

Beyond 800V - Challenges in Delivering the Next Generation of High Voltage Systems

Ian Cotton – Technical Director



See our test capabilities/services and sign up to our newsletter at portal.ahv.solutions

About Us

- Specialist provider of electrical testing – centred around high voltage and high current testing.
- Significant capabilities in ‘non-standard’ insulation testing – particularly that needed to deliver the next generation of electric propulsion systems
- Highly skilled workforce with significant experience in high voltage and high current testing
- AS9100 certified and deliver testing for >40 companies in the aerospace sector while working in other sectors including automotive and power systems



magniX propulsion system under test at NASA NEAT facility – aHV delivered partial discharge test capability



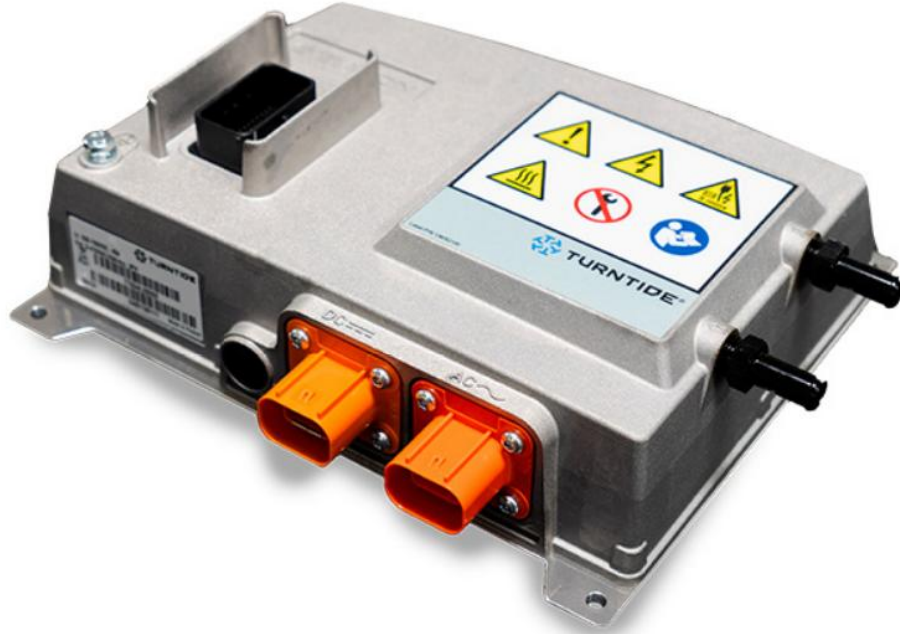
AEROSPACE
& DEFENCE

- **800V systems being used across automotive and aerospace applications**
- **Products typically qualified to an altitude of 5,000m**



- **Suppliers producing components see similar, not identical, requests for product**
- **No established standards – committees are playing catch-up and knowledge gaps exist**

Pushing Beyond 800V



- Solid insulation (connectors, busbars / PCBs)
- Gaseous insulation (air around all major parts)
- Gels / liquid insulation (such as those within power electronic modules)
- Mix of DC / AC (including switched) waveforms making electric fields less predictable

