AMERICAN RIVER COLLEGE

Electrical Design

Lesson Plan

- PV Markets and Applications – any questions?
- NABCEP Learning Objectives: Electric Design

NABCEP Learning Objectives

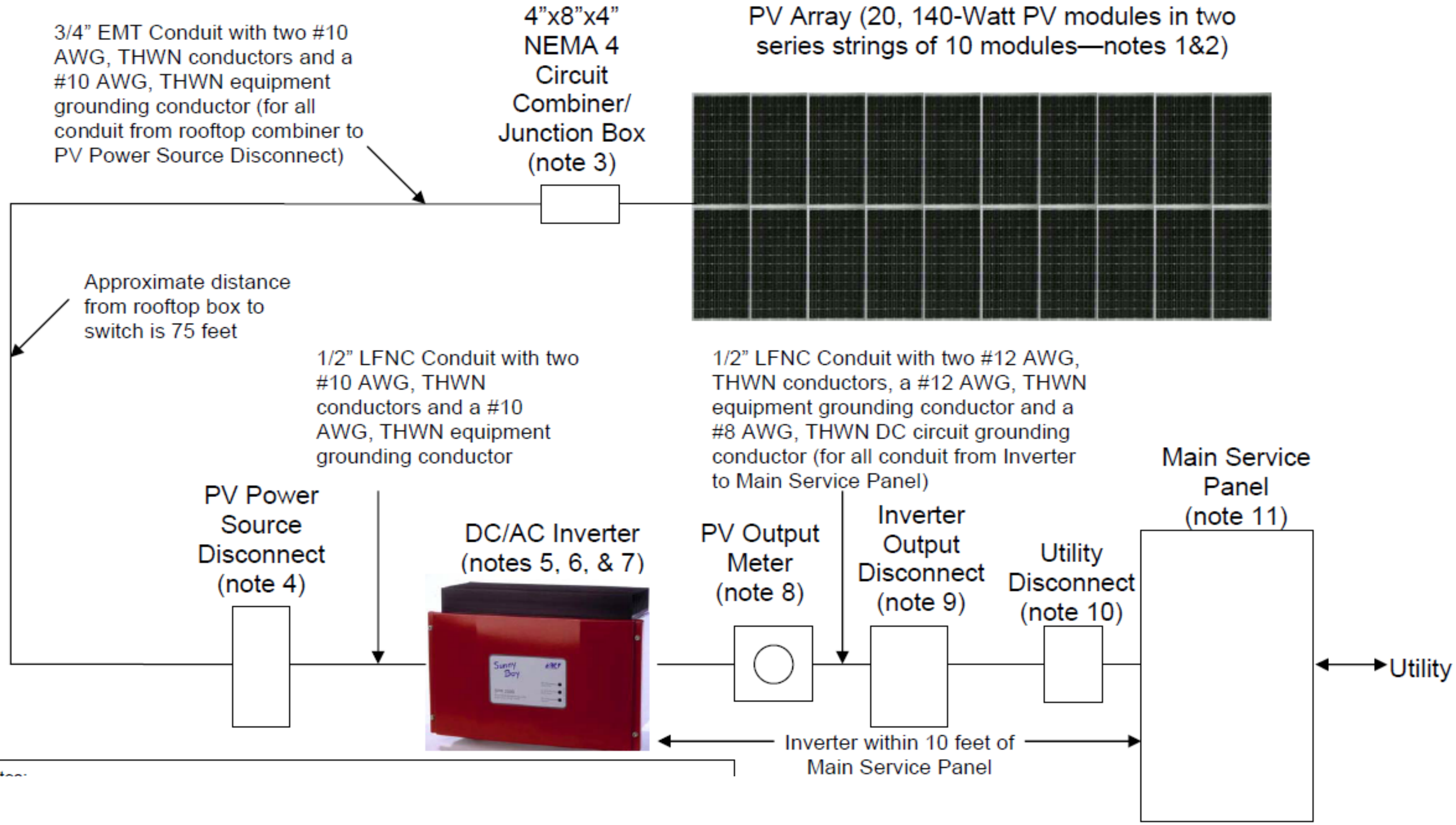
Category	Course Time By %	Exam Items	Level of Testing	
1. PV Markets & Applications	5%	3	Comprehension	✓
2. Safety Basics	5%	3	Comprehension Application	✓
3. Electricity Basics	10%	6	Comprehension Problem Solving	✓
4. Solar Energy Fundamentals	10%	6	Comprehension Application Problem Solving	✓
5. PV Module Fundamentals	10%	6	Comprehension Application Problem Solving	✓
6. System Components	15%	9	Comprehension Application Problem Solving	✓
7. PV System Sizing Principles	10%	6	Application Problem Solving Design	✓
8. PV System Electrical Design	15%	9	Application Problem Solving Design	
9. PV System Mechanical Design	10%	6	Application Problem Solving Design	
10. Performance Analysis, Maintenance and Troubleshooting	10%	6	Analysis Problem Solving	
Totals	100%	60		

