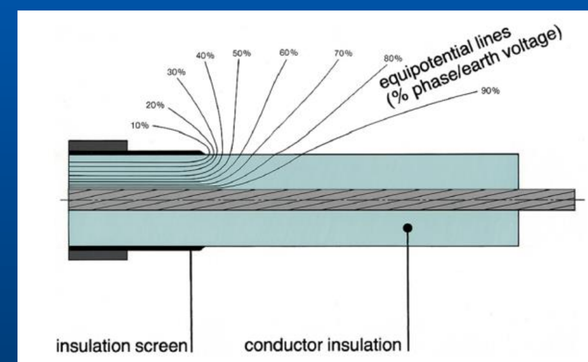
Modeling of Cable Terminations with FEA - QuickField



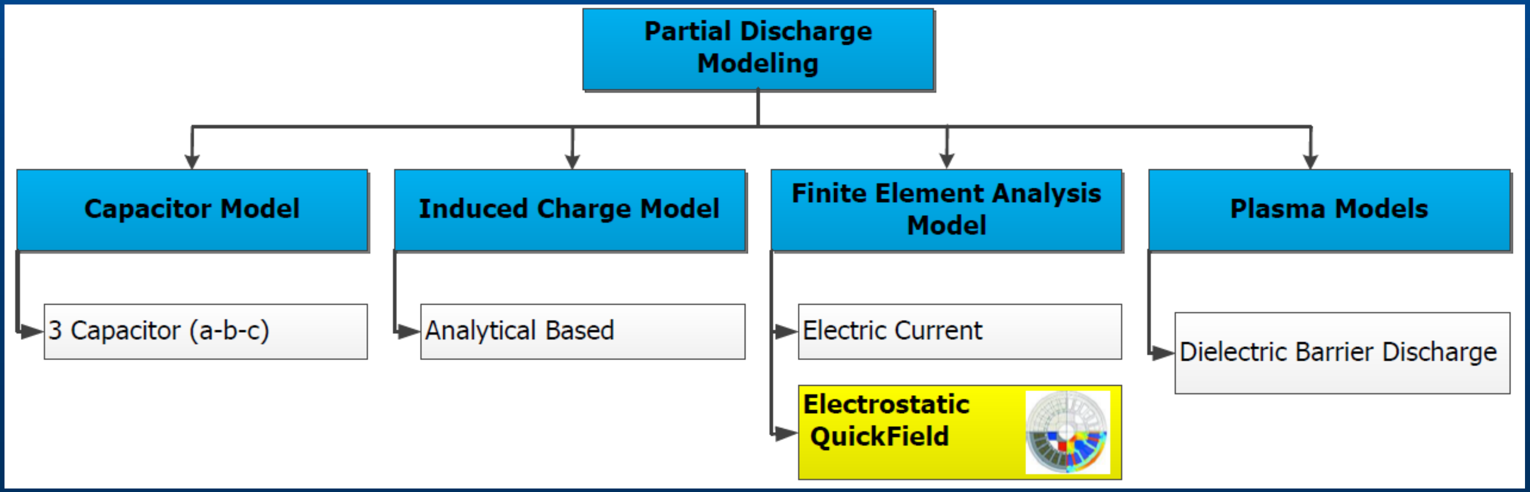
Vermaas Bissett

Importance and Reason for termination modeling

1. Critical component of power system
2. Evidence of high failure rates: MV terminations
3. Specialised and complicated domain
4. Many defects due to poor workmanship
5. Understand the behaviour and root cause failure
6. Support factory and on-site commissioning tests
7. Improve Quality Assurance
8. Integrate: Theory, Practice and Modeling

Modeling: Why Finite Element Analysis (FEA)?

1. Traditionally, Partial Discharge modeling
   - 3 Capacitor model to simulate PD is most common
2. Electrostatic with FEA is "attractive" alternative
   - Increase engineering understanding
   - Visual presentation
   - Electric Field strength that relates to PD

