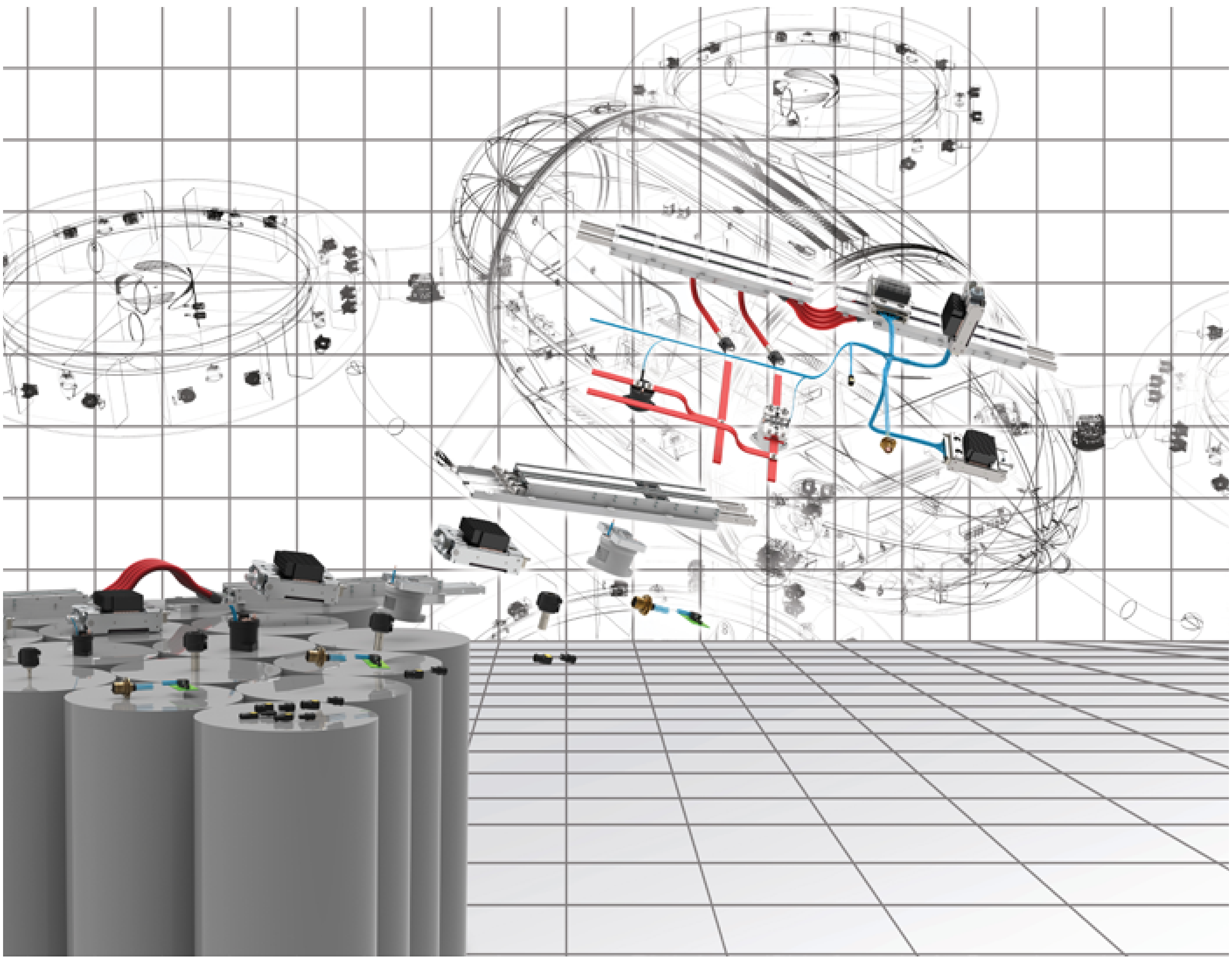
ADDRESSING THE TOP 10 CONNECTIVITY CHALLENGES IN DEVELOPING ELECTRIC AIRCRAFT

by: Matthew McAlonis, Technical Fellow and global leader
of Engineering for the Aerospace Defense & Marine



Electric Vertical Takeoff and Landing (eVTOL) aircraft designers are addressing voltage and power challenges in batteries, pods, and fast-charging stations with advanced connectivity solutions

