United States Patent	12388322
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Molnar, Jr.; Daniel E. et al.

Electric generator behind fan in turbine engine

Abstract

A turbine engine includes a core section comprising at least one compressor and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a core vane assembly coupled to the core section, wherein the core vane assembly comprises a plurality of core vanes configured to modify core fluid flow; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to a vehicle that includes the turbine engine; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of the at least one compressor, wherein the electrical generator comprises: a rotor mechanically rotated via the fan or a shaft that is rotationally coupled to the fan, wherein the rotor rotates about the longitudinal axis; and a stator.

Inventors: **Molnar, Jr.; Daniel E. (Indianapolis, IN), Heeter; Robert W. (Indianapolis, IN), Maners; Brian S. (Indianapolis, IN)**

Applicant: **Rolls-Royce North American Technologies, Inc.** (Indianapolis, IN)

Family ID: **1000008751896**

Assignee: **Rolls-Royce North American Technologies, Inc. (Indianapolis, IN)**

Appl. No.: **18/417938**

Filed: **January 19, 2024**

Prior Publication Data

Document Identifier	Publication Date
US 20240322646 A1	Sep. 26, 2024

Related U.S. Application Data

us-provisional-application US 63492040 20230324

Publication Classification

Int. Cl.: **H02K7/18** (20060101); **F02C7/36** (20060101)

U.S. Cl.:

CPC **H02K7/1823** (20130101); **F02C7/36** (20130101); F05D2220/76 (20130101)

Field of Classification Search

USPC: None

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
3900274	12/1974	Johnston	416/157R	F01D 7/00
4043121	12/1976	Thomas et al.	N/A	N/A
5595474	12/1996	Girard	416/162	B64C 11/44
5867980	12/1998	Bartos	N/A	N/A
6467725	12/2001	Coles et al.	N/A	N/A
7140174	12/2005	Johnson	N/A	N/A
7216475	12/2006	Johnson	N/A	N/A
7246484	12/2006	Giffin, III et al.	N/A	N/A
7395657	12/2007	Johnson	N/A	N/A
7468561	12/2007	Kern et al.	N/A	N/A
7475545	12/2008	Johnson	N/A	N/A
7514810	12/2008	Kern	290/52	F02C 7/32
7631484	12/2008	Giffin et al.	N/A	N/A
7758303	12/2009	Wadia et al.	N/A	N/A
7841163	12/2009	Welch et al.	N/A	N/A
7926290	12/2010	Johnson	N/A	N/A
7952244	12/2010	Colin	N/A	N/A
8492920	12/2012	Huang et al.	N/A	N/A
8522522	12/2012	Poisson	60/39.093	F02K 3/06
8695324	12/2013	Giffin et al.	N/A	N/A
8789376	12/2013	Coffinberry	N/A	N/A
9016041	12/2014	Baughman et al.	N/A	N/A
11131208	12/2020	Auker et al.	N/A	N/A
2004/0070211	12/2003	Franchet	290/31	F02C 7/32
2006/0137355	12/2005	Welch et al.	N/A	N/A
2007/0022735	12/2006	Henry et al.	N/A	N/A
2011/0120083	12/2010	Giffin et al.	N/A	N/A
2011/0167792	12/2010	Johnson et al.	N/A	N/A
2011/0171007	12/2010	Johnson et al.	N/A	N/A
2012/0189432	12/2011	Jordan et al.	N/A	N/A
2018/0230805	12/2017	Miller	N/A	F01D 5/03
2019/0002115	12/2018	Miller	N/A	B64D 31/06
2019/0101057	12/2018	Stevenson et al.	N/A	N/A

2019/0145322	12/2018	Sellick	290/52	F02C 7/36
2021/0164392	12/2020	Harvey	N/A	N/A
2022/0049648	12/2021	Hughes	N/A	F01D 17/08
2022/0176900	12/2021	Klemen et al.	N/A	N/A
2023/0399983	12/2022	Ganiger	N/A	F01D 15/10
2024/0068377	12/2023	Sibilli	N/A	F01D 15/10

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
1849987	12/2006	EP	N/A

OTHER PUBLICATIONS

U.S. Appl. No. 18/417,907, filed Jan. 19, 2024, naming inventors Molnar et al. cited by applicant

---

Primary Examiner: Duger; Jason H

Attorney, Agent or Firm: Shumaker & Sieffert, P.A.

