Maximising HV Cable Asset Lifespan with Predictive Modelling

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- The challenge with HV Cables
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Worldwide

Innovating for power network operators for over 50 years

A leading turnkey Smart Grid solutions provider

Five key business units, each with distinct offerings

Headquarters in the UK with 4 global offices (USA, Australia, Singapore, China)

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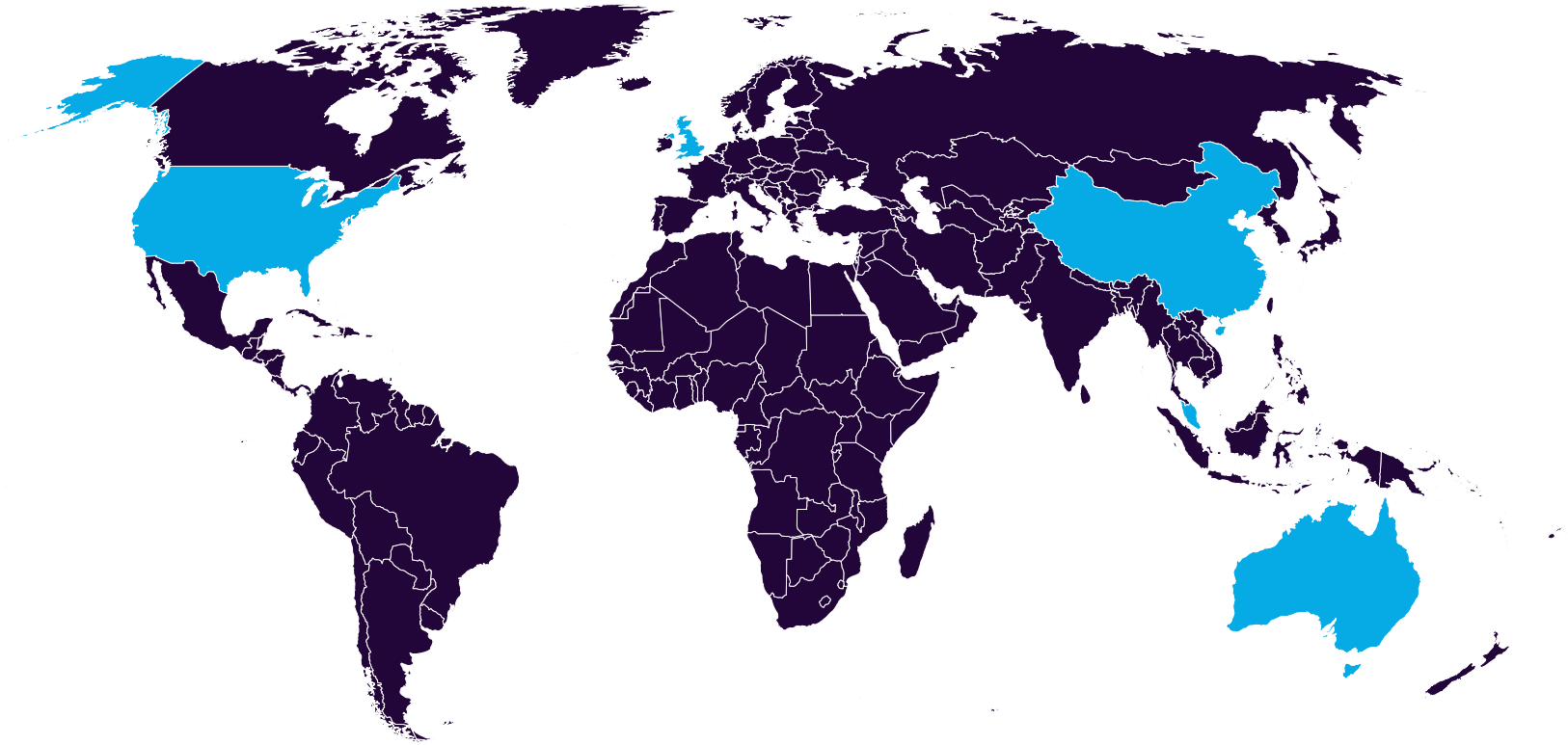


HV Underground Cables

The challenge of information

- Failures cause significant negative impact on network performance
- Ageing assets of different types and quality
- Difficult to manage an asset without any data, make best use of data that we do have
- Typically limited condition data is available for cables