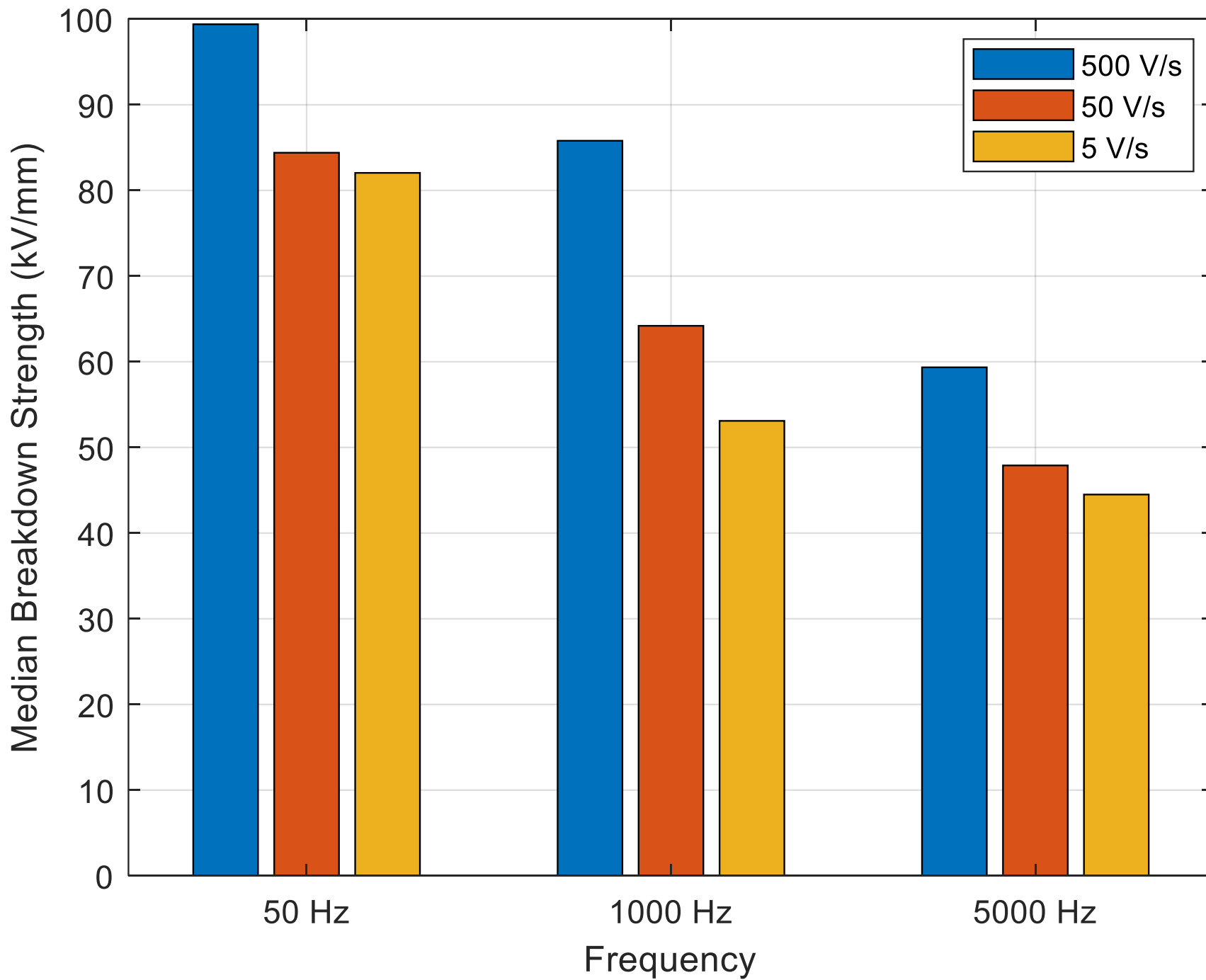


- Need for thin insulation systems to ensure power density is maximised
- Management of partial discharge challenge a typical focus for designers – the risk of this is heavily influenced by the magnitude of voltage overshoot at the machine terminals