Just as electric vehicles are revolutionizing the automotive industry, electric aircraft promise to boost the sustainability and convenience of air travel. Designers of urban-air/advanced-air mobility (UAM/AAM) “air taxis” and electric-powered vertical-takeoff-and-landing (eVTOL) vehicles face numerous challenges when connecting High Voltage (HV) and High Power (HP) systems. Electrical Wiring Interconnection Systems (EWIS) engineers and eVTOL aircraft designers are finding a wide range of solutions are now available to address these 10 connectivity challenges:

1. Significantly Higher Voltages (kV) and Power (MW)

Applying high voltage cables and power systems is nothing new for electrical engineers acquainted with Ohms law (P=IxV). But applying appropriate technologies for hybrid and electric aircraft presents novel situations. By using a “follow-the-wire” design approach, EWIS engineers can help ensure that all the links—connectors, wiring, jackets/insulation, converters, contactors, power sharing networks, and more—can handle the voltage and environmental conditions unique to electric aircraft.

Higher voltages are found in the following situations:

- Electrical systems for conventional aircraft employ 115VAC/400Hz and 270VDC with “high-voltage” (HV) power requirements typically limited to 230VAC. In eVTOL aircraft, the thrust required over rotor area for lift during vertical takeoff and hovering, referred to as disc loading, can necessitate fan speeds from 2,300 to 20,000 RPM delivered by brushless 800VDC motors.

- HV alternating current (AC) is encountered in generators, power converters, and controllers employed in fast-charging stations. Other electrical differences include non-linear power-sharing networks and multi-directional charge paths.

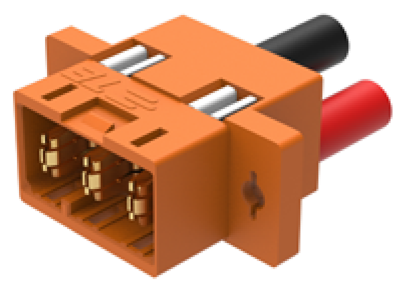
Of course, designing for higher voltage typically translates into using products with thicker dielectric materials and are consequently heavier, stiffer, and take up more space. Advanced power wiring must allow flexibility for routing and dynamic bending of pods and wings, with optimized wiring weight, cable cross sections, and consider ribbon-type (flat) cable geometries. Respective HV connector solutions must enable current carrying capability often up to 1,000 Amps in non-traditional connector geometries. These and other connectivity solutions must address the challenging power density, power frequency, and size, weight, and power (SWaP) requirements for electric aircraft.

2. Mitigation of Partial Discharge/Corona Effect

Managing HV at altitude is more complicated than on the ground. That’s because HV can ionize surrounding air particles more quickly with catastrophic effects, due to lower air densities at altitude as the less constrained particles can achieve higher velocities sooner. Released energy generates a corona discharge resulting in power losses through voids, cavities, and electrical treeing in insulation. Electrical discharges can occur across a voltage gap between two points/surfaces, because the high electrical field cannot be contained by the material(s) in the area. The discharge can also initiate electrical arcing, potentially igniting a fire. Selecting dielectric materials and constructions suited to HV conditions--such as corona-resistant polytetrafluoroethylene (PTFE)--can minimize discharge risks due to insulation breakdown. Elimination of air bubbles/pockets (porosity) can be achieved by employing over-molding and insert molding around connector contacts.

3. Increased Reliability for Harsher Environment, Frequent Maintenance and Inspection, Shock, and Vibration

eVTOL vehicles fly shorter distances than commercial aircraft and are anticipated to make numerous takeoffs and landings per day. Consequently, they require high reliability in interconnects that can withstand vibration and shock from more frequent landings and takeoffs. Reliability is essential because eVTOL flight paths may typically occur over densely populated urban environments. To help ensure performance, electronic/electrical compartments need to be easily inspected. Strain relief on connectors, molded cable assemblies, and secure tiedowns can help avoid chafed components and material fatigue. High reliability connectivity products include high performance, fatigue and stress relaxation resilient connector materials and redundancy in connector contact systems.



Unmanned Power connector (UMP) offers up to 80Amps per contact and mix power flexibility.

4. Premium on Weight Reduction

Unlike conventional aircraft that become lighter by burning fuel, eVTOL aircraft weight does not diminish over distance and discharged batteries are quite literally "dead weight". That's why EWIS designers need to carefully calculate and compare the weight of connectivity components for a given amperage and wiring architecture. Components used in industrial energy storage and management are typically not weight optimized. Advanced, lightweight materials (plastics and composites) and 3D printing can create "right sized" components for tight spaces and weight optimization.

