MarSum Solutions: Megawatt Flight - Power Electronics in Electric and Hybrid-Electric Aircraft

Aircraft electrification is moving beyond small demonstrators. Electric aircraft, electric vertical takeoff and landing (eVTOL) vehicles, hybrid-electric propulsion systems, and more-electric aircraft architectures all depend on compact, efficient, and certifiable power electronics. At aircraft scale, the challenge is not simply converting battery or generator power into motor torque. The inverter, converter, high-voltage distribution, thermal system, electromagnetic compatibility strategy, and fault-handling architecture determine whether electrified propulsion can meet the safety, weight, and reliability expectations of aviation.

This paper explains the power electronics requirements behind electric and hybrid aircraft, with a focus on propulsion inverters, high-voltage DC distribution, lightweight conversion stages, redundancy, thermal management, EMI/EMC control, and certification readiness. The goal is to frame electrified flight as a system-level power conversion problem where early architecture decisions shape performance, safety, manufacturability, and program risk.

Why electrified flight is a power electronics problem

Aircraft power systems have always been constrained by weight, reliability, and safety. Electrified propulsion adds a new layer of difficulty because propulsion power must move through semiconductor switches, DC-link capacitors, buswork, filters, cables, connectors, motors, and controls before it becomes useful thrust. Every conversion loss becomes heat that must be removed in an environment where airflow, altitude, packaging volume, and allowable mass are limited.

Electric and hybrid aircraft also operate across demanding modes: takeoff power, climb, cruise, descent, hover for eVTOL aircraft, regeneration where applicable, battery charging, engine-generator operation, emergency operation, and fault recovery. A design that performs well at a single steady-state operating point may still fail the aircraft-level requirement if it cannot tolerate transients, partial failures, thermal extremes, altitude effects, EMI exposure, and certification-driven failure cases.

What is inside an electrified aircraft power system

The architecture differs between all-electric aircraft, eVTOL vehicles, hybrid-electric demonstrators, and more-electric aircraft subsystems, but the major engineering functions are consistent.

Energy source and DC bus

Battery packs, fuel cells, turbo-generators, or hybrid sources feed a high-voltage DC bus. Common aircraft concepts often use hundreds of volts DC, such as 540 VDC class buses, with some emerging propulsion architectures moving toward roughly 800 VDC or higher to reduce current and cable mass.

Motors and distributed propulsion

Electric motors may be installed as a few high-power propulsors or distributed across many smaller propulsors. Distributed layouts can improve control authority and redundancy, but they multiply inverter count, wiring complexity, EMI sources, and fault-management cases.

Protection and high-voltage distribution

Contactors, fuses, solid-state protection, isolation monitoring, precharge circuits, connectors, and wiring harnesses must manage high-voltage DC safely. Arcing, creepage, clearance, partial discharge, and maintenance access become central design concerns.

Propulsion inverter

The propulsion inverter converts the DC bus into controlled three-phase motor power. It must deliver high torque response, high efficiency, low mass, stable control, and predictable behavior under current limits, faults, and aircraft-level command changes.

DC/DC conversion and auxiliaries

Aircraft still need lower-voltage buses for avionics, actuation, pumps, fans, sensors, and control electronics. Isolated and non-isolated DC/DC converters must step down high-voltage propulsion power while maintaining efficiency and fault containment.

Controls, monitoring, and health management

Flight controls, propulsion controllers, battery management systems, thermal controls, and health monitoring must coordinate power limits, torque commands, fault response, and degraded-mode operation without creating unsafe interactions.

Propulsion inverter design for megawatt-class aircraft

The propulsion inverter is one of the highest-consequence blocks in an electrified aircraft. It is not only a motor drive. It is a flight-critical power conversion system that must translate aircraft-level thrust commands into controlled motor torque while staying inside electrical, thermal, battery, and certification limits.

High power density is the dominant design pressure. Increasing voltage reduces current for a given power level, which can reduce cable mass and conduction losses. Wide-bandgap semiconductors such as silicon carbide (SiC) can improve switching performance and operating temperature margin, but faster switching also increases the importance of gate-drive design, insulation stress, common-mode current, bearing current, EMI/EMC behavior, and layout discipline.

