SIERRA COLLEGE

# Class 11

# Lesson Plan

- 3 phase power and transformers – any questions?
- Project update and next steps

- Next Saturday Session – Roseville campus, 8a
  - Need load equipment (trucks are welcome)

# Project Progress

- Structural mounts installed
- Attachment points installed
- Rails are installed
- Rails are bonded
- Modules mounted
- Combiner box installed
- Inverter and disconnect installed

Need to

- Wire modules as 3 x 11 array and land at the combiner box
- Lay conduit from combiner box to inverter
- Pull wire

# Project Open Issues

- Structural still need be cross-braced
- Need determine where and how we will mount BOS
- (What is the BOS)
- How do we ground the system?
- How do we connect to AC system?

Need to

- Determine conductor type, size, length, color
- Determine conduit type, size, length
- Determine fuse and breaker requirements
- Determine conduit run

# DC Circuit Calculations



Consider an array of 33 Sharp NT175U1 modules, three parallel strings of 11. Use the NEC tables to answer the following questions. (Isc = 5.40A)

1.What is the Continuous Current for each string of the array?

**5.4A * 1.25 = 6.75A**

2.Each string is connected through an fused combiner box. What is the over current device rating for each string?

**5.4A * 1.25 * 1.25 = 8.44A , go to next higher fuse value – 10Amp**

3.What is the required ampacity at 30C for each string?

**5.4A * 1.25 * 1.25 = 8.44A**

4.We want to use USE02 conductors in these circuits. What is the temperature derating factor if the expected temperature is 135F? What is the conduit fill derating factor?

**Temperature Derate = 0.71** **Conduit Derate = 1.0**

5. Using NEC tables, select a conductor size. **I chose 14AWG USE-2**

6.Derate the conductor you selected based on the derating factors above. What is the derated amapacity? **35A * 0.71 * 1 = 24.8A**

7.Is the derated ampacity greater than the Continous Current ? If yes, move ahead, if no, repeat steps 5,6,7 **Yes**

8. Is the derated ampacity greater than the over current protection device rating? If yes, move ahead, if no, repeat steps 5,6,7,8. **Yes**

9. The combiner box terminals are rated at 75C. What is the ampacity at 30C of the combiner box terminals?

   **The 14AWG USE-2 conductor ampacity at 75C = 30A**

10. Are the combiner box terminals acceptable for this application?

    **Yes**

11. The combiner box is outside but not in direct sunlight. The expected temperature is 40C. Is this acceptable?

    **Yes, but if temperature is greater than 40C then we need to refer to the manufacture's specifications to determine if we can use.**

# DC Circuit Calculations

Consider the same array of 33 Sharp NT175U1 modules (Isc = 5.40A) and the circuit between the combiner box and the inverter disconnect switch

1.What is the Continuous Current for the circuit out of the combiner box?

**5.4A * 3 * 1.25 = 20.25A**

2.What is the over current device rating for the circuit?

**5.4A * 3 * 1.25 * 1.25 = 25.3A , go to next higher fuse value – 30Amp**

3.What is the required ampacity at 30C for each string?

**5.4A * 3 * 1.25 * 1.25 = 25.3A**

4.We want to use THWN-2 conductors in conduit. What is the temperature derating factor if the expected temperature is 140F? What is the conduit fill derating factor?

**Temperature Derate = 0.71** **Conduit Derate = 1.0**

5. Using NEC tables, select a conductor size. **I chose 10AWG THWN-2**

6.Derate the conductor you selected based on the derating factors above. What is the derated amapacity? **40A * 0.71 * 1.0 = 28.4A**

7.Is the derated ampacity greater than the Continous Current ? If yes, move ahead, if no, repeat steps 5,6,7 **Yes**

8. Is the derated ampacity greater than the over current protection device rating? If yes, move ahead, if no, repeat steps 5,6,7,8.

**No, pick next larger conductor – 8AWG**

9. The disconnect switch terminals are rated at 75C not 90C. What is the ampacity at 30C of the inverter terminals?

   **The 8AWG THWN-2 conductor ampacity at 75C = 50A**

10. Are the terminals acceptable for this application?

    **Yes**

11. The disconnect switch is not in direct sunlight. The expected max temperature is 40C. Is this acceptable?

    **Yes**

# AC Circuit Calculations

Consider the same system of 33 Sharp NT175U1 modules (Isc = 5.40A). The modules are connected to a SMA Sunny Boy 6000US with an output continous current rating of 29A.AC.