Background/Summary

(1) This application claims the benefit of U.S. Patent Application No. 63/492,040, filed 24 Mar. 2023, the entire contents of which is incorporated herein by reference.

TECHNICAL FIELD
(1) This disclosure relates to electrical power generation in turbine engines.
BACKGROUND
(2) A turbine engine is a type of internal combustion engine that may drive an electric generator for converting mechanical power produced by the turbine engine to electrical power used by other components of a system. Some applications (e.g., due to size and weight restrictions) may require the electric generator to be located within the housing of the turbine engine. During operation, some internally-located electric generators may produce excess heat that may interfere with operations being performed by the electric generator and/or other collocated components of the turbine engine. In addition, performing maintenance or inspections of some internally-located electric generators may be difficult as other collocated components of the turbine engine obstruct access to the electric generator.
SUMMARY
(3) Recently, demand for electrical power on vehicles (e.g., aircraft and others) has increased. For example, larger electronics and/or hybrid consideration has encouraged incorporation of new or additional electrical generator capability on turbine engines, including turbofans. Electrical generators may be positioned at various locations on turbine engines. As one example, an electrical generator may be positioned inside a tail cone of the engine. However, the tail cone may be exposed to hotter turbine temperatures, which may degrade generator performance. As another example, an electrical generator may be positioned on an outside of the turbine engine and be driven by a drive shaft off a compressor. However, positioning the generator on the outside may be limiting due to size constraints (e.g., on generator physical size).
(4) In accordance with one or more aspects of this disclosure, an electrical generator may be positioned in a cavity behind a fan rotor of a turbine engine. For instance, the electrical generator rotor and stator may be concentric with a drive shaft of the fan, and may be placed in a space between the fan rotor and the first compressor stage. Such a location may provide various advantages (e.g., over tail cone or external positions). For instance, temperatures in such a space

may be relatively low, which may improve generator performance. Furthermore, there may be a relatively large volume available, which may enable use of a larger generator (e.g., for a wider range of power extraction options). As another example, positioning the electrical generator in said cavity may enable integration of the electrical generator with existing engine components, such as a core vane. In this way, this disclosure may enable turbine engine to include relatively larger and/or relatively more efficient electrical generators.
(5) The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a conceptual diagram illustrating a cross-section of turbine engine **100** with an electric generator **132** for producing electrical power, in accordance with one or more techniques of this disclosure
(2) FIG. **2** is a conceptual diagram illustrating further details of the turbine engine **100** of FIG. **1**.
(3) FIG. **3** is a conceptual diagram illustrating further details of one example of turbine engine **100** of FIG. **1** with an electrical generator having a fan-driven rotor, in accordance with one or more aspects of this disclosure.
(4) FIG. **4** is a conceptual diagram illustrating further details of one example of turbine engine **100** of FIG. **1** with an electrical generator having a rotor driven by an independent turbine, in accordance with one or more aspects of this disclosure.
(5) FIG. **5** is a conceptual diagram illustrating an example aircraft, in accordance with one or more aspects of the disclosure.
DETAILED DESCRIPTION
(6) FIG. **1** is a conceptual diagram illustrating a cross-section of turbine engine **100** with an electric generator **132** for producing electrical power, in accordance with one or more techniques of this disclosure. Turbine engine **100** may be configured to convert one form of power to mechanical energy in the form of a rotating turbine. The mechanical energy produced by turbine engine **100** may be used in a variety of ways or for a variety of systems and applications (e.g., aircraft, locomotives, watercraft, power plants, electric generators, and any or all other systems and applications that rely on mechanical energy from a turbine engine to perform work). As illustrated in FIG. **1**, turbine engine **100** may be a ducted fan gas-turbine engine, which may be used to propel an aircraft.
(7) As shown in FIG. **1**, turbine engine **100** has a principal and rotational axis **111**. Turbine engine **100** may include, in axial flow series, air intake **112**, propulsive fan **113**, intermediate pressure compressor **114**, high-pressure compressor **115**, combustion equipment **116**, high-pressure turbine **117**, intermediate pressure turbine **118**, low-pressure turbine **119** and core exhaust nozzle **120**. Turbine engine **100** may include nacelle **121**, which may generally surround turbine engine **100** and defines intake **112**, bypass duct **122** and an exhaust nozzle **123**. Turbine engine **100** may include center-plug **129** is positioned within the core exhaust nozzle **120** to provide a form for the core gas flow C to expand against and to smooth its flow from the core engine. Centre-plug **129** may extend rearward of the core nozzle's exit plane **127**.
(8) Turbine engine **100** may operate such that air entering the intake **111** is accelerated by fan **113** to produce two air flows: a first airflow C (i.e., “core airflow”) into intermediate pressure compressor **114** and a second airflow B (i.e., “bypass airflow”) which passes through bypass duct **122** to provide propulsive thrust. Turbine engine **100** may be a high-bypass engine (e.g., a ratio of B to C is greater than a threshold ratio) or a low-bypass engine (e.g., a ratio of B to C is less than

