Design and Construction Standards
Division 33 – Utilities

General

In general, follow the guidelines below when designing, specifying and installing utility infrastructure within or to a building or facility on campus. Unless specifically indicated otherwise, these guidelines are not intended to restrict or replace professional judgment.

1. Applications:
   a. This Standard shall apply on all buildings, sitework, and facilities within the main campus of Eastern Michigan University.
   b. This Standard shall apply for all temporary power for construction within the main campus of the University.
   c. This Standard may be applied for all other satellite locations and campuses of the University at various locations identified by the University.

2. Definitions:
   a. High Voltage: Voltages higher than 35 kV (thirty-five kilo-volts).
   b. Low Voltage: Voltages less than 600V (six hundred volts).
   c. Medium Voltage: Voltages less than 35 kV (thirty-five kilo-volts) and higher than 600V (six hundred volts). 13.2 kV (thirteen-point-two kilo-volts) and 4,160V (four thousand one hundred sixty volts) are medium voltages.
   d. Service Connection: A pair of service drops from a pair of medium voltage feeders.

3. Acronyms:
   a. AEIC: Association of Edison Illuminating Companies (Codes and Standards, most current versions).
   b. ANSI: American National Standards Institute (Codes and Standards, most current versions).
   c. AWG: American Wire Gauge.
   d. CDF: Controlled Density Fill
   e. DAS: Data Acquisition Software
   f. EEPROM: Electrically Erasable Programmable Read Only Memory.
   g. EMT: Electrical Metallic Tubing.
   h. EPR: Ethylene Polypropylene Rubber (insulation).
   i. FPC: Facilities Planning and Construction Department, within the Physical Plant, at the Eastern Michigan University.
   j. FOM: Facilities Operations and Maintenance Division, at the Eastern Michigan University.
   k. HMI: Human Machine Interface.
   l. Hi Pot: High Potential (high voltage testing).
   m. ICEA: Insulated Cable Engineers Association (Codes and Standards, most current versions).

n. IEEE: Institute of Electrical and Electronics Engineers, Inc. (Codes and Standards, most current versions).
o. KCMIL: Wire size unit, is the equivalent cross sectional area in thousands of circular mills. A circular mill (CMIL) is the area of a circle with a diameter of one thousandth (0.001) of an inch, (1 KCMIL = 1,000 CMIL).
p. kV: Kilo-volt (thousands of volts).
q. KVA: Kilo Volt-Amps (thousands of volt amps).
r. kW: Kilo-watt, a rate of energy delivered or consumed
s. kW-hr: Kilo-watt hour, a cumulative sum of energy delivered or consumed.
t. LOTO: Lock Out, Tag Out (procedure).
u. MBC: State of Michigan Building Code
v. MCOV: Maximum Continuous line-to-neutral Operating Voltage.
w. MVA: Mega Volt-Amps (millions of volt-amps).
x. NEC: National Electrical Code, (Codes and Standards, most current versions), plus version(s) as Code-applied within the State of Ohio, Ohio Building Code (OBC)
y. NEMA: National Electrical Manufacturer's Association (Codes and Standards, most current versions)
z. NESC: National Electrical Safety Code (Codes and Standards, most current versions)
aa. NETA: InterNational Electrical Testing Association (Codes and Standards, most current versions)
bb. NFPA: National Fire Protection Association (Codes and Standards, most current versions)
cc. NIST: National Institute of Science and Technology (Codes and Standards, most current versions)
dd. OEM: Original Equipment Manufacturer
ee. O-&-M: Operations and Maintenance manuals as published and provided by manufacturers and Contractors.
ff. EMU: Eastern Michigan University.
gg. PILC: Paper Insulated Lead Covered (cable and splices).
hh. PP: Eastern Michigan University Physical Plant
ii. PVC: Polyvinyl Chloride.
jj. RFI: Resettable Fault Interrupter (switch).
kk. SF6: Sulfur hexafluoride (gas-filled switch).
ll. TSP: Twisted-Shielded Pair (of wires).
mm. TSQ: Twisted-Shielded Quad (of wires).
nn. TTR: Transformer Turns Ratio.

4. Site Utility Identification: The Design Professional must check with both the Eastern Michigan University Physical Plant - Electrical Shop (734-487-3405) coordinating with the EMU Project Manager and the State of Michigan MISS DIG (800-482-7171) to identify and locate all known utility lines in the construction area. A minimum of 72

hours' advance notice, excluding weekends and holidays, will be required to allow utility lines to be marked.

a. All bid documents for projects with any site work identified shall contain the following statement, to appear on the appropriate site plan sheet(s), as well as in the appropriate sections of the project specifications:
    i. "Contractor shall notify the EMU Project Manager, EMU Principal Plant Engineer for the appropriate discipline, and MISS DIG a minimum of 120 hours, excluding any holidays or weekends, prior to any excavating, fencing, planting, or other work that disturbs earth for the location of existing underground facilities. The University will require a minimum of 72 hours to allow utility lines to be marked. The Eastern Michigan University will not permit any site work to proceed until utility marking has been completed."

5. PAYMENT OF FEES: In the event that the project requires a direct utility tap which is not to a University owned utility, all associated charges shall be paid by the contractor doing the work. The contractor shall pay the fees to the governing authority prior to commencing the work and shall provide to the University a written receipt as proof of payment. The Professional must check with the University regarding connections and utility ownership prior to contacting the governing authorities. For non-EMU owned Utilities, the Professional shall contact the governing authority to determine the tap fees and capacity charges and these costs shall be noted in the bid documents.
    a. No tap fees or system capacity charges are required for connection to the University systems. However, the details of connection must be arranged with the Project Manager and Principal Plant Engineer for the appropriate discipline.

33 00 00 Utilities

1. System Design Criteria
    a. The requirements and guidelines set forth in this Standard support meeting the basic design criteria in a manner consistent with the University's objectives for service continuity and safety. Life Safety and preservation of property and business operations are the two most important factors in the design of the electrical utility system.
    b. This Standard is the 'minimum' requirement. This Standard is not intended as a replacement for the electrical Codes.
    c. General system design criteria are as follows:
        i. The main electrical system shall be designed such that a single Primary electrical power component outage shall result in prolonged outage to no more than one service connection.
        ii. No service connection shall be designed or operated in a way that places the reliability of the Primary electrical power sources in jeopardy, or places the safety of the Public or University Staff in jeopardy.

iii. No single failure in the protection or control systems for critical main power system components shall result in total loss of component or system protection.
iv. No single failure of the control system shall result in loss of redundant systems or components.
v. Equipment and circuit loading shall be kept within the ratings of the components that make up the system.
vi. System components shall be designed so as to make them maintainable and facilitate operating condition monitoring.
vii. All critical components shall be monitor-able and testable
viii. To the extent practicable, systems shall be designed to minimize operator and maintenance personnel disorientation and /or need for additional training because of unwarranted inconsistencies in operating, maintenance requirements or Human Machine Interface (HMI).
ix. The design shall meet the requirements of the National Electric Safety Code (NESC), NFPA 70E and other utility industry recognized Codes and Standards.
x. Main electrical power system designs shall address both system reliability and component protection in a way that balances the need for continuity of service and protection of physical assets.
xi. No design shall contain features that present a risk to life safety, public or facilities personnel safety beyond what can be reasonably controlled by training, administrative safety procedures, Lock Out – Tag out (LOTO) and personal protective equipment.
xii. All installations shall be designed and engineered in a way as to reduce the maximum arc fault potential at the equipment.
xiii. All components shall be Utility grade quality.

2. System Protection
   a. System Protection is the protection of the electrical power system. There are two classes of electrical protection: that which is designed to protect equipment or personnel from the potentially harmful effects of overloads or inadvertent grounding and that which is designed to limit the severity or extent of loss of power supply.
      i. Common requirements of the initial class are overload devices and ground fault isolators. These act to interrupt power before damage can occur. See Division 26 sections for this class of devices for these types of applications.
      ii. Common requirements of the latter class are fuses set to isolate failed transformers from the Primary electrical system, and protective relays that act to isolate faulted portions of the Primary electrical system to allow the remainder to function normally.
         1. As a general rule, Primary electrical system protective devices are applied to isolate to protect the supply rather

that operate to protect the downstream component (failed device).

2. Fuses or electronic fuse emulation on gas (SF_6) or vacuum switches used for the primary service drop are set to ride through transformer magnetization transients and load transients. They are not intended to provide overload protection for the transformer or downstream switchgear or bus-work.
3. Primary circuit protection is designed to isolate faulted circuits from the main 13.2 kV supply bus. This protection is set to coordinate with the service drop protection and should be set to stay under the cable damage curves for faults. It provides little or no overload protection.
4. Major Primary electrical system components are provided with differential-type protection that is designed to isolate the faulted component in a very short time (less than 50 millisecond). This limits damage to the components, the threat of collateral damage to other components in the area or upstream electrically from the faulted component. It also serves to limit the electrical voltage transient experienced by other power system components and loads. (Examples of component and equipment afforded such protection are: large transformers, buses, generators, very large motors and cable feeders that connect major busses).
5. Primary power system protective relay applications are designed so that no single failure of a protective relay or fuse will result in the total loss of ability to isolate the failed component. This involves the use of a diverse relay function such as coordinated time over-current relaying. These relays are applied to wait out the time the failed relay should have taken to initiate a trip and then trip. This protection takes longer to act and generally results in less selectivity (more components are de-energized than the faulted component).
6. Three key attributes of the protection system are speed, selectivity and reliability. These must be factored into every primary electrical power sources and power supply protection scheme.
7. Testability and routine surveillance are key to assuring the reliability of the power supply protection. Protective relays must be testable in service without lifting wires. Because of this requirement, they shall be equipped with integral test plugs or external test switches. Modern solid-

state microprocessor and multifunction relays are equipped with built-in diagnostics that aid greatly in performing periodic inspections. These features do not substitute for testing and calibration checks that force currents and apply voltages and develop output trip functions.

