Incab

OPGW Engineering 301

Fault Current – Principles and Applications

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Registered Continuing Education Program

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PURPOSE STATEMENT/COURSE DESCRIPTION

OPGW Engineering 301 – Principles and Applications of Fault Current will teach attendees:

- What fault current is
- What fault current capacity is
- How to calculate how much capacity is needed for a transmission line
- How to calculate the capacity for a cable
  - Detailed discussion of the key variables and methodology used
- The fault current capacity uncertainty and pitfall presented by traditional ground wires
- Possible solutions to fault current capacity challenges

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LEARNING OBJECTIVES

After this webinar you will be able to:

1. State that fault current capacity is defined as Current^2 x Time with current in kA and time in seconds
2. Understand where how to determine both the current and the time
3. State what the initial cable temperature is and why it is important
4. State what the final cable temperature is and why it is important
5. State what IEEE standard 738-2012 is and why it is important
6. Explain capacity uncertainty and pitfall presented by traditional ground wires
7. Explain your design options in in situation that requires a very high fault current capacity

Learning Hub

INCABAMERICA.COM

Webinar Rules

- Introduction and sound check
- Presentation: 60 min
- Use chat for questions during presentation
- Q&A (NB! Technical questions only)
- Let’s start!

Quick Review

Recall from OPGW Engineering 101 that OPGW…

- Primary function of OPGW is to be a shield or ground wire for a transmission line:
  - To protect the phase conductors from lightning
  - To provide a path for fault current
- "Secondary" function: Housing optical fiber for data and communications
- Note that "shieldwire" and "groundwire" are used synonymously

Remember back to OPGW Engineering 101….

FAULT CURRENT

Utility Side

I^2t

- kA squared X duration in seconds
- Current (kA) – Expected fault current (1 phase or 3?)
- Duration – Expected clearing time
  - Single contingency: 4-6 cycles (highest risk)
  - Allow for re-close: 8-12 cycles
  - Back-up protection: 22-30 cycles (most conservative)

Manufacturer Side

Temperature delta is the single most important variable in computing fault current capacity!

- 210°C (410°F) standard maximum final (hottest part of cable, NOT coolest!)
- Initial cable temperature, NOT the ambient air temperature! 40°C (104°F) is typical, because it's a realistic <u>CABLE</u> temp on a summer day
- IEEE 738 methodology

Fault Current Design is a function of your design philosophy:
How much risk is acceptable to you?

Now we'll do a deep dive into these variables!

OPGW Fault Current Capacity – Utility Side

Background – What Causes Faults?

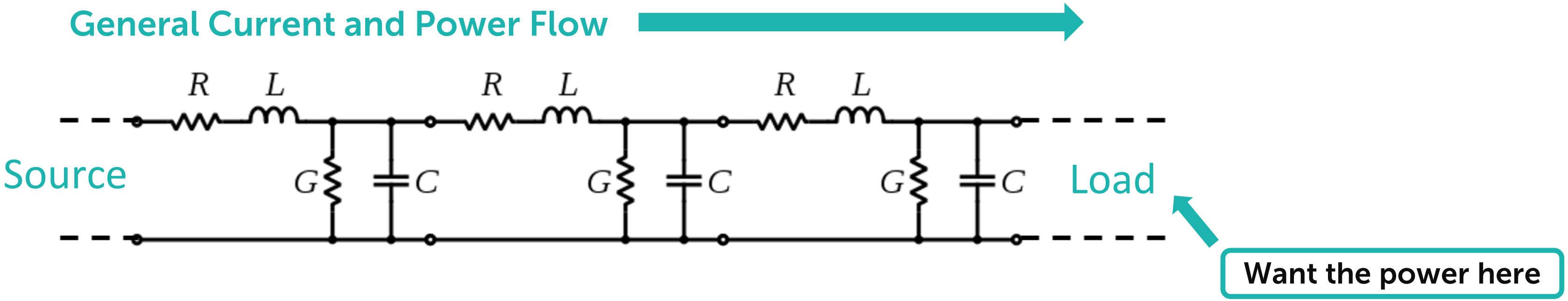
Let's start at the beginning

- Civil Structural Engineers and most people see something like this when they think about transmission lines:

OPGW Fault Current Capacity – Utility Side

Background – What Causes Faults?

- Electrical Engineers see something like this cool circuit diagram:



- The source will be a substation bus or generator (another bus really)
- The load will be another substation bus (typically feeding distribution)
  - Ultimately the load is homes, businesses, etc. using electricity

