



**US Army Corps  
of Engineers**

**Afghanistan Engineer District - North**

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# AED-N Electrical Design Requirements

Various Locations,  
Afghanistan

27 July 11

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# 1. General Electrical Requirements for Design and Construction

## Design Requirements

1. 50Hz. systems shall be designed to BS7671 17<sup>th</sup> Edition. 60Hz. systems shall be designed to NFPA 70 (NEC) 2011.
2. Demand Factors shall be applied using NEC Article 220 and UFC 3-501-01 Table 2 for individual panels and buildings. For compounds/bases/garrisons with more than five (5) buildings, total system demand load shall be calculated using AED-N Design Tool entitled "Total System Demand Calculation." See Section 3. This tool was developed IAW UFC 3-501-01 section 2.3 "Area Loads" and Tables 1 and 8.
3. All interior conduit shall be surface-mounted electrical metallic tubing (EMT) conduit.
4. All large electrical equipment (exhaust fans over 1/8hp., unit heaters, water heaters, etc.) shall be provided with a disconnecting switch within sight of the equipment. Split-pack HVAC units shall be powered by a lockable interior disconnect switch.
5. A ground rod shall be installed at the manholes, hand holes and pull boxes. Ground rods shall be driven into the earth before the manhole floor is poured so that approximately 100mm of the ground rod will extend above the manhole floor. When precast concrete manholes are used, the top of the ground rod may be below the manhole floor and a 50 square millimeters ground conductor brought into the manhole through a watertight sleeve in the manhole wall.

## Construction Requirements

1. Provide bushings where wiring and/or conduit enters junction boxes, panelboards, and light fixtures.
2. 4mm<sup>2</sup> and 6mm<sup>2</sup> conductors shall be solid, not stranded.
3. Do not use electrical tape to insulate splices. Splices shall be made by use of a device that is identified for use (E.G. – twist-on wire connectors)
4. Ground connections below grade shall be made by an exothermic weld. Ground connections above grade shall be made by an exothermic weld or bolted solderless connectors, in compliance with UL 467. Where grounding conductors are connected to aluminum conductors, specially treated or lined copper to aluminum connectors suitable for this purpose shall be used.

## **Product Requirements**

### **50 Hz Systems**

All electrical material and equipment shall be IEC manufactured and type-tested by an independent testing laboratory. The independent testing laboratory must be certified by the Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components (IECEE). Contractor shall supply product-specific testing certification and IECEE certification for all IEC manufactured equipment. After construction submittals are sent to USACE, product-specific certificates will be verified with the independent testing agency. Material tested and marked by a Nationally Recognized Testing Laboratory (NRTL) such as Underwriters Laboratories (UL) or Canadian Standards Association (CSA), may be used in lieu of IEC-manufactured, type-tested material as long as it is rated for use at the system voltage and frequency.

### **60 Hz Systems**

All electrical material and equipment shall be tested and marked by a Nationally Recognized Testing Laboratory (NRTL), such as Underwriters Laboratories (UL) or Canadian Standards Association (CSA). After construction submittals are sent to USACE, product-specific certificates will be verified with the independent testing agency.

In the event that NRTL-tested materials are not available, the contractor may then select applicable IEC manufactured material that has been type-tested by an independent testing laboratory. The testing laboratory must be certified by the Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components (IECEE). Contractor shall supply testing certification and IECEE certification for all IEC manufactured equipment.

## 2. Electrical Cable and Conductor Sizing

Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in the **conductors or conductor insulation**. It is very important that the ampacity of the breaker properly protect the conductors. This document does not include instruction for motor protection (See National Electrical Code (NEC) Article 430 for motor protection).

- Breakers are normally sized based on the maximum load that will pass through them on a continuous or non continuous operation (NEC Article 210.20(A)).
  1. Non continuous operation: The load is not operating over 3 hours continuous. The breaker size would be based on maximum load. Example: 100 amp maximum load x 100% = 100 amp breaker size.
  2. Continuous operation: Defined by the NEC is the maximum load on for 3 hours are more. The breaker would be sized for the maximum load plus 25 percent. Example: 100 amp load x 125% = 125 amp breaker size.
  3. Continuous and non continuous mixed loads: The breaker would be sized for not less than 100 % of the non continuous load plus 125 % of the continuous load. Example: 50 amp maximum non-continuous load @ 100% plus 50 amp continuous load @ 125% = 112.5 amp minimum breaker size. Next standard size larger is 125 amp breaker.
- Conductors shall be sized based on Table 1 below, and NEC 240.4. The table was created based on a worst case capacity from NEC Table 310.16 and IEC 60364 Table A.52-4. Table 1 ampacity values are valid for 3 current carrying-conductors or less in a conduit or raceway, at an ambient temperature of 30°C. If actual conditions differ from these values, Table 2 (correction for number of conductors) and Table 3 (correction for ambient temperature) shall be used to adjust the capacity for conductors shown in Table 1.

<b>ALLOWABLE CAPACITIES OF CONDUCTORS RATED 0 THRU 2000 VOLTS</b>					
Not more than 3 Current-Carrying Conductors in Raceway/Cable/Earth (86°F)			Effective (Z) @ .85 PF Uncoated Copper (ohm/km)		
Size		Ampacity	Conduit Type		
AWG (Cu)	mm <sup>2</sup>		PVC	Aluminum	Steel
12	4*	20	5.60	5.60	5.60
10	6*	30	3.600	3.6	3.6
8	10*	40	2.260	2.26	2.3
6	16*	55	1.440	1.48	1.48
4	25*	70	0.950	0.95	0.98
3	35*	85	0.750	0.79	0.79
2	35**	89	0.620	0.62	0.66
1	50**	108	0.520	0.52	0.52
1/0	70**	136	0.430	0.43	0.43
2/0	70**	136	0.360	0.36	0.36
3/0	95**	164	0.289	0.302	0.308
4/0	120**	188	0.243	0.256	0.262
250	150**	216	0.217	0.230	0.24
300	150**	216	0.194	0.207	0.213
350	185**	245	0.174	0.190	0.197
400	240**	286	0.161	0.174	0.184
500	300**	328	0.141	0.157	0.164
600	300**	328	0.131	0.144	0.154

\*Based on NEC Table 310.16

\*\* Based on IEC 60364-5-52 Table A 52-4

**Table 1**

<b>ADJUSTMENT FACTOR FOR MORE THAN 3 CURRENT CARRYING CONDUCTORS</b>	
Number of Conductors	Percentage of Adjustment
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

*Table 2*

<b>CORRECTION FACTORS</b>		
<u>Ambient Temp</u>		X
°C	°F	
21-25	70-77	1.05
26-30	78-86	1.00
31-35	87-95	0.94
36-40	96-104	0.88
41-45	105-113	0.82
46-50	114-122	0.75
51-55	123-131	0.67

*Table 3*

### 3. Total System Demand Calculation (using UFC 3-501-01 and the included spreadsheet)

**STEP 1: INDICATE BUILDINGS IN PROJECT - [“Building Name” and “Number of Buildings”]**

The Contractor shall determine the name and number of all building types covered in this project. The building name information for each building type is entered in to the spreadsheet in the column with the header “Building Name”. The number of buildings of that specific name and type in the project is entered in to the spreadsheet in the column with the header “Number of Buildings”.

**STEP 2: FIND TOTAL CONNECTED LOAD OF A BUILDING - [“Connected Load (per Building)(kVA)”]**

The total connected load of a specific building type and name is found by summing the connected load of all panels within that building. Once the Total Connected Load has been determined for a specific building type and name, this information is entered in to the spreadsheet in the column with the header “Connected Load (per building)(kVA)”.

**Equation 1**

$$\text{Total Connected Load} = \Sigma(\text{All Connected Panel Loads within a Building})$$

**STEP 3: FIND BUILDING CLASSIFICATION - [“Building Classification (per UFC)”]**

Using Table 1 (UFC 3-501-01), determine the building classification for each building name and type in the project. Once the building classification has been determined, select this information in the spreadsheet in the drop down selection menu in the column with the header “Building Classification (per UFC)”.

**STEP 4: FIND THE DEMAND FACTOR - [“Demand Factor (average)”]**

**Equation 2**

$$\text{Demand Factor} = \frac{\text{Demand Load}}{\text{Total Connected Load}}$$

The Demand Factor, from Table 1 (UFC 3-501-01) is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Demand Factor is automatically populated in the spreadsheet in the column with the header “Demand Factor (average)”.

**STEP 5: FIND THE DEMAND FACTOR - [“Load Factor (average)”]**

**Equation 3**

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Max Load}}$$

The Load Factor, from Table 1 (UFC 3-501-01) is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Load Factor is automatically populated in the spreadsheet in the column with the header “Load Factor (average)”.

