Electrical Single-Line Diagram Exercise

Draw an Electrical Single-Line Diagram to depict the following:

Overall Diagram Description: A Utility Company transformer feeding a Main Distribution Panelboard (MDP). The MDP will feed the following: a branch circuit panelboard, a step-down transformer serving a branch circuit panelboard, and a branch circuit serving a motor. The MDP will also have a spare circuit breaker.

Suggested Workflow: Draw a rough sketch single-line of the required major elements listed above to determine the diagram layout. Once diagram layout is determined, redraw the working diagram to depict the specific information below, with labels, sizing information, etc. Refer to Single-Line Symbols reference information included in this handout.

- For Incoming Power Delivery: Indicate a Utility Company transformer and label as *"Utility Co. Transformer, 300kVA (Estimated Size), 12.47kV, 3-PH, 3-W PRI and 480Y/277V, 3-PH, 4-W SEC"*.

- For the MDP: Indicate a 400 Amp, 480Y/277V, 3-Phase, 4-Wire Main Distribution Panelboard with 400 Amp Main Circuit Breaker and label MDP as *"Main Distribution Panelboard MDP, 400 Amp 480Y/277V, 3-Phase, 4-Wire"*.
    - Indicate a feeder (conductors and conduit) from the Utility Company Transformer to the MDP and size Phase and Neutral conductors and conduit accordingly for the size of the Main Circuit Breaker. **(Note: Ground conductor is separate from feeder for services and is not included in this exercise).** Refer to Conductor and Conduit Sizing reference information included in this handout.

- Indicate a branch circuit panelboard, fed from MDP:
    - Indicate a 100 Amp branch circuit breaker in MDP to feed branch circuit panelboard.
    - Indicate branch circuit panelboard "HP": A 100 Amp 480Y/277V, 3-Phase, 4-Wire Main Lug Only (no Main Circuit Breaker) branch circuit panelboard. Label branch circuit panelboard as *"HP, 480Y/277V, 3-PH, 4-W, 100 A, MLO"*.
    - Indicate feeder conductors/conduit feed this panelboard and size accordingly for the 100 Amp circuit (<u>feeder conductors will consist of 3 Phase conductors, 1 Neutral conductor and 1 Equipment Ground conductor</u>). Refer to Conductor and Conduit Sizing reference information included in this handout.

- Indicate a 45kVA step-down transformer serving a branch circuit panelboard, fed from MDP:
    - Indicate transformer "T-LP" and label as *"T-LP, 45kVA, 480V, 3-PH, 3-W PRI and 208Y/120V, 3-PH, 4-W SEC"*.
    - Size and indicate circuit breaker in MDP feeding transformer (Primary Overcurrent Protection). Refer to Transformer Primary and Secondary Overcurrent Protection Sizing reference information included in this handout.
        - Size and indicate primary feeder conductors/conduit serving this transformer (<u>primary feeder conductors will consist of 3 Phase conductors and 1 Equipment Ground conductor</u>). Refer to Conductor and Conduit Sizing reference information included in this handout.
    - Indicate a branch circuit panelboard, fed from Transformer "T-LP":
        - Indicate branch circuit panelboard "LP": A 225 Amp 208Y/120V, 3-Phase, 4-Wire Main Circuit Breaker branch circuit panelboard. Label branch circuit panelboard as *"LP, 208Y/120V, 3-PH, 4-W, 225A, MCB"*.
        - Size and indicate Main Circuit Breaker in Panelboard "LP" (size of main circuit breaker in panelboard in this application is considered as transformer