NABCEP Learning Objectives

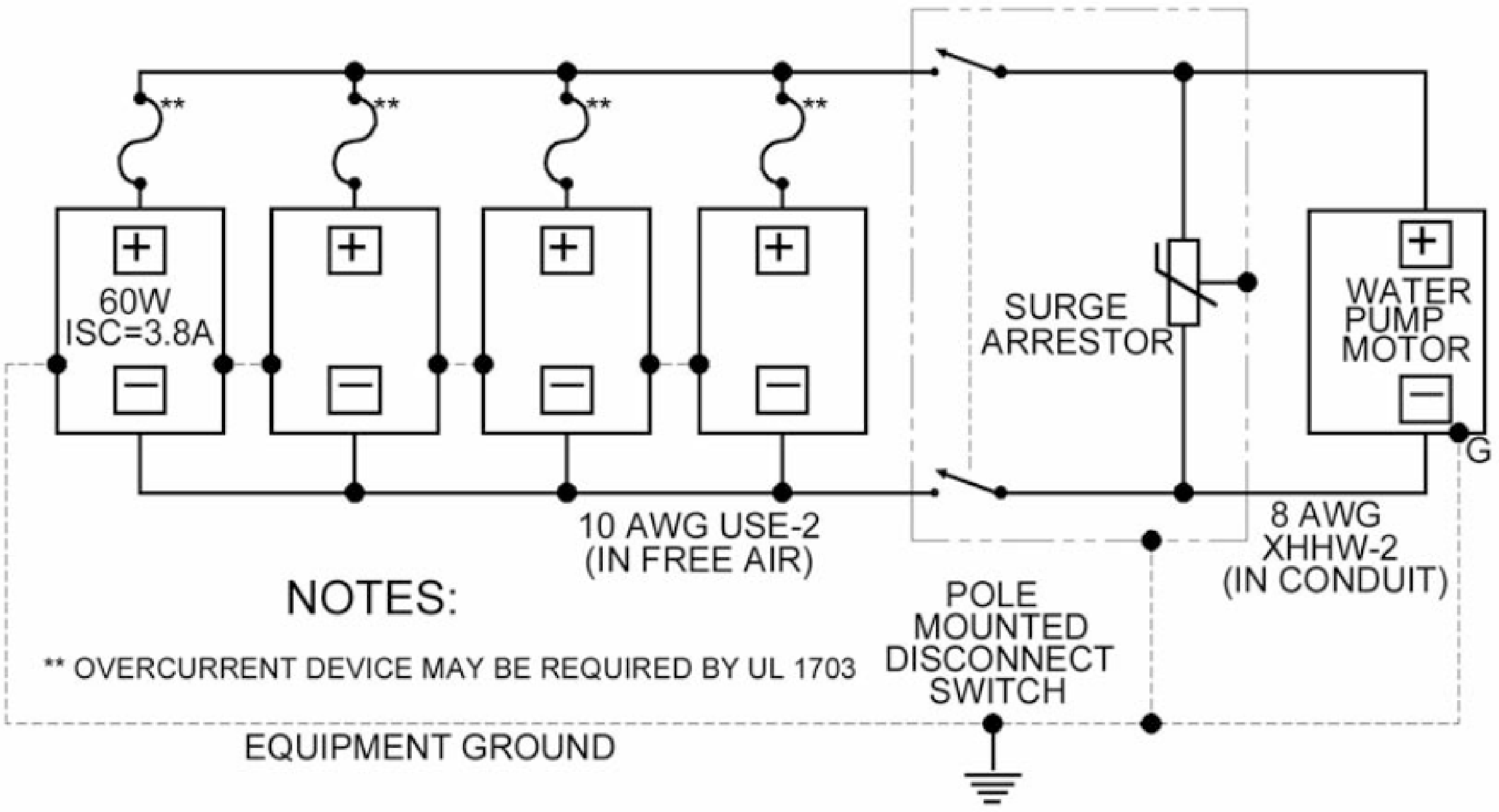
Energy Instructor
www.energyinstructor.info

