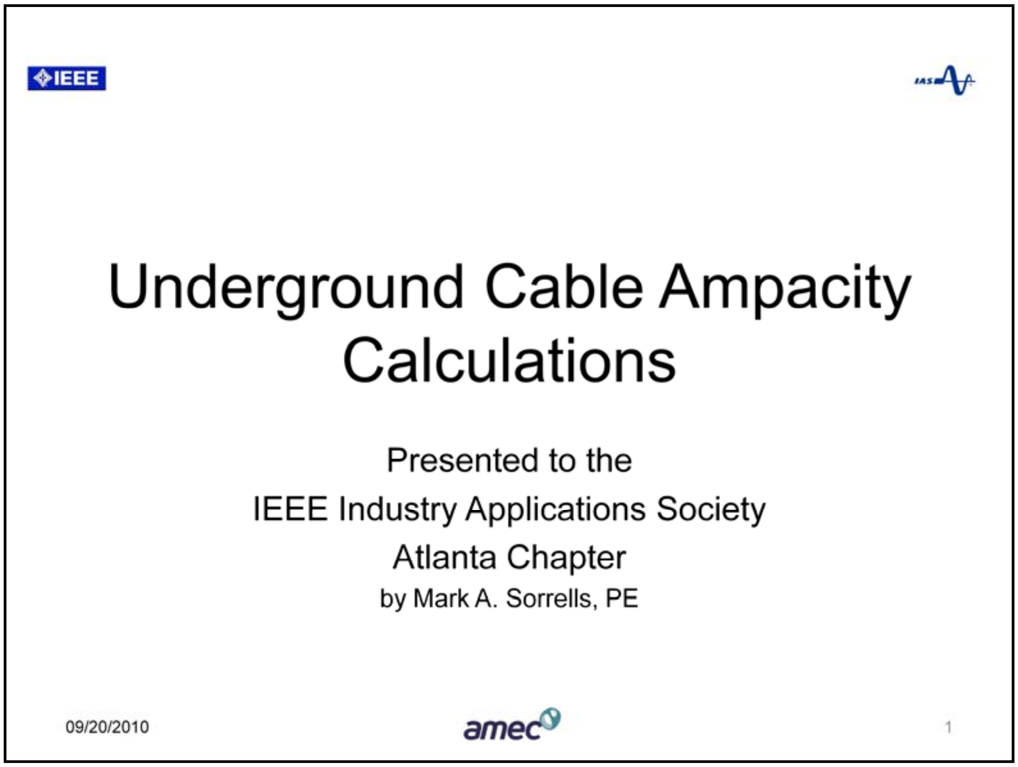

I was originally asked to develop due to experience with UG calcs over past several years. Primarily in Food & Beverage, Cement

Please note: I have to cram ~ 1 year of (cumulative) experience gained over 9½ years into a 1 hour presentation. My posted handout will contain reference “footnotes” for further reading.

Underground Cable Ampacity Calculations

Agenda

Guidelines

Specifics

Reports

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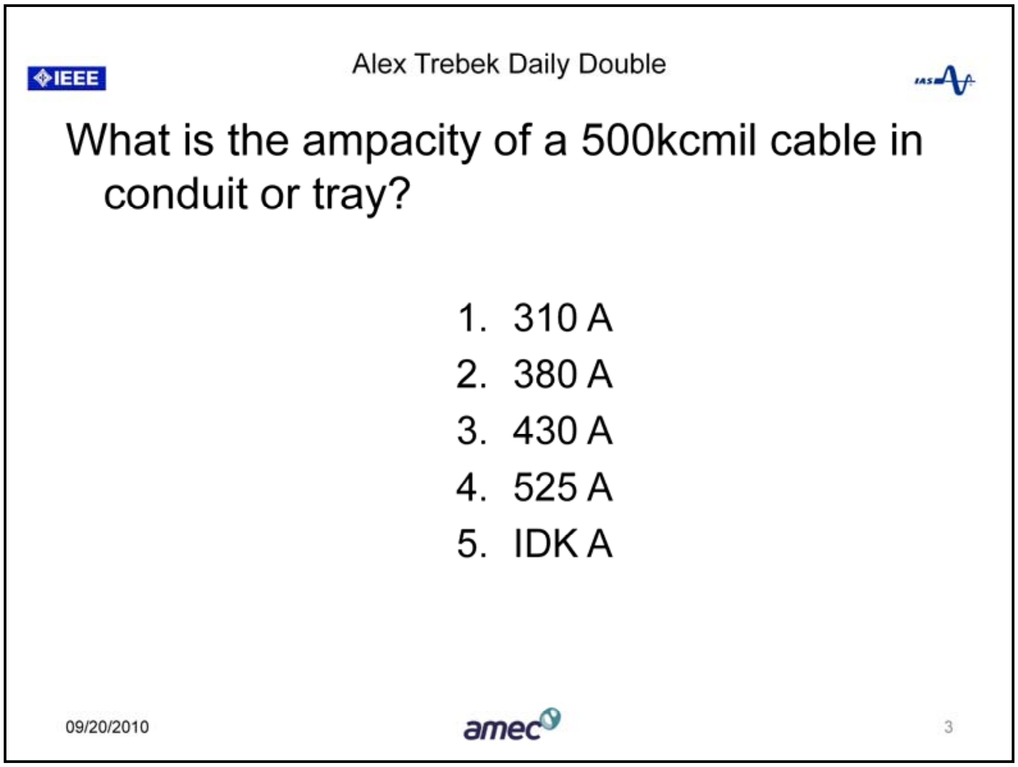
Guidelines: Need to know / High level overview – 1000 m level

