Incab

ADSS in High Electric Fields

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President

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ENGINEERING RCEP
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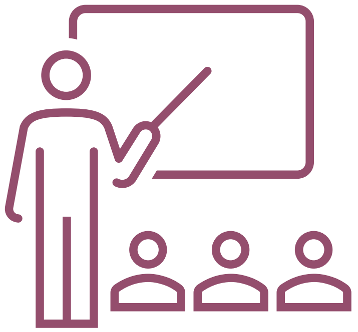
PURPOSE AND LEARNING OBJECTIVES

The purpose of this activity is to cover ADSS in High Electric Fields

After this class, you will be able to:

1. Explain why ADSS is sometimes used in "high electric fields"
2. State what a "**high electric field**" is
3. Be able to compare and contrast the problems of **corona** and dry band arcing, and what mitigative actions can be taken against each
4. Explain the difference between **space potential** and **electric field**
5. Explain why **space potential analysis** is done instead of electric field analysis
6. Be able to apply the results of space potential analysis to your ADSS cable design

How To Earn PDH Credits



- You will receive a follow up email with these details:
  - Link to 10 question quiz
    - Must pass quiz with 70% or higher to receive credits
  - Participation will be submitted within 1 business day
  - Recording of presentation will be uploaded on our Learning Hub

- Please respond to follow-up email if you need a copy of presentation

- If you do not receive an email or have questions please reach out to marketing@incabamerica.com

Incab University "School of Excellence in Fiber Optics"
Agenda

- Introduction
- Learning Objectives
- PDH Information
- Presentation
- Q&A (Technical questions only)
- Let's start!

ADSS Cable in High Electric Fields

Cable Basics – A Quick Reminder

All Dielectric Self-Supporting

- "Dielectric" = No metallic components
- "Self-Supporting" = Designed to support its own weight

This webinar assumes that you are already familiar with basic ADSS design concepts from our ADSS Engineering 101 webinar

Recall the next slide that was included in 101…

Electric Field Guidelines

ADSS specific issues

- Standard polyethylene jacket (MDPE or HDPE) is limited to < 12 kV space potential
  - PE degrades in a strong electric field which leads to tracking on the jacket
  - Jacket burns through, and the breech leads to mechanical or optical failure
- For > 12 kV Space Potential, need track-resistant jacket, and…
  - Corona at the tips of the accessories can damage the jacket
    - Solution: "Corona Coils" must be used at the ends of all armor rods
  - Caution: Could have induction issues with pulling line during installation
- Absolute maximum space potential is 25 kV

My memory bubble

ADSS cable in High Electric Fields

Cable Engineering Toolkit

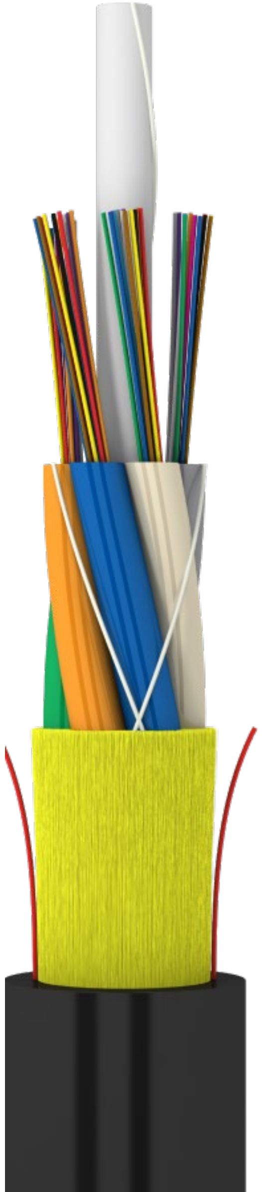
- Now we will expand on that slide and add these “tools” to our cable engineering “toolkit”

Why? Why even consider using ADSS in a “high electric field” in the first place?

What? What is a “high electric field” anyway?
What is the difference between an “electric field” and “space potential”

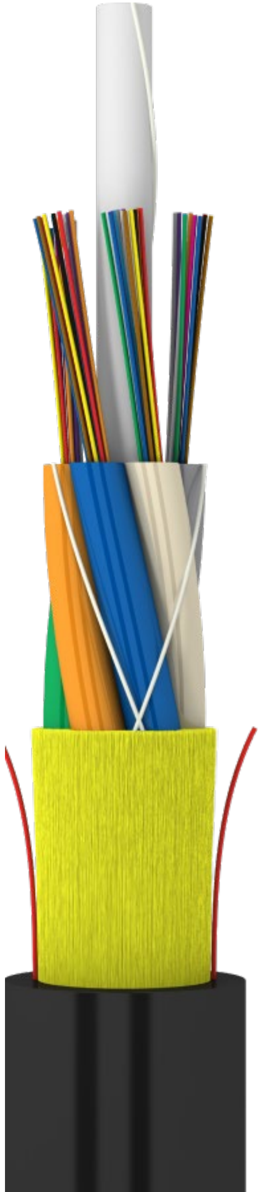
Where & Which? Knowing where to put which type of ADSS jacket so that the system provides long-term reliability

➔ This will lead us to Space Potential Analysis, and we’ll learn how to easily do that too!



ADSS cable in High Electric Fields

Cable Engineering Toolkit



The Why = Because sometimes ADSS is the best or even the only solution

- Some HV/UHV transmission lines do not have a shield wire, so OPGW not an immediate option
  - Example: Parts of the western USA (notably BPA's region)
- Outages on HV/UHV transmission lines are difficult to impossible to get
  - Makes installing OPGW problematic (Doable, but…)
  - ADSS can be installed "hot" (easy compared to OPGW!)
- Cost! Material cost for ADSS can easily be 40 – 50% cheaper than OPGW

ADSS cable in High Electric Fields

Cable Engineering Theory

The What = Now it's time to define and describe what an **electric field** is and compare/contrast it with what **space potential** is

- An electric field is a region of space around an electrically charged particle or object in which an electric charge would experience a force

- On transmission lines, the "object" is the conductors, and the operating voltage is the source of the "electrically charged"

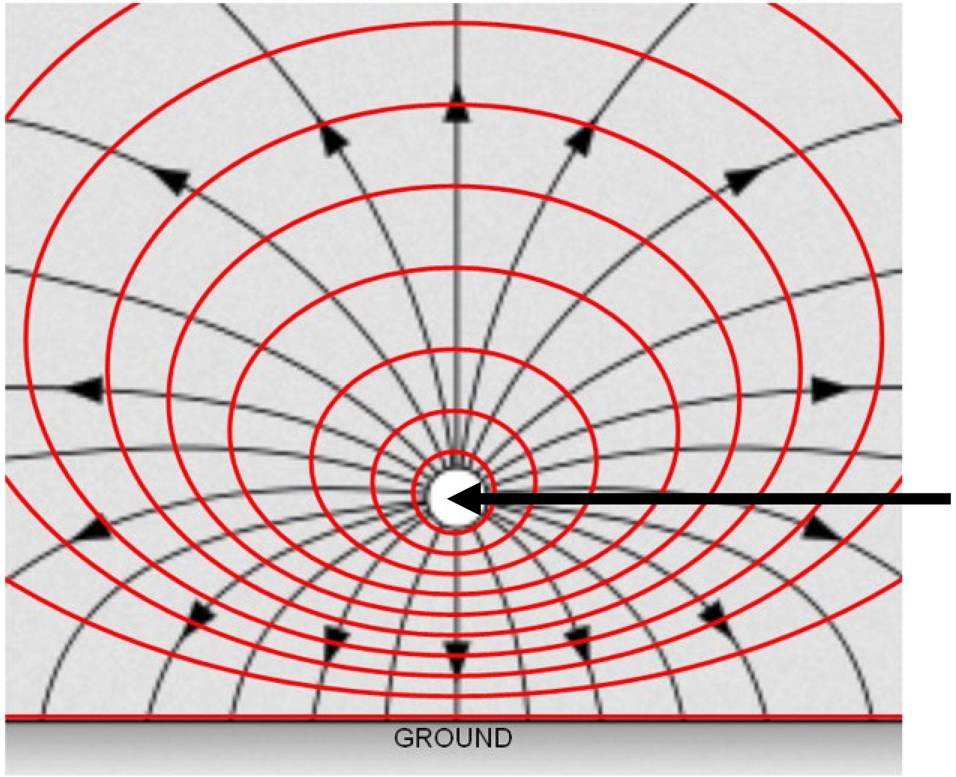
- And, "force" implies a direction and direction implies distance

➔ So, what we discover is that the voltage is not really confined to the conductors, but rather radiates outward from them to create a "field"

ADSS cable in High Electric Fields

Cable Engineering Theory

- That “Field” is what we call the “Electric Field”
- Imagine a single conductor with an applied voltage of 1,000 V above ground,
  we can visualize its electric field as…