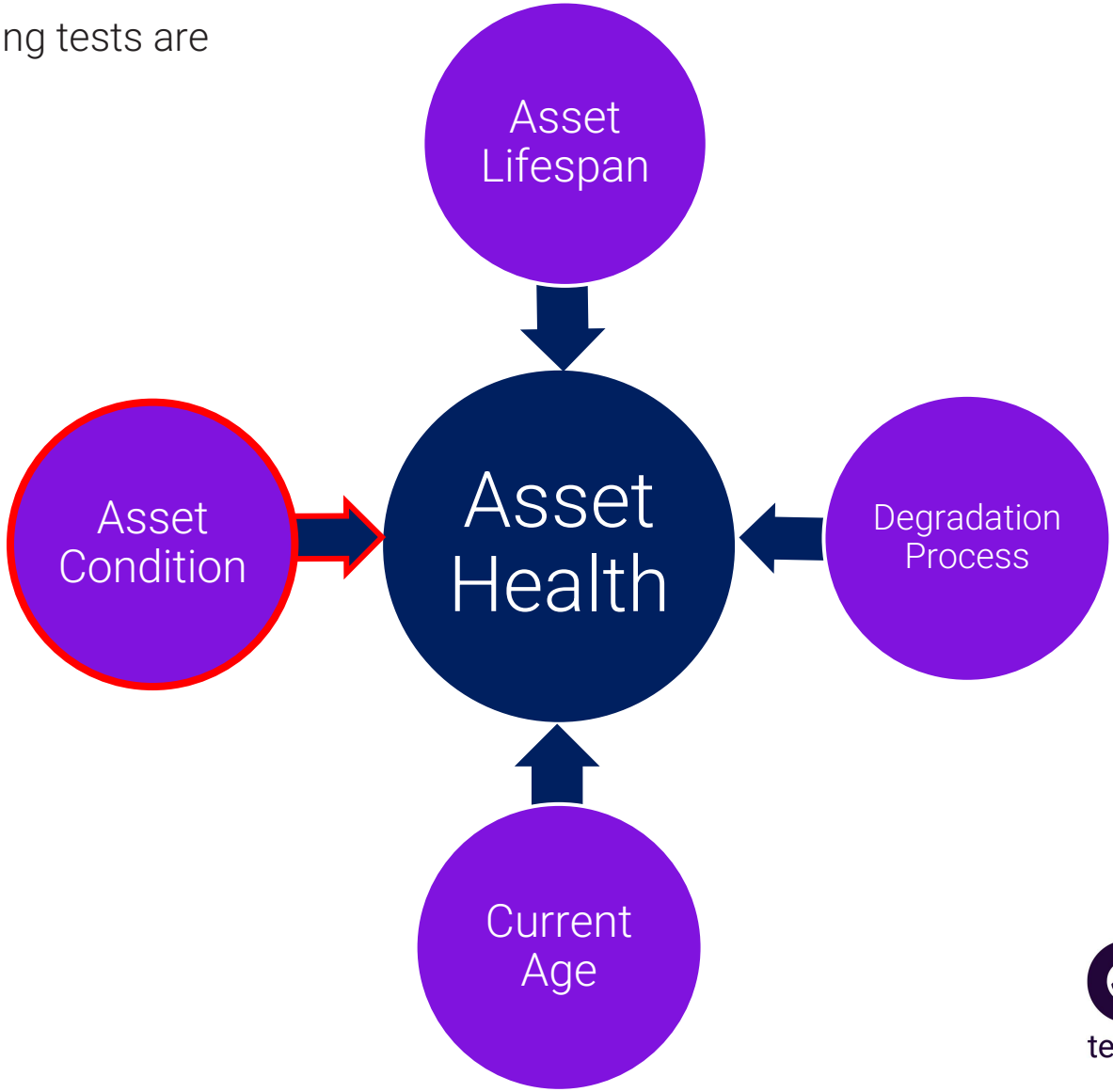
Condition Assessment

Evaluating cable health through advanced condition assessment techniques

Condition Assessing

For many projects, the following condition monitoring tests are conducted;

1. Offline Partial Discharge testing
2. Offline Tan Delta Testing
3. Offline LIRA Testing
4. IR and Sheath Testing
5. Online Partial Discharge testing
    a. TEV Testing
    b. Ultrasonic Testing
    c. UHF Testing
    d. VPIS Testing
6. Visual inspection
    a. Installation Condition
    b. Visual Condition
    c. Joint Condition



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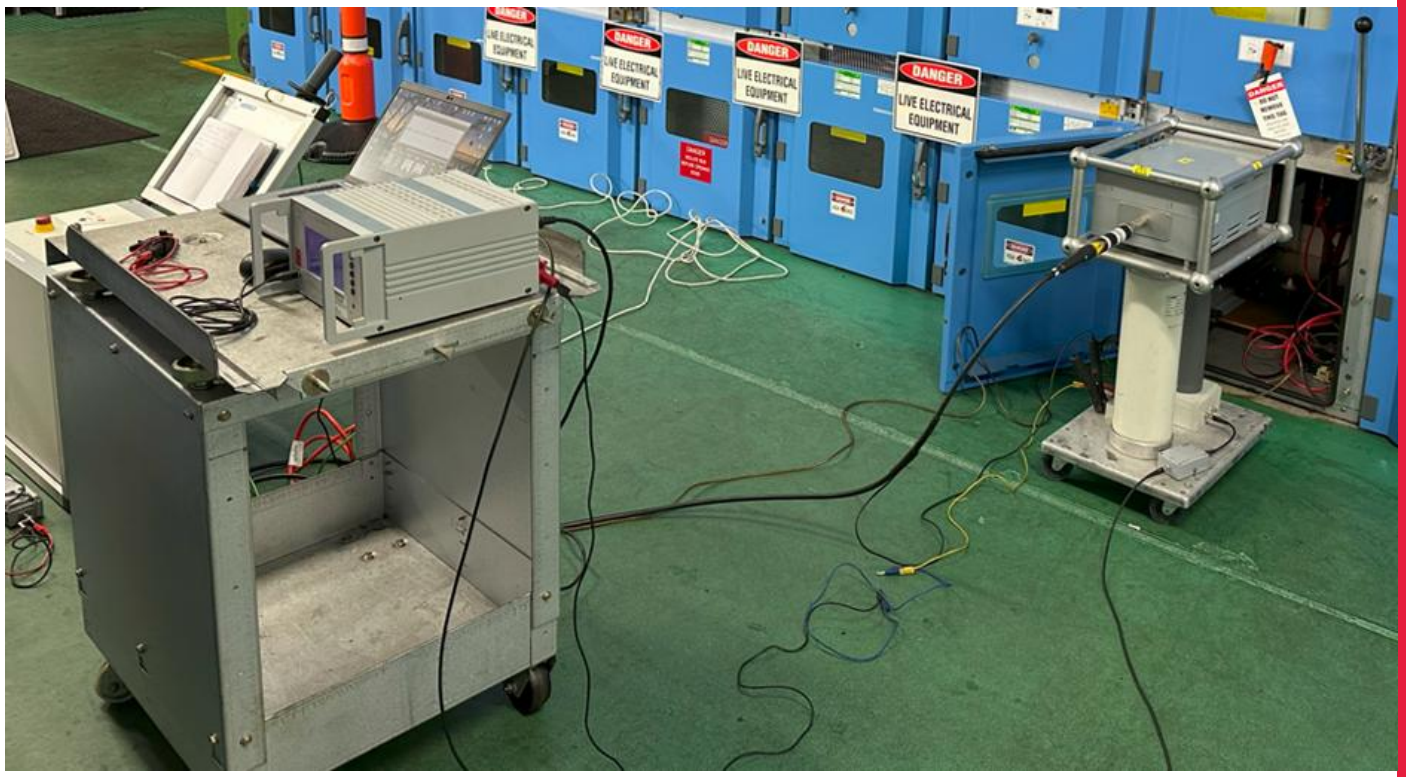
Offline PD Testing