Specifics: Drilldown / Data input – 100 m level

Reports: Results / Why we do these calculations 10 m level

NEC® 310.15 Ampacities for Conductors Rated 0–2000 Volts. (A) General. (1) Tables or Engineering Supervision. Ampacities for conductors shall be permitted to be determined by tables as provided in 310.15(B) or under engineering supervision, as provided in 310.15(C).

NEC® 310.60 Conductors Rated 2001 to 35,000 Volts. (B) Ampacities of Conductors Rated 2001 to 35,000 Volts. Ampacities for solid dielectric-insulated conductors shall be permitted to be determined by tables or under engineering supervision, as provided in 310.60(C) and (D).



Take vote starting by Show of hands

310 is T310.16 AL 75ºC. 380, 430 are T310.16 Cu 75ºC, 90ºC, 525 is 310.75 Cu MV-105 15kV

Real answer: IDK. Not enough info.

Grade (if I had given all five answers to start with): answers 1 thru 4 = 25%; numerical answer other than 1-4 50%; just stating Other or IDK 100%. All answers were correct, best answer was Other or IDK.

IEEE Underground Cable Ampacity Calculations IAS

- Guidelines
  - DON'T RUSH IN.
  - This is a Heat Transfer Problem.
  - Results Should be Reproducible.

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Don't rush in – There are items that you really need to know up front.

This is a Heat Transfer Problem – Things to do to help maximize cable ampacity.

Results Should be Reproducible – This is the biggest problem. Suggestions to assist with this.

Analogy to 3 Laws of Robotics (from Assimov Robot Series)

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Zeroth Law: A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

Zeroth Law Analogy: There is NO silver / magic bullet.

Underground Cable Ampacity Calculations (Guidelines)

- Don't rush in.
  1. Is a soils report available?
  2. Has the ductbank routing and configuration been established?
  3. Is a single line available?
  4. Are material / installation specs available?

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1st slide: note that emphasis was added.

Soils report: thermal resistivity (442-1981 IEEE Guide for Soil Thermal Resistivity Measurements, ASTM D5334–08 Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure) AND electrical conductivity (Dr. Sakis Meliopoulos Jan 19, 2010: 81-1983 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System)

Ductbank

Routing: Depth, external heat sources, multiple scenarios

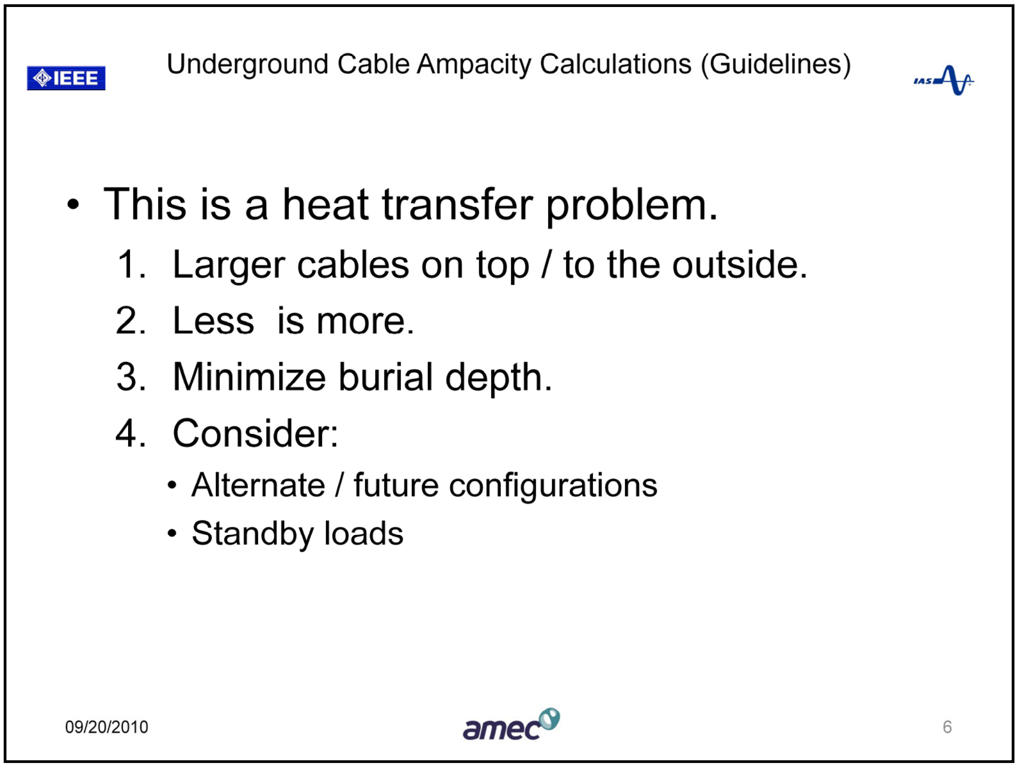
Configuration: If you are performing a calc, then you are into NEC 310.15(C) / 310.60(D) and the standard tables no longer apply

