PART 1 - GENERAL

1.01 SUMMARY

The scope of this document is to provide the specifications for a static frequency converter (SFC) system for the SEPTA Wayne Junction SFC (WJSFC) Rehabilitation Project. This specification shall be used as the basis for designing and procuring new SFCs at Wayne Junction SFC Station.

This specification section for SEPTA’s Wayne Junction SFC Station is intended to define to the SFC Contractor (SFCC) the technical requirements associated with the detailed design, manufacturing, procurement, delivery, installation, testing, and commissioning of the SFC system and equipment specified herein.

The SFCC responsibilities include detailed design, manufacturing, procurement of SFC related equipment, delivery, installation supervision and support, installation of specialized equipment, testing, and commissioning of the SFC system and equipment specified herein.

The Electrical Contractor (EC) will function as the Coordinating Contractor and will remove the existing SFC electrical equipment and install the majority of SFC electrical equipment under the supervision of the SFCC.

The Mechanical Contractor (MC) will remove the existing SFC mechanical equipment and install the SFC mechanical equipment, such as the heat exchangers, coolers, and piping, under the supervision of the SFCC.

The General Contractor (GC) will remove foundations, pedestals, structures, and metal works with the retired filters yards. The GC will install the SFC foundations, anchors, and construct the new building for SFC #4.

The SFC specification covers the following equipment:

A. SFC power block equipment
B. SFC input and output transformers
C. SFC harmonic and power factor correction filters
D. SFC precharging circuit breakers and auxiliary transformers
E. SFC control system
F. SFC cooling system, including pumps, piping, and heat exchangers
G. SFC power distribution system and UPS equipment
H. SFC protection system equipment
I. Sequence of events recorder
J. Transient disturbance recorder
K. Remote terminal units (RTUs)
L. SFC interconnecting cabling, conduits, and accessories

The proposed project single-line diagram is provided as part of the Contract Drawings.
1.02 RELATED SECTIONS
A. Section 01010 – Summary of Work
B. Section 01011 – Summary of Project
C. Section 01025 – Measurement & Payment
D. Section 01041 – Project Coordination
E. Section 01100 – Special Project Procedures
F. Section 01300 – Submittals
G. Section 01400 – Quality Requirements
H. Section 01452 – Contractor Quality Control - TP Equipment
I. Section 01822 – Demonstration and Training
J. Section 01830 – Operation & Maintenance Data
K. Section 01832 – Operations & Maintenance Manuals - TP Equipment
L. Section 05120 – Structural Steel
M. Section 05500 – Metal Fabrications
N. Section 05610 – Miscellaneous Metals
O. Division 16 specifications
P. Section 16262A – Appendix A - SFC Technical Data Sheets
Q. Section 16262B – Appendix B - SFC Document Submittal Schedule
R. Section 16262C – Appendix C - SFC Contractor Questionnaire
S. Section 16262D – Appendix D - SFC PQ Curves
T. Eval-4017500-E-002, Wayne Junction SFC Design Criteria

1.03 DEFINITIONS
CMU  concrete masonry unit
NEHRP  National Earthquake Hazards Reduction Program
PECO  Philadelphia Electric Company (60 Hz utility company)
SEPTA  Southeastern Pennsylvania Transportation Authority
SER  sequence of events recorder
SFC  static frequency converter
TP  traction power
TPSS  traction power substation
WJSFC  Wayne Junction Static Frequency Converter
WJTPSS  Wayne Junction Traction Power Substation (connects the Wayne Junction SFC Station output to the 24/12 kV traction power system)
1.04 PROJECT/SITE CONDITIONS

Refer to the 30% Submittal Contract Drawings for the definition of areas to be allocated for the SFC equipment at WJSFC Station.

A. Site Name: Wayne Junction SFC Station

B. Site Address: SEPTA Wayne Junction
   4505 Germantown Ave
   Philadelphia, PA 19144

C. Project Owner: Southeastern Pennsylvania Transportation Authority (SEPTA)

D. Owner’s Address: SEPTA
   1234 Market St.
   Philadelphia, PA 19103

E. Quadrangle Name: Germantown

F. Decimal Degrees: 40.0261 N, -75.1552 W (Google Maps)

G. Proposed Construction: PECO provides electrical power for SEPTA’s train service. At present, frequency conversion is accomplished by three 1980 vintage, 15 MVA static converters at WJSFC station. Four new 15 MVA frequency converters are proposed for WJSFC station. The existing three SFCs will be removed one at a time and replaced with three new SFCs. A new building will be constructed as shown on Contract drawings to house one new SFC.

H. Major SFC Equipment: Four identical SFCs, each rated at 15 MVA, located within a concrete masonry unit (CMU) constructed building. The SFC equipment includes four new step-down transformers, power converters, filters, cooling equipment, local controls, and step-up transformers, as required.

I. Auxiliary Equipment: An existing SFC Building contains SFC controls, SCADA, SER, power distribution switchgear, batteries, lighting, HVAC, and plumbing for the existing three SFC units. An addition will extend the building to house one new SFC unit and all appurtenances.

   There are two existing 1500/2250 kVA, 13.2 kV-480Y/277 V, 3-phase, 60 Hz transformers that supply auxiliary power to the SFC Building.

J. Converter Input Voltage: 13.2 kV, 60 Hz, 3-ph from the 230 kV Substation Control Building.

   480Y/277 V, 60 Hz, 3-ph, 4-wire for auxiliary equipment.

K. Converter Output Voltage: 24/12 kV, 1-ph, 25 Hz, to the SEPTA Wayne Junction Traction Power Substation (WJTPSS). The converter output transformer supplies a traction power system directly. The system voltages are 12 kV from trolley-to-
rail, 24 kV from feeder-to-rail, and 36 kV from trolley-to-feeder. The output transformer secondary is rated 36 kV bushing-to-bushing with the winding tapped at 1/3 from the trolley bushing. The connection to rail is solidly-grounded.

L. Environmental Requirements

1. Equipment Location
   a) The transformers, circuit breakers, filtering and power factor supporting equipment shall be suitable for outdoor installation.
   b) The power equipment cubicles (thyristors, GTOs), control system equipment, protective equipment, and auxiliary distribution system for each SFC shall be suitable for either indoor or outdoor installation, depending upon the final design proposed by the SFC Contractor.

2. Atmospheric Data
   Outdoor air design conditions for heating, ventilation, and air-conditioning (HVAC) will be based on the 2009 ASHRAE Handbook of Fundamentals for North East Philadelphia, PA.

<table>
<thead>
<tr>
<th>Table 1 - Outdoor Design Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>Winter Design Temperature</td>
</tr>
<tr>
<td>(ASHRAE 50 year extreme winter design condition)</td>
</tr>
<tr>
<td>Summer Design Conditions</td>
</tr>
<tr>
<td>(ASHRAE 50 year extreme summer design condition)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 - Indoor Design Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>SFC rooms</td>
</tr>
<tr>
<td>Other spaces</td>
</tr>
</tbody>
</table>

1.05 QUALITY ASSURANCE

A. Regulatory Requirements

The latest approved revision of all applicable Standards shall apply to all material, equipment and tests supplied under the Contract, including but not limited to the standards listed in this section.

If any conflict arises between provisions of this specification and the provisions included in the listed documents, such conflict shall be brought to the attention of the SEPTA Project Manager (PM). The SEPTA PM’s decision shall be in accordance with the Contract.


2. ASA S1.4-1993(R2006), Specification for Sound Level Meters.
3. ASA S1.6-1984(R2011), Preferred Frequencies, Frequency Levels and Band Numbers for Acoustical Measurements.
5. ASA S1.13-2005(R2010), Measurement of Sound Pressure Levels in Air.
21. DIN 45635-1-1984, Measurement of noise emitted by machines; airborne noise emission; enveloping surface method; basic method, divided into 3 grades of accuracy.
27. EN 50163:2006, Railway applications - Supply voltages of traction systems.
28. EN 50327:2003, Railway applications - Fixed installations -Harmonization of the rated values for converter groups and tests on converter groups.
32. IEC 60050, International Electrotechnical Vocabulary
33. IEC 60060-1-2010, High voltage test techniques, Part 1: General definitions and test requirements.
34. IEC 60060-2-2010, High voltage test techniques, Part 2: Measuring systems.
36. IEC 60068-2-6-2007, Environmental testing, Part 2-6: Test Fe and guidance: Vibration (sinusoidal).
39. IEC 60146-1-1-2009, Semiconductor converters, General requirements and line commutated converters, Part 1-1: Specifications of basic requirements.
41. IEC 60146-1-3-1991, Semiconductor converters, General requirements and line commutated converters, Part 1-3: Transformers and reactors.
44. IEC 60329-1985, Strip-wound cut core of grain oriented silicon-iron alloy, used for electronic and telecommunication equipment.
45. IEC 60529-2013, Degrees of protection provided by enclosures (IP Code).
47. IEC 60664-3-2010, Insulation coordination for equipment within low-voltage systems, Part 3: Use of coatings to achieve insulation coordination of printed board assemblies.
48. IEC 60721-3-1-1997, Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Section 1: Storages.
49. IEC 60721-3-2-1997, Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Section 2: Transportation.
50. IEC 60721-3-3-2002, Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Section 3: Stationary use at weather protected locations.
53. IEC 61000-4-1-2016, Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series.
54. IEC/TR 61000-3-6-2008, Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.
55. IEC 61355-1-2009, Classification and designation of documents for plants, systems and equipment.
57. IEC 81346-2-2009, Industrial systems, Installations and Equipment and Industrial Products - Structuring Principles and Reference Designations - Part 2: Classification of objects and codes for classes
64. IEEE C37.06-2009, Switchgear - AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities.
74. IEEE C57.12.00-2010, General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers.
77. IEEE C57.16-2011, Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors.
80. IEEE C57.21-2008, Standard Requirements, Terminology, and Test Code for Shunt Reactors over 500 kVA.
84. NEMA ICS 2-2000, Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 V.
86. NEMA MG 1-2014, Motors and Generators.
87. NEMA PB 1-2011, Panelboards.
88. NEMA PB 2-2011, Deadfront Distribution Switchboards.
89. NEMA TR 1-2013, Transformers, Regulators, and Reactors.
96. UL 891-2005, Safety Switchboards.

1.06 SYSTEM DESCRIPTION

A. General
The design and operation of the SFCs shall account for the unique operating characteristics (traction system loads) and be optimized for the highest efficiency, input power factor, reliability, and minimal harmonic effects under full load conditions. All equipment and material supplied under this Contract shall be designed to be capable of providing service at its rated power under the specified service conditions for a period of forty (40) years. Detailed design criteria and equipment requirements are as defined herein.

B. Static Frequency Converters
The SFC Contractor shall supply four new static frequency converters each rated 15 MVA continuous. Overload and short-circuit ratings are given in this specification.

C. 13.2 kV, 60 Hz, 3-phase input
The converter input transformers will be supplied at 13.2 kV, 60 Hz, 3-phase from existing 13.2 kV switchgear.

D. SFC rooms
The SFCs shall be located in separate SFC rooms. SFC #1, #2, and #3 shall be located in existing rooms. SFC #4 represents additional capacity and shall be located in a new room being constructed under this project by others. Local control equipment shall be provided for each SFC and located in corridors just outside of each SFC room.

SFC rooms shall house individual SFC units and their corresponding power distribution switchboards and control panels shall be placed just outside of these rooms. SFC input and output transformers shall be located near each corresponding SFC just outside each SFC room. The SFC rooms will be automatically de-energized upon opening a door to the room using an interlock scheme provided by the SFC Contractor.

E. 24/12 kV, 25 Hz, 1-phase output
Each of the SFC output transformers shall be connected to the 24/12 kV traction power system via a dedicated circuit breaker provided by others.
F. Auxiliary Power System

Auxiliary power, consisting of 480Y/277 V, 60 Hz, and 125 V dc shall be provided in each SFC room. Two 480 V, 3-phase feeders shall be routed to each SFC room in order to supply auxiliary power to the SFC equipment. Each feeders shall be supplied by an independent feeder circuit breaker in order to ensure power is available to each SFC in the event of an interruption on one of the incoming 13.2 kV, 60 Hz, three-phase power sources supplying the SFC Building.

G. Instrumentation and Control System

The SFC Station shall be remotely controlled by a Supervisory Control and Data Acquisition (SCADA) System via Remote Terminal Units (RTUs) from SEPTA’s 1234 Market St. location.

Control from Wayne Junction’s SFC Main Control Room shall be via a local SCADA terminal working through a RTU as described in Specification 16910, 2.02, supplied by the Electrical Contractor (EC). RTUs shall be required in each local SFC Room supplied by the SFCC.

H. SCADA Interface

A preliminary tabulation of input/output points has been included in this specification. The SFC Contractor shall supply all transducers required for interface to the SCADA RTU supplied by the Electrical Contractor (EC). The SCADA System shall provide dry contacts for 125 V dc, 10 amp inductive load for each digital output from the RTU and expects to receive 125 V dc status signals for digital inputs to the RTU. Analog inputs to the RTU shall be 0 to +/-5 V dc. Current-source signals shall be scaled by a resistor at the RTU. Analog outputs from the RTU shall be 0 to 5 V dc. The SFC Contractor shall be responsible for converting those signals to the type required for the equipment being supplied. Transducers shall be wired from the SFC points and current transformers to terminal blocks located in the appropriate control enclosures.

The SCADA RTU shall consist of two identical (redundant) halves. The RTU shall be based on a system selected by SEPTA along with the corresponding input/output cards and auxiliary equipment. Digital output from the RTU shall be diode-ORed. Digital inputs to the RTU shall be paralleled across the input terminals of each RTU half. Analog signals to the RTU shall be paralleled across the input terminals of each RTU half. The SFC Contractor shall arrange its equipment to receive analog signals from each RTU half independently, and to receive as well a digital signal from each RTU half indicating which half is active. The inputs and outputs to each RTU half shall provide and shall indicate identical information (within the transducer and equipment tolerances for analog signals). SEPTA requires discrete indication of switchgear open and switchgear closed and shall not accept a single signal which, if high, indicates switchgear open and, when low, indicates switchgear closed, or vice versa.

1.07 DESIGN REQUIREMENTS

The following design criteria define the system configuration and performance requirements for the station. The design of the static frequency converter integrated equipment block must be coordinated with the overall station design.

A. 60 Hz, 3-phase System

The Wayne Junction SFC Station is fed from the Wayne Junction 230 kV Substation.

Table 3 - 230 kV, 60 Hz System Characteristics
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal operating voltage</td>
<td>230 kV</td>
</tr>
</tbody>
</table>
| Operating voltage range              | 242 kV normal high  
225.5 kV normal low  
218.5 kV emergency low for 15 minutes  
213.5 kV load dump for 5 minutes      |
| Phase number                         | 3                                                                                                                                       |
| Frequency                            | 60 Hz  
57.5 Hz for 5 seconds  
58 Hz for 30 seconds  
Up to 62 Hz for a limited duration (typically 1 minute) |
| Impulse withstand (BIL)              | 900 kV (Note: Existing transformers are rated 750 kV BIL)  
1.2 x 50 µs (lightning impulse) minimum CFO |
| Minimum distance between conducting parts | 89 inches @ 900 kV BIL, phase-to-phase  
71 inches @ 900 kV BIL, phase-to-ground |
| Spacing                              | 144 inches @ 900 kV BIL, phase-to-phase                                                                                               |
| Fault clearing time                  | Normal clearing time for all types of faults = 5 cycles. Fault clearing due to failed primary line relaying = 33 cycles. Fault clearing due to stuck breaker = 17 cycles. |
| System grounding                     | Effectively grounded neutral (always)                                                                                                  |
| Harmonic voltage distortion limits   | 1.0% individual frequency voltage harmonic  
1.5% THD in 230 kV switchyard                                                                                                            |
| Harmonic current distortion limits   | Must be low enough to meet voltage distortion requirements.                                                                            |

The Wayne Junction SFC station was upgraded in 1990 for 3 x 15 MVA units, with provision for a future fourth 15 MVA unit. The two incoming PECO 230 kV, 60 Hz supply lines and switchgear were sized and installed to accommodate the initial and the future load of the entire station. The incoming PECO lines are adequate for this project.

There are no planned modifications to the 230 kV switchyard equipment within the scope of this project. The new SFC #4 and its auxiliary equipment will be supplied from these existing transformers.

Neutral grounding resistors are mounted on stands next to the transformers.

The two main transformers convert the 230 kV 60 Hz power to 13.2 kV 60 Hz with a 3 winding transformers rated at 45/60/75 MVA each. With air cooling only, the transformers are rated for 45 MVA each at 55°C rise. However, with fan cooling, they are capable of being loaded up to 75 MVA. When the fourth SFC is installed, the total connected load will be 60 MVA for the converters plus the auxiliary loads. Therefore, if all frequency converters are operating, and one transformer is out for maintenance, the transformers fans may be required if the load goes above 45 MVA.

These two transformers feed two separate 13.2 kV switchgear lineups, one for the static frequency converters (NPS-SWGX) and one for the auxiliary loads (NPS-SWGY).

Any modifications to the station load demand or energy usage must comply with PECO requirements and standards.
## Table 4 - Existing 230-13.2 kV, 60 Hz Substation Transformer 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>YWT-XMT1 (From PECO Line 220-42)</td>
</tr>
<tr>
<td>Power rating</td>
<td>55°C Rise: H: 45 MVA OA/60 MVA FAI/75 MVA FAII X: 45 MVA OA/60 MVA FAI/75 MVA FAII Y: 6 MVA OA/8 MVA FAI/10 MVA FAII</td>
</tr>
<tr>
<td></td>
<td>65°C Rise: H: 84 MVA FAII X: 84 MVA FAII Y: 11.2 MVA FAII</td>
</tr>
<tr>
<td>Voltage rating</td>
<td>230 kV Δ-13.2 kV GndY-13.2 kV GndY, 3-phase, 60 Hz</td>
</tr>
<tr>
<td>Impedance</td>
<td>H-X: 7.64% at 45 MVA H-Y: 1.97% at 6 MVA X-Y: 24.9% at 45 MVA</td>
</tr>
<tr>
<td>Resistance</td>
<td>H-X: 0.18% at 45 MVA H-Y: 0.08% at 6 MVA X-Y: 0.75% at 45 MVA</td>
</tr>
<tr>
<td>Insulation rating</td>
<td>H: 750 kV BIL X: 110 kV BIL Y: 110 kV BIL</td>
</tr>
<tr>
<td>Weight</td>
<td>230,600 lbs (complete)</td>
</tr>
<tr>
<td>Tap changer</td>
<td>No-load tap changer on H winding only</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Trafo-Union, Nuremberg, West Germany</td>
</tr>
<tr>
<td>Transformer type</td>
<td>TLUJ7954</td>
</tr>
<tr>
<td>No. N</td>
<td>407393</td>
</tr>
<tr>
<td>Year of manufacture</td>
<td>1988</td>
</tr>
<tr>
<td>Standard</td>
<td>ANSI C57.12.00-1980</td>
</tr>
<tr>
<td>Grounding</td>
<td>20 ohms, 400 A, 10 seconds (each wye winding)</td>
</tr>
</tbody>
</table>

## Table 5 - Existing 230-13.2 kV, 60 Hz Substation Transformer 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>YWT-XMT2</td>
</tr>
<tr>
<td>Power rating</td>
<td>55°C Rise: H: 45 MVA OA/60 MVA FAI/75 MVA FAII X: 45 MVA OA/60 MVA FAI/75 MVA FAII Y: 6 MVA OA/8 MVA FAI/10 MVA FAII</td>
</tr>
<tr>
<td></td>
<td>65°C Rise: H: 84 MVA FAII X: 84 MVA FAII Y: 11.2 MVA FAII</td>
</tr>
<tr>
<td>Voltage rating</td>
<td>230 kV Δ-13.2 kV GndY-13.2 kV GndY, 3-phase, 60 Hz</td>
</tr>
<tr>
<td>Impedance</td>
<td>H-X: 7.69% at 45 MVA H-Y: 1.98% at 6 MVA X-Y: 25.3% at 45 MVA</td>
</tr>
</tbody>
</table>
The 13.2 kV switchgear NPS-SWGX is located in the 230 kV Control Building and supplies power to the SFCs with a main-tie-main automatic transfer system and a 3000 A bus. The 13.2 kV power tie-in shall consist of four independent feeders from the existing 13.2 kV, 60 Hz, 3-phase switchgear in the SEPTA 230 kV Control Building.

