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SIERRA COLLEGE

Class 4

Lesson Plan

- Conductors, PV, and NEC
  - Voltage drop
- Conduit
- Next Week
  - Class project discussion
  - Conductor ampacity and voltage drop review

Voltage Drop Calculation

- Voltage drop is NOT an NEC code issue
  - It is not a safety issue
  - Still important design consideration ($$$$)
  - Power = I * V, as V drops, P drops
- Ohms Law
  - V = I * R
  - ΔV = I * R where I = amperage in conductor,
    R = property of the conductor
- Conductor resistance
  - Decreases as conductor size increases
  - Increases as conductor temperature increases

Voltage Drop Calculation

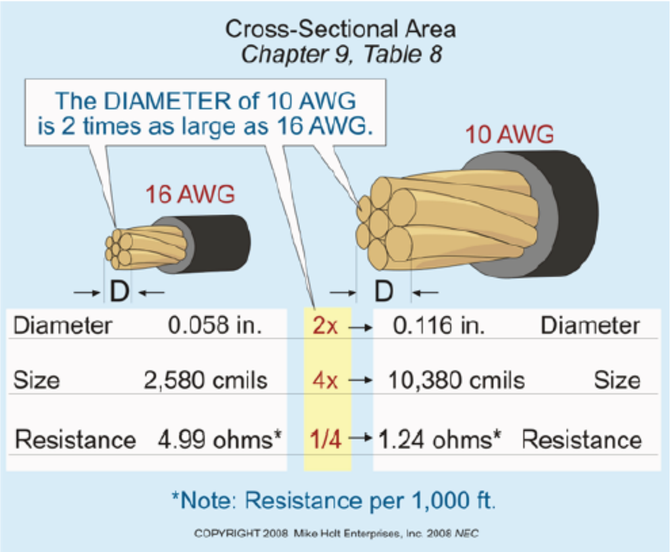
- NEC Chapter 9, Table 8 – Conductor properties
  - Direct Current Resistance at 75C
  - Stranded versus solid conductors
  - Copper versus Aluminum
  - Size 18 to 4/0
  - Area, diameter, and Ohm/kFT / Ohm/km

Table 8–1. Conductor Properties, *NEC* Chapter 9, Table 8

Conductor Size American Wire Gage	Conductor Resistance Per 1,000 Feet at 75°C	Conductor Diameter Inches	Conductor Area Circular Mils
14 AWG	3.140 ohms (stranded)	0.073	4,110
12 AWG	1.980 ohms (stranded)	0.092	6,530
10 AWG	1.240 ohms (stranded)	0.116	10,380
8 AWG	0.778 ohms (stranded)	0.146	16,510
6 AWG	0.491 ohms (stranded)	0.184	26,240

Voltage Drop Calculation

- Resistance as a function of diameter
  - How does resistance change if diameter is doubled?



- Resistance as a function of temperature
  - How does resistance change if temp = 150C?

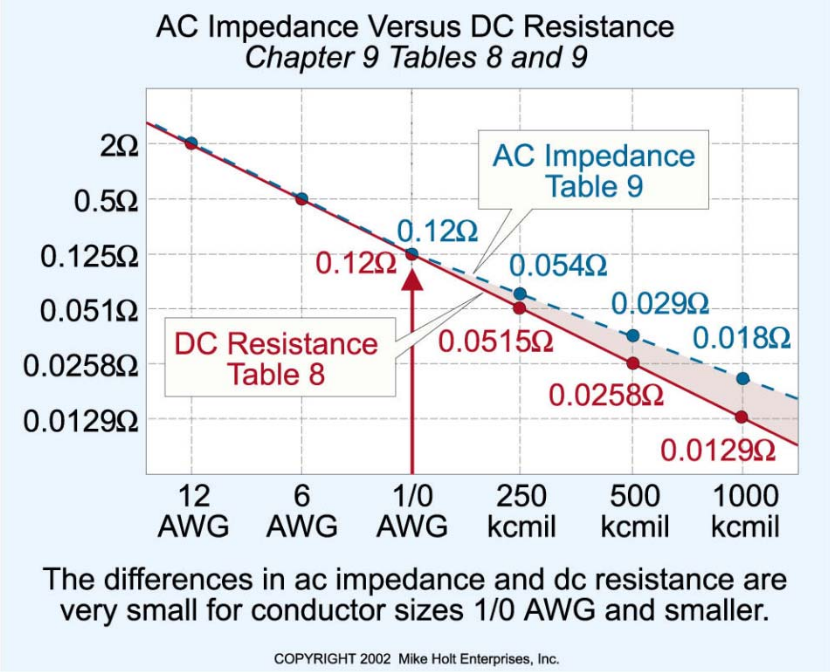
Temperature Adjustment, Table 8, Note 2:

$$R \text{ for CU} = \text{Table } R \times [1 + (0.00323 \times (\text{Temp}^\circ C - 75^\circ))]$$

$$R \text{ for AL} = \text{Table } R \times [1 + (0.00333 \times (\text{Temp}^\circ C - 75^\circ))]$$