1.What is the Continuous Current for the circuit between the inverter and AC disconnect?

**29A**

2.What is the over current device rating for the circuit?

**29A* 1.25 = 36.25A , go to next higher circuit reaker value – 40Amp**

3.What is the required ampacity at 30C for each string?

**29A * 1.25 = 36.25A**

4.We want to use THWN conductors in conduit. What is the temperature derating factor if the expected temperature is 110F? What is the conduit fill derating factor if there are 3 current carrying conductors in the conduit?

**Temperature Derate = 0.82** **Conduit Derate = 1.0**

5. Using NEC tables, select a conductor size. **I chose 8AWG THWN**

6.Derate the conductor you selected based on the derating factors above. What is the derated amapacity? **50A * 0.82 * 1.0 = 41A**

7.Is the derated ampacity greater than the Continous Current ? If yes, move ahead, if no, repeat steps 5,6,7 **Yes**

8. Is the derated ampacity greater than the over current protection device rating? If yes, move ahead, if no, repeat steps 5,6,7,8. **Yes**

9. The disconnect switch terminals are rated at 75C not 90C. What is the ampacity at 30C of the inverter terminals?

   **The 8AWG THWN conductor ampacity = 50A (same temp rating as conductor)**

10. Are the terminals acceptable for this application?

    **Yes**

11. The disconnect switch in direct sunlight. The expected temperature is 45C. Is this acceptable?

    **Yes**

# Conduit Calculation



- NEC Chapter 9, Table 1: Percent of Cross Section of Conduit

| Number of Conductors | All Conductor Types |
|---|---|
| 1 | 53 |
| 2 | 31 |
| Over 2 | 40 |

- NEC Chapter 9, Table 4: Cross sectional area of EMT Conduit

**Article 358 — Electrical Metallic Tubing (EMT)**

| Metric Designator | Trade Size | Nominal Internal Diameter | | Total Area 100% | | 2 Wires 31% | | Over 2 Wires 40% | | 1 Wire 53% | | 60% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm | in. | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² | mm² | in.² |
| 16 | ½ | 15.8 | 0.622 | 196 | 0.304 | 61 | 0.094 | 78 | 0.122 | 104 | 0.161 | 118 | 0.182 |
| 21 | ¾ | 20.9 | 0.824 | 343 | 0.533 | 106 | 0.165 | 137 | 0.213 | 182 | 0.283 | 206 | 0.320 |
| 27 | 1 | 26.6 | 1.049 | 556 | 0.864 | 172 | 0.268 | 222 | 0.346 | 295 | 0.458 | 333 | 0.519 |
| 35 | 1¼ | 35.1 | 1.380 | 968 | 1.496 | 300 | 0.464 | 387 | 0.598 | 513 | 0.793 | 581 | 0.897 |
| 41 | 1½ | 40.9 | 1.610 | 1314 | 2.036 | 407 | 0.631 | 526 | 0.814 | 696 | 1.079 | 788 | 1.221 |
| 53 | 2 | 52.5 | 2.067 | 2165 | 3.356 | 671 | 1.040 | 866 | 1.342 | 1147 | 1.778 | 1299 | 2.013 |
| 63 | 2½ | 69.4 | 2.731 | 3783 | 5.858 | 1173 | 1.816 | 1513 | 2.343 | 2005 | 3.105 | 2270 | 3.515 |
| 78 | 3 | 85.2 | 3.356 | 5701 | 8.846 | 1767 | 2.742 | 2280 | 3.538 | 3022 | 4.688 | 3421 | 5.307 |
| 91 | 3½ | 97.4 | 3.834 | 7451 | 11.545 | 2310 | 3.579 | 2980 | 4.618 | 3949 | 6.119 | 4471 | 6.927 |
| 103 | 4 | 110.1 | 4.334 | 9521 | 14.753 | 2951 | 4.573 | 3808 | 5.901 | 5046 | 7.819 | 5712 | 8.852 |