8. All Primary power supply protective relays should be surveyed quarterly and subjected to a full re-calibration and trip check on a minimum of a four-year interval.
9. Any changes to the Primary power supply, primary distribution or primary service connections must be in conformance with the above stated design and operating philosophy and shall not degrade the overall performance of the Primary system.

3. Professional and Contractor Provisions
   a. Information for Design of System: During the initial planning conference, Professional shall consult with the EMU PP regarding the sizing and configuration of the primary service.
   b. The Professional shall specify only Underwriters Laboratories listed equipment, assemblies, and materials when such items are available and technically acceptable to the design. The equipment and materials shall be installed in accordance with its listing. Equipment and materials shall be selected from a pre-approved Manufacturer list, and subject to EMU PP FOM & FPC approval.
   c. Professionals submitting proposals to provide electrical engineering, design or construction services shall be required to demonstrate adequate competency, and recent relevant work history. This requirement applies to the Professional’s supervision and work force as well as to sub-Professionals, their supervision and work force. Work experience, personnel credentials and work references shall be submitted in writing at the request of EMU PP for their review and approval. This requirement applies to all sub-Professionals as well. No one shall be permitted from working in electrical substations, the medium voltage power distribution system, the power plant, or related facilities unless they demonstrate they have established a verifiable record of safe work practices and training suitable for work around high and medium voltage equipment.
   d. The Professional is responsible for addressing and resolving all review comments by EMU PP concerning primary power system design to the satisfaction of EMU PP.
   e. The connection to the Utility electrical system shall not be energized if these Standards are not met or if the design or Professional approved equipment or installation fails these Standards or inspections by the EMU PP.
   f. The Professional shall direct the contractor(s), through the construction documents, to meet the following requirements:

- i. The Contractor(s) and its sub-contractor(s) shall purchase only Underwriters Laboratories listed equipment, assemblies, and materials when such items are available and technically acceptable to the design. The equipment and materials shall be installed in accordance with its listing. Equipment and materials shall be selected from a pre-approved Manufacturer list, and subject to EMU PP approval.
- ii. Contractors submitting proposals to provide electrical construction and installation services shall be required to demonstrate adequate competency, and recent relevant work history. This requirement applies to the Contractor's supervision and work force as well as to subcontractors, their supervision and work force. Work experience, personnel credentials and work references shall be submitted in writing at the request of the EMU PP for their review and approval. This requirement applies to all sub-contractors as well. The Contractor and sub-contractors shall be prohibited from working in electrical substations, the medium voltage power distribution system, the power plant, or related facilities unless they demonstrate they have established a verifiable record of safe work practices and training suitable for work around high and medium voltage equipment, and a verifiable record of quality of workmanship and reliability.
- iii. The connection to the Utility electrical system shall not be energized if these Standards are not met or if the purchased equipment or installation fails these Standards or inspections by the EMU PP.

4. Configuration Management
   - a. Professional's designs shall be submitted to and approved by the EMU PP, before publication for Bid.
   - b. Professional's designs shall include related studies and reports. The Professional shall supply facility coordination studies, short circuit analysis, load flow studies, and arc flash analysis to EMU PP for approval.
   - c. Labeling: The Contractor, at the time of installation, shall field-label all major power components. Equipment labels shall provide the name and function of the equipment as well as its power source. When the equipment is made up of two or more separately identifiable devices, sections or compartments; these too shall be individually labeled. Nomenclature used on the field-labels shall be consistent with that used on the Contract Documents, O & M documents and training materials. All field-labels shall be readable from a distance of three feet.
   - d. Control devices such as control switches, relays, displays and instruments shown on One Lines, schematics, interconnection wiring diagrams etc., shall be field-labeled with nomenclature consistent with that used on the Contract Documents.
5. Training and Support

a. Operator Training: Operator training for routine operation of systems or equipment shall be provided: The University on a case-by-case basis shall set Training requirements. Such training shall at a minimum include one full instructor-day, minimum 8-hours per shift, of on-site instruction for the daily operation of the system, to be attended by University's designated Operations personnel. All training shall be scheduled by the contractor in coordination with the University's Project Manager and Principal Plant Engineer for the appropriate discipline.

b. Additional Technical Support During Warranty: In addition to the warranty for labor and materials as specified in General Terms and Conditions: the contractor shall at the request of the University, provide additional technical support up to a maximum of two full person-days, minimum 16-hours, on-site support for the system during warranty. All support shall be at the request of the University's Project Manager and Principal Plant Engineer for the appropriate discipline.

c. Training for System Maintenance: The University desires to become self-sufficient and skilled to the point of being able to perform regular preventive maintenance, annual system inspections, remedial maintenance, and small renovations. The Contractor shall include the following Training for System Maintenance, including the OEM manufacturer's standards for:

    i. OEM hardware tools and documentation,
    ii. OEM software tools and documentation,
    iii. OEM training on the use of the above hardware and software tools,
    iv. OEM certificate of "Authorized Warranty Service Technician" or equivalent.
    v. All training and diagnostics shall be identical to that as provided and available to the factory authorized service representatives. The training shall allow the University to perform all maintenance and inspection functions. The hardware tools shall include EEPROM programmers using industry standard IBM-compatible desktop PC's. The software tools shall perform on industry standard IBM-compatible desktop PC's, using industry standard MS-Windows operating systems. The training shall be conducted at the University either on-site or at the location selected by the University, conducted by the manufacturer's trainers, and shall include classroom hands-on training with instructor, travel included, for minimum of five instructor-days, minimum 40 hours, of instructional time.

33 08 70 Commissioning of Electrical Utilities

1. Testing

    a. Factory Testing: Factory testing for major equipment and integrated systems shall demonstrate design compliance to procurement and functional specifications. It shall be conducted to appropriate industry Standards and include third party testing and verification. The option for University acceptance by participation in the testing or through a review of the testing results shall be made available with a minimum of two weeks written notice to planned commencement of testing.

b. Installation Quality Control Testing
    i. The contractor shall supply appropriate technically competent support to monitor workmanship and completeness. This shall involve in-line work inspection or audit inspection with rigorous corrective action, follow up and closure on non-conforming work products and methods. Tests and inspections shall include compliance to EMU Standards, and compliance to good industry practices. Instrument calibration and set point verification shall be included in the contractors test and inspection planning and execution.
    ii. The contractor shall supply appropriate third party technically competent support to test and inspect installations for fitness for service in accordance with NETA guidelines.
    iii. Testing shall be performed to demonstrate fitness for service of all components. A representative from the EMU PP (FOM when possible) shall witness the testing. Copies of test results shall be provided to the EMU PP through the EMU Project Manager.

c. Post Installation Testing
    i. The contractor shall supply appropriate technically competent third party support to conduct thorough pre-operational testing of all installed systems and components for all modes of operation in accordance with NETA guidelines. Testing shall include equipment controls, protective relays and safety interlocks.
    ii. System Functional Testing: All systems shall be tested to demonstrate their ability to function as required over the full limits of their normal operational range and for any emergency range as called for in the system design. This testing shall be conducted with the systems and associated equipment installed and operating in their normal mounted orientation, settings and conditions of power supply and environment. This testing may be conducted in an integrated fashion with all system interfaced as designed or may be done piecemeal (overlapping) in a manner that demonstrates acceptable functionality of all interfaces, shared functions and dependencies.
    iii. Interlock verification testing: Once all construction has been completed and all system installation and construction testing completed, the University or their appointed agent shall conduct testing designed to validate the proper operation of all system permissives, trips, critical sequences, operator HMI functions and annunciations.

d. Certification Process: The University requires all test reports and records as well as individual certifications of any and all test authorities, the manufacturer or independent testing agencies be provided for review and acceptance. These records, along with supporting documents showing acceptable resolution of open items, test discrepancies, failures and repair, retesting etc., will serve as the basis for certifying equipment for service by the University.

e. University Acceptance Process: The University shall follow due process and demonstrate due diligence in their review and acceptance of all processes relating to quality, completeness and conformance to applicable Codes and Standards. University acceptance will be granted only after the certification process has been completed to the University's satisfaction and all documentation has been received, reviewed and accepted.
    i. Tests must be conducted in accordance with University requirements and shall be witnessed by representative(s) of the EMU PP (FOM when possible).
    ii. Medium and low voltage cable testing shall comply with NETA and Association of Edison Illuminating Companies (AEIC) guidelines with the following exceptions:
        1. The University deviates from the Industry Standard of 64 kV and 96 kV at 133% cable insulation level due to destructive nature of this testing, field experience and the potential for cumulative damage.
        2. Hi-pot testing on 133% EPR insulated 13,200-volt system cable shall be a 42,000-volt DC High Pot performed by an approved test instrument witnessed by EMU PP. The 2,000-volt High Pot test shall be applied in 7,000 volt intervals of one-minute duration with a 5-minute sustained interval at 42,000 volts. High Pot testing of existing installed primary cables is limited under normal conditions to 10,000 volts. This 10,000-volt DC High Pot is applied gradually with a sustained duration at 10,000 volts for five minutes. The 42,000-volt test shall only be done after pulling, termination and splicing of new cables, but before splicing to the existing cables. A maximum of 10,000 volts DC high pot test shall be applied for all installations after splicing to existing cable.
        3. Hi-pot testing on shielded 133% EPR insulated 4,160-volt system cable shall be a 28,000-volt DC High Pot performed by an approved test instrument witnessed by EMU PP. The 28,000-volt High Pot test is applied in 7,000 volt intervals of one-minute duration with a 5-minute sustained interval at 28,000 volts. High Pot testing of existing installed primary cables is limited under normal conditions to 19,000 volts. This 19,000-volt DC High Pot is applied gradually with a sustained duration at

19,000 volts for five minutes. The above limits apply to cables without the presence of a surge suppressor.

