CHAPTER 7

SURGE PROTECTIVE DEVICES

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- "Telephone/Control/Data Network Circuit SPDs" on page 7-34
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7.1 INTRODUCTION

The installation of Transient Voltage Surge Suppression (TVSS) devices is a requirement for all communication sites and is essential for all facilities where communication- related electronics and electrical equipment is in use. Surges and transient power anomalies are potentially destructive electrical disturbances, the most damaging being over-voltage occurrences and short duration over-voltage events. Sometimes referred to as "spikes", high-energy transient power anomalies can arise from inductive load switching or other events within the power system or capacitive and inductive coupling from environmental events such as nearby lightning activity. Environmental and inductive power anomalies are wideband occurrences with a frequency range from close to DC to well into the RF high frequency spectrum. It is critical that each point-of-entry (AC, telephone, LAN, signal/control and RF) into the equipment area be protected against these anomalies. This protection is essential to reduce the risk of personal injury, physical equipment damage, and loss of operations (equipment down time). Although lightning can cause the most visible damage, it is not the predominant cause of transient voltages.

Transient voltage sources include, but are not limited to the following:

- Power company switching
- Generator transfer
- Shared commercial feeders with poor line regulation
- Load switching
- Fault currents
- HVAC units
- Heating elements
- Power tools
- Electric motors
- Fluorescent lights

- Elevators
- Switching of inductive loads
- Lightning activity

There are four major site entrances for surges that require individual attention in order to effectively protect a site and reduce the probability of damage.

- AC Power
    - Main service
    - External branch circuits or feeders
    - Generator
- Telephone/Data
    - Data circuits
    - LAN
    - Control
    - Security and card access
    - CCTV
- RF Cabling
    - Antenna transmit and receive lines
    - Cable TV service
- Tower Lighting Systems

Effective grounding or earthing alone will not protect a communications facility from damage due to surges, transients, and lightning. However, an effective combination of facility grounding, equipment bonding, and properly installed Surge Protection Devices (SPDs) on all circuit conductors entering the equipment area can significantly help maximize total site protection.

CAUTION

Transient voltage surge suppression (TVSS) techniques using surge protection devices (SPD) alone are not enough to adequately protect a communications site. Proper grounding (earthing) and bonding shall be incorporated at a communications site in order to provide an adequate level of protection. See Chapter 4, "External Grounding," and Chapter 5, "Internal Grounding" for grounding and bonding details and requirements.

NOTE: The term "SPD" is used interchangeably with TVSS. IEEE C62.45 and UL defines TVSS as an SPD.

Figure 7-1 on page 7-3 shows the minimum SPD installation complement for a typical communications facility.

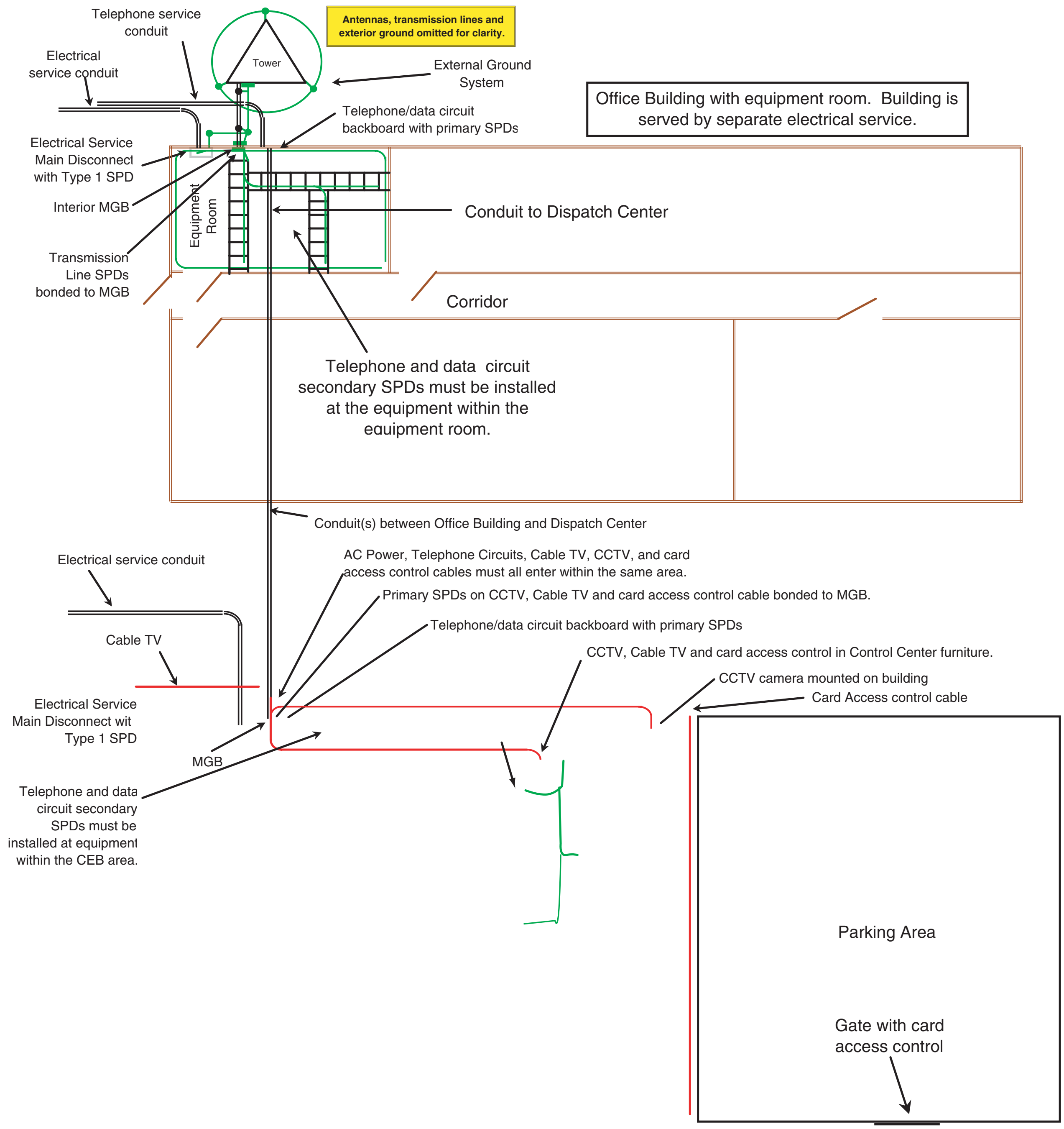


FIGURE 7-1 MINIMUM REQUIRED SPD FOR TYPICAL INSTALLATION

The requirements presented in this chapter will provide a suitable level of protection for communications equipment and sites in most areas. Areas subject to more severe lightning activity will require additional SPD design considerations which are beyond the scope of this chapter.

The ultimate goal of Transient Voltage Surge Suppression is to keep communications sites and systems operating reliably. Failure of a single SPD at a communications site would leave the site vulnerable to further damage. To maintain a backup level of protection, it may be necessary to install a redundant SPD. Another important design philosophy is that the AC power SPDs **shall not** cause interruptions to the site power when it operates. Therefore, to reduce this probability, all AC power SPDs **shall** be designed for and installed as parallel devices. A suitable disconnecting means **shall** be provided to permit servicing. Type 3 devices could be considered a series connected device as this is placed between the receptacle outlet and the load. In the Type 3 devices the surge protection medium **shall** be parallel connected between the phase conductor and the neutral conductor in a manner that will not interrupt power to the load should the surge suppression device fail. Alarms to report a device failure are recommended.

7.2 TECHNOLOGIES AVAILABLE

There are several major types of SPD technologies available today. The most common and most reliable are the Metal Oxide Varistor (MOV) and the Silicon Avalanche Diode (SAD) devices. These devices are ideal for protection of power and telephone or data circuits because of their fast response time and high energy handling capability. There are other components such as gas discharge tubes, spark gaps, surge relays, capacitors, inductors, and selenium devices that, although somewhat effective in specific applications, are not acceptable as power, telephone or data circuit SPDs at communications facilities as the typical response time is too slow.

It may be necessary to use more then one type of component in a protective device to obtain the best possible combination of SPD characteristics. The most common combination forming a “hybrid circuit” incorporates a high current, slower-acting component with a faster acting, but lower-power rated component. For AC power, this is typically a coordinated MOV and SAD combination.

WARNING

Gap Type SPDs shall not be used as AC power line surge suppression devices in TN-C-S grounding systems, common in North America. However, in TT grounding systems, typical for those countries that follow the IEC grounding system, Gap Type SPD's are the one of the preferred components in a common mode protection scheme, as long as the device meets the follow-current requirements detailed in this chapter.

7.3 SUPPRESSION MODE DEFINITIONS

Normal Mode is defined as voltage appearing between line and neutral (L-N) and line to line (L-L) conductors.

Common Mode refers to voltages appearing between line or neutral conductors and ground (L-G or N-G).

WARNING

Common Mode AC power surge suppression devices shall not be utilized. These devices may fail in a short circuit condition. Should this occur, the AC power neutral conductor becomes bonded to the ground or equipment grounding conductor causing undesired currents in the ground or equipment grounding conductor(s). This may constitute a personnel safety hazard and could constitute an NFPA 70 violation by creating a neutral-ground bond at a location other than at the main service disconnect. (Common Mode surge suppression devices may be used on telephone or data circuits.)

WARNING

All AC power SPDs used within the United States shall be UL 1449, 2nd Edition (or later revision) listed.

NOTE: There may be specific nondomestic applications where common mode protection may be advantageous although not recommended by Motorola. Installation of a transformer creating a separately derived electrical system is recommended for these applications. The SPD manufacturer should be contacted regarding these applications.

In non-domestic applications that have power systems based on the TT grounding scheme, the utilization of Gap Type SPDs in the line-to-ground, or neutral-to-ground configuration is the preferred methodology. However, the GDTs must be preceded by circuitry that limits the follow current to the levels defined further within the specification.

7.4 AC Power SPD Requirements

SPDs are required on all power feeders to and from communications facilities. All devices **shall** be installed per the manufacturer’s installation instructions. The facility grounding and bonding systems **shall** be properly implemented to help ensure that the electrical service, all surge suppression devices, and the communication system components within the equipment area are at the same ground potential. This is **critically important** to help ensure maximum safety of personnel and maximum effectiveness of the SPDs.

The SPDs **shall** be installed within the equipment shelter, room or area to achieve maximum effectiveness. Installation at locations away from the equipment area **shall not** be performed, as it reduces the effectiveness of the SPD.

7.4.1 AC SPD Requirements Based on Facility Description

Table 7-1 on page 7-7 specifies the minimum AC power SPD requirements for various communications facilities. (The voltage and phase requirements are site specific and depend on the electrical service characteristics for the specific location.)

7.4.1.1 DETERMINING REQUIRED SPD COMPLEMENT

Use Table 7-1 to determine the SPD complement best suited for a particular application as follows:

1. In the **Service Type** column, note the type of electrical layout that best describes the site, facility or equipment location.
2. Review the **Interconnect Diagram** (**A** through **M**; Figures 7-2 through 7-14) associated with the **Service Type** to ensure the electrical service and distribution arrangement selected best matches the site, shelter or equipment area. (Figures 7-2 through 7-14 are on pages 7-11 through 7-23, respectively.)
3. Order and install the Type SPD(s) correspondingly listed for the selected service and distribution system.

   EXAMPLE: Assuming a stand-alone shelter as follows:

   - Without a generator
   - Main disconnect and all disconnects located within the shelter

   SPD requirements are determined as shown below.

1. In Table 7-1, find the Service Type description that best matches site.

2. Compare site to corresponding Figure shown. Verify that site matches electrical service and distribution arrangement shown.

3. Note the required location and SPD type for the Service Type.

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./ Shelter
Stand-alone Building/shelter without Generator					
Main disconnect and all panelboards located within the same shelter, room or equipment area	**A (Figure 7-2)**			Type 1[1]	

In this example, a shelter with main disconnect and panelboard all located within shelter fits the description shown above and additionally matches Figure A. As such, the SPD type and location is correspondingly shown above.

For a given application, the SPDs **shall** be installed at the panelboard correspondingly specified in Table 7-1 and the associated figure.

Installation of a Type 3 device is also recommended for high exposure locations when the branch circuit is greater than 3 m (10 ft.) of conductor length or 1.5 m (5 ft.) of circuit length from the panelboard where a Type 1 device is installed.

7.4.1.2 INSTALLATION WITH MAIN DISCONNECT AWAY FROM AREA

For installations where the main disconnecting means is located away from the shelter, room or equipment area (Diagrams **B** through **J**; Figures 7-6 through 7-11 on pages 7-15 through 7-20, respectively), a separately derived electrical system is an option within the shelter, room or equipment area to establish the neutral-ground bond. Other means are described in "Location of Neutral-Ground Bond" on page 6-4.

A separately derived electrical system can be achieved by installation of a step down or isolation transformer, or by the installation of a suitable UPS that qualifies as a separately derived electrical system. Similarly, when a power feed is provided to another building, shelter or equipment area (Diagrams **K** through **M**; Figures 7-12 through 7-14 on pages 7-21 through 7-23, respectively), a separately derived electrical system should be installed within that shelter, building or equipment area to minimize potential damage resulting from power line anomalies generated by loads or lightning activity within that shelter, building or equipment area.

7.4.1.3 INSTALLATION WITH EQUIPMENT INSTALLED IN POLE OR PAD MOUNTED CABINETS

For installations where the equipment is installed within pole or pad mounted cabinets (Diagrams **N** through **P**; Figures 7-15 through 7-17 on pages 7-24 through 7-26), SPDs are required as specified in Table 7-1. Where a pole or pad mounted cabinet is installed and the electrical feeder originates from within another building or shelter (Diagram **Q**; Figure 7-18 on page 7-27), a Type 3 SPD is required to be installed on all equipment within the cabinet. In installations of this type it may be desirable to install additional SPDs at the branch circuit panelboard. Where the level of exposure is high a Type 1 SPD is recommended. See Table 7-1 and footnotes for further information.

NOTE: Single conversion (forward transfer mode) UPS systems do not provide transient voltage surge suppression. Double conversion (reverse transfer mode or rectifier-inverter) UPS systems offer surge suppression to source induced transients. No surge suppression is afforded for load induced transients on either type.

TABLE 7-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
Stand-alone Building/shelter without Generator						
Main service disconnect and all panelboards located within the same shelter, room or equipment area	**A (Figure 7-2)**			Type 1		Type 3[1]
Main service disconnect located outside the equipment area (greater than 3 m (10 ft.)): • At fence or property line utilizing a separately derived system supplying equipment area	**B (Figure 7-3)**			Type 1		Type 3[1]

TABLE 7-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES (CONTINUED)

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
• Within other building or structure utilizing a separately derived system supplying equipment area	**C (Figure 7-4)**			Type1		Type 3[1]
Stand-alone Building/shelter with Generator						
Main service disconnect and all panelboards located within the same shelter, room or equipment area	**D (Figure 7-5)**	Type 2 or Type 1[2]		Type 1		Type 3[1]
Main service disconnect located outside the equipment area (greater than 3 m (10 ft.)):						
• At fence or property line utilizing a separately derived system supplying equipment area	**E (Figure 7-6)**		Type 2 or Type 1[2]	Type 1		Type 3[1]
• Within other building or structure utilizing a separately derived system supplying equipment area	**F (Figure 7-7)**		Type 2 or Type 1[2]	Type 1		Type 3[1]
Equipment Area Located within a Larger Structure without Generator						
Main service disconnect located in another part of same structure utilizing a separately derived system supplying equipment area	**G (Figure 7-8)**			Type 1		Type 3[1]
Main service disconnect located within another structure utilizing a separately derived system supplying equipment area	**H (Figure 7-9)**			Type 1		Type 3[1]
Equipment Area Located within a Larger Structure with Generator						
Main service disconnect located in another part of same structure utilizing a separately derived system supplying equipment area	**I (Figure 7-10)**		Type 2 or Type 1[2]	Type 1		Type 3[1]
Main service disconnect located within another structure utilizing a separately derived system supplying equipment area	**J (Figure 7-11)**		Type 2 or Type 1[2]	Type 1		Type 3[1]

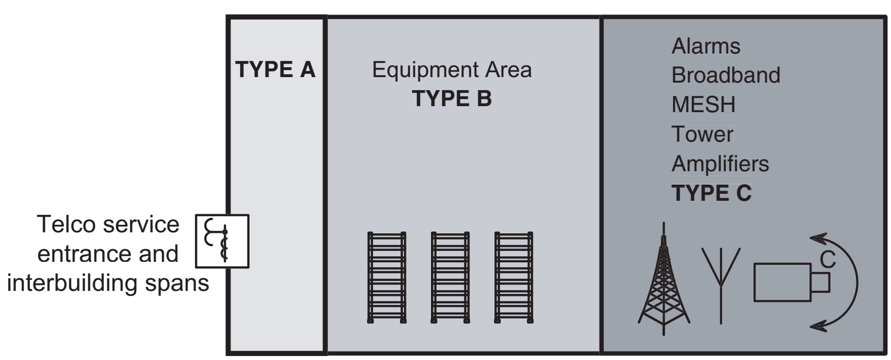
TABLE 7-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES (CONTINUED)

