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### CONNECTION STRUCTURE FOR A GENERATOR ASSEMBLY

#### Abstract

A generator assembly includes a stator assembly coupled to an engine stator component of a propulsion engine, the stator assembly including: a stator support structure fixedly attached to the engine stator component; a stator disposed on a supporting surface of the stator support; a manifold coupled to the stator support, the manifold defining a connection volume and including at least one coolant opening at a connection end of the manifold; and an electrical connector extending between the stator and a connection device disposed on the connection end. The generator assembly also includes a rotor assembly comprising a rotor support structure connected to a shaft of the propulsion engine and a rotor attached to the rotor support structure, wherein the rotor rotates in conjunction with the shaft to generate a power signal that travels through the electrical connector to the connection device.

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## Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] The present application is a divisional of Ser. No. 18/225,933 filed Jul. 25, 2023, which is a divisional of Ser. No. 17/397,290 filed Aug. 9, 2021, which claims the priority benefit of Polish Patent Application No. P-435036, entitled “Connection Structure for a Generator Assembly” and filed Aug. 20, 2020, the entire contents of which is hereby incorporated by reference herein.

### BACKGROUND

#### Field

[0002] The present specification generally relates to a gas turbine engine including an embedded electrical machine and, more particularly, connections between the electrical machine and other components of the gas turbine engine.

#### Technical Background

[0003] Incorporating an electrical machine (e.g., an electrical generator) into a propulsion engine to generate electrical power from mechanical energy generated by the propulsion engine may enhance the capabilities of aircraft by eliminating the need for heavy and bulky energy storage devices on the aircraft. For example, the electrical power generated by the electrical machine may be used to operate an accessory propulsor (e.g., an electric fan, motor, or the like) to supplement thrust provided via the turbine engine. Introduction of such an electrical machine, however, may introduce challenges relating to size, weight, accessibility, and aerodynamic performance.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The embodiments set forth in the drawings are illustrative and exemplary in nature and not intended to limit the subject matter defined by the claims. The following detailed description of the illustrative embodiments can be understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals and in which:

[0005] FIG. 1 schematically depicts a propulsion engine including an electrical system, according to one or more embodiments described herein;

[0006] FIG. 2 depicts a cross-sectional view of the propulsion engine depicted in FIG. 1 above a central axis A-A thereof, according to one or more embodiments described herein;

[0007] FIG. 3 depicts an enlarged view of a generator assembly of the propulsion engine depicted in FIGS. 1-2, according to one or more embodiments described herein;

[0008] FIG. 4A depicts a perspective view of a turbine rear frame and a generator coupler of the propulsion engine depicted in FIG. 1, according to one or more embodiments described herein;

[0009] FIG. 4B depicts a cross-sectional view of a strut of the turbine rear frame depicted in FIG. 4A, according to one or more embodiments described herein;

[0010] FIG. 5 depicts a cross-sectional view of a stator assembly of the generator assembly depicted in FIG. 3, according to one or more embodiments, described herein.

[0011] FIG. 6A depicts a cross-sectional view of a first illustrative cooling duct of the propulsion engine depicted in FIG. 1, according to one or more embodiments described herein;

[0012] FIG. 6B depicts a cross-sectional view of a second illustrative cooling duct of the propulsion engine depicted in FIG. 1, according to one or more embodiments described herein; and

[0013] FIG. 6C depicts a cross-sectional view of third illustrative cooling duct of the propulsion engine depicted in FIG. 1, according to one or more embodiments described herein.

#### DETAILED DESCRIPTION

[0014] Reference will now be made to generator assemblies for integration into a propulsion engine such as a turbine engine. In various embodiments, the generator assemblies described herein include a single structure that forms various different types of connections (e.g., mechanical, fluidic, electrical) between the generator assembly and the propulsion engine that are conventionally formed separately. For example, various embodiments described herein include a stator assembly that includes a manifold incorporating both an electrical connection device for conductively coupling an electrical connection line extending through the propulsion engine and a coolant opening for receiving coolant from a cooling duct of the propulsion engine. Both the electrical connection device and the coolant opening may be disposed on a connection end of the manifold such that the generator assembly may be both fluidly coupled to the cooling duct and the electrical connection line via a single structure.

[0015] The integrated connections for the generator assemblies described herein provide weight and size savings over existing approaches for incorporation of generator assemblies into propulsion engines. Such weight and size savings may improve performance of the generator assembly. For example, if the size and weight of the generator assembly is too large, any propulsive benefits attained via the electrical power generated by the generator assembly may be outweighed by a reduction in aerodynamic performance in the propulsion engine. Such concerns may be even more pronounced in situations where the electrical power generated via the generator assembly is communicated through the propulsion engine or where the generator assembly is situated in a relatively hot portion of the turbine engine (e.g., within a tail cone of the turbine engine).

[0016] The integration of the connections described herein beneficially facilitates making the generator assembly as compact as possible, reducing weight and enhancing aerodynamic performance. To facilitate forming the integrated connection described herein, the electrical connection lines of the propulsion engines described herein may be routed through cooling ducts such that the coolant and the electrical connection lines are collocated. Not only does such a configuration facilitate making the integrated connection described herein, but it also provides the additional benefit of the electrical connection lines being cooled by coolant circulating in the cooling duct. Such cooling reduces the need for thermal insulation of the electrical connector lines, further reducing the overall weight of the electronics associated with the generator assembly.

[0017] Moreover, the positioning of the generator assembly described herein (e.g., in an aft portion of the engine proximate to a turbine rear frame) beneficially renders the generator accessible for maintenance and repair while the propulsion engine and generator assembly are installed on an aircraft (e.g., on a wing, on a fuselage, or the like). Additionally, in embodiments, the generator assembly may be positioned within a tail cone of the propulsion engine and be directly accessible for repairs after performance of a non-invasive procedure (e.g., opening of core cowl, removal of aft skin, and

removal tail cone) on the remainder of the propulsion engine. This way, the generator assembly may be efficiently maintained while not disrupting operation of the other components of the propulsion engine. Such non-invasive access to the generator assembly beneficially facilitates maintenance and repair of the generator assembly while the propulsion engine is installed on an aircraft (e.g., on a wing, a fuselage, or the like of the aircraft).

[0018] Referring to FIGS. **1** and **2**, a propulsion engine **100** including an electrical system **102** and a cooling system **110** is schematically depicted. The propulsion engine **100** may take various forms depending on the implementation. In the embodiments described herein, the propulsion engine **100** is a high-bypass turbofan engine. However, other types of turbine engines are contemplated and are within the scope of the present disclosure. As depicted in FIG. **1**, the electrical system **102** includes a generator assembly **300** disposed in an aft portion **104** of the propulsion engine **100**. The aft portion **104** is disposed axially downstream (e.g., in a direction parallel to a central axis A-A of the propulsion engine **100**) of a core portion **220** of the propulsion engine **100**. The generator assembly **300** converts mechanical energy (e.g., generated from exhaust gases generated in the core portion **220**) produced by the propulsion engine **100** into electrical energy that may be used to power electrical devices of the propulsion engine **100** or components disposed elsewhere on an aircraft (including components that incorporate the propulsion engine **100**). As described herein, positioning the generator assembly **300** in the aft portion **104** of the propulsion engine **100** beneficially renders the generator assembly **300** accessible for maintenance, repair, and replacement while the propulsion engine **100** is disposed on an aircraft (e.g., on a wing or fuselage of the aircraft). The generator assembly **300** is designed to be integrated into the propulsion engine **100** via a set of connections that may be removed without invasively disassembling the entirety of the propulsion engine **100** (e.g., removing without detaching the propulsion engine **100** from the aircraft).

