear"

- ANSI C57.12.80, “Standard Terminology For Power and Distribution Transformers”
- ANSI C57.18.10, “Practices and Requirements for Semiconductor Power Rectifier Transformers”
- IEC 60298

1.2 TRACTION POWER SUBSTATIONS

1.2.1 GENERAL

The transit vehicles shall be propelled and operated from a direct current power source. Electric power shall be supplied to the vehicles from the wayside contact rail system installed parallel to each track. See also Volume VII, Chapter 2, Contact Rail and Protective Coverboard Design Criteria.

Direct current traction power shall be provided by the Traction Power substations with rated voltage output of 750 volts dc at 100 percent full load.

The rectifier output voltage based on inherent regulation at various loading shall be as follows:

Table 1

Load, Percent	**Volts, dc**
Zero Load	820 Maximum
1	795.0 – 798.2
50	773.1 – 777.3
100	750 – 757.4
150	724.9 – 737.4
300	652.7 – 684.8
450	561.8 – 617.8

The base load resistor with disconnecting means shall be provided to limit absolute zero load voltage of 820 volts dc maximum.

In order to sustain normal traction motor performance under various operating scenarios, the contact rail voltage drop shall fall within the limits as stated in Table 1. The basis of design of the traction power substations shall be to provide sources of power near points of utilization.

Branch line interfaces to existing MDT operating territory shall be facilitated using a Gap Tie Breaker or Traction Power Substation facility. Unless otherwise approved by MDT, in each case, bridgeable gaps and normally closed dc circuit breakers shall be provided in either facility to sectionalize the branch line extension. The use of wayside disconnect switches for isolation of branch line power circuits are permitted at select locations upon MDT approval.

Disconnects shall be:

- Manually operated
- Interlocked to permit only "no load operation" and prevent their operation when power is applied
- Connected to the SCADA system to indicate and record their operation and status at the CCF
- Enclosed in a weathertight, UV resistant fiberglass NEMA 4X cabinet with a hinged door
- Properly labeled on the exterior of the cabinet with disconnect identification and any other related information needed for safe operation.

Each contact Rail power zone sections shall be fed from a minimum of two substation sources. At terminal end stations, where loss of the dc switchgear or any one dc feeder breaker would result in a loss of power to a contact rail zone, additional gap tie circuit breakers shall be provided unless MDT has previously approved the use of motor operated disconnect switches. The gap breakers will facilitate powering the contact rail zone from a second source.

1.2.2 LOCATION AND RATING

The design of the traction electrification system shall be based on the results of a computerized traction power simulation. All necessary parameters for the traction electrification system design shall be determined and calculated. The traction power simulation shall be performed to determine among other things, train run times, root-mean squared power loading, contact (third) rail and negative rail voltages, all substation equipment ratings and optimum substation spacing along the right-of-way.

Traction power simulations shall be performed using a computer program specifically developed for simulation of dc transit power supply and distribution systems. The program shall have been validated on previous design projects and approved by MDT. The trains shall be simulated to operate on the system at the specified projected headway, (randomized by adjusting station dwell times), under normal operating conditions, (i.e. all substations in service), and under abnormal operating conditions, (i.e. individual substation, rectifier and feeder breaker outages, train bunching and simultaneous train starts) as stated in Table 2. Under abnormal operating conditions, the substation rectifiers shall be allowed to operate within the limits of NEMA RI-9 extra heavy traction rating.

The program input data shall include representations of the track gradients (i.e. vertical and horizontal), posted track speed limits and restrictions, passenger station locations, station dwell times (randomized), train passenger loading assuming AW2 passenger loading, and electrical and mechanical characteristics of the train consists and traction power distribution system. The program shall model the latest MDT vehicle and associated propulsion system, including current limiting and / or performance degradation for falling voltage conditions with provisions for regenerative braking. Upon request, MDT will provide vehicle parameters for input to the simulation program.

Output data for each Table 2 scenario shall be provided, and include moment-by-moment train operational data such as time, speed, distance, voltage, current and power demand for each station-to-station run. For each substation, the program results shall include maximum and root mean square power demand, energy consumption, rectifier current and voltage, individual dc feeder current and individual track negative return current. In order to validate the rectifier NEMA RI-9 ratings, an analysis of the worse case root mean squared rectifier / substation power demand for 15 seconds, 1 minute and 2 hours shall also be provided. For each substation-to-substation section of distribution system, the results shall include positive and negative train voltage vs. distance scatter plots. Additionally, the report shall provide analysis of FP&L power consumption and power demand for each MDT substation, assuming design scenarios 1 through 10 in Table 2, and assuming a typical 24 hour demand period and a worst case 15 minute demand period.

The basis of substation spacing, dc feeder breaker ratings, dc feeder conduit provisioning and physical size of the substation area, both indoor and outdoor, shall be based upon the “Ultimate Upgrade in the Future” design requirements, for all case scenarios, as identified in Table 2. The “Initial

Substation Design" shall be based on a dual rectifier unit design with provisions for a third rectifier unit (if necessary) for the ultimate upgrade in the future operations. The ratings selected for the dual rectifier-transformer units shall be determined and based upon the "Initial Operations", such that the substations can be easily expanded to accommodate the addition of an identical transformer–rectifier unit (if necessary) and additional dc feeder cabling for "Ultimate Upgrade in the Future Operations". Substations shall be located at or near passenger stations, to the extent possible.