4. Hi-pot testing for 600 volt circuits may be elevated to a maximum 2,500 VDC 1-minute duration for certain critical control components as identified by EMU PP on a case by case basis.

iii. Primary transformer and switchgear testing shall be conducted per NETA standards and witnessed by EMU PP. The tests shall be performed after installation of the transformer and switchgear.

33 09 70 Instrumentation and Control for Electrical Utilities

1. Metering
   a. Metering System: A meter with system display is required for each building, transformer or service, both permanent and temporary services. Approved and acceptable meters and manufacturers for EMU facilities are:
      i. Power Measurement Ltd. shall be model 7300, 7500 and 7600 ION series with fused control transformer or 125 VDC power supply option
      ii. Each individual kW-hr meter specified must have analog communications and impulse capability.
      iii. If complete meter setup cannot be done from the front panel, any required software, cables, and keys shall be provided to the EMU PP.
      iv. The height of the meter display shall be five feet (5.0') from the finished floor or 4 ½ feet from the switch pad to the center of the meter.
      v. Provide four current transformers and circuit monitor that indicate true RMS current for phase and neutral.
      vi. The monitor shall provide the following information:
         1. Voltage - phase to neutral and phase to phase ABC
         2. Amps - present reading and 15-minute maximum demand ABCN
         3. Kilowatt-hours
         4. Kilowatt maximum demand based on 15 minute intervals
         5. Power Factor, Kilo VAR, Kilo VAR Hour, KVA
      vii. A 6-pole GE PK-2 panel-mounted test plug shall be installed flush on switchgear for portable test metering connection and use by Utilities personnel. Specify that three left poles be factory-wired to the phase current transformer secondaries; wire the right hand poles to the phase to neutral potential source. Current transformer poles shall have shorting auxiliary contacts.
      viii. If the meter used for kW-hr reading does not have a meter serial number on the front of the display, then an engraved name plate shall be installed below the meter with the meter serial number engraved on it.

ix. Avoid metering schemes that are only capable of measuring partial loads connected to the distribution system or electrical apparatus being monitored. Specify that a meter shall be installed to measure electrical load from the distribution system including fire pumps.

b. Construction Metering: The prime construction contractor shall provide one kW-hr meter suitable to record the total electrical consumption of the construction site. The contractor is responsible for the proper connection and installation of the meter and associated sources of current and potential. Meters shall be maintained accessible to and will be read by University Personnel. Failure to place a proper functioning meter into service prior to drawing electrical load will result in electrical usage charges that are estimated by the University based on the greater of the first full month of properly metered service or an estimate by EMU PP FOM of likely usage based on worst case connected load for the period whichever is greater. EMU PP reserves the right to refuse or disconnect electrical service to any site with dysfunctional metering. The meter shall be in full compliance with the requirements as stated above.

33 40 00 Storm Drainage Utilities

1. Preparation of Documents: Before preparing final documents, consult the University Architect. On some projects, it might be desirable to make this work a part of the Plumbing Contract.
2. Materials: All work shall consist of materials meeting the intent and requirements of Eastern Michigan University, Washtenaw County, MDEQ, and/or MDOT, and the local codes, whichever is stricter.
   a. Piping
      i. For Pipe 12” and larger: Reinforced Concrete Pipe Corrugated Polyethylene Pipe and fittings – smooth interior – type S Ribbed Poly Vinyl Chloride (PVC) – smooth interior – Uni-bell
      ii. For piping less than 12”: Service weight cast iron Poly Vinyl Chloride (PVC) – smooth interior – type psm Ribbed Poly Vinyl Chloride (PVC) – smooth interior – Uni-bell Corrugated Polyethylene Pipe and fittings – smooth interior – type S
      iii. Jointing Materials:
         1. Solvent welded joints are not permitted
         2. Concrete Pipe: Rubber gasket ASTM C443
         3. PVC Pipe: Joints shall comply with ASTM D3212; Elastomeric gaskets shall comply with ASTM F477 and as recommended by the manufacturer.
   b. Catch Basins, Curb Inlets, Manholes (ASTM C478 & AASHTO M315)
      i. Basin Lid and Frame: Cast iron construction, heavy duty, removable lid. Surface shall be a “studded” pattern with the following words
         1. “Storm Sewer”

2. "Fish" symbol with words "No Dumping – Drains to River"

ii. Shaft and Top Section: Reinforced precast concrete, lipped male/female joints; nominal dimensions as shown on plans. Cast-in-place, brick or block side walls may be used in place of precast construction. Brick or concrete block side walls shall be 8 inches' nominal thickness and shaped appropriate to the structure. When brick or concrete block is used, the outside walls of the manhole shall be plastered with a 1/2-inch coat of lime cement mortar, applied with a trowel and finished to an even glazed surface.

iii. Base Pad: Cast-in-place concrete with leveled top surface to receive concrete shaft sections, sleeved to receive storm sewer pipe sections. Precast base sections may be used in lieu of cast-in-place base.

c. Under Drains
   i. Filter Aggregate: MDOT #8/Type H.
   ii. Tubing: Polyethylene tubing, ASTM F-405

d. Cleanouts
   i. Cleanouts shall be adjustable, vandal-proof with heavy duty cast iron top for exterior use.
   ii. Cleanouts shall be placed at every change in direction, and at maximum 100' spacing in straight runs.

e. Trench Drains
   i. Lid and Frame: Cast iron construction, heavy duty. Minimum 6" wide.
   ii. Surface Drainage: Must have slope no less than 1 percent to insure positive drainage. Drain away from sidewalks and driveways.
   iii. Yard/Area Drains: Are not generally permissible. If one is needed approval is needed from Director of Roads and Grounds.
   iv. Bends in Piping and at Manholes: All piping shall be run straight, structure to structure. If a bend is necessary, a cleanout shall be provided. Transitions at manholes shall not be 90 degrees or less.

f. Drain Opening Protection: Install removable bars or grills at open ends of culverts, drains and pipes 10-inch diameter and larger to prevent access by children or animals.

g. Manholes and Catch Basins:
   i. Refer to City of Ypsilanti standard drawings for manhole and catch basin standard materials and installation requirements within Washtenaw County and the State of Michigan Department of Transportation standard drawings for work outside Washtenaw County.
   ii. Refer to City of Ypsilanti and the State of Michigan Department of Transportation construction and materials specifications for minimum requirements.

33 71 26 Transmission and Distribution Equipment

1. Main Substation(s) Power Distribution
   a. Bulk electrical power is delivered to the University at 41,000 Volts. The University transforms this power down to 13.2 kV at the main substation(s) bus(es), which in turn then distributes it to Primary feeder pairs that traverse the campus. All permanent buildings, and building complexes, and construction temporary power are provided with service drops from both circuits of a feeder pair through one or more primary switches. These switches allow the buildings to be switched between primary feeders when feeders need to be de-energized for construction work, maintenance, or due to failure. Each building or building complex has one or more transformers fed from the primary switches through a variety of switch and secondary feeder arrangements designed to suit the specific needs of the buildings.
2. Campus Primary voltage: The available underground primary distribution voltage is 13.2 kV volt 4-wire, 3-phase, 60-cycle. This system is a solidly grounded Wye system. The University owns and operates a 4800-volt primary system. All new buildings must be added to the 13.2 kV system.

33 71 49 Medium Voltage Wiring

1. Exterior Underground Raceways:
   a. All underground cables of any classification shall be installed in approved duct raceway systems.
   b. Direct burial of underground cables is prohibited.
   c. Cold bending of PVC conduits is prohibited.
   d. New raceway installations shall be designed for future capacity addition.
   e. Additional spare ducts shall be included as required by the University to afford spare ducts for failure or circuit additions. Duct banks that are intended to carry Primary circuits shall be provided with enough spare ducts to accommodate a minimum of one additional circuit pair. Duct banks intended to carry lateral building feeder taps shall be designed with a minimum of one spare duct per duct bank. The EMU PP shall determine the requirement for additional spares on a case by case basis.
   f. Raceway ducts within duct banks for Primary cables shall be schedule 40 PVC conduit. PVC conduit shall be adapted to rigid steel conduit beginning at ten feet (10') before entrance to outside of building foundations, and beginning at ten feet (10') before entrance to manholes. Raceways shall be encased in concrete as Primary duct bank.
2. Primary Duct Banks
   a. Raceways for primary electric shall be encased in a reinforced concrete (3" minimum cover) envelope. The standard size for primary electric ducts shall be 6 inches for Primary mains, and 5 inches for Primary building laterals and Primary loadways.
   b. Ducts for Primary mains shall be placed on 9 1/2 inch centers for a 3-inch spacing between power ducts. Ducts for Primary laterals and Primary loadways shall be in duct banks with power ducts placed on 8 1/2 inch

centers for a 3-inch spacing between power ducts. Primary mains shall contain a minimum of six 6-inch diameter schedule 40 PVC power ducts and two concentrically located 2-inch diameter schedule 40 PVC ducts provided for ancillary use. Primary laterals and Primary loadways shall contain a minimum of four 5-inch diameter schedule 40 PVC power ducts and one concentrically located 2-inch diameter schedule 40 PVC conduit provided for ancillary use. Carlon Snap-Loc Spacers, or approved equivalent, supported on concrete or ceramic blocks shall be placed at eight (8) ft intervals.

c. Ducts shall be installed below the frost line at a minimum forty-eight (48) inches below finished grade and shall be sloped to drain into manholes.

d. Multiple parallel duct bank installations shall observe a minimum horizontal spacing of two (2) feet. This provision does not apply to duct bank crossings with an acute angle of greater than 30 deg.

