SECTION 34 21 16
34.5 kV VACUUM FAULT INTERRUPTER SWITCHGEAR

PART 1 – GENERAL

1.01 SECTION INCLUDES
A. General Requirements
B. AC Vacuum Fault Interrupter Switchgear
C. Integrated Protection Relay
D. 125 Volt DC Control Power
E. 120 Volt AC Power
F. Instrument Transformers
G. Terminations
H. Separable Insulated Connectors
I. Factory Testing
J. Traction Power System Field Acceptance Testing

1.02 RELATED SECTIONS
A. Refer to the following Sections for requirements:
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   2. Section 01 33 23 Shop Drawings, Product Data, and Samples
   3. Section 01 45 24 Testing Program Requirements
   4. Section 01 78 23 Operation and Maintenance Data
   5. Section 01 79 00 Demonstration and Training
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   7. Section 34 21 01 General Requirements for the Traction Power System
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   10. Section 34 21 33 Control, Monitoring and Display Panel
11. Section 34 21 40 DC Control Power System
12. Section 34 21 50 Common Materials and Methods for Traction Power
13. Section 34 21 80 Traction Power System Field Acceptance Testing
14. Section 34 22 23 Traction Power Cables

1.03 MEASUREMENT AND PAYMENT

A. Measurement: Vacuum fault interrupter switchgear units will be measured for payment per individual unit that is fabricated, factory tested, delivered to site, installed and field functioning tested in accordance with the Contract Documents.

B. Payment: Vacuum fault interrupter switchgear units will be paid for at the Contract unit price per each individual unit as indicated in the Bid Schedule of the Bid Form.

1.04 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. IEEE C37.60 High-Voltage Switchgear and Controlgear – Part III: Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV.

2. IEEE C37.74 Standard Requirements for Subsurface, Vault, and Pad-Mounted Load-Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV.


7. IEEE C57.13 Standard Requirements for Instrument Transformers.

B. National Electrical Manufacturers Association (NEMA):

1. NEMA C12.11 Instrument Transformers for Revenue Metering 10 kV BIL through 350 kV BIL (0.6 kV NSV through 69 kV NSV).
C. National Electrical Safety Code (NESC):

D. National Fire Protection Association (NFPA):
   1. NFPA 70 National Electrical Code.

1.05 SUBMITTALS

A. General: Refer to Section 01 33 00, Submittal Procedures; and Section 01 33 23, Shop Drawings, Product Data, and Samples for submittal requirements and procedures.

B. Product Data: Submit product data for components specified herein.

C. Shop Drawings:

   1. Provide design drawings for the 34.5 kV switchgear and associated devices, including equipment layouts, circuit breaker control schematics, and wiring diagrams.

   2. Include VFI mounting, cable entry, and conduit design for cable connections to the rectifier transformer.

   3. Separable insulated connector section details for materials and assembly construction. Connector and cable terminators showing cross section and installation details.

D. Protective relay settings software, and device ladder logic diagrams communications interfaces with C02 Panel PLC, software, and ladder logic diagrams.

E. Test plan and procedures for factory testing.

F. Test report for factory testing.

G. Operation and Maintenance Manuals: Provide operation and maintenance manuals in accordance with Section 01 78 23, Operation and Maintenance Data.

H. Equipment and software configuration control logs.

1.06 QUALITY ASSURANCE AND SUPPLIER QUALIFICATIONS

A. Electrical components, devices, and accessories shall be listed and labeled in conformance with NFPA 70, Article 100.

B. The manufacturer of the 34.5 kV vacuum fault interrupter switchgear shall have a minimum of 5 years of successful and proven transit, industrial, or utility experience of providing equipment similar to the one specified herein.
C. Auxiliary equipment, devices and components comprising the AC switchgear shall be proven standard products, or equivalent to the standard products of manufacturers engaged in the production of such equipment, devices, and components for at least the past 5 years.

1.07 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be weatherproofed for shipment. Connection openings shall be closed to prevent entrance of foreign material during shipment and storage.

B. Equipment shall be handled and stored in conformance with manufacturer’s instructions. One copy of these instructions shall be included with the equipment at time of shipment.