The Offline Partial Discharge test results are broken into the following condition brackets;

- No PD (confirmed)
- Low
- Medium
- High (Not Confirmed)
- High (Confirmed)

PD Level	XLPE		PILC	
	Cable	Accessories	Cable	Accessories
Acceptable - no action required	PD Free	0-500pC	0-2,500pC	0-4000pC
Some concern - monitor	<500pC Ideally PD free	500-2,500pC	2,500-7,000pC	4,000-10,000pC
Major concern - investigate	>500pC	>2,500pC	>7,000pC	>10,000pC



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Offline Tan Delta Testing

The Tan Delta test results are broken into the following condition brackets;

- No Action Required
- Further Study Advised
- Action Required
- Repair before Reinstatement

Condition assessment	TD Temporal stability (measured by standard deviation) at U_0 $[10^{-3}]$		Differential TD (difference in mean TD) between $2U_0$ and U_0 $[10^{-3}]$		Mean TD at $2U_0$ $[10^{-3}]$
No Action Required	< –0.5	and	–20 to 20	and	< 50
Further Study Advised	0.5 to 1	or	–20 to –50 or 20 to 50	or	50 to 100
Action Required	> 1	or	< –50 or > 50	or	> 100

Condition assessment	TD stability (measured by standard deviation) at U_0 $[10^{-3}]$		Differential TD (difference in mean TD) between $2U_0$ and U_0 $[10^{-3}]$		Mean TD at $2U_0$ $[10^{-3}]$
No Action Required	< 0.1	and	< 0.6	and	< 1.2
Further Study Advised	0.1 to 0.5	or	0.6 to 1	or	1.2 to 2
Action Required	> 0.5	or	> 1	or	> 2

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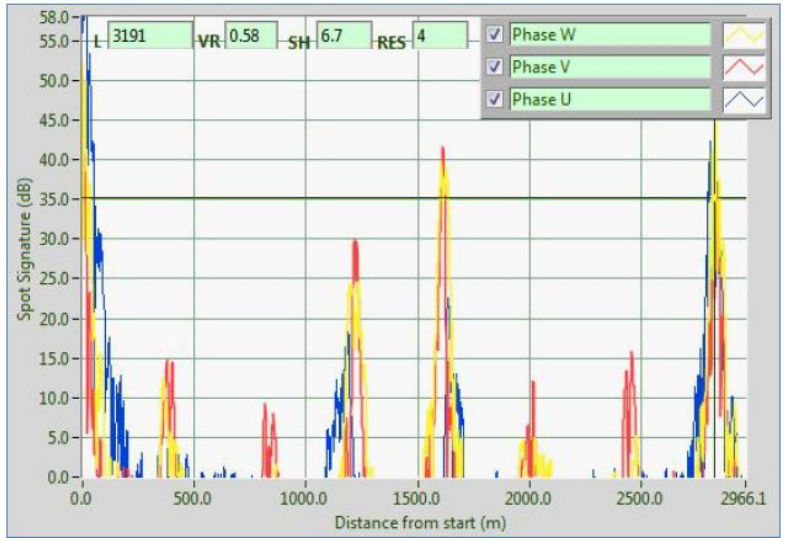
Offline LIRA Testing

What can it find?

- Global insulation degradation
- High temperature damage
- Moisture damage
- Radiation damage
- Mechanical effect/defects



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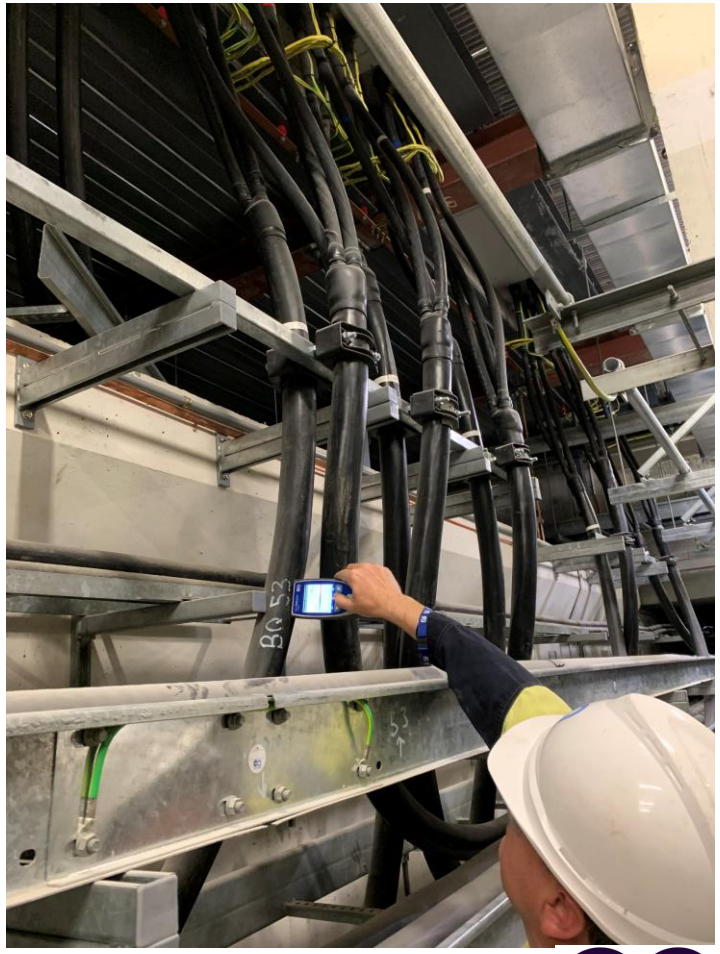
Online PD Testing

