DESIGN GUIDELINE 5.7
UNIT SUBSTATION ROOMS

Scope
This guideline applies to rooms that contain unit substations. The guideline covers basic design requirements for associated architectural, mechanical and electrical systems.

Related Sections

Design Guidelines:
5.4 DG - Telecommunications Rooms
6.3 DG 260526 - Grounding and Bonding for Electrical
6.3 DG 260533 - Electrical Materials and Methods
6.3 DG 260543 - Underground Services for Electrical Systems
6.3 DG 260800 - Electrical Acceptance Tests
6.3 DG 261000 – Medium Voltage Electrical Distribution
6.3 DG 265100 - Interior Lighting
6.3 DG 283100 - Fire Detection and Alarm

U-M Master Specifications:
7.3 MS 261100 - Unit Substations
7.3 MS 261102 - Installation of Pre-Purchased Unit Substations

Reference Documents:
- International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines
- NESC, "National Electrical Safety Code"
- Michigan Building Code (MBC)

Architectural Design Requirements:
Separate the room from occupied spaces or provide sound-proofing so the 60 Hz hum is not audible to occupants (sound level of 40dB or less) in adjacent areas, including those rooms above and below the substation room. Sound proofing, if required, shall be solid sheet material. Spray-on and friable sound proofing material is prohibited.

Separate the room and large secondary feeder circuits leaving the room from areas containing computers, computer servers, telecom equipment, electronic instruments and other electronic equipment which could be affected by electromagnetic fields (EMF). University studies have shown that substation transformers and secondary feeder circuits 400 amps and larger can produce EMF of sufficient strength to impact nearby electronic equipment. If applicable, perform a study to determine the effects unit substations may have on adjacent sensitive electronic equipment.

Review locations of unit substations with University of Michigan Environment, Health & Safety (EHS).

When the electrical service to the building is a medium voltage, loop style circuit, the substation room shall be designed as a transformer vault as required by NFPA 70 Article 450 (NEC). Provide fire rated doors and walls which extend to the deck above. Required fire ratings shall apply to room floors, decks above and associated steel structure. In no case shall the minimum fire resistance rating be less than two hours. Spray-on and friable fire proofing materials are prohibited.

Wall construction for substation rooms shall be reinforced concrete or CMU block (as a listed assembly). Stud and wallboard construction, expanded metal mesh, woven wire mesh or chain link fence are not acceptable for unit substation rooms.

Provide a minimum of 6 feet clear above the substation primary switches and secondary switchgear. Obtain Design Manager's approval of primary and secondary conduit and cable tray routes and installation details before providing less clear space above electrical equipment.

Egress doors shall swing outward from the room as required by code.

- Egress doors shall be equipped with listed fire exit devices, gaskets and bottom edge door sweeps. Door locks shall be keyed with High Voltage Shop series cores.
- One door shall be large enough for the passage of the largest shipping section of the substation. Typically, this means a minimum 8 foot tall by 7 foot wide double door with a removable mullion.
- Additional egress doors may be single doorsand shall be a minimum 36 inches wide.

If floor drains are provided, slope the floor toward the drain. The floor drain shall be the low point of the floor.

Provide a 4 inch minimum housekeeping pad under each piece of floor-mounted equipment.

- Pads shall conform to the footprint of the equipment and shall be the full width and depth of the equipment, but shall not extend beyond the equipment by more than 4 inches. Pad edges shall be chamfered.
- Pads shall be smooth and level to 1/8 inch per 6-foot distance in any direction. Pads that fail to meet this criteria shall be corrected before installation of the equipment. Correcting deficiencies of an uneven pad by the use of leveling shims is not acceptable.

Provide 2 coats of water-borne epoxy paint over a compatible primer on the concrete floor and exposed portions of housekeeping pads. Provide paint on the walls and ceiling.

Provide a 10 pound Type ABC fire extinguisher at each exit.

Provide an unobstructed route to the building exterior to permit replacement of the largest shipping section of the substation. Entire equipment access pathway, including egress route exterior door, and all intervening doors shall have free and clear area that complies with size requirements for substation room doors listed above. Interior intervening doors/frames and other secondary systems constructed to be easily removable are an acceptable alternative. Design the floor of the entire route for the weight of the largest transformer.