8.	PV System Electrical Design *Suggested Percentage Time Allotment: 15%*	Learning Priority
8.1	Draw and prepare simple one-line electrical diagrams for interactive and stand-alone PV systems showing all major components and subsystems, and indicate the locations of the PV source and output circuits, inverter input and output circuits, charge controller and battery circuits, as applicable, and mark the directions of power flows through the system under various load conditions.	Critical
8.2	Understand how PV modules are configured in series and parallel to build voltage, current and power output for interfacing with inverters, charge controllers, batteries and other equipment.	Critical
8.3	Identify basic properties of electrical conductors including materials, size, voltage ratings and insulation coverings and understand how conditions of use, such as location, other conductors in the same conduit/raceway, terminations, temperature and other factors affect their ampacity, resistance and corresponding overcurrent protection requirements.	Critical
8.4	Understand the importance of nameplate specifications on PV modules, inverters and other equipment on determining allowable system voltage limits, and for the selection and sizing of conductors, overcurrent protection devices, disconnect means, wiring methods and in establishing appropriate and safe interfaces with other equipment and electrical systems.	Critical
8.5	Determine the requirements for charge control in battery-based PV systems, based on system voltages, current and charge rates.	Important
8.6	Identify the labeling requirements for electrical equipment in PV systems, including on PV modules, inverters, disconnects, at points of interconnection to other electrical systems, on battery banks, etc.	Important
8.7	Understand the basic principles of PV system grounding, the differences between grounded conductors, grounding conductors, grounding electrode conductors, the purposes of equipment grounding, PV array ground-fault protection, and the importance of single-point grounding.	Critical
8.8	Apply Ohm's Law and conductor properties to calculate voltage drop for simple PV source circuits.	Important
8.9	Identify the requirements for plan review, permitting, inspections, construction contracts and other matters associated with approvals and code-compliance for PV systems.	Critical
8.10	Demonstrate knowledge of key articles of the National Electrical Code, including Article 690, Solar Photovoltaic Systems.	Important