[0019] In embodiments, the generator assembly **300** may be attached to an inner hub **226** of a turbine rear frame **222** of the propulsion engine **100** via a generator coupler (not depicted in FIG. **1**) that beneficially collocates connections of the generator assembly **300** between the electrical system **102** and the cooling system **110**. Example embodiments of the structure of the generator assembly **300** are described in greater detail herein with respect to FIGS. **3** and **5** herein. Still referring to FIG. **1**, it should be understood that the depicted arrangement of the propulsion engine **100** is only exemplary is not intended to be limiting. For example, in alternative embodiments, the generator assembly **300** may be disposed axially forward of the core portion **220**.

[0020] Positioning the generator assembly **300** in the aft portion **104** provides accessibility, but creates additional design considerations for the propulsion engine **100**. Exhaust gases generated via the core portion **220** are at relatively high temperatures (e.g., in excess of about 700° C. or more in various embodiments), which renders cooling the generator assembly **300** beneficial. Additionally, the aft portion **104** of the propulsion engine **100** may not be directly connected to an aircraft incorporating the propulsion engine **100**. Given this, to provide the electrical power generated via the generator assembly **300** to other portions of the aircraft, the electrical power is routed to a different portion propulsion engine **100**.

[0021] In view of the foregoing, the electrical system **102** includes a connection assembly **108** that is routed through the cooling system **110**. The connection assembly **108** includes a plurality of electrical connector lines (e.g., power cables) that conductively connect the generator assembly **300** to a converter **112**. For example, the generator assembly **300** may generate an alternating current (“AC”) power signal via the mechanical energy generated via the remainder of the propulsion engine **100** that is provided to the converter **112** via the connection assembly **108**. While the converter **112** is depicted in FIG. **1** as being disposed in a forward position within the propulsion engine **100**, it should be understood that, in embodiments, the converter **112** may be disposed in a central portion (e.g., extending radially outward of the core portion **220**) or the aft portion **104** of the propulsion engine **100**. In embodiments, the converter **112** may be disposed externally to the

propulsion engine **100** (e.g., in a pylon or elsewhere in the aircraft). In embodiments, the converter **112** may be disposed within the cooling system **110** (e.g., in any of the cooling ducts **122**, **124**, and **126** described herein) such that the connection assembly **108** (or a portion thereof) routes a converted DC power signal.

[0022] Still referring to FIG. **1**, the converter **112** may generate DC output voltages from the AC power signal to provide DC power for alternative locations on the aircraft (e.g., via an electrical communications bus, not depicted). The structure of the converter **112** and connection assembly **108** may vary depending on the structure and capabilities of the generator assembly **300**. For example, in various embodiments, the generator assembly **300** may generate an AC power signal having any number of phases (e.g., one phase, two phases, three phases, four phases, etc.). The connection assembly **108** may include a plurality of sets of electrical connector lines, with each set of electrical connector lines including a number of electrical connector lines that corresponds to the number of phases in the AC power signal generated via the generator assembly **300**. The number of sets of electrical connector lines of the connection assembly **108** may vary depending on the implementation. Incorporating a number of different sets of electrical connector lines in the connection assembly **108** beneficially provides electrical connection redundancies that facilitate provision of the AC power signal to the converter **112** even if one of the sets of the electrical connector lines fails during operation.

[0023] Referring still to FIG. **1**, the cooling system **110** routes cooling air (e.g., from a bypass section **116** disposed radially outward of the core portion **220**) to the generator assembly **300** to maintain the generator assembly **300** in a temperature range despite the generator assembly **300** being disposed proximate to high temperature exhaust generated via the core portion **220**. In embodiments, the cooling system **110** includes a valve **114** in fluid communication with the bypass section **116**. In embodiments, the valve **114** may be controlled by a controller (not depicted) that may open the valve **114** to allow entry of cooling air into the cooling system **110** during operation of the propulsion engine **100**. The cooling system **110** further includes a bypass cooling duct **118** including a fan **120** that may be controlled via the controller to operate during time periods when the valve **114** is closed such that cooling air may be provided to the generator assembly **300** irrespective of a state of operation of the propulsion engine **100**. Additionally, the converter **112** may be designed to incorporate any number of phases depending on the implementation of the generator assembly **300**.

[0024] In embodiments, the cooling system **110** includes a plurality of different cooling ducts having structures extending in different directions at various positions within the propulsion engine **100**. As depicted, the cooling system **110** includes a main cooling duct **122**, a circumferential cooling duct **124**, and a plurality of generator cooling ducts **126**. In embodiments, the main cooling duct **122**, the circumferential cooling duct **124**, and the plurality of generator cooling ducts **126** possess structures that are dependent on positioning within the propulsion engine **100**. In embodiments, the main cooling duct **122**, the circumferential cooling duct **124**, and the plurality of generator cooling ducts **126** are designed to provide adequate space for routing the connection assembly **108** to the generator assembly **300** while minimizing impacts on aerodynamic performance of the propulsion engine **100**. Example embodiments of various cooling ducts, including, but not limited to, the main cooling duct **122**, the circumferential cooling duct **124**, and the plurality of generator cooling ducts **126** are described in more detail herein with respect to FIGS. **6A**, **6B**, and **6C**.

[0025] Referring still to FIG. **1**, the main cooling duct **122** receives cooling air from the valve **114** and directs the cooling air towards the aft portion **104** where the generator assembly **300** is disposed. The circumferential cooling duct **124** divides the cooling air into circumferential portions and directs the cooling air in a circumferential direction around an outer casing **228** of the turbine rear frame **222**. In embodiments, the plurality of generator cooling ducts **126** divide each circumferential portion of the cooling air into cooling portions that are provided to the generator

assembly **300** via struts **224** of the turbine rear frame **222**. In embodiments, the cooling system **110** may include any number of generator cooling ducts **126**. In some embodiments, the number of generator cooling ducts **126** may correspond to a number of the plurality of struts **224** of the turbine rear frame **222** through which coolant is provided to the generator assembly **300**. As should be understood in view of the description of the turbine rear frame **222** contained herein, the number of the plurality of struts **224** through which coolant is provided to the generator assembly **300** may vary depending on the implementation. For example, in embodiments, coolant may be provided to the generator assembly **300** through at least two of the plurality of struts **224** (e.g., two, four, six, or eight of the plurality of struts). In such embodiments, the cooling system **110** may include a corresponding number of generator cooling ducts **126** that provide coolant into a corresponding strut of the turbine rear frame **222**.