High-efficiency relays and contactors are now available that can handle HV and high amperage within a compact footprint. Advanced HV relays and contactors offer voltage ratings up to 70 kV DC and current ratings up to 1,000 Amps within a useful size-to-power ratio. Compact cables, terminations, and connectors are also available for optimal size, weight, and power rating.

KILOVAC CAP120 high-voltage contactor

5. Resistance Against Arc Tracking and Hydraulic Fluid

With higher voltages come unusual causes of catastrophic failure. Dust, moisture, exhaust, and other pollutants can create pathways for current to travel across a material. Electric discharges can then occur, which risk causing an explosion in flight--or on the ground when fast charging aircrafts are in high moisture environments. An arc-tracking index can be used to evaluate how readily a given voltage travels across a material's surface if it's clean or polluted. Wire is available with dual-wall construction using radiation cross-linked modified materials that resists carbon arc tracking even when contaminated with hydraulic and de-icing fluids.

6. Strict Flammability, Toxicity, and Smoke Requirements

The air inside aircraft circulates within an enclosed space. That's why all materials are flammability, smoke, and toxicity rated. Connectors, wiring jackets, and other insulating materials must not only be self-extinguishable but also limit emission of toxic smoke. Silicone may be suitable for high voltages but tends to be very smokey when ignited. Halogenated flame retardants act directly against the chemistry of a flame, but the smoke can be toxic. Flame-retardant materials that are either low-smoke zero halogen or low-smoke free of halogen are ideal.

SHF260 highly flexible wire provides oustanding chemicals and fluid resistance

7. Altitude and Pressure Effects

Voltage differences become more extreme as altitude, temperature, and frequency increase. The conditions under which a given material supports partial discharge inception voltage (PDIV) and partial discharge extinction voltage (PDEV) can be mapped in a Paschen curve. These points can be used to determine the thickness of dielectric insulation required at specific altitudes and distances between conductive surfaces.

Higher altitudes not only make the system more vulnerable to partial discharge, it also promotes water seepage into gaps in components and eventual corrosion. Other conditions—power switching, lightning strikes—cause surges in power cable systems that can cause cable voltage to exceed PDIV momentarily, leading to insulation erosion or catastrophic failure. The usage of appropriate dielectric materials and design constructions that eliminate air gaps will result in designs with minimal air pressure effects.

8. Handling Operating Temperatures Ranges and Thermal Management Requirements

In battery charge cycles, a balance must be struck between higher energy transfer and higher temperatures. During high power charging (HPC), individual components are subjected to temperature extremes at resistance points along the HV path. Every microohm (υΩ) of resistance must be minimized. Areas to reduce resistance include cable terminations, contact interfaces (crimps and contact types), and contact materials. Liquid-cooled cables and laying cables in convective- or conductive-cooling heat sinks are also solutions. Thermal sensing and thermal modeling can be employed to design a cooling “ecosystem” for charging systems on the ground—and to detect high temperatures during power surges on landing and take-off.

9. New Cabling, Management and Crimping Techniques

Sharp edges and non-smooth conductive surfaces in HV connectors can produce concentrated voltage gradients contributing to corona discharge. Electrically sealing crimp regions smooth out surfaces and the electrical geometries to reduce the likelihood of voltage stress. Any change in geometry requires analysis to determine: Is that edge going to contribute to a partial discharge or corona effect? If so, then construction must be modified to mitigate that risk. Just as HV utility power lines use circular corona rings to prevent corona losses, rounded features can be added to HV cables to control electrical stress. Even a single loose strand of wire sticking out of a shielded cable can cause problems. All components must be carefully designed, tested, and maintained to help ensure performance.

10. Accommodating High-Volume Production

While not directly under a EWIS engineer’s purview, designers must consider the ability of a manufacturer to handle the production, delivery, and quality of components at scale. The eVTOL market is projected to grow exponentially—and the ability to supply quality components in quantity is essential. All products should be 100% tested and inspected to help ensure performance and fitness for the application. Manufacturers who can handle the tooling, supply chain, cost control, and certifications for today’s demanding aerospace and eVTOL programs can address tomorrow’s innovative electric-aircraft projects.

About the author: Matthew McAlonis is Technical Fellow and global leader of Engineering for the Aerospace Defense & Marine Business Unit at TE Connectivity. He can be reached at mmcaloni@te.com.

For more information on TE’s product solutions for the urban-air/advanced-air mobility (UAM/AAM) market, check out www.te.com/urban-air-mobility

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