EPRI

ENERGY DELIVERY AND CUSTOMER SOLUTIONS

CableInfo Proposal

Prepared for IEC CIM WG 14

Celso Rocha, Engineer Scientist
Andres Ovalle, Technical Leader

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Outline

- Background
- Reference UML Model
- Identified Gaps
- Proposed Model to Address Gaps and Identified Needs
- Sample Cases

Background

- EPRI has been developing mappers from/to CIM to/from commercial and open-source distribution and transmission planning and short circuit analysis tools.
- Identified gaps are being documented and proposals are being developed.
- Focus is given to *template data*.

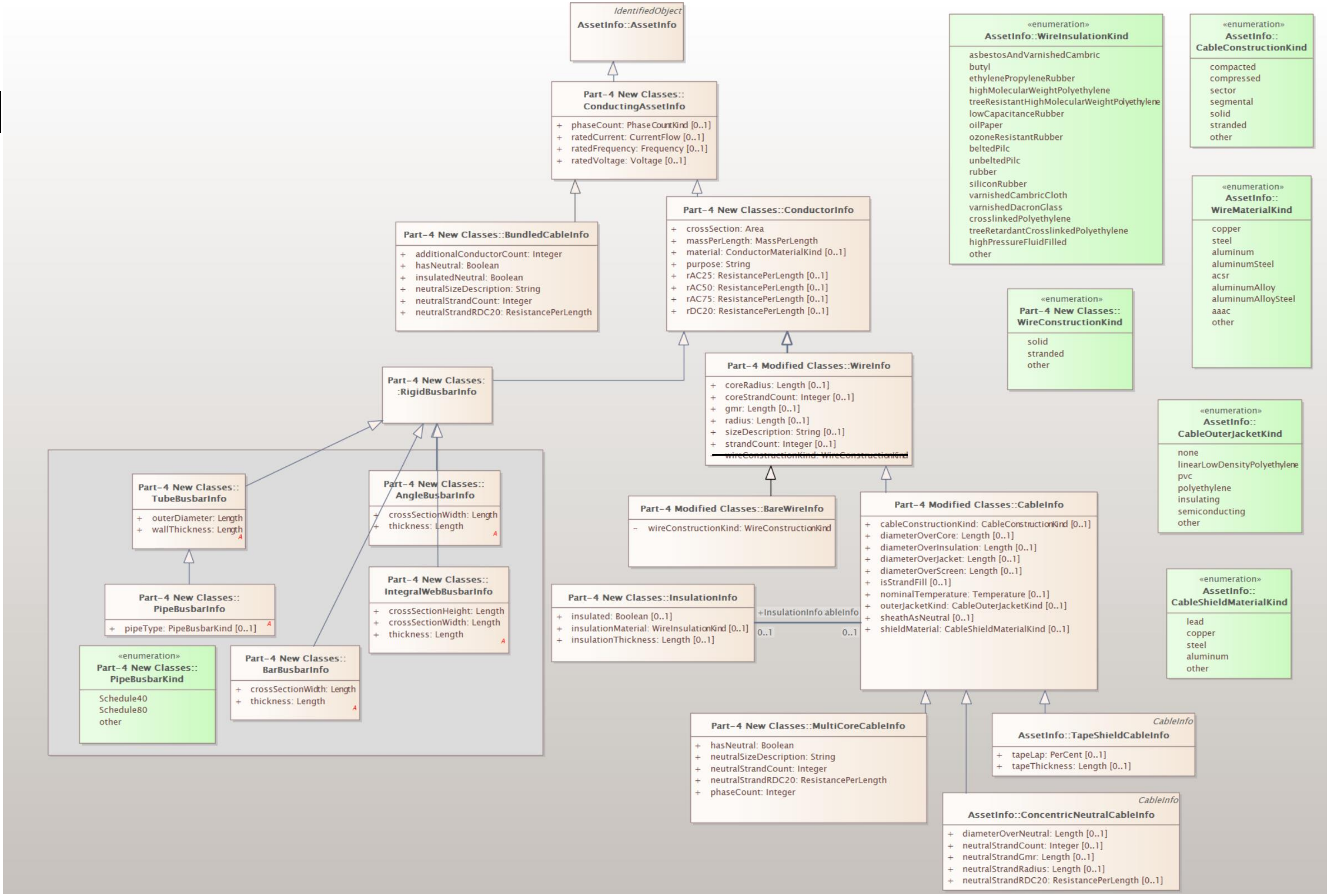
Tool	Vendor	Main Application
CYME	Eaton	Distribution, Planning
Synergi	DNV	Distribution, Planning
OpenDSS	EPRI – Open Source	Distribution, Planning, Research
One Liner	ASPEN	Transmission, Short-Circuit
CAPE	Siemens	Transmission, Short-Circuit
PSCAD	Manitoba Hydro	EMT

Background

- The proposal herein focuses on Cable datasheet information.
- Use cases involve information exchange between Asset Management and other utility enterprise applications such as Grid Model Managers and planning (for power flow studies, cable ampacity ratings calculation, etc.) and operation tools
- Process started with the intention to handle cable datasheet information as required by some distribution planning tools
- As this proposal was being developed, modifications and adjustments were made to handle additional information needed for cable ampacity ratings following IEC 60287 series and CIGRE’s TB 880

Reference UML Model

- As recently updated by WG 14:61968-Part 4_Ed3 work in Q4 2023



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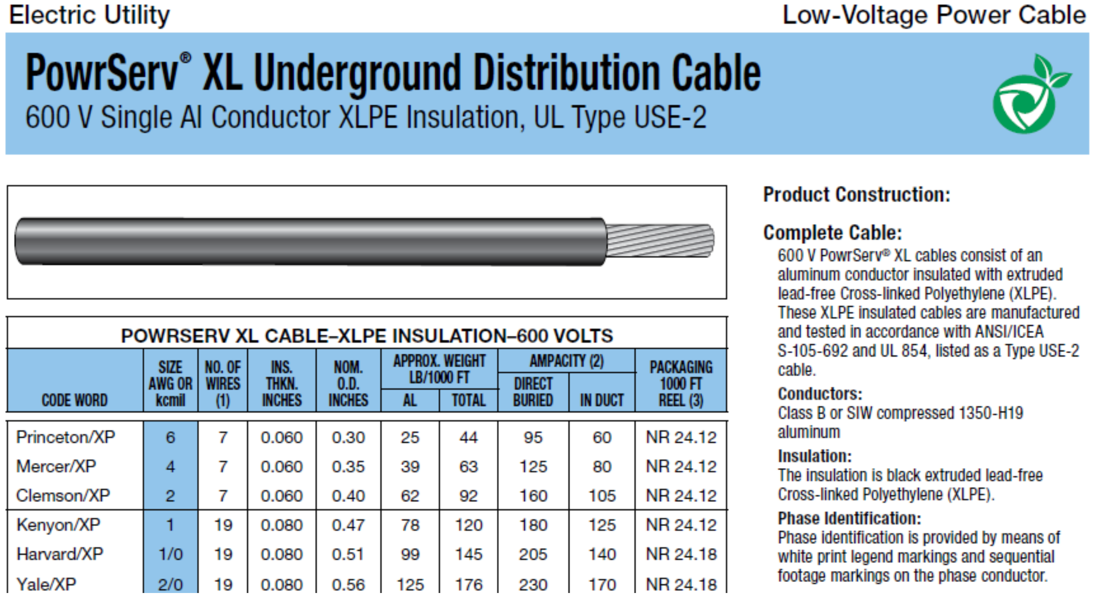
Identified Gaps

1 – Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Cables can include multiple layers (anywhere from a single insulation layer to 10-20 layers depending on the cable application and customizations)



Electric Utility — Low-Voltage Power Cable

PowrServ® XL Underground Distribution Cable

600 V Single Al Conductor XLPE Insulation, UL Type USE-2

POWRSERV XL CABLE–XLPE INSULATION–600 VOLTS

CODE WORD	SIZE AWG OR kcmil	NO. OF WIRES (1)	INS. THKN. INCHES	NOM. O.D. INCHES	APPROX. WEIGHT LB/1000 FT AL	APPROX. WEIGHT LB/1000 FT TOTAL	AMPACITY (2) DIRECT BURIED	AMPACITY (2) IN DUCT	PACKAGING 1000 FT REEL (3)
Princeton/XP	6	7	0.060	0.30	25	44	95	60	NR 24.12
Mercer/XP	4	7	0.060	0.35	39	63	125	80	NR 24.12
Clemson/XP	2	7	0.060	0.40	62	92	160	105	NR 24.12
Kenyon/XP	1	19	0.080	0.47	78	120	180	125	NR 24.12
Harvard/XP	1/0	19	0.080	0.51	99	145	205	140	NR 24.18
Yale/XP	2/0	19	0.080	0.56	125	176	230	170	NR 24.18

Product Construction:

Complete Cable:
600 V PowrServ® XL cables consist of an aluminum conductor insulated with extruded lead-free Cross-linked Polyethylene (XLPE). These XLPE insulated cables are manufactured and tested in accordance with ANSI/ICEA S-105-692 and UL 854, listed as a Type USE-2 cable.

Conductors:
Class B or SIW compressed 1350-H19 aluminum

Insulation:
The insulation is black extruded lead-free Cross-linked Polyethylene (XLPE).

Phase Identification:
Phase identification is provided by means of white print legend markings and sequential footage markings on the phase conductor.

Low-Voltage Application: Source

Submarine Application: Source

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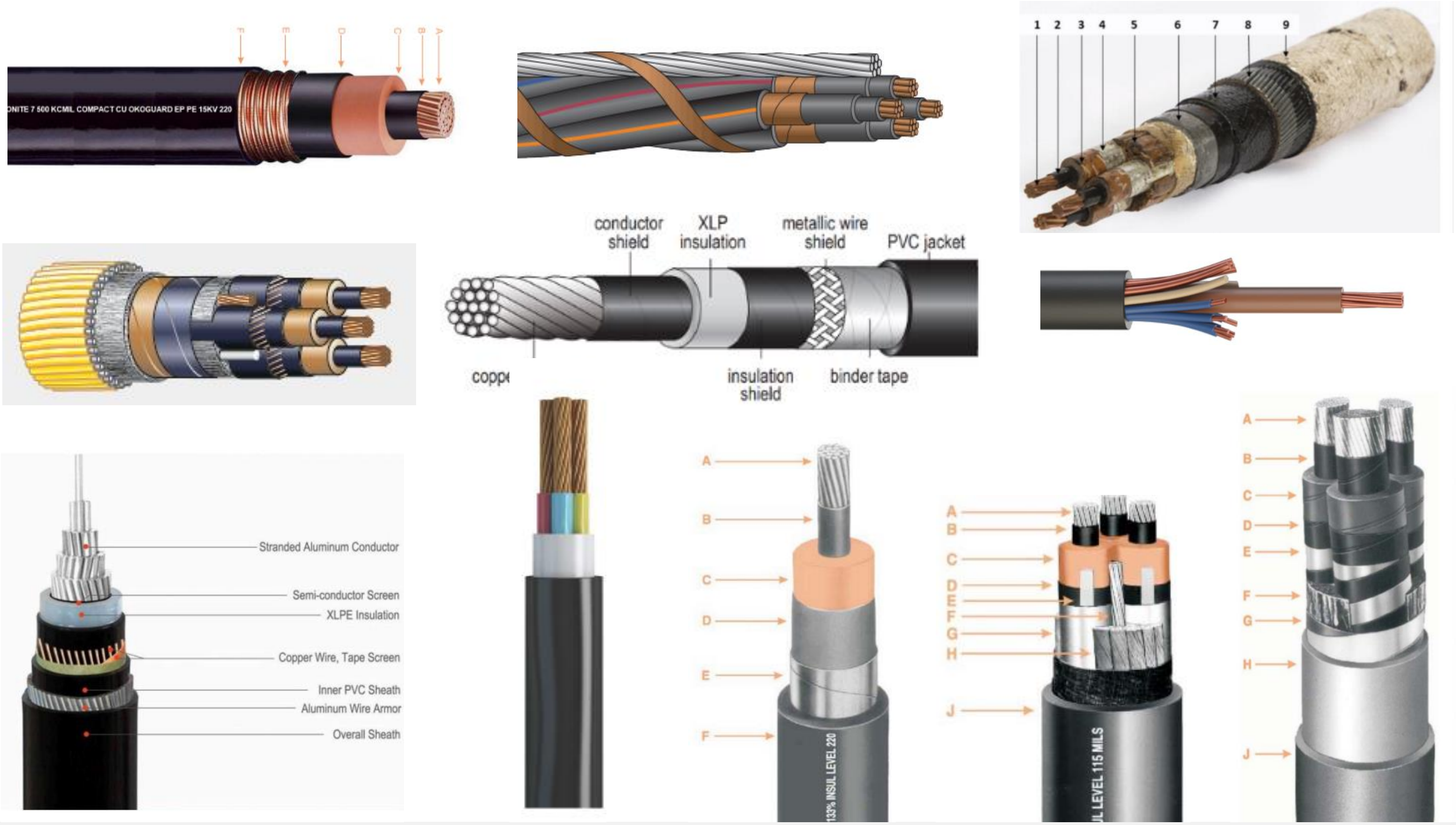
1 – Lack of flexibility to handle varying cable configurations/layering and associated attributes