[0026] In embodiments, the generator cooling ducts **126** extend through the struts **224** into a generator coupler (not depicted in FIG. 1) in fluid communication with the generator assembly **300** to cool the generator assembly **300**. An example embodiment of the generator coupler is described herein with respect to FIGS. 3 and 4A herein. In embodiments, each of the generator cooling ducts **126** attach to a radially outer end **234** of one of the struts **224** to provide cooling air into an internal cavity defined by the strut to which that generator cooling duct **126** is attached.

[0027] As depicted in FIG. 1, the electrical connector lines of the connection assembly **108** extend through the main cooling duct **122**, the circumferential cooling duct **124**, the plurality of generator cooling ducts **126** and the struts **224** of the turbine rear frame **222** to conductively connect the converter **112** to the generator assembly **300**. In embodiments, various sets electrical connector lines of the electrical connection assembly **108** extend through different combinations of cooling ducts of the cooling system **110** to connect different portions (e.g., terminations) of the generator assembly **300** to the converter **112**. For example, a first subset of electrical connector lines **128** may be directed through a first portion of the circumferential cooling duct **124** and a second subset of electrical connector lines **130** may be directed through a second portion of the circumferential cooling duct **124**. The first and second subsets of electrical connector lines **128** and **130** may be further divided such that baseline sets of electrical connector lines **132** are routed through each generator cooling duct **126**, through one of the struts **224**, and into a generator coupler for electrical connection to the generator assembly **300** described herein.

[0028] FIG. 2 depicts a sectional view of the propulsion engine **100** depicted in FIG. 1 taken above the central axis A-A. The propulsion engine **100** includes a fan **201**, a low pressure compressor **202**, a high pressure compressor **204**, and a combustor **206**, which mixes air compressed via the high pressure compressor **204** with fuel for generating combustion gases that flow downstream through a high pressure turbine **208** and a low pressure turbine **210** to generate pressurized exhaust. A first shaft **212** joins the high pressure compressor **204** to the high pressure turbine **208**. A second shaft **216** joins the low pressure turbine **210** to the fan **201** and the low pressure compressor **202**. In embodiments, the high pressure compressor **204**, the combustor **206**, and the high pressure turbine **208** may collectively form the core portion **220**. The core portion **220** may generate combustion gases that are channeled to the low pressure turbine **210**, which in turn powers the fan **201** via the second shaft **216**. The low pressure turbine **210** may include a plurality of rows of blades that rotate in response to the combustion gases from the core portion **220** and thereby cause the second shaft **216** to rotate, thereby powering the fan **201**, low pressure compressor **202**, and the generator assembly **300**.

[0029] The turbine rear frame **222** is disposed aft of the low pressure turbine **210** (e.g., offset from the low pressure turbine **210** in an aft direction **270** extending parallel to the central axis A-A). The turbine rear frame **222** includes a plurality of struts **224** extending between an inner hub **226** and an outer casing **228**. The turbine rear frame **222** provides an exhaust flow path for exhaust flowing from the low pressure turbine **210**. The inner hub **226** and the outer casing **228** may circumferentially surround the second shaft **216** and the plurality of struts **224** may be distributed

around the second shaft **216**. In embodiments, the plurality of struts **224** function as outlet guide vanes to straighten the exhaust airflow, which may flow over a tail cone **230** to improve performance of the propulsion engine **100**. It should be understood that the turbine rear frame **222** may include any number of struts **224** in any arrangement consistent with the present disclosure.

[0030] Referring still to FIG. 2, the propulsion engine **100** includes a core cowl **250** and an aft skin **252**. The core cowl **250** delineates a flow path air compressed by the fan **201**. In embodiments, the aft skin **252** is connected to the outer casing of the turbine rear frame **222** via a bolted connection **260**. In embodiments, exhaust exits the propulsion engine via an outlet **254** defined by the turbine rear frame **222**, the aft skin **252**, and the tail cone **230**. In embodiments the core cowl **250** includes a hinge or the like such that the core cowl **250** may be opened with respect to the aft skin **252**.

[0031] Referring now to FIG. 3, a detailed view of the generator assembly **300** depicted in the dashed boundary of FIG. 2 is shown. The generator assembly **300** includes a stator assembly **302** including a stator **314** and a rotor assembly **304** including a rotor **346**. The rotor assembly **304** includes a rotor support structure **338** that is attached to the second shaft **216** via a locking nut **344**. In embodiments, the rotor support structure **338** includes an attachment element (e.g., a groove, protrusion, or the like, which is not depicted) that slidably engages with a corresponding attachment element on the second shaft **216**. For example, in embodiments, the rotor support structure **338** may slidably engage with the second shaft **216** at an aft end **217** of the second shaft **216**. The locking nut **344** may secure the rotor support structure **338** to the second shaft **216** such that the rotor assembly **304** rotates in conjunction with the second shaft **216** to facilitate generation of electrical power via the rotation of the second shaft **216**.

[0032] The rotor assembly **304** further includes a rotor attachment arm **340** attached to the rotor support structure **338** via a bolt **342**. The rotor attachment arm **340** maintains the rotor **346** in spaced relation to the stator **314**. In embodiments, the rotor **346** comprises a plurality of permanent magnets circumferentially distributed about the stator **314** such that rotation of the rotor **346** about the stator **314** generates an AC power signal. It should be understood that alternative configurations for the rotor **346** are envisioned depending on the implementation of the generator assembly **300**. For example, in embodiments, the rotor **346** may include a plurality of electromagnets and active circuitry. Various implementations are envisioned wherein the generator assembly **300** is configured as an induction type generator, a switched reluctance generator, an asynchronous AC electrical machine, or any suitable type of electric generator.

[0033] The stator assembly **302** is attached to an engine stator component (e.g., a turbine frame, such as the turbine rear frame **222**). The stator assembly **302** includes a stator support assembly **308** that includes a mounting flange **310** that is coupled to the a bearing housing **240** of the bearing assembly **306** via a connection bolt (not depicted). The inner hub **226** of the turbine rear frame **222** supports the second shaft **216** via a support structure **236** and a bearing support **370** extending radially outward from the second shaft **216**. As depicted, the inner hub **226**, the support structure **236**, and the bearing support **370** delineate a substantially annular-shaped coupling cavity **238** for coupling the generator assembly **300** to the struts **224** of the turbine rear frame **222**. As shown, the bearing housing **240** is attached to both the support structure **236** and the mounting flange **310** of the stator support assembly **308**. Integrating the connections of the turbine rear frame **222** and the stator support assembly **308** beneficially saves space and reduces the overall weight of the generator assembly **300**.

[0034] The stator assembly **302** further includes a stator support structure **312** on which a stator **314** of the generator assembly **300** is disposed. In embodiments, the stator support structure **312** comprises a stator support surface **313** and a liquid cooling jacket **315** (e.g., an oil cooling jacket). Still referring to FIG. 3, in embodiments, the stator **314** includes a plurality of windings conductively connected to an electrical connector **336**. While the stator **314** is depicted to be disposed radially inward from the rotor assembly **304**, it should be appreciated that alternative embodiments are envisioned where substantially the entirety of the stator assembly **302** (e.g.,

including the stator **314**) is disposed radially outward relative to the rotor assembly **304**.

