UNIVERSITY OF TORONTO | Facilities & Services

# ELECTRICAL DESIGN STANDARD

Revision 01

Last Updated 2022-07-15

# TABLE OF CONTENTS

# TABLE OF FIGURES



# LIST OF TABLES

# INTRODUCTION

## 1. General

1. The University of Toronto's (the "university") Building Design Standards apply to new construction, renovation, renewal, and maintenance projects on the St. George campus.
2. The Building Design Standards are intended to be a reference and a minimum baseline upon which bid, and construction documents are to be prepared by the Design Team within the constraints of the university's construction budget. These Standards are NOT contract technical specifications and shall not be used as such.
3. The Building Design Standards do not relieve the Design Team of its professional responsibility, due diligence, duty of care or legal liability for any bid and construction documents that are created from these Standards.
4. The university makes no guarantee, warranty, or representation in any way (express or implied) with respect to the accuracy, suitability, reliability, usability, legality, or completeness of the Building Design Standards for a specific project or contract.
5. When reviewing a project or initiative against the design standards, the Design Team shall check Compliant (C), Not Compliant (NC), or Not Applicable (NA) for all sections and submit it prior to, or with the Schematic Design (SD) for the university's review. The checklist is in Appendix C – Electrical Design Standards - Checklist.
6. The university constructs a wide range of facilities and recognizes that specific projects may require an approach or have requirements that are not adequately addressed by the Building Design Standards. In addition, technology, products, and regulatory requirements may change over time. In these instances, the university expects the Design Team to propose alternatives or deviations from the Building Design Standards. The Design Team must submit a written request to propose an alternative or deviation to the university for review. All proposed alternatives require sufficient explanation and supporting material. In the absence of any proposed alternatives or deviations from the Building Design Standards, bid and construction documents will be reviewed strictly for conformance with the Building Design Standards.

7. The Building Design Standards will continue to evolve to incorporate innovation, new concepts, feedback, and practical applications without any prior notice. At the start of each project, the Design Team will acknowledge the current version of the university's standards intended to be implemented.

8. The Building Design Standards are numbered based on the Construction Specifications Institute (CSI) 2020 MasterFormat to enhance the speed and quality of communication. Where a division is not listed in this document, there is no current university standard. The Design Team may choose to add sections that are not included in our design standard to their specifications, provided it is not in conflict with this standard.

9. The university welcomes proposals to revise the Building Design Standards. All feedback shall be sent to: standard-feedback@utoronto.ca

10. All requests for Electrical Services, including Power and Shutdown Requests, shall be submitted online through the 'Request for Electrical Services' (RES) portal (https://res.fs.utoronto.ca), which requires UTORid authentication. Design Team and Contractors shall work with the project manager (PM) to complete these submissions.

## 2. Project Life Cycle and Design Reviews

1. The following are the stages of conception and design of a typical Level 2 and Level 3 capital project at the University of Toronto. Each stage will be defined, and the electrical review requirements will be identified. Other projects that are not included within the scope of the Capital Project Policy may have lesser requirements. Two common examples of these types of projects are those that do not meet the criteria of Level 1, and Deferred Maintenance projects. These projects typically have fewer stages in the project life cycle, but generally fall into the following three categories: Intent, Design, and Tender/Execution.
2. A 'Request for Power' application must be submitted for any new load connections to the university electrical system, regardless of whether the net load is increasing or not. This process is used to determine the available capacity requested for the specific application or project. It will also assist in determining where this capacity resides in the system. Should the request exceed the total capacity available, the project would be required to upgrade the electrical system to allow for the new connection. Likewise, should there be sufficient capacity in the system, but where the changes would violate the requirements of this design standard, the project would be responsible for upgrading the electrical system to allow for the new connection.
3. Submitting a Power Request that only asks for available capacity is not acceptable. At a minimum, an estimate must be provided for evaluation.
4. If engineering stamped drawings are required for the project, the university shall be contacted to provide reference drawings. Depending on the project's stage and scope, CAD or PDF copies will be provided. Project stages from initial Design onward shall include marked-up reference drawings, showing the scope of work within the electrical system.

### *2.1 Pre-Design*

The Pre-Design stages of the project shall be used as input to the consultant-lead design initiated per section 2.2 Schematic Design.

#### 2.1.1 Project Planning Report (PPR)

The initial proposal for new projects that define early-stage requirements from an end-user perspective. At this stage the utilities division will provide the infrastructure requirements that may be required. Facilities & Services (F&S) Utilities shall provide reference drawings at this stage.
Upon completion of PPR, the review process may require additional design or loading calculations, based on the intent and scope of the project.

#### 2.1.2 Feasibility Study

A power request shall be submitted during the feasibility study to determine if the existing electrical infrastructure can accommodate projected new loading requirements. Loading calculations shall be broken down, as a minimum, to total building load, mechanical load, and emergency system load.
Feasibility studies may not be available for all projects depending on scope, complexity and other constraints.

### *2.2 Schematic Design (SD)*

During the Schematic Design phase, an electrical design brief shall be developed to support an initial set of electrical drawings and refined power request(s) for the project. These documents shall be submitted for a detailed review by F&S before proceeding to the next stage of development.

### *2.3 Design Development (DD)*

During the Design Development phases, the design brief, drawings, electrical specifications, and power requests are iteratively updated with each stage, following a further review by F&S. There may be multiple stages of design development review with different percentages of completion. Projects of complex scope may require more reviews than others and it is always encouraged to submit the DD design stages for review with F&S. Approval of 90% DD or greater by F&S is required before proceeding to the next stage of development.

## *2.4 Construction Documents (CD)*

Prior to issuing documents for tender and/or construction, F&S shall review and approve the drawings and specifications to be issued. Projects of complex scope may require more reviews than others and it is always encouraged to submit the CD design stages for review with F&S. Approval of 90% CD or greater by F&S is required before proceeding to the next stage of development.

## *2.5 Issued for Tender Documents (IFT)*

Reviews for IFT documents are only required if there are any significant changes to the electrical distribution system from the approved CD set. Significant changes may include the following:

- New loads added to the design (including moving existing project loads to new locations)
- Increased/Decreased ampacity and/or kVA of equipment
- Change of equipment type (e.g., Withdrawable to Fix Mount breakers, liquid filled to dry type transformers, EMT to Teck cable, etc.)
- Electrical/mechanical room layout changes for electrical equipment
- Electrical equipment location changes (incl. panelboards, splitters, etc..) to a different room

In these instances, a revised power request is required.

## *2.6 Issued for Construction Documents (IFC)*

Reviews for IFC documents are only required if there are any significant changes to the electrical distribution system from the approved IFT set. Significant changes may include the following:

- New loads added to the design (including moving existing project loads to new locations)
- Increased/Decreased ampacity and/or kVA of equipment

- Change of equipment type (e.g., Withdrawable to Fix Mount breakers, liquid filled to dry type transformers, EMT to Teck cable, etc.)
- Electrical/mechanical room layout changes for electrical equipment
- Electrical equipment location changes (incl. panelboards, splitters, etc..) to a different room

In these instances, a revised power request is required for the sole purpose of reviewing the change for compliance with the electrical design standard.

### *2.7 Requests for Information (RFI) or Contemplated Change Notice (CCN) Impacting Electrical Systems*

Any changes or deviations from the IFC documents requiring an RFI or CCN shall be sent to F&S for review. F&S does not answer the RFI, they simply review the response by the Design Team on the project.

Approvals for CCN documents are only required if there are any significant changes to the electrical distribution system from the approved IFC set. Significant changes may include the following:

- New loads added to the design (including moving existing project loads to new locations)
- Increased/Decreased ampacity and/or kVA of equipment
- Change of equipment type (e.g., Withdrawable to Fix Mount breakers, liquid filled to dry type transformers, EMT to Teck cable, etc.)
- Electrical/mechanical room layout changes for electrical equipment
- Electrical equipment location changes (incl. panelboards, splitters, etc..) to a different room

In these instances, a revised power request is required for the sole purpose of reviewing the change for compliance with the electrical design standard.

### *2.8 Requirements during project stages:*

Required documentation during different project stages are listed in Table 1.

*Table 1 – Requirements during project stages*

| Stages of the project | Report | Electrical Design Brief | Electrical Drawings | Electrical Specification | Power Request |
|---|---|---|---|---|---|
| Pre-Design (PPR) | X $^{\gamma}$ | | | | |
| Pre-Design (Feasibility Study) | X $^{\gamma}$ | | | | X |
| SD | | X | X | | X |
| Initial DD (Typically 30%) | | X | X | X $^{\beta}$ | X |
| Subsequent DD Submissions | | X $^{\alpha}$ | X $^{\alpha}$ | X $^{\beta}$ | X $^{\alpha}$ |
| Final DD (90% - 100%) | | X $^{\alpha}$ | X $^{\alpha}$ | X $^{\beta}$ | X $^{\alpha}$ |
| Initial CD (<90%) | | | X | X | X $^{\alpha}$ |
| Final CD (90% - 100%) | | | X $^{\alpha}$ | X $^{\alpha}$ | X $^{\alpha}$ |
| IFT | | | X $^{\alpha}$ | X $^{\alpha}$ | X $^{\alpha}$ |
| IFC | | | X $^{\alpha}$ | X $^{\alpha}$ | X $^{\alpha}$ |
| RFI/CCN | | | X $^{\alpha}$ | | X $^{\alpha}$ |

$^{\alpha}$ Required only if there is an electrical change from previous project stage

$^{\beta}$ Electrical specification may be incomplete but should have relevant sections outlined at a minimum

$^{\gamma}$ These documents will be provided by the university to be used as input to the consultant-lead design initiated per section 2.2 – Schematic Design.

## 2.9 Other (Non-Traditional) Projects

Projects where the traditional gates of design are not required may have lesser requirements than stated above in Project Life Cycle and Design Reviews. The stages of such projects may differ, but generally fall into the following three categories: Intent, Design, and Tender/Execution.

### 2.9.1 Power Request

A power request is required for each project and shall be submitted at or before the design stage. Table 2 lists the supporting documents required for Power Request:

*Table 2 – Requirements for Power Request Supporting Documentation*

| Scope | Design Brief | Engineer Stamped Drawings α | Revised Panel Schedule | Load Calculations β | Arc Flash / Coordination Study δ |
|---|---|---|---|---|---|
| Two or less branch circuits to be added/moved, or total connected load less than or equal to 2.5kW | | | X$^{\gamma}$ | X | |
| Greater than two branch circuits to be added/moved, or total connected load greater than 2.5kW | X | X$^{1}$ | X | X | |
| Panelboard replacement in-situ due to obsolescence or to increase circuit capacity | X | X$^{1}$ | X | X | |
| Panelboard replacement or relocation (within the same room) | X | X$^{2}$ | X | X | X |
| Addition of new panelboard | X | X$^{3}$ | X | X | X |
| Addition of new transformer | X | X$^{3}$ | X | X | X |
| Addition of new transfer switch | X | X$^{3}$ | X | X | X |

α Stamped drawing requirements:

1. Updated Floorplans with circuiting information
2. Requirement 1 plus and partial single line showing point of connection (panel designation) to electrical distribution system
3. Requirement 2 plus modifications to reference drawings provided by utilities

β Load calculation shall be added to the panel schedule as per section 26 06 20 Schedules for Low-Voltage Electrical Distribution.

γ Panel schedule shall be submitted at the Shutdown Request stage, should the panelboard or circuits not be known at the Power Request Stage.

δ Refer to section 26 05 73 Power System Studies for specific requirements.

## 2.10 Project Closeout (all projects)

Project closeout consists of three key items, to be submitted to the university. Failure to do so will result in the project not being signed off as complete and ready for takeover.

### 2.10.1 Updating as-built data

Project shall provide one hard copy of complete electrical as-built drawings on ANSI size E paper, plus an electronic copy of as-built drawings in CAD format (.dwg files) as part of the closeout documentation package. The package shall also contain a PDF copy of each CAD drawing. Panelboard schedules shall also be included as part of the electronic as-built documentation package provided. Refer to the university's templates for schedules available on the Facilities & Services website: https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/

### 2.10.2 Commissioning Test Results (Baseline data)

All equipment testing data from factory and site shall be provided to the university upon project closeout. Refer to specific equipment sections for testing requirements. All commissioning test results shall be submitted in electronic format as part of the closeout documentation package.

### 2.10.3 Approvals from Authorities Having Jurisdiction

Documentation for compliance by various authorities having jurisdiction (ESA, TSSA, etc.) shall be provided at the closeout.

### 2.10.4 Co-ordination of Operation and Maintenance Material

One hard copy of the operating and maintenance manuals, plus an electronic, text searchable, PDF copy shall be provided as part of the closeout documentation package

# 26 00 00 – ELECTRICAL

## General Design Considerations

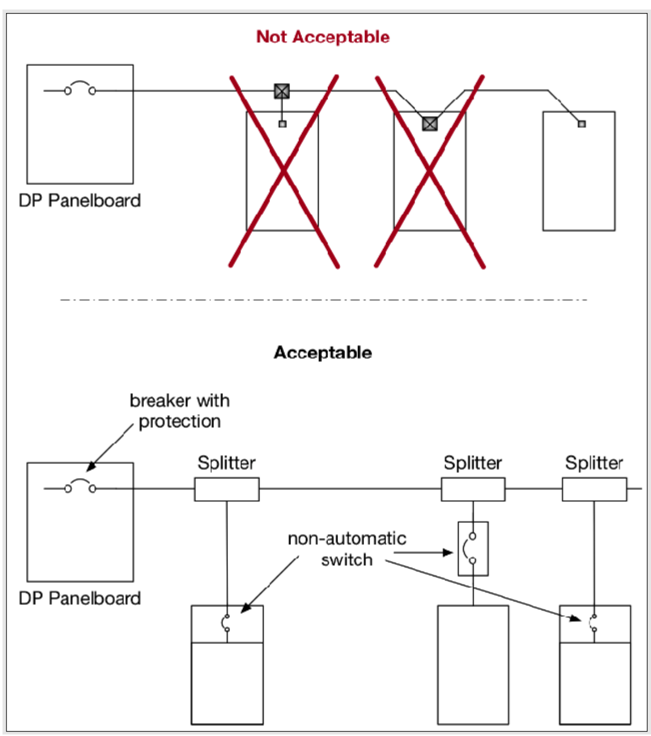
1. All conductors shall be copper. This includes all feeders, regardless of ampacity, transformers windings, and branch circuits.
2. No splices shall be permitted on any low voltage feeders.
3. Electrical rooms shall be used for the exclusive use of electrical equipment. Electrical rooms shall not be shared with telecom/IT equipment, etc.
4. The following voltage and phasing configurations are acceptable at the university:
   - 120/208V, 3 phase, 4 wire
   - 600/347V, 3 phase, 4 wire
   - 600V, 3 phase, 3 wire
   - 120/240V, single phase, 3 wire, for modification of existing installations only
   - 416/240V, 3 phase, 4 wire, for modification of existing installations only
5. All equipment (including end-user loads) shall be rated for -15% to +10% nominal available voltages (120/208V, 600V) (e.g., a piece of equipment connected to a standard receptacle shall be capable of operating within a range of 102V to 132V)
6. All motors greater that ½ HP shall be 600V, 3 phase, 3 wire.
7. Any electrical panelboards or cables older than 25 years old shall be replaced with new or proven to be serviceable and maintainable for another 25 years. To be proven serviceable, a letter from the OEM shall be provided stating parts are currently available and will be supported for another 25 years.
8. Any feeder(s) compliant with clause 4 above and being reused or re-purposed shall be proven with an Insulation Resistance test with NETA MTS as the threshold for passing.
9. All Arc Flash and Short Circuit studies shall be performed using ETAP software (version 19 or higher) and updated electrical models shall be made available to the university at project closeout.
10. All new electrical distribution equipment (including branch circuit panelboards) shall be provided with arc flash labels, based on short circuit, coordination, and arc flash study required as a project

deliverable. The arc flash labels shall detail arc and shock hazards as per CSA-Z462. Final label configuration shall be approved by the university before installation.

11. If equipment is of metal-clad construction, at a minimum, each barriered section shall have its own arc flash label. (e.g., a double-ended switchboard with a main/tie/main configuration shall minimally have a label on each main breaker compartment, on the tie-breaker compartment, and each of the two load section compartments).
12. High ampacity power distribution within buildings greater than or equal to 800A, shall be by the means of bus duct, with the following exceptions:
    - buildings with less than five floors may use cable conductors
    - buildings with the total number of floors between five and seven must prove significant economic installation cost benefits to use cable conductors
13. Cable conductor installations, if used, shall have strain relief provided every four floors as a minimum requirement.
14. Protection equipment rated higher than 40 cal/cm2 shall be remotely operable and/or withdraw- able from a safe area (outside of the arc flash boundary) or outside of the electrical room/substation.
15. 120/208V branch circuit panelboards shall have incident energies of 4 cal/cm2 or less.
16. All 600V panelboards shall be installed in locked electrical rooms. Lockable disconnecting means may only be permitted in labs or mechanical rooms where the equipment they serve is installed.
17. All panelboards and splitters with incident energies more than 1.2 cal/cm2 shall be in locked electrical rooms.
18. Panelboards and splitters with incident energies less or equal to 1.2 cal/cm2 may be installed in labs provided that the loads they serve are contained within that space.
19. Panelboards are not permitted in hallways or general public spaces such as offices, lounges, lobbies, etc.
20. Branch circuit panelboards shall only service loads on the floor in which it is installed.
21. No room shall be serviced by more than one branch circuit panelboard type (RP, LP, PP). For example, a lab or classroom may be fed by a maximum of 3 branch panelboards, provided each one is of a different type.

22. All branch circuit panelboards shall be located no further than 23m (75 ft) from the loads. This is to ensure that a voltage drop of no greater than 3% is seen between the panelboard and the load. Provide key plan indicating area covered by the panelboard.
23. Each panelboard shall have a single means of electrical protection.
24. Individual panelboard isolation means shall be provided when retrofitting multiple panelboards sourced from a feed-through or split bolt configuration. Each panelboard shall have an accessible external point of isolation consisting of a non-automatic switch with no protection settings or be a 'service entrance' panelboard with a non-automatic switch with no protection settings.  Refer to Figure 1 for further illustration.
25. Feed-through panelboards or daisy-chaining is not permitted. In retrofit situations where a single panel that is part of feedthrough/daisy-chain installation is being replaced, the new panelboard shall have individual isolation or protection means. Individual isolation or protection means on the downstream panelboards of the feedthrough/daisy-chain installation shall be considered, if deemed appropriate by the university. Refer to Figure 1 for further illustration.

*Figure 1 – Multiple Panelboard Fed from Single Protection*



26. Splitters feeding branch circuit panels shall be installed in accessible locations. The following locations are not considered accessible:
    - Ceiling Spaces
    - Drywall partitions (regardless of any attempts to make accessible through access hatches)
    - Locations over 2m above floor level, when outside an electrical or mechanical room
    - Crawl spaces
    - Confined spaces
27. Power transformer shall be installed in appropriate locations. The following locations are not considered appropriate:
    - Ceiling Spaces
    - Crawl spaces
    - Confined spaces
    - Steam tunnels or other mechanical service tunnels
28. Power transformers may be installed in labs if they serve specific equipment within the lab. The transformers shall remain accessible for maintenance. If high-wall or ceiling mounted, the transformer shall be directly accessible by use of a ladder.
29. Refurbished electrical equipment (breakers, MCC buckets, etc.) shall be tested to the latest PEARL/ANSI EERS standard and the certificate shall be provided to the university before installation.

## 26 05 00 Common Work Results for Electrical

1. Electrical room shall not be shared with telecommunication/IT equipment. Electrical rooms shall not be shared with Caretaking or Janitorial spaces. Any room containing a panelboard with an incident energy greater than 1.2 cal/cm2 shall be considered an electrical room.
2. Door sweeps shall be installed on the bottom of the doors of all substation and electrical rooms.

## 26 05 05 Selective Demolition for Electrical

1. All electrical equipment deemed for demolition or decommissioning shall be removed back to the source of supply. This includes all conduit, wire, junction/pull boxes, etc. It is unacceptable to ‘abandon’ and make safe, regardless of site conditions.

2. Knockout(s) shall be filled when removing circuits from any panelboard or splitter.

# 26 05 13 High-Voltage Cables

## 26 05 13.16 High-Voltage, Single- and Multi-Conductor Cables

1. **Materials**

    .1 Cable conductors shall be provided with three 750 kcmil conductors with a concentric neutral. Insulation shall be TR-XLPE. Multiconductor cable shall have a 133% insulation level. Cables to be supplied in continuous lengths, free from kinks and defects. Any cable sections that are terminated on both ends within the same building shall be armoured Teck cable.

.2 Splices shall be performed by using an approved splicing kit or by a qualified and trained specialist. All splices, regardless of construction, shall be warranted for a minimum of 5 years.

.3 Cables in HV Substations, manholes, or cable chambers shall be properly identified with permanent labels indicating voltage and loop section (e.g., 13.8kV Loop 6B). Where the cables or trays are visible inside buildings, this permanent labeling shall be applied every 10m.

2. **Installation**

.1 All high voltage cables shall be installed in underground duct banks when outside of buildings. Installation of cables in tunnels and steam areas is not acceptable.

.2 Duct banks shall be installed with 50% spare capacity, or four empty ducts, whichever is greater. Ducts carrying fibreoptic cables shall be counted as ‘used’ for this calculation.

## *26 05 19 Low-Voltage Electrical Power Conductors and Cables*

### 26 05 19.01 Wires and Cables

1. All wire and cable ampacity shall be sized as per the 75°C rating in the OESC.
2. Armoured cables exposed to the exterior climate/weather shall be suitable for UV exposure.
3. Use of AC90 cables (BX):

.1 For areas with drywall partitions, type AC90 armoured cable shall only be used:

- for fixture down drops above accessible drop ceilings with a maximum down drop not greater than 6m (20 feet) from the ceiling junction box to fixture. Finished cable length shall be the shortest distance permissible between junction box and fixture.
- for single and multi-branch circuit installations within wall space, provided the length of armoured cable does not exceed 3m; or
- for open office areas using system furniture and partitions where underfloor wiring is impractical.

.2 Cables shall be neatly installed, coordinated, and aligned with adjacent surfaces. Cables shall be independently and appropriately supported and shall not rest on ceiling tiles or supports.

.3 The extent of AC90 cables (BX) usage shall be communicated with the university before finalizing the design.

4. SPC90 Cable (combination power + control cable) shall follow the same requirements as AC90 cable.
5. Mineral Insulated (MI) cables shall be terminated with moisture proof connectors.
6. Based on circuit rating, size conductors for a 2% maximum voltage drop from the branch circuit panel to the farthest outlet.
7. Termination lugs for feeder cables shall be of the compression type. Mechanical lugs are not acceptable for feeders.

## *26 05 23 Control-Voltage Electrical Power Cables*

Refer to section *26 05 19.01 Wires and Cables*.