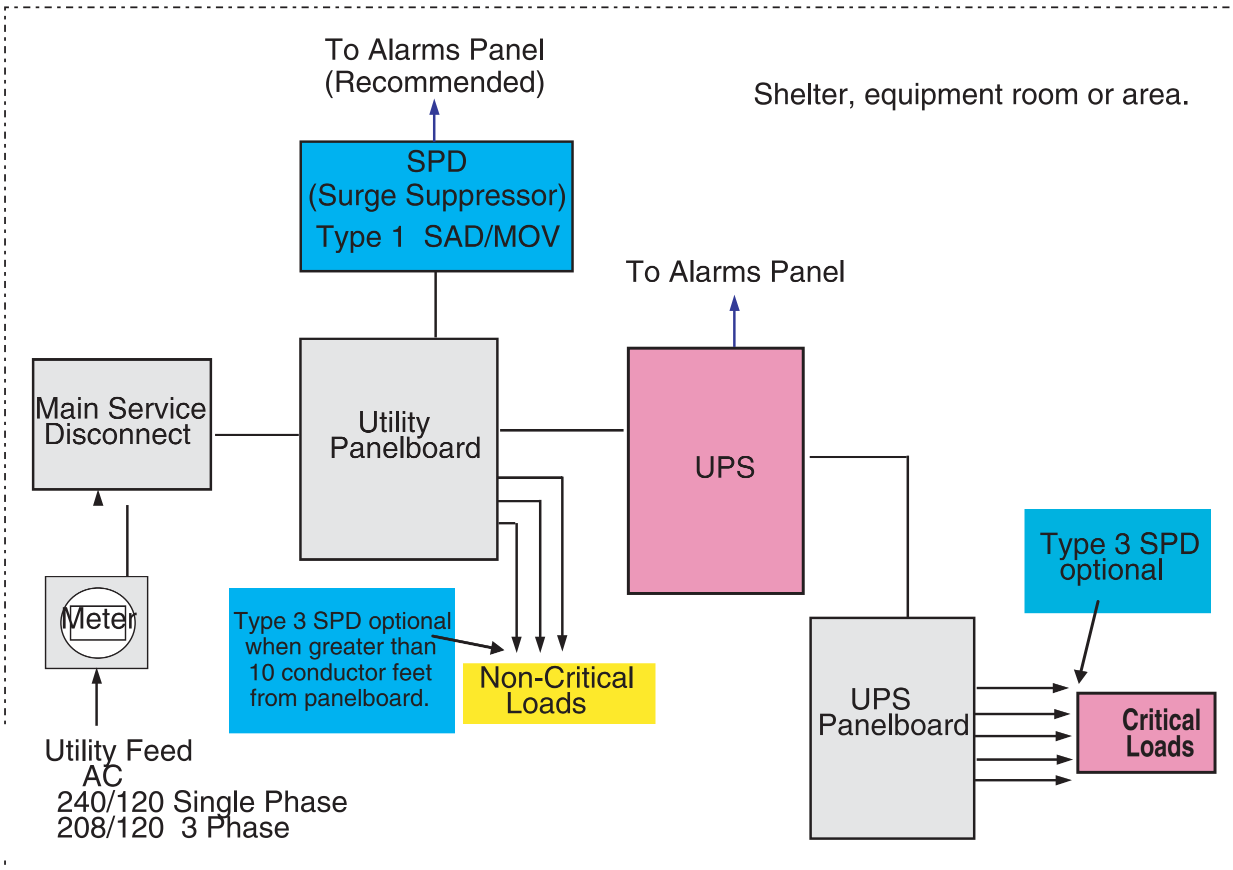
Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
Feeder From Same Service Feeds Another Building or Shelter with Equipment on Same Service in Both Buildings or Shelters						
Feeder (no generator backup)	**K (Figure 7-12)**			Type 1	Type 1	Type 3[1]
Generator backed feeder	**L (Figure 7-13)**		Type 2 or Type 1[2]	Type 1	Type 1	Type 3[1]
Generator and UPS backed feeder	**M (Figure 7-14)**		Type 2 or Type 1[2]	Type 1	Type 1	Type 3[1]
Pole or Pad Mount Cabinets with Independent Dedicated Service						
Complete System without Generator	**N (Figure 7-15)**			Type 1		Type 3
Complete System with Generator	**O (Figure 7-16)**	Type 1		Type 1		Type 3
Stand Alone Equipment (Single Repeater, Base Station, Receiver or Control Station)	**P[3] (Figure 7-17)**			Type 1		Type 3
Branch Circuits						
Stand Alone Equipment (Single Repeater, Base Station, Receiver or Control Station)	**Q (Figure 7-18)**			Type 1		Type 3[3]

1. A Type 3 device is **optional** for these installations.
2. A Type 1 device is **optional** for these installations.
3. A Type 3 device is **required** for these installations.

TABLE 7-2 APPLICATION TYPE DESIGNATION FOR NETWORK SPDS

Application Type Designation	Circuit Characteristics Bandwidth	SPD Requirement	Typical Service Applications	Safety Listing (one or both)	Peak Short Circuit (peak amperes)	Current Waveform (µs)	Life Operations
A Primary SPD intended for use at end of paired conductor spans from a common carrier or as inter-building spans	Up to 1.1 MHz operating bandwidth	Voltage limiter and non-resetting current limiter Voltage limiter and resetting current limiter	Voice, ISDN, ADSL, SDSL, T1/E1-Carrier, Alarms	UL 497, CE	1000 +/-	8/20 µs	10
B Secondary SPD intended for use as a voltage limiting device at network equipment	Up to 16 MHz operating bandwidth	Voltage limiter Voltage limiter with fast resetting current limiter	HDSL, VDSL, T1/E1, Ethernet, Gigabit Ethernet	UL 497A, CE	100 +/-	10/1000 µs	300
C Primary SPD applied externally to network-powered broadband communications coaxial, ethernet and Power Over Ethernet (POE)	Up to 5 GHz operating bandwidth	Voltage limiter	Voice, Audio, Data, Video	CE	100 +/-	8/20 µs	10

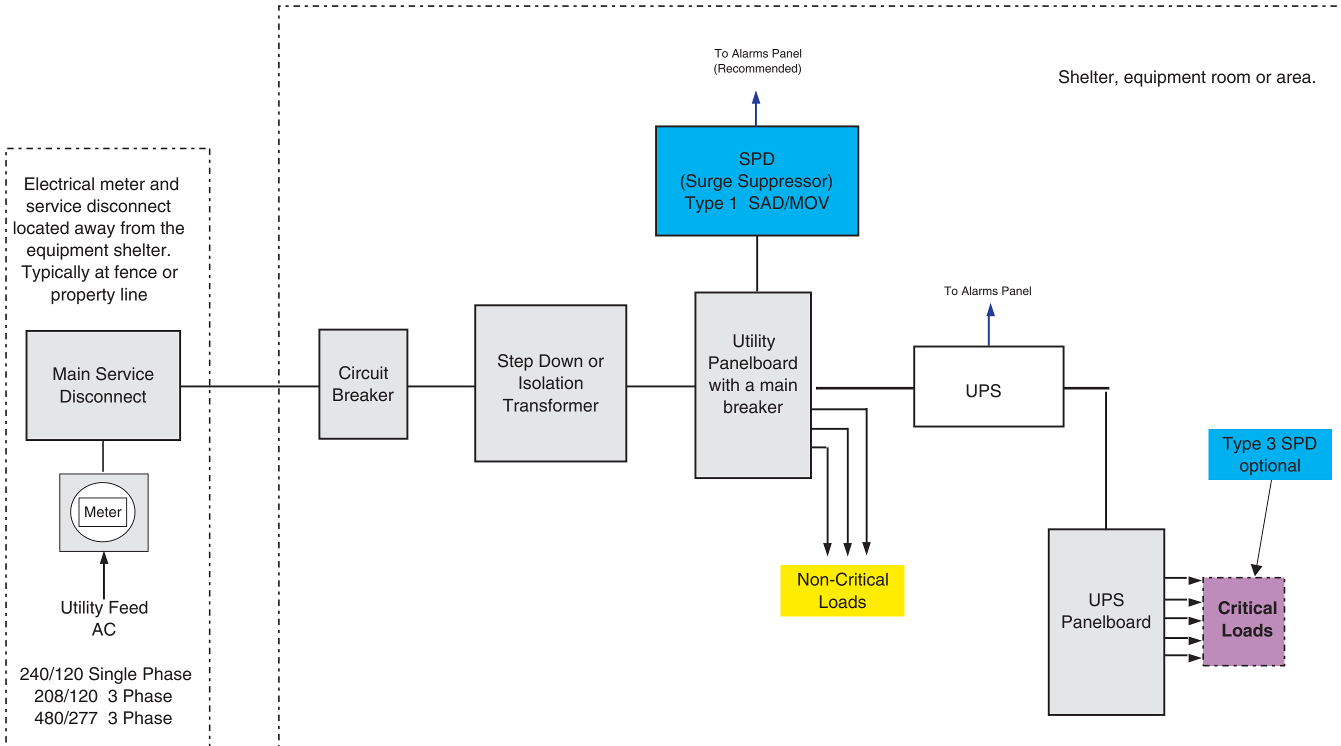




NOTES:
1. The main service disconnect may be an integral part of the Utility Panelboard.
2. The main service disconnect and Utility Panelboard are collocated within the equipment area.
3. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting device (60 Amp Circuit Breaker typical) shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
5. The SPD disconnecting device should be installed in the top most space available within the panelboard.
6. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
7. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 7-2 SPD INTERCONNECT BLOCK DIAGRAM 'A'

Block Diagram of AC Power Distribution, SPD and Alarm Circuits with main disconnect located outside the equipment shelter or area and typically at the fence or property line. A separately derived system is utilized.



NOTES:
1. The main service disconnect is located outside the equipment shelter, room or area, typically at the fence or property line.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility Panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 7-3 SPD INTERCONNECT BLOCK DIAGRAM 'B'

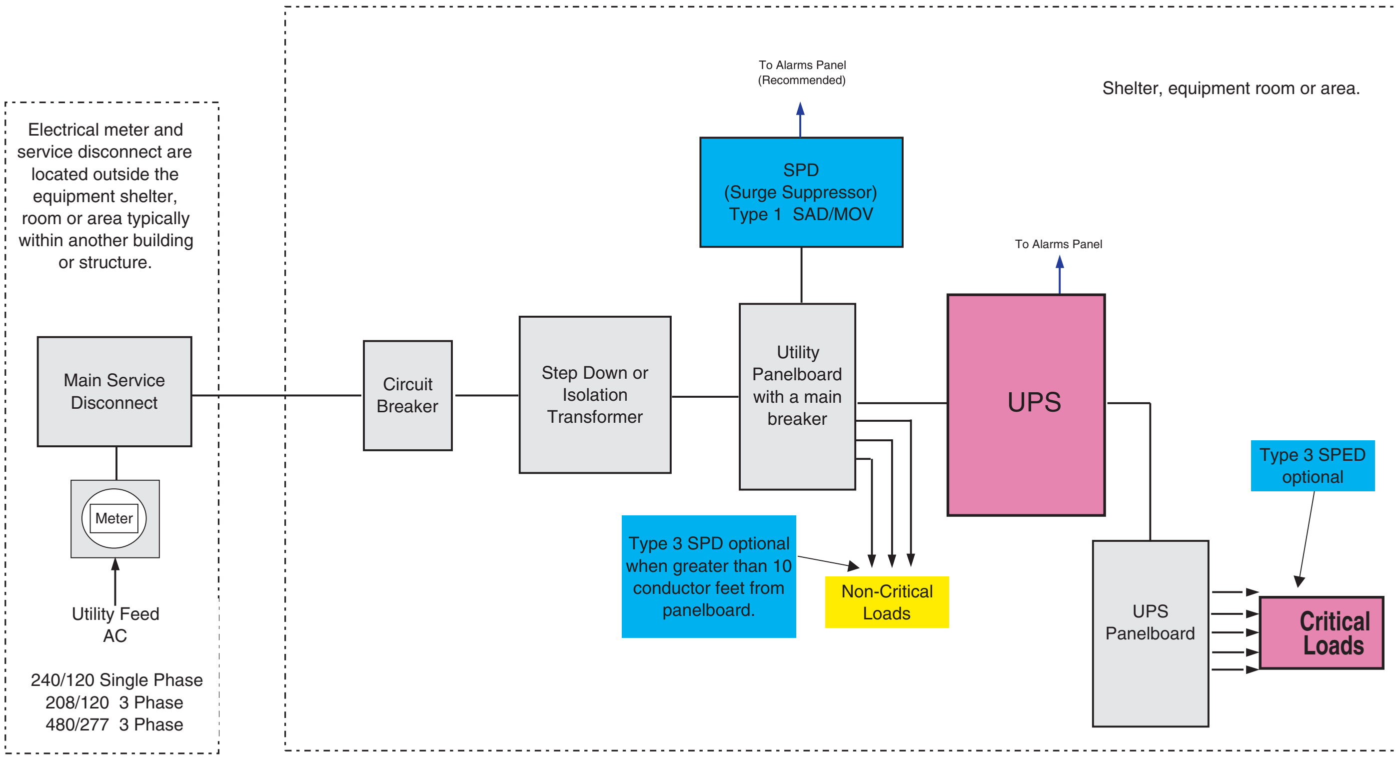


FIGURE 7-4 SPD INTERCONNECT BLOCK DIAGRAM 'C'

NOTES:

1. The main service disconnect is located outside the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility Panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

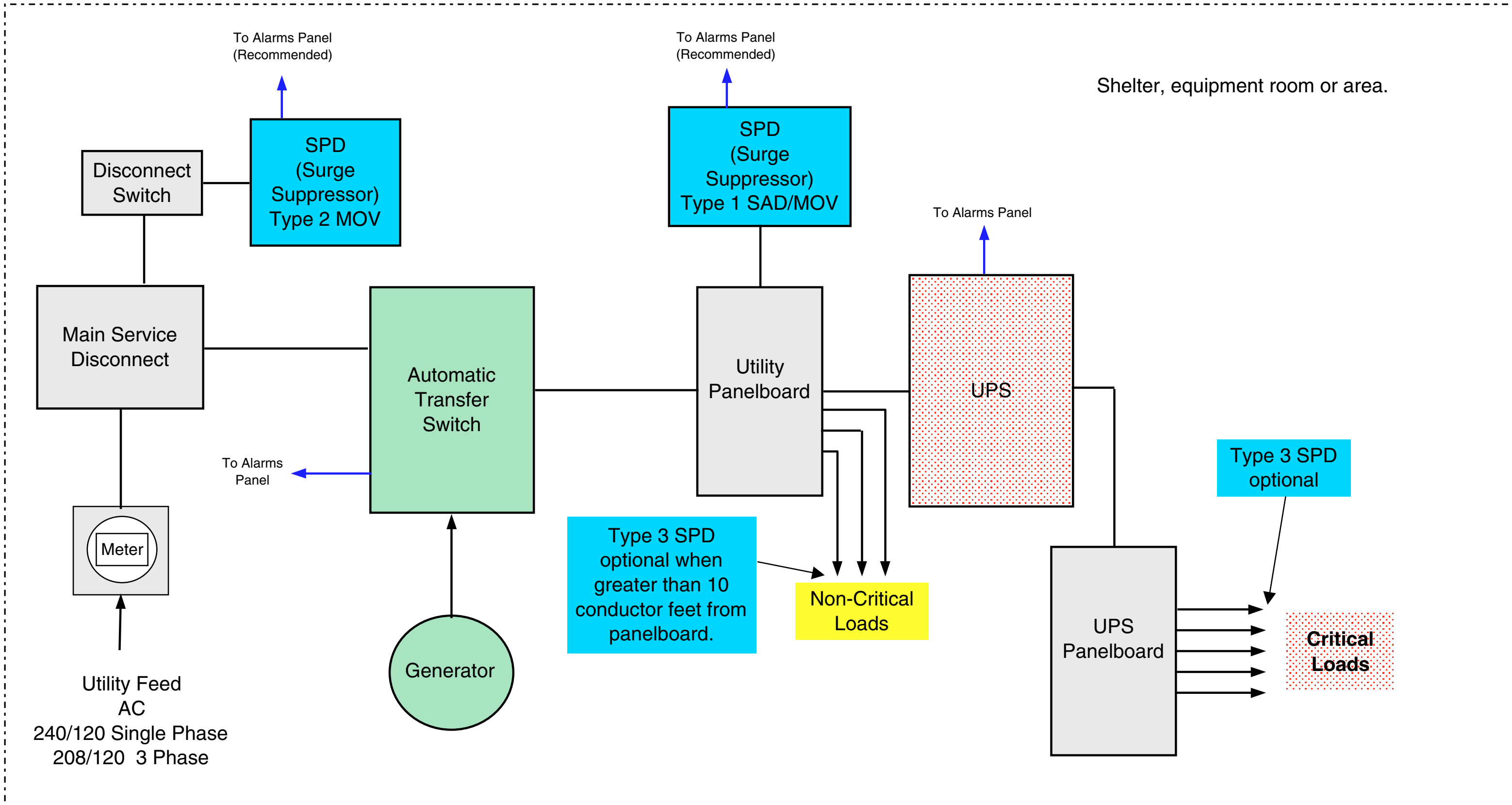


Figure 7-5 SPD Interconnect Block Diagram 'D'

NOTES:
1. All electrical panelboards shown are collocated within the shelter, room or equipment area.
2. The SPDs shall be installed per the manufacturer's installation instructions.
3. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
4. The SPD disconnecting device in the Utility Panelboard should be installed in the top most space available.
5. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
6. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