Mechanical Design Requirements

Access to unit substation rooms is limited to authorized personnel, making it difficult for others to perform maintenance inside the room. Avoid locating mechanical equipment including fans and fan coil units inside the unit substation room.

Ductwork, piping, clean-outs, and other mechanical system components are not permitted in the room unless they serve the room.

Provide wet sprinklers if the building will be sprinkled.

- Locate the sprinkler heads and route the piping over aisles, not over the electrical equipment.
- Provide wire guards on the sprinkler heads.

In below-grade substation rooms only, provide a floor drain at the low point of the room floor. Locate the floor drain in front or behind the middle of the substation and tight to the front or rear wall. Provide a backwater check valve for the floor drain. Locate the check valve outside of the room.

When a floor drain is provided, provide a water leak detector adjacent to the floor drain and tight to the wall to prevent becoming a trip hazard. The leak detector shall be outside of the working space of the substation. Connect its alarm contact to the nearest Building Automation System DDC panel.

Ventilation systems shall be designed for a year-round set point temperature of 85 degrees F (knowing the summer space temperature will rise to a maximum of 10 degrees F over outside ambient). Provide ventilation to remove equipment heat and maintain equipment within their ambient temperature ratings under all weather and electrical load conditions. Provide supply and exhaust fans with variable speed control to maintain the set point temperature. Preferred design shall be fully ducted (SA & EA) to the outside louvers with motorized isolation dampers on both the supply fan(s) and exhaust fan(s). For the purpose of controlling wind-driven dust infiltration, un-ducted OA or EA louvers that can be open to the substation room are not allowed. An alternate design with un-ducted exhaust fan shall be acceptable if the preferred design is not possible due to space constraints. See Appendix A for schematic diagrams depicting design intent. Avoid supplying unheated outside air directly into the room, which can freeze sprinkler lines. Mix return air with outside air so that tempered air above freezing is discharged into the room.

- Design for a summer design space temperature of 10 degrees F over outside ambient.
- Base cooling load calculations on space envelope loads and on equipment heat rejection data. Use basis of design transformer heat rejection data (provided by the manufacturer) at the anticipated transformer peak loading percentage.
- Design the supply and exhaust systems to produce positive space pressurization at all times the fans are in operation.
- Filter the supply air to the room. Minimum filter efficiency shall be MERV 11.
- Air condition the room only if the room can't be ventilated with outside air. If building chilled water is used, verify the chilled water system operates all year long.
- Heating shall be provided to maintain the room temperature to a minimum of 45 degrees F based on minimum substation loading.
- Provide DDC monitoring & alarming of space temperature and filter pressure drop

Electrical Design Requirements

Do not locate ancillary equipment in the room; including power distribution panels, lighting and receptacle panels, central UPS systems, Building Automation System DDC panels, fire alarm control panels, security panels, MOSCAD or McEdge RTU panels.

Do not locate emergency or standby power system equipment, including transfer switches and panels, in the unit substation room. Level 1 Emergency Power Supply System equipment shall not be installed in the same room with the normal power service equipment, per NFPA 110.

Provide a 1/4 inch x 2 inch solid copper ground bus bar on the wall behind each substation. Extend it the full length of the substation and mount it 18 inches AFF. Where not continuous due to structural columns, egress, etc., connect multiple ground bus bars together using #4/0 AWG copper grounding conductors. Do not wrap ground bus bars around the room doors.

- Connect both ends of each substation internal ground bus bar to its room ground bus bar using #4/0 AWG copper grounding conductors embedded in the housekeeping pad and floor. Connect the internal ground bus bars of other equipment to the room ground bus bar in a similar manner.
- For renovation projects only where the floor is not being cut, connect the substation ground bus bar to the room ground bus bar by routing the grounding conductors overhead.
- Connect the room ground bus bar with #4/0 AWG copper grounding conductors to all available grounds including the ground grid, concrete-encased foundation rebar, building steel, incoming water services, duct bank ground conductors, lightning protection ground rods, and the ground bus bars in other electrical rooms in the building. Grounding conductor to telecommunications main grounding bar shall be sized per DG 5.4.