### 26 05 33.13 Conduit for Electrical Systems

1. Unless specified otherwise, all conduits inside buildings shall be electrical metallic tubing (EMT).
2. Conduits exposed to the exterior climate/weather shall be rated for UV exposure and be sealed against water ingress. When penetrating buildings, the conduit shall be filled to prevent water ingress.
3. Conduits subject to mechanical injury, or in any hazardous locations or where required by Code, shall be threaded galvanized rigid conduit (GRC).
4. Motor feeder drops shall be in a threaded galvanized rigid conduit. A maximum of 1m (39 in) may be of armoured flexible liquid-tight conduit for final connection to motor termination enclosure.
5. Expansion fittings shall be installed in conduits crossing expansion joints.
6. Connectors for EMT conduit shall be steel, compression type, and nylon insulated. Steel set screw type is acceptable.

7. All EMT connectors and couplings shall be rain tight.
8. Fish wires shall be installed in all empty conduits, including fire alarm, telephone, and computer conduits.
9. A separate insulated ground wire shall be installed in all conduits, except computer, telephone/control conduits.
10. Joints in conduits installed underground, in the concrete slab on grade, or in a concrete duct bank shall be made completely watertight.
11. Minimum concrete thickness over or around a conduit in a concrete slab shall be 75mm (3 in).
12. Conduits for computer systems shall comply with the university's Communications Infrastructure Specifications, Standards and Practices Standards.

## *26 05 43 Underground Ducts and Raceways for Electrical Systems*

### 26 05 43.01 Ductbanks and Cable Chambers

1. Ductbanks shall consist of conduit(s) encased in concrete. Bell end couplings shall be used to terminate the ducts.
2. The ducts shall be CSA certified, PVC Type 2 with an internal diameter of 150mm (6 in), and shall include the duct manufacturer's watertight couplings, duct bends, and duct supports.
3. Adjacent duct couplings shall be staggered by at least 200mm (8 in) with duct support within 600mm (24 in) on either side of the furthest couplings.
4. Duct bends shall be paralleled sweeping type, with a minimum bending radius of the inside bends sized to suit the recommended bending radius of the largest cable that will be installed in the duct bank.
5. The ducts shall be laid with a minimum spacing of 200mm (8 in) centre to centre, horizontally and vertically, or as the duct manufacturer's duct supports for concrete encasement dictate.
6. The duct run shall be reinforced with a minimum 13mm (½ in) diameter PVC coated steel reinforcing rods laid longitudinally on top, bottom, and sides of the duct bank and secured to the duct manufacturer's duct supports. Where reinforcing rod overlap occurs between duct supports, they shall be overlapped a minimum of 300mm (12

in) and tied together.

7. The ducts shall be encased with a minimum 2,000 psi concrete with a minimum cover of 75mm (3 in) on all sides.
8. To prevent any displacement of the duct structure during pouring, the duct structure shall be braced down every 3m (10 ft), and the concrete shall be deflected down alongside the ducts to the bottom and up through the duct assembly.
9. The duct bank elevations shall be arranged to slope downwards with a 2% slope towards the designation termination points in the system such that water cannot accumulate anywhere along the length of the duct bank. Termination points shall be equipped with a means of removing accumulated water (e.g., pump, drain).
10. The ducts entering buildings, substations, or manholes shall be bell-shaped and sealed.
11. When completed, the ducts shall be cleaned. Cleaning shall include a properly sized steel brush mandrel pulled through each duct, followed by swabbing to ensure the removal of all dirt and other debris that could damage cable insulation. A test piece of the largest cable to be installed in the duct bank shall be pulled through each duct to ensure no cable insulation damage will occur. When each duct has been proven, the ends shall be plugged.
12. One continuous length of 13mm (½ in) diameter polyethylene rope shall be installed in each duct to facilitate the installation of the cables in the duct.
13. Cable Chamber:
    .1 Cable chamber cover shall be minimum 840 mm (33 in) in diameter

    .2 Cable chamber shall be minimum 1.8m x 2.4m (6 ft x 8 ft)

    .3 Cable chamber shall be provided with means of active or passive water removal.

    .4 Cable chamber floor shall be sloped at 1% into a sump pit.

    .5 Provide cable pulling eyes cast into the walls. Cable pulling eyes shall be located opposite to ductbanks entering cable chamber.

    .6 Bottom of cable ductbanks entering cable chamber shall be at least 600mm (2 ft) from cable chamber floor.

    .7 Cables inside cable chamber shall be properly supported by cable racks.

    .8 Height of cable chamber shall be minimum 2m (78 in)

## *26 05 53 Identification for Electrical Systems*

### 26 05 53.01 Colour Codes for electrical equipment

1. All electrical equipment shall be ANSI 61 grey unless otherwise specified in this standard, or equivalent. Other colours shall be pre-approved by the university before ordering. Submit colour samples with colour code numbers for approval.

### 26 05 53.02 Colour Codes for electrical receptacles

1. Red = Emergency
2. Blue = UPS

### 26 05 53.03 Colour Codes for Junction Box Cover Plates on Various Systems

1. All junction box cover plates on various systems shall be colour-coded according to Table 3 – Colour Codes for Junction Boxes below.

*Table 3 – Colour Codes for Junction Boxes*

| System | Colour Code | Written Code |
|---|---|---|
| 120/208V Normal lighting and power | White | |
| 120/208V Emergency power | White / Red | |
| 120/208V UPS | White / Blue | |
| 240/416V Normal lighting and power | Pink | |
| 240/416V Emergency power | Pink / Red | |
| 240/416V UPS | Pink / Blue | |
| 347/600V Normal lighting and power | Yellow | |
| 347/600V Emergency power | Yellow / Red | |
| 347/600V UPS | Yellow / Blue | |
| Fire Alarm | Red | |
| Telephone | Orange | |
| Cable TV | Purple | |
| Data | Brown | |
| Control HVAC | Green | |
| Control L.V. Lighting | Green / Black | |

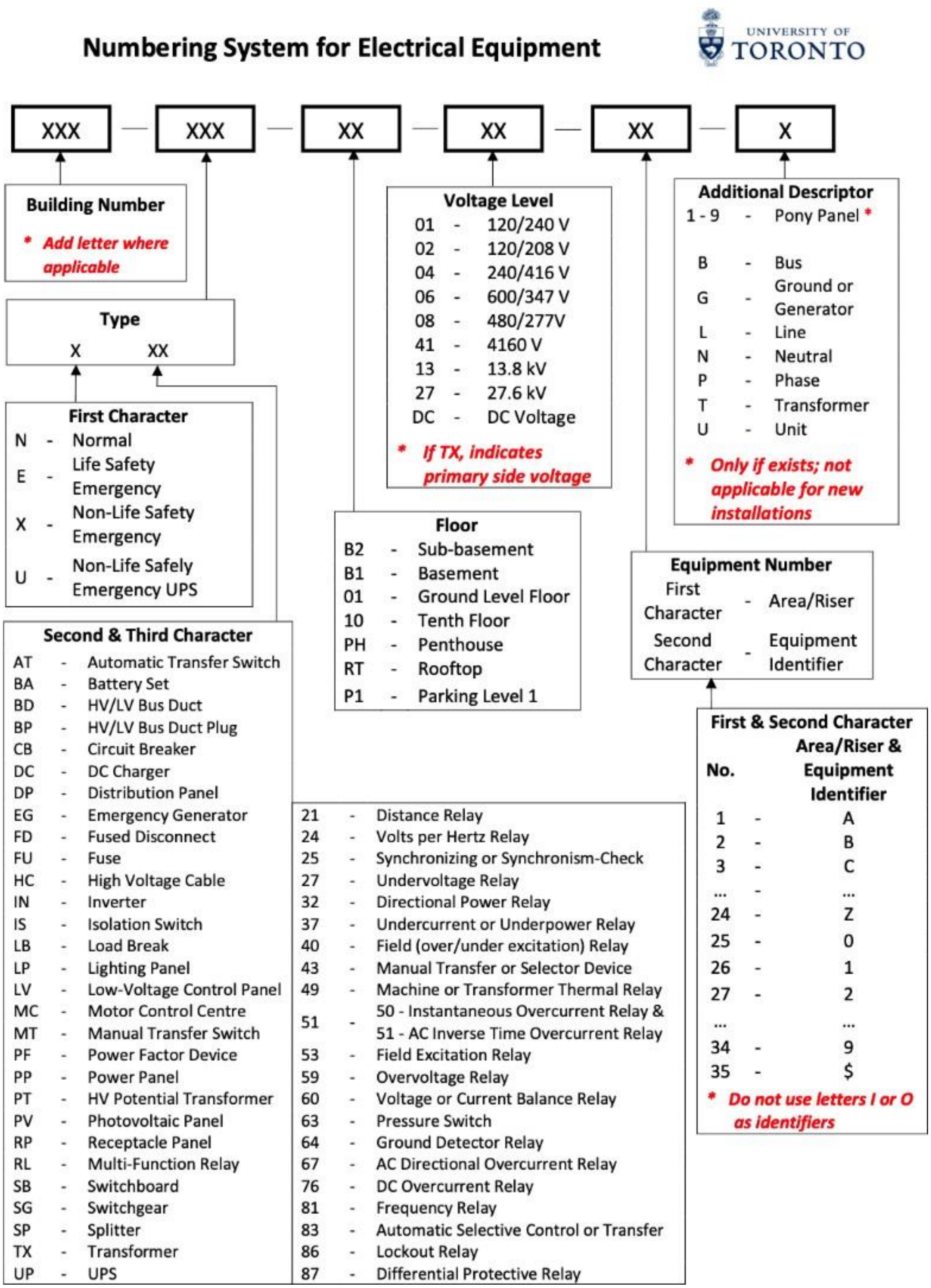
| | | |
|---|---|---|
| Security | Grey | |
| Surveillance, CCTV | Grey / Black | |
| Public Address | | “PA” |
| Audio Visual | | “AV” |
| Paging | | “PG” |
| Intercom | | “ICOM” |
| Note: Light colours shall be chosen for Green, Blue, Brown, and Grey. | | |

### 26 05 53.04 Identification for Electrical Systems and Accessories

1. Electrical equipment and accessories shall have identifiers that will consist of Lamacoid(s) permanently affixed to the equipment.
2. Lamacoid shall have white text with height as indicated below:
   - Size A: 25mm
   - Size B: 13mm
   - Size C: 6mm
3. When identifying pieces of electrical equipment, except for breakers/switches, the Primary Lamacoid of size A shall indicate the equipment identifier tag as per Figure 2 – Numbering System for Electrical Equipment below. The Secondary Lamacoid of size C shall be installed immediately below the Primary and indicate the source of supply identifier tag and room number. For any subsequent requirements, refer to the specific equipment sections within this document.
4. Lamacoid background colour shall be black except in the following cases:
   - Green for emergency, both life, and non-life safety
   - Blue for UPS
5. The numbering system for electrical equipment shall follow the guidelines outlined in Figure 2 – Numbering System for Electrical Equipment.
   Panelboard Example:
      - Primary Lamacoid: 155-NSB-03-02-AA

- Secondary Lamacoid: Fed from 155-NSG-B1-02-AA in room B05

*Figure 2 – Numbering System for Electrical Equipment*



## *26 05 73 Power System Studies*

1. The university has standardized ETAP® for carrying out all power system studies on campus.
2. A model shall be created, and electrical study shall be carried out for the addition of any of the following pieces of equipment:
   - Panelboards
   - Transformers
   - Switchgear
   - Transfer Switches
   - Generators
   - Inverter / DC Systems
3. Version 19 or greater of ETAP shall be used and shall be backward compatible with version 19.
4. For studies where the new equipment is downstream of the local utility, the university shall provide the existing model for any required changes to perform the studies.
5. The electronic files for the electrical model for all reports and studies shall be provided to the university at the completion of the project as part of the closeout documents.
6. All electrical system studies shall consider the following three scenarios:
   - Utility maximum contribution
   - Utility minimum contribution
   - Building on Emergency supply

### 26 05 73.13 Short-Circuit Studies

1. Short circuit studies shall be conducted to identify the withstand and interrupting capability of electrical equipment; and determine the bolted fault currents (Ibf) required for arc flash calculations.
2. Short circuit calculations shall be calculated at all points in the electrical system down to each 120/208V branch panel, regardless of the kVA rating of the upstream transformer.

3. All three-phase induction motors greater than 40HP shall be modeled and contribute to the available short circuit current in the model. If the motor to be modeled is connected to a VFD, it shall be modeled as such but will still allow full fault contribution as if it were connected directly to the line voltage. This is to assume the worst case should the VFD be in bypass mode.
4. Inverters rated 10kW or above and connected to DC systems shall be modeled. Their short circuit let-through values shall be modeled as per manufacturer specifications.

### 26 05 73.16 Coordination Studies

1. Coordination studies shall be undertaken for each coordination path down to the main isolation point for each branch circuit panel.
2. The Time Current Curves (TCCs) shall show coordination between each level of protection for a bolted fault downstream of the main isolation point for the worst-case branch circuit panel.

### 26 05 73.19 Arc-Flash Hazard Analysis

1. Arc Flash studies shall be performed for all electrical equipment where there may be a potential for exposed live electrical work (transformers, motor disconnects, VFDs, etc.)
2. Where the nominal voltage is less than 240V and the calculated Ibf is less than or equal to 2000A, the label shall show an incident energy of 1.2 cal/cm2. Otherwise, the calculation shall be performed in accordance with IEEE 1584-2018.
3. The following considerations shall be considered for each panelboard or switchgear. Using global defaults in the model is not acceptable:
   - Electrode configurations (VCB, VCBB, HCB, VOA, HOA) for each applicable cell or instance. For example, an MCC enclosure may contain both VCB and VCBB instances and the worst case shall be calculated.
   - Number of separately barriered sections (such as the main breaker, withdrawable breakers, etc.).
   - Enclosure dimensions.
   - Conductor distance to worker.

### 26 05 73.23 Load Flow Studies

1. Load flow studies shall be conducted using ETAP and shall take as input the electrical reference model, which shall be provided by the university. Any changes to the model to accommodate the requirements of the load flow study shall be the responsibility of the party performing the study.
2. Load flow studies are not typically performed at the university, and the scope of the study will be defined by the requirements at the time of the request. The university shall approve the final scope of the study.

### 26 05 73.26 Stability Studies

1. Stability studies are not typically performed at the university, and the scope of the study will be defined by the requirements at the time of the request. The university shall approve the final scope of the study.

### 26 05 73.29 Power Quality - Analysis Studies

1. Power Quality studies may be required at certain locations within the university's distribution system. The purpose of these studies is typically in response to a problem.
2. All electrical systems at the University of Toronto shall comply with the requirements set out in IEEE Standard 519 "Recommended Practice and Requirements for Harmonic Control in Electric Power Systems".
3. Should a new project or piece of equipment be responsible for creating conditions on the electrical system that fall outside the boundaries outlined in IEEE 519, the equipment shall either be removed from the system, or be fitted with harmonic mitigating filters.
4. Power quality reports is required for any individual nonlinear load 50kW or greater as part of the commissioning process to ensure equipment operates in accordance with its published data for all loading points (e.g., a large VFD chiller with harmonic filters).
5. Should a study investigate potential transients on the systems, the default triggers for waveform capture and logging shall be those outlined in the ITIC Curve (formerly the CEBMA Curve). Any additional setpoints based on published equipment

recommendations may be added to the ITIC curve.

### *26 05 83 Wiring Connections*

1. No splices shall be installed on any low voltage feeders.
2. Terminals and terminations not designed for multiple connections shall only have a single current-carrying conductor landed.
3. All devices will be terminated with the recommended torque as specified by the manufacturer. Consult with the university if no torque specification is available.

## 26 06 00 Schedules for Electrical

### *26 06 10 Schedules for High Voltage Electrical Distribution*

1. Schedule shall be summarized in a single line diagram, showing physical circuit layout, including loads, spares and spaces.
2. Breaker frame sizes and trip settings shall be included on single line diagram(s).
3. High Voltage electrical distribution equipment shall have breakers/switches permanently labelled with a primary Lamacoid of size A indicating equipment identifier tag for breaker/switch, and a secondary Lamacoid of size B indicating load equipment identifier tag, and room number. e.g.:
   - Primary Lamacoid: 068A-NCB-B1-13-AA
   - Secondary Lamacoid: Feeds 068A-NTX-B1-13-AA in Rm. 006

### *26 06 20 Schedules for Low-Voltage Electrical Distribution*

1. All low voltage electrical distribution equipment shall have schedules that comply with the university's templates available on the Facilities & Services website: [https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/](https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/).
2. Where existing panel schedules are not currently available in electronic format, the electrical contractor shall be responsible for entering both existing and new circuit loads into the template, with existing in red and new in black. Loading information on existing loads is not required.
3. Electronic file for schedules in Excel format shall be provided to the university as part of the close-out documentation.

### 26 06 20.13 Electrical Switchboard Schedule

1. Schedule shall be summarized in a single line diagram, showing physical circuit layout, including loads, spares, and spaces.
2. Breaker frame sizes and trip settings shall be included on single line diagram(s).
3. Low Voltage electrical distribution equipment shall have breakers permanently labelled with a primary Lamacoid of size B indicating equipment identifier tag for breaker, and a secondary Lamacoid of size C indicating load equipment identifier tag, and room number, e.g.:
   - Primary Lamacoid: 135-NCB-P1-06-AA
   - Secondary Lamacoid: Feeds 134-NDP-02-06-AA in Rm. 214

### 26 06 20.16 Electrical Panelboard Schedule

1. A printed version of schedules shall be installed inside the panel on the backside of the door. Changes to the panel schedule shall be indicated on a newly printed schedule from template with revision date for each change. Handwritten or marked up copy of existing schedule is not permitted.

### 26 06 20.19 Electrical Motor-Control Center Schedule

1. A printed version of schedules shall be installed on the equipment, inside a weatherproof sleeve.

### 26 06 20.26 Wiring Device Schedule

1. Electronic file and physical copy shall be provided to the university as part of the close-out documentation.

## *26 06 30 Schedules for Facility Electrical Power Generating and Storing Equipment*

1. Electronic file and physical copy shall be provided to the university as part of the close-out documentation.

## *26 06 40 Schedules for Electrical Protection Systems*

1. Electronic file and physical copy shall be provided to the university as part of the close-out documentation.

### *26 06 50 Schedules for Lighting*

1. All low voltage electrical distribution equipment shall have schedules that comply with the university's templates available on the Facilities & Services website: https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/.
2. Where existing panel schedules are not currently available in electronic format, the electrical contractor shall be responsible for entering both existing and new circuit loads into the template, with existing in red and new in black. Loading information on existing loads is not required.
3. Electronic file for schedules shall be provided to the university as part of the close-out documentation.

#### 26 06 50.13 Lighting Panelboard Schedule

1. Refer to section *26 06 20.16 Electrical Panelboard Schedule*.

## 26 08 00 Testing, Commissioning, and Training on Electrical Systems

#### 26 08 00.01 Testing and Adjustments

1. All testing results and outcomes referred to in this section shall be documented and returned to the university as part of the closeout process by the commissioning agent. Test documentation shall be provided to the university upon request before delivery of project closeout and acceptance.

#### 26 08 00.02 Factory Acceptance Testing (FAT)

1. The contractor shall be fiscally responsible for costs associated with the university representation at FATs, when in continental North America. Up to two representatives from the university shall be planned for at each FAT. Four weeks' notice shall be provided.
2. The following guidelines to be used for cost estimation:
    - Travel by air shall be limited to economy flights and shall contain no more than 1 connecting flights
    - Per diems of $60 per person for a full day and $30 for a half day.
    - Kilometers in a personal vehicle shall be reimbursed at a rate of 0.56$/km
    - Rental vehicles of a standard sized sedan from an airport rental facility

3. **High Voltage Transformers over 225kVA:** Before shipment to the university, the transformer shall be tested at the factory under actual load conditions for performance and proper functioning of parts. The Design Team shall ensure that the following tests are carried out as per ANSI/IEEE C57.12.90. (Type tests are not acceptable):
   .1 AC Hipot Withstand
   .2 Ratio Test (On all taps and windings configurations)
   .3 Percent Impedance test used to stamp nameplate
   .4 Winding resistance on all taps
   .5 Impulse Testing (2 full wave, 2 reduced wave, one chopped wave)
   .6 Sound level
   .7 Temperature Rise Test (Heat Run)
   .8 Polarity
   .9 For liquid filled types, Transformer liquid analysis in accordance with ASTM standards following the FAT
4. **High Voltage Switchgear:** Before shipment to the university, the switchgear shall be tested at the factory. The Design Team shall ensure that the following tests are carried out for witnessing.
   .1 Switchgear assembly:
   - AC Hipot Withstand for each phase
   - Confirmation of meter and relay functionality and any lockouts
   - Confirmation of any Kirk Key Interlocks
   - Racking in/out breakers and swapping of breakers into different cells
   - Manual Open and Close Operation of all breakers, if equipped
   - Electrical Open and Close Operation of all breakers

   .2 High Voltage Circuit Breakers as per IEEE C37.09
   - Contact Resistance

- Insulation resistance (across phases and across open breaker)
- Timing Test

5. **Low Voltage Switchgear:** Before shipment to the university, the switchgear shall be tested at the factory. The Design Team shall ensure that the following tests are carried out for witnessing:
   - Insulation resistance test phase to phase and phase to ground, for all phases
   - Confirmation of meter functionality
   - Confirmation of any Kirk Key Interlocks
   - Racking in/out breakers and swapping of breakers into different cells
   - Manual Open and Close Operation of all breakers, if equipped
   - Electrical Open and Close Operation of all breakers
   - Testing of breakers with trip units via secondary current injection, or suitable test kit
   - Primary Current injection testing for all applicable settings (LSIG)
6. **Generators:** Before shipment to the university, the generator shall be tested at the factory under actual load conditions for performance and proper functioning of component parts. The Design Team shall ensure that the following tests are carried out. (Type tests are not acceptable):

   .1 Safety shutdowns

   .2 Transient testing, with the following minimum testing load steps, measuring generator frequency and voltage response. Transient oscillography plots shall be provided for each of the following tests, showing voltage and frequency response:

   - 0-100%
   - 20-100%
   - 40-100%
   - 60-100%
   - 80-100%
   - 100-80%

- 100-60%
- 100-40%
- 100-20%
- 100-0%
- 50-100%
- 100-50%

.3 Four hour run test in accordance with CSA C282, monitoring all essential parameters.

7. **Withdrawable High Voltage Circuit Breakers:** Withdrawable high voltage breakers shall be bench tested prior to delivery to the university with the following tests performed:
   - Contact resistance
   - Insulation resistance across all phases and from each phase to frame
   - Manual Open and Close Operation, if equipped
   - Electrical Open and Close Operation
   - Timing Test as per IEEE C37.09
8. **Withdrawable Low Voltage Circuit Breakers:** Withdrawable low voltage breakers shall be bench tested prior to delivery to the university with the following tests performed:
   - Contact resistance
   - Insulation resistance across all phases and from each phase to frame
   - Manual Open and Close Operation
   - Electrical Open and Close Operation
   - Primary Current injection testing for all applicable settings (LSIG)

### 26 08 00.03 Commissioning Testing

1. The university's representatives shall have the right to witness all commissioning tests and shall be given 14 days' notice.
2. IR scanning shall be completed for all equipment under normal operating conditions

prior to handover.