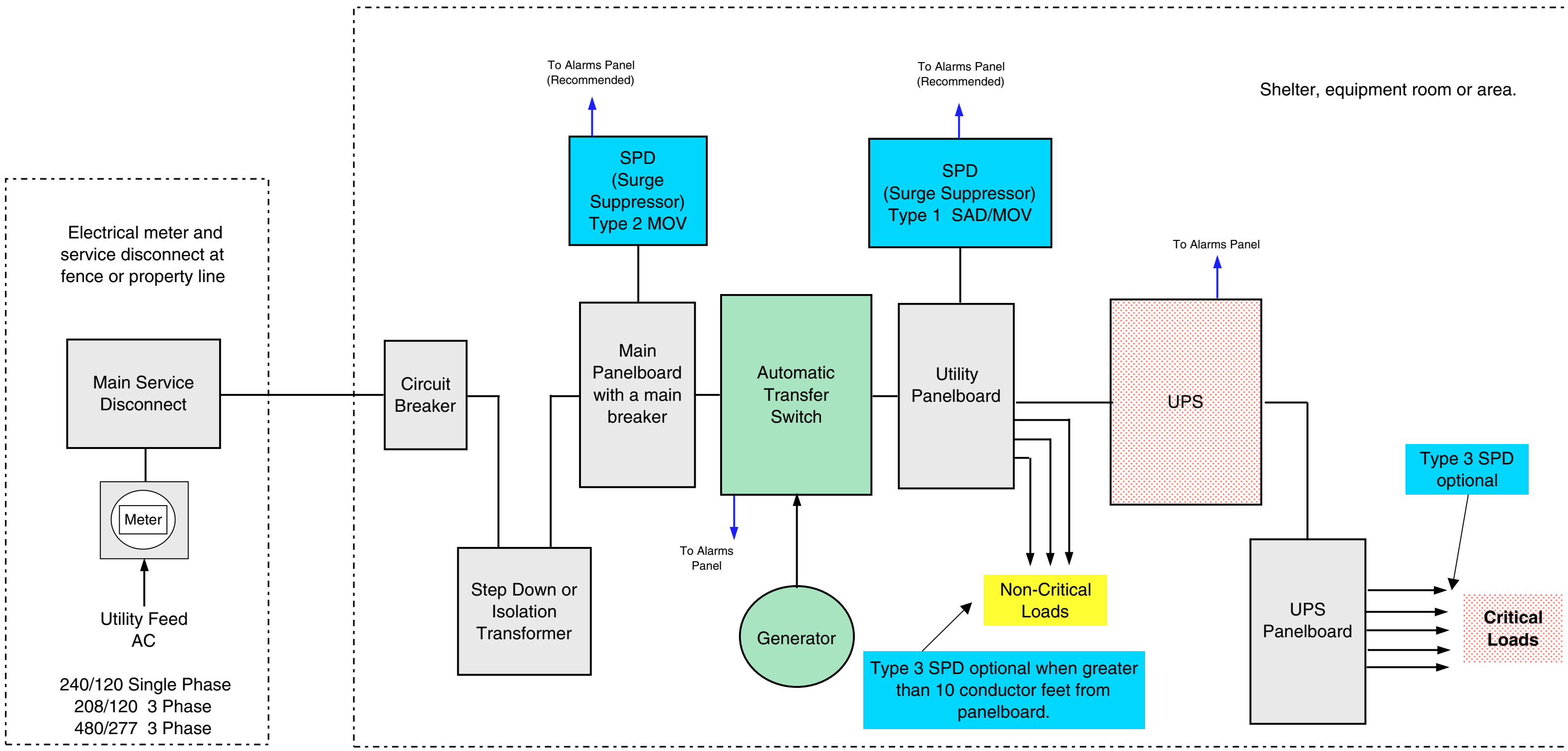
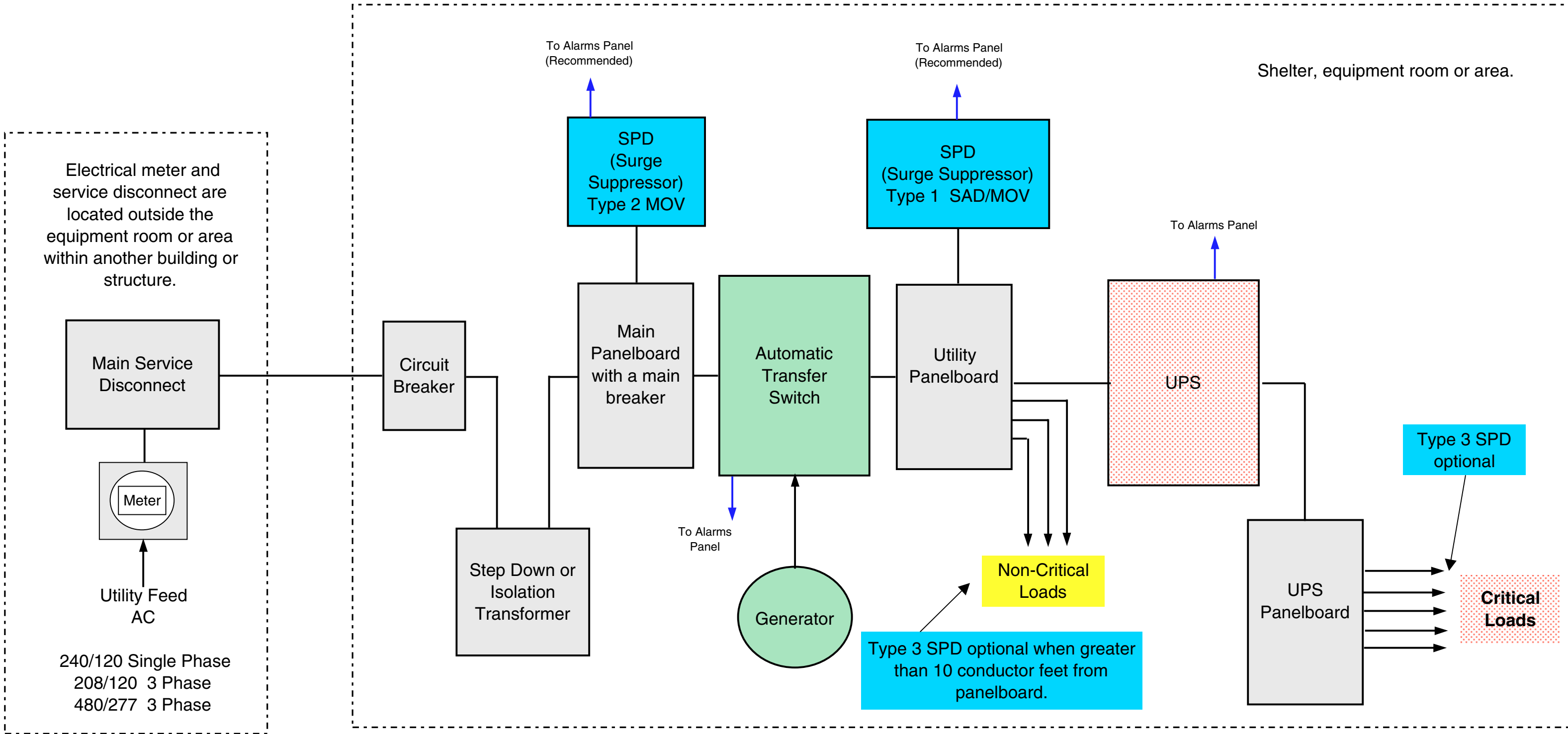


FIGURE 7-6 SPD INTERCONNECT BLOCK DIAGRAM 'E'

NOTES:
1. The main service disconnect is located outside the equipment shelter, room or area, typically at the fence or property line..
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load are recommended at locations with high lightning activity.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended at locations with high lightning activity.



NOTES:
1. The main service disconnect is located outside the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 7-7 SPD INTERCONNECT BLOCK DIAGRAM 'F'

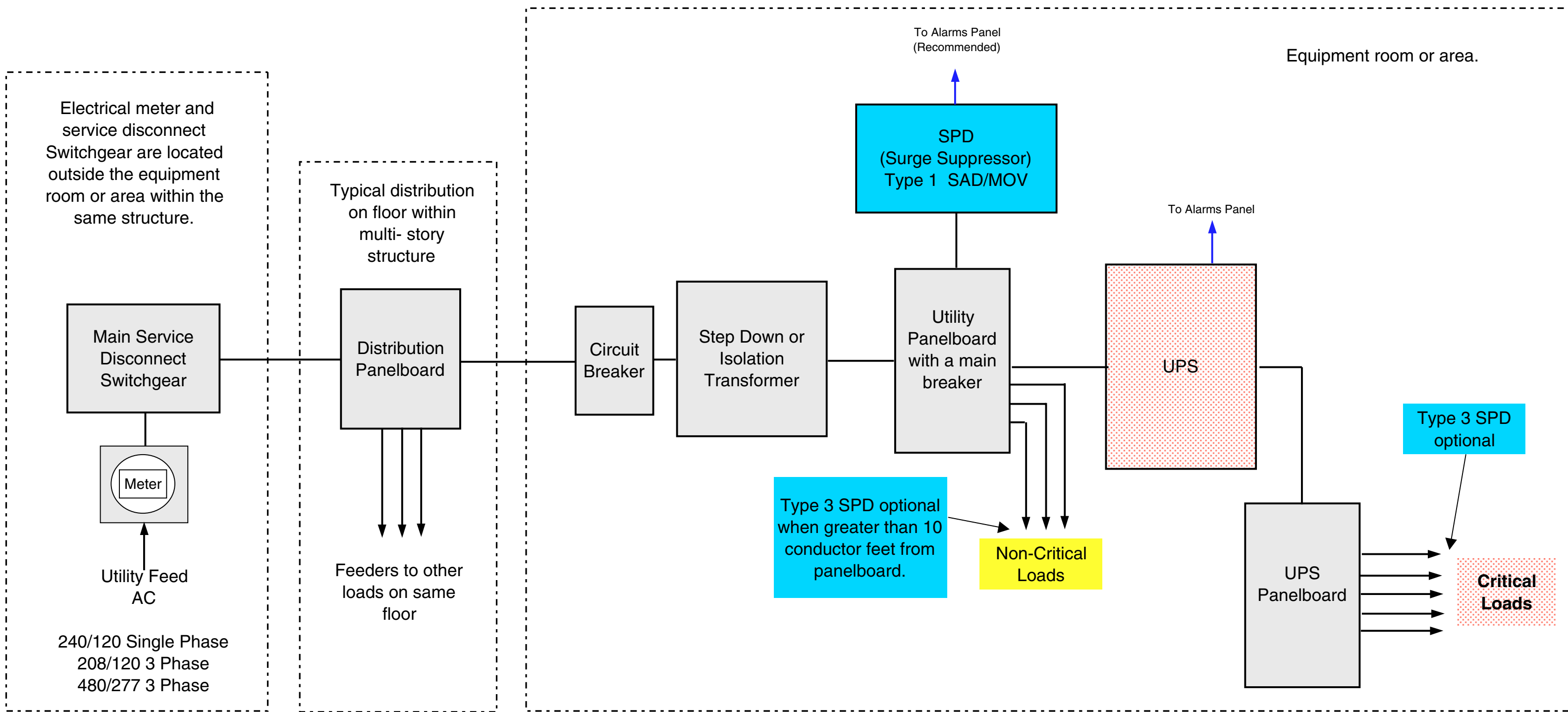
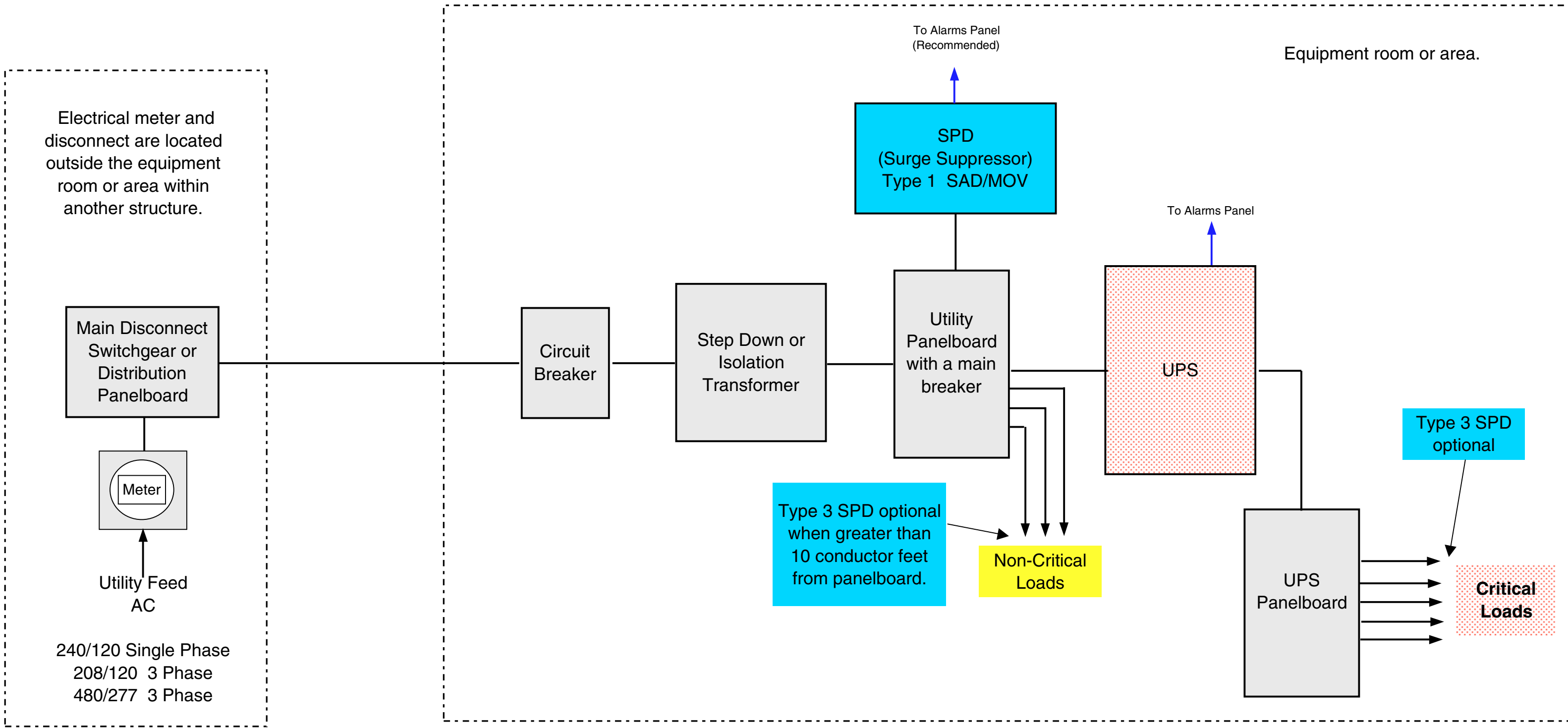


FIGURE 7-8 SPD INTERCONNECT BLOCK DIAGRAM 'G'

NOTES:

1. The main service disconnect is located outside the equipment room or area within the same structure. Additional distribution panelboards may be located within the structure, typically one per floor.
2. The service to the equipment room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the topmost space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

Figure 7-9 SPD Interconnect Block Diagram 'H'



NOTES:

1. The main service disconnect is located outside the equipment room or area within another structure.
2. The service to the equipment room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the topmost space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

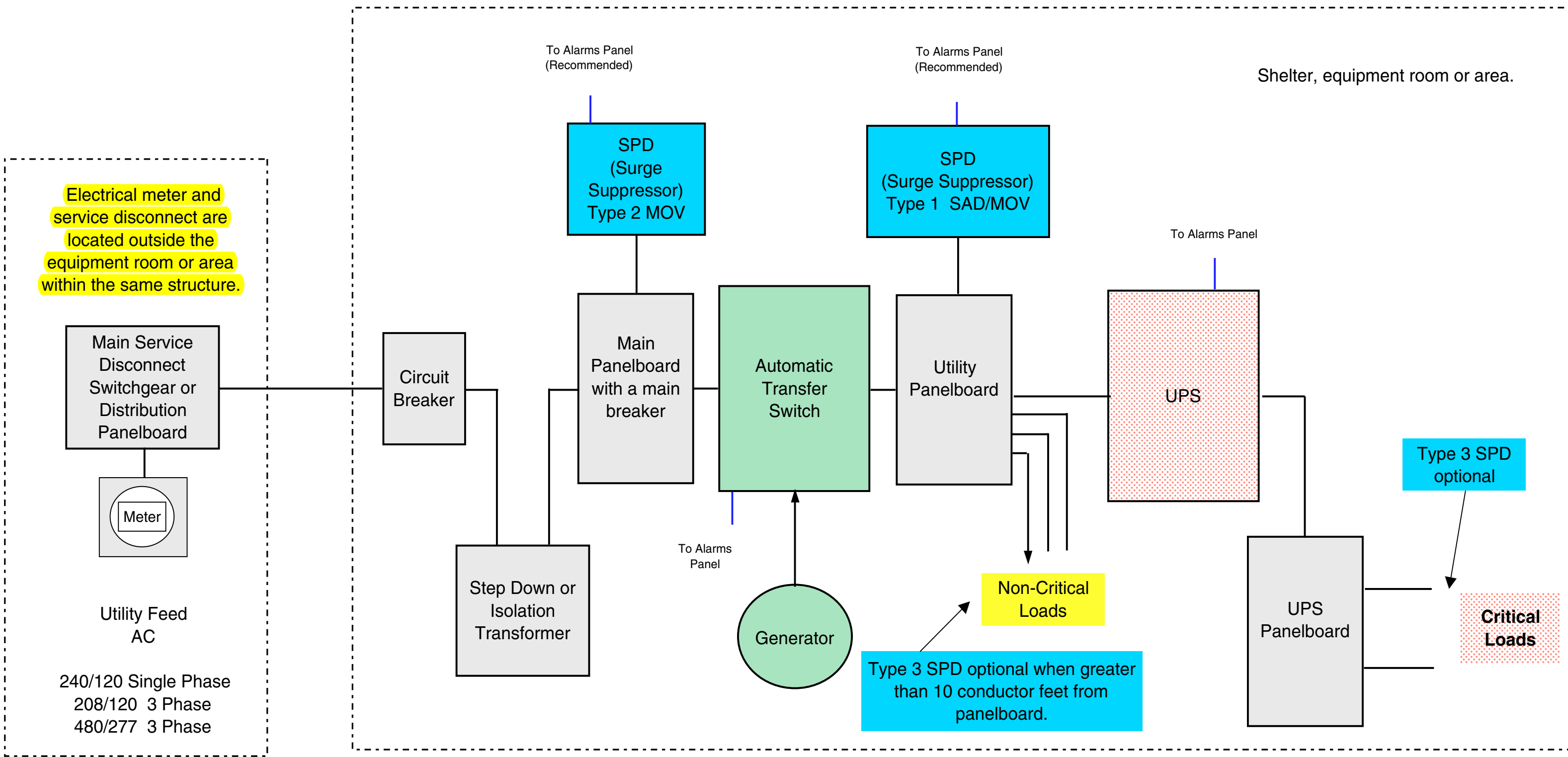


FIGURE 7-10 SPD INTERCONNECT BLOCK DIAGRAM 'I'

NOTES:

1. The main service disconnect is located outside the equipment shelter, room or area, typically within the same building or structure. Additional distribution panelboards may be located within the structure, but are not shown.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