the threshold ratio). Intermediate pressure compressor **114** may compress the airflow C directed into it before delivering that air to the high-pressure compressor **115** where further compression may occur.

(9) The compressed air exhausted from the high-pressure compressor **115** may be directed into combustion equipment **116** where it is mixed with fuel and the mixture combusted. The resultant hot combustion products may then expand through, and thereby drive the high, intermediate and low-pressure turbines **117**, **118**, **119** before being exhausted through nozzle **120** (and may thereby provide additional propulsive thrust). The high, intermediate and low-pressure turbines **117**, **118**, **119** may respectively drive the high and intermediate pressure compressors **115**, **114** and the fan **113** by suitable interconnecting shafts. For instance, turbine engine **100** may include low-pressure shaft **180** that rotationally connects turbine **119** to fan **113**.

(10) While illustrated and described as a multi-shaft design, turbine engine **100** is no so limited. For instance, in some examples, turbine engine **100** may be a single shaft design (e.g., without separate HP/LP spools). Similarly, aspects of this disclosure are applicable to turbine engines of all ranges of thrust and sizes.

(11) As noted above, fan **113** may be rotated using energy collected via turbine **119** (e.g., a power-turbine). As shown in FIG. **1**, fan **113** may include a plurality of fan blades **138** connected to hub **140**. Fan **113** may be circumferentially surrounded by a structural member in the form of a fan casing **124** (e.g., where turbine engine **100** is a ducted turbofan engine), which may be connected to an annular array of outlet guide vanes **128**. Fan casing **124** may comprise a rigid containment casing **125** and attached rearwardly thereto is rear fan casing **126**. As shown in FIG. **1**, fan **113** (and/or other components of the engine core such as the high and intermediate pressure compressors **115**, **114**) may be connected to core vane assembly **135**, including core vanes **134**. Core vanes **134** may provide several functions. For instance, in addition to or in place of supporting fan **113**, core vanes **134** may be shaped and arranged to straighten core airflow C before it reaches compressor **114**. While illustrated in FIG. **1** as being a directly driven fan, in other examples fan **113** may be a geared turbofan. For instance, turbine engine **100** may include a gearbox mechanically between turbine **119** and fan **113**. Core vane assembly **135** may have diameter D.sub.135, which may approximately correspond to a diameter of at least a forward section of compressor **114**.

(12) One or more components of turbine engine **100** may be considered to form a core section. For instance, one or more of compressor **114**, compressor **115**, combustion equipment **116**, and turbines **117**, **118**, **119** may form the core section of turbine engine **100**. As noted above, core vanes **134** may be attached to the core section.

(13) In accordance with one or more aspects of this disclosure, turbine engine **100** may include electrical generator **132**, which may be positioned in a cavity behind fan **113** (e.g., aft of fan hub **140**). Electrical generator **132** may be any type of electrical generator and may generally include a rotor and a stator that rotate relative to each other. The rotor and the stator of electrical generator **132** may be concentric with a drive shaft of fan **113** (e.g., shaft connecting turbine **119** to fan **113**), and may be placed in a space between fan **113** and compressor **114**. Such a location may provide various advantages (e.g., over tail cone or external positions). For instance, temperatures in such a space may be relatively low, which may improve performance of electrical generator **132** (e.g., as performance of electrical generators may degrade when heated). Furthermore, there may be a relatively large volume available, which may enable use of a larger generator (e.g., for a wider range of power extraction options). As another example, positioning electrical generator **132** in said cavity may enable integration of electrical generator **132** with existing engine components, such as a core vane (e.g., core vane **135** of FIG. **2**). In this way, this disclosure may enable turbine engine **100** to include relatively larger and/or relatively more efficient electrical generators.