3. **High Voltage Cables:**

.1 All high voltage cables shall be tested in accordance with the most recent version of NETA ATS. In addition, each cable shall undergo a high voltage withstand test and a dielectric response withstand test. All testings shall be in accordance with IEEE Standard 400.2 and use a 0.1 Hz sinusoidal waveform.

.2 Testing to include complete cable installation, including terminations. Each phase of the cable shall be tested separately. It is not appropriate to test all cables at once unless the test equipment is designed to do so.

.3 This standard recognizes that there may be a need to re-use or make modifications to existing HV cable sections. In these instances, the withstand test requirements are subject to a reduced voltage potential as per Table 4 – Withstand Testing Requirements below.

.4 When re-using or making modifications to PILC cables, the university shall be contacted for guidance on commissioning tests.

*Table 4 – Withstand Testing Requirements*

| Acceptance Withstand Test (New Cable) | Re-Use / Modification Withstand Test (Existing Cable) | Dielectric Response Test |
|---|---|---|
| 21kV rms / 27kV peak for 60 minutes | 16kV rms / 22kV peak for 60 minutes | VLF Tan Delta (VLF-TD) testing with measurements at 0.5Uo$^{\alpha}$, 1Uo, and 1.5Uo for 15 minutes per test while collecting information. |
| $^{\alpha}$ Uo: Rated RMS to Ground Voltage, for 15kV Cable, this is 8.66kV | | |

.5 DC high voltage withstand tests are only appropriate on PILC cables. Since this standard only allows for TR-XLPE insulated cables, it is expected that no DC withstand tests will be done on new HV cables.

4. **Low Voltage Cables**

.1 All LV cables shall be insulation resistance tested for 1 minute at 1000VDC, following installation, before final terminations. Each phase shall be tested separately.

5. **High Voltage Transformers over 225 kVA**

.1 Prior to energizing or commissioning the transformer on site, it shall be 'acceptance tested' in its final position. Testing requirements for acceptance prior to energization shall comply with NETA ATS for the following at a minimum:

- Grounding points
- Fan Operation (if applicable)
- Ratio (On all taps and at service winding configuration)
- Polarity
- Insulation resistance (H-L, H-L&G, L-H&G)
- Winding resistance (On all taps and at service winding configuration)

.2 Dry type transformers shall be de-energized and cleaned by a qualified electrical worker prior to final handover. A final insulation test shall be performed as per the latest NETA ATS.

.3 For liquid filled types, transformer liquid analysis shall be performed in accordance with ASTM standards following initial energization.

.4 Prior to handover, all transformer alarm and status points shall be tested back to their respective local and remote devices (BAS/SCADA)

6. **Switchgear**

.1 Prior to energizing or commissioning the switchgear on site:

.1 Final cleaning of the equipment shall be done, including bus work, power/control compartments, and complete exterior surfaces.

.2 Factory-made connections shall be checked for mechanical security, and electrical continuity.

.3 Test all mechanical and electrical components for proper operation and function in accordance with the manufacturer's recommendations, including but not limited to the following:

- Perform insulation resistance measurements on bus, phase-to-phase and phase- to-ground with all switches and breakers in the normal operating position, and all PTs / Arrestors disconnected.

- Manually open and close each breaker and switch, adjusting main contact alignment and wiping action in accordance with manufacturer's recommendation. Measure contact resistance with a low resistance ohmmeter of the breakers and switches in the closed position.
- Measure control circuit insulation resistance to ground.
- Test all protective relays and overcurrent devices, and verify the settings comply with the co-ordination study. Testing to include all tripping circuits to the end protective device.
- Inspect all current transformers and relays for correct polarity connections and installation of jumpers in unused current transformer circuits. Confirm there is but one grounding point on each CT secondary circuit.
- Verify mechanical interlocks, simulating potential operating conditions (e.g., closing tie breaker on double ended board with both mains closed).
- Check that all ground connections have been securely made.
- Confirm any switchgear accessories operate as intended (breaker hoists, breaker rails, racking tools, etc.)

.2 Once energized:

.1 Phasing shall be performed across any breaker or switch fed from two alternate sources. (e.g., HV loop breakers, HV/LV tie breakers)

.2 Voltage indicators (Martindale) if present, shall be verified for proper operation.

7. **Emergency Generators**

.1 Prior to connecting the generator on site, it shall be ‘acceptance tested’ in its final position with all environmental controls enabled and functional in the automatic mode of operation. Testing requirements for acceptance prior to energization are the following:

- Safety shutdowns

- Four hour run test in accordance with CSA C282, monitoring all essential parameters
- Functional test of emergency system through isolation of normal supply to transfer switch, confirming automatic startup and load acceptance.

.2 Prior to handover, all generator alarm and status points shall be tested back to their respective local and remote devices (BAS/SCADA)

.3 Prior to handover, all generators equipped with fuel tank(s) shall be filled to the full level as defined by the associated fuel gauge(s). Tank(s) to include both day-tank and main- tank.

.4 Generator shall be clear of all alarms and in normal operating mode prior to handover.

8. **Automatic Transfer Switches**

.1 Perform functional testing of transfer switch, by isolating normal supply, confirming transfer, and reinstating normal supply to transfer back to main source. During this time the following shall be measured:

- Time delay normal to emergency (TDNE)
- Time delay emergency to normal (TDEN)
- Time delay neutral (TDN), if applicable
- Generator cool down timer, if applicable

.2 All ATS I/O shall be tested back to the source (e.g., meters, elevator controls, etc.).

.3 All load side meters to be commissioned with appropriate settings (IP address, CT/PT ratio, etc.) and I/O points to be tested and integrated into EMRS.

.4 Provide all control logic, drawings, sequence of events, settings, and passwords in electronic format, upon closeout.

9. **Charging Systems for Electrical Substations**

.1 Prior to battery installation, a measurement of each cell's open circuit voltage shall be measured and recorded. If any of the cell values deviate by more than 0.1V from the published open circuit voltage, it shall not be used.

.2 Prior to battery installation, a measurement of each cell's internal ohmic resistance shall be measured and recorded (with a BITE3 tester or equivalent). If any individual cell's measurement deviates more than 50% from the average in the string, the university shall be notified, and the battery installation shall stop until further direction is provided by the university.

.3 Confirm DC polarity markings and connections before connecting supply to the charger loads. To ensure correct polarity, it is recommended to connect battery cells in small increments and to measure the voltage as additional cells are added until nominal voltage is achieved.

.4 Apply individual cell/module numbers in sequence beginning with number one at the most positive end of the battery string.

.5 Interconnection resistance from post to post shall be measured and recorded to determine the adequacy of initial installation and as a reference for future maintenance.

.6 Perform function testing on at least one load, but perform test on all loads, if feasible.

.7 All Charger I/O shall be function tested back to the source and recorded (e.g., BAS, local annunciator, etc.). Function tests shall mimic the actual alarm condition as best as possible. The following is a sample of the types of tests that shall be performed:

  .1 Function test of ground fault shall be accomplished by introducing a ground onto the system.

  .2 Function testing of battery symmetry shall be accomplished by moving the measuring conductor to an off-centre location on the string.

  .3 Function testing of Hi and Lo output voltages shall be accomplished by changing the alarm setpoint in the charger.

.8 If a single cell is being replaced, it shall be individually charged to float voltage prior to its entry into the string.

.9 When performing the initial charge on a string, the manufacturer's instructions regarding the applied voltage, charge current limit, and duration shall be respected. Battery voltage, charge current, and temperature shall be recorded, including date, time, initial charge voltage and current. These measurements shall be repeated every 5 minutes until final steady state values have been achieved.

.10 After the temperature of the installation has stabilized (less than 1˚C change in 2 hours), the following measurements shall be recorded and compared against battery manufacturer's recommendations:

.1 AC ripple current and voltage as per IEEE 1188.

.2 Battery temperatures (at negative posts) and ambient temperature (with doors shut) as per IEEE 1188.

.11 Provide all control logic, drawings, sequence of events, settings, and passwords in electronic format, upon closeout.

10. **Bus Ducts**

.1 All bus ducts shall be insulation resistance tested for 1 minute at 1000VDC, following installation.

.2 Any bus plugs installed shall be verified for electrical continuity with a low resistance ohmmeter.

11. **Withdrawable High Voltage Breakers**

.1 Withdrawable high voltage breakers shall be site tested prior to energization with the following tests performed:

- Contact resistance
- Insulation resistance across all phases and from each phase to grounded frame
- Manual Open and Close Operation in test position, if equipped
- Electrical Open and Close Operation in test position
- Secondary Current injection testing for all applicable settings for which any protection relays are programmed
- Timing Test as per IEEE C37.09, indicating total trip time, including relay latency

12. **Withdrawable Low Voltage Breakers**

.1 Withdrawable low voltage breakers shall be site tested prior to energization with the following tests performed:

- Contact resistance

- Insulation resistance across all phases and from each phase to grounded frame
- Manual Open and Close Operation in test position
- Electrical Open and Close Operation in test position
- Secondary Current injection testing for all applicable settings (LSIG) and verification settings comply with the co-ordination study

13. **Protective Relays**

.1 Verify and test the protection settings comply with the co-ordination study prior to initial energization.

.2 Test each protective element individually to physical relay trip output. (e.g., 51A, 51B, 51C, 50A, 50B, etc.). Schemes requiring remote tripping shall be fully function tested as part of this requirement (e.g., 87/87L functions while injecting locally and remotely)

.3 Test each physical relay trip output at least once to the end protective device (e.g., circuit breaker, lockout relay, etc.).

.4 Provide all control logic, drawings, sequence of events, settings, and passwords in electronic format, upon closeout.

14. **Electrical Meters**

.1 Verify the settings are consistent with instrumentation transformer nameplates.

.2 Confirm all I/O values are programmed correctly and wired to the correct terminals.

.3 Program assigned IP/Gateway/Subnet addresses and confirm remote network connection.

.4 Confirm voltage and current phasor relationships by verifying with an independent piece of test equipment.

15. **Equipment with Harmonic mitigating filters.**

.1 Measurement and verification of Total Demand Distortion (TDD) and Total Harmonic Distortion (THD) against published equipment data at the following loading points:

- 10%
- 25%
- 50%
- 75%
- 100%

### 26 08 00.04 Training and Demonstration of Electrical Systems

1. Training shall be provided on all aspects relating to new electrical equipment. The following shall be included in the training session:
    - System overview referencing main single line drawing
    - Operating Voltages and short circuit levels
    - Arc flash levels and associated boundaries and incident energies
    - List of distribution level equipment (upstream of branch circuit panels)
2. Hands on demonstrations shall be scheduled for the following tasks:
    - Racking in and out a withdrawable breaker of each type/make into test and fully withdrawn positions
    - Removal of a racked-out breaker (of each type/make) from cell using hoists/lifts
    - Starting and stopping the generator remotely and locally
    - Operating transfer switches, remotely and locally
    - Set points for fans on transformers, and proof of operation at those set points

# 26 10 00 – HIGH-VOLTAGE ELECTRICAL DISTRIBUTION

## 26 11 00 Substations and Switching Stations

1. Where the term substation is used in this section, it is intended to refer to both substations and switching stations.
2. All substations shall be located at grade level or above unless the condition in clause 3 below is met.
3. Substations may be below grade, provided there is at least one level below within the building.
4. Substations must remain fully accessible from street level allowing for equipment routing and maintenance.
5. Substations shall be equipped with temperature and humidity control.
6. Substation egress shall comply with the following requirements:
   .1 There shall be a minimum of two exit doors for egress located at opposite ends of the substation. The two exit doors must be at least three-quarters (3/4) of the length of the longest diagonal distance of the room from each other.

   .2 One exit door shall egress directly outside if the substation is located at grade. Otherwise, it shall egress to a designated fire escape stairwell.

   .3 Access provisions, which may include one of the two egress doors, shall be provided for the removal of the largest piece of substation equipment.

   .4 At least one of the substation doors shall be equipped with electronic access control, compliant with the University of Toronto's "Security and Access Control System Specification".

   .5 Egress doors shall be fitted with panic type hardware on the substation side and fitted with a keyed cylinder and handle on the opposite side of the door. Type of cylinder and keying, and type of panic hardware will be specified by the university. Access to Electrical room shall only be permitted through public spaces or mechanical rooms.
7. All substations shall comply with the following climate control requirements during peak loading periods, for all degree days:
   - Temperature shall be regulated to maintain an ambient of 25 $^{O}$C +/- 2 $^{O}$C
   - Humidity shall not exceed 40% RH

- Substation shall maintain positive pressure

8. Air filters for substation ventilation shall be readily accessible for routine maintenance/replacement
9. Climate controls shall be:
   - located within the substation,
   - integrated into the BAS as a separate zone, and
   - capable of local override.
10. Ventilation for the substation shall be dedicated to the substation only.
11. Housekeeping pads shall be installed for all high and low voltage switchgear, station battery supply, and any other floor mounted equipment. Switchgear manufacturer's floor channels, if equipped, shall be embedded into the switchgear concrete pads. Height of the concrete pads shall not be less than 100mm (4 in) above finished substation floor.
12. Adequate substation drainage shall be provided.
    - Floor drains shall be designed with capacity to prevent flooding in the substation.
13. Drains shall be provided with backflow preventer(s). A single backflow preventer may be installed should multiple drains connect to a single discharge pipe. Backflow preventer(s) shall be located no further downstream than where the pipe exits from the substation or the next drainpipe connection. Should breakers within the switchgear require floor level withdrawal (roll-out type) from the cell, ramps shall be provided. Ramps may be removable when not required and constructed such that they meet the minimum height requirement of the housekeeping pads. Ramps shall be rated for the weight loading of the breaker and be sloped to allow for clearance of entire breaker from the cell.
14. The substation concrete floors, housekeeping pads, and permanent ramps shall be completely sealed and finished with an epoxy based high wear non-conductive concrete finish. A minimum of two coats is required. Concrete floor finish shall be non-slip.
15. The substation ceiling height (floor to ceiling) shall be no less than 4m (13 ft). Ceiling height shall otherwise be designed for high voltage cable entry into the top of the high voltage switchgear using recommended minimum bending radii.

16. Clearances between housekeeping pads shall be installed a minimum distance from one another to allow unfettered operation of all auxiliary equipment/tools necessary to operate and maintain the electrical equipment.
17. Housekeeping pads shall not interfere with the operation of the auxiliary equipment/tools. (e.g., A breaker lifting hoist shall be capable of removing any breaker for which it is designed in the substation).
18. Substations shall have a dedicated normal and a dedicated emergency branch circuit panelboard. Panelboards shall be NEMA 3R or equivalent, at a minimum, 120/208 $V_{AC}$ 3 phase, four-wire, and supplied with a breaker sized not less than 100A.
19. The normal supply panelboard shall be fed directly from the main LV distribution, located in the substation, and used exclusively for substation non-emergency lighting and receptacles.
20. The emergency supply panelboard shall be fed from the emergency distribution system and shall contain the following loads:
    - Station Battery's Secondary Input power source
    - Substation exhaust fan(s) (30A 3 Phase maximum)
    - Substation emergency lighting (minimum 2 circuits)
    - Receptacles used for substation battery emergency lights
    - Substation exit signs
    - Substation perimeter receptacles (minimum 2 circuits)
    - HV/LV Circuit Breaker Testing Equipment (if required)
    - Sump Pump (30A 3 Phase maximum)
21. Lighting shall provide a minimum lighting level of 550 Lux (51 Ft-c) at 1m (39 in) from floor level throughout the room.
22. Placement of lighting fixtures shall allow easy access for lamp replacement, accessible only by a stepladder and not requiring standing on nor leaning on or over electrical equipment.
23. One-half of the substation lighting fixtures shall be fed from the substation normal supply panelboard, and one-half fed from the substation emergency supply panelboard.

24. Lighting shall be controlled from illuminated light switches located on the substation latch side of each exit door, within 250mm (10 in) of the door frame.
25. Substation lighting shall not be integrated with any lighting control systems and manually switched.
26. If a substation has a dedicated stairwell for access to, or egress from the area, lighting for the stairwell shall be fed from the substation emergency supply panelboard.
27. Wall-mounted rechargeable battery operated, and self-contained emergency lighting units shall be installed within the substation. These units shall be plugged into emergency receptacles and spaced to illuminate all aisle ways and exits.
28. Receptacles shall be spaced no more than 3.5m (12 ft) apart along the substation wall. One-half of the total outlets shall be fed from the substation normal supply panelboard, and the other half from the substation emergency supply panelboard.
29. A minimum of two circuits per supply panelboard (normal and emergency) shall be used to feed all receptacles in the substation. A minimum of four service receptacles is therefore required in each substation.
30. No adjacent receptacles shall be fed from the same circuit.
31. Conduit and cable connectors into all equipment in the substation shall be rain-tight.
32. All cable trays in the substation shall be constructed of non-ferrous material and be appropriately grounded.
33. Substation perimeter grounding bus shall be constructed of rigid copper bus and shall not be made of cable.
34. All substations containing HV, or LV breakers shall be equipped with a control panel for the operation and indication of the breakers in the substation. The control panel shall be equipped with a lockable Local/Remote selector switch, whose status shall be tied to the substation RTU. The control panel shall only function for controlling breakers when the selector switch is in the 'Local' position. When in the 'Local' position, the RTU shall re-alarm to the SCADA system every hour to ensure it is not left in that position.
35. The control panel's location in the substation shall allow for the maximum distance between the control panel and the greatest incident energy breaker in the substation. Ideally, it shall be placed such that it is outside the arc flash boundary of all breakers in the substation.

36. All substations shall contain a single line diagram and layout drawing, each framed in wood and installed under glass with a UV inhibitor. The drawing shall be plotted on ANSI Size E paper and permanently affixed to the substation wall where the bottom of the frame shall be at the height of
1.5m (5 ft) from the floor.
37. All equipment shall be placed plumb and square with respect to substation walls and housekeeping pads.
38. No conduits, pipes, ducts, or other services shall pass through the substation unless terminating on equipment inside the substation or supplying a service to the substation.
39. A minimum 25mm (1in) thick G1S fire retardant plywood backboard shall be installed on a wall of the substation for mounting all tools necessary for the safe maintenance and testing of the electrical equipment within. The board shall be primed and painted with a minimum of two coats of high- quality enamel paint, grey.
40. Additional space to accommodate future equipment shall be discussed with the university for each substation.

### *26 11 10 Substation Communication Architecture*

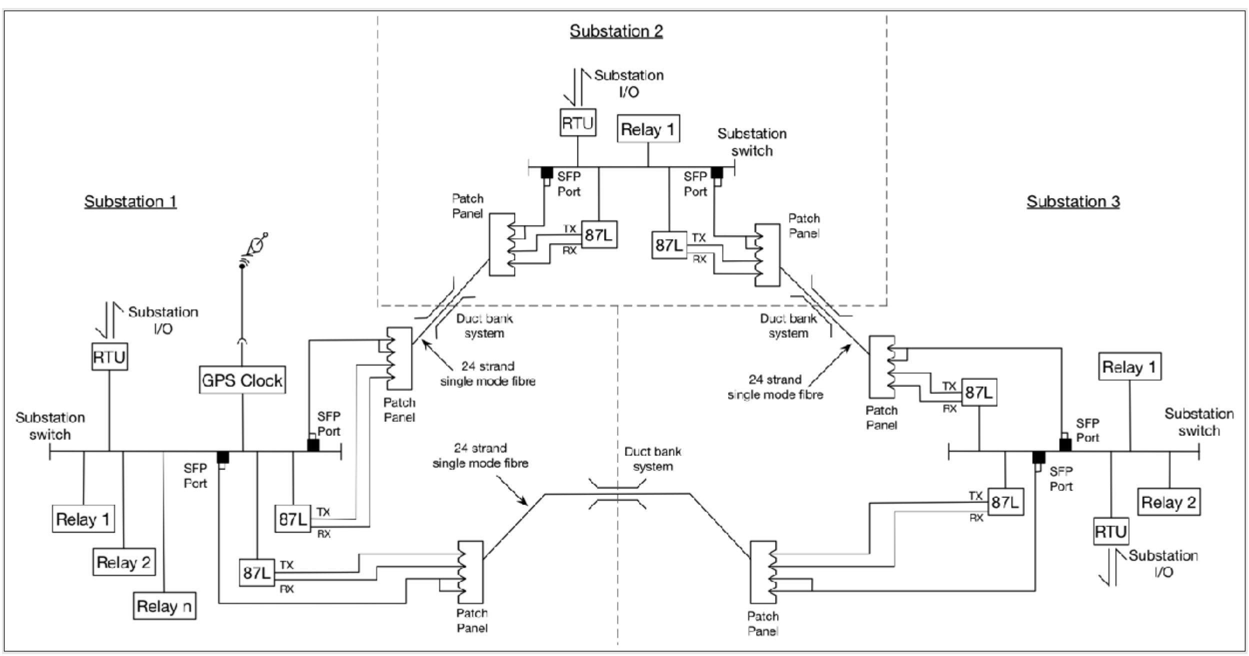
1. Substation communication for Supervisory Control and Data Acquisition (SCADA) shall be based on Gigabit Ethernet using 1000BASE-T for copper networks and 1000BASE-SX/LX for fibreoptic networks.
2. Communication between substations shall be achieved by routing a 24-strand single mode (OS2) fibreoptic cable through the HV duct bank system and shall travel in the same manner as the HV loop sections (e.g., HV cable section 2D travelling between substations shall have a separate fibreoptic cable run along it within the duct bank system, in a separate duct from the HV cables).
3. Each end of the fibreoptic cable shall be terminated within the substation on a wall mounted patch panel. The patch panel shall have all 24 strands terminated, regardless of how many are used.
4. Two of the fibreoptic patch panel ports shall be used for the line differential protection relay communication.
5. Two of the fibreoptic patch panel ports shall be used for connection to the substation switch, via an SFP port.

6. Each substation switch shall be Gigabit switch with:
    - A minimum of four SFP ports for fibreoptic connections, and
    - Sufficient RJ45 Ports to accommodate the number of protection relays, RTUs, and other devices required on the network, plus 25% spare capacity.
7. All HV protection relays shall connect directly to the substation switch by means of a CAT6 cable
8. RTUs required for supervision/control shall be connected directly to the substation switch by means of a CAT6 cable. RTU hard wired signals shall be those which are not accessible through the DNP3 or IEC 61850 protocols. See *Table 5 – Substation Network Required Signals* for a list of signals required to be routed to the substation network.
    - For signals required on both the BAS system (*Appendix A – Table of Signals for BAS Remote Monitoring*), the signals shall be wired to the RTU first and relayed to the BAS from the RTU via a hardwired connection.
9. Satellite clocks required for time synchronization hall be connected directly to the substation switch by means of a CAT6 cable
10. LV equipment that supports DNP3 or IEC 61850 protocols shall be connected directly to the substation switch by means of a CAT6 cable
11. No CAT6 cables or other cables carrying a routable protocol connected to the substation switch shall exit the substation, except for the fibreoptic cables travelling in the duct bank system.
12. See Figure 3 – Substation Communications for details on substation communication architecture.