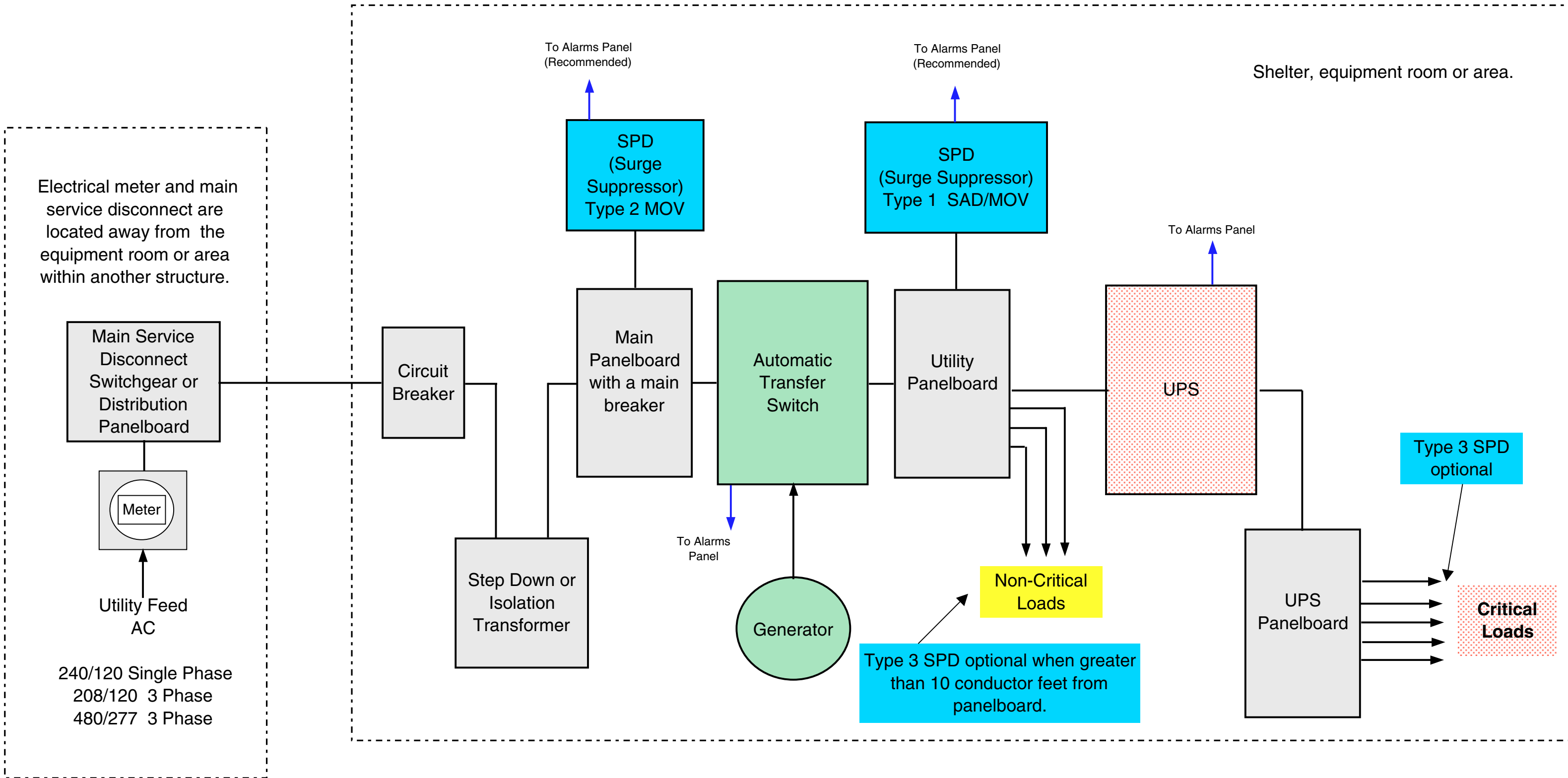


FIGURE 7-11 SPD INTERCONNECT BLOCK DIAGRAM 'J'

NOTES:

1. The main service disconnect is located away from the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturers installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

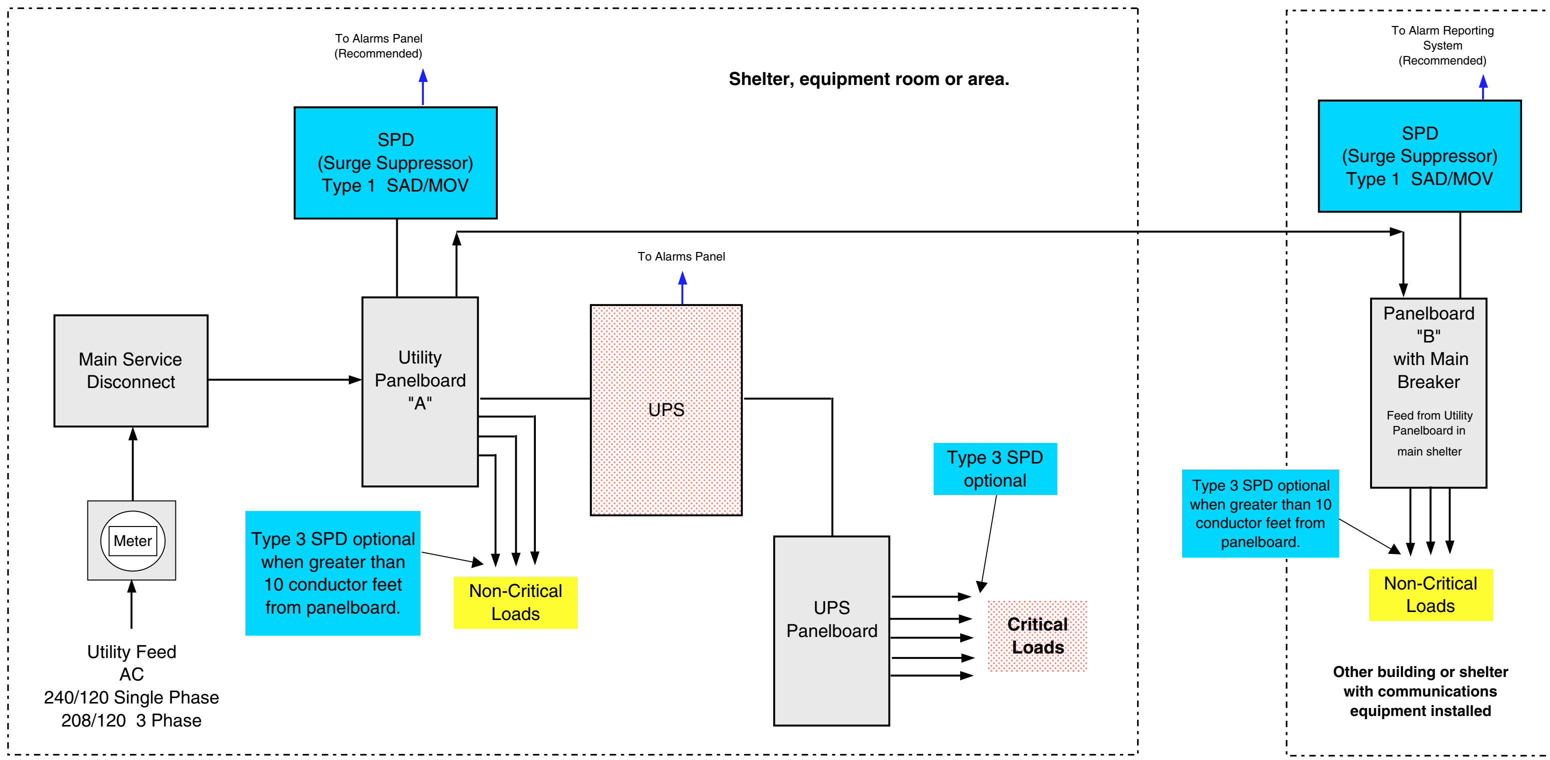
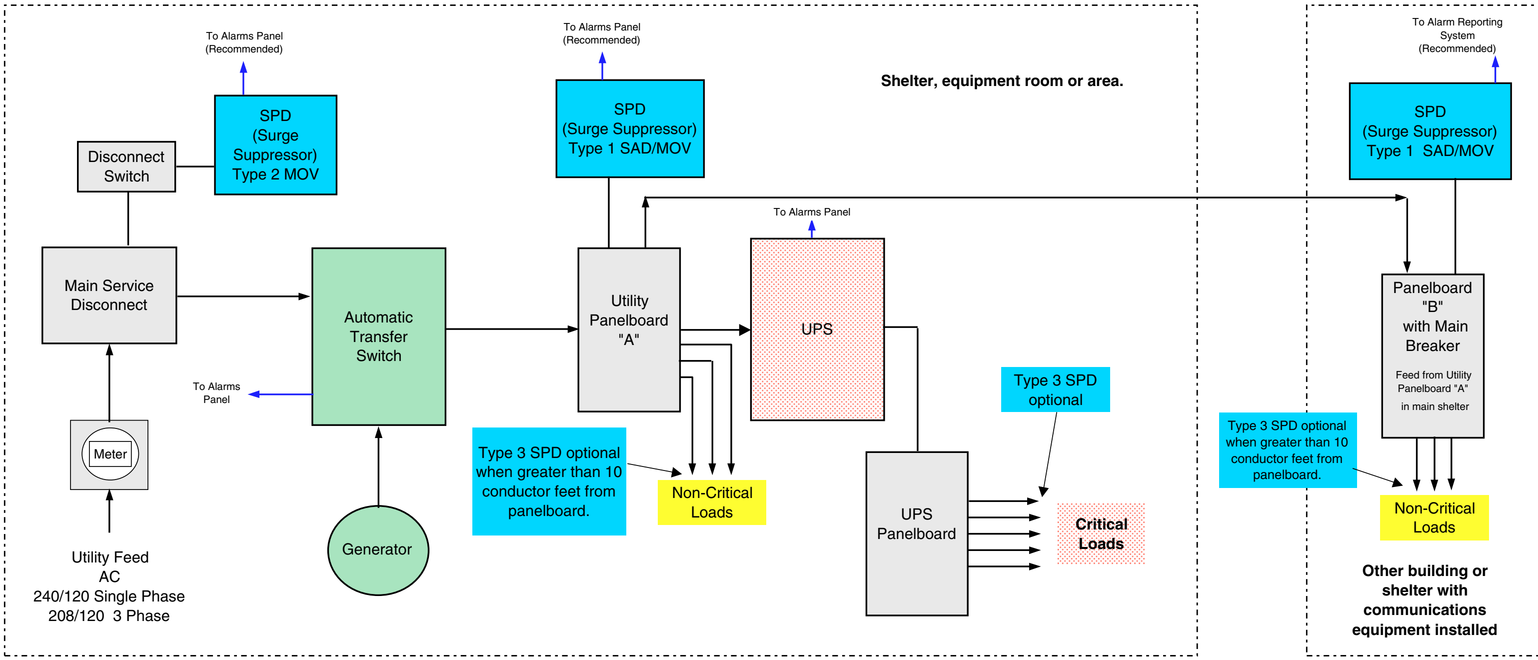


FIGURE 7-12 SPD INTERCONNECT BLOCK DIAGRAM 'K'

NOTES:
1. The main service disconnect may be an integral part of the Utility Panelboard.
2. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or a suitable UPS system.
4. The main service disconnect and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
5. The SPDs shall be installed per the manufacturers installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top-most space available within panelboards "A" and "B."
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

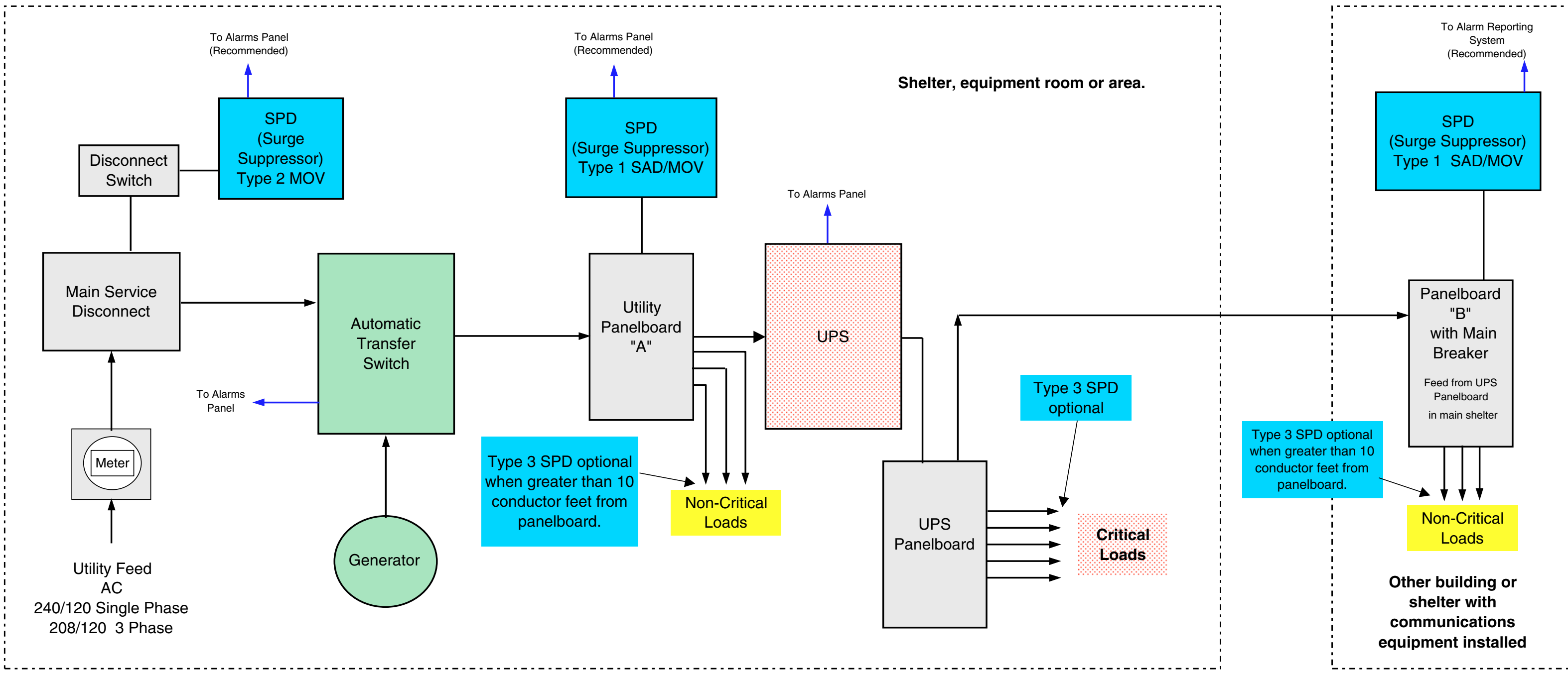


NOTES:

1. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
2. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or a suitable UPS system.
3. The main service disconnect, Automatic Transfer Switch and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
4. The SPDs shall be installed per the manufacturers installation instructions.
5. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
6. The SPD disconnecting devices should be installed in the top most space available in Panelboards "A" & "B".
7. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
8. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

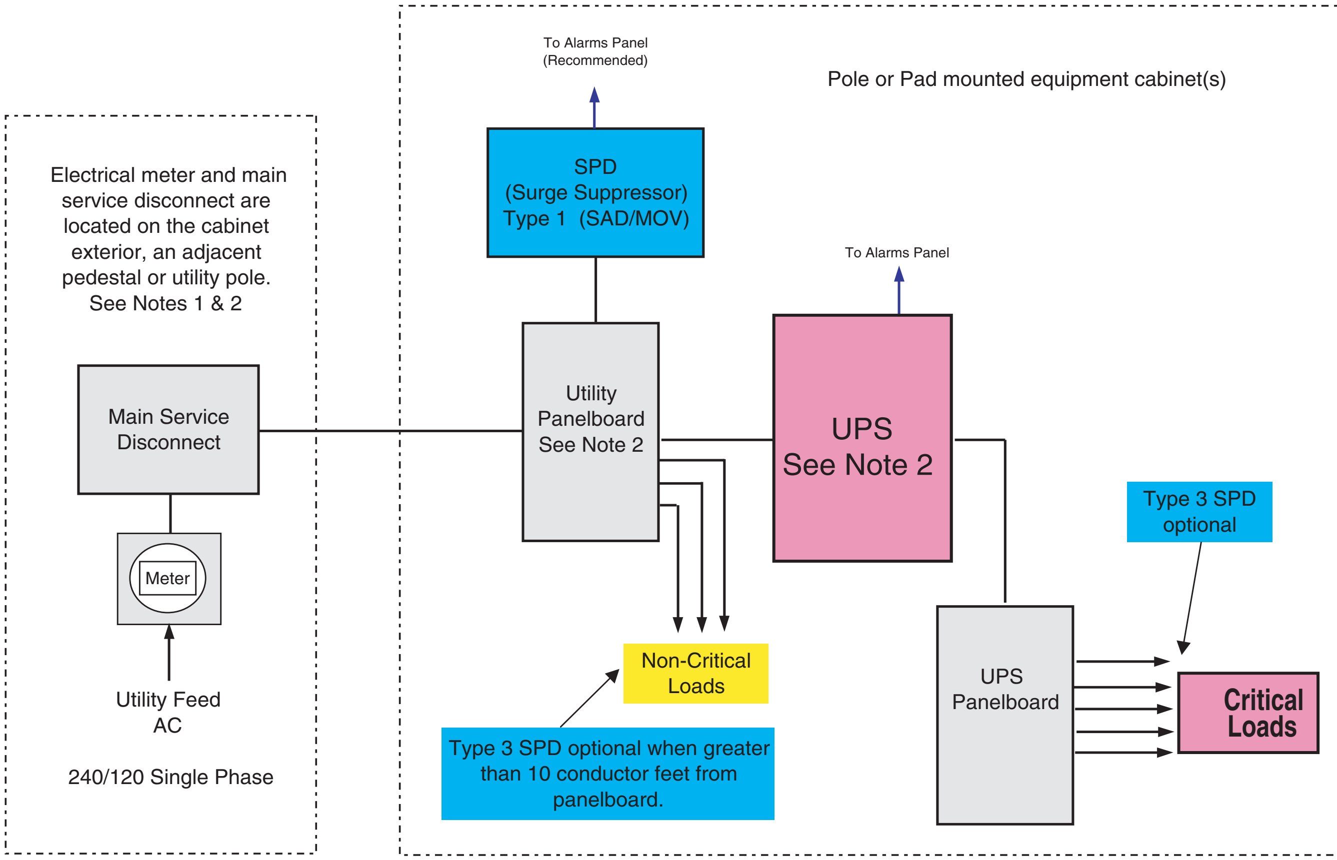
Figure 7-13 SPD Interconnect Block Diagram 'L'

Figure 7-14 SPD Interconnect Block Diagram 'M'



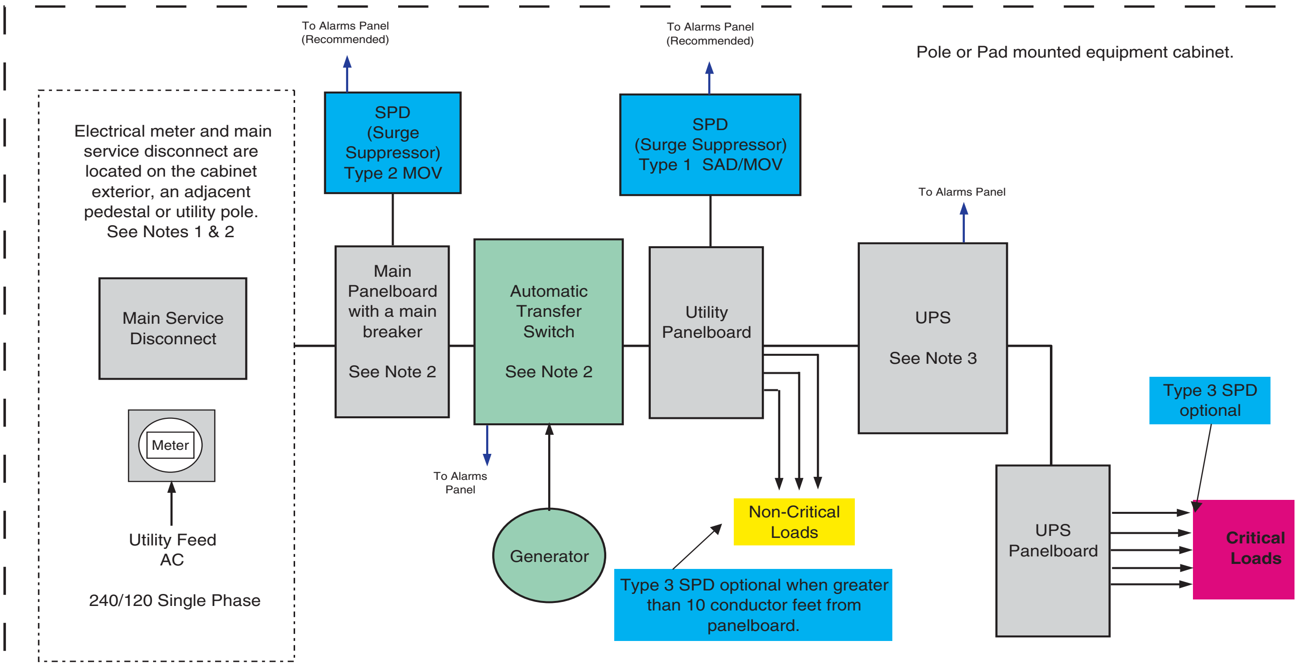
NOTES:

1. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
2. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or suitable UPS system.
2. The main service disconnect, Automatic Transfer Switch and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
3. The SPDs shall be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
5. The SPD disconnecting devices should be installed in the top most space available in Panelboards "A" & "B".
6. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
7. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.