1000 volts in center

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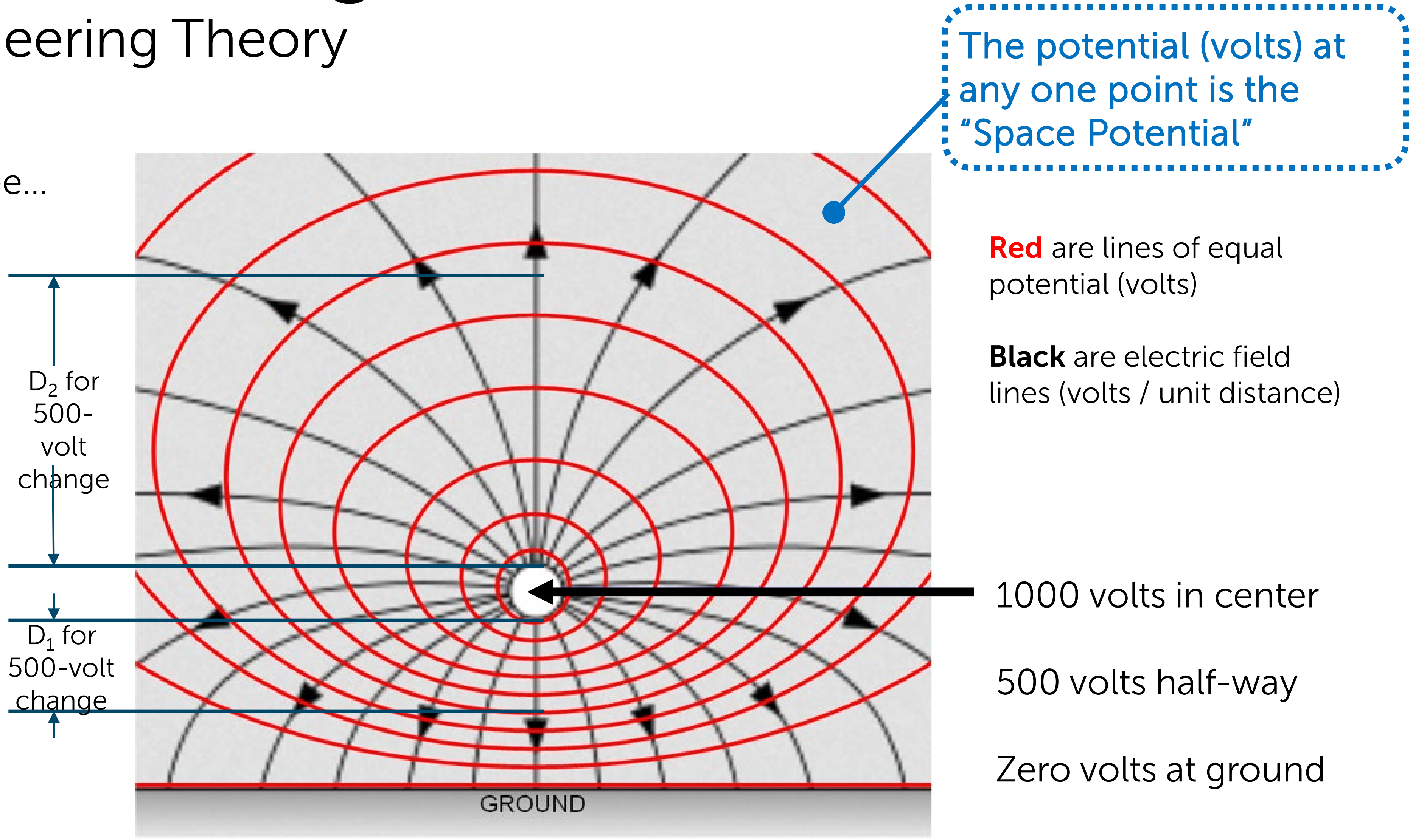
Cable Engineering Theory

- We can also see…

Notice that $D_2 > D_1$

The ground distorts the field (forces it to zero)



Red are lines of equal potential (volts)

Black are electric field lines (volts / unit distance)

500 volts half-way

Zero volts at ground

ADSS cable in High Electric Fields

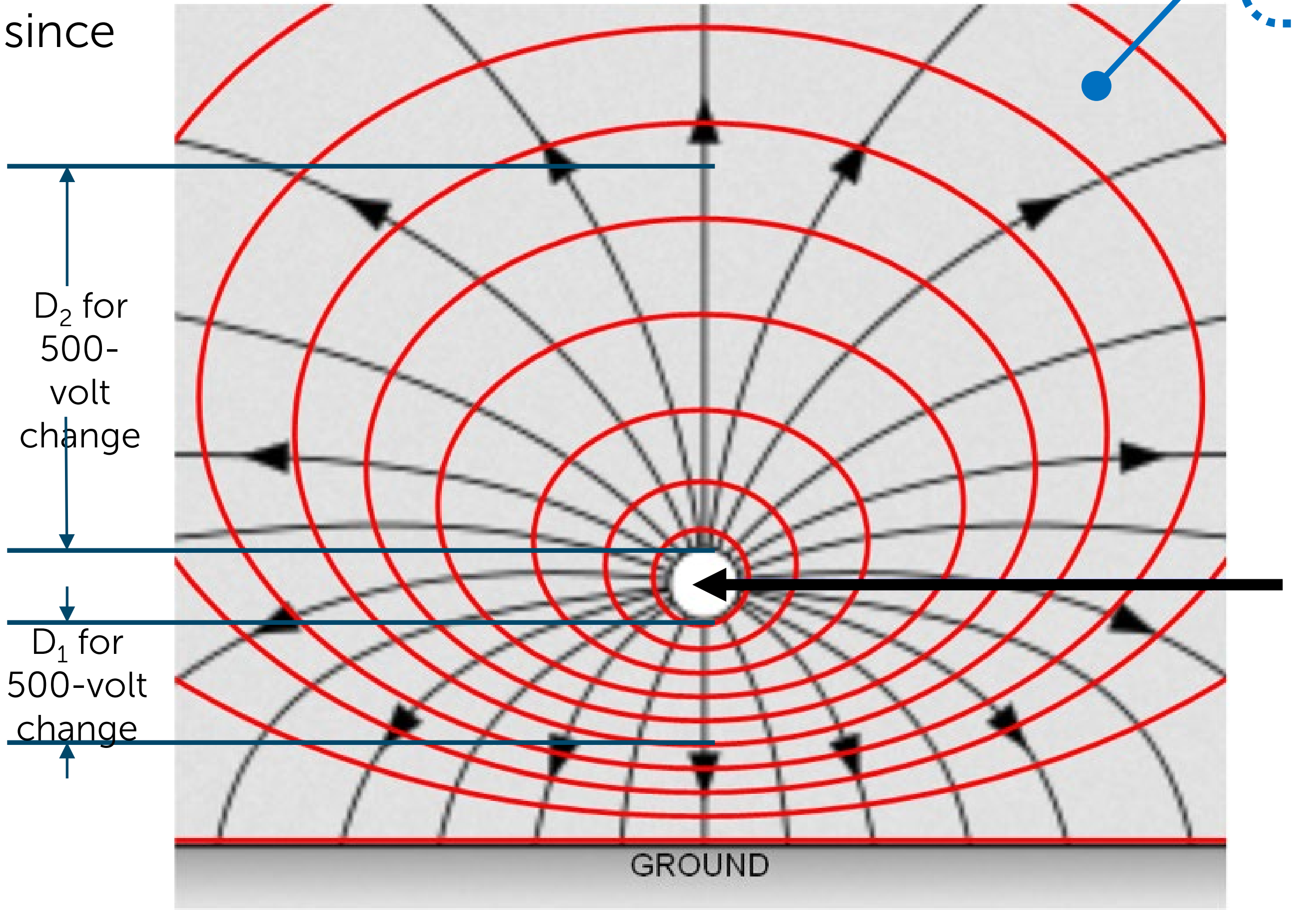
Cable Engineering Theory

The potential (volts) at any one point is the “Space Potential”

- Also note that since D2 > D1 ….

$$\frac{500\text{ volts}}{D_2} < \frac{500\text{ volts}}{D_1}$$

So, we say that the field from the conductor to ground (D_1) is higher, stronger, or more <u>intense</u> than the field above the conductor (D_2)



Red are lines of equal potential (volts)

Black are electric field lines (volts / unit distance)

1000 volts in center

500 volts half way

Zero volts at ground

ADSS cable in High Electric Fields

Cable Engineering Theory

- **Now we see and know that**

Space potential is the electric force (V or kV) at any one point in space

- No direction, no distance
- It's helpful to work with equipotential lines which means that all points on a line are at the same space potential

Electric field (V/distance) has direction and can change over distance (strength or intensity)

- The common unit used is kV/m
- A high electric field is simply a relative term
  - It's convenient to use the point at which real world problem start to occur
  - That point ranges from 500 kV/m – 3500 kV/m (5 kV/cm – 35 kV/cm)