- A thorough investigation of different cable types and applications revealed the existence of typical types of layers

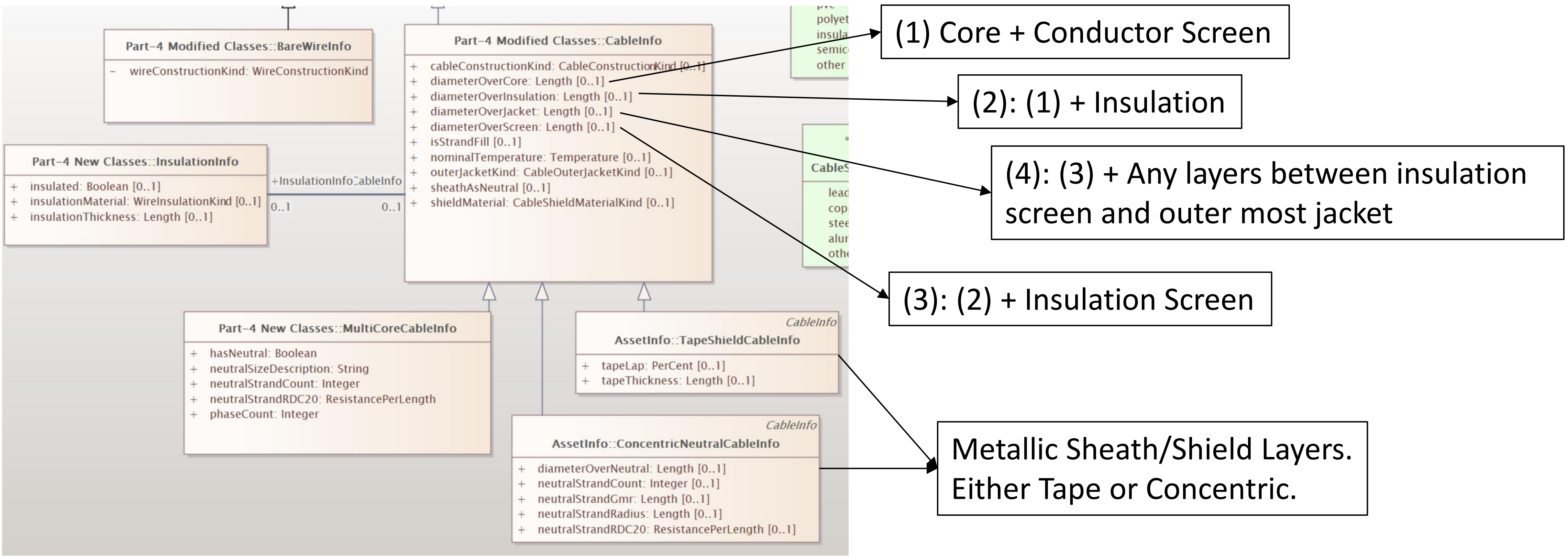


Center Outwards

1- Conductor
2- Water Blocking Layer
3- Conductor Screen Layer
4- Insulation
5- Insulation Screen Layer
6- Water Blocking Layer
7- Metallic Sheath/Shield Layer
8- Water Blocking Layer
9 – Outer Sheath Layers
10 – Filling (MultiCore)
11 – Binding Tapes (MultiCore)
12 – Inner Sheath Layer (MultiCore)
13 – Armor Layer (MultiCore)
14 – Water Blocking Layer (MultiCore)
15 – Outer Sheath Layer (MultiCore)
16 – Skid Wire Layer (MultiCore)

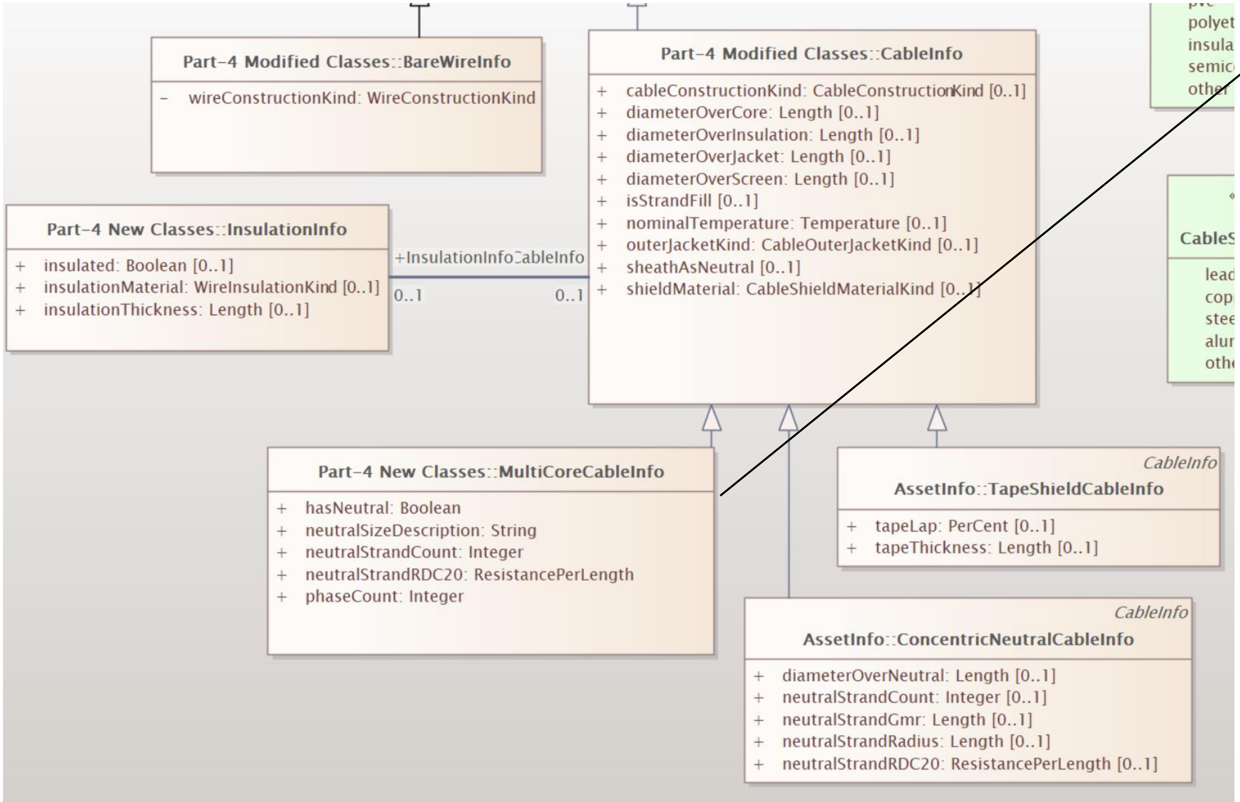
1 – Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Issue 1.1: Current modeling supports information for a limited number of layers. Information on other layers, required for cable ampacity calculations and impedance computations, is missing



1 – Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Issue 1.2: Modeling of belted layers in multi core cables is not supported

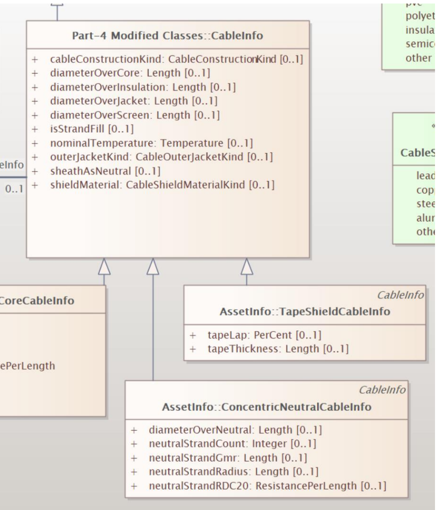


No attributes relative to belted layers

Submarine Application: Source

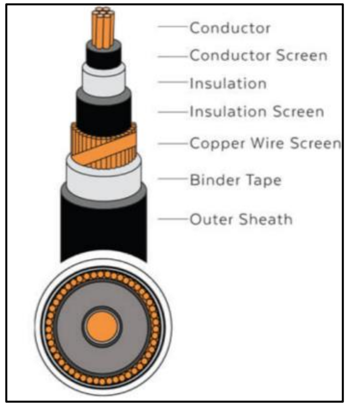
1 – Lack of flexibility to handle varying cable configurations/layering and associated attributes

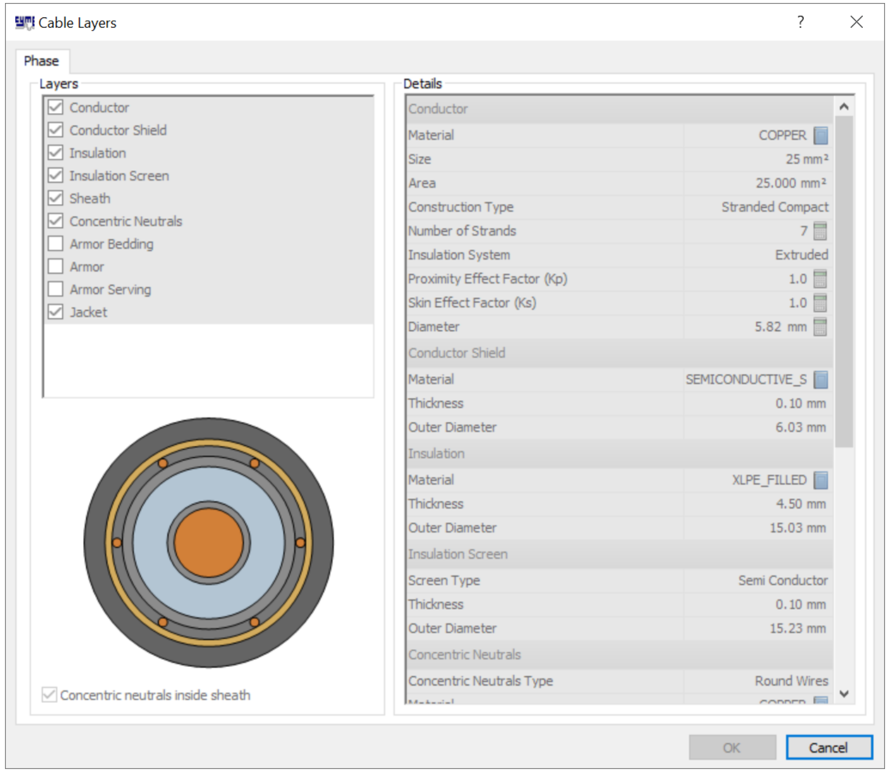
- Issue 1.3: CableInfo existing specializations TapeShieldCableInfo and ConcentricNeutralCableInfo are limiting. In reality, tape and concentric conductors are just layers in the cable, and a cable can have one or more of each.



Conductor: Plain annealed copper or aluminium wire. Copper conductors shall be stranded (class 2) and a stranded (class 2).
Conductor Screen: Extruded layer of semi-conducting cross-linkable compound.
Insulation: cross-linked polyethylene compound XLPE or EPR.
Insulaton Screen: Extruded layer of semi-conducting cross-linkable compound is applied over the insulat
Metallic Layer: copper tapes or a concentric layer of copper wires or a combination of tapes and wires.
Separation Sheath (for armoured cable): PVC, PE or LSZH.
Armour (for armoured cable): round aluminium wire.
Over Sheath: PVC or MDPE. LSZH can be offered as an option.

Concentric Conductor: Bare copper concentric neutral wires helically applied sized 1/3, 1/6 or 1/12 or based on fault current requirements. Optional shields include a combination of copper tape and wires or a longitudinal corrugated copper tape. A C-L-X® armor covering is also available.