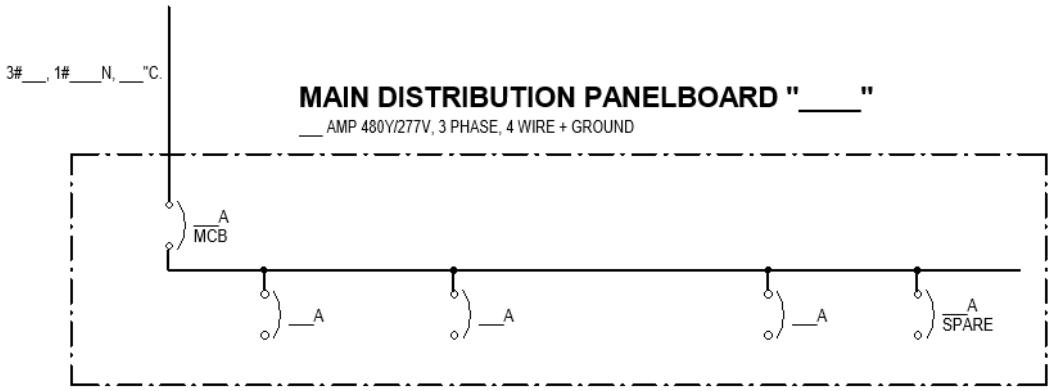
Secondary Overcurrent Protection). Refer to Transformer Primary and Secondary Overcurrent Protection Sizing reference information included in this handout. ***(Hint: The Main Circuit Breaker sized for proper secondary overcurrent protection for this application will be smaller than the 225 Amperage Rating of Panelboard "LP")***.

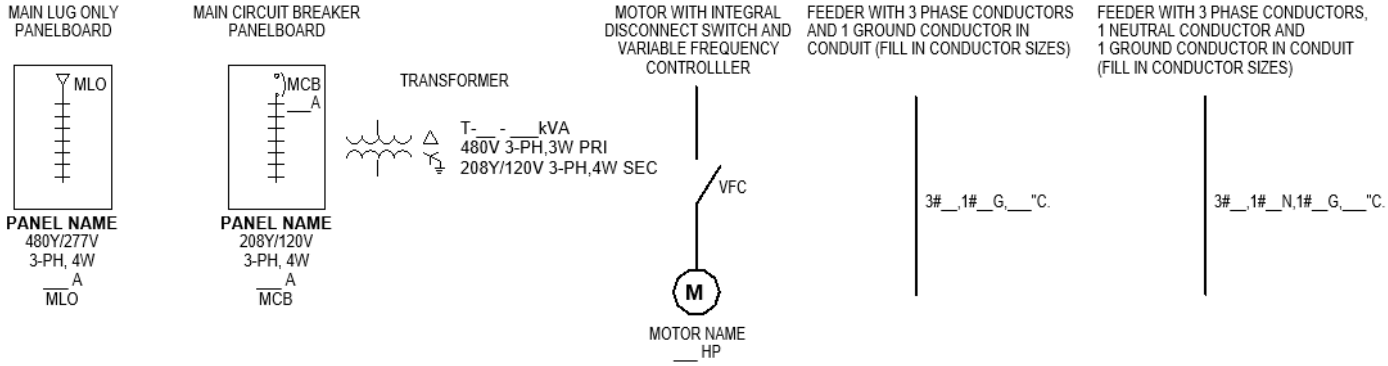
- Size and indicate secondary feeder conductors/conduit serving Panelboard "LP" (secondary feeder conductors will consist of 3 Phase conductors, 1 Neutral conductor and 1 Ground conductor). Refer to Conductor and Conduit Sizing reference information included in this handout. **(Note: The Ground conductor in a secondary feeder is considered a Grounding Electrode Conductor and is sized differently than other Grounding conductors you will size in this exercise. Refer to Transformer Secondary Ground Sizing reference information included in this handout).**

- Indicate motor circuit serving a 15 Horsepower Air Handling Unit (AHU) with integral disconnect switch and Variable Frequency Controller (VFC), fed from MDP:
  - Indicate a motor for AHU and label as *"AHU, 15 HP"* and indicate VFC with a disconnect switch symbol and note as *"VFC"*.
  - Size and indicate circuit breaker in MDP feeding AHU. Refer to Motor Overcurrent Protection Sizing reference information included in this handout.
  - Size and indicate feeder conductors/conduit serving this AHU (feeder conductors will consist of 3 Phase conductors and 1 Equipment Ground conductor). Refer to Conductor and Conduit Sizing reference information included in this handout.

- Indicate a 225 Amp Spare circuit breaker in MDP.