Single line will help determine loading, actual OCPD, any initial intentions

Cable spec should define insulation (XHHW or –2, MV-90 or MV-105, etc) and may define minimum or "standard" sizes

Conduit spec may define types (RMC, PVC, HDPE), sizes to use.

Installation spec may define depth, envelope.



At this point, I need to explain that the purpose of UG calcs is to find the current which the cable can safely conduct. This current is based on the temperature which the materials can handle without damage. Obviously the limiting factor is the insulation. (Melting point of copper is 1084°C. One polymer found on-line which is listed for XHHW-2 stated a melt temperature of 115-135ºC.) Actually all NEC tables are based on heating calculations. To reiterate, the UG calcs are based on balancing the current against the maximum temperature. Note: when running parallel cables, this temperature will probably be in only one or two paths.

Larger cables = more heat. Heat transfers more readily through concrete. Want to keep heat from going through other cables.

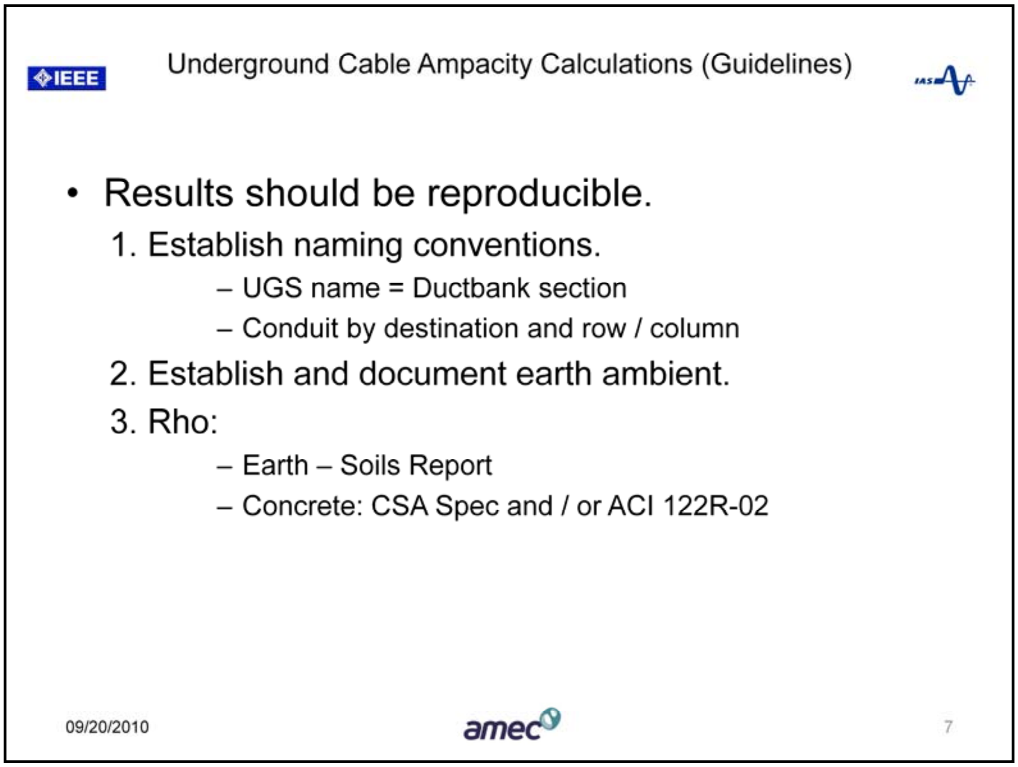
Due to heating, less cables per ductbank = more amps per cable. Also, can use earth as “insulator” to route parallel runs.

Shallow = closer to air for heat dissipation. Must be balanced against installation considerations (under roadway, crossing piping, etc.)

Consider:

Alternate configurations – what if top conduit / conductor is damaged beyond repair? Future transformer capacity?

Standby loads: May be required to run beyond 3 hours



Numbering scheme

One scheme for ductbank & conduits: Main incoming / Outgoing ManHole = MH01, Numbers radiate outward. Example: Ductbank MH01-MH02. Number conduits by looking into face of destination ductbank, column row convention. MH02-11.

IEEE C37.232 IEEE Recommended Practice for Naming Time Sequence Data Files. File name contains location as part of the naming convention. UGS = 0048 Section A.