Metallic wires, lapped tapes, gapped tapes, longitudinally corrugated tapes with overlap and sealed overlap, straps, and extruded metal (**including combinations of these**) have been used to provide the metallic shield component with the foremost objective of draining the capacitive charging current. [3]

2 – Lack of ability to model materials properties and custom materials

- Thermal and electrical characteristics of materials are important for ampacity and impedances calculation. Many of those properties can be taken from standards.
  - Thermal Resistivity (Non-Metallic Materials)
  - Dielectric Constant, Dielectric Strength, Dissipation Factor (Insulation)
  - Temperature Coefficient, Thermal Capacitance, Specific Heat (Metallic Materials)
  - Electrical Resistivity

Note: existing enumerations such as CableShieldMaterialKind, WireMaterialKind, CableOuterJacketKind, WireInsulationKind are helpful but are limited since multiple values can be defined within a single standard

Table 1 – Electrical resistivities and temperature coefficients of metals used

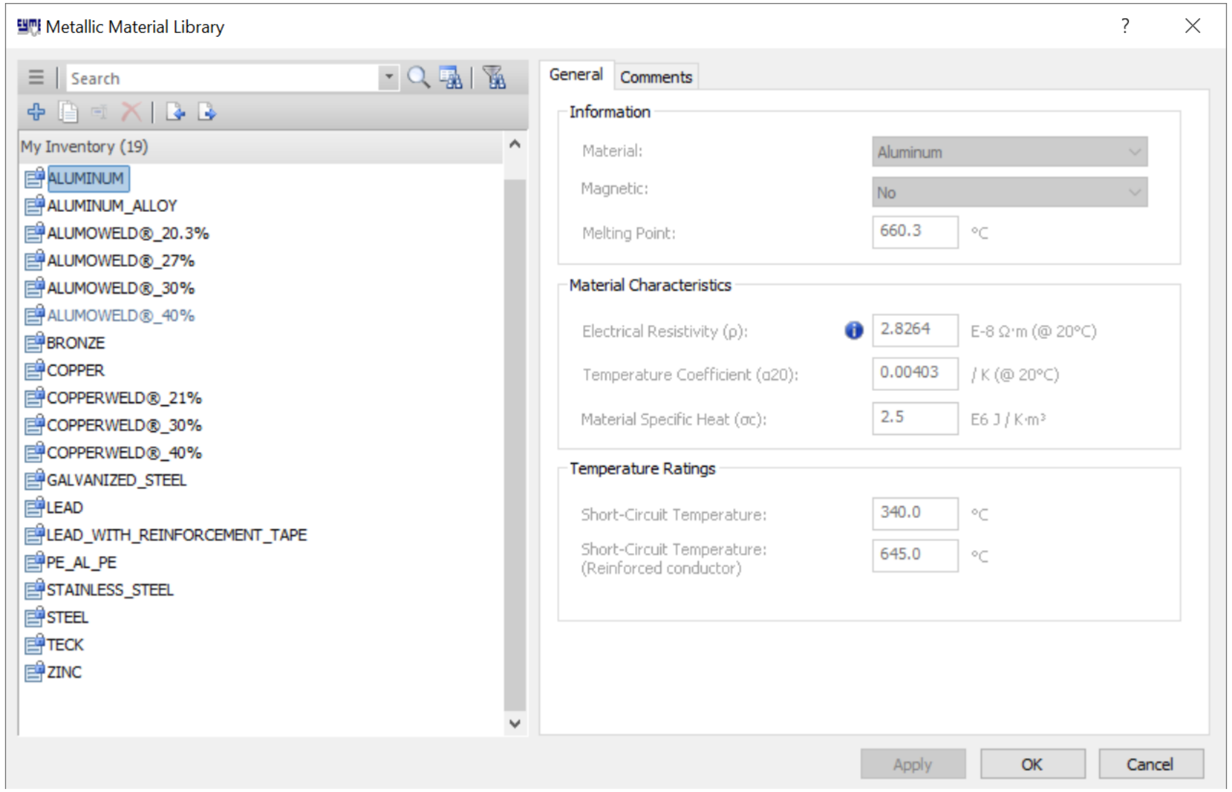
Material	Resistivity (ρ) ohm · m at 20 °C	Temperature coefficient (α_{20}) per K at 20 °C
a) *Conductors*		
Copper	1,724 1 10^{-8}	3,93 10^{-3}
Aluminium	2,826 4 10^{-8}	4,03 10^{-3}
b) *Sheaths and armour*		
Lead or lead alloy	21,4 10^{-8}	4,0 10^{-3}
Steel	13,8 10^{-8}	4,5 10^{-3}
Bronze	3,5 10^{-8}	3,0 10^{-3}
Stainless steel	70 10^{-8}	Negligible
Aluminium	2,84 10^{-8}	4,03 10^{-3}

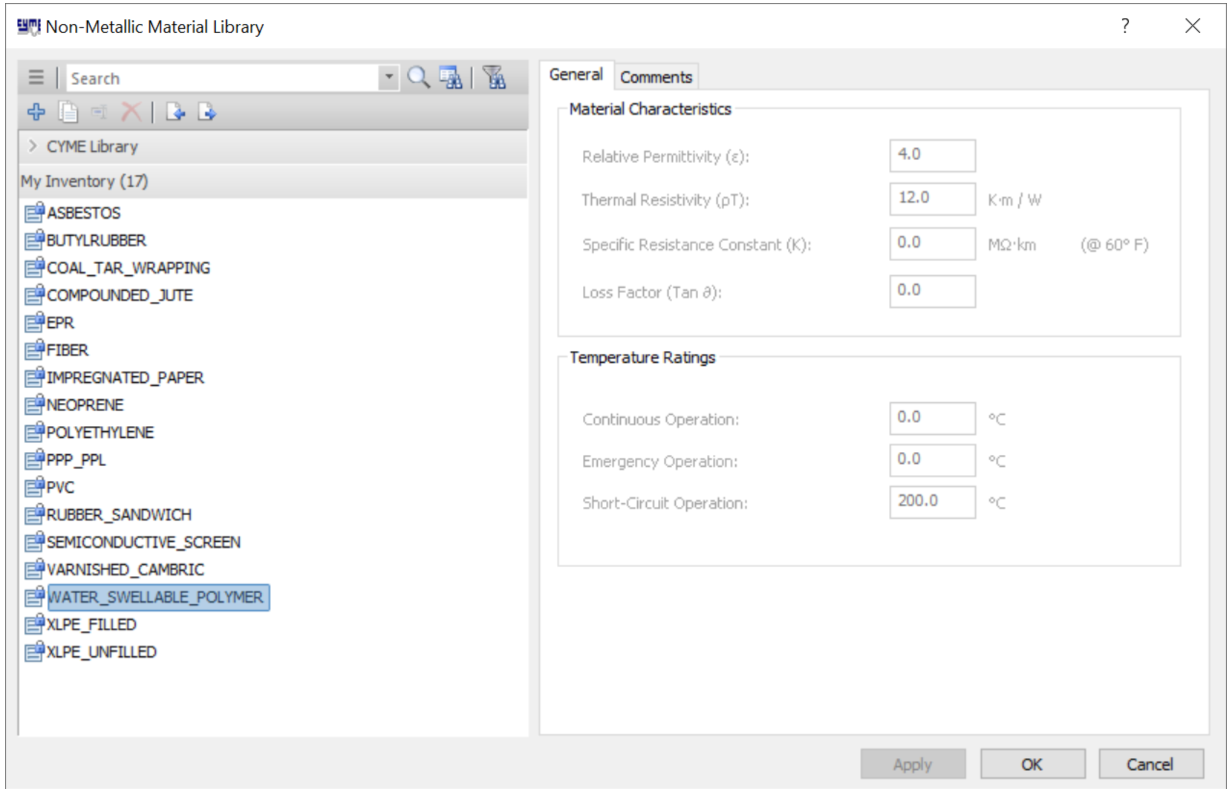
NOTE Values for copper conductors are taken from IEC 60028. Value for aluminium conductors are taken from IEC 60889.

Source: [5]

2 – Lack of ability to model materials properties and custom materials

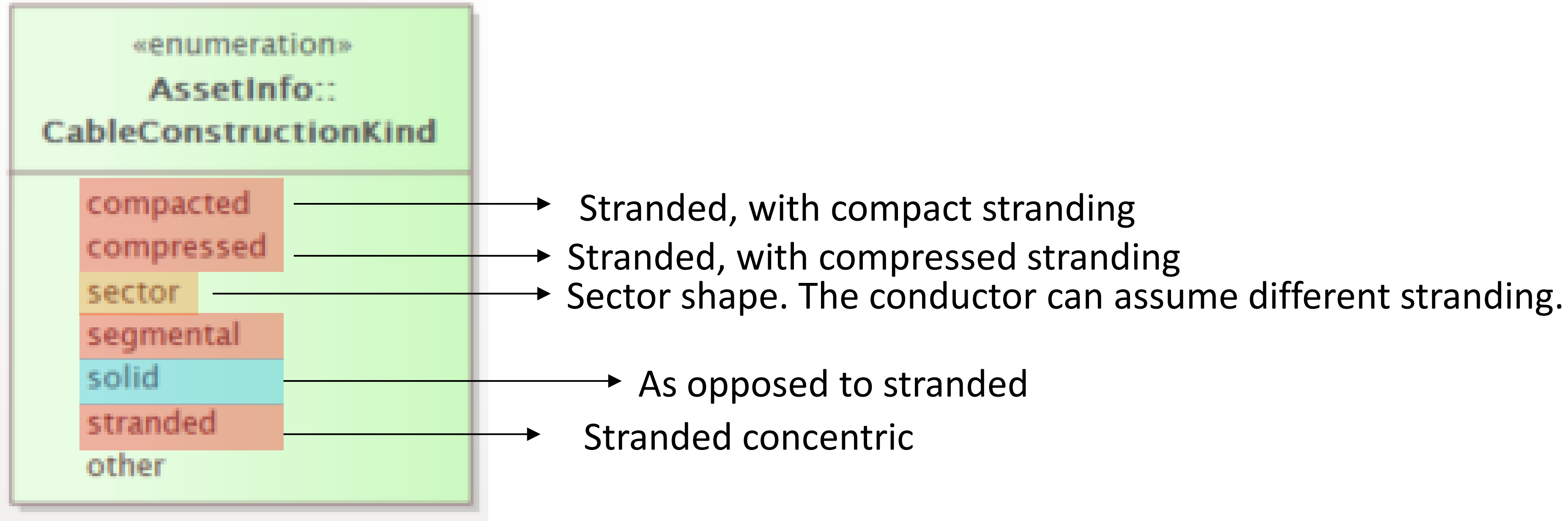
- Example from CYME (9.4 r1)





3 – Lack of clarity on CableConstructionKind

- CableConstructionKind enumerations mix conductor stranding with shape
  - “Construction” is also a **bit misleading** as one would think of typical cable constructions (HPFF, HPFG, SCFF, LTS, HTS) rather than the construction of the cable/core conductor
  - From IEC 60050-461, Cable is defined as: “assembly consisting of: (1) one or more cores, (2) their individual coverings (if any), (3) assembly protection (if any), protective covering(s) (if any); additional uninsulated conductor(s) may be included in the cable.