**STEP 6: FIND THE COINCIDENCE FACTOR - [“Coincidence Factor (average)”]**

**Equation 4**

$$\text{Diversity Factor} = \frac{1}{\text{Coincidence Factor}}$$

Solving Equation 4 for Coincidence Factor, the following equation is obtained:

**Equation 5**

$$\text{Coincidence Factor} = \frac{\text{Total System Demand}}{\Sigma(\text{All Building Demands})}$$

The Coincidence Factor, from Table 1 (UFC 3-501-01) is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Coincidence Factor is automatically populated in the spreadsheet in the column with the header “Coincidence Factor (average)”.

**STEP 7: FIND THE BUILDING DEMAND - [“Building Demand (per building)”]**

**Equation 6**

$$\text{Building Demand (per building)} = \text{Connected Load} * \text{Demand Factor} * \text{Coincidence Factor}$$



The Building Demand (per building) is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Building Demand (per building) is automatically populated in the spreadsheet in the column with the header “*Building Demand (per building)*”.

**STEP 8: FIND THE TOTAL BUILDING DEMAND - [“Total Building Demand (per building type)”]**  
**Equation 7**

$$\text{Total Building Demand (per building type)} = \text{Building Demand (per building)} * \text{Number of Buildings}$$

The Building Demand (per building) is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Building Demand (per building) is automatically populated in the spreadsheet in the column with the header “*Building Demand (per building)*”.

**STEP 9: FIND TOTAL SYSTEM DEMAND - [“Total System Demand”]**

**Equation 8** 
$$\text{Total System Demand} = \sum(\text{All Total Building Demands})$$

The Total System Demand is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Total System Demand is automatically populated in the spreadsheet box indicate “*Total System Demand*”.

**STEP 10: FIND TOTAL SYSTEM DEMAND + 25% SPARE - [“Total System Demand + 25% Spare”]**

**Equation 8** 
$$\text{Total System Demand} + 25\% \text{ Spare} = \text{Total Building Demand} * 1.25$$

The Total System Demand + 25% spare is automatically populated in the spreadsheet once all of the required user populated cells and user selected drop down menus (4 columns require user inputs total) have been completed. The Total System Demand is automatically populated in the spreadsheet box indicate “*Total System Demand + 25% Spare*”.

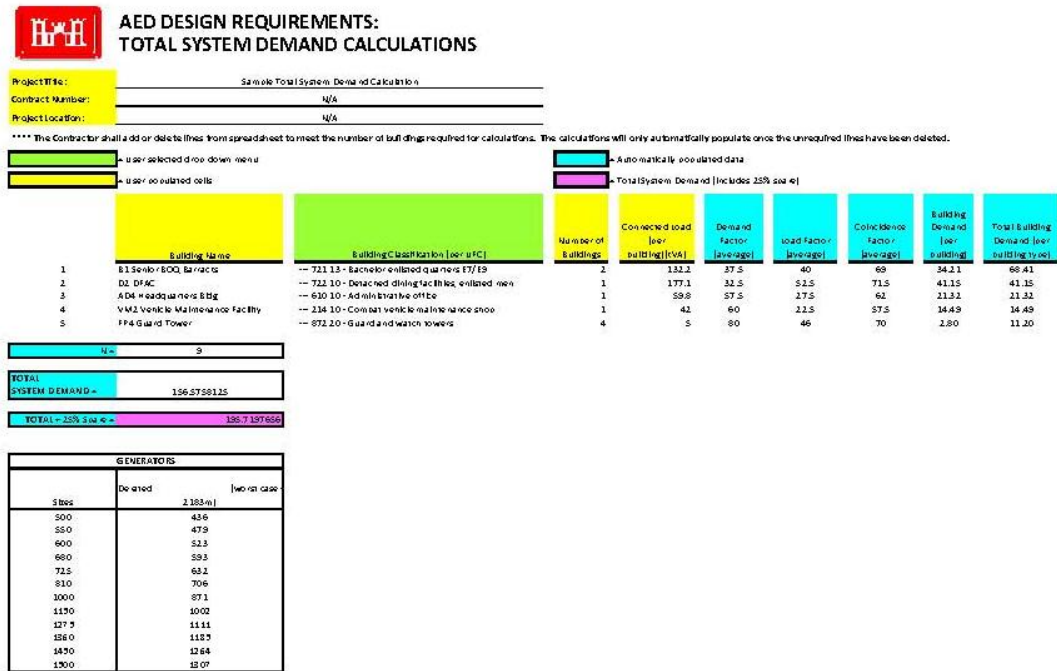
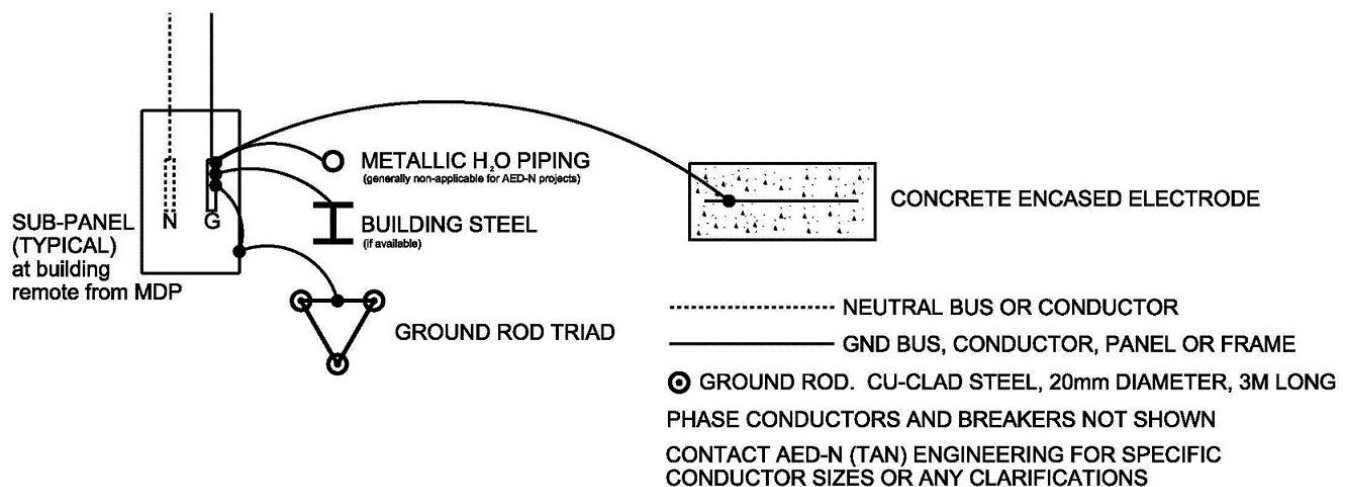


Figure 1

## 4. Grounding

**60Hz systems:** Grounding shall be designed and installed IAW NEC Article 250. Most AED-N projects have central diesel power plants, and a main distribution panel that feeds all buildings. Each building in these compounds is considered a “Building Supplied by a Feeder” by NEC 225.30, and is bound by the grounding requirements of NEC 250.32. NEC 250.32(A) requires a grounding electrode at buildings supplied by a feeder.

**50Hz systems:** Grounding system shall be TN-S Earthing System, as identified in BS7671. Additional earthing of the Protective Earth is required for all projects. The PE shall be connected to all available grounding electrodes available at the building, including but not limited to: Building Steel, Concrete Encased Electrode, and Ground Rods.



*Figure 2 (Applicable to both 50Hz and 60Hz systems)*

If a transfer switch is provided ahead of the Main Distribution Panel, it must be Service-Entrance rated, or a Service-Rated disconnect switch with an overcurrent protection device must be provided on the utility (transformer) side of the transfer switch. See NEC 230.83 “Equipment Connected to Supply Side of Service Disconnect.”

See Appendix A for Generator Grounding Schematics

## 5. Voltage Drop Calculations

The voltage drop of any insulated cable is dependent upon the length of the cable, the current on the cable and the impedance (ohm) per unit length of the cable based on the type of conduit.

Voltage drop on the cable shall be limited to the following:

- The voltage drop of the secondary service of 3%.
- The voltage drop of a feeder or branch circuit of 2%.

The combined voltage drop of feeder and branch circuit shall not exceed 5%.

Voltage Drop Calculations shall be provided in accordance with the NEC, regardless of where the cable was manufactured.

### U.S Formula (NEC)

For three phase:  $VD = 1.732 \times L \times R \times I / 1000$

For single phase:  $VD = 2 \times L \times R \times I / 1000$

VD: The voltage drop (V)

L : The length of conductor (m)

R: The impedance value from NEC Chapter 9, Table 9 (ohm/km) [or Table 1 of Section 2 above]

I : The load current (A)

The value R is determined from the National Electrical Code (NEC), Chapter 9, Table 9 column "Effective Z at .85 PF for Uncoated Copper" using the ohm/km column. See Table 2 below for the NEC table data presented in the USACE Allowable Capacities of Conductors chart.