The 13.2 kV switchgear NPS-SWGX has one spare cubicle dedicated to supply the new SFC #4. It contains electromechanical relays for protecting the new SFC #4 feeder. The protective relays will need to be set to the requirements of the new static frequency converter equipment. The types of relays and auxiliary devices are listed below:

1. 50/51 overcurrent, phases 1, 2, 3
2. 50GS overcurrent
3. 0-2000 A ammeter
4. 86 lockout relay
5. Ammeter switch
6. SFC No. 4 breaker control
7. Local/remote key switch
8. 50GS test switch
9. 87BX2 test switch
10. Current circuit test switch
11. PK-2 current circuit

A spare 3000 A circuit breaker, presently used during maintenance activities, is available for use by the future SFC #4. The new SFC #4 will be supplied using this spare 3000 A circuit breaker from the allocated cubicle. All existing protective relays will be used.

Each SFC unit shall be fed via an independent 13.2 kV circuit breaker.

Table 6 - SFC Input Circuit Breaker Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>SFC #4 Input Breaker</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Siemens</td>
</tr>
</tbody>
</table>

Wayne Junction SFC 16262-13 90% Design Submittal
Rehabilitation Project
March 17, 2017
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>15-GM-1000-3000-77</td>
</tr>
<tr>
<td>Amps</td>
<td>3000</td>
</tr>
<tr>
<td>Frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Serial No.</td>
<td>R-80650B-1</td>
</tr>
<tr>
<td>Manufacture Date</td>
<td>August 1989</td>
</tr>
<tr>
<td>Rated Max. Voltage</td>
<td>15 kV</td>
</tr>
<tr>
<td>Voltage Range Factor</td>
<td>K=1.30</td>
</tr>
<tr>
<td>BIL</td>
<td>95 kV</td>
</tr>
<tr>
<td>Rated Short-Circuit Current</td>
<td>37 kA</td>
</tr>
<tr>
<td>Close and Latch</td>
<td>77 kA</td>
</tr>
<tr>
<td>Interrupting Time</td>
<td>5 cycles</td>
</tr>
<tr>
<td>Motor Voltage and Current</td>
<td>100-140 V dc, 3 A nom.</td>
</tr>
<tr>
<td>Close Circuit Voltage and Current</td>
<td>100-140 V dc, 5 A nom.</td>
</tr>
<tr>
<td>Trip Circuit Voltage and Current</td>
<td>70-140 V dc, 5 A nom.</td>
</tr>
</tbody>
</table>

**Table 7 - 13.2 kV, 60 Hz System Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal operating voltage</td>
<td>13.2 kV</td>
</tr>
<tr>
<td>Operating voltage range</td>
<td>13.86 kV normal high</td>
</tr>
<tr>
<td></td>
<td>12.94 kV normal low</td>
</tr>
<tr>
<td></td>
<td>12.54 kV emergency low for 15 minutes</td>
</tr>
<tr>
<td></td>
<td>11.88 kV load dump for 5 minutes</td>
</tr>
<tr>
<td>Phase number</td>
<td>3</td>
</tr>
<tr>
<td>Frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td></td>
<td>57.5 Hz for 5 seconds</td>
</tr>
<tr>
<td></td>
<td>58 Hz for 30 seconds</td>
</tr>
<tr>
<td></td>
<td>Up to 62 Hz for a limited duration (typically 1 minute)</td>
</tr>
<tr>
<td>Rated maximum voltage</td>
<td>15 kV</td>
</tr>
<tr>
<td>Power frequency withstand (BIL)</td>
<td>36 kV</td>
</tr>
<tr>
<td>Lightning impulse withstand (BIL)</td>
<td>95 kV BIL indoors</td>
</tr>
<tr>
<td></td>
<td>110 kV BIL outdoors</td>
</tr>
<tr>
<td>Minimum distance between conducting parts</td>
<td>12 inches @ 110 kV BIL, phase-to-phase</td>
</tr>
<tr>
<td></td>
<td>7 inches @ 110 kV BIL, phase-to-ground</td>
</tr>
<tr>
<td>Phase spacing - vertical break disconnect switches and bus supports</td>
<td>24 inches @ 110 kV BIL, centerline-to-centerline</td>
</tr>
<tr>
<td>Phase spacing - horizontal break disconnect switches and bus supports</td>
<td>30 inches @ 110 kV BIL, centerline-to-centerline</td>
</tr>
<tr>
<td>Short-circuit availability</td>
<td>381 A 1LG</td>
</tr>
<tr>
<td></td>
<td>24,594 A 3LG</td>
</tr>
<tr>
<td>Earth fault factor</td>
<td>1.732 (resistive grounded-wye)</td>
</tr>
<tr>
<td>Fault clearing time</td>
<td>Approx. 8 cycles at maximum 3-ph fault current</td>
</tr>
<tr>
<td></td>
<td>(3 cycles for relays, 5 cycles for breaker)</td>
</tr>
<tr>
<td>System grounding</td>
<td>Effectively grounded neutral (always), low-resistance grounded (20 ohms per transformer)</td>
</tr>
</tbody>
</table>

The allowable power factor range on the 60 Hz side, over the entire operating range of the
25 Hz side power demand shall be as defined in the attached PQ curves (Appendix D). The allowable power factor requirement shall be met regardless of the station loading, load power factor, input voltage and the reactive losses in transformers.

It shall be possible to preset the magnitude of the output voltage in the range of plus or minus 5% of the nominal output voltage. The magnitude of the output voltage shall be automatically held within plus or minus 1% at all times for an input change of plus or minus 5% on the 13.2 kV system.

The 13.2 kV input power frequency may drift between 60Hz +/-2% (57.5 Hz to 62Hz)

SFC design must limit harmonic voltage distortion to limits given in IEEE 519 and PECO design standards at the 230 kV bus in the PECO 230 kV Wayne Junction switchyard. In addition, an output capability curve or table as a function of the electrical stiffness between the specified minimum and maximum values shall be provided.

Voltage distortion limits for the SFC units shall be limited to 1.0% individual frequency voltage harmonic and 1.5% total harmonic distortion (THD) on PECO side of the point of common coupling.

The 60 Hz current distortion limits for harmonics shall be in accordance with IEEE 519.

The voltage and current distortion limits shall be based on the total harmonic spectrum (including sub-harmonics, integer harmonics and non-integer harmonics).


Figure 1 - PECO 230 kV System Supplying Wayne Junction

Table 8 - 60 Hz Short-Circuit Characteristics
Two SFCs are supplied by YWT-XMT1-X1 and the other two from YWT-XMT2-X2.

The minimum short-circuit current availability shall be obtained by the SFC Contractor upon award of the Contract in order to perform the harmonic studies required for designing the converter facility.

The SFC Contractor shall provide a tabulation of harmonic current and voltage distortion values, in amperes, for operation of the SFCs in the following circumstances. Included in the tabulation shall be all distorting frequencies (whether even or odd multiples of the fundamental, non-integer multiples of the fundamental, or frequencies below the fundamental) generated by the dc-link converters, as seen at the 230 kV, 60 Hz bus. Both the minimum and maximum available short-circuit current values at the 230 kV level shall be considered.

- One (1) converter in operation
- All of converters in operation, including the existing cycloconverter
- The combination of converters which results in the worst case amount of distortion injected into the Utility.

The SFC Contractor shall identify the magnitude of any dc bias that may be present in the SFC output resulting from their equipment.

B. 25 Hz, 1-Phase System

The existing output transformers are located on the west side of the SFC building. Each transformer is surrounded on its sides by CMU firewalls. Electrical bus duct supplies the transformers from the converter. Insulated cable connects the transformer output to the 25 Hz filter yard via duct banks that run underneath the road between the transformers and filter yard.

The transformers are grounded through the rail bus that is common to all output transformers located in the 25 Hz filter yard.

<table>
<thead>
<tr>
<th>Location and Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>YWT-XMT1, 230 kV (From PECO Line 220-42)</td>
<td>32,111 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>24,109 A, 1LG</td>
</tr>
<tr>
<td>YWT-XMT2, 230 kV (From PECO Line 220-28)</td>
<td>25,903 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>18,630 A, 1LG</td>
</tr>
<tr>
<td>YWT-XMT1, 13.2 kV, X winding (TRF 1, X1)</td>
<td>24,594 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>381 A, 1LG</td>
</tr>
<tr>
<td>YWT-XMT1, 13.2 kV, Y winding (TRF 1, Y1)</td>
<td>13,000 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>380 A, 1LG</td>
</tr>
<tr>
<td>YWT-XMT2, 13.2 kV, X winding (TRF 2, X2)</td>
<td>24,206 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>381 A, 1LG</td>
</tr>
<tr>
<td>YWT-XMT2, 13.2 kV, Y winding (TRF 2, Y2)</td>
<td>12,867 A, 3LG</td>
</tr>
<tr>
<td></td>
<td>380 A, 1LG</td>
</tr>
</tbody>
</table>

Table 9 - 25 Hz Output Transformer Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>T2</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Power rating         | Temperature rise 60°C  
X1 X2: 15.366 MVA OA  
H1 H2: 12.5 MVA OA  
H2 H3: 7.5 MVA OA |
| Voltage rating       | X1 X2: 1.62 kV  
H1 H2: 13 kV  
H2 H3: 25.8 kV  
Single-phase, 25 Hz |
| Impedance            | X1 X2/H1 H2: 4.19% @ 15.366 MVA, 1.62/13 kV  
X1 X2/H2 H3: 8.94% @ 15.366 MVA, 1.62/26 kV  
H1 H2/H2 H3: 3.72% @ 15.366 MVA, 13/26 kV  
X1 X2/ H1 H3: 5.44% @ 15.366 MVA, 1.62/39 kV |
| Insulation rating    | X1 X2: 60 kV BIL  
H1 H2: 250 kV BIL  
H2 H3: 250 kV BIL |
| Weight               | 106,648 lbs |
| Tap changer          | None |
| Oil type             | Mineral oil |
| Oil quantity         | Oil in tank: 2985 gal  
Oil in coolers: 420 gal |
| Manufacturer         | ASEA |
| Transformer type     | TMZ 31 |
| Serial No.           | 7288530 |
| Year of manufacture  | 1984 |
| Standard             | ANSI C57.12-1980 |
| Grounding            | Solid, H2 bushing |

Each SFC output transformer shall be connected to the 24/12 kV, 25 Hz system through its own circuit breaker supplied by others.

Table 10 - 24/12 kV, 25 Hz System Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>12 kV trolley system</th>
<th>24 kV feeder system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal operating voltage</td>
<td>12 kV</td>
<td>24 kV</td>
</tr>
<tr>
<td>Operating voltage range</td>
<td>-5% to +10% (due to train regenerative braking)</td>
<td></td>
</tr>
<tr>
<td>Phase number</td>
<td>Single-phase, two-pole</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>25 Hz</td>
<td></td>
</tr>
<tr>
<td>Insulation class</td>
<td>27 kV</td>
<td>46 kV</td>
</tr>
<tr>
<td>Impulse withstand (BIL)</td>
<td>150 kV</td>
<td>250 kV</td>
</tr>
</tbody>
</table>

The SFCs shall provide full rated output power over the output frequency of 25 Hz +/- 2% (24.5 Hz to 25.5 Hz) as defined by the fixed ratio of 5/12 of the input frequency, which can drift by 60 Hz +/- 2%.

C. 25 Hz Harmonics

The traction power system operates with a significant content of harmonics caused by power electronic equipment switching. The harmonics consist of two parts:
1. Harmonics generated by the traction load. The traction load consists of number of multi-car trains operating simultaneously on the system. The propulsion system of the existing cars is thyristor controlled. The new fleet of the cars expected to be procured by SEPTA over next several years will have propulsion system based on integrated gate bipolar thyristors (IGBTs).

2. Harmonics generated by the static frequency converters (SFCs). The SFCs are thyristor controlled cyclo-converters connected in twelve-pulse arrangement.

The existing SFC manufacturer, ABB, performed extensive studies of the system harmonics and their results are shown below. The Table shows the overall system harmonics when one SFC is operating at 100% rated power and at 200% rated power.

The SFCC shall use Table 11 as the basis for guaranteed loss reporting at the bidding stage. However, the SFCC is required to take harmonic measurements on SEPTA’s system during the design stage. The SFCC shall perform harmonic voltage measurements at PECO’s 230 kV, 60 Hz substation and SEPTA’s 24/12 kV, 25 Hz traction power substation early in the project and prior to completing the design of the SFC equipment. Those measured harmonics shall be the basis for the final SFC design. If the measurements are substantially different than the harmonics provided in Table 11, the SFCC guaranteed loss reporting can be adjusted at that time based on the actual measurements.

Table 11 - Harmonics from One Existing Cycloconverter

<table>
<thead>
<tr>
<th>Harmonic</th>
<th>Frequency (Hz)</th>
<th>Current Harmonics at Converter Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>15 MVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A)</td>
</tr>
<tr>
<td>1</td>
<td>25</td>
<td>1,456</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>269</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
<td>444</td>
</tr>
<tr>
<td>7</td>
<td>175</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>225</td>
<td>41.7</td>
</tr>
<tr>
<td>9.6</td>
<td>240</td>
<td>5.6</td>
</tr>
<tr>
<td>11</td>
<td>275</td>
<td>16.7</td>
</tr>
<tr>
<td>11.6</td>
<td>290</td>
<td>5.6</td>
</tr>
<tr>
<td>13</td>
<td>325</td>
<td>8.8</td>
</tr>
<tr>
<td>13.6</td>
<td>340</td>
<td>5.6</td>
</tr>
<tr>
<td>15</td>
<td>375</td>
<td>5.6</td>
</tr>
<tr>
<td>15.6</td>
<td>390</td>
<td>19.4</td>
</tr>
<tr>
<td>17</td>
<td>425</td>
<td>5.6</td>
</tr>
<tr>
<td>17.6</td>
<td>440</td>
<td>36.1</td>
</tr>
<tr>
<td>19</td>
<td>475</td>
<td>5.6</td>
</tr>
<tr>
<td>19.6</td>
<td>490</td>
<td>63.9</td>
</tr>
<tr>
<td>21</td>
<td>525</td>
<td>5.6</td>
</tr>
<tr>
<td>21.6</td>
<td>540</td>
<td>75.0</td>
</tr>
<tr>
<td>23</td>
<td>575</td>
<td>5.6</td>
</tr>
<tr>
<td>23.6</td>
<td>590</td>
<td>33.3</td>
</tr>
<tr>
<td>25.6</td>
<td>640</td>
<td>5.6</td>
</tr>
<tr>
<td>27.6</td>
<td>690</td>
<td>19.4</td>
</tr>
<tr>
<td>29.6</td>
<td>740</td>
<td>2.8</td>
</tr>
<tr>
<td>31.6</td>
<td>790</td>
<td>16.7</td>
</tr>
<tr>
<td>Harmonic</td>
<td>Frequency (Hz)</td>
<td>Current Harmonics at Converter Load</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 MVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A)</td>
</tr>
<tr>
<td>33.6</td>
<td>840</td>
<td>33.3</td>
</tr>
<tr>
<td>35.6</td>
<td>890</td>
<td>30.6</td>
</tr>
<tr>
<td>37.6</td>
<td>940</td>
<td>19.4</td>
</tr>
</tbody>
</table>

The maximum harmonic voltage distortion levels for the new SFCs shall be limited as follows for the measurement of voltage distortion into a resistive load (unity power factor load). The voltage distortion limits shall be based on the total harmonic spectrum (including sub-harmonics, integer harmonics and non-integer harmonics):

Table 12 – Maximum Voltage Distortion Limits at Full-Load through a Resistive Load

<table>
<thead>
<tr>
<th>Supply Current Through a Resistive Load</th>
<th>Individual Voltage Distortion %</th>
<th>Total Voltage Distortion THD %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Load</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Full-Load</td>
<td>3.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

D. Station Loading/Operating Conditions

The rail traction power demand is of a highly fluctuating pattern. It is non-sinusoidal in wave form due to harmonics generated by the thyristor equipment both in the SFC and on board rail cars that subjects the traction equipment to pulsating forces. The heating effect on the converter due to non-sinusoidal current wave form is greater than that produced by a steady current equal to the mean value of the fluctuating current.

The 12 kV trolley and 24 kV feeder system are susceptible to many electrical short-circuits due to pollution, vandalism, icing, bird life, and other factors. The short-circuits are repetitive and of varying duration and severity, subjecting the SFC equipment to significant compressive and tensile forces.

The SFC Contractor shall measure the voltage and current waveforms at Wayne Junction to determine the characteristics of the line that the converter shall be synchronized to and the type of load the converter shall be feeding. However, the SFC Contractor must ensure that his design is compatible with existing wave forms.

E. Harmonics

1. 60 Hz Harmonics

The SFC Contractor shall ensure that the existing harmonics on the single-phase side of the converter are taken into account during the equipment design and that their effects shall not reduce the specified performance or life expectancy of the converter equipment or the 60 Hz source equipment. The SFC Contractor shall state what, if any, limitations on converter performance are to be expected from these harmonics, and the amount of harmonic power “let thru” the filter bank to the converter itself. The SFC Contractor shall also indicate the effect of the 25 Hz side harmonics on the 60 Hz system.

2. 25 Hz Harmonics

The SFC Contractor shall perform an analysis of the station 25 Hz power distribution system to determine the size and characteristics of any required harmonic filter equipment to limit harmonic currents and voltages generated by the converter system to acceptable
levels. The harmonic frequencies generated by the 25 Hz system load profile shall be considered in the design and rating of all SFC equipment.