Insulation Strength

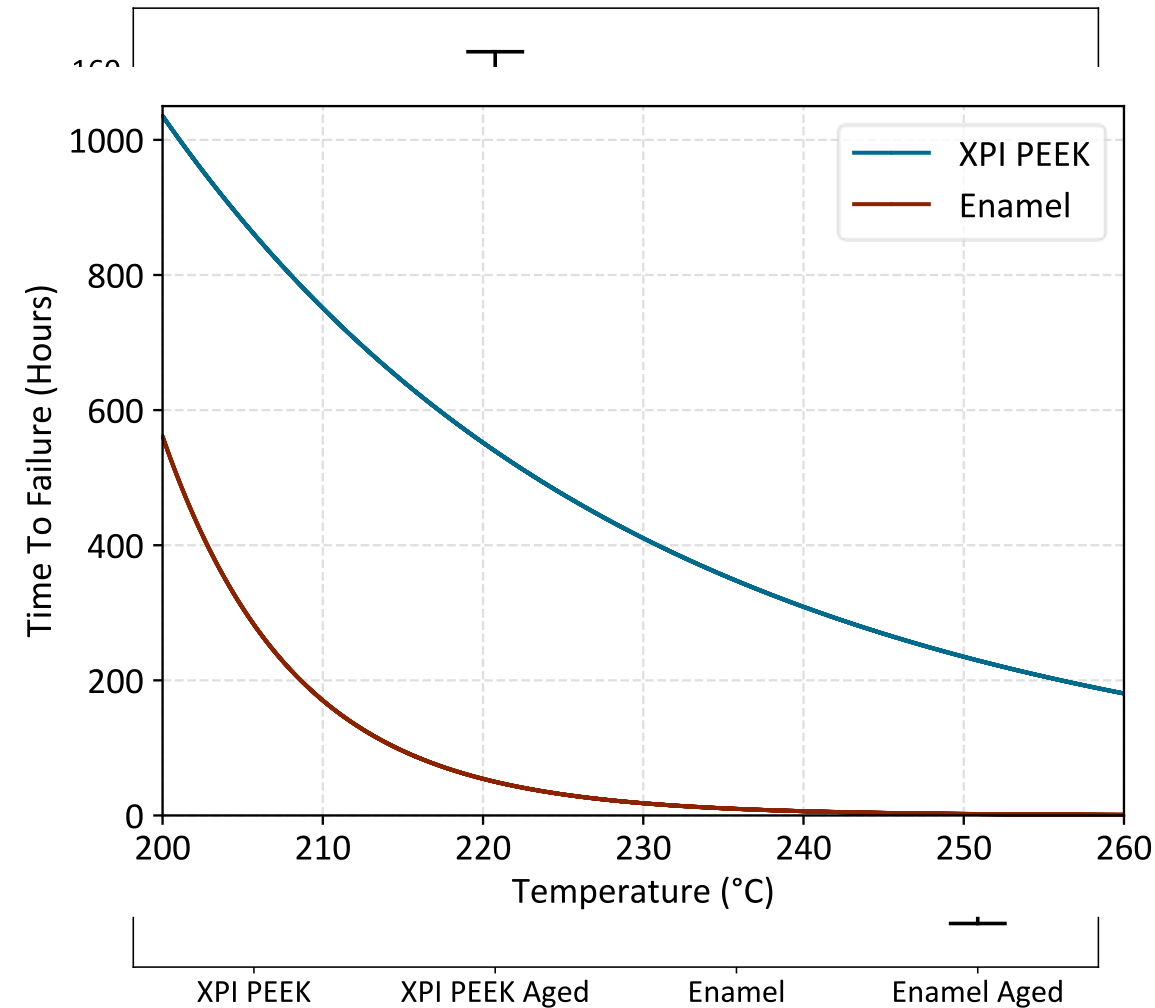
- Take a 1200V inverter – typical worst case scenario would see $4800V_{pk-pk}$ across the phase-phase insulation
- If we used insulation with a thickness of 0.1mm (this is below the level used in aerospace machines) – that would mean a working electric field of $3.4 kV_{rms}/mm$
- When new, insulation should be capable of at least $50kV/mm$
- The challenge is ensuring the insulation remains capable of providing that electrical strength at the end-of-life





