NABCEP Exam Study Guide

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1. 200 Sample NABCEP Test Question
2. MP3 audio files so you can study anywhere. Have the questions, answers, and explanations for each read to you.
3. Cliff Notes so you can skim content quickly and determine where to focus your studying.
4. NEC Citations Throughout so you can review and study your code.

NABCEP Prep Course Cliff Notes

The following are the cliff notes I took while studying for the NABCEP Solar PV Installer Exam. My goal in putting these notes together was principally to help me study but I realized that others might find this information extremely useful.

The idea was to condense what we learned in the course so that it can be reviewed quickly and provide you reference for aspects of the exam that you need to review further.

Cliff Notes Format

The cliff notes are segmented into 4 sections based on what we covered in the training

1. Concepts to Remember
2. Equations to Remember
3. Code to Remember
4. Be Aware of for the NABCEP

Sections of the Cliff Notes

Section 1: Safety

1. Concept to Remember

- Working space. 36 inches in front, 30 inches or cabinet wide (whichever is larger), 6.5 high. Door hinge at least at 90 degrees. [NEC 110.26]
- Fall protection. All heights greater then 6 feet
- OHSHA CFR Part 29 Safety and Health for Construction
  - C for general safety
  - D occupational health and environmental controls
  - E personal protection and life saving equipment
  - I tools, hand power
  - K electrical
  - M fall protection
  - X stairways and laders
- 10 mA can freeze muscles, and 75 mA can cause death
- Lockout-tagout is required when working more then 50 feet or beyond line of site from disconnecting means
- Guardrails
  - Needed on "open sided floors" must have top rails between 39 inches and 45 inches.
  - Needed on a flat area between 36 and 42 inches

    - 42 inches top rails on stair cases

- Tow board on guard rails must be 3.5 inches. Think 2x4 used for a tow board.

- Fall protection no further then 30 feet

- 19 inches elevation break between two planes requires ladders or steps.

- A break with 4 risers or higher then 30 inches must have handrail

- Handrails must hold 200 pounds

- Ladder must be between 30 and 50 angle

- Ladder: 3 ft clearance, 1/4 slope ratio, non-conductive siderails

- Class b hardhat offer the max protect from impacts and electrical shock

1.2 Equations

- 1/4 slope for ladders

- Trig calculation for ladder high. SOH, CAH, TOA. trig can only be used with right angles.

1.3 Code

- Working space article NEC 110.26

1.4 NABCEP

- Remember which articles in OSHA cover each

- Know how to calculate ladder height and when and where you need guardrails. There's a high chance questions will be asked regarding this.

Section 2. Electrical Basics

2.1 Concepts

- E = IR --> E = volts, I = amps, R= resistence --> ohms law
- P=EI --> P = watts, E = volts, I = amps
- The relationship between resistance and power. More amps can flow because there is less resistance given voltage is the same. Least resistance = most power. Resistance and amps have an opposite relationship.
- Voltage ads in series, amps ad in parallel
- Transformers need AC
- One watt is when one volt causes one ampere of current to flow
- In parallel circuits the current splits between the two paths based on resistance

2.2 Equation

- See above

2.3 Code

- AC/DC wire sizing take nominal amps (adjust for 1.56 if array and DC) and (1.25 for any continuous load) then look at NEC table 310.16 in 310.15 for wire ampacity and 240.40D for exceptions

2.4 NABCEP

- Know how to do basic circuit calculations and compare differences
- Remember the relationship between resistance and power
- Know how to derate wire

Section 3. Irradiance and Site Selection

3.1 Concepts to Remember

- High Irradiance = High Current
- Cold temp = High voltage
- STC = 1000 W/M2 25C and 77F at sea level
- Insulation = Irradiance over time. Metric = kWh/m2
- True south and magnetic south must be adjust based on where you area. Boston, true south is 17 west of magnetic south, true north is 17 east of magnetic north. east = + , west= -
- PV is best product @ 90 degrees to the sun
- Best year round production with no tilt changes= your latitude --> +15 for winter, -15 for summer. these +/- will change based on your latitude
- Benefits of tracking is 35-40%
- Vmp is 80% of VoC: Rule of thumb
- Inverter finds Max Power by regulating and sweeping voltage
- Reading sunchart. see page 28 in the course packet for good examples
- Conversion: 10.76 square feet in 1 square meter
- Solar power = irradiation solar energy = insolation (irradiance over time)
- Know SOH, CAH, TOA for sun chart readings and how to do trig calculations.
- Rule of thumb to avoid inter-row spacing is the distance between rows is 3 times the height of the angle.