OPGW Fault Current Capacity – Utility Side

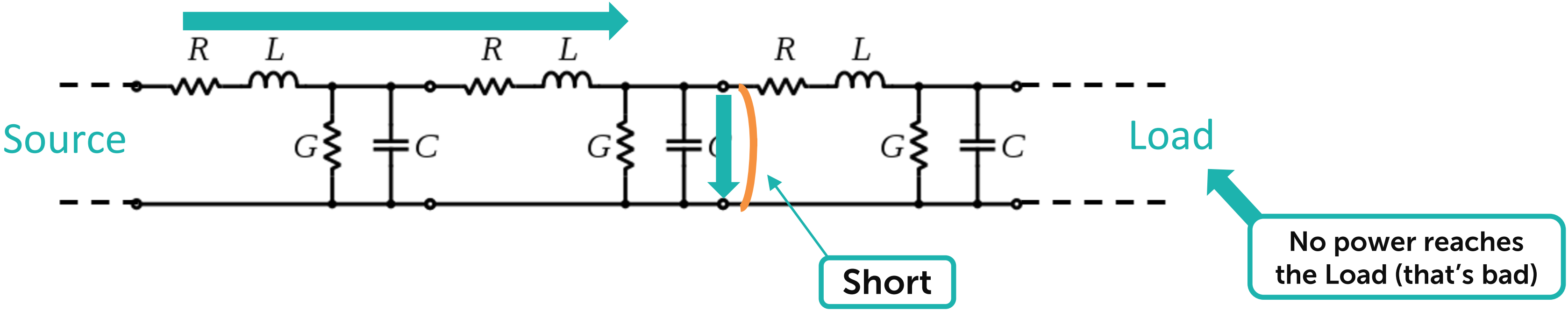
Background – What Causes Faults?

What's a Fault?

- A "Fault" is another word for a "Short Circuit" which is defined as:

  - C/S Engineers and most people. An electrical connection between two parts of the line that you don't want to be there

  - EE's = An abnormal condition in the line (circuit) where the current flows through an unintended, lower resistance pathway instead of following the line (circuit)…like this:

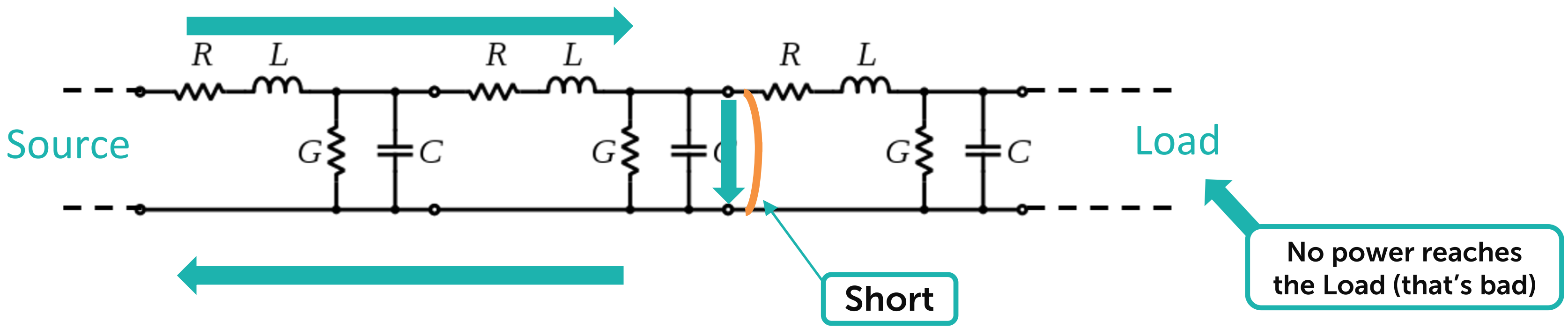


OPGW Fault Current Capacity – Utility Side

Background – What Causes Faults?

So, if no power reaches the load, where does it go?

- Answer: To complete the circuit, the current *must* get back to the source.
  - To a EE, this looks something like…



  - And, that "lower resistance pathway" means that the current is **greatly** increased

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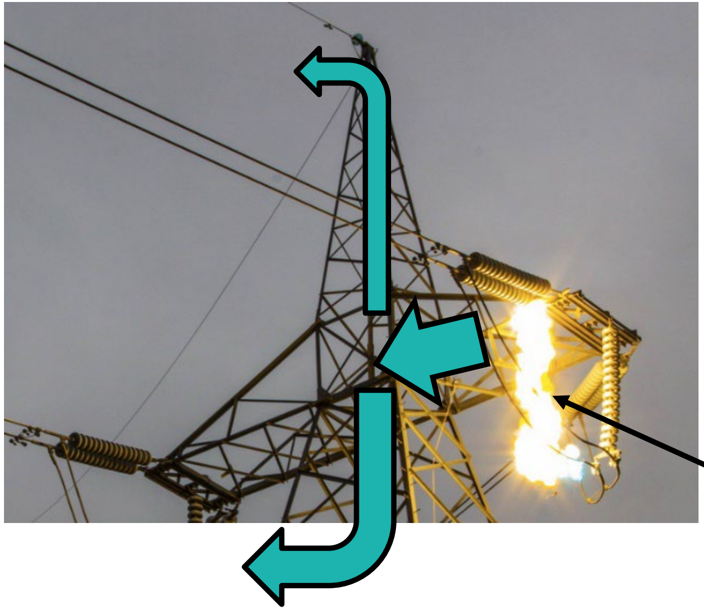
Background – What Causes Faults?

On a "real world" transmission line, this looks like this:

Source assumed to be this way



The current flows through the tower, and it divides up into two paths:

1. Some goes up and through the shield wire/ground wire/OPGW
2. Most goes down and through the earth

- But, *all* is going back to the source to complete the circuit

The "Short" here is a flashover arc from a phase to the tower

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Background – What Causes Faults?

In that "real world" what causes faults? Many things, including:

- Contact with one of the phase conductors (example: a tree limb)
- Insulator failure – electrical (tracking) or mechanical (breaks)
- Conductor or conductor splice mechanical failure (breaks)
- Structure failure (lots of pictures on the internet)
- And more besides, up to and including….