NOTES:
1. The main service disconnect may be located outside the pole or pad mounted equipment cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole.
2. The main service disconnect may be an integral part of the Utility Panelboard.
3. The UPS may not be present in which case all loads will be fed from the Utility Panelboard
4. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
5. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
6. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
7. Installation of Type 3 SPDs on critical and non critical loads, although optional, is recommended where the level of exposure is high.

FIGURE 7-15 SPD INTERCONNECT BLOCK DIAGRAM 'N'

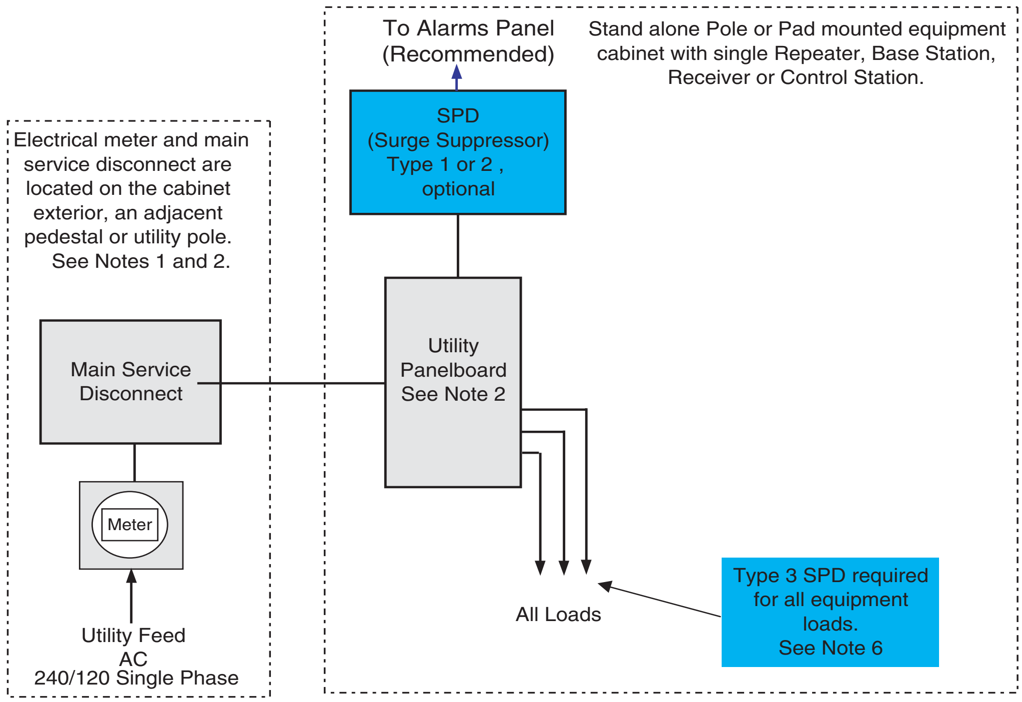


Block Diagram of AC Power Distribution, SPDs' and Alarm Circuits for pole or pad mounted cabinet(s) for a complete system with independent dedicated service and a standby generator.

NOTES:

1. The main service disconnect may be located outside the pole or pad mounted equipment cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole. This may also be incorporated within the main panelboard.
2. The main panelboard, Type 2 or optional Type 1 SPD and Automatic Transfer Switch may be located outside the cabinet(s). (If located outside the cabinet these **shall** be in weatherproof enclosures.)
3. The UPS may not be present in which case all loads will be fed from the Utility Panelboard.
4. The Type 1 and Type 2 SPDs **shall** be installed per the manufacturer's installation instructions.
5. All conductors between the SPDs and the associated disconnecting device **shall** be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
6. The SPD disconnecting devices should be installed in the top most space available in the Panelboards.
7. Installation of Type 3 SPDs on critical and non critical loads, although optional, is recommended where the level of exposue is high.

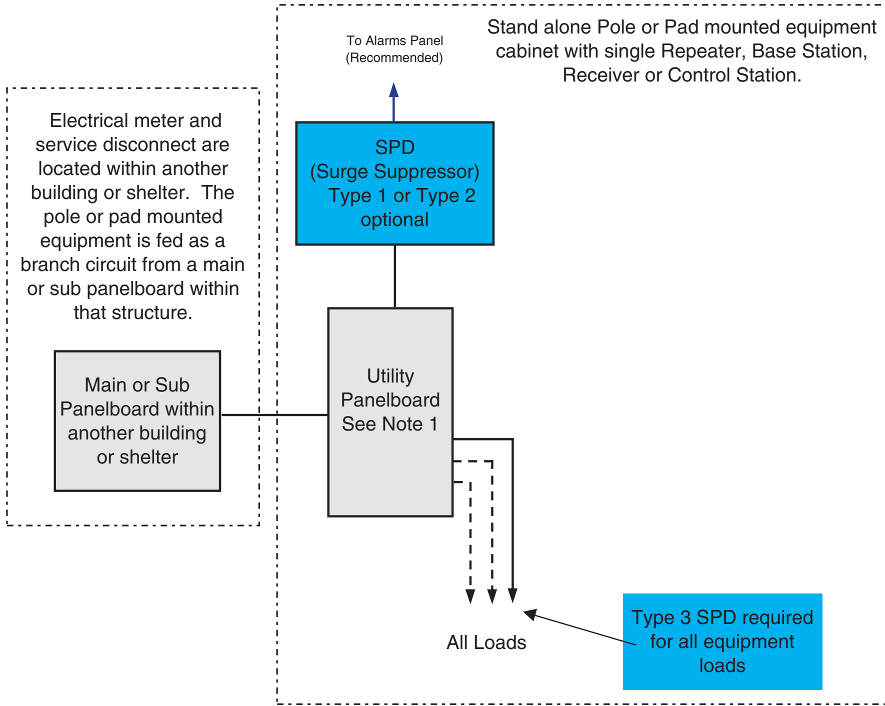
FIGURE 7-16 SPD INTERCONNECT BLOCK DIAGRAM 'O'



NOTES: 1. The main service disconnect may be located outside the equipment pole or pad mounted cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole.

2. The Main service disconnect may be a part of the Utility Panelboard.
3. When installed the Type 1 or Type 2 SPD **shall** be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting device **shall** be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
5. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
6. Installation of Type 3 SPDs on each load is required unless a Type 1 SPD is installed on the Utility Panelboard.

FIGURE 7-17 SPD INTERCONNECT BLOCK DIAGRAM 'P'



NOTES:
1. A disconnecting device is required within the pole or pad mounted cabinet. This may be a single disconnect if no Type 1 or Type 2 SPD is installed and there is only one load.
2. When installed the Type 1or Type 2 SPDs **shall** be installed per the manufacturer's installation instructions.
3. All conductors between the SPDs and the associated disconnecting device **shall** be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
4. The SPD disconnecting devices should be installed in the topmost space available in the Utility Panelboard.
6. Installation of Type 3 SPDs on each load is required unless a Type 1 SPD is installed on the Utility Panelboard.

FIGURE 7-18 SPD INTERCONNECT BLOCK DIAGRAM 'Q'

7.4.2 SPD TYPES

SPDs used for AC power protection referenced in this section are defined as Type 1, Type 2, or Type 3 and are defined below.

Table 7-4 on page 7-32 lists required specifications for various SPDs.

7.4.2.1 TYPE 1 PANEL TYPE SURGE SUPPRESSION DEVICE

Type 1 SPD provides protection for the service entrance, and all branch panel locations within the same equipment room. The requirements are as follows:

- The device **shall** consist of primary modules using SAD technology and secondary modules using MOV technology.
- The SPD **shall** be a permanently connected, one-port, or parallel configuration
- The suppression components **shall** be voltage limiting type. Voltage switching components **shall not** be utilized as a suppression element in the SPD.
- All suppression modules **shall** be installed from each phase conductor to the neutral conductor (L-N, Normal Mode).

- Suppression modules or devices of any type **shall not** be connected between any phase conductor and the equipment grounding conductor or ground (L-G, Common Mode Neutral to Ground).
- The primary module(s) **shall** consist of a SAD module(s) providing 20KA per phase, per polarity, minimum energy absorption.
- The secondary module(s) **shall** consist of a Metal Oxide Varistor (MOV) module(s), with sufficient energy handling capability to meet the maximum discharge current requirement of 160 kA per mode.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 7-4 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- SPD **shall** be properly selected based on the operating voltage and number of phases of the circuits to be protected.
- Each module or subassembly **shall** be modular in design to allow for easy field replacement.
- The SPD **shall** use integral over-current protective devices, and the SPD **shall** have a short circuit current rating of 25,000 amperes, as defined by UL 1449, second edition, Section 39.
- The SPD **shall** have a nominal discharge current of 10,000 amperes, as defined, and tested by IEEE IEEE C62.45-2002 waveform characteristics (Category C high 10 kA 6kV minimum) SPD tested in accordance with IEEE C62.45-2002.
- The SPD **shall** have a voltage protection level (at the nominal discharge current of 10,000 amperes) of 600 Vpk or less from each phase-to-neutral mode, when tested in accordance with IEEE C62.45-2002. Test points are measured using specified conductor size at a distance of 150 mm (6 in.) outside of the enclosure.
- The SPD **shall** have a Suppressed Voltage Rating (SVR) of 330 Vpk, as determined by testing in accordance with UL 1449, second edition, Section 34.
- The SPD **shall** have a maximum discharge current of 160 kA per mode, as tested in accordance with IEC 61643-1
- The enclosure rating of the SPD **shall** be NEMA 4. The maximum dimensions of the enclosure **shall** be 406 mm × 406 mm × 228 mm (16 in. × 16 in. × 9 in.) for single-phase, 3W+G configurations, and 508 mm × 508 mm × 228 mm (20 in. × 20 in. × 9 in.) for three-phase wye, 4W+G configurations. The maximum weight of the SPD **shall** be 13.6 kg (30 lb), and 18 kg (40 lb) respectively.
- The environmental parameters of the SPD are as follows:
  - Operating temperature range: -40 °C to +65 °C
  - Storage temperature range: -40 °C to +65 °C
  - Operating humidity range: 0-95%, non-condensing
  - Altitude range: -152.4 m to 4572 m (-500 ft to +15,000 ft.)
- Connection to the SPD **shall** be conducted with a wire range of 16 mm^2 csa (#6 AWG) or coarser. Per NFPA 70-2005, Article 110, the conductor size **shall** match the breaker size.
- Each SPD **shall** have indicator lamps on or visible from the front of the device showing that power is applied and that the protection integrity has not been compromised.

- The SPD **shall** include a set of form "C" dry contacts, rated at a minimum of 250 VAC, and a minimum of 2.0 amperes, with a power factor of 1.0, for remote alarm reporting capability. This set of contacts **shall** operate when there is an input power failure or the integrity of any module has been compromised. This contact set **shall** be isolated from the AC power circuitry to safeguard the alarm circuit or reporting device should there be a catastrophic event. Connection to the remote monitoring contacts of the SPD **shall** utilize 0.34 mm^2 (#22 AWG) or coarser conductors.
- The SPD **shall** be UL 1449, 2nd Edition listed, and tested to clause 7.10. A test report from a Nationally Recognized Testing Laboratory (NRTL), NAVLAP or A2LA, or a Certified UL client testing data laboratory detailing the procedures used, and the results obtained **shall** be made available.

7.4.2.2 TYPE 2 PANEL TYPE SURGE PROTECTION DEVICE 120VAC SINGLE AND 3 PHASE SERVICES

Type 2 SPDs provide protection for the service entrance locations within the same equipment room. The requirements are as follows:

- The device **shall** consist of primary modules using MOV technology.
- The SPD **shall** be a permanently connected, one-port, or parallel configuration
- The suppression components **shall** be voltage limiting type. Voltage switching components **shall not** be utilized as a suppression element in the SPD.
- All suppression modules **shall** be installed from each phase conductor to the neutral conductor (L-N, Normal Mode).
- Suppression modules or devices of any type **shall not** be connected between any phase conductor and the equipment grounding conductor or ground (L-G, Common Mode Neutral to Ground).
- The primary module(s) **shall** consist of a Metal Oxide Varistor (MOV) module(s), with sufficient energy handling capability to meet the maximum discharge current requirement of 160kA per mode.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 7-4 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- SPD **shall** be properly selected based on the operating voltage and number of phases of the circuits to be protected.
- Each module or subassembly **shall** be modular in design to allow for easy field replacement.
- The SPD **shall** use integral over-current protective devices, and the SPD **shall** have a short circuit current rating of 25,000 amperes, as defined by UL 1449, second edition, Section 39.3.
- The SPD **shall** have a nominal discharge current of 10,000 amperes, as defined, and tested by IEEE C62.45.2-2002 waveform characteristics (Category C high 10 kA 6 kV minimum) SPD tested in accordance with IEEE C62.45-2002.
- The SPD **shall** have a voltage protection level (at the nominal discharge current of 10,000 amperes) of 800Vpk or less from each phase-to-neutral mode, when tested in accordance with IEEE C62.45-2002, Test points are measured using specified conductor size at a distance of 150 mm (6 in.) outside of the enclosure.
- The SPD **shall** have a Suppressed Voltage Rating (SVR) of 400 Vpk, as determined by testing in accordance with UL 1449, Second Edition, Section 34.

- The enclosure rating of the SPD **shall** be NEMA 4. The maximum dimensions of the enclosure **shall** be 406 mm × 406 mm × 228 mm (16 in. × 16 in. × 9 in.) for single-phase, 3W+G configurations, and 508 mm × 508 mm × 228 mm (20 in. × 20 in. × 9 in.) for three-phase wye, 4W+G configurations. The maximum weight of the SPD **shall** be 13.6 kg (30 lb), and 18 kg (40 lb) respectively.
- The environmental parameters of the SPD are as follows:
  - Operating temperature range: -40 °C to +65 °C
  - Storage temperature range: -40 °C to +65 °C
  - Operating humidity range: 0-95%, non-condensing
  - Altitude range: -152.4 m to 4572 m (-500 ft to +15,000 ft.)
- Connection to the SPD **shall** be conducted with a wire range of 16 mm^2 csa (#6 AWG) per NFPA 70-2005, Article 110 the conductor size must match the breaker size.
- Each SPD **shall** have indicator lamps on or visible from the front of the device showing that power is applied and that the protection integrity has not been compromised.
- The SPD **shall** include a set of form "C" dry contacts, rated at a minimum of 250 VAC, and a minimum of 2.0 amperes, with a power factor of 1.0, for remote alarm reporting capability. This set of contacts **shall** operate when there is an input power failure or the integrity of any module has been compromised. This contact set **shall** be isolated from the AC power circuitry to safeguard the alarm circuit or reporting device should a catastrophic event.occur. Connection to the remote monitoring contacts of the SPD **shall** utilize 0.34 mm^2 (#22 AWG) or coarser conductors.
- The SPD **shall** be UL 1449, 2nd Edition listed, and tested to clause 7.10. A test report from a Nationally Recognized Testing Laboratory (NRTL), NAVLAP or A2LA, or a Certified UL client testing data laboratory detailing the procedures used, and the results obtained **shall** be made available to the Motorola National Site Design and Integration Process and Product Manager.