The online Partial Discharge test results are broken into the following condition brackets:

- Red
- Amber
- Green



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Visual Inspections of HV Cables

The visual inspection results are broken into the following condition brackets:

- No Deterioration
- Limited Deterioration
- Moderate Deterioration
- Substantial Deterioration

Visual Findings can include:

- Incorrect Terminations
- Failed Cable Clamps
- Damaged Cable Trays
- Cables fallen from Cable Trays
- Corroded Cable Screens/ Glands/ Lugs
- Punctured Outer Sheaths
- Oil/pitch leaks
- Bend radius issues

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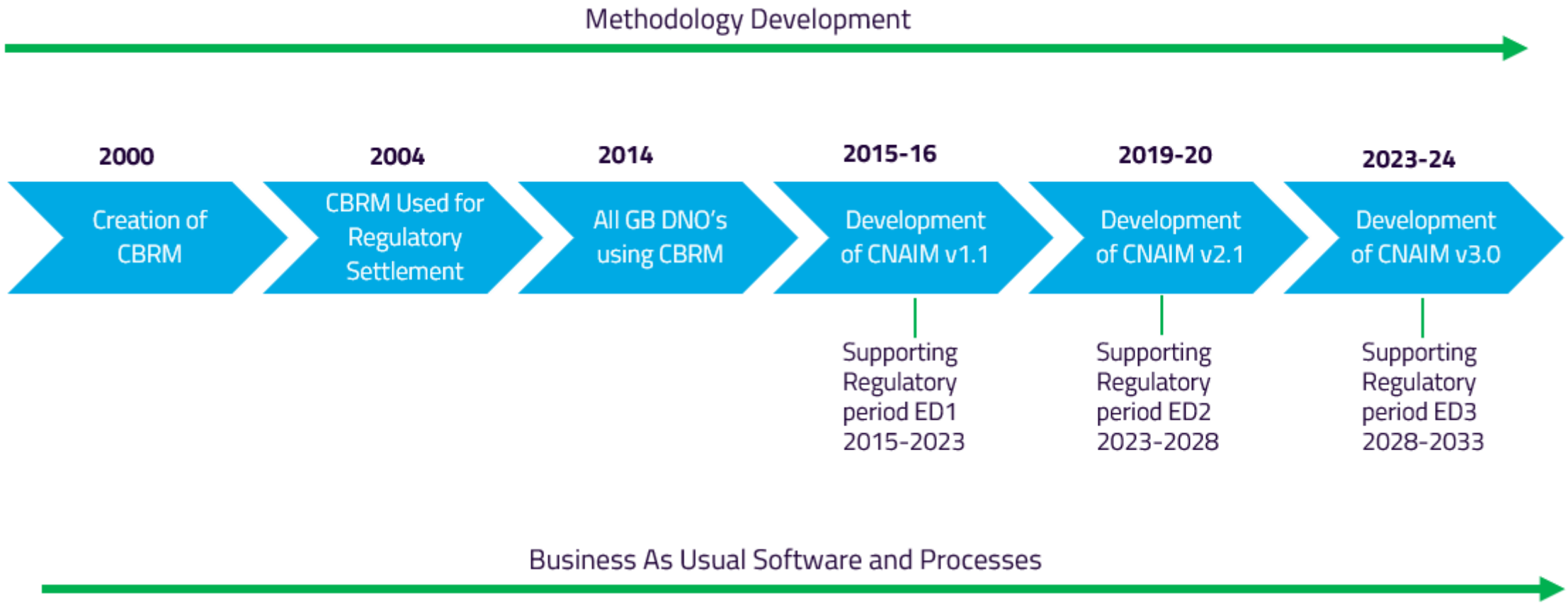
Estimate Remaining Life of HV Cables

Leveraging condition-based risk modelling and data analytics to estimate the remaining service life of HV cables

What is CBRM?



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Where is it used?

- Based on over 50 years of experience
- +20 years in development
- Refined though R&D and Failure investigation experience
- +70 global utility clients
  - UK (de facto standard)
  - Australia
  - Middle East
  - Far East
  - Canada
  - China

The CBRM Methodology has been used to model assets worldwide.

This includes:-

- +600,000 HV Switchgear
- +32,000 Km of Cable
- +150,000 Transformers
- +3,300 Km of Tower Lines
- +37,000 Km of Wooden Pole Lines