1.08 SPARE PARTS, TEST EQUIPMENT AND TOOLS

A. Mandatory Spare Parts: For each vacuum fault interrupter delivered, furnish the following mandatory spare parts required to maintain and operate the 34.5 kV vacuum fault interrupter switchgear with the requirements of Section 01 78 44, Spare Parts and Maintenance Materials.

1. Two integrated protection relays.

2. One vacuum fault interrupter.

3. 10 percent spares of fuses, indication lights, and control power circuit breakers.

B. Recommended Spare Parts: Provide a recommended list of spare parts required to maintain and operate the vacuum fault interrupter switchgear in accordance with the requirements of Section 01 78 44, Spare Parts and Maintenance Materials.

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. The Supplier shall furnish, factory test, and provide field test support for the following major equipment/devices, and necessary accessories for installation, as specified below:

1. AC vacuum fault interrupter switchgear.

2. Integrated protection relay (IPR).

3. Instrument transformers.
2.02 AC VACUUM FAULT INTERRUPTER SWITCHGEAR

A. Supplier shall provide a self-contained outdoor-type three-phase 35 kV AC nominal vacuum fault interrupter (VFI) switchgear with 38 kV AC maximum voltage and 150 kV BIL suitable for use with a rectifier transformer. VFI continuous current rating shall be 600 A with current interrupting capability of 3 cycles, 12.5 kA symmetrical, and 20 kV asymmetrical. VFI switchgear shall include visible break switch window and motor operator.

B. VFI switchgear shall meet IEEE C37.74.

C. VFI shall be a sealed insulation system, not using oil.

D. VFI shall use resettable interrupter controls and shall not use fuses.

E. VFI shall include remote close, remote trip, alarm indications, and shall indicate open and close status at the C02 Panel and OCC.

F. VFI shall use an IPR as specified in 34 21 12, Integrated Protection Relay Equipment.

G. VFI switchgear shall be housed in a portable substation trailer as specified in Section 34 21 07, Prefabricated Portable Substations and shall meet requirements for underground devices in IEEE C57.12.28 and IEEE C57.12.29.

H. VFI switchgear shall be mounted to the 34.5 kV switchgear and rectifier transformer trailer tongue as shown in the Contract Drawings.

2.03 INTEGRATED PROTECTION RELAY

A. For each 34.5 kV VFI, a PLC/Microprocessor based multi-function protection relay, referred to as IPR shall interface with the control, indication, and metering hardwire circuits, and with remote signals from the DC house control, monitoring, and display C02 panel. Signals between the IPR and the C02 shall be transmitted over fiber optic communication cables through an Ethernet switch and PLC IOMs as indicated in the Contract Drawings and Specifications. The IPR shall process data to provide appropriate outputs for the hard wire controls, and for the PLC display and controls with the following functions.

1. Phase Instantaneous and Time Overcurrent Functions (250/251): Relay shall be set to operate for faults on the incoming line cables and equipment.

2. Ground Instantaneous and Time Overcurrent Functions (250N/251N): Relay shall be set to operate for ground faults on the incoming line cables and equipment. Relay shall operate on the calculated residual or an independent ground current input for detection of ground faults.

   a. Phase and ground overcurrent relays devices 250/251 and 250N/251N shall trip vacuum fault interrupter directly, and shall enable the 286 lockout relay, as indicated. Device 286 lockout relay failure shall provide both local and remote annunciators.
3. Phase imbalance or negative sequence protection (Device 246), intended to provide protection against a loss of phase in the incoming 34.5 kV feeder or rectifier transformer.

4. Phase under/overvoltage (Device 227/259), relay shall include phase undervoltage and phase overvoltage functions for detecting single voltage event.

B. Sensing and Control:

1. The IPR shall have minimum of four optically isolated inputs, five general purpose output contacts, and one fail-safe normally closed alarm output contact. Each output shall be optically isolated and rated for tripping duty.

2. The IPR shall have front panel controls to open and close the vacuum fault interrupter. The controls shall allow setting of a time delay to allow to the operator, after activating a pushbutton, to move to an alternate location before the command is executed.