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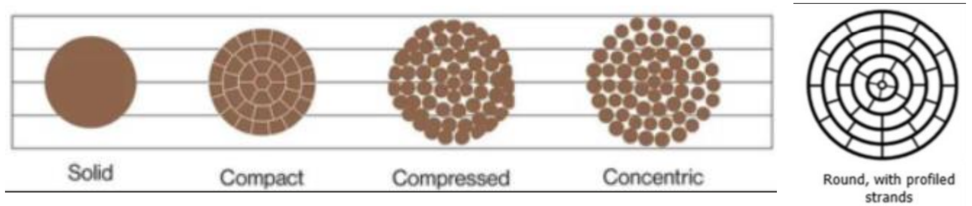
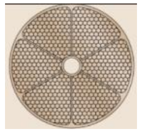
Shape	Stranding
Round	Solid
Round	Stranded (Concentric)
Round	Stranded (Compressed)
Round	Stranded (Compact)
Round	Stranded (Profile Strands - wires are not originally round)
Round	Segmental
Sector	Solid
Sector	Stranded

Shape	Stranding
Sector	Compact
Sector	Compressed
Oval	Solid
Oval	Stranded
Oval	Compact
Oval	Compressed

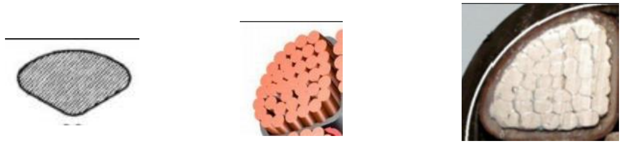
Round





Segmental

Sector



Solid Stranded Compact

Oval

Solid Stranded

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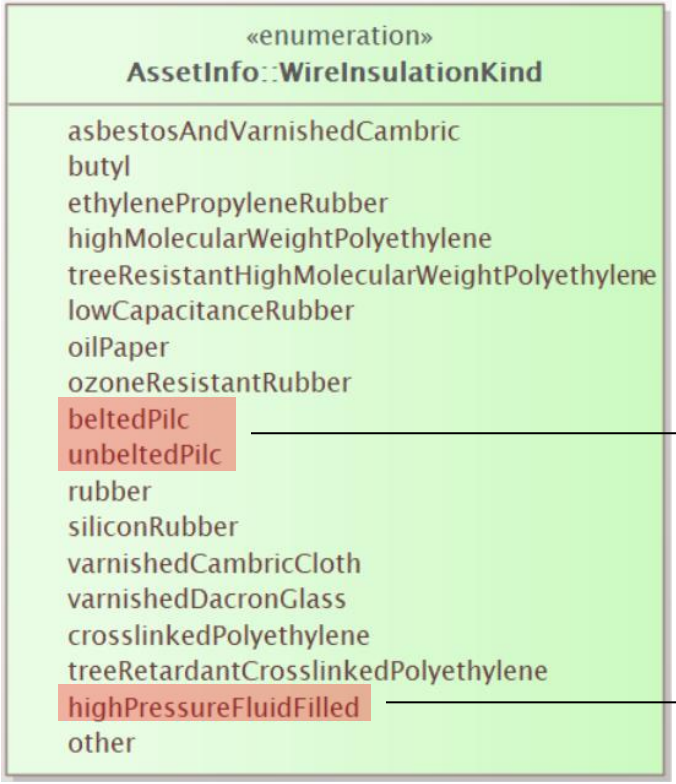
4 – WireInsulationKind mixes insulation materials with cable installation/construction

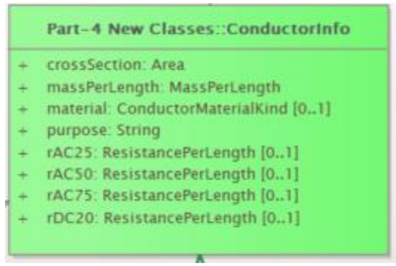


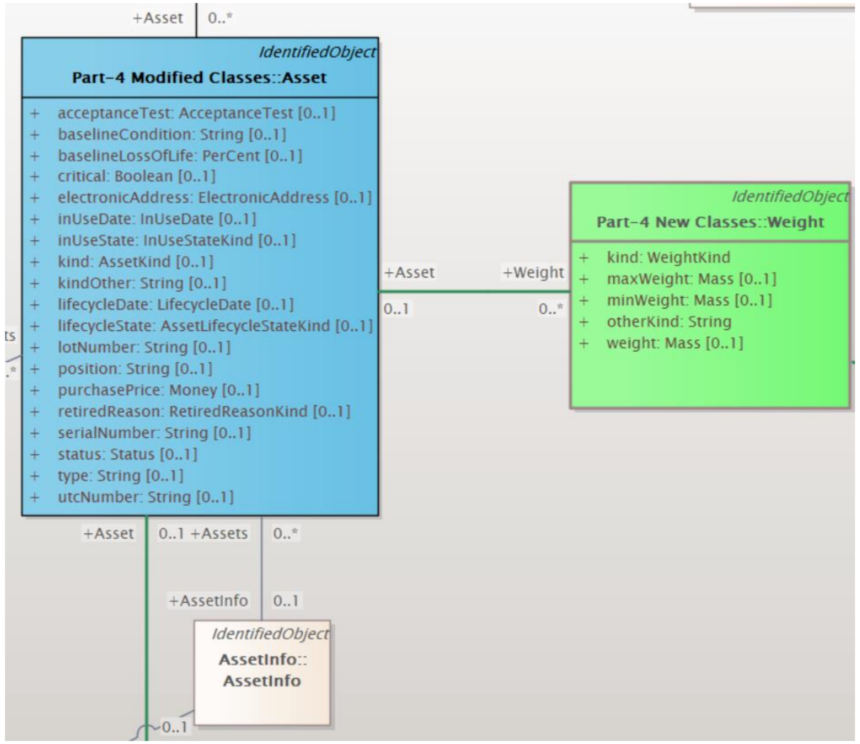
Insulation is Oil Paper

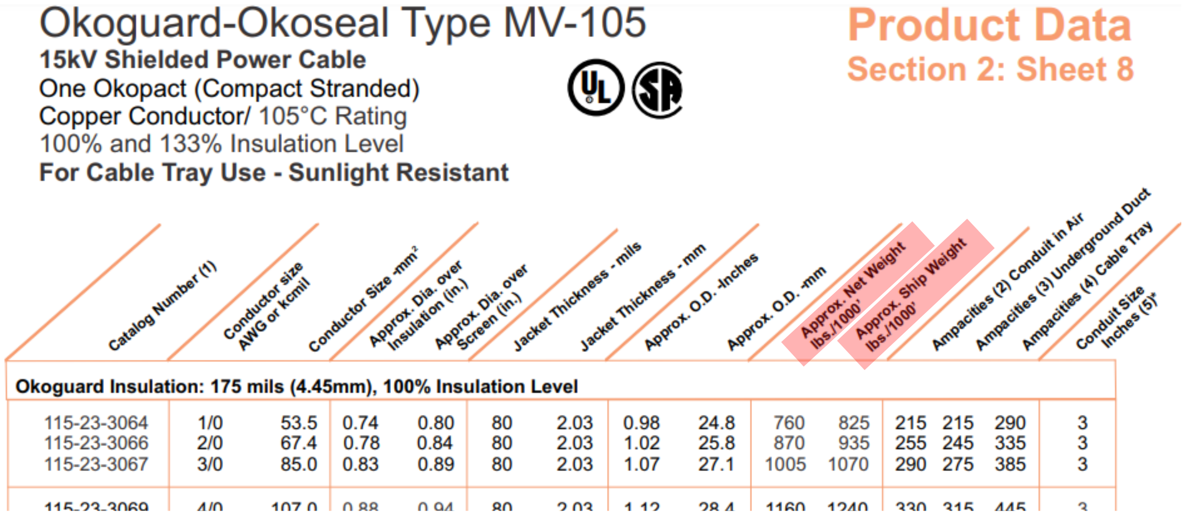
Insulation is Oil Paper

5 – Use of ConductorInfo.massPerLength

- Description must be updated. Currently says “Area of conducting material cross section”
- Property itself seems redundant with recently added Weight class
- It seems reasonable to have a per-length weight to Weight class







Okoguard-Okoseal Type MV-105

15kV Shielded Power Cable

One Okopact (Compact Stranded)

Copper Conductor/ 105°C Rating

100% and 133% Insulation Level

For Cable Tray Use - Sunlight Resistant

Product Data

Section 2: Sheet 8

Catalog Number (1)	Conductor size AWG or kcmil	Conductor Size -mm²	Approx. Dia. over Insulation (in.)	Approx. Dia. over Screen (in.)	Jacket Thickness - mils	Jacket Thickness - mm	Approx. O.D. -inches	Approx. O.D. -mm	Approx. Net Weight lbs./1000'	Approx. Ship Weight lbs./1000'	Ampacities (2) Conduit in Air	Ampacities (3) Underground Duct	Ampacities (4) Cable Tray	Conduit Size Inches (5)*
Okoguard Insulation: 175 mils (4.45mm), 100% Insulation Level														
115-23-3064	1/0	53.5	0.74	0.80	80	2.03	0.98	24.8	760	825	215	215	290	3
115-23-3066	2/0	67.4	0.78	0.84	80	2.03	1.02	25.8	870	935	255	245	335	3
115-23-3067	3/0	85.0	0.83	0.89	80	2.03	1.07	27.1	1005	1070	290	275	385	3
115-23-3069	4/0	107.0	0.88	0.94	80	2.03	1.12	28.4	1160	1240	330	315	445	3

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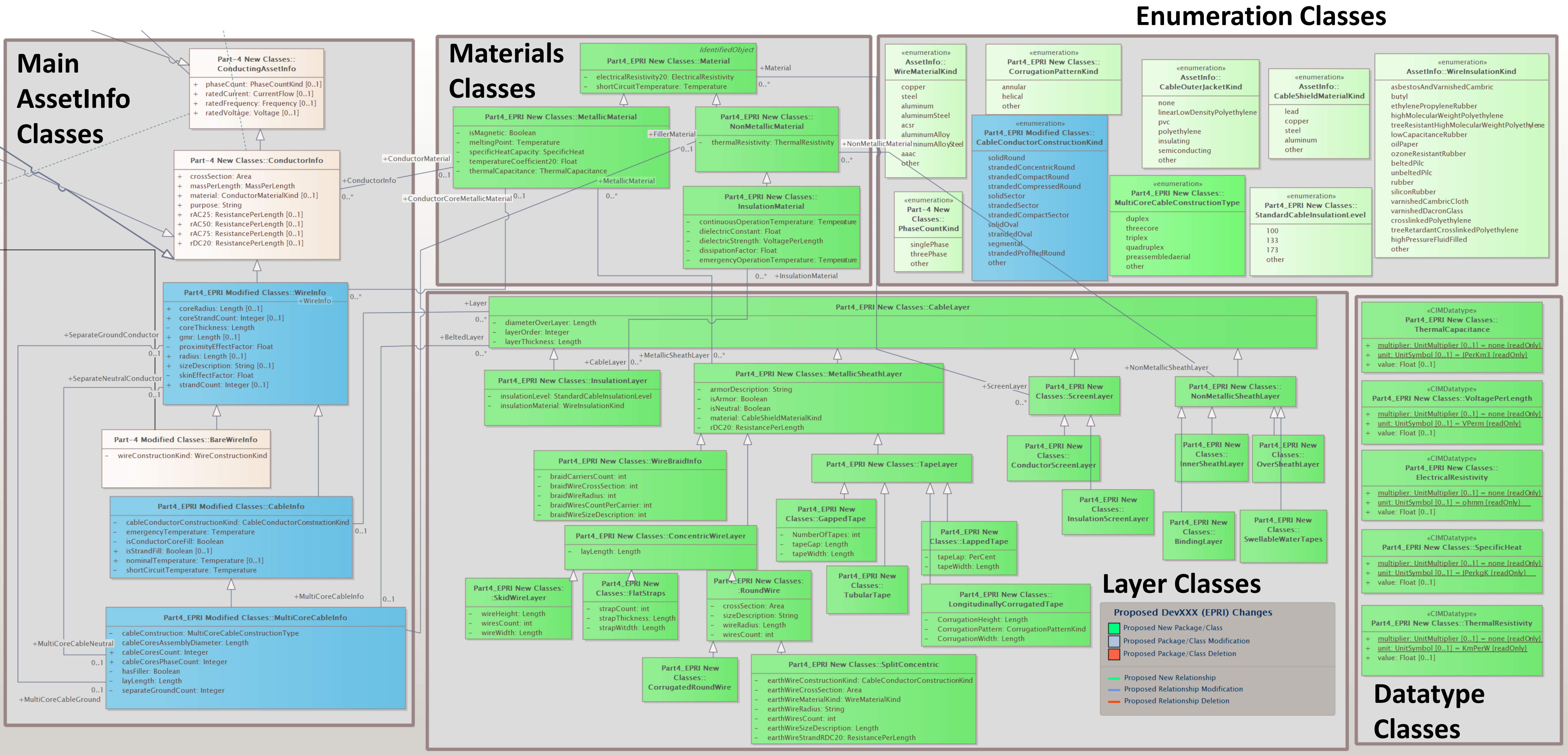
Proposed Model to Address Gaps and Identified Needs

Proposed Modeling (*Current Draft*)