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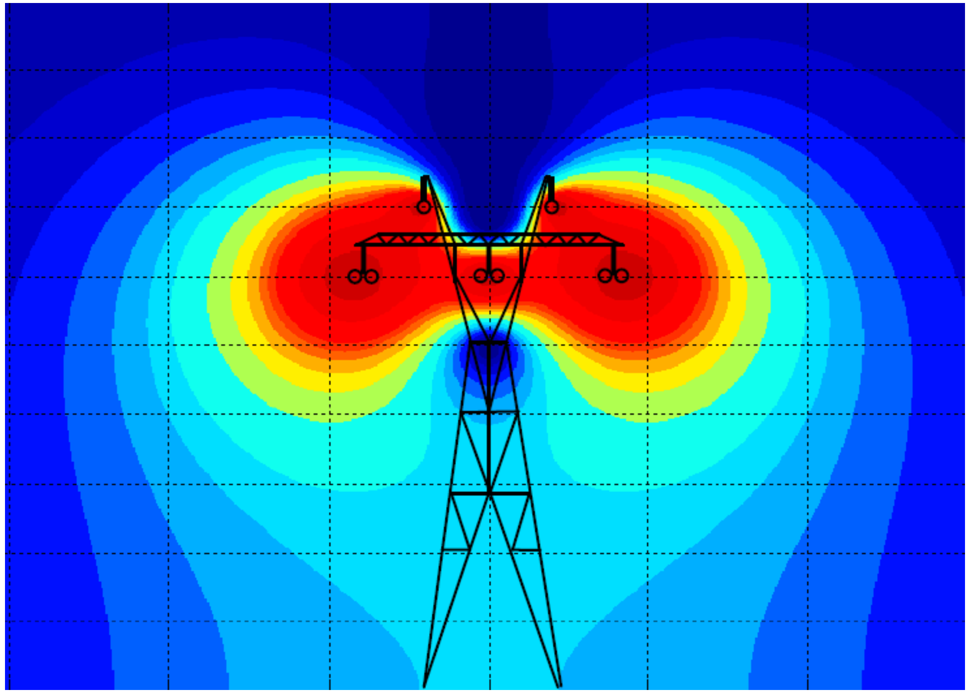
Cable Engineering Theory

But you are now probably thinking:

Don't actual transmission lines have more than one conductor?

Answer: **Yes, they do!** Typically, three conductors or bundles of conductors

- Each conductor or bundle (phase) has its own field that interacts with those of the other two
- Each can also interact with the structure which distorts the fields like the ground did in our single conductor example



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Cable Engineering Theory

This additional complexity leads to a classic "Good News, Bad News" type situation

- The **Bad News** is the complexity itself
  - Do we have to do 3D modeling of the electric field all along a transmission line in order to properly deploy ADSS in a high electric field?! Yikes!
    - Difficult on transmission lines because the geometry will change along a span because of the different sag characteristics of the phase conductors versus the ADSS and will further vary with temperature and current flow (thermal effects on the conductors)

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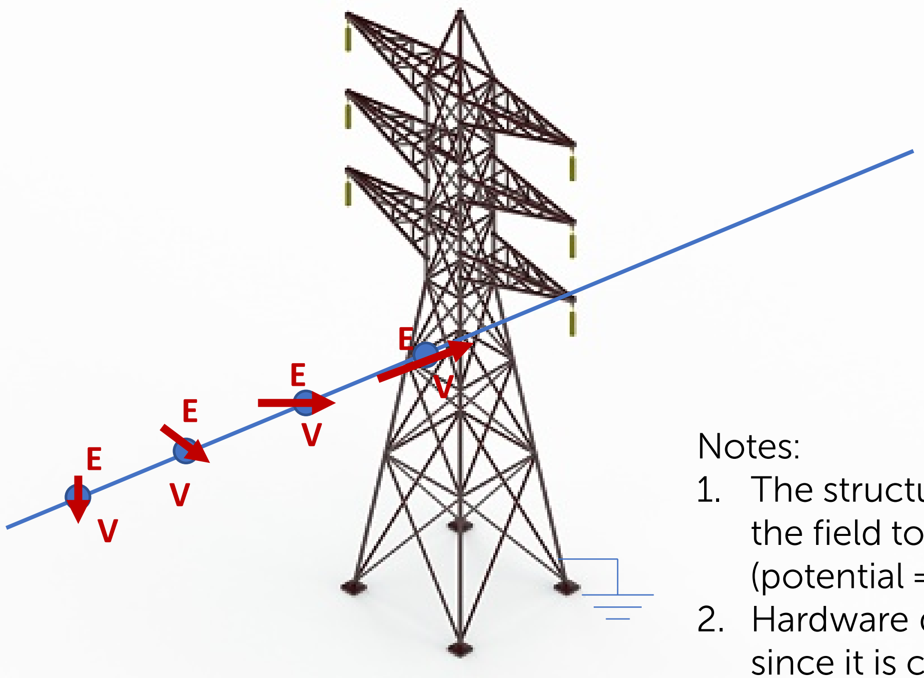
Cable Engineering Theory

- The **Good News** is that by the grace of "Maxwellian Math," we catch a lucky break!

- At points along a hypothetical longitudinal axis along the line, the direction and strength of the electric field (E) changes

- The changes happen to be favorable to our cause!
    - The field is along the axis close to the structure
    - The field is orthogonal (perpendicular) to the axis by the middle of the span between structures, and its intensity tends to decrease moving towards mid-span (just the field, *not* the space potential)

E = the electric field
V = the space potential



Notes:

1. The structure forces the field to "ground" (potential = zero)
2. Hardware does too since it is connected to the structure

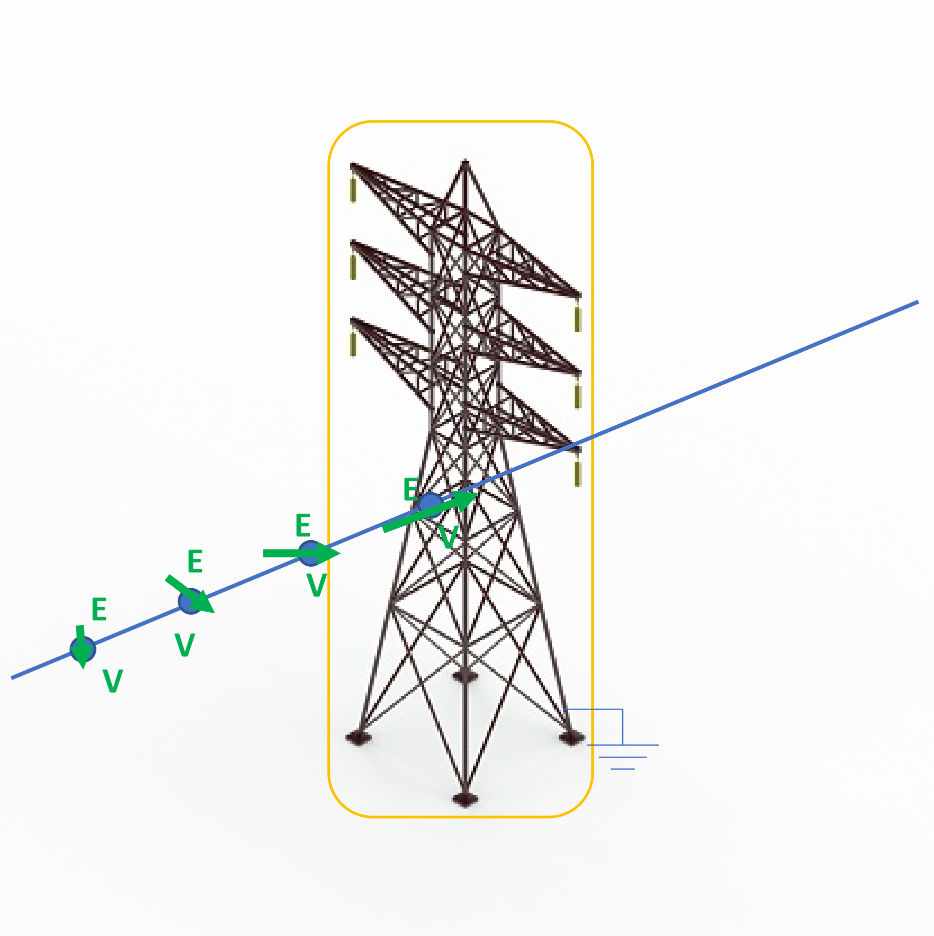
ADSS cable in High Electric Fields

Cable Engineering Theory

- Why is this favorable?