*Table 5 – Substation Network Required Signals*

| Signals Required on the Substation Network |
|---|
| Substation sump float switch |
| Transformer temperatures and alarms (BAS Remote Monitoring: **High Voltage Liquid Filled Transformers** & **High Voltage Dry-Type Transformers**) |
| Station Battery alarms (BAS Remote Monitoring: **Station Battery Supply & Charger**) |
| Protection and control alarms |
| Substation temperature |
| HV circuit breaker status (Closed / Open / Tripped / Locked Out) |
| HV circuit breaker control (Close / Open / RackIN / RackOUT) |
| HV disconnect status (Closed / Open) |
| LV Main (transformer secondary) circuit breaker status (Closed / Open / Tripped) |
| LV Main (transformer secondary) circuit breaker control (Close / Open / RackIN / RackOUT) |
| Transfer switch(es) status (BAS Remote Monitoring: **Automatic Transfer Switches**) |
| Breaker Loading information (V, I, kVA, kW, PF) |

*Figure 3 – Substation Communications*



## 26 12 00 High Voltage Transformers

1. Liquid filled transformers are the preferred installation type at the university.
2. All transformers shall be three-phase with Delta primary and Wye secondary, with the XO bushing accessible.
3. All transformers shall have an efficiency greater than 99.3% when operating at full load.
4. All transformer impedances shall be between 4% and 6%, including all tolerances.
5. All transformers shall have five off-load full kVA rated primary taps, at 95%, 97.5%, 100%, 102.5% and 105% nominal voltage.
6. All transformers shall have a basic impulse insulation (BIL) level of 95 kV.
7. All transformers shall come complete with the following standard accessories:
   - Two frame/tank grounding studs for No. 4/0 AWG conductor in diagonally opposite positions.
   - Lifting eyes, welded bottom corner jacking steps, and provisions for skidding.
   - Analog 4-20mA winding temperature sensors with winding temperature alarm contacts.
8. All alarm contacts shall be rated to make, break, and withstand up to 125VDC/AC and 5A continuously.
9. A NEMA 3R or higher control panel shall be mounted on the side of the transformer and shall house the following:

   .1 Terminations for all contacts and signals associated with the transformer destined for remote locations.

   .2 Hand/Off/Auto switch for fan testing.

   .3 Any visual or audible local alarms.

### *26 12 13 Liquid-Filled, High Voltage Transformers*

1. Insulating liquid shall be silicone oil or FR3.
2. Cooling type shall be LNAN-LNAF 55/65 degree rated.
3. Transformers shall have a single secondary voltage winding.
4. Transformers located on roofs shall be fully enclosed within a walk-in enclosure and adequately ventilated.

5. Transformers shall have a concrete cast-in-place dyke, with perimeter and height sized to contain the total liquid volume of the transformer in the event of a transformer leak. Waterproofing of the containment area and dykes shall be non-conductive and compatible with the transformer liquid.
6. Transformers shall be complete with all standard accessories, including, but not limited to, the following:
   - Off load circuit tap changer operable from ground level by a single external wheel, with provision for padlocking in any position
   - Tap position indicator
   - High internal tank pressure relief device
   - Hermetically sealed dial type oil temperature thermometer, three stages: fan start, alarm and trip contacts
   - Analog 4-20mA oil temperature sensor
   - Liquid level gauge with alarm contact
   - Bottom drain valve and sampling port
   - Sudden gas pressure relay with trip and alarm contacts, rated for the equipment providing isolation
   - Pressure relief device
   - Hand/Off/Auto selector switch for fans
7. The control panel shall have the following alarm contacts as shown in *Table 6 – Alarm Contacts for Liquid-Filled Transformers*. Where:
   LOCAL indicates control panel audible and/or visual alarm.

   REMOTE indicates a termination at the control panel terminal block for remote

   connection. SEAL-IN contacts remain in the alarm state until manually reset.

*Table 6 – Alarm Contacts for Liquid-Filled Transformers*

| **Conditions** | **Local Visual** α | **Local Audible** α | **Remote** β | **Seal-in Contact** |
|---|---|---|---|---|
| Low Oil Level | Yes | Yes | Yes | No |
| Oil Temp Fan | Yes | No | No α | No α |
| Oil Temp Hi | Yes | Yes | Yes | No |
| Oil Temp HiHi | Yes | Yes | Yes (x2) | Yes |
| Winding Temp Hi | Yes | No | Yes | No |
| Sudden Gas | Yes | Yes | Yes (x2) α | Yes α |
| α Does not apply to pad-mount transformers | | | | |
| β Refer to *Appendix A – Table of Signals for BAS Remote Monitoring* to identify which contacts shall be directed to the Building Automation System. | | | | |

### *26 12 16 Dry-Type, High Voltage Transformers*

1. High Voltage Dry Type power transformers shall only be used with explicit written authorization from the university.
2. Transformers shall be power type ANN/ANF indoor, air cooled, dry type with continuous ANN capacity as specified.
3. Dry-type transformers shall be installed indoors at ground level or above.
4. Transformer enclosures shall be NEMA 2S, sprinkler proof construction.
5. The insulation shall be Class H, 220 °C, with maximum temperature rise 150°C over 40°C ambient at ANN rating.
6. The maximum sound level at ANN rating shall be 64 dB as per IEEE Std C57.12.90.
7. The control panel shall have the following alarm contacts as shown in *Table 7 – Alarm Contacts for Dry-Type Transformers*. Where:
   LOCAL indicates control panel audible and/or visual alarm.

   REMOTE indicates a termination at the control panel terminal block for remote connection. SEAL-IN contacts remain in the alarm state until manually reset.

*Table 7 – Alarm Contacts for Dry-Type Transformers*

| Conditions | Local Visual | Local Audible | Remote $^{\alpha}$ | Seal-in Contact |
|---|---|---|---|---|
| Winding Temp Fan | Yes | No | No | No |
| Winding Temp Hi | Yes | Yes | Yes | No |
| Winding Temp HiHi | Yes | Yes | Yes (x2) | Yes |
| $^{\alpha}$ Refer to *Appendix A – Table of Signals for BAS Remote Monitoring* to identify which contacts shall be directed to the Building Automation System. | | | | |

8. A digital three winding temperature indicator shall be mounted on the exterior of the transformer enclosure.
9. Transformers having hinged access doors to the HV compartment shall have Kirk key interlocking to prevent access unless the respective primary isolation means is in the open position. Co-ordinate keying with the switchgear manufacturer.

### *26 12 19 Pad-Mounted, Liquid-Filled, High-Voltage Transformers*

Refer to section 26 12 13 Liquid-Filled, High Voltage Transformers.

## 26 13 00 High Voltage (15kV) Switchgear

### 26 13 00.01 General

1. Where the HV gear is connected directly to the utility (not on the CED), the standards and requirements of the utility shall be met. Should this design standard and the source utility having jurisdiction's standards conflict, the utility standard shall take precedence over this design standard. Please consult with the university in determining which HV network is being connected to.
2. The completed assembly shall comply with the requirements of all authorities having jurisdiction and including Canadian Standards Association IEEE Standard 48, ANSI Standard C37.85, Ontario Electrical Safety Code, ANSI C37.04 to C37.18, and C37.20. Where the university's requirements exceed those of the foregoing Standards, those university requirements shall be met.

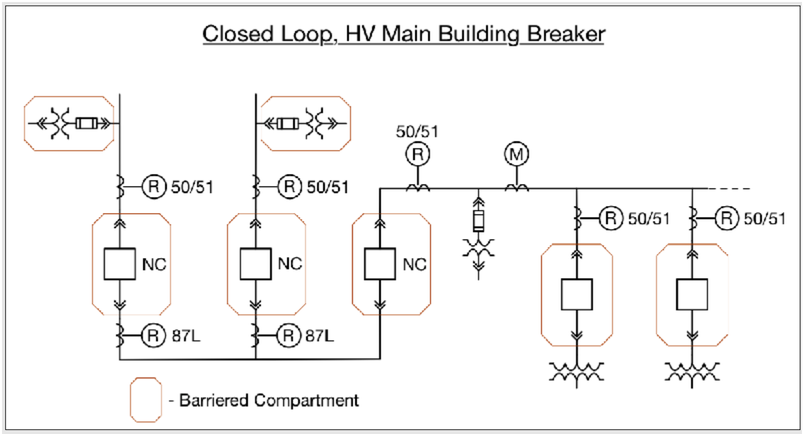
3. The switchgear, including all cells and the equipment therein, unless otherwise noted, shall comply with the following minimum ratings:
    - Continuous current rating: 1200 A rms for main bus and loop breakers, 600A rms for all other disconnecting means
    - Minimum X/R Adjusted Instantaneous fault current rating of 22kA
    - Nominal Voltage: 13.8kV rms
    - Rated Voltage: 15kV rms
    - Rated Frequency: 60 Hz
    - Power Frequency Withstand Voltage: 36 kV rms
    - BIL: 95 kV
4. Primary isolation devices shall be circuit breakers for transformers sized 2000kVA or greater.
5. Load break interior compartments shall be Kirk key interlocked with the upstream source, such that access to exposed components cannot occur until the line side source is open/isolated.
6. Refer to specific HV equipment section for Kirk key interlocking requirements specific to that equipment.

### 26 13 00.02 Typical 15kV Switchgear Configurations

1. The university shall be consulted for final switchgear layouts at the SD stage.
2. Buildings located on the central area of campus shall be fed from the university's Central Electrical Distribution (CED) System. The central area of campus is defined as the region bounded by Bloor Street to the north, Queen's Park to the East, College Avenue to the south and Spadina Avenue to the west.
3. The following are typical acceptable configurations. Each switchgear configuration is suited for building types as noted:
    - Non-critical buildings shall use Configuration #1, Closed Loop, HV Main Building Breaker.
    - Critical buildings shall use Configuration #2, Closed Loop, HV Main-Tie-Main.
    - Local Distribution Company fed buildings shall use Configuration #3, HV Dual Radial.
    - High voltage sub fed buildings shall use Configuration #4, Basic HV Sub Feed.

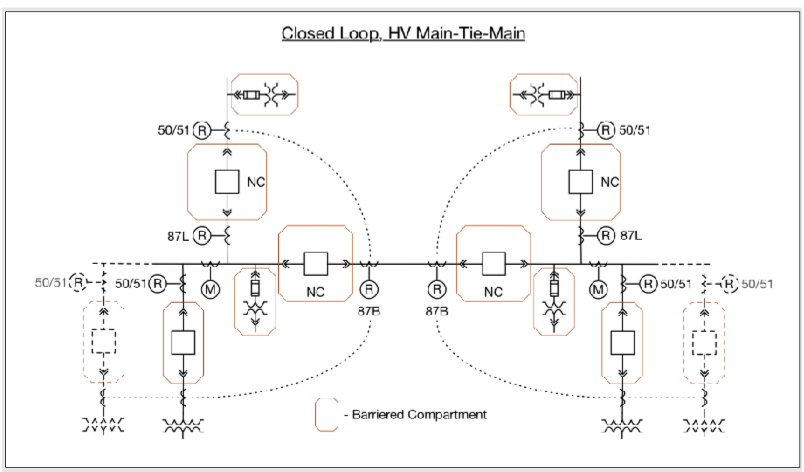
**Configuration 1:** Typical Building, Closed loop, main building breaker as shown in *Figure 4 – HV Switchgear Configuration: Closed Loop, HV Main Building Breaker.*

*Figure 4 – HV Switchgear Configuration: Closed Loop, HV Main Building Breaker*



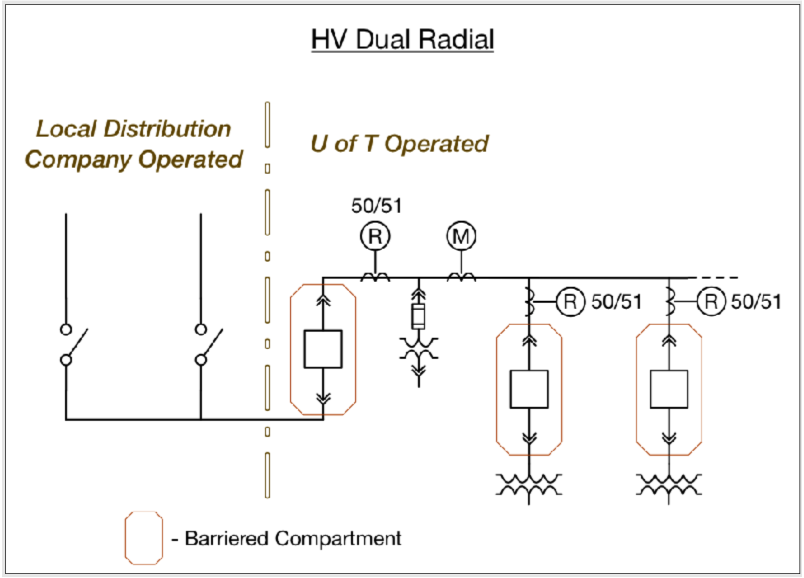

***Configuration 2:** Critical Building, Closed loop, HV Main-Tie-Main as shown Figure 5 – HV Switchgear Configuration: Closed Loop, HV Main-Tie-Main.*

*Figure 5 – HV Switchgear Configuration: Closed Loop, HV Main-Tie-Main*



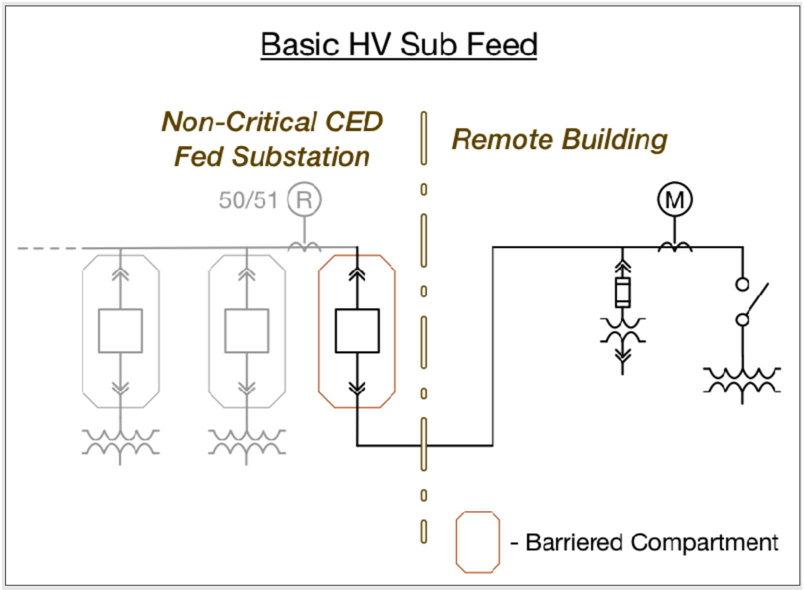

**Configuration 3:** HV Dual Radial as show in *Figure 6 – HV Switchgear Configuration: HV Dual Radial.*

*Figure 6 – HV Switchgear Configuration: HV Dual Radial*




**Configuration 4:** Basic HV Sub Feed as show *Figure 7 – HV Switchgear Configuration: Basic HV Sub Feed.*

*Figure 7 – HV Switchgear Configuration: Basic HV Sub Feed*



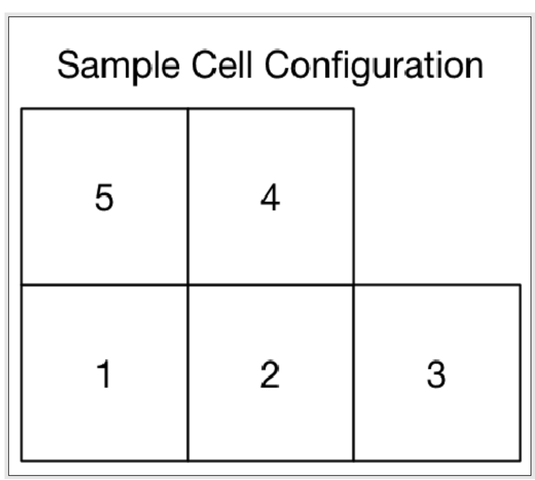

4. The specific components in each configuration may differ based on the load requirements. For example, transformers may require individual remote isolation/protection, thereby necessitating a circuit breaker as opposed to a fused disconnect switch. Please consult with the university for any such specific requirements at the SD stage.

### 26 13 00.03 Construction

1. Cells shall be of metal clad construction and divided into separately grounded steel compartments for each of the following:
   - Main and Tie Breakers
   - Cable entry and terminations
   - Each main bus with load breakers
   - Potential transformers
   - Metering, relaying and auxiliary devices
2. Grounding means shall be provided for:
   - Incoming high voltage cables
   - Outgoing high voltage cables

3. For switches, grounding provision may be stirrup or ball type. For breakers, grounding provision shall be ball type only. Ball type grounding studs shall have a diameter of no greater than 25mm (1 in) and shall be rated for the available fault current. Ball type grounding studs shall come with insulating boots requiring a hook stick for removal. With the insulating boots removed, the spacing between grounding studs shall not encroach on the spacing requirements between phases.
4. Designs shall ensure that a failure within any compartment or cell shall not propagate to adjacent cells or compartments.
5. The switchgear manufacturer shall supply mounting channels and to ensure proper leveling of the switchgear.
6. After installation and levelling, all switchgear, switchboards, and other equipment shall be caulked to prevent bottom entry of vermin.
7. All door swings on all cells shall be minimum 135 degrees.
8. Where access to potential energized equipment is possible through a hinged panel, provisions for padlocking shall be provided for each panel. (e.g., Rear or side entry cable compartments)
9. Lamacoids of size A shall be provided on each cell, both front and rear, indicating cell number.  Cell number shall begin at 1 for the left most cell as viewed from the front and increment for each adjacent cell moving towards the right.  In the situation where there are rear facing cells, the numbering shall continue in a counterclockwise fashion. See *Figure 8 – HV Switchgear Sample Cell Configuration* below.

*Figure 8 – HV Switchgear Sample Cell Configuration*



### 26 13 00.04 Buses

1. Buses shall be high conductivity, tin plated copper. Bus joint hardware shall be non-corroding.
2. Busbar insulation shall be bed fluidized.  Bus joints shall be fully insulated. Through- bushings, where buses pass through metallic barriers, shall be fully rated for the insulation level of the switchgear and provide full separation between compartments.
3. Bus joint covers shall be sized to suit the joint and cover fastenings (e.g., nylon bolts and nuts) shall be reusable.
4. A copper ground bus shall be run the full length of the switchgear capable of withstanding the available three-phase bolted fault current. The ground bus shall be installed  immediately inside the bottom lower rear of each circuit breaker cell and immediately inside the bottom lower front of each load break switch cell, allowing the owner to attach external grounds for owner maintenance testing and maintenance grounding requirements without interference from the main bus. Provide a pressure connector lug at each end of the switchgear ground bus for connecting a #4/0 AWG station grounding conductor. The switchgear framework, channel bases, and enclosures of the gear shall be bonded to the ground bus.
5. Ground bus extensions with lugs shall be provided in the incoming HV cable compartments to allow the stress cones on the incoming cables to be grounded with short leads.
6. Provision shall be made to extend the main bus and ground bus to future switchgear cells. This shall include main bus predrilled bus stubs with insulating boots over the stubs, and a predrilled ground bus. Extensions could be single-ended or double-ended depending on specific switchgear configuration or placement of equipment in the substation.

### 26 13 00.05 15 kV Rated Load Break Switches

1. Load break switches shall be of the load break interrupter type, quick make, quick break, gang operated, with chain coupled mechanism and operating handle on the front of the cell. Provision shall be made for padlocking the operating mechanism with

the switch in the open and closed position, with positions clearly labelled. Access door shall be interlocked with switch operating mechanism such that it cannot be opened unless the switch is in the open position. Interrupters shall be rated for 600 Amps RMS interrupting current.

2. Chain operated switches shall have chain guards designed to prevent contact of chain with live parts in the event of chain failure.
3. Fusible load break switches shall be provided with:
   .1 disconnect opening style fuse holders operated with a hook stick
   .2 non-deteriorating, refillable power type fuses
   .3 appropriate fuse snuffers
   .4 switch mechanism located at the top and fuses at the bottom
   .5 hinged safety screens installed in front of the interrupter units and all live parts, with padlock provision. The hinged safety screen shall be mechanically interlocked with the cell door to prevent closing the cell door with the hinged panel unsecured.
   .6 three spare fuse refill units housed on the back of the door of the switch cell.
4. Voltage indicators shall be provided, one per phase for all three phases, on the load side of each switch and shall be visible through a viewing window. Voltage indicators shall be self-powered.
5. Viewing windows shall be provided for visual inspection of each switchblade position. Viewing windows shall also allow infrared inspections of the switchblades through the window with the switch in the closed position.
6. Each fused load break switch shall be provided with a Kirk key interlock where the switch supplies a dry type transformer having hinged access doors to HV components within the transformer enclosure. The switch must be in the open position to release the Kirk key to enable opening the Kirk key interlock on the transformer. Co-ordinate keying with the transformer manufacturer.

### 26 13 00.06 15 kV Rated Circuit Breakers

1. Each breaker shall have a minimum of three 52a and three 52b contacts, brought out to accessible terminals inside the equipment.

2. Each breaker shall be equipped with provisions for remote operation. These signals shall be brought out to accessible terminals inside the equipment.
3. Each breaker shall be equipped with provisions for remote racking to the connected, test and disconnected positions. These signals shall be brought out to accessible terminals inside the equipment.
4. All circuit breakers shall be SF6 or vacuum type.
5. All breakers shall be draw-out type, shall have self-aligning auxiliary contacts, and shall be fully interchangeable with any other breaker of the same frame rating in the line up without any changes to the breaker or protection settings.
6. Fixed mounted breakers may be considered for specific retrofit applications for failed equipment where replacement components of original configuration are no longer available.
7. Circuit breakers shall have the following minimum ratings, in addition to those detailed in section 26 13 00.01 General
   - 22 kA rms asym closing and latching
   - 3 cycle rated interrupting time
   - Control voltage operating range of 90-140 $V_{DC}$ for closing, and 70-140 $V_{DC}$ for tripping
8. Withdrawable breakers shall have a ‘test’ position where the primary contacts are physically separated from both ‘line’ and ‘load’ conductors. Auxiliary contacts shall remain connected in the ‘test’ position.
9. Breakers shall be equipped with automatic safety tripping mechanism should a loss of gas or vacuum occur.
10. Each circuit breaker shall be equipped with two tripping coils, each able to independently trip the circuit breaker.
11. Breakers shall be lockable in the ‘disconnected’ position. The cell door shall be capable of remaining closed while the breaker is racked out to the ‘disconnected’ position.
12. Automatic shutters shall separate all HV circuit breaker contacts from the breaker compartment when the breaker is in the disconnected position.

13. Mechanical interlocks shall ensure that a breaker is open before it can be racked into or out of the 'connected' position.
14. A position indicator shall be provided to indicate the location of the circuit breaker on the connected/test/disconnected path.
15. A sliding ground contact shall be provided to ensure the breaker frame is grounded before the primary or auxiliary contacts are made.