In aviation, efficiency and weight cannot be optimized independently. Raising switching frequency may shrink magnetics and filters, but it can increase switching loss and electromagnetic emissions. Aggressive liquid cooling can improve power density, but it adds pumps, plumbing, leak risks, maintenance constraints, and failure modes. The practical design task is to optimize the complete propulsion channel rather than any single device or thermal datapoint.

High-voltage distribution and aircraft integration

High-voltage DC distribution is attractive because aircraft propulsion power can reach hundreds of kilowatts to multiple megawatts. At those levels, low-voltage distribution becomes impractical due to current, copper mass, connector heating, and voltage drop. Moving to 540 VDC, 800 VDC, or similar high-voltage architectures can reduce current, but it also raises the burden on insulation coordination, wiring installation, fault interruption, and service procedures.

Aircraft integration makes these problems harder than they appear in a bench-top inverter test. Cable routing may pass near avionics, sensors, composite structures, fuel systems, and passenger areas. Altitude changes affect cooling and insulation behavior. Vibration, thermal cycling, humidity, contamination, and maintenance access all influence long-term reliability. Successful high-voltage integration therefore requires coordinated design of the power electronics, wiring, protection, mechanical packaging, and aircraft-level safety assessment.

Thermal management, EMI/EMC, and redundancy

Electrified aircraft power electronics must reject heat without consuming the mass and volume that make the aircraft viable. Air cooling may be attractive for simplicity but becomes difficult at high power density or altitude. Liquid cooling can support higher power density, but the thermal loop becomes part of the safety architecture. Heat exchangers, cold plates, pumps, coolant, sensors, and leak detection must be treated as aircraft systems, not accessories.

Thermal limits and altitude

Lower air density, climb profiles, hover operation, and hot-day requirements can create the worst thermal cases. Semiconductor junction temperature, capacitor life, motor heating, coolant temperature, and enclosure heat rejection must be evaluated across the flight envelope.

Fault tolerance and redundancy

Safety-critical propulsion requires defined behavior after component faults, sensor failures, controller faults, communication loss, or loss of a propulsion channel. Redundancy must be designed at the aircraft level, not only inside the inverter.

EMI/EMC near avionics

Fast-switching propulsion inverters can inject conducted and radiated noise into aircraft wiring, structures, and sensors. Filter design, shielding, grounding, bonding, cable routing, switching strategy, and enclosure design must protect avionics and communications.

Degraded-mode operation

The aircraft may need to continue flight, transition to a safe landing mode, isolate a failed channel, or limit thrust after a fault. Power electronics controls must support predictable degraded operation while preserving enough diagnostic information for maintenance.

Demonstrators and aircraft electrification pathways

Public demonstrators show both the promise and the difficulty of electrified flight. NASA X-57 Maxwell was developed to share electric-propulsion design and airworthiness lessons for distributed electric propulsion, and NASA reported high-voltage ground testing as well as X-57 power converter work such as a 538 VDC cruise motor controller with more than 97% efficiency. Although X-57 did not become a production aircraft, the program illustrates how integration, safety process, power conversion, and certification planning matter as much as the motor and battery hardware.

Airbus and Rolls-Royce also used the E-Fan X program to explore hybrid-electric propulsion at megawatt scale before the demonstrator was ended in 2020. The technical lesson remains relevant: hybrid-electric aircraft require coordinated design of generators, rectifiers, DC distribution, propulsion inverters, motors, batteries, thermal systems, and fault handling. eVTOL and advanced air mobility programs add another dimension because distributed lift, transition flight, battery energy limits, acoustic goals, and high dispatch reliability must all be solved together.

Markets moving toward aircraft electrification

Aircraft electrification interest is rising because regional aviation, advanced air mobility, defense programs, and more-electric aircraft subsystems all need higher-performance electrical power conversion. Market forecasts point to strong growth in aircraft electrification, with one projection estimating an increase from roughly $11.5 billion in 2025 to about $46.8 billion by 2035. The engineering driver is straightforward: as more aircraft functions become electric, power electronics become a larger share of aircraft performance and certification risk.