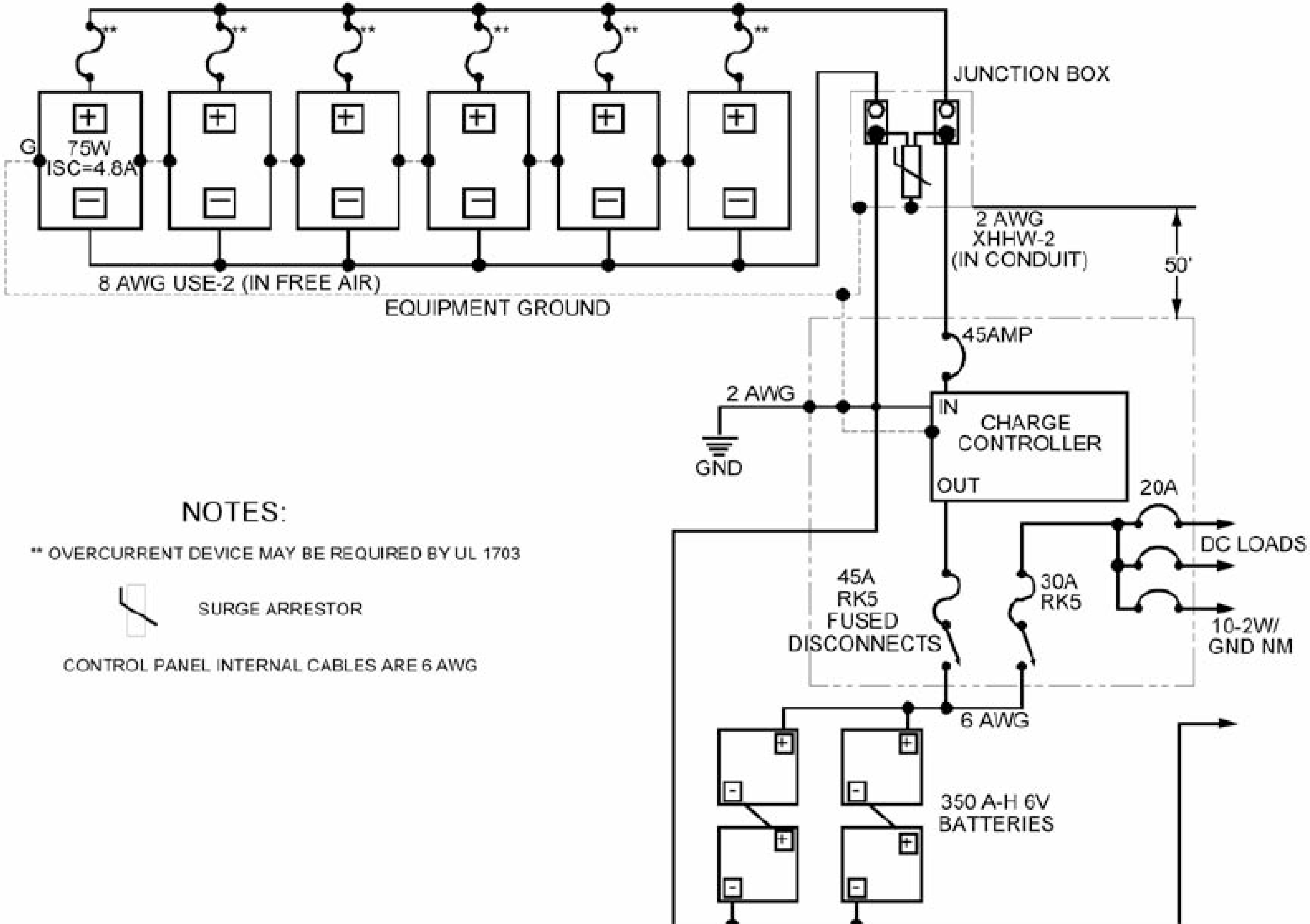
- Single line drawings