Design Criteria for Normal and Abnormal Operating Schedules for MAIN LINE AND Branch Line Operations

TABLE 2
Design Scenarios for Mainline and Branch Line Train Operation
AW2 Train Loading

Design Scenarios	Design Criteria	Minimum Voltage
1) Voltage drop - Normal operations - initial installation	6 car trains 3 minute headways	525 volts or higher
2) Voltage drop - Normal operations - Ultimate upgrade in the future	8 car trains 3 minute headways	525 volts or higher
3) Voltage drop - Abnormal operations, 1 rectifier out - initial installation	6 car trains 3 minute headways	490 volts or higher
4) Voltage drop - Abnormal operations, Train bunching - initial installation	6 car trains 2.5 minute headways	490 volts or higher
5) Voltage drop - Abnormal operations, 1 rectifier out Ultimate upgrade in the future	8 car trains 3 minute headways	490 volts or higher
6) Voltage drop - Abnormal operations, Train bunching - Ultimate upgrade in the future	8 car trains 2.5 minute headways	490 volts or higher
7) Voltage drop - Abnormal operations, 1 rectifier out in two adjacent substations - initial installation.	6 car trains 3 minute headways	455 volts or higher

8) Voltage drop - Abnormal operations, 1 entire TPSS out, all dc breakers closed - Initial installation	6 car trains 3 minute headways	455 volts or higher
9) Voltage drop - Abnormal operations, 1 rectifier out in two adjacent substations - Ultimate upgrade in the future	8 car trains 3 minute headways	455 volts or higher
10) Voltage drop - Abnormal operations, 1 entire TPSS out, all dc breaker closed - Ultimate upgrade in the future.	8 car trains 3 minute headways	455 volts or higher
11) Voltage drop – Normal Operations - two simultaneous train starts from a passenger station up to a distance and speed where maximum train power demand occurs, initial installation	6 car trains	455 volts or higher
12) Voltage drop – Normal Operations - two simultaneous train starts from a passenger station up to a distance and speed where maximum train power demand occurs, Ultimate upgrade in the future	8 car trains	455 volts or higher
13) Abnormal Operations – Substation Spacing and dc feeder breakers and cables sized and rated to allow one train to accelerate under full ATO, fed from a single dc breaker (i.e. start and accelerate to posted speed limit) - Initial Installation and Ultimate Upgrade in the Future	6 & 8 car trains respectively	455 volts or higher
Note 1: If Case 13 results in a large increase in cable/feeder size, or reduction in substation spacing, the Designer should review the likelihood of this situation actually occurring, and propose to MDT the scenario to be modeled based on proposed power sectionalizing and operations. The Designer should also consider the relatively short duration of this load and thermal characteristics of the cables in determining the quantity of cables required.		
Note 2: If at terminal stations the train voltage requirements cannot be met under abnormal operations and the projected cost to correct the deficiency is deemed to be excessive, the Designer shall advise MDT of this condition and any mitigating conditions that can be incorporated into the design of the TPSS at the terminal station. This information shall be submitted to MDT to review. If satisfied with the mitigating conditions, MDT will direct the Designer on the revised design requirements for the terminal TPSS.		

Note 3: When referring to 6 car dc trains in design scenarios 1, 3, 4, 7, 8, 11, 13 the headways are six minutes instead of three minutes or less as specified in Table 2.

1.2.3 RESERVED

1.2.4 SUBSTATION POWER SUPPLY

Designer will coordinate with Florida Power & Light Company (FP&L) to provide, at time of construction, two (2) dedicated 13.2kV, 3 phase, 60 hertz power circuits as primary service to each traction power substation, one for each rectifier unit. Each of these 13.2kV circuits shall be furnished from separate FP&L substations or from separate 13.2 kV feeders from one FP&L substation, separated by at least two 13.2 kV bus-tie breakers. Optional electrical service connections may consist of multiple FP&L owned and operated (or MDT owned and operated) 13.2 kV distribution feeders running along the guide-way right-of-way, fed from independent FP&L substations, with provisions for pad mounted tap switches (as required) to supply both the traction power substations and passenger station unit substations. No adjacent passenger station or traction power substations will be allowed to be fed from the same 13.2 kV feeders.

Each circuit of the utility company will have sufficient capacity to support the load of the combined capacity of all installed transformers including the Traction Power Substation NEMA Standard RI-9 short time ratings as well as the Passenger Station auxiliary power requirements. Each FP&L utility circuit shall be made available to either transformer-rectifier unit and / or either passenger station transformer unit by means of an automatic 13.2 kV bus-tie breaker(s). The traction power and passenger station transformers shall be designed to accommodate a utility voltage variation of plus / minus 7-1/2 percent.

1.2.5 SUBSTATION ENCLOSURE

The substation equipment shall be housed in a weatherproof enclosure providing a dry internal environment, designed to maintain the installed equipment within the temperature and humidity limits recommended by the equipment manufacturers. The general appearance and the materials used for the substation enclosure shall be approved by MDT. The substation shall be designed to withstand the maximum wind loading and seismic loading in accordance with Local and State Building Codes for the Miami-Dade County area. The substation may require the installation of special decorative finishes; anti-graffiti paint coatings, unique indigenous colors, and special roofs to meet the local building zoning requirements, as applicable.

For equipment requiring a forklift for installation and removal, consideration shall be given to the required access and maneuvering clearances within the structure.

Sufficient spacing and separation of equipment shall be made to allow removal of any equipment without having to disassemble or remove other equipment.

Transformers shall be installed in a separated room or enclosed yard, depending on the type of transformer used. Dry type transformers shall be in a totally enclosed room with a separate ventilation system designed for failure of one fan. Wet type (liquid or oil filled) transformers, if pre-approved by MDT, shall be installed in a transformer yard, with totally enclosed walls and access gate area with locks.