- It means that electric-field-related <u>problems</u> are likely limited to at or near the structures
  - So, we can focus/limit our attention there

- It means that we can simply do our analysis in two very practical ways:
- — We can use 2D analysis instead of 3D analysis (thereby focusing specifically *at* the structure)
- — We can use space potential as a “stand in” for the electric field’s intensity
- * Rather than having to model and analyze the electric field which would be very difficult to do for real-world conditions



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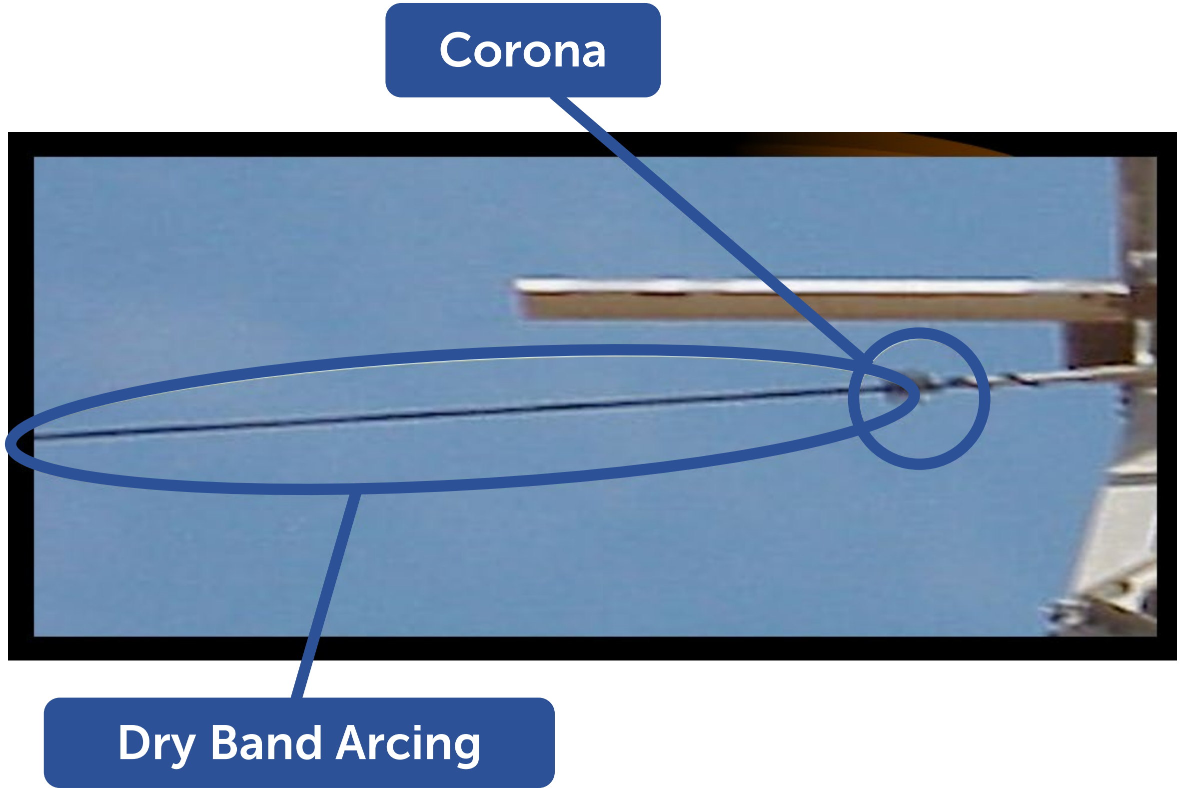
Cable Engineering Theory

- The reference to "**problems**" throws up a **red flag**, doesn't it?
- There are 2 for certain, and sometimes a 3rd that we'll discuss later
  - Corona
  - Dry Band Arcing
  - Microsparking
- Let's talk about the first two for now, we'll circle back later to the third...



Note: Shout out to Monty Tuominen for this picture!

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Cable Engineering Theory

- Corona is an electric discharge that on ADSS will occur on the tips of the armor rods used in the suspension clamps and dead ends
    - The rods act to distort the electric field by "quickly" forcing it to zero.
    - This causes the field intensity (Remember: kV/cm) close to the rods to increase at the rod tips beyond the ionization limit (a.k.a. dielectric strength) of the air
    - Charge "leaks off" the tips into the air and in the process burns through or damages the jacket
        - Leads to "catastrophic mechanical failure" (= cable falls down = very bad)

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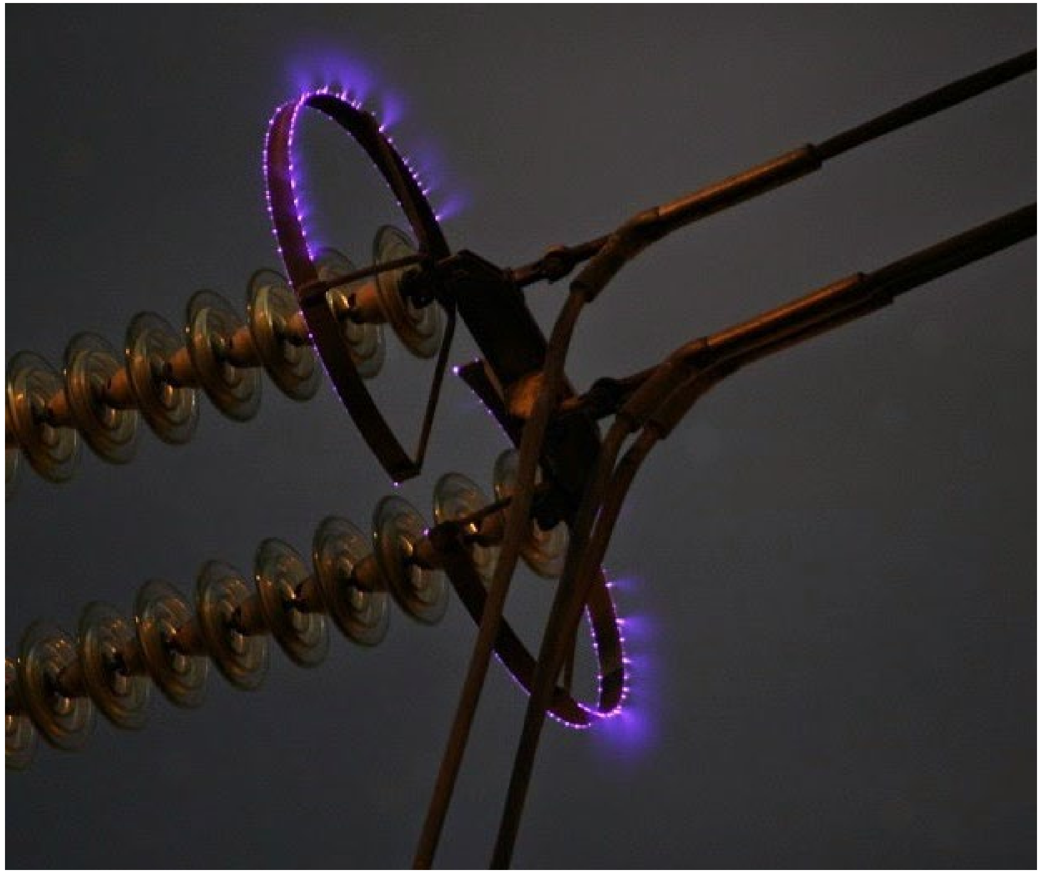
Cable Engineering Theory

- I do not have any pictures of corona on ADSS (hard to be there when it is happening), but here it is on a conductor bundle

- For fun: Why is there corona here? Shouldn't the "corona coils" prevent it?

- Answer: Assuming the coils are properly designed (big if), then maybe they were not made correctly. That is, the edges are not sufficiently rounded. Corona loves any kind of a sharp edge or protrusion. Contamination (pollution, salt) is another possibility.

- BTW: I've also seen this on UHV spacer-dampers that were not made correctly



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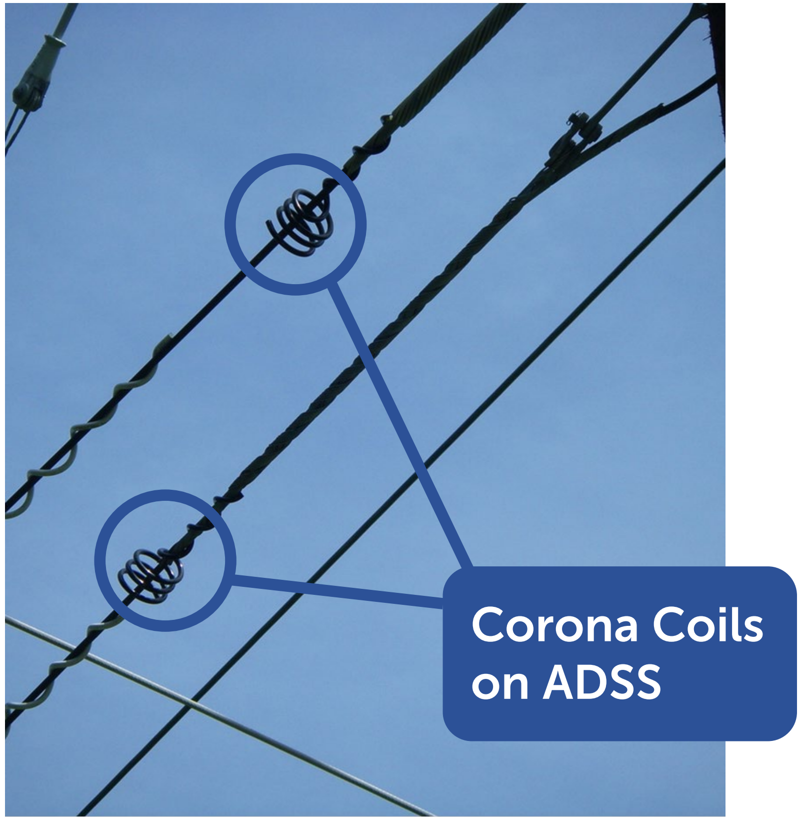
Cable Engineering Theory

Here is a picture of the damage that corona can do on ADSS

ADSS cable in High Electric Fields

Cable Engineering Theory

- The “corona problem” can readily be solved using “corona coils”
  - The coils “grade” or smooth the electric field so that its strength/intensity stays below the ionization limit/dielectric strength of air
- Another solution is to have perfectly rounded armor rod tips that are installed perfectly evenly
  - Good luck with this option! Try corona coils instead!!