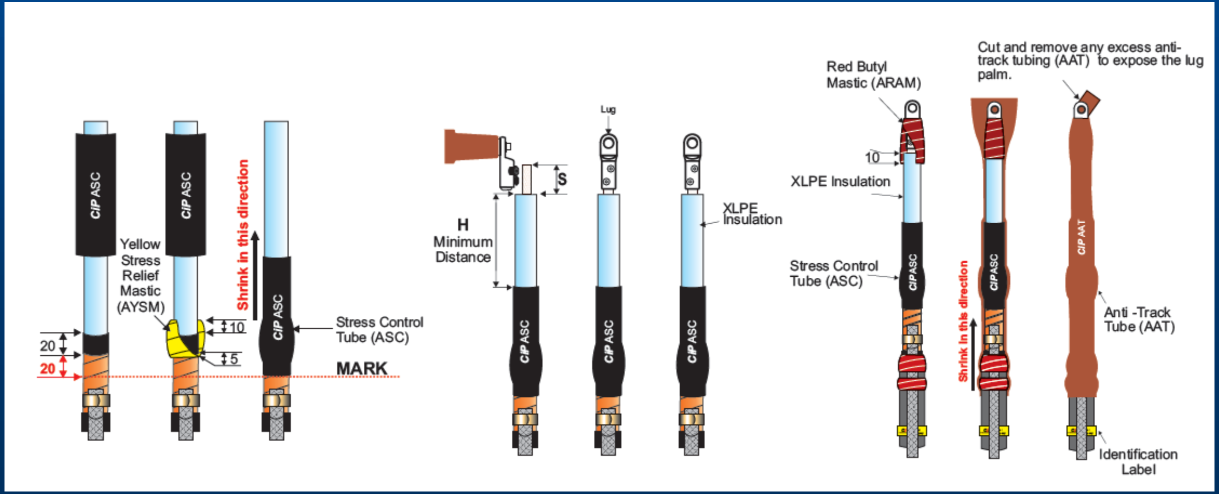


Overview of presentation and demonstration

1. Explain and demonstrate with QF the critical stress area at the "triple point"
2. 3 x QF models to be presented
   – Termination defect (ring-cut) at triple point [Axisymmetric]
   – Defect-free termination with all sub-components [Axisymmetric]
   – Cable preparation for termination [3D Extrusion]
3. Calculate mathematically the Electric Field strength at "triple point"

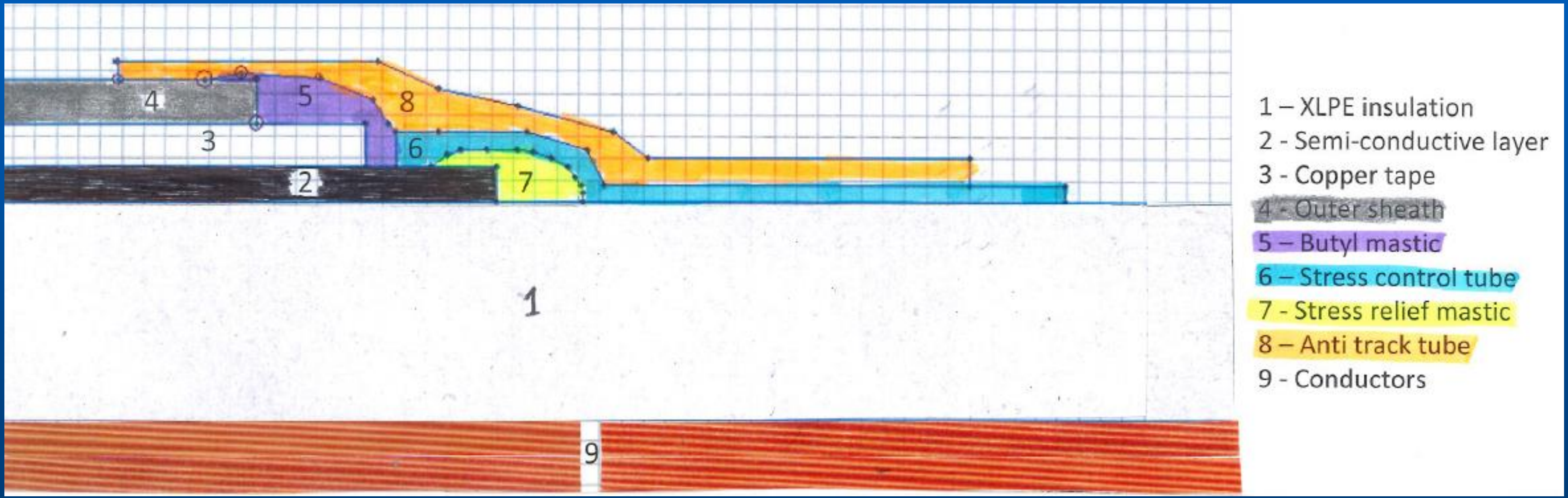
Create accurate model for Defect-Free termination