e. Two longitudinal steel reinforcing bars with a minimum of 18-inch overlap shall be used for each layer of duct in all duct banks. In instances where the duct bank crosses a road way or high vehicle traffic area, two additional steel reinforcing bars shall be provided at the top and bottom of the bank to assist in distributing the load. Ducts shall be bundled and tie-wired to assure integrity of the duct array during pour. Concrete shall encase the duct bank installation a minimum of 3-inches on all sides. Provide one (1) #5 steel reinforcing bar for each conduit in the duct bank). Tie off the reinforcing bars to the plastic supports holding the conduit in place. Allow for a minimum of 2” of concrete over the reinforcing. Concrete envelopes shall extend through foundation and manhole walls designed so that the envelope becomes a structural member providing support for bridging the area that has been excavated and back filled for foundation or manhole walls.

f. Tear tape shall be placed approximately one foot above the duct bank when being backfilled.

g. Elbows shall be long-radius rigid steel conduit.

h. End Bells shall be steel. Aluminum, plastic or pot metal end bells are prohibited. End bells on conduit entering a building or manhole shall have their broader opening mounted flush with the interior surface of the wall penetrated by the duct.

i. Duct banks of 6 or more ducts should avoid crossing an area with an unfavorable thermal environment (i.e., crossing steam pipes, parking lots) as such cable installations may require derating.

j. Ducts banks shall not pass within 10 feet of a buried steam line in any direction. If it becomes necessary to cross a steam line, acceptable insulation of the crossing must be provided and approved by EMU PP.

k. Primary ducts banks shall cross gas lines below the gas piping without exception.

l. Primary voltage cable within a building shall be installed in rigid steel conduit with UL approved steel pull boxes. Label conduit every 10 feet and pull boxes shall be labeled "DANGER 13,200 VOLTS".

m. Cable or conductor bending radius shall not be less than eight times the overall diameter for non-shielded cable and twelve times the diameter of shielded cable during or after installation. On systems operating above 1 kV to ground, cables installed in nonmetallic conduit shall have an effectively grounded shield, and one 4/0 copper single conductor 600 V insulated ground wire run with the three phase circuit in the same conduit.
n. Primary cable ducts between manholes or other terminal points shall be as straight as practical. All bends shall be "sweep" bends and any bend greater than ten (10) degrees per ten (10) foot length of duct, shall be made with rigid steel conduit. Where possible, duct banks shall be run straight from manhole to manhole; where bends are necessary, the total shall not exceed 90 degrees in addition to any turn up at the pad or equipment.
o. Layout: Primary duct banks shall be a three or more ducts wide by two ducts high.
p. For final preparation, a properly sized steel mandrel shall be pulled through all new or repaired ducts. Mandrel shall be ¼” to ½” smaller in diameter than the duct; this shall be a test witnessed by the EMU PP (FOM when possible). Each duct shall be proved clear and usable, cleaned, have a No. 12 type TW pull wire left in place, and spare ducts shall have duct plugs installed.
q. Color Additive: Concrete for Primary duct banks shall have a red color additive mixed in the concrete for identification. Specify Solomon 417, or New Davis Color Super Conduit Red #10329; mix approximately three and a half pounds (3-1/2 lbs.) per 80 pounds of cement to provide identifiable red color as warning to any one digging into the high voltage cable run. The concrete supplier shall premix concrete. Color additive shall not be hand-troweled in, and shall not be sprinkled.
r. A member of the EMU PP (FOM when possible) shall approve primary ducts before concrete is poured. A member of the EMU PP (FOM when possible) shall witness the concrete pour.
s. Excess concrete shall not be placed in the hole or used to raise the top of the duct bank greater than 3 " above the top of the ducts. Duct banks shall be a continuous pour from bottom to top. Concrete shall be poured and compacted so as to avoid inclusion of air pockets or areas where concrete doesn’t completely cover ducts and reinforcements. Remove all excess concrete from University property.
t. Soil may be used to backfill duct bank excavations provided they are not in streets or where recurrent heavy surface loadings are anticipated. High traffic and heavy load areas must be backfilled with ¾” crushed stone or CDF with a covering layer of compacted soil or gravel and resurfaced to original wear surface.
u. Quazite boxes shall not be used for medium voltage cabling.

3. Manholes
   a. Manholes shall not be installed inside buildings or in areas of public assembly.

b. All medium voltage manholes or vaults shall have High Voltage Line and Utility truck access.
c. Manhole covers shall be round, 30-inch diameter, heavy duty, traffic rated with the word "ELECTRIC" cast in cover as applicable. Covers shall not have gaskets or be bolted down. Two slots, on opposite edges, shall be provided to permit using manhole hooks to remove cover.
d. Flame Proofing: Cables in manholes, vaults, cable spreading areas, and at conductor terminations where more than one Primary Circuit is present shall be flame proofed with tape (3M #77l). Control cables and fiber optic cables shall also be flame proofed in manholes, vaults and cable spreading areas where power cables are present and can pose a threat if faulted.
e. Cables in manholes shall be tagged with phase and feeder numbers marked using 1" x 3" plastic tags with 1/2" high by 1/16" thick engraved lettering (black on white).
f. Primary Cables to the Transformers and Switches: Cables going into buildings from manholes shall be marked with the building's name for identification using plastic with engraved 1/2" high by 1/16" thick lettering (black on white).
g. Manholes shall be located and sized to allow workable pulling tension on cables and other considerations in planning. Minimum inside measurement of the medium voltage compartment shall be 6 feet wide by 10 feet long by 7 feet high. Maximum spacing between successive manholes shall be 400 feet measured along the length of the duct bank.
h. Access shall not be less than a 30 inch round chimney equipped with removable steel ladder placed in each manhole.
i. Hardware shall include pulling eyes in each wall opposite of a duct bank at 3ft AFF and the center of the floor, inserts, and cable racks. Racks shall be Hubbell/Chance No. R1474. Support arms shall be Hubbell/Chance No. 1293. Insulators shall be Hubbell/Chance No. 1115.
j. At least one 5/8" diameter by 10' long driven copper-clad steel ground rod shall be installed in each manhole 6 inches from a wall.
k. A 1" x 1/4" copper ground bus shall be placed around the perimeter of the manhole walls 6" from the ceiling for bonding all cable shields. Connect to ground rod with 4/0 copper cable. Connect manhole reinforcing steel, duct bank reinforcing steel and manhole metal hardware with #2 copper cable. Use Cadweld® for ground connections.
l. All electrical ducts entering manhole shall be perpendicular to the manhole wall and shall be at least a minimum of ten feet (10 ft.) straight from the manhole wall. All ducts banks shall enter manhole within one foot of a corner. Do not center manhole on duct bank.
m. End bells shall have their wide end positioned flush with the interior of the manhole wall.
n. Provide a sump hole in manhole floor in area below cover. Slope floor to sump.

o. Manhole covers shall be at finished grade. The ring and cover shall be centered over chimney.

4. Wire and Cable
    a. Copper conductors of 98 percent conductivity shall be used. Aluminum conductors are prohibited.
    b. Color Coding
        i. Color coding for 13.2 kV cables and 5 kV cables shall be as follows:
            1. Phase Voltage 13.2 kV and 5 kV (Each with identifiable colored stripe)
            2. Neutral: White
            3. A: Black
            4. B: Red
            5. C: Blue
            6. Equipment: Bare Copper
5. Primary Voltage Cables (13,200 Volt)
    a. The insulation must be compounded and mixed by the cable manufacturer in its own facilities using a closed, clean process to ensure maximum control and continuity of quality. The strand shield and insulation shield shall be extruded, semi conducting thermosetting material that is compatible with the insulation.
    b. Cable shall be suitable for normal installation in conduit and shall be suitable for continuous submersion in water. The cable shall be capable of continuous operation in both a wet or dry environments at a conductor temperature of 105 degrees C in normal operation, 130 degrees C in emergency overload operation, and of 250-degree C in short-circuit operation.
    c. Main feeders in the EMU campus power system shall be minimum of 500 kcmil copper.
    d. Only cables from companies with an established reputation and an excellent track record in the medium voltage power cable manufacturing industry shall be installed in primary system applications.
    e. 13,200-volt primary feeder and service cables shall be UL Listed and from a list of approved manufacturers:
        i. General Cable
        ii. Okonite Company
        iii. Prysmian Power Cables and Systems USA, LLC
        iv. Southwire Company
            1. One conductor compressed soft-annealed copper per ASTM B-3, stranding per ASTM B-8.
            2. Comply with UL 1072, AEIC CS8 and ICEA S-94-649.
            3. 220 mil ethylene Propylene Rubber (EPR) insulated, 15 kV, 133% rated, MV 105-degree C cables.
            4. Conductor Stranding: Compact round, concentric lay, Class B, Concentric neutral.

5. The jacket shall be sunlight resistant, continuously extruded, 80 mil, ‘low-smoke (260 degree C spread temperature) zero halogen’.
6. Cable construction shall comply with the latest requirements of ICEA S-93-639/NEMA WC-74.

f. Primary circuits shall have the power conductors arranged in three phase arrays in separate ducts. Each 3 conductor array shall include within its duct a 4/0 green XHHW, 600-volt insulation class ground wire bonded to all splices and terminations and grounded in substation(s) and manholes.

g. Primary circuits comprised of multiple conductors per phase shall have the power conductors arranged in three phase arrays in separate ducts. Each 3 conductor array shall include within its duct a 4/0, 600-volt insulation class ground wire bonded to all splices and terminations and grounded in substation(s) and manholes.

h. Phase rotation of primary service termination shall be established prior to termination. Phase positions at terminating equipment shall be Phase "A", "B", and "C" left to right facing the front, or "A", "B", and "C" front to rear. Circuit phasing shall be from the Substation to the point of splicing/termination and be performed with the assistance and under the observation of an EMU PP representative. Two circuits must be phase tested in the field and verified to be “in-phase” before any switch may be operated to close the two circuits together.