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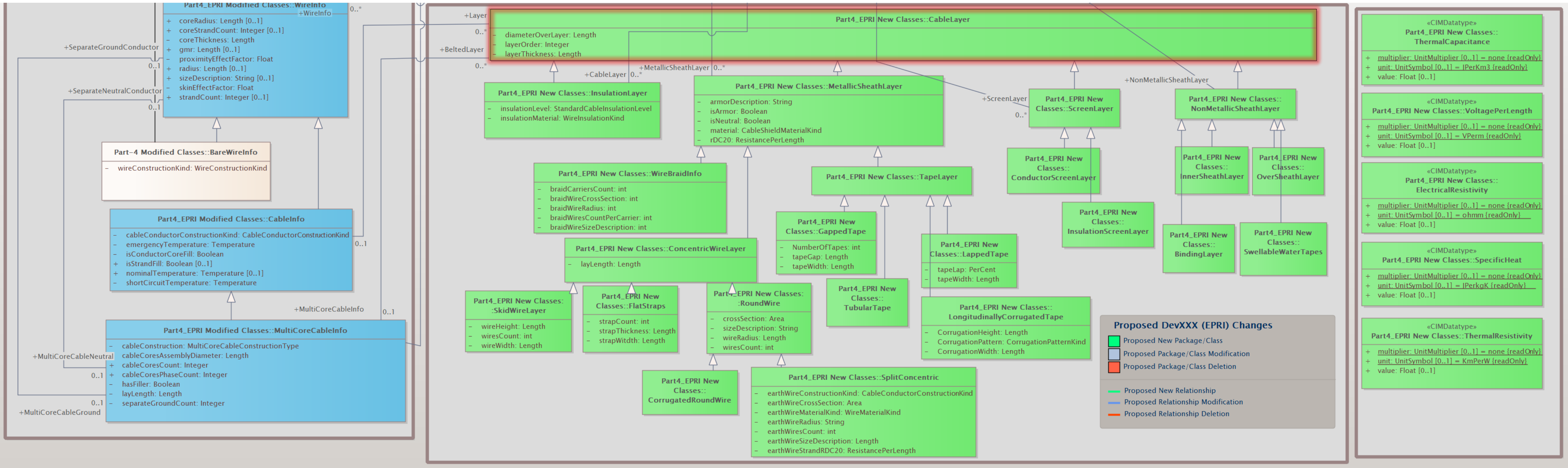
Gap 1: Lack of flexibility to handle varying cable configurations/layering and associated attributes

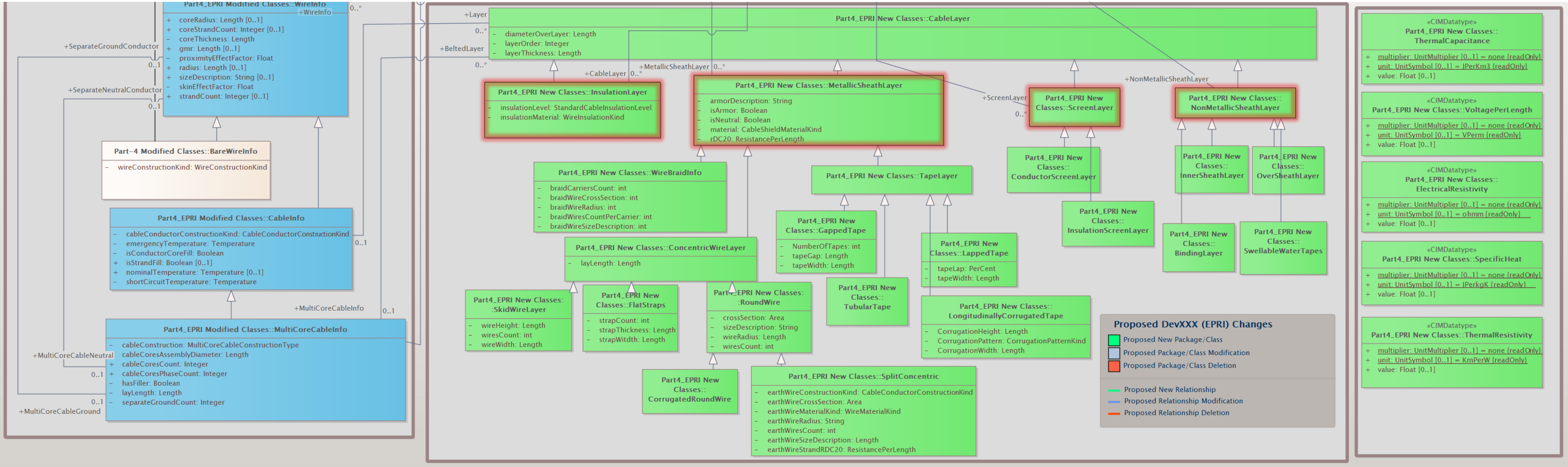
- Approach: proposed CableLayer class



EPRI

Gap 1: Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Approach: proposed CableLayer class
  - 4 specializations based on the material and role of layer, main factors to be considered in ampacity and impedances calculation



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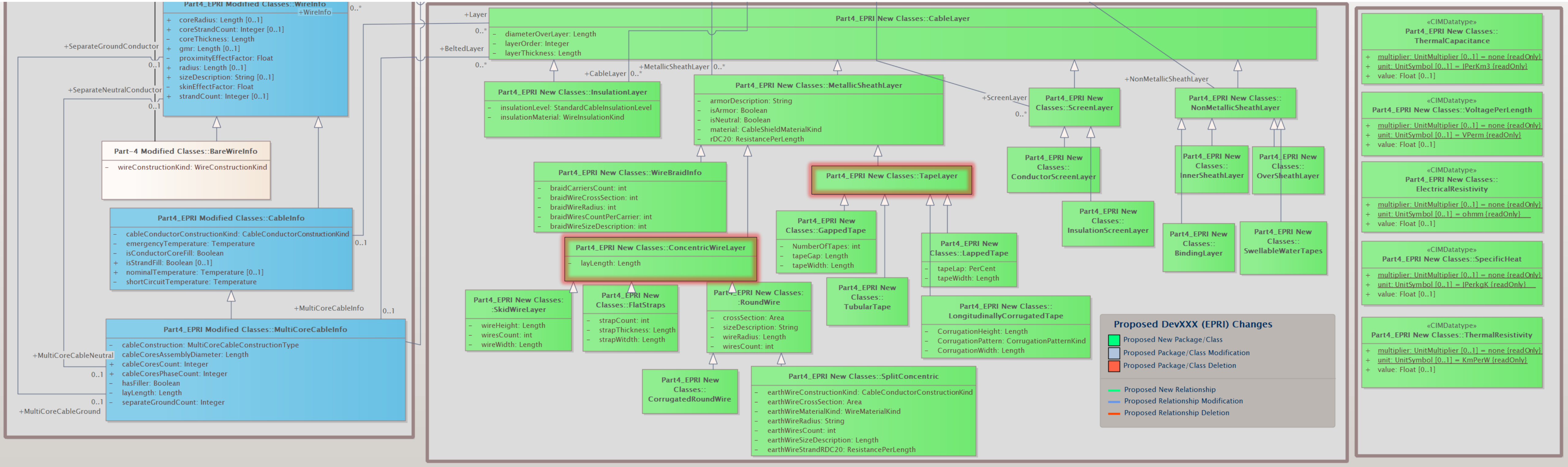
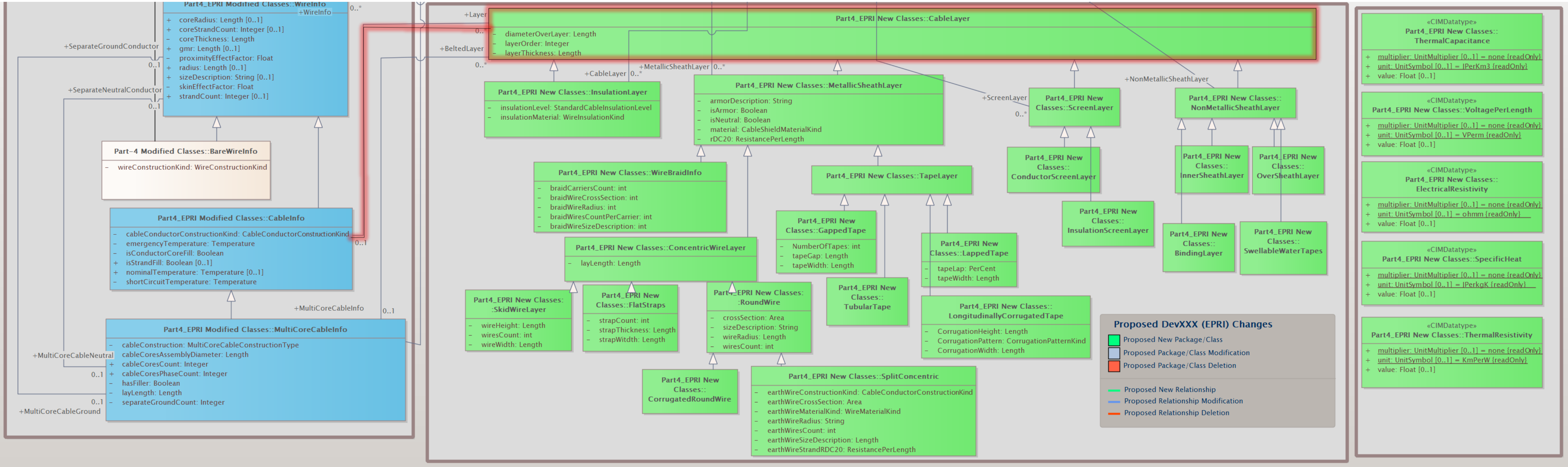
Gap 1: Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Approach: proposed CableLayer class
  - **Deprecate ConcentricNeutralCableInfo** class and introduce **ConcentricWireLayer** class to represent any concentric wire
    - From IEC 60050-461, a “concentric conductor is a conductor so constructed as to surround one or more insulated conductors ” and concentric neutral (conductor) is a “concentric conductor which is intended to be used as a neutral conductor”.
    - To indicate a concentric layer is meant to carry neutral current, MetallicSheathaLayer.isNeutral property has been added.
  - **Deprecate TapeShieldCableInfo** class and introduce **TapeLayer** class



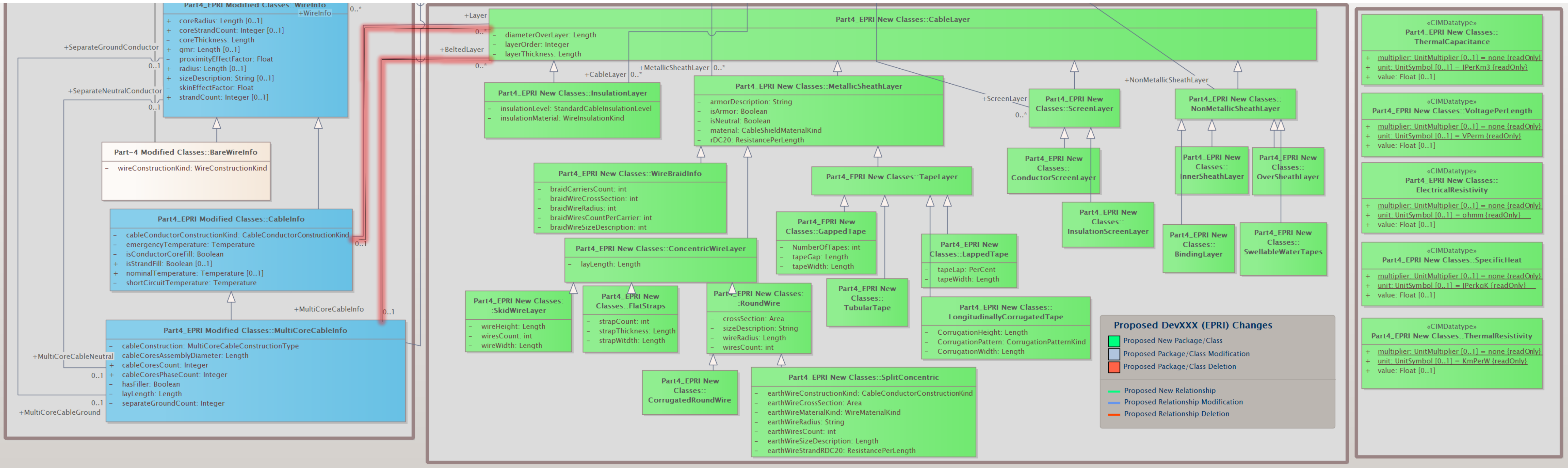
Gap 1: Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Approach: proposed CableLayer class
  - Issue 1.1: Current modeling support information on a limited number of layers. Information on other layers, required for cable ampacity calculations and impedance computations is missing
  - Proposed Approach: any number of layers is allowed in a CableInfo