### 26 13 00.07 Monitoring & Control

1. Circuit breaker control switches, status and trip indicating LEDs, and 'LAMP TEST' buttons, shall be mounted on the front of the switchgear.
2. Circuit breakers indicators shall have separate status LEDs indicating CLOSED, OPEN, and TRIPPED conditions. Colour coding shall be as follows:
   .1 RED: Breaker CLOSED
   
   .2 GREEN: Breaker OPEN
   
   .3 WHITE: Breaker TRIPPED
3. Other indicating LEDs may not use the colours above. The following trip indication lights shall be provided as applicable:
   .1 SF6 Pressure Low TRIP
   
   .2 Transformer Protection TRIP
   
   .3 Control Power Available
   
   .4 Controls on 'Local'
4. A 'LAMP TEST' push button shall be provided on each breaker cell/compartment to test the integrity of all associated LEDs for the breakers.
5. Circuit breaker control switches shall be pistol grip type, three positions (open-home-close) with target indication of the last operation and spring return to the home position. Target indication shall be red for breaker close and green for breaker open.
6. Any trip on a breaker will initiate a lockout condition which will require a manual reset locally at the breaker. This will be accomplished by installing a mechanical lockout relay

which will prevent closing the breaker until physically reset. This relay shall be labeled “86” and be a two-position pistol grip style with rotary contacts.

7. Circuit breaker status and remote open/close signals shall be provided, and signals shall be terminated in the designated control compartment of the breaker and subject to section 26 11 00 Substations and Switching Stations.

### 26 13 00.08 Wiring and Connections

1. A removable nonferrous cable entry plate shall be provided where the cables enter or leave the cell; unless bottom entry/exit in indoor locations.
2. Top-Entry cable connections into the switchgear shall be rain-tight.
3. Secondary and control wiring shall be identified at each point of connection/termination by permanent, printed, non-metallic wire markers, which shall agree with the wiring diagrams.
4. All wiring within the control compartments shall be free of splices and terminated on appropriately rated termination points. All terminal blocks shall be barriered type, permanently labelled and shall agree with the wiring diagrams. Terminals shall be identified with electronically printed characters and made permanent. Terminal blocks shall have no more than one wire under each terminal connection.
5. Secondary and control wiring originating and terminating inside the switchgear shall be copper SIS type. Wiring shall be minimum #14 AWG. Current transformer secondary wiring shall be minimum #12 AWG.

### 26 13 00.09 Protective Relaying

1. All protective relaying schemes for HV equipment shall be approved in writing by the university.
2. Relays shall be microprocessor based, multi-function type. They shall be capable of up to 125VAC/125VDC input and be equipped with a self-diagnosing alarm connected to a dry type contact.
3. Relays shall be capable of communication via Ethernet networks and shall be capable of MODBUS/TCP, DNP3, and IEC 61850 protocols for both data acquisition and remote control.

4. Relays shall be capable of basic rudimentary metering functions (A, V, kVA, kW, kVAr, kWh, PF) and shall also store max/min values for each parameter over a user defined interval up to one year.
5. Relays shall make use of COMTRADE files as per IEEE C37.111 for playback of electrical protection events.
6. Relays shall be equipped with provisions for time synchronization with Ethernet SNTP/NTP and/or BNC IRIG-B.
7. Loop Breaker (excluding tie) protection requirements

.1 Primary ‘A’ relays shall have at a minimum, the following elements for:

- Line differential (87L)
- phase and ground overcurrent (50/51 [P/G/N/Q])
- directional overcurrent (67 [P/G/Q])
- loss of PT signal (60)
- Sync Check (25)
- Overvoltage (59)
- Undervoltage (27)

.2 Primary ‘B’ relays shall have at a minimum, the following elements for

- phase and ground overcurrent (50/51 [P/G/N/Q])
- directional overcurrent (67 [P/G/Q])
- loss of PT signal (60)
- Sync Check (25)
- Overvoltage (59)
- Undervoltage (27)

.3 Primary ‘A’ Relays and Secondary ‘B’ relays shall not be of the same model, but may be of the same make.

8. Non-Loop Breaker (excluding tie) protection requirements:
   .1 Relays shall have at a minimum, the following elements for:
   - phase and ground overcurrent (50/51 [P/G/N/Q])
   - directional overcurrent (67 [P/G/Q])
   - loss of PT signal (60)
   - Overvoltage (59)
   - Undervoltage (27)
9. Tie Breaker protection requirements
   .1 No protection requirements exist for tie breakers.
   .2 Breaker shall be monitored and controlled by communication protocols listed in this section, clause 3.
10. Each relay shall have its own set (three) protection current transformers. Relays shall not share a set of current transformers.
11. Relay settings shall be programmed as per the coordination and arc flash study.

### 26 13 00.10 Instrument Transformers

1. Current transformers shall have withstood ratings equal to the momentary rating of the downstream circuit breakers. They shall be insulated for the full voltage rating of the switchgear.
2. Metering CTs shall be separate from protection CTs and shall be revenue grade, rated ANSI/IEEE C57.13 0.3B0.5 or greater (0.3% accuracy at 100% rated primary current with a burden not to exceed 0.5 Ohm). Primary current rating shall be specified as the closest rating available, equal to or greater than the long-time trip rating of device being metered.
3. All protection CTs shall be of class rating ‘C200’ or greater. Relaying CTs shall be sized such that they do not saturate during bolted fault conditions while remaining within the CT’s burden rating for the connected secondary circuit. Refer to coordination study for these values.

4. Potential transformers shall be configured for 120 Volt ‘grounded B-Phase delta’ secondary wiring. Potential transformer shall be draw-out type, protected by fuses on both the primary and secondary windings. Transformer kVA ratings shall be sized to provide the designed load when used for purposes other than metering and relaying (e.g., Station battery charger).
5. All voltage and current secondary circuits shall be brought out to an FT switch located on the front of the switchgear for secondary injection testing/calibration. Secondary current circuits shall be provided with shorting means through the FT switches. Secondary voltage circuits shall be provided with an isolating means through FT switches.

### 26 13 00.11 Accessories

1. Lamacoid(s) of size B shall be used for meters, relays, test blocks, and controls. Lamacoid(s) of size C shall be used for indicating lights.
2. Warning Lamacoid(s) of size A, with white letters on red background shall be permanently affixed with rivets onto each hinged cell/compartment having access to energized HV equipment. Lamacoid shall read “DANGER: HIGH VOLTAGE”.
3. A Mimic bus shall be installed on the front of the switchgear clearly identifying the internal electrical arrangement of the equipment in each cell. The Mimic bus shall show all devices in white on red background, including but not limited to circuit breakers, load break switches, fuses, PTs, CTs, voltage indicators, arrestors, and grounding points. CT ratios shall be shown with Lamacoid(s) of size C beside Mimic bus CT symbol(s). PT ratios shall be shown with Lamacoid(s) of size C beside Mimic bus PT symbol(s). Fuse current rating shall be shown with Lamacoid(s) of size C beside the Mimic bus fuse symbol(s).
4. All tools required for operating, removing, and maintaining equipment shall be supplied along with the switchgear. Provision for storage of said tools shall be allocated within the gear itself or in a wall-mounted location within the substation.
5. The following tools at a minimum shall be provided as required:
   - Breaker racking tool
   - Breaker racking rails

- Breaker hoist/lift for removal (including all accessories)
- Fuse puller

6. The following accessories shall be provided as spares:
   - Minimum one dozen LED type indicating lamps
   - A complete set of spare LV fuses (for auxiliary and secondary circuits)

### 26 13 00.12 Switchgear Control Power (Station Battery Supply & Charger)

1. Chargers shall be dual source input 120VAC nominal, 125VDC output, in a free standing sprinkler proof cabinet, housing batteries, charger, controls and alarms. Charger's secondary input shall be connected to an emergency power circuit.
2. Two lifting eyes shall be provided. All interior surfaces shall be factory finished corrosion resistant enamel.
3. Batteries shall be mounted in the lower compartment and rows shall be tiered to ensure access to battery terminals for testing. All door swings shall be minimum 135 degrees.
4. Venting of the cabinet shall be located at the top of the completed charger assembly.
5. The battery bank shall consist of Valve Regulated Lead Acid (VRLA) type batteries. No other battery type is acceptable.
6. The battery capacity shall be such that after 24 hours operation without the charger, operating two simultaneous tripping events followed by two consecutive closings of all HV circuit breakers, the output voltage shall not be lower than 105V.
7. The battery shall be capable of supplying the loads to an end voltage of 1.14V per cell at 25°C.
8. The charger output (without battery support) shall be sized to power all auxiliary relays and operate all tripping coils associated with the worst-case electrical fault as defined by the protection scheme of the gear. For example, a bus differential scheme, requiring tripping of 4 breakers, each rated 5A at 125VDC per trip coil, and auxiliary relays drawing 1A total, would require a charger with a continuous DC output of 21A, for the required duration as specified by the breaker and relay manufacturers.

9. The charger shall be self-regulating, current limited, automatic dual rate, with indicating, control and protective devices. The charger and its controls shall be such that the charging rate decreases as the battery approaches full charge and provides a trickle charge to maintain the battery at a fully charged state.
10. The charging circuit shall be able to be electrically disconnected without affecting the DC power supply to loads via the batteries.
11. The charger system shall have the following:
    - Sequence of events recorder with date and time stamp
    - Two AC input breakers, each single pole
    - A two pole DC breaker for charger output
    - A two pole DC breaker for battery power output
    - Display Capabilities:
        - Float Current
        - Float Voltage
        - Ripple Current (% rms)
    - Battery string symmetry monitoring, or individual battery voltage monitoring
    - Battery temperature monitoring
    - Rectifier temperature monitoring
    - Float-equalize switch
    - Float and equalize adjustments independent of each other
    - Lockable control of battery compartments with provisions for padlock
    - LED status lamp or integrated display panel
    - Minimum of two Form ‘C’ dry contacts for remote alarming and indication. Contacts shall be rated up to 120VAC/125VDC, 0.5A continuous current

- Pre-manufactured and insulated inter-cell connectors (between adjacent cells), and cables (between rows/tiers)
- Ethernet connectivity and ability to communicate via MODBUS/TCP protocol with SNTP/NTP time synchronization

12. The control panel shall have the following alarm contacts as shown in *Table 8 – Switchgear Control Panel Alarm Contacts*:
    Where:

    LOCAL indicates control panel audible and/or visual alarm.

    REMOTE1 indicates a termination at a control panel terminal block for remote connection. Deemed Critical and requiring immediate attention and action.

    REMOTE2 indicates a termination at a control panel terminal block for remote connection. Deemed important and requiring attention at the next available opportunity.

    SEAL-IN contacts remain in the alarm state until manually reset.

*Table 8 – Switchgear Control Panel Alarm Contacts*

| Conditions | Local Visual | Local Audible | Remote $^{\alpha}$ | Seal-in Contact |
|---|---|---|---|---|
| AC Failure $^{\beta}$ | Yes | Yes | 1 | No |
| Hi Output Voltage | Yes | No | 1 | No |
| Lo Output Voltage | Yes | Yes | 1 | Yes |
| Rectifier Hi Temp | Yes | No | 1 | No |
| Rectifier Failure | Yes | Yes | 1 | Yes |
| Ground Fault | Yes | No | 1 | No |
| Battery Sym. Fault | Yes | No | 1 | No |
| Battery Breaker Status | Yes | Yes$^{\delta}$ | 1 | Yes |
| Charger Output Breaker Status | Yes | No | 1 | No |
| $^{\alpha}$ Refer to *Appendix A – Table of Signals for BAS Remote Monitoring* to identify which contacts shall be directed to the Building Automation System. | | | | |

| |
|---|
| $^{\beta}$ Alarm shall come with a 0 to 60 second adjustable time delay on pickup |
| $^{\delta}$ Audible alarm shall come with a silence feature, on a 1 hour reset timer |

13. A lamp test pushbutton shall be provided for testing all equipped LED indicating lamps.
14. The following battery accessories shall be included with all physical installations:
    - Insulated wrench
    - Operations and Maintenance manuals
    - WHMIS MSDS for the system
    - 2 spare intercell connectors
    - Corrosion inhibiting grease

### *26 13 13 High-Voltage Circuit Breaker Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 13 16 High-Voltage Fusible Interrupter Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 13 19 High-Voltage Vacuum Interrupter Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 13 23 High-Voltage Metal-Enclosed Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 13 26 High-Voltage Metal-Clad Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 13 29 High-Voltage Compartmentalized Switchgear*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

## 26 15 00 High-Voltage Enclosed Bus Assemblies

Refer to Section *26 13 00.04 Buses*.

## 26 16 00 High-Voltage Metering

For metering of High Voltage Electrical Distribution see section *26 27 13 Electricity Metering*.

## 26 18 00 High-Voltage Circuit Protection Devices

Refer to Section *26 13 00.06 15 kV Rated Circuit Breakers*.

### *26 18 13 High-Voltage Cut-outs*

Refer to Section *26 13 00 High Voltage (15kV) Switchgear*.

### *26 18 16 High-Voltage Fuses*

Refer to Section *26 13 00.05 15 kV Rated Load Break Switches*.

### *26 18 23 High-Voltage Surge Arresters*

1. Surge arrestors shall be installed at the following locations on the HV distribution system:
   - Upstream of main service loop breakers and instrument transformers
   - Immediately upstream of HV distribution transformers
2. All surge arrestors shall have an MCOV of 15kV.
3. All surge arrestors shall limit the voltage to the appropriate levels for the equipment being protected, typically the BIL.

### *26 18 39 High-Voltage Motor Controllers*

1. High voltage motor starters and controllers are not permitted on campus. All motor loads to be connected to LV distribution system.

# 26 20 00 – LOW-VOLTAGE ELECTRICAL DISTRIBUTION

## 26 21 00 Low-Voltage Electrical Service Entrance

### *26 21 16 Low-Voltage Underground Electrical Service Entrance*

1. Where the LV gear is connected directly to the utility, the source utility having jurisdiction's shall be met. Should this design standard and the utility standards conflict, the utility standard shall take precedence over this design standard. Please consult with the university in determining which LV network is being connected to.
2. Building service entrances shall be installed in concrete encased duct banks.
3. Service cables shall terminate directly into the main distribution equipment. No individually enclosed protection means permitted for service entrances for reasons other than arc flash incident energy mitigation on the main distribution panelboard or switchgear.

## 26 22 00 Low-Voltage Transformers

### *26 22 13 Low-Voltage Distribution Transformers (600V or below on Primary)*

1. Transformers shall be rated 75kVA or less and be dry type.
2. Transformers shall be rated NEMA 3R at a minimum with weather-shield and watertight connectors.
3. Transformers shall have a BIL of 1.2 kV or better. Insulation shall be Class H, 220°C, with maximum temperature rise 150°C or more over 40°C ambient.
4. Transformers shall be equipped as required with eye bolts, braces, etc. to enable them to be wall mounted, floor mounted or suspended.
5. External, anti-vibration provisions shall be supplied and installed for all transformers.
6. Transformers shall be rated at K-13 or greater.
7. Transformer efficiency shall be 98.6% or better at full load.
8. Transformer name plates shall be installed in an accessible location for viewing.

### *26 22 19 Control and Signal Transformers*

Refer to the "Building Automation Systems Design Standards and Guidelines".

## 26 23 00 Low-Voltage Switchgear

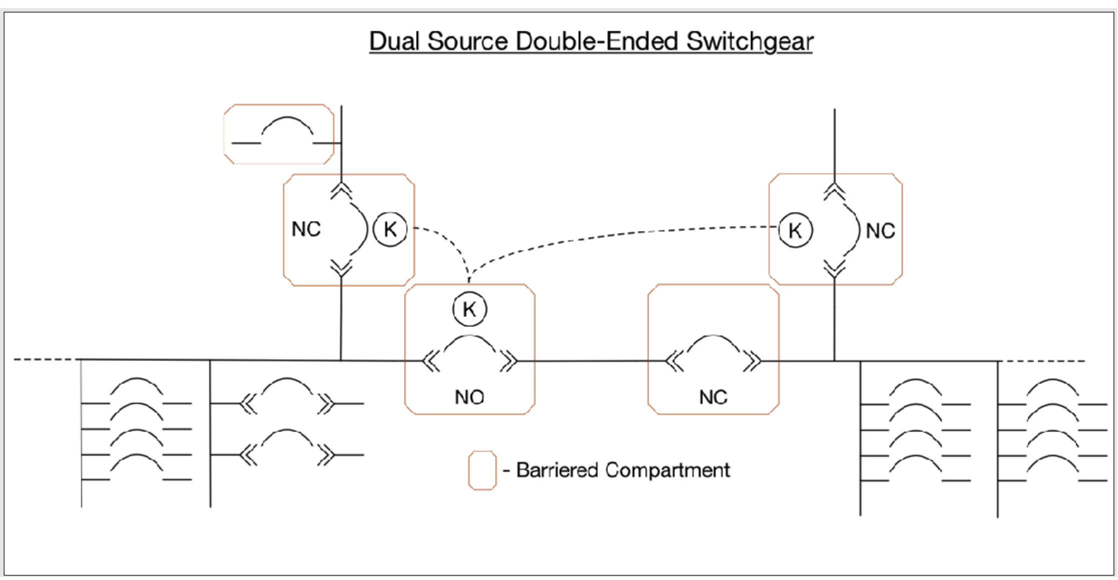
### 26 23 00.01 General

1. Where the LV switchgear is connected directly to the utility, the standards and requirements of the utility shall be met. Should this design standard and the utility standards conflict, the utility standard shall take precedence over this design standard. Please consult with the university in determining which LV network is being connected to.
2. Arc Flash Warning labels shall be installed on the front of the switchgear. There shall be a minimum of two labels per switchgear: one indicating incident energy upstream of the main breaker, and one for the remaining feeder breakers and bus.

### 26 23 00.02 Configuration

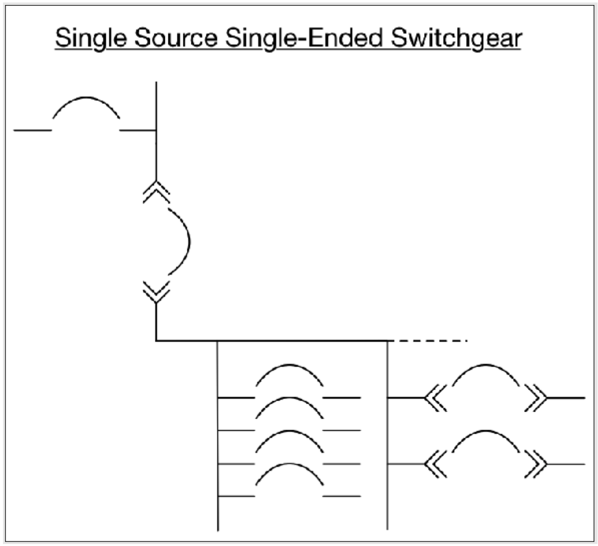
1. The specific components in each configuration may differ based on the load requirements of the building. Please consult with the university for any such specific requirements and switchgear layouts at SD stage.
2. The following are typical acceptable configurations, in order of preference:
   **Configuration 1:** Dual Source, Double-Ended Switchgear as shown in *Figure 9 – LV Switchgear Configuration: Dual Source, Double-Ended.*

*Figure 9 – LV Switchgear Configuration: Dual Source, Double-Ended*



**Configuration 2**: Single Source, Single-Ended Switchgear as shown in *Figure 10 – LV Switchgear Configuration: Single Source Single-Ended.*

*Figure 10 – LV Switchgear Configuration: Single Source Single-Ended*




**Configuration 3:** Utility *or 'building sub-fed' feed for Small (<100kVA demand) building*

3. Configuration 3 will depend on the requirements of the building and/or utility. Main breaker may be required to be 'draw-out' type, the fire pump may be downstream of main breaker, the main panelboard may simply be a service entrance panelboard, etc. Please consult with the university for specific requirements.

### 26 23 00.03 Construction

1. Cells shall be of metal clad construction and divided into separately grounded steel compartments for each of the following:
    - Main and Tie breakers
    - Cable entry and terminations
    - Each main bus with load breakers
    - Metering, relaying and auxiliary devices
    - Any loads upstream of Main breaker(s) (e.g., Fire Pump breaker)

2. For double-ended configurations, interlocking of the main breakers and the tie breaker shall be provided by use of a Kirk key. This key shall require a main to be open before the tie can be closed to avoid paralleling the main distribution transformers.
3. A third spare Kirk key shall be provided to the university as part of the closeout package.
4. Designs shall ensure that a failure within any compartment or cell shall not propagate to adjacent cells or compartments.
5. Mounting channels and hardware shall be supplied by the switchgear manufacturer to ensure proper leveling of the switchgear.
6. After installation and levelling, all switchgear, switchboards, and other equipment shall be caulked to prevent bottom entry of vermin.
7. All door swings shall be minimum 135 degrees.
8. Where access to potential energized equipment is possible through a hinged panel, provisions for padlocking shall be provided for each panel. (e.g., Rear or side entry cable compartments)
9. Compartments for future withdrawable breakers shall be complete with bus connections, disconnecting contacts and supporting rails, ready for the insertion of a breaker and with insulating covers for the disconnecting contacts.
10. The structure shall be mounted on a channel base supplied by the manufacturer. The structure shall be suitable for lifting from a truck and being rolled and jacked into position.
11. Hardware shall be steel with non-corroding plating.

### 26 23 00.04 Buses

1. Buses shall be high conductivity, tin plated copper. Bus joint hardware shall be non-corroding.
2. Provision shall be made for extending the buses to future sections of the switchgear. Extensions could be single-ended, or double-ended depending on specific switchgear configuration or placement of equipment in the substation.
3. Buses and connections shall be designed so that the maximum temperature rise of any part will not exceed 65°C in an ambient temperature of 40°C.
4. A copper ground bus shall be run the full length of the switchgear capable of

withstanding the available three phase bolted fault current. The metal frames of all components shall be connected to the ground bus. Provide a pressure connector at each end of the switchgear ground bus for connecting a #4/0 AWG station grounding conductor.

### 26 23 00.05 Circuit Breakers

1. Withdrawable type breakers shall:
   - .1 have a minimum of three 52a and three 52b contacts, brought out to accessible terminals inside the equipment.
   - .2 be equipped with a minimum of 3 racking positions: ‘connected’, ‘test’, ‘disconnected’. Visual or mechanical indication shall be provided showing the 3 positions in the racking path.
   - .3 be equipped with a provision for remote operation. This signal shall be brought out to accessible terminals inside the equipment. Breakers shall also be capable of being manually charged, opened, and closed.
   - .4 have mechanical interlocks to ensure that a breaker is open before it can be racked in to or out of the ‘connected’ position.
   - .5 come with an electronic LSI(G) trip unit, fully programmable to allow time delays for each trip type to aide with short circuit coordination. The trip unit shall digitally display rudimentary real time metering values (I, V, kW).
   - .6 be lockable in the disconnected position. The cell door shall be capable of remaining closed while the breaker is racked in to and out of the ‘disconnected’ position.
   - .7 be equipped with a breaker operations counter.
2. Mains and Tie breakers shall be of the withdrawable type and shall be capable of being remotely racked in to and out of to the ‘test’ position. These signals shall be brought out to accessible terminals inside the equipment.
3. All breakers shall be thermal magnetic type. Thermal motor breakers are not acceptable in any panelboards or switchgear.