# Conduit Calculation



- NEC Chapter 9, Table 5: Dimensions of insulated wires

| Type | Size (AWG or kcmil) | Approximate Diameter | | Approximate Area | |
|---|---|---|---|---|---|
| | | mm | in. | mm² | in.² |
| THHN, THWN, THWN-2 | 14 | 2.819 | 0.111 | 6.258 | 0.0097 |
| | 12 | 3.302 | 0.130 | 8.581 | 0.0133 |
| | 10 | 4.166 | 0.164 | 13.61 | 0.0211 |
| | 8 | 5.486 | 0.216 | 23.61 | 0.0366 |
| | 6 | 6.452 | 0.254 | 32.71 | 0.0507 |
| | 4 | 8.230 | 0.324 | 53.16 | 0.0824 |
| | 3 | 8.941 | 0.352 | 62.77 | 0.0973 |
| | 2 | 9.754 | 0.384 | 74.71 | 0.1158 |
| | 1 | 11.33 | 0.446 | 100.8 | 0.1562 |
| | 1/0 | 12.34 | 0.486 | 119.7 | 0.1855 |
| | 2/0 | 13.51 | 0.532 | 143.4 | 0.2223 |
| | 3/0 | 14.83 | 0.584 | 172.8 | 0.2679 |
| | 4/0 | 16.31 | 0.642 | 208.8 | 0.3237 |
| | 250 | 18.06 | 0.711 | 256.1 | 0.3970 |
| | 300 | 19.46 | 0.766 | 297.3 | 0.4608 |

- How many 10AWG THWN-2 conductors can be run through ¾ inch EMT?

0.213 / 0.0211 = 10 conductors

# DC Design Requirements

Combiner to Inverter

- Determine conductor type, size, length, color

  **The 8AWG THWN-2 150ft Black, White, Green (or bare)**

- Determine conduit type, size, length

  **EMT ½ inch 200ft**

- Determine fuse and breaker requirements

  **10amp fuses in the combiner box**

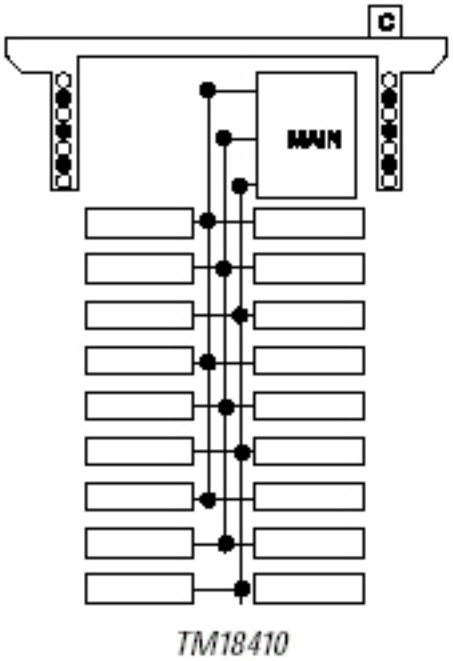
  **30amp fuse in the DC disconnect switch**

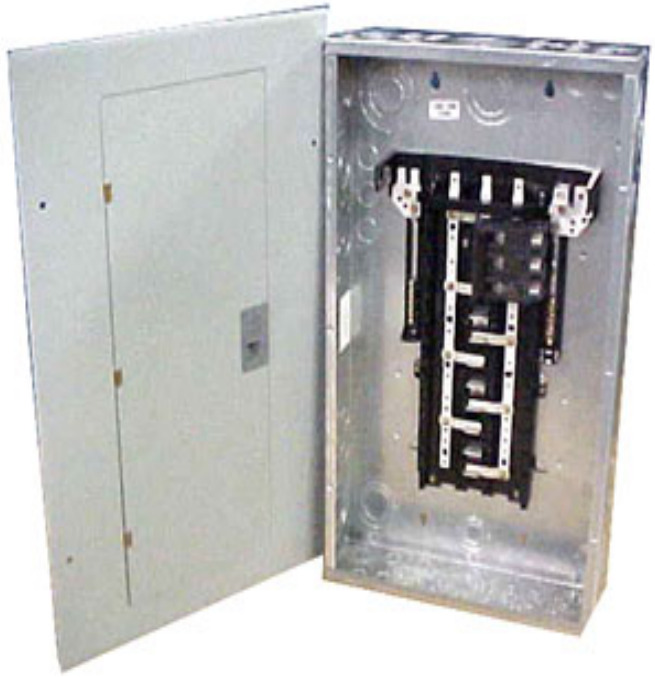
- What is the expected voltage drop in the DC circuits?