Ambient:

Earth follows “mean” temperature

http://www.ecolo.org/documents/documents_in_english/kasuda-ground-temp-profile.doc

http://soilphysics.okstate.edu/software/SoilTemperature/document.pdf

Weather data:

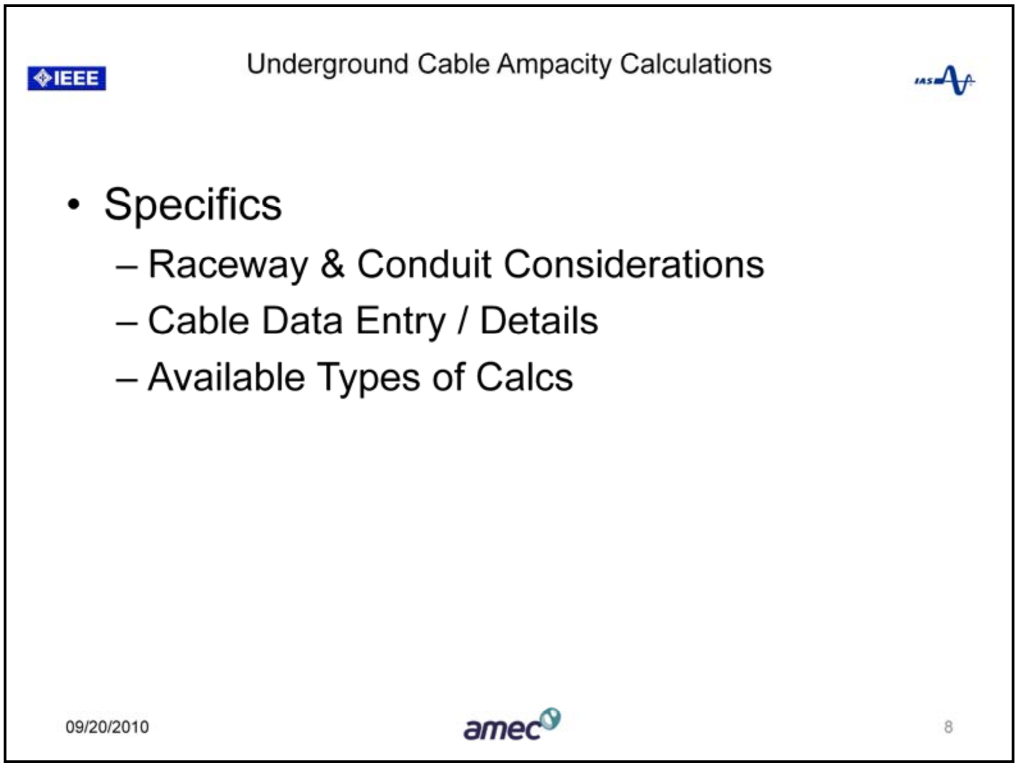
UFC 3-400-02 Design: Engineering Weather Data (http://www.wbdg.org/ccb/DOD/UFC/ufc_3_400_02.pdf)

National Climate Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html)

Rho CAN vary!

Soil: 220 for OroGrande, 250 for LANL, 120 for Hunter, (Damp 60, Average 90, Dry 120) – NEC® B.310.15(B)(2)

Concrete: ACI 122R-02 Guide to Thermal Properties of Concrete and Masonry Systems, (55) – NEC® B.310.15(B)(2)



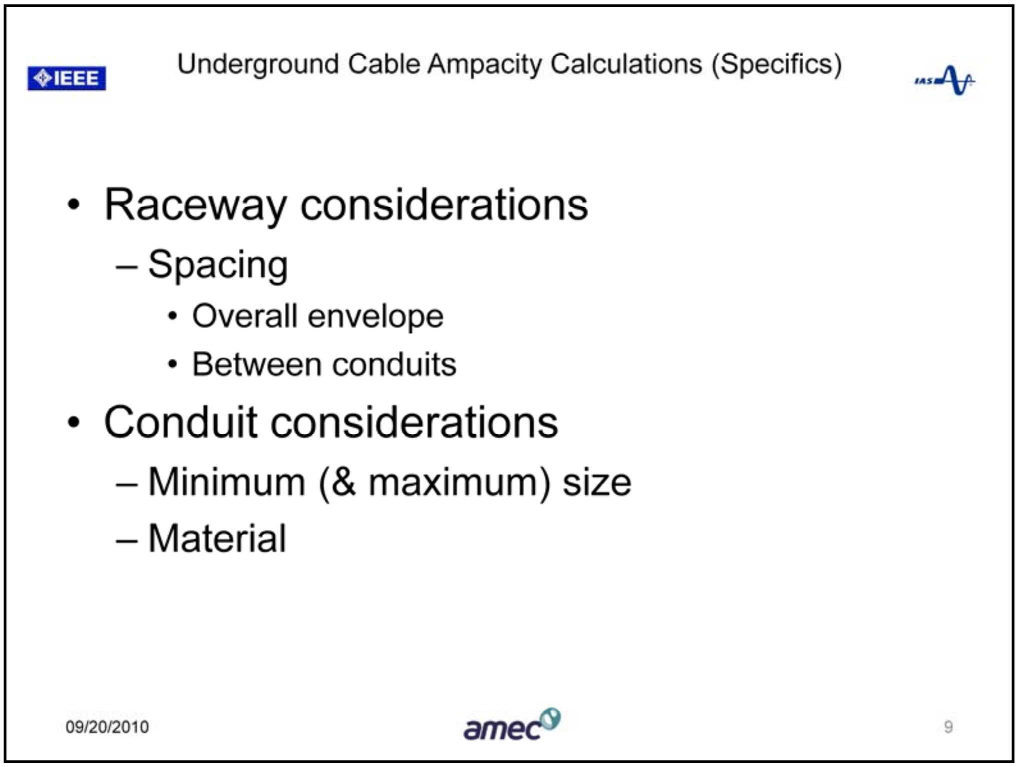
Assuming all up-front data is available: Let’s move into setup of the calc.