Voltage Drop Calculation

- What about Alternating Current Resistance?
  - NEC Chapter 9, Table 9
  - More complex considerations
  - Power factor, and effective impedance
  - DC table is fairly accurate for conductors smaller than 2AWG



Voltage Drop Calculation

- Calculate resistance in conductors

  (Uncoated is used, it does not mean uninsulated)

  – What is the resistance in 200ft of 12AWG copper stranded at 30C?

    1.98 Ohm/kFT * 200/1000 = 0.396 Ohm

  – What is the resistance of 400ft of 10AWG copper stranded at 100C?

    1.24 Ohm/kFT * 400/1000 * (1+ 0.00323 * (Temp – 75C)) = 0.536 Ohm

  – What is resistance in <u>circuit</u> between junction box and inverter if distance between them is 300ft and we are using 10AWG copper stranded at 50C?

    1.24 Ohm/kFT * 600/1000 = 0.744 Ohm

Voltage Drop Calculation

- What is an acceptable voltage drop?
  - No code requirements
  - Typically measured as a percentage of the nominal voltage
  - 5% or greater bad
  - 2% - 3% is considered “good: design practice
  - What is the voltage drop in 200ft of 12AWG copper stranded at 30C if amperage is 4A?

    4A * 0.396 Ohm = 1.58V

  - If circuit voltage is 12V, what is the percent voltage drop?

    1.58V / 12V = 13.2%

  - If circuit voltage is 48V, what is the percentage drop?

    1.58V / 48V = 3.3%

Voltage Drop Calculation

- What amperage do we use in PV voltage drop calcs?
  - The higher the amperage, the greater the calculated drop
  - Rule of thumb:
    - Use Peak Power amperage (IMP) for grid-tied PV currents
    - Use ISC for battery charging circuits PV circuits
    - Use max steady state current of the load
    - Use max steady state current for battery to inverter circuits
- What voltage do we use in PV voltage drop calcs?
  - Doesn’t matter if we are trying to measure the actual voltage loss
    - Example calculating voltage drop to make sure on/off set point is not reached
  - Use nominal percentage if you are looking for percentage

Voltage Drop Calculation

Example 4 (breakout into groups and try): (RT=Round Trip)

(Distance must be multiplied by 2 unless round trip is stated.)

- Determine voltage drop in grid-tied PV source circuit
  (12AWG stranded, 200FT RT, ISC = 5.2A IMP = 4.95, Temp = 40C)