ADSS cable in High Electric Fields

Cable Engineering Theory

- Dry-Band Arcing on ADSS is similar* to tracking on insulators

    - It has three “ingredients” that must be present at the same time:
        1. High electric field
        2. Contamination on the jacket (pollution, saltwater)
        3. Moisture

* - Yet also very different…explaining why is outside the scope of this presentation

ADSS cable in High Electric Fields

Cable Engineering Theory

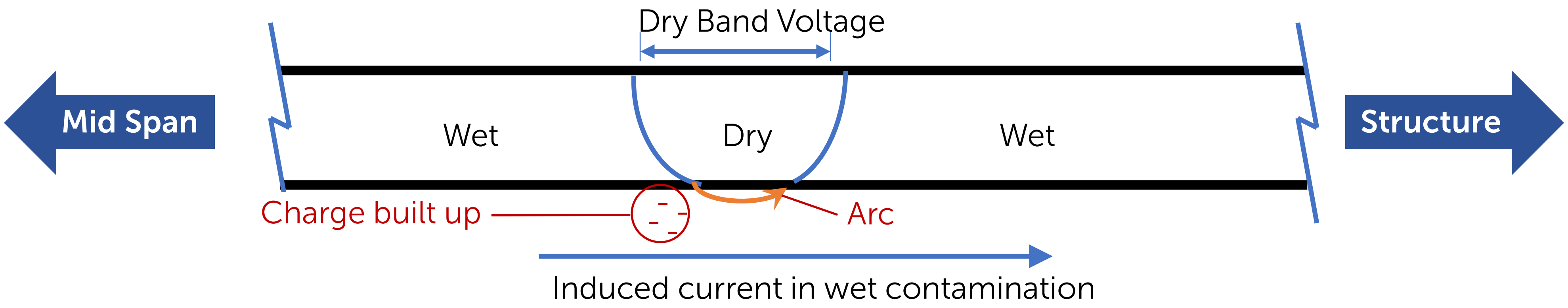
- Dry-Band Arcing on ADSS is similar* to tracking on insulators
  - Here's how these work together to wreck your cable in six easy steps:
    - When the cable gets wet, the contamination makes its surface semi-conductive
    - Meanwhile, capacitive coupling between the cable and the conductors (the electric field) induces a current to flow
    - The current dries the cable, but unevenly, causing small dry bands to form
    - The bands interrupt the current, but this causes a charge to build up (in other words, a voltage across the dry band)
    - Once enough charge builds up, it arcs across the band (like a capacitor)
    - Heating from the arc extends the dry band eventually to the point that the arcing stops, but by that point, it has done "tracking" damage to the jacket

* - Yet also very different...explaining why is outside the scope of this presentation

ADSS cable in High Electric Fields

Cable Engineering Theory

- I do not have any pictures of dry-band arcing occurring, but I can better illustrate it with this sketch:

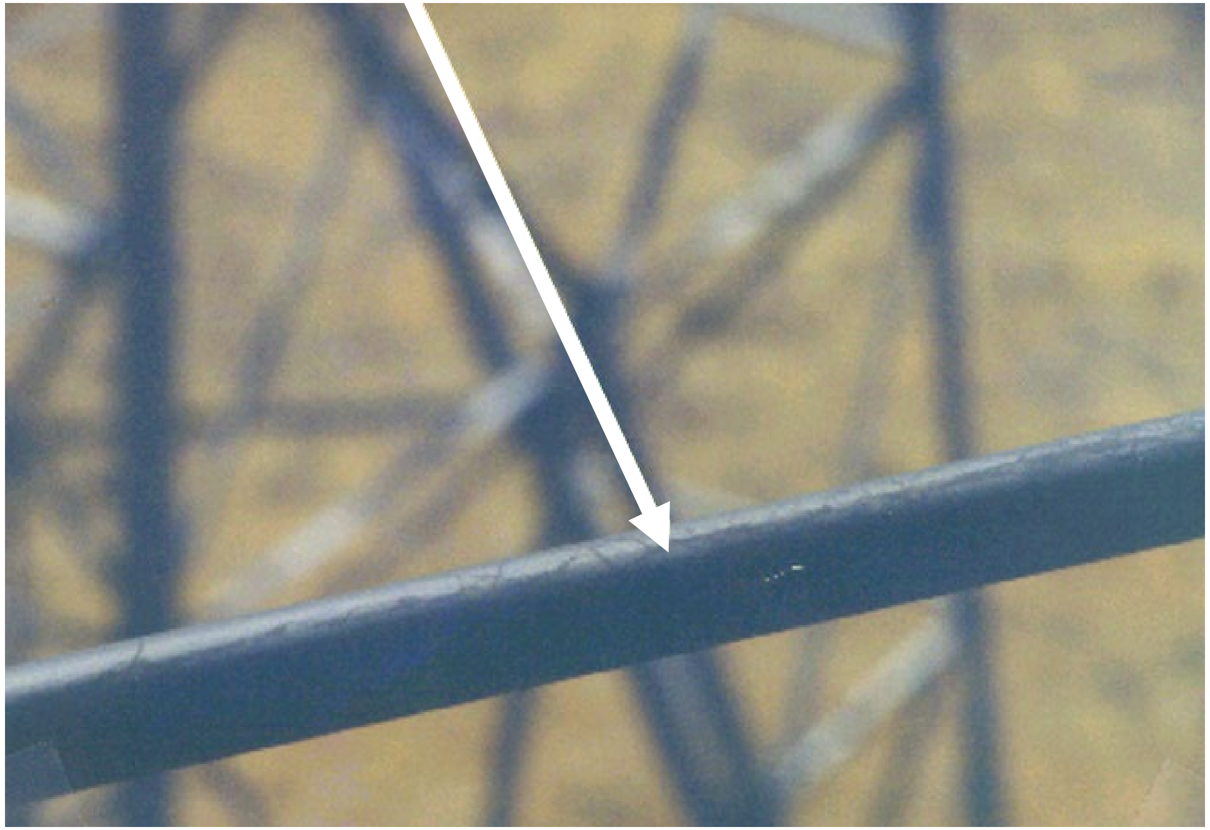


Note: Another shout out to Monty!

ADSS cable in High Electric Fields

Cable Engineering Theory

Here is a picture of the damage that tracking can do on ADSS



Note: Yet another shout out to Monty!

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Cable Engineering Theory

- Solving the problem of dry-band arcing is why tracking resistant jackets were invented
  - Today, most companies that make ADSS offer both standard polyethylene (PE) and tracking resistant (TR) jackets
  - Materials used for TR jackets vary
    - PE with anti-tracking additives is an excellent one

- Now you are wondering: OK, so how do I know if dry-band arcing may be a problem and that I should use a TR jacket?

➔ Great question! This is exactly what space potential analysis is for!

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Cable Engineering Theory

- Recall the **“Where”** and the **“Which”** from some minutes ago?
  - Space potential analysis will enable you to determine the “Where”
    - Where you can safely use (attachment point) a standard PE jacket
    - Where you can safely use a TR jacket
- The “Which” follows directly from the “Where”
  - You will know which jacket type you can or must use

ADSS cable in High Electric Fields

Cable Engineering Theory

- Let's start with: Here are the standard space potential limits by jacket material:

  - Standard polyethylene jacket (MDPE or HDPE) is limited to < 12 kV space potential
  - For > 12 kV Space Potential, need track-resistant jacket and corona coils too
  - The standard maximum space potential is 25 kV
    - We'll discuss a possible exception at the end of this presentation

ADSS cable in High Electric Fields

Cable Engineering Theory

- Using the standard limits and field (pardon the pun) experience, we can develop these general guidelines for TR jackets:

  - Up to 35 kV = No danger of tracking

  - From 35 kV to 138 kV = Likely no danger, unless you install the cable "close" to the phase conductors
    - Space potential analysis can confirm that a standard jacket is OK

  - From 138 kV to 230 kV = Could be a danger. Should check.
    - Space potential analysis is "highly recommended"

  - At 230 kV and Above = Absolutely a danger. Must use track-resistant jacket and corona coils
    - Space potential analysis is a must!