(14) As noted above, positioning electrical generator **132** in the cavity behind fan **113** may provide several benefits. For instance, the large volume available may allow for larger sized components of

electrical generator **132**. As one example, an outer diameter of electrical generator **132** may be a large percentage of a diameter of core vane assembly **135** (e.g., 70%, 80%, 90%, 95%, etc.)

(15) Electrical generator **132** may be any type of electrical generator. Examples of electrical generator **132** include, but are not limited to, alternators, dynamos, permanent magnet generators, field wound generators, synchronous, asynchronous, brushed, brushless, etc. In general, electrical generator **132** may include a stator and a rotor configured to rotate relative to the stator.

(16) FIG. **2** is a conceptual diagram illustrating further details of the turbine engine **100** of FIG. **1**. As shown in FIG. **2**, turbine engine **100** may include core vane assembly **135**, which may encircle longitudinal axis **111**. Core vane assembly **135** may include core vanes **132**, each extending radially between inner hub **142** and outer band **144**.

(17) As discussed above, turbine engine **100** may include a core flow path and a bypass flow path. Core airflow C may flow through the core flow path and bypass airflow B may flow through the bypass flow path. As shown in FIG. **2**, turbine engine **100** may include splitter ring **146**, which may bifurcate the flow of fluid in the turbine engine **100**. The core airflow C may pass inside the outer band **144** and the bypass airflow B may pass outside the outer band **144**.

(18) Components of core vane assembly **135** may be formed from any suitable substance. For instance, one or more of core vanes **132**, inner hub **142**, and outer band **144** may be formed from aluminum alloy, titanium, etc.

(19) In accordance with one or more aspects of this disclosure, at least a portion of electrical generator **132** may be integrated into core vane assembly **135**. As one example, a frame of electrical generator **132** may be integrated into inner hub **142** of core vane assembly **135**. As discussed in further detail below, the frame may include a stator (e.g., which may include field windings/poles).

(20) In some examples, a rotor of electrical generator **132** may be rotated by fan **113** or a shaft rotationally coupled to fan **113**, such as shaft **180**. For instance, turbine engine **100** may include a mechanical linkage connecting fan **113** to the rotor of electrical generator **132**, such that fan **113** drives the rotor of electrical generator **132**. In some examples, the mechanical linkage may be a direct linkage. For instance, the rotor of electrical generator **132** may be directly connected to fan **113** such that the rotation speeds of fan **113** and the rotor of electrical generator **132** are the same. In some examples, the mechanical linkage may include a gearbox connected between the rotor of electrical generator **132** and fan **113** such that the rotation speeds of fan **113** and the rotor of electrical generator **132** are different (e.g., such that the rotor of electrical generator **132** either spins faster or slower than fan **113**).

(21) In some examples, core vane assembly **135** may be structural. For instance, core vane assembly **135** may be considered structural where core vane assembly **135** is used to transfer mechanical loads to the core section of turbine engine **100** (e.g., transfer thrust produced by turbine engine **100** to a forward engine mount structure, which may then transfer said thrust to a vehicle that carries turbine engine **100**). In some examples, core vane assembly **135** may be non-structural. For instance, core vane assembly **135** may be considered non-structural where core vane assembly **135** is not used to transfer substantial mechanical loads to the core section of turbine engine **100** and/or is not used to support fan **113**.

(22) FIG. **3** is a conceptual diagram illustrating further details of one example of turbine engine **100** of FIG. **1** with a fan-driven rotor, in accordance with one or more aspects of this disclosure. As noted above, turbine engine **100** may include electrical generator **132** positioned behind fan **113**. Electrical generator **332** may be an example of electrical generator **132**. As shown in FIG. **3**, electrical generator **332** may include stator **350** and rotor **352**. Stator **350** may include frame **354**, windings **356**, and pole **358**. Rotor **352** may include armature **360** and commutator **362**. In general, rotor **352** may rotate about longitudinal axis **111** relative to stator **350**. The relative rotation of rotor **352** and stator **350** may generate electrical power. In general, frame **354** may mechanically support one or more other components of electrical generator **332**, such as windings **356**, and pole **358**.