4. All breakers with frame sizes of less than 200A may require an electronic trip unit with LSI settings as warranted by design requirements. Typical situations may include breaker coordination and incident energy mitigation.
5. All breakers with frame sizes of 200A or greater shall have an electronic trip unit with LSI settings at a minimum.
6. All breakers with frame sizes starting at 400A through 800A may be required to be withdrawable type, at the request of the university. This shall be confirmed at the Schematic Design stage.
7. All breakers with frame sizes 800A or greater shall be of the withdrawable type.
8. Breaker trip units shall be self-powered and shall not require an external power source for proper operation. Battery use for protection functions is not acceptable.
9. Trip units shall have visual indication of the reason for tripping. Trip indicators shall be latching type and remain in position until manually reset.

### 26 23 00.06 Monitoring and Control

1. Where remote operation and monitoring is required, circuit breakers shall have separate status LEDs indicating CLOSED, OPEN, and TRIPPED conditions. A ‘LAMP TEST’ push button shall be provided to test the integrity of all associated LEDs for that breaker. A complete set of spare LEDs shall be provided. Colour coding shall be as follows:
   - .1 RED: Breaker CLOSED
   - .2 GREEN: Breaker OPEN
   - .3 WHITE: Breaker TRIPPED
2. The location of the remote operating and monitoring system shall be located in accordance with section 26 11 00 Substations and Switching Stations.
3. Circuit breaker control switches shall be pistol grip type, three positions (open-home-close) with target indication of the last operation and spring return to the home position. Target indication shall be red for breaker closed and green for breaker open.
4. Circuit breaker remote open/close signals shall be provided, and signals shall be

terminated in the designated control compartment of the breaker and subject to section *26 23 00.05 Circuit Breakers*.

### 26 23 00.07 Wiring and Connections

1. Where single conductor cables or bus ducts are used, a removable nonferrous cable entry plate shall be provided where the conductors enter or leave the cell, unless bottom entry/exit in indoor locations.
2. Secondary and control wiring shall be identified at each point of connection/termination by permanent, printed, non-metallic wire markers, which shall agree with the wiring diagrams.
3. All wiring within the control compartments shall be free of splices and terminated on appropriately rated termination points. All terminal blocks shall be barriered type, permanently labelled and shall agree with the wiring diagrams. Terminals shall be identified with electronically printed characters and made permanent. Terminal blocks shall have no more than one wire under each terminal connection.
4. Secondary and control wiring originating and terminating inside the switchgear shall be copper SIS type. Wiring shall be minimum #14 AWG. Current transformer secondary wiring shall be minimum #12 AWG.
5. Any fuses used shall be installed in finger safe disconnecting style fuse holders. Three phase applications shall be gang operated.

### 26 23 00.08 Instrument Transformers

1. Metering CTs shall be revenue grade and rated ANSI/IEEE C57.13 0.3B0.5 or greater (0.3% accuracy at 100% rated primary current with a burden not to exceed 0.5 Ohm). Primary current rating shall be specified as the closest rating available, equal to or greater than the trip rating of device being metered.
2. Potential transformer(s), where required, shall be configured as three 120V ‘Wye’ connected secondary windings. Transformer kVA rating shall be sized to provide the designed load when used for metering. Potential transformers shall not be used for providing power to any device. An appropriately sized Control Power Transformer (CPT) shall be used for power applications.
3. All voltage and current secondary circuits shall be brought out to an FT switch located on the front of switchgear for secondary injection testing/calibration. A

separate FT switch shall be used for each device. Secondary current circuits shall be provided with shorting means through the FT switches. Secondary voltage circuits shall be provided with an isolating means through the FT switch.

4. Metering CTs shall all be installed on the immediate load side of any breaker being metered.
5. Metering PT's primary or voltage sensing shall all be connected on the immediate load side of any breaker being metered.
6. Metering CPT's primary or control power shall be connected on the immediate line side of any breaker being metered.

#### 26 23 00.09 Accessories

1. Lamacoid(s) of size B shall be used for meters, test blocks, and controls. Lamacoid(s) of size C shall be used for indicating lights.
2. All tools required for operating, removing, and maintaining equipment shall be supplied along with the switchgear. Provision of storage of said tools shall be allocated within the gear itself or in a location within the substation or electrical room on the wall. The following tools as a minimum shall be provided, as required:
   - Racking and Removal tools
   - Breaker racking rails
   - Breaker hoist/lift for removal (including all accessories)
   - Fuse puller
3. Warning Lamacoid(s) of size A, with white letters on red background shall be permanently affixed with rivets onto each hinged cell/compartment having access to energized equipment. Lamacoid shall read “DANGER: LIVE PARTS”.

## 26 24 00 Switchboards and Panelboards

### *26 24 13 Switchboards*

For the purpose of this document, switchboards and switchgear refer to the same type of equipment. Please refer to section *26 23 00 Low-Voltage* Switchgear.

### *26 24 16 Panelboards*

1. Note that panelboards may also be referenced simply as panels.
2. Emergency panelboards shall be Pantone 335 C (green) or approved equivalent.
3. UPS panelboards shall be Pantone 285 C (blue) or approved equivalent.
4. Panelboards shall be equipped with a hinged front cover.
5. Circuit breakers shall be of the bolt-on type. Multi-pole breakers shall come factory assembled. All interrupting ratings shall exceed available fault levels as determined by coordination studies.
6. All circuit breakers shall be thermal magnetic type.
7. The panelboard's primary overcurrent protection device shall have a trip rating of at least four times that of any load breaker's rating. Should the main protection device be operating at a different voltage than the branch circuit breakers, the ratio of the voltages shall be considered when calculating this ratio.
8. Tandem double density (mini) circuit breakers are not acceptable.
9. Panelboards are to be mounted so that the top of the panels are located 2m (78 in) above finished floor.
10. Panelboard directories shall be typewritten using the templates provided by the university. Directories shall indicate the final room numbers as designated by Academic & Campus Events (ACE) Office.
11. 10% of any panelboard shall constitute spare breakers of sizes not to exceed any installed breaker.
12. 10% of any panelboard shall constitute spaces where future breakers can be installed. The appropriate bus mounting hardware for these spaces shall also be installed within the panelboard.
13. Filler plates shall be provided on all blank breaker spaces.
14. All panelboards rated greater than 120/208V shall not contain any single-phase loads or single- phase spares.
15. If panelboard is equipped with an integral main breaker or switch, it shall be of the 'service entrance' type and be appropriately barriered from the downstream branch circuits.

### 26 24 16.01 Power Distribution Panelboards (DP Panelboards)

1. DP panelboards shall be double row. When the DP panelboard is an integral part of a switchgear lineup, the panelboard shall extend the entire height of the switchgear cell and contain spaces for breakers for that entire height.
2. Lamacoids of size B shall be installed next to each circuit breaker, detailing the panelboard or equipment it is feeding, including room number where the feeder terminates.
3. All DP Panelboards shall be equipped with solid core 80mA secondary CTs with accuracy consistent with the NRG type multipoint meter requirements in Table 9, on each phase of each circuit. CT primary ratings shall match the associated breaker trip rating for each circuit. All CT secondary wiring shall be brought out to a separate enclosure adjacent to the panel and terminated on a shorting style terminal block. The terminals shall be permanently labelled for future metering connections. See 26 27 13 Electricity Metering for appropriate multi-circuit meter requirements.

### 26 24 16.02 Lighting (LP) and Receptacle (RP) Panelboards

1. Provide two 25mm (1 in) empty conduits from each flush mounted panelboard to the ceiling spaces above for future installation of wiring. The conduits shall terminate in junction boxes with fish wires.
2. Three pole circuit breakers shall not be installed.
3. Maximum breaker ampacity shall be less than 30A.
4. All LP loads shall be lighting or lighting control.
5. Neutral bus shall be rated 200% of main bus rating.
6. Panelboards shall be equipped with a lockable hinged door covering breaker handles. Each panelboard shall be provided with two keys.
7. The upstream protective device shall be rated no less than 100A

### 26 24 16.03 Power Panelboards (PP)

1. All hard-wired loads shall be installed in power panelboards, unless supplied from an emergency source.
2. All three phase loads shall be installed in power panelboards.

3. Where there are no existing MCCs, all mechanical loads shall be installed in power panelboards.
4. All mechanical control loads shall be fed from the same source of supply as the equipment it is controlling. When a device controls multiple pieces of equipment fed from different sources, the control load shall be powered from an emergency supply via a UPS.
5. The neutral bus shall be rated 200% of main bus rating when the power panel is operated as a 4W 120/208V panelboard.
6. Panelboards shall be equipped with a lockable hinged door covering breaker handles. Each panelboard shall be provided with two keys.

### *26 24 19 Motor Starters and Motor Control Centers (MCC)*

Refer to the appropriate university's mechanical design standard (https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/) for specific requirements in addition to those below.

1. Control power for mechanical services fed from MCCs or VFDs shall be derived from the same source as the main power for the equipment in question. Power to control circuits shall not be derived from any LP or RP panelboards.
2. The only exception to the requirement above is if the controlling device is controlling equipment from multiple sources. In this case, the power is to be supplied from an emergency source and backed up with a UPS.
3. All MCCs shall be installed with a 120V panel (including any necessary voltage transformation hardware) with a minimum of 12 circuits to be used only for mechanical purposes, including controls.

## 26 25 00 Low-Voltage Enclosed Bus Assemblies

### *26 25 13 Low-Voltage Busways*

1. Transformers with secondary Full Load Amps (FLA) of 800A or greater shall be connected to the main distribution panelboard using bus ducts.

2. Bus plugs shall be used to connect to bus ducts for power distribution. Distribution panelboards shall not be mounted or coupled directly to bus ducts.

### *26 25 16 Low-Voltage Cablebus Systems*

1. Cablebus systems may be used in lieu of bus ducts, provided it is approved by the university for specific applications.

## 26 27 00 Low Voltage Distribution System Equipment (600 Volts Maximum)

#### 26 27 00.01 External Isolating / Protective Equipment

1. Externally mounted isolation switches used to interrupt normal load current shall be non- automatic switches unless otherwise approved by the university.
2. Externally mounted isolation switches used for opening under no load conditions shall be unfused disconnect switches where visual isolation can be confirmed, and a lock applied in the open position.
3. Externally mounted protective devices shall comply with the requirements outlined in section

   *26 28 16.13 Enclosed LV Circuit Breakers*.
4. Fused disconnect switches shall not be used, unless otherwise approved in writing by the university.

### *26 27 13 Electricity Metering*

Metering systems at the university will fall into one of four categories, and the type of meter to be used shall depend on the specific application in which they are installed.

#### 26 27 13.01 Meter Construction

All metering devices shall be installed in an accessible location indoors. All meters shall be installed such that they can be easily read or interfaced with by complying with the following:

1. Top of meter display shall be installed no higher than 1.9m (75 in) from the floor.
2. Bottom of the meter display shall be installed no lower than 1.2m (47 in) from the floor.

3. Meters may be installed within enclosures provided the preceding height requirements are preserved, and no tools are required to open the enclosure.

### 26 27 13.02 Meter Requirements

1. All meters shall be bi-directional.
2. All meter front panel instantaneous-value update intervals shall be no greater than once every 60 seconds.
3. All meters shall have an operating temperature range between -20˚C and +40˚C.
4. All RMS measurements shall be True RMS, not Average RMS.
5. All meters shall have a digital display allowing for configuration of settings and displaying instantaneous metering values at a minimum.
6. All max/min values shall be individually resettable, both locally and remotely through the associated communication protocols.

*Table 9 – Meter Requirement Summary Table*

| | NRG Multi Point | NRG Single Point | PQ | PQ+ |
|---|---|---|---|---|
| Communication Protocols | MODBUS/TCP<br>BACnet IP | MODBUS/TCP<br>BACnet IP | MODBUS/TCP ION<br>DNP3 | MODBUS/TCP ION<br>DNP3 |
| Time Sync Protocols | - | SNTP | NTP/SNTP IRIG-B<br>PTP | NTP/SNTP IRIG-B<br>PTP |
| Min Sample Rate (samples/cycle) | 64 | 128 | 256 | 1024 |
| CT Accuracy Class Meter | 0.5 | 0.2 | 0.2 | 0.1 |
| CT Secondary Ratio | 80mA | 5A | 5A | 5A |
| Minimum Connected CT Accuracy Class | 1.0 $^{\alpha}$ | 1.0 $^{\alpha}$ | 0.5 | 0.3 |
| Voltage Sensing Maximum | $300V_{AC}$ | $600V_{AC}$ | $600V_{AC}$ | $600V_{AC}$ |
| ***Measurements:*** | | | | |
| kW | X | X | X | X |
| kWh | X | X | X | X |

| | NRG Multi Point | NRG Single Point | PQ | PQ+ |
|---|---|---|---|---|
| kVA | X | X | X | X |
| kVAh | X | X | X | X |
| kVAr | X | X | X | X |
| kVArh | X | X | X | X |
| Vrms | X | X | X | X |
| Irms | X | X | X | X |
| PF | X | X | X | X |
| THD | - | X | X | X |
| TDD | - | X | X | X |
| Individual Harmonics | - | up to 63rd | up to 63rd | up to 63rd |
| kW max/min | - | X | X | X |
| kVA max/min | - | X | X | X |
| kVAr max/min | - | X | X | X |
| Vrms max/min | - | X | X | X |
| Irms max/min | - | X | X | X |
| PF man/min | - | X | X | X |
| Voltage Sag/Swell | - | - | X | X |
| Flicker | - | - | - | X |
| Inter-harmonic Distortions | - | - | - | X |
| Symmetrical Components | - | - | - | X |
| Phasor Display | - | X | X | X |
| Event Logging | - | X | X | X |
| Waveform Capture | - | - | X | X |
| Disturbance Detection | - | - | - | X |
| Local Data Storage Duration | - | up to 30 days | up to 30 days | up to 30 days |
| Digital Inputs | - | 2 | 4 | 6 |
| Digital Outputs | - | 2 | 4 | 6 |
| Analog Inputs (4-20mA) | - | - | - | 2 |
| Control Voltage | 110-130$V_{AC}$ | 100-240$V_{AC}$ | 100-400$V_{AC}$ 110-150$V_{DC}$ | 100-400$V_{AC}$ 110-150$V_{DC}$ |

| | NRG Multi Point | NRG Single Point | PQ | PQ+ |
|---|---|---|---|---|
| $^{\alpha}$ If meter is used for billing purposes, accuracy requirements must comply with Measurement Canada Standards. | | | | |

### 26 27 13.03 Meter Accessories

1. Metering CTs shall be solid core type. Split core type may be used only in retrofit applications where the primary value of the CT ratio is greater than 100A.
2. If PTs are required, they shall be metering grade (CPTs are not acceptable).
3. Primary CT rating shall match (as close as practicable) the ampacity of the circuit it is measuring.
4. If required, potential transformers to meters shall be primary fused with HRC type fuses. Fuses shall be located inside a compartment that is accessible without exposure to primary conductors. PT secondary voltage shall be 120V.
5. Meters shall be powered from a separate power supply or control power transformer and shall not be powered from the metering PTs.
6. All meters' monitoring ATSs (Automatic Transfer Switch) shall be powered from a UPS connected to the load side of the ATS, capable of powering the meter through a source transition to an emergency source.
7. Each meter shall have a unique CAT6 Ethernet communication cable run to the nearest F&S switch. Installation and connection/patching requirements shall comply with the latest "Building Automation Systems Design Standards and Guidelines".
8. The image below (*Figure 11 – Typical Meter Implementation*) gives a typical representation of where each type of meter would be installed within the university's electrical distribution system. These are general guidelines and final meter styles shall be approved by the university at the SD phase.

   **.1 NRG Meters:**

   - Sub-metering for mechanical building loads, or building automation systems

- Metering for building tenants who purchase power from the university
- Any faculty request for metering of their equipment
- Emergency generator transfer switch loads
- “Smaller” building’s main electrical service when sub-fed at a low voltage
- Metering for temporary construction power

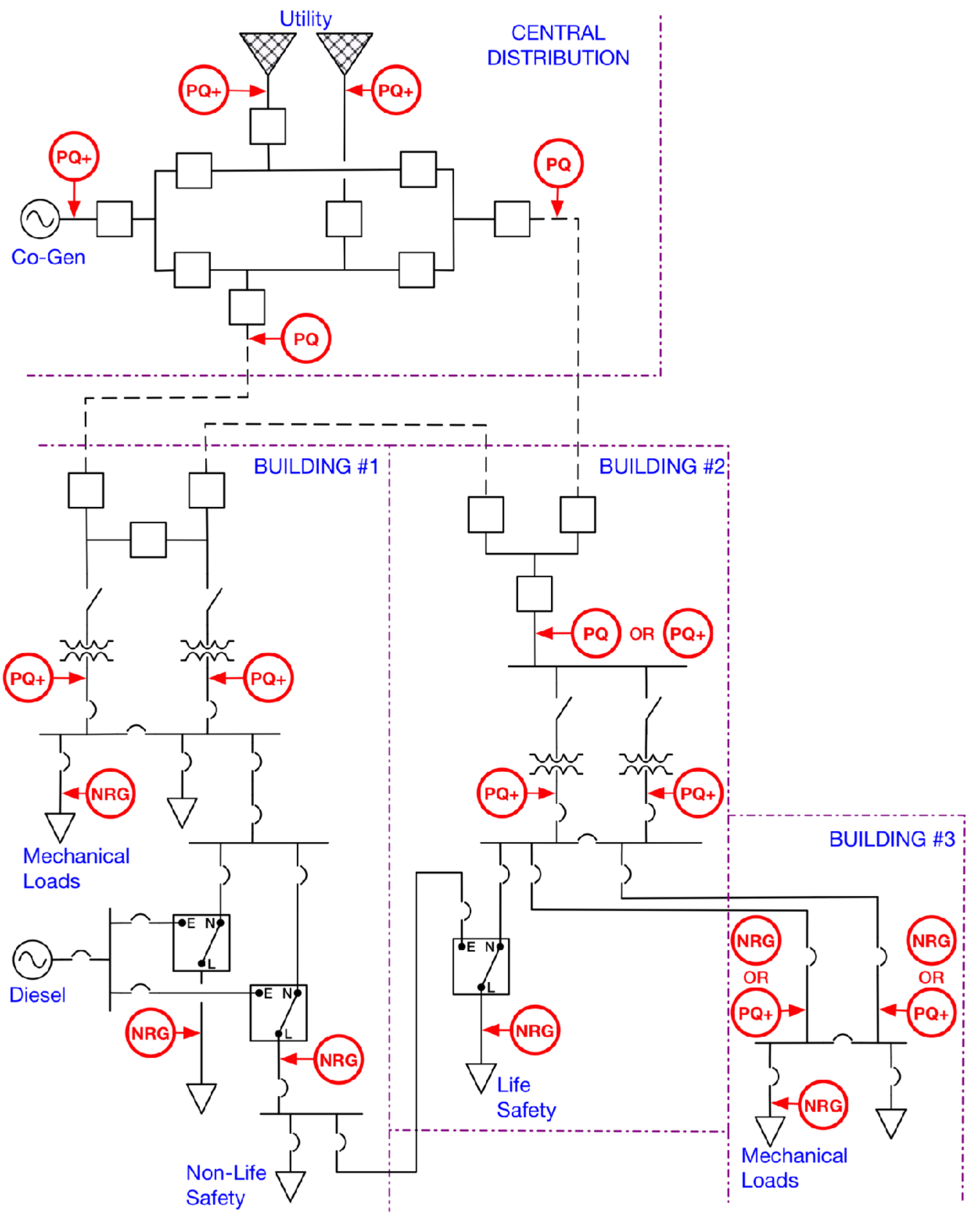
**.2 PQ Meters**

- Loop feeders from the central distribution system
- Buildings whose main low voltage supply service is sub-fed from other another building
- Less critical building’s main high voltage service

**.3 PQ+ Meters**

- Utility feeders into the central distribution system
- Generator feeders into the central distribution system
- Critical building’s main high voltage service
- Secondary side of building’s main power transformers

*Figure 11 – Typical Meter Implementation*



### *26 27 26 Wiring Devices*

1. Light switches and receptacles on normal power shall not be red or orange.
2. Light switches and receptacles on emergency power shall be red.
3. Isolated ground receptacles shall be orange.
4. Wall plates (for receptacles and/or switches) for flush mounted devices in mechanical spaces shall be stainless steel grade 302 or better.
5. Opposing outlets on partition walls shall have a 150mm (6 in) horizontal separation. They shall not be mounted back-to-back.
6. All Receptacle outlets shall be permanently identified indicating the circuit number and source of supply, e.g.

   004-NRP-03-02-AG: 23

   009-NRP-02-02-AA: 5/7

7. All light switches shall be permanently identified indicating the circuit number and source of supply, e.g.

   073-ELP-04-02-AF: 02

## 26 28 00 Low-Voltage Circuit Protective Devices

### *26 28 13 Fuses*

1. Fuses shall not be used for any low voltage power distribution equipment. Fuses are only acceptable for monitoring and control circuits.

### *26 28 16 Enclosed Switches and Circuit Breakers*

#### 26 28 16.13 Enclosed LV Circuit Breakers

1. Enclosed LV circuit breakers shall maintain coordination with their downstream devices by maintaining a trip rating ratio of 4:1 or greater with downstream devices.
2. Electronic trip module requirements for breaker frame sizes shall be in accordance with the requirements outlined in section *26 23 00.05 Circuit Breakers*.

#### 26 28 16.16 Enclosed Switches

1. Enclosed switches with circuit protection shall not be used. Please refer to *26 27 00.01 External Isolating / Protective Equipment* for requirements regarding externally enclosed isolating switches.

## 26 29 00 Low-Voltage Controllers

### *26 29 13 Enclosed Controllers*

#### 26 29 13.13 Across-the-Line Motor Controllers

1. Across the line motor controllers may only be installed on motor loads that are less than 1 HP.

#### 26 29 13.16 Reduced-Voltage Motor Controllers

1. Reduced Voltage motor controllers shall not be used.

### *26 29 23 Variable-Frequency Drive (VFD) Motor Controllers*

1. All VFDs shall have a Lamacoid of size ‘C’ located on the same side as the local isolating means. The Lamacoid shall reference the upstream protection device’s panelboard, circuit, and room number, e.g.

   Fed from 006-NPP-PH-06-
   AC CCT #20 in Rm. 1405

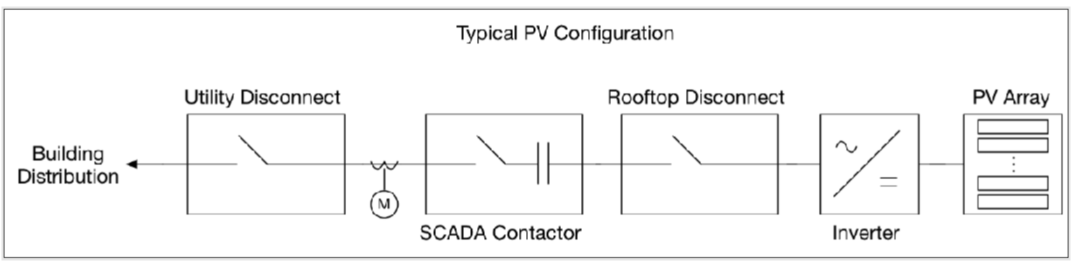
2. All VFDs shall be equipped minimally with a line side passive harmonic filter.
3. Voltage Total Harmonic Distortion (THD) shall not exceed 5% THD (V) at the point of common coupling.
4. Total Demand Distortion (TDD) shall not exceed 5% of the total full load fundamental current (I).
5. VFD shall be equipped with a local disconnect switch, lockable in the open position. A means of visual confirmation of isolation of the conductors shall be provided when in the open position.
6. For design and performance requirements, refer to the university’s mechanical design standard (https://www.fs.utoronto.ca/projects/design-standards-and-project-forms/).