3. Harmonic Analysis Objectives

The objective of the harmonic analysis shall be:

a) To characterize the existing harmonics at the 230 kV, 60 Hz substation and 24/12 kV, 25 Hz traction power substation,

b) To evaluate the impact of the new harmonic producing source, i.e., the SFCs,

c) To use the results of the study to design harmonic controls into the SFC equipment, if required, and
d) To size the SFC equipment load carrying capacity based on total harmonic current.

4. Harmonic Measurements and Modeling

In order to ensure that SEPTA’s harmonic voltage distortion at the 230 kV, 60 Hz substation and 24/12 kV, 25 Hz traction power substation is not degraded by the addition of the new SFCs, the following procedure shall be followed:

a) Preliminary simulations shall be performed to identify expected harmonic levels and system response characteristics. Different system conditions shall be modeled in accordance with IEEE 519.

b) Perform harmonic voltage measurements at PECO’s 230 kV, 60 Hz substation and SEPTA’s 24/12 kV, 25 Hz traction power substation prior to the design of the SFC equipment. Measurements shall be performed at the point of common coupling, e.g., 230 kV switchyard bus in the PECO substation and the 12 kV trolley bus and 24 kV feeder bus in the Wayne Junction Traction Power Substation.

c) Prepare a detailed model of the SFC units to analyze harmonic voltages produced by the power block equipment based on the system harmonic currents under various load conditions. Provide a tabulation of harmonic current and voltage distortion values, in amperes, for operation of the SFCs in the following circumstances. Included in the tabulation shall be all distorting frequencies generated by the converters as seen at the 230 kV and 24/12 kV point of common connections. Both the minimum and maximum available short circuit MVA values at the 230 kV and 24/12 kV levels shall be considered for the following modes of operation:

1) One converter in operation;

2) All converters in operation including the existing cycloconverters;

3) Various loads connected to the 24/12 kV switchyard through the 12 kV trolley and 24 kV feeder systems.

5. Using a detailed SFC model, demonstrate that the recommended voltage distortion limits in Table 7 can be met for no-load and full-load conditions.

6. PECO’s and SEPTA’s voltage and current distortion shall not be degraded by the installation and operation of the new converters. If existing harmonic currents and voltages are affected by the installation of the new SFC equipment, the SFC
Contractor shall develop solutions to the harmonic problems caused by the SFC power block equipment and implement those solutions at the SFC Contractor’s cost.

7. At the time of final commissioning, perform harmonic voltage and current measurements at PECO’s 230 kV substation and SEPTA’s 24/12 kV traction power substation. Ensure that harmonic distortion limits are not exceeded.

F. Functional Requirements

1. The plant shall be designed to accept basic control commands (such as start, stop, raise/lower voltage, raise/lower power, etc.) locally and remotely via SEPTA’s SCADA RTU (normal source of commands). These commands shall initiate start-up, normal running, and shutdown functions that shall be controlled automatically by the SFC Contractor’s control system. The SFC Contractor shall develop a signals exchange list and identify all control, status, and metering information that shall represent the complete SFC system input/output (I/O) interface points.

2. The control equipment shall controls and supervise the SFCs. The control equipment, will among other things, control the amplitude and phase of the converter output voltage, limit the output current in case of short-circuits in the 25 Hz network, and automatically synchronize the converter to the 25 Hz network.

3. The plant shall automatically synchronize and deliver power to the 24/12 kV, 25 Hz, single-phase traction power system.

4. Each converter shall be capable of operating independently or in parallel with the other new SFCs and existing cycloconverters at the Wayne Junction SFC Station.

5. Each unit shall be able to operate in stand-alone or network operation. In stand-alone operation, each unit shall be able to black start SEPTA’s 25 Hz system. In network operation, the units shall be able to operate as synchronous machines either manually or in automatically.

6. Station load sharing controls shall be provided, in addition to local load sharing controls at each SFC.

7. The SFCs shall operate with a fixed electrical frequency ratio of 5/12 between the 25 Hz and 60 Hz systems.

8. Controls shall be provided to allow the SFC to operate in the following modes:
   a) Synchronous machine mode: each unit operates similarly to a synchronous machine. The voltage magnitude, phase shift angle, and droop characteristics can be manually adjusted, with the SFC following the system load demand.
   b) Automatic load sharing mode: each SFC operates similarly to a synchronous machine, while sharing load proportionally with other SFCs. Real and reactive power limits, as well as proportional load sharing settings, can be programmed.
   c) Phase shifting mode: each SFC provides reactive power compensation to the 24/12 kV, 25 Hz system, such as during 25 Hz faults or loss of the 13.2 kV, 60 Hz input power.

9. The SFC shall be capable of operating independently and feed the single-phase network without working in parallel with the cycloconverters.
10. The SFC shall be capable of operating in parallel with cycloconverters and/or static converters at the same or adjacent stations. Presently, Wayne Junction Station operates as the only supply of 25 Hz power in SEPTA’s Reading Railroad System and does not synchronize with any other traction power sources.

11. The converter shall not trip for any overload or short-circuit in the 12 kV trolley or 24 kV feeder 25 Hz network extremal to the Wayne Junction Traction Power Substation. An overload or short-circuit at the local Wayne Junction Traction Power Substation may require the SFCs to trip.

G. Automatic Controls

The converter shall be equipped with a computerized automatic startup system. It shall automatically start-up and stop the converters at preset values of station load. The automatic start-up equipment shall be used to minimize the operating cost for the converter station and shall therefore be capable of the following:

1. Cycling the start and stop to equalize the hours of operation as well as equalize the number of “on/off” operations of each converter.

2. Include a memory which stores the station load measurement during SFC Contractor defined intervals in a statistical table for one week for providing a forecast of expected load to determine if the converters are to be connected/disconnected immediately.

3. The start-up system shall also connect more converters if the converters are operating in the current-limit mode or the station voltage is under the preset output values.

4. The start-up equipment shall also allow the presetting of parameters such as start-up levels, stop levels, delay times, hysteresis, etc.

5. The control shall be capable of automatically starting up the converters and synchronizing to the single phase network. The start-up time shall be less than five (5) seconds. Converters shall start at zero MW/zero MVAR and ramp up to the desired power level after the synchronization process is complete.

The SFC shall be capable of a black start to the 25 Hz single-phase system.

The SFC load sharing shall control the output power from the SFC to be a pre-adjusted part of the total station load demand, both active and reactive power, with a tolerance of 2% or better.

Suitable converter and load sharing controls shall be provided to facilitate light load operations where a specific number of converter units are required to remain on-line in order to develop the necessary fault current levels at the 12 kV trolley and 24 kV feeder systems for protective relay actuation during a fault.

The plant shall minimize distortion (due to harmonics) of the 60 Hz utility power system as well as SEPTA’s 25 Hz system.

Short-circuits in the SEPTA single-phase traction power network shall not decrease the life of the converters. It is anticipated that up to twenty-five thousand (25,000) of these short-circuit operations are possible over the life of the converters.

The short-circuit capability of each SFC shall be 4000 A for 2 seconds at the 12 kV output bushing of the SFC 25 Hz transformer.

The SFC Contractor is responsible for the overall system design in order to establish the
corresponding requirements for transformer impedances and short-circuit capability of the SFC units.

The frequency converter and associated protective devices shall be designed so that any tripping of breakers or converters not caused by the converter station equipment shall be controlled in a manner which permits the SEPTA Load Dispatcher to reset the equipment and restart the converters from the remote control location (SCADA).

H. Seismic Requirements

The seismic requirements are provided on Contract drawing S-001. They are summarized below for reference.

Table 13 - Seismic Loading

<table>
<thead>
<tr>
<th>Methodology</th>
<th>2003 NEHRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Location</td>
<td>Philadelphia, Pennsylvania</td>
</tr>
<tr>
<td>Seismic Occupancy Category</td>
<td>II</td>
</tr>
<tr>
<td>Seismic Importance Factor</td>
<td>1.0</td>
</tr>
<tr>
<td>Maximum Considered Earthquake (MCE) Ground Motion</td>
<td></td>
</tr>
<tr>
<td>0.2 Second Spectral Response</td>
<td>( S_s = 0.274 )</td>
</tr>
<tr>
<td>1.0 Second Spectral Response</td>
<td>( S_1 = 0.060 )</td>
</tr>
<tr>
<td>Seismic Site Classification</td>
<td>D (Assumed)</td>
</tr>
<tr>
<td>Short Period Site Coefficient</td>
<td>( F_a = 1.581 )</td>
</tr>
<tr>
<td>Long Period Site Coefficient</td>
<td>( F_v = 2.4 )</td>
</tr>
<tr>
<td>Maximum Considered Earthquake</td>
<td></td>
</tr>
<tr>
<td>Short Period, ( F_a \times S_s )</td>
<td>( S_{M_S} = 0.433 )</td>
</tr>
<tr>
<td>1s Period, ( F_v \times S_1 )</td>
<td>( S_{M_1} = 0.145 )</td>
</tr>
<tr>
<td>Design Spectral Acceleration</td>
<td></td>
</tr>
<tr>
<td>Short Period</td>
<td>( S_{D_s} = 0.289 )</td>
</tr>
<tr>
<td>1s Period</td>
<td>( S_{D_1} = 0.096 )</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Seismic Design Category</td>
<td>B</td>
</tr>
<tr>
<td>Basic Seismic Force Resisting System</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Response Modification Factor, ( R )</td>
<td>3.5</td>
</tr>
<tr>
<td>System Overstrength Factor, ( W_O )</td>
<td>2.5</td>
</tr>
<tr>
<td>Deflection Amplification Factor, ( C_d )</td>
<td>1.75</td>
</tr>
<tr>
<td>Seismic Response Coefficient, ( C_s )</td>
<td>0.144</td>
</tr>
<tr>
<td>Analysis Procedure</td>
<td>Equivalent Lateral Force</td>
</tr>
</tbody>
</table>

1.08 MAINTAINABILITY

A. Panel indicating devices shall be selected to facilitate diagnostic procedures which will be employed by maintenance and/or repair personnel and be described in the SFC Contractor provided manual in a Troubleshooting Section.

B. The internal converter circuitry, insofar as practical, shall be modular in construction, and the physical implementation of such modules, components, subassemblies, and other parts shall be easily and quickly replaceable. All quick release items shall be secured by “captive hardware” to prevent their dislocation by vibration.
C. All modules, cards, and subassemblies shall have lights indicating normal circuitry operation.

D. All fuses shall be readily accessible, shall use captive hardware, and shall be provided with individual blown fuse indicators (non-incandescent) mounted inside panel. All fuses shall be sensed in such a manner to provide an alarm output.

E. All front panel indicators and other components shall be clearly identified with functional English language nomenclature.

F. All panels shall be accessible from the front and be suitable for mounting back-to-back or against walls.

G. Each individual component of the converter heavier than sixty-five (65) lbs. shall have provision for lifting by two persons and each component heavier than one-hundred (100) lbs. shall have provision for lifting by a crane or hoist.

H. The SFC Contractor shall furnish two (2) portable diagnostic test terminals and associated microprocessor adapter cards for monitoring, trouble shooting, and programming of converter control electronics. The test terminals shall permit SEPTA to read system inputs and force system outputs. The test terminal also shall permit SEPTA to adjust the system control parameters. Test terminals shall be off-the-shelf ruggedized, portable PC’s suitable for industrial service and shall be equipped with suitable software.

1.09 SERVICE LIFE

A. The converter shall be designed to be capable of providing services at its rated level under the service conditions for a period of forty (40) years.

B. The SFC Contractor shall ensure that the system harmonics are taken into account during the equipment design and that their effects shall not reduce the specified performance or life expectancy.

C. The fluctuating power demand and high incidence of short circuit faults of varying magnitude shall be taken into account during the equipment design. The converter equipment shall be designed and constructed so that it can withstand the effects of the compressive and tensile forces without any adverse effects on the specified performance and life expectancy.

D. The SFC Contractor shall provide a recommended inspection/maintenance schedule.

1.10 PERFORMANCE GUARANTEES AND WARRANTY

A. All equipment supplied by the SFC Contractor shall be warranted in accordance with the requirements defined in the Contract from the date the commissioning testing is finally completed and SEPTA accepts the facility. The warranty shall guarantee SFC availability over the warranty period. It shall be the SFC Contractor’s responsibility for timely repair and/or replacement of defective items or parts within the warranty period.

B. The SFC Contractor’s equipment shall meet the guaranteed performance for output, efficiency, noise, and auxiliary load demand. The SFC Contractor shall provide warranties for all equipment and materials furnished as to their fitness for the service intended and the workmanship of manufacture.

C. Warranty for spare parts supply and satisfactory operation is required.
1.11 AVAILABILITY

A. The Wayne Junction SFC Station shall operate as the only source of power to SEPTA’s Regional Rail System and as such, SEPTA requires that this station be highly reliable. There is no backup power source for the 25 Hz traction power system should the Wayne Junction SFC Station be offline.

B. The SFC system is expected to continuously perform the services for which it is intended and to deliver capacity from zero to full design levels. It shall be of heavy-duty design consistent with the specified services with minimum maintenance. The system shall operate properly under the technical and ambient conditions as defined in this specification.

C. All equipment, material, and services offered shall be of such quality as to make the equipment and material safe with high availability. All items offered, including all accessories, shall be of proven reliability.

D. The design and configuration of this station shall be adequate to allow scheduled on-line and off-line maintenance of individual sub-systems and equipment so that the railroad is supplied with reliable electrical power. Standby spare equipment in the station shall be included as necessary to ensure degree of reliability proposed by the SFC Contractor and accepted by SEPTA.

E. SFC systems shall also be capable of performing the protective actions required to accomplish a protective function in the presence of any single detectable failure in a system without loss of both SFCs (no single failure shall affect more than one SFC unit). Common mode failures (multiple failures resulting from a single cause) shall be mitigated by system design and quality assurance process.

1.12 SUBMITTALS

The SFC Contractor shall prepare Project Specific Design Drawings and Specifications. Progress submissions of designs shall be made at the 30%, 60%, 90% and 100% design submittals. These designs shall be subject to review by SEPTA and the Engineer. The SFC Contractor shall gather all comments and incorporate them into a single conformed set. Necessary changes shall be implemented by the SFC Contractor at no additional cost to SEPTA for design, manufacture, delivery or testing of the equipment and material.

This specification requires specific documents to be formally submitted to SEPTA through the SFC Contractor for information, approval, or approval with subsequent certification. When required by this specification, those documents generated by the SFC Contractor’s suppliers shall also be submitted. Prior to submittal to SEPTA, the SFC Contractor shall review them for conformance to the requirements and note his approval on the face of the documents. The SFC Contractor shall submit the following for approval:

A. Detailed plans with the requirements of all control and power equipment showing anchor bolt locations, floor steel requirements, dead weights and available space for primary and secondary cables.

B. Detailed drawings for erection and installation of SFC equipment, transformers, filter capacitors and reactors, busbar, power cables, etc.

C. Equipment drawings shall include the following:
   1. Location and required size of conduit.
   2. Location and size of junction boxes.
   3. Piping connections.
4. Location and size of all accessories.
5. Loading diagram anchorage and foundation requirements.
6. Horizontal and vertical clearances necessary for installation and dismantling purposes.
7. Approximate locations of lifting lugs.

D. Wiring diagrams, showing the interconnection of all equipment including grouping of outgoing leads in accordance with cable schedule and elementary diagrams and “from” and “to” identification of all equipment terminals by rear view arrangement. Wiring connection diagrams covering all electrical devices. The connection diagrams shall be in accordance with IEEE 315 and the following:
1. Switch developments shall be shown.
2. Internal connections of all devices and relays shall be given.
3. Control panel devices and terminal blocks shall be in their approximate physical positions.

E. Copies of data accumulated during the twenty-four (24) Hour Test and thirty (30) Day Reliability Test shall be furnished to SEPTA either as the files are written during the test or within three (3) days following the end of each test.

F. Detailed and separate operating and maintenance manuals shall be furnished covering the following information:
1. Installation procedures, including unloading, equipment placement and cable connections.
2. Operational procedures, including preliminary checks, off-line tests, on-line tests and all required adjustments.
3. Special requirements for placement of equipment by use of cranes.
4. Recommended and required maintenance.
5. Recommended troubleshooting procedures.
6. Complete parts list for individual pieces of equipment.
7. Spare parts list.
8. All electrical and electronic components shall be identified by JEDEC/EIA, or by Industry Standard part numbers. The JEDEC Solid State Technology Association, formally known as the Joint Electron Device Engineering Council (JEDEC), is an independent semiconductor engineering trade organization and standardization body. Associated with the Electronic Industries Alliance (EIA), a trade association that represents all areas of the electronics industry in the United States.

G. The final manuals, drawings and spare parts list shall be technically accurate and complete and shall represent the complete system supplied by the Vendor or SFC Contractor.

H. Test procedures for SEPTA approval prior to acceptance testing and commissioning of the equipment.

I. Analysis of the station 25 Hz and 60 Hz power distribution system to determine the size and characteristics of harmonic filter equipment to limit harmonic currents and voltages generated by the converter system to acceptable levels without overloading the harmonic filters.
J. The SFC Contractor shall perform and submit calculations to determine the design basis and safety margin required for the static frequency converter components. These calculations shall, as a minimum, address short-circuit limits and power limits under different operating modes and filter designs. As a minimum, the calculations shall cover the power electronics (thyristors, diodes, GTO’s, etc.) and SFC transformers. These calculations shall convey, as a minimum, the following specifications:

1. Design parameters and limits
2. Thermal limits
3. Losses
4. Temperature rise
5. Efficiencies

K. Provide a final point count for the equipment interface to SEPTA’s SCADA system during the 60% design submittal.

L. Provide ac and dc auxiliary power requirements during the 60% submittal.

M. Provide a relay protection study addressing equipment provided under the Contract resulting from this RFP and as the equipment interfaces to SEPTA’s existing relay protection in its traction power system. The study shall be submitted in the form of a formal calculation including relay selection tables, recommended relay set points and coordination curves. Relays to be included in this study are located in the 13.2 kV, 60 Hz switchgear in the 230 kV Control Building and the 24/12 kV, 25 Hz protective relay panels located in the 25 Hz Wayne Junction Traction Power Substation (TPSS).

N. Submit all factory test plans with detail procedures for approval.

O. Submit all field test plans with detail procedures for approval.

P. Alarm annunciation point count.

Q. An itemized list of special tools shall be submitted.

R. A list of spare parts.

S. Technical training sessions per Specification Section 01822, Demonstration and Training.

T. For additional Submittal requirements refer to Specification Section 01300, Submittals, and Specification Section 16262, Appendix B, SFC Document Submittal List.

1.13 SHIPPING REQUIREMENTS

A. The SFC Contractor shall be responsible for all storage, shipping and handling. Items shall be stored, shipped and handled in a manner which is consistent with safe and sound material handling practices and per manufacturers’ recommendation.

