Estimating the impact of VLF Frequency on Effectiveness of VLF Withstand Diagnostics for MV Cable Systems

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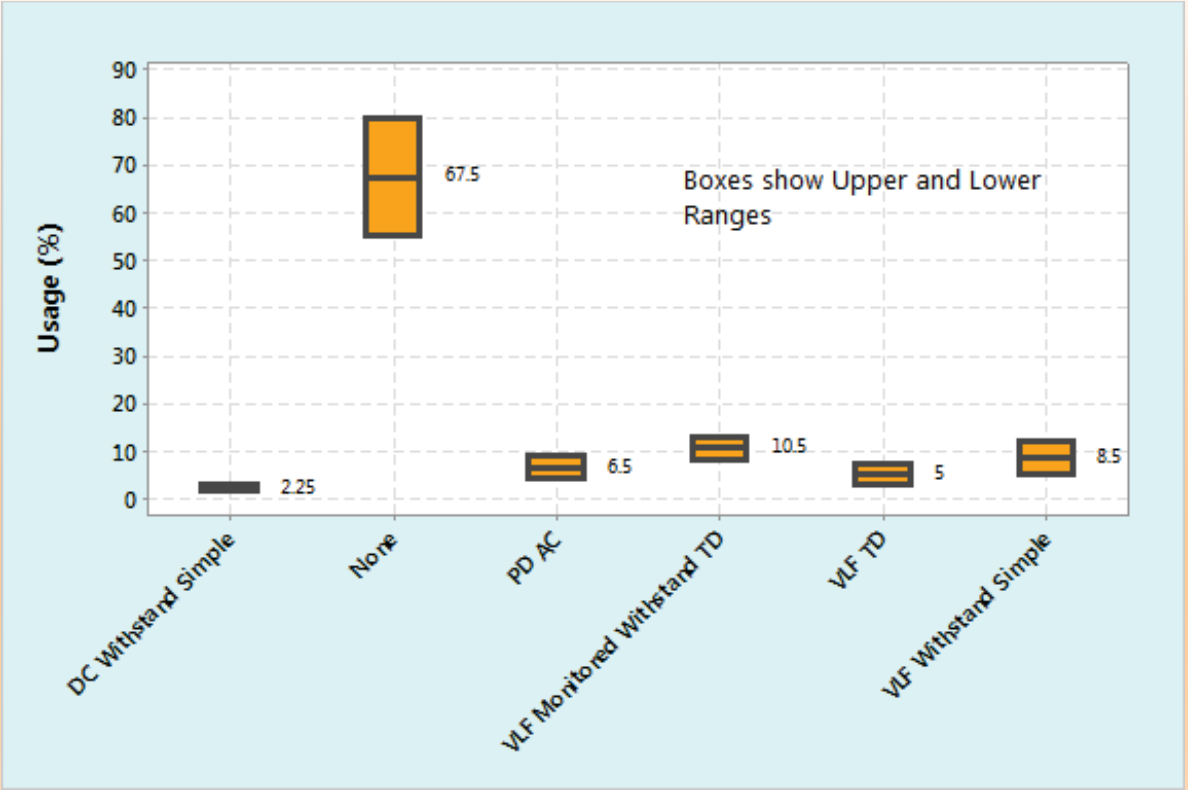
Outline

- Background
- Length Issues
- Test Protocols
- Water Tree Lengths
- Breakdown Strengths
- Conclusions

Introduction

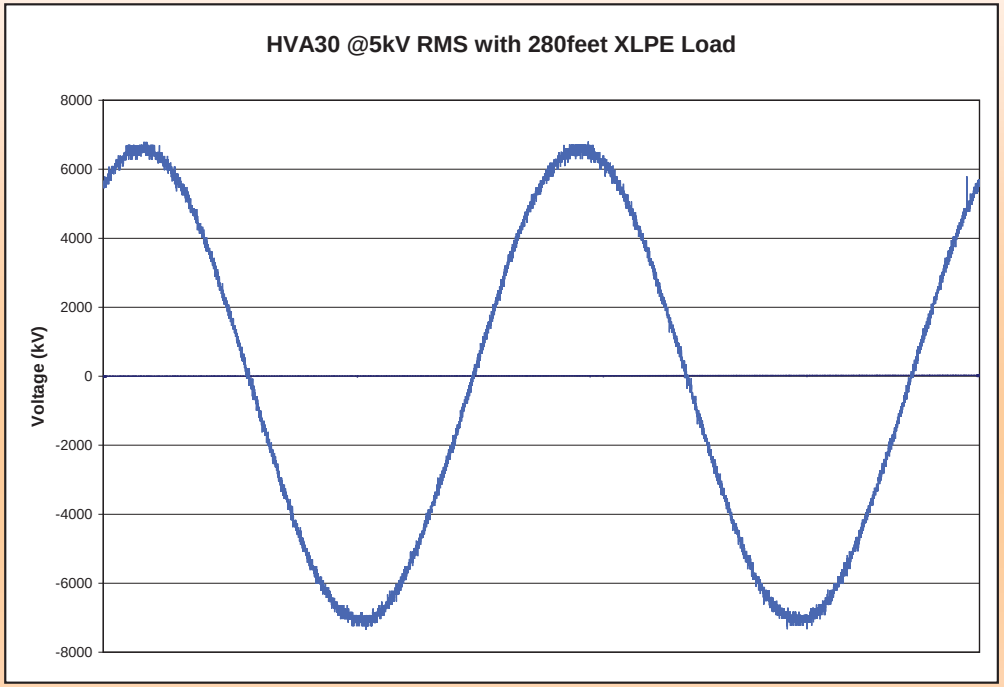
- VLF is the waveform most widely used by utilities who employ diagnostic tests



