# Electrical Engineering

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# 6.1 General Requirements

This chapter identifies criteria to program and design electrical and communications systems in GSA buildings. The purpose of Chapter 6 is to establish minimum standards, acceptable to the GSA, to be used as the basis of design of electrical and communications systems for the various GSA regions throughout the USA.

Electrical and communications systems shall provide the infrastructure for an efficient work environment for the occupants. These systems must support the many types of equipment used in a modern office setting in a reliable fashion.

There are three characteristics that distinguish GSA buildings: long life span, changing occupancy needs, and the use of a life cycle cost approach to account for total project cost.

During the life span of a typical Federal building, many minor and major alterations are necessary as the missions of Government agencies change. The flexibility to adjust to alterations easily must be designed into the building systems from the outset. Electrical and communications systems shall provide ample capacity for increased load concentrations in the future as described in section 6.3 and allow modifications to be made in one area without causing major disruptions in other areas of the facility.

It is GSA's goal to build facilities equipped with the latest advances in office technology and communication. This intent shall be extended to include the future evolution of automated office and telecommunications equipment as well. Making this concept a reality requires a comprehensive design for engineering systems that goes beyond the requirements of the immediate building program. It also requires a higher level of integration between architecture and engineering systems than one would usually expect in an office building.

The Government recognizes that communications needs and technology are growing at an increasingly rapid pace. Work stations are becoming more powerful, requiring faster and easier access to more information. GSA must install the wiring and interfaces to support these requirements. It shall be noted that the design of all communications cabling systems is the responsibility of GSA's Federal Technology Service (FTS).

A computer-based Building Automation System (BAS) that monitors and automatically controls lighting, heating, ventilating and air conditioning is critical to the efficient operation of the modern Federal office building. GSA encourages integration of building automation systems with the exception of fire alarm and security systems, which shall function as stand-alone systems with a monitoring only interface to the BAS.

The design of the electrical systems and other building components shall all combine together to produce a building that meets the project's programmed sustainability rating (LEED rating) and assigned energy target, as referenced in Chapter 1.

Security is an important consideration in electrical engineering systems design. Refer to Chapter 8: *Security Design* for detailed criteria related to this matter.

Consult Chapter 4.1: *Installation Standards of the Fine Arts Program Desk Guide* for additional information.

Submission Requirements are addressed in Appendix A.3.

# 6.2 Codes and Standards

As stated in Chapter 1, *General Requirements, National Codes and Standards, Building Codes*, facilities shall comply with the ICC's International Building Code, International Fire Code, International Plumbing Code, International Mechanical Code, and International Energy Conservation Code, as well as the Life Safety Code (NFPA 101) and the National Electrical Code (NFPA 70).

The latest editions of publications and standards listed here are intended as guidelines for design. The list is not meant to restrict the use of additional guides or standards.

### Electrical Design Standards

The electrical system shall be designed by a professional electrical engineer.

- ANSI: American National Standards Institute
- ASTM: American Society for Testing and Materials
- ASHRAE: Standard 90.1: *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- CBM: Certified Ballast Manufacturers
- ETL: Electrical Testing Laboratories
- FAA: Federal Aviation Agency
- IESNA: Illuminating Engineering Society of North America
- IEEE: Institute of Electrical and Electronics Engineers
- ICEA: Insulated Cable Engineers Association
- NEMA: National Electrical Manufacturers Association
- NFPA: National Fire Protection Association
- UL: Underwriters' Laboratories

### Communication System Pathways and Spaces Design Standards

The communication system pathways and spaces shall be designed by a Registered Communications Distribution Designer (RCDD). The following standards define the minimum allowable requirements.

Electronic Industries Alliance/Telecommunications Industry Association (EIA/TIA) Standards:

- EIA/TIA Standard 568: *Commercial Building Telecommunications Wiring Standard* (and related bulletins)
- EIA/TIA Standard 569: *Commercial Building Standard For Telecommunications Pathways And Spaces* (and related bulletins)
- EIA/TIA Standard 606: *Administration Standard For The Commercial Telecommunications Infrastructure* (and related bulletins)
- EIA/TIA Standard 607: *Commercial Building Grounding (Earthing) And Bonding Requirements For Telecommunications* (and related bulletins)
- EIA/TIA Standard 758: *Telecommunication Standards for Customer Owned OSP* (outside plant)

# 6.3 Design Criteria

## Whole Building Energy Performance

A whole building energy analysis shall be performed to demonstrate that the building design meets or exceeds the energy performance goals established for the project. The requirements for this analysis are described in Chapter 5.

## Load Studies

In establishing electrical loads for Federal buildings it is important to look beyond the immediate requirements stated in the project program. Future moves and changes have the effect of redistributing electrical loads. The minimum connected receptacle loads indicated in Table 6-1 combined with other building loads multiplied by appropriate demand factors, and with spare capacity added, shall be used for obtaining the overall electrical load of the building. If the load requirements stated in the program are higher, the program requirements must be satisfied.

**Load Groups:**

- Lighting
- Receptacle Loads
- Motor and Equipment Loads
- Elevator Loads
- Miscellaneous Loads

**Lighting Loads.** A summary of the lighting load assumptions are in Table 6-1. These are assumptions for the design of the electrical system that supports the lighting and are not maximum design values for the lighting system. Refer to Section 6.10 for further information on the lighting design conditions and constraints.

**Receptacle Loads.** A summary of the receptacle load assumptions are in Table 6-2.

**Motor and Equipment Loads.** Loads associated with motors and equipment must use the rated brake horsepower of specified equipment.

**Elevator Loads.** Elevator loads must use the rated brake horsepower of the specified equipment. Demand factors identified in *National Electrical Code* Table 620-14 shall be included.

**Miscellaneous Loads.** These loads include:

- Security, Communication, and Alarm systems
- Heat Tracing
- Kitchen Equipment
- Central Computer Servers and Data Centers

## Table 6-1
## Lighting Load for Equipment Sizing

| Area/Activity | Design Lighting Demand VA/m² | VA/sq. ft. |
|---|---|---|
| Office/Enclosed* | 16.1 | 1.5 |
| Office Open** | 14 .0 | 1.3 |
| Conference Meeting/Multipurpose | 16.1 | 1.5 |
| Classroom/Lecture/Trainings | 17.2 | 1.6 |
| Lobby | 19.4 | 1.8 |
| Atrium–first three floors | 14.0 | 1.3 |
| Atrium–each additional floor | 2.2 | 0.2 |
| Lounge/Recreation | 15.1 | 1.4 |
| Dining Area | 15.1 | 1.4 |
| Food Preparation | 23.7 | 2.2 |
| Restrooms | 10.8 | 1.0 |
| Corridor/Transition | 7.5 | 0.7 |
| Stairs | 9.7 | 0.9 |
| Active Storage | 11.8 | 1.1 |
| Inactive Storage | 3.2 | 0.3 |
| Electrical/Mechanical/Technology/Server Rooms | 14.0 | 1.3 |

* This number is based on a 125 sq. ft. office module. **Load is based on an 80 sq. ft. furniture module.

## Table 6-2
## Minimum Receptacle Load for Equipment Sizing

| Area/Activity | Minimum Design Load: Service Equipment VA/m² | Minimum Design Load: Service Equipment VA/sq. ft. | Minimum Design Load: Distribution Equipment VA/m² | Minimum Design Load: Distribution Equipment VA/sq. ft. |
|---|---|---|---|---|
| **General Purpose systems** | | | | |
| Office/Enclosed* | 14 | 1.3 | 27 | 2.5 |
| Office Open** | 14 | 1.3 | 35 | 3.25 |
| Non-Workstation areas (such as public and storage) | 5 | .5 | 10 | 1 |
| Core and Public areas | 2.5 | 0.25 | 5 | 0.5 |
| | | | | |
| **Electronic systems** | | | | |
| Office/Enclosed* | 13 | 1.2 | 32 | 3.0 |
| Office Open** | 13 | 1.2 | 43 | 4.0 |
| Technology/Server Rooms | 540 | 50 | 700 | 65 |

* This number is based on a 125 sq. ft. office module. **Load is based on an 80 sq. ft. furniture module.

### Standards for Sizing Equipment and Systems

To ensure maximum flexibility for future systems changes, the electrical system must be sized for the demand load with additional spare capacity as follows:

- Panelboards for branch circuits: 50% spare ampacity as well as 25% spare circuit capacity.
- Panelboards serving lighting only: 25% spare ampacity as well as 25% spare circuit capacity.
- Switchboards and distribution panels: 35% spare ampacity and 25% spare circuit capacity.
- Main switchgear: 25% spare ampacity and 25% spare circuit capacity.

Spare overcurrent devices shall be provided as well as bus extension for installation of future protective devices.

Prior to adding the spare equipment ampacity to account for future load growth, it is important that the load study reflect actual demand loads rather than connected loads. The designer shall apply realistic demand factors by taking into account various energy conserving devices such as variable frequency drives applied to brake horsepowers, energy efficient motors, occupancy sensors, etc. The designer shall also avoid adding the load of stand-by motors and shall be careful to distinguish between summer and winter loads by identifying such “non-coincidental” loads. A “diversity factor” shall be applied to account for the fact that the maximum load on the elevator system, as a typical example, does not occur at the same time as the peak air conditioning load. Once the estimated “peak demand” load is established then the factor for load growth shall be added.

**Visual Impact.** Options regarding the location and selection of electrical work that will have a visual impact on the interior and exterior of the building shall be closely coordinated with the architectural design. This includes placement and specification of lightning protection system, colors and finishes of lights, outlets, switches, and device plates.

**Equipment Grounding Conductor.** Except for isolated ground systems, all low voltage power distribution systems shall be supplemented with a separate, insulated equipment grounding conductor.

**Lightning Protection.** Lightning protection shall be provided in accordance with NFPA 780. The system shall be carefully designed to ensure that static discharges are provided with an adequate path to ground. Surge arrestors on the main electrical service shall also be considered.