Terminate the incoming primary duct bank with end bells embedded in and flush with the inside of the room wall, and as high off of the floor as possible. Slope the duct bank away from the room. If a duct bank must enter the room from below floor level, stub it up along the inside of the wall. Obtain permission through the UPE Primary Systems Engineer before stubbing ducts up into the bottoms of the primary loop switches.

Provide 36 inch wide aluminum ladder-type cable tray with 36 inch minimum radius fittings to route the primary cables up the wall and across the ceiling of the room. Locate the tray 3 feet minimum above the primary switches, but low enough to provide 24" clear above the tray to accommodate cable pulling. Provide cable tray roll-outs where the cables drop down into the primary loop switches.

Provide switched LED lighting in front of and behind each substation, and in front of other electrical equipment. Connect this lighting to emergency power. LED lighting shall be provided with diffuse acrylic lens. Provide a battery-backed lighting fixture or an emergency lighting battery pack in front and behind each substation. If emergency power is not available, provide battery-backed lighting fixtures or battery packs throughout the room.

Provide exit signs above the exit doors.

Provide warning signs outside of exit doors "DANGER - HIGH VOLTAGE - KEEP OUT" prior to energizing substations. UPE will furnish and install permanent warning signs at completion of construction.

Provide duplex receptacles and connect them to standby power.

Provide two hard-wired IT data connections to each substation.

Substation rooms shall be covered by the building wide Wi-Fi coverage. Wi-Fi antennas and associated wiring shall not be located in substation rooms.

To protect unit substation equipment from water damage by activation of the fire protection sprinkler system, provide fire alarm system, multi-sensor, smoke/heat detectors to give an early warning of a possible fire. Also provide a minimum of one combination audible/visual appliance. Fire alarm system devices shall be installed in accordance with Specifications 283100, Fire Detection and Alarm System and/or 283102, Fire Detection and Alarm System (Hospital Projects).

Provide full size copies of the building's One Line Diagrams and Riser Diagrams on the wall in front of the unit substation. Drawings shall be minimum 24"x36", installed in wooden frames and protected by glass.

Appendix A

OPTION 1 - PREFERRED
OUTSIDE WALL
OTS
CAMPUS WIDE
OUTSIDE AIR TEMP
SENSOR
EXHAUST AIR
PLENUM
DM-3
EF-1
VFD
EG-1
ELECTRICAL SUBSTATION ROOM
RTS
ROOM TEMP
SENSOR
SG-1
VFD
BELLMOUTH
FITTING
W/ WMS
DM-2
FH-1
V-BANK FILTER
HOUSING WITH
ANALOG DP SENSOR
REPORTING TO DDC
MAT
MIXED AIR
TEMP SENSOR
SF-1
INTAKE AIR
PLENUM
DM-1
DESIGN INTENT SEQUENCE OF OPERATION
SF-1 CONTROL:
1. SF-1 IS ON WHEN RTS IS ≥ 85F
2. SF-1 IS OFF WHEN RTS IS < 85F
EF-1 CONTROL:
1. EF-1 IS ON WHEN SF-1 IS ON
2. EF-1 IS OFF WHEN SF-1 IS OFF
DAMPER CONTROL:
1. WHEN SF-1 IS OFF, DM-1, DM-2, DM-3 ARE CLOSED
2. WHEN SF-1 IS ON AND OTS IS 55F OR GREATER, DM-1 100% OPEN, DM-2 100% CLOSED, DM-3 100% OPEN
3. WHEN SF-1 IS ON AND OTS IS LESS THAN 55F, DM-1 & DM-2 MODULATE TO MAINTAIN MAT AT 55F, DM-3 100% OPEN
SPACE TEMPERATURE CONTROL:
1. WHEN RTS IS ≤ 85F, SF-1 OPERATES AND VFD SHALL RAMP FROM 15 HZ TO 60 HZ IN 15 HZ INCREMENTS (15,30,45,60)
THE GREATER AND LONGER RTS IS ABOVE 85F
SPACE PRESSURIZATION CONTROL:
1. WHEN DAMPERS TRACK, OPEN AND DM-2 IS 100% CLOSED, EF-1 SPEED TRACKS SF-1 SPEED WITH A 400 CFM GREATER
OFFSET TO ENSURE POSITIVE SPACE PRESSURIZATION (NOMINALLY 0.05 TO 0.2 IWC)
2. WHEN DM-1 AND DM-2 ARE MODULATING TO MAINTAIN A MIXED AIR TEMPERATURE, EF-1 SPEED TRACKS DM-2
POSITION TO ENSURE POSITIVE SPACE PRESSURIZATION (NOMINALLY 0.05 TO 0.2 IWC). A RESET SCHEDULE
SHALL BE DEVELOPED FOR EACH OF THE SF-1 FAN SPEEDS (15, 30, 45, 60 HZ) THAT INDICATES DM-2 DAMPER POSITION
AND THE CORRESPONDING EF-1 VFD SPEED SETTING TO ENSURE POSITIVE SPACE PRESSURIZATION AT ALL TIMES THE
FANS ARE IN OPERATION.
ALARMS:
1. DDC ALARMS WHEN ROOM TEMPERATURE EXCEEDS 104F
2. DDC ALARMS WHEN FILTER PRESSURE DROP EXCEEDS SETPOINT OF 1.0 IWC