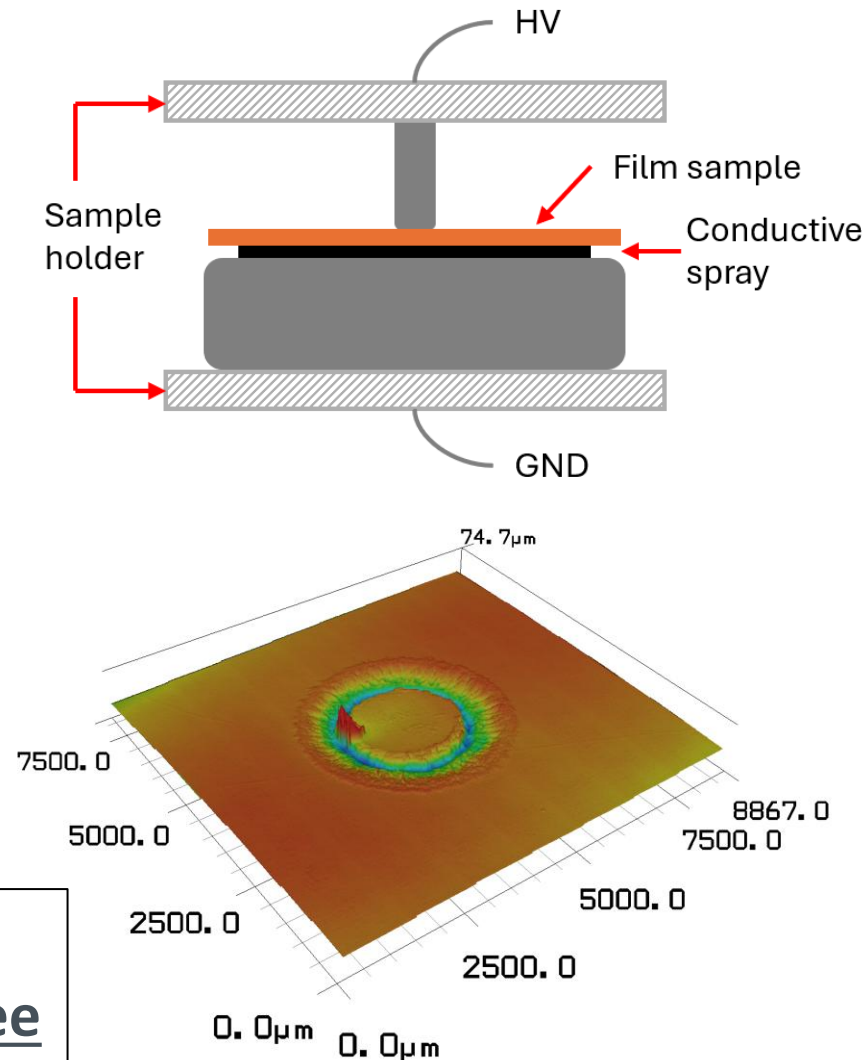
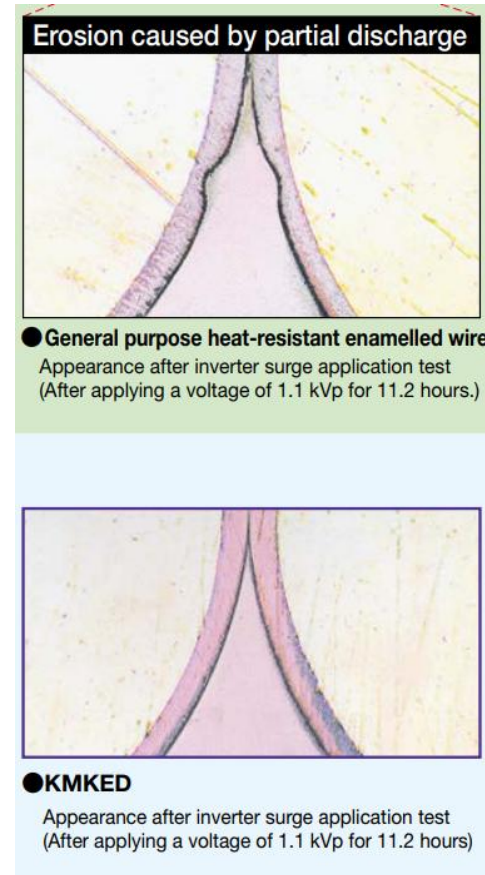
Thermal Degradation