**Artwork.** Museum standards for lighting works of art range from 5 to 10 foot-candles for extremely light sensitive materials such as paper and textiles, to 20 to 40 foot-candles for moderately sensitive materials such as oil paintings and wood.

Please consult Chapter 4.1, *Installation Standards,* of the *Fine Arts Program Desk Guide* for additional information.

# 6.4 Utility Coordination

**Power Company Coordination.** See Chapter 2: *Site Planning and Landscape Design, Site Utilities, Utilities Services.*

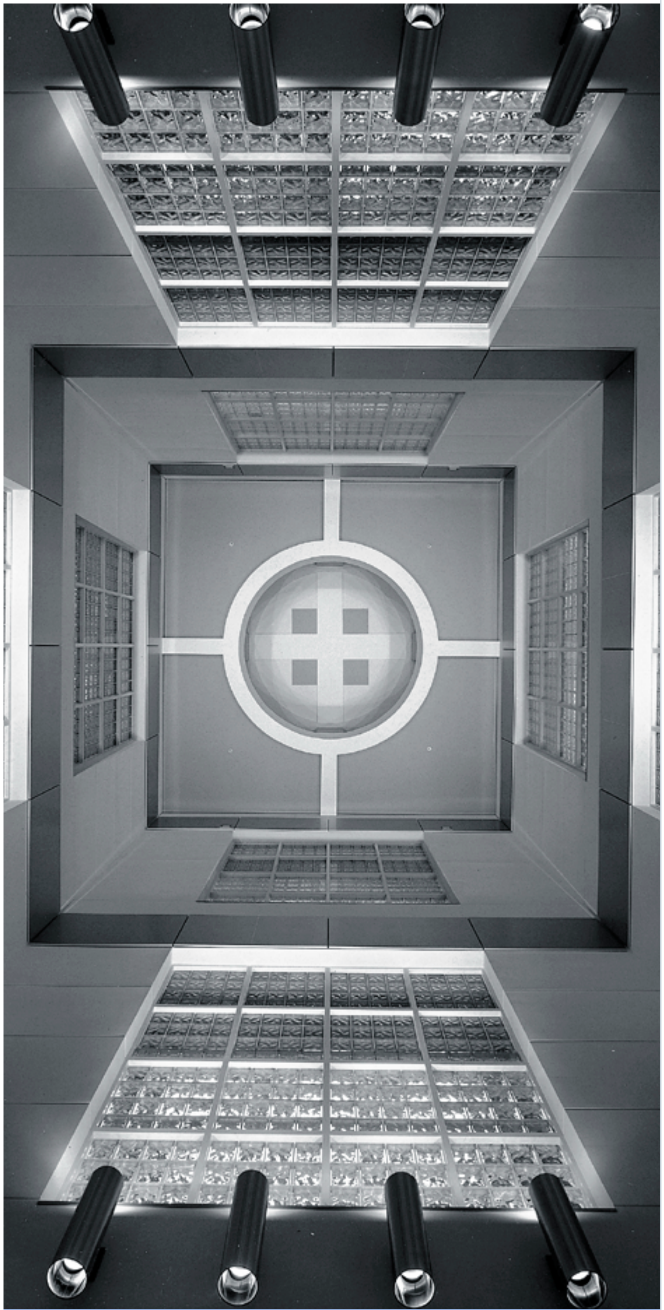
A detailed load study, including connected loads and anticipated maximum demand loads, as well as the estimated size of the largest motor, shall be included in the initial contact with the local utility in order to prepare them for discussions relative to the required capacity of the new electrical service.

The service entrance location for commercial electrical power shall be determined concurrently with the development of conceptual design space planning documents, and standards for equipment furnished by utility companies and shall be incorporated into the concept design. Locations of transformers, vaults, meters and other utility items must be coordinated with the architectural design to avoid conflicts with critical architectural features such as main entrances and must consider both equipment ventilation and equipment removal.

**Site Considerations.** The routing of site utilities and location of manholes must be determined early in the design process. The designer shall determine the utility's capability, rate structure options and associated initial costs to the project and shall evaluate the available utility service options.

For small buildings, less than 100,000sf utility power shall be requested at the main utilization voltage, i.e., 480/277V or 208/120V.

For medium size buildings up to 250,000sf, or buildings with large footprints, more than one electrical secondary service shall be considered.



U.S. Courthouse, Kansas City, KS

Oakland Federal Building, Oakland, CA.

For large buildings, greater than 250,000sf or buildings with large footprints and campus situations, more than one electrical service shall be considered, as well as medium voltage distribution, up to 15KV, for primary power distribution to substations.

The routing of site utilities and location of manholes shall be determined early in the design process in coordination with the Site Civil Engineer.

**Cable Selection.** Cable selection shall be based on all aspects of cable operation and the installation environment, including corrosion, ambient heat, rodent attack, pulling tensions, and potential mechanical abuse and seismic activity.

**Direct Buried Conduit.** Direct buried PVC, coated intermediate metallic conduit (IMC) or rigid galvanized steel (RGS) shall be used only for the distribution of exterior branch circuits 38 mm (1 1/2") or smaller. Direct buried cable shall not be used.

**Concrete-Encased Ductbank.** Concrete-encased PVC Schedule 40 ductbanks shall be used where many circuits follow the same route, for runs under permanent hard pavements and where service reliability is paramount, such as service entrances and medium voltage cables.

Concrete encased ducts shall be provided with a cover of at least 600 mm (24 inches). Ductbanks under railroads shall be reinforced. Ducts shall slope toward manholes. Changes in direction shall be by sweeps with a radius of 7.5 m (25 feet) or more. Stub-ups into electrical equipment may be installed with manufactured elbows. Duct line routes shall be selected to avoid foundations of other buildings and other structures. Electrical and communication ducts shall be kept clear of all other underground utilities, especially high temperature water or steam.

Where it is necessary to run communication cables parallel to power cables, two separate systems must be provided with separate manhole compartments. The same holds true for normal and emergency power cables. Ductbanks shall be spaced at least 300 mm (1 foot) apart. Site entrance facilities including ductbanks and manholes must comply with requirements stated in Federal Information Processing Standard 175: *Federal Building Standard for Telecommunication Pathways and Spaces* (see also EIA/TIA [Electronic Industrial Association/ Telecommunication Industry Association] Standard 568-A and related bulletins).

Where redundant service is required (power, communications and/or life safety) systems alternate, diverse paths and separation shall be maintained.

**Duct Sizes.** Ducts shall be sized as required for the number and size of cables. All ducts for medium voltage services shall be a minimum of 100 mm (4 inch). Inner ducts must be provided inside communication ducts wherever fiber optic cables will be used. A sufficient number of spare ducts shall be included for planned future expansion; in addition, a minimum of 25 percent spare ducts must be provided for unknown future expansion.

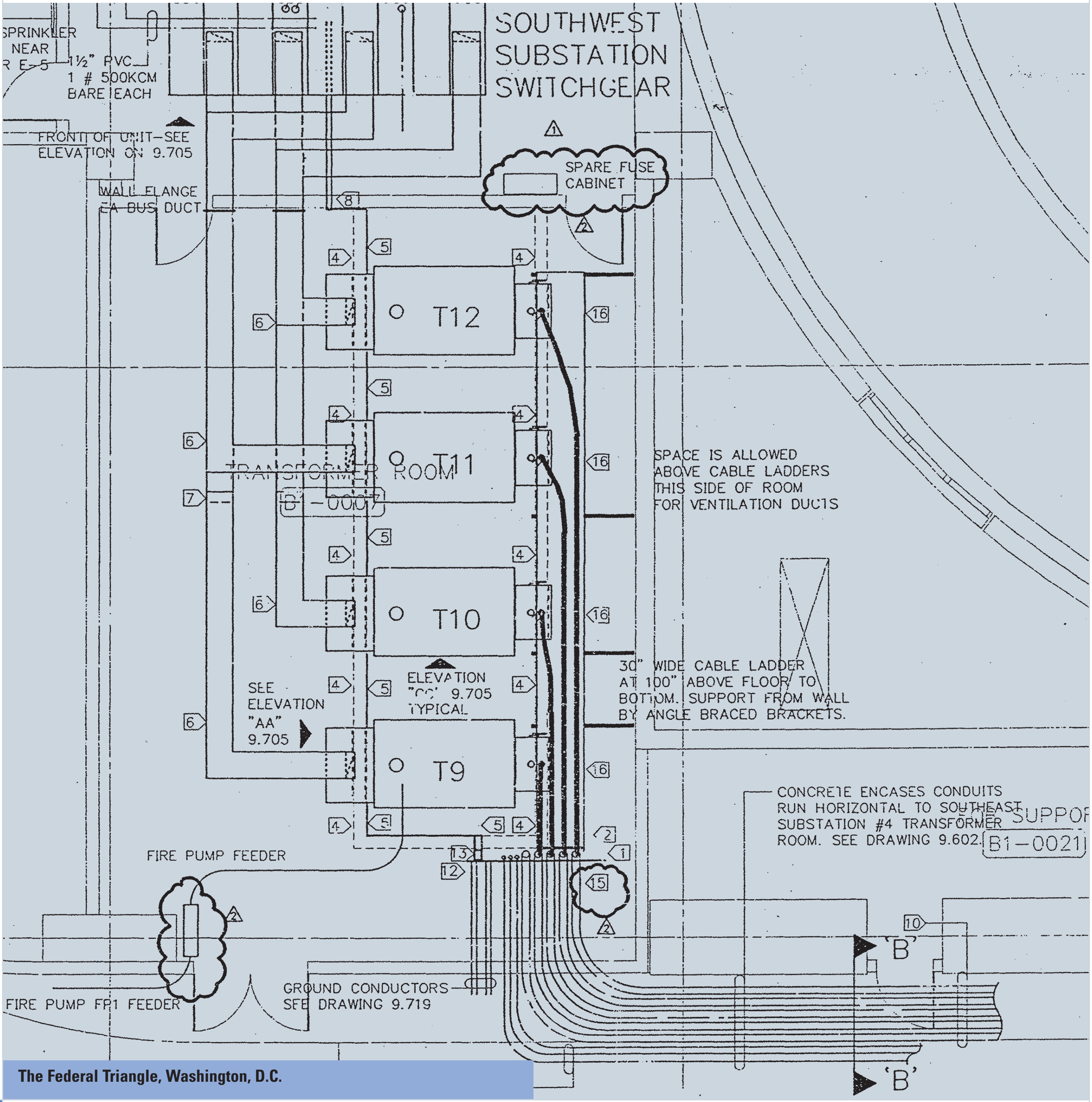
**Manholes.** Manholes shall be spaced no farther than 150 m (500 feet) apart for straight runs. The distance between the service entrance and the first manhole shall not exceed 30 m (100 feet). Double manholes shall be used where electric power and communication lines follow the same route. Separate manholes shall be provided for low and medium voltage systems. Manholes shall have clear interior dimensions of no less than 1800 mm (6 feet) in depth, 1800 mm (6 feet) in length, and 1800 mm (6 feet) in width with an access opening at the top of not less than 750 mm (30 inches) in diameter. Medium voltage manholes shall be sized in accordance with Utility Company requirements. Manholes must have a minimum wall space of 1800 mm (6 feet) on all sides where splices are to be racked. Manholes shall be provided with pulling eyes, sumps and grounding provisions as necessary.