- VLF is used in Simple Withstand, Monitored Withstand and Tan Delta Tests
- A range of frequencies are permitted: 0.01 to 1 Hz

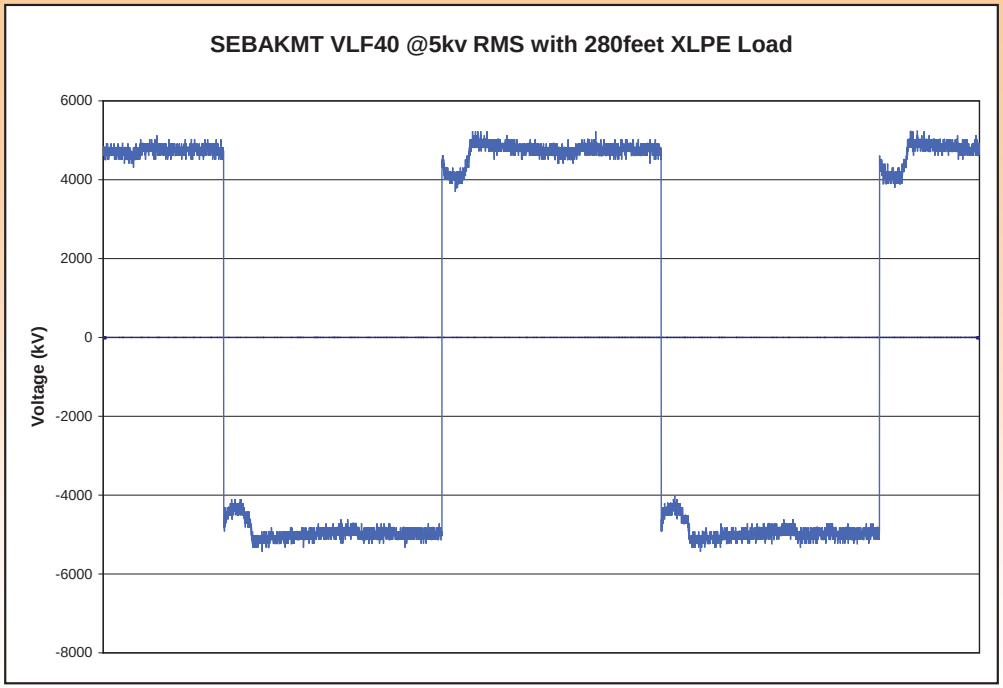
Examples of VLF Sources

VLF Waveforms

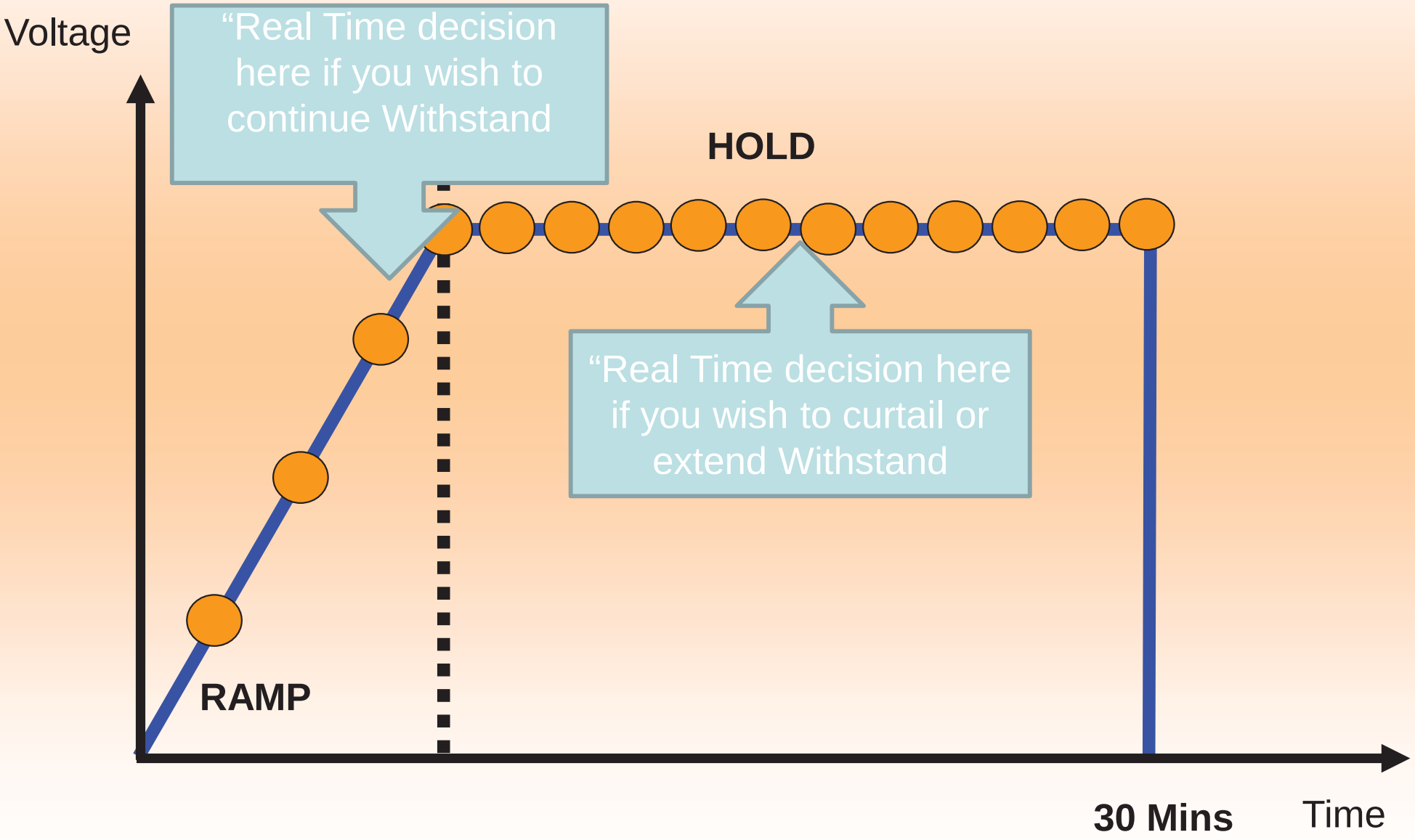


Sinusoidal