- Single line drawings



- Single line drawings



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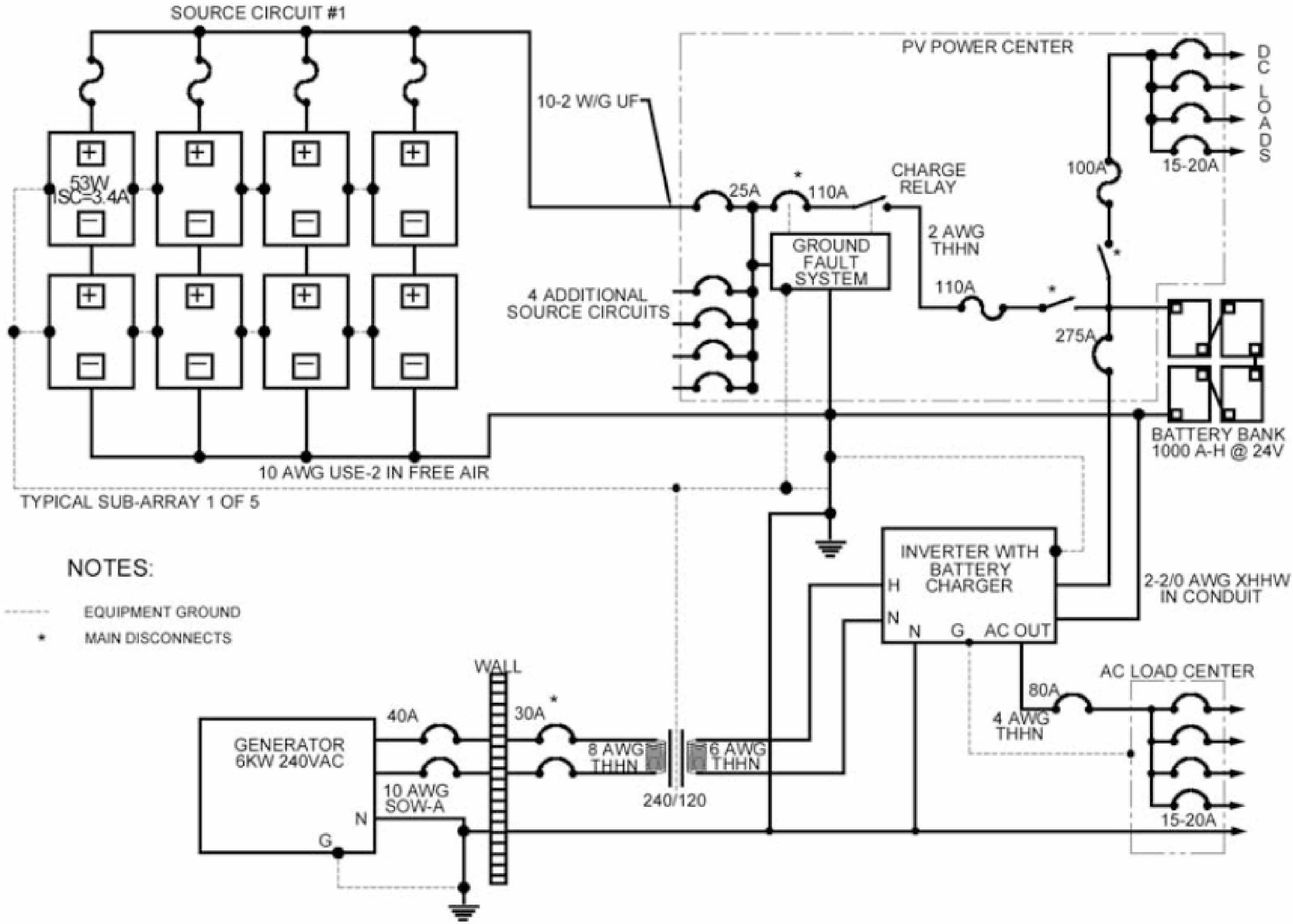