ADSS cable in High Electric Fields

Cable Engineering Theory

- There are at least two good options for doing space potential analysis

  - Excel workbooks exist for doing space potential analysis
    - Monty Tuominen has been mentioned several times already
      - He is a retired engineer from Bonneville Power Administration (BPA) who has extensive experience with ADSS in high electric fields and now does consulting
  - BPA is a US federal entity, and you can get their (= Monty's) workbook from them

  - Incab offers a free online tool that we call ACES SPOT
    - ACES = Advanced Cable Engineering System
    - SPOT = Space POTential analysis

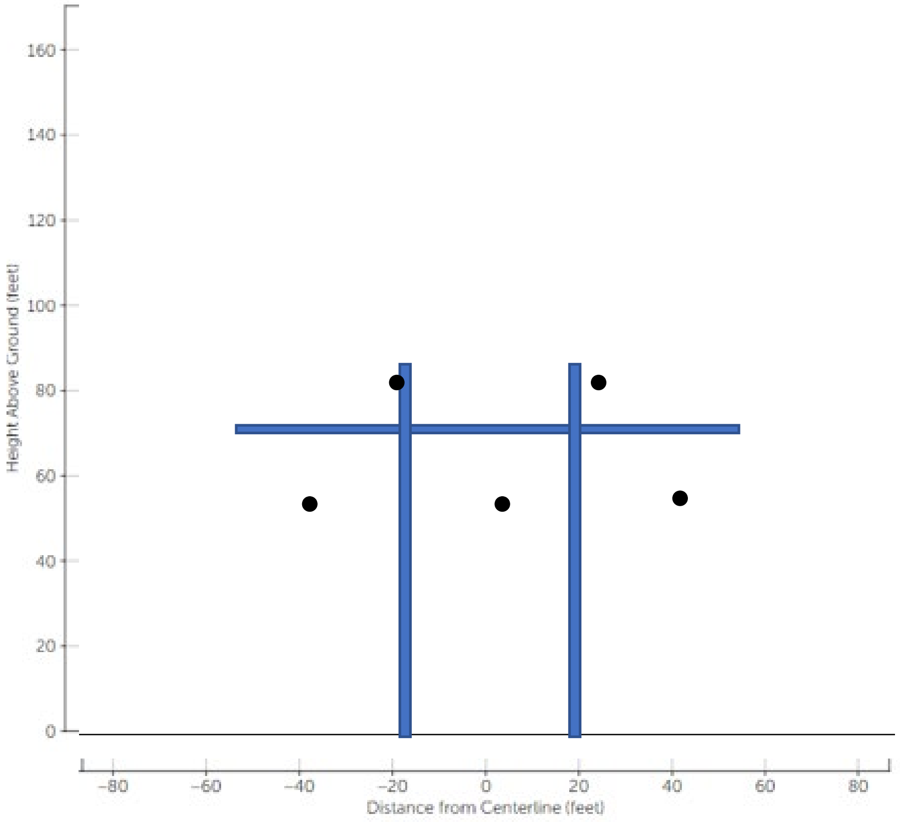
➔ We'll use SPOT....we like it, we think you'll like it too!

SPOT

ADSS cable in High Electric Fields

Cable Engineering Theory

Step 1 Regardless of what specific tool you use, you must have your line geometry

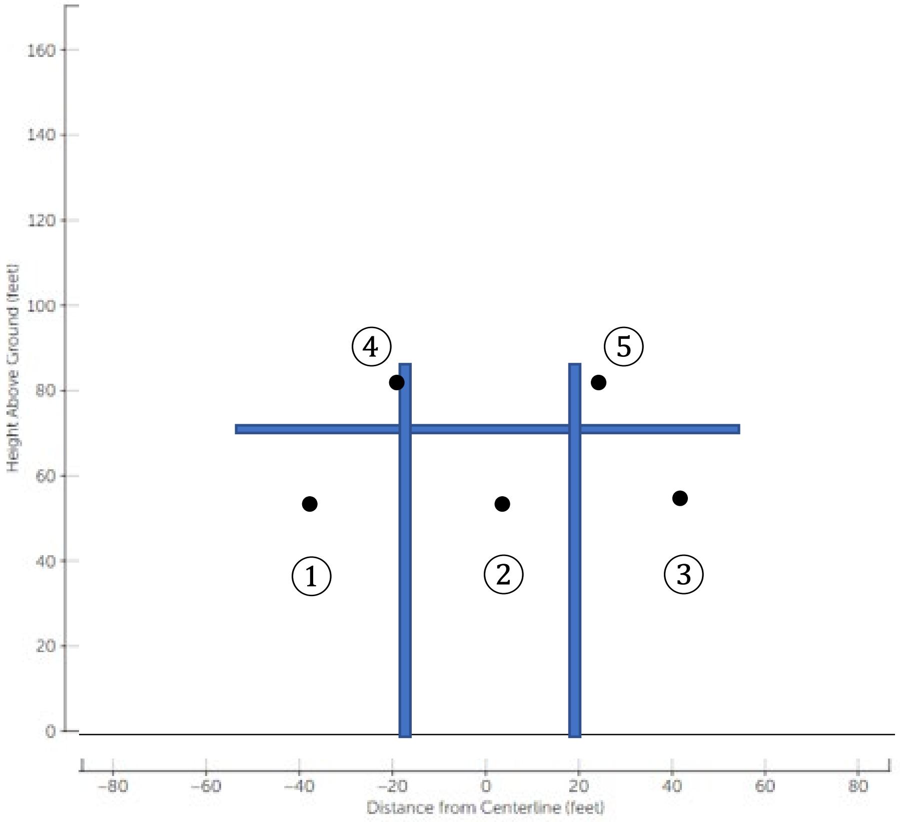


Example: 345 kV H-frame transmission line

ADSS cable in High Electric Fields

Cable Engineering Theory

Step 2 Enter the data about your line



Example: 345 kV H-frame transmission line

(1) = Phase A bundle (-27 ft, +50 ft)

(2) = Phase B bundle (0 ft, +50 ft)

(3) = Phase C bundle (+27 ft, +50 ft)

(4) = OPGW with diameter 0.364 inches (-13.5 ft, +74 ft)

(5) = 3/8-inch shieldwire (diameter = 0.36 inches) (+13.5 ft, +74 ft)

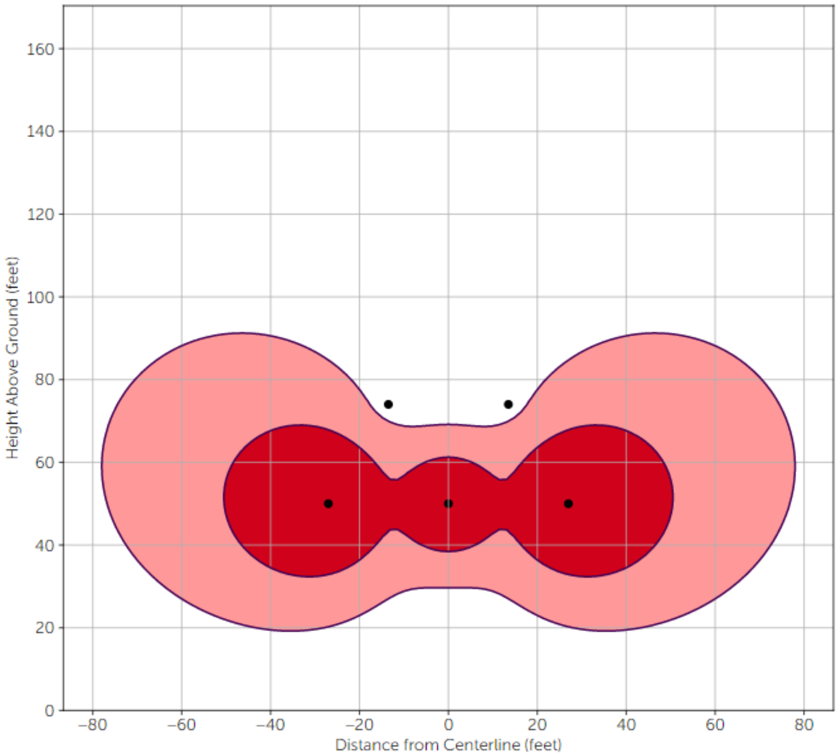
Phase bundles consist of 2 x 795 kcm “Drake” conductors (1.108 inches) spaced at 18 inches

Cable Engineering Analysis

Space Potential Analysis

Step 3 Generate the space potential showing equipotential lines

Example: 345 kV H-frame transmission line



Space Potential (kV)

- 0–12 kV
- 12–25 kV
- above 25 kV

- For zones with electric field **up to 12 kV** it's possible to use ADSS with standard jacket
- For zones with electric field **between 12 kV and 25 kV** it is advisable to use ADSS with track-resistant jacket
- For zones with electric field **above 25 kV** the use of ADSS cable is not recommended

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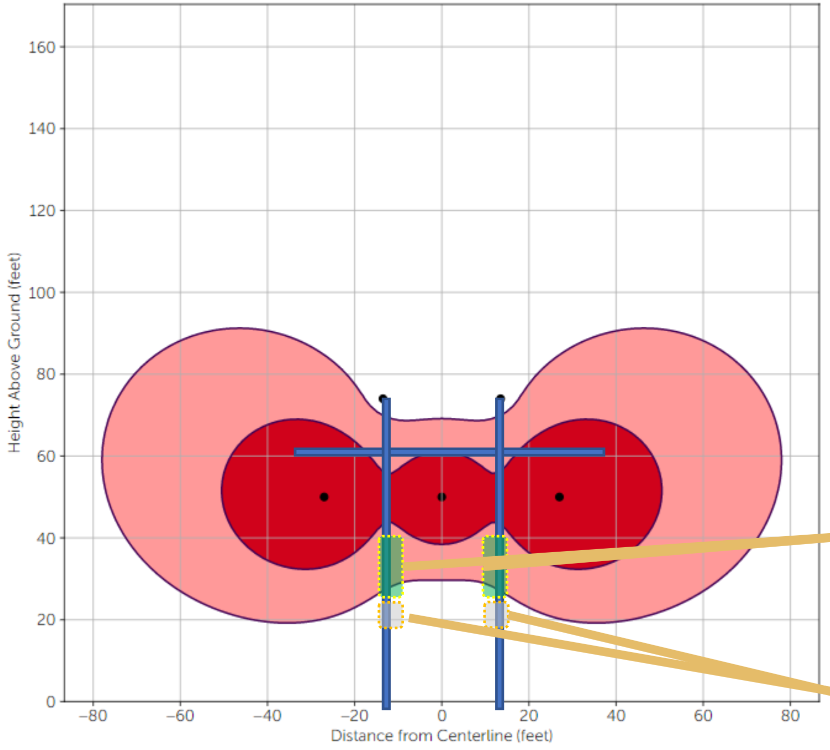
Cable Engineering Analysis