1.14 SUPPLEMENTAL PROVISIONS

A. Release For Material Purchase and Fabrication

Written approval of SFC Contractor Final Design to the SFC Contractor to start material purchase, and/or fabrication of the equipment covered by these specifications will be provided by SEPTA. Material purchase and/or fabrication are to be based on drawings reviewed and approved by SEPTA.

B. Tools
The SFC Contractor shall furnish two (2) complete sets of all special tools, all new and of first class manufacture, which shall be required for maintenance of the equipment installed under the project. Identification of all tools by name and number shall be provided, and this number shall appear on drawings and operating and maintenance manuals, to indicate the application of these special tools and to permit ordering replacements. These special tools shall be furnished at no additional cost to SEPTA.

C. Spare Parts

The SFC Contractor shall provide on-site sufficient spare parts for the first five (5) years of operations of the equipment following substantial completion. In addition to the warranty provided under the Contract, the SFC Contractor further warrants that if the quantity and type of spares provided are insufficient during this time period he shall provide additional spares and replace all depleted spares until expiration of the five (5) years. These spare parts shall be furnished by the SFC Contractor at no additional cost to SEPTA.

PART 2 - PRODUCTS

2.01 GENERAL

The following is a list of the major components associated with each SFC power block:

A. Static frequency converter power block
B. 60 Hz input filters, if required
C. SFC isolation transformer (3-phase, 60 Hz input transformer)
D. 25 Hz output filters, if required
E. Output transformer (1-phase, 25 Hz)
F. All associated power connections between the equipment associated with the power block
G. Cooling equipment
H. Power distribution equipment

2.02 STATIC FREQUENCY CONVERTER

A. Ratings

The static frequency converter unit shall be designed in accordance with the following technical data:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total capacity of station</td>
<td>60 MVA</td>
</tr>
<tr>
<td>Number of converters</td>
<td>4</td>
</tr>
<tr>
<td>Rating (each unit) - continuous</td>
<td>15 MVA</td>
</tr>
<tr>
<td>Rating (each unit) - overload</td>
<td>18 MVA for 1 hour</td>
</tr>
<tr>
<td></td>
<td>24 MVA for 6 minutes</td>
</tr>
<tr>
<td></td>
<td>30 MVA for 30 seconds</td>
</tr>
<tr>
<td></td>
<td>4000 A for 2 seconds at 12 kV</td>
</tr>
<tr>
<td></td>
<td>followed by 15 MVA for 1 hour before next overload cycle</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>Power factor (design)</td>
<td>0.7 pf lagging @ rated output, 24/12 kV, 25 Hz 0.95 pf lagging @ rated output, 13.2 kV, 60 Hz</td>
</tr>
<tr>
<td>Power factor (operating limit)</td>
<td>0.95 pf lagging @ rated output, 230 kV, 60 Hz</td>
</tr>
<tr>
<td>Rated current at 60 Hz, 3-ph (Assuming a 3% loss)</td>
<td>15 MVA / 0.97 loss / 13.2 kV / 1.732 = 676 A rms cont. 18 MVA / 0.97 loss / 13.2 kV / 1.732 = 812 A rms for 1 hr.</td>
</tr>
<tr>
<td>Calculated load currents (four converters)</td>
<td>15 MVA x 4 / 0.97 loss = 61.9 MVA 61.9 MVA / 13.2 kV / 1.732 = 2707 A rms during normal operating conditions 2707 A / 0.98 pu = 2762 A rms during normal low voltage conditions 2707 A / 0.95 pu = 2849 A during emergency low voltage conditions</td>
</tr>
<tr>
<td>Rated current at 25 Hz, 1-ph (each converter)</td>
<td>15 MVA / 36 kV = 417 A rms balanced (no rail return) 15 MVA / 24 kV = 625 A rms feeder (feeder-to-rail) 15 MVA / 12 kV = 1250 A rms trolley (trolley-to-rail)</td>
</tr>
<tr>
<td>Operating output voltage range</td>
<td>24/12 kV +/-5% (25 Hz system may reach +10% due to train regeneration.)</td>
</tr>
<tr>
<td>Calculated load currents (one converter)</td>
<td>15 MVA / 36 kV / 0.95 pu = 439 A rms balanced (no rail return) 15 MVA / 24 kV / 0.95 pu = 658 A rms for feeder-to-rail 15 MVA / 12 kV / 0.95 pu = 1316 A rms for trolley-to-rail</td>
</tr>
<tr>
<td>Outgoing 24/12 kV feeder minimum ampacity</td>
<td>658 A rms feeder cable 1316 A rms trolley cable</td>
</tr>
<tr>
<td>Operating modes</td>
<td>Synchronous machine mode (converter acts like a synchronous-synchronous motor-generator set) Constant power mode (converter delivers settable power to the 25 Hz network) Phase shift mode (converter delivers reactive power to the 25 Hz network during loss of the 60 Hz network)</td>
</tr>
<tr>
<td>Power flow direction</td>
<td>From 60 Hz to 25 Hz only. Reverse power flow not required.</td>
</tr>
<tr>
<td>Loss of 13.2 kV, 60 Hz power</td>
<td>Converter shall continue to supply reactive power to the 25 Hz network</td>
</tr>
<tr>
<td>Loss of 480 V, 60 Hz auxiliary power supply</td>
<td>Converter shall continue to fully function and supply both real and reactive power to the 25 Hz system during a loss of auxiliary power up to 3 seconds.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Harmonic distortion on 60 Hz system</td>
<td>SFC design must limit harmonic voltage distortion to limits given in IEEE 519 and PECO design standards at the 230 kV cable terminations in the PECO 230 kV switchyard</td>
</tr>
<tr>
<td>Harmonic distortion on the 25 Hz system</td>
<td>SFC design must limit harmonic voltage distortion to limits given in IEEE 519 at the 24/12 kV, 25 Hz cable terminations at the SFC 24/12 kV output transformers</td>
</tr>
</tbody>
</table>

B. General

1. The converter system power electronic equipment (i.e., IGBTs, IGCTs), power distribution panels, controls, and cooling pump will be installed indoors. Transformers, reactors, filters, and heat exchangers will be installed outdoors.

2. The SFC Contractor shall provide equipment that physically fits within the designated site areas as defined by this specification and project drawings.

3. The converter shall be self-protected to prevent tripping due to overloads.

4. The converter shall be capable of supplying the above power requirements over the entire range of utility input voltage.

5. The converter output frequency shall be exactly 5/12 of the input frequency (60 Hz input supply) and shall drift in that proportion with the input frequency. The control system shall also incorporate the provisions necessary to accept an external 25 Hz pilot signal.

6. The converter shall be capable of supplying the rated power specified above at a load power factor as indicated in the PQ Curve provided in this specification.

C. Fault Level at Input

The SFC will be supplied by 13.2 kV, 60 Hz, 3-phase switchgear that has a maximum available fault current of 25,000 A rms for 3-phase-to-ground faults and 381 A rms for line-to-ground faults. The 230-13.2-13.2 kV step-down transformers have a resistance-grounded neutrals that limit the line-to-ground fault levels. The SFC input transformers shall have the neutral bushing brought out of the tank to accessible terminals on the transformer.

D. Fault Level at Output

1. During fault conditions, the static frequency converter can be subjected to fault in-feeds from other SFCs at Wayne Junction and regenerative braking power from trains.

2. Each SFC must have the capability to deliver 4000 A rms for 2 seconds at 12 kV. This is necessary to permit proper operation and coordination of existing protective relaying on the 25 Hz traction power distribution system.

3. The SFC Contractor shall coordinate the overall system design with SEPTA and PECO to establish the appropriate requirements for transformer impedances and short-circuit capabilities of the converters.

E. Standards

The SFC Contractor shall ensure that the SFC’s comply with the latest issue of the
applicable equipment standards identified in this specification.

SFC power block equipment may follow IEC standards. Cooling and control cabinets shall comply with UL standards.

The SFC Contractor may use IEC drawing formats and drafting symbols. However, document and drawing sizes shall follow ANSI sizes, e.g., A-size 8.5 x 11”, B-size 11 x 17”, C-size 11 x 22”, D-size 22 x 34”.

F. Power Block Equipment

Power block equipment includes the power electronic devices used for converting the 60 Hz, 3-phase to 25 Hz, 1-phase voltage and current waveforms. Typical devices, for example, include thyristors, IGBTs, GTOs, and IGCTs. All power block equipment used in the SFC shall be the cataloged items of recognized manufacturers and used at their nominal ratings.

1. Ratings

The SFC shall be designed with proper ratings and designed with sufficient quantities to obtain the SFC rating as specified in Section A.

2. Power Electronic Cubicles

a) The power electronic components shall be installed on racks or in cubicles of standard design and delivered with a closed-loop cooling system (one (1) per converter unit) consisting of water-air heat exchanger (outdoor) with cooling fan, redundant circulating pumps, strainers, reservoir, filter, de-ionizer, instrumentation and control system (including gauges, control and regulating valves, isolation and shut off valves, water purity monitor, electrical controls and status/alarm system), and other associated equipment. Field piping between outdoor heat exchangers and the power electronic equipment shall be provided and installed by the SFC Contractor.

b) All cooling system equipment shall be in accordance with the applicable ANSI, IEEE, NEMA, ASTM, and ASHRAE standards. The SFC Contractor shall perform a hydrostatic test of all field piping.

c) The cooling system shall be a closed-loop self-venting system with a covered reservoir for makeup coolant. The coolant shall be a mixture of deionized water and ethylene glycol to maintain the required freeze protection. The reservoir shall be equipped with local level indication and alarm and trip level switches.

d) The heat exchanger shall be a full capacity unit with cooling fans. It shall be hydrostatically tested prior to shipment. Fan noise shall not exceed 55 dBA at 100'-0”.

e) All outdoor equipment shall come complete with manufacturer’s standard primer and finish paint coat.

f) A deionizer system with isolation valves, temperature regulating valve, drain valves, filters, and water purity monitor system (including alarm and trip functions) shall be provided.

g) Redundant full capacity coolant circulation pumps with automatic changeover and isolation valves for maintenance shall be provided. Motors greater than or equal to 3/4 horsepower shall be rated for 3-phase,
460 V, 60 Hz operation. Noise level shall not exceed 85 dBA at 3'-0". If the SFC Contractor’s standard design is a single-capacity pump without redundancy, identify this in the proposal and provide the cost difference.

h) All pump and fan motors shall be provided with motor starters and required controls to form a complete package.

i) Instrumentation shall include as a minimum, the following:
   1) Differential pressure switch and gauge across bridge
   2) Coolant temperature switches (high and low) and gauge
   3) Coolant resistivity (high and low)
   4) Hand-Off-Auto pump control switches
   5) Auto changeover control for pumps
   6) Loss of power alarms (control and power)
   7) Pump overload alarm

j) All gauges shall be installed with isolating shutoff valves to allow gauge removal with the system in operation.

k) Filters and cartridges that require changing shall be easily accessible. Valve handles and fill, drain, and vent connections shall be easily accessible.

l) Factory testing prior to shipment shall include as a minimum the following:
   1) Hydrostatic test of complete Pumping Station
   2) Hydrostatic test of outdoor heat exchanger
   3) Operational check of pumps
   4) Calibration and setting of all indicating devices, switches and sensors

G. Control Unit

Control equipment shall be provided to permit startup and shutdown of the converter either manually by a single pushbutton switch or automatically by a substation load sensing device, e.g., load sharing control system.

1. Control Equipment

   a) After start-up, the synchronizing of the converter to the voltage magnitude and phase of the single-phase bus shall be carried out automatically. This is based on the converter being initially in its normal shutdown mode and only control power being on.

   b) The SFC Contractor’s design shall take into consideration the non-sinusoidal nature of the voltage waveforms. Therefore, the control equipment shall not rely on zero-crossing for synchronization.

   c) The time from initiation of start-up to the single-phase breaker closure after synchronizing shall not exceed five (5) seconds.
d) Once the SFC is connected to the single-phase busbar it shall be capable of satisfactory parallel operation with rotary converters and with any combination of the rotary converters and SFC units.

e) Once in parallel, the SFC shall be capable of no-load operation and capable of sharing the load with other converters in an adjustable ratio.

f) Initially, the SFC shall be paralleled with existing static converters on the 25 Hz system. The SFC control system must also be suitable for operation in conjunction with other paralleled SFCs.

g) All equipment needed to provide the load sharing capabilities required shall be provided by the SFC Contractor.

h) Redundancy shall be provided in the control system for providing reliable operation. No single failure of any device that controls, covers, monitors, or otherwise interacts with more than one (1) SFC unit shall result in any loss of functionality, control or information from working SFCs.

2. Individual Operation

The SFC units shall be capable of satisfactory operation on their own with no other converters in parallel.

3. Voltage Control

When the converter is not running in parallel with other converters and not supplying a fault on the system, the rms value of the single phase output voltage shall be kept within 1% of the preset value. When the converter is running in parallel with other converters or rotary converters, the voltage shall be kept within 2%.

4. Control of the Converter

a) Full manual control of the converter functions shall be possible from the local control at each SFC as well as in the Wayne Junction SFC Main Control Room. Provisions shall be made to allow for supervisory control from 1234 Market Street in Philadelphia via a local SCADA RTÜ located within the Wayne Junction Main Control room. A master local/remote control switch is required with a yellow flashing beacon when in local control.

b) The converter shall be allowed to start up only when the input voltage is within its normal limits. It shall be possible to control the apparent and reactive output power flow by adjustment of the voltage and power electronics firing angles.

5. Measuring and Indicating Instruments

a) Measuring instruments indicating the converter input and output voltage, current, real power, reactive power and power factor shall be provided on the local panels together with provisions for connecting a portable recorder to each of the measuring instruments. Recording ammeter for the output current shall also be provided on the local panel. Visual indications of the positions of all main electrical equipment and alarms shall be displayed via panel mounted annunciator on the local panel.

b) Digital waveform recorders shall be installed to record thirty (30) minutes of voltage and current waveforms on both the 60 and 25 Hz sides of each
Triggering of each recorder shall occur (a) manually (including via SCADA), and (b) by the action of any protective relay or converter control system fault detector. Waveform records shall be automatically written to non-volatile media and available for review using Microsoft Windows based software.

c) In addition to the measuring instrument and indication instruments requirements stated in this specification section, the SFC shall provide inputs to the Main Sequence of Events Recorder in the Wayne Junction SFC Main Control room. Refer to specification section 16910 for requirements.

6. Arrangement of the Control Equipment

The control equipment shall be arranged so that the functions pertaining to more than one (1) converter, such as paralleling and load sharing equipment shall be installed in one (1) cubicle or group of cubicles. Functions pertaining to an individual converter such as start up or shut down controls, synchronizing equipment, voltage control, measuring instruments, annunciators and power factor and harmonic filter equipment shall be located in a separate group of cubicles to ensure maximum reliability. Control and monitoring of the SFC station through the paralleling and/or load sharing equipment shall not be dependent on the availability of the individual converter controls.

7. Synchronizing Operation

a) If the 24/12 kV, 25 Hz, single-phase buses at the Wayne Junction Traction Power Substation are energized (live bus), the SFC control equipment shall automatically synchronize the converter based on the difference in voltage magnitude, phase angle, and rate-of-change of phase angle in order to close the circuit breaker. If the 24/12 kV, 25 Hz, single-phase buses are not energized (dead bus), the SFC control equipment shall close the single-phase circuit breaker, once the converter output can provide the required voltage and frequency, assuming the dead bus permissive relay scheme requirements are satisfied. The time from the initiation of start-up to the single-phase breaker closure shall not exceed five (5) seconds.

b) The converter shall have manual controls (coarse and fine adjustments) to change the output voltage and phase angle so that synchronizing and circuit breaker closing can take place. The output voltage shall be controlled in 1% steps and the phase angle in 2-1/2 degree steps or less, to ensure that damage cannot occur to the SFC when the circuit breaker is closed.

H. Equipment Protection

The protective equipment described in the following sections constitutes the minimum requirements. The SFC Contractor shall provide additional protection, other than that stated herein, which may be required for the safe and proper operation of the equipment.

1. General

a) Protective relays shall be of flush-mounted, withdrawable pattern and shall be mounted on the protective relay cubicle panel. The relays shall be dustproof and shall be free from effects of equipment vibration. The relays shall remain operative at the minimum and maximum ambient
temperature. Relays shall be suitable for the non-sinusoidal waveforms they would be subjected to.

b) All protective relays shall be equipped with test plugs and shall be readily accessible so that routine testing, calibration, resetting and maintenance may be carried out without operating the relay.

c) All relays shall be of the self-resetting type. Relay contacts shall be adequately rated for the duty. All relays shall be furnished with target indicators that may be operated either mechanically or electrically via a shunt connected coil. The target indicators shall be capable of being reset by hand.

d) It shall be possible to remove the front cover of the protective relay cubicle panel during routine maintenance without operating the protection equipment or the circuit breaker.

e) The converter system shall include voltage surge protection and full fault suppression capability for internal faults and malfunctions.

f) The frequency converters and associated protective devices shall be designed so that any tripping of breakers or converters from overloads not caused by converter station equipment faults shall be controlled in a manner which permits the SEPTA Load Dispatcher to reset equipment and restart the converters from a remote location.

g) All fuses shall be easily accessible and exchangeable.

h) The SFC Contractor shall document all parts and operation of the entire protective relay system in a system description document, including a list of all components.

2. Converter Protection

a) The protective equipment, described in this section, constitutes the basic requirement. The SFC Contractor is required to recommend additional protection if considered necessary or appropriate.

b) The thyristor equipment shall be protected and supervised with as a minimum the following. These protection systems are required and shall be designed to keep the converter operating under safe and reliable conditions:

1) Overcurrent protection
2) Ground fault protection
3) Unbalance protection
4) Circulating current protection
5) Power electronics protection
6) Cooling system protection
7) Over-temperature protection
8) Fan fault protection

c) Phase Overcurrent Protection - Primary and backup phase current protection shall be provided to prevent damage to the thyristors due to
external faults. The primary and backup protection shall trip and lockout both input and output circuit breakers. The converter shall be protected against overloads and short circuits occurring in the 25 Hz network.

d) Ground Fault Protection - Ground fault protection shall be provided to trip and lockout the input and output circuit breakers if the thyristor circuit is not electrically floating. Otherwise, this protection need only provide an alarm.

e) Unbalanced Current Protection - Unbalanced current protection shall be provided to detect no current in each branch or series of thyristors. The detection of no current in one (1) branch shall sound an alarm. The detection of no current in two (2) or more branches shall result in the trip and lockout the input and output circuit breakers.

f) Circulating Current Protection - In the event that a double converter connection is used, a circulating current protection shall be provided to prevent current flow between the multiple converter bridges.

g) Power Electronic Protection - The protection circuits shall be designed to protect the devices from transient overvoltages.

h) Cooling System Protection - Required alarms and protection devices are defined in this specification.

i) High Temperature Protection - Alarms shall be provided in the event that the temperature of the SFC cooling system fluid reaches a preselected temperature. An automatic load reduction system shall activate upon receiving the high temperature alarm. If the high temperature condition persists, the converter input and output circuit breakers shall be tripped.

j) Cooling Fan Protection - The motor operating the cooling system heat exchanger fan shall be adequately protected against internal faults and overheating.

k) Control Equipment Protection - The SFC Contractor shall provide suitable protection equipment necessary for the control equipment.

l) Delayed Start Time Protection - In the event that the converter fails to start within six (6) seconds from the initiation signal, the converter shall be shut down and automatically reset for a second start-up attempt.

m) Reverse Power Protection - To protect against current flowing in the wrong direction.