Cosine-Rectangular



Preferred Test Protocol



VLF Frequency

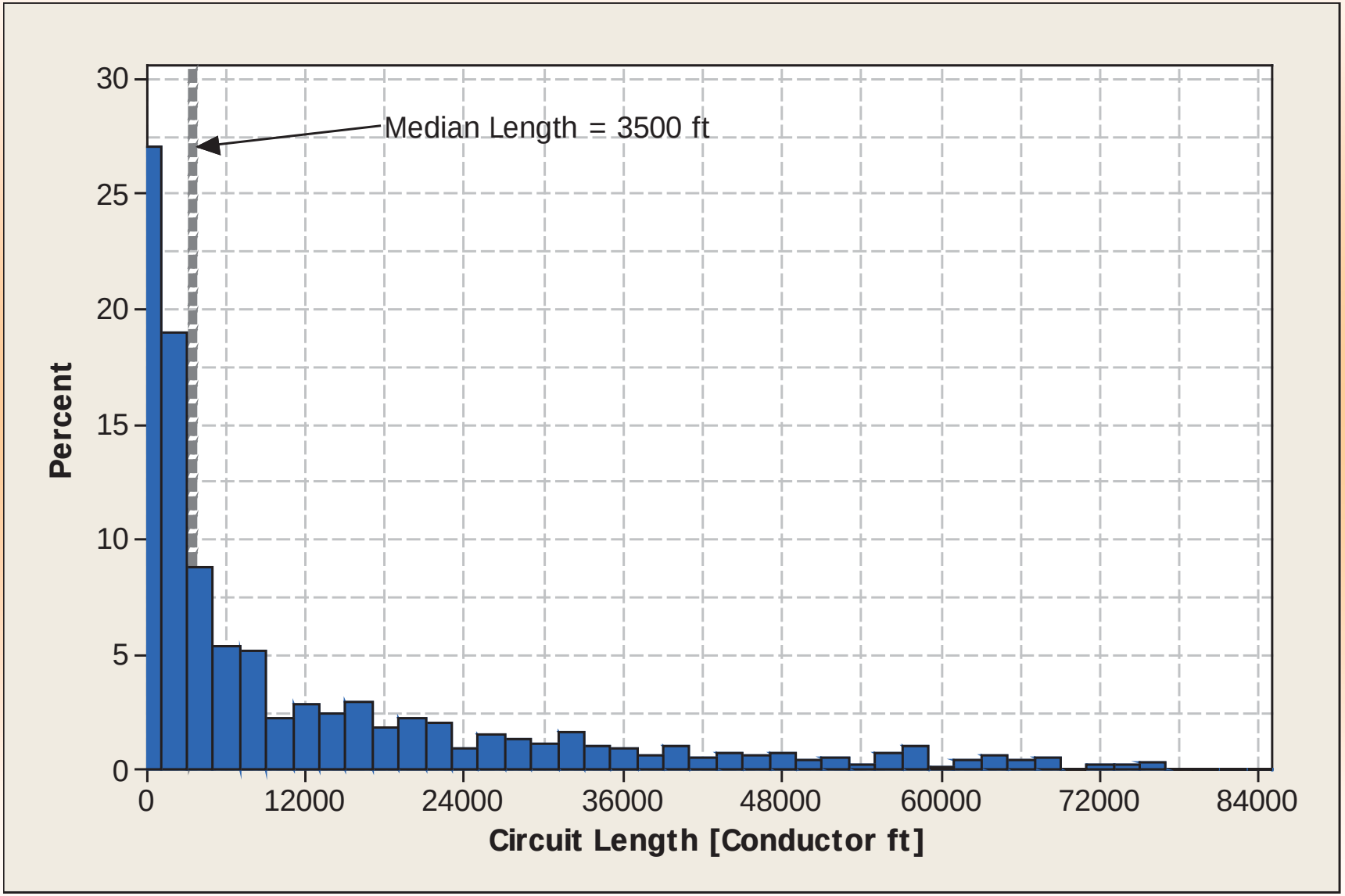
- A range of frequencies are permitted: 0.01 to 1 Hz

- The frequency changes when the length of the cable system being tested increases – longer cable require lower frequencies