North America: The U.S. market is shaped by eVTOL certification activity, NASA and defense research, regional aircraft concepts, and strong investment in advanced air mobility. Program teams need power electronics that can move from prototype demonstrations toward certifiable, maintainable aircraft systems.

Europe: European aerospace programs are focused on decarbonization, hybrid-electric propulsion, more-electric aircraft, and high-voltage distribution research. These projects place heavy emphasis on certification, safety assessment, system integration, and supplier readiness.

Advanced Asian markets: Japan, South Korea, Singapore, and other advanced aviation markets are evaluating eVTOL operations, urban air mobility, and electrified aviation infrastructure. Weight, reliability, safety compliance, and manufacturable power electronics remain central concerns.

Integration challenges that determine program success

The hardest aircraft electrification problems usually appear at the interfaces between subsystems. A motor supplier may define torque capability, a battery supplier may define current limits, an inverter supplier may define thermal limits, and the aircraft integrator must prove safe behavior across the full flight envelope. Those boundaries need to be engineered together from the beginning.

Power density and packaging

Inverters, converters, filters, contactors, busbars, cooling hardware, and wiring must fit into constrained aircraft volumes while meeting weight, vibration, accessibility, and maintainability targets.

Controls and transient response

Propulsion torque commands, bus voltage control, battery limits, generator dynamics, thermal derating, and fault response must be coordinated so the aircraft behaves predictably during maneuvers and disturbances.

Safety assessment and certification evidence

Aviation programs need traceable requirements, failure-mode analysis, environmental qualification, software and hardware assurance planning, and test evidence that supports the intended certification path.

High-voltage safety and insulation

Creepage, clearance, partial discharge risk, arcing, grounding, bonding, isolation monitoring, and connector selection must be evaluated under altitude, contamination, vibration, and maintenance conditions.

EMI/EMC and avionics compatibility

High dv/dt propulsion switching can affect sensors, radios, flight controls, and data links. EMI mitigation must be built into the power stage, cabling, grounding, shielding, and validation plan.

Manufacturing and serviceability

A flightworthy design must be buildable, inspectable, and maintainable. Connector access, coolant service, diagnostic coverage, module replacement, and production variation all affect lifecycle cost and fleet availability.

How MarSum supports aircraft electrification programs

MarSum Solutions supports aerospace electrification, high-power conversion, motor-drive, controls, and system-integration programs with an engineering-first approach focused on performance, robustness, and manufacturability. Electric and hybrid aircraft power electronics sit at the intersection of propulsion, high-voltage distribution, thermal design, EMI/EMC, protection, and certification planning, which is where early engineering decisions have the largest effect on program risk.

Our work can include propulsion inverter architecture review, SiC-based power-stage support, DC/DC converter strategy, high-voltage distribution review, EMI/EMC mitigation planning, thermal and reliability assessment, controls and protection sequencing, model development, and validation planning. We also help teams translate broad requirements such as power density, fault tolerance, altitude operation, ride-through behavior, and safe degraded operation into testable engineering criteria.

For aircraft developers, suppliers, and defense or advanced mobility teams, electrified propulsion should be treated as a core system architecture decision rather than a late-stage component selection. A disciplined system-level approach can reduce integration risk, improve certification readiness, and support a faster path from prototype hardware to flightworthy operation.

Engagement models

We support customer teams through focused technical consulting, design reviews, modeling and controls support, and deeper co-development efforts depending on program phase. Typical engagements range from early feasibility and requirements definition to prototype validation, field-debug support, and production-readiness planning for aerospace power electronics and electrified propulsion systems.

Selected sources: NASA X-57 Maxwell public program materials; NASA X-57 power converter materials; Airbus/Rolls-Royce E-Fan X public program materials; RTCA DO-160 / FAA DO-254 guidance; Future Market Insights aircraft electrification forecast.

Contact us today to scope your electric aircraft, hybrid-electric propulsion, or aerospace power electronics project!