6. Splicing and Cable Terminations

a. All work performed on non-lead, medium voltage cables shall be performed by personnel with adequate training and experience and certified as qualified by the EMU PP. To be considered qualified for cable splicing, the individual’s employer must submit a resume with past training and experience supported by documentation of their having had the appropriate formal training in the preparation of relevant medium voltage splices and terminations prior to the individual performing any work. Splicing and termination experience shall be recent (one to five years depending on extent of prior experience) and relevant to the type of splice and cables being spliced.

b. Every splice shall be labeled with an engraved plastic tag (black on white) containing the following information:
   i. Date of splicing
   ii. Name of company that performed splicing; this shall include both lead and non-lead splices.

c. All work performed on lead sheathed, medium voltage (1 kV to 35 kV) cables shall be performed only by personnel who have been tested and certified by EMU PP FOM to be qualified. Contractor personnel approved by EMU PP FOM as certified lead-cable splicers shall perform Paper Insulated Lead Covered (PILC) to PILC Splices and shall use EMU PP approved materials utilizing historical lead-wiping methods.

d. PILC to Polymeric Splices are not permitted. Cable must be run back to the nearest switch for termination at 15 kV.
e. EMU PP approved, Raychem factory-manufactured heat shrink splice kits shall be used.
f. Kits shall be factory-engineered to contain all necessary materials, electrical stress control, insulation, shielding and environmental sealing. The kit shall allow for external grounding.
   i. Straight splices shall use Raychem or as specified by the Professional subject to EMU PP approval.
g. Terminations shall meet Class I requirements and be design-proof tested to IEEE Standard 48, most current edition, and be capable of passing a test sequence per IEEE 404, most current edition. Termination kits shall be approved for the type and size of cables used and rated for 15 kV 133%.
h. Polymeric Terminations shall consist of shrinkable stress control and outer nontracking silicone rubber insulation tubing with two or greater silicone rubber skirts. In addition, PILC terminations require an oil stop tube. All terminations and splices shall be grounded. Heat-shrinkable tubing shall have high relative permittivity stress relief mastic for insulation shield cutback treatment with a heat activated sealant for environmental sealing. Termination kits shall be from Raychem Corporation:
   i. For 4/0 cables - use type HVT-152-SG for outdoor -unheated areas.
   ii. For 500 KCMIL cable - use HVT-153G for indoor or HVT-152-SG for outdoor/unheated areas.
i. Cold Shrink splice kits and terminations are prohibited for use on 15 kV and 5 kV class cables.
j. Potheads may only be used to replace existing potheads in outdoor installations of existing PILC cable.

7. Primary Voltage Cables (15 kV)
   a. 15,000-volt service cables shall be UL Listed, 1/c, copper, 220 mil EPR insulated, 15 kV, 133% rated, shielded, MV 105 degrees C cables with low smoke (260 deg C spread temperature) zero Halogen. Tape Shield Cables shall have a 5 mil bare copper tape applied helically over the extruded insulation with an average minimum overlap of 25 percent of the tape width. The overall jacket shall be a continuous extruded, 80 mil polyolefin jacket, which meets or exceeds the requirements of ICEA S-93-736, latest edition.
   b. Extension or modification of existing 4,800 volt cables can only be done with prior written approval of the EMU PP.

33 71 73 Electric Utility Services

1. Primary Service
   a. Primary Service Drops: Primary service drops and their associated equipment applications are strictly regulated for acceptability of design, impact on power system reliability, safety to University personnel, and human error concern. Other considerations include Codes and Standards compliance,

personnel access, switching flexibility, aesthetics and design consistency. EMU PP maintains a listing of approved switch manufacturers and designs.

b. Primary Select Switches and Service Connections: Primary switches and service connections shall be fused load break designs with an interrupt rating greater than the maximum primary feeder fault duty (9600 amps). All new and upgraded Primary Select switches are to be SF6 (Gas) switches. The use of air break switches is restricted to switch applications such as transfers and equipment disconnection that do not serve a Primary Select function and will not be operated routinely by EMU PP FOM personnel. When the use of airbreak switches is approved by the University, the primary switches shall employ fully insulated bus. Exposed energized bus terminations and connection points are to be taped or booted. All bus connections are to be bolted or brazed. All internal bus jumpers and connecting cables are to be made with 15 kV cable. Internal jumpers and connections to mating equipment such as primary transformers are to be made with unshielded 15 kV rated cable. All jumpers or connectors routed outside the switch to components remote from the switch cabinets are to be made with 15 kV shielded cable of a construction compliant with the requirements of this Standard. Jumper cables shall be terminated in crimped lugs in conformance with the requirements set forth in this Standard for medium voltage cable termination. Power cables are to be terminated in EMU PP approved solid, long barrel, plated lugs secured with two or more bolts. Crimps are to be made by a crimp tool approved by the lug manufacturer following their approved procedures. All crimps shall be six point or more. A 360 deg crimp is preferred. In instances where the equipment accepting the termination does not support two or more bolts, EMU PP shall be consulted and will determine the acceptability of the single bolt termination. Compression type connectors are not generally considered acceptable for power applications.

2. Primary Select Switches - Medium Voltage

a. Provide products from the following manufacture meeting the requirements listed below and in other areas of the standard(s);

i. G & W Electric.

b. A medium voltage service shall consist of a set of primary lightning/surge arrestors (line side of primary select), primary selective switches, fused primary disconnect switches, lightning/surge arrestors (load side of primary disconnect), medium voltage transformer, arc fault mitigation relays and equipment, ground fault indicators and low voltage unit substation application section.

c. The transformer primary fuses shall be located in an accessible area but shall not be located within the transformer enclosure.

d. If the anticipated load requires a transformer larger than 1,500 KVA, or if the interruption of building power for maintenance of the low voltage unit substation is unacceptable, then the low voltage unit substation shall be double ended with the appropriate number of primary selective switches, two separately fused primary disconnect switches, two transformers, and two low voltage sections with a tie breaker provided. On double ended substations, the main secondary breakers shall be sized per requirements of Division 26.

e. For critical installations, such as research laboratories, vivaria, or computer centers, a complete double ended switchgear lineup shall be provided consisting of:
    i. A pair of Primary Select Switches with cross-tie,
    ii. Secondary distribution: two sets of fused primary disconnect switches, two sets of lightning/surge arrestors, two medium voltage transformers, and two low voltage sections with the main breakers and tie breaker.
    iii. Secondary bus tie and busses shall be sized for the emergency ratings of the transformers, and electrically operated main and tie breakers, with provisions for remote operation.

f. Primary Select Switches shall be rated electrically and mechanically for a minimum of 1,000 load break operations.

g. The Primary Select switches for the incoming power to each building shall be located outside or in a dedicated switch room directly accessible from the outside at ground level. When located inside a building, the Primary Select switch must be in plain sight from the point of entry to the building or within twenty (20) feet of entering into a building. The room containing the Primary Select switch shall be of a two-hour fire rated construction. The switch must be directly accessible from the outside. Primary cable pull boxes and conduit, ahead of the current limiting fuses shall not be located in or above public occupied areas.

h. Indoor applications shall be rodent proof and have drip shields to protect exposed High Voltage surfaces; outdoor applications shall be rodent and weatherproof. Switches shall not have floors. Switches shall be constructed to provide safe access to terminals without de-energizing the switch. Switches and bussing shall use porcelain insulators throughout. Switches shall be built on a raised channel or I beam, or minimum six (6) inch minimum height concrete slabs above finished grade.

i. There shall be provisions to protect outdoor mounted switches and associated enclosures from physical damage from Building and Grounds maintenance equipment and private, commercial or delivery vehicles (mowers, tractors, motor vehicles).

j. Switches shall not be placed in open underground or below grade vaults subject to flooding.

k. Gas switch handles and elbows shall face the front of the switch enclosure.

l. In primary select applications, low profile SF6 switches are to be applied exclusively where electrical cable access permits. Adequate termination space must be provided to accommodate elbow fuses if approved in writing by the EMU PP, stress cones and minimum cable bend radius. The termination space provided shall not require bending the cable in the area of the stress cone.

m. SF6 switch gear design shall be three phase, 15 kV and shall be rated 60 Hz, 600 amps minimum continuous, load break, and pad mount for outdoor at grade type applications. The switch shall be three phase with 3-way, 4-way 5-way, or 6-way circuit configurations as required and may be provided with a tie switch. Load ways shall be rated at a minimum 600 A, continuous.

n. At the University's option the switch may be equipped with an automatic transfer capability to an alternate power supply upon loss of voltage on the preferred feeder. The switch shall also be equipped with user friendly, Human-Machine Interface (HMI) that allows personnel to set and adjust parameters for operation, maintenance and configuration. The EMU PP shall be the sole judge as to whether or not this transfer shall be set up as automatic transfer, or shall be set up as manual transfer.

o. Switch housings shall be installed to provide sufficient safe access for switching and maintenance personnel.

p. Cable connection points to the Primary Select switch shall all be 600-amp dead break bushing for incoming cables and 600-amp deep well load break bushings. Bushings shall be welded, not gasketed. The switch tank shall be stainless steel with all welded construction. Self-contained switch tripping protection, when required, shall be a three phase resettable fault interrupter (RFI) field adjustable simulating E fuses. Load ways shall be either RFI or gas switch equipped in accordance with the technical requirements of the installation. An RFI is required when the load way powers a transformer through a fused air break disconnect switch. A gas switch is required when the transformer is supplied through a fuse directly and there is no air break switch installed. Power and sensing for the fault interrupter control shall be supplied by integral current transformers and not require auxiliary power or batteries.

