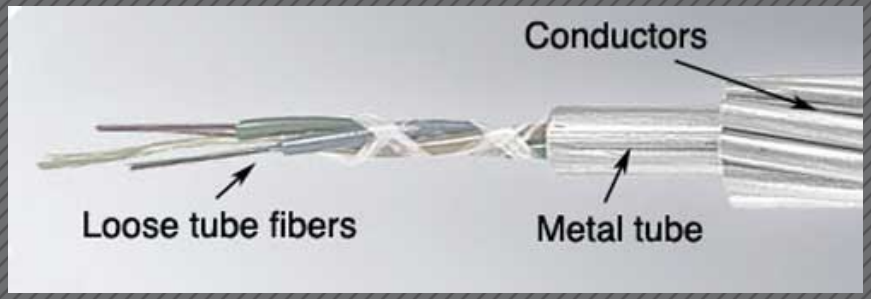
OPGW Thermal Rating Analysis



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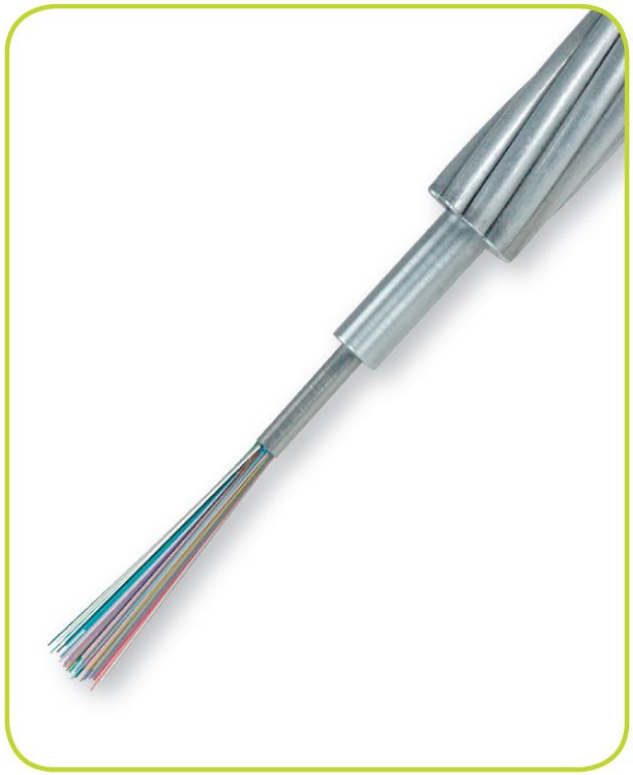
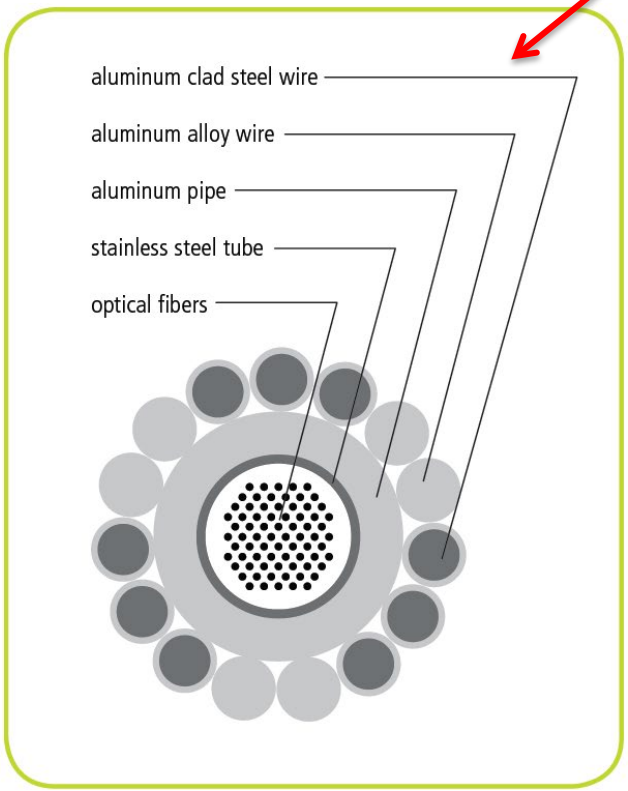
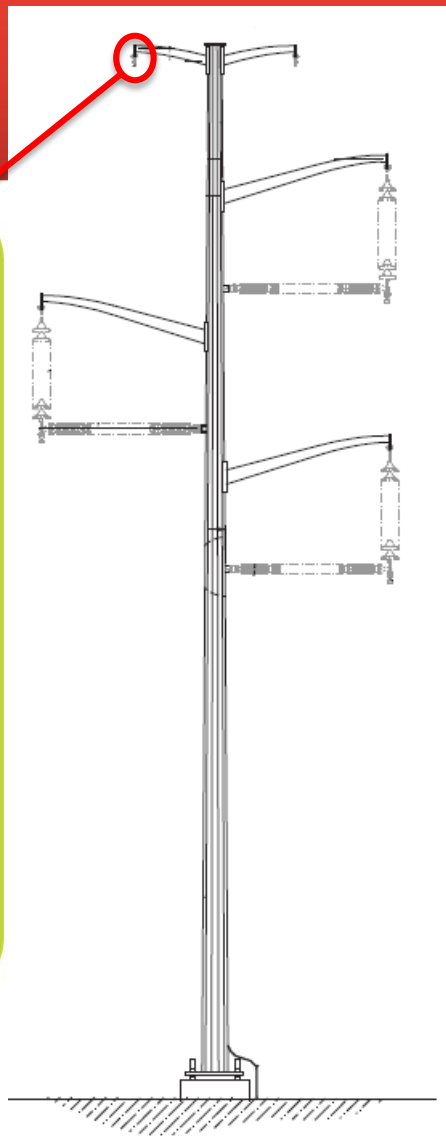
What is Optical Ground Wire?