C. Security: The IPR shall have two user level groups as a minimum:

1. Basic Level: Allow access to:
   a. Time and date set function
   b. Alarm log displays
   c. Download stored data traces to laptop computer
   d. Download stored Alarm Log entries to laptop computer

2. Expert Level: Allow access to:
   a. All functions and their parameter settings
   b. Security passwords

3. A physical lock/key type security system is not acceptable.

D. Relay Logic. The relay shall include programmable logic for each output, input, and at least eight additional virtual outputs for user programming.

E. Selectable Wye or Delta Voltage Inputs. The relay shall be field selectable after installation to operate with either wye-connected (four-wire) or open-delta-connected (three-wire) potential transformers.

F. Terminal Blocks and Wiring. Connections, with the exception of the USB and Ethernet connections, or other communications wiring, shall be to barrier terminal strips capable of accepting ring lug connection. DIN style rail terminal blocks applied with wire pin terminal connectors may be used as an option.
G. Reporting and Alarms:

1. Data. The relay shall be capable of recording disturbances events up to 512 cycles (user adjustable lengths). The relay shall be capable of storing up to 2,048 cycles of data and events recorder. The relay shall be capable of automatically recording disturbance events of 15 to 40 cycles (user adjustable), with four cycles of prefault duration and user-defined triggering. The relay shall include sequence of events recording for the last 1,028 logic events minimum.

2. Oscillograph. The data shall be capable of display in graphical (oscilloscope) format on test equipment connected to the relay or downloaded to a remote location.

3. Nonvolatile Memory Status and Trip Target LEDs. The relay shall retain recent target, alarm, oscillography, and sequence of events recording information in nonvolatile memory.

4. Nonvolatile Status and Trip Target LEDs. The relay shall capture recent target and alarm information in nonvolatile memory. Information shall be provided locally through the user interface/LEDs at the C02 display panel and remotely via communication ports. The relay shall have three programmable alarm bits: major, minor, and logic, based upon relay logic states.

5. Circuit Breaker Monitor. The relay shall include breaker status and operations counter reporting, fault current interruption duty monitoring, and trip-speed monitoring. A trip coil monitor circuit shall be internally connected across the trip output to provide trip circuit continuity monitoring.

6. Multi-line display panel, capable of showing continuously monitored phase currents and single phase voltage, and alarms.

H. Communications Interface:

1. Relay Interface: The relay shall include three independent general-purpose communication ports. The function for each port is defined as follows:

   a. USB or serial port shall be provided to allow programming of the relay and retrieve data. The port shall be capable of the following functions:

      1) Receive trip indications.
      2) View relay settings, alarm history, and recorded current and voltage data.
      3) Revise user-adjustable relay settings.
      4) View system diagnostics indicating source of any relay malfunction.
      5) View system status indications.
      6) Download, install, remove, and re-configure relay operational software.
b. Controls and indications port shall interface with the control, monitor, and
display C02 panel as indicated in Contract Specifications Section 34 21 33,
Traction Power Control, Monitoring, and Display Panel. The port shall provide
the following input/output functions:

1) VFI OPEN command.
2) VFI CLOSE command.
3) VFI OPEN indication.
4) VFI CLOSE indication.
5) VFI overcurrent trip.
6) View relay settings, alarm history, and recorded current and voltage data.
7) Analog data output: Instantaneous 34.5 kV AC voltages and currents.

c. Maintenance Ethernet Port. The Ethernet port shall be Internet Protocol (IP)
addressable, capable of remote access through a non-routable implemented
IP address schema from maintenance workstations. The maintenance port
shall be capable of providing remote programming and retrieval of stored
relay settings, alarms, diagnostics, current, and voltages.

I. Setting and Analysis Software:

1. Software shall be freely reproducible within the end user’s organization without
additional charge. The software shall include serial communications for settings
upload and download; graphical programming and display of logic equations
(including pictorial display of AND, OR and exclusive XOR gates); and ability to
display and print oscillography and event files.

2. A laptop with software shall be provided as indicated in Contract Specifications
Section 34 21 11, Multi-Function Protection Relay Equipment.