Kids Bouncy House (not properly secured) + High Winds
+ Proximity to Transmission Line = Unplanned Outage

Needs no explanation
(The pilot did survive)

OPGW Fault Current Capacity – Utility Side

Background – Classifying Faults

- Although many causes, <u>for our purposes</u>, there are only two classifications:

  1. **Single-Phase** = Contact, insulator failure, conductor or splice failure,

  2. **Three-Phase** = Structure failure

     (Bouncy houses and airplanes could be either)

- There *are* other types, but these two give us the "**best**" and "**worst**" cases
  - We'll see why this is important real darn soon

OPGW Fault Current Capacity – Utility Side

Analyzing the Characteristics of Faults

- Now that we know what can cause a fault and what types of faults there are, we can proceed to analyze the key characteristics:

  1. The **current**, expressed in kiloamperes (kA) = i

  2. The **time** or duration of the fault, expressed in seconds = t

- We can use these to calculate the total energy flow which we'll describe as the required "**fault current capacity**"

  Fault current capacity = **Current² x time = $i^2 \cdot t$** (unit: **kA^2s**)

OPGW Fault Current Capacity – Utility Side

Now we are back to...

Utility Side

I^2t

- kA squared X duration in seconds
- Current (kA) – Expected fault current (1 phase or 3?)
- Duration – Expected clearing time
  - Single contingency: 4-6 cycles (highest risk)
  - Allow for re-close: 8-12 cycles
  - Back-up protection: 22-30 cycles (most conservative)

Manufacturer Side

Temperature delta is the single most important variable in computing fault current capacity!

- 210°C (410°F) standard maximum final (hottest part of cable, NOT coolest!)
- Initial cable temperature, NOT the ambient air temperature! 40°C (104°F) is typical, because it's a realistic <u>CABLE</u> temp on a summer day
- IEEE 738 methodology

And, ready to move on to understand what data we need to calculate the required fault current capacity

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- First, we need the current…
- Recall we had two classifications for faults and that these gave us the best and worst cases.

1. Single-Phase
2. Three-Phase

➔ Which do you use?

Answer: It's up to you!

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Whether to use single or three phase fault current is a “risk management” decision. Consider these observations:

  1. Single-Phase Faults. Uncommon (my qualitative characterization)

  2. Three-Phase Faults. Very rare in comparison to single phase faults

  (But, both **do** happen, so cannot just overlook them)

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- From the preceding observations, we can infer:
  - A financial argument can be made that it is more economical long-term to compute the required fault current capacity using the **single-phase** fault current
  - An engineering argument can be made that reliability is better assured by using the **three-phase** fault current to compute the required fault current capacity

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- So, the decision is really a question of "Design Philosophy"
  = *"How much risk do you want to take?"*

  - Utilities tend to be conservative, so most use the three-phase fault current
    - I'm an engineer (and worked at a utility before), so I would use the three-phase fault current
  - Nevertheless, some utilities use the single-phase fault current, and as was said, a financial case can be made to support this decision

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Repetition to underscore the point
  - Which fault current value you use is up to you!
    - It’s **not** your OPGW supplier’s decision
    - Strictly speaking, your OPGW supplier should **not care** which you use
      (I do care, because that’s the kind of guy I am)

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- You can obtain either or both values from your System Planning Department
  - They use special software to compute the values
  - It is outside the scope of today's webinar to discuss the actual calculation
  - It may be career enhancing to be nice to them since you need information from them

    But we'll see later how they will need information from you!

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- In case you were wondering about the magnitude of the difference between single- and three-phase fault current…
  - Three-phase value ≈ 2 x single-phase value
  - Consider: Fault Current Capacity = I^2t
    - The square means the current differential will have a huge impact.

      Example:

      Single-phase current = 10 kA ➡ becomes 100 kA^2
      Three-phase current = 20 kA ➡ becomes 400 kA^2

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Second, we need the expected duration of the fault
  (Trigger Warning: More Design Philosophy/Risk Management talk ahead!)

1. The duration will be the expected time the protective relay system will take to clear the fault (“tripping out” the line)

2. As with the current itself, there are multiple possibilities
   - Three scenarios, to be precise

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- The three clearing time scenarios to consider

1. Single contingency
   - Assume the line trips out, and that's it
   - Typically, **4 – 6 cycles** = 0.067 – 0.1 s
   - Highest risk because most systems (all?) make one attempt at a re-close

2. Double contingency
   - Allow for a re-close after the line trips
   - Typically, 1 – 2 cycles between initial trip and re-close attempt
     - No cable cooling in this time, so can be ignored
   - Total time = 4 – 6 cycles + 4 – 6 cycles = **8 – 12 cycles** = 0.13 – 0.2 s

3. Back-up system protection (primary system fails (breaker failure))
   - Primary system failure (breaker failure)
   - Typically, **22 – 30 cycles** total = 0.37 – 0.5 s
   - Most conservative – Very rare, but it happens

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Which scenario to use?
  Answer: It's up to you! (I warned you this was coming!)

- We again see a question a risk management or design philosophy
  - A financial case can support using the single contingency scenario
  - A reliability case supports using the back-up system scenario
  - Plus, you can "split the difference" and choose the double contingency scenario

- As with the current, most utilities go conservative and use the back-up system scenario
  - I know one that uses the single contingency
  - There are a handful that use the double contingency

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Where to get these durations?

  Answer: It's back to the System Planning Department!