[0035] The stator assembly **302** further includes a cooling manifold **316** coupled to the stator support assembly **308** at the mounting flange **310**. As depicted, the stator support assembly **308** generally extends in the aft direction **270** from the mounting flange **310** to define the stator support surface **313**. The cooling manifold **316** extends in the fore direction (e.g., opposite to the aft direction **270**) from the mounting flange **310**. The cooling manifold **316** includes a connection end **324** extending substantially in the radial direction to define a coolant cavity **317** through which the generator assembly **300** is fluidly coupled to the cooling system **110** and conductively coupled to remainder of the electrical system **102** described herein. The cooling manifold **316** includes an aft portion **325** extending toward the aft direction **270** from the connection end **324** to a mounting flange **320**. As depicted, a connection bolt **327** extends through the mounting flange **320**, a connection tab **322** extending from the inner hub **226** of the turbine rear frame **222**, and a thermal shield **348** of the generator assembly **300**. In embodiments, the thermal shield **348** does not directly attach to the second shaft **216** but rather circumferentially surrounds the aft end **217** of the second shaft **216**, the stator assembly **302**, and the rotor assembly **304**. As such, the cooling manifold **316** and the thermal shield **348** are connected to the turbine rear frame **222** via a single connection point (via a plurality of connection bolts **327** extending around the circumference of the mounting flange **320**). Such an integrated connection beneficially facilitates efficient maintenance of the generator assembly **300**, particularly in embodiments where the propulsion engine **100** (FIG. 2) is located on an aircraft (e.g., installed on a wing or fuselage). That is, the integrated connection allows for access to the generator assembly **300** without removal of the propulsion engine **100** (FIG. 2) from an aircraft.

[0036] Still referring to FIG. 3, the stator assembly **302** further includes a coolant guide **318** attached the mounting flange **320**. The coolant guide **318** may guide coolant received via the cooling manifold **316** to the rotor **346** and stator **314**. The coolant guide **318** defines a connection cavity **329** housing a connection device **326** that receives the electrical connector **336**. The coolant guide **318** is also coupled to the inner hub **226** and the aft portion **325** of the cooling manifold **316** via the connection bolt **327**. The connection device **326** is an electrical coupler configured to create a conductive connection between the electrical connector **336** attached to the stator **314** and electrical connector lines **350**, **352**, **354** extending through the one of the struts **224** of the turbine rear frame **222**. As depicted, the connection device **326** includes a first portion **328** (e.g., a female port receiving conductors of the electrical connector **336** or a male port engaging with the electrical connector **336**) disposed in the connection cavity **329** and a second portion **330** extending between the cooling manifold **316** and a generator coupler **332**. The generator coupler **332** routes coolant and the electrical connection lines **350**, **352**, and **354** extending through one of the struts **224** towards the cooling manifold **316** for connection to the generator assembly **300**. The structure of the generator coupler **332** will be described in more detail herein with respect to FIG. 4A.

[0037] Having described various components of the generator assembly **300** and the propulsion engine **100**, various advantages of the structures described with respect to FIGS. 2 and 3 can now be appreciated. For example, referring to FIG. 2, a process of removing the generator assembly **300** from the propulsion engine **100** may include a first step of opening the core cowl **250** via a hinged portion of thereof to facilitate access to the turbine rear frame **222**. The aft skin **252** may then be removed via the bolted connection **260** with the outer casing **228** of the turbine rear frame **222**. The tail cone **230** may then be removed via a single bolted connection (e.g., to the inner hub **226**) to render the generator assembly **300** entirely accessible.

[0038] Referring to FIG. 3, after removal of the tail cone **230**, the thermal shield **348** may then be removed by removing the connection bolts **327**, which also decouples outward ends of the cooling manifold **316** and the coolant guide **318** from the inner hub **226**. After removal of the thermal shield **348**, the locking nut **344** may then be disengaged from the second shaft **216** to allow the entire rotor assembly **304** to be slid off the second shaft **216** to provide access to the stator



assembly **302**. After this, a fastener may be removed that couples the mounting flange **310** to the bearing housing **240**, enabling the entire stator assembly **302** (including the cooling manifold **316**) to be removed from the propulsion engine **100** in the aft direction **270** (e.g., after oil lines supplying oil to the generator assembly **300** from a lubrication system are removed). As such, removal of the entire generator assembly **300** from the propulsion engine **100** may occur in only six steps without disturbing any mechanical couplings of other components of the propulsion engine **100** other than the tail cone **230** and core cowl **250**.

[0039] The manner with which the generator assembly **300** is positioned and connected within the propulsion engine **100** thus facilitates access and removal of the generator assembly **300** without removing any components of the propulsion engine **100** that are disposed forward (e.g., the opposite of the aft direction **270**) or radially-inward of the turbine rear frame **222**. Accessing the generator assembly **300** in such a non-invasive manner facilitates maintenance or replacement of various components of the generator assembly **300** while the propulsion engine **100** is disposed on a wing or fuselage of an aircraft, which minimizes time that the aircraft may be out of commission if the generator assembly **300** needs repairs. Furthermore, the manner with which the generator assembly **300** is connected to various components of the propulsion engine **100** provides for a streamlined process for removal of the generator assembly **300** from the propulsion engine **100**.

[0040] FIG. **4A** depicts a perspective view of the turbine rear frame **222** described herein with respect to FIGS. **1**, **2**, and **3**, according to an example embodiment. In the example shown, electrical connections between the generator assembly **300** (not depicted in FIG. **4A**) are established through multiple ones of the plurality of struts **224** of the turbine rear frame **222**. A first strut **412** routes a first set of electrical connector lines **420**, a second strut **414** routes a second set of electrical connector lines **422**, a third strut **416** routes a third set of electrical connector lines **424**, and a fourth strut **418** routes a fourth set of electrical connector lines **426**. The electrical connector lines **350**, **352**, and **354** described with respect to FIG. **3** make up the first set of electrical connector lines **420**. In embodiments, the first, second, third, and fourth sets of electrical connector lines **420**, **422**, **424**, and **426** are each routed through a separate one of the generator cooling ducts **126** described herein with respect to FIG. **1**. It should be understood that the embodiment depicted in FIG. **4A** is exemplary only and is not intended to be limiting. For example, embodiments where different numbers of the plurality of struts **224** are used to route electrical connector lines are envisioned. Moreover, the struts of the plurality of struts **224** used to route electrical connector lines may include differing numbers and types of electrical connector lines. For example, in embodiments, some of the plurality of struts **224** may include power cables (e.g., for the power signal(s) generated via the generator assembly **300**), while other struts of the plurality of struts **224** may include signal cables (e.g., routing temperature signals generated via a temperature sensor such as a thermocouple of the generator assembly **300**, or velocity signals generated via a velocity sensor of the generator assembly **300**). As will be understood, the signal cables and the power cables may differ in size based on the different signals contained therein.