**Stubs.** Minimum of two spare stubs shall be provided (to maintain a square or rectangular ductbank) so that the manhole wall will not need to be disturbed when a future extension is made. Stubs for communications manholes must be coordinated with GSA Federal Technology Service.

Handholes may be used for low voltage feeders (600V and below), branch circuits or communications circuits. They must be not less than 1200 mm (4 feet) in depth, 1200 mm (4 feet) in length, and 1200 mm (4 feet) in width with a standard manhole cover and sump of the same type provided for manholes. Generally, at least four racks shall be installed. Where more than two splices occur (600V feeders only), a 1800 mm (6 feet) by 1800 mm (6 feet) by 1800 mm (6 feet) manhole shall be required.

**Communications Service Coordination.** The Telecommunications Design professional shall contact the local telephone company and coordinate with the client agency to determine the size and location of the incoming service and to determine the enclosure and pathway requirements for telecom systems. The Scope of Services varies with each project; it includes as a minimum the design of the infrastructure (pathway and enclosure) and may include full design and specification of the telecommunications system. The design professional shall contact the local telecommunications providers early in the project.

Provision shall also be made to provide cable television (CATV) service to the facility. Typically, CATV service is independent from other communications services.




**The Federal Triangle, Washington, D.C.**

# 6.5 Distribution System Alternatives

Where the design alternatives have been thoroughly evaluated, and a medium voltage (15kV) service is selected as the optimal utility service for the application, the design professional shall request that the utility company provide a minimum of three (3) 15 kV (nominal) feeders to serve the facility.

### Primary Distribution

The following types of primary distribution systems are listed in terms of increasing flexibility, reliability and cost:

- Looped primary (not recommended)
- Radial primary
- Primary Selective
- Primary Selective-Secondary Selective
- Network

The selection of a primary distribution system shall be based upon a study comparing the relative advantages and disadvantages of the feasible alternatives including a life cycle cost comparison. Where primary service is provided, GSA will provide, own and maintain the transformers.

**Medium Voltage Switchgear.** Design of the medium voltage switchgear shall meet all of the requirements of the local utility. Switchgear shall be provided with enclosed, draw-out type vacuum interrupter breakers. Provide one (1) per each size fully equipped spare cubicle/breakers up to 1600 Amps. Provide breaker lifting device. Provide Ground and Test device.

Note: Alternate type circuit breakers will be considered. Provide voltmeter, ammeter and watt-hour meter with demand register on each feeder in addition to utility approved relaying. Meters shall be pulse-type for connection to the BAS.

**Medium Voltage Conductors.** Conductors shall be copper, insulated with cross linked polyethylene (XLP) or ethylene propylene rubber (EPR). Insulation shall be rated at 133 percent. Conductor size shall not exceed 240 $mm^2$ (500 Kcmil).

**Network Transformers.** Where continuity of service is critical and where even a momentary disruption of service due to the loss of a single incoming feeder cannot be tolerated, then network transformers shall be considered. Network transformers shall be liquid-filled, kVa rating as required, with copper primary and secondary windings. Transformers shall be equipped with provisions for fans and/or dual temperature ratings to increase the rated capacity and shall be provided with sufficient contacts to permit the remote monitoring of the status of the network protector, temperature and pressure in the enclosure and other components recommended by the manufacturer. In addition, transformers shall be provided with voltage taps ±2.5% with on-load tap changer.

**Double-ended Substations.** Where either a primary selective or primary selective – secondary selective (double-ended substation) is selected, the following paragraphs apply:

If reliability is critical and spot networks are not feasible, double-ended substations shall be used. Transformers shall be equipped with provisions for fans to increase the rated capacity. The sum of the estimated demand load of both ends of the substation must not exceed the rating of either transformer, and must not exceed the fan cooling rating. All double-ended substations shall be equipped with two secondary main breakers and one tie breaker configured for open transition automatic transfer initiated through the use of an under-voltage relaying scheme. Breakers shall be of the electrically operated draw-out type.

**Network Substations.** Generally speaking, network substations are close-coupled to the secondary switchboards servings the respective loads. All circuit breakers up to and including the secondary switchgear main circuit breaker and accessories shall be of the draw-out type.

**Transformers.** Substation transformers shall be dry-type with epoxy resin cast coils or liquid filled, 300 degree C insulation, non-petroleum based insulating oil type. Liquid filled transformers shall be used outdoors and for below grade vault construction. Substations shall be located at least 30 m (100 feet) from communications frame equipment to avoid radio frequency interference. Provide lightning arrestors on the primary side of all transformers. Provide surge suppression on the secondary and/or downstream busses.

Where silicon or oil filled transformers are used, the design must comply with all spillage containment and electrical code requirements.

## Secondary Distribution

**Main Switchgears (480 V service).** In the case of double-ended substations all main and secondary feeder breakers are draw-out power type.

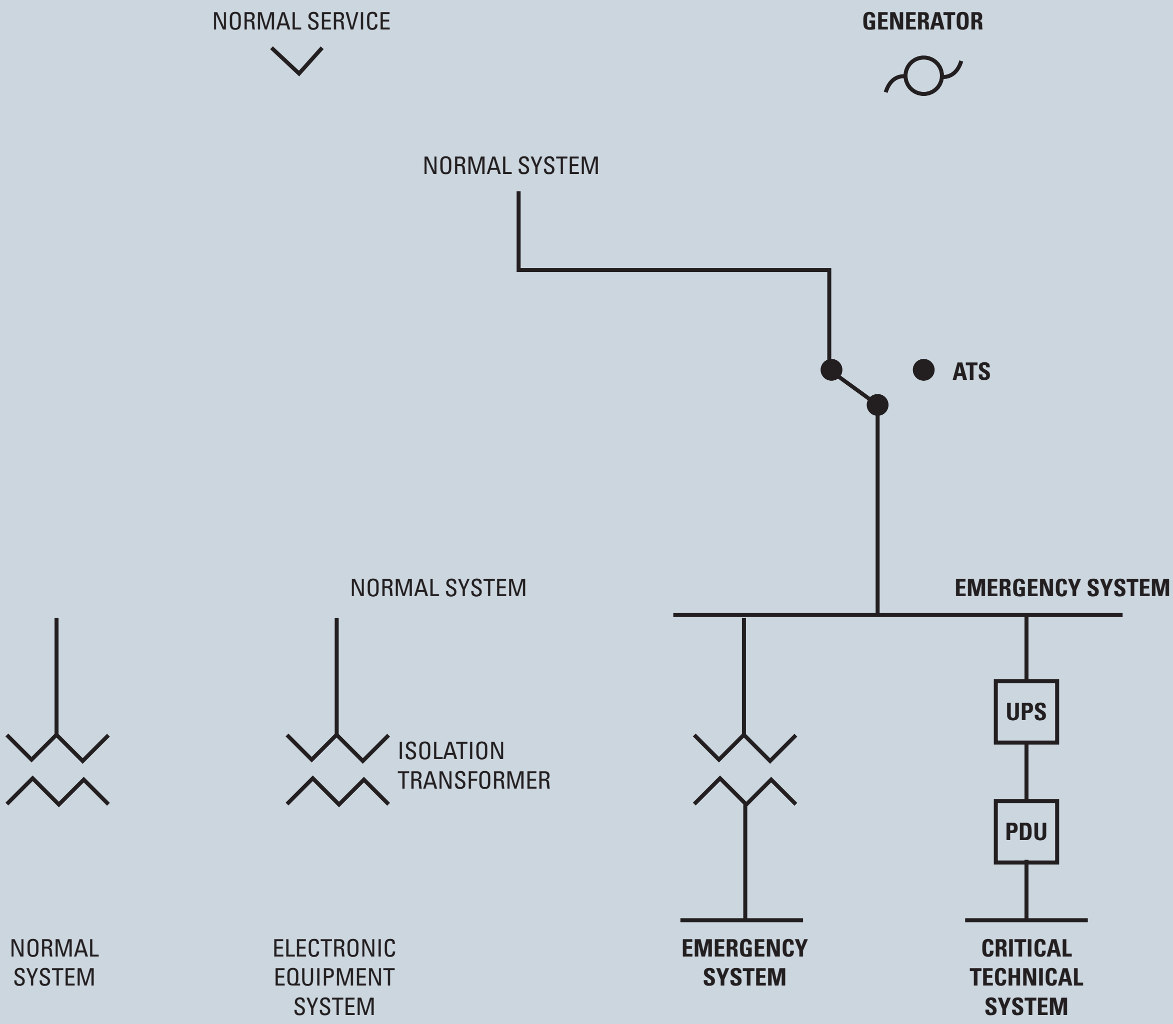
Each metering section shall contain a voltmeter, ammeter and watt-hour meter with demand register. Meters shall be pulse type for connection to the BAS. Switchgear shall be front and rear accessible. Aluminum bus will not be acceptable.