Electrical generator **332** may also include brush **364**.
(23) Rotor **352** may be mechanically rotated by fan **113** or a drive shaft connected to fan **113** (e.g., low pressure shaft **180**). For instance, turbine engine **300** may include mechanical linkage **366** which may rotationally couple rotor **352** to fan **313**. In some examples, mechanical linkage **366** may be a direct linkage. For instance, mechanical linkage **366** may directly link rotor **352** to fan **113** (e.g., such that rotor **352** rotates at a same rate as fan **113**). In some examples, mechanical linkage **366** may be an indirect linkage. For instance, mechanical linkage **366** may include a gearbox mechanically connected between rotor **352** and fan **113** (e.g., such that rotor **352** can rotate at a different rate from fan **113**, such as 0.5× the rate, 2× the rate, etc.). In some examples, mechanical linkage **366** may include a clutch such that rotor **352** may be selectively rotationally coupled to fan **113**. While illustrated as being connected to fan **113**, in some examples mechanical linkage **366** may be connected to a shaft that drives fan **113**, such as low pressure shaft **180**.
(24) One or more components of electrical generator **332**, such as at least a portion of stator **150**, may be at least partially integrated into core vane assembly **335**. As one example, stator **350** may be integral to inner hub **142** of core vane assembly **335**. For instance, frame **354** of stator **350** may be integrated into inner hub **142**. In some examples, frame **154** may be considered as being integrated into inner hub **142** where inner hub **142** is profiled to form frame **354**. In other examples, frame **354** may be considered as being integrated into inner hub **142** where frame **354** is a discrete component that is directly attached to inner hub **142**.
(25) Components of electrical generator **332** may generate heat during operation. As electrical generator **332** may operate more efficiently at lower temperatures, it may be desirable to remove heat (i.e., cool) electrical generator **332**. Aspects of this disclosure may enable beneficial cooling of electrical generator **332**. For instance, core vane assembly **135** may cool electrical generator **332**. As one example, such as where components of electrical generator **332** are integrated into core vane assembly **135**, core vane assembly **135** may conduct heat from electrical generator **332** into the core fluid flow C (i.e., radiate heat into the core fluid flow). With the cooling provided by core vane assembly **135**, aspects of this disclosure may allow for higher power extraction by electrical generator **332** (e.g., through thermal management). Another benefit that the arrangements of this disclosure may provide is a simpler system without separate or active thermal management (such as oil cooling or refrigerant, etc.). For instance, this disclosure enables cooling without using pumps or moving parts (e.g., cooling via core fluid flow C), which may be attractive in certain applications.
(26) Power generated by electrical generator **332** may be carried through conductors routed through any suitable pathway. As one example, core vane assembly **135** may include conductors configured to carry electrical power generated by electrical generator **132**. For instance, the conductors may pass through core vanes **134** (e.g., in order to transport the power out of the core section).
(27) FIG. **4** is a conceptual diagram illustrating further details of one example of turbine engine **100** of FIG. **1** with an independent turbine driven rotor, in accordance with one or more aspects of this disclosure. As noted above, turbine engine **100** may include electrical generator **132** positioned behind fan **113**. Electrical generator **432** may be an example of electrical generator **132**. As shown in FIG. **4**, electrical generator **432** may include stator **450** and rotor **452**. Stator **450** may include frame **454**, windings **456**, pole **458**. Rotor **452** may include armature **460**. In general, rotor **452** may rotate about longitudinal axis **111** relative to stator **450**. In contrast to the example of FIG. **3** where rotor **352** rotates within stator **350**, rotor **452** may rotate around stator **450** in FIG. **4**. The relative rotation of rotor **452** and stator **450** may generate electrical power.
(28) When turbine engine **100** is operating, fan **113** generates a pressure ratio from which work can be extracted. In accordance with one or more aspects of this disclosure, electrical generator **432** may include a turbine configured to extract work from the core fluid flow. For instance, rotor **452** of electrical generator **432** may include turbine **475** that includes a plurality of turbine blades **474** radially distributed on an outer surface of rotor **452**. Turbine blades **474** may be rotated by the core