- Inter-row spacing example and correction for sun angle. see example we did after page 54.

3.2 Equations

- Same as concepts

3.3 Code

- None. All concepts

3.4 NABCEP

- Be very comfortable with be able to read a SunChart

- Know your STC by heart so you know the adjustments when given differently. STC are 25 C, 77F, 1000W/M2 at sea level.

Section 4 Sizing A System

4.1 Concepts

- Rule of thumb: Derating to grid = 80%, with battery back up= 70%

- Inverter should be sized within top 25% output of array so it hits the MPPT. Or 20% then DC size of the array to account for derating and also so the inverter is functioning at higher voltages and thus efficiency more often. For example, if array is 5kW DC, inverter can be 4kW.

- Inverter has an continuous amp current output --> that's all you need to size wires and OCPD for code

- Maximum system voltage. VoC of module x number of modules in series x low temperature correction

- Minimum voltage = Vmp x number of modules in series x voltage drop correction for temperature and conduit fill on the roof (for hot weather)

- Correction wires for ampacity by 1 - ambient air temperature and 2 conduit fill.

- Know how to derate for MMPT charger controllers and standard chard controllers. page 45 on your class booklet

- In bi polar arrays add the two voltages together.

- 5/9 is metric between F and C for temp conversions from STC to others.

- After the array and before the inverter only deals with maximum and minim voltages, irradience, and temperature, no derating. After the inverter you have the average 20% dirtying for soiling, mismatch, inverter, etc.

- After array amperes must be rated for 1.25 for irradiance and 1.25 for continue use. After inverter, just 1.25 for continuous

4.2 Code

- NEC TABLE 690.7 max system voltage, worst case temperature corrections.
    - A) temperature corrections must be used if supplied. Rule of thumb is .36%/C for crystalline PV.
    - B) MUST USE WORST CASE Temperature in your region. Assume -25C is you have nothing
- NEC 2008 310.15B 2C. Temperature correction factors for exposure to sunlight. Ambient temperature adjustment for conduits exposed to sunlight son or above rooftops.

4.3 Equations

- Max = Voc X number in string X low temp correction for worst case scenario NEC 2008. Min = Vmp X number in string X temp correction for exposed conduit (NEC 310.15B2C)
- Remember the difference between the conversions/deratings of charge controllers that MPPT versus conventional charge controllers

4.4 NABCEP

- REMEMBER irradiance impacts ONLY CURRENT and temp ONLY VOLTAGE. They may try and trick you with giving you a different irradiance from STC then ask what the ARRAY VOLTAGE will be going into the inverter
- Know how to calculate min and max string size.

Section 5 Conductors

5.1 Concepts

- 75C common wire

- OCPD must be sized over at least at the corrected ampacity of the wire, so it is never overloaded.

- Understand different wire colors, meaning, ratings.

    -COLOR –

        - AC wiring. black = ungrounded hot, white=grounded conducts, green or bare = equipment ground, red or any other color= ungrounded hot

        - DC Wiring. red (not NEC requirement)=positive, white= negative or grounded conductor, green or bare = equipment ground.

    - Meanings - NEC Table 310.13A

        - Commons are

            - THHN: used in dry, indoor locations

            - THW, THWN, TW can be used indoors or for wet outdoor applications in conduit

            - UF and USE or PV Wire) are good for mount or unground applications

            - Wires expressed to sunlights must be labelled sunlight residence

    Ratings USE - see NEC table 310.13

- Current carrying after array. 1.25 for high irradiance and 12.5 for continuous. Great diagram on page 51 of course book

- Wire sizing example on page 53

- Continuous load is 3 hours

- Voltage drop = power consumer to move electrician over resistence

- Good voltage drop example on page 57.