All breakers in the 480 volt rated service main switchgear shall be fully rated. Series rating will not be permitted for this equipment. Main and feeder breakers shall be provided with integral solid-state ground-fault protection tripping elements.

**Main Switchgears (208 V service).** 208 V service switchboards as well as substation secondary switchboards shall be freestanding and shall be provided with a single main service disconnect device. This main device shall be insulated case, power air circuit breaker or bolted-pressure fusible switch (where appropriate), shall have ground fault protection, and shall be individually mounted, draw-out type (as applicable). Insulated case and power air circuit breakers shall be electrically operated. Branch feeders shall be protected, either by fusible load-break switches or fully rated molded case circuit breakers. Front access only will be acceptable. Aluminum bus will not be acceptable.

**Surge Suppression.** Provide surge suppression on the main incoming service secondary switchboard.

Figure 6-1 Typical Power Distribution Scheme



# 6.6 Space Conditions

It is the joint responsibility of the architect and the electrical designer, functioning as part of an integrated design team, to provide adequate space and suitable locations for the electrical systems serving the facility, and a planned method to install and replace this equipment. However, it is the sole responsibility of the electrical designer, during the concept phase, to provide detailed space requirements and suggested preferred locations of all critical space requirements for the power and communication systems for the facility. It then requires the cooperation of the architect to provide the required space conditions, clear of any structural columns or beams as well as shear walls, stairways, duct shafts and other obstructions. Equipment space selection shall take into consideration adjacencies, such as stairs, mechanical rooms, toilets, elevators, air/piping shafts, and fire rated assemblies to permit secondary distribution of electrical and telecom circuitry to exit the assigned spaces. In addition, electrical equipment shall be located at a level above the 100-year flood plain.

Note: The designers shall refer to Chapter 3: *Architectural and Interior Design, Building Planning, Placement of Core Elements and Distances*, for design criteria related to the following elements of the electrical and communication systems:

- Main Equipment Rooms
- Electrical Rooms
- Communications Rooms
- Building Engineer's Office
- Security Control Center
- Fire Command Center
- UPS Systems and Batteries

**Main Equipment Rooms – Electrical and Telecommunications.** The size of the Electrical Service Room will depend upon the type of service provided by the local utility. If a secondary (480V or 208V) service is provided, the size of the room shall be approximated by the number of service stubs into the room and the respective number and size of switchgears. In this case the room must be located securely in a vault or inside the building along a perimeter wall at an elevation that minimizes the transformer secondary feeder lengths. Main switchgear room doors shall be large enough (width and height) to allow for the removal and replacement of the largest piece of equipment. Both equipment and man doors shall swing out and be provided with panic hardware.

The size and location of the Telecommunications Service Room shall be established in concert with the local telephone service provider and shall be provided with 24-hour HVAC service and protected from contaminants by proper filtration equipment.

**Electrical Rooms.** Electrical rooms are generally located within the core areas of the facility and shall be stacked vertically. Adequate numbers of electrical rooms shall be provided such that no electrical room serves more than 930 $m^2$ (10,000 sq. ft.). Electrical rooms shall be provided with minimum clear dimensions of 1800 mm by 3000 mm (6 feet by 10 feet). If transformers are located in the rooms, ventilation must be provided. Doors shall swing out.

**Communications Rooms.** Communications rooms are also generally located within the core areas of the facility and shall be stacked vertically. Rooms shall be sized to contain adequate floor space for frames, racks and working clearances in accordance with (EIA/TIA) standards. Provisions shall be made for air conditioning these rooms.

**Building Engineer's Office.** Even if not included in the building program, office space for the building engineer shall be evaluated. Most GSA buildings require such a space, which houses the consoles for the Building Automation System and satellite annunciators for other critical systems such as fire alarm, generator status, miscellaneous alarm systems and lighting control systems. This space is normally located near the loading dock or main mechanical spaces.

**Security Control Center.** Each GSA building with a local security force shall have a control center. In the event that the building will not be served by a local security force, this room could be combined with the building engineer's office or the fire control center.

The security control center shall be generally located within the most secure area of the building and shall be sized to house the command station for the security guards and their equipment for current as well as future building needs.

**Spaces for Uninterruptible Power Systems (UPS) and Batteries.** Since all UPS systems are considered above standard for GSA space, the requirement for a UPS system will be a tenant agency requirement. In order to establish the proper size, location and environmental requirements for the system, the designer shall arrange to meet with the architect and a representative of the tenant agency to determine the required/estimated load and physical size requirements, and nature of the critical loads. Refer to the UPS and battery manufacturers' installation instruction for weights, dimensions, efficiency, and required clearances in the design.

- For small systems, up to 50kva, the UPS modules and sealed cabinet batteries shall be installed in the room with the equipment being served.
- For medium and large systems, greater than 50kva, the UPS system shall be provided with standby generator back-up to limit the battery capacity. The UPS system equipment and batteries shall be in separate rooms, located on the lowest level, because of the weight of the batteries and the noise of the UPS equipment.

Allow space for storage of safety equipment, such as goggles and gloves. Special attention shall be given to floor loading for the battery room, entrance door dimensions for installation of the UPS and ceiling height for clearance of the appropriate HVAC systems and exhaust systems.

**Fire Command Center.** The Fire Command Center (FCC) shall be provided in all high rise Federal buildings. It shall be located so that it will be readily accessible to the local fire department in the event of an alarm. The FCC shall be sized to contain the following equipment:

- Fire, smoke and sprinkler alarm control panels
- Amplifier rack for voice alarms
- Graphic Annunciator
- Fire-fighters smoke control panel in accordance with [F] Section 909 Smoke Control Systems of the ICC including Pars. [F] 909.16, 909.16.1, 909.16.2 & 909.16.3
- Fire alarm system computer and printer
- Status of emergency generator annunciator
- Status of transfer switches annunciator
- Elevator Status Panel

The FCC shall be a minimum of 10 meters square (100 sq. ft.).

See Chapter 7: *Fire Protection & Life Safety* for additional requirements.

# 6.7 Secondary Branch Power Distribution

**Feeder Assignments (Bus Ducts vs. Cable-In-Conduit).** The secondary main branch power distribution system is designed to convey power to the various load groups distributed throughout the building. The decision as to whether this power is conveyed to the various loads in copper cables-in-conduit, or copper bus duct, will affect the following:

- Design of the main switchgears
- Coordination in the lower levels
- Design of the electric rooms
- Flexibility
- Reliability
- Cost

At the early stages of a project, alternate designs comparing the factors listed above would determine the scheme to be recommended. The size of the floor plate (i.e. gross area of the floor) and the height of the building are also important factors in the determination of the recommendation.

**Bus Duct.** Bus ducts shall be copper, fully rated, 3-phase, 3-wire or 3-phase, 4-wire with 100% neutral and an integral ground bus, sized at 50 percent of the phase bus. Provide calculations supporting the specified short circuit rating.

**Conductors.** The base bid specifications shall require that copper be utilized throughout, including motor windings, transformer windings, switchgear bussing, switchboard and panelboard bussing, bus duct, and primary and secondary feeders, branch feeders, and branch circuits.

Note: The use of aluminum may be permitted via a deduct alternate listing the specific items of equipment and material in which the use of aluminum would be permitted. The alternate shall list and address the comparative increase in conductor and conduit sizes. The Contracting Officer shall decide whether or not the alternate is accepted.

**Motor Control Centers.** Grouped motor controls shall be used where eight (8) or more starters are required in an equipment room. Motor control center (MCC) construction shall be NEMA Class I, Type B, copper, with magnetic (or solid state if appropriate) starters and either molded case circuit breakers or fused switches. Minimum starter size in motor control centers shall be Size 1. Control circuit voltage shall be 120V connected ahead of each starter via fused control transformer. Reduced voltage starters may be used for larger motors to reduce starting KVA.

Time delay relays shall be incorporated in the starters or programmed in the BAS system to reduce inrush currents on the electrical system.

Where variable frequency drives are used on a project, it should be economically evaluated to specify VFDs incorporated into the MCCs. If determined not appropriate, then VFDs should be powered for distribution panels installed for that purpose.

**Elevator Power.** It is recommended that the load of the elevator feeders be divided among the secondary switchgears, provided that there are 2 or more switchgears, and that alternate elevator machines shall be fed from different switchgears.

Note: One (1) elevator in each bank shall be connected to the emergency generator. Where multiple elevators are in a common bank, provide a common emergency feeder from the Elevator ATS to allow each elevator to be operated individually during an emergency. By interlocking the ATS with the elevator group controller, programming shall be made by the elevator supplier to set up a controlled return to the terminal floor and then limit the number of elevators in that bank that can be run.

Elevator machines shall be powered from circuit breakers with a shunt trip and with padlocking capability, located in the elevator machine rooms. Electrical design standards in Elevator Standard ANSI/ASME A17.1 shall be followed.

**Variable Frequency Drives (VFD).** VFD's are now in general use on all projects by virtue of their contribution to the energy efficiency of the project. They also generate harmonics which are injected into the secondary power distribution system and need to be minimized through the use of filters tuned to the peak harmonic generated by the drive.

VFDs shall utilize a minimum 12-pulse, pulse width modulation (PWM), design because of their low harmonic output, excellent power factor and high efficiencies. VFDs shall be specified with passive harmonic filters. VFDs shall also be specified with isolation transformers where required.