fluid flow C, and may in turn rotate rotor **452** thereby causing electrical generator **432** to generate electrical power.
(29) In some of such examples, core vane assembly **135** may include (in addition to or in place of core vanes **134**) inlet guide vanes **472** and outlet guide vanes **476**. Inlet guide vanes **472** may be angled to direct flow at a desired incidence to turbine blades **474**. Outlet guide vanes **476** may re-straighten core fluid flow C as needed (e.g., to control flow into compressor stages).
(30) As noted above, turbine **475** may include turbine blades **474**. In some examples, turbine **475** may be a single stage turbine. For instance, turbine blades **474** may be arranged in a single row. In some examples, turbine **475** may be a multi-stage turbine. For instance, turbine blades **474** may be arranged in multiple rows (e.g., displaced along longitudinal axis **111**).
(31) In some examples, turbine **475** may be directly attached to rotor **452**. For instance, turbine blades **474** may be directly mounted to rotor **452**.
(32) Utilizing core fluid flow C to drive electrical generator **432** may provide various advantages. As one example, driving electrical generator **432** directly by extracting energy from the fan discharge flows may allow electrical generator **432** to be packaged independently from other shafting. In such examples, electrical generator **432** may become a standalone component that may only share a centerline with turbine engine **100** (i.e., longitudinal axis **111**) but not other engine shafting. For instance, electrical generator **432** may not be rotationally coupled to low pressure shaft **180**. Similar to electrical generator **332** of FIG. **3**, electrical generator **432** may also be cooled by flow straightening vanes that are part of a single or multi-stage turbine on the outer diameter of electrical generator **432**.
(33) In some examples, electrical generator **432** may include various components that may assist in the rotation of rotor **452**. For instance, electrical generator **432** may include bearings **470**. In some examples, electrical generator **432** may include one or more structural elements configured to physically support electrical generator **432**. For instance, electrical generator **432** may include support element **478**, which may support at least frame **454** of electrical generator **432**.
(34) As discussed above, electrical generator **432** may include inlet guide vanes **472** and outlet guide vanes **476**. In some examples, one or both of inlet guide vanes **472** and outlet guide vanes **476** may be fixed pitch vanes. For instance, where inlet guide vanes **472** are fixed pitch, inlet guide vanes **472** may not have adjustable pitch. In some examples, one or both of inlet guide vanes **472** and outlet guide vanes **476** may be variable pitch vanes. For instance, where inlet guide vanes **472** are variable pitch, electrical generator **432** may include actuators that adjust the pitch of inlet guide vanes **472**. In some examples, electrical generator **432** may include a controller, such as controller **484** which may control actuator **482** to change the pitch of inlet guide vanes **472**. In operation, controller **484** may change the pitch of inlet guide vanes **472** in order to adjust an amount of power generated by electrical generator **432**.
(35) Controller **484** may adjust the pitch of inlet guide vanes **472** with some independence from the rest of the system especially with turbine engine **100** operating at higher power. Controller **484** may adjust the pitch of inlet guide vanes **472** to control generator speed (e.g., a rotational speed of electrical generator **432**) to the desired power level or charge a battery. This may be especially valuable at cruise where electrical power demands may be less compared to situations where electrical power is needed for other reasons like managing distributed fans for flow or distortion management, deicing power, auxiliary systems, etc. that may be less in demand at cruise. In some examples, the battery may discharge electrical power to supplement electrical generator **432** at these conditions after being charged.
(36) Being decoupled from low-pressure shaft **180**, turbine engine **100** can also mitigate electrical overload/faults that may result from electrical generator **432** being at high speed (higher electrical load). Indication of fault could be managed by unloading the generator turbine with the variable vane to reduce generator speed (e.g., by controller **484**).
(37) Turbine engine **100** may include one or more safety features for electrical generator **132**. As