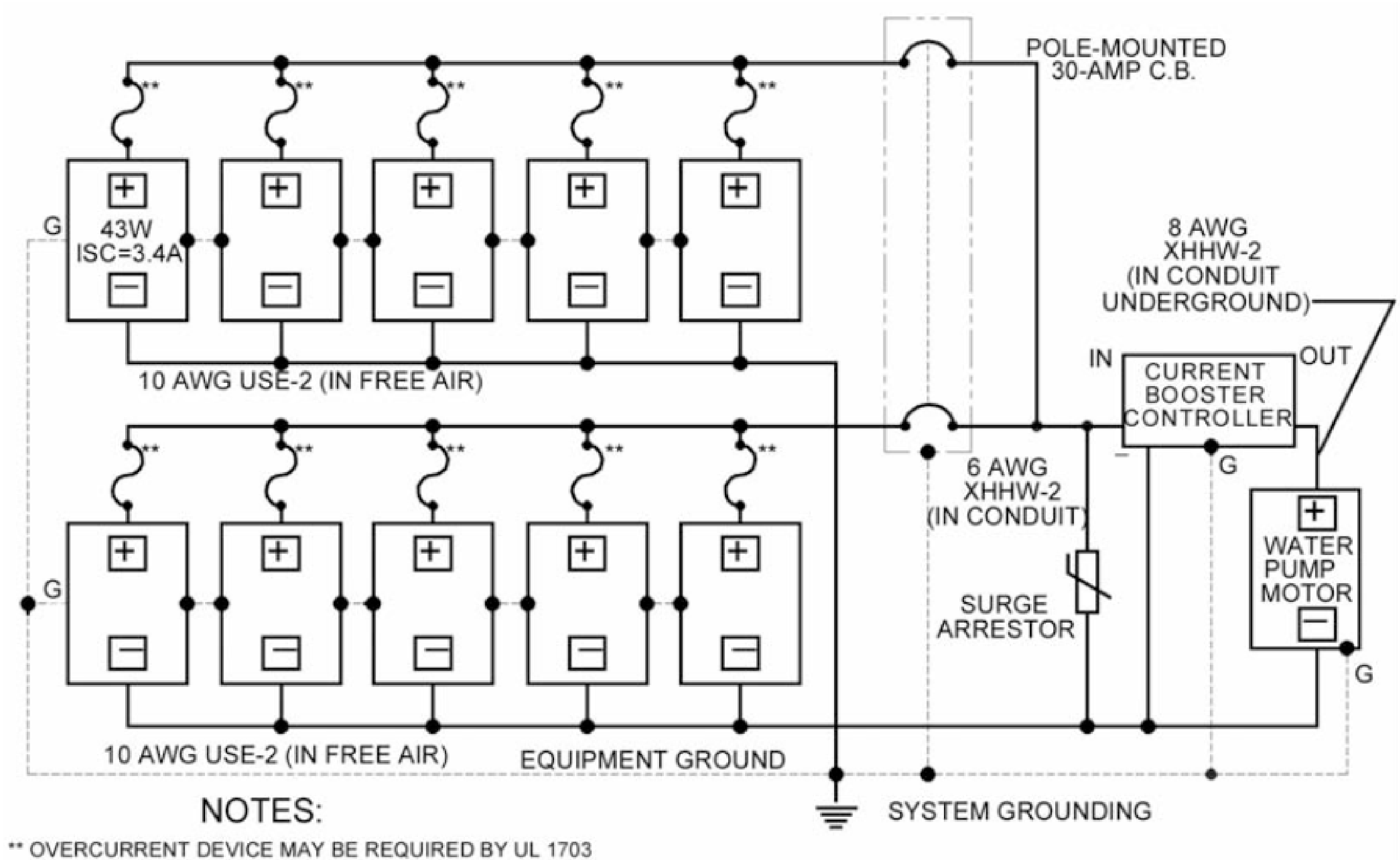
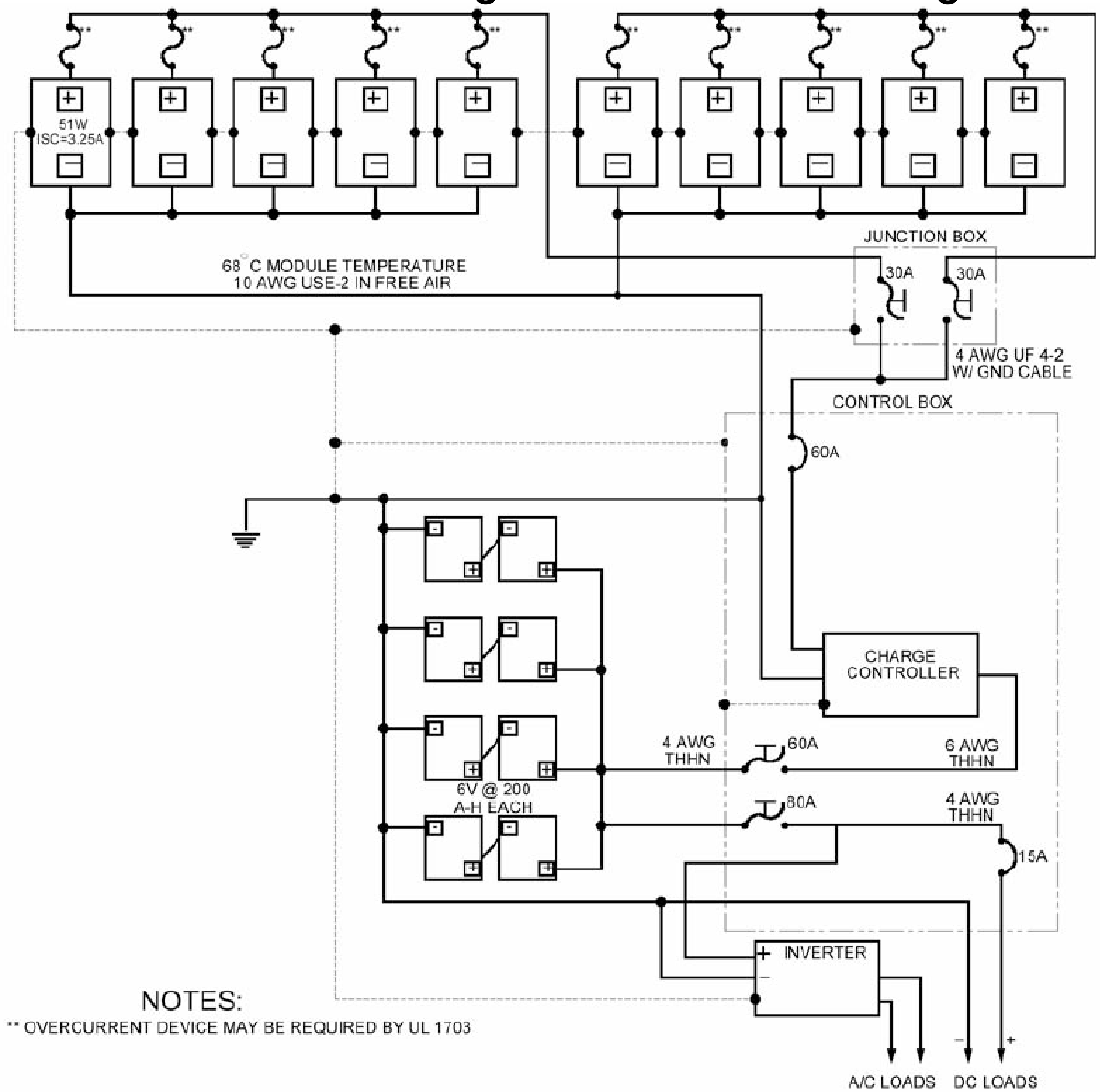