  Note: The clearing times that I have shown are what I have seen
  - Your System Planning Department will have the actual values for your system

OPGW Fault Current Capacity – Utility Side

Computing the Required Fault Current Capacity

- Now we have both the current and time we need!
  We are ready to do some math!! 😃

1. Example 1:
   Single-phase current = 10 kA
   Single contingency clearing = 6 cycles
   Required fault current capacity = $10^2 \times 0.1 = 10\ kA^2s$

2. Example 2:
   Three-phase current = 20 kA
   Back-up system clearing = 30 cycles
   Required fault current capacity = $20^2 \times 0.5 = 200\ kA^2s$

Note: We typically see values in the range of <u>50 – 150 kA²s</u>

OPGW Fault Current Capacity – Utility Side

Now we know how to calculate the required fault current capacity, so we can move on to…

Utility Side

I^2t

— kA squared X duration in seconds
— Current (kA) – Expected fault current (1 phase or 3?)
— Duration – Expected clearing time
- Single contingency: 4-6 cycles (highest risk)
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Manufacturer Side

Temperature delta is the single most important variable in computing fault current capacity!

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— Initial cable temperature, NOT the ambient air temperature! 40°C (104°F) is typical, because it's a realistic <u>CABLE</u> temp on a summer day
— IEEE 738 methodology

Now we will see how a cable designer computes the fault current capacity for a cable design

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- The goal is simple:

  Required Fault Current Capacity $\leq$ Cable Fault Current Capacity

- To compute the cable's capacity, we *must have* two things…

1. An equation – Just as we had one for the required capacity
2. The data (variables) that go into the equation – Again, just as we had for the required capacity

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- … and we *ought to have* a third:

3. The utility ought to have all cable suppliers use the same “must haves”

   - Otherwise, you cannot compare “apples to apples” designs from different suppliers

Let’s look at the equation and data/variables…

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- The equation
  - The industry standard equation (methodology) comes from IEEE Standard 738-2012 which at 4.4.2, equation 2b, has this non-steady state heat balance equation:

$$\frac{dT_{avg}}{dt} = \frac{1}{m \cdot C_p}\left[R(T_{avg}) \cdot I^2 + q_s - q_c - q_r\right]$$

  - Remain calm! We don't need to "unpack" this equation! (Insufficient time anyway)
    - Understand that it is the general equation to describe a step increase in current
    - In the Southwire Overhead Conductor Manual (SOCM) (2nd edition), we find at 3.2.5, equation 3-17, the equation specifically applied to fault current ratings

Let's look at the applied fault current rating version of the equation…

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- The equation, as “distilled” in the SOCM:

$$i^2\, t = A^2 K\ log\left(\frac{T_2 + \lambda}{T_1 + \lambda}\right)$$

- Some of you may be thinking “How’s this equation any easier to understand than the previous one?”

- Technically, I did *not* claim it would be easier to understand
  - I only said it would “applied”
  - Hang with me because we’ll see this form will prove very helpful!

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Let's look at the SOCM equation closely…

$$i^2 t = A^2 K \log\left(\frac{T_2 + \lambda}{T_1 + \lambda}\right)$$

- $i^2 t$ is the equation that we already know! (So, we know we're on the right track)
- A^2 = the area of the cable squared. That's easy!
- K = a value computed from the materials used in OPGW (equation 3-16):
  - Materials: aluminum, aluminum-clad steel (ACS) wire, and aluminum-alloy (AY) wire
  - Data: density, specific heat, resistivity - Basic data that's readily available! Easy!
- λ = "Inferred temperature of zero resistance" which may sound esoteric or intimidating, but the values we need are at Table 3-6 in the SOCM! So, also easy!

This only leaves the two T's…

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- About those T's...

$$i^2 t = A^2 K \log\left(\frac{T_2 + \lambda}{T_1 + \lambda}\right)$$

- T_1 is the initial *cable* temperature before the fault
  - *Not* the air or ambient temperature!
  - The cable will absorb solar radiation, and will often be hotter than the air around it
    - Just like your car gets hot when parked outside on a sunny day

- T_2 is final temperature = highest temperature that we will allow the cable to experience

➔ We can readily see that these two variables will have a huge influence on the result
  - So, what values should we use?

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Choosing the temperature limits:
  - T_1 = 40°C (104°F) is a realistic *cable temperature* on a hot summer day
    - Reasonably conservative and widely applicable
    - Appropriate to adjust up or down based on local climate conditions
      Examples:
      Utility in Maine opted for 35°C (95°F), West Texas might use 45°C (113°F)
    - *Not* appropriate in my opinion to use 20°C (68°F)
      - Merely a rough average *ambient air temperature* in most of the world

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Choosing the temperature limits:
  - T_2 = 210°C (410°F) is a reasonable, safe final temperature for *any* OPGW design
    - Above this, the optical unit could be damaged
      - In aluminum pipe type designs, the plastic buffer tubes and gel inside at risk
      - In designs with stainless steel loose tubes, the gel inside at risk
    - Above this, AY wires could lose strength
      - They don't contribute a lot, but they are contributing
      - Any good from risking turning them into just "dead weight"?
        - And thereby increasing the cable's sag

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Choosing the temperature limits:

  - The final temperature should apply to the **hottest part of the cable**
    - Current not evenly distributed within a cable:
      - AY wires tend to heat up the most
      - Optical unit the least