The walls shall be provided with thermal and acoustic insulation. Sound levels measured at 50 feet in any direction from the substation shall not exceed 35 db over ambient background noise. Electrical insulation will be provided under dc switchgear and rectifiers and on walls (if necessary) to provide a high resistance structure grounding design.

A ventilation system shall be provided for the traction power substation building as described in Volume II - Station Criteria, Chapter 5, "Mechanical Design Criteria". Intrusion detection alarms shall be provided in the traction power substations to prevent access by unauthorized personnel.

An Access Control and Intrusion System, CCTVs, and a Fire Alarm System compatible with the existing Metrorail systems shall be installed at the traction power substation. See Volume II, Station Design Criteria, Chapter 4 "Electrical Design Criteria".

1.2.6 SUBSTATION EQUIPMENT

Substation equipment shall be designed to operate unattended. Controls shall be provided to operate all switchgear from Central Control and, should the need arise, operated locally at the equipment or local control panel by an MDT Technician.

Equipment at each substation shall mainly include:

- 13.2kV primary switchgear,
- Rectifier transformers,
- Rectifier assemblies,
- The dc switchgear,

- Positive bus, negative bus panel with interconnecting buswork,
- Control batteries and charger,
- Protective relaying and isolated with an isolated Ground,
- Provisions for stray current corrosion control drain cables, and
- An annunciator panel and a Supervisory Control Interface Terminal Cabinet (SCITC Panel) to interface to the PLC based SCADA system to allow traction power control and indications to be exchanged with the Central Control Facility (CCF) over the Metrorail Communications system.
- A Blue Light Station (BLS) cabinet containing an ETS button and telephone mounted externally at the entrance to the substation. The BLS shall be for emergency personnel use to de-energize the dc traction power zone.

Equipment cabinets shall have doors with keyed locks and safety interlocks to allow access to internal equipment for maintenance, unless otherwise prohibited by codes or standards.

1.2.6.1 AC Switchgear

Primary switchgear equipment for each substation shall consist of 13.2kV incoming lines, bus tie and feeder circuit breakers (vacuum type preferred), indoor metal clad draw out type, with interrupting capacity for 13.2kV service as required by FP&L.

The 15kV cable termination chambers shall be air insulated and suitable for either top or bottom entry cable access with blank, undrilled gland plates suitable for up to 9 single cores or 3, three core cables. The cable chamber shall be separated from the circuit breaker and busbar chambers.

The required ac switchgear features are:

- 20 Inch wide feeder panel (Approximate)
- 3 position off-load disconnect switch mounted in series with the circuit breaker in same panel
- Fully interlocked disconnect mechanism operable from front of switchgear.
- Circuit and bus bar grounding achieved through vacuum circuit breaker.
- Keyless circuit test access available from the front of the switchgear without racking out of breaker
- Electronic control unit incorporating:
  - Illuminated Indication of circuit breaker status
  - Trip circuit Supervision
  - Circuit Breaker timing and diagnostic functions
- Circuit breaker electrical interlocking
- Provision for circuit breaker operation from a remote position via optional cable connected remote close / trip unit
- Electro-mechanical operations counter, incrementing on successful close operation
- Internal Arc Resistant Switchgear
- Front panel animated mimic diagram
- Maintenance free mechanism
- Single coil magnetically actuated opening and closing mechanism.
- Circuit breaker life 10,000 operations without maintenance

The normal continuous current rating of the complete switchgear, vacuum circuit breaker and busbars shall be no greater than 2,000 Amps and as specified. The switchboard shall have the following ratings:

(i)	Rated Voltage	12 - 15kV
(ii)	Normal Operating Voltage	3.3 - 13.8kV
(iii)	Rated Frequency	60Hz
(iv)	Rated Short Time Current	20/25kA for 3 Seconds
(v)	Rated Short Circuit Breaking Current	20/25kA
(vi)	Power Frequency 1 minute withstand Voltage	28 / 32 / 38kV
(vii)	Impulse Withstand Voltage	75 / 95kV

1.2.6.2 Construction

The switchboard(s) shall be air insulated, of robust construction and shall be unaffected in part or whole by the forces imposed by short circuit or other fault currents, operation, vibration or temperature changes. The switchboard shall be in accordance with British Standards (BS) or its approved equivalent, unless specified otherwise and shall be extensible at both ends. Phase rotation and color markings shall comply with BS. Mechanical protection of the switchgear shall be a minimum of Class IP4X.

The switchboard shall be metal clad in accordance with IEC 60298 and divided into separate compartments. The circuit breaker, busbars, HV cable connection and LV devices shall be arranged in different compartments. For the safety of the operating personnel, is it essential that should an “arc” develop in any of the compartments for any reason whatsoever, it shall be confined to that compartment without affecting other compartments. The switchboard as a whole shall be tested and conform to IEC 60298 Appendix AA (1-6).

Switchgear room floors shall be provided with ‘unistrut’, or equivalent, mounting rails for location of the HV Switchgear.

1.2.6.2.1 Temperature Rise

The temperature rise in any part shall comply with ANSI taking into account the site ambient temperatures.

1.2.6.3 Busbars

The busbar shall be of hard drawn, high conductivity copper bars and sleeved. The busbars shall be air insulated and arranged in sections to permit future extension. Provision shall be made for extending the busbar at either end without any need for cutting or drilling the busbar.

1.2.6.4 Circuit Breakers

Vacuum circuit breakers with totally enclosed and maintenance free contact system will be preferred. Circuit breakers utilizing SF6 as an interruption or insulation medium will be considered as an alternative.