one example, turbine engine **100** may include a clutch, such as dog clutch, which may be engaged to stop rotation of electrical generator **132** (e.g., in the event of a fault). In examples where electrical generator **132** is mechanically rotated by fan **113** (e.g., the example of FIG. **3**), the connecting components may be configured to shear (e.g., such that fan **113** may still freely rotate).
(38) FIG. **5** is a conceptual diagram illustrating an example aircraft, in accordance with one or more aspects of the disclosure. Aircraft **10** of FIG. **5** may be aircraft that includes one or more turbine engines **500**A and **500**B (collectively, "turbine engines **500**"), which may provide thrust and/or electrical power to aircraft **10**. Examples of aircraft **10** include, but are not limited to fixed wing, rotorcraft, vertical takeoff (e.g., VTOL), short takeoff (e.g., STOL), and the like.
(39) Each of turbine engines **500** may be an example of turbine engine **100** of FIG. **1**. As one example, turbine engine **500**A may include an electrical generator having a fan-driven rotor (e.g., similar to the example of FIG. **3**). As another example, turbine engine **500**A may include an electrical generator having a rotor driven by an independent turbine (e.g., similar to the example of FIG. **4**).
(40) One or more of turbine engines **500** may output electrical power to a load of aircraft **10**, such as load **550**. In some examples, load **550** may be a relatively high power consumption load. As such, it may be desirable to include higher power generation capacity electric machines, such as those described in this disclosure.
(41) The following numbered examples demonstrate one or more aspects of the disclosure.
Example 1A
(42) A turbine engine comprising: a core section comprising at least one compressor and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a core vane assembly coupled to the core section, wherein the core vane assembly comprises a plurality of core vanes configured to modify core fluid flow; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to a vehicle that includes the turbine engine; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of the at least one compressor, wherein the electrical generator comprises: a rotor mechanically rotated via the fan or a shaft that is rotationally coupled to the fan, wherein the rotor rotates about the longitudinal axis; and a stator.
Example 2A
(43) The turbine engine of example 1A, wherein the rotor of the electrical generator is directly mechanically linked to the fan or a shaft that is directly mechanically linked to the fan.
Example 3A
(44) The turbine engine of example 2A, wherein the rotor is configured to rotate at a same rate as the fan.
Example 4A
(45) The turbine engine of example 1A, further comprising a gearbox mechanically connected between the rotor of the electrical generator and the fan such that the rotor of the electrical generator rotates at a different rate from the fan.
Example 5A
(46) The turbine engine of any of examples 1A-4A, wherein the stator of the electrical generator is integral to an inner hub of the core vane assembly.
Example 6A
(47) The turbine engine of example 5A, wherein the core vane assembly radiates heat emitted by the electrical generator into the core fluid flow.
Example 7A
(48) The turbine engine of any of examples 1A-6A, wherein the stator of the electrical generator comprises one or more windings that are mechanically supported by a frame, and wherein the frame is integrated into an inner hub of the core vane assembly.
Example 8A

(49) The turbine engine of example 7A, wherein the inner hub of the core vane assembly is profiled to form the frame.

Example 9A

(50) The turbine engine of example 8A, wherein the frame is a discrete component that is directly attached to the inner hub.

Example 10A

(51) The turbine engine of any of examples 1A-9A, wherein the core vane assembly is non-structural.

Example 11A

(52) The turbine engine of any of examples 1A-9A, wherein the core vane assembly is structural.

Example 12A

(53) The turbine engine of any of examples 1A-11A, wherein the core vane assembly includes conductors configured to carry electrical power generated by the electrical generator.

Example 1B

(54) A turbine engine comprising: a core section comprising at least one compressor and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to a vehicle that includes the turbine engine; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of the at least one compressor, wherein the electrical generator comprises: a turbine configured to extract work from a core fluid flow, the turbine configured to rotate about the longitudinal axis; a rotor mechanically rotated by the turbine of the electrical generator, the rotor configured to rotate about the longitudinal axis; and a stator.

Example 2B

(55) The turbine engine of example 1B, further comprising: a core vane assembly coupled to the core section, wherein the core vane assembly comprises: a plurality of inlet guide vanes upstream from the turbine of the electrical generator; and a plurality of outlet guide vanes upstream from the turbine of the electrical generator.

Example 3B

(56) The turbine engine of example 2B, wherein at least some of the plurality of inlet guide vanes are fixed pitch vanes.

Example 4B

(57) The turbine engine of example 2B, wherein at least some of the plurality of inlet guide vanes are variable pitch vanes.

Example 5B

(58) The turbine engine of example 4B, further comprising: a controller configured to adjust the variable pitch vanes to adjust an amount of power generated by the electrical generator.

Example 6B

(59) The turbine engine of any of examples 1B-5B, wherein the core vane assembly radiates heat emitted by the electrical generator into the core fluid flow.

Example 7B

(60) The turbine engine of any of examples 1B-6B, further comprising a low pressure shaft connecting the at least one turbine to the fan, wherein the rotor of the electrical generator is not rotationally coupled to the low pressure shaft.