- Models developed for every asset type

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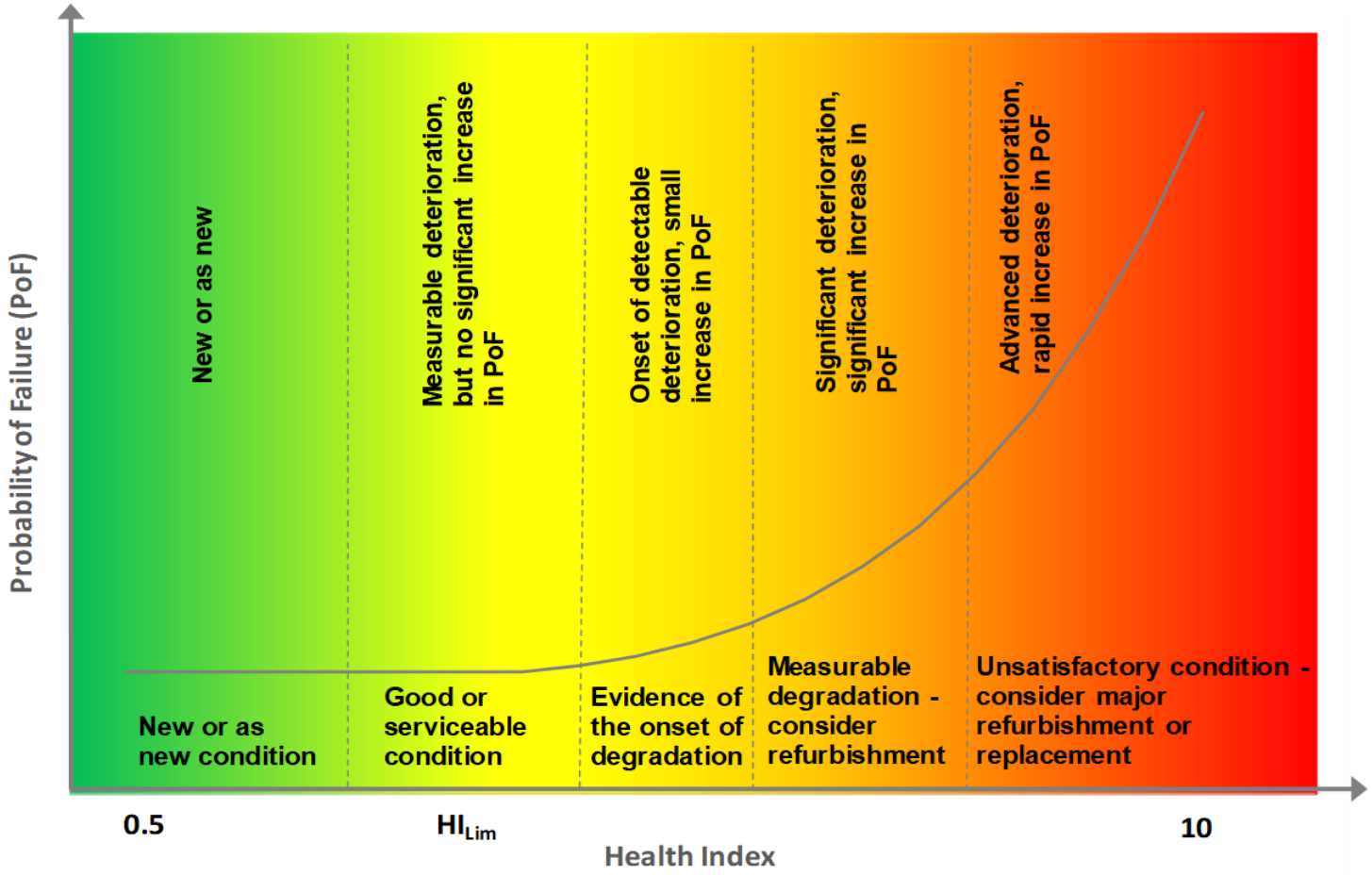
Health Analysis

- Using all available information to determine what stage of its lifespan each HV cable is at
- Primary factors;
    1. Age
    2. Condition Monitoring results
    3. Cable Loading
    4. Cable Voltage utilisation
    5. Cable Location
    6. Installation method
    7. Comparison to specs, ratings etc



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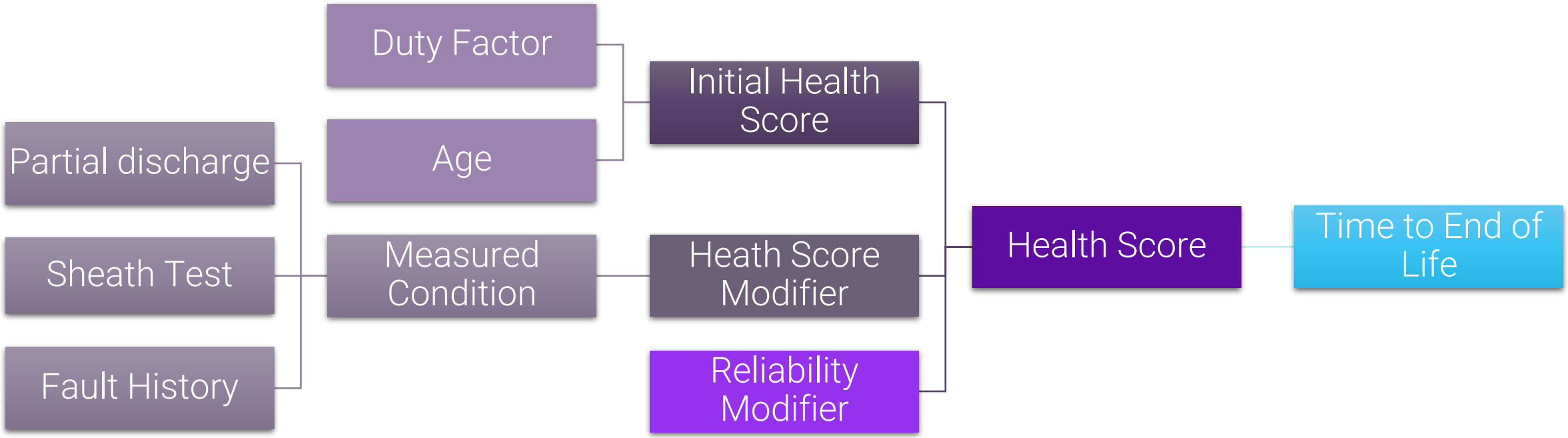
Health Score Methodology - Cables