1. The following aspects are important
   - Precise dimensions by following instructions
   - Material detail for all sub-components
2. Important sub-components include
   - Stress relieve mastic
   - Stress control tube
   - Anti track tube

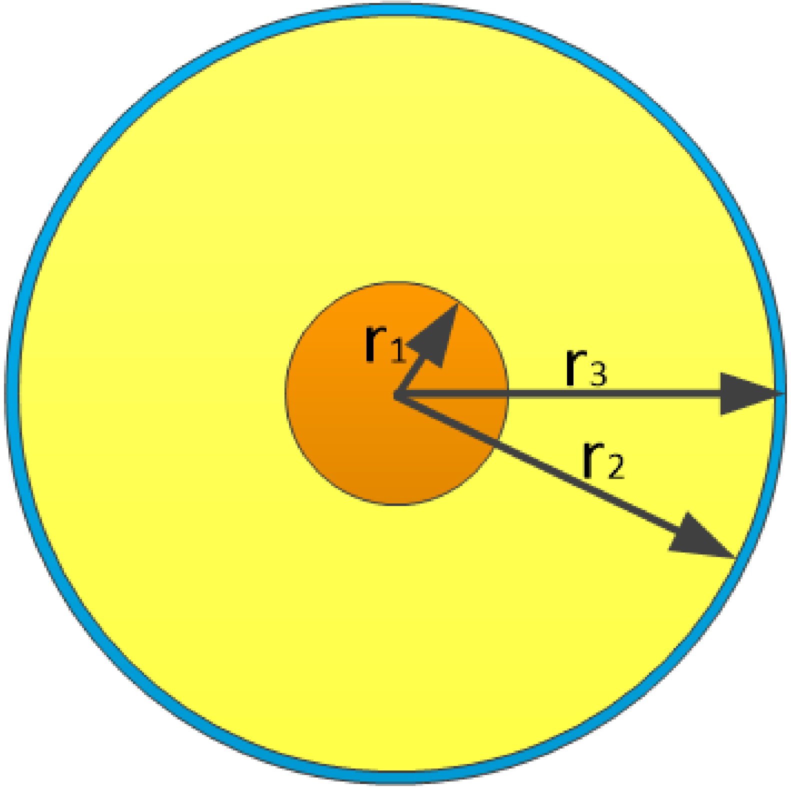


Block	Levels		
Conductor	0	80	
Insulation	0	60	80
SemiConductive layer	0	50	80
Copper tape	0	40	80
Inner bedding	0	20	80
Sheath	0	10	80
Air	0	80	

Building the accurate QF termination model



Cable dimensions for calculations & modeling



r_1 = radius of conductor = 4.9mm

r_2 = inner radius of air = 11.2mm

r_3 = outer radius of air = 12.2mm

Formula for Electric Field Strength

$$V_{surface} = \frac{V \epsilon_1 \ln \frac{r_3}{r_2}}{\epsilon_2 \ln \frac{r_2}{r_1} + \epsilon_1 \ln \frac{r_3}{r_2}}$$