  1.98 Ohm/kFT * 200/1000 * 4.95A = 1.96V

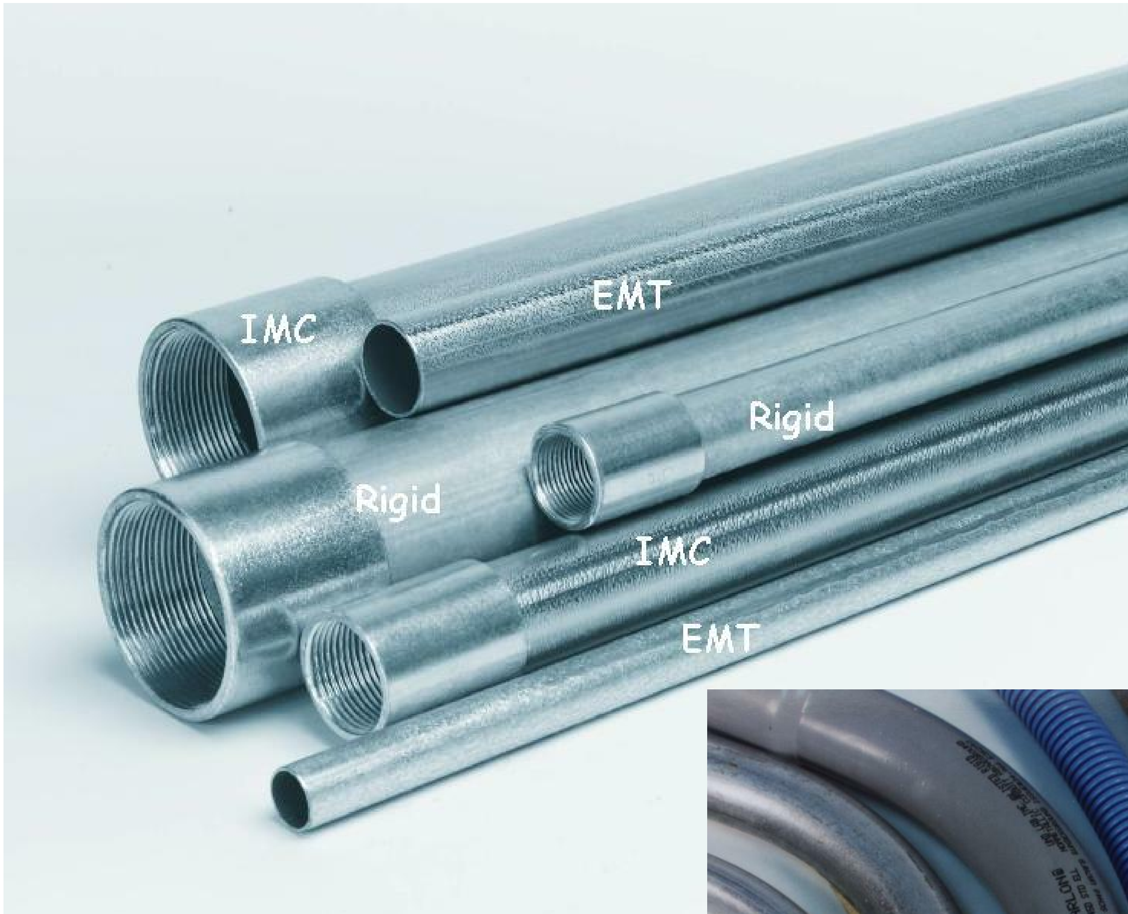
- Determine voltage drop in battery charging circuit
  (2AWG, 50FT RT, ISC = 41.6A IMP = 39.6A, Temp = 120C)

  0.194 Ohm/kFT * 50/1000 * 41.6A*(1 + 0.00323*(120C-75C)) = 0.46V

- Is this acceptable for a 12V system with 2%-3% voltage drop?

  0.46V / 12V = .03833 * 100 = 3.8%, NO

Conduit Discussion



Conduit Discussion

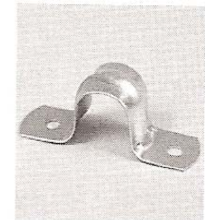
- Conduit comes in various configuration
  - EMT – Electrical Metallic Tubing
    - Thin wall conduit
    - 40% thinner than rigid
    - Lighter, easier to bend, & no threading
  - RMC – Rigid Metal Conduit
    - Heavy duty
    - Requires threading-like plumbing
    - Generally used for service entrance risers.
  - IMC – Intermediate Metal Conduit
    - Between RMC and EMT
    - Can be threaded
  - PVC – Polyvinylchloride
    - Cheaper alternative
    - High coefficient of thermal expansion
  - FMC – Flexible Metal Conduit
  - LFMC – Liquidtight Flexible Metal Conduit
  - FMT, LFNMC, ENT

Conduit Discussion

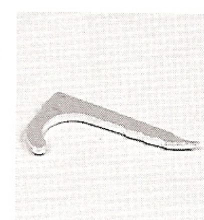
- Conduit comes in various sizes
  - ½”, ¾”, 1”, 1-¼”, 1-½”, 2”, 2-½”, 3”, 4”
  - For the “same size” conduit- EMT, IMC and RMC may have a different inside area
- Per NEC
  - Min size = ½ inch
  - Permitted usages vary for each type
  - Article 358: EMT
- Support requirements (RMC, EMT, IMC)
  - Securely fastened every 3m (10ft)
  - Within 0.9m (3ft) from every junction box, outlet, transition, direction change
  - Should follow horizontal and vertical lines, smooth transitions
  - No more than 4 quarter bends between pull points