3. SFC Transformer Protection

a) Gas Detector and Sudden Oil Pressure Relay - The gas detector relay for constant oil pressure systems shall be used to provide an alarm to warn against incipient faults. The fault pressure relay shall be provided to trip out the converter for a sudden transformer fault.

b) Winding Temperature Relay - Relay protecting the transformer from excessive hot-spot temperature shall be provided. The relay shall be connected to initiate an alarm and trip out the converter at preselected temperatures.
c) Liquid Temperature Relay - A two (2) stage relay monitoring the top oil temperature shall be provided to initiate an alarm and trip out the converter at preselected temperatures.

d) Phase Overcurrent Protection - An inverse time phase overcurrent protection shall be provided for both the input and output. The protection shall trip and lockout both input and output circuit breakers.

e) Ground Overcurrent Protection - A ground overcurrent protection shall be provided for both the input and output converter transformers. The protection shall trip and lockout both input and output circuit breakers.

f) Fan Motor Protection - The motor operating the cooling fans shall be adequately protected against internal faults and overheating.

g) Liquid Level Relay - A two (2) stage relay monitoring the liquid level shall be provided to initiate an alarm at the first stage and to trip and lockout the converter at the second stage of loss of cooling liquid.

4. Filter Bank Protection (if filters are required, early in the project after design calculations are prepared)
   a) Overcurrent protection - Each capacitor bank shall be protected by an easily replaceable current limiting fuse.
   b) Differential Protection - In the event that two (2) or more capacitor banks are required, a suitably sensitive differential type protection shall be provide

5. Potential Transformer Protection

Both windings of potential transformer shall be protected by easily replaceable fuses. Current limiting fuse is required for the high voltage winding

6. Undervoltage Protection

The converter shall be allowed to start up only when a sufficient voltage exists on all three phases of the transformer input terminals.

I. Load Sharing

1. The load sharing equipment shall be required (a closed loop control system) to control the output power from each SFC to a pre-adjusted part of the total station load demand. In event that a SFC is operating in parallel with other Wayne Junction SFCs, the load sharing equipment shall control the SFC to take an adjustable portion of the total load demand on the station.

2. The converter control equipment shall start-up and shut-down the converter automatically depending on the total substation load.

3. The load sharing control system shall be capable of optimizing the efficiency of the station by dispatching the appropriate number of SFC units necessary to be in operation and to establish load distribution among the operating units to satisfy a given demand load.

4. During normal operation, the load demand for the station and sharing of load between SFCs will be controlled by a load sharing system supplied by the SFC Contractor to be located at Wayne Junction SFC Station. The load sharing system will monitor all four SFCs on its own using equipment supplied by the SFC
Contractor. The system shall be designed to calculate and predict load trending to control the SFCs automatically and will cycle the SFCs in a rotating order.

5. Incorporated into the load sharing design shall be the capability to accept a demand load signal to be provided by SEPTA’s SCADA system, which would establish the required MW output of the station, should future SFCs be installed at another site in the future. The MVAR output shall respond to the system demand within the rated capability of the equipment.

6. The load sharing control system shall poll individual SFC units to determine availability in managing the load.

7. While operating in the automatic mode, provisions shall be made to permit SEPTA to pre-select load limits for individual SFC units. The load sharing control system shall make the necessary adjustments in the distribution of the load to meet the demand requirement.

8. The load sharing control system shall schedule the operation of individual SFC units to balance their operating time.

9. Automatic scheduling of the SFC operation and loading shall not over-ride manual limits imposed by SEPTA.

10. It shall be possible to set the converter power output constant at any value between 0% and 100% of its own rating or limit it to a maximum value and have the other converters supply the rest of the load.

11. The load sharing system shall ensure that each converter shall share the total load demand in equal basis within 2% of the SFC load.

12. The converter station shall be able, by preset values from 0 to 60 MVA (full station output power), to feed the single-phase network or, as an alternative, have each converter supply its portion of the single-phase load. The control system for each converter shall be designed such that it has the same voltage and phase angle characteristics as a synchronous generator. It shall be possible to preset and adjust the voltage and phase angle shift parameters of the converter.

13. The load sharing control shall be provided with a general diagnostic program to identify internal malfunctions.

14. Should the load sharing system fail, all four converters shall still have the capability to individually share load, but may do so at reduced tolerance.

J. Converter Enclosure and Assembly

1. Open Frame Equipment Cubicles

Open frame construction is acceptable for the SFC equipment cubicles. Access to open frame equipment containing exposed or energized devices shall be prohibited by the building design when such devices are in the energized state.

2. Enclosed Equipment Cubicles

a) If personnel require access to equipment during the SFC power operation, all enclosed cubicles containing power electronic equipment or control and protective equipment shall be accessed via a hinged door or panel. A provision for locking each cubicle by padlock shall be installed.

b) The converter shall be enclosed in a ventilated, steel cabinet of the free-standing floor-mounted type suitable for power plant application. Framing
shall be adequate to support all components during shipment and installation. Sheet steel for the enclosure shall be minimum No. 14 gauge.

c) The converter enclosure shall have screened ventilation openings, with filtering as required. Filters shall be designed so that cleaning or replacement is not required more often than quarterly.

d) All enclosed cubicles shall be vermin proof and suitably vented.

3. General Equipment Cubicles

a) Standard cubicle design shall incorporate indoor sheet steel, floor, free-standing design features.

b) The building housing the equipment shall not utilize underfloor ventilation ducts nor a basement ventilator area.

c) The cubicles shall be of ample size to permit ready access to all components and wiring through hinged doors or removable panels and shall allow opening of doors or removal of panels without requiring the disconnection of wiring. All steel work shall be carefully finished to remove sharp edges and burrs.

d) The assembly of components and wiring within the cubicles shall be so arranged that all components are accessible for inspection, testing, or removal without unnecessary disassembly of other equipment. Each item of equipment shall be identified by labels or other means to facilitate maintenance or testing. Metallic labels may be used only on major components, i.e., transformer shells, chassis, subassemblies, etc. Where metallic labels are used, they must be affixed by rivets or other means to ensure against inadvertent dislocation.

e) The windings of inductive components shall be encased or conformably coated to protect windings; however, such encasement or coating shall not restrict air flow over core lamination. Sufficient space is to be provided between inductive components and enclosure to avoid inductive heating.

f) Lifting eyes shall be provided, if necessary, together with sufficient additional permanent or temporary removable bracing and stiffening, to permit lifting, skidding, or rolling the assembly without deformation or damage. Two grounding pads with compression-type lug for SFC Contractor’s No. 4/0 AWG copper ground cable shall be furnished.

4. Auxiliary and Control Connections

All auxiliary wires and control cables shall be numbered at each end and cross-referenced to wiring diagrams to facilitate construction. Ring type or approved alternatives shall be used for all control connections.

5. Alarm Annunciation

An annunciator panel shall be provided for the local and remote control (via SCADA) equipment to give a visual alarm when an item of equipment has reached dangerous operating conditions or has been tripped out. The annunciator panel shall enable an easy identification of the faulted equipment. A point count for this equipment shall be submitted for approval.

K. Control Unit Enclosure and Assembly
1. Control cabinets shall be complete assemblies ready for installation. They shall be constructed to withstand normal shipping and installation handling. Appropriate provisions to mitigate the deleterious effects of RF and electromagnetic fields on the control system shall be incorporated.

2. Interconnecting cabling between shipping sections shall be furnished by the SFC Contractor. All control cabinet equipment shall be mounted or otherwise located to be easily accessible for maintenance or replacement.

3. Sufficient circuit breakers, fuses and disconnect switches shall be supplied for equipment protection due to faults and to ensure ease of equipment maintenance.

4. All components mounted on or within control cabinets shall be permanently marked in a conspicuous place to minimize maintenance errors. Marking shall not be placed on removable covers or interchangeable parts.

5. Removable covers shall be permanently marked so that they may be identified with their corresponding panel or piece of equipment.

6. All panelboard front nameplates shall be white with black lettering and shall be screwed to the cabinet with stainless steel screws. Nameplates for devices mounted inside panels shall be the manufacturers’ standard

7. Furnish and install the necessary control components for forced cooling of the enclosure where necessary.

L. Losses

1. No-Load Loss

No-Load Loss shall be defined as the total input power to the SFC equipment, including ac power of any frequency and dc power, with the three-phase, 60 Hz and single-phase, 25 Hz systems connected to the SFC equipment (input and output transformer breakers closed), all auxiliary equipment on-line, and no converter power flow from the 60 Hz to 25 Hz system or vice-versa. This definition of No-Load Loss includes the excitation currents drawn by the input and output transformers.

2. Load Loss

Load Loss shall be defined as: Total Losses minus No-Load Loss. Total Loss shall be defined as the total input power minus total output power from the SFC equipment with the three-phase, 60 Hz and single-phase 25 Hz systems connected to the SFC equipment (input and output transformer breakers closed), all auxiliary equipment on-line, and full rated power flow through the SFC equipment at nominal input and output voltage.

3. Back-to-Back Operation

“Back-to-back” operation shall be defined as the connection of two (2) SFCs such that one (1) acts as the load to the other. SFC #1 transmits power in the forward direction (60 Hz to 25 Hz) and SFC #2 is connected to SFC #1 operating in the regenerative mode, transmitting power back to 60 Hz (25 Hz to 60 Hz). In this configuration, one (1) SFC is used as a power source in the forward direction while the other is used as a load (or a source in the reversed direction), both converters shall be connected together on the 25 Hz bus and isolated from 25 Hz network. This type of test may be used to measure the total losses of two SFCs operating at 30 MVA without actually using the full power of 30 MVA from the utility or
traction power network.

4. Guaranteed Loss Reporting

The SFC Contractor shall state in its proposal the No-Load Loss and Load Loss for two (2) circumstances: (1) with the converters absorbing the fundamental and non-fundamental currents from the railroad network that shall be experienced in service, and (2) with only those fundamental and non-fundamental currents that the converters will experience when one converter is used in 25 to 60 Hz conversion mode as a load for the converter whose losses are being evaluated. For both of these circumstances, the No-Load and Load Losses shall be stated at a 25 Hz lagging power factors of 0.70, 0.75, 0.80, 0.85, and 0.90. The no-load losses shall be measured within nominal input and output voltage ranges and shall include all auxiliary power required to maintain the equipment at no-load output.

5. Loss Values

The Load Loss and the No-Load Loss shall be stated in kilowatts for each converter system. The system shall be designed for minimum No-Load losses.

6. Loss Penalties

For evaluating the overall cost of the converter system during final commissioning, the following US dollar per kilowatt values shall be utilized:

<table>
<thead>
<tr>
<th>Type of Loss</th>
<th>Loss Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Loss</td>
<td>$2635 / kW</td>
</tr>
<tr>
<td>No-Load Loss</td>
<td>$5525 / kW</td>
</tr>
</tbody>
</table>

7. Revenue-Class Metering

Revenue-class metering equipment shall be permanently installed on the 60 Hz feeds to each converter unit and the 25 Hz outputs from each converter unit by the SFC Contractor as part of the this project. This equipment shall be used to measure the primary energy to and 25 Hz energy from the converter units during the loss evaluation tests described below. Factory calibration certificates shall be furnished by the SFC Contractor for the revenue-class metering equipment described herein prior to the Loss Evaluation test described in this Section. Portable instruments of equal or better accuracy and precision, subject to SEPTA’s approval, shall be furnished by the SFC Contractor to measure auxiliary power (ac and dc) required by each converter unit. The certified accuracy of these instruments shall be taken into account during the Loss Evaluation Test and damages as described below shall be owing to SEPTA only to the extent that the measured losses are in excess of the certified instrument errors. Multipliers and scaling factors of the revenue-class metering equipment may be temporarily adjusted by SEPTA or the SFC Contractor for the benefit of the Loss Evaluation test described herein. SEPTA will provide written explanation of any such adjustments to the SFC Contractor.

8. Loss Evaluation Test

A Loss Evaluation Test of each converter shall be conducted in the field by the SFC Contractor to verify that the guaranteed losses of each SFC have not been exceeded. SEPTA reserves the right to witness testing unless this right is waived by SEPTA in writing. During the test, the converters shall be subjected to the
following:

a) **No-Load Loss** shall be evaluated on each unit with the unit under test energized from the three-phase power source and the 25 Hz system, with NO power flow from the 60 Hz to 25 Hz system or vice-versa. The No-Load Losses Test shall be conducted over a period of no less than two (2) hours, but at least long enough for the energy meters described in section 0 to accumulate two-hundred (200) counts, and the Measured No-Load Loss for each converter unit shall be the total energy input to the converters from all sources (expressed in kilowatt-hours) divided by the elapsed time of the test expressed in hours.

b) The **Total Loss** shall be measured on each converter within nominal input and output voltage ranges, at 15 MVA, 25 Hz load and power factor held as close as practical to 0.80 with filters and appropriate power factor correction equipment in service and shall include the increase in auxiliary power over no-load auxiliary power required. This test shall be run for no less than twenty-four (24) hours, but at least long enough for the energy meters described in section 0 to accumulate two-hundred (200) counts. The Measured Total Loss shall be the difference between the total energy input to the converters and the total energy output from the converters, expressed in kilowatt-hours, divided by the elapsed time of the test expressed in hours. All sources of energy to the converter unit shall be included in this measurement.

c) At the option of SEPTA, the Total Loss Test may be done by either furnishing 25 Hz power to the railroad, or by circulating current between the converter under test while connected in a back-to-back arrangement. If the Total Loss Test is made by furnishing power to the railroad, then the Guaranteed Losses for circumstance (1) described in paragraph 2.02.L.4 shall be used for comparison with the realized losses and determination of damages if any, as described in paragraph 2.02.L.6. If the Total Loss Test is made by circulating current between two converters, one acting as a 60 to 25 Hz converter and the other acting as a load, then the Guaranteed Losses for circumstance (2) described in paragraph 2.02.L.4 shall be used for comparison with the realized losses and determination of damages, if any. SEPTA shall inform the SFC Contractor which of these two methods shall be used at the time the SFC Contractor informs SEPTA that he is ready to perform the test.

d) The Measured Load Loss for each unit shall be the difference between the Measured Total Loss and the Measured No-Load Loss.

e) The **Load Power Factor at 25 Hz** for the Measured Total Loss shall be:

\[
\frac{kW}{\sqrt{kW^2 + kvar^2}}
\]

f) The Load Power Factor during Total Loss Test shall be held to as near 0.80 as railroad circumstances permit.

g) Load loss testing shall be conducted on each unit, using the SFC Contractor’s control system configured to hold the converter unit under...
test to a constant 25 Hz power of 15 MVA at the output of the SFC transformer or reactor.

h) The Measured No-Load Loss of each unit shall be compared to the SFC Contractor’s guaranteed No-Load Loss stated as shown in section 4. If the Measured No-Load Loss exceeds the guaranteed No-Load Loss, then the SFC Contractor shall pay damages to SEPTA in the amount of the number of kilowatts that the Measured No-Load Loss exceeds the guaranteed No-Load Loss, times the dollar value per No-Load Loss kilowatt shown in paragraph 6. This determination of damages shall be made for each converter unit furnished and the No-Load Loss damages owing to SEPTA shall be the sum of the No Load Loss damages for each converter unit. If the Measured No-Load Loss for any converter unit is equal to or less than the guaranteed No-Load Loss stated as shown in paragraph 4, then no No-Load Loss damages for that converter unit shall be owed by the SFC Contractor to SEPTA.

i) The Measured Load Loss of each unit shall be compared to the SFC Contractor’s guaranteed Load Loss stated as shown in paragraph 4. The Load Power Factor shall be determined as defined in section e).

1) If the Load Power Factor is equal, to two (2) decimal places, to any of the power factors for which guaranteed Load Loss values have been stated by the SFC Contractor, then the Measured Load Loss shall be compared to the guaranteed Load Loss at that power factor. If the Measured Load Loss exceeds the guaranteed Load Loss at the Load Power Factor, then the SFC Contractor shall pay damages to SEPTA in the amount of the number of kilowatts that the Measured Load Loss exceeds the guaranteed Load Loss, times the dollar value per Load Loss kilowatt shown in section 6. This determination of damages shall be made for each converter unit furnished, and the Load Loss damages owing to SEPTA shall be the sum of the Load Loss damages for each converter unit. If the Measured Load Loss for any converter unit is equal to or less than the guaranteed Load Loss stated as shown in paragraph 4, then no Load Loss damages for that converter unit shall be owed by the SFC Contractor to SEPTA.

2) If the Load Power Factor, expressed to two (2) decimal places, is between Power Factors for which guaranteed Load Losses have been stated, then by interpolation, Interpolated Guaranteed Load Losses for a power factor equal to the Load Power Factor shall be determined from the data furnished by the SFC Contractor as required by paragraph 4. If the Measured Load Loss exceeds the Interpolated Guaranteed Load Loss at the Load Power Factor, then the SFC Contractor shall pay damages to SEPTA in the amount of the number of kilowatts that the Measured Load Loss exceeds the Interpolated Guaranteed Load Loss, times the dollar value per Load Loss kilowatt shown in paragraph 6. This determination of damages shall be made for each converter unit furnished, and the Load Loss damages owing to SEPTA shall be the sum of the Load Loss damages for each converter unit. If the Measured Load Loss for any converter unit is equal to or less than the Interpolated guaranteed Load Loss stated as shown in
paragraph 4, then no Load Loss damages for that converter unit shall be owed by the SFC Contractor to SEPTA.

9. Opportunity to Repair or Replace Equipment

If the test described above shows that any damages are owing to SEPTA for excess losses, SEPTA shall afford the SFC Contractor a reasonable opportunity to repair or replace equipment in order to meet the guaranteed No-Load and Load Loss values, including repeats of the Loss Evaluation described in this section, subject to the operating needs of SEPTA. However, if more than two (2) attempts on any converter unit are made by the SFC Contractor, then the SFC Contractor shall pay SEPTA’s direct expenses of the repeated tests, including but not limited to personnel costs for witnessing the excess tests, personnel costs for dispatching power and/or arranging SEPTA’s electrical system to facilitate the test, and excess cost of electric energy and demand during the repeated tests. Repeated Loss Evaluation Tests shall not be an excusable delay.