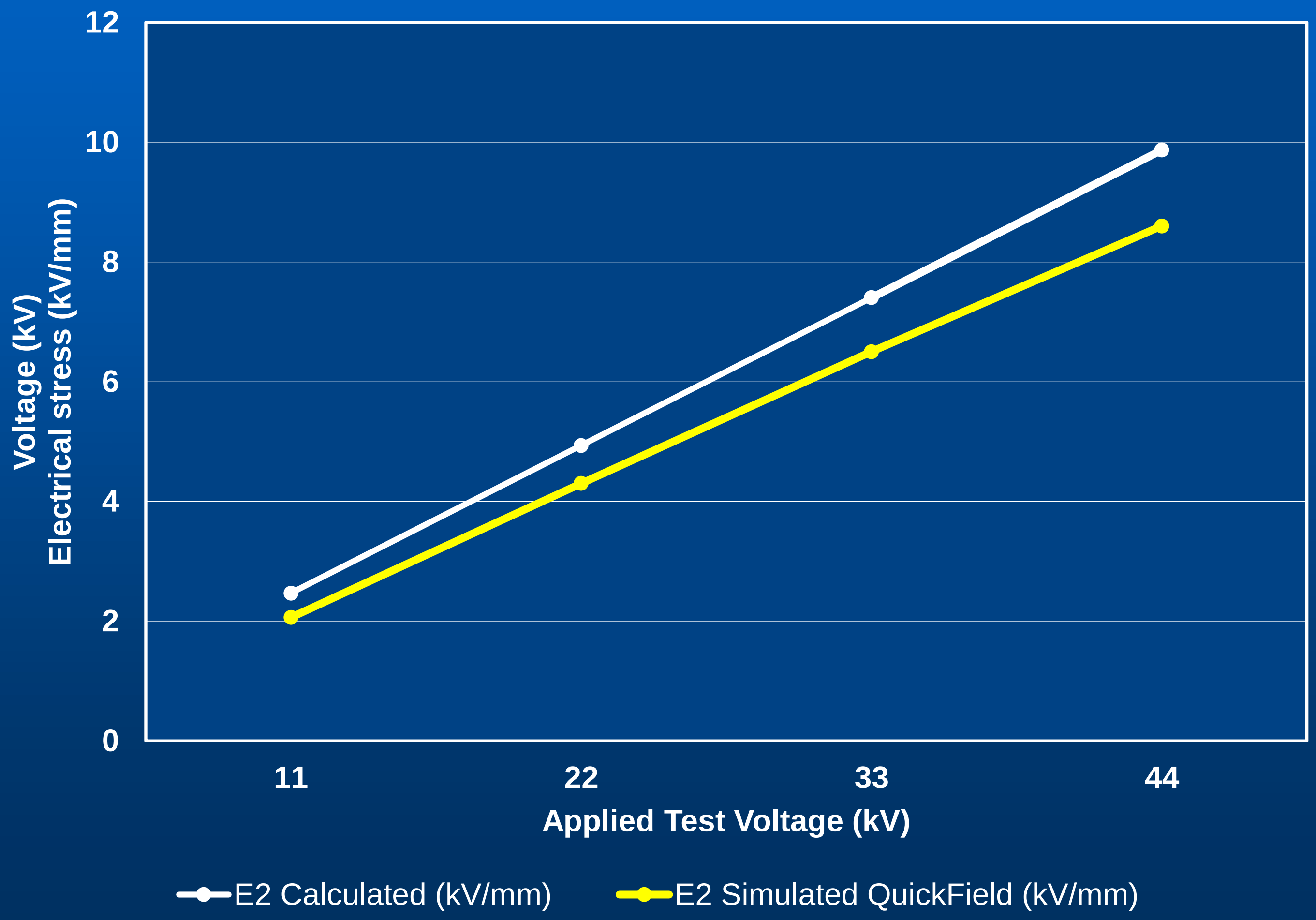
$$E_{insulation} = \frac{V_{insulation}}{r_1 \ln \frac{r_2}{r_1}}$$

$$E_{surface} = \frac{V_{surface}}{r_2 \ln \frac{r_3}{r_2}}$$

Electric Field Strength "E" Comparison Calculated versus Modelled values

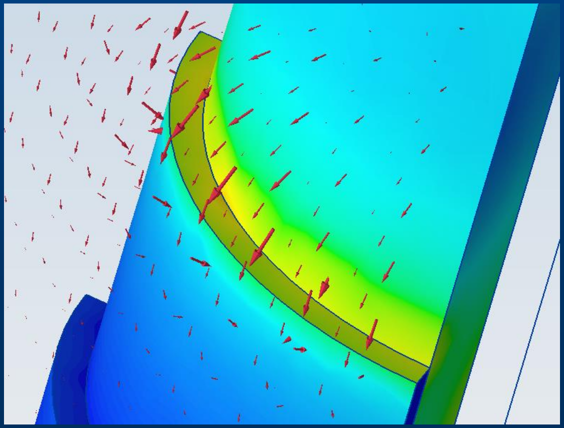
Voltage (kV)	11	22	33	44
Ɛ1	2.645	2.645	2.645	2.645
Ɛ2	1	1	1	1
r1	4.9	4.9	4.9	4.9
r2	11.2	11.2	11.2	11.2
r3	12.2	12.2	12.2	12.2
a	2.49	4.98	7.46	9.95
b	1.05	1.05	1.05	1.05
V_2 Voltage on surface of insulation (kV) [1mm air gap]	2.36	4.73	7.09	9.45
V_2 Voltage on surface of insulation (kV) peak [1mm air gap]	3.34	6.68	10.03	13.37
V1 (kV)	8.64	17.27	25.91	34.55
E_1 stress at conductor	2.13	4.26	6.40	8.53
E_2 Calculated (kV/mm)	2.47	4.93	7.40	9.87
E_2 peak stress at insulation/air interface (kV/mm)	3.49	6.98	10.47	13.96
E_2 Simulated QuickField (kV/mm)	2.06	4.3	6.5	8.6