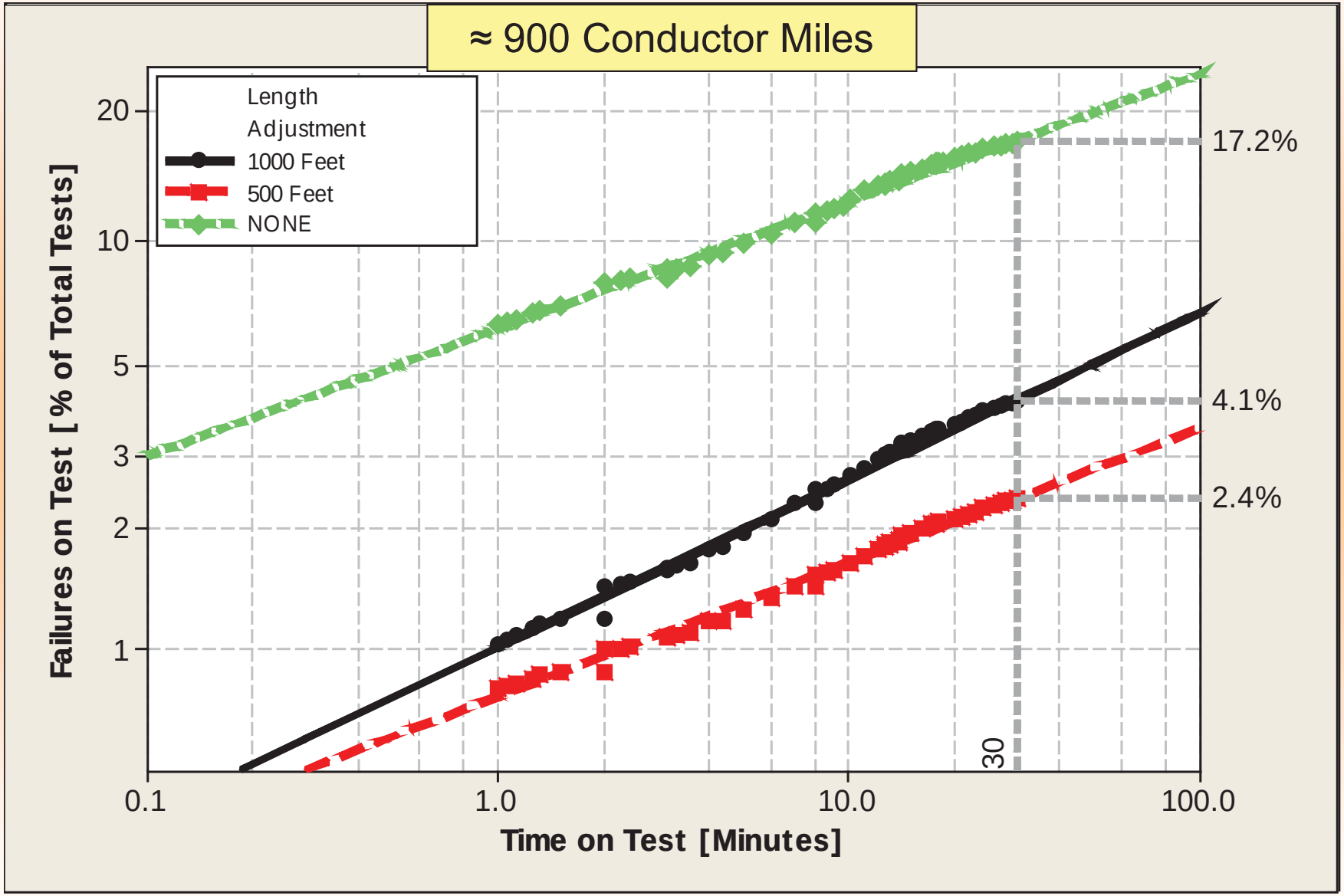
Concern that the withstand result may depend upon frequency

Malaysia 11 & 33kV System, Moh, CIRED 2003			
	0.1Hz	0.05Hz	0.02Hz
Survival	87%	75%	74%
Fail On Test (FOT)	10%	19%	20%
Fail In Service (FIS)	3%	6%	6%