10. Portable Instruments

During any informal preliminary evaluation of losses, and during all attempts at the Loss Evaluation Test described herein, SEPTA may install or have installed any portable instruments he desires for purposes of monitoring the tests, and SEPTA may make use of instruments permanently installed as part of the Converter Station by either the SFC Contractor or the SFC Contractor for the same purpose. The SFC Contractor shall reasonably accommodate SEPTA’s instruments.

11. Copies of Data

Copies of all data accumulated by the SFC Contractor during the Loss Evaluation Test and any informal, preliminary loss evaluations shall be deliverable to SEPTA no later than five (5) days after the data is accumulated, at no additional expense to SEPTA.

2.03 SINGLE AND THREE-PHASE FILTER BANKS

A. Basis for Design

The equipment shall be rated to complement the converter ratings.

The power factor correction equipment on the three-phase input side shall correct the power factor to within the limits required by PECO. The single- and three-phase harmonic frequency filters shall be designed to limit the input and output voltage waveform distortion to the specified values contained herein.

The equipment shall be designed and constructed to achieve the specified performance under the described service conditions without overheating or shortening the life of the equipment.

B. Standards

The SFC Contractor shall assure that the reactors, capacitors and resistors comply with the latest issue of the applicable equipment standards.

C. Switching Devices

The minimum design life (before replacement) for switching devices employed in the filter control shall be ten (10) years for vacuum switches or twenty (20) years for circuit breakers. Sample 60 Hz and 25 Hz load profiles shall be considered in the selection of a suitable
switching device for the output filter. Static switching is also an acceptable alternative.

D. Capacitors

The capacitors forming part of the power factor correction equipment and harmonic filters shall be manufactured in accordance with the latest revision of IEEE 18. They shall be the open-rack substation type and be individually fused with a current limiting fuse. The assembled structures shall be supported and insulated from ground using properly rated insulators. The stack height shall be kept to a minimum using horizontally mounted capacitor units. Capacitors shall be supplied with an unbalance protection scheme. Nameplates shall list style, serial number, kvar, rated voltage, frequency, number of phases and BIL. Connectors shall be clamp, parallel groove type accommodating one (1) or two (2) conductors, copper or aluminum. Internally connected discharge resistors shall be sized to reduce the residual voltage to 50 V within five (5) minutes. Bushings shall utilize wet process porcelain coated with a non-tracking glaze and shall be solder sealed to the capacitor case.

Spare capacitors shall be provided for each capacitor bank. Three (3) are required per bank on the 60 Hz side and one (1) per bank on the 25 Hz side. These spare capacitors units shall be installed in the stack rack (one (1) per phase), but not energized at this time. The capacitor units shall be energized following failure of the other capacitor units or if harmonic tuning requirements dictate unit energization.

The SFC Contractor shall provide the actual capacitance in microfarads obtained by measurement or test for each capacitor unit, including the spare capacitors. The SFC Contractor shall provide the location data by phase for each unit in each bank.

Each capacitor can shall be labeled with its position and keyed to a permanent nameplate on the cap rack so that the electrical position of any capacitor can be determined.

E. Reactors

The reactors for the harmonic filters shall be the dry-type comprised of fiberglass encapsulated winding groups. The reactors shall be equipped with bushings of an insulation class not less than the transformer winding terminal to which they are connected. The reactor winding design shall take into account the high voltage stresses caused on the insulation system due to lightning and switching surges. The winding insulation of series reactors shall be adequate to withstand the effects of harmonics and high thermal and mechanical stresses which may be caused due to fluctuating and sustained overloads during emergency conditions or by short circuits. Winding bracing shall be designed to withstand shocks and severe mechanical forces which may occur during transport, switching, or overload and fault conditions without causing excessive stress on the core bolt insulation.

Reactor rating shall be based on the self-cooled type cooling system and selected to operate in the linear portion of the magnetic characteristic curve.

Reactors shall be suitably sized taking into account ambient conditions, be rated for continuous operation at 105% of rated voltage at a frequency of 60 Hz (or 25 Hz as applicable), be manufactured with no more than a 5% tolerance, and taking into account the worst case harmonics anticipated in the installation.

Reactors shall be manufactured and tested in accordance with IEEE Standards C57.16 and/or IEEE C57.21

Consideration shall be given to specifying taps on the reactors to compensate for manufacturing tolerances and field tuning with capacitor banks. The reactor “continuous current rating” shall be selected such as to provide the required power output. Harmonic
currents and voltages shall be accounted for in determining stray losses, turns insulation and coil height.

The SFC Contractor shall provide actual inductance in ohms and X/R ratio at fundamental frequency as obtained by measurement or test for each reactor at all tap positions. The SFC Contractor shall provide a fundamental frequency I^2t thermal heating limit capability curve for the design supplied for the filter.

F. Protection

Each capacitor in a bank shall be protected by an easily replaceable current limiting fuse.

In the event that two (2) or more capacitor banks are required, a suitable sensitive differential type protection shall be provided.

The fans, if used, of forced air cooled reactors shall be adequately protected against internal faults and overheating.

The capacitors in any series filters shall be protected by an overvoltage type protection.

G. Bussing and Connectors (For Outdoor Application)

The busbars shall be of adequate continuous and short-time rating for the application described herein. The busbars and busbar joints shall be capable of withstanding the mechanical forces experienced during frequent fault currents expected on the system. The design shall avoid any sharp corners on the busbar. Exposed busbar in the converter housings is not permissible. The connection between the thyristor cubicles and low voltage terminals of the transformer shall be via enclosed busbar or insulated cables installed in cable tray and shall enter the thyristor cubicles at the top.

1. Bussing

Material shall be rigid non-breech drawn seamless aluminum tubing, alloy 6063-T-6, meeting ASTM specification B241.

2. Loadings

Fault current force is determined by formula:

\[ F = \frac{K I^2}{(d \times 10^7)} \]

where:

- \( F \) = force (in pounds) per foot,
- \( I \) = RMS amperes, asymmetrical, short circuit current
- \( d \) = phase spacing in inches, and
- \( K \) = 8.694

Ice and wind force, use 1/2” ice and 4 pound per square foot wind at 0°F plus a constant (0.30 lb/ft for all conductors) added to the resultant of loading as specified by NESC.

Fault current force is assumed to occur simultaneously with ice and wind loading.

3. Deflection

Maximum allowable vertical deflection of conductor with 2” ice loading shall be equal to or less than vertical dimension of conductor.

4. Fiber Stress

Maximum allowable fiber stress
a) Loading including fault current = 18,000 lbs./sq.in.
b) Loading without fault current = 15,000 lbs./sq.in.

Point of application of coupler connectors shall fall within 1/4 span of a support point where practicable.

5. Thermal Expansion
   a) The temperature range of -5°F to 195°F (-20°C to 90°C) is used for calculating expansion of conductors. When expansion connectors are used, expansion of conductor shall be limited to the capability of available approved expansion connectors.
   b) Expansion connectors shall be installed only at support points, such as at bus supports or switch terminals.

H. Instrument Transformers
   1. Potential and current transformers shall be provided on the 3-phase side upstream of the input filter and on the 1-phase side downstream of the output filter for performance monitoring. Additional potential and current transformers shall be provided, as necessary, for the control and protection of the SFC units.
   2. The potential transformers (PT) shall supply SFC protective relays, metering, and control equipment. The PT rating, ratio, and accuracy shall be stated in the data sheets which shall be included in the maintenance manual.
   3. Both windings of potential transformers shall be protected by easily replaceable fuses. Current limiting fuses are required for the high voltage winding.
   4. Ring-type current transformers (CT) shall be supplied for relays with C400 accuracy class for metering and control equipment. It shall be possible to remove CTs with a minimum of disturbance to other components. The CT rating, ratio, and accuracy shall be stated in the data sheets which shall be included in the maintenance manual.

2.04 60 HZ, 3-PHASE FILTERS

A. Harmonic and power factor correction filters shall be installed on the 60 Hz three-phase input side of the converter, as required, to reduce harmonic currents fed into the supply system and to generate reactive power in order to compensate for reactive power consumption in the converter.

B. The filters shall be classified by their location, connection to the main circuit, sharpness of tuning, and the number and frequencies of their resonances.

C. The three-phase input filter shall provide voltage damping, surge suppression, harmonic suppression and power factor correction.

D. The capacitors forming part of the power factor correction equipment and harmonic filters shall be manufactured in accordance with the latest revision of IEEE 18. They shall be the open-rack substation type and be electrically protected using the SFCC’s standard protection scheme for harmonic filter protection. Capacitors shall be supplied with discharge resistors, connectors, and an unbalance protection scheme. Spare capacitors shall be provided for each capacitor bank.

E. Reactor rating shall be based on the self-cooled type cooling system and selected to operate in the linear portion of the magnetic characteristic curve.
F. The 60 Hz filter banks shall be connected to a tertiary winding of the SFC isolation transformer.

2.05 25 HZ, 1-PHASE FILTERS

A. Harmonic filters may be required on the 25 Hz single-phase output side of the converter to reduce harmonic currents fed into SEPTA’s traction power system.

B. The filters shall be classified by their location, connection to the main circuit, sharpness of tuning, and the number and frequencies of their resonances.

C. The single phase output filter shall provide voltage damping, surge suppression and harmonic suppression.

D. The capacitors forming part of the harmonic filters shall be manufactured in accordance with the latest revision of ANSI/IEEE 18. They shall be the open-rack substation type and be electrically protected using the SFCC’s standard protection scheme for harmonic filter protection. Capacitors shall be supplied with discharge resistors, connectors, and an unbalance protection scheme. Spare capacitors shall be provided for each capacitor bank.

2.06 SFC INPUT AND OUTPUT TRANSFORMERS

A. Basis of Design

The SFC 60 Hz three-phase input transformers and the 25 Hz single-phase output transformers shall be designed specifically for single phase converter service. The design shall provide for essential service under the loadings, system capabilities, and environment defined elsewhere in this specification, including ambient temperatures, weather, and other conditions usually associated with outdoor installations. The SFC Contractor shall size these transformers to meet the requirements of the static frequency converters.

B. Conditions of Service

Service conditions shall be “usual” as defined in IEEE C57.12.00 (ambient air does not exceed 40°C maximum, and the average for any twenty-four (24) hour period does not exceed 30°C maximum).

C. Standards

The SFC Contractor shall assure that the input and output transformers comply with the latest issue of the applicable equipment standards identified in this specification.

D. System Grounding

1. Three-Phase System Grounding

The three-phase SFC input transformer shall provide a means for 60 Hz system grounding via a solidly grounded neutral.

2. Single-Phase System Grounding

The 24/12 kV, 25 Hz traction power system is presently supplied by three cycloconverter output transformers that have the 36 kV output side tapped at 2/3 winding length to make up a 12 kV trolley and 24 kV feeder system. The tapped connection is solidly grounded to the rail return system.

E. Sound

The audible sound level shall not exceed 71 dBA, consistent with IEEE C57.12.90, when the transformer is operating at full-load, rated tap voltage, rated frequency, and with all
auxiliary cooling equipment functioning.

F. Oil Preservation System

The transformers shall be furnished with a constant pressure type oil preservation system utilizing an air conservator where the oil is sealed from atmosphere by an expandable bladder which is allowed to expand or contract as the oil volume changes due to temperature. The system shall include a gas detector relay and a sampling valve located at ground level. The System shall be suitable for operation over an ambient temperature range of -18°C to +40°C.

G. Impedance

Measured impedances from primary to each secondary winding of the three-phase transformer shall be within 7 ½ percent of the SFC Contractor specified value. Similarly, the impedance of the primary to secondary winding of the single-phase transformer shall be within 7 ½ percent of the SFC Contractor specified value.

H. Temperature Rise

The temperature rises shall be separately guaranteed and measured for the high voltage and each low-voltage winding. All temperature rises shall be shown on the test report. The temperature rise of the transformers based on the nominal MVA rating shall not exceed 65°C by resistance measurement and 80°C for hot spot winding temperature above a 40°C ambient when operating at the specified continuous rating to assure a normal life expectancy of forty (40) years. The hot spot temperatures shall not be exceeded during the rating duty cycle.

The transformer shall be designed to permit loading in accordance with IEEE C57.91.

I. Short-Circuit Capability

The transformer shall, as a minimum, have the short-circuit capability described in IEEE C57.12.00.

J. Taps

The transformers shall have a manual tap changer suitable for operation from ground level when the transformers are de-energized only. Full kVA taps shall be provided as shown under the transformer rating.

Two (2) 2.5% taps above nominal and two (2) 2.5% taps below nominal shall be provided. The SFC Contractor shall ensure that the converter receives adequate voltage based on the voltage swing criteria described this specification.

The tap changer handle shall have provisions for padlocking, and visible indication of tap position shall be provided. The position of the tap changer shall be visible to a person standing on the ground. The number “1” or the letter “A” shall be assigned in accordance with IEEE C57.12.00.

K. Windings

The transformer winding design shall take into account the high voltage stresses on the insulation system due to lightning and switching surges on the system.

The winding insulation shall be adequate to withstand the effects which may be caused by harmonics and high thermal and mechanical stresses due to fluctuating and sustained overloads during emergency conditions or by short circuits. The SFC Contractor shall include in his bid drawings showing the winding construction, end packing, support arrangements, and the winding damping structure proposed. The high voltage and low
voltage windings shall be capable of withstanding full and chopped-wave impulse voltage
tests detailed in the test section.

Winding bracing shall be designed to withstand shocks and severe mechanical forces which
may occur during transport, switching, or under overload and fault conditions without
causing excessive stress in the core bolt insulation.

Tapping shall be arranged at such positions on the winding so as to preserve as far as
possible the electromagnetic balance of the transformer at all voltage ratios.

L. Insulating Oil

The SFC Contractor shall furnish a sufficient quantity of insulating oil, which, as delivered,
conforms to the requirements of ASTM D3487. The oil also shall conform to any
additional or more stringent requirements imposed by the transformer vendor in order that
the oil be completely compatible with the transformer insulation system.

M. Tank Design

The transformer tanks and grounding terminals shall be as recommended in IEEE C57.97.
The transformer cover shall be designed so that bushings and other top-mounted equipment
is attached to elevated sections of the cover to prevent the accumulation of water under this
equipment.

As far as practicable, gaskets, below oil level shall be eliminated, unless isolating valves
are provided to permit replacement of gaskets during operation.

After completion of factory assembly and testing, the equipment shall be thoroughly
cleaned. Except for match marking, all nonpermanent marks and coatings shall be
removed, and the finish shall be clean and undamaged.

The transformer tanks and any attached compartment that is subjected to operating
pressures shall be designed to withstand, without permanent distortion, pressures 25%
greater than the maximum operating pressure resulting from the system of oil preservation
used. The maximum operating pressures (positive and negative) which the transformer
tank is designed to withstand shall be indicated on the nameplate. Either bolted or welded
main cover construction shall be considered.

One or more manholes shall be provided on the transformer top. As a minimum, manholes
shall be located above side-mounted bushings, and above no-load tap changers. Opening
and covers shall be designed to prevent water or snow entering the transformer.

The center of gravity lines of the tank and assembled transformer shall be clearly marked
or etched on all sides.

The base shall permit rolling in the directions of both major centerline (front to back and
deside to side) of the transformer and provision shall be made for pulling the transformers in
these directions. The transformer, as normally prepared for shipment, shall not fall outside
the base support members when the base is tilted 15 degrees from the horizontal, with or
without oil in the transformer.

Jacking aids shall be located near the extreme ends of the junctions of the segments. There
shall be a minimum of four (4) jacking lugs in accessible positions to enable the
transformer, complete with oil, to be raised or lowered using hydraulic or screw jacks. The
minimum height of the lugs above the base shall be 20”.

Means shall be provided for lifting each complete transformer. The bearing surfaces of the
lifting means shall be free from sharp edges. Methods shall be provided for guying the
transformers. Means shall also be provided for untanking the transformers, which would be an in-shop process.

The SFC Contractor’s outline drawing shall show recommended support locations for jacking and lifting the transformer. These support locations shall be indicated on the transformer base by painting or otherwise

N. Core

The transformer cores shall be carefully assembled and clamped to ensure adequate mechanical strength to support the windings and to minimize movement during handling, transport, and to reduce vibration to a minimum under operating conditions. The design shall also inhibit movement of the core due to forces caused by traction system currents.

The prime consideration in the design of the magnetic circuit shall be the prevention of:
1. Static discharge development and short circuit to the grounded coupling structure.
2. Flux component at right angles to the plane of lamination, which may cause local heating.

O. Equipment Grounding

Two (2) grounding pads shall be furnished, located diagonally opposite on the transformer case or frame. Each pad shall have two holes on 1.75” centers, drilled and tapped 0.5” - 13NC. Grounding pads shall be made of copper-faced steel or stainless steel without copper facing.

P. ACCESSORIES

1. Liquid Indicator

Dial-type liquid level indicator (two stage) with separate alarm and trip contacts. The indicator shall have provisions for resetting. The indicator shall indicate below normal oil level and, if constant oil pressure system is used, damaged air cell. The indicator shall have a dark face dial with light indicating hand and light markings, which shall indicate maximum level, minimum level and 25°C level.

2. Dissolved Gas Analysis Monitor (Hydran Monitor)

Each of the converter transformers shall be equipped with a continuous, on-line, real-time, dissolved gas-in-oil monitoring system for use in the detection, monitoring and alarming of composite values of fault gases (hydrogen, carbon monoxide, acetylene and ethylene) dissolved in the transformer dielectric oil. The monitor shall be Syprotec® HYDRAN 201R Model I system or SEPTA approved equivalent.

Each monitoring system (one (1) per transformer) shall consist of an intelligent transmitter and a one-channel controller. The one-channel controller shall link with one (1) transmitter, and shall provide a remote display of the dissolved gas level, alarm relay contacts, local alarm indicators and analog outputs.

An intelligent transmitter shall be provided:

a) The transmitter shall contain the sensor assembly and all electronics and any associated software necessary for stand-alone operation as a gas-in-oil monitor. The transmitter shall provide the following:

1) Local display and controls to display measured data and allow for parameter set-up.
2) RS-232 port for local computer access.
3) Supervisory RS-485 or Ethernet link port for connection to one (1) of the before mentioned controllers.
4) One (1) isolated 4-20 mA output.
5) Gas alarm and system fault relays.
6) Capability for remote upgrade of any embedded software.

b) The transmitter software shall enable the following:
   1) Real-time display of gas level in PPM.
   2) Displays of twenty-four (24) hour and thirty (30) day gas trends (user adjustable periods).
   3) System date and time and alarm messages.
   4) Multiple levels of alarming with adjustable delays on gas level.
   5) Gas trends and sensor temperature.
   6) Password-protected menu-access to alarm settings.
   7) Set-up parameters and historical data.
   8) Automatic sensor test.
   9) Thermal enclosure control.
   10) Software calibration of analog inputs and outputs.

c) The SFC Contractor shall install the intelligent transmitter at a readily accessible location on the transformer per the Vendor’s instructions. The SFC Contractor shall provide 120 V ac, 60 Hz power to the transmitter.

d) The transmitter shall have a one-channel controller:
   1) The one-channel controller shall provide a supervisory link with one (1) transmitter. The controller shall have the capability of being networked with multiple controllers. The controller shall provide the following:
      • Display of the dissolved gas level.
      • Gas alarm indicators with acknowledge.
      • One (1) non-isolated, configurable analog output (4-20 mA or 0-10 V)
      • One (1) isolated, configurable analog output (4-20 mA or 0-10 V) for connection to the SEPTA’s SCADA system.
   2) The SFC Contractor shall locate and install the controller.