1.2.6.4.1 Circuit Breaker Operating Mechanisms

The preferred Circuit breaker operating mechanism shall be of the single coil magnetic actuator type, suitable for operation from a 110 Vdc supply. Mechanisms utilizing hand charged or motor wound spring elements will be considered. However, where these are offered, facility shall be provided for the removal of the mechanism for maintenance and/or repair without the requirement for removal of the relevant panel from the switchgear assembly.

All 3 vacuum interrupters shall be operated simultaneously through a single drive beam by the magnetic actuator mechanism. The actuator shall use stored spring energy to ensure that the electrical energy required to trip is significantly less than that required to close.

A positively driven mechanical operating indicator shall be provided to show whether the circuit breaker is open or closed.

The switchgear shall include a manually operated trip lever located on the front panel which shall allow easy manual operation in case of emergency.

The circuit breaker shall be maintenance free for 10,000 load / mechanical operations.

1.2.6.5 Isolation

The switchgear shall be provided with a 3 position disconnector to provide busbar and circuit isolation/grounding facilities and a circuit access socket to provide testing facilities from the front of the panel. The following circuit breaker positions shall be provided:

- Service
- Isolated
- Ground / test access

Mechanical indication shall be provided to show the location of the disconnector. Such indications shall be visible from the front of the equipment at all times. There shall be provision to padlock the circuit breaker in any of the 3 positions listed above.

1.2.6.6 Grounding / Test Access

Means shall be provided in the switchboard for circuit and busbar grounding through the vacuum circuit breaker.

The grounding connections and devices shall have instantaneous peak and short time current ratings equivalent to that of the circuit breakers.
Such grounding shall be achieved by the following means:

- Circuit grounding. By moving the 3 position disconnector into the ground / test access position and closing the circuit breaker in order to ground the circuit.
- Busbar grounding. Where the switchboard includes a bus section, it shall be possible for either section of busbar to be grounded, leaving the other section live, by selecting which section to ground using the 3 position disconnector and then grounding the busbar through the circuit breaker.

If it is necessary to ground both sides of the busbar at the same time, or if the switchboard does not contain a bus section, a separate busbar grounding switch shall be provided on one end of the switchboard.

Circuit test access shall be from the front of the equipment through a padlockable access cover. This cover shall be interlocked with both the circuit breaker and the 3 position disconnector to ensure that it can only be opened when the disconnector is in the ground/test position and the circuit breaker has been closed.

1.2.6.7 Protective Relaying

The rectifier assemblies and the dc switchgear enclosures shall be insulated from the transformer case, from each other and from any other grounded metal. An insulation failure between the live bus and the rectifier enclosure shall be detected by means of a ground relay device 64/64G which will trip and lock out the ac feeder breaker and main dc breaker for the faulted rectifier assembly. The relay shall also provide a visible warning at the substation with alarm indication transmitted to Central Control. In the event that floor surface covering insulation fails from the enclosure to ground, a visible warning shall be given at the substation, with alarm indication transmitted to Central Control. Similarly, an insulation failure between the positive bus and the dc switchgear enclosure shall be detected by means of a ground relay, device 164/164G, which will trip and lock out both dc main breakers and all dc feeder breakers and also provide a visible warning at the substation with alarm indication transmitted to Central Control. In the event that floor surface covering insulation fails from the enclosure to ground, a visible warning shall be given at the substation, with alarm indication transmitted to Central Control.

1.2.6.8 Interlocks

The switchgear must be fully mechanically interlocked in order to prevent mal-operation. The interlocking arrangement shall prevent:

- The movement of the disconnector when the circuit breaker is in the closed position.
- The closing of the circuit breaker when the disconnector is in the isolated position.
- The opening of the test access cover until the disconnector is in the Ground/test position and the circuit breaker has been closed.

- Electrical tripping of the circuit breaker when the disconnector is in the Ground/test position and the circuit breaker is in the closed position.
- The movement of the disconnector from the Ground/test position to the isolated position when the circuit breaker is closed.

All interlocking associated with circuit or busbar grounding shall be mechanical. Exclusively electrical interlocking shall not be permitted.

1.2.6.9 Grounding of Metal Parts

All panels shall be inter-connected with a copper ground bus running along the switchboard. The cross section of this copper shall be designed to withstand the rated short circuit current of the switchgear. All metal, instrument and relay cases of the panels shall be connected to the ground bar by copper conductors not less than 2.5 sq.mm cross section.

1.2.6.10 Small Wiring

All wiring shall be copper conductor, 600 volt tropical grade PVC insulated. All small wiring shall be suitably terminated with circuit numbers. The size of the conductors shall be no less than:

- 10 AWG for the magnetic actuator control circuits
- 12 AWG for the CTs and ground connections
- 14 AWG for all other wiring

1.2.6.11 Labels

Each panel of the switchboard shall have a blank circuit label approximately 30cm x 8cm mounted on the front of the panel in a prominent position. These labels shall be made of a suitable engraving material approximately 2 mm thick, white surface with black engraving.

1.2.6.12 Fuses and Links

Fuses shall be of the high rupturing capacity cartridge type; rewirable fuses shall not be acceptable. Fuse holders shall be designed to lock the cartridge firmly into position without the use of screw clamping devices.

Carriers and bases for 16 Amp fuses shall be colored green and those for 6 Amp fuses shall be black. Link carriers and bases shall be white or another distinctive color.

1.2.6.13 Current Transformers

Current transformers shall be air insulated. They shall be so rated and designed that they shall not sustain any damage due to through fault currents expected on a system fault level of 25kA.

All secondaries shall be 1 or 5 amps.

1.2.6.14 Potential Transformers

All potential transformers shall be of fixed pattern, 3 phase, cast resin encapsulated construction. Provision shall be made for isolation of the PT via a rotary disconnecting device, accessible from the front of the switchgear panel.