Lengths Tested with VLF

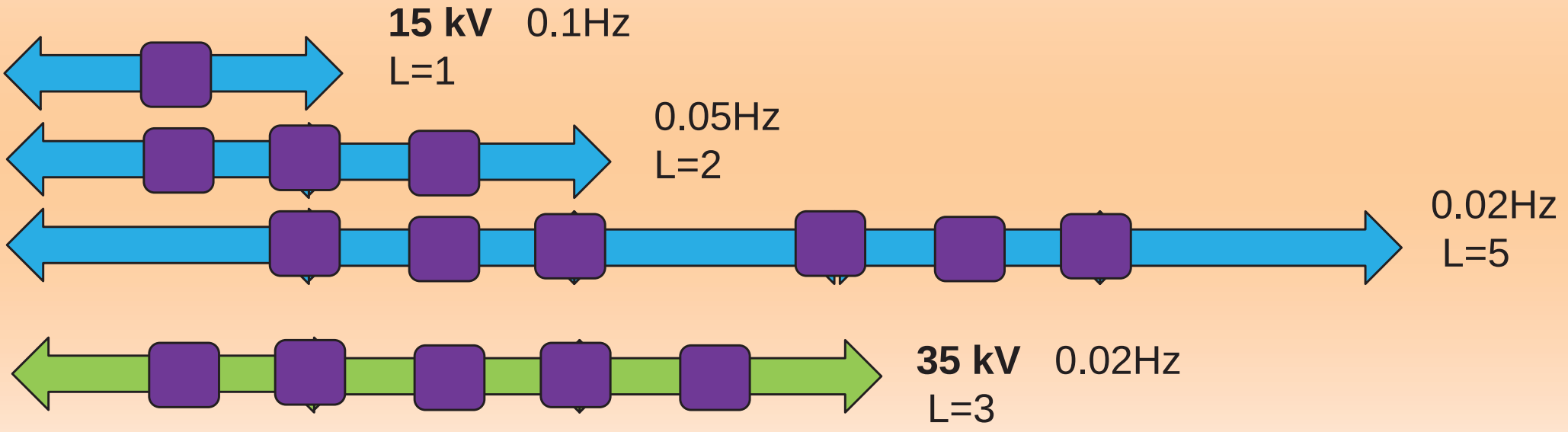


Length Effect on Failures on Test



Length Effects

- Comparison of withstand failure on test rates must include length adjustments
- Lower test frequencies come from the longer lengths



	0.1Hz	0.05Hz	0.02Hz
Fail On Test	10%	19%	20%
Length Adj FOT	10%	20 – 30%	30 – 50%

Effect of Frequency

- Observed effect is likely not an effect of frequency
- Observed effect is likely an effect of length which in turn impacts frequency

- Is there an effect of frequency?

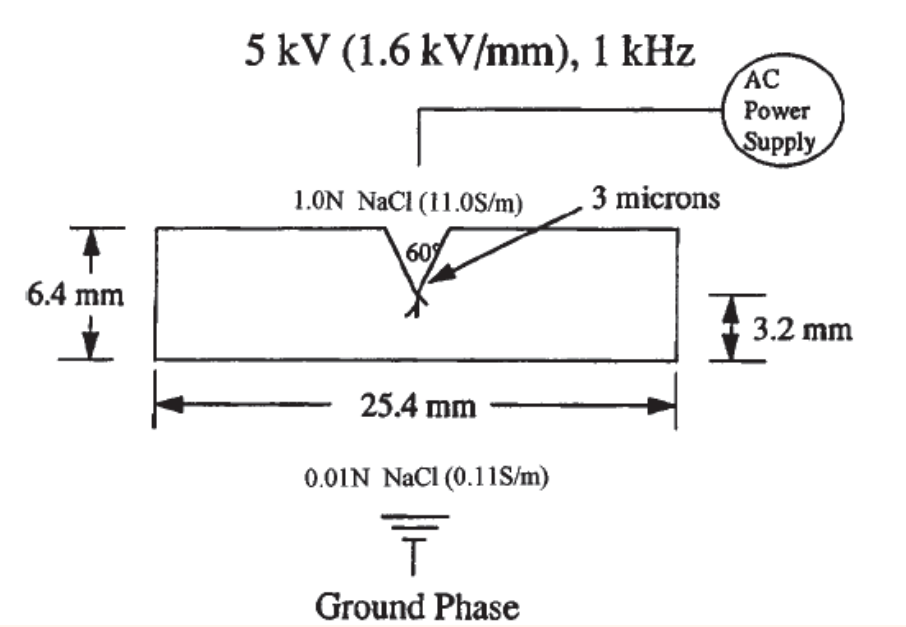
- To investigate will need

1. consistent defects
2. forced frequency

Ashcraft Test

- Ashcraft test is a way to reproducibly grow water trees in the laboratory
- Water trees grow from a water needle
- Tree inception & growth are accelerated by
  - Field enhancement

    at the water needle
  - Ionic solution
  - High AC frequency



- After 30 days we end up with consistently treed cells that can be VLF tested at selected conditions

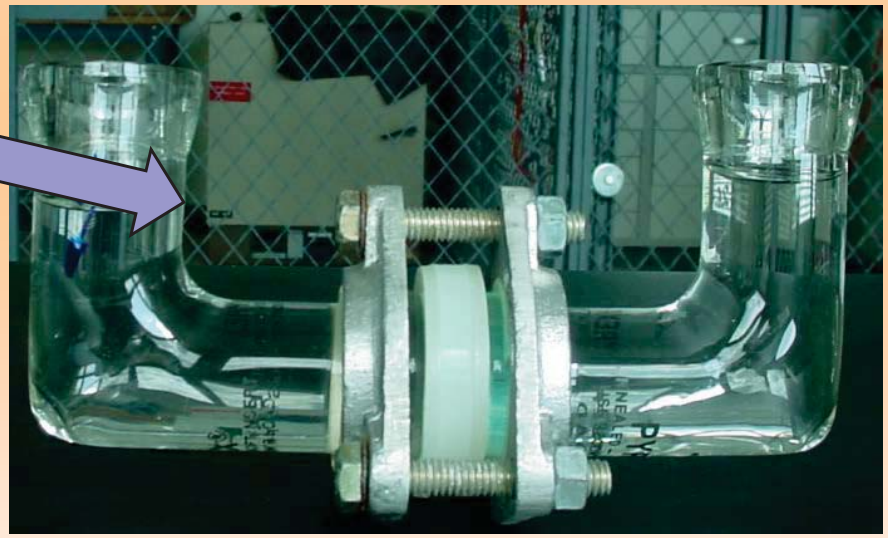
Test Program

- Grow water trees to consistent lengths in selected materials: EPR, WTRXLPE, XLPE
- Step Test groups (4) to failure