1st step: BUILD a single line!

Promotes cable naming

Forces parallel conductors

Helps insure appropriate voltage level for cables



Raceway

Minimum cover requirements: NEC 300.5 for 0-600V, 300.50 for 600V - 22kV, 22kV - 40kV, over 40kV

Conduit spacers are not always 7.5” Center to Center (NEC Appendix B). Centerline for unequal sizes will not be on same horizontal plane

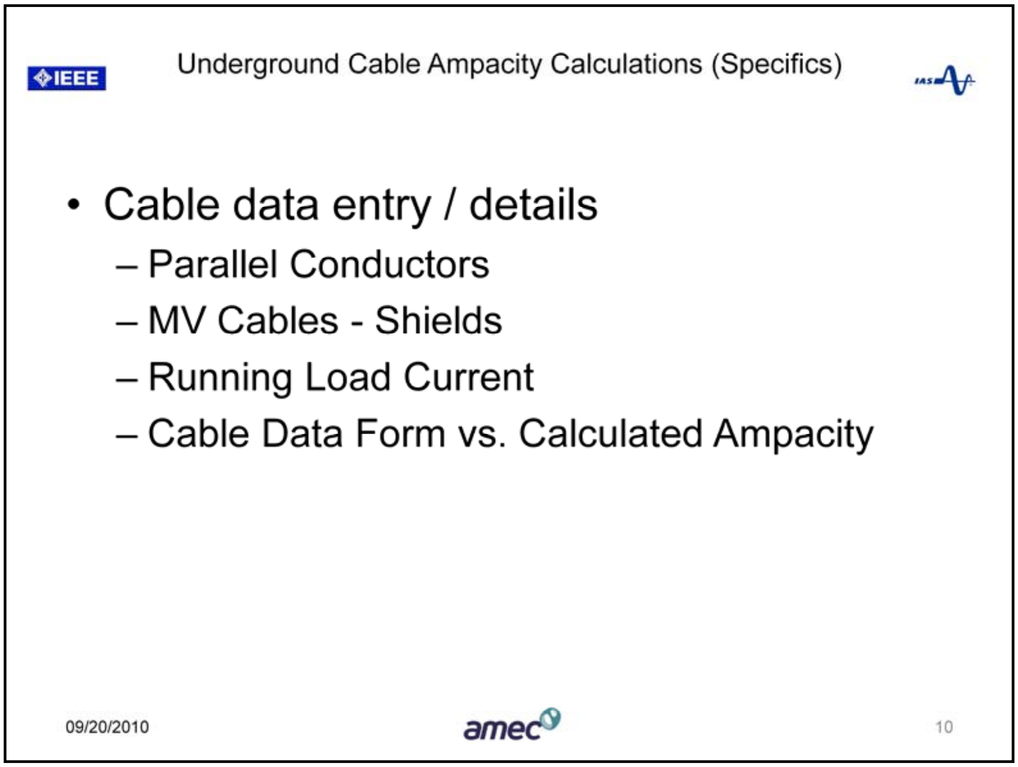
Spreadsheet which calculates conduit centerlines

Conduit

Usually a minimum of 2”, but what about largest? Can it accommodate cable / conductors?

PVC vs RMC (GRC): RHO is different

Temperature Rating of the conduit: 90°C vs. 105°C



Parallel conductors WILL make a difference in how the calculations distribute the current

Normally ground shields on MV cables: ETAP defaults to ungrounded; Neutral current on shield

RLC – Set a value; base on FLA of certain elements

Form will give a “guesstimate” based on certain tables

IEEE/ICEA Standard S-135/P-46-426, Power Cable Ampacities Withdrawn 2000
AMEC hardcopy 2nd printing dated 1978: © 1962, errata 1966

IEEE 835-1994 IEEE Standard Power Cable Ampacity Tables 3086 pages

Class Exercise

How many factors are there to consider when sizing a circuit?