3. Thermometry System

   The SFC input and output transformers shall have a 4-channel fiber optic thermometry system that provides temperature measurements of the transformers similar to Luxtron Fluoroptic thermometry system or SEPTA approved. A minimum of four (4) probes shall be installed in each winding of each phase of the transformers. For the transformer to be considered acceptable, at least three (3) of
the probes in each winding of each phase must survive manufacturing and be operable on the finished transformer during commissioning.

All the probe leads shall be brought outside of the transformer tank and terminated appropriately in a single location. A minimum of six (6) sensors per transformer shall be telemetered to SCADA via 4-20 mA, 0-10 V or equivalent SEPTA approved analog signal.

The instrumentation package shall be mountable in a standard 19” rack mount. The high voltage transformer winding monitoring system shall have, as a minimum, the following features:

a) Measurement of the transformer winding temperature shall be by direct reading fiber optic probe.

b) The monitor shall be modular and have the capability to display temperature readings on a minimum of four (4) independent channels.

c) The monitoring probes shall be electrically isolated from the monitor (electronics unit).

d) The monitoring system shall include a temperature display for each channel consisting of a three (3) digit LCD.

e) The minimum temperature measurement range shall be from 0°C to 200°C.

f) Temperature resolution of the LCD display shall be 1°C.

g) The monitoring system shall have a temperature accuracy of 2°C or better.

h) The monitoring system shall have the capability to communicate temperature readings to SEPTA’s SCADA system and/or remote indicating displays.

i) The maximum temperature measurement update rate shall be ten (10) seconds or less.

j) Each monitor output channel shall include a user selectable temperature alarm output limit with relay and monitoring system status indicators.

k) The temperature probes shall function properly when completely immersed in hot transformer oil.

l) The probes shall withstand exposure to hot kerosene vapor during the transformer insulation drying process.

m) System shall come complete with instrumentation (electronics unit), fiber optic temperature probes, tank wall penetrators, tank wall adapter plate, external fiber optic extension cables, and all other require hardware and equipment.

n) Tank wall penetrators, extensions, and under-oil connectors shall be of a leak free design.

o) The electronics unit shall be protected against the surge conditions specified in IEEE C37.90.1

Provide dial-type liquid thermometer with alarm and trip contacts for indication the top oil temperature. The indicator shall have provisions for resetting and be mounted in a thermowell as shown in IEEE C57.12.00 for indicating the top oil
temperature. The thermometer shall have a dark face dial with light markings, a light colored indicating hand and an orange/red maximum indicating hand with provisions for resetting.

4. Upper and lower filter connection

5. Drain valve

6. Oil sampling valve

NOTE: If drain and sampling valves are furnished combined in one (1) unit, the sampling device shall be on the discharge side of the main valve, and a pipe plug for the valve shall be furnished.

7. Nameplate

A diagram nameplate shall be furnished and shall be located near eye level above the base of the transformer. The information furnished shall be in accordance with nameplate C of Section 5.12.2 of IEEE C57.12.00. Zero- and negative- sequence impedances shall be shown on transformer nameplates.

8. Pressure test valve

9. Pressure vacuum relief device

A pressure vacuum relief device shall be located on the cover. Electrical alarm contacts shall be provided for indicating operation of the pressure vacuum relief device.

10. Breather

If a constant oil-pressure system is provided, a breather enabling a passage of air in and out of the air cell as it inflates or deflates shall be provided.

11. Temperature gauge

Dial type hot spot winding temperature gauge (including associated current transformer) with four (4) single pole normally open contacts. The dial face shall be similar to that of the liquid indicator. Gauge shall include a resettable maximum temperature reading indicator.

Q. Cooling Equipment

Forced air cooling (FA) shall be provided as required and shall include as a minimum the current carrying parts sized for the forced air rating, fans, and control cabinet. The cooling system shall be by removable radiators, fitted with valves, which can be easily shipped and fitted on site. The fan motors shall have individual thermal protection. Fans shall be readily replaceable.

Terminals shall be provided in the control circuit for connecting contacts to trip the fans automatically on operation of the transformer protective relays.

If forced air cooling is required, each transformer shall be equipped with at least two (2) separately controlled fan groups. The control shall be so arranged that any group may be manually selected as the initial group or a subsequent group. The control shall be so arranged that both groups of fans can be started manually and run continuously if desired.

Fans shall be automatically controlled from winding hottest-spot temperature by a dial hot-spot indicating relay. This relay shall have a scale with a range of at least 0-180°C and shall be provided with an alarm contact set to close at 115°C on rising temperature. Ready means shall be provided for externally checking and calibrating the entire internal thermal...
assembly, and shall include provisions for inserting test ammeters in any current transformer secondary circuits, for inducing test current in the current transformer secondary circuits without using the primary winding, and necessary calibrating information. Data of ultimate temperature gradient above top oil temperature vs. test current in the current transformer circuit shall be furnished. Fan wiring shall be in conduits suitable for outdoor service.

R. Connections

All terminals and interconnecting wiring for sudden pressure relays, winding temperature indicator, and fan control switches shall be located in a vermin-proof, ventilated, weatherproof control cabinet mounted on the transformer tank. The wiring used shall be copper, insulation type XHHW, 600 V insulation and be of suitable gauge. It shall have markings indicating maximum voltage, identification letters or numbers, and manufacturer’s name or trademark. The cabinet shall contain switches for auxiliary supply, space heaters with thermostat and a lamp.

All live terminals and components contained in the control cabinet shall be suitably screened and labeled to prevent inadvertent contact and provide safe working space. All alarms shall be individually wired to an easily accessible terminal block. A removable bottom drill plate shall be supplied with the cabinet to accommodate cables of various sizes.

Cover mounted bushings shall be provided on the primary side of the SFC input transformer to accommodate connection by overhead rigid bus. Provisions shall be provided on the secondary (low-voltage) side of the SFC input transformer for connection of non-segregated bus duct.

An air-terminal chamber shall be provided on the input side of the SFC output transformer for connection to cable or bus. Cover mounted bushings shall be provided for connections to 12 kV trolley, 24 kV feeder, and rail return terminals on the output side of the SFC transformer.

Fan wiring shall be in conduits suitable for outdoor service.

2.07 TRANSFORMER FACTORY TESTS

A. General

All transformers shall be subjected to manufacturer’s standard factory and quality control tests and all applicable tests required by IEEE C57.12.00. The tests shall be carried out in the manner described in IEEE C57.12.90 and IEEE C57.12.00 unless otherwise specified below. The SFC Contractor shall submit a complete Certified Test Report containing of all factory test results.

B. Standard Tests

Tank welds shall be given a pressure test by filling the tank with dry nitrogen, dry carbon dioxide, or dry air to the highest pressure for which the tank is designed and exploring all welded seams with a suitable leak detector.

C. The following tests identified in IEEE C57.12.90 shall be included:

1. Resistance measurement
2. Ratio
3. Polarity and Phase Relation
4. Excitation Current
5. Impedance, Voltage and Load Loss
6. No-Load Loss
7. Applied Voltage
8. Induced Voltage
9. Temperature Rise
10. Impulse test

D. In addition to the standard tests identified above, the following shall apply:

1. Ratio and Regulation Tests

   Ratio tests for full windings and for all taps of each type of transformer shall be made. The transformer vendor shall calculate and record regulation for each type based on impedance voltage and impedance power corrected to a temperature equal to the limiting winding temperature rise by resistance covered in Table 14 of IEEE C57.12.00 plus 20°C. The SFC Contractor shall be responsible for providing the required test to SEPTA.

2. Impedance Characteristics

   The impedance characteristics of the complete tapping range shall be determined by measurement of values of impedance voltage between the high voltage and low voltage winding on every tap position.

3. Highest Total Loss Test

   Total losses of the input and output transformers shall be measured on each tapping position so as to identify the tapping having the highest total loss. These losses shall be guaranteed by the manufacturer within a tolerance of 7.5% of the stated losses.

4. Temperature Rise Test

   Temperature rise test shall be made on one (1) completely assembled oil-immersed transformer. The tap selected shall be the one (1) which produces the highest temperature rise. The ambient temperature shall be taken as that of the surrounding air, which shall not be less than -18°C or more than 40°C.

5. Impulse Test

   Complete applied impulse test sequence is required for all outdoor transformers.

2.08 SFC INPUT TRANSFORMERS (3-PHASE, 60 HZ)

A. The SFC isolation transformer shall be a multi-winding transformer designed to step down the 13.2 kV power source voltage to the proper utilization voltage required for the SFC power block input.

B. The high voltage primary of the transformer shall be solidly grounded and a tertiary winding shall be provided for the SFC 60 Hz, 3-phase filter connection, if required.

C. Surge protection shall be provided for each incoming 13.2 kV line on the transformer bushings.

D. As a minimum, the input transformer protective relaying shall include the following protection schemes as depicted on project drawings:
1. Phase Overcurrent
2. Standard transformer accessories
3. Differential
4. Ground Overcurrent

2.09 OUTPUT TRANSFORMERS (1-PHASE, 25 HZ)

A. Each Wayne Junction SFC shall operate through its own output transformer at the rated output fundamental frequency of 25 Hz and supply 15 MVA, 24/12 kV at its output terminals.

B. Surge protection shall be provided on the 24/12 kV side of the SFC output transformers.

C. The single phase output transformer shall isolate the dc component of currents generated by the static frequency converter from the 1-phase distribution system and serve as a means to step-up the SFC output voltage to the required 24/12 kV level.

D. As a minimum, the output transformer protective relaying shall include the following protection schemes as depicted on project drawings:

   1. Phase Overcurrent
   2. Standard transformer accessories
   3. Differential
   4. Ground Overcurrent

2.10 NON-SEGREGATED PHASE BUS (BUS DUCT)

A. General

1. This section describes the electrical and mechanical requirements for metal-enclosed 60 Hz and 25 Hz bus if required. Alternative methods of connecting the SFC equipment shall be submitted for approval and the SFC Contractor shall be responsible for the development and safety of the alternative design. The bus system described is to be suitable for outdoor installations, with nominal current ratings maintained in ambient temperatures to 40°C.

2. This specification covers the general requirements for the bus duct assemblies. The general requirements for the assembly (plan, arrangement, dimensions, and components) shall be developed by the SFC Contractor and approved by SEPTA. This drawing shall form the basis for detailed manufacturing and installation drawings to be developed by the SFC Contractor.

3. The assemblies shall be constructed, wired, and tested in accordance with all applicable sections of the latest standards and codes.

4. It shall be the SFC Contractor’s responsibility to be, or to become, knowledgeable of the requirements of these standards and codes. Any changes or alterations to the equipment to make it meet standards and codes requirements shall be at the expense of the SFC Contractor.

B. Installation and Operating Instructions

Installation specifications and operating instructions shall be provided covering all the equipment furnished (including, but not limited to: bus duct sections and connection details, support structures details and equipment termination details).
C. Housing

1. The bus duct shall be non-ventilated. Housing and accessory flanges, terminal enclosures, etc., shall be primed and of corrosion-resistant aluminum construction. All outdoor hardware shall be 316 stainless steel.

2. Aluminum housings shall be nominal 1/8” thickness material minimum throughout. Top covers shall be sloped to shed water.

3. Totally enclosed, non-ventilated housings shall be fitted with screened breathers and space heaters in sufficient quantity and rating to minimize condensation. Space heaters shall be completely factory wired with no exposed wiring inside the bus housing. Heaters shall be thermostatically controlled. Heater wiring shall be terminated in an octagonal box at designated end of bus housing and wired into switchgear power source by the SFC Contractor. Heaters shall be rated at 240 V and operated at 120 V (2 voltage) to maintain low heater surface temperature, and shall be designed for easy removal without requiring opening of the bus housing.

4. All housing and flange gasketing shall be closed-cell neoprene rubber, or other noncorrosive material, and shall be completely concealed for protection against deterioration.

5. The temperature rise at any point on the housing shall not exceed 30°C above an ambient temperature of 40°C.

6. A wall flange shall be provided at the point where the bus duct extends through all building and transformer fire walls.

7. Housings shall be phosphate treated and be applied with two coats of oven-baked corrosion-resistant ANSI 61 gray acrylic enamel paint.

D. Phase Bus Bars

1. Phase bus bars shall be of the non-segregated phase type, completely metal enclosed.

2. Bus bars shall be full round-edge rectangular 98-percent IACS copper of sufficient cross section to ensure full current rating without exceeding a hot spot temperature rise of 65°C in an ambient air temperature of 40°C. Joints between bus bar sections and at terminal connections shall be designed for a maximum rise of 65°C in a 40°C ambient.

3. Phase bus bars shall be mounted and secured against movement during short circuits in high-tracking-resistant, high-impact-resistant, flame-retardant, bus bar supports, spaced along the bus run as required to meet the short-circuit current rating. The support blocks shall be ribbed to provide long creepage paths and fitted with corona suppressors, consisting of silicone rubber inserts between the insulated bus bars and support blocks.

4. Phase bus bars, at 5 kV class and above, shall be insulated with extruded Noryl tubing, rated for continuous operation at 130°C.

5. Contact surfaces of copper bus bars shall be silver plated. All bus bar connections shall be bolted. Bolts shall pass through the bus bar conductors, and shall be capable of being properly torqued and locked in place, to provide and maintain full and uniform pressure under all operating conditions. (Torque requirements in ft-lb shall be furnished by Vendor.) Temperature rise of bus bar joints shall not
exceed bus bar rise by more than 5°C and in no case shall such bus bar joint
temperature rise exceed 65°C.

6. A ground bus shall be furnished which shall electrically connect together all
equipment connected to the bus duct. The ground bus shall be copper and have
suitable terminating pads for connections to station ground system.

7. Flexible connections shall be provided for connecting bus to porcelain transformer
bushings, switchgear bus risers and SFC equipment. All necessary adapter bars
and spacers, bolting hardware, and insulating materials, for connection to
transformer and switchgear terminals, shall be provided and the proper
coordination of connections between bus and terminal equipment shall be the
responsibility of the SFC Contractor. A phase transposition shall be incorporated
to account for difference in phasing (where required).

E. Supports

Bus duct supports shall be outdoor column type with base plates for attaching to
foundations furnished and installed by the SFC Contractor. Column supports, anchor bolts,
etc., shall be hot-dipped galvanized materials.

F. Ratings

1. The maximum hot-spot temperature rise at any point in the bus duct at continuous
rated load shall not exceed 65°C above an ambient temperature of 40°C.

2. The ratings of the bus duct shall be defined by the Vendor based on the
requirements for his equipment.

G. Installation

The SFC Contractor shall install the busway and accessories in accordance with vendor’s
instructions.

H. Tests

The SFC Contractor shall furnish the vendor’s Certified Test Reports for the bus. Tests
shall be performed in accordance with the latest issue of IEEE Standard C37.23 and shall
include the following:

1. Power Frequency Withstand Test Report

2. Impulse Voltage Withstand Test Report

3. Continuous Current Rating (Heat Run) Test Report

2.11 WIRING REQUIREMENTS

The SFC Contractor shall provide detailed supplemental specifications and cable schedules for all
power, control, signal wire and any special cable assemblies, i.e., cables with plug connectors, etc.,
required to interconnect the SFC Contractor’s equipment in accordance with the requirements of
Section 16120, Conductors and Cables. Any special pre-fabricated cables and/or connectors,
including internal SFC equipment wiring, shall be provided by the SFCC.

2.12 INSPECTION

Shop fabrication shall be subject to inspection and approval by SEPTA and/or its representatives,
who shall have free access to the SFC Contractor’s and the Vendor’s shops for inspection of
fabrication and for observing shop tests. All tests required for certification of equipment shall be
made at the SFC Contractor’s expense.
2.13 SFC COMPONENT FACTORY TESTS

A. Factory tests in accordance with the requirements of the technical specifications shall be performed by the SFC Contractor on the equipment specified herein and may be inspected, verified, or witnessed by the SEPTA or representative as noted below. The test procedure shall be developed by the SFC Contractor and submitted for review and comment prior to performing the testing. For those items listed below, the SFC Contractor shall give the SEPTA twenty-four (24) days’ notice before the start of any test. A copy of the factory test procedures shall be submitted to SEPTA prior to commencement of the test program. SEPTA reserves the right to witness any factory tests.

B. The factory tests on all equipment shall be performed in the manufacturer’s plant and shall be arranged to represent the working conditions as closely as possible. The tests shall be carried out in accordance with the approved test plans and procedures to ensure that satisfactory operation is obtained at rated frequency, voltage and power.

C. The SFC Contractor shall submit complete test plans and procedures for review and approval at least thirty (30) days prior to the desired testing date. The plans and procedures must include detailed information on the test type, identify what is being tested, how the test shall be performed, all necessary prerequisites, the pertinent codes and standards that apply, the anticipated results, as well as the pass/fail criteria for the test. The submittal shall include proposed test record forms.

The following sections indicate the minimum tests required.

D. Factory Inspection and Tests
   1. Prior to the start of manufacture, the SFC Contractor shall provide a list and schedule, of all proposed tests and inspections. SEPTA shall be notified at least ten (10) working days in advance of the actual tests and the inspections. SEPTA reserves the right to witness testing unless this right is waived by SEPTA in writing. SEPTA may photograph, or video-tape the work-in-progress and under test in the SFC Contractor’s or subcontractors’ facilities. Alternatively, the SFC Contractor or the subcontractor may furnish the photographs at no cost to SEPTA.
   2. The SFC Contractor shall provide SEPTA with five (5) certified copies of all factory test data.

E. Power Block Electronics Shop Tests
   The following tests shall be performed on the power block conversion equipment and their auxiliaries in accordance with the applicable IEEE Standards.
   1. Dielectric Test - Dielectric tests shall be performed in the Vendor’s plant and in the field on the main circuit, auxiliary circuits and fan motor supply to demonstrate the adequacy of the insulation, the creepage distances and clearances between device terminals and elements.
   2. Load Tests - The power electronics shall be subjected to rated voltage and rated current tests in the Vendor’s plant. The mode of operation during the testing shall be substantially the same as in regular service. The power electronics shall withstand, without injury, the continuous and short time loadings described in this Specification Section. Test results must include the verification of thermal calculations.
   3. Efficiency and Losses
a) The efficiency shall be determined by calculation based on separately measured losses in the various components of the power electronic unit for rated voltage, current and frequency and for the normal mode of operation obtained with the proposed input and output transformer connection.

b) The loss calculation shall include the power electronics losses, transformer losses and all the auxiliary loads such as fan motors, auxiliary power transformers, protective relaying, metering and other devices.