Specify thermal sensors that interlock with the VFD control circuit for additional solid state motor protection for motors running at low speeds and subject to overheating. This is in addition to the standard over-current protection required.

**Ronald Reagan Building, Washington, D.C.**

# 6.8 Interior Lighting, Daylighting, and Control Systems

The lighting and daylighting systems of a building represent one of the most critical components to the architectural aesthetic, the successful completion of tasks, and the annual energy consumption of the building. In order to effectively address all these concerns, the lighting systems must be sensitive to the interior and architectural design while providing an adequate quality and quantity of illumination throughout the building. Yet, the lighting system must maintain an energy efficient design that, at minimum, meets ASHRAE/IES 90.1 lighting power density requirements. In addition, the lighting design shall attempt to minimize maintenance requirements.

## General Lighting Design Criteria

The electric lighting design criteria are intended to ensure sufficient visual comfort and performance of the lighting environment provided by the electric lighting systems. Lighting designs must minimize harsh contrasts by employing a combination of direct and indirect lighting sources. This can be accomplished through the use of indirect/direct lighting systems, wall sconces or a combination of uplighting and downlighting. In addition, vertical surface illumination shall be considered, where applicable.

Task/ambient lighting strategies are designs that break down the lighting system by the lighting purpose. Lower levels of even, ambient illumination are provided throughout the space with local task lights providing greater illuminance at the task.

Specific lighting design issues associated with individual space types are discussed later in this chapter in the subsection titled *Specific Lighting Constraints*.

**Qualifications of the Lighting Practitioner.** Lighting design shall be performed or supervised by a practitioner credentialed as Lighting Certified (LC) by the National Council on Qualifications for the Lighting Professions (NCQLP). Visit **www.ncqlp.org** for more information.

**Illumination Levels.** Required illumination level ranges for typical interior spaces are indicated in Table 6-3. These ranges of illumination require the average illumination at the task (workplane) to be greater than the minimum value and less than the maximum value. For those areas not listed in the table, the IES Lighting Handbook may be used as a guide. The design illumination levels shall be confirmed by computer simulation for each of the typical space types throughout the building.

**Visual Comfort.** The lighting system must be designed to reduce glare, minimize contrast ratios, and provide proper color rendering as recommended in the latest issue of the Illuminating Engineering Society of North America (IES) *Lighting Handbook*.

**Energy Efficient Design.** At a minimum, lighting design must comply with the current version of ASHRAE/IES Standard 90.1 maximum lighting power densities. Table 6-3 lists the requirements for typical interior spaces; the Standard shall be consulted for other space types. Task lighting is included in the maximum LPDs provided by the Standard.

**Accessibility for Servicing.** Careful consideration must be taken in the design of lighting systems regarding servicing of the fixtures and replacement of lamps. This issue needs to be discussed with building operation staff to determine the dimensional limits of servicing equipment.

# Table 6-3
## Lighting Requirements by Space Type

| Area/Activity | Required Illumination Levels: Lux (lumens/m²) | Footcandles (lumens/sq. ft.) | Maximum Lighting Power Density: W/m² | W/sq. ft. |
|---|---|---|---|---|
| Office – Enclosed[1] | 450 – 600 | 41.8 – 55.8 | 16.1 | 1.5 |
| Office – Open[1] | 450 – 600 | 41.8 – 55.8 | 14 .0 | 1.3 |
| Conference Meeting/Multipurpose | 275 – 425 | 25.6 – 39.5 | 16.1 | 1.5 |
| Classroom/Lecture/Trainings | 450 – 600 | 41.8 – 55.8 | 17.2 | 1.6 |
| Lobby | 175 – 275 | 16.3 – 25.6 | 19.4 | 1.8 |
| Atrium – first three floors | 175 – 275 | 16.3 – 25.6 | 14.0 | 1.3 |
| Atrium – each additional floor | n/a | n/a | 2.2 | 0.2 |
| Lounge/Recreation | 275 – 425 | 25.6 – 39.5 | 15.1 | 1.4 |
| Dining Area | 175 – 275 | 16.3 – 25.6 | 15.1 | 1.4 |
| Food Preparation | 450 – 600 | 41.8 – 55.8 | 23.7 | 2.2 |
| Restrooms | 175 – 275 | 16.3 – 25.6 | 10.8 | 1.0 |
| Corridor/Transition | 175 – 275 | 16.3 – 25.6 | 7.5 | 0.7 |
| Stairs | 175 – 275 | 16.3 – 25.6 | 9.7 | 0.9 |
| Active Storage | 175 – 275 | 16.3 – 25.6 | 11.8 | 1.1 |
| Inactive Storage | 100 – 175 | 9.3 – 16.3 | 3.2 | 0.3 |
| Electrical/Mechanical/ Telecommunication Rooms | 175 – 275 | 16.3 – 25.6 | 14.0 | 1.3 |

[1] Level assumes a combination of task and ceiling lighting where systems furniture is used. (This may include a combination of direct/indirect fixtures at the ceiling for ambient lighting.)

## Technology and Product Criteria

Any lighting that comprises at least 5% of the total building connected load must comply with the following luminaire, ballast and lamp requirements.

Incandescent lighting must be used only sparingly.

**Luminaires.** All luminaires must be appropriately selected based upon the expected application.

Luminaires shall be recessed, pendant, or surface mounted. Indirect/direct fixtures shall have a minimum 2% indirect component and 50% direct (maximum) component. Fixtures must have a minimum efficiency of 65%.

Where parabolic fixtures are used, louvers shall be semi-specular or diffuse finishes; specular finishes shall not be used.

All recessed downlights must use compact fluorescent or ceramic metal halide lamps as follows. No incandescent technology shall be used:

- Where a general broad distribution is required, downlights shall use CFLs with a minimum fixture efficiency of 50%. No black baffles are allowed.
- Where a narrow distribution or specific cutoff is required, downlights shall use ceramic metal halide PAR lamps with a minimum fixture efficiency of 50%.

Many fixtures have different lamp and ballast options. For ease of maintenance, all similar building luminaires shall use the same lamps and ballasts.

**Lamps.** Effort shall be made to minimize the number of lamp types within a facility to simplify lamp maintenance.

All linear fluorescent lamps must be SuperT8 or T5, low mercury lamps with efficacies above 90 Lumens/W. The maximum lumen depreciation must be 5%. Lamp color temperature must be either 3500K or 4100K and be consistent throughout the building. Lamps must have a color rendering index (CRI) greater than or equal to 80. Minimum rated lamp life must be 20,000 hours.

All compact fluorescent lamps (CFL) must have minimum efficacies of 60 lumens/W, maximum lumen depreciation of 15%. Minimum rated lamp life must be 10,000 hours. Lamp color and CRI must be consistent with the linear fluorescent lamps. No CFLs below 13W shall be used; these lamps typically have lower efficacy, poor PF, and no electronic ballast options. In addition, lamps with integrated ballasts or screw bases shall not be used.

All ceramic metal halide lamps used in finished spaces shall have a CRI greater than 75.

In retrofit scenarios, all fluorescent lighting lamps and ballasts must be disposed of through specialized disposal firms that destroy the PCBs and recover the mercury that is contained in the lamps.

**Ballasts.** Ballasts for linear and compact fluorescent lamps shall be electronic with a minimum power factor (PF) of 0.95 and a maximum total harmonic distortion (THD) of 15%. When applicable, programmed start ballasts shall be specified for use in linear fixtures that are frequently switched on/off, such as with occupancy controls.

Ballasts shall have a sound rating of "A" for 430 MA lamps, "B" for 800 MA lamps and "C" for 1500 MA lamps. Electronic ballasts shall be used. Special consideration shall be given to the ballast types where an electronic clock system is also specified to confirm compatibility of application.

## Daylighting

Daylighting typically refers to two separate concepts: the ability of regular occupants to see outside and the displacement of electric lighting due to the harvesting of daylight.

In order to maintain a relationship between the building occupants and the outdoors, direct views of the outside must be provided for at least 75% of the regularly occupied area on above grade levels.

If daylighting systems, beyond just windows, are to be included in the design for daylight harvesting, special daylighting consultants must be engaged to ensure adequate daylight illumination, avoid common glare issues, and assist in the integration of the lighting and mechanical systems with the architectural, interior, and daylighting designs.

## Circuiting and Switching

Lighting circuits shall be designed based on a realistic and adequate zoning analysis. The zoning analysis must account for separate lighting control strategies, unique occupancy areas, and maintain lighting zones smaller than 100 $m^2$ (1,100 sq. ft.) or one bay. Proper zoning allows for better control of lighting, especially during after-hours operation, while proper circuiting can minimize the complexity and cost of the lighting control system.

For general illumination, fixtures with more than 2 lamps shall be provided with two ballasts for A/B switching or dimming ballasts that allow the lighting output to be reduced to at least 50%. There maximum power penalty due to dimming shall be no greater than 20% of the full power input.

Where applicable, tandem wiring shall be implemented to reduce number of ballasts.

## Lighting Controls

Manual, automatic, or programmable microprocessor lighting controls shall be provided for all lighting, with the exception of exit sign branch circuitry and life safety egress lighting defined by NFPA 101. The application of these controls and the controlled zones depend on a number of space factors such as: space type, frequency of use, available daylighting, and typical schedule.

Microprocessor controls range from simple line voltage automated switches to complex low-voltage lighting control panels. Lighting control systems typically include standard or astronomical time clocks, occupancy sensors, photosensors (light level), and override switches, but can include a myriad of options such as ID card readers and individual PC-based lighting controls.

**Time Clocks.** An on/off time schedule must be included in the control system for all lighting except security lighting and lighting in spaces where occupants could be in physical danger due to loss of light. This control system shall incorporate lighting sweeps, warning flashes, or other methods to insure lighting is off in unoccupied spaces during scheduled unoccupied times.