1. 15
2. 24
3. 37
4. 41
5. 50

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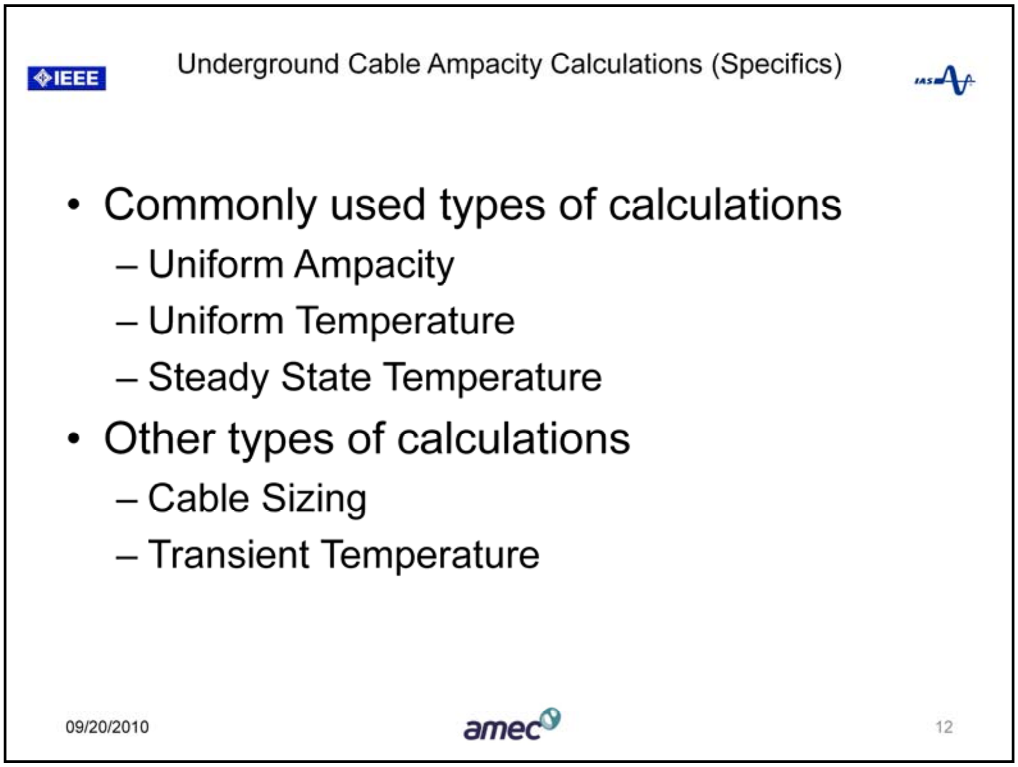
Class Exercise: Do a listing on overhead or white board, Person by person, list ~ 10
Answer is 41: “NEC ampacity tables, circuit sizing, and developing standardized tables”; Fuselier, R.A.; Industry Applications, IEEE Transactions on; Volume: 26 , Issue: 3 Publication Year: 1990



Method of calculation

“The Calculation of the Temperature Rise and Load Capability of Cable Systems”, Neher, J. H.; McGrath, M. H.; Power Apparatus and Systems, Part III. Transactions of the American Institute of Electrical Engineers, Volume: 76 , Issue: 3 Publication Year: 1957

IEC 60287 Electric cables — Calculation of the current rating – (Multiple Parts)

Three (3) temperatures entered during raceway setup

Earth ambient - default 35°C

Warning – default 88°C (2°C below max)

Alarm – default 90°C

UA or UT depending on circuitry. SS is a good backcheck.

TT: Remember this is a function of heat transfer over time. Non continuous loads may be accommodated by not exceeding thermal limits over time.

Word of caution: Use prompt for names when generating output reports. Output will be overwritten without warnings.

Underground Cable Ampacity Calculations (Specifics - Types)

- Uniform Ampacity
  - Determines the maximum allowable load currents when all the cables in the system are equally loaded to the same percentage of their base loading
  - Useful when:
    - Circuit conductors are similar size
    - At least one circuit is 2/C (or more) per Ø

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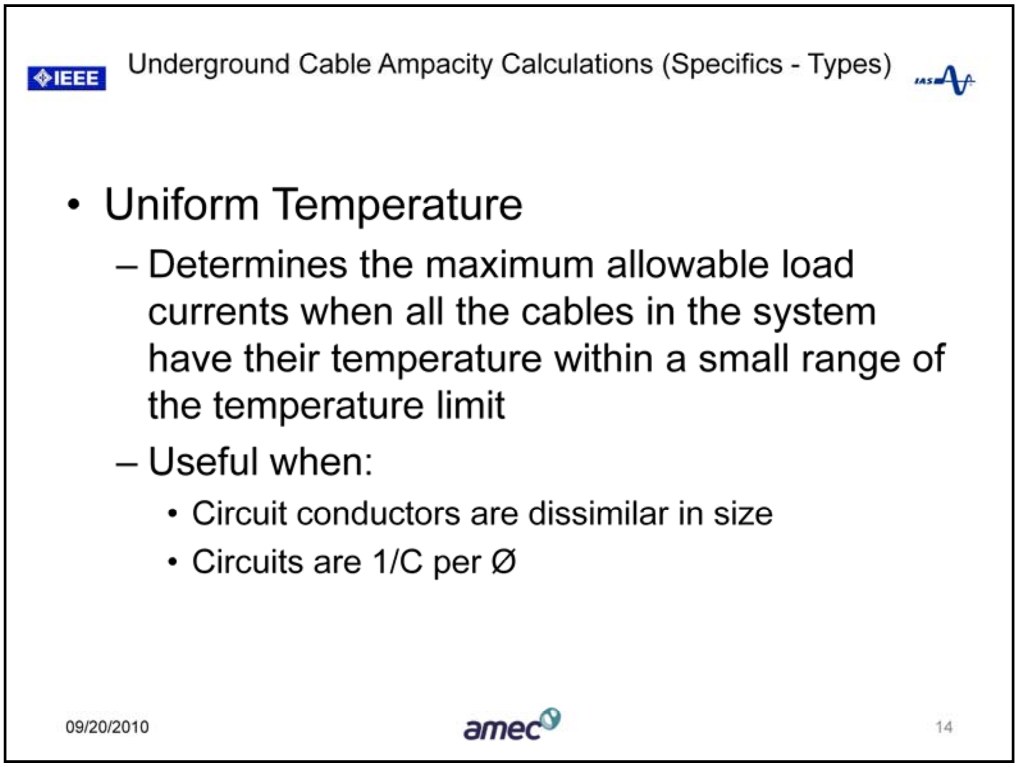
Note that temperature still defines the limit