- Insulation for machines typically fails as a result of thermomechanical degradation
 - Heating causes oxidation / embrittlement – along with vibration this then causes cracking / insulation loss
- Testing for established industrial machines sees ageing at fixed temperatures carried out to establish lifetime.
 - Some challenges in determining the lifetime estimate of an automotive machine
 - Challenge of adapting existing standards

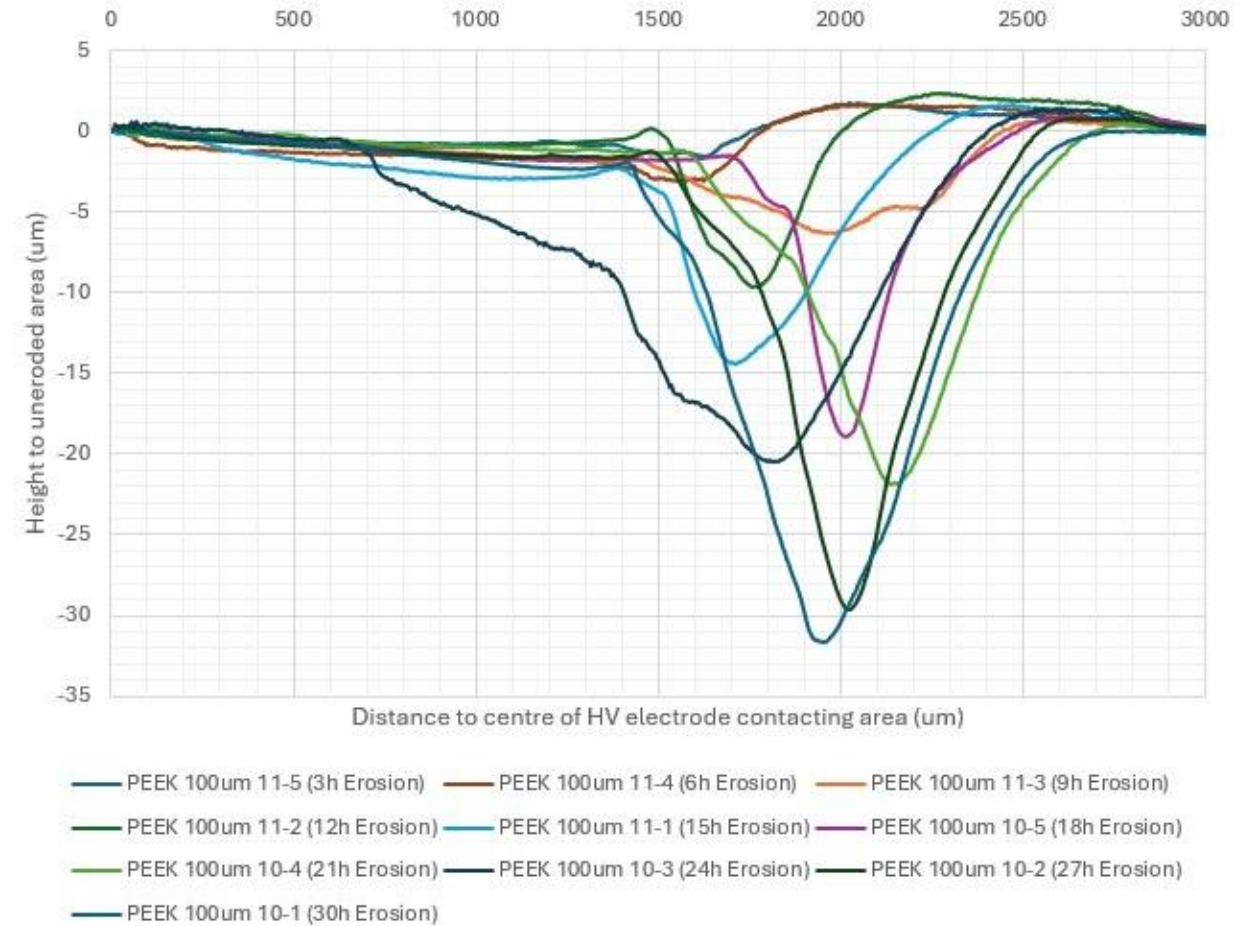
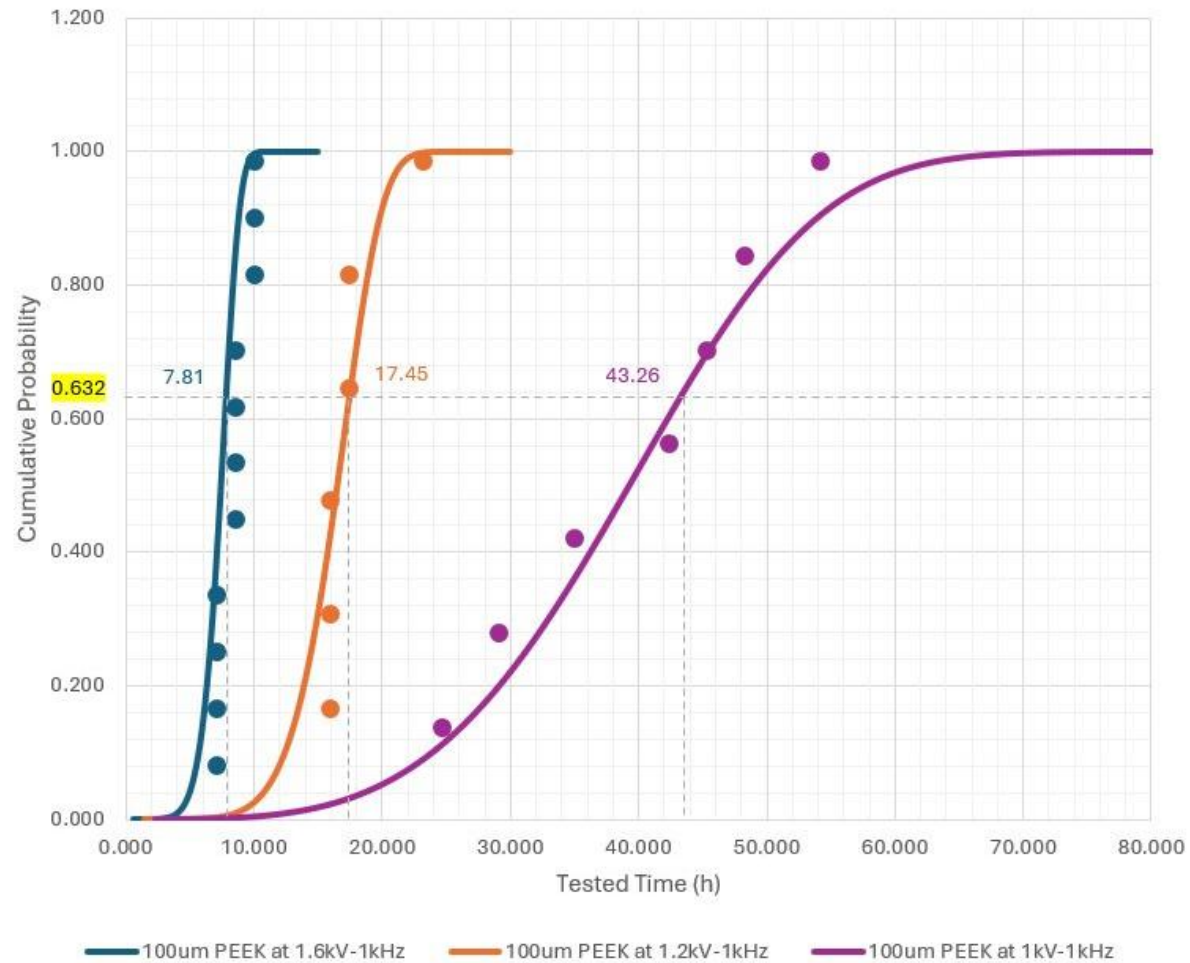