1.2.6.15 Protection & Control Equipment

Unless otherwise pre-approved by MDT, Protection & Control relays shall be from the Alstom ‘K-Series’ or ‘Micom’ ranges.

1.2.6.16 Rectifier Transformers

Rectifier transformers shall be self-cooled indoor dry type, cast coil or, if pre-approved by MDT, outdoor, oil-filled type, suitable for extra heavy duty traction service conforming to NEMA Standard RI-9. The transformer shall be ANSI circuit 31 and be designed and manufactured in accordance with ANSI C57.18.10.

The rectifier transformer secondary output shall be 6 phase with primary voltage consistent with utility supply and equipped with appropriate no-load taps. The taps shall enable the transformer to compensate for utility voltage variation and permit the transformer rectifier to output the specified nominal voltage.

The transformer shall be designed to withstand the system fluctuating load currents and fault currents without overheating or decrease in life expectancy. The transformer windings shall be adequately designed, insulated, braced and strengthened to withstand without damage the thermal, mechanical and electrical stresses occurring during system operation and short circuits.

Rectifiers shall be silicon diode type, contained in a free standing, metal natural convection, air-cooled indoor enclosure. The rectifier units shall each be rated in accordance with NEMA Standards Pub. No. RI-9-1.04 C for extra heavy-duty service. The rectifier will be designed and tested in accordance with the requirement set forth in ANSI C34.2. Over-temperature, detect diode fuse failure and rectifier door open protection circuitry shall also be provided. Each Rectifier structure shall be designed for high resistance grounding.

Both the rectifier and rectifier-transformer shall be capable of operating at 100 percent rated current continuously followed by two hours of 150 percent rated current with five cycles of 300 percent rated current of one minute duration each, spaced evenly within the two hour period and one cycle of 450 percent rated current for fifteen seconds at the end of the two hour peak period. The rectifier must withstand two such overload duties per day spaced about seven hours apart.

1.2.6.17 DC Switchgear

The dc switchgear assembly shall consist of indoor, metal enclosed, dead front, self-supporting units containing cathode (main dc) and feeder power circuit breakers. Dc switchgear panels are of robust steel construction, metal-clad, and segregated into Medium Voltage and Low Voltage compartments. As standard, the robust structure of dc switchgear shall offer the safety benefit of having been tested for 'Internal Arc Withstand Capability' in accordance with IEC60298, Appendix AA, Test Criteria 1-6, Accessibility Class A. Each of the Medium Voltage (Busbar, Circuit Breaker and Cable Termination) compartments is fitted with exhaust flaps, providing venting of arc products at the rear of the equipment, ie. away from the operator, in the unlikely event of an internal arc fault.

Removable elements if the same type rating shall be completely physically and electrically interchangeable. Removable elements not of the same type of rating shall not be physically interchangeable. The feeder breaker switchgear shall be designed to accommodate up to 8000 Amp circuit breakers.

Each dc Switchgear structure shall be designed for high resistance grounding.

1.2.6.18 DC Circuit Breakers

The dc circuit breakers shall be single pole, air-break, high speed, removable type, capable of interrupting the maximum short circuit current from the substation installed rectifiers and including the short current contributions from adjacent substations. The breaker will be able to be removed by the roll out method with no less than 6 highly durable Teflon/PVC constructed rollers. The circuit breakers shall be manufactured in accordance with ANSI C37.14-2002 and rated to the preferred ratings listed in ANSI C37.16-2000. The circuit breakers shall be electrically and mechanically trip free. A standing trip signal shall not allow the main contacts to touch temporarily energizing the line when a close signal is given.

The circuit breakers shall be 800 Vdc class, and shall be 4, 6 or 8kA continuously rated per ANSI C37.14-2002.

The circuit breakers shall be designed for control from a 125 Vdc control power bus with operation range capabilities by ANSI standards.

Current interrupting arc chutes shall be of the metal plate cold cathode type suitable for bi-directional current flow and designed for positive interruption of all currents within the circuit breaker ratings. Low current arc interruptions shall not be dependent on mechanical puffer devices.

Contact surfaces of moving and stationary contact members of the main contacts shall be silver tungsten carbide or equivalent which combines high conductivity and necessary arc-resistant properties capable of 50,000 mechanical operations before replacement

The operating mechanism shall be magnetically actuated or solenoid operated type. The mechanism shall be non-pumping and the design shall ensure positive opening of the moving contacts and circuit interruption when the tripping impulse is received at the fully closed or any partially open position. The mechanism shall operate at high speed for any trip signal. If required, a capacitive impulse trip coil should be used. The impulse trip coil shall be tested for the same number of operations as the circuit breaker operations. Solenoid operated mechanisms shall be connected such that the control voltage is removed from the closing coil after a preset time. The speed of each close shall be identical and not dependent on control voltage amplitude. Provision shall be made for moving each breaker to a “connected”, “test/disconnected” position via automatic disconnector umbilical cord. In the “connected” position, both the primary disconnecting devices and the secondary disconnecting devices shall be in full contact and the breaker shall be in position for normal operation.

The following are requirements of the dc breakers:

- Capable of high speed operation from the switchgear mounted protective relays without the use of capacitor discharged impulse coils.
- Minimum life of the operating mechanism 200,000 operations.
- Magnetically actuated opening and closing mechanism.
- Bi-directional magnetic low current blow-out system capable of extinguishing 5 amps immediately after full short circuit current in the opposite direction.

- Arc chute shall weigh less than 90 pounds with the arc runners an integral part of the arc chute.
- Completed a severe shake test.
- Racking handle incorporated in the breaker as an integral part.