**Occupancy Controls.** Occupancy sensors shall be provided for the following space and occupancy types:

- Offices smaller than 30 $m^2$ (325 sq. ft.) or with less than 4 people.
- All pantries and conference rooms.
- Restrooms with 3 or fewer toilets/urinals.
- All storage and file rooms smaller than 60 $m^2$ (650 sq. ft.).
- Any other regularly unoccupied spaces not mentioned.

Occupancy sensors shall be ultrasonic, or passive dual sensors based on the application. Each occupancy sensor shall have a manual override and shall control no more than one enclosed space, though some applications may

U.S. Census Bureau, Bowie, MD

require multiple occupancy sensors to adequately control a single space. Each occupancy sensor shall be marked by a label identifying the panel and circuit number.

No occupancy controls shall be used in mechanical or electrical rooms or other spaces where occupants could be in physical danger due to loss of light (see discussion in *Specific Lighting Constraints*).

**Photo Controls.** Photosensors are typically used to either control dimming ballasts for lumen maintenance or reduce lighting levels in response to available daylighting. Photo sensors shall be provided for the following space and occupancy types:

- All regularly occupied perimeter spaces.
- All other spaces that are anticipated to provide daylight that will displace the installed lighting by at least 1,000 full load hours per year.

In addition, integrated photo/occupancy sensors shall be provided for the following space and occupancy types:

- Perimeter offices smaller than 10 $m^2$ (108 sq. ft.).

Photo control system shall reduce the electric lighting by simple on/off, stepped dimming, or full dimming controls. Control strategy can be either open-loop or closed loop, but needs to be programmed to minimize lamp cycling and occupant distraction.

**Override Controls.** An easily accessible local means of temporary override must be provided in all spaces to continue operations per IBC or local energy code. This override is typically embedded in a space located timer switch, but PC-based and other override strategies are acceptable. However, overrides must be automatic; phone systems that depend on facility managers to control the local lighting are not allowed.

### Safety Lighting Design Criteria

**Security Lighting.** Security lighting is lighting that remains on during unoccupied hours per applicable code. Security lighting in daylit spaces must be controlled by the photosensors. If security lighting is doubling for emergency lighting, then separate circuits and emergency ballasts are required.

**Exit Signs.** Exit signs shall be of the LED type, have an EnergyStar rating, and meet the requirements of NFPA 101.

**Emergency Lighting.** Emergency lighting shall be provided in accordance with the requirements of NFPA 101, and the applicable building code. At a minimum, unswitched emergency lighting shall be provided in the following areas:

- Lighting in zones covered by CCTV cameras
- Security zones
- Stairways
- Exit signs
- Egress corridors
- UPS and battery rooms

Emergency lighting may be switched in the following areas:

- Communication equipment rooms
- Electrical rooms
- Fire command centers
- Security control centers
- Technology/server rooms
- Building exits (switched by photocell)
- Engineer's office

Supplemental battery powered emergency lighting is recommended in the following spaces to bridge the generator startup time:

- Generator Rooms
- Main mechanical and electrical rooms

### Specific Lighting Constraints

**Mechanical and Electrical Spaces.** Lighting in equipment rooms or rooms shall be provided by industrial-type fluorescent fixtures. Care shall be taken to locate light fixtures so that lighting is not obstructed by tall or suspended pieces of equipment. Physical protection such as wireguards or fixture location shall be provided for light fixtures to prevent lamp/fixture damage.

**High Bay Lighting.** Lighting in shop, supply, or warehouse areas with ceiling above 5.0 m (16.4 ft) must be metal halide pendant hung fixtures or T5HO reflectorized fixtures. Metal halide fixtures with prismatic lenses can only be used with a minimum mounting height of 7.5 m (25 ft). No high pressure sodium lamps are allowed.

**Conference Rooms and Training Rooms.** These spaces shall have a combination of lighting options to provide multiple scenes for space flexibility. Typical scenes would be table illumination for facial rendering at meetings, higher light at the front for speakers illumination, and lower light at front for media presentations.

**Other Special Areas.** Special lighting design concepts are encouraged in these spaces. The lighting design shall be an integral part of the architecture. Consideration must be taken by the certified lighting designer to integrate the design with the interior finishes and furniture arrangement to enhance the functionality of the spaces. Further consideration must be taken to adhere to the energy criteria, maintenance criteria, as well as minimizing the number of special lamp types and fixtures required.

Areas generally requiring special lighting treatment are as follows:

- Main Entrance Lobbies
- Atriums
- Elevator Lobbies
- Public Corridors
- Public Areas
- Auditoriums
- Conference Rooms
- Training Rooms
- Dining Areas and Serveries
- Libraries

Criteria on courtrooms and judges' chambers can be found in Chapter 9, *Design Standards for U.S. Court Facilities*.

**Atrium, Sandra Day O'Connor U.S. Courthouse, Phoenix, AZ**

# 6.9 Exterior Lighting and Control Systems

## Exterior Lighting Design Criteria

An exterior lighting system shall be provided to ensure the security and safety of the occupants and passersby, as well as to support the architectural aesthetic of the building. The properly designed exterior lighting system must provide the minimum required illumination while simultaneously preventing light pollution and light trespass, minimizing glare, and avoiding over lighting. Exterior luminaries must comply with all local zoning laws and lighting levels for exterior spaces must be as indicated by the IES *Lighting Handbook*.

U.S. Courthouse, Erie, Pennsylvania

**Architectural Lighting.** Architectural lighting is considered to be any lighting that illuminates the architectural building form, and is typically uplighting from the ground with minimum use of downlighting from the building to minimize light pollution. The following guidelines must be met.

For stone and masonry:

- Total architectural lighting connected wattage must not be more than 0.125 W/sq. ft. of exterior surface area.
- No uplighting fixture shall use a higher rated lamp than 250W.
- All light from uplighting fixtures must be directed onto the building. No light can trespass around the architectural form.

For metal or glass curtainwall:

- Total architectural lighting connected wattage must not be more than 0.100 W/sq. ft. of exterior surface area.
- No uplighting fixture shall use a higher rated lamp than 175W.
- All light from uplighting fixtures must be directed onto the building. No light can trespass around the architectural form.

**Site Lighting.** Site lighting is considered any exterior lighting that illuminates the area around the building, defines entrances and exits, or provides traffic flow. Site lighting must adhere to the following guidelines.

- Luminaires selected must have a minimum cutoff of 80°.
- Illumination shall be well controlled and no light can trespass off the building property.
- Implement bollards for pathway illumination.

Lighting fixtures at all entrances and exits shall be connected to the emergency lighting system. Where security lighting is required and HID restrike time is not acceptable, UPS backup, HID capacitive/ridethrough circuitry or instant-on lamp sources may be required.

**Parking and Roadway Lighting.** Parking lots and roadway lighting shall be designed with high-efficiency, pole-mounted luminaries with a maximum cutoff of 80°. Illumination ratios shall not exceed a 10 to 1 maximum to minimum ratio and a 4 to 1 average to minimum ratio.

**Structured Parking.** Fixtures for parking areas must be either fluorescent or HID. Care must be taken in locating fixtures to conform to the traffic patterns and maintain the required vehicle clearance.

### Exterior Lighting Controls

Exterior lighting circuits shall be controlled by photocell and a time clock controller, with an astronomical dial, to include both all-night and part-night lighting circuits. |A minimum of 75% of the architectural, site, and parking lighting shall be switched off three hours after the building is typically unoccupied or 11:00 pm, whichever is later.

## 6.10 Branch Wiring Distribution Systems

**Lighting – Circuit Loading**

- 120 volt circuits shall be limited to a maximum of 1400 volt-amperes.
- 277 volt circuits shall be limited to a maximum of 3200 volt-amperes.

**Receptacles – Circuit Loading**

- 120 volt circuits for convenience receptacles shall be limited to a maximum of 1440 volt-amperes (8 receptacles @ 180 watts).
- Each special purpose receptacle shall be circuited on a dedicated circuit to a protective device to match the rating of the receptacle.

In GSA buildings, general wiring devices shall be specification grade. Emergency receptacles shall be red. Isolated grounding receptacles shall be orange. Special purpose receptacles shall be brown. The color of standard receptacles and switches shall be coordinated with the architectural color scheme; for example, white, not ivory, devices shall be used if walls are white or light gray.

Building standard receptacle shall be duplex, specification grade NEMA 5-20R. Special purpose receptacles shall be provided as required. Device plates shall be plastic, colored to match the receptacles.

### Placement of Receptacles

**Corridors.** Receptacles in corridors shall be located 15 m (50 feet) on center and 7.5 m (25 feet) from corridor ends.

**Office Space.** Receptacles for housekeeping shall be placed in exterior walls and walls around permanent cores or corridors. Except for these, placement of receptacles in walls shall be avoided where raised floors are utilized to the maximum extent possible. See Chapter 3: *Architectural and Interior Design, Building Planning, Planning Module, Floor-to-Floor Heights and Vertical Building Zoning, and Space Planning, Office Space, Utility Placement.*

**Raised Access Floor.** All wiring beneath a raised access floor shall be routed in rigid metal or flexible conduit to underfloor distribution boxes. One distribution box per bay is recommended (see section *Placing Electrical Systems in Buildings, Horizontal Distribution of Power and Communications*). Flush-mounted access floor service boxes shall be attached to the underfloor distribution boxes by means of a modular, prewired system to facilitate easy relocation.

**Conference Rooms.** Conference rooms shall be served in the same fashion as general office space, except where specifically outfitted for audio-visual equipment.

**Maintenance Shops.** Maintenance shops require plug-mold strips above work benches with duplex outlets 900 mm (36 inches) on center. Receptacles shall be wired on alternating circuits. Receptacles or circuit breakers shall be of the GFI type. Provide EPO (Emergency Power Off Stations) and associated contactors for shops containing freestanding equipment.