Partial Discharge

- Even if insulation is thick enough to avoid dielectric breakdown, air gaps between wires can see partial discharge
 - The electric field in the gap becomes sufficient to cause small discharges that over time erode the insulation away
 - Phase to phase cross-overs the main area of challenge in automotive machines
- Avoiding partial discharge
 - Thicker insulation
 - Avoiding air gaps (encapsulation / fluid filled systems)
 - Controlling voltage (particularly overshoot)
- Managing partial discharge
 - Using 'partial discharge resistant' materials – these may give you hours of life but are unlikely to give you hundreds of hours in inverter fed systems

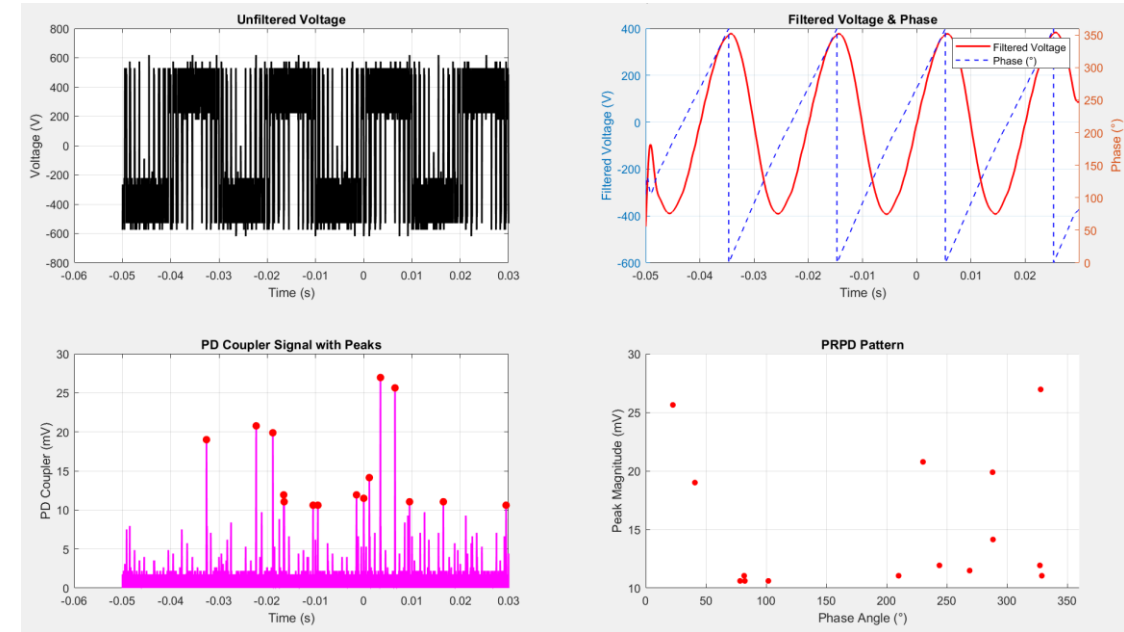


A 1200V DC bus would require an insulation thickness 2.2x larger than that seen in an 800V system to ensure it was PD free