Below is an example calculation for determining voltage drop.

Determine the voltage drop of a 380V, 3 phase circuit with a current of 100A and a length of 150 m and a conductor size of 50 mm in steel conduit. This is a secondary service feed.

$VD = 1.732 \times \text{Length} \times \text{Impedance} \times \text{Current} / 1000$ . Impedance is found in Table 1 of Section 2 above:

$$= 1.732 \times 150 \times 0.52 \times 100 / 1000$$

$$= 13.51 \text{ V}$$

The maximum voltage drop allowed is 12 V. To determine the size of cable that will be required to meet the voltage drop requirement, determine the value of R that will meet the requirement.

$$\begin{aligned}12 &= 1.732 \times 150 \times R \times 100 / 1000 \\R &= 11.4 \times 1000 / 1.732 \times 150 \times 100 \\&= 0.462 \text{ ohm/km}\end{aligned}$$

Referencing Table 1 of Section 2 above indicates that the cable size with a voltage drop of 0.462 ohm/km or less is 1/0 AWG (70 mm) cable with a resistance of 0.43 ohm/km.

Calculating the voltage drop for the 1/0 AWG (70mm) cable results in:

$$\begin{aligned}VD &= 1.732 \times L \times R \times I / 1000 \\&= 1.732 \times 150 \times 0.43 \times 100 / 1000 \\&= 11.17 \text{ V}\end{aligned}$$

The percentage voltage drop is:

$$\text{Percentage Voltage Drop} = 11.17 \times 100 / 400 = 2.79 \%$$

Therefore, in order to transmit a 3 phase current of 100A per phase over a length of 150 m, with a total voltage drop equal to or less than the maximum 11.4 volts, a 1/0 AWG (70 mm<sup>2</sup>) cable is needed.

This same procedure would be repeated for a feeder or branch circuit and the results added. The total voltage drop should not exceed 5%.

Computer programs can be used to calculate the voltage drop, however the Contractor shall provide a sample hand calculation for a single feeder, branch circuit or secondary service to identify the formula that is being used to calculate voltage drop.

## 6. Insulation Color Coding

Conductor Color Codes for Afghanistan Projects						
	Frequency	50Hz*		60Hz**		
	Phase	3Φ	1Φ	3Φ		1Φ
Conductor	Voltage	400/230V	220V	480/277V	208Y/120V	120/240V
A (left)		Brown	-	Brown	Black	-
B (middle)		Black	-	Orange	Red	-
C (right)		Grey	-	Yellow	Blue	-
Line		-	Brown	-	-	Black or Red
Neutral		Blue	Blue	White	White	White
Grounding Conductor (Earth GND)		Green with Yellow Stripe	Green with Yellow Stripe	Green with Yellow Stripe	Green with Yellow Stripe	Green with Yellow Stripe

\* Based on current version of IEC 60446

\*\* Based on 2008 NEC and UFGS 26 20 00 Aug 2008

Figure 3

The following sign/sticker shall be placed in all 400Y/230V panelboards:






IEC WIRE COLORS (60227) - 400Y/230V Systems				
(60227) رنگهای لاین				
Ground	Neutral	Phase 1	Phase 2	Phase 3
yel/grn	blue	brown	black	gray
زمین	خنثی	فاز 1	فاز 2	فاز 3
زرد/سبز	آبی	نصواری	سیاه	خاکستری
				

Figure 4

## 7. Generator Sizing and Derating

Generator sizing and derating calculations must be shown in the design analysis. These calculations should be based on UFC 3-540-04N “Diesel Electric Generating Plants” and manufacturer’s recommendations. Calculations at a minimum shall include: total system demand load that will be powered by the generator, elevation of the site, ambient temperature of the site, and percent difference between the total system demand load and derated generator capacity.

Approximate elevations and ambient temperatures for various sites in Afghanistan:

**Bagram area :**

Elevation – (approx.) 1490 M (4888 ft.)

Summer - 35 deg C (95 deg F) Dry Bulb (DB)

**Darualaman area:**

Elevation – (approx.) 1737 M (5700 ft.)

Summer – 34 deg C (93 deg F) Dry Bulb (DB)

**Farah area:**

Elevation – (approx.) 700 M (2297 ft.)

Summer – 41.1 deg C (106 deg F) Dry Bulb (DB)

**Gardez area:**

Elevation – (approx.) 2350 M (7710 ft.)

Summer – 29 deg C (84 deg F) Dry Bulb

**Ghazni/ Khair Kot area:**

Elevation – (approx.) 2183 M (7162 ft.)

Summer – 30.5 deg C (87 deg F) Dry Bulb (DB)

**Herat area:**

Elevation – (approx.) 964 M (3163 ft.)

Summer – 38 deg C (100 deg F) Dry Bulb (DB)

**Jalalabad area:**

Elevation – (approx.) 580 M (1903 ft.)

Summer – 39.6 deg C (103 deg F) Dry Bulb (DB)

**Kabul area:**

Elevation – (approx.) 1790 M (5876 ft.)

Summer – 34 deg C (93 deg F) Dry Bulb (DB)

**Kandahar area:**

Elevation – (approx.) 1010 M (3314 ft.)

Summer – 41 deg C (106 deg F) Dry Bulb (DB)

**Khost:**

Elevation - 1146 meters (3760 ft.)

Summer - 35.5 C (96° deg F) Dry Bulb (DB)

**Kunduz area:**

Elevation – (approx.) 432 M (1417 ft.)

Summer – 38.8 deg C (102 deg F) Dry Bulb (DB)

**Lashkar Gah (unconfirmed):**

Elevation - 773m (2536 ft.)

Summer - 44.4 C (112 deg F) Dry Bulb (DB)

**Mazar-e-Sharif area:**

Elevation – (approx.) 391 M (1284 ft.)

Summer – 37.8 deg C (100 deg F) Dry Bulb (DB)

**Pol-e-Charki area:**

Elevation – (approx.) 1830 M (6000 ft.)

Summer – 34 deg C (93 deg F) Dry Bulb (DB)

**Qalat:**

Elevation - 1565 meters (5135 ft.)

Summer - 37.7 C (100 deg F) Dry Bulb (DB)

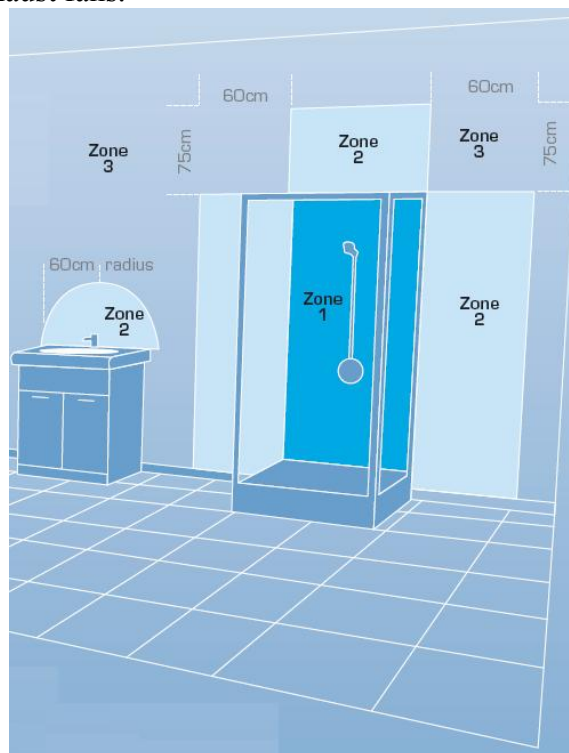
## 8. Wet Areas

**60Hz systems:** Receptacles shall be Ground Fault Circuit Interrupter (GFCI) protected IAW NEC 210.8(B). This may be provided either by breaker or GFCI receptacles. Locations requiring GFCI protection include, but are not limited to: bathrooms, kitchens, rooftops, outdoors, and within 1800mm of sink basins. GFCI devices shall have a trip rating of 4-6mA.

**50Hz systems:** Provide Residual Current Devices (RCD's) where required by BS7671. RCD's shall be used in conjunction with overcurrent protection, preferably in the same device (Residual Current Breaker with Overload, or RCBO). All circuits feeding locations with showers shall be protected by RCD's. These circuits include, but are not limited to: receptacles, lights, split-pack HVAC units, exhaust fans, unit heaters, water heaters, and exhaust fans. Current-using devices shall NOT be provided within Zone 1. Receptacles shall NOT be provided within 3 meters of the boundary of Zone 2. RCD's shall have a maximum trip rating of 30mA.

**ANSF projects:** Omit general-purpose receptacles from all wet areas. Remove receptacles from wet areas if shown on Site-adapt drawings.

**U.S./NATO Occupied Facilities:** All branch circuits with latrine/shower/shave (LSS) units shall be protected by either GFCI's or RCD's. These circuits include, but are not limited to: receptacles, lights, split-pack HVAC units, exhaust fans, unit heaters, water heaters, and exhaust fans.