q. The minimum Primary connection shall consist of one Primary Selective switch (three way) with two primary feeds off two associated primary pairs. Building specific usage and design considerations shall determine the appropriate number of primary switch ways, and fused sub-switches. Single phase Primary transformer connections are prohibited. The Professional, in collaboration with the EMU PP, and subject to EMU PP approval, shall establish the required Primary Selective switch configuration for each Primary Service based upon a careful evaluation of building service requirements and what is appropriate for the campus power system.

r. A primary selective switch may be used to provide primary power to as many as four sub-switches or transformers through separate load ways and fuses. The maximum number of transformers that can be powered on a single way is dependent on the acceptability of simultaneous transformer outages for the buildings or services involved. The general practice is to have no more than one building in outage for a single transformer outage.

s. Multiple buildings may be fed from one primary select switch equipped with multiple load ways.

t. The primary selective switch shall not be used as a junction box or a tie point to provide power to another building when two transformers are not in the same building or room.
u. Provide intermediate class, 10 kV, 8.4 kV MCOV (Maximum Continuous line-to-neutral Operating Voltage) polymer enclosed surge arresters on the line side of all primary select switches, and on the load side of all fused primary disconnect switches. Arresters shall be mounted inside of the switchgear compartment with the line side cables they are protecting. Arresters shall be mounted and connected in a manner to be easily disconnected for Hi potting or Hi potential testing of cables.
v. When the primary select switch is equipped with electronic fuse emulation, the chosen characteristic must provide coordination with the fused primary disconnect switch fuse.
w. Doors to primary select switches shall be key-locked with locks and cylinders complying with Corbin Russwin Access Systems cylinders with removable 7-pin cores or as specified by the EMU Lock Shop.

3. Primary Disconnect Switches
   a. Air switch handles, fuses, and elbows (if used) shall face the front of the switch enclosure.
   b. Primary disconnect air switches shall be a minimum rated 600 amp, 15 kV stored energy, load break fault interrupting switches. The switches shall be capable of being operated with the operator standing safely away from the front of the switch.
   c. Primary air break switches shall be Kirk key interlocked. Spare keys shall be provided to EMU PP. Both switches shall be capable of being closed at the same time, paralleled, provided the spare key is used. Both fuse compartment doors shall be key interlocked with the switches. The spare key shall permit opening the fuse compartment doors with the switch closed.
   d. All medium voltage switches shall be top fed with fuses (if used) below the switch. The switchblades shall pivot at the bottom (load side). Provide bussing to the top of the switch, if the switch enclosure is to be bottom feed.
   e. Doors to fused primary disconnect switches shall be key-locked with locks and cylinders complying with Corbin Russwin Access Systems cylinders with removable 7-pin cores or as specified by the EMU Lock Shop.
4. General
   a. Where applied, fuses shall be E fuses sized to provide thermal short circuit protection to the transformer and effective fault current limiting.
   b. The selected E fuse shall be applied to the Primary of the Transformer based on the size (KVA) of the transformer. The fuse chosen shall accommodate transformer in rush and the ANSI damage curve.
   c. All locks shall have manufacturer furnished covers and be provided with two sets of keys. Contractor is to provide all spare keys to the EMU PP.
   d. Switch access door handles shall have provisions for padlocks or other locking means acceptable to the EMU PP in both the open and closed positions. Front and rear compartment doors shall be hinged and have

provisions for padlocks. If a door is required to be opened to operate a switch, the door shall be hinged on the opposite side from the switch handle.

e. Padlocks for all fused primary disconnect switch handles (open and closed position), doors, and panels shall be supplied by the contractor. At Final EMU PP inspection and acceptance, contractor shall supply all locks with an approved core. Keys for these padlocks shall not to be provided to the contractor(s).

f. Electric Heaters: All fused primary disconnect air switches located outdoor or located in unheated rooms shall be equipped with electric heaters, the size of the heaters shall be 500 watts/cubicle front and rear. The power supply to the heaters shall be from the secondary side of the transformer or from a reliable, labeled, and supervised building power source.

g. Tempered viewing windows shall be provided through which it shall be possible to verify that all phases are opened or closed. All air break primary disconnect switches shall have visible contact with a 6” minimum break. Switch contact status for gas switches or vacuum switches shall be derived from positive position sensing of the primary contacts and be visually inspectable with the switch energized.

h. Insulation: All medium voltage connections, bus bars, and devices in switchgear shall be insulated. Insulated barriers shall not be allowed to come in contact with insulated conductors and shall maintain a 3” clearance. A minimum of 6” clearance shall be observed as minimum required spacing for insulated and uninsulated barriers from uninsulated conductors.

i. All primary switches shall be marked on the front by the switch handle with the feeder numbers and phases identified by 1" x 3" engraved, plastic tags screwed to front door or panel near the handle.

j. The electrical contractor shall be responsible for ensuring that a level concrete pad is provided. Electrical gear must be installed plumb and level on a concrete pad or mounted on rails embedded in a level concrete pad.

5. Switchgear - Low Voltage

a. The trip settings on the Secondary Main shall support proper coordination with the Primary Transformer fuses and any intervening devices. The Professional and Contractor shall provide design and As-Built settings and coordination information prior to Primary Service initial energization. See Division 26, for specific requirements concerning sizing of facility distribution system, arc flash, coordination study, load flow, and short circuit analysis.

b. The Secondary Mains and Secondary Bus tie breakers, where they exist, shall be fully rated, metal clad, draw-out circuit breakers. The breakers shall be electrically operated both for close and for trip. The maximum operating force required to manually open or close a switch or breaker shall not be greater than 75 pounds’ force applied to the operating handle.

c. Building Emergency generation shall be designed so that no single failure of switching equipment or controls can result in back-feeding the primary transformer and inadvertently energizing the Primary system.

33 72 33 Substation Control Houses and Associated Facilities

1. Wire and Cable
    a. Copper conductors of 98 percent conductivity shall be used unless use is restricted by Government Agencies. Aluminum conductors are prohibited.
    b. Color Coding
        i. Color coding for 480/277V and 208/120V shall be as follows:

Phase	480/277	208/120
Neutral	White or Gray	White
A	Brown	Black
B	Orange	Red
C	Yellow	Blue
Equipment Ground	Green w/Yellow stripe	Green or Bare

2. Low Voltage Cable (600 volt): For Power, Control and Protection
    a. Solid and Stranded Wire: No. 12 AWG and smaller may be solid. No. 10 and larger shall be stranded.
    b. Minimum size for all 125 V DC and 124/240 V AC branch circuits is No. 12 AWG.
    c. Use of minimum No. 14 AWG stranded for AC control wiring and auxiliary system circuits is permitted.
    d. Use No. 12 AWG or greater for 125 V DC control wiring is required.
    e. Use of No 10 AWG for all current transformer circuit wiring is required.
    f. Use No 16 AWG TSP or TSQ for instrumentation analog current loop or voltage signal.
    g. General Use insulation for 600 volt rated wire and cable shall be NEC, 600-volt class type XHHW2 with SIS allowed for power component internal control wiring. Jacketing shall be Low Smoke Zero Halogen. Nylon conductor jackets and the use of PVC for conductor insulation or jacketing are prohibited for Utility applications. All wiring between equipment, cabinets or control panels for low voltage power equipment power and control circuits shall be in conduit or tray. All control wiring between power components, cabinets and control panels shall be in jacketed color coded cables bearing suitable durable cable identifiers. Panel and component wiring shall have individual wire labels. Acceptable labeling conventions include: destination labeling, unique wire numbering.
    h. Power cables are to be terminated in EMU PP approved solid, long barrel, plated lugs. Power cables carrying high current (greater than 50 Amps) shall have two or more bolts. Crimps are to be made by a crimp tool approved by the lug manufacturer following their approved procedures. All crimps shall be six point or more. A 360 deg crimp is preferred. In instances where the equipment taking the termination does not support two or more bolts, The EMU PP shall be consulted and will determine the acceptability of the single

bolt termination. Compression type connectors are not considered acceptable for power applications.

3. Instrumentation (300-volt class and below)
    a. Use of minimum No. 16 AWG for all analog instrument circuit wiring is required.
    b. Use of manufacturers approved plenum rated cable for all communications and digitally based signal cables is required within Substation Control Houses, Power Plants, Regional Chilled Water Plants, and Associated Facilities.
4. General Requirements for Control and Instrumentation
    a. AC and DC control circuits shall not be run in the same control cable. Low level (< 50 volts) instrument cables shall not be run in conduit or in tray shared by power or 110 v ac, 125 v dc control cables.
    b. All control panel, control cabinet and switchgear wiring No. 10 AWG and smaller shall be landed on EMU PP approved terminal blocks. Stranded wire termination shall be with approved ring type solid uninsulated barrel design. No more than two wires shall be terminated on any screw type terminal point. Thread on wire nuts or split bolt connectors are prohibited. In-line control wire splices are not acceptable for new installations. Control cable butt splicing for modifications or upgrades is permitted with prior written approval of the EMU PP. Butt splices in control and instrument cable conductors shall be made with the appropriate sized Butt Connectors and insulated with electrical tape or approved heat shrink tubing with appropriate shimming.
    c. All control components are to be secured firmly to their supporting structures. Self adhesive fasteners and thermo plastic fasteners are not acceptable.
    d. All cable and wiring that is field run to control panels or equipment enclosures shall be terminated on EMU PP approved terminal blocks. Landing field wires directly on serviceable components is prohibited. Small local control stations, local starters and local instruments may be excluded from this requirement. Purchased equipment and systems may come supplied with high density terminations. Termination of stranded wire to high density terminal blocks, or to terminal blocks that employ pressure type terminal clamping, shall be via ferrule. In instances where the use of ferrules is not practical, the wires are to be stripped to allow enough exposed conductor to permit full penetration into the terminal and tinned to form a solid conductor. Terminations made to terminal blocks that employ a pressure type terminal shall have conductor insulation extend up to the block and not show exposed conductor. High density screw type terminations, where permitted, shall employ insulated barrel lugs where necessary to maintain adequate electrical clearance between adjacent terminations.
    e. All current transformer secondary circuits shall be wired through shorting type terminal blocks.