The dc feeder breaker switchgear cubicles shall be equipped with automatic reclosure devices which allow up to two reclosure attempts (selectable up to four) after which, activates a reclosure lockout requiring another breaker closure command either remotely from the Central Control Facilities (CCF) or locally to re-initiate closure. Bi-directional over current protection shall be provided with each dc feeder circuit breaker for instantaneous, short time, long time and rate-of-rise fault detection. Cathode breakers shall be provided with reverse current protection for rectifier fault detection and forward inverse-time over current protection to detect bus faults and backup protection for feeder faults. In addition, all circuit breakers controlling power zones shall be normally operated and monitored remotely from Central Control by means of the Supervisory Control System. Local controls shall also be provided to permit local manual operation of all circuit breakers within each substation.

1.2.6.19 Other

The negative bus panel shall consist of a metal enclosed, free-standing, indoor type enclosure. The panel shall be for common termination of negative returns from the wayside running rails, from the negative terminal of the rectifiers and for the stray current drain cables.

All substation interconnecting buses shall be copper with silver-plated joints at pressure connections. Buses shall be sized for the application and adequately supported to withstand available short circuit currents at the appropriate bus voltage level.

The substation control battery shall be a round “tropical” battery design specified to operate for its intended life cycle, within the ambient temperature limits expected in a traction power substation. Any special handling and/or environmental conditions required for battery storage, installation, and operation shall be addressed.

The primary service cables from the utility company shall be extended into the substation and terminated in appropriate cubicles by the utility company. Utility company metering equipment will be accommodated and installed as required. Protective relaying of the incoming line breakers, as well as control of the primary bus tie breaker shall be in accordance with the requirements of the utility company.

The traction power substation auxiliary power requirements shall be furnished from auxiliary circuits within the substation derived from the 13.2 kV service entrance feeders or the adjacent passenger unit substation. For details, see Volume II - Station Criteria, Chapter 4 “Electrical Design Criteria".

1.3 GAP TIE STATIONS

1.3.1 GENERAL

Gap Tie stations are part of the Traction Power system. Generally, gap tie stations will be located at track crossovers and pocket tracks except when special trackwork is located near a traction power substation. Its function will be to bridge the gap between sections of contact rail to provide a continuous 750 Vdc loop over the entire system during normal operating conditions. During maintenance, repairs or emergency conditions, the gap tie stations will be used to isolate appropriate contact rail sections.

Volume VII, Chapter 2 – Contact Rail and Coverboard Design Criteria provides preferred contact rail electrification configurations. Gap tie station locations and use of disconnects for controlling contact rail electrification shall be coordinated with MDT.

1.3.2 LOCATION AND RATING

Sectionalizing breakers within the gap tie stations shall be of identical rating and construction as substation feeder breakers. These are described in Section 1.2.6 above. Gap tie station buildings shall be located adjacent to or under the tracks depending on the design of the line.

1.3.3 GAP TIE STATION EQUIPMENT

Equipment at each gap tie station shall mainly include:

- The dc switchgear,
- Control batteries and charger, and
- A Supervisory Control Interface Terminal Cabinet (SCITC Panel) to interface to the input/output modules of the PLC based SCADA

system to allow traction power control and indications to be exchanged with the CCF over the Metrorail Communications system.

- A Ventilation System
- Access and Intrusion Alarm System with CCTV.

The design criteria stated in above sections 1.2 for the Traction Power building and equipment shall apply to the Gap Tie building and applicable equipment.

1.4 GROUNDING AND LIGHTNING PROTECTION

A grounding and lightning protection system shall be provided for the traction power substations and gap tie stations as described in Volume II - Station Design Criteria, Chapter 4 "Electrical Design Criteria", and Volume III – Guideway Design Criteria, Chapter 4 “Electrical Design Criteria”.

Each substation will be equipped with a 2 inch-by-0.25 inch copper ground bus and necessary extension cabling to a substation ground grid, as required, to obtain a maximum resistance to earth ground not to exceed 5 ohms. Non-current-carrying metal enclosures or parts of ac equipment, including ac apparatus and rectifier-transformers, shall be securely grounded to the ground grid.

Ground grid design will include provisions for safe touch and step potentials in accordance with the IEEE 80 standard. Ground grid potential rise shall be limited to the maximum projected ac phase by the ground fault current expected at each substation from the power utility.

Non-current-carrying metal enclosures or parts of ac equipment, including ac apparatus and rectifier-transformers, shall be securely grounded to the ground grid.

To help mitigate the effects from lightning surges, lightning surge protection shall be provided on the right-of-way, connected at every supply point on the positive contact rail and on the running rail negative return. Refer to Volume III – Guideway Design Criteria, Chapter 4 “Electrical Design Criteria”.

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1.5 CORROSION CONTROL

For Corrosion Control information refer to Volume III – Guideway Design Criteria, Chapter 4 “Electrical Design Criteria”, and Volume II – Station Design Criteria, Chapter 4 “Electrical Design Criteria”. These criteria also apply to the Traction Power Substation and Gap Tie station and equipment.

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1.6 LIGHTING SYSTEM

For details see Volume II Station Design Criteria, Chapter 4 "Electrical Design Criteria". These criteria also apply to the Traction Power Substation and Gap Tie station.

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1.7 SUPERVISORY CONTROL

1.7.1 GENERAL

This section includes functional and design requirements for the supervision and control of the Traction Power System Equipment. The Electrical Supervisory Control System shall utilize the PLC based SCADA System for transmission of all supervisory data between field controlled equipment and the (CCF). The design of the Traction Power Supervisory System must be closely coordinated, particularly with respect to details of the interface to the existing Metrorail SCADA system and Metrorail Communications Network (MCN).