May have to set the number of iterations for a solution to converge

IEEE Underground Cable Ampacity Calculations (Specifics - Types) IAS

- Steady State Temperature
  - The temperature of all the cable conductors involved in the raceway system under a specified loading condition
  - Useful for evaluating the running load i.e. “a sanity check”

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Usually design a system for future growth. This gives a look at the current state of affairs.

- Reports (assist with Reproducibility)
  - Input - Data
  - Output – Results
- Recommend a calculation sheet for documentation. Minimum of 2 or 3 support documents
  - UG calc reports
  - Single Line(s)
  - Ductbank drawing(s)

Underground Cable Ampacity Calculations (Reports)

- “Input” Sections
  - Cover
  - External Heat Source Data
  - Ductbank Raceway Data
  - Conduit Data
  - Cable Data

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Cover

Numbers of raceways and external heat sources, etc; Type, RHO and ambient temperature of Soil, and temperature limits.

External Heat Source Data

Locations, OD and temperatures of ext. heat sources

Ductbank Raceway Data

Physical information of the Duct Bank Raceways, such as their Locations, Dimensions, Fill Materials, and Numbers of Conduits and Cables.

Conduit Data

Physical information of conduits, such as their Locations, Type, Size, Thickness, OD, RHO, Thermal Resistance, and Fill%.

Cable

Physical information of cables, such as Size, Rated kV, Current, and parameters of Conductor, Insulation, Sheath and Jacket

Underground Cable Ampacity Calculations (Reports)

- "Output" Sections
  - Analysis Results
  - Summary

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Analysis Results

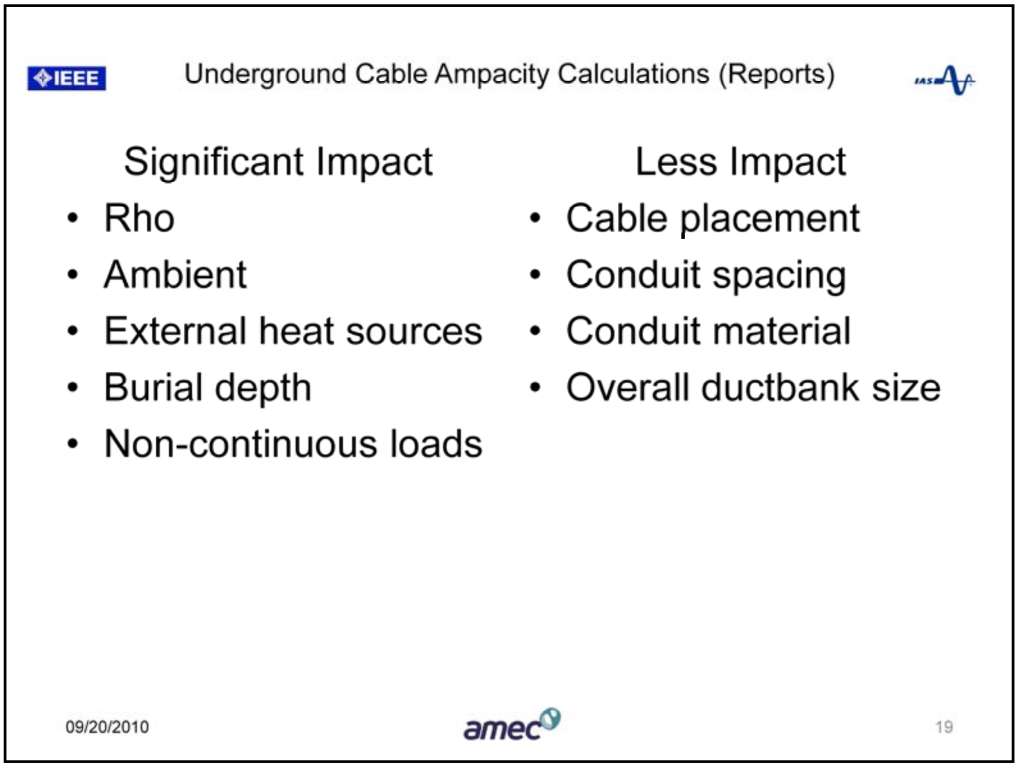
Listed by individual cable (3-1/c or 1-3/c): Cable ID, followed by conduit/location ID, cable dielectric losses, current & temperature

Ampacity (UA or UT): cable maximum allowable load at final temperature

steady-state: Conductor temperature at preset load

Summary

Cable location, size, current, and temperature.