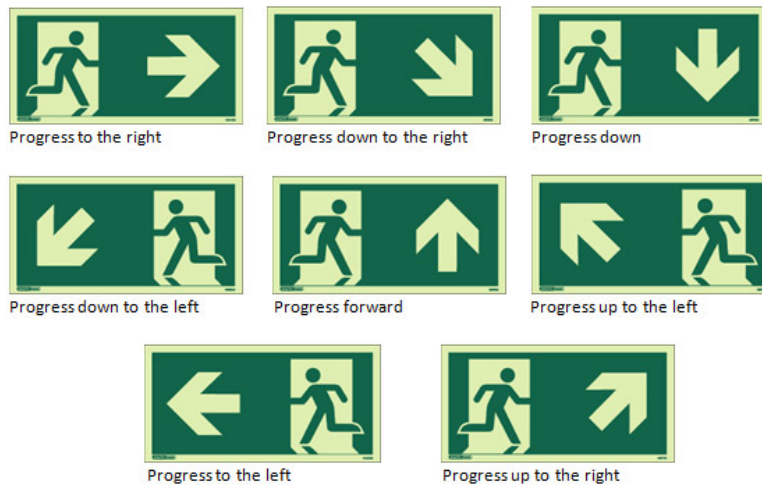


**Figure 5**






## 9. Exit Signs

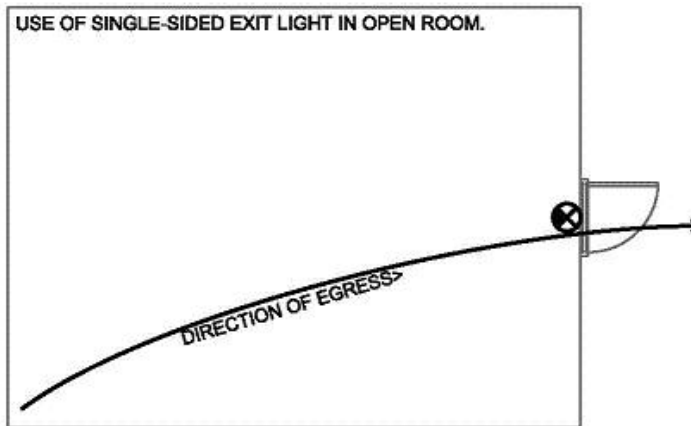
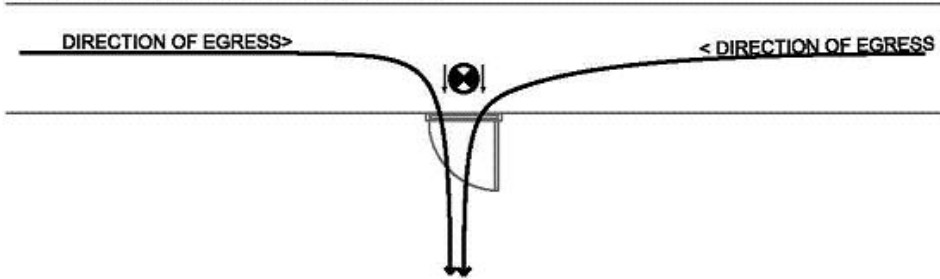
Illuminated exit signs shall be shown on the plans to mark exits and access to exits per NFPA 101 7.10. Exit signs are not needed where the exit or exit access is obvious. Exit sign symbols shown on electrical plans shall clearly show which faces are illuminated, how the exit sign is oriented with respect to the exit, and the direction of chevron-type indicators. Illuminated exit signs shall be green “Running Man” style, in accordance with ISO 7010 or CAN/ULC-S572, and ISO 3864-1.



*Figure 6a*

- SHADED SIDES OF SYMBOL ARE THE FACES OF THE EXIT SIGN
-  DOUBLE-SIDED EXIT LIGHT
  -  SINGLE-SIDED EXIT LIGHT
  -  DOUBLE-SIDED EXIT LIGHT with directional chevrons

USE OF DOUBLE-SIDED EXIT LIGHT IN HALLWAY,  
WHERE EXIT IS PERPENDICULAR TO HALLWAY.



FOR ADDITIONAL INFORMATION SEE NFPA 101 SECTION 7.10

*Figure 6b*

## Appendix A: Generator Grounding Schematics

Page	Future Utility Power?	Generators Running Simultaneously?	Switching Mechanism between Gensets	Switching Mechanism between Gensets/Utility
1	YES	YES	Synchronizer	4-Pole ATS
2	YES	YES	Synchronizer	3-Pole ATS
3	YES	NO	4-Pole ATS	4-Pole ATS
4	YES	NO	3-Pole ATS	3-Pole ATS
5	YES	NO	3-Pole ATS	4-Pole ATS
6	YES	NO	4-Pole ATS	3-Pole ATS
7	NO	YES	Synchronizer	-
8	NO	NO	3-Pole ATS	-
9	NO	NO	4-Pole ATS	-

Although Afghanistan’s electrical grid is developing, most projects currently constructed by the U.S. Army Corps of Engineers in Afghanistan are powered by diesel generator sets. The grounding systems related to these generators are not intuitive. It is imperative to install these systems correctly to stabilize voltage, establish an effective ground-fault current path, and facilitate breaker operation.

The USACE Afghanistan Engineer District – North Engineering Office has reviewed numerous projects that do not show electrical grounding systems adequately. The following schematics serve as a baseline for the design and construction of grounding systems for diesel-generator-powered construction projects in Afghanistan. Questions about the schematics can be directed to USACE AED-North Engineering.