7.4.2.3 TYPE 3 INDIVIDUAL EQUIPMENT SPDS

Individual equipment SPDs are available in many varieties. These may be wire-in receptacle outlet replacement types, plug-in adapters, or receptacle outlet panels or strips. General requirements are as follows:

- All individual equipment devices **shall** provide Normal Mode (L-N) circuit protection.
- Common Mode (L-G) circuit protection **shall not** be permitted.
- Individual devices with the plug manufactured as a combined part of the device **shall** be designed to be plugged into a single simplex receptacle outlet and **shall** incorporate a single simplex receptacle outlet for the load connection. Individual plug-in units with a duplex receptacle outlet **shall not** be used.
- Multi-receptacle outlet strip devices may incorporate multiple receptacle outlets and may also incorporate telephone or data circuit secondary protection devices within the same housing.
- Multi-receptacle outlet strip devices **shall** incorporate an independent ground point on the exterior of the device. This attachment point or stud **shall** be suitable for attachment of a lug sized for a 16 mm^2 csa (#6 AWG) conductor.
- Multi-receptacle device housings **shall** be metallic and **shall** be provided with mounting ears, tabs or brackets. Devices may be suitable for standard EIA 483 mm (19 in.) rack mounting.

- Each device **shall** have an indicator lamp visible from the front of the device showing that the module has power applied and that the protection integrity has not been compromised. Alarm relay contacts to remotely report device failure may be offered but are not required.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 7-4 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- Installation of Type 3 SPDs on each critical load is recommended in locations highly vulnerable to transient surges or lightning activity when the critical load is located greater than 3 m (10 ft.) of conductor length from the Type 1 SPD. Where the load is located between 3 to 15.2 m (10 to 50 ft.) of conductor length from Type 1 devices a Type 3 device is optional. Where the load is located greater than 15.2 m (50 ft.) of conductor length (7.6 m (25 ft.) of circuit length) from the Type 1 device, a Type 3 device is highly recommended. (See Table 7-3.)

TABLE 7-3 SPD REQUIREMENTS BASED ON CONDUCTOR LENGTH

Conductor Length *		
0 - 3 m (0 - 10 ft.)	3 - 15.2 m (10 - 50 ft.)	> 15.2 m (>50 ft.)
Type 1 Required	Type 1 Required Type 3 Optional	Type 1 Required Type 3 Highly recommended**

* Lengths shown denote CONDUCTOR length. The CIRCUIT distance is ½ of conductor length shown.

In applications for standalone pole- or pad-mounted cabinets, where an SPD or a Type 2 SPD is not installed on the Utility Panelboard, Type 3 devices **shall be installed on all loads.

- The device **shall** be UL 1449, 2nd Edition listed. Devices may also conform to the international CE certification mark, and tested to clause 7.10. A test report from a Nationally Recognized Testing Laboratory (NRTL), NAVLAP or A2LA, or a Certified UL client testing data laboratory detailing the procedures used, and the results obtained **shall** be made available to the Motorola National Site Design and Integration Process and Product Manager.
- Each multiple receptacle outlet strip type device incorporating telephone or data circuit protection **shall** be UL 1449 and UL 497A listed or recognized. Devices may conform to the international CE certification mark.

TABLE 7-4 SPD SPECIFICATIONS

Type	Service Configuration	MCOV	Required Measured Testing				
			Safety	Performance			
			Surge Voltage Rating (SVR) UL 1449-2nd Edition	Duty Cycle Test, IEEE C62.41, 200A ringwave	Duty Cycle Test, IEEE C62.41	Nominal Discharge Current (I_n)[1]	Maximum Discharge Current (I_{max})
			6kV, 500A	6kV, 200A, 100 kHz	6kV, 3 kA	6kV, 10 kA	
Manual Section				7.10.3 3	7.10.3.4	7.10.3	7.10.4
Type 1							
High lightning exposure or main utility service on the load side of the disconnect	120/240 1ϕ	145	330	n/a	Required	VPL Recorded	Required
	120/208 3ϕ	145	330	n/a	Required	VPL Recorded	Required
	480/277 1ϕ	320	800	n/a	Required	VPL Recorded	Required
	230/380 3ϕ	280	n/a	n/a	Required	VPL Recorded	Required
Type 2							
High lightning exposure Service entrance Suitable for branch service applications on load side of utility disconnect	120/240 1ϕ	145	400	n/a	Required	VPL Recorded	Required
	120/208 3ϕ	145	400	n/a	Required	VPL Recorded	Required
	480/277 1ϕ	320	800	n/a	Required	VPL Recorded	Required
	230/380 3ϕ	280	n/a	n/a	Required	VPL Recorded	Required
Type 3							
Branch circuit protection device	120 V	145	330	Required	n/a	n/a	n/a
	230-240V	280	570	Required	n/a	n/a	n/a

1. Nominal Surge Current Value (In) is a single 10 kA impulse.This single impulse **shall** be applied at the SPDs and the Voltage Protection Level (VPL) measured and recorded.

7.4.3 INSTALLATION REQUIREMENTS

All SPDs **shall** be installed per the manufacturer's installation instructions and in accordance with all applicable codes. Type 1 and Type 2 devices **shall** be securely attached to the mounting surface and **shall not** depend on the interconnecting raceway for support.

7.4.3.1 LOCATION

When selecting the location, consideration must be given to conductor routing, length and required number of bends in each conductor. The SPD **shall** be installed as close as possible to the associated main disconnect or panelboard, and in a location that permits the shortest and most direct electrical connection. The most suitable location is immediately adjacent to the associated panelboard keeping the conductor length as short as possible. To accommodate this specification some manufacturers have developed specific models for installation directly above, below, or to the right or left of the associated panelboard.

7.4.3.2 INTERCONNECTING RACEWAY OR CONDUIT

The raceway or conduit between the panelboard (or disconnecting means) and the SPD **shall** be sized for the size and number of conductors to be routed through it. A non metallic conduit (such as PVC) or raceway is recommended. The length **shall** be as short as possible. This raceway **shall** be routed as direct as possible between the SPD, the disconnecting means (if a separate enclosure is used), and the associated panelboard. The raceway or conduit **shall not** be used as a support for the device.

7.4.3.3 CIRCUIT BREAKER OR DISCONNECTING MEANS

The SPD **shall** be wired through a 60-Ampere (or larger) circuit breaker, NFPA 70-2005, Article 110.9, or in accordance with local jurisdictional codes.

7.4.3.4 CONDUCTOR SIZE, LENGTH AND ROUTING

Conductor size, total circuit length, and routing are critical to proper SPD performance. The conductor **shall** be of the minimum size recommended by the manufacturer, however, **shall not** be smaller than 16 mm^2 csa (#6 AWG). Larger conductor sizes are most desirable. A maximum conductor length of 610 mm (2 ft.) is most desirable. The conductors **shall** be routed together and **shall** be free of sharp bends or angles of less than 90 degrees.

7.4.3.5 PERFORMANCE EVALUATION

SPDs **shall** be evaluated using the specific criteria outlined in "AC Power Line SPD Test Certification Requirements" on page 7-47, and **shall** meet the requirements established in this section and Table 7-4 on page 7-32. Devices that do not meet this minimum criteria **shall not** be furnished, installed, or recommended for installation.

7.5 TELEPHONE/CONTROL/DATA NETWORK CIRCUIT SPDS

All copper circuit conductors entering any communications site, shelter, room equipment area or pole/ pad mounted cabinet **shall** be protected with suitable SPDs. NFPA 70 requires that telephone, communications or data type circuit conductors be properly surge protected with a primary SPD as close as practicable to the point of entry into the structure or building (NFPA 70-2005, Article 800.90). Some applications may require fused or resetable fuse type primary protection devices. SPDs equipped with jacks or cords and plugs **shall** have all through conductors protected. Conductors that are not extended through the device **shall** be bonded to the ground (earth) connection point. The protected (equipment) and unprotected (line or CO) terminations **shall** be clearly marked. A grounding conductor or a ground connection post or terminal **shall** be provided. Devices that have the grounding conductor incorporated by the manufacturer as an integral part of the device **shall** utilize an 4 mm^2 csa (#12 AWG), green jacketed, stranded copper conductor for a single line (2 pr, 4 conductor) device or a 16 mm^2 csa (#6 AWG), green jacketed, stranded copper conductor for a multi-line device. The conductor provided as an integral part of the device by the manufacturer **shall** be a minimum of 1.2 m (4 ft.) in length to accommodate various installation requirements. When installed, this conductor **shall** be cut to the length required to permit attachment to the ground bus or equipment grounding conductor and **shall** be as short as possible to help ensure maximum protection. The ground connection post or terminal **shall** be suitable for connection of an 4 mm^2 csa (#12 AWG) conductor for a single line device or a 16 mm^2 csa (#6 AWG) conductor for a multi-line device. All ground conductors **shall** be mechanically attached to the device circuit board and **shall not** be dependent on solder for connection integrity. The voltage limiting devices **shall** be connected between the line conductors and ground.

Primary and secondary SPD operating voltages are application dependent and **shall** be properly chosen. Coordination between the Primary and Secondary devices **shall** be considered to ensure the most effective level of surge protection. High speed data circuits require SPDs designed for these applications.

WARNING

See Chapter 5 for the proper grounding of the metallic sheathing of communications cables.

7.5.1 PRIMARY PROTECTION

The primary SPD installation **shall** comply with all applicable codes. The devices **shall** be UL 497 listed or conform to the international CE certification mark (NFPA 70, Article 800.90(A) and Article 800.170(A)). The SPD **shall** be installed at the entrance point into any building and within close proximity to the electrical service entrance and the master ground bus bar. In lightning prone areas, a primary SPD **shall** also be installed on each end of an inter-building cable run to help ensure that high energy is not allowed to penetrate the building interior (NFPA 70-2005, Article 800.90(A)). In some applications a fused type primary SPD may be required. (See NFPA 70-2005, Article 800.90(A)(2) for additional information.) To reduce the need for fuse replacement, devices that incorporate resetable fuse technology are recommended. Primary SPDs are available from most telephone product distributors and are typically supplied during installation by the telephone circuit supplier. The purpose of primary protection is to help ensure personnel safety and help protect internal cables from extremely high voltage. The primary SPD **shall** be grounded (earthed) in accordance with NFPA 70-2005 Article 800.100 or other applicable codes, industry standards, and as outlined in Chapter 5, "Internal Grounding (Earthing)." The ground conductor **shall** be as short as possible, **shall** be routed as directly as possible to the ground bus or MGB, and **shall** be as free of bends as is possible.

NOTE: Contractors engaged by Motorola to install or move communications cable runs between buildings **shall** abide by local codes and standards governing the installation of communication cable runs.

7.5.2 SECONDARY PROTECTION

Secondary SPDs (silicon avalanche diode technology preferred) **shall** be installed. The SPDs **shall** be installed as close to the equipment being protected as possible. This includes (but is not limited to) the circuits associated with the base stations, repeaters, remotes, modems, consoles, Network Interface Units (NIUs) and channel banks that extend from the shelter, room or equipment area. This also includes any circuit located within one building, but extending outside the immediate equipment room or area. Secondary SPDs **shall** comply with safety and performance standards for their designated use per Table 7-2 on page 7-10, and be UL 497A listed for the purpose (NFPA 70, Article 800.90(D) and Article 800.170(B)).The device may also conform to the international CE certification mark. Secondary protection may be included as an integral part of a Type 3 multiple receptacle outlet strip.

NOTE: The installation of a secondary SPD does not negate the need for a primary device where copper circuit conductors enter the building, shelter or equipment area.

The purpose of secondary SPDs is to limit transient over voltages to as close to the prescribed operating level of the protected equipment as is possible. The SPD also serves as a barrier against transient anomalies that may be induced between the cable entrance point and the equipment, and in cable runs within the building or shelter interior. The secondary SPD ground conductor **shall** be bonded to the equipment grounding (earthing) conductor or ground bus conductor as outlined in Chapter 5, "Internal Grounding (Earthing)." This conductor **shall** be as short as possible, free of sharp bends, and **shall** be routed as directly to the equipment grounding conductor or ground bus as is possible.

The operating voltage and SPD configuration is application dependent. The lowest suitable voltage should be chosen to ensure the most effective level of surge suppression.

CAUTION

The manufacturer must verify that the SPD is suitable for use on high bandwidth data circuits in excess of 1.54 Mbs.

CAUTION

SPDs using SAD technology may develop an artificial diode bias when subjected to strong RF fields that may be experienced at AM, FM or TV broadcast sites. This bias may cause data circuit errors.

7.5.3 FIBER OPTIC CABLES

An intrinsic benefit of fiberglass (fiber optic) telephone lines is that they offer excellent isolation from lightning induced ground potential rise, line-induced lightning strikes, RF, and electrical noise coupling. The “fiber” telephone/data line is far from perfect as it can melt when subjected to high energy strikes or fire. No primary SPD is required for fiber circuits entering a building, shelter or equipment area; however, any metallic shield, jacket or drain conductor **shall** be bonded to the MGB. A secondary SPD may be installed on the equipment end of copper circuit conductors originating at a fiber optic network interface unit (NIU) in areas where the level of lightning exposure is high.

Suitable surge suppression devices offering primary and secondary protection are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

7.6 RF COMPONENTS PROTECTION

RF transmission lines from the antenna structure to the shelter or building **shall** be grounded (earthed) as described in Chapter 4, “External Grounding (Earthing).” Upon entering the shelter or building, all RF transmission lines (including sample port (test) and unused spares) **shall** route through coaxial RF-type SPDs. The coaxial RF devices **shall** be bonded to the single point ground window as described in Chapter 5, “Internal Grounding (Earthing).” The SPD **shall** be located within the shelter, room or equipment area and **shall** be a maximum distance of 610 mm (2 ft.) from the transmission line entrance point into the shelter, room or equipment area as shown in Figure 7-22 on page 7-42. Some RF surge protection products can be installed at or within the entry port; this is the most desirable location to install coaxial cable SPDs if the entry port is located in the wall of the shelter, equipment room or area. If the equipment room or area is located within a larger building (such as a high rise structure), it is desired that the SPDs are installed and grounded at the coaxial entry point into the structure. In this application, the transmission lines **shall** also have SPD installed and **shall** be grounded at the point where they enter the equipment room(s) or area(s).

NOTE: SPDs are required to be installed at the building entry point to reduce the radiated RF energy generated by a lightning strike.

NOTE: Unused coaxial cables connected to the outside **shall** be properly terminated by grounding the shield to the ground entry port and installing a SPD with a shorting stub or 50 ohm load. Excess cable **shall** be stored so as not to come in contact with equipment or personnel.

7.6.1 RF SURGE SUPPRESSION TECHNOLOGY OVERVIEW

There are three basic technologies used in the design of RF surge protection devices:

- RGT (Replaceable Gas Tube), DC open
- Quarter Wave Stub, DC short
- Broadband High Band Pass Filter, DC blocked

When selecting the proper RF suppression technology for a given application, attention should be paid to the operating characteristics inherent to each type of device, as well as system compatibility and surge suppression performance. Examples of surge performance characteristics for the three basic RF suppression technologies are provided below.

7.6.1.1 REPLACEABLE GAS TUBE

A straight Gas Tube-based coaxial protector without DC blocking has DC continuity from the surge-side connector center pin to the equipment-side connector center pin. The fast rise-time lightning pulse can produce a high magnitude voltage across the Gas Tube before the gas can ionize and begin to conduct. Because there is no DC blocking mechanism, this high voltage impulse is applied directly to the equipment input before the gas tube “turns on.” If the protected equipment input routes through a ferrite circulator/isolator, the incoming pulse is converted to current in the ferrite's resistive load. This creates a magnetic field that can realign the critically adjusted field in the circulator, thereby changing the magnet's flux density. This can damage or destroy the resistive load. If the incoming voltage pulse appears across a coupling loop (as in most filters and combiners), it sees a low resistance short and is almost entirely converted to current. A DC-shorted equipment input loop, which is quite common, directly shorts the Gas Tube. The Gas Tube may never see enough voltage to “turn-on” because current flow must go through the coaxial cable jumper and equipment input before an inductive voltage drop across the Gas Tube can reach a potential high enough to ionize the gas. Do not assume that a 90V gas tube will provide a 90V protection level for the equipment, because the voltage rating is based on a static DC voltage measurement. The Gas Tube is essentially a voltage dependent switch that reacts to the dv/dt of a lightning impulse. The typical voltage breakdown level for a 5kV/µs impulse is approximately 700 Vpk.

Straight Gas Tube protection devices allow DC current and voltage to be supplied to the tower top electronics. It is important to understand the operating characteristics of this protection technology. Tower top electronics consists of semiconductor-based preamps, power supplies, diplexers, telemetry, etc. Coordination of protection levels of the Gas Tube-based devices and the susceptibility of the protected electronics must be taken into account.

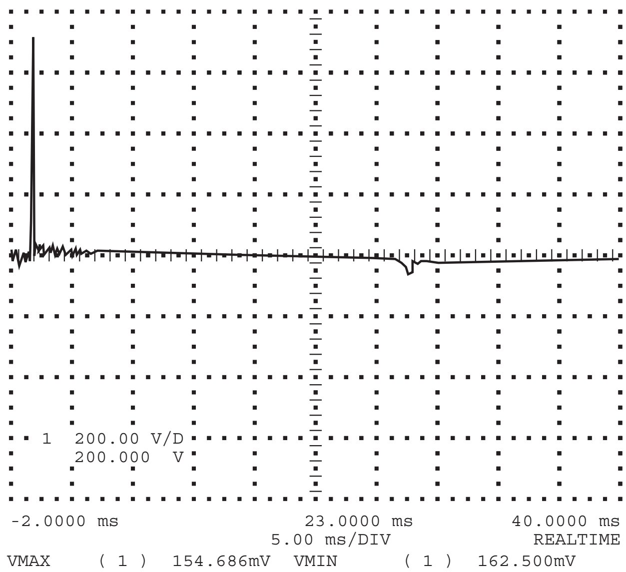


FIGURE 7-19 GAS TUBE AT 200V/DIV V AND 5 µS/DIV H, 8X20 µS/3KA

7.6.1.2 QUARTER WAVE STUB

The "Quarter Wave Stub" coaxial protector is based on the well-known bandpass/band-reject principle. Using a coaxial **T** fitting and calculating the length of a quarter-wave coaxial section from the horizontal center conductor to the grounded (earthed) base of the **T** can form a bandpass filter at a given frequency. Because most of the energy in a lightning strike is from DC to 1 MHz, it falls on the lower frequency reject side of the bandpass filter and is conducted to ground. However, because the equipment input is usually DC-shorted to chassis or earth, and because the quarter-wave stub is connected to earth with an inductive copper conductor, there will be divided DC and low-frequency energy flowing into the equipment input.

Quarter-wave devices cannot be used where DC currents and voltages are required to power RF electronics. By their nature, they are tuned devices, and therefore have relatively narrow operating bandwidths (approximately +/-10% of the operating frequency).