[0041] As depicted in FIG. **4A**, the first, second, third, and fourth struts **412**, **414**, **416**, and **418** that route electrical connector lines to the generator assembly **300** are not adjacent to one another. That is, the plurality of struts **224** includes struts disposed between the first, second, third, and fourth struts **412**, **414**, **416**, and **418**. Such an arrangement may avoid restricting the exhaust flow path of the turbine rear frame **222**, as the first, second, third, and fourth struts **412**, **414**, **416**, and **418** (or any strut used to route electrical connector lines) may have a different cross-sectional area than other types of struts included in the plurality of struts **224**. For example, in addition to struts having a structure described herein with respect to FIG. **4B** to route electrical connector lines, the plurality of struts **224** may include service struts that contain service piping (e.g., oil pipes, drain pipes) that are smaller than the struts used to route electrical connector lines. In embodiments, the plurality of struts also includes structural struts that are still smaller than the service struts. The plurality of struts **224** may include any number of each of these types (or any other type of strut) arranged in

any manner.

[0042] Referring to FIGS. 3 and 4A, the generator coupler 332 is disposed at a first circumferential region of the inner hub 226 of the turbine rear frame 222. As depicted in FIG. 4A, the generator coupler 332 overlaps with the first strut 412 and the second strut 414 in a radial direction such that the generator coupler 332 routes the first and second sets of electrical connector lines 420 and 422 in the aft direction for connection with the generator assembly 300. The generator coupler 332 includes a first coolant opening 432 and a second coolant opening 434. In embodiments, the first and second coolant openings 432 and 434 may correspond in shape to coolant openings of the cooling manifold 316 (e.g., at the connection end 324) described with respect to FIG. 3. Ends of the connections lines 350, 352, and 354 protrude from the generator coupler 332 for mating with the second portion 330 of the connection device 326. A second generator coupler 428 is disposed at a second circumferential region of the inner hub 226. The second generator coupler 428 radially overlaps the third strut 416 and the fourth strut 418 to guide the third and fourth sets of electrical connector lines 424 and 426 towards the generator assembly 300.

[0043] The first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426 may each carry a separate portion of the power signal generated by the generator assembly 300 and transmitted through the electrical connector 336 (see FIG. 3). The electrical connector 336 may include any number of electrical conductors (or the generator assembly 300 may include any number of electrical connectors 336) to route various portions of the power signal generated via the generator assembly 300 through the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426. As used herein, the “electrical conductor” refers to a conductive portion of an electrical connector line. For example, a power cable may include an electrical conductor and a cover portion providing insulation, electrical shielding, and thermal protection. An electrical connector line may include any number of electrical conductors. In embodiments, each electrical connector line of the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426 is coupled to a separate one of the electrical conductors contained in the electrical connector 336 (e.g., via a separate port in a connection device 326) to route a different portion of the power signal to the converter 112. In embodiments, each portion of the power signal routed by a separate one of the electrical connector lines corresponds to a different phase of the power signal generated by the generator assembly 300.

[0044] Still referring to FIG. 4A, in embodiments, each phase of the power signal generated by the generator assembly 300 is divided into different portions that is routed through each one of the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426. In embodiments, the generator assembly 300 includes a plurality of electrical connectors 336 (e.g., six electrical connectors 336), with each electrical connector 336 carrying a single phase (e.g., sets of three of the electrical connectors 336 may each route a three phase power signal to one of the generator couplers 428 and 432). The generator couplers 428 and 432 may divide each three phase power signal in half (e.g., via six electrical connector lines disposed therein) to route each phase through each of the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426. The connections may be arranged such that each of the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426 receives all three phases of the power signal, such that each phase is routed up each of the first, second, third, and fourth struts 412, 414, 416, and 418. Such a connection redundancy ensures that each phase of the power signal will be provided to the converter 112 even if one, two, or even three of the sets of the electrical connections between the generator assembly 300 and the first, second, third, and fourth sets of electrical connector lines 420, 422, 424, and 426 fail. Additionally, dividing the power signals into multiple portions allows for greater flexibility in the type of electrical connector lines that may be used. For example, by dividing the power signals, thinner electrical connector lines may be used to facilitate routing of the electrical connector lines through the turbine rear frame 222.

[0045] As depicted in FIG. 4A, the radially outer ends 234 of the first, second, third, and fourth

struts **412**, **414**, **416**, and **418** include openings to be coupled to the generator cooling ducts **126** described herein with respect to FIG. **1**. Each of the first, second, third, and fourth sets of electrical connector lines **420**, **422**, **424**, and **426** may be routed through a separate one of the generator cooling ducts **126**, through a portion of circumferential cooling duct **124**, and into the main cooling duct **122** described with respect to FIG. **1**. The main cooling duct **122** routes the first, second, third, and fourth sets of electrical connector lines **420**, **422**, **424**, and **426** to the converter **112** for conversion to DC voltage.

[0046] FIG. **4B** depicts a cross sectional view of the first strut **412** of the turbine rear frame **222** depicted in FIG. **4A**. As depicted, the strut **412** is substantially hollow. For example, in embodiments, the strut **412** is constructed from an outer layer **448** having a wall thickness. In embodiments, a cooling duct **450** extends through the strut **412** to separate an internal volume of the strut **412** into an inner cavity **452** defined by the cooling duct **450** and an outer cavity **454** extending between the cooling duct **450** and the outer layer **448**. The cooling duct **450** routes coolant (e.g., from the generator cooling ducts **126** described herein with respect to FIG. **1**) from the cooling system **110** to the generator coupler **332**. The electrical connector lines **350**, **352**, and **354** extend through the coolant cooling duct **450** and are routed through the generator coupler **332** to connect to the connection device **326** to conductively connect the stator **314** to the converter **112** described with respect to FIG. **1**. In embodiments, a portion of return coolant from the generator assembly **300** (e.g., after circulation through the generator assembly **300**) may be routed through the outer cavity **454** for expulsion from the cooling system **110**. In embodiments, another portion (e.g., a majority) of such return coolant from the generator assembly **300** may be routed through openings in the tail cone **230** via perforations (not depicted) formed in the generator assembly **300** (e.g., in the connection tab **322** described with respect to FIG. **3**).

[0047] FIG. **5** depicts a cross-sectional view of a portion of the stator assembly **302**. As depicted, the cooling manifold **316** includes a first coolant opening **500** for receiving coolant traveling through one of the struts **224**. The first coolant opening **500** may correspond in shape to the first coolant opening **432** of the generator coupler **332** described with respect to FIG. **4A**. Still referring to FIG. **5**, in embodiments, the cooling manifold **316** also includes a second coolant opening **502** for providing coolant air to the generator assembly **300**.

[0048] The second portion **330** of the connection device **326** includes a plurality of ports **506** for receiving ends of the electrical connector lines **350**, **352**, and **354**. It should be understood that the configuration of the connection device **326** will vary depending on the mode of operation and the capabilities of the generator assembly **300**. For example, depending on a number of phase windings of the stator **314** and the variable rotational speed of the rotor **346**, the generator assembly **300** may generate an AC power signal having variable frequency. In embodiments, the electrical connector **336** (not depicted in FIG. **5**) extending through the coolant guide **318** may include a number of separate electrical conductors or cables that corresponds to the number of phases in the AC power signal, and the second portion **330** of the connection device **326** includes a number of ports **506** corresponding to that number of phases. In embodiments, multiple electrical connectors **336** extend from various different circumferential portions of the stator **314**, and each one of the electrical connectors **336** may contain a portion of the phases in the AC power signal. Different ones of the electrical connectors **336** may be routed to different connection devices coupled to different generator couplers, as described with respect to FIG. **4A**.