    - The difference between the hottest and the coolest can be ≈ 30°C (86°F)

    - If "coolest part of the cable", then effectively a way to "cheat"
      (Hiding what is really a higher final limit)

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Let's recap…

1. We now *have* an equation/methodology for computing a cable's fault current capacity!

2. We now *have* the data/variables that we need, and we understand both the nature and importance of the initial cable temperature and the final cable temperature

3. We know we ought to have: The utility should require that all cable suppliers use the same "must haves"
   - Otherwise, you cannot compare "apples to apples" designs from different suppliers

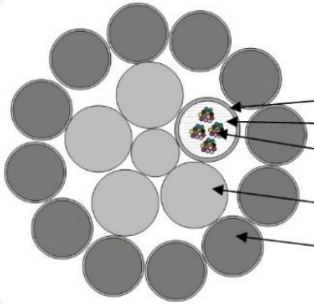
Let's illustrate point (3)…

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Let's see an example of the influence of the temperature limits:
- First, the basic cable data we'll need and use:

Design



Design element	Material	Count	Diameter Metric (mm)	Diameter Customary (inches)
Center member	AY wire	1	2.60	0.1024
1st stranded layer	AY-wire/SSLT	4/1	3.65	0.1437
2nd stranded layer	20% ACS wire	12	3.25	0.1280

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- More cable data…

Technical Specifications

Mechanical	Metric	Customary
Cable diameter ± 0.2 mm (0.008 in)	16.4 mm	0.646 in
Cable unit weight	818 kg/km	0.550 lb/ft
Rated breaking strength (RBS) (without SSLT's)	140.6 kN	31 608 lb
Maximum rated design tension (MRDT) (80% RBS) with 0% fiber strain	111.8 kN	25 138 lb
Zero fiber strain margin (ZFSM) (80% RBS)	111.8 kN	25 138 lb
Cross-sectional area of ACS wire	101.7 mm^2	0.158 in^2
Cross-sectional area of AY wire	47.2 mm^2	0.073 in^2
Cable total cross-sectional area	148.8 mm^2	0.231 in^2
Modulus of Elasticity, initial	105.8 kN/mm^2	15 348 ksi
Modulus of Elasticity, final	124.9 kN/mm^2	18 118 ksi
Temperature coefficient of linear expansion	14.29 E^{-6}/°C	7.94 E^{-6}/°F
Southwire Sag10™ coefficient chart number	1-1457	-
Lay direction of outer layer	Left	-

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Yet more cable data…

Electrical	Metric	Customary
DC resistance at 20°C (68°F)	0.387 Ω/km	0.6224 Ω/mile
Short circuit capacity	146.4 $kA^2 \cdot s$	-
Basis: Initial cable temp = 40°C (104°F), Final = 210°C (410°F), Duration = 0.5 s		
Short current circuit for 0.5 s	17.1 kA	-
Rac/Rdc ratio	1.012	-
AC resistance at 25°C (77°F)	0.3981 Ω/km	0.6406 Ω/mile
AC resistance at 50°C (122°F)	0.4324 Ω/km	0.6958 Ω/mile
AC resistance at 75°C (167°F)	0.4667 Ω/km	0.7510 Ω/mile
Geometric Mean Radius (GMR)	2.4035 mm	0.0079 ft
Inductive Reactance (Xa) @ 60 Hz	0.3651 Ω/km	0.5876 Ω/mile
Capacitive Reactance (X'a) @ 60 Hz	0.1726 MΩ-km	0.1072 MΩ-mile

(Not directly stated, but I know this supplier calculates fault current capacity per IEEE 738-2012)

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

1. Baseline: Per the datasheet, fault current capacity of the cable is:
   - 146.4 kA^2s
   - Key assumptions:
     - Initial cable temperature = 40°C (104°F)
     - Final cable temperature (hottest component) = 210°C (410°F)
     - Duration = 0.5 s
     - Method = IEEE 738-2012

2. Let's change those assumptions:
   - 189.5 kA^2s (+29% just by changing the key assumptions! Still the same cable!)
   - New assumptions:
     - Initial cable temperature = <u>20°C (68°F)</u>
     - Final cable temperature (coolest component) = 210°C (410°F)
     - Duration = 0.5 s
     - Method = IEEE 738-2012

OPGW Fault Current Capacity – Cable Design Side

Computing the Fault Current Capacity of a Cable

- Hopefully, you now understand why it is essential to have all suppliers use the same key assumptions and methodology

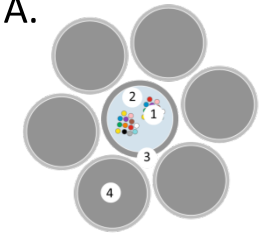
- In my opinion, all key assumptions should be shown on the cable datasheet

Qualitative Assessment of Fault Current Capacity by Design

The Three Types of OPGW Used Today

Center Tube Types

A.

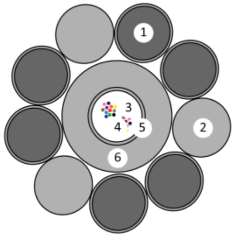


OPGW C **Low**

CONSTRUCTION:

1. Optical fiber Corning SMF-28 Ultra
2. Water-blocking gel
3. Stainless Steel Loose Tube (SSLT)
4. Aluminum-Clad Steel Wire (ACS)

B.