  **.778 * 300/1000 * 30A = 7.002V / 488.4VOC = .014 (1.43%)**

# AC Calculations

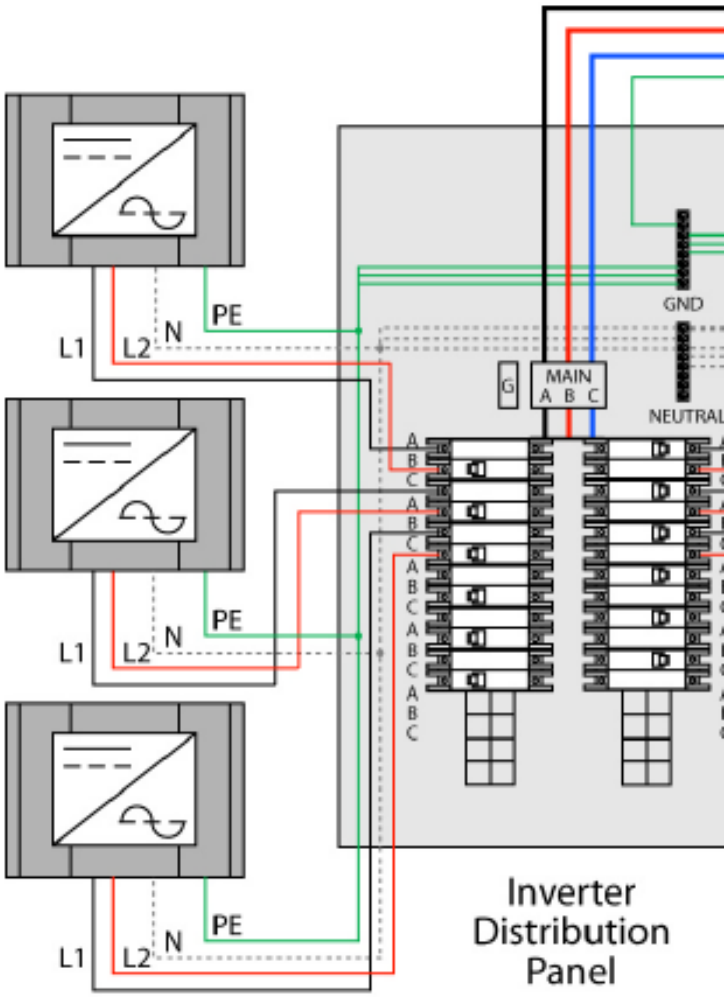
- How do we design a 3-phase PV system
- Use multiple single phase inverters