REFERENCE INFORMATION - ELECTRICAL SINGLE-LINE DIAGRAMS SYMBOLS





REFERENCE INFORMATION – CONDUCTOR SIZING

PHASE/NEUTRAL CONDUCTOR SIZING – 2023 NEC 310.16, TABLE 310.16

Size AWG or kcmil	Temperature Rating of Conductor			
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	T
	COPPER			A
18**	—	—	14	
16**	—	—	18	
14**	15	20	25	
12**	20	25	30	
10**	30	35	40	
8	40	50	55	
6	55	65	75	
4	70	85	95	
3	85	100	115	
2	95	115	130	
1	110	130	145	
1/0	125	150	170	
2/0	145	175	195	
3/0	165	200	225	
4/0	195	230	260	
250	215	255	290	
300	240	285	320	
350	260	310	350	
400	280	335	380	
500	320	380	430	
600	350	420	475	

-Size per Amperage rating of applicable circuit breaker.
-Conductors sizes less than 1 AWG – Use 60 Deg. C (140 Deg. F) Column (per NEC 110/14(c)(1)(a)(1).
-Conductors sizes 1/0 AWG and larger – Use 75 Deg. C (1167 Deg. F) Column.

Note: Conductor sizing in this exercise is based on the Amperage rating of the connected overcurrent protection device (circuit breaker). In some cases, the NEC allows for conductor to be sized smaller than the rating of the overcurrent protection device.

REFERENCE INFORMATION – GROUNDING CONDUCTOR SIZING

EQUIPMENT GROUNDING CONDUCTOR SIZING – 2023 NEC 250.122, TABLE 250.122

TABLE 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

TRANSFORMER SECONDARY GROUNDING CONDUCTOR SIZING – 2023 NEC 250.66, TABLE 250.66

TABLE 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

REFERENCE INFORMATION – CONDUIT SIZING

CONDUIT SIZING – RIGID METALLIC CONDUIT (RMC) – 2023 NEC, ANNEX C, TABLE C.10

TABLE C.10 Continued

Type	Conductor Size (AWG/kcmil)	Trade Size (Metric Designator) ¾ (12)	½ (16)	¾ (21)	1 (27)	1¼ (35)	1½ (41)	2 (53)	2½ (63)	3 (78)	3½ (91)	4 (103)	5 (129)	6 (155)
	250	—	0	0	0	1	1	2	3	5	7	9	15	22
	300	—	0	0	0	1	1	1	3	5	6	8	13	19
	350	—	0	0	0	1	1	1	2	4	6	7	12	17
	400	—	0	0	0	1	1	1	2	4	5	7	10	15
	500	—	0	0	0	1	1	1	1	3	4	5	9	13
	600	—	0	0	0	0	1	1	1	2	3	4	7	10
	700	—	0	0	0	0	1	1	1	2	3	4	6	9
	750	—	0	0	0	0	0	1	1	1	3	4	6	8
	800	—	0	0	0	0	0	1	1	1	3	3	6	8
	900	—	0	0	0	0	0	1	1	1	2	3	5	7
	1000	—	0	0	0	0	0	1	1	1	2	3	5	7
	1250	—	0	0	0	0	0	1	1	1	1	2	4	5
	1500	—	0	0	0	0	0	0	1	1	1	1	3	4
	1750	—	0	0	0	0	0	0	1	1	1	1	3	4
	2000	—	0	0	0	0	0	0	0	1	1	1	2	3
THHN, THWN, THWN-2	14	—	9	17	28	51	70	118	170	265	358	464	736	1055
	12	—	6	12	20	37	51	86	124	193	261	338	537	770
	10	—	4	7	13	23	32	54	78	122	164	213	338	485
	8	—	2	4	7	13	18	31	45	70	95	123	195	279
	6	—	1	3	5	9	13	22	32	51	68	89	141	202
	4	—	1	1	3	6	8	14	20	31	42	54	86	124
	3	—	1	1	3	5	7	12	17	26	35	46	73	105
	2	—	1	1	2	4	6	10	14	22	30	39	61	88
	1	—	0	1	1	3	4	7	10	16	22	29	45	65
	1/0	—	0	1	1	2	3	6	9	14	18	24	38	55
	2/0	—	0	1	1	1	3	5	7	11	15	20	32	46
	3/0	—	0	1	1	1	2	4	6	9	13	17	26	38
	4/0	—	0	0	1	1	1	3	5	8	10	14	22	31
	250	—	0	0	1	1	1	3	4	6	8	11	18	25
	300	—	0	0	0	1	1	2	3	5	7	9	15	22
	350	—	0	0	0	1	1	1	3	5	6	8	13	19
	400	—	0	0	0	1	1	1	3	4	6	7	12	17
	500	—	0	0	0	1	1	1	2	3	5	6	10	14
	600	—	0	0	0	0	1	1	1	3	4	5	8	12
	700	—	0	0	0	0	1	1	1	2	3	4	7	10
	750	—	0	0	0	0	1	1	1	2	3	4	7	9
	800	—	0	0	0	0	1	1	1	2	3	4	6	9
	900	—	0	0	0	0	0	1	1	1	3	3	6	8
	1000	—	0	0	0	0	0	1	1	1	2	3	5	7