5.2 Equations

- Drop = (I x 2D x resistance) / 1000

- % voltage drop = catalo /operation

- Usable power = watt at load/watt a source

5.3 Code

- When derating wire best to think about 1) what the wire needs to hold, what's coming from the array and 2) what it can hold due to derating (temperature and conduit fill based on conditions)

    - **1 - what the wire needs to hold**

        - At the Array NEC 690.31 B Single Conductor at Array

        - 1.25 for High Irradiance NEC 690.8A

        - 1.25 for continuous Current NEC 690.8B and 210.19A1

    - **2 - what the wire can hold**

        - Select Wire: NEC Table 310.16 in 310.15 for wire sizing and ampacity, NEC 240.4D for wire sizes #14, #12, #10 AWG. and MAx OCPD one temperature fill and correction factors

        - Ambient Temperature Correct: NEC Table 310.16 on the bottom SAME AS Table 690.31C

        - Conduit Temperature Correction. Need inches conduit will be above roof: NEC Table 310.15B2C

- Conduit Fill: 310.15B2A

See example of this on page 53 of the course package.

- Remember after combination box you must ad the number of strings that are combined to find the starting Isc, before you ad 1.25 for continuous

- NEC Table 310.13A Conductor Applications and Insulation Ratings

- NEC Table 8 (back of the book reference section) conductor resistance properties in the back of the book on Ohms. Needed for selecting wire to change voltage drop.

- NEC 690.8 A3 - max inverter output current shall be the continuous output current rating, not peak

- Acceptable voltage drop. 210.A1 note #4 - 3% branch, 215.2 A4 note #2 3% for feeders, 210.19 A1 #4 5% total voltage drop

5.4 NABCEP

Section 6. Roof Mounted Systems

6.1 Concepts

- How many modules can fit on a roof?
- Spacing, 2 foot walk on each side, 2 below peak, 1 above gutter. 1 inch between modules
- wind force based on ASCE 7-05 chapter 6,5,13,2
- Dead load vs Live load
    - Dead load = 10lbs/sf. 1 layer of shingles = alb, flush mounted solar is 3lb
    - Live load is snow and wind
    - Wind load is in square pounds per square foot based on 1) your basic wind speed in your are 2) your expoures 3) height of roof. Category b = sheltered c= semi-sheltered c=exposed
- Square inches to feet multiply by 144
- Rule of thumb is 250 pull strength per inches of thread in rafter
- Good wind load example on page 69 of class notebooks
- Rule of thumb: Pilot holes should be 2/3 diameter

6.2 Equations

6.3 Code

6.4 NABCEP

- Know how to do calculations for dead-load and live load on a roof, with pull out strength based on screw length

Section 7 - Grounding

7.1 Concepts

- Grounding. Why ground? Stabilize voltage and to provide common reference point - the earth -, limit voltage due to lightening, line surges, and provide a path in order to allow OCPDs to work, and for safety of people and to reduce fire hazards.

- Equipment Grounding: provides protection from shock caused by a ground fault to the equipment and is required in all PV systems.

    - Ground fault happens when the current carrying conductor comes into contact with any equipment used in electrical system.

    - The ground wire must be continuous, connection every non-current carrying metal part of the installation ton group.

    - It must bond or connect to every metal box and can never be fused, switched or interrupted in anyway.

- System Grounding: System grounding is taking one conduct from a two wire system and connecting it to ground.

    - NEC requires this for all system over 50 volts (NEC 690.41)

    - In DC, bonding negative to ground at one single point (NEC 690.42) must be locoed as close as practicable to pv source.

    - In grounded negate biomes grounded and positive is ungrounded. If under 50 volts and no grounding, both wires must have OCPD (NEC 240.41)

- Ground Fault Protection. Roof mounted DC PV array on dwellings must be DC ground fault (NEC 690.5) most inverters have build in GFP. GFP isolate the grounded conduct (negative in DC) under ground fault conductions and disconnects the ungrounded conductor.

- Sizing Equipment Ground.

    - Sizing depends on weather system has GFP. IF GFP, must be as large as the current carrying conduct, the positive and negatives, but not smaller then specific on NEC Table 250.122. table is based on rating of OCPD. If conducts have been oversized for voltage drop, equipment ground must also be oversee proportionally NEC 250.122B. IF NOT GFP, equipment grounding must be no less then 125% of the PV array short circuit. Must be proportionally oversized if conducts are sized to voltage drop.