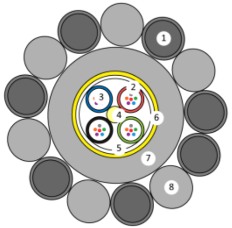


OPGW C **Low - Medium**

CONSTRUCTION:

1. Aluminum-Clad Steel Wire 20SA
2. Aluminum alloy wire
3. Water-blocking gel
4. Optical fiber Corning SMF-28 Ultra
5. Stainless Steel Loose Tube (SSLT)
6. Aluminum jacket

Aluminum Pipe Type

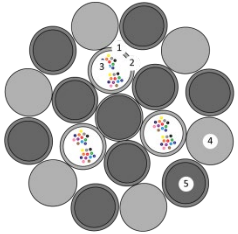


OPGW AP **Medium - High**

CONSTRUCTION:

1. Aluminum-Clad Steel Wire 20SA
2. Gel filled loose tube
3. Optical fiber Corning SMF-28 Ultra
4. Central strength member FRP
5. Water-swellable tape
6. Thermal barrier
7. Aluminum pipe
8. Aluminum alloy wire

Stranded Stainless Steel Tube (SSLT) Type



OPGW S **Medium - High**

CONSTRUCTION:

1. Stainless Steel Loose Tube (SSLT)
2. Water-blocking gel
3. Optical fiber Corning SMF-28 Ultra
4. Aluminum alloy wire
5. Aluminum-Clad Steel Wire 20SA

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

- Perhaps you are working on a project to replace a conventional shield wire such as 3/8-inch EHS or 7#8 ACS with OPGW
  - Or any other steel or ACS cable
- In that case, you may wonder why you can't just say:

  "Please design an OPGW with fault current capacity equivalent to 3/8-inch EHS"

- There are two reasons this is not a good idea

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

- Reason #1 – The concept lacks precision; it is too vague
  - There's no published fault current capacities for conventional cables
  - The published data for R_{ac} is only up to 75°C and shows a non-linear increase
  - What upper temperature limit do you use?
    - Much higher than 210°C is possible!
      (because no optics/optical unit and no AY wire)

See for example...

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

Here's ACS cable data from a leading ACS cable supplier…

CONDUCTOR SIZE AWG	DIAMETER		BREAKING LOAD		WEIGHT		RESISTANCE ①		CROSS SECTION	
	Inches	mm	lbs.	kN	lbs./kft	kg/km	Ohm/kft	Ohm/km	sq.Inches	mm^2
7 No. 5	0.546	13.87	27,030	120.2	524.9	781.1	0.2264	0.7428	0.1820	117.4
7 No. 6	0.486	12.34	22,730	101.1	416.3	619.5	0.2803	0.9197	0.1443	93.09
7 No. 7	0.433	11.00	19,060	84.8	330.0	491.1	0.3535	1.160	0.1145	73.87
7 No. 8	0.385	9.78	15,930	70.9	261.8	389.6	0.4458	1.463	0.09077	58.56
7 No. 9	0.343	8.71	12,630	56.2	207.6	308.9	0.5621	1.844	0.07198	46.44
7 No. 10	0.306	7.77	10,020	44.6	164.7	245.1	0.7088	2.326	0.05708	36.82
7 No. 11	0.272	6.91	7,945	35.3	130.6	194.4	0.8938	2.933	0.04523	29.18
7 No. 12	0.242	6.15	6,301	28.0	103.6	154.2	1.1270	3.698	0.03590	23.16

① DC resistance at 20°c

➔ Notice There's no "Fault Current Capacity" column
- You won't find such data from any other ACS cable supplier
- You won't even find DC resistance from steel cable suppliers

Data courtesy of intrAl

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

- Reason #2 – Capacities are too low for today's power grid

  — These cables adopted around 100 years ago, and demand on our grid was much lower then than it is today

  — Although available electrical data is incomplete and we can debate what final temperature limit to use, let's use the electrical data we find in the SOCM and proceed to "best guess" the capacities of common cables

Following is what we come up with...

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

Estimated Fault Current Capacities (kA²s) of Conventional Cables Used a Shieldwires/Groundwires

	Final Temperature			
Steel Cables	350°C (662°F)	1,000°C (1,832°F)	Average	
3/8-inch	9.7	16.2	13.0	!
1/2-inch	34.8	58.2	46.5	
5/8-inch	85.9	143.8	114.9	
ACS Cables	350°C (662°F)	645°C (1,193°F)	Average	
7#9 ACS	17.4	25.5	21.4	
7#8 ACS	26.9	39.1	33.0	!
7#7 ACS	41.6	59.8	50.7	
7#6 ACS	63.3	90.0	76.6	
7#5 ACS	94.6	132.9	113.7	

Recall: "We typically see values in the range of 50 – 150 kA²s"

OPGW Fault Current Capacity – Cable Design Side

Conventional Cables Ratings

- In the 2020’s:

  “Friends don’t let friends use 3/8-inch HS/EHS and 7#8 ACS”

  (at least not for shieldwire/groundwire)

OPGW Fault Current Capacity – Special Cases

"Uber High" Required Fault Current Capacity

- What can you do when you've diligently investigated your required fault current and come up with a very high value? (Over ≈ 200 kA^2s)