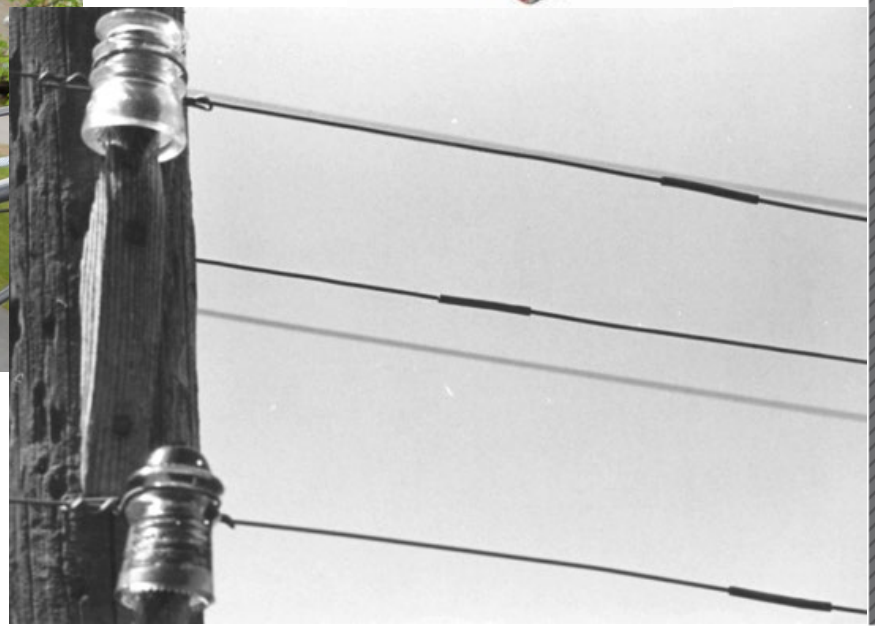






Engineering Considerations

- What happens if the OPGW is damaged?



OPGW Thermal Limitations

- Fiber optic glass has >300°C temperature limit.
- Excessive heat can anneal supporting conductor, 180-200°C temp limit is common.
- OPGW manufacturer cut-sheets provide I^2t (kA^2*s) transient current thermal rating.

Electrical		
DC Resistance at 20°C	1.2128 Ω/mile	0.7536 Ω/km
Rated Short Circuit Current (0.5 sec)	8.5 kA	-
Rated Fault Current (40°C ambient initial/200°C max. final)	35.9 (kA)2 s	-

Fault Thermal Duty Calculation Process

1. Establish mutually-agreed worst-case fault sequence of events for design
   - » **Initial DC offset of fault**
   - » **Pre-fault contingency**
   - » **Reclosing effects**
   - » Fault clearing with stuck breaker
2. Simulate faults for each step of SOE
3. Determine fault clearing time
4. Calculate I^2t
5. Mitigate design

Case Study – OPGW Retrofit

- Re-conductoring of double circuit 115 kV line – existing monopoles, single shield position.
- OPGW Selection – 109.0 kA^2s; matches mechanical properties of existing shield.
- Line Protection – dual pilot schemes (POTT and DCB); five-cycle normal clearing.
- Breaker Failure Protection – 15 cycle clearing.
- Reclosing Philosophy – one shot taken from one terminal on dead 115 kV line.

Case Study – OPGW Retrofit

- With 5-cy+15-cy = 20-cy fault duty, max fault kA through OPGW is

  $[109.0\ kA^2\ s \div (20/60\ s)]^{1/2} = 18.09\ kA$, neglecting DC offset factor and infeed effects.
- From utility protection study short circuit model, actual highest branch current =~ 30.0 kA symmetrical with both terminals closed and strongest infeed removed prior to fault.
- Utility decided on a 10% fault current growth factor.

Case Study – OPGW Retrofit

DC Offset Heating Factor

- X/R = 5.14 of system supplying the line
- Multiplying factor to account for initial DC offset =1.078 for X/R = 5.14 and five-cycle fault

Case Study – OPGW Retrofit

Worst Case SOE

- Utility decided that normal clearing then reclose into stuck breaker too unlikely to justify as design basis.
- Two-shot normal clearing produces less heating than single stuck breaker event.

Case Study – OPGW Retrofit

- Thermal rating required – stuck breaker: $(1.078*30.0\ kA)^2*(5/60\ s) + (30.7\ kA)^2*(10/60\ s) = 247.9\ kA^2s$
- No fault current growth factor included yet!