4. Voltage Regulation and Power Factor - The voltage regulation and power factor shall be calculated in accordance with the applicable IEEE Standards.

5. Control Equipment - The control equipment shall be checked and tested to ensure the performance as specified. The tests shall include, but not be limited to:
   a) Control of power electronic current sharing
   b) Tests of supply voltages to individual control units
   c) Checking of measuring circuits
   d) Test of protective equipment operation
   e) Test of control pulse units
   f) Test of control oscillator amplitude and phase position
   g) Test of synchronizing, load sharing and current limiting functions
   h) Test of blocking unit operation

6. Converter Unit - The SFC Contractor shall provide certification of the no-load distortion measurements of the converter unit.

PART 3 - EXECUTION

3.01 PROJECT INTEGRATION

A. The project integration requirements are summarized as follows:

1. The final project configuration with have four 15 MVA SFCs with ratings given in this specification.

2. The new frequency converters shall be required to operate both independently and in parallel with each other under either manual or automatic load sharing control.

3. Always keep two SFC units in operation (live) with a third in stand-by (de-energized, but ready to start when needed).

4. Minimize disruption to existing SFC station operations during design, construction, testing, and commissioning.

5. Accommodate concurrent infrastructure improvement projects.

6. Minimize adverse operational, aesthetic, and environmental impacts.

7. The spare 13.2 kV, 60 Hz, 3-phase circuit breaker in the 230 kV control building (contains 13.2 kV switchgear) will be used for powering the new SFC #4.

8. The spare 480 V, 60 Hz, 3-phase circuit breakers in the 230 kV control building will be used for supplying auxiliary power to the new SFC #4.
9. Existing filter equipment in the 60 Hz filter yard will be removed. The foundations for these filters will remain in place. Any new reactors, charging transformers/circuit breakers, or heat exchangers can be located in these areas.

10. A new duct bank will be constructed from the 230 kV control building to the new SFC #4 open-air bus to be constructed in the 60 Hz filter yard. Another duct bank will be constructed from the open-air bus to the SFC #4 input transformer, with a portion extended to the basement of the SFC #4 building. The duct banks will contain power and control cables. The existing 60 Hz filter yard duct banks will be re-used for SFCs #1, #2, and #3.

11. The new SFC #4, 60 Hz open-air bus will utilize a manually-operated grounding switch similar to SFCs #1, #2, and #3. The open-air bus will also have a set of PTs and CTs for use with the new SFC #4 protective relaying, metering, and/or control scheme.

12. The existing 60 Hz, 13.2 kV, 1000 kcmil cables will be replaced between the 13.2 kV switchgear and open-air bus. The existing 60 Hz, 13.2 kV, 500 kcmil cables to SFC #1, #2, and #3 input transformers will be replaced as required by the new SFC design.

13. All duct banks associated with SFCs #1, #2, and #3 will remain in place in the 60 Hz filter yards in order to minimize risks and operational impact during construction.

14. The existing grounding switches, PTs, and CTs will remain connected to the existing 60 Hz open-air bus for SFCs #1, #2, and #3. Based on the accuracy class, the PTs and/or CTs may be replaced if required by the SFC vendor.

15. New input transformers must fit into the existing 60 Hz transformer areas.

16. New SFC equipment must fit into the existing converter rooms with sufficient working space to meet all building and electrical codes and standards.

17. New SFC equipment will be transported into the existing SFC rooms through doorways that are approximately 6 ft wide and 13 ft-4 in high (182.9 cm x 406.4 cm).

18. The new SFC #4 building addition will have the same overall dimensions as the SFC #3 room.

19. The existing and new converter rooms are approximately 45 ft-8 in long, 28 ft wide, and 19 ft-1 in high to lowest overhead beam (13.9 m x 8.5 m x 19.1 m).

20. New SFC heat exchangers shall be located on the roof of the converter buildings. These heat exchanges will share room with roof top units used for building heating and cooling.

21. New output transformers must fit into the existing 25 Hz transformer areas.

22. The existing filter equipment in the 25 Hz filter yard will be removed. The foundations for these filters will remain in place.

23. A new duct bank will be constructed from the output of the SFC #4 building basement, joining a new duct bank from the 25 Hz output transformer to the 25 Hz yard cable riser. The duct bank will contain power and control cables. A new open-air bus will be constructed to terminate the SFC #4, 24/12 kV cables from the 25 Hz output transformer. The new open-air bus will contain surge arresters, PTs, CTs, disconnect switches, grounding switches, and a circuit breaker. An
exposed rail return bus will be constructed near the SFC #4 output breaker, similar to the SFC #1, #2, and #3 rail return buses, in order to bond the transformer rail return cable to station ground.

24. A new duct bank will constructed from the SFC #4 output circuit breaker to the 25 Hz traction power substation. The duct bank will contain power and control cables.

25. All duct banks associated with SFC #1, #2, and #3 will remain in place in the 25 Hz filter yards in order to minimize impact during construction.

26. The existing 25 Hz, 12 kV, 24 kV, and rail return cables will be replaced between the 25 Hz traction power substation and the SFC disconnect switches located next to the SFC output circuit breakers.

27. The existing SFC output circuit breakers will be replaced for each SFC. The new circuit breakers are ABB model FSKII. Each is supplied with a CT on both line and load side of each pole. These CTs will replace the existing CTs.

28. The existing 25 Hz disconnect and grounding switches next to the cable riser on the load side of the circuit breaker will be replaced.

29. The 25 Hz disconnect and grounding switches, PTs, and surge arresters on the SFC side of the circuit breaker will be relocated and replaced, as required, based on the size of the new ABB FSKII circuit breakers.

30. SFC #2 60 Hz input and 25 Hz output transformers do not presently have oil containments. If the new SFC design requires oil-filled transformers, new oil containments will be required for SFC #2 and SFC #4. The existing SFC #1 and SFC #3 both have existing transformer oil containments.

3.02 CONSTRUCTION SEQUENCE

A. The main priority in developing a construction sequence will be to keep at least two SFCs in operation at all times with a third in stand-by. Each new SFC will be fully commissioned individually.

B. The second priority is to avoid construction traffic exposure to any unit while in operation. Presently, the SFC rooms function strictly to contain power block equipment and associated buswork. Walking through a room while the SFC is functioning, is kept to a minimum. However, during construction, it is strongly discouraged to keep SFC room doors open or allow construction materials to be transported through the room while the SFC is operating. In order to avoid exposure to construction traffic, a wall and doors will be constructed in front of the SFC power block equipment in order to isolate the sensitive equipment from dust and debris, as well as personnel.

C. With these two main concepts in mind, the following general sequence will be followed:

1. Prepare the site on the north side of the existing SFC filter yards and building.

2. Construct the new SFC #4 building, including 60 Hz and 25 Hz power feeder duct banks, 25 Hz output circuit breaker, and make connections to the existing Wayne Junction 25 Hz traction power substation. The new SFC #4 converter room will have a wall with doors between the SFC power electronics and the power distribution/control equipment.

3. Establish a new station computer in the existing Control room. Depending on SFC Contractor options, the existing computer equipment will need to be removed one unit at a time or it can be left in place until the final new SFC is commissioned.
4. Install the new SFC #4 equipment, 25 Hz transformer, 60 Hz transformer/reactors, 25 Hz circuit breaker, and route all new power feeders in new and/or existing duct banks. Commission the new SFC unit.

5. Demolish the SFC #3 cycloconverter cubicles and buswork, remove 25 Hz and 60 Hz SFC transformers, and modify existing 25 Hz and 60 Hz open-air bus and duct banks, as required. Modify 25 Hz and 60 Hz filter yards.

6. Install a new wall and doors in the SFC #3 building. Install the new SFC #3 equipment, 25 Hz transformer, 60 Hz transformer/reactors, 25 Hz circuit breaker, and route all new power feeders in new and/or existing duct banks. Commission the new SFC unit.

7. Demolish the SFC #1 cycloconverter cubicles and buswork, remove 25 Hz and 60 Hz SFC transformers, and modify existing 25 Hz and 60 Hz open-air bus and duct banks, as required. Modify 25 Hz and 60 Hz filter yards. Note that the reason that SFC #1 is selected to be demolished after the construction of SFC #3 is so that all debris to be carried from SFC #2 demolition will only occur after constructing a wall in front of SFC #1 power electronics equipment.

8. Install a new wall and doors in the SFC #1 building. Install the new SFC #1 equipment, 25 Hz transformer, 60 Hz transformer/reactors, 25 Hz circuit breaker, and route all new power feeders in new and/or existing duct banks. Commission the new SFC unit.

9. Demolish the SFC #2 cycloconverter cubicles and buswork, remove 25 Hz and 60 Hz SFC transformers, and modify existing 25 Hz and 60 Hz open-air bus and duct banks, as required. Modify 25 Hz and 60 Hz filter yards.

10. Install a new wall and doors in the SFC #2 building. Install the new SFC #2 equipment, 25 Hz transformer, 60 Hz transformer/reactors, 25 Hz circuit breaker, and route all new power feeders in new and/or existing duct banks. Commission the new SFC unit.

11. After all new SFCs are commissioned, the existing computer system can be removed. The final Control room will either have a complete new computer system or a HMI interface that coordinates control of all new SFCs. The SFC Contractor shall provide a wall-mounted master local/remote switch with a yellow flashing beacon to switch from local to remote control for the SFC system. The beacon shall flash when the system is in local control.

D. Refer to Eval-4017500-E-002, Wayne Junction SFC Design Criteria, for further information regarding station modifications and construction requirements.

3.03 SURFACE PREPARATION AND PAINTING

A. All metal parts of outdoor equipment, such as transformer tanks and radiators, circuit breaker enclosures, capacitor, reactor and resistor enclosures shall be protected against corrosion. All surfaces shall be grit blasted to clean textured metal for ideal paint adhesion and primed with a rust inhibiting coat. Two (2) coats of ANSI Standard 61 Gray pigment topcoat shall be used unless otherwise indicated.

3.04 SFC FIELD TESTS

A. General Field Tests
1. Field acceptance tests shall be conducted by the SFC Contractor after installation is complete.

2. As part of the 60% design submittal, the SFC Contractor shall submit a list of any and all field tests which must be performed during installation and initial start-up of the equipment.

3. Detailed test and startup procedures shall be submitted to SEPTA for approval no less than three (3) months prior to the proposed start of test date.

4. Detailed test and startup procedures shall include pass/fail criteria.

5. SEPTA and Design Consultant shall be the sole judge as to whether or not a test has passed.

6. These tests shall be conducted in accordance with the latest applicable ANSI, NEMA, and IEEE standards, to demonstrate the ability of the equipment furnished to operate under the conditions specified and to meet the guaranteed performance. If the results of the tests conducted indicate that the equipment does not meet its guaranteed performance, the SFC Contractor shall at his expense make all necessary adjustments or changes required to meet the guaranteed performance. After the required adjustments and/or changes are made, the equipment shall be retested at the SFC Contractor’s expense.

7. Sound pressure level data shall be measured in decibels, referenced to 0.0002 microbars, using a sound level meter conforming to ASA S1.4, Type 1 tolerance limits. The nine (9) preferred octave band filter sets shall conform to ASA S1.11, Class 2, Type E tolerance limits.

B. Thirty (30) Day Reliability Field Test (Burn in Period)

1. The Performance Tests shall not take place until all major plant systems and equipment are mechanically complete and the plant has demonstrated reliability by running automatically for a thirty (30) day period. For a period of thirty days, the converter station shall be operated by SEPTA personnel under the guidance of the SFC Contractor. Operations shall be continuous, subject to on-off actions required by SEPTA’s 25 Hz Network. The converter station shall be operated in every possible mode, both locally and remotely via the SCADA system, and in such a manner as to demonstrate that the continuous, overload, and tripping capabilities of the station as a whole, and each converter individually, have been met.

2. During the thirty (30) day period the SFC Contractor shall conduct on-site training of SEPTA’s operations and maintenance personnel. Training materials shall be prepared in accordance with Specification 01822.

3. The burn-in period shall be deemed successful if no false alarms are received either locally or via SCADA and, during the thirty (30) day period availability has been 99.98% or better, meaning that all control functions requested within the specified response time, that all indications work as intended, that all metering circuits give accurate values, that all apparatus works in the intended manner, that power is delivered to the railroad in the quantity required, that all temperatures are within specification and within design limits, and that the station auxiliary systems perform as they should. Total downtime may not exceed (1-0.9998) times the thirty (30) days times twenty-four (24) hours/day in order for this test to be successful.
4. If the thirty (30) day burn-in test is not successful, the SFC Contractor shall promptly make repairs, and the entire test shall be run again. The Facility Acceptance Test shall not commence until the thirty (30) day burn-in test has been passed to the satisfaction of SEPTA.

C. Facility Acceptance Field Test (Performance Test)

1. As a condition of acceptance, the supplied equipment shall successfully pass the facility acceptance test conducted by the SFC Contractor and witnessed by the Design Consultant and SEPTA. The SFC Contractor shall develop such test plan and shall address the following:

   a) Converter controls and indications, demonstrating that all controls and indications associated with the converters work as intended in both local and remote modes.

   b) The function and accuracy of each telemetry circuit in the station related to the Vendor’s equipment including signal conditioning devices, SCADA and metering devices.

   c) Doble test and high potential test of all transformers, capacitors and inductors.

   d) Full gas analysis of all oil-filled equipment.

   e) Load-Sharing Test

2. Testing of the completed converter station shall be developed along the lines outlined below. The SFC Contractor’s personnel shall operate the equipment under direction of SEPTA’s Load Dispatcher during these tests.

   a) A twenty-four (24) Hour Test demonstrating the general functionality of the station during which time the converter station shall be operated feeding power to the railroad, locally for that length of time.

   b) Following the twenty-four (24) hour test, staged fault tests shall be made in order to demonstrate the capability of each converter unit to supply the specified short circuit current for the required period. Each converter shall be subjected to three (3) short circuit events over a ten (10) minute period. Each event shall involve driving the converter to the rated short circuit output power and verification that this output is maintained for the required period without tripping of or damage to the converter.

   c) A thirty (30) Day Endurance Test, following the Staged Fault Test, shall have the converter station operate in MW load-sharing mode with SEPTA’s 24/12 kV traction power system. Operations during this test period are intended to demonstrate the ability of the plant to accomplish load sharing between the individual converters and the 24/12 kV network. The Station shall follow a MW reference signal which shall vary in accordance with the railroad system time of day load demand. Voltage/reactive power support shall follow the 24/12 kV system demand up to the rated capability of the converters as indicated in this Specification. Load sharing capabilities and functional requirements contained in this specification shall be demonstrated during this period.

   d) A black start demonstration test. This test shall demonstrate the SFC Station’s ability to energize a dead section of the 24/12 kV, 25 Hz, single-phase system.
e) A load-sharing test shall be performed to test the capability of each SFC to operate in parallel and share load with other frequency converters including the existing rotary frequency converter at Wayne Junction. During operations, record load-sharing characteristics of each frequency converter in parallel operation. Record the following data, as a minimum:

1) Converter output current (before and after load changes).
2) Converter output voltage (before and after load changes).
3) Power division and exchange between converters.
4) Real power (watts) and reactive power (vars) on each frequency converter.
5) System frequency (60 Hz and 25 Hz).

f) Verify that all frequency converters have appropriate droop characteristics and share real and reactive load proportionally in a stable manner. Document the active power division, active power exchange, reactive power division and transient response in the following steps for each combination:

1) Divide the load proportionally between the frequency converters and operate in parallel for 15 minutes.
2) Increase the load in steps until each frequency converter is loaded in accordance with SEPTA’s requested power output.
3) Decrease the load in steps until each frequency converter is loaded in accordance with SEPTA’s requested power output.
4) Transfer load in accordance with SEPTA’s direction between frequency converters.
5) Dispatch the new Wayne Junction SFCs and existing cycloconverters to share load. Without any manual adjustment, operate in load sharing mode for 24 hours. Monitor and record station operation. Both the new SFCs and existing cycloconverters shall operate in a stable manner without oscillating while sharing load proportionally and following the required droop characteristics and loading characteristics.

3.05 SITE SUPPORT PERSONNEL

A. The SFC Contractor shall provide commissioning services as follows:

1. Inspection and checkout of the equipment after installation.
2. Performance tests required by the specification.
3. Adjustment and calibration of devices as required, to avoid start-up damage and for safety prior to start-up.
4. Participation as the equipment and system are placed into service to demonstrate satisfactory operation and specified performance. This shall include on-site surveillance, over-view and assistance by the Vendor’s qualified Service Engineer for a period of sixty (60) days following SEPTA’s complete acceptance.
5. Technical advice as necessary for the proper maintenance of the equipment.
B. The SFC Contractor shall provide the services of a field service engineer (FSE) to give technical direction for the installation and startup of equipment. Technical direction does not include any supervision, management, regulation, arbitration, or measurement of work capability of site personnel.

C. The FSE responsibilities include the following:

1. Incoming inspection of the material for:
   a) conformity/completeness according to dispatch notes;
   b) transport damages;
   c) appropriate storage.

2. Assembly of the materials according to:
   a) design plan, layout, and assembly drawings;
   b) operation instructions of sub-suppliers;
   c) internal assembly and mounting instructions;
   d) VDE, DIN, ANSI, NEMA guidelines

3. Supervising the assembly and mounting processes.

4. Establishing the assembly and mounting flowchart.

5. Coordination of the third party companies according to the progress of works.

6. Supervision of third party companies by means of schedules, working reports, and checklists.

7. Checking the execution of assembly and mounting works including:
   a) visual inspections, comparison with drawings;
   b) verification of cable and wiring connections;
   c) initial functional tests of subsystem or components.

8. The SFC Contractor shall provide, as a part of this Contract, the following site support personnel:
   a) A qualified person, eight (8) hours/day, five (5) days/week for the next ninety (90) days after final completion of the project to provide assistance during operation. Salary, transportation and other expenses shall be included in the Contract Price. This person shall also be on-call twenty-four (24) hours/day for emergencies and shall respond in one (1) hour.
   b) A qualified person on call for the remainder of the warranty period for emergencies. They shall respond to the site in three (3) hours. Time spent by the Service Engineer on Vendor’s standard tests, tests outlined elsewhere, correcting manufacturing mistakes, and/or replacing faulty equipment in the field shall not be considered as part of assistance outlined above.

3.06 TRAINING

The SFC Contractor shall conduct a comprehensive training course for SEPTA’s personnel. The SFC Contractor shall provide a training person to perform a comprehensive Task and Skill analysis of the SEPTA employees, who shall operate and maintain the Converter Station and develop a
formal training program based on that Task and Skill analysis. Training shall be provided as specified in accordance with Specification Section 01822.

END OF SECTION