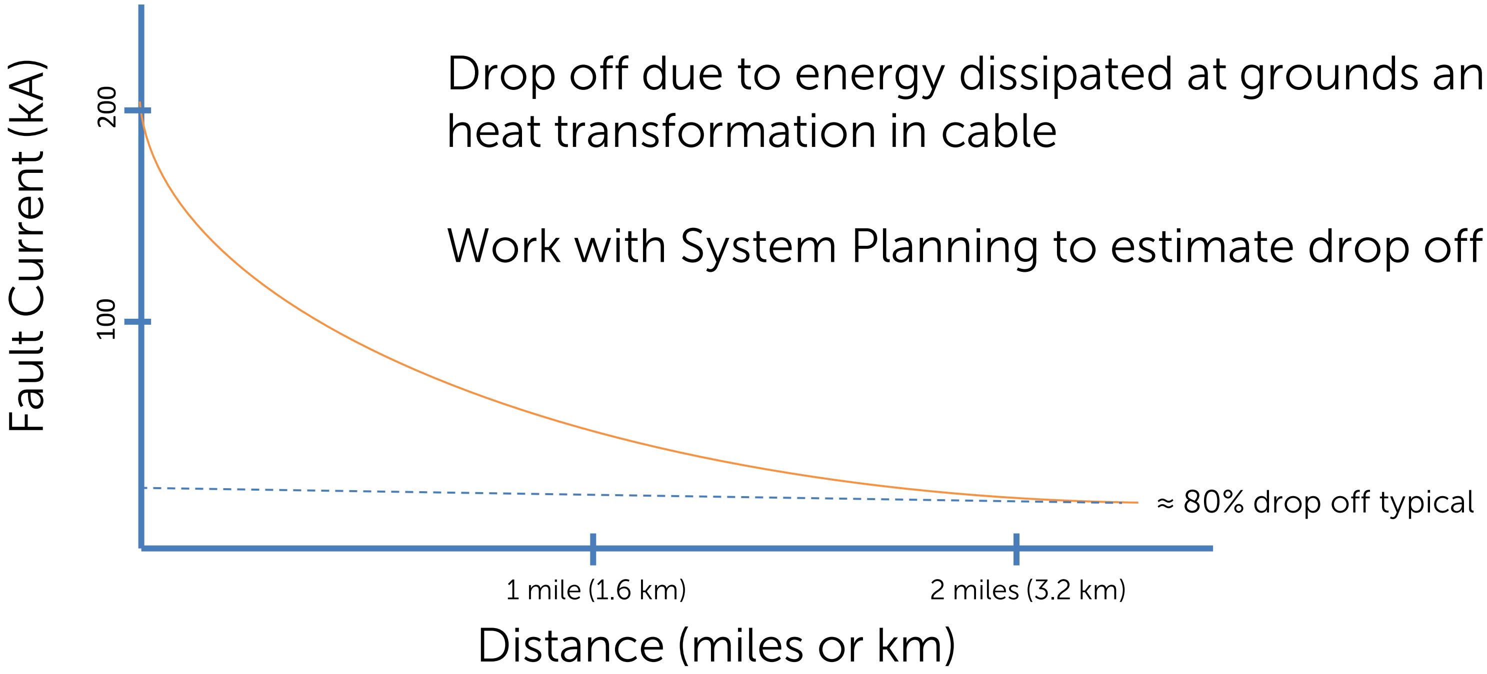
- Five Options:

1. Just suck it up!
   The preferred solution of many OPGW suppliers, because…
   High rating = more material = more money! 😉

2. Live with a lower cable rating
   Higher risk, but can make financial sense long-term
   Consider too that fault current drops off exponentially with distance…

OPGW Fault Current Capacity – Special Cases

“Uber High” Required Fault Current Capacity



Drop off due to energy dissipated at grounds and heat transformation in cable

Work with System Planning to estimate drop off

OPGW Fault Current Capacity – Special Cases

“Uber High” Required Fault Current Capacity

Five Options, continued:

3. Use two OPGW cable designs

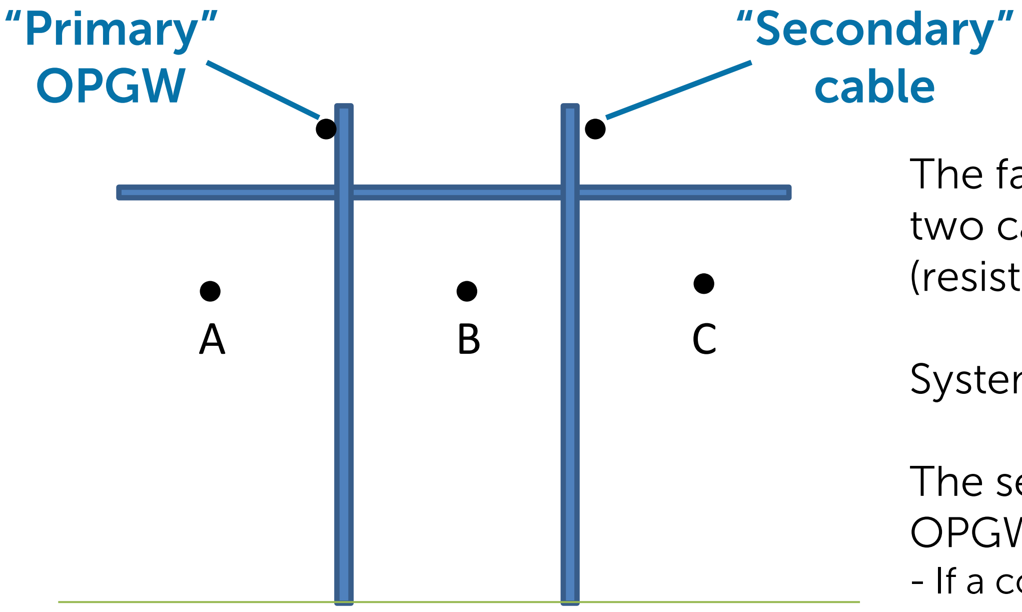
   - “High Capacity” cable for first 1 – 2 miles, then transition to one with less