Gap 1: Lack of flexibility to handle varying cable configurations/layering and associated attributes

- Approach: proposed CableLayer class
  - Issue 1.2: Modeling of belted layers in multi core cables is not supported
  - Proposed Approach: Individual core layers and belted layers are treated with the same CableLayer class. Association to CableInfo and MultiCoreCableInfo dictates type of layer



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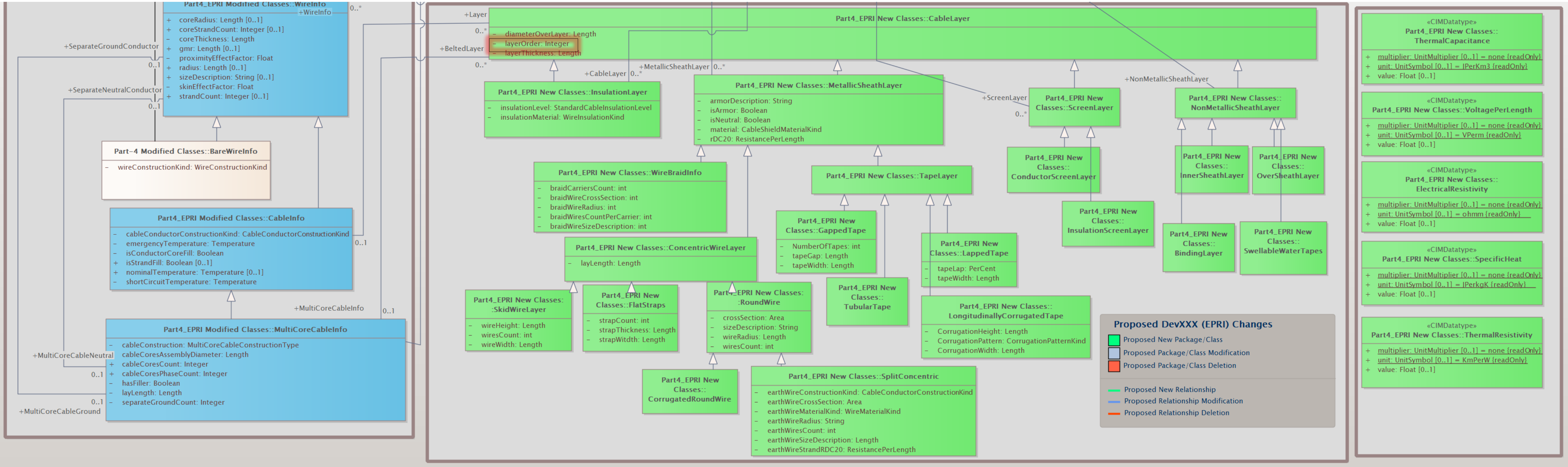
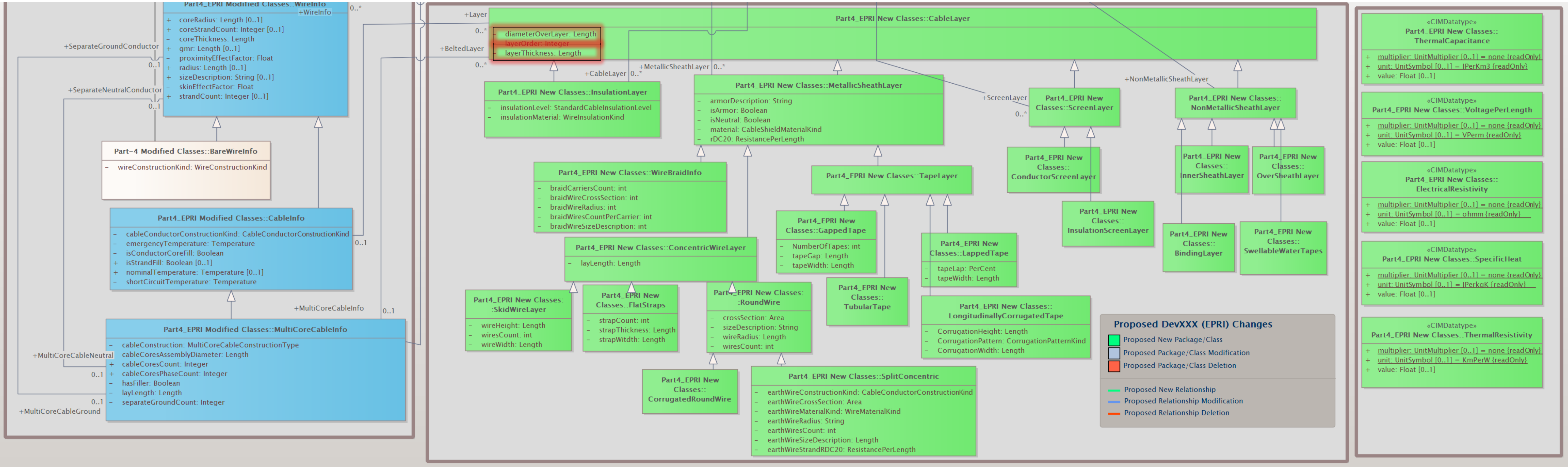
Other Needs Associated with Layering

- 1: Handle Layer Ordering → Layer order attribute
  - Ascending order corresponds to layering outwards
  - Ordering should re-start for Belted Layers (i.e., 1st belted layer →1, 2nd belted layer →2, etc.)



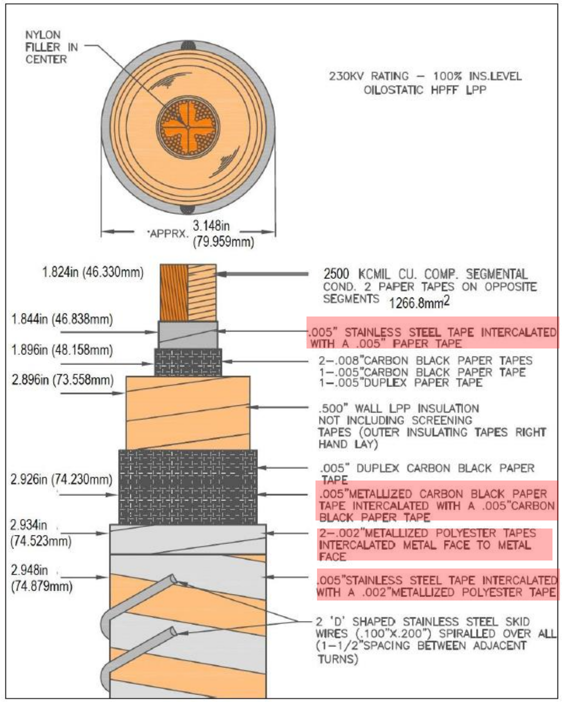
Other Needs Associated with Layering

- 2: Handle Layer Dimensions by Thickness and Diameter → diameterOverLayer and layerThickness attributes
  - This is needed because manufacturers can provide one or the other (or both) dimensions. It typically depends on the controlled dimensions during the cable manufacturing process [4]



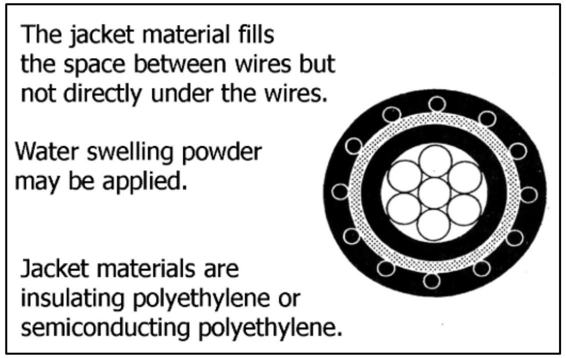
Other Needs Associated with Layering

- 3: Handle Intercalated/Mixed Layers
  - Case 1: Intercalated Tape Layers are tapes that are applied simultaneously in a way that each layer overlays a portion of the other layer.
  - Case 2: Imbedding type jacket in Concentric Neutral Cables
  - Proposed solution supports this by allowing multiple layers with the same layerOrder

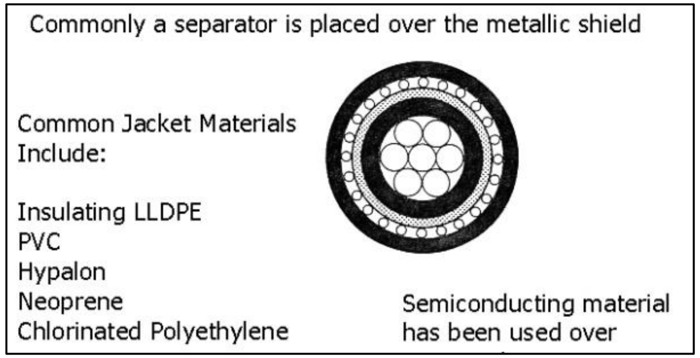


Source: [4]

Figure 30: Cable data sheet: 1266,8mm² pipe-type cable with laminated paper polypropylene insulation and stainless steel skid wires



Imbedding Type Jacket in CNC

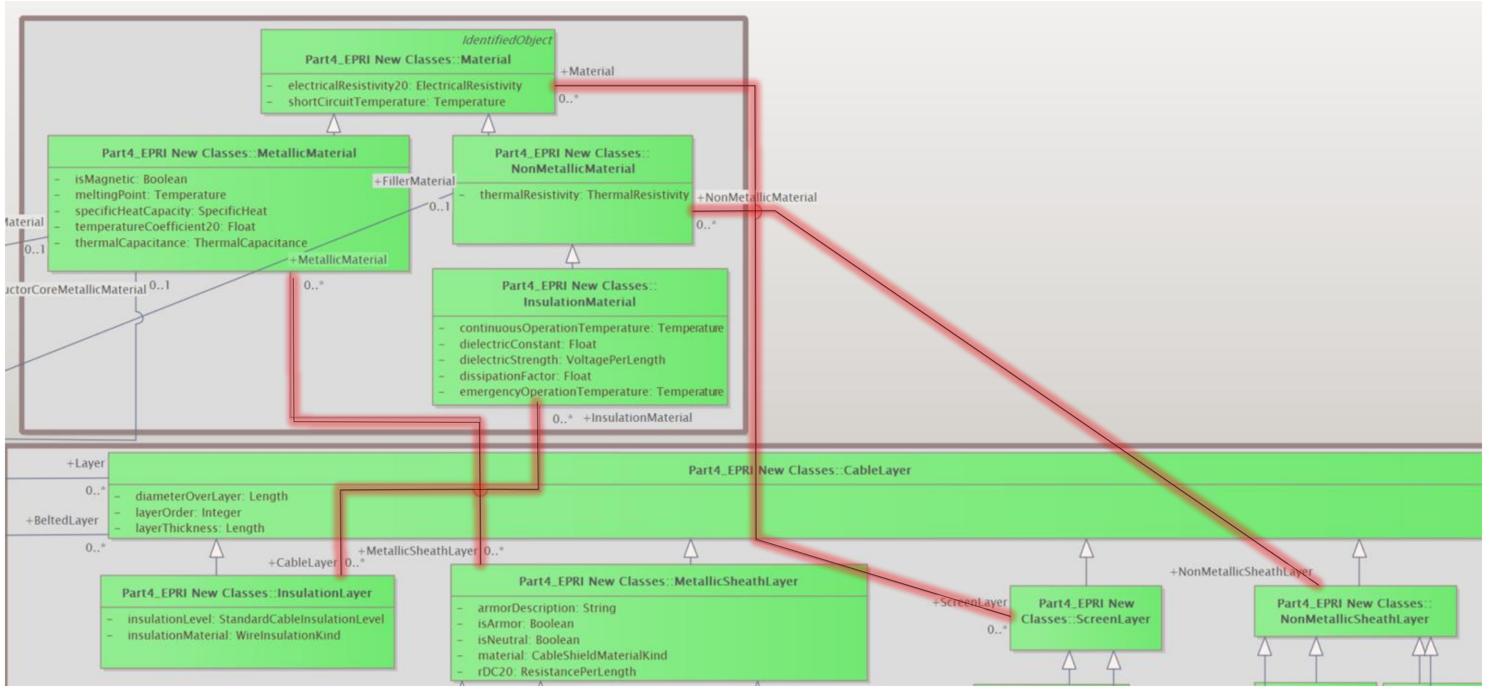


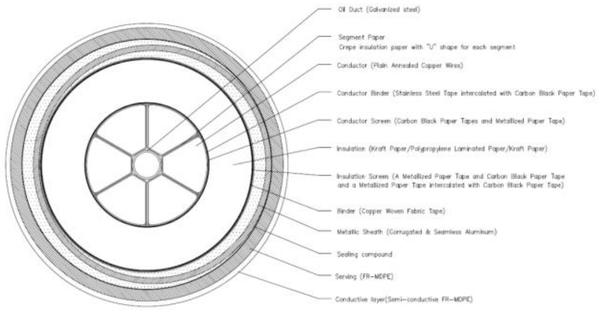
Overlaying Type Jacket in CNC

Source: [2]