  - Sizing grounding electrode conductor. DC system which is the bare copper connecting grounded conductor and/or equipment conducts to the ground electric cannot be smaller then #6 AWG aluminum or #8 AWG copper or the largest conduct by the system NEC 250.166

- If ground electrode is ground rode, grounding electric is NOT required to be large then #6 AWG. Why? ground can only allow so much current due to its resistance level.

- Sizing of equipment grounding for PV source circuits should be not smaller then #10 AWG copper or #6 is exposed.

- EG is green wire or bare

- Ground rode needs to be 8 foot deep

- GFP required on all systems mounted to building

7.2 Equations

7.3 Code

- 2008 requires system and equipment grounding

- NEC 690.35 Ungrounded PV Systems

- NEC 690.41 System Grounding

  - In Accordance with NEC 250.4 A, Exceptions systems complying with 690.35

  - Low voltage systems not grounded can comply with NEC 240.21

- NEC 690.43 Equipment Grounding
    - Done in accordance with NEC 250.123 or 250.136A regardless of voltage
    - Also NEC 250.110
- NEC 690.45 Size of Equipment Grounding
    - Sized in accordance with table 250.11.
    - Equipment grounding shall be no smaller then #14
- NEC 690.46 Array Equipment Grounding
    - Smaller then #6AWG must comply with 250.120C
- NEC 690.47 Grounding Electrode System
    - AC done in accidence with 250.50 through 250.60
    - DC systems grounded 250.166 or 250.169 for ungrounded
    - Grounding electrode conductor installed accordance to 250.64
    - Systems with DC and AC to 1 through 8.
- NEC 690.48 Continuous of Equipment Grounding Systems
- NEC 690.49 Continuity of PV source and output ciruits ground conducts
- 250.122 A+B conductor and equipment grounding

7.4 NABCEP

- Remember the difference between 2008 and 2011 if you're using 2011. 2008 Requires both EG and system grounding, 2011 only requires EG but the TEST is on 2008 code!

Section 8 Grid Tied Connection

8.1 Concepts

- Service can be overloaded by 120% of the OCPD ratings of the CURRENT back at opposite end of the buss. For example if you had a 200A service and needing to connect three 2.4kW inverters (10.43 amps) you can connect each inverter to a 40A subpanel. 40A can be fed into the 200amp service (200 x 20%=40A). 3, 15 amp can be fed into a 40a sub-panel because each breaker is actually only get 10.43 amps X 3 = only 31.5 amps. 31.5 X 1.25 for continuous = LESS then 40AMP.

- Line side tap. PV system can any size as long as it doesn't not overload any conductor

8.2 Equations

8.3 Code

- NEC 690.64B dedicated backfed breakers
  - Only inverters listed as gid interactive, must de-energize
- NEC 690.64 B2 - Panel Boards Mounted in Series. Always use rating of the first OCPD connected to inverter out in calculation FOR ALL bus bars.
- NEC 408.36D breakers must be bolted down --> NEC 690.64B5 DOES NOT need to be bolted down.
- NEC 690.64 B2 exception: bus can overload 120% of all the rated OCPD devices
- NEC 690.63B7 point of interconnection
- NEC 690.B2 panel board in series.
- NEC 690.63 unbalance interconnection
- NEC 690.64 Point of tap before main

8.4 NABCEP

Section 9 Battery Systems

8.1 Concepts

- Match battery voltage to inverter
- Critical design moth = worst case scenario --> largest load and lower insolation
- Batteries never go below 70% empty
- 390 Ahrs = 1am for 390 hours, or 390Amps for 1 hour (batteries can't discharge this fast) @ XXX voltage. must have the voltage level
- Max battery charge rate = batter capacity / 5 is c = c/5. C/20 Means If the capacity is 200Ahrs, it can be fully charge in 10 hours. (200/20=10)
- Inverter capacity can handle the largest load based on all loads
    - Charging capacity usually 2/3 of inverter capacity
    - Batteries can take 5 hours to charge/discharge
- Sell mode = excess power to grid
- Charge controller adjusted for battery types
- Bulk is charging voltage, float is continue
- Charge controller higher voltage then inverter but both need to high enough to charge better

9.2 Equations

9.3 Code

9.4 NABCEP

- Know the safety around batteries

- Have a good idea of the role of charge controllers, where they're wired and how to derate them.