1.7.2 EQUIPMENT AND SYSTEM INTERFACE

1.7.2.1 Power Control Center Console

The Power Control Center Console location in the CCF shall contain an electrical display and control console, which gives immediate alarm, and visual indication of status changes, faults or other abnormal conditions associated with traction power substations and gap tie stations. This Power Control Center Console shall be further equipped to provide the operating attendant with the capability to control and monitor the electrification system serving the transit facility to maintain continuous operation of the overall transit system. Remote monitoring terminals shall be provided to allow monitoring of all TPSS alarms and mimics.

1.7.3 SCITC PANELS AND THE SCADA INTERFACE

The traction power substations and gap tie stations equipment installation contractor shall be required to route and connect all supervisory control cabling from the devices to be controlled in each substation and gap tie station to a Supervisory Control and Interface Terminal Cabinet, referred to as the SCITC panel.

A SCITC panel for each traction power substation and gap tie station shall be located in the traction power substation and the gap tie station buildings respectively. The installation contractor shall further be required to make the necessary supervisory control connections to the devices to be controlled and to the terminal strips provided in the SCITC panel.

The SCADA system interfaces to the SCITC panel consist of connection to the station's PLC I/O modules. Commands from the Central Control Facility (CCF) are transmitted over the Metrorail Communications Network (MCN) to the Station's PLC. The PLC's output modules energize the SCITC panel's relays to execute the TPSS command from Central. Status of the TPSS is monitored as Indications from the SCITC panel's relays sent to the PLC input modules. These indications are then transmitted by the MCN to central. The SCADA system and MCN is covered in Volume VII, Chapter 7, Communications System Criteria.

Implementation of the Supervisory Commands and Indications shall follow the existing MDT system configuration for consistency of design and compatibility with the existing system. Any deviation will require the approval of MDT.

1.7.4 SUPERVISORY CONTROL INTERFACE FUNCTIONS

Appendices A and B list the various supervisory control interface functions for the electrification system. Refer also to existing MDT SCITC functional listing and Volume VII, Chapter 7, Communications System Criteria – Appendix A. Example Data Point listing.

APPENDIX A

ELECTRIFICATION SYSTEM

SUPERVISORY CONTROL INTERFACE

EXAMPLE OF TYPICAL TRACTION POWER SUBSTATION

A. Ac SWITCHGEAR

1. Control Circuits

a. Incoming line feeder breaker No. 4 - Close
b. Incoming line feeder breaker No. 4 - Trip
c. Incoming line feeder breaker No. 7 - Close
d. Incoming line feeder breaker No. 7- Trip
e. Tie Breaker No. 6 - Close
f. Tie Breaker No. 6 - Trip
g. Rectifier transformer feeder breaker No. 2 - Close
h. Rectifier transformer feeder breaker No. 2 – Trip
i. Rectifier transformer feeder breaker No. 9 – Close
j. Rectifier transformer feeder breaker No. 9- Trip
k. Passenger substation feeder breaker No. 1- Close
l. Passenger substation feeder breaker No. 1- Trip
m. Passenger substation feeder breaker No. 10- Close
n. Passenger substation feeder breaker No. 10- Trip

2. Indication Circuits

a. Incoming line feeder breaker No. 4 – Closed
b. Incoming line feeder breaker No. 4- Open

c. Incoming line feeder breaker No. 7 - Closed
d. Incoming line feeder breaker No. 7 – Open
e. Tie breaker No. 6 - Closed
f. Tie breaker No. 6 - Open
g. Rectifier transformer feeder breaker No. 2 - Closed
h. Rectifier transformer feeder breaker No. 2 – Open
i. Rectifier transformer feeder breaker No. 9- Closed
j. Rectifier transformer feeder breaker No. 9 – Open
k. Passenger substation feeder breaker No. 1 – Closed
l. Passenger substation feeder breaker No. 1 – Open
m. Passenger substation feeder breaker No. 10 – Closed
n. Passenger substation feeder breaker No. 10 – Open

B. Dc SWITCHGEAR

1. Control Circuits
   a. Cathode feeder breaker No. 1 – Close
   b. Cathode feeder breaker No. 1 – Trip
   c. Cathode feeder breaker No. 6 – Close
   d. Cathode feeder breaker No. 6 – Trip
   e. Feeder breaker No. 2 – Close
   f. Feeder breaker No. 2 – Trip
   g. Feeder breaker No 3 – Close
   h. Feeder breaker No 3 – Trip
   i. Feeder breaker No 4- Close
   j. Feeder breaker No 4 – Trip
   k. Feeder breaker No 5 - Close
   l. Feeder breaker No 5 – Trip

2. Indication Circuits
   a. Cathode feeder breaker No. 1 – Closed
   b. Cathode feeder breaker No.1 - Open
   c. Cathode feeder breaker No. 6 – Closed
   d. Cathode feeder breaker No. 6 - Open
   e. Feeder breaker No. 2 - Closed
   f. Feeder breaker No. 2 - Open
   g. Feeder breaker No. 3 - Closed
   h. Feeder breaker No. 3 - Open
   i. Feeder breaker No. 4 - Closed
   j. Feeder breaker No. 4 - Open
   k. Feeder breaker No. 5 – Closed
   l. Feeder breaker No. 5 – Open
   m. Cathode feeder breaker No. 1 Load Amps
   n. Cathode feeder breaker No. 6 Load Amps
   o. 750 Vdc Main Bus Voltage