[0049] Referring to FIG. **6A**, a cross-sectional view of the main cooling duct **122** described herein with respect to FIG. **1** is depicted. The main cooling duct **122** includes an insulation layer **602** disposed around a core **604**. The insulation layer **602** thermally insulates the core **604** to prevent heating of air disposed in an internal cavity **606** defined by the core **604**. In the example depicted, the core **604** possesses a substantially elliptical cross-section (e.g., a substantially circular cross section), through it should be appreciated that any shape can be used. Moreover, it should be appreciated that the size and shape of the main cooling duct **122** may vary depending on the

implementation and available space within the propulsion engine **100**.

[0050] A plurality of electrical connector lines **614** are routed through the main cooling duct **122**. The plurality of electrical connector lines **614** may correspond to the electrical connector lines of the connection assembly **108** described herein with respect to FIG. **1**. In embodiments, the plurality of electrical connector lines **614** are each a separate power cable including electrical shielding. The plurality of electrical connector lines **614** are routed through the main cooling duct **122** via a support bracket **608**. The support bracket **608** includes a plurality of support arms **610** attached to the core **604**. The support arms **610** extend inward from the core **604** and support a body **612** of the support bracket **608** within the internal cavity **606**. The support arms **610** beneficially prevent contact between the body **612** and the core **604** such that air may be routed around the body **612** to cool the entirety of the body **612**. The body **612** includes openings **616** through which the plurality of electrical connector lines **614** extend. Because the body **612** is supported within the internal cavity **606** and cooled on all sides, the electrical connector lines **614** are also maintained at a lower temperature than if the electrical connector lines **614** were not routed through the main cooling duct **122**. As such, the support brackets **608** facilitate using electrical connector lines **614** that are smaller and include less thermal shielding, reducing the overall weight of the electrical system **102**.

[0051] As depicted, the support bracket **608** supports 12 different electrical connector lines **614**. The openings **616** in the body **612** may be arranged based on the manner with which the electrical connector lines **614** are routed through the cooling system **110**. For example, as depicted, the openings **616** are arranged in four groupings of three, with each grouping corresponding to a set of electrical connector lines that is eventually separated within the cooling system **110** (e.g., in a manner similar to the first, second, third, and fourth sets of electrical connector lines **420**, **422**, **424**, and **426** described herein with respect to FIG. **4A**). It should be understood that various alternative routing schemes are envisioned based on the implementation. For example, certain embodiments may utilize power cables containing a plurality of electrical conductors (rather than each power cable containing a single electrical conductor, as depicted in FIG. **6A**).

[0052] In embodiments, the support bracket **608** only partially extends through the main cooling duct **122** and the plurality of electrical connector lines **614** are supported within the main cooling duct **122** at a plurality of discrete locations throughout the main cooling duct **122** via a plurality of the support brackets **608**. Positioning a plurality of the support brackets **608** throughout the main cooling duct **122** may beneficially maintain the plurality of electrical connector lines **614** in a central region of the internal cavity **606** to facilitate coolant being evenly distributed around the body **612**. Such a coolant distribution maintains each of the plurality of electrical connector lines at a cool temperature. Maintaining a positioning of the plurality of electrical connector lines **614** within a central region the internal cavity **606** also prevents contact between the plurality of electrical connector lines **614** and the core **604** to prevent wear and heating of the plurality of electrical connector lines **614**.

[0053] Still referring to FIG. **6A**, the body **612** of the support bracket **608** further includes a central opening **617** not containing an electrical connector line. The central opening **617** allows coolant to flow through a central region of the support bracket **608** and reduces disruptions of coolant flow caused by the support bracket **608**. Additionally, the central opening **617** beneficially allows coolant to flow proximate to electrical connector lines of the plurality of electrical connector lines **614** that are centrally disposed within the body **612**, and thus displaced from direct contact with coolant flowing around an external surface of the body **612**.

[0054] FIG. **6B** depicts a cross-sectional view of the circumferential cooling duct **124** described herein with respect to FIG. **1**. The example depicted includes an insulation layer **618** and a core **620**. The core **620** defines an internal cavity **622**. The circumferential cooling duct **124** may have a different cross-section than the main cooling duct **122** described with respect to FIG. **6A** due to space constraints in the region of the propulsion engine **100** where the circumferential cooling duct **124** is disposed. Such a different size and shape of the circumferential cooling duct **124** may

necessitate a different support bracket structure for electrical connector lines extending therethrough. In embodiments, the circumferential cooling duct **124** may have the same or similar cross-section as the main cooling duct **122**.

[0055] As depicted in FIG. **6B**, a plurality of electrical connector lines **624** (e.g., corresponding to a subset of the electrical connector lines **614** described with respect to FIG. **6A**) are supported within the internal cavity **622** via a support bracket **625**. The support bracket **625** includes a body **626** and support arms **628** attached to the core **620** and supporting the body **626** within the internal cavity **522**. Similar to the support bracket **608** described with respect to FIG. **6A**, the body **626** may include a plurality of openings **630** for receiving the plurality of electrical connector lines **624** that are arranged based on a manner with which the plurality of electrical connector lines **624** are routed through a remainder of the cooling system **110** (e.g., the way the plurality of electrical connector lines **624** are divided between the generator cooling ducts **126**).

[0056] Referring now to FIG. **6C**, a cross-sectional view of one of the generator cooling ducts **126** described with respect to FIG. **1** is shown. The example depicted includes an insulation layer **632** and a core **634**. The core **634** defines an internal cavity **636**. The generator cooling duct **126** may have a different cross-section than the circumferential cooling duct **124** described with respect to FIG. **6B** due to space constraints in the region of the propulsion engine **100** where the generator cooling duct **126** is disposed. Such different size and shape of the generator cooling duct **126** may necessitate a different support bracket structure for electrical connector lines extending therethrough. In embodiments, the generator cooling ducts **126** may have the same or similar cross-section as the circumferential cooling duct **124**.

[0057] As depicted in FIG. **6C**, a plurality of electrical connector lines **638** (e.g., corresponding to a subset of the electrical connector lines **624** described with respect to FIG. **6B**) are supported within the internal cavity **636** via a support bracket **640**. The support bracket **640** includes a body **642** with attachment points **644** that connect to the core **634**. Unlike the support bracket **625** described with respect to FIG. **6B**, the support bracket **640** does not include support arms to facilitate mounting within the smaller generator cooling ducts **126** while still providing adequate clearance for coolant flow. The support bracket **640** may include support arms in alternative embodiments. In embodiments, the plurality of electrical connector lines **638** depicted in FIG. **6C** corresponds to a set of electrical connector lines that is routed through one of the struts **224** of the turbine rear frame **222** (e.g., corresponding to one of the first, second, third, and fourth sets of electrical connector lines **420**, **422**, **424**, and **426** described herein with respect to FIG. **4A**).