OPTION 2
OUTSIDE WALL
OTS
CAMPUS WIDE
OUTSIDE AIR TEMP
SENSOR
EF-1
DM-3
HOUSED WALL FAN
WITH INTEGRAL
MOTORIZED DAMPER
VFD
ELECTRICAL SUBSTATION ROOM
RTS
ROOM TEMP
SENSOR
SG-1
VFD
BELLMOUTH
FITTING
W/ WMS
INTAKE AIR
PLENUM
DM-1
DM-2
FH-1
V-BANK FILTER
HOUSING WITH
ANALOG DP SENSOR
REPORTING TO DDC
SF-1
MAT
MIXED AIR
TEMP SENSOR
DESIGN INTENT SEQUENCE OF OPERATION
SF-1 CONTROL:
1. SF-1 IS ON WHEN RTS IS ≥ 85F
2. SF-1 IS OFF WHEN RTS IS < 80F
EF-1 CONTROL:
1. EF-1 IS ON WHEN SF-1 IS ON
2. EF-1 IS OFF WHEN SF-1 IS OFF
DAMPER CONTROL:
1. WHEN SF-1 IS OFF, DM-1,DM-2, DM-3 ARE CLOSED
2. WHEN SF-1 IS ON AND OTS IS GREATER THAN 55F, DM-1 IS 100% OPEN, DM-2 100% CLOSED, DM-3 100% OPEN
3. WHEN SF-1 IS ON AND OTS IS LESS THAN 55F, DM-1 & DM-2 MODULATE TO MAINTAIN MAT AT 55F, DM-3 100% OPEN
SPACE TEMPERATURE CONTROL:
1. WHEN RTS IS ABOVE OR BELOW SETPOINT BY 2 DEGREES AND VFD SHALL RAMP FROM 15 HZ TO 60 HZ IN 15 HZ INCREMENTS (15,30,45,60)
THE GREATER IN AND LOWER RTS IS ABOVE 85F
SPACE PRESSURIZATION CONTROL:
1. WHEN RTS IS SATISFIED AND OTS IS ABOVE 55F, DM-1 & DM-2 ARE 100% CLOSED, EF-1 SPEED TRACKS SF-1 SPEED WITH A 400 CFM GREATER
OFFSET TO ENSURE POSITIVE SPACE PRESSURIZATION (NOMINAL 0.1 TO 0.2 IWC)
2. WHEN DM-1 AND DM-2 ARE MODULATING TO MAINTAIN A MIXED AIR TEMPERATURE, EF-1 SPEED TRACKS DM-2
DAMPER POSITION TO ENSURE A 400 CFM GREATER OFFSET THAN SF-1. DURING COMMISSIONING, A RESET SCHEDULE
SHALL BE DEVELOPED FOR EACH OF THE SF-1 FAN SPEEDS (15, 30, 45, 60 HZ) THAT INDICATES DM-2 DAMPER POSITION
AND THE CORRESPONDING EF-1 VFD SPEED SETTING TO ENSURE POSITIVE SPACE PRESSURIZATION AT ALL TIMES THE
FANS ARE IN OPERATION.
ALARMS:
1. DDC ALARMS WHEN ROOM TEMPERATURE EXCEEDS 104F
2. DDC ALARMS WHEN FILTER PRESSURE DROP EXCEEDS SETPOINT OF 1.0 IWC