C. <u>RECTIFIER TRANSFORMER</u>

1. Control Circuits

   None

2. Indication Circuits

   None

D. <u>RECTIFIER</u>

1. Control Circuits

   None

2. Indication Circuits
   a. Energized / Grounded Structure
   b. Diode Failure

E. BATTERY SYSTEM

1. Control Circuits

   None

2. Indication Circuits
   a. Summary Alarm Failure

F. ANNUNCIATOR PANEL

1. Control Circuits
   a. Annunciator acknowledge
   b. Annunciator reset

2. Annunciation Circuits

   (Abnormal conditions) - Alarm circuits

Ac Switchgear

a. Failure of incoming 13.2 kv Line 1
b. Failure of incoming 13.2 kv Line 2

Dc Switchgear

c. Dc switchgear structure grounded/energized

Rectifier Transformer

d. Transformer No. 1- Trouble

Includes:

1. Sudden pressure
2. Low oil level
3. Winding high temp.
4. Oil high temp.

e. Transformer No. 2 - Trouble

Includes:

1. Sudden pressure
2. Low oil level
3. Winding high temp.
4. Oil high temp.

f. Lock out relay No. 1 - Trip

g. Lock out relay No. 2- Trip

Rectifier

h. Rectifier No. 1 - Structure grounded/energized

i. Rectifier No. 2 - Structure grounded/energized

j. Rectifier No. 1- Trouble

Includes:

1. Diode high temp.
2. Diode failure
3. Dc surge protection

k. Rectifier No. 2 - Trouble

Includes:

1. Diode high temp.

2. Diode failure
3. Dc surge protection

Battery

l. Battery- Trouble
m. Failure of ac power to battery charger

Contact Rail System

n. Loss of potential CR Section 1
o. Loss of potential CR Section 2
p. Loss of potential CR Section 3
q. Loss of potential CR Section 4

Switchgear Circuit Breakers

r. Remote - Local Control

Transfer Trip System

s. Failure of pilot wire circuit

Security

t. Intrusion alarm
u. Fire alarm indication
v. High temperature

G. CONTACT RAIL SYSTEM

1. Control Circuit
   a. Motor Operated Switch Open
   b. Motor Operated Switch Close

2. Indication Circuits
   a. Motor Operated Switch Open
   b. Motor Operated Switch Close
   c. Motor Operated Switch Trouble

   (if wayside disconnects are implemented)

   d. Manually operated wayside disconnect open

   e. Manually operated wayside disconnect closed

H. EMERGENCY TRIP SYSTEM (ETS)

1. Control Circuits
   a. Feeder breaker No. 2 ETS Reset
   b. Feeder breaker No. 3 ETS Reset
   c. Feeder breaker No. 4 ETS Reset
   d. Feeder breaker No. 5 ETS Reset

2. Indication Circuits

   Activation of ETS pushbutton

L. SPARES

1. Control Circuits

   20 percent

2. Indication Circuits

   20 percent

3. Annunciation Circuits

   20 percent

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APPENDIX B

ELECTRIFICATION SYSTEM

SUPERVISORY CONTROL INTERFACE

EXAMPLE OF TYPICAL GAP TIE STATION (HAVING 5 dc BKRS)

A. Dc SWITCHGEAR

1. Control Circuits

   a. Feeder breaker No. 1 – Close
   b. Feeder breaker No. 1 - Trip
   c. Feeder breaker No. 2 - Close
   d. Feeder breaker No. 2 - Trip
   e. Feeder breaker No. 3 - Close
   f. Feeder breaker No. 3 - Trip
   g. Feeder breaker No. 4 - Close
   h. Feeder breaker No. 4 - Trip
   i. Feeder breaker No. 5 - Close
   j. Feeder breaker No. 5 - Trip

2. Indication Circuits

   a. Feeder breaker No. 1- Closed
   b. Feeder breaker No. 1 - Open
   c. Feeder breaker No. 2 - Closed
   d. Feeder breaker No. 2 - Open
   e. Feeder breaker No. 3 – Closed
   f. Feeder breaker No. 3 - Open
   g. Feeder breaker No. 4 - Closed

h. Feeder breaker No. 4 – Open

i. Feeder breaker No. 5 - Closed

j. Feeder breaker No. 5 - Open

B. BATTERY SYSTEM

1. Control Circuits

None

2. Indication Circuits

None

C. ANNUNCIATOR PANEL

1. Control Circuits

a. Annunciator acknowledge

b. Annunciator reset

2. Annunciator Circuits

(Abnormal conditions) Alarm circuits

Dc Switchgear

a. Dc switchgear structure grounded/energized

Battery

b. Battery Trouble

c. Failure of ac power to Battery Charger

Contact Rail System

d. Loss of potential CR Section 1

e. Loss of potential CR Section 2

f. Loss of potential CR Section 3

g. Loss of potential CR Section 4

h. Loss of potential CR Section 5

Switchgear Circuit Breakers

i. Remote - local control

Transfer Trip System

j. Failure of pilot wire circuit

Security

k. Intrusion alarm

l. Fire alarm indication

D. CONTACT RAIL SYSTEM

1. Control Circuit

   None

2. Indication Circuit

   None

E. EMERGENCY TRIP SYSTEM (ETS)

1. Control Circuit

   a. Feeder breaker No. 1 ETS Reset

   b. Feeder breaker No. 2 ETS Reset

   c. Feeder breaker No. 3 ETS Reset

   d. Feeder breaker No. 4 ETS Reset

2. Indication Circuits

   Activation of ETS pushbutton – Separate inputs for each pushbutton

F. SPARES

1. Control Circuits

20 percent

2. Indication Circuits

   20 percent

3. Annunciation Circuits

   20 percent