**Electrical and Communications Rooms.** Electrical rooms require one emergency power receptacle that is identified as Emergency Power at the receptacle. The communications room will contain power and grounding for the passive and active devices used for the telecommunications system, including at least two dedicated 20A, 120 Volt duplex electrical outlets on emergency power, and additional convenience outlets at 1800mm (6 foot) intervals around the walls and direct connection to the main building grounding system. If uninterruptible power is required in communications rooms, it will be furnished as part of the communications system.

**Main Mechanical and Electrical Rooms.** Main mechanical and electrical equipment rooms shall each have, at a minimum, one emergency power receptacle that is identified as Emergency Power at the receptacle.

**Exterior Mechanical Equipment.** Provide one receptacle adjacent to mechanical equipment exterior to the building, including each roof. Receptacles shall be of the weatherproof GFI type. Receptacles must be located within 25 ft. (7.62m) of each piece of equipment in accordance with NEC 210-63.

**Toilet Rooms.** Each toilet room shall have at least one GFI receptacle at the vanity or sink. Carefully coordinate the location of the receptacles with all toilet accessories.

### Underfloor Raceway Systems

Underfloor raceways fall into two (2) categories:

- A cellular metal deck framing the concrete floor slabs in a steel building, in which the cells are generally fully "electrified" by the placement of steel sheets enclosing the underside of the cells. Access to the individual cells is obtained by a series of compartmented header ducts. The width of the header duct is sized according to the area served and the depth is 63 mm (2 1/2").
- A conventional 3-cell underfloor duct system placed in a 100 mm (4") concrete fill over the concrete slab in an all concrete building. The cells are generally located on 1500mm (5') to 1800 (6') centers. Note: This type of raceway system is frequently found in existing buildings selected for modernization.

The cell assignments in 3-cell systems are generally designated as: (1) power; (2) voice/data; (3) signal.

However, the recent increase in bandwidth required by the latest IT equipment has been accompanied by the use of CAT 6 cables and fiber optic cables. Neither of these cables can tolerate the proximity to the power cables or the sharp bends from the header ducts to the cells to the outlets, which significantly deminshes the practical use of these systems.

## Panelboards

- Panelboards shall be constructed to comply with the requirements of UL 67 and UL 50.
- All panelboard interiors shall be constructed using hard-drawn copper of 98% conductivity, with AIC bracing greater than the calculated available fault current. Minimum short circuit rating for 208/120v panelboards shall be 10,000 amperes symmetrical. Minimum short circuit rating for 480/277v panelboards shall be 14,000 amperes symmetrical. A 200% neutral shall be provided for panelboards serving office loads served from the secondaries of K-rated transformers or harmonic canceling transformers. A full size copper ground bus for connecting ground conductors shall be bonded to the steel cabinet. Provide isolated ground bus where required.
- Branch circuit breakers shall be bolt-on designed for replacement without disturbing adjacent units. Breakers shall comply with the requirements of UL 489, thermal magnetic type with short-circuit rating greater than the calculated available fault current. Panels shall be specified with "door-in-door" trim.

**Power Distribution Panels.** In general, circuit breaker type panels will be the standard of construction for federal buildings. With the exception of lighting and receptacle panel boards, fusible switches may be considered if specific design considerations warrant their application, such as in electrical coordination of electrical over-current devices.

**Lighting and Receptacle Panelboards.** Lighting and receptacle panelboards shall be circuit breaker type. Provide minimum 30 poles for 100 amps panelboards and minimum 42 poles for 225 amp panelboards.

**Conduit Systems.** The specification shall list the various types of conduit systems which are approved for use on the project and the specific raceway applications for which they are to be used, as follows:

- RSC Rigid galvanized steel conduit – ANSI C80.1 Exposed outdoors
- RAC Aluminum conduit (with steel elbows) Indoor feeders – exposed and/or concealed
- IMC Intermediate steel conduit – ANSI C80.6 Indoor feeders – exposed and/or concealed
- EMT Electrical Metallic Tubing (compression fittings) – ANSI C80.3 Branch circuit wiring, exposed and/or concealed
- FMC Flexible steel conduit – connections to recessed lighting fixtures and concealed in movable and/or dry wall partitions
- LFMC Flexible steel conduit with PVC jacket. Connections to vibrating equipment (motors, transformers, etc.)
- PVC Underground feeders encased in concrete envelope. Indoors and outdoors. Transition to steel or aluminum when exposed.

# 6.11 Voice and Data Distribution System

The configuration and type of the voice and data cabling distribution systems shall be developed at the earliest stages of design, since the space requirements are so significant and widespread. System requirements are user generated and are generally translated into distribution system requirements by a Registered Communications Distribution Designer (RCDD).

### Communications Raceways

**Raised Access Floor.** The standard option for delivering communications services in Federal buildings is by laying the cable in a tray for main runs and then branching directly on the floor slab below the raised access flooring system.

**Cable Trays in Hung Ceilings.** Since underfloor raceway systems cannot accommodate the large turning radii required by the CAT 6 and fiber optic cables, the primary alternative to a raised floor system is a series of cable trays installed above accessible hung ceilings. Cable trays shall be grounded.

**Alternate Raceways.**

- Exposed cable trays
- Conduits in hung ceiling


U.S. Custom House, New Orleans, LA

# 6.12 Emergency Power Systems

Emergency power systems must be designed to comply with the requirements of NFPA 110, *Emergency and Standby Power Systems*. See Chapter 7: *Fire Protection & Life Safety* for additional requirements. Unless otherwise specifically authorized by the Contracting Officer all facilities shall be provided with a standby generator to supply power to the facility in the event of a sudden loss of power.

## Generator Systems

The system shall consist of a central engine generator and a separate distribution system with automatic transfer switch(es), distribution panels, and 480/277V lighting panel (if applicable) with dry-type transformers feeding 208/120V panels as required. Effort must be made to ensure proper coordination of mechanical engineering elements of the generator systems design.

**Service Conditions.** If the unit is to be installed outdoors, it shall be provided with a suitable walk-in acoustic enclosure and jacket water heaters to ensure reliable starting in cold weather.

When installed at high altitudes or in areas with very high ambient temperatures, the unit must be derated in accordance with manufacturers' recommendations. Operation of starting batteries and battery chargers must also be considered in sizing calculations. In humid locations heaters can reduce moisture collection in the generator windings. Critical silencers are required for all generators. Acoustical treatment of the generator room shall be provided if necessary. Temperature and ventilation shall be maintained within the manufacturer's recommendations to assure proper operation of the unit. Calculations to support the size of the intake air supply for combustion, cooling and radiation as well as exhaust piping, and exhaust paths shall be provided by the design engineer.

Radiators shall be unit-mounted if possible. If ventilation is restricted in indoor applications, remote installation is acceptable. Heat recovery and load shedding shall not be considered. Remote location of radiators shall be designed to avoid excess pressure on the piping seals.

Provide permanently installed load bank sized at 50% of generator rating. Load bank shall be factory mounted to the radiator.

**Capacity.** The engine generator shall be sized to serve approximately 110 percent of design load; ideally it shall run at 60 percent to 80 percent of its rated capacity after the effect of the inrush current declines. When sizing the generator, consider the inrush current of the motors that are automatically started simultaneously. The initial voltage drop on generator output due to starting currents of loads must not exceed 15 percent. Day tanks shall be sized for a minimum capacity of four hours of generator operation. Provide direct fuel oil supply and fuel oil return piping to the on-site storage tank. Piping shall not be connected into the boiler transfer fuel oil delivery "loop".

**Emergency Power Loads.** Emergency power shall be provided for the following functions:

- Emergency lighting as defined in 6.10
- Fire alarm system
- Generator auxiliaries
- Fire pump
- Visitor screening equipment
- Telephone switch
- Security systems
- Mechanical control systems
- Building Automation System (BAS)
- Elevators (one per bank)
- Sump pumps
- Sewage ejector pumps
- Smoke control systems
- High Rise Stairway Pressurization Fans
- Uninterruptible power systems serving technology/server rooms
- Air conditioning systems for technology/server and UPS rooms
- Exhaust fan in UPS battery rooms
- Power and lighting for Fire Control Center and Security Control Center
- Air conditioning systems for communications rooms
- FAA Aircraft Obstruction Lights.
- Other associated equipment designated by code

**Generator Alarms.** Generator alarms must be provided in the generator room. All malfunctions shall be transmitted to the BAS. In all buildings, with or without BAS, a generator alarm annunciator shall be located within the Fire Command Center.

**Automatic Transfer Switches.** Automatic transfer switches serving motor loads shall have in-phase monitor (transfer when normal and emergency voltages are in phase) to reduce possible motor damage caused by out-of-phase transfer. They shall also have pre-transfer contacts to signal time delay returns in the emergency motor control centers.

Automatic transfer switches shall include a bypass isolation switch that allows manual bypass of the normal or emergency source to insure continued power to emergency circuits in the event of a switch failure or required maintenance.

**Fuel Distribution System.** See Chapter 5: *Mechanical Engineering, Heating Systems, Boilers and Heat Exchangers*, for information on fuel oil piping and underground fuel oil tanks.

**Location.** Generators shall be located at least 30 m (100 feet) from communications frame equipment to avoid radio frequency interference. See Chapter 3: *Architectural and Interior Design, Space Planning, Building Support Spaces, Mechanical and Electrical Rooms, Emergency Generator Rooms* for additional generator room requirements. Generator and generator control panel shall be located in a separate room or enclosure.

# 6.13 Clean Power Systems


## Uninterruptible Power Systems

In some facilities technology/server room back-up systems may be designed by the tenant agency. If this is the case, shell space and utility rough-ins shall be provided. In facilities where uninterruptible power supply (UPS) systems are to be provided as part of the building construction, they shall be designed as described in this section. All UPS systems are considered to be above standard for GSA space. Tenant agencies with UPS requirements are advised that a maintenance contract is recommended.