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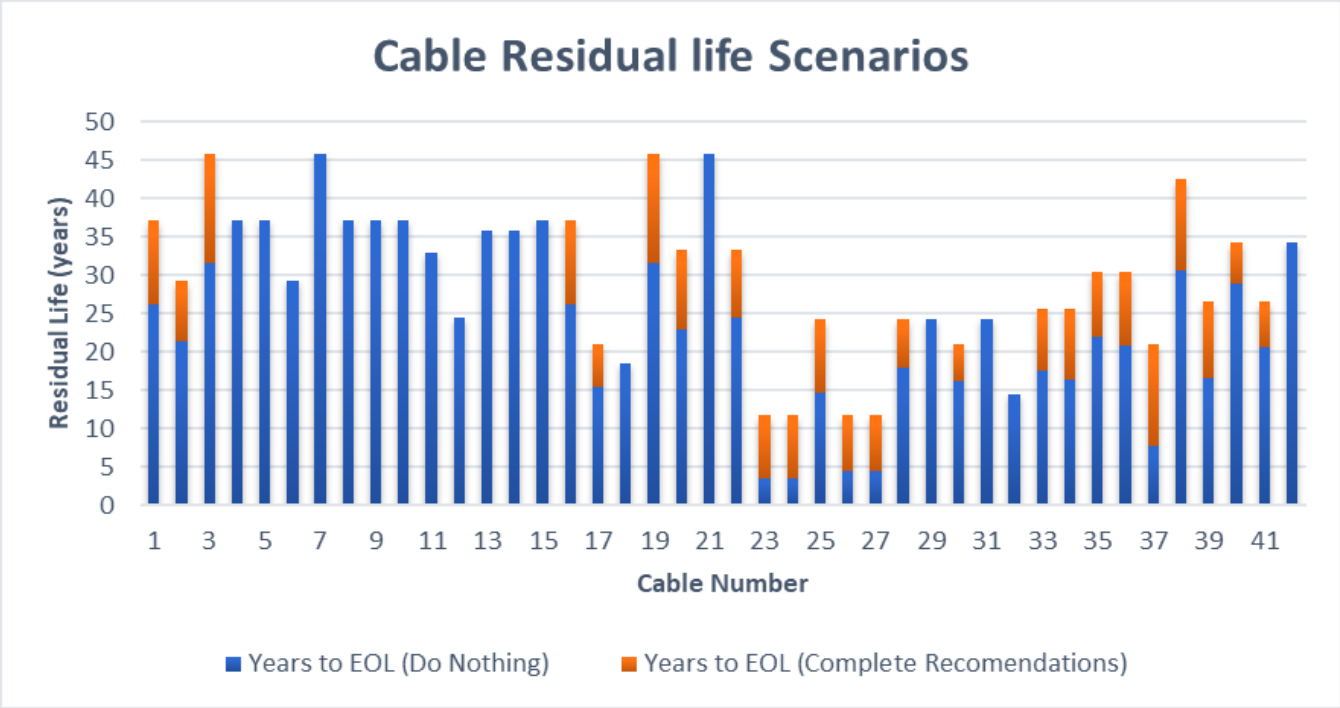
Cable Residual Life

- Once the health index of a cable is known the residual life can be estimated
- Residual life is based on assumed asset life
  - Traditionally based on manufacture recommendations
  - Can be altered based on previous experience



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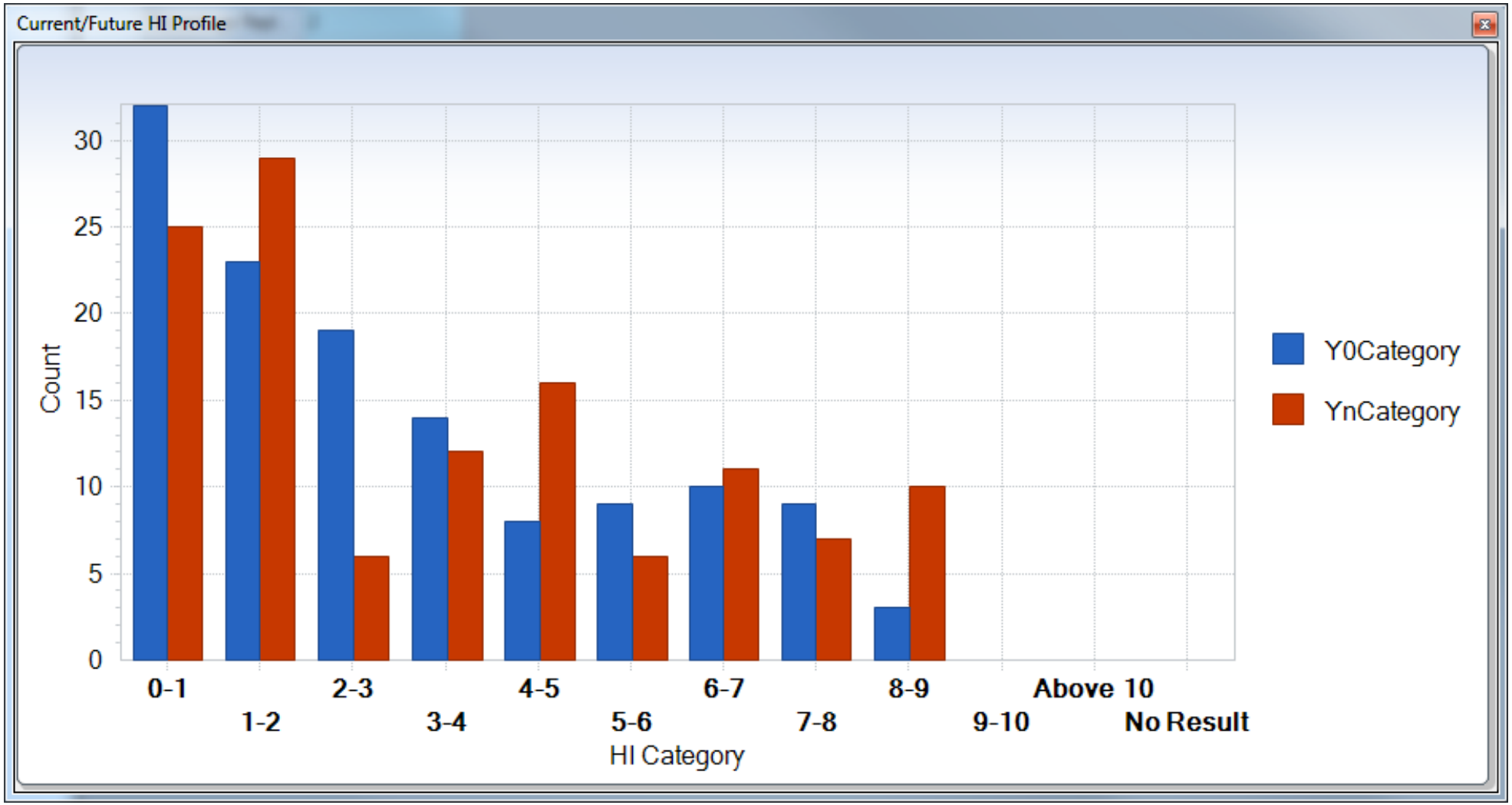
Modelling Proactive Maintenance