f. All control cabinet and enclosure control wiring shall be dressed neatly, bundled and laced. Heavy duty UV resistant tie-wraps are an acceptable method of lacing. Panduit may be used to organize and support control wiring in high density applications. Cable bundles shall be supported at regular intervals. Generally lacing to cabinet mounted tie points is an acceptable approach. Self-adhesive tie-downs are not acceptable.

g. Every reasonable effort shall be made to separate 480 V equipment and circuits from control wiring. 480 V components and wiring shall be mounted separate from control components and provided separate access. Control components accessed for operations or maintenance shall not share the same enclosure with the power switching components or exposed power wiring without adequate protection from accidental contact by personnel or tools.

h. In instances where low voltage (125 volts or less) control components and wiring must be housed in a common enclosure with power circuits (208 volts or above), exposed power circuit conductor surfaces shall be provided with a barrier to reduce the likelihood of accidental shock or burn.

i. The preferred configuration for the separation of power and control is to have the power cabinet separate and to the side of the control cabinet. If this is not possible, the power cabinet and components should be mounted above rather than below the control cabinet or panel. Points of interface between control and power circuits, such as control transformers, shall be located with the power equipment. Secondary (control) fuses shall be located in the control area, not on the control transformer or in the power area.

j. Adequate consideration shall be given to the operating temperature environment for temperature sensitive components. Electronics shall be mounted below the mid-plane of their housing enclosure. Sources of heat generation such as transformers and power supplies shall be mounted above, not under temperature sensitive equipment and enclosures shall be sized to operate closed without forced ventilation or the need for fans or filters. A maximum of 10 deg C temperature rise is allowed on enclosures for equipment rated 60 Deg C or less. This shall be verified by heat run test or analysis and the rise shall be measured at the top of the enclosure.

k. All control cables entering control cabinets and enclosures shall be secured by their jackets to a cabinet or enclosure support to provide a strain relief for the cable wire terminations.

l. Control wiring traversing hinges or other forms of flexible constructions shall be high stranded and shall traverse the area of bending normal to the plane of rotation so as to impart a twisting rather than a bending motion to the cable or wire bundle.

5. Conduit and Fittings

a. Conduits shall be galvanized rigid steel. The use of EMT or aluminum for conduit or fittings is strictly prohibited for power and control circuits within Substation Control Houses, Power Plants, Regional Chilled Water Plants, and Associated Facilities. Fiberglass conduit may be used in tunnels or basements where wet conditions persist, only by written approval from the

EMU PP. Fiberglass conduit is prohibited for general use or in explosion hazard areas (Class I Div II or more stringent).

b. Conduit shall be sized for the number and gauge of the wire contained. The minimum conduit size allowed is 1-inch conduit. NEC requirements for conductor count and fill shall be followed except where specifically waived by EMU PP.

c. Pull boxes shall be spaced at appropriate intervals to allow for pulling cable and not exceeding the manufacturer’s maximum pulling tension or sidewall pressures.

d. Cable minimum bend radius limits shall be observed for all cables during installation and in the final installed condition. “L” boxes shall not be used for shielded power cables, multi-conductor control or instrument cables with more than four conductors of AWG #14 wire or greater.

e. Conduits and boxes shall be routed and installed clear of traffic areas, equipment access lay-down or removal areas, mechanical equipment subject to high temperatures or movement or thermal displacement.

f. Conduit shall be supported at regular intervals in both the vertical and horizontal directions.

g. Multiple circuit power cables shall have all three phases and ground present in each conduit.

h. All rigid steel conduits shall be provided with grounding bushings.

i. Fittings for rigid steel conduit shall be galvanized steel, threaded, 2” diameter and below with insulated throats, 2.5” and above with grounding bushings. Compression fittings are permitted where use of threaded fittings are not practical, based on prior approval by the EMU PP. Setscrew type fittings are prohibited.

6. DC Battery System

a. Battery

i. A central substation battery system operating isolated from ground at a nominal 125 VDC is provided. The battery must be rated to handle worst-case switchgear and anticipated DC system loads for a minimum of 8 hours from an 80% charge condition. Battery cells shall be connected in series to achieve the desired battery terminal voltage. Battery cells shall be rated for the entire ampere-hour rating of the battery. Paralleling of cell strings is not acceptable.

ii. Batteries shall be located in clean dry and temperature controlled areas. They shall not be located within three feet of uninsulated outside walls to insure uniform cell temperatures are maintained.

b. Battery Charger

i. A dedicated Battery charger is provided that is rated to handle full dead battery charging current simultaneously with normal DC system continuous loads. The battery charger shall be rated to carry the DC system normal continuous load and recharge the battery from a 100% discharged state in a minimum of 16 hours.

ii. Battery chargers shall be located in clean dry and temperature controlled areas.
iii. The battery charger must be designed to maintain a float voltage on the battery while carrying the DC system load and be rated to support full DC system load currents for a worst case switching scenario.
iv. The battery charger must be designed to apply a programmed equalizing charge to the battery manufacturers' requirements.
v. The battery charger shall have an output breaker sized to automatically isolate the charger from the DC system battery for an internal charger fault without loss of DC system load or opening of the battery output breaker/fuse.

c. DC System
i. The DC system must be supplied with:
1. Battery voltage and current indication
2. Ground detection and alarming
3. Off-nominal voltage and alarming
4. Charger failure alarming
5. Alarming for loss of charger AC power
ii. DC system protection shall be provided either by selectively applied Fuses or Circuit breakers. Protection is designed to isolate and eliminate faults. Battery and main distribution circuit fuses and breakers shall be sized to accommodate the short circuit duty of the system. If provided with a main breaker or fuse, the battery powered DC system circuit breaker or fuse shall be rated to ride through all DC system load faults.
iii. DC system loads shall be restricted to loads required for the safe and reliable operation of the power system.
iv. The normal source of power to DC loads shall be the battery charger. In critical applications the University may require redundant battery chargers aligned in a primary and backup configuration. Switching shall be accomplished with a transfer switch or through the use of output isolation devices in each charger. An acceptable alternative to two (2) permanently installed chargers is a cross-tie to another battery system or a provision to attach a temporary charger.
v. The battery is the principal source of power. The system control, monitoring, provisions for maintenance and protection shall reflect this.
vi. DC System loads shall not require a battery tap, but shall be designed to operate at full battery voltage under normal and equalize voltage conditions. The use of low voltage control devices with series resistors is discouraged with the exception of indicating lamps that require series fusing for circuit reliability reasons.

vii. Surge or transient suppression schemes that can provide a short circuit path between battery positive and negative or from battery positive and negative to ground shall be fused.
viii. All circuit alarming and monitoring devices connected to the DC Battery System shall be protected by breaker or fuse.

7. Annunciators
   a. Local annunciators and remote annunciators shall be equipped with identical displays. All annunciators and remote annunciators shall be fully supervised, and the annunciator system shall be self-monitoring. The alarm state on the annunciators shall remain locked in until manually reset.
   b. Annunciation shall be provided to support the maintenance and operational needs of the system or equipment being monitored. Individual annunciation points shall be grouped into one of three categories:
      i. Operations (critical) - Operations alarms are alarms requiring prompt remedial corrective action.
      ii. Maintenance (non critical) - Maintenance alarms are alarms for conditions that need to be addressed in a planned or routine manner.
      iii. Status (informational) - Status alarms are alarms that provide information on the condition or change of state of equipment that might be of interest but of limited immediate concern to operations or maintenance staff.
      iv. Operations and maintenance alarms must be communicated to a manned location. Local annunciation shall be provided only in instances where the operators or maintenance personnel can be expected to require this information to be presented locally.
   c. Annunciator power shall be supplied from the plant or substation 125 VDC system. Communications relaying the annunciator activity to a remote manned location shall also be powered from the plant or substation 125 VDC system.
8. Lighting
   a. The lighting design shall provide for both task and access/egress lighting.
   b. Task lighting shall be at illumination levels appropriate for reading labels, metering, test instruments, and written instructions.
   c. Access/Egress lighting levels shall be adequate to insure that personnel gaining access to and traversing high voltage areas or leaving those areas can move safely and efficiently without concern for obstacles, tripping and bumping hazards.