J. Other Relay Requirements

1. Control power: 125 V DC.
3. Noise rejection: meet requirements of IEEE C37.90.1, Surge Withstand
Capability (SWC) Tests.
4. The IPR shall be capable of accepting a synchronization signal from the SCADA
system so that clocks of the protective relays are synchronized to the same time.

K. Local Operator Interface

1. The local operator interface shall include:

a. An LCD display with a minimum of four lines and 16 characters per line. The
LCD display shall be backlit so as to be legible in the dark.
b. A numeric or arrow keypad featuring pull-down menus allowing the user to:

1) View relay settings.
2) View alarm and measurement memories.
3) Change user-adjustable relay settings and parameters.
4) View system diagnostics.

2.04 125 VOLT DC CONTROL POWER

A. Control power for vacuum fault interrupter closing and tripping functions, and for energizing control, indication, monitoring and protective devices shall be from the 125 V DC control power as specified in Section 34 21 40, DC Control Power System.

B. A dedicated NEMA 3R enclosure box with terminal strip suitable for a two-conductor AWG No. 6 or larger, 125-volt DC control circuit shall be provided. Molded-case, thermal magnetic circuit breakers shall be provided for protection and isolation of each control circuit.

C. Control power voltage-monitoring relay shall be furnished and connected on the line side of the molded-case circuit breakers. Loss of control power shall be monitored locally and remotely.

D. Control power for the protection relay and VFI controls shall be provided by separate circuits.

E. Loss of protection relay control power shall cause tripping of the VFI.

2.05 120 VOLT AC POWER

A. A 120 V AC, 60 Hz, No. 2 AWG or larger 2-wire bus shall be provided for devices such as heaters, fans, lights, and receptacles.

2.06 INSTRUMENT TRANSFORMERS

A. Instrument transformers shall conform to IEEE C57.13 and NEMA C12.11. The current and potential transformers shall comply with the ANSI/IEEE relays and metering accuracy standards, and shall have 0.6 accuracy class or better, under the burdens imposed by the connected services.

B. Instrument transformers shall be insulated for 38 kV voltage class, and shall have basic impulse insulation (BIL) level of 200 kV full-wave.

C. Current Transformers

The current transformers (CTs) shall be dry type, of molded rubber or epoxy construction, multi-ratio, bushing, toroidal or wound-type:

1. Ratio and phase-angle characteristics of current transformers shall be suitable for the relaying or metering, as indicated.
2. CTs shall be installed in a manner such that they are easily accessible for inspection and maintenance.

3. Each VFI bushing shall be provided with one current transformer per phase rated 600/5A.

4. CTs and their secondary wiring shall be protected from induced voltages by metallic shielding. Secondary wiring shall utilize No. 10 AWG copper wire, and shall be run to readily identifiable terminal blocks in the VFI control compartment. The terminal blocks for the CTs shall be suitable for ring type wire connections, shall have covers, and shall feature integral shorting bars for the CT leads.

5. CTs shall be capable of withstanding thermal, magnetic, and mechanical stresses from the flow of current equal to the interrupting and momentary routings of the circuit breakers.

D. Potential Transformer

Potential transformer (PT) shall be of the molded rubber or epoxy-encapsulated construction, with primary current-limiting fuses as indicated:

1. Primary and secondary circuits of PT shall be protected by means of non-renewable cartridge type fuses. Secondary circuit fuses shall be installed in the low voltage circuits of the PT. Blown fuse shall be indicated locally and remotely.

2. PT shall have voltage ratio of 34,500 V primary to 115 V secondary, and shall be connected between phase A and phase B.

2.07 TERMINATIONS

A. The incoming line section of the VFI shall accommodate 3-# 2/0 AWG, 35 kV power cable entering from below. At least 24 inches below the switchgear floor shall be provided for terminating the cable as indicated.

B. The load side section of the VFI shall accommodate 3-# 2/0 AWG, 35 kV cable entering from above originating from the primary side of the rectifier transformer as indicated.

C. 35 kV power cable terminations shall be as specified in Section 34 21 23, Traction Power Cables. NEMA 2-hole cable connections shall be provided.