Electric Field Strength "E"Comparison Calculated versus Modelled values

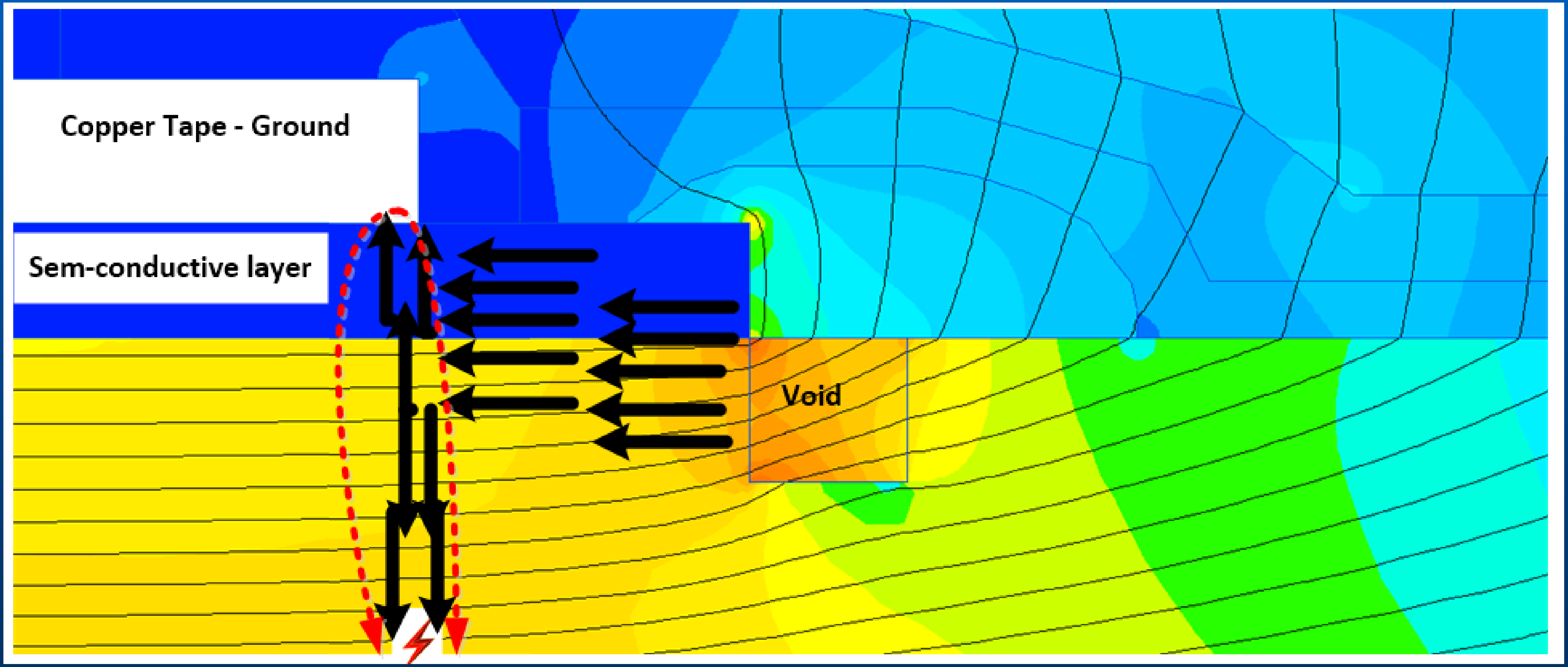


Observations

1. Model and build cable terminations successfully
2. Evaluate electric field strength in relation to variations and applied voltage.
3. Modeling defects and prepared cable ends
4. Confirm high stress area in termination – “triple point”
5. Importance of dimensions and material details
6. Correlation between “Theory-Practice-Modeling”



Defect developing from void to high voltage & ground



Conclusions

1. Excellent correlation between calculated and simulated values for Eletric Field Intensity
2. Confirm “triple point” is most critical
3. FEA simulation with QF adds value:
   - Application of termination to end user
   - Engineer to understand and comprehend practice and theory
   - Designers of cable terminations

The End

Thank you!