# 26 30 00 - FACILITY ELECTRICAL POWER GENERATING AND STORING EQUIPMENT

## 26 31 00 Photovoltaic Systems

1. All photovoltaic installations shall comply with all the university roofing standards with regards to equipment placement.
2. All photovoltaic systems shall have a PQ type meter installed between the breaker that is connected to the building's AC distribution system and the contactor. Should an anti-islanding feature be installed, the meter's voltage sensing, and power connections shall remain energized if the anti- islanding contactor is opened.
3. Refer to *Figure 12 – Typical PV Configuration* below showing a typical configuration.

*Figure 12 – Typical PV Configuration*




4. Photovoltaic systems with outdoor disconnecting means shall be equipped with a tamper proof metal cage, complete with locking mechanism that will accommodate a 'U' bolt permitting installation of two individual padlocks. 'U' bolt shall allow the opening of the cage with only one lock removed.

## 26 32 00 Packaged Generator Assemblies

### *26 32 13 Engine Generators*

Natural Gas vs Diesel

1. Natural Gas is the preferred generator type provided it can meet the performance criteria as outlined in section 26 32 13.05 Generator Set Performance.

2. For retrofit applications diesel may be considered should size and weight requirements be an issue.

### 26 32 13.01 General

1. At least one of the generator room/enclosure doors shall be equipped with electronic access control, compliant with the university's "Security and Access Control System Specification".
2. Generator set shall be rated as specified at 0.85 power factor for continuous prime power duty.
3. Engine Governor shall be capable of maintaining the engine speed within 3% of the rated frequency from no load to full load generator output. The frequency at any constant load, including no load, shall remain within a steady state band width of 0.25% of rated frequency.

### 26 32 13.02 Enclosures

1. Prefabricated generator enclosures shall only be installed outdoors and shall be rated to operate in ambient temperatures between -30˚C to +40˚C.
2. Enclosures shall have an internal clearance of a minimum of 1m (39 in) on either side of the generator for maintenance purposes.
3. Enclosures shall have two access doors, each with a lockable cylinder door lock.
4. Prefabricated enclosures shall be sized to accommodate all accessories required by this standard.
5. Enclosures at grade shall be equipped with anti-intrusion provisions.
6. Enclosures shall have adequate air flow provisions to ensure sufficient heat rejection of the enclosure once the generator has shutdown.
7. At grade installations shall have sound attenuating enclosures such that the maximum sound level from the enclosure shall not exceed 80dBA at a distance of 5m (16 ft).

### 26 32 13.03 Diesel Engine Starting System

1. The engine shall be provided with DC voltage electric starting system using valve regulated lead acid (VRLA) batteries.

2. Batteries shall be capable of cranking for 10 seconds, at least six times, while maintaining battery voltage above 80% of rated, in an ambient temperature between 10°C and 40°C.

### 26 32 13.04 Exhaust System

1. A ‘Hospital Grade’ silencer shall be furnished with the engine.
2. A flexible, continuous, bellows type, stainless steel interlocking joints exhaust pipe, at least 61cm (24 in) long, shall be furnished for each engine exhaust outlet.
3. The exhaust pipe shall be terminated as required by code. In instances where code height is less than immediately adjacent buildings, consult with the university for required minimum.
4. The exhaust pipe shall be provided with a rain guard.
5. The muffler shall in insulated and shall have a drain line extended to a building drain.

### 26 32 13.05 Generator Set Performance

1. The voltage regulation from no load to rated load shall be within a band of 1% of rated voltage. The steady state voltage stability shall remain within a 0.5% band of rated voltage. Steady state voltage modulation shall not exceed one cycle per second.
2. For general emergency system loads (e.g., lighting, elevators and general-purpose receptacles), the voltage dip shall not exceed 20% of the rated voltage for any addition of load up to and including 100% of the rated generator load.
3. For loads consisting of only UPS protected systems (e.g., data centres, critical equipment), the voltage dip shall not exceed 10% of the rated voltage for any addition of load up to and including 100% of the connected load.
4. For loads consisting of both general purpose and UPS protected systems (e.g., mixture of UPS and non-UPS loads), the voltage dip shall not exceed 10% of the rated voltage for any addition of load up to and including 100% of the rated generator load.
5. Engine Governor shall be capable of maintaining the engine speed within 3% of the rated frequency from no load to full load generator output. The frequency at any constant load, including no load, shall remain within a steady state band width of 0.25% of rated frequency.

### 26 32 13.06 Generator Instrumentation and Control

1. An engine or generator-mounted control panel shall contain the following display indicators for proper engine/generator monitoring and maintenance:
   - Engine coolant temperature
   - Engine lube oil pressure
   - Engine lube oil temperature
   - Engine exhaust temperature
   - Engine running hour meter
   - Engine speed
   - Generator voltages
   - Generator currents
   - Generator real, reactive, and apparent power
   - Battery charging indicator
2. Generator control panel shall have a sequence of events recorder of all alarm and events. All associated settings and/or passwords shall be provided at closeout.
3. Generator control panel shall have a T-base 100 Ethernet port and support both MODBUS/TCP and BACnet/IP protocols.
4. Generator control panel shall have a unique CAT6 Ethernet communication cable run to the nearest F&S switch. Installation and connection/patching requirements shall comply with the latest "Building Automation Systems Design Standards and Guidelines" (15900_Building Automation Systems).
5. An engine or generator-mounted control panel shall contain the following alarm indicators for proper engine/generator surveillance and maintenance. The control panel shall have the following alarm contacts as shown in *Table 10 – Generator Instrumentation Alarm Contacts*: Where:

   LOCAL indicates control panel audible and/or visual alarm.

REMOTE indicates a termination at a control panel terminal block for remote connection.

SEAL-IN contacts remain in the alarm state until manually reset

*Table 10 – Generator Instrumentation Alarm Contacts*

| Conditions | Local Visual | Local Audible | Remote $^{\alpha}$ | Seal-in Contact |
|---|---|---|---|---|
| Coolant Temp Lo | Yes | Yes | Yes | Yes |
| Coolant Temp Hi | Yes | No | Yes | No |
| Lube Oil Pres. Lo | Yes | Yes | Yes | No |
| Lube Oil Temp Lo | Yes | Yes | Yes | Yes |
| Lube Oil Temp Hi | Yes | No | Yes | No |
| Engine Overcrank | Yes | Yes | Yes | No |
| Engine Over Speed | Yes | No | Yes | No |
| Engine Exhaust Hi | Yes | No | Yes | No |
| Battery Voltage Lo | Yes | Yes | Yes | Yes |
| Charger Failure | Yes | Yes | Yes | Yes |
| Gen. Breaker Tripped | Yes | Yes | Yes | Yes |
| Gen. Breaker Open | Yes | Yes | Yes | No |
| Room Temp Lo | Yes | Yes | No | Yes |
| Room Temp Hi | Yes | No | No | No |
| Gen. Not in Auto | Yes | Yes | Yes | Yes |
| Gen. E-STOP Activated | Yes | Yes | Yes | Yes |
| $^{\alpha}$ Refer to *Appendix A – Table of Signals for BAS Remote Monitoring* to identify which contacts shall be directed to the Building Automation System. | | | | |

6. If the life safety transfer switch is not located in the same room as the generator, a remote annunciation panel of generator alarms shall be supplied and installed in the room where the life safety transfer switch is located.

### 26 32 13.07 Generator Accessories

1. Provide an emergency fed (shore) panelboard inside the generator room or

enclosure. Loads to include:

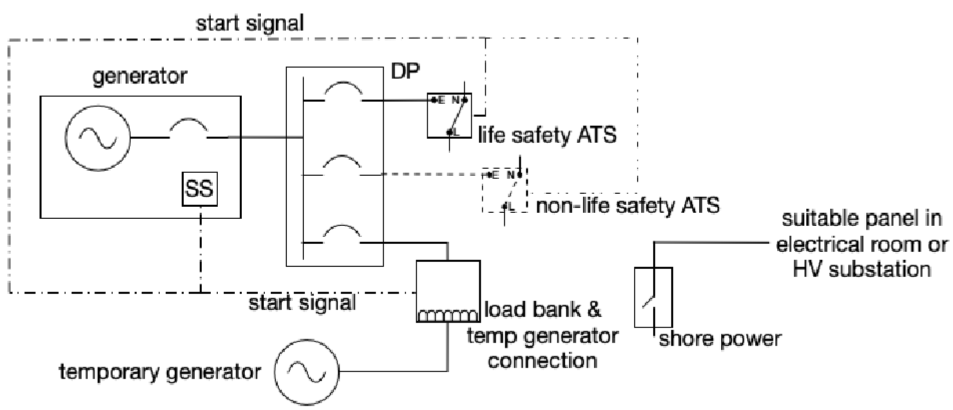
- Block heater
- Room/enclosure unit heaters
- Air circulation loads (fans, louvers)
- Battery charger
- Room lighting
- Emergency generator BAS controllers
- Minimum of two maintenance receptacles inside the generator room or enclosure

2. Provide a generator distribution panelboard, only energized when generator is running. Loads to include:

- Breaker(s) for life-safety transfer switch(es)
- Breaker(s) for non-life-safety transfer switch(es)
- Breaker for load bank/mobile generator connection box.

Refer to Figure 13 – Generator System Accessories Configuration below:

*Figure 13 – Generator System Accessories Configuration*




3. A terminal block connection for generator start signals shall be provided at the permanent generator in an accessible location.
4. Provide a pad-lockable load bank /mobile generator connection box at grade in an accessible, environment appropriate location for testing and emergency connection scenarios. The connection box shall have the following features:
   - Female Camlock connectors for all three phases, neutral and ground of the appropriate ampacity to achieve full load on the generator.
   - A push button with a shunt trip signal to the upstream generator panelboard breaker.
   - The remote end of the generator start signal shall be terminated at the permanent generator's start signal terminal block, on an unused terminal pair. This is to allow the start signal(s) to be moved to this unused terminal, in the event a mobile temporary generator is required. Wires terminated on the unused terminal shall be tagged with the following: 'Start Signal from Mobile Generator Connection Box'.
   - The local end terminals/connections for the generator start signal shall be labelled with a lamacoid of size C, stating: 'Generator Start Signal'.

### 26 32 13.13 Diesel Generator Set

#### 26 32 13.13.01 General

1. Diesel generators are preferred to be located on the ground level or below grade and shall be close to the exterior wall of the building for fuel fill access and vent pipe discharge. If a diesel generator is chosen to be located outdoors, then the generator shall be installed in an enclosure subject to section *26 32 13.02 Enclosures*.

#### 26 32 13.13.02 Fuel System

1. A control panel for the fuel system shall be provided. It shall be a wall-mounted or free- standing with a hinged, handle operated door, and be lockable with a padlock.
2. The fuel control panel shall have the following alarm contacts as shown in *Table 11 – Fuel System Alarm Contacts*: Where:

    LOCAL indicates control panel audible and/or visual alarm.

    REMOTE indicates a termination at a control panel terminal block for remote connection.

    SEAL-IN contacts remain in the alarm state until manually reset.

*Table 11 – Fuel System Alarm Contacts*

| Conditions | Local Visual | Local Audible | Remote $^{\alpha}$ | Seal-in Contact |
|---|---|---|---|---|
| Fuel Level Lo | Yes | Yes | Yes | Yes |
| Fuel Leak | Yes | Yes | Yes | Yes |
| Fuel Fill Cap Open | Yes | No | Yes | No |
| Day Tank Level Lo $^{\beta}$ | Yes | Yes | Yes | No |
| Day Tank Level Hi $^{\beta}$ | Yes | Yes | Yes | No |
| Day Tank Level HiHi $^{\beta}$ | Yes | Yes | Yes | No |
| Fuel Transfer System NOT in Auto $^{\beta}$ | Yes | Yes | Yes | No |
| Fuel Transfer System Trouble $^{\beta}$ | Yes | Yes | Yes | Yes |
| $^{\alpha}$ Refer to *Appendix A – Table of Signals for BAS Remote Monitoring* to identify which contacts shall be directed to the Building Automation System. | | | | |

| Conditions | Local Visual | Local Audible | Remote [α] | Seal-in Contact |
|---|---|---|---|---|
| [β] Only required if a Fuel Transfer system is used | | | | |

### 26 32 13.16 Gas-Engine-Driven Generator Sets

1. Natural gas generators shall have an accumulator tank at the same level of the generator if the generator is located higher than the fourth floor.

## 26 33 00 Battery Equipment

### *26 33 13 Batteries*

1. New BESS designs shall be coordinated with and accepted by the university prior to implementation. More information will be provided in the next revision of the Electrical Design Standard.

### *26 33 53 Static Uninterruptible Power Supply (UPS)*

2. This section refers to 3-phase centralized offline or double conversation UPS systems. Pluggable or Rack mounted UPS systems are not covered in this section.
3. All UPSs shall have a Lamacoid as indicated in 26 05 53.04 Identification for Electrical Systems and Accessories .
    a. Emergency non-life safety UPS equipment identifier shall use the "U" prefix.
        i. Example: 062-**U**UP-B2-06-AA
    b. Emergency life safety UPS equipment identifier shall use the "E" prefix -.
        i. Example: 062-**E**UP-B2-06-AA
4. Emergency Life Safety (LSUPS) shall be compliant with the latest *IEEE 446 Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*
5. The UPS system shall use batteries for energy storage and have an external maintenance bypass.
6. The UPS system shall be designed for a minimum 15-year life cycle.

7. The UPS and batteries shall be installed in electrical spaces that are keyed to the same access level as high voltage substations.-.
8. The manufacturer shall provide a minimum of a 3-year warranty on all UPS components.
9. When the UPS inputs are fed from multiple different sources, the UPS shall be sized to carry the load for the longest transition time between sources, or five minutes, whichever is greater. .
10. Acceptable battery technologies shall be either VRLA or LiON.
11. Minimum Electrical Requirements:
    a. System input/output voltages shall adhere to acceptable voltage requirements as noted in the General Design Consideration section, clause 5.
    b. The UPS shall be capable of supplying loads with power factor between 0.85 lag and 0.9 lead.
    c. Input and output current TDD shall be less than 5%
    d. Input and output voltage THD shall be less than 5%
12. Shall be monitored for the alarms listed in the table below:

*Table 12 - UPS Contact Requirements*

| Conditions | Local Visual | Local Audible | Remote |
|---|---|---|---|
| UPS on Battery | Yes | Yes | Yes |
| UPS Battery Level Low | Yes | Yes | Yes |
| UPS Battery Charging | Yes | No | No |
| UPS in Normal Operation | Yes | No | No |
| UPS on Maintenance Bypass | Yes | No | Yes |
| UPS on Static Bypass $^{\alpha}$ | Yes | No | Yes |
| UPS Offline | No | No | Yes |
| UPS High Battery Temperature Alert | Yes | Yes | Yes |
| $^{\alpha}$ If feature included on UPS. | | | |

## 26 35 00 Power Filters and Conditioners

### *26 35 26 Harmonic Filters*

Refer to section *26 29 23 Variable-Frequency Drive (VFD) Motor Controllers*.

### *26 35 33 Power Factor Correction Equipment*

#### 26 35 33.16 Low-Voltage Power Factor Correction Equipment

1. Shall be installed when the projected power factor is less than 0.8 and sized to bring power factor to unity.

## 26 36 00 Transfer Switches

### *26 36 23 Automatic Transfer Switches*

1. All automatic transfer switches shall be contactor type. Breaker type transfer switches are not acceptable.
2. The Design Team shall determine if a four-pole or overlapping neutral transfer switch is required based on the location of the transfer switches, generators, and system grounds.
3. All ATSs rated greater than 100A or in buildings classified as a residence, shall have a manual bypass for both the normal and emergency supplies, which can be engaged without interrupting power to the loads. The transfer switch mechanism shall be fully withdrawable when bypassed to perform maintenance.
4. Closed transition automatic transfer switches (CT-ATS) shall be installed when the emergency supply to the transfer switch is connected directly to a generator's emergency distribution system. (e.g., emergency supply normally unavailable/de-energized)
5. Open transition automatic transfer switches (OT-ATS) shall be installed when the emergency supply to the transfer switch is connected to the load side of another transfer switch (e.g., emergency supply normally available)
6. CT-ATSs shall have a selector switch with a "remote start" position/setting and a "remote start and transfer" position/setting.
7. OT-ATSs shall have a selector switch or button with a "transfer test" position/setting.
8. Automatic transfer switch shall have the following settings available:
   - Time delay normal to emergency (TDNE) adjustable from 0 to 60 seconds
   - Time delay emergency to normal (TDEN) adjustable from 0 to 600 seconds

- Time delay neutral (TDN) adjustable from 0 to 5 seconds
- Generators cool down timer adjustable from 0 to 600 seconds

9. All transfer switches shall have a dry type contact which will be open when the transfer switch is in the emergency position and closed when in the normal position. Dry contact shall be rated up to 125VAC/125VDC.
10. All Transfer switches shall be equipped with a meter of type 'NRG', measuring the current and voltage on the load side of the transfer switch. Refer to section 26 27 13 Electricity Metering for metering requirements. Power for the meter to be derived from the load side of the transfer switch through an uninterruptable power supply (UPS). Control power for any digital inputs to the meter shall be derived from the same UPS. The meter's first discrete input shall be wired to the transfer switch output described in 9 above.
11. Start signal shall be subject to the wiring and control methods in section 26 05 19.01 Wires and Cables.
12. Generators cool down timer shall be coordinated with generator controls. If the generator has its own cool down function, then the ATS cool down timer shall be set to zero.
13. If the ATS is not tied to an emergency source directly connected to a generator, the ATS cool down timer shall be set to zero, as is the case for OT-ATS installations.
14. Refer to Appendix A – Table of Signals for BAS Remote Monitoring for a list of required auxiliary contacts.

# 26 50 00 LIGHTING

## 26 50 01 General Requirements

1. All lighting to be LED type with electronic driver (refer to lighting controls 26 09 24 for further LED driver specifications and requirements)
2. Power factor shall be greater than or equal to 0.80 with driver at full load
3. All fixtures shall be rated at 120V
4. All lighting shall be fed from lighting panels (LP)

## 26 51 00 Interior Lighting

### *26 51 13 Incandescent Interior Lighting*

Not permitted for new installations.

### *26 51 16 Fluorescent Interior Lighting*

Not permitted for new installations.

### *26 51 19 LED Interior Lighting*

All new interior lighting installations shall be LED type.  Refer to general requirements in section 26 50 01 for specific details.

### *26 51 23 HID Interior Lighting*

Not permitted for new installations.

## 26 52 00 Safety Lighting

### *26 52 13 Emergency and Exit Lighting*

1. All new emergency lighting installations shall be LED type.  Refer to general requirements in section 26 50 01 for specific details.
2. All emergency and exit lighting shall be fed from a life safety lighting panel.

3. Where a centralized emergency source is available in the building, all emergency and exit lighting shall be fed from that source. Rechargeable battery operated and self-contained emergency lighting units are not permitted with the exception noted in section 26 52 13.13.

#### 26 52 13.13 Emergency Lighting

In addition to the requirements outlined in section 26 52 13, substations and generator rooms/enclosures shall also have emergency wall mounted rechargeable battery operated and self-contained emergency lighting units as outlined in section 26 11 00 .15.

#### 26 52 13.16 Exit Signs

In addition to the requirements outlined in section 26 52 13, exit signs shall be of Green Running Man style or match existing building type.

## 26 54 00 Classified Location Lighting

### *26 54 13 Incandescent Classified Location Lighting*

Not permitted for new installations.

### *26 54 16 Fluorescent Classified Location Lighting*

Not permitted for new installations.

### *26 54 19 LED Classified Location Lighting*

All new classified lighting installations shall be LED type. Refer to general requirements in section 26 50 01 for specific details.

## 26 55 00 Special Purpose Lighting

All new special purpose lighting installations shall be LED type. Refer to general requirements in section 26 50 01 for specific details.

# 26 56 00 Exterior Lighting

## *26 56 13 Lighting Poles and Standards*

All new lighting poles and standings lighting installations shall be LED type. Refer to general requirements in section 26 50 01 for specific details.

## *26 56 17 Fluorescent Exterior Lighting*

Not permitted for new installations.

## *26 56 18 Incandescent Exterior Lighting*

Not permitted for new installations.

## *26 56 19 LED Exterior Lighting*

All new exterior lighting installations shall be LED type. Refer to general requirements in section 26 50 01 for specific details.

## *26 56 21 HID Exterior Lighting*

Not permitted for new installations.