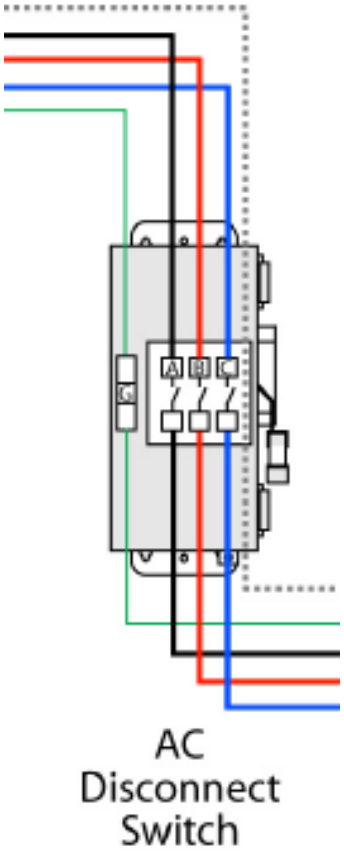


# AC Calculations

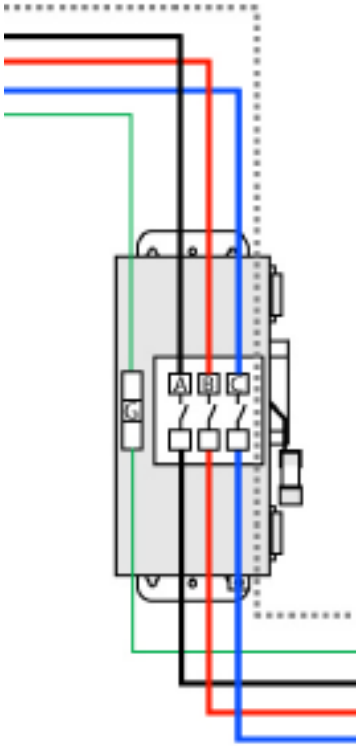




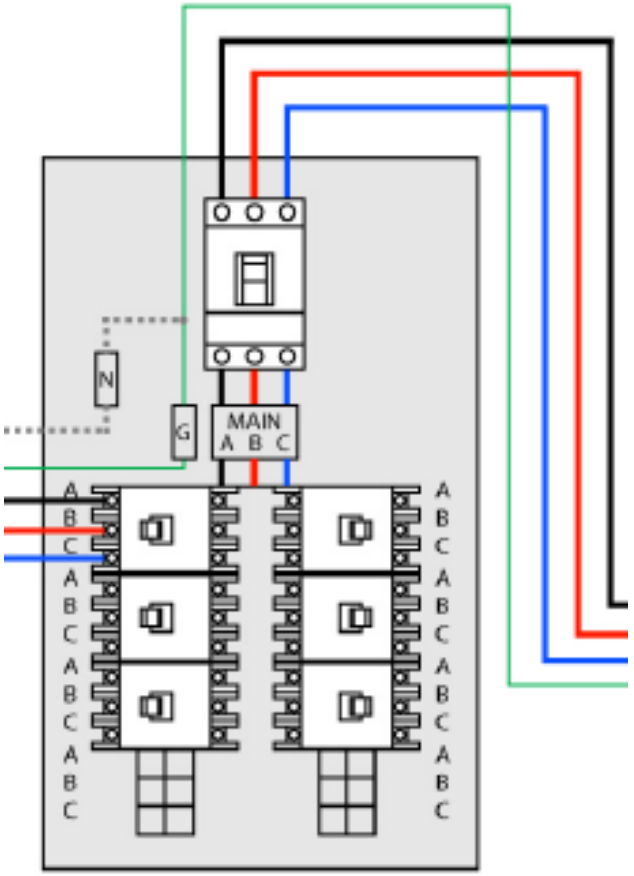



# AC Calculations





AC Disconnect Switch




Main Building Distribution Panel

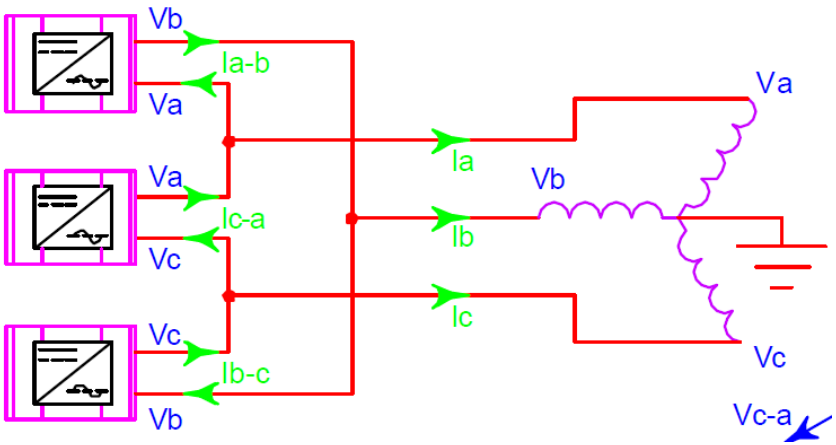
# Inverter data sheet



| | SB 5000US | SB 6000US | SB 7000US |
|---|---|---|---|
| Recommended Maximum PV Power (Module STC) | 6250 W | 7500 W | 8750 W |
| DC Maximum Voltage | 600 V | 600 V | 600 V |
| Peak Power Tracking Voltage | 250–480 V | 250–480 V | 250–480 V |
| DC Maximum Input Current | 21 A | 25 A | 30 A |
| Number of Fused String Inputs | 3 (inverter), 4 x 20 A (DC disconnect) | 3 (inverter), 4 x 20 A (DC disconnect) | 3 (inverter), 4 x 20 A (DC disconnect) |
| PV Start Voltage | 300 V | 300 V | 300 V |
| AC Nominal Power | 5000 W | 6000 W | 7000 W |
| AC Maximum Output Power | 5000 W | 6000 W | 7000 W |
| AC Maximum Output Current (@ 208, 240, 277 V) | 24 A, 21 A, 18 A | 29 A, 25 A, 22 A | 34 A, 29 A, 25 A |
| AC Nominal Voltage Range | 183 – 229 V @ 208 V<br>211 – 264 V @ 240 V<br>244 – 305 V @ 277 V | 183 – 229 V @ 208 V<br>211 – 264 V @ 240 V<br>244 – 305 V @ 277 V | 183 – 229 V @ 208 V<br>211 – 264 V @ 240 V<br>244 – 305 V @ 277 V |
| AC Frequency: nominal / range | 60 Hz / 59.3 – 60.5 Hz | 60 Hz / 59.3 – 60.5 Hz | 60 Hz / 59.3 – 60.5 Hz |
| Power Factor (Nominal) | 0.99 | 0.99 | 0.99 |
| Peak Inverter Efficiency | 96.8% | 97.0% | 97.1% |
| CEC Weighted Efficiency | 95.5% @ 208 V<br>95.5% @ 240 V<br>95.5% @ 277 V | 95.5% @ 208 V<br>95.5% @ 240 V<br>96.0% @ 277 V | 95.5% @ 208 V<br>96.0% @ 240 V<br>96.0% @ 277 V |
| Dimensions: W x H x D in inches | 18.4 x 24.1 x 9.5 | 18.4 x 24.1 x 9.5 | 18.4 x 24.1 x 9.5 |
| Weight / Shipping Weight | 141 lbs / 148 lbs | 141 lbs / 148 lbs | 141 lbs / 148 lbs |
| Ambient Temperature Range | –13 to 113 °F | –13 to 113 °F | –13 to 113 °F |
| Power consumption at night | 0.1 W | 0.1 W | 0.1 W |