**GENERATOR  
GROUNDING  
SCHEMATICS**

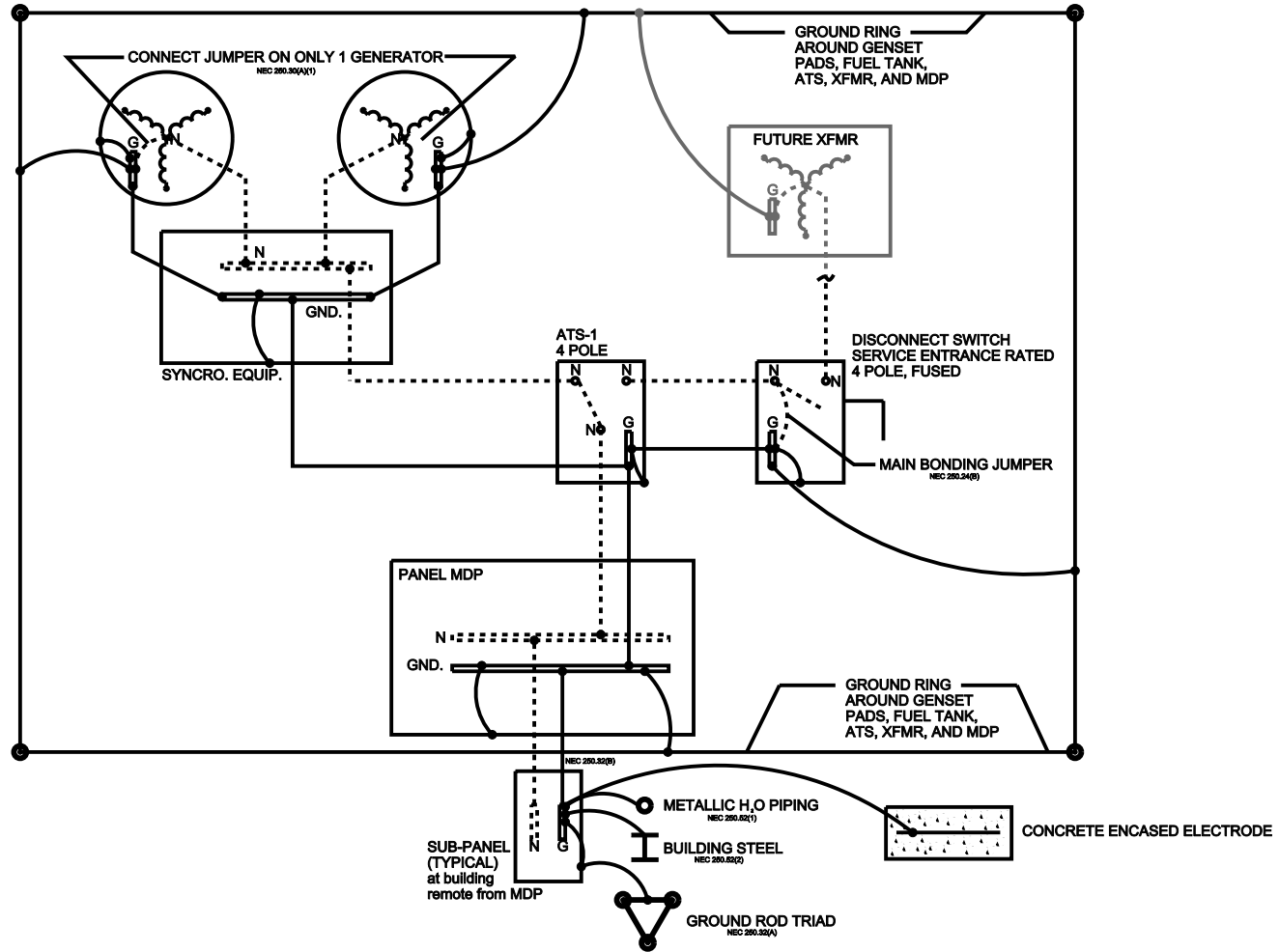
# INDEX

<b>Page</b>	<b>Future Utility Power?</b>	<b>Generators Running Simultaneously?</b>	<b>Switching Mechanism between Gensets</b>	<b>Switching Mechanism between Gensets/Utility</b>
1	YES	YES	Synchronizer	4-Pole ATS
2	YES	YES	Synchronizer	3-Pole ATS
3	YES	NO	4-Pole ATS	4-Pole ATS
4	YES	NO	3-Pole ATS	3-Pole ATS
5	YES	NO	3-Pole ATS	4-Pole ATS
6	YES	NO	4-Pole ATS	3-Pole ATS
7	NO	YES	Synchronizer	-
8	NO	NO	3-Pole ATS	-
9	NO	NO	4-Pole ATS	-

Although Afghanistan's electrical grid is developing, most projects currently constructed by the U.S. Army Corps of Engineers in Afghanistan are powered by diesel generator sets. The grounding systems related to these generators are not intuitive. It is imperative to install these systems correctly to stabilize voltage, establish an effective ground-fault current path, and facilitate breaker operation.

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# 1

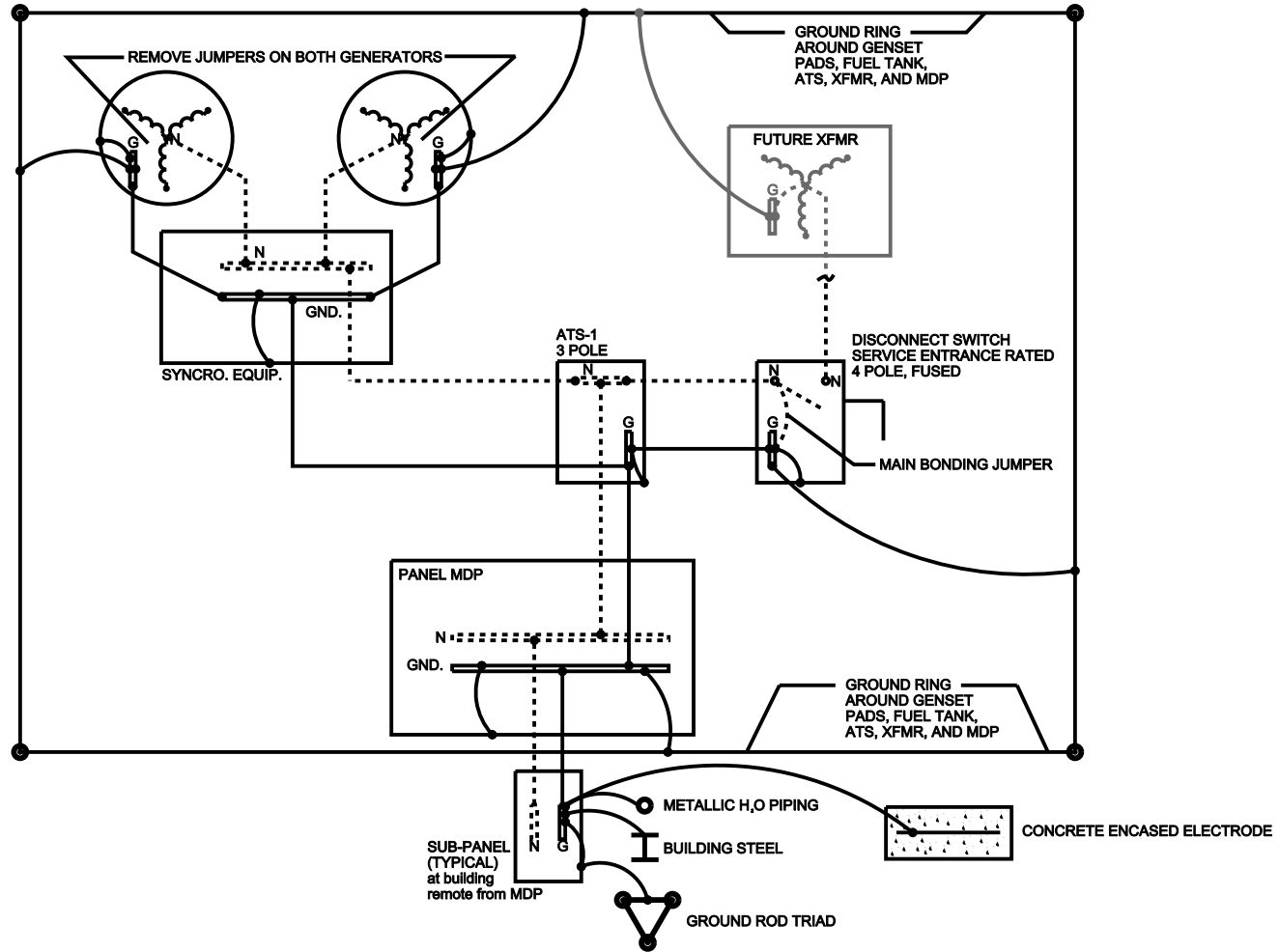


## GENSET GROUNDING DIAGRAM

GENERATORS RUNNING SIMULTANEOUSLY  
(SYNCHRONIZED ON COMMON BUS)  
4-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS

# 2

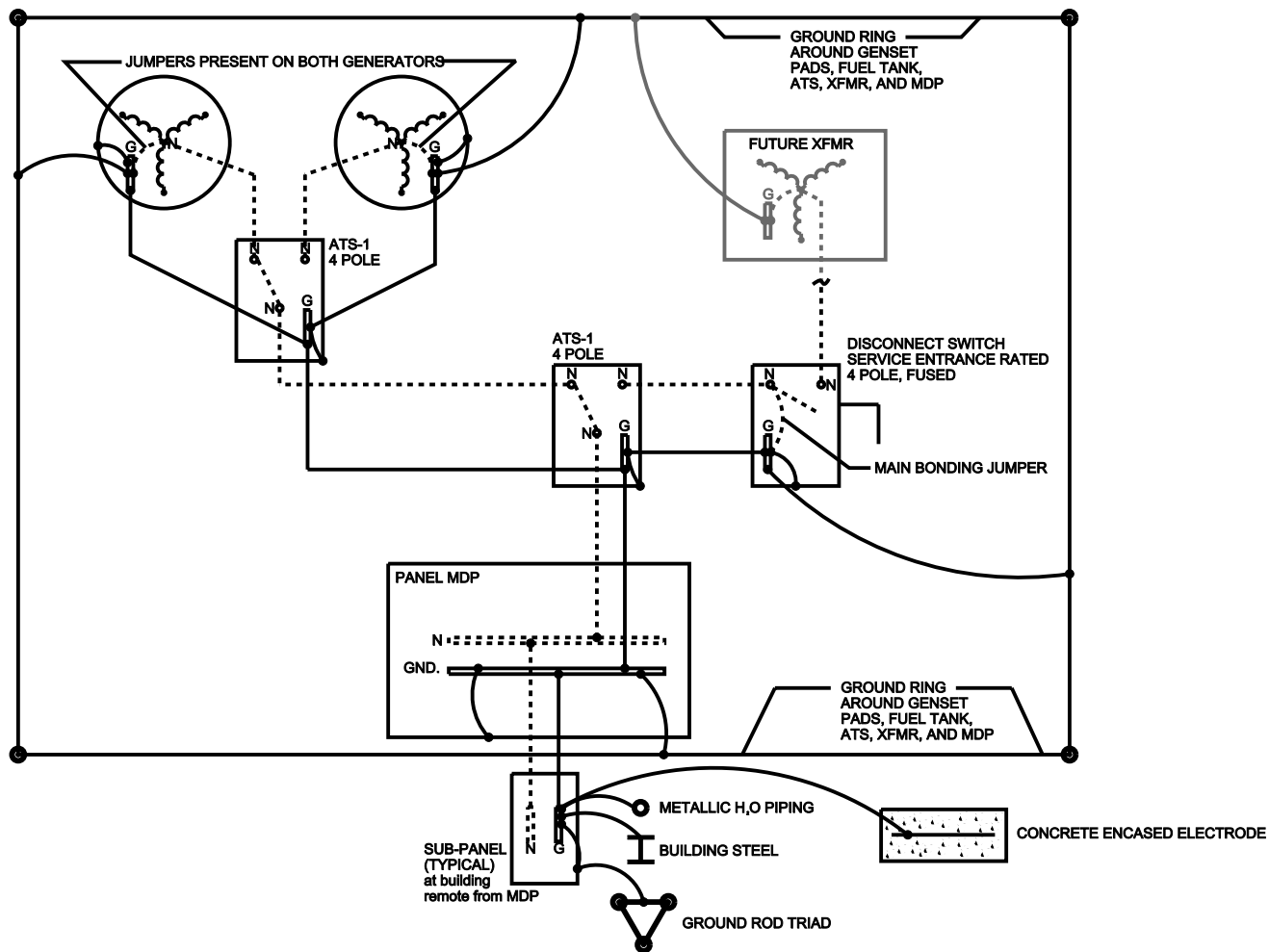


## GENSET GROUNDING DIAGRAM

..... NEUTRAL BUS OR CONDUCTOR  
 ——— GND BUS, CONDUCTOR, PANEL OR FRAME  
 ● GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG  
 PHASE CONDUCTORS AND BREAKERS NOT SHOWN  
 CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC  
 CONDUCTOR SIZES OR ANY CLARIFICATIONS