Non – continuous loads – Verify whether off or on

Class exercise:

Rho (Note that ETAP defaults to soil – 90, concrete – 90)
Burial Depth
Spacing
Cable Placement

Group Exercise – Find off-baseline parameters

Calculated Ampacity of 308.07 (UT) , 314.97 (UA) for Swgr301A-F

Calculation	UT	UA	Rho	Ambient	Depth	Spacing	Cbl Place
BaseLine	308.07 A	314.97 A	90	20 °C	24	7.063	Top
1	238.74 A	246.19 A	200	20 °C	24	7.063	Top
2	221.07 A	227.65 A	200	30 °C	24	7.063	Top
3	285.14 A	291.37 A	90	30 °C	24	7.063	Top
4	271.42 A	277.61 A	90	30 °C	36	7.063	Top
5	293.34 A	300.12 A	90	20 °C	36	7.063	Top
6	299.24 A	305.90 A	90	20 °C	36	8.563	Top
7	314.64 A	321.21 A	90	20 °C	24	8.563	Top
8	312.83 A	319.85 A	90	20 °C	24	8.563	Bot
9	306.65 A	313.88 A	90	20 °C	24	7.063	Bot
10	237.88 A	245.67 A	200	20 °C	24	7.063	Bot
		1326.42 A					
		1927.26 A					

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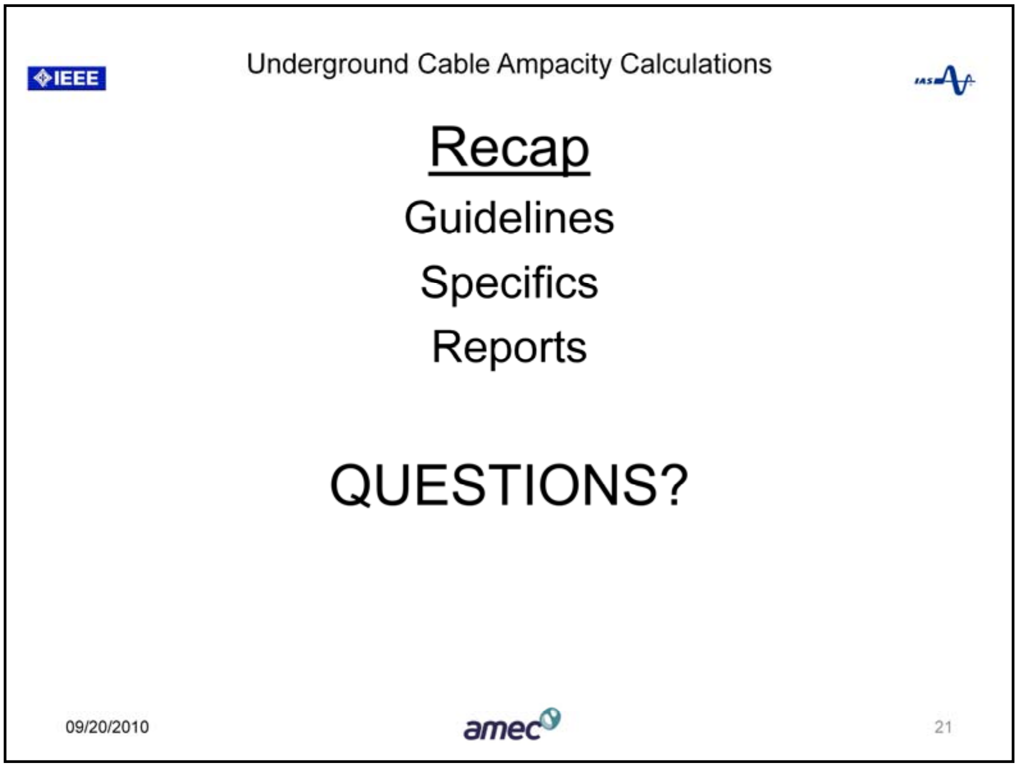
Base loading 1000kVA: 13.8kV @ 41.837A, .48kV @ 1202.813A needs 5 secondary feeders @ 241A each

Uprated loading 1250kVA: 13.8kV @ 52.296A, .48kV @ 1503.516A needs 5 secondary feeders @ 301A each

380 A, 430 A are T310.16 Cu 75ºC, 90ºC; 310A, 350 are T310.16 Al 75ºC, 90ºC



Guidelines: Need to know / High level overview

Specifics: Drilldown / Data input

Reports: Results / Why we do these calculations