Conduit Discussion

ONE HOLE PUSH-ON CONDUIT STRAP



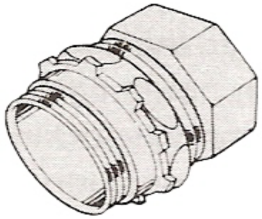
TWO HOLE CONDUIT STRAP



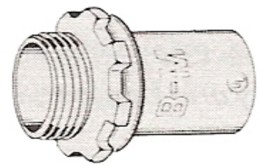
NAIL-UP CONDUIT STRAP

Conduit Discussion

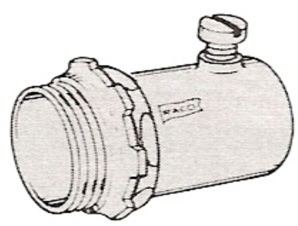
- EMT must be firmly secured to electrical boxes using compression, indenter, or screw set connectors.
  - Compression – firmly secures the conduit by utilizing a nut that compresses a tapered metal ring into the conduit.
    - Can be reused several times
  - Indenter – Use of a special tool to make an indention (swaging)
  - Set Screw – used to connect two runs of conduit together and maintain a smooth inside run.



COMPRESSION



INDENTER



SET SCREW

Conduit Discussion

- 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.	mm^2	$in.^2$	mm^2	$in.^2$	mm^2	$in.^2$	mm^2	$in.^2$	mm^2	$in.^2$
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 Discussion

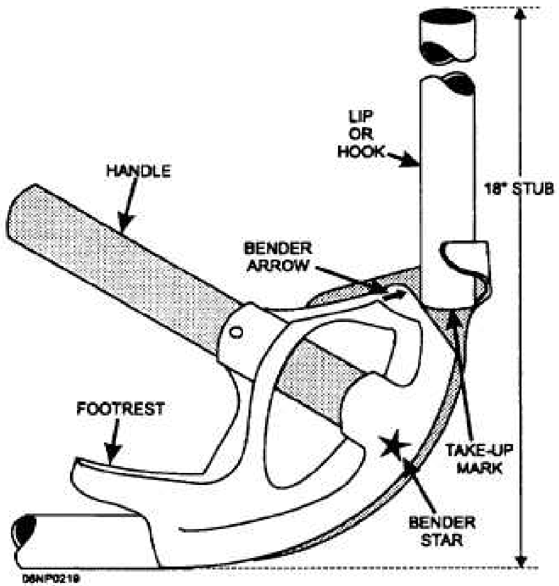
- NEC Chapter 9, Table 5: Dimensions of insulated wires

Type	Size (AWG or kcmil)	Approximate Diameter		Approximate Area	
		mm	in.	mm^2	$in.^2$
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

Conduit Bender



- Stub in – 90 degree bend
- Run – the complete path between two points
- Rise – distance the conduit will stub up
- Offset bend – allows run to change plane but same direction
- Kick – bend less than 45 degrees that changes direction
- Back to back bend – 90 degree bend off another bend
- Box offset - offset that allows conduit to align with box opening
- Dog leg – Mistake in bends when legs do not line up

Conduit Discussion

- Take-up is the length of pipe to remove from desired height to make the a stub
  - 5 inch for ½ inch bender
  - 6 inch for ¾ inch bender
  - 8 inch for 1 inch bender

- Offset chart is used to calculated proper lengths for various bends
  - 30 degree = 2X length
  - 30 degree = ¼ X shrink

Degree of Bend

Offset Depth Inches	22-1/2°		30°		45°		60°	
2"	5-1/4"	3/8"						
3"	7-3/4"	9/16"	6"	3/4"				
4"	10-1/2"	3/4"	8"	1"				
5"	13"	15/16"	10"	1-1/4"	7"	1-7/8"		
6"	15-1/2"	1-1/8"	12"	1-1/2"	8-1/2"	2-1/4"	7-1/4"	3"
7"	18-1/4"	1-5/16"	14"	1-3/4"	9-3/4"	2-5/8"	8-3/8"	3-1/2"
8"	20-3/4"	1-1/2"	16"	2"	11-1/4"	3"	9-5/8"	4"
9"	23-1/2"	1-3/4"	18"	2-1/4"	12-1/2"	3-3/8"	10-7/8"	4-1/2"
10"	26"	1-7/8"	20"	2-1/2"	14"	3-3/4"	12"	5"

Conduit Videos

Conduit Bend: 90 degree stub and back to back

Video Link:
http://www.youtube.com/watch?v=Ws1QifXhh4U&feature=player_embedded

Conduit Videos

Conduit Bend: 30 offset

Video Link:
http://www.youtube.com/watch?v=8zY91dJYFRk&feature=player_embedded

Conduit Exercise

Every get a 10ft piece of ½ in EMT

- Bend a 12” stub in
- Bend a 24” back to back from the first stub
- Cut and file the tube so that you have two 12” back to back stubs

Using remaining piece of ½ in EMT

- Bend a 30 degree 5” offset