Modelling proactive maintenance frameworks that balance risk, cost, and operational efficiency

Current vs Future Health Index



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Introducing Risk

The network analytics followed the following process;

1. Determine the HV Cable Health
2. Find the Probability of the HV Cable Failing
3. Find the Consequences if the HV Cable does go to failure
4. Develop the Risk Model
5. Use the model to forecast potential scenarios

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Risk Analysis

- Network risk analysis combines asset health with network data
- The model identify and quantifies the costs associated with cable failures, including
  - Network performance
  - Direct financial costs
  - Safety implications
  - Environmental costs
- Risk can be modelled or forecast using the aging factors of the health index

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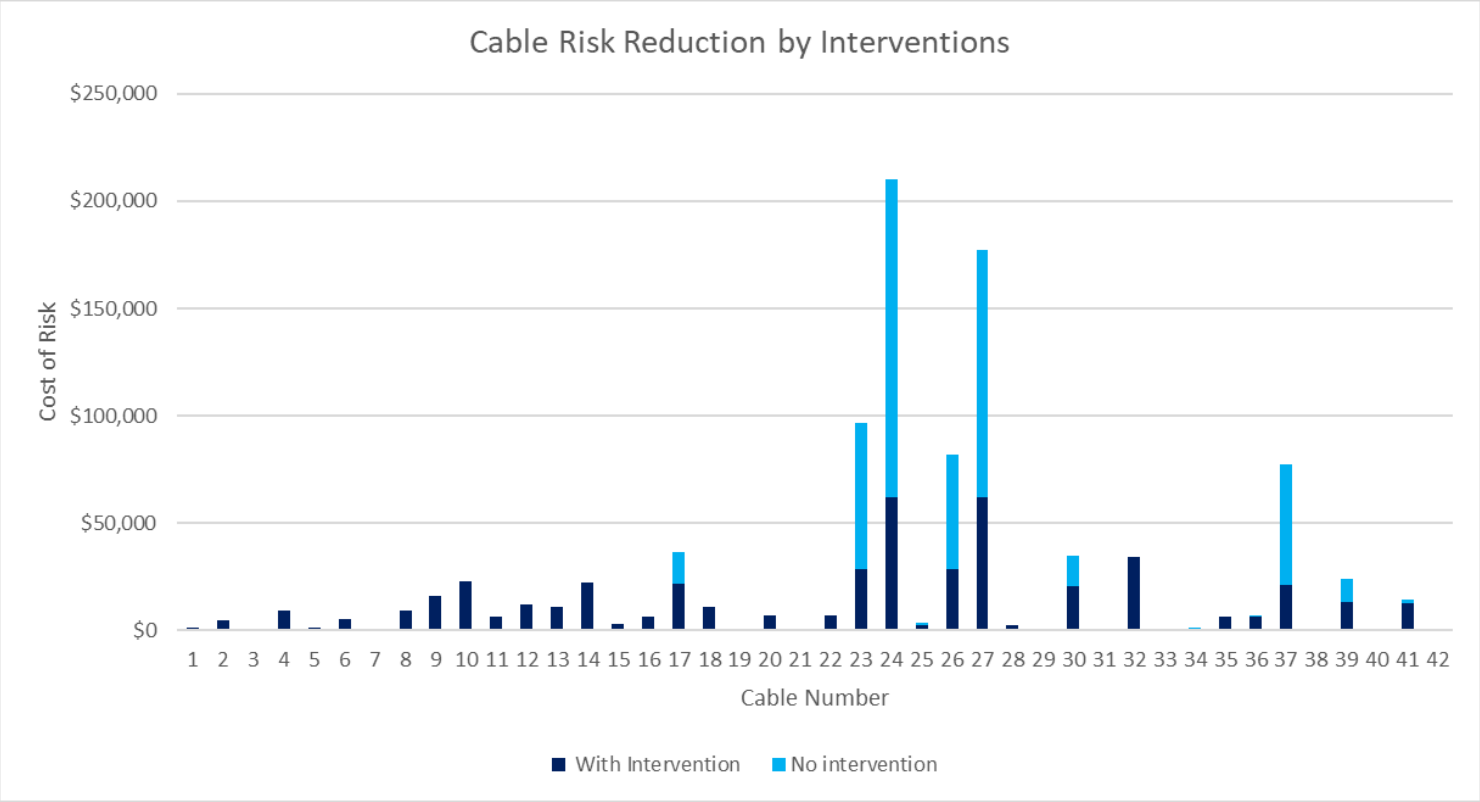
Risk Analysis - Interventions

- Risk can be calculated per HV cable
- Reduction of risk via interventions can be shown
- Used as justification in planned works