33 73 00 Utility Transformers

1. General
   a. Position transformers for proper cooling, service, replacement and expansion room for future capacity addition.
   b. Outdoor transformers shall be pad mounted Envirotemp FR3 liquid filled type. Manufactures meeting this requirement:
      i. Cooper Power Systems.

c. Liquid filled pad mount and dry type transformers shall have a low loss, amorphous metal core. If other domain refined grain oriented silicon steels are used rather than amorphous metal core to achieve high performance unit then, the Manufacturer(s) must supply to the EMU PP (Project Manager) the Certified Test Reports (CTR) referencing actual data taken from the units ordered for related project and the electrical, thermal and audible noise requirements. Measurements taken must meet the requirements of NIST Standards. Insulating fluid shall be Envirotemp FR3.
    i. No-load losses for new primary service transformers shall not exceed the following:
        1. Transformer Size No-Load Losses
            a. 300 KVA 532 Watts
            b. 500 KVA 650 Watts
            c. 750 KVA 830 Watts
            d. 1,000 KVA 1,000 Watts
            e. 1,500 KVA 1,300 Watts
            f. 2,000 KVA 1,660 Watts
            g. 2,500 KVA 2,050 Watts
            h. 3,000 KVA 2,500 Watts
            i. >3,000 KVA*

            *Any proposed design for any transformer larger than 3,000 KVA must be submitted by the Professional for prior review and approval by EMU PP. Submittal must include proposed load-losses, no-load-losses, and auxiliary losses.
    ii. Note: The requirements of this section apply in whole to all new installations. When the transformer application is for a repair or replacement or an upgrade to an existing building; one or more of the above requirements may be relaxed with the written consent from EMU PP, through the Project Manager.

d. Primary winding shall be 13.2 kV 3 phase connected Delta. The secondary winding shall be connected grounded Wye. Primary winding shall be equipped with no load tap changing switch with two (2) 2½% percent taps above rated voltage, plus two (2) 2½% percent taps below rated voltage. Special applications may require different secondary connections. Any variance from the specified configuration to meet the service requirements of an application must be reviewed and approved by EMU PP.

e. The transformer coils shall be wound of electrical grade copper and continuous wound construction; aluminum windings are prohibited.
    i. Transformers applied in primary service shall be supplied with a minimum 95 kV BIL on the primary and an appropriate BIL on the secondary (10 kV for 480 V dry type, 30 kV liquid filled).

f. Buildings with critical loads such as research or main computer facilities or medical buildings shall have double ended substations with transformers sized to handle 120% of anticipated maximum normal secondary load without fan cooling or 110% of emergency loading with fan cooling whichever requires the larger self cooled rating.

g. For liquid filled transformers, provide pressure-vacuum and liquid level gauges. Provide a temperature gauge with max pointer and alarm contacts. Provide fan control on all cooling fan assisted transformers. Liquid filled Transformers shall have an over pressure relief with indicator.

h. Silicone oil transformer shall be equipped with service Viton gaskets.

i. The name of original manufacturer of the transformer shall be identified on the transformer nameplate. If the transformer has been supplied through another manufacturer or vendor, the name of that manufacturer or vendor shall also appear on the nameplate.

j. All transformer fans are to be fully guarded. Guarding must be effective for personnel protection and for protecting transformer bus and windings from loose blades and blade assemblies.

k. Intermediate class polymer enclosed surge arresters shall protect the primary of the transformer. Porcelain enclosed arrestors are not acceptable. Arresters shall be 10 kV rated, 8.4 kV MCOV (Maximum Continuous line to neutral Operating Voltage). Locate arresters as close to the transformer primary bushing with phase and ground leads as short as practical.

l. The fuses in the primary selective switches and the primary disconnect switches shall be "E" fuses sized to supply and isolate their associated transformer. If more than one transformer is fed from the same primary select switch or primary disconnect switch, then each shall be separately fused.

m. Liquid filled transformer termination enclosures shall provide adequate termination room for both primary and secondary terminations, and a reasonable level of physical separation consistent with the voltages involved.

n. Outdoor, oil filled transformers shall not be located within ten feet of building openings or fire escapes. If directly opposite a window or door, a blast wall shall be erected.

o. Work Space about transformers shall have minimum clear working space of five feet (5’0) to permit ready and safe access for preventative maintenance, emergency repair and inspection.

p. The transformer load and secondary bus voltage regulation requirements of the design, and practical fault limits of the applied switchgear, shall determine the Primary Transformer impedance. Low transformer impedance provides good voltage regulation and low flicker but increases the cost of the downstream switchgear and may also interfere with the proper coordination of Primary Transformer fuse and secondary main circuit breaker. It will also increase Arc Flash values and make in-service maintenance more difficult. High impedance can lead to excessive voltage dips on starting large motors and unacceptable levels of flicker in the lighting system. In general, for the size transformers applied as Primary Transformers and the types of loads supplied, the impedance will not need to exceed 7 % or be less than 3 % on the transformer Base KVA.

i. Acceptable Primary transformer impedances are impedance values that allow for proper coordination between Secondary Main Circuit breaker protection and standard Primary transformer protection without the need to resort to external reactors or current limiting devices, and still provide acceptable voltage regulation for power quality considerations, and acceptable arc flash values. EMU PP reserves the right to deny primary electrical service to any facility that cannot demonstrate proper coordination or fault rating of secondary switchgear. See Division 26, for specific requirements concerning sizing of facility distribution, arc flash, coordination study, load flow, and short circuit analysis.

ii. Main and Primary Distribution system Fault, Load Flow, Arc Flash, and Coordination studies are maintained centrally by EMU PP FOM. System fault levels (phase and ground fault currents, X/R ratios and coordination requirements) for individual building service connections are available to the Professional for their use in performing facility electrical systems studies, by written request to EMU Project Manager.

q. The transformer manufacturer shall provide the ANSI damage curve for the transformer.

r. Liquid filled transformers shall be designed for continuous operation at the rated KVA with a nominal 40-year life expectancy in accordance to the latest ANSI Standards. The temperature rise of these transformers shall be 55 deg C. over a 40 deg. C ambient.

s. The sound levels of the transformer shall be designed in accordance with ANSI/NEMA recommended levels.

t. Transformer enclosures shall match or exceed the NEMA class associated with the location and service chosen for the transformer. The transformer enclosure shall not rely on the addition of external enclosures, hoods or other forms of drip proofing to avoid the risk of spillage or contamination from sources known to be in the area.

u. Transformers shall be Factory tested prior to shipment in conformance with the applicable IEEE/ANSI Standards.

v. The Primary Transformer enclosure shall not be used as a place to mount metering CT's or a point of connection for cables providing a power to the secondary bus for fire pumps or other loads. Metering CT's and PT's are prohibited from being installed within the primary transformer enclosure. Power taps to serve the Fire Pump are prohibited from being installed within the primary transformer enclosure.

w. When enclosure doors are provided for access to primary transformers, the doors shall be key-locked with locks and cylinders complying with Corbin Russwin Access Systems cylinders with removable 7-pin cores or as specified by the EMU Lock Shop.

x. Indoor dry type transformer/unit substations shall not be used.

33 79 19 Utilities Grounding (Electrical)

1. General
   a. Station grounding is provided for personnel protection, reduce equipment overvoltage exposure due to lightning, and to control stray voltage caused by static charges and electrical faults. Perimeter grounds are run to reduce the likelihood of personnel experiencing injury from stray contact potential. Equipment case or enclosure grounding serves the same purpose.
   b. The 13.2 kV power system is a multiple grounded design. There are no single phase loads connected phase-to-ground. All major primary power circuits are provided with grounds that run continuously back to the power source. Loads on the system are connected phase to phase. Feeders that traverse the campus to supply building loads are shielded cables with their shields grounded at all splice and termination points.
   c. Grounding of major power components serves the purpose of conducting equipment fault currents safely away with very little increase in local contact potential.
2. Practices:
   a. Design and installation of grounds shall follow IEEE 142 Recommended Practice for Grounding of Industrial and Commercial Power Systems, most current edition.
   b. Submitted designs and Contract Documents shall show ground systems, protective conduit sizes, and relative locations. Specifications and Drawings shall include detailed requirements of the grounding system.
   c. Grounding systems applied shall at a minimum conform to applicable requirements of the National Electric Safety Code (NESC) for medium voltage installations (13.2 and 5 kV) and the NEC for low voltage installations. Where NEC requirements conflict with this Standard, the Professional and Contractor shall review the conflict with EMU PP.
   d. All connections in the primary grounding system shall be clamped, exothermic welded, Cadweld® or equivalent. Individual grounding rods connected to the grounding system shall have a measured ground resistance of ten ohms (10 Ω) or less. This measurement may be made by any of the commonly accepted methods for measuring ground rod resistance to earth. Grounding for power equipment power circuit neutral grounding shall be no greater than one tenth ohm (0.1 Ω) measured from the neutral bus to the local ground bus or building structural steel. Primary circuit (13.2 kV system) grounding shall conform to the NESC for potential rise during ground fault. Ground resistance shall be no greater than three ohms (3 Ω) for cabinet and control circuit grounds. Only copper to copper ground connections may be clamped or bolted. All other terminations shall be Cad welded.
3. Service Ground
   a. Grounding rods shall be a minimum size of 5/8" x 10' copper clad steel and shall not be placed in back-fill.
   b. Interconnection of the service ground, system neutral, and equipment ground conductors shall be made within the service equipment.

c. All feeder circuit conduits shall include a 4/0 grounding conductor. The equipment enclosure (transformer case, etc.) shall not be used as a grounding path. Two independent paths to a common ground point or ground reference shall ground all high voltage apparatus enclosures.
d. Grounding conductors shall be 600-volt insulated installed in rigid PVC or rigid galvanized conduit along with the circuit phase conductors. Main and Primary service transformers shall have a bonded secondary neutral that connects to an established ground grid, or grounding system. Cabinet grounds shall be 4/0 solid bare copper and run to an existing grounding system, an adjacent grounded cabinet or, in the absence of an established grounding system, to grounded building steel.
e. Equipment case grounding shall be via 4/0 bare copper solid conductor. It shall be attached to the grounded equipment via Cadweld® or bolted connection where required to facilitate removal for equipment maintenance. It shall be bonded to an established ground grid, ground system, or grounded building steel.

33 79 93 Site Lightning Protection

1. Lightning Protection
   a. Buildings and structures shall have lightning protection. This protection shall be designed to effectively protect not only the building but associated electrical structures and major electrical power equipment including transformers and cables.
   b. Protection may be afforded through the selective placement of air terminals on the buildings or structures or by shielding through the use of aerial ground wires placed to afford a 30 deg cone of protection.
   c. Protection from lightning induced voltage transients and large changes in local ground potential shall be afforded by properly applied lightning arrestors, spark gaps, and surge suppressors.
   d. Design and installation shall follow NFPA 780 Standard for the Installation of Lightning Protection Systems, most current edition.
   e. See Division 26, for requirements for building/structure lightning protection.

End of Division 33 – Utilities