Design Guideline 261100
Unit Substations

Scope

This guideline defines the requirements and standards for design of unit substations. The guideline covers basic requirements for design, system ratings, designated spaces, primary switches, transformers, secondary switchgear and testing. Unit substation assemblies shall be configured as single-ended or double-ended and consisting of primary sections, transformer sections, and secondary voltage distribution sections.

Related Sections

U-M Design Guideline Sections:

5.7 DG - Unit Substation Rooms
6.3 DG 260513 - Medium, Low and Control Voltage Cables
6.3 DG 260526 - Grounding and Bonding for Electrical
6.3 DG 260533 - Electrical Materials and Methods
6.3 DG 260800 - Electrical Acceptance Tests
6.3 DG 261000 - Medium Voltage Electrical Distribution

U-M Master Specification Sections:

7.3 MS 261100 – Unit Substations
7.3 MS 261102 – Installation of Pre-Purchased Unit Substations

U-M Standard Details:

Standard Details 9.3-Series Details

Reference Documents:

- MV Load Interrupter Switchgear: ANSI C37.20.3, ANSI C37.20.4, ANSI C37.22, ANSI C37.57, ANSI C37.58, NEMA SG-5 and NEMA SG-6.
- Secondary Substation Transformers: 10 CFR Part 431, ANSI C57, IEEE 100, NEMA 201 and 210, and UL 1562.
- LV Metal-Enclosed Switchgear Assemblies: ANSI-C37.20, NEMA SG-5, and UL 1558.
- Low-Voltage Power Circuit Breakers: ANSI-C37.13, NEMA SG-3.
- Circuit Breaker Trip Devices: ANSI-C37.17.
- Michigan Electrical Code (MEC).

Design Requirements

Use U-M Master Specification 261100, “Unit Substations”, as basis for design and specifying unit substations. For the required configuration of University substations see Standard Electrical Detail 26110001 for single-ended substations and Standard Electrical Detail 26110002 for double-ended substations. Edit the specification and details to make them project specific. When editing the specification, turn on hidden text and follow the Spec Editor notes.

Rating Requirements

Unit substations shall be 500 kVA minimum and 2000 kVA maximum unless approved otherwise by the University.

System fault contribution of 1000 MVA with an X/R ratio of 23 shall be used when determining the required interrupting rating for unit substation equipment.

Provide a short circuit, protective device coordination and arc flash hazard study per DG 260500, "Common Work Results for Electrical".

Base calculations to determine the degree of arc flash hazard on actual field installation data and coordinate with UM Primary System Engineer. Design distribution systems to limit the arc flash incident energy to a magnitude requiring PPE of Level 4 or below.

Size single ended unit substations so that the transformer's AA rating equals roughly 150 percent of the projected peak demand. Size double ended unit substations so that each transformer's AA rating equals roughly 115 percent of the projected peak demand for the entire double ended unit substation.

Loop style feeders of the University medium voltage distribution system are considered service entrance conductors. The transformer secondary main breaker of unit substations shall be regarded as the service disconnect and shall be suitable for use as service entrance equipment.

Space Requirements

See DG 5.7 for associated architectural, mechanical and electrical space requirements.

The substation shall be a front-aligned structure. Any variations in section depth shall be reflected on the rear side of the substation. Label front of substations on plan view drawings.

Provide working clearances as required by MEC and indicate them on plan view drawings. Provide required dedicated work space above the unit substation and delineate them on drawings with an elevation view. Space and room requirements for unit substations shall be determined and accounted for during the Schematic Design Phase.

Provide rear access to all unit substations. Working space for rear access shall be based upon clearances required for working on energized parts at the system voltage. Where applicable, include clearance allowances for wall mounted ground bars.

Incoming Line Section Requirements

Provide 15kV incoming line sections with two loop switches for the two incoming lines, and a fused load interrupter transformer primary switch.

The transformer primary switch shall be key-interlocked with its associated secondary main breaker so that the secondary main breaker closes after and must be opened before the transformer primary switch.

UM Primary Systems Engineer and Engineer-of-Record shall agree on rating of the primary fuses or work with the manufacturer to propose an alternate rating after review of the coordination study.

Specify installation of warning labels on loop switches with the following verbiage; ‘Danger – Contacts on either side of this device may be energized by backfeed’.

Transformer Requirements

Provide only dry type transformers, unless an alternate for a given project is specifically approved by the University.

Unit substation transformer coils shall be copper.

Transformers shall have five full capacity, 2.5 percent taps on the primary winding, two below and two above the nominal voltage.

Transformers shall be equipped with forced air cooling fans and controls. The transformers FA ratings shall equal 133 percent of their AA ratings.

Transformers shall be equipped with temperature monitoring systems that start the fans on high AA temperature, alarms on high FA temperature and initiates a second alarm and closes a breaker ‘trip’ contact on high-high FA temperature.

The temperature monitor shall include LED’s indicating "power on" and "fans running".

The temperature monitor shall include an RS485 data port for future connection to a remote monitor.

Secondary Switchgear Section Requirements

Provide secondary main breakers in all unit substations.

Bonding of the transformer secondary neutral conductor to the grounding electrode shall be performed within the secondary switchgear enclosure.

Secondary mains and tie breakers shall be electrically operated (electrically charged). Each electrically operated breaker shall be powered by a dedicated, charging motor.