Applying Space Potential Analysis

Step 4 Analyze and apply the output

Example: 345 kV H-frame transmission line



Space Potential (kV)

- 0–12 kV ← Standard jacket is OK
- 12–25 kV ← Need tracking resistant jacket
- above 25 kV ← "No Go" for any ADSS

- For zones with electric field **up to 12 kV** it's possible to use ADSS with standard jacket
- For zones with electric field **between 12 kV and 25 kV** it is advisable to use ADSS with track-resistant jacket
- For zones with electric field **above 25 kV** the use of ADSS cable is not recommended

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Possible attachment points if using tracking resistant jacket

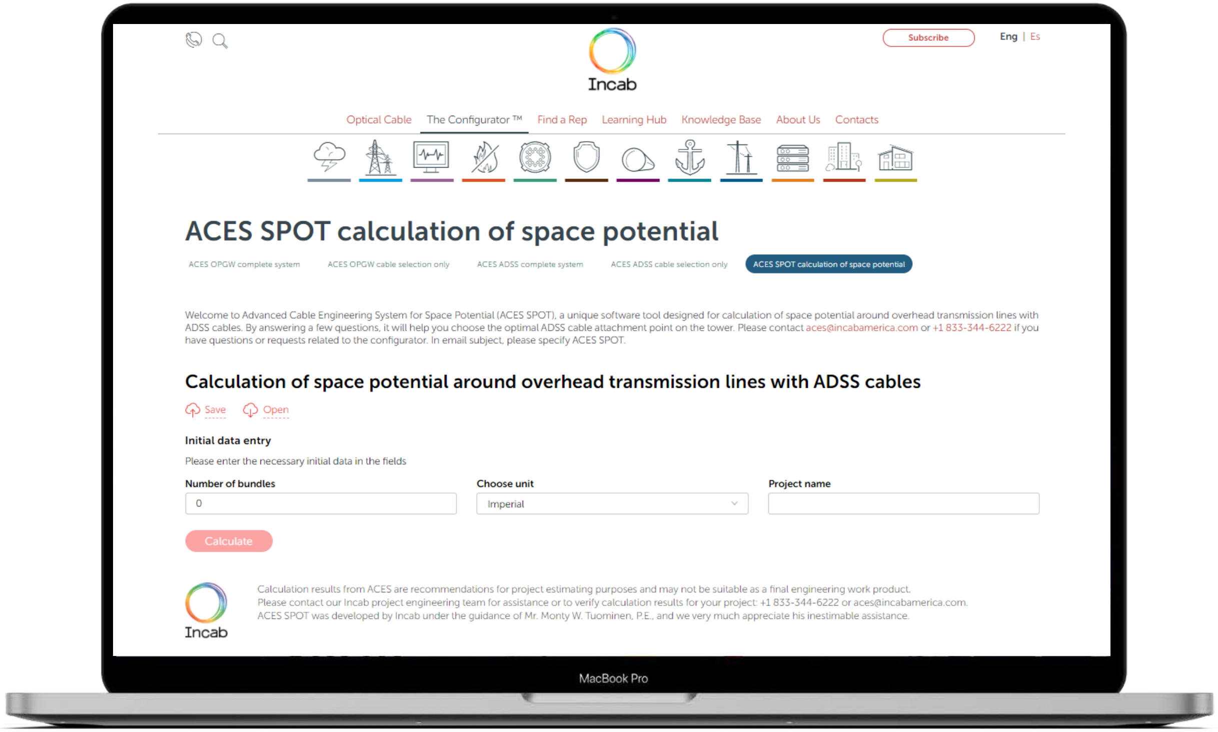
Possible attachment points if using standard jacket – but would ground clearance be adequate?

ADSS cable in High Electric Fields

Cable Engineering Analysis

- Now let's do it in ACES SPOT…

1. Go to: https://incabamerica.com/aces-configurator/aces-spot/



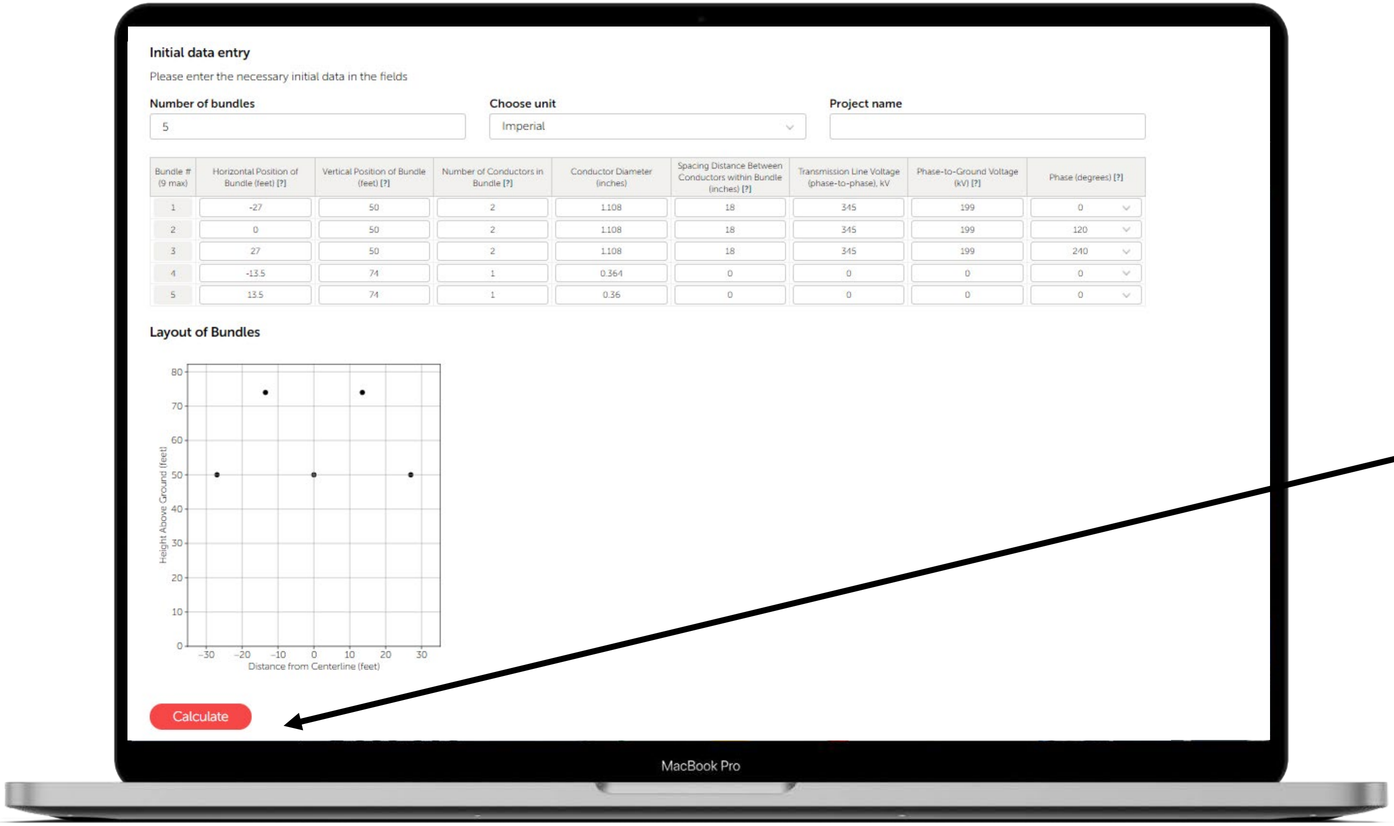
- There's a simple, very basic registration process
- After completing that, you will be logged in

SPOT

ADSS cable in High Electric Fields

Cable Engineering Analysis

2. Enter your project data



Bundle # (9 max)	Horizontal Position of Bundle (feet) [?]	Vertical Position of Bundle (feet) [?]	Number of Conductors in Bundle [?]	Conductor Diameter (inches)	Spacing Distance Between Conductors within Bundle (inches) [?]	Transmission Line Voltage (phase-to-phase), kV	Phase-to-Ground Voltage (kV) [?]	Phase (degrees) [?]
1	-27	50	2	1.108	18	345	199	0
2	0	50	2	1.108	18	345	199	120
3	27	50	2	1.108	18	345	199	240
4	-13.5	74	1	0.364	0	0	0	0
5	13.5	74	1	0.36	0	0	0	0

Then push "Calculate"