- Understanding PV module configurations



- What is the DC voltage and current from the array?

- Understanding PV module configurations



- What is the DC voltage and current from the array?

- Size, insulation type, resistances, and other information are printed on the outer jacket of conductors.

Conductor Insulation Markings

- Conductor sizes typically used in PV systems range from 20 AWG to 2/0 AWG. Conductors may be solid or stranded.

Conductor Sizes

AWG	DIAMETER*	AREA	AWG	DIAMETER*	AREA
20	0.0320		6	0.1620	
18	0.0403		4	0.2043	
16	0.0508		3	0.2294	
14	0.0641		2	0.2576	
12	0.0808		1	0.2893	
10	0.1019		0 (1/0)	0.3249	
8	0.1285		00 (2/0)	0.3648	

* in in.

Recommended Insulation Types for PV Systems

APPLICATION	REQUIRED RESISTANCES: Moisture	Sunlight	≥ 90°C	Fire	NUMBER OF CABLE CONDUCTORS: One	Multiple	INSTALLATION: Exposed	Conduit	RECOMMENDED INSULATION TYPE
Source-circuit wiring	✓	✓	✓		✓		✓	✓*	USE, USE-2, UF, SE
Output-circuit wiring	✓		✓		✓			✓	USE-2, XHHW-2, RHW-2, THWN-2
	✓	✓	✓			✓	✓		UF, TC
Interior wiring				✓	✓			✓	THHN, THW, RHW, XHHW, RH
				✓		✓	✓†		NM, NMB, UF
Battery wiring	✓				✓		✓		USE, RHW, THW

* only flexible conduit
† may not be permitted in local jurisdiction

- Conductors in different parts of a PV system have different requirements.

- Ampacity is the current-carrying capacity of a conductor and depends on conductor type and size.

Ampacities of Insulated Copper Conductors*

	TYPE OF INSULATION	TW, UF	RHW, THHW, THW, THWN, XHHW, USE, ZW	TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW-2, ZW-2
	AWG	60°C Rated	75°C Rated	90°C Rated
CONDUCTORS IN A RACEWAY, CABLE, CONDUIT, OR EARTH (DIRECTLY BURIED)	18	—	—	14
	16	—	—	18
	14	20	20	25
	12	25	25	30
	10	30	35	40
	8	40	50	55
	6	55	65	75
	4	70	85	95
	3	85	100	110
	2	95	115	130
	1	110	130	150
	0 (1/0)	125	150	170
	0 (2/0)	145	175	195
CONDUCTOR IN FREE AIR	18	—	—	18
	16	—	—	24
	14	25	30	35
	12	30	35	40
	10	40	50	55
	8	60	70	80
	6	80	95	105
	4	105	125	140
	3	120	145	165
	2	140	170	190
	1	165	195	220
	0 (1/0)	195	230	260
	0 (2/0)	225	265	300

* Based on ambient temperature of 30°C (86°F) and not more than three current-carrying conductors when in a raceway, cable, or earth (directly buried). Excerpted from NEC® Table 310.16 and Table 310.17. Reprinted with permission from NFPA 70-2005, the National Electrical Code® Copyright© 2004, National Fire Protection Association, Quincy, MA 02169. This reprinted material is not the official position of the NFPA on the referenced subject which is represented solely by the standard in its entirety.

Ampacity Correction Factors for High Temperatures

AMBIENT TEMPERATURE*	CONDUCTOR TEMPERATURE RATING		
	60°C Rated	75°C Rated	90°C Rated
21 to 25	1.08	1.05	1.04
26 to 30	1.00	1.00	1.00
31 to 35	0.91	0.94	0.96
36 to 40	0.82	0.88	0.91
41 to 45	0.71	0.82	0.87
46 to 50	0.58	0.75	0.82
51 to 55	0.41	0.67	0.76
56 to 60	—	0.58	0.71
61 to 70	—	0.33	0.58
71 to 80	—	—	0.41

* in °C

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- Conductor ampacity must be derated for high temperatures.

Ampacity Correction Factors for Number of Conductors

NUMBER OF CURRENT-CARRYING CONDUCTORS	CORRECTION FACTOR
4 to 6	0.80
7 to 9	0.70
10 to 20	0.50
21 to 30	0.45
31 to 40	0.40
Over 40	0.35

- Conductor ampacity must be derated for more than three current-carrying conductors together in a conduit or cable.