D. Low voltage terminations shall be as specified in Section 34 21 50, Common Materials and Methods for Traction Power.
2.08 SEPARABLE INSULATED CONNECTORS

A. The separable insulated connectors shall be elbow type connectors, made of vacuum cast resin, submersible, rated at 35 kV, 600A rms continuous, 1 kA rms for 24 hour overload, 25 kA rms symmetrical for 0.17 second, and 10 kA symmetrical for 3 seconds, deadbreak type, with test points and operating eye. Provide ground provisions rated 10 kA symmetrical, or per system coordination study.

B. Refer to Section 34 21 19, Separable Insulated Connectors for requirements related to:

1. Article 2.01.B.2 regarding material construction, vendors and standard compliance.
2. Article 2.01.B.4 regarding traction power cable type.
3. Article 2.01.B.2 regarding shielding and grounding.

2.09 FACTORY TESTING

A. General: Testing of the VFI shall be in accordance with the requirements of Contract Specification Section 01 45 24, Testing Program Requirements.

B. Design Tests: The following design tests shall be performed on one VFI. The testing shall be performed by a company or agency certified by the International Electric Testing Association (IETA):

1. For the AC vacuum fault interrupter switchgear, perform design test or submit certified design test data for the following:
   a. Switch ratings in accordance with IEEE C37.74.
   b. Interrupter ratings in accordance with IEEE C37.60.
   c. Construction and cubicle coatings in accordance with IEEE C57.12.29.
2. For the integrated protection relay, perform design test or submit certified design test data for the following:
   a. Dielectric Strength: Tests per IEEE 37.90 and for the instrument transformer inputs at voltages as required.
   c. Performance Verification Tests: These tests shall be developed in adequate detail by the Supplier and the testing agency, and shall be used to ascertain the proper functioning, accuracy, and response time of the IPR. At a minimum, design tests shall include the following:
      1) Input voltage measurements (accuracy and range verification).
      2) Input current measurements (accuracy and range verification).
3) Verification of the proper operation of protective functions.

4) Verification of the proper functioning of the self-diagnostic features, including trouble alarms, events storage, and current and voltage data traces.

5) Verification of the proper operation of user interfaces, including parameter updates through the operator interface panel and interrogation/diagnostics via the communications ports.

6) Verification of the correct operation of the IPR when the control power supply voltage is varied within the specified operating range.

7) Verification of the proper functioning of IPR inputs and outputs.

8) Verification of proper communications between the IPR communications module and the C02 panel as indicated in Contract Specifications Section 34 21 33, Traction Power Control, Monitoring, and Display Panel. The Supplier shall supply a PLC to the IPR manufacturer for test purposes.

C. Production Tests:

1. Switchgear factory tests shall consist of the following production tests:
   a. Continuity test.
      1) Perform continuity checks to verify current transformer connections, shunt leads, and medium voltage fuses.
   b. Hi-pot test.
      1) Perform dielectric withstand (high-potential) test at 50 kV for one minute on each phase with the VFI closed and the poles not under test grounded.
      2) For each test, record date, time, temperature, humidity, voltage levels, leakage current, and megaohm values.
   c. Pressure test to assure tank is completely sealed.
   d. Electrical functional testing with remote control and indication.
   e. PT and CT ratio tests.

2. IPR factory tests shall consist of the following production tests:
   a. Confirmation of the correct calibration for current and voltage measurements of the isolation transducer, and proper functioning of the IPR software.
   b. Confirmation of the correct values for all default settings.
   c. Confirmation of the proper operation of user interfaces including operator interface, RS-232, and Ethernet user interfaces.
   d. Confirmation of the proper operation of protective functions, by the use of simulated fault conditions.
   e. Confirmation of the proper functioning of inputs and outputs of the IPR, by use of secondary voltage and current injection.
D. Instrument Transformers:

1. Instrument transformers shall be factory tested in accordance with IEEE C57.13.

PART 3 – EXECUTION

3.01 TRACTION POWER SYSTEM FIELD ACCEPTANCE TESTING

A. Refer to Section 34 21 80, Traction Power System Field Acceptance Testing, for requirements.

B. Provide recommended field test procedures.

END OF SECTION 34 21 16