# AC Calculations

- How do we design a 3-phase PV system
- Use multiple single phase inverters




- What is the OCPD rating for inverter output?

  (max AC output of SB6000US at 208V = 29A)

  **29A * 1.25 = 36.25A  next size = 40A**
- What is the OCPD rating of each phase?  **40A**
- What is the OCPD for the 3 phase subpanel?

  **29A * √3 = 50.2A * 1.25 = 62.8A  next size = 70A**

# AC Design Requirements

Inverter to Solar Subpanel

- Determine conductor type, size, length, color

  **The 8AWG THWN-2 25ft Red, Black, White, Green (or bare)**

- Determine conduit type, size, length

  **EMT ½ inch 25ft**

- Determine fuse and breaker requirements

  **40amp breaker in the solar subpanel**

- What is the expected voltage drop in the AC circuits?

  **.778 * 50/1000 * 40A = 1.556V / 208V = .0075 (.75%)**

# AC Design Requirements

Solar Subpanel to Building Subpanel

- Determine conductor type, size, length, color

  **The 4AWG THWN-2 75ft Red, Black, Blue, White, Green (or bare)**

- Determine conduit type, size, length

  **Rigid or PVC 1 1/4 inch 75ft**

- Determine fuse and breaker requirements

  **70amp breaker in the solar subpanel**

- What is the expected voltage drop in the AC circuits?

  **.308 * 150/1000 * 70A = 3.234V / 208V = .0155 (1.55%)**

# AC Design Requirements

Need to

- Determine conductor type, size, length, color

| | | |
|---|---|---|
| **The 8AWG THWN-2** | **10ft** | **Black, White, Red, Green (or bare)** |
| **The 4AWG THWN-2** | **75ft** | **Black, White, Red, Blue, Green (or bare)** |

- Determine conduit type, size, length

| | |
|---|---|
| **EMT ½ inch** | **20ft** |
| **Rigid PVC Sch40 1 1/4" inch** | **10ft** |

- Determine fuse and breaker requirements

**3x 2 pole 40amp circuit breakers in the inverter sub panel**

**Need a 3 phase MLO load center, 125A, 12 slot, NEMA 3R**

**1x 3 pole 70amp circuit breaker in the supply panel**