GENERATORS RUNNING SIMULTANEOUSLY  
 (SYNCHRONIZED ON COMMON BUS)  
 3-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

# 3



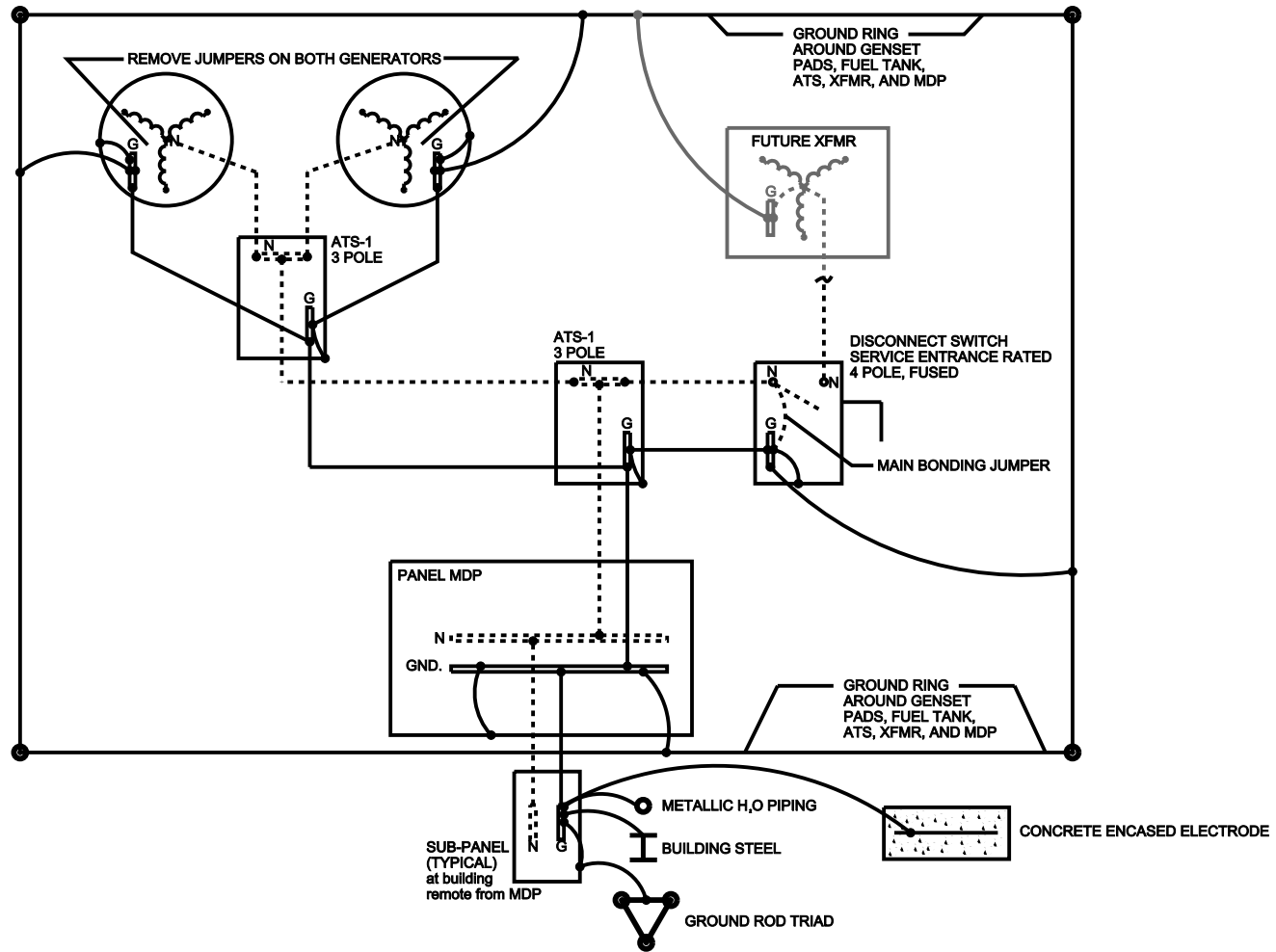
## GENSET GROUNDING DIAGRAM

ONE GENERATOR RUNNING AT A TIME  
(SWITCHED BETWEEN 4-POLE ATS)  
4-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS



# 4

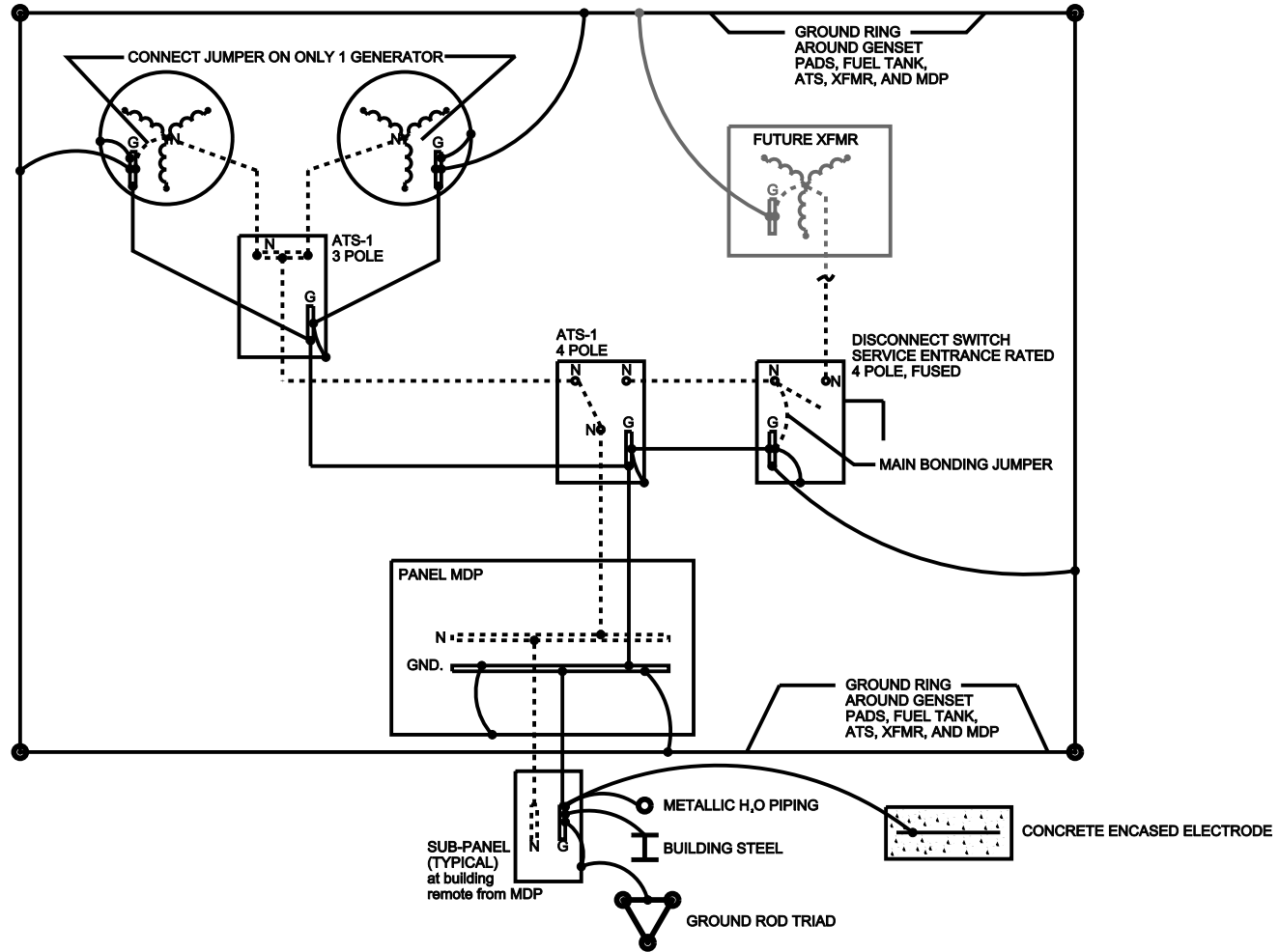


## GENSET GROUNDING DIAGRAM

ONE GENERATOR RUNNING AT A TIME  
(SWITCHED BETWEEN 3-POLE ATS)  
3-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS

# 5

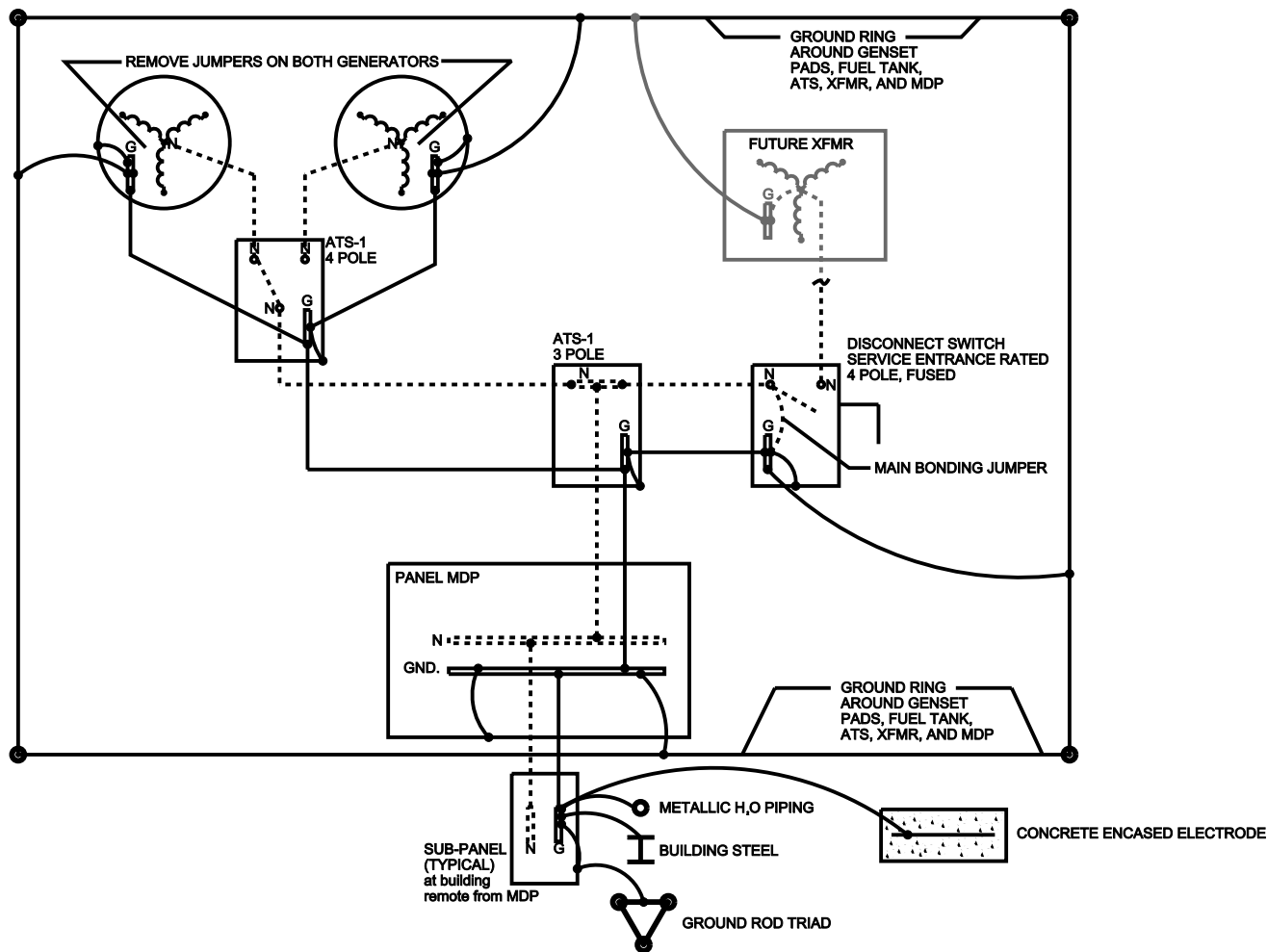


## GENSET GROUNDING DIAGRAM

..... NEUTRAL BUS OR CONDUCTOR  
 ——— GND BUS, CONDUCTOR, PANEL OR FRAME  
 ● GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG  
 PHASE CONDUCTORS AND BREAKERS NOT SHOWN  
 CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC  
 CONDUCTOR SIZES OR ANY CLARIFICATIONS

ONE GENERATOR RUNNING AT A TIME  
 (SWITCHED BETWEEN 3-POLE ATS)  
 4-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

# 6

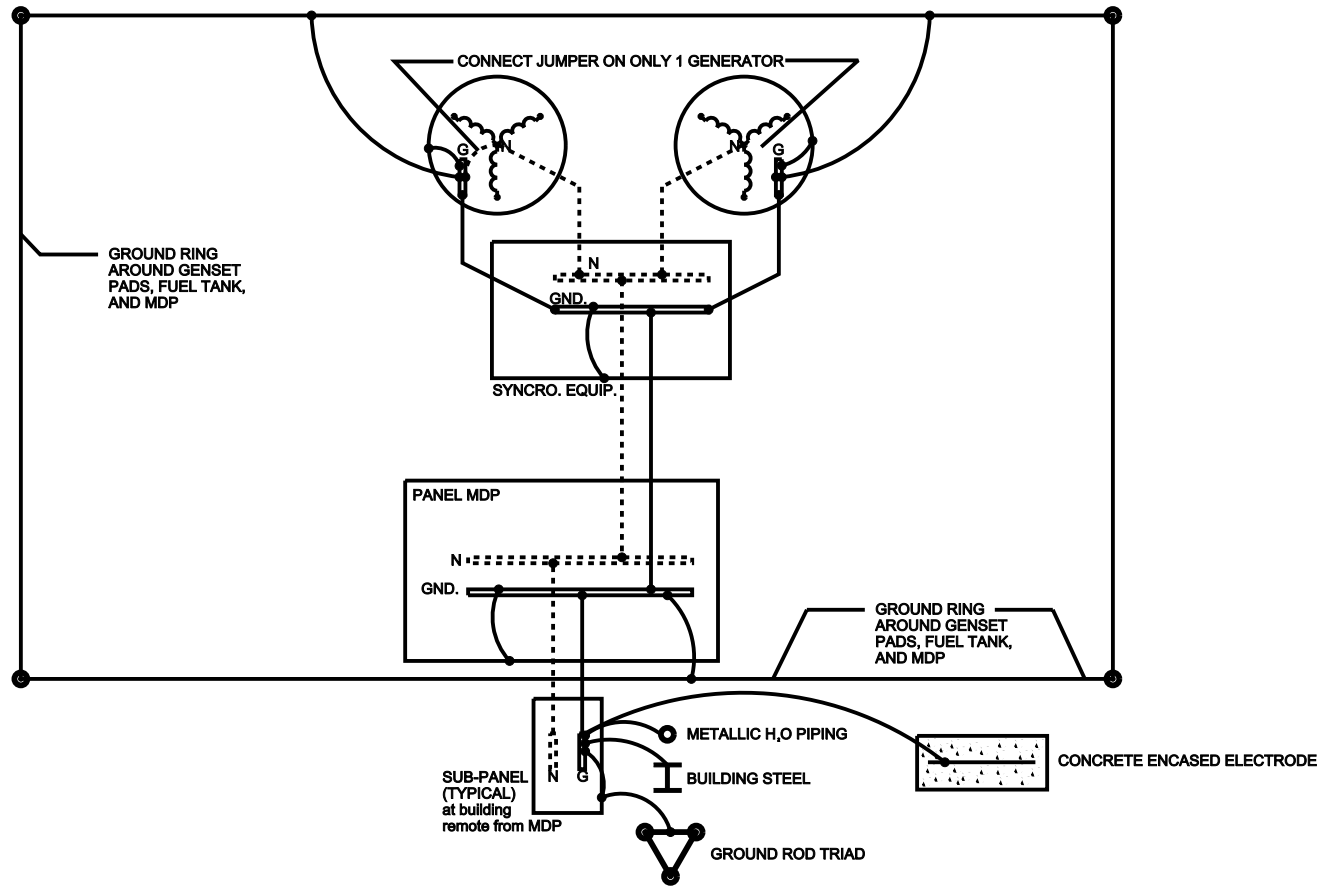


## GENSET GROUNDING DIAGRAM

ONE GENERATOR RUNNING AT A TIME  
(SWITCHED BETWEEN 4-POLE ATS)  
3-POLE ATS BETWEEN GENERATORS AND UTILITY POWER

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 10M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS

# 7

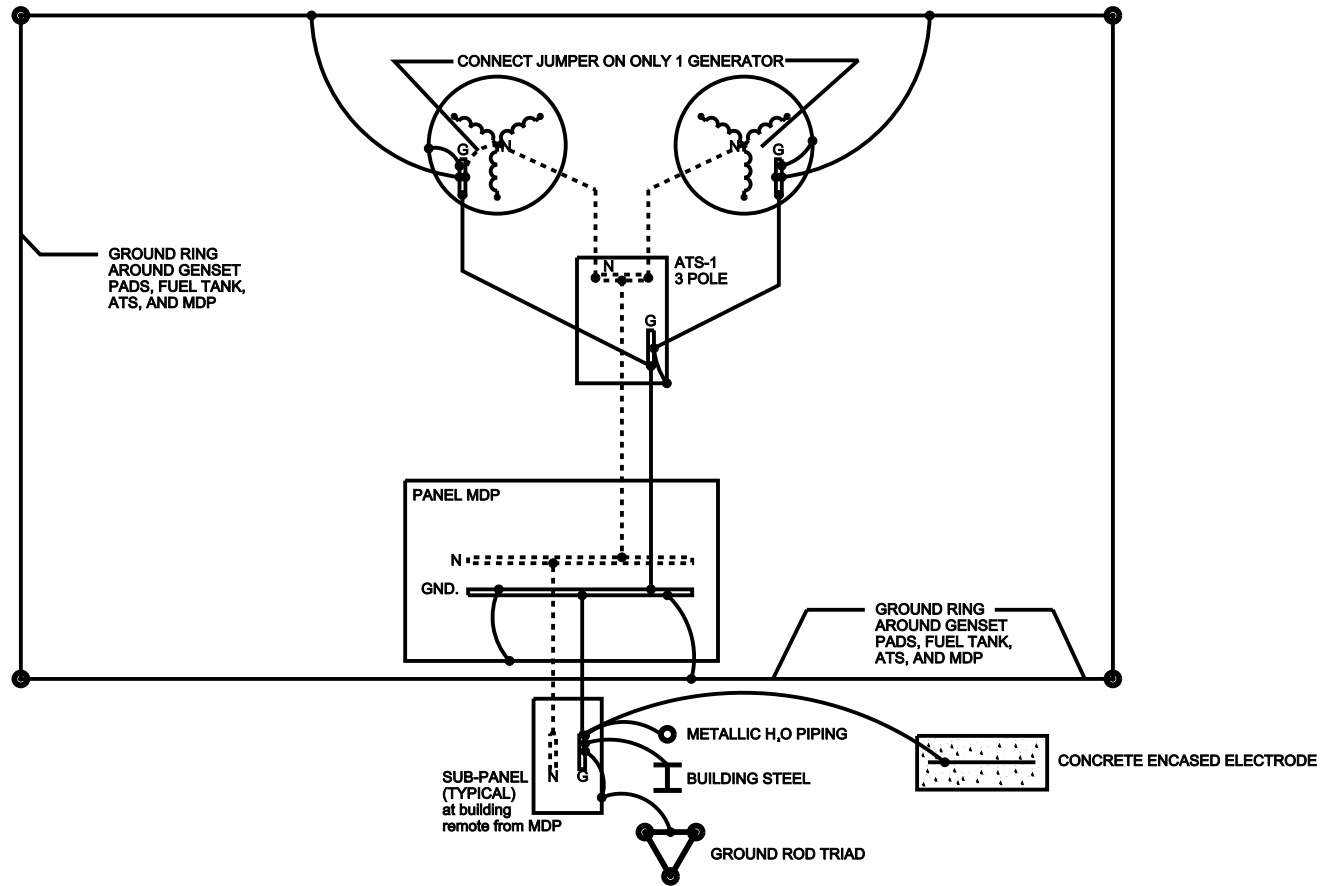


## GENSET GROUNDING DIAGRAM

GENERATORS RUNNING SIMULTANEOUSLY  
(SYNCHRONIZED ON COMMON BUS)

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS

# 8

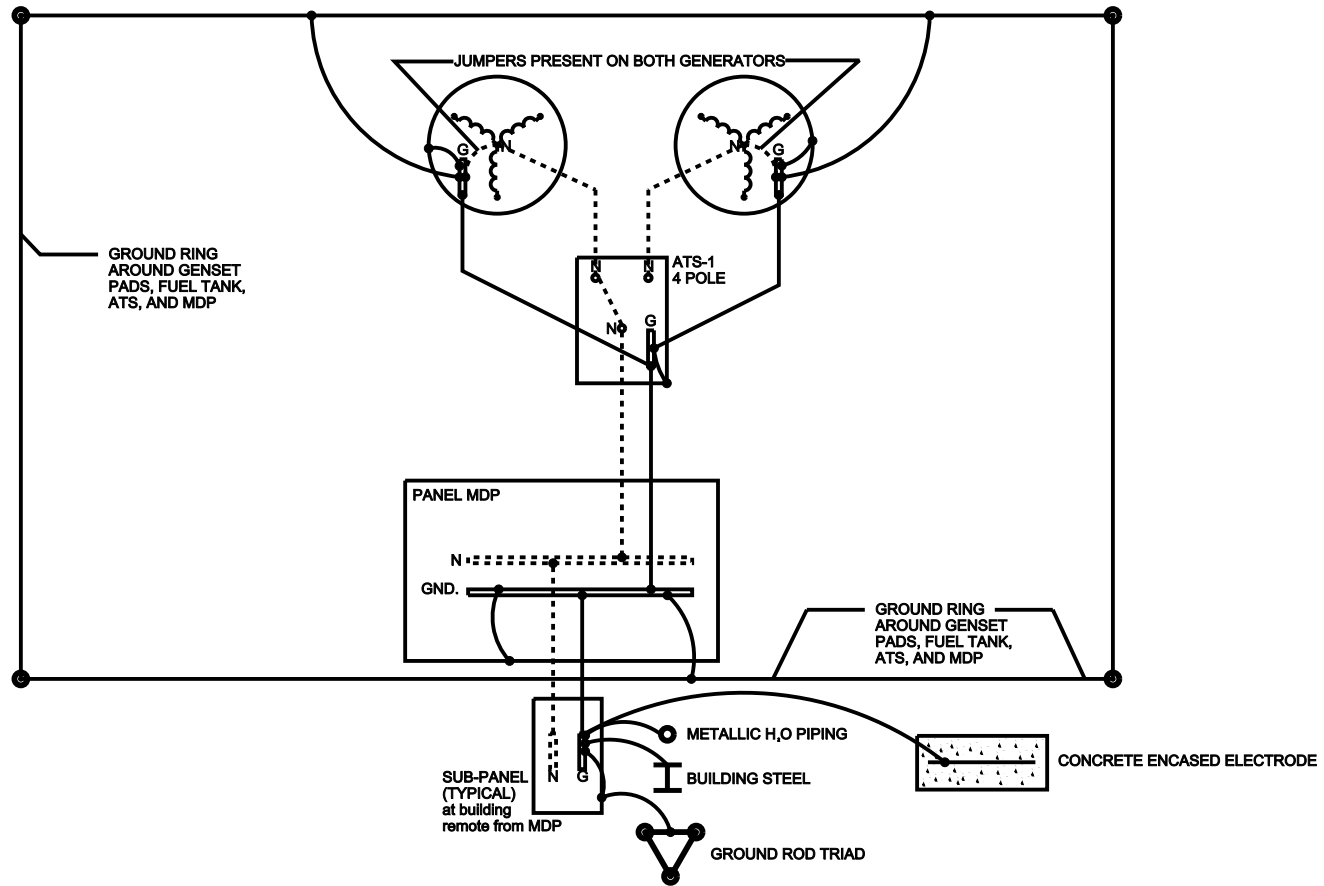


## GENSET GROUNDING DIAGRAM

ONE GENERATOR RUNNING AT A TIME  
(SWITCHED BY 3-POLE ATS)

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS

# 9



## GENSET GROUNDING DIAGRAM

ONE GENERATOR RUNNING AT A TIME  
(SWITCHED BY 4-POLE ATS)

- NEUTRAL BUS OR CONDUCTOR
- GND BUS, CONDUCTOR, PANEL OR FRAME
- ⊙ GROUND ROD. CU-CLAD STEEL, 20mm DIAMETER, 3M LONG
- PHASE CONDUCTORS AND BREAKERS NOT SHOWN
- CONTACT AED-N (TAN) ENGINEERING FOR SPECIFIC CONDUCTOR SIZES OR ANY CLARIFICATIONS