Other Needs Associated with Layering

- 4: Flexibility in allowing layers to be defined with multiple materials
  - Layers may involve a combination of multiple materials/layers.
  - Proposed solution supports that by allowing multiple material to be associated with a single layer



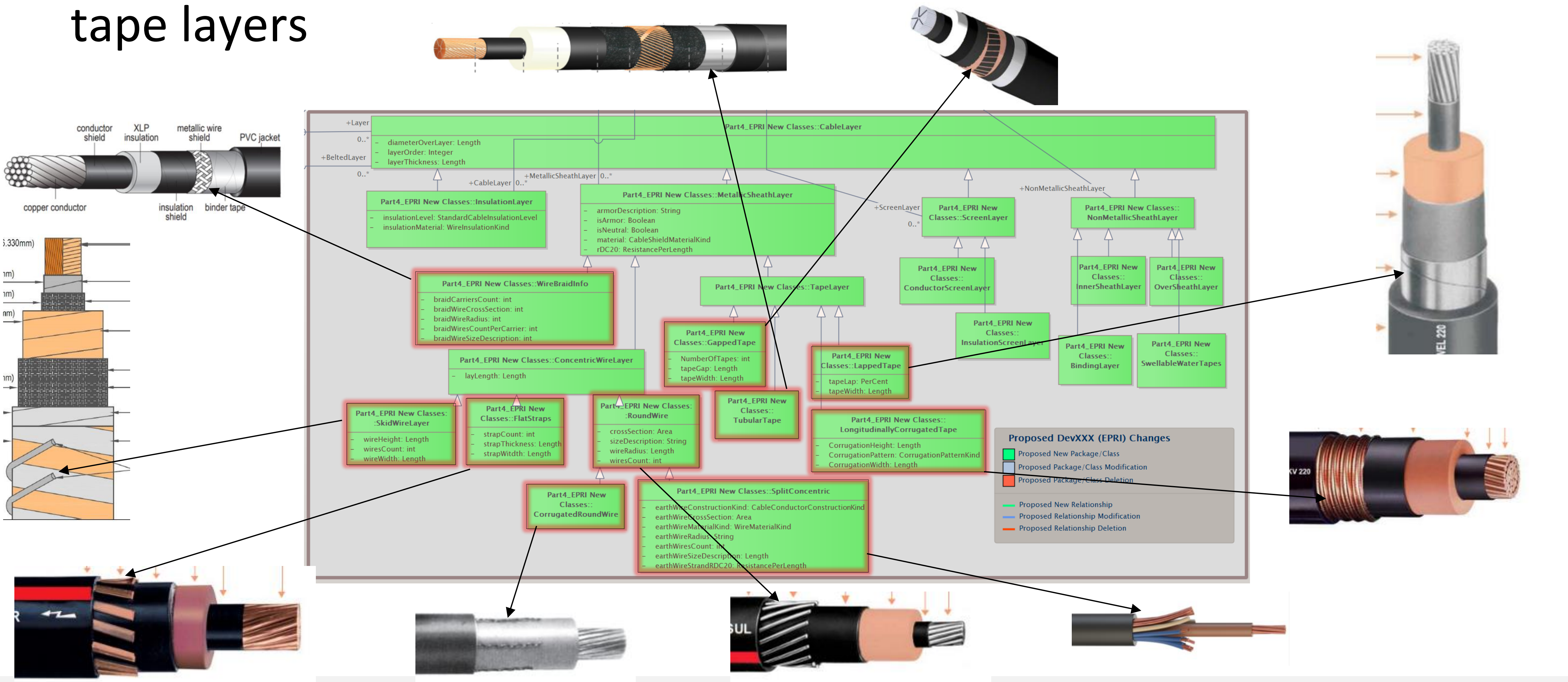


No	Description	Thickness (mm)	Details	Thermal Resistivity (K.m/W)	Nominal Diameter (mm)
1	Oil duct	Nom. 0.8	Galvanized steel	N/A	18,0
2	Conductor	-	Plain annealed copper wires	N/A	58,8
3	Conductor Binder	Nom. 0.25	Stainless Steel tape intercalated with carbon black paper tape	6,0	59,3
4	Conductor screen	Nom. 0.3	Carbon black paper tapes and metallized paper tape	5,0	60,2
5	Insulation	Nom. 0.5/20.0/4.5	Kraft paper/Polypropylene laminated paper/Kraft paper	5,0 (Kraft) 5,5 (PPLP) 5,0 (Kraft)	111,2
6	Insulation screen	Nom.0.4	A metallized paper tape and carbon black paper tape	5,0	112,4
7	Binder	Nom.0.4	Copper woven fabric tape	6,0	113,3
8	Metallic sheath	Nom.2.9	Corrugated & seamless aluminium (Wave height : Approx. 5.9mm, Pitch : Approx. 28.0mm)	N/A	131,4
9	Sealing compound	Nom. 0.2	Bitumen compound	6,0	131,8
10	Serving	Min. 5.0	FR-MDPE compound	3,5	142,8
11	Conductive layer	Min, 2.0	Semi-conductive FR-MDPE	2,5	148

Source: [4]

Other Needs Associated with Layering

- 5: Modeling of different types of metallic sheaths, concentric and tape layers



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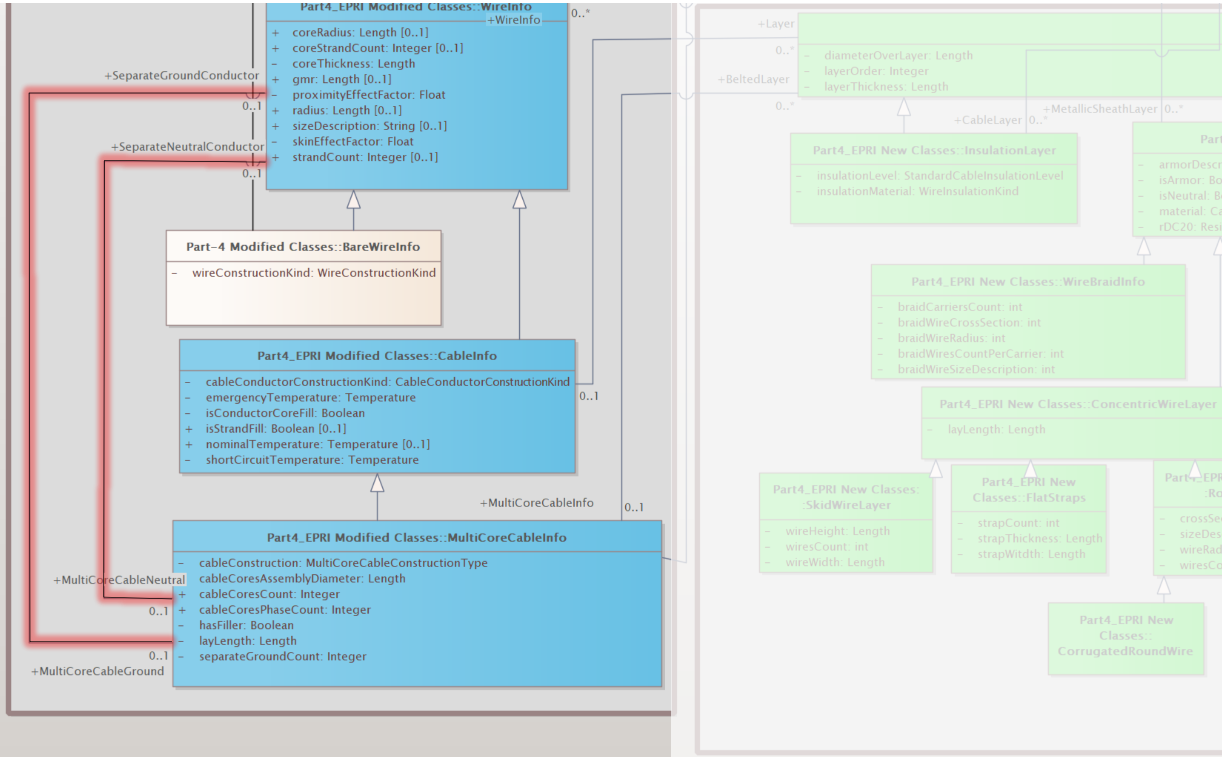
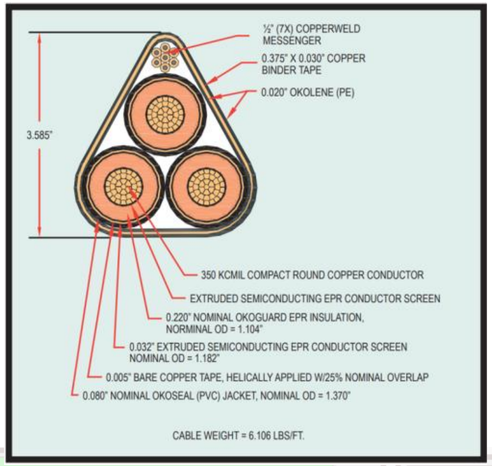
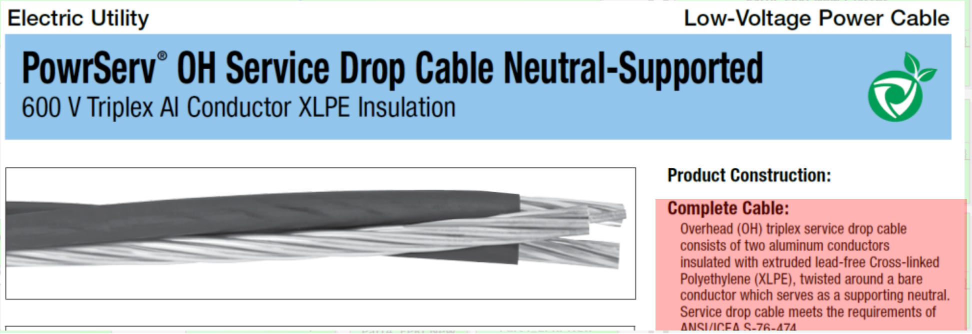
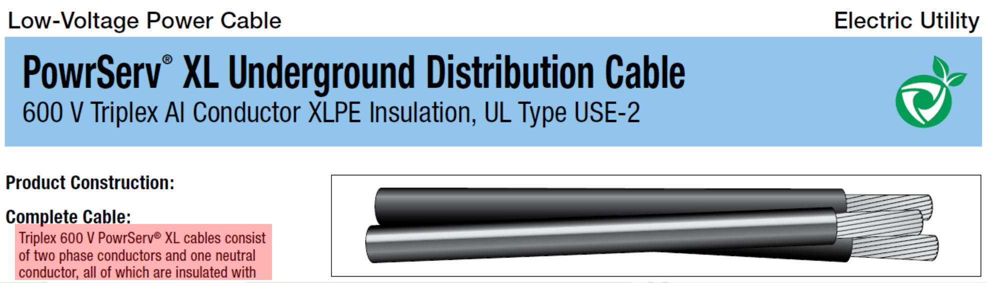
Other Needs Associated with Layering

- 6: Ability to model separate ground conductors or neutral conductors to cables with multiple cores
  - Characteristics of these additional conductors are typically different from the core conductors
  - This applies to ABC/Bundled conductors