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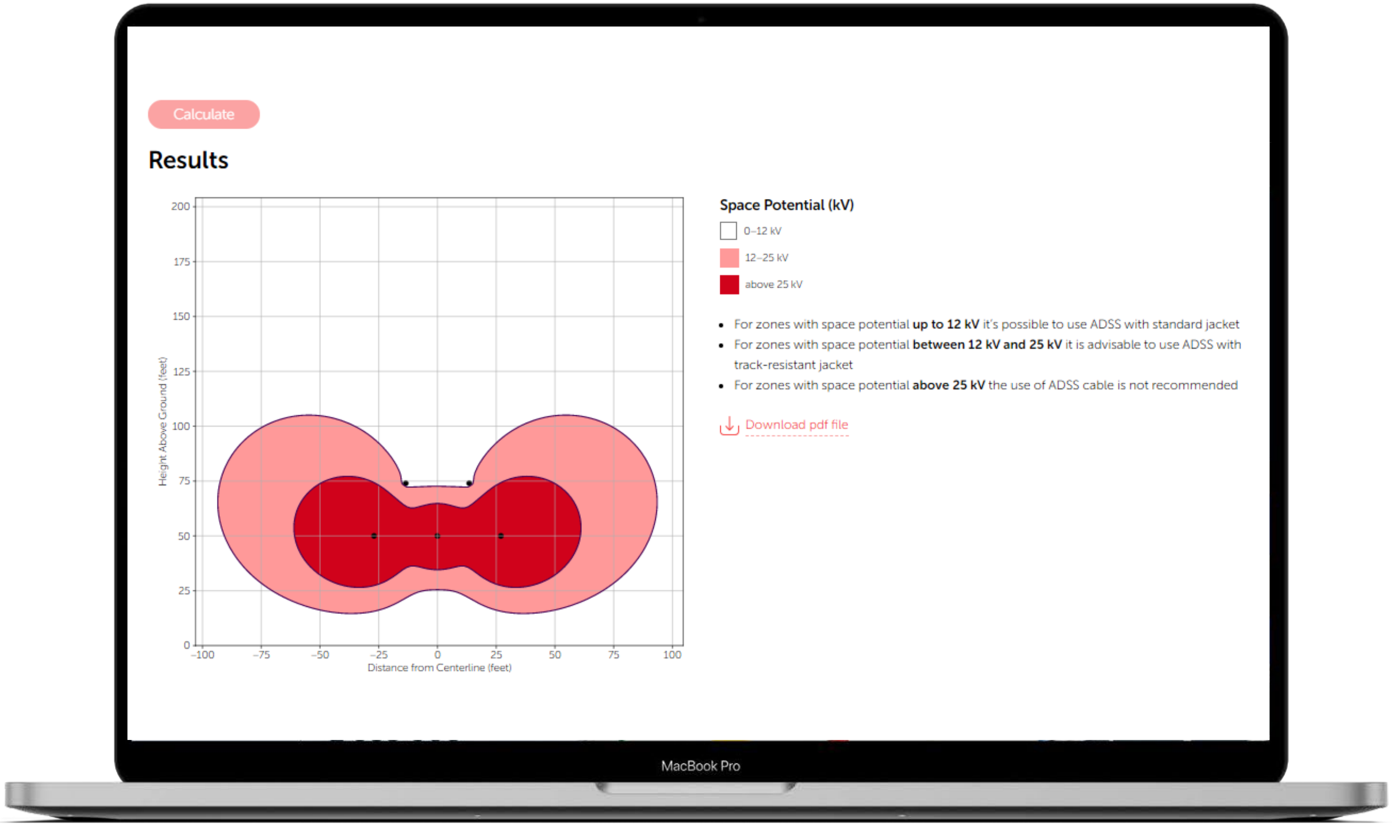
ADSS cable in High Electric Fields

Cable Engineering Analysis

3. Get the output

4. Analyze and apply it

SPOT

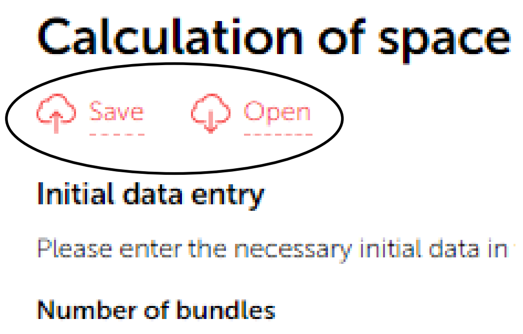


ADSS cable in High Electric Fields

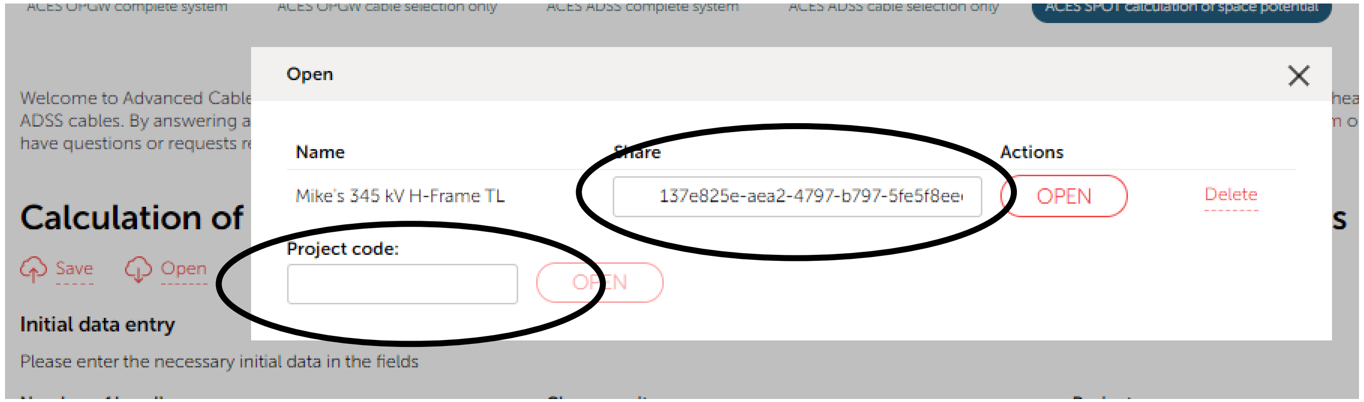
Cable Engineering Analysis

Two other features to note…

- You can save your work and re-use it later
  – Excellent for “what if” analysis!



- You can use the **“Project code”** to share your work – Copy/past the code for a colleague



SPOT

ADSS cable in High Electric Fields

Cable Engineering Theory

- Closing topic: "**Microsparking**" (Did you think I'd forgotten?)

- The term is used in different ways. I'm going to use it as a "catch all" for two issues:

  - Tracking because a jacket is simply in too high of an electric field (standard or TR)
    - Recall the limits we discussed: 12 kV for standard PE, 25 kV for TR
    - Eventually the cable will fail

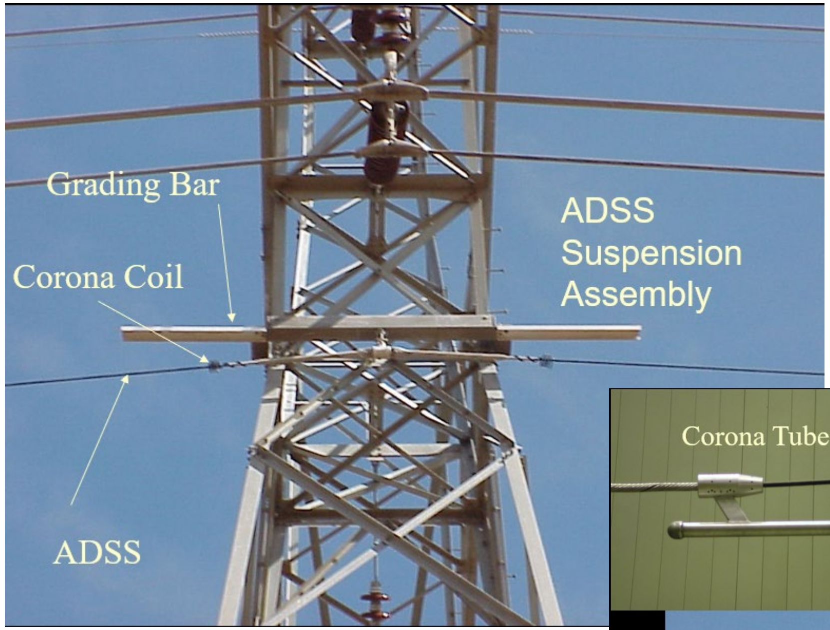
  - Tracking on a TR jacket in high contamination area without good natural wet/dry cycle
    - Pollution accumulates because of poor natural washing
    - Moisture then leads to tracking that exceeds the jacket's capability
      - So, what's "high" and "good"?
        - ➔ Very experiential! But, likely if you have tracking issues with your insulators, then you will also have it with your ADSS

ADSS cable in High Electric Fields

Cable Engineering Theory

- If a cable is in too high of a field for its jacket, is there nothing that can be done?

- A: Yes, you can cheat Maxwell's Equations by using a "grading bar" or "corona tube"
  - Work by reducing the electric field close to the cable
  - The grading bar has an extensive track (pardon the pun) record at BPA on 500 kV transmission lines



or

Note: One more shout out to Monty Tuominen for these pictures!

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Thank you

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