Shorted inductor (or shorted stub) lightning surge protection devices can appear electrically as an open circuit or a short circuit, depending on the applied radio frequency and physical dimensions of the transmission line inductor or stub. Within the designed frequency band, the shorted inductor or stub appears as an infinite impedance, producing very little passive insertion loss. Shorted inductors are indeed "shorted" at DC and frequencies outside the designed passband.

Shortcomings of the shorted inductor lightning protector which must be considered are that it will pass on-frequency lightning energy and that it must be made of compatible, non-ferrous materials or it also generates intermodulation. The shorted inductor will not allow DC to pass; therefore it is not suited in CCTV, tower top amplifier, and GPS receiver applications where DC bias is multiplexed on the RF transmission line. There are shorted stub inductor lightning protectors available that place a neon tube device in series with the tuned circuit to provide DC isolation.

While this solves the DC voltage problem for tower top amplifier and GPS applications, it significantly limits current-handling capacity of the protection device and does not reduce the let through voltage to the level required for equipment survivability; such devices **shall not** be used.

The shorted stub inductor device is frequency-sensitive, therefore it must be selected for the specific frequency band in use. Different bands multiplexed on the same transmission line will not work with band-limiting devices such as the shorted stub inductor. The shorted stub inductor device is mechanically large compared to other gas protector/reactive filter lightning surge protector devices in common use. There could quickly develop an installation space problem if a number of transmission lines are protected by individual shorted stub inductor devices at the common facility cable entrance port. The shorted inductor type device differs somewhat from the shorted stub inductor type device in that the shorted inductor type device incorporates a helical wound shorted inductor. These devices typically exhibit an open DC circuit through the device and have a much larger bandpass than a shorted stub inductor device.

All coaxial RF surge suppression devices **shall** exhibit an open DC circuit through the device (unprotected port center pin to protected port center pin), except those specifically designed to pass DC for CCTV, tower top amplifiers and GPS installations as described in this chapter and “GPS Receiver Protection” on page 7-44. The input and output ports **shall not** be directly connected and may have a capacitive or reactive network installed within the device to permit the RF energy to pass. The unprotected port and the protected port **shall** be clearly marked on the device.

Typical RF characteristics for RF SPD are voltage standing wave ratio (VSWR) of less than or equal to 1.1:1 (return loss of -26.4dB) and an insertion loss of less than or equal to 0.1 dB over the network operating frequency range. These devices are also specified to handle surge currents from 10-20kA 8/20 µs waveform. Selection of the proper SPD for RF transmission lines depends on the specific application.

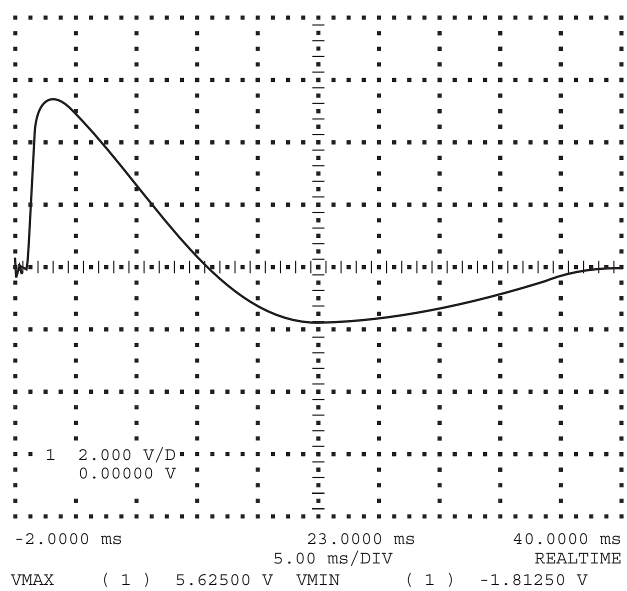


Figure 7-20 Quarter-Wave stub, Oscilloscope Set at 2V/div V and 5 µs/div H, 8x20µs/3kA

7.6.1.3 FILTER-BASED COAXIAL PROTECTORS

Filter-based lightning protection devices are characterized by their broadband performance characteristics and can cover multiple transmit/receive frequency bands. These cavity-based designs can be characterized as bandpass filters. They consist of tuned inductive capacitance (LC) networks operating on a bandpass/band-reject principle, with an operating band as broad as 2 GHz. Utilizing the inductive current discharge circuit to shield/ground, followed by a DC blocking capacitive component on the center pin, ensures not only broadband RF performance, but also the desired surge suppression characteristics. Designs based on this principle allow a closer match to 50 ohms over a broader range than the quarter-wave technique. These devices cannot be utilized in applications where DC currents and voltages are supplied to the RF electronics via the coaxial cable's center conductor.

Note that a modified form of this filter-based technology can be deployed in applications requiring DC power for the tower top electronics. There are designs combining DC blocking for the RF while passing DC power for the tower top electronics. The design is similar to the Bias-T concept. While the RF surge performance relies on the filter concept, the DC path is isolated from the RF path, conditioned, and re-injected at the appropriate port. While selecting this type surge protector, attention should be paid to the resistance of the DC protection circuit. The typical DC resistance range could be from a few milliohms to a few ohms.

Some tower top amplifier configurations incorporate a control and alarm cable in addition to the RF transmission line and sample port (test) cable. This control and alarm cable is typically a multi-conductor cable connecting the tower top amplifier unit collocated with the receive antenna to the control chassis collocated with the receiver multicoupler. This cable is typically installed and routed with the receive antenna transmission line. Any shield within this cable **shall** be bonded to the MGB.

All conductors of this cable **shall** be protected by installation of a suitable SPD within a maximum of 610 mm (2 ft.) of the point of entry into the shelter, room or equipment area. The ground (earth) terminal of the SPD **shall** be bonded to the MGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed, stranded copper conductor.

The specifications for this SPD will be dependent on the design parameters of the tower top amplifier system, including the operating voltage and number of conductors within the control or alarm cable. The proper SPD **shall** be selected for the specific application. The device selected should have a turn-on voltage that is nominally 20% higher than the maximum DC operating voltage; however, the turn-on voltage **shall** be low enough to provide suitable protection. The tower top amplifier system and SPD manufacturer should be consulted for guidance in selecting the proper SPD.

CCTV and Cable TV system cables entering a communications facility **shall** have SPDs installed. These cables, like RF transmission lines, should by design enter the shelter, room or equipment area at the same location as the RF transmission lines. When there are no RF transmission lines at the facility where these systems are installed (dispatch and command centers) the cables should enter as close as is practicable to the point where the power and telephone conductors enter the facility. The shield of these cables **shall** be bonded to the MGB. The SPD **shall** be installed within 610 mm (2 ft.) of the point of entry of the cable(s) into the shelter, room or equipment area. The ground terminal of the SPD **shall** be bonded to the MGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed, stranded copper conductor as described in Chapter 5.

The proper SPD **shall** be selected based on the application. Some CCTV systems will provide DC power to the remote camera via the coaxial cable. The cable TV service provider or the CCTV manufacturer, as well as the SPD manufacturer, should be consulted for guidance in selecting the proper SPD for the specific application.

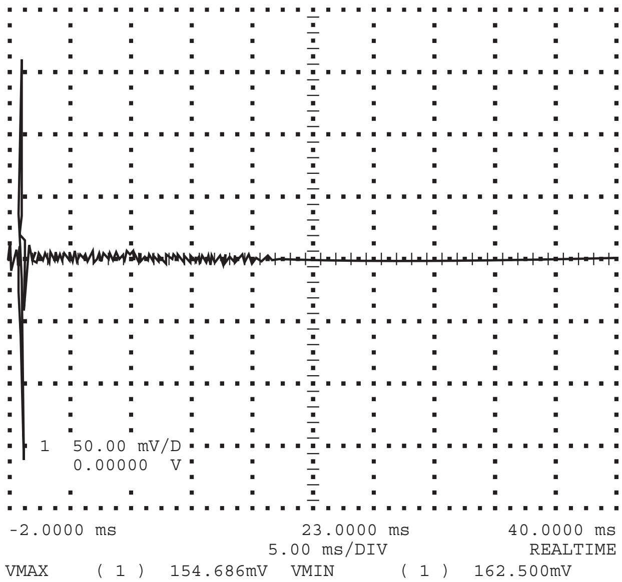
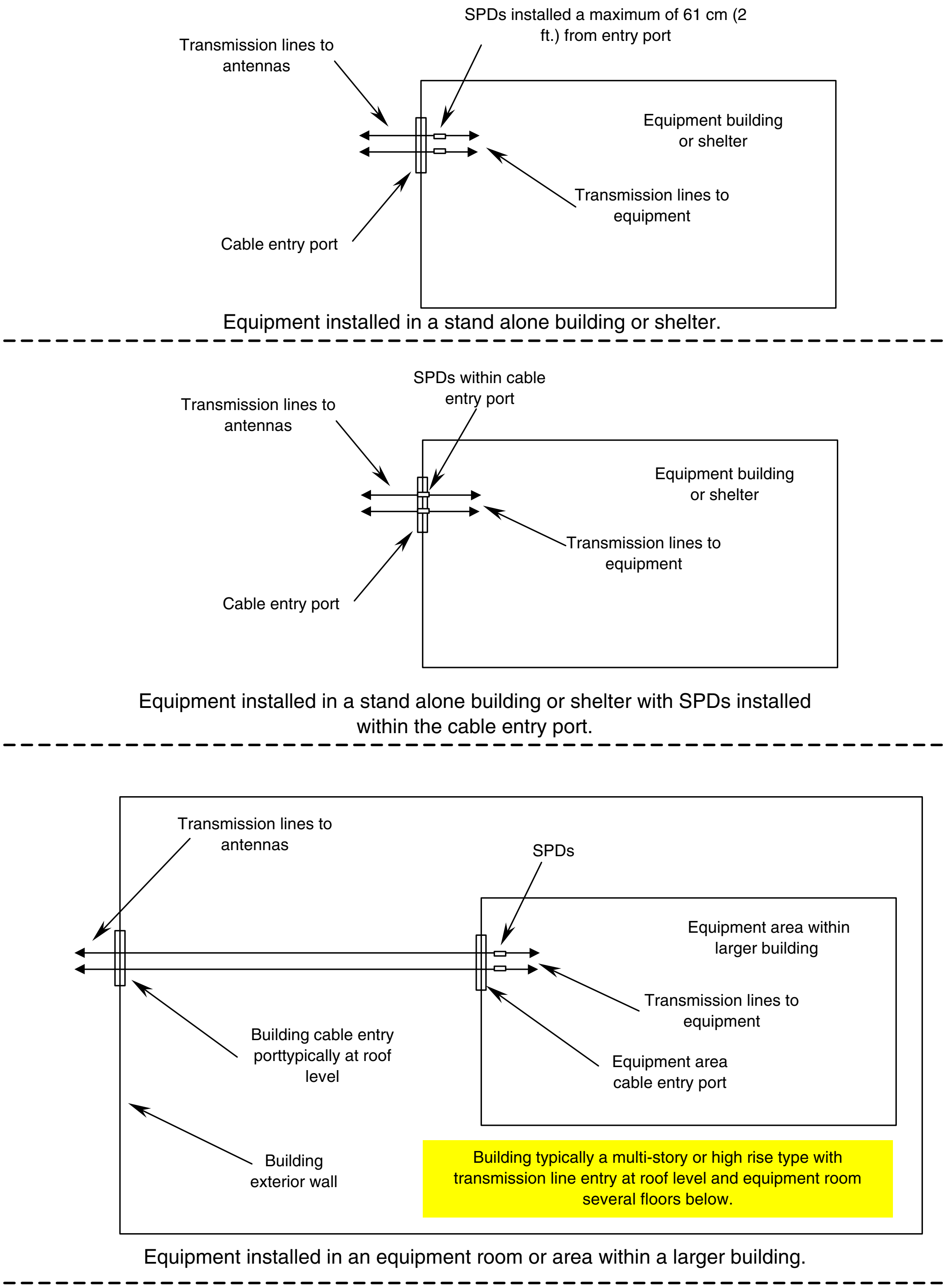


FIGURE 7-21 FILTER-BASED RF PROTECTION DEVICE, OSCILLOSCOPE SET AT 0.05V/DIV V AND 5µS/DIV H, 8X20 µS/3KA



NOTE: Grounding and electrical details not shown.

FIGURE 7-22 TRANSMISSION LINE SPD INSTALLATION LOCATIONS

7.6.2 SURGE PROTECTION CONSIDERATIONS FOR DISPATCH CENTERS AND OPERATOR POSITIONS

Dispatch centers co-located with communications towers require special protection considerations due to the critical nature of their operation and due to the inherent risk to personnel from lightning. For optimum dispatch center protection, the following **shall** be considered:

- Site design recommendations given in “Design Considerations to Help Reduce Effects of Lightning” on page 2-19.
- Internal grounding and bonding as defined in “Grounding (Earthing) for Dispatch Centers and Network Operator Positions” on page 5-62.
- Electrostatic discharge (ESD) precautions as defined in Appendix B.
- External grounding as defined in “External Grounding (Earthing) For Dispatch Centers Co-located With Communications Towers” on page 4-81.
- Transient Voltage Surge Suppression as follows:

7.6.2.1 MINIMUM SPD REQUIREMENTS

- Type-2 (min) service panel SPDs **shall** be required for AC electrical panels servicing the dispatch operations center and **shall** be located so as to provide the most effective surge protection (see “Installation Requirements” on page 7-33).
- Type-1 (min) SPDs are required for UPS panelboards located within the dispatch operations center when the UPS system is located more than 15.2 m (50 ft.) from the center.
- Type-3 SPDs are required for each dispatch operator position. Type-3 SPDs used **shall** be qualified Motorola compliant devices and must incorporate an external ground (earth) stud or connection point and **shall** be grounded to the operator position ground bus bar in accordance with ANSI T1.321-R2000.
- Telephone and network interface cables **shall** be surge protected and grounded as described under “Telephone/Control/Data Network Circuit SPDs” on page 7-34. Additional surge protection for headset jack interface points is recommended to reduce the possibility of shock or discomfort caused by lightning and electrostatic discharge (ESD). Headset protection units **shall** be grounded to the operator position ground bus bar.

NOTE: ESD is generally the cause for many complaints generated by dispatch personnel. Measures to control ESD **shall** be taken when designing for this environment. Most ESD problems are mitigated through proper bonding and grounding techniques, relative humidity control (between 40% and 55% relative humidity is ideal) and attention to the resistivity of flooring and furniture. Video Display Terminals (VDT), keyboards and the mouse are additional areas where energy can build up between the equipment and personnel. Proper static resistive mats and pads can reduce discomfort and injury caused by ESD. Cathode tubes used in some VDTs generate powerful electrical fields, and while there are screens and mats to help to minimize the effects of electrostatic discharge between equipment and personnel, it does not negate the need for training personnel on the proper skills to avoid coming in contact with ESD.

7.6.3 CABLE TELEVISION AND SECURITY SYSTEMS

Closed circuit television (CCTV), cable television, and security system cables entering a communications facility **shall** have SPDs installed. Cable television and CCTV cables, like RF transmission lines, should by design enter the shelter, room or equipment area at the same location as the RF transmission lines. When there are no RF transmission lines at the facility where these systems are installed (dispatch and command centers), the cables should enter as close as is practicable to the point where the power and telephone conductors enter the facility. The shield of these cables **shall** be bonded to the MGB. The SPD **shall** be installed within 610 mm (2 ft.) of the point of entry of the cable(s) into the shelter, room or equipment area. The ground (earth) terminal of the SPD **shall** be bonded to the MGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed, stranded copper conductor as described in Chapter 5, “Internal Grounding (Earthing).”

The proper SPD **shall** be selected based on the application. Fixed camera systems can be AC or DC powered; Pan Tilt Zoom (PTZ) cameras are typically 24 or 110 volt AC powered. Consult with the security provider or the manufacturer before selecting the SPD for this application. It is highly recommended to protect PTZ cameras at both ends of the cable run.

SPDs **shall** be installed on alarm circuits entering the communications site and installed within 610 mm (2 ft.) of the cable entry port and with the shields bonded to the MGB (NFPA 70-2005 Article 800.100(B)). Primary SPDs, within 610 mm (2 ft.) of where the cable enters the building, **shall** be installed in accordance with NFPA 70-2005 Article 800.90, and secondary SPDs, NFPA 70-2005 Article 800.90(D), are highly recommended at the security systems head-in.

7.6.4 BROADBAND - WIRELESS ACCESS POINT NETWORKS

SPD considerations for broadband **shall** include the use of SPDs to protect pole-mounted access points and ground-based cabinet architecture. It is important to install proper SPD applications on both ends of Ethernet, Power-Over Ethernet (POE), Giga-Ethernet (GigE) and AC cable runs. SPDs **shall** be located within the node or cabinet, or as close to the entrance as possible, and properly installed into load centers, control panels and utility power cabinets. While RF protection is a consideration, it **shall** only be required when antennas are connected to the node with coaxial cables greater than 610 mm (2 ft.) in length.

7.7 GPS RECEIVER PROTECTION

Global Positioning System (GPS) receivers are often a part of a modern communications system. GPS receivers are used for site timing and synchronization. Failure of a GPS receiver will usually render the radio system unusable. GPS receiver systems on telecommunications sites typically include a GPS receiver which is built-into the basic radio equipment, an amplified GPS antenna unit, and low-loss transmission line. The GPS antenna includes a GaAsFET device wideband RF amplifier. The RF amplifier is fed with low-voltage DC (around 15 VDC) through a multiplex arrangement using a single coaxial transmission line which also serves to couple the incoming GPS signal from the antenna to the receiver. A fused power supply within the radio equipment provides the RF amplifier operating voltage.

Damage to the GPS receiver can be induced directly from an antenna head strike, or through induced coupling from other transmission lines on the same antenna structure. There is little that can be done to effectively protect the GPS antenna unit itself from direct lightning strikes, other than to assure that it is **never** mounted at the highest point on the tower. The GPS system coaxial transmission line **shall** be installed and grounded (earthed) in accordance with the practices described in Chapter 4, "External Grounding (Earthing)." A special GPS coaxial RF SPD **shall** be installed within 610 mm (2 ft.) of the cable entry port and bonded to the MGB as described in Chapter 5, "Internal Grounding (Earthing)." Also see "RF Components Protection" on page 7-36 and Figure 7-22 on page 7-42.