using sinusoidal VLF at selected

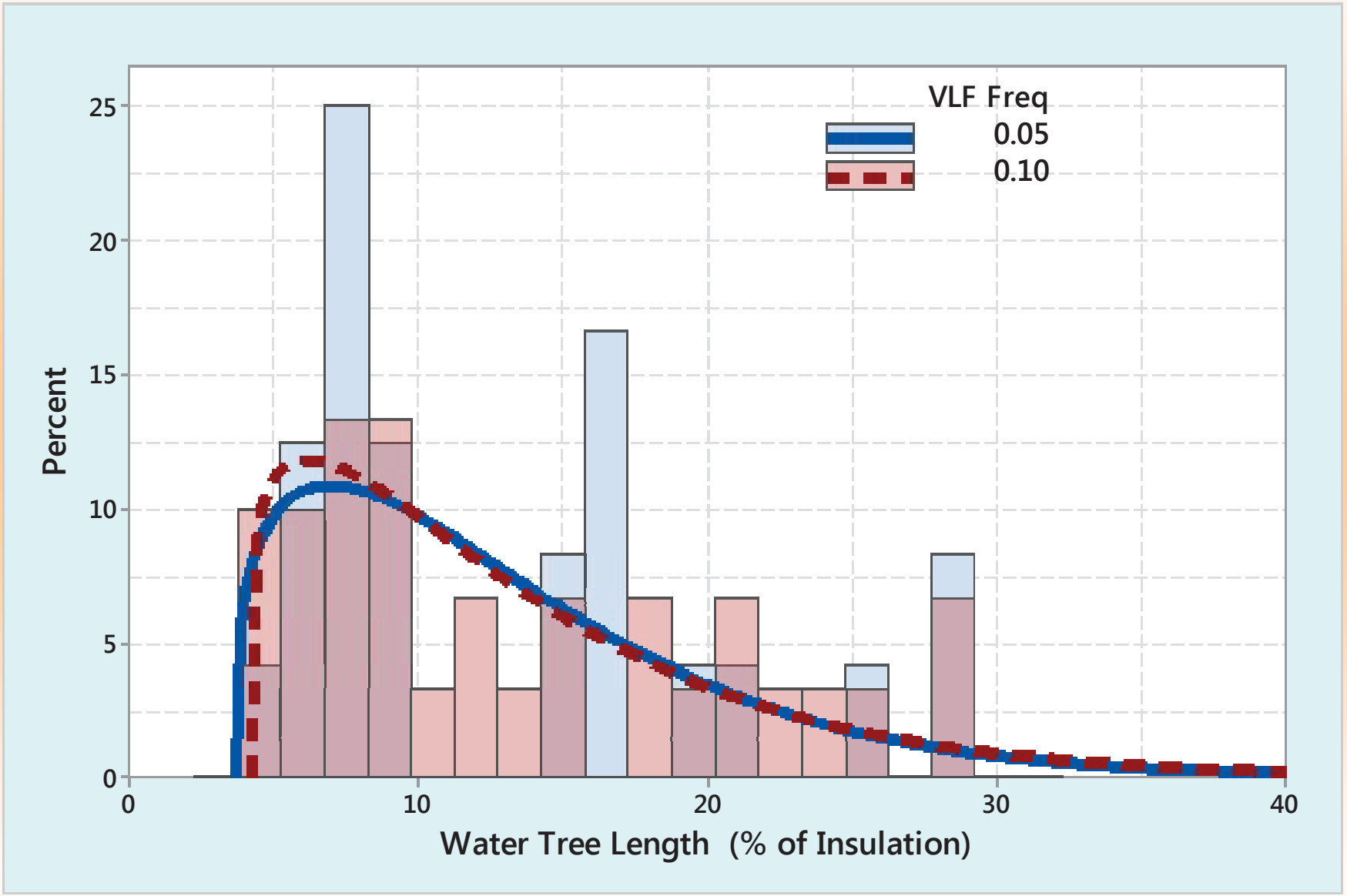
frequencies (0.1 & 0.05Hz)