[0058] In view of the foregoing description, it should be appreciated that collocating an electrical connection and a coolant connection of a generator assembly to a propulsion engine facilitates a compact design for the generator assembly while providing numerous other benefits. For example, routing electrical connector lines conductively connected to the generator assembly through cooling ducts facilitates cooling of the electrical connector lines, thereby facilitating weight savings by reducing thermal insulation requirements for the electrical connector lines. Such weight savings are further enhanced in embodiments where the generator assembly is disposed in an aft portion of the propulsion engine and the electrical connector lines axially extend through the propulsion engine. Such positioning of the generator assembly in the aft portion beneficially renders the generator assembly accessible for maintenance and repair while the propulsion engine is installed on a wing or fuselage of an aircraft. Moreover, the collocated connections described herein facilitate efficient removal and replacement of the components of the generator assembly by requiring a relatively small number of connections to be removed as compared to existing structures not including the collocated connections described herein.

[0059] As used herein, the term “about” means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art. When the term “about” (or

“substantially” or “approximately”) is used in describing a value or an end-point of a range, the specific value or end-point referred to is comprised. Whether or not a numerical value or end-point of a range in the specification recites “about,” two embodiments are described: one modified by “about,” and one not modified by “about.” It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. For example, the approximating language may refer to being within a 1, 2, 4, 10, 15, or 20 percent margin in either individual values, range(s) of values and/or endpoints defining range(s) of values.

[0060] Directional terms as used herein—for example up, down, right, left, front, back, top, bottom—are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0061] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order, nor that with any apparatus specific orientations be required. Accordingly, where a method claim does not actually recite an order to be followed by its steps, or that any apparatus claim does not actually recite an order or orientation to individual components, or it is not otherwise specifically stated in the claims or description that the steps are to be limited to a specific order, or that a specific order or orientation to components of an apparatus is not recited, it is in no way intended that an order or orientation be inferred, in any respect. This holds for any possible non-express basis for interpretation, comprising: matters of logic with respect to arrangement of steps, operational flow, order of components, or orientation of components; plain meaning derived from grammatical organization or punctuation, and; the number or type of embodiments described in the specification.

[0062] As used herein, the singular forms “a,” “an” and “the” comprise plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a” component comprises aspects having two or more such components, unless the context clearly indicates otherwise.

[0063] Further aspects of the invention are provided by the subject matter in the following clauses:

[0064] 1. A generator assembly comprises a stator assembly coupled to an engine stator component of a propulsion engine, the stator assembly comprising: a stator support structure fixedly attached to the engine stator component; a stator disposed on a supporting surface of the stator support; a manifold coupled to the stator support, the manifold defining a connection volume and comprising at least one coolant opening at a connection end of the manifold; and an electrical connector extending between the stator and a connection device disposed on the connection end; and a rotor assembly comprising a rotor support structure connected to a shaft of the propulsion engine and a rotor attached to the rotor support structure, wherein the rotor rotates in conjunction with the shaft to generate a power signal that travels through the electrical connector to the connection device.

[0065] 2. The generator assembly of any preceding clause, further comprising a cooling duct in fluid communication with a coolant supply and a generator coupler connecting the stator assembly to the cooling duct, wherein the generator coupler includes an opening in fluid communication with the coolant opening of the manifold such the coolant from the coolant supply is provided into the connection volume via the generator coupler.

[0066] 3. The generator assembly of any preceding clause, further comprising an electrical conductor extending through the cooling duct and the generator coupler to the connection device such that the electrical conductor is conductively connected to the electrical connector via the connection device.

[0067] 4. The generator assembly of any preceding clause, wherein a plurality of electrical conductors extend through the cooling duct and the generator coupler to the connection device such that each of the electrical conductors is conductively connected to the electrical connector and the power signal is provided to the plurality of electrical conductors via the connection device.

[0068] 5. The generator assembly of any preceding clause, wherein a number of electrical conductors in the plurality of electrical conductors corresponds to a number of phases in the power

signal.

[0069] 6. The generator assembly of any preceding clause, wherein the engine stator component comprises a turbine frame comprising a strut, wherein the cooling duct extends through the strut into the generator coupler, wherein the strut comprise an airfoil or vane.

[0070] 7. The generator assembly of any preceding clause, wherein the generator coupler is attached to an inner hub of the turbine frame.

[0071] 8. The generator assembly of any preceding clause, wherein the manifold comprises an opening creating fluid communication between the connection volume and at least one of the rotor, the stator, the rotor support structure, and the stator support structure.

[0072] 9. A propulsion engine comprises a core portion generating exhaust that travels in an axial direction; a turbine section coupled to a shaft, wherein the turbine section receives the exhaust and generates mechanical energy to rotate the shaft; a turbine frame attached to the turbine section, the turbine frame comprising an outer casing coupled to the turbine section; an inner hub supporting the shaft via a bearing assembly; and a plurality of struts extending between the outer casing and the inner hub, wherein at least one strut of the plurality of struts defines an internal cavity having a cooling duct disposed therein; and an electrical system comprising: a generator assembly coupled to the shaft and to the inner hub via a generator coupler; and an electrical connector line extending through the cooling duct and the generator coupler to a connection device electrically coupled to the generator assembly, wherein the generator assembly comprises a manifold that includes a coolant opening to receive coolant from the cooling duct via the generator coupler, wherein the plurality of struts may comprise an airfoil or vane.

[0073] 10. The propulsion engine of any preceding clause, wherein the electrical system comprises a plurality of electrical connector lines extending through the cooling duct and the generator coupler to the connection device.

[0074] 11. The propulsion engine of any preceding clause, wherein at least two of the plurality of struts of the turbine rear frame define internal cavities having cooling ducts therein, wherein each of the internal cavities of the at least two of the plurality of struts include electrical connector lines extending therethrough to connect to the generator assembly.

[0075] 12. The propulsion engine of any preceding clause, wherein a first one of the electrical connector lines extends through a first one of the cooling ducts and through a first generator coupler in fluid communication with a first coolant opening in the manifold, wherein a second one of the electrical connector lines extends through a second one of the cooling ducts through a second generator coupler in fluid communication with a second coolant opening in the manifold.

[0076] 13. The propulsion engine of any preceding aspect, wherein a first strut of the at least two of the plurality of struts defining an internal cavity having a cooling duct therein includes a power cable extending therethrough, and a second strut of the at least two of the plurality of struts defining an internal cavity having a cooling duct therein includes a signal cable extending therethrough.

[0077] 14. The propulsion engine of any preceding clause, wherein the generator assembly comprises: a stator assembly coupled to the turbine frame via a bearing housing, the stator assembly comprising a stator support structure fixedly attached to the bearing housing, the stator support structure supporting the manifold; and a rotor assembly comprising a rotor support structure connected to the shaft and a rotor attached to the rotor support such that the rotor assembly is disposed radially outward of the stator assembly.