Mitigation Design

- Model line constants with greater accuracy using detailed line design.
- Re-build system in alternate software to model footing resistances and measure OPGW branch current specifically.
- 10% fault current growth factor included by reducing equivalent source impedances by 10%.
- Determine structure footing resistance by taking actual soil resistivity measurements, modeling soil and grounding design.

Results of Case Study – No Mitigation

- First verified conversion of boundary equivalent model into new software. Results varied less than 1% between models.
- Remodeling line constants reduced overall fault current by ~12%, relatively insensitive to footing resistance.
- Soil and grounding model yielded 40 ohm footing resistance even with 150' long "crow's feet" counterpoise.
- With footings added, OPGW current was 16% less than total branch current.
- Revised model reduced heating by 30%, but further reduction was required.

Mitigation Options – Enhanced Grounding

- Utility would normally design structure grounding to achieve 15 ohm resistance.
- Changing footing resistance to 15 ohm had little effect on overall fault current, but OPGW return current was reduced by 12%.
- Total thermal duty was reduced to 110.2 kA^2s.
- Given extensive bedrock, achieving 15 ohm resistance was not deemed cost effective.

Mitigation Options – Add Second Conductor

- Continuous counterpoise or second OHGW
- Effectively reduce current through each path by ~50%, total heating to ~25% of original.
- May not be cost-effective for retrofit projects.

Mitigation Options – Increase OPGW Size

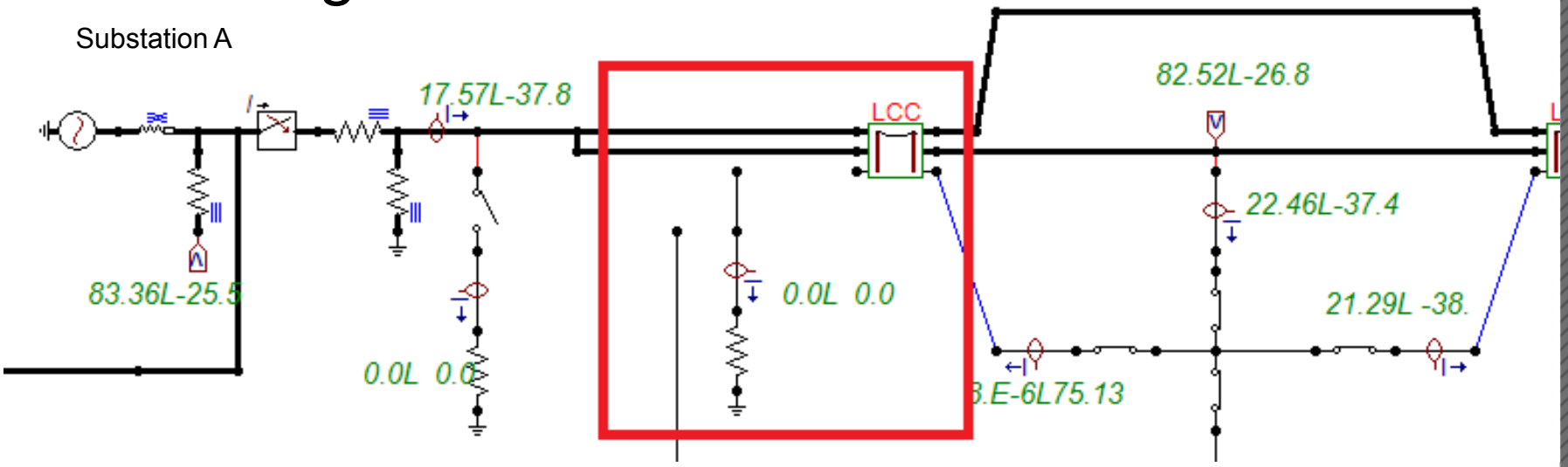
- OPGW size can be increased in sections with worst heating, then step down in size as allowed.
- Not an particularly effective option with short lines.

Mitigation Options – Reduce Clearing Time

- Already using fastest relays available and tripping diodes for failed breaker clearing.
- Utility approved reducing breaker failure delay for 13-cycle total clearing.
- Reduced fault duration reduced heating by 15%.

Mitigation Options – Isolate OPGW from substation ground grid

- Isolating the OPGW from the substation ground grid at both ends reduced worst-case OPGW current from 24.66 kA to 21.29 kA (15.8%), total heating to 82.37 kA^{2}s.



Mitigation Options – Isolate OPGW from substation ground grid

- OPGW isolation design needs 60 Hz wet frequency withstand rating greater than voltage rise on OPGW during ground fault.
- Isolating OPGW increases ground grid current split factor at substation, may require ground grid design mitigation.
- Isolated OPGW affects ground fault currents and must be accounted for in protection short circuit model.

Approved mitigated design from case study

- 109 kA^2s OPGW.
- Reduced breaker failure time delay for 15 cycle total clearing.
- Standard “crow’s feet” structure grounding design.
- OPGW is isolated from ground grid at both ends.
- 10% fault current growth factor.

Questions?