  - Establish VLF strength
  - Water Tree Length

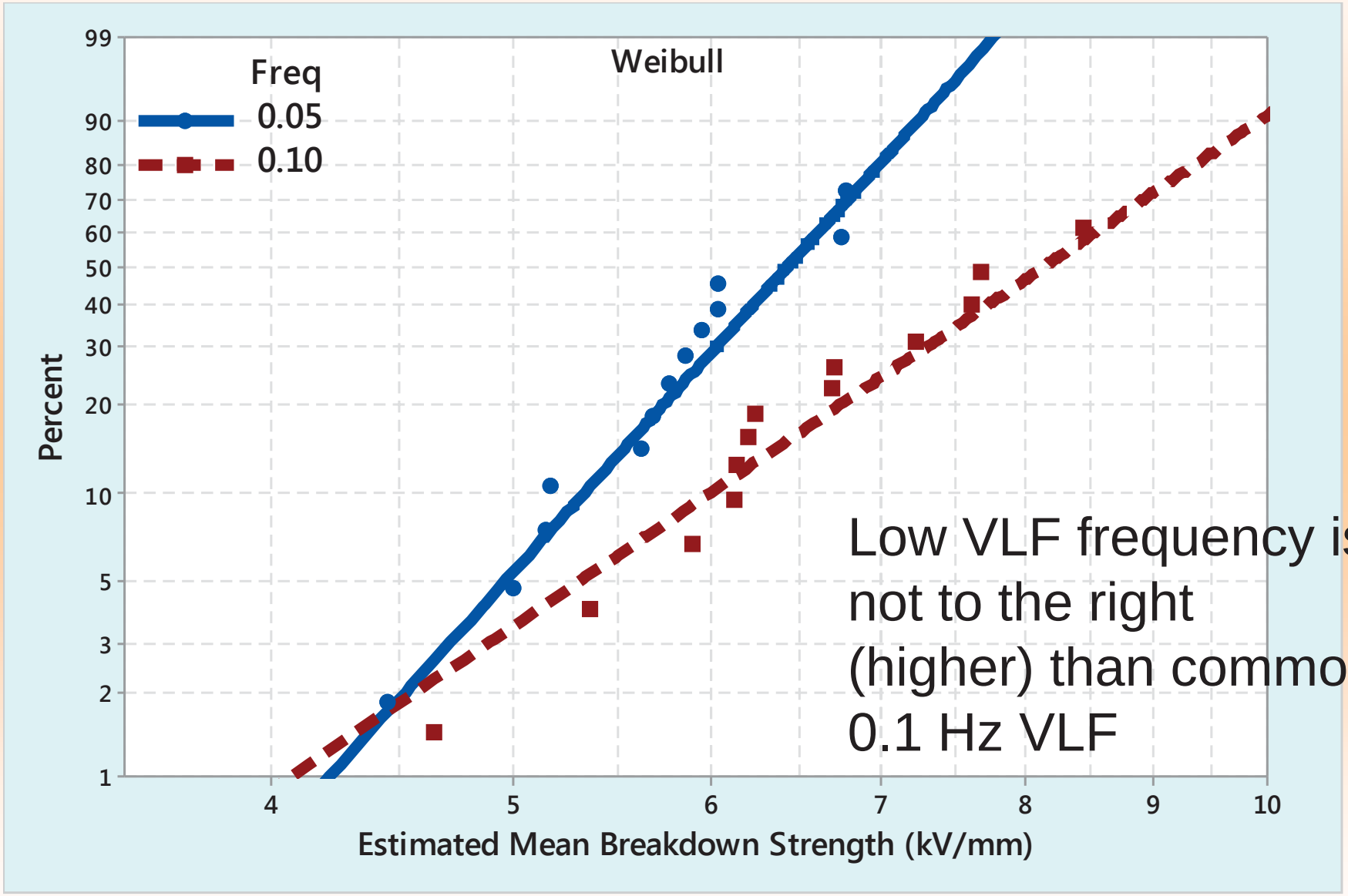


- If low frequency VLF is <u>less effective</u> then there should be a measurable <u>increase</u> in the VLF breakdown strength