# APPENDIX A – TABLE OF SIGNALS FOR BAS REMOTE MONITORING

*Table 13- Table of Signals for Remote Monitoring*

| Name | Signal Type | Number | BAS Alarm Class |
|---|---|---|---|
| **High Voltage Liquid Filled Transformers** | | | |
| Low Oil Level | DO | 1 | CRITICAL |
| Oil Temperature Hi (Fan Start) | DO | 1 | LOW |
| Oil Temperature HiHi | DO | 1 | CRITICAL |
| Oil Temperature | AO: 4 - 20mA | 1 | Consultant Defined |
| Winding Temperature Hi | DO | 1 | HIGH |
| Winding Temperature (Hot Spot) | AO: 4 - 20mA | 1 | Consultant Defined |
| Sudden Gas Trip | DO | 1 | CRITICAL |
| **High Voltage Dry-Type Transformers** | | | |
| Winding Temperature Hi (Fan Start) | DO | 1 | LOW |
| Winding Temperature HiHi | DO | 1 | CRITICAL |
| Winding Temperature (Hot Spot) | AO: 4 - 20mA | 1 | Consultant Defined |
| **Station Battery Supply & Charger** | | | |
| AC Failure | DO | 1 | LOW |
| Hi Output Voltage | DO | 1 | LOW |
| Lo Output Voltage | DO | 1 | HIGH |
| Rectifier Hi Temp | DO | 1 | HIGH |
| Rectifier Failure | DO | 1 | CRITICAL |
| Ground Fault | DO | 1 | HIGH |
| Battery Sym. Fault | DO | 1 | HIGH |
| Battery Breaker Status | DO | 1 | LOW |
| Charger Output Breaker Status | DO | 1 | LOW |
| **Generators** | | | |
| Coolant Temp Lo | DO | 1 | HIGH |
| Coolant Temp Hi | DO | 1 | HIGH |
| Lube Oil Pres. Lo | DO | 1 | HIGH |
| Lube Oil Temp Lo | DO | 1 | HIGH |

| Name | Signal Type | Number | BAS Alarm Class |
|---|---|---|---|
| Lube Oil Temp Hi | DO | 1 | HIGH |
| Engine Overcrank | DO | 1 | HIGH |
| Engine Over Speed | DO | 1 | HIGH |
| Engine Exhaust Hi | DO | 1 | HIGH |
| Battery Voltage Lo | DO | 1 | HIGH |
| Charger Failure | DO | 1 | HIGH |
| Gen. Breaker Tripped | DO | 1 | CRITICAL |
| Gen. Breaker Open | DO | 1 | HIGH |
| Gen. Not in Auto | | | HIGH |
| Gen. E-STOP Activated | | | HIGH |
| Room Temp | AO: 4 - 20mA | 1 | Consultant Defined |
| **GENERATOR FUEL SYSTEMS** | | | |
| Main Tank Fuel Level Lo | DO | 1 | HIGH |
| Fuel Leak | DO | 1 | CRITICAL |
| Main Tank Fuel Overfill | DO | 1 | LOW |
| Day Tank Level Lo (Pump Start) $^{\alpha}$ | DO | 1 | LOW |
| Day Tank Level Hi (Pump Stop) $^{\alpha}$ | DO | 1 | LOW |
| Day Tank Level HiHi $^{\alpha}$ | DO | 1 | LOW |
| Fuel Transfer System NOT in Auto $^{\alpha}$ | DO | 1 | HIGH |
| Fuel Transfer System Trouble $^{\alpha}$ | DO | 1 | HIGH |
| $^{\alpha}$ Only required if a Fuel Transfer system is used | | | |
| **AUTOMATIC TRANSFER SWITCHES** | | | |
| Closed on Normal | DO | 1 | LOW |
| Closed on Emergency | DO | 1 | LOW |
| Loss of Normal | DO | 1 | LOW |
| Bypass to Normal | DO | 1 | LOW |
| Bypass to Emergency | DO | 1 | LOW |
| Not in Automatic Mode | DO | 1 | HIGH |

# APPENDIX B – GLOSSARY OF ABBREVIATIONS

*Table 14 - Glossary of Abbreviations*

| Abbreviation | Description | Category |
|---|---|---|
| A | Amps or Amperage | Unit of Measurement |
| AC | Alternating Current | Unit of Measurement |
| ACE | Academic & Campus Events | Administration |
| ANF | Forced Air Cooling | Electrical |
| ANN | Air Natural Convection Cooling | Electrical |
| ANSI | American National Standards Institute | Standard / Code |
| ATS | Automatic Transfer Switch | Equipment |
| AV | Audio Visual | Equipment |
| AWG | American Wire Gauge | Unit of Measurement |
| BAS | Building Automation System | Equipment |
| BESS | Battery Energy Storage Systems | Electrical |
| BIL | Basic Insulation Level | Unit of Measurement |
| BNC | Bayonet Neill-Concelman | Networking/IT |
| CaPS | Capital Projects & Space Planning Committee | Administration |
| CCN | Contemplated Change Notice | Administration |
| CCT or cct | Panel Circuit Number | Electrical |
| CCTV | Closed-circuit television | Equipment |
| CED | Central Distribution System | Electrical |
| CPT | Combination CT/PT | Equipment |
| CSA | Canadian Standards Association | Standard / Code |
| CT | Current Transformer | Equipment |
| CT-ATS | Closed Transition ATS - "Make-before-Break" | Equipment |
| DC | Direct Current | Unit of Measurement |
| DD | Design Development | Administration |
| DP | Distribution Panel | Equipment |
| EMRS | Energy Management Reporting System | Equipment |

| Abbreviation | Description | Category |
|---|---|---|
| EMT | Electrical Metallic Tubing | Equipment |
| F&S | Facilities & Services | Administration |
| FLA | Full Load Amps | Unit of Measurement |
| FT | Flexitest | Networking/IT |
| ft or ' | Feet | Unit of Measurement |
| HP | Horsepower | Unit of Measurement |
| HRC | HRC Fuse? | Equipment |
| HV | High Voltage | Electrical |
| Hz | Hertz | Unit of Measurement |
| I | Current | Unit of Measurement |
| I/O | Input/Output | Electrical |
| ICOM | Intercom | Equipment |
| IEEE | Institute of Electrical and Electronics Engineers | Standard / Code |
| IFC | Issued for Construction | Administration |
| IFT | Issued for Tender | Administration |
| in | Inches | Unit of Measurement |
| Irms | Current Root Mean Square | Unit of Measurement |
| kA | Kilo-Amps | Unit of Measurement |
| Kcmil | Kilo (Thousand) circular mil | Unit of Measurement |
| kV | Kilo-Volt | Unit of Measurement |
| kVA | Apparent Power - Kilo-Volt-Amps | Unit of Measurement |
| kVAh | Kilo-Volt-Amps-hours | Unit of Measurement |
| kVAR | kilo-Variance | Unit of Measurement |
| kVARh | kilo-Variance hours | Unit of Measurement |
| kW | Kilo-Watts | Unit of Measurement |
| kWh | kilo-Watt - hours | Unit of Measurement |
| LED | Light Emitting Diodes | Equipment |
| LiON | Lithium Ion | Electrical |
| LP | Lighting Panel | Equipment |
| LRA | Locked Rotor Amps | Unit of Measurement |
| LSI | Long, Short, Instantaneous | Electrical |

| Abbreviation | Description | Category |
|---|---|---|
| LSIG | Long, Short, Instantaneous, Ground | Electrical |
| LV | Low Voltage | Electrical |
| m | Meters | Unit of Measurement |
| MCC | Motor Control Centre | Equipment |
| MCM | Thousand circular mil | Unit of Measurement |
| MCOV | Maximum Continuous Operating Voltage | Unit of Measurement |
| NC | Normally Closed | Electrical |
| NO | Normally Open | Electrical |
| No. | Number | General |
| NTP | Network Time Protocol | Networking/IT |
| OESC | Ontario Electrical Safety Code | Standard / Code |
| OT-ATS | Open Transition ATS - "Break-before-Make" | Equipment |
| PA | Public Address | Equipment |
| PF | Power Factor | Unit of Measurement |
| PG | Paging | Equipment |
| PILC | Paper Insulated Lead Covered | Equipment |
| PME | Power Monitoring | Equipment |
| PP | Power Panel | Equipment |
| PPR | Project Planning Report | Administration |
| PT | Power Transformer | Equipment |
| PV | Photovoltaic | Electrical |
| R | Resistance | Unit of Measurement |
| RFI | Request For Information | Administration |
| rms | Root-Mean Square | Unit of Measurement |
| RP | Receptacle Panel | Equipment |
| RTU | Remote Terminal Unit | Equipment |
| SCADA | Supervisory Control and Data Acquisition | Electrical |
| SCCR | Short Circuit Coordination Study Report | Electrical |
| SD | Schematic Design | Administration |
| SFP | Small Form Factor | Equipment |
| SNTP | Simple Network Time Protocol | Networking/IT |

| Abbreviation | Description | Category |
|---|---|---|
| TCC | Time Current Curves | Electrical |
| TCP | Transmission Control Protocol | Networking/IT |
| TDD | Total Demand Distortion | Unit of Measurement |
| TDEN | Time Delay Emergency to Normal | Electrical |
| TDN | Time Delay Neutral | Electrical |
| TDNE | Time Delay Normal to Emergency | Electrical |
| THD | Total Harmonic Distortion | Unit of Measurement |
| TS | Transfer Switch | Equipment |
| TX | Transformer | Equipment |
| The university | The University of Toronto | Administration |
| UPS | Uninterruptible Power Supply | Equipment |
| UV | Ultra Violet | Electrical |
| V | Voltage or Volt | Unit of Measurement |
| VA | Apparent Power - Volt-Amps | Unit of Measurement |
| VAC | Voltage AC | Unit of Measurement |
| VDC | Voltage DC | Unit of Measurement |
| VFD | Variable Frequency Drive | Equipment |
| VLF | Very Low Frequency | Electrical |
| VRLA | Valve Regulated Lead Acid | Electrical |
| Vrms | Voltage Root Mean Square | Unit of Measurement |
| W | Wattage or Watts | Unit of Measurement |
| X | Reactance | Unit of Measurement |
| X/R | Reactance over Resistance Ration - "X over R - Ratio" | Unit of Measurement |
| XLPE | Cross-Linked Polyethylene | Equipment |
| Z | Impedance | Unit of Measurement |

## APPENDIX C – ELECTRICAL DESIGN STANDARDS - CHECKLIST

*The Design Team is required to read and comply with the full Design Standard as it applies to this project. A completed copy of this checklist must be submitted by the Design Team to the university's Project Manager (PM) at the end of the Schematic design Phase.*

*For each section, indicate Compliant (C), Not Compliant (NC), or Not Applicable (NA) as appropriate. In all cases, if a "NC" has been noted, please indicate why. Attach additional sheets as necessary.*

*Table 15 – Electrical Design Standards - Checklist*

| SECTION | C | NA | NC |
|---|---|---|---|
| **26 00 00 Electrical** | | | |
| **General Design Considerations** | ☐ | ☐ | ☐ |
| 26 05 00 Common Work Results for Electrical | ☐ | ☐ | ☐ |
| 26 05 05 Selective Demolition for Electrical | ☐ | ☐ | ☐ |
| 26 05 13 High-Voltage Cables | | | |
| *26 05 13.16 High-Voltage, Single- and Multi-Conductor Cables* | ☐ | ☐ | ☐ |
| 26 05 19 Low-Voltage Electrical Power Conductors and Cables | | | |
| *26 05 19.01 Wires and Cables* | ☐ | ☐ | ☐ |
| 26 05 23 Control-Voltage Electrical Power Cables | | | |
| *26 05 33.13 Conduit for Electrical Systems* | ☐ | ☐ | ☐ |
| 26 05 43 Underground Ducts and Raceways for Electrical Systems | | | |
| *26 05 43.01 Ductbanks and Cable Chambers* | ☐ | ☐ | ☐ |
| 26 05 53 Identification for Electrical Systems | | | |
| *26 05 53.01 Colour Codes for electrical equipment* | ☐ | ☐ | ☐ |
| *26 05 53.02 Colour Codes for electrical receptacles* | ☐ | ☐ | ☐ |
| *26 05 53.03 Colour Codes for Junction Box Cover Plates on Various Systems* | ☐ | ☐ | ☐ |
| *26 05 53.04 Identification for Electrical Systems and Accessories* | ☐ | ☐ | ☐ |
| 26 05 73 Power System Studies | ☐ | ☐ | ☐ |
| *26 05 73.13 Short-Circuit Studies* | ☐ | ☐ | ☐ |
| *26 05 73.16 Coordination Studies* | ☐ | ☐ | ☐ |
| *26 05 73.19 Arc-Flash Hazard Analysis* | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| *26 05 73.23 Load Flow Studies* | ☐ | ☐ | ☐ |

| SECTION | C | NA | NC |
|---|---|---|---|
| *26 05 73.26 Stability Studies* | ☐ | ☐ | ☐ |
| *26 05 73.29 Power Quality - Analysis Studies* | ☐ | ☐ | ☐ |
| 26 05 83 Wiring Connections | ☐ | ☐ | ☐ |
| 26 06 00 Schedules for Electrical | | | |
| 26 06 10 Schedules for High Voltage Electrical Distribution | ☐ | ☐ | ☐ |
| 26 06 20 Schedules for Low-Voltage Electrical Distribution | ☐ | ☐ | ☐ |
| *26 06 20.13 Electrical Switchboard Schedule* | ☐ | ☐ | ☐ |
| *26 06 20.16 Electrical Panelboard Schedule* | ☐ | ☐ | ☐ |
| *26 06 20.19 Electrical Motor-Control Center Schedule* | ☐ | ☐ | ☐ |
| *26 06 20.26 Wiring Device Schedule* | ☐ | ☐ | ☐ |
| 26 06 30 Schedules for Facility Electrical Power Generating and Storing Equipment | ☐ | ☐ | ☐ |
| 26 06 40 Schedules for Electrical Protection Systems | ☐ | ☐ | ☐ |
| 26 06 50 Schedules for Lighting | ☐ | ☐ | ☐ |
| *26 06 50.13 Lighting Panelboard Schedule* | ☐ | ☐ | ☐ |
| 26 08 00 Testing, Commissioning, and Training on Electrical Systems | | | |
| *26 08 00.01 Testing and Adjustments* | ☐ | ☐ | ☐ |
| *26 08 00.02 Factory Acceptance Testing (FAT)* | ☐ | ☐ | ☐ |
| *26 08 00.03 Commissioning Testing* | ☐ | ☐ | ☐ |
| *26 08 00.04 Training and Demonstration of Electrical Systems* | ☐ | ☐ | ☐ |
| **26 10 00 High-Voltage Electrical Distribution** | | | |
| 26 11 00 Substations and Switching Stations | ☐ | ☐ | ☐ |
| 26 11 10 Substation Communication Architecture | ☐ | ☐ | ☐ |
| 26 12 00 High Voltage Transformers | ☐ | ☐ | ☐ |
| 26 12 13 Liquid-Filled, High Voltage Transformers | ☐ | ☐ | ☐ |
| 26 12 16 Dry-Type, High Voltage Transformers | ☐ | ☐ | ☐ |
| 26 12 19 Pad-Mounted, Liquid-Filled, High-Voltage Transformers | ☐ | ☐ | ☐ |
| 26 13 00 High Voltage (15kV) Switchgear | | | |
| *26 13 00.01 General* | ☐ | ☐ | ☐ |
| *26 13 00.02 Typical 15kV Switchgear Configurations* | ☐ | ☐ | ☐ |
| *26 13 00.03 Construction* | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| *26 13 00.04 Buses* | ☐ | ☐ | ☐ |

| SECTION | C | NA | NC |
|---|---|---|---|
| *26 13 00.05 15 kV Rated Load Break Switches* | ☐ | ☐ | ☐ |
| *26 13 00.06 15 kV Rated Circuit Breakers* | ☐ | ☐ | ☐ |
| *26 13 00.07 Monitoring & Control* | ☐ | ☐ | ☐ |
| *26 13 00.08 Wiring and Connections* | ☐ | ☐ | ☐ |
| *26 13 00.09 Protective Relaying* | ☐ | ☐ | ☐ |
| *26 13 00.10 Instrument Transformers* | ☐ | ☐ | ☐ |
| *26 13 00.11 Accessories* | ☐ | ☐ | ☐ |
| *26 13 00.12 Switchgear Control Power (Station Battery Supply & Charger)* | ☐ | ☐ | ☐ |
| 26 13 13 High-Voltage Circuit Breaker Switchgear | ☐ | ☐ | ☐ |
| 26 13 16 High-Voltage Fusible Interrupter Switchgear | ☐ | ☐ | ☐ |
| 26 13 19 High-Voltage Vacuum Interrupter Switchgear | ☐ | ☐ | ☐ |
| 26 13 23 High-Voltage Metal-Enclosed Switchgear | ☐ | ☐ | ☐ |
| 26 13 26 High-Voltage Metal-Clad Switchgear | ☐ | ☐ | ☐ |
| 26 13 29 High-Voltage Compartmentalized Switchgear | ☐ | ☐ | ☐ |
| 26 15 00 High-Voltage Enclosed Bus Assemblies | ☐ | ☐ | ☐ |
| 26 16 00 High-Voltage Metering | ☐ | ☐ | ☐ |
| 26 18 00 High-Voltage Circuit Protection Devices | ☐ | ☐ | ☐ |
| 26 18 13 High-Voltage Cutouts | ☐ | ☐ | ☐ |
| 26 18 16 High-Voltage Fuses | ☐ | ☐ | ☐ |
| 26 18 23 High-Voltage Surge Arresters | ☐ | ☐ | ☐ |
| 26 18 39 High-Voltage Motor Controllers | ☐ | ☐ | ☐ |
| **26 20 00 Low-Voltage Electrical Distribution** | | | |
| 26 21 00 Low-Voltage Electrical Service Entrance | | | |
| 26 21 16 Low-Voltage Underground Electrical Service Entrance | ☐ | ☐ | ☐ |
| 26 22 00 Low-Voltage Transformers | | | |
| 26 22 13 Low-Voltage Distribution Transformers (600V or below on Primary) | ☐ | ☐ | ☐ |
| 26 22 19 Control and Signal Transformers | ☐ | ☐ | ☐ |
| 26 23 00 Low-Voltage Switchgear | | | |
| *26 23 00.01 General* | ☐ | ☐ | ☐ |
| *26 23 00.02 Configuration* | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| *26 23 00.03 Construction* | ☐ | ☐ | ☐ |

| SECTION | C | NA | NC |
|---|---|---|---|
| *26 23 00.04 Buses* | ☐ | ☐ | ☐ |
| *26 23 00.05 Circuit Breakers* | ☐ | ☐ | ☐ |
| *26 23 00.06 Monitoring and Control* | ☐ | ☐ | ☐ |
| *26 23 00.07 Wiring and Connections* | ☐ | ☐ | ☐ |
| *26 23 00.08 Instrument Transformers* | ☐ | ☐ | ☐ |
| *26 23 00.09 Accessories* | ☐ | ☐ | ☐ |
| 26 24 00 Switchboards and Panelboards | | | |
| 26 24 13 Switchboards | ☐ | ☐ | ☐ |
| 26 24 16 Panelboards | ☐ | ☐ | ☐ |
| *26 24 16.01 Power Distribution Panelboards (DP Panelboards)* | ☐ | ☐ | ☐ |
| *26 24 16.02 Lighting (LP) and Receptacle (RP) Panelboards* | ☐ | ☐ | ☐ |
| *26 24 16.03 Power Panelboards (PP)* | ☐ | ☐ | ☐ |
| 26 24 19 Motor Starters and Motor Control Centers (MCC) | ☐ | ☐ | ☐ |
| 26 25 00 Low-Voltage Enclosed Bus Assemblies | | | |
| 26 25 13 Low-Voltage Busways | ☐ | ☐ | ☐ |
| 26 25 16 Low-Voltage Cablebus Systems | ☐ | ☐ | ☐ |
| 26 27 00 Low Voltage Distribution System Equipment (600 Volts Maximum) | | | |
| *26 27 00.01 External Isolating / Protective Equipment* | ☐ | ☐ | ☐ |
| 26 27 13 Electricity Metering | ☐ | ☐ | ☐ |
| *26 27 13.01 Meter Construction* | ☐ | ☐ | ☐ |
| *26 27 13.02 Meter Requirements* | ☐ | ☐ | ☐ |
| *26 27 13.03 Meter Accessories* | ☐ | ☐ | ☐ |
| 26 27 26 Wiring Devices | ☐ | ☐ | ☐ |
| 26 28 00 Low-Voltage Circuit Protective Devices | | | |
| 26 28 13 Fuses | ☐ | ☐ | ☐ |
| 26 28 16 Enclosed Switches and Circuit Breakers | | | |
| *26 28 16.13 Enclosed LV Circuit Breakers* | ☐ | ☐ | ☐ |
| *26 28 16.16 Enclosed Switches* | ☐ | ☐ | ☐ |
| 26 29 00 Low-Voltage Controllers | | | |
| 26 29 13 Enclosed Controllers | | | |

| | | | |
|---|---|---|---|
| *26 29 13.13 Across-the-Line Motor Controllers* | ☐ | ☐ | ☐ |
| *26 29 13.16 Reduced-Voltage Motor Controllers* | ☐ | ☐ | ☐ |

| SECTION | C | NA | NC |
|---|---|---|---|
| 26 29 23 Variable-Frequency Drive (VFD) Motor Controllers | ☐ | ☐ | ☐ |
| **26 30 00 Facility Electrical Power Generating and Storing Equipment** | | | |
| 26 31 00 Photovoltaic Systems | ☐ | ☐ | ☐ |
| 26 32 00 Packaged Generator Assemblies | | | |
| 26 32 13 Engine Generators | ☐ | ☐ | ☐ |
| *26 32 13.01 General* | ☐ | ☐ | ☐ |
| *26 32 13.02 Enclosures* | ☐ | ☐ | ☐ |
| *26 32 13.03 Diesel Engine Starting System* | ☐ | ☐ | ☐ |
| *26 32 13.04 Exhaust System* | ☐ | ☐ | ☐ |
| *26 32 13.05 Generator Set Performance* | ☐ | ☐ | ☐ |
| *26 32 13.06 Generator Instrumentation and Control* | ☐ | ☐ | ☐ |
| *26 32 13.07 Generator Accessories* | ☐ | ☐ | ☐ |
| *26 32 13.13 Diesel Generator Set* | | | |
| *26 32 13.13.01 General* | ☐ | ☐ | ☐ |
| *26 32 13.13.02 Fuel System* | ☐ | ☐ | ☐ |
| *26 32 13.16 Gas-Engine-Driven Generator Sets* | ☐ | ☐ | ☐ |
| 26 33 00 Battery Equipment | | | |
| 26 33 13 Batteries | ☐ | ☐ | ☐ |
| 26 33 53 Static Uninterruptible Power Supply (UPS) | ☐ | ☐ | ☐ |
| 26 35 00 Power Filters and Conditioners | | | |
| 26 35 26 Harmonic Filters | ☐ | ☐ | ☐ |
| 26 35 33 Power Factor Correction Equipment | | | |
| *26 35 33.16 Low-Voltage Power Factor Correction Equipment* | ☐ | ☐ | ☐ |
| 26 36 00 Transfer Switches | | | |
| 26 36 23 Automatic Transfer Switches | ☐ | ☐ | ☐ |
| **26 50 00 Lighting** | ☐ | ☐ | ☐ |
| 26 50 01 General Requirements | ☐ | ☐ | ☐ |
| 26 51 00 Interior Lighting | ☐ | ☐ | ☐ |
| 26 51 13 Incandescent Interior Lighting | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| 26 51 16 Fluorescent Interior Lighting | ☐ | ☐ | ☐ |
| 26 51 19 LED Interior Lighting | ☐ | ☐ | ☐ |

| SECTION | C | NA | NC |
|---|---|---|---|
| 26 51 23 HID Interior Lighting | ☐ | ☐ | ☐ |
| 26 52 00 Safety Lighting | ☐ | ☐ | ☐ |
| 26 52 13 Emergency and Exit Lighting | ☐ | ☐ | ☐ |
| *26 52 13.13 Emergency Lighting* | ☐ | ☐ | ☐ |
| *26 52 13.16 Exit Signs* | ☐ | ☐ | ☐ |
| 26 54 00 Classified Location Lighting | ☐ | ☐ | ☐ |
| 26 54 13 Incandescent Classified Location Lighting | ☐ | ☐ | ☐ |
| 26 54 16 Fluorescent Classified Location Lighting | ☐ | ☐ | ☐ |
| 26 54 19 LED Classified Location Lighting | ☐ | ☐ | ☐ |
| 26 55 00 Special Purpose Lighting | ☐ | ☐ | ☐ |
| 26 56 00 Exterior Lighting | ☐ | ☐ | ☐ |
| 26 56 13 Lighting Poles and Standards | ☐ | ☐ | ☐ |
| 26 56 17 Fluorescent Exterior Lighting | ☐ | ☐ | ☐ |
| 26 56 18 Incandescent Exterior Lighting | ☐ | ☐ | ☐ |
| 26 56 19 LED Exterior Lighting | ☐ | ☐ | ☐ |
| 26 56 21 HID Exterior Lighting | ☐ | ☐ | ☐ |