[0078] 15. The propulsion engine of any preceding clause, wherein the rotor assembly is secured to the shaft via a connection such that the rotor assembly, stator support structure, and manifold are removable from the propulsion engine without removing any components of the propulsion engine that are disposed forward or radially outward of the generator assembly.

[0079] 16. The propulsion engine of any preceding clause, wherein the rotor assembly and the stator assembly are accessible for repair or replacement while the propulsion engine is installed on

an aircraft.

[0080] 17. The propulsion engine of any preceding clause, further comprising a converter for converting a power signal generated by the generator assembly into a DC voltage, the converter conductively connected to the generator assembly via the electrical connector line; and a main cooling duct in fluid communication with a coolant source, the main cooling duct extending at least partly between the converter and the turbine frame, wherein the electrical connector line extends through the main cooling duct into the cooling duct, wherein the electrical connector line is supported within the main cooling duct via a first support bracket and supported within the cooling duct via a second support bracket that is different than the first support bracket.

[0081] 18. A propulsion engine comprises a shaft; an electrical system comprising a generator assembly disposed in the propulsion engine, the generator assembly coupled to the shaft; and an electrical connector line extending from the generator assembly; a cooling system comprising a first cooling duct in fluid communication with a coolant source, wherein the electrical connector line extends through the first cooling duct such that the electrical connector is cooled via coolant from the coolant source; and a first plurality of support structures supporting electrical connector line at a plurality of discrete locations within the first cooling duct, wherein each of the first plurality of support structures contacts an internal surface of the first cooling duct at a plurality of points such that the electrical connector does not directly contact an internal surface of the first cooling duct.

[0082] 19. The propulsion engine of any preceding clause, further comprising: a second cooling duct in fluid communication with the first cooling duct, the second cooling duct having a different cross-sectional area than the first cooling duct, wherein the electrical connector line extends through both the first cooling duct and the second cooling duct; and a second plurality of support structures supporting the electrical connector line at a plurality of discrete locations within the second cooling duct, wherein the second plurality of support structures have a different structure than the first plurality of support structures.

[0083] 20. The propulsion engine of any preceding clause, wherein the electrical connector line comprises a plurality of electrical conductors, wherein each the first plurality of support structures comprises a first plurality of cavities for the plurality of electrical conductors, wherein each the second plurality of support structures comprises a second plurality of cavities for a portion of the plurality of electrical conductors.

[0084] It will be apparent to those skilled in the art that various modifications and variations can be made to the embodiments described herein without departing from the spirit and scope of the claimed subject matter. Thus, it is intended that the specification cover the modifications and variations of the various embodiments described herein provided such modification and variations come within the scope of the appended claims and their equivalents.

## Claims

1. A propulsion engine, comprising: a shaft; an electrical system comprising: a generator assembly disposed in the propulsion engine, the generator assembly coupled to the shaft; and an electrical connector line extending from the generator assembly; a cooling system comprising a first cooling duct in fluid communication with a coolant source, wherein the electrical connector line extends through the first cooling duct such that the electrical connector is cooled via coolant from the coolant source; and a first plurality of support structures supporting electrical connector line at a plurality of discrete locations within the first cooling duct, wherein each of the first plurality of support structures contacts an internal surface of the first cooling duct at a plurality of points such that the electrical connector line does not directly contact an internal surface of the first cooling duct.

2. The propulsion engine of claim 1, further comprising: a second cooling duct in fluid



communication with the first cooling duct, the second cooling duct having a different cross-sectional area than the first cooling duct, wherein the electrical connector line extends through both the first cooling duct and the second cooling duct; and a second plurality of support structures supporting the electrical connector line at a plurality of discrete locations within the second cooling duct, wherein the second plurality of support structures have a different structure than the first plurality of support structures.

**3.** The propulsion engine of claim 2, wherein the electrical connector line comprises a plurality of electrical conductors, wherein each the first plurality of support structures comprises a first plurality of cavities for the plurality of electrical conductors, wherein each the second plurality of support structures comprises a second plurality of cavities for a portion of the plurality of electrical conductors.

**4.** The propulsion engine of claim 1, wherein the first cooling duct comprises an insulation layer disposed around a core of the first cooling duct.

**5.** The propulsion engine of claim 1, wherein the first support structure comprises a support bracket comprising a body through which the electrical connector line extends.

**6.** The propulsion engine of claim 5, wherein the support bracket comprises support arms that extend outward from the body toward an insulation layer disposed around a core of the first cooling duct.

**7.** The propulsion engine of claim 6, wherein the support arms are configured to provide space between the insulation layer and the body of the support bracket.

**8.** The propulsion engine of claim 5, wherein the electrical connector line is one of a plurality of electrical connector lines that extend through the body of the support bracket.

**9.** The propulsion engine of claim 8, wherein the body of the support bracket comprises a plurality of openings, where each of the plurality of electrical connector lines extends through a respective one of the plurality of openings.

**10.** The propulsion engine of claim 9, wherein the body of the support bracket comprises a central opening that is configured to allow coolant to flow through a central region of the support bracket.

**11.** The propulsion engine of claim 8, wherein the first coolant duct is one of a plurality of coolant ducts including a second coolant duct in communication with the first coolant duct, the support bracket being a first support bracket, the second cooling duct comprising a second support bracket through which a subset of the plurality of electrical connector lines extends.

**12.** A propulsion engine, comprising: a shaft; an electrical system comprising: a generator assembly disposed in the propulsion engine, the generator assembly coupled to the shaft; and a plurality of electrical connector lines extending from the generator assembly; a cooling system comprising a first cooling duct in fluid communication with a coolant source, wherein the electrical connector line extends through the first cooling duct such that the electrical connector is cooled via coolant from the coolant source; and a support bracket located in the first cooling duct, the support bracket comprising a body having a plurality of openings through which the plurality of electrical connector lines extends.

**13.** The propulsion engine of claim 12, wherein the support bracket is a first support bracket, the propulsion engine further comprising: a second cooling duct in fluid communication with the first cooling duct, the second cooling duct having a different cross-sectional area than the first cooling duct, wherein the plurality of electrical connector lines extends through both the first cooling duct and the second cooling duct; and a second support bracket supporting the plurality of electrical connector lines within the second cooling duct, wherein the second support bracket having a different structure than the first support bracket.

**14.** The propulsion engine of claim 12, wherein the body comprises one or more attachment points that connect to the first cooling duct.

**15.** The propulsion engine of claim 12, wherein the first cooling duct comprises an insulation layer disposed around a core of the first cooling duct.

- 16.** The propulsion engine of claim 15, wherein the body comprises one or more attachment points that are attached to the insulation layer.
- 17.** The propulsion engine of claim 12, wherein the support bracket comprises support arms that extend outward from the body toward an insulation layer disposed around a core of the first cooling duct.
- 18.** The propulsion engine of claim 17, wherein the support arms are configured to provide space between the insulation layer and the body of the support bracket.
- 19.** The propulsion engine of claim 12, wherein the body of the support bracket extends only partially through the first cooling duct.
- 20.** The propulsion engine of claim 19, wherein the body of the support bracket comprises a central opening that is configured to allow coolant to flow through a central region of the support bracket.
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