The GPS compatible RF coaxial lightning protector is different from normal coaxial protectors in that it is designed to pass the DC bias through the coaxial line which is required to power the antenna-mounted amplifier. Before selecting a coaxial SPD, it should be verified that the GPS receiver can operate with an SPD in the coaxial line. In most installations the GPS receiver will require optimization to compensate for the delay caused by the SPD and the variations in the length of the transmission line (which is site specific). The GPS antenna transmission line **shall** be cut to the proper length as excess transmission line **shall not** be coiled either inside or outside the shelter, room or equipment area.

All coaxial RF surge suppression devices **shall** exhibit an open DC circuit through the device except those specifically designed to pass DC for CCTV, tower top amplifiers and GPS active antenna installations. These devices **shall** incorporate a circuit to pass the DC power while providing suitable surge protection for the DC circuit path. The input and output ports **shall not** be directly connected and may have a capacitive or reactive network installed within the device to permit the RF and DC energy to pass.

A DC injector/DC path coaxial hybrid RF SPD will typically have a turn-on voltage nominally 20% above the maximum DC operating voltage, with a turn-on time of 4 nsec for 2 kV/nsec. This protector will also offer a VSWR of less than or equal to 1.2:1 (return loss of -20.8dB) over the frequency range, and an insertion loss of less than or equal to 0.3 dB, handling a 20 kA, ANSI C62.1 8/20 waveform of 200 Minimum (+ and -) Alternating at 200 A per 62.41-2002.

The proper surge suppression device **shall** be selected for the specific application. Different active GPS receiver antennas will have different DC power supply voltages on the transmission line. The device selected should have a turn-on voltage that is nominally 20% higher than the maximum DC operating voltage; however, the turn-on voltage **shall** be low enough to provide suitable protection.

7.8 TOWER LIGHTING PROTECTION

All tower lighting system power, control and alarm conductors **shall** have SPDs installed at the point of entry into the building, shelter, room or equipment area. If the equipment room or area is located within a larger building and several ft away from the point where the conductors enter the building, the SPDs **shall** be installed within 610 mm (2 ft.) of the equipment room or area entry point or wall penetration.

AC power conductors **shall** have normal mode (L-N or L-L) surge suppression devices installed. Common mode (L-G) devices **shall not** be used on AC power circuits, although common mode devices will provide the most effective suppression on alarm and modem circuits and may be used on these circuits.

Tower lighting protection is typically overlooked in communications facility design. Tower lighting systems typically use either incandescent lamps, strobe lighting or both. These systems are typically powered from an AC circuit originating from the utility panelboard. Conductors connecting the lamps or lighting heads to a control unit at the tower base may be installed within conduit or be attached directly to the tower structure. Routing of flexible lighting power and controller cables is critically important.

CAUTION

Tower lighting cables shall not be bundled along with transmission lines or other conductors anywhere within cable ladders, or the building interior.

Tower lights or beacon power and control conductors can provide a path for conducting lightning energy into the shelter, building or equipment area. These conductors should be installed such that lightning energy **shall not** be routed through the building, shelter, room or equipment area where this energy may be inductively coupled into critical equipment interconnecting cables. For this reason an exterior location is preferable and highly recommended for the light controller panel. Many manufacturers provide a weatherproof enclosure suitable for outdoor installation as a standard product. Others offer the weatherproof enclosure as an option, which can be easily ordered. The weatherproof tower light controller housing may be mounted to a tower leg, a pedestal alongside of the antenna structure or to the exterior surface of the shelter or building.

If the tower lighting controller is installed within the building, shelter, room or equipment area, it **shall** be located as close to the cable entrance port as practicable. All control unit metallic housings **shall** be bonded to the exterior ground (earth) system or the interior perimeter ground bus or MGB based on their location.

Strobe lighting systems may use voltages in excess of 600 VDC; therefore, installation of a surge suppressor on these power conductors to the strobe light heads is not reasonable and will not adequately reduce surge voltages that may enter the shelter. For this reason it is recommended that tower lighting controllers be located outside the shelter. Suppressing voltage transients on the AC power, alarm and modem conductors of control units located outside the shelter, building or equipment area can be effectively done by installation of a suitable SPD at the point of entry of the conductors into the shelter, building or equipment area. Tower light AC power, alarm and modem cables **shall** enter the shelter, building or equipment area within or adjacent to the antenna transmission line entry port location. The ground conductors of the SPDs **shall** be bonded to the MGB at this point.

Some tower lighting manufacturers offer an optional surge suppression device that may be installed within the tower lighting control unit. Although this device may be suitable for protecting the control unit circuitry, it does not provide adequate protection to inductively coupled energy that may enter the shelter, building or equipment area through the tower light power or control conductors.

Suitable surge suppression devices offering protection for AC power, control and modem circuits are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

7.9 BATTERY POWERED PROTECTION

As telecommunications systems and sites have changed, so have power requirements. Cellular, PCS, and iDEN systems typically operate from a battery plant. Motorola Communications Enterprise equipment is also available with a DC power capability. The battery plants are usually powered by AC battery charging systems. Cellular, PCS and iDEN Mobile Switching Offices (MSO) or Central Offices also operate from a large battery system. Most of these sites adopt the telephone/microwave systems convention of -48 VDC, but some applications can use ±24 VDC as well as 12 VDC.

A battery powered site offers a level of isolation from the AC power system affording some surge protection, voltage regulation, and electrical feed noise suppression to the equipment load. A battery system will attempt to maintain a normalized voltage, absorbing variations in voltage. This can be an effective method of surge suppression when the equipment is located within a conductor length of 6.1 m (20 ft.) from the battery plant; or a circuit length of 3 m (10 ft.) from the battery plant.

A DC SPD in the form of a SAD and MOV matrix device is recommended for installations where the equipment is separated from the battery plant by a conductor length exceeding 6.1 m (20 ft.); or a circuit length exceeding 3 m (10 ft.) from the battery plant. This protection is also recommended for installations in an area where the level of lightning exposure is high. The SPD voltage rating and polarity **shall** be coordinated with the circuit voltage and polarity of the battery plant. To maximize the effectiveness, the SPD should be installed at the equipment to be protected. Additional devices are recommended for each DC equipment load at the site.

Suitable surge suppression devices are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

7.10 AC POWER LINE SPD TEST CERTIFICATION REQUIREMENTS

AC power line SPDs which are recommended, distributed or installed by Motorola **shall** meet the specifications requirements cited in “AC Power SPD Requirements” on page 7-5, and those specified in Table 7-4 on page 7-32. Additionally, these devices **shall** have been certified as meeting the criteria cited in “Impulse Surge Durability Test Requirements” on page 7-49 below.

Manufacturers of AC power line surge suppression devices have an independent Nationally Recognized Testing Laboratory (NRTL)), NAVLAP or A2LA, or a Certified UL client testing data laboratory detailing the procedures used, and the results obtained **shall** be made available.

Each manufacturer will submit and test their products for compliance with the specifications cited in “AC Power SPD Requirements” on page 7-5, and Table 7-4 on page 7-32. These tests **shall** follow the procedure outlined in the “Impulse Surge Durability Test Requirements” below and **shall** be done at no cost to Motorola. The results of these tests **shall** be certified by the independent laboratory and **shall** be submitted to representatives of Motorola for review. Devices that have been tested following the procedure established below and found to be compliant with the specifications cited in “AC Power SPD Requirements” on page 7-5, and those specified in Table 7-4 on page 7-32 **shall** be considered to have met the device requirements established by Motorola.

Motorola **shall** be afforded the opportunity to have their representative or representatives present at the time of the testing to witness and verify the test data compiled by the independent laboratory. The manufacturer may request that the test results be considered proprietary and may request that the information not be disclosed by representatives of the independent laboratory or Motorola. Motorola will be notified 30 days prior to the test in order to facilitate scheduling to witness the testing. After completion of the testing, manufacturers will have 30 days to compile the testing data and submit to Motorola for review. Motorola will have 30 days to advise the manufacture as their acceptance, or refusal of the results of the test data.

Motorola, at their option and expense, may purchase additional units from the manufacturer's normal production and have these devices tested by an independent laboratory of their choice following the same test criteria. Should it be found that the units purchased fail to meet the requirements as defined in "AC Power SPD Requirements" on page 7-5, and Table 7-4 on page 7-32, the manufacturer **shall** be notified. Motorola may, at their option, discontinue recommending, distributing or installing the product at any time.

7.10.1 TEST METHODS

This section describes the required tests for motorola certification. These tests are designed to stress the SPD to meet the requirements in this document. These are performance tests that exceed the UL 1449 2nd edition safety test. In addition to these required tests, UL 1449 2nd edition listing is required.

All tests for Type 1 and 2 SPDs will require a pre-test of 6 kV (minimum), 10 kA 8x20 usec Impulse as described in IEC 61643-1. The Voltage protection Level (VPL) is then recorded. After the required tests are preformed a Post-Test of 6kV (minimum), 10kA 8x20usec Impulse as described in IEC 61643-1 will be performed and the result from the Post-Test must be within 10% of the Pre-Test VPL.

Each Test will require one test sample

7.10.2 COMPONENT LEVEL SURGE TEST

7.10.2.1 GENERAL

This test will test the individual surge module/s of Type 1 and 2 SPD's to show that they meet the requirements in this document. The SAD module/s are required to meet 20 kA single impulse with the VPL not deviating more then 10% in pre and post In (Nominal) testing. The MOV module/s are required to meet 160 kA single Impulse with the VPL not deviating more then 10% in Pre and Post In (Nominal) testing. All referenced surge currents are based on 8X20 uSec waveforms.

7.10.2.2 I_N (NOMINAL CURRENT TEST)

The module/s must be first be subjected to an In test impulse as described in IEC 61643-1. The Test current I_n is 10kA 8x20uSec. The Clamping voltage measured 150 mm (6 in.) from the module/s connection is then recorded and the current waveform plotted.

7.10.2.3 COMPONENT SURGE TEST CALIBRATION

The surge generator must be calibrated to the test current and the current waveform plotted as per UL 1449 2nd Edition. Calibration should be performed with the actual lead wires used to connect the module/s. This will allow the delivered current to closely match the short circuit current. Calibration for the SAD module/s **shall** be 20 kA. Calibration for the MOV module/s **shall** be 160 kA. No AC is required for this test. The clamping voltage measurement is not required for this test.

7.10.2.4 MODULE(S) TESTING

The SAD module(s) are then subjected to the 20 kA impulse.
The MOV module(s) are then subjected to the 160 kA impulse.

7.10.2.5 PASS CRITERIA

The modules are then subjected to the I_n 10 kA test as described in paragraph 7.10.2.2. The VPL is then measured and recorded. The current/voltage waveform is plotted. The Pre-test In VPL is compared to the post-Test In VPL. The modules passes the requirement if the post VPL is within 10% of the Pre VPL.

7.10.3 IMPULSE SURGE DURABILITY TEST REQUIREMENTS

7.10.3.1 GENERAL

The impulse surge durability test is designed to test the endurance of the SPD. Each Type of SPD is subjected to it's own set of impulses. For Type 1 and 2 devices the SPD is first subjected to a pre-test In impulse and it's VPL is measured and recorded. After the Duty cycle testing the SPD is again subjected to an In impulse and it's VPL is measured and recorded. The Post In VPL must be within 10% of the Pre In VPL. All referenced surge currents are based on 8X20 uSec waveforms except for the 100 kHz ringwave. The total number of impulses for each type is 400. Two hundred (200) impulses **shall** be applied positive at a phase angle of 90° (+0°,-15°) and 200 impulses **shall** be applied negative at a phase angle of 90° (+0°,-15°).

7.10.3.2 I_N PRE-TEST (NOMINAL CURRENT TEST)

The SPD must be first be subjected to an In test impulse as described in IEC 61643-1. The Test current In is 10 kA 8x20uSec. The Clamping voltage measured 150 mm (6 in.) outside of the enclosure is then recorded and the current and voltage waveform plotted.

7.10.3.3 DUTY CYCLE CALIBRATION

The surge generator **shall** be calibrated as specified in UL 1449, 2nd Edition, subsection 34.5. Tolerances and waveform are described in UL 1449, 2nd Edition section 34.5. This test is for Type 1, and 2 SPDs only. For Type 1 SPDs a Calibration of 6 kV, 3 kA and 6 kV, 10 kA is required. For Type 2 SPDs a calibration of 6 kV, 3 kA is required. All calibration current waveforms must be measured and plotted.

7.10.3.4 SPD DUTY CYCLE TEST

Type 1 SPDs, the test voltage and current **shall** be a combination of pulses at 6 kVp minimum at 3 kA and 6 kVp minimum at 10 kA. This test **shall** consist of 20 impulses at 6 kVp minimum / 10 kA, followed by 160 impulses at 6 kVp / 3 kA, followed by 20 impulses at 6 kVp minimum/ 10 kA respectively per polarity. The surges **shall** be conducted in succession with a maximum 60 second period between each surge. The total number of impulses being 400.

Type 2 SPDs, the test voltage and current **shall** be a combination of pulses at 6 kVp minimum at 3 kA. This test **shall** consist of 400 impulses at 6 kVp minimum/ 3 kA. The surges **shall** be conducted in succession, with a maximum 60 second period between each surge. The total number of impulses being 400.

Type 3 SPDs, the test voltage and current, **shall** be 6 kVp at 200 A, and 100 kHz (ringwave test) as described by IEEE C62.41. This test **shall** consist of 400 impulses conducted in succession with a maximum 60 second period between each surge.

7.10.3.5 PASS CRITERIA

After Duty Cycle testing, the SPD is then allowed to cool to room temperature. The SPD is then subjected to the In 10 kA test as described in 7.10.2.2 on page 7-48. The VPL is measured and recorded. The current and Voltage waveform is plotted. The Pre-test In VPL is compared to the post-Test In VPL. The SPD passes the requirement if the post VPL is within 10% of the Pre VPL. For Type 3 devices if the SPD remains fully functional the unit passes.

7.10.4 MAXIMUM DISCHARGE CURRENT TEST

7.10.4.1 GENERAL

The Maximum Discharge Current test is designed to test the maximum surge capability of the SPD. Maximum Discharge Current, I_{max}, for Class II Test - Crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the test sequence of the Class II operating duty test. I_{max} for Type 1 and Type 2 SPDs is 160 kA. The SPD **shall** be mounted and connected as per the manufacturer's installation instructions.

If manufacturer provides electrical conductors as a part of the product, testing and measurements **shall** be conducted on the full length of conductor provided

If no electrical conductors are provided, testing and measurements **shall** be conducted at the terminal block

Testing **shall** be performed in free air, 20 °C, ± 15 °C.

During the testing, maintenance or modifications **shall not** be performed.

All referenced surge currents are based on 8 × 20 uSec waveforms.

7.10.4.2 I_N PRE-TEST (I NOMINAL CURRENT TEST)

The SPD must be first be subjected to an In test impulse as described in IEC 61643-1. The Test current In is 10 kA 8x20uSec. The clamping voltage measured 150 mm (6 in.) outside of the enclosure. The VPL is then recorded and the current and voltage waveform plotted.

7.10.4.3 IMAX SURGE GENERATOR CALIBRATION

The surge generator **shall** be calibrated as specified in UL 1449, Second Edition sub section 34.5. Tolerances and waveform are described in UL 1449, 2nd Edition section 34.5. This test is for Type 1, and 2 SPDs only. Calibration should be performed with the actual lead wires used to connect the module/s. This will allow the delivered current to closely match the short circuit current.

1. Calibrate the Surge Generator with an 8/20 msec short circuit current of 16 kA. Denote and record the charge voltage of the surge generator. Measure, record and plot the short circuit current including peak amplitude, rise time and duration.
2. Calibrate the Surge Generator with an 8/20 msec short circuit current of 40 kA. Denote and record the charge voltage of the surge generator. Measure, record and plot the short circuit current including peak amplitude, rise time and duration.
3. Calibrate the Surge Generator an 8/20 msec short circuit current of 80 kA. Denote and record the charge voltage of the surge generator. Measure, record and plot the short circuit current including peak amplitude, rise time and duration.
4. Calibrate the Surge Generator with an8/20 msec short circuit current of 120 kA. Denote and record the charge voltage of the surge generator. Measure, record and plot the short circuit current including peak amplitude, rise time and duration.
5. Calibrate the Surge Generator with an 8/20 msec short circuit current of Imax 160 kA. Denote and record the charge voltage of the surge generator. Measure, record and plot the short circuit current including peak amplitude, rise time and duration.

7.10.4.4 IMAX DISCHARGE TEST

Connect the Positive Terminal of the Surge Generator to the L1 terminal or conductor of the SPD.

Connect the Negative Terminal of the Surge Generator to the N terminal or conductor of the SPD.

1. Apply a surge current of 16 kA with a positive polarity, no AC applied. Measure, record and plot the delivered current.
2. Apply a surge current of 40 kA with a positive polarity, no AC applied. Measure, record and plot the delivered current.
3. Apply a surge current of 80 kA with a positive polarity, no AC applied. Measure, record and plot the delivered current.
4. Apply a surge current of 120 kA with a positive polarity, no AC applied. Measure, record and plot the delivered current.
5. Apply a surge current of Imax 160 kA with a positive polarity, no AC applied. Measure, record and plot the delivered current.
6. Repeat Steps 1 through 5 above for the remaining modes of protection of the SPD.
7. Apply thermocouples to the top and two-sides of the SPD.
8. Connect the SPD to the voltage, phase and power circuit configuration as detailed on the data label.
9. Energize the SPD for a period of 30 minutes. Measure and record the temperatures obtained.

7.10.4.5 PASS CRITERIA

After I_{max} testing the SPD is allowed to cool to room temperature. The SPD is then subjected to the In 10 kA post-test as described in “I_N (Nominal Current Test)” on page 7-48. The VPL is measured and recorded. The current and Voltage waveform is plotted. The Pre-test In VPL is compared to the post-Test In VPL. The SPD passes the requirement if the post VPL is within 10% of the Pre VPL.

During the Residual Voltage Measurement, Pre-conditioning and I_{max} Operating Duty Cycle Tests, the following conditions **shall not** occur:

- Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
- Ignition of the enclosure.
- Creation of any openings in the enclosure that results in accessibility of live parts.
- Opening, temporary, or permanent, of over-current protective components.
- Errors resulting from a failure, temporary, or permanent, in the indication circuitry
- A supplementary protection device opening.