Requirements for UPS systems must be evaluated on a case by case basis. If UPS is required, it may or may not require generator back-up. When generator back-up is unnecessary, sufficient battery capacity shall be provided to allow for an orderly shut-down.

**Critical Technical Loads.** The nature, size, and locations of critical loads to be supplied by the UPS will be provided in the program. The UPS system shall serve critical loads only. Non-critical loads shall be served by separate distribution systems supplied from either the normal or electronic distribution system. A UPS system shall be sized with 25 percent spare capacity The specification of a redundant module shall depend upon the criticality of the loads.

**Emergency Electrical Power Source Requirements.** When the UPS is running on emergency power, the current to recharge the UPS batteries shall be limited. This limited battery charging load shall be added when sizing the emergency generator.

If the UPS system is backed up by a generator to provide for continuous operation, the generator shall provide power to all necessary auxiliary equipment, i.e., the lighting, ventilation, and air conditioning supplying the UPS and the critical technical area.

**System Status and Control Panel.** The UPS shall include all instruments and controls for proper system operation. The system status panel shall have an appropriate audio/visual alarm to alert operators of potential problems. It shall include the following monitoring and alarm functions: system on, system bypassed, system fault, out of phase utility fault, closed generator circuit breaker. It shall have an audible alarm and alarm silencer button. Since UPS equipment rooms are usually unattended, an additional remote system status panel must be provided in the space served by the UPS. The alarms shall also be transmitted to the BAS.

**UPS and Battery Room Requirements.** Provide emergency lighting in both spaces. Provide a telephone in or adjacent to the UPS room. Battery room design must accommodate: proper ventilation, hydrogen detection, spill containment, and working clearances. See Chapter 3: *Architectural and Interior Design, Space Planning, Spaces for Uninterruptible Power Systems (UPS) and Batteries* for additional requirements for UPS and battery room. Also, see NEC and Chapter 7: *Fire Protection & Life Safety* for additional requirements.

## Computer Center Power Distribution Unit

In some GSA buildings the power distribution system for computer centers will be designed by the tenant agency. In that case, utility rough-in shall be provided under the construction contract. If distribution is to be provided under the building contract, it shall be designed according to the criteria in this section.

**Power Distribution Units (PDU's).** PDU's with internal or remote isolation transformers and output panelboards shall be provided in all computer centers to reduce/eliminate harmonic currents generated by non-linear loads and reflected back to the neutral service conductors. Neutral busses/conductors shall be sized at 200% of phase busses/conductors. PDU's with internal or remote isolation transformers shall be K-rated to serve non-linear loads. The transformer rating must take the increased neutral size into account.

**Computer Center Grounding.** To prevent electrical noise from affecting computer system operation, a low-frequency power system grounding and a high-frequency signal reference grounding system shall be provided. The design of the technology/server room grounding system shall be discussed with the computer center staff.

**Low Frequency Power System Grounding.** The primary concern is to provide a safe, low-frequency, single point grounding system that complies with Article 250 of the *National Electrical Code*. The single point ground must be established to ground the isolation transformer or its associated main service distribution panel.

A grounding conductor shall be run from the PDU isolation transformer to the nearest effective earth grounding electrode as defined in the NEC. All circuits serving Automated Data Processing (ADP) equipment from a PDU shall have grounding conductors equal in size to the phase conductors.

**High Frequency Power System Grounding.** If requested by the User Agency, in addition to the low frequency power system grounding, a high frequency signal reference grounding system for radio frequency noise is required (with the two systems bonded together at one point). A grid made up of 600 mm (2-foot) squares will provide an effective signal reference grounding system. The raised floor grid may be used if it has mechanically bolted stringers. Alternatively, a grid can be constructed by laying a 600 mm mesh (2-foot squares) of braided copper strap or 1.3 mm (16 gauge, 0.051 inch) by 50 mm (2-inch) copper strap directly on the structural floor below the raised access floor. Data processing equipment shall be connected to the reference grid by the most direct route with a braided copper strap.

**Common Mode Noise Reduction.** The reduction of common mode noise is particularly important for the proper operation of computer-based, distributed microprocessor-based systems, i.e., building automation systems, electronic security systems, card access control systems, and local area networks.

The following guidelines shall be considered to reduce common mode noise:

- Avoid running unshielded metallic signal or data lines parallel to power feeders.
- Where metallic signal or data lines must be routed in noise prone environments, use shielded cables or install wiring in ferrous metal conduit or enclosed cable trays.
- Locate metallic signal or data lines and equipment at a safe distance from arc producing equipment such as line voltage regulators, transformers, battery chargers, motors, generators, and switching devices.
- Provide isolation transformers, electronic power distribution panelboards or power conditioners to serve critical electronics equipment loads.
- Provide isolated grounding service on dedicated circuits to critical data terminating or communicating equipment.
- Replace metallic data and signal conductors with fiber optic cables where practical.

### Harmonic Generation, K-Rated Transformers, Sizing of Neutrals

Harmonic frequencies are introduced into the branch circuit distribution system by the power supplies of the following items of equipment:

- Electronic ballasts
- Variable frequency drives
- PC's
- Laser printers
- File servers
- Fax machines
- Copiers

The third order harmonics (180 Hz) add in the neutral conductor and, in the case of 100 percent total harmonic distortion, would result in a neutral current of 1.73 times the phase current.

K-Rated Transformers: (K-13) with a 200 percent neutral shall feed branch circuit panelboards with 200 percent neutrals.

# 6.14 Grounding Systems

**General.** Grounding systems shall be designed to coordinate with the specific type and size of the electrical distribution system, including the following applicable generic types of grounding systems, or grounding components:

Metzenbaum Courthouse, Cleveland, OH

**Separate equipment ground conductors.** Comply with NFPA 70, Article 250, for types, sizes, and quantities of equipment grounding conductors, unless specific types, larger sizes, or more conductors than required by NFPA 70 are indicated.

Install insulated equipment grounding conductor with circuit conductors for the following items, in addition to those required by NEC:

- Feeders and branch circuits
- Lighting circuits
- Receptacle circuits
- Single-phase motor and appliance branch circuits
- Three-phase motor and appliance branch circuits
- Flexible raceway runs
- Metal clad cable runs

**Busway Supply Circuits.** Install insulated equipment grounding conductor from the grounding bus in the switchgear, switchboard, or distribution panel to equipment grounding bar terminal on busway.

**Separately Derived Grounds.** Good practice dictates that, in order to minimize extraneous "noise" on certain systems, particularly those in which harmonics are generated, the specific system grounds shall be separated prior to grounding at the service grounding electrode or counterpoise.

**Isolated Grounds.** Isolated grounds are applied where the equipment served may be particularly sensitive to external interference from sources generating third harmonics and higher. In these instances the grounds, beginning from the panelboard ground and the grounding conductor from the raceway to the grounding terminal at the receptacle or outlet box, shall be electrically isolated from the main grounding system. The isolated grounds shall terminate at a common ground or counterpoise.

In buildings where a 208/120V service is supplied by the power company, and there is no intermediate transformer isolating the utilization voltages from the various harmonic generators previously mentioned, the use of isolated ground panels serving the office power requirements shall be considered.

**Raised floors.** Access floors shall be grounded. A grounding conductor shall be bonded to every other floor pedestal and shall be extended to the technology/server room common ground bus.

**Counterpoise.** Where feasible, a grounding conductor (counterpoise) shall be provided in an isosceles triangle configuration with sides greater than or equal to 3 meters(10 feet). The conductor shall be tinned copper not less than No. 4/0 AWG and shall be electrically connected to the incoming domestic water services on either side of the building as well as the various clusters of three (3) ground rods spaced at intervals. Ground rods shall be 15mm (5/8'') dia. by 2400mm (96'') long and shall be tin coated copper. The counterpoise loop will involve direct burial in earth 1200mm (24'') min. below grade. The following items shall be connected to the counterpoise loop:

- Lightning protection system "down conductors"
- Transformers in substations
- Emergency generator ground
- Telecom and data room grounds
- Separately derived grounds
- Isolated ground panels
- Main switchgears
- Normal and emergency distribution systems
- Flagpoles

# 6.15 Lightning Protection Systems

**General.** Lightning protection systems are important safety features in the design of electrical distribution systems. Their application on any specific project is a function of its geographic location, height, proximity of taller adjacent structures and the architectural configuration of the building. The decision to recommend a lightning protection system shall be made at the earliest stages of design and shall be supported by a study as prescribed by NFPA 780.

**Master Label.** If a decision is made to provide a lightning protection system it shall be installed in compliance with UL 96 and NFPA 780. A UL Master Label shall be required.

**Alternate Systems.** The requirement of a "Master Label" imposes certain restrictions or limitations on the design of the system which may be in conflict with the architectural design, particularly if the façade includes large curved surfaces which preclude the installation of air terminals and where the spacing of down conductors are limited. In those instances the design engineer may appeal to the Contracting Officer to waive the "Master Label" requirement on the basis that the design generally follows the "Faraday Cage" principle of lightning protection.

**Grounding.** The down conductors shall follow direct paths from the air terminals to ground connections or to the counterpoise loop.

## 6.16 Security Systems

Every government building, virtually without exception, whether new or existing, large or small, recent vintage or historic, must have provisions for a security system. The type and level of security system designed shall be determined by a security design professional and shall be commensurate to the threat evaluation of the facility. The system must be integrated into the design, if a new building, or provided for in a non-intrusive way, in the case of an existing building. The systems shall be provided with integral battery back-up and connected to the building emergency generator.

## 6.17 Short Circuit and Coordination Study

The design engineer shall submit a preliminary computer generated short circuit analysis on all projects. The final coordination and analysis shall be done by the contractor's testing agency or by the independent agency employed by the client, and a report shall be submitted.