Feeder breakers shall be manually 'charged' unless noted otherwise. Frame sizes of feeder breakers shall be 800-ampere minimum.

Tie breakers shall be identical to the main breakers and shall be capable of being exchanged with either main breaker.

If required, provide a fire pump breaker vertical section between the transformer section and secondary main breaker section. The fire pump section shall be completely barriered from the transformer and secondary sections. The section shall comply with all requirements of NEC Articles 230 and 695. The breaker shall not trip (only alarm) on ground fault and the trip button shall be disabled so it cannot be inadvertently pushed. The cubical door shall be painted red.

For double-ended substations, provide main and tie circuit breaker controls with auto-manual selector switch to automatically or manually transfer one or both secondary main buses to the opposite power source. When transferring or retransferring an energized bus to the opposite power source, the transfer shall be closed-transition.

On a project-by-project basis, the designer shall discuss with the UM Primary System Engineer, the consideration of a 'main-tie-tie-main' arrangement in lieu of a 'main-tie-main' arrangement. If an M-T-T-M arrangement is approved, modify the spec section accordingly.

Vertical bus ratings for feeder breaker sections shall be based on breaker cell frame size ratings including spares and spaces.

Blank compartments are not permitted. Spaces shall be fully bused, fitted with neutral current sensors rated to match the breaker frame sizes, and ready to accept future circuit breakers.

An Ethernet connection shall be provided for each revenue meter and a secondary Ethernet connection shall be provided to monitor circuit breakers (a single point of connection shall be provided for monitoring circuit breakers). Connections and wiring shall be shown on drawings.

UM Primary System Engineer may opt to extend UM's Distribution Management System from the watt-hour meter by connecting some or all of the points listed below:

- Open-Close status contacts of loop switches and transformer primary fused switch.
- Alarm contacts on the transformer temperature monitoring system.
- Status contacts of main and tie circuit breakers in unit substations.

Secondary main, tie, and feeder breakers shall be as noted below:

- Individually mounted, draw out, metal-clad, stored energy type, quick-make and quick-break air circuit breakers.
- Breakers shall be rated for 100 percent continuous duty, with frame, sensor and rating plug ratings shown on the drawings. Sensor and rating plug ratings shall match the breaker frame size.
- Breakers shall be capable of being manually racked into three positions; "connected", "test" and "disconnected". The breaker frames shall be grounded in all positions.
- The compartment front doors shall be closable in all breaker positions and shall permit breaker operation with door open or closed. The doors shall be capable of being opened without tripping breakers in the "connected" position.
- Each breaker shall be equipped with three-phase current sensors and a microprocessor-based RMS sensing trip unit.
- A Kirk Key interlock shall be provided to prevent the operation of the fused primary switch unless the main breaker is open. Kirk Key interlock shall also be provided on double ended substations (if designed without automatic transfer controls) to prevent the operation of the tie breaker unless one of the mains is open.

Breaker RMS sensing trip units shall be as noted below:

- Solid-state trip units shall be true RMS sensing. The trip units shall be magnitude and time adjustable,

and shall include a local indication of the cause of a trip. The trip unit settings shall be indicated on the drawings.

- The trip units shall coordinate with the primary fuses, main breaker and largest downstream feeder breakers. UM Primary System Engineer and Project Engineer-of-Record shall specify secondary main breaker settings to limit arc flash incident energy exposure.
- The trip units shall allow adjustment without breaker trips and routine testing without removing the breakers from service.
- Trip units shall be provided with long time, short time, instantaneous and ground fault functions as a minimum. Instantaneous trip function on main and tie breakers shall be defeatable.
- The main and tie breaker trip units shall include technology to reduce arc flash incident energy during maintenance activities.
- Power for ancillary functions of the solid state trip unit shall be obtained from within the circuit breaker assembly itself, or it shall be provided by a separate control power circuit connected to the secondary bus ahead of the main breaker. Solid state trip units shall have non-volatile memory to maintain all settings, trip indications and fault data during a power outage. Batteries to maintain the memory are not acceptable.
- Trip units shall be provided with integral metering functions including an integral keypad and display.
- Trip units shall be equipped to provide alarms. Alarms shall have separate adjustable pick-up and delay settings.
- Trip units shall have open protocol communication capabilities (Modbus TCP/IP).

Design the overcurrent protective system so it can be set in a 'selective' manner, to minimize the disruption from any given fault, to as small an area as possible. Prepare the settings for the overcurrent protective system to ensure proper selectivity and coordination.

Require contractors to provide test reports showing that the overcurrent system has been set and tested, before the system is commissioned. All breakers (new and existing) shall be tested via primary current injection.

Adjacent to secondary main circuit breakers, in a separate cubicle, provide an analog voltmeter with selector switch, an analog ammeter with selector switch and a revenue kilowatt-hour meter. Selector switches shall have an off position.

Sub-metering components (metering of feeders) shall be located in the associated secondary switchgear section or, due to space limitations, provide separate wall mounted metering enclosures located within the substation room. Coordinate with UM Primary System Engineer for locating sub-meters.

Testing

Instruct the Contractor to perform testing in accordance with manufacturer instructions and Design Guideline 260800, and to provide the University Project Manager and UM Primary System Engineer with test reports.

Manufacturer's start up responsibilities shall include point-to-point testing of metering CT circuits.