Note: Count the typically small Ground conductor for a feeder as an additional conductor of the same size as the phase conductors in the conduit when sizing conduit.

REFERENCE INFORMATION – TRANSFORMER PRIMARY AND SECONDARY OVERCURRENT PROTECTION (CIRCUIT BREAKER) SIZING

2023 NEC 450.3, TABLE 450.3(B)

TABLE 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers 1000 Volts and Less (as a Percentage of Transformer-Rated Current)

	Primary Protection			Secondary Protection (See Note 2.)	
Protection Method	Currents of 9 Amperes or More	Currents Less Than 9 Amperes	Currents Less Than 2 Amperes	Currents of 9 Amperes or More	Currents Less Than 9 Amperes
Primary only protection	125% (See Note 1.)	167%	300%	Not required	Not required
Primary and secondary protection	250% (See Note 3.)	250% (See Note 3.)	250% (See Note 3.)	125% (See Note 1.)	167%

Notes:
1. Where 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.

Calculation Notes:

Calculate primary and secondary overcurrent protection for Transformer T-LP using the following Transformer Rated Currents: Primary=54.2 Amps Secondary=125 Amps.

Table indicates allowable Maximum Rating for sizing of circuit breaker at maximum allowable percentages indicated. In this exercise, use a more conservative approach and use 125% in your calculation for the primary circuit breaker. For the secondary circuit breaker, us a more conservative approach by selecting the next lower standard size circuit breaker than the value calculated. This approach will provide better protection of the transformer in an overload condition on the transformer secondary.

2023 NEC 240.6 – (Reference for Note 1 in Table 450.3(B) above).

240.6 Standard Ampere Ratings.

(A) Fuses and Fixed-Trip Circuit Breakers. The standard ampere ratings for fuses and inverse time circuit breakers shall be considered as shown in Table 240.6(A). Additional standard ampere ratings for fuses shall be 1, 3, 6, 10, and 601. The use of fuses and inverse time circuit breakers with nonstandard ampere ratings shall be permitted.

TABLE 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers

Standard Ampere Ratings				
15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

REFERENCE INFORMATION –
MOTOR OVERCURRENT PROTECTION (CIRCUIT BREAKER) SIZING

MOTOR BRANCH-CIRCUIT SHORT-CIRCUIT AND GROUND-FAULT PROTECTION (CIRCUIT BREAKER) – 2023 NEC 430.52, TABLE 430.50

TABLE 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

	Percentage of Full-Load Current			
Type of Motor	Nontime Delay Fuse[1]	Dual Element (Time-Delay) Fuse[1]	Instantaneous Trip Breaker	Inverse Time Breaker[2]
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor	300	175	800	250
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1100	250
Synchronous[3]	300	175	800	250
Wound-rotor	150	150	800	150
DC (constant voltage)	150	150	250	150

Note: Table indicates maximum allowable Percentage of motor Full-Load Current for sizing of circuit breaker at maximum allowable rating. In this exercise, use a more conservative approach and use 175% in your calculation.

If the size of the motor circuit breaker as calculated at 175% of motor Full-Load Current does not correspond to a standard rating of a circuit breaker, select a higher rating that does not exceed the next higher standard rating. Refer to Table 240.6(A) on the previous page.