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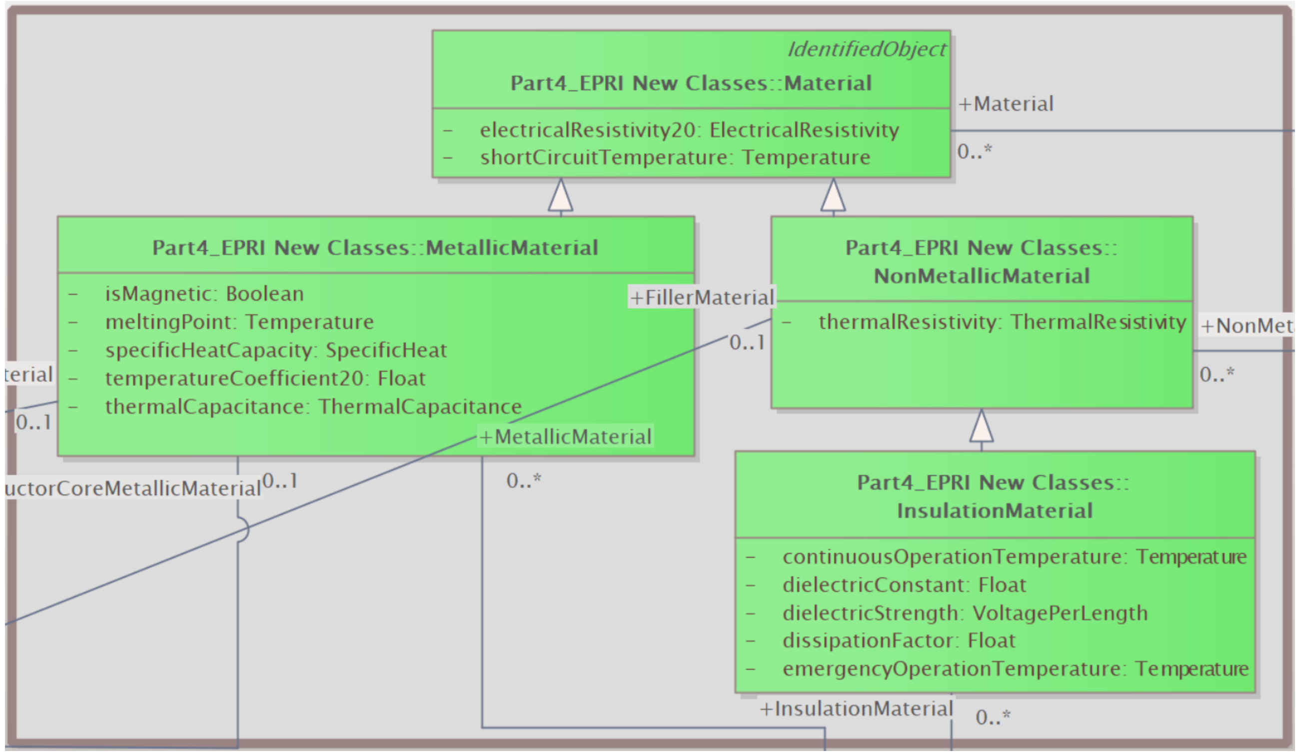
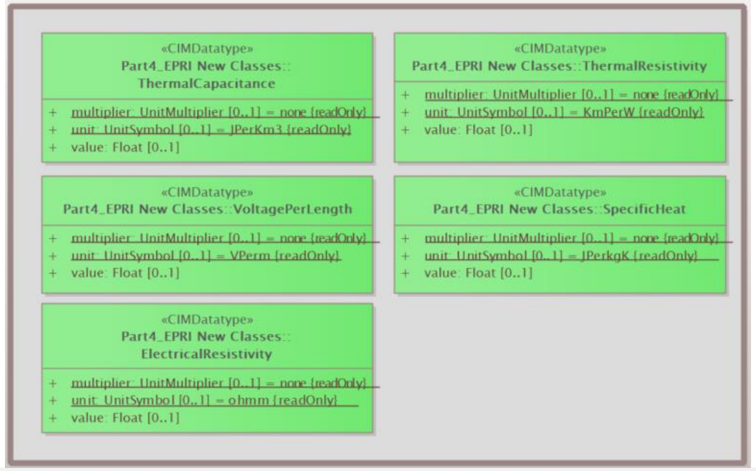
Gap 2 – Lack of ability to model materials properties and custom materials

- Thermal and electrical characteristics of materials are important for ampacity and impedances calculation. Many of those properties can be taken from standards.
- Proposed approach is to include Material classes to be associated with:
  - Conductor Material
  - Conductor Core Material
  - Insulation Layer
  - Metallic Sheath Layer
  - Non-Metallic Sheath Layer
  - Screen Layer
  - Multi Core cable Filler
  - Perhaps other uses outside the scope of CableInfo classes
- Separation between Metallic and non-metallic materials
- Further specialization of non-metallic materials for insulation materials

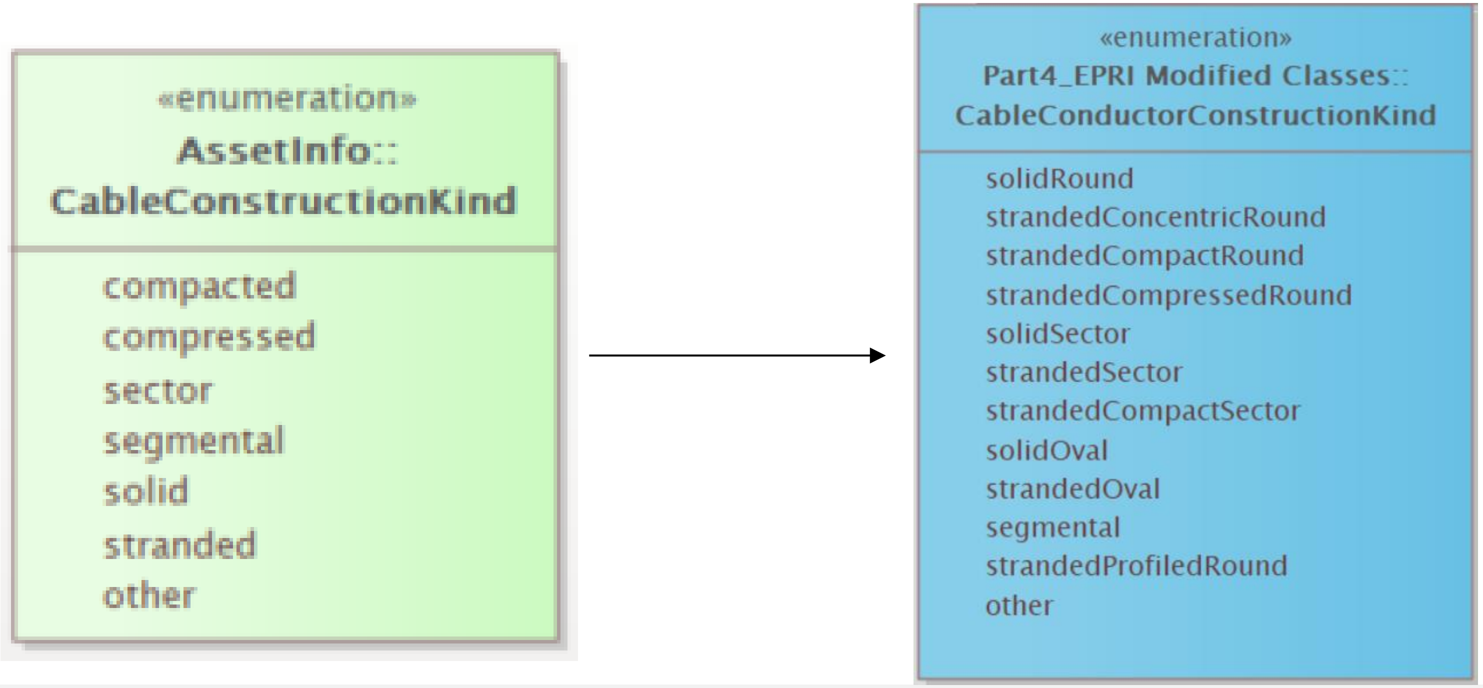


Required Datatypes (new)



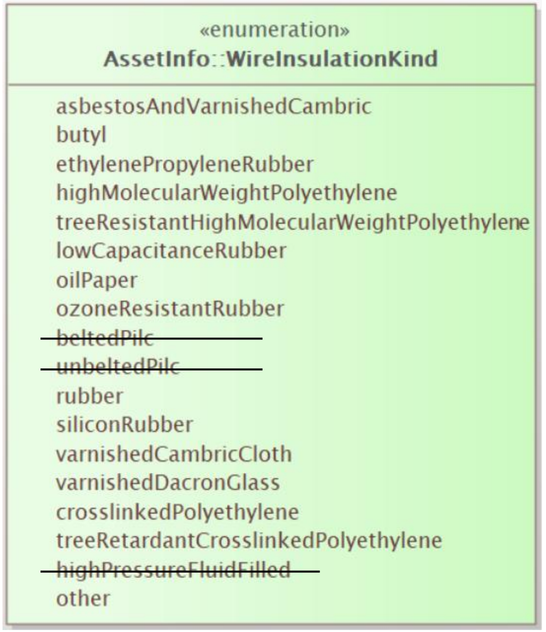
Gap 3 – Lack of clarity on CableConstructionKind

- CableConstructionKind enumerations mix conductor stranding with shape
  - Proposed approach:
    - Clearly differentiate conductor shape from stranding;
    - Also, rename CableConstructionKind to CableConductorConstructionKind so that construction kind is self-explanatory (applies to cable conductor, not the cable itself – in which case MultiCoreCableInfo.cableConstruction must be used)



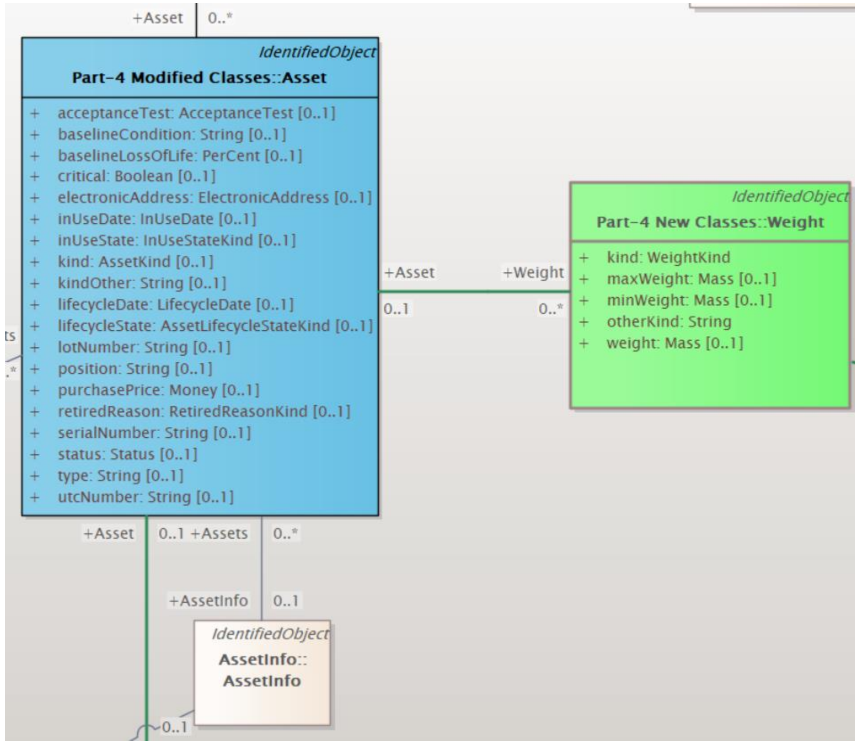
Gap 4 – WireInsulationKind mixes insulation materials with cable installation/construction

- Proposed: Remove *beltedPilc*, *unbeltedPilc* and *highPressureFluidFilled*



Gap 4 – Use of ConductorInfo.massPerLength

- Proposed: consider removing *ConductorInfo.massPerLength* and use Weight class.
  - A per-length weight attribute in the Weight Class might be needed.



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References

- [1] EPRI Underground Transmission Systems Reference Book: 2023 Edition. EPRI, Palo Alto, CA: 2023. 3002027228.
- [2] EPRI Underground Distribution Systems Reference Book: 2023 Updated (Bronze Book). EPRI, Palo Alto, CA: 2023. 3002026871.
- [3] CIGRE "TB 640, A Guide for Rating Calculations of Insulated Cables", CIGRE, 2015-12.
- [4] CIGRE "TB 880, Power Cable Rating Examples for Calculation Tool Verification", CIGRE, 2022-09.
- [5] "IEC 60287-1-1, Electric Cables - Calculation of the Current Rating - Part 1-1: Current Rating Equations (100 % load factor) and Calculation of Losses – General", IEC, 2014-11.
- [6] "IEC 60287-2-1, Electric Cables – Calculation of the Current Rating – Part 2-1: Thermal Resistance – Calculation of Thermal Resistance, Edition 2.0", IEC, 2015-2.
- [7] "IEC 60050-461, International Electrotechnical Vocabulary (IEV) - Part 461: Electric cables, Edition 3.0 - CDV", IEC, 2024.

Sample Cases

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