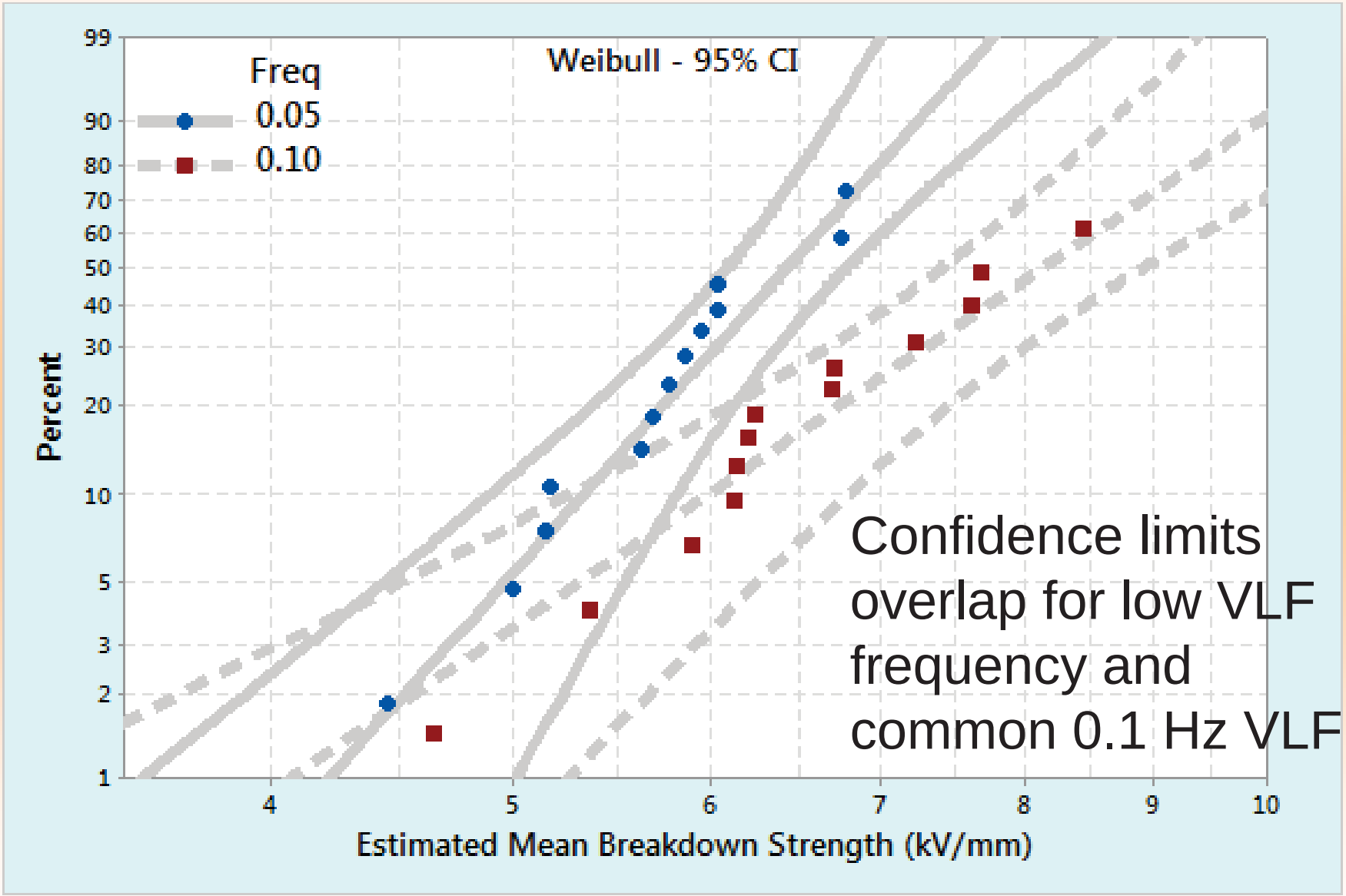
Water Tree Lengths very Comparible



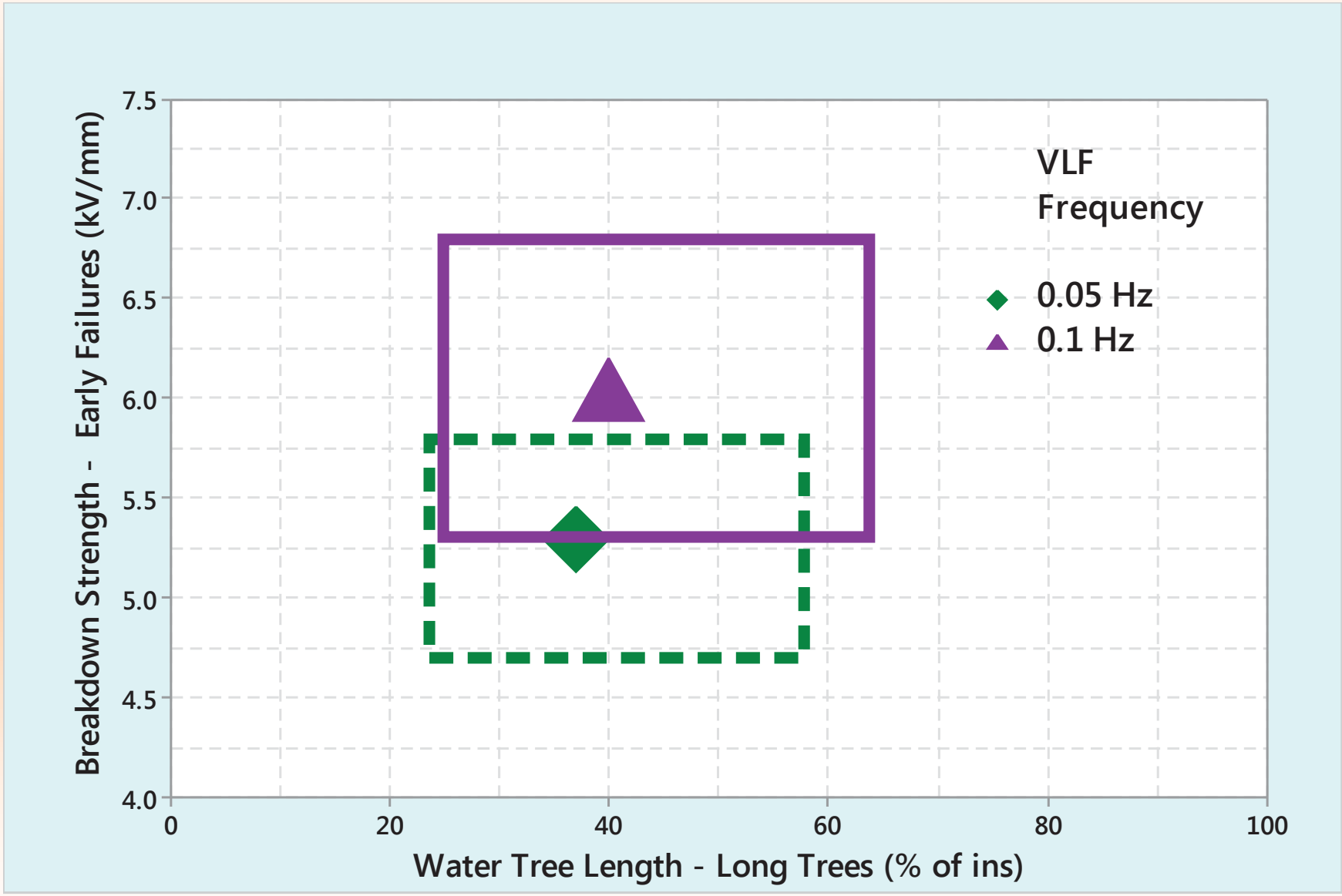
VLF Breakdown Strength – water treed



Weibull Confidence Limits



Breakdown Strength & Water Trees



Conclusions

- The reported VLF frequency effect on simple withstand is consistent with being due to the increased length of the circuits tested not VLF frequency
- VLF frequency is correlated with increased FOT & FIS but does not cause the effect
- Controlled tests, on very similarly degraded samples, does not show the hypothesised increase in breakdown strength with decreasing frequency
- VLF tests at lower frequencies are likely to be, wrt common 0.1 Hz, either
  - as effective or
  - marginally more effective (resulting in lower breakdown strengths)