   - Good solution, but complicates design and logistics

4. If “H-Frame” or other line design with two shieldwire positions, share the load…

OPGW Fault Current Capacity – Special Cases

"Uber High" Required Fault Current Capacity



The fault current will divide between the two cables based on relative resistance (resistance in parallel)

System Planning can help estimate

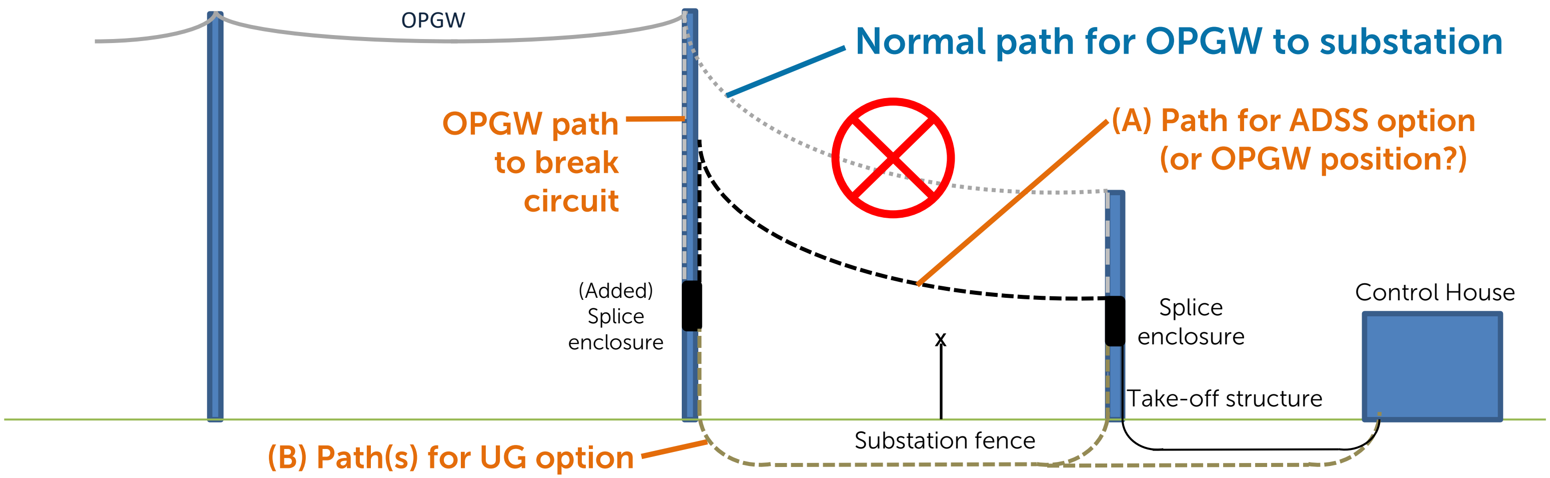
The secondary cable can be another OPGW (yay!) or a conventional cable

- If a conventional cable, consider a 19#8 ACS or other 19-strand construction with higher capacity than 7-strand cables

OPGW Fault Current Capacity – Special Cases
"Uber High" Required Fault Current Capacity

Five Options, continued:

5. Break the electric circuit just outside the substation



OPGW Fault Current - Principles and Applications

What System Planning Will (Eventually) Need

Recall this data extract from earlier....

Electrical	Metric	Customary
DC resistance at 20°C (68°F)	0.387 Ω/km	0.6224 Ω/mile
Short circuit capacity	146.4 $kA^2 \cdot s$	-
Basis: Initial cable temp = 40°C (104°F), Final = 210°C (410°F), Duration = 0.5 s		
Short current circuit for 0.5 s	17.1 kA	-
Rac/Rdc ratio	1.012	-
AC resistance at 25°C (77°F)	0.3981 Ω/km	0.6406 Ω/mile
AC resistance at 50°C (122°F)	0.4324 Ω/km	0.6958 Ω/mile
AC resistance at 75°C (167°F)	0.4667 Ω/km	0.7510 Ω/mile
Geometric Mean Radius (GMR)	2.4035 mm	0.0079 ft
Inductive Reactance (Xa) @ 60 Hz	0.3651 Ω/km	0.5876 Ω/mile
Capacitive Reactance (X'a) @ 60 Hz	0.1726 MΩ-km	0.1072 MΩ-mile

To set up their models for calculating the fault current, System Planning will need this data!

- Your OPGW supplier can provide it

OPGW Fault Current - Principles and Applications

Recap

- **Analyze** your utility's fault currents and expected clearing times
- **Determine** what current and clearing time you will use
- **Consider** what initial and final cable temperature is most appropriate for your operating area OPGW
- **Calculate** your required fault current capacity based on the preceding
- **Require** all OPGW suppliers to use the same methodology and assumptions when computing the fault current capacity of their cable(s)

Thank you!

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