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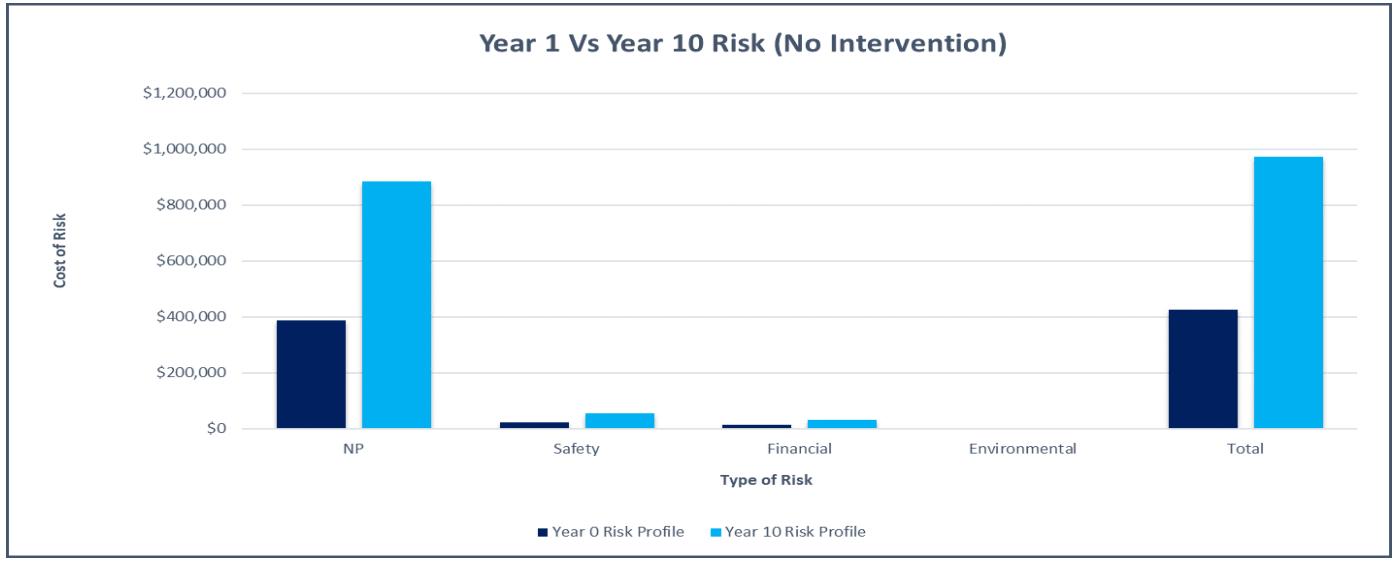
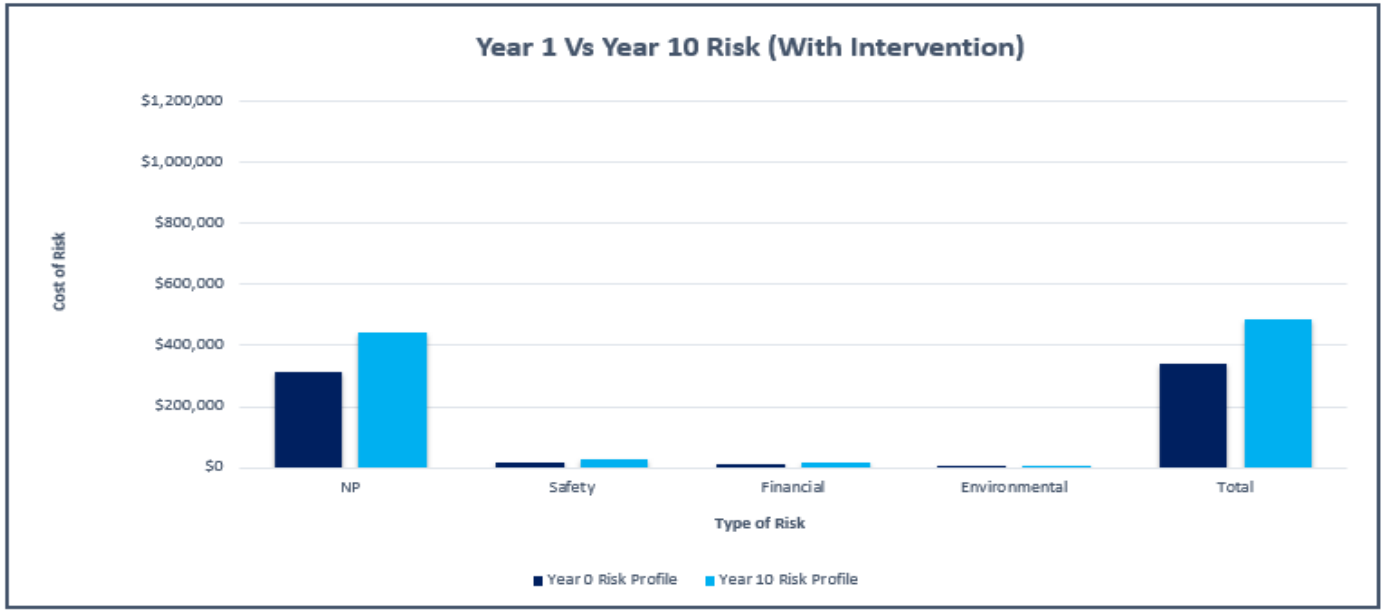
Financials over time

- Shows the tangible financial risk of all cables in the model based on all combined factors
- This models shows the Current Risk vs the “Do Nothing Scenario”
- Financial justification of expenditure to reduce risk





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Conclusions

- Use the data we have, and the data that we can obtain to determine health
- Calculate end of life based on an asset management methodology
- Calculate the risk based on PoF and Consequence
- Modelling intervention scenarios can show the direct financial impact of interventions
- Trending future Asset Health & Risk can be used to build maintenance programs
- Risk reduction scenarios can be used in justification for planned works or maintenance

With you today

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