Online PD Testing

- Essential to monitor presence of partial discharge during dyno test campaigns – ideally at maximum altitude product is expected to operate at
- We have a custom test system that monitors whether any PD is present in a system
 - Includes a PD source that injects a known level of PD into the test object on a regular basis to confirm that the measurement system is functional



- While not standardised test techniques, higher voltage systems may see more requirements for chemical compatibility testing & thermal cycling testing



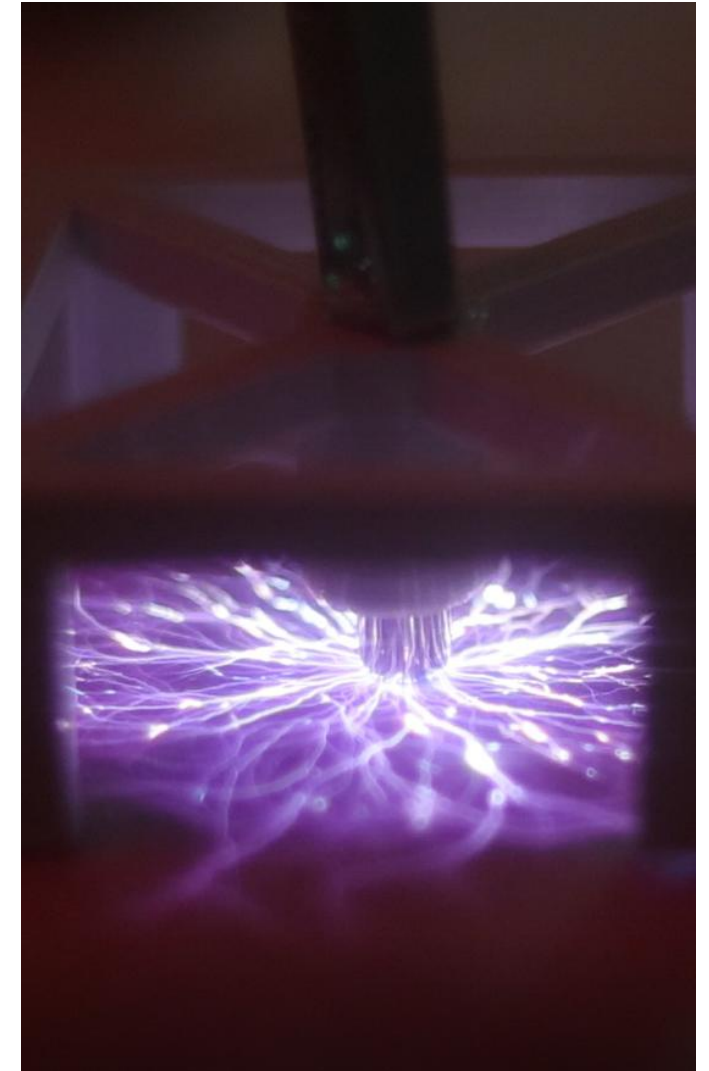
- Insulation may degrade in the presence of specific chemicals
- Oil compatibility testing and increasing focus given flooded oil systems can partial discharge be eliminated while also gaining cooling benefit
- If fluid shared across a transmission system – potential contamination



- Rapid thermal cycles may be expected in some electrical machines (particularly on start-up)
- Thermal cycling testing common for large generators that are used on a cyclic basis
- Joule heating of wires preferred method as delivers appropriate representation of thermal stress

Summary

- As we increase the voltages, it's firstly essential we communicate to the insulation designers what the voltages actually are
 - Simply stating a DC bus voltage of 1000V is not likely to be sufficient – details of issues like overshoot are required
- 1000V+ systems are possible but failure modes need to be understood – testing is often the only answer to do this
- Chemical ageing / thermal cycling may become increasingly important
- Without any mitigating, moving from 800V to 1200V will require the insulation system to be 2.2 thicker





Thank You

Please See Us At
Stand C3-622a



See our test capabilities/services and sign up to our newsletter at portal.ahv.solutions