Example 8B

(61) The turbine engine of any of examples 1B-7B, further comprising: a clutch configured to selectively inhibit rotation of the rotor.

Example 9B

(62) The turbine engine of any of examples 1B-8B, wherein the turbine of the electrical generator is a single stage turbine.

Example 10B
(63) The turbine engine of any of examples 1B-8B, wherein the turbine of the electrical generator is a multi-stage turbine.
Example 11B
(64) The turbine engine of any of examples 1B-10B, wherein the turbine of the electrical generator is attached directly to the rotor of the electrical generator.
Example 1C
(65) Any combination of examples 1A-11B.
(66) Various examples have been described. These and other examples are within the scope of the following claims.

Claims

1. A turbine engine comprising: a core section receiving a core fluid flow, the core section comprising one or more compressors and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a core vane assembly coupled to the core section, wherein the core vane assembly comprises a plurality of core vanes configured to modify the core fluid flow; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to a vehicle that includes the turbine engine; a splitter ring that bifurcates a flow from the fan into the core fluid flow and a bypass airflow that passes into a bypass duct; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of a most upstream stage of all the one or more compressors, the electrical generator having an upstream end fore of the splitter ring and a downstream end aft of the plurality of core vanes, wherein the electrical generator comprises: a rotor including an armature mechanically rotated via the fan by a linkage, the linkage having a first end fixed to the armature at the upstream end of the electrical generator and a second end fixed to the fan, wherein the rotor rotates about the longitudinal axis at a same rate as the fan; and a stator including a frame extending to the upstream end of the electrical generator and formed by an inner hub of the core vane assembly, the plurality of core vanes extending from the frame.
2. The turbine engine of claim 1, wherein the stator of the electrical generator is integral to the inner hub of the core vane assembly.
3. The turbine engine of claim 2, wherein the core vane assembly radiates heat emitted by the electrical generator into the core fluid flow.
4. The turbine engine of claim 1, wherein the stator of the electrical generator comprises one or more windings that are mechanically supported by the frame.
5. The turbine engine of claim 4, wherein the frame mechanically supports a pole of the stator.
6. The turbine engine of claim 1, wherein the core vane assembly is non-structural.
7. The turbine engine of claim 1, wherein the core vane assembly is structural.
8. The turbine engine of claim 1, wherein the core vane assembly includes conductors configured to carry electrical power generated by the electrical generator.
9. The turbine engine of claim 1, wherein the electrical generator is concentrically located with the plurality of core vanes.
10. The turbine engine of claim 9, wherein the electrical generator is not axially overlapping with any of the one or more compressors.
11. The turbine engine of claim 1, wherein the one or more compressors comprise intermediate pressure and high pressure compressors.
12. An airframe comprising: a first turbine engine of one or more turbine engines, the first turbine engine comprising: a core section receiving a core fluid flow, the core section comprising one or more compressors and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a core vane assembly coupled to the core section, wherein the core vane assembly

comprises a plurality of core vanes configured to modify the core fluid flow; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to the airframe; a splitter ring that bifurcates a flow from the fan into the core fluid flow and a bypass airflow that passes into a bypass duct; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of a most upstream stage of all the one or more compressors, the electrical generator having an upstream end fore of the splitter ring and a downstream end aft of the plurality of core vanes, wherein the electrical generator comprises: a rotor including an armature mechanically rotated via the fan by a linkage, the linkage having a first end fixed to the armature at the upstream end of the electrical generator and a second end fixed to the fan, wherein the rotor rotates about the longitudinal axis; and a stator including a frame extending to the upstream end of the electrical generator and formed by an inner hub of the core vane assembly, the plurality of core vanes extending from the frame.

13. The airframe of claim 12, wherein the stator of the electrical generator is integral to the inner hub of the core vane assembly.

14. The airframe of claim 13, wherein the core vane assembly radiates heat emitted by the electrical generator into the core fluid flow.

15. The airframe of claim 12, wherein the stator of the electrical generator comprises one or more windings that are mechanically supported by the frame.

16. The airframe of claim 12, further comprising: a second turbine engine of the one or more turbine engines; and a load that receives electrical energy produced by electrical generators of the one or more turbine engines, the electrical generators of the one or more turbine engines including the electrical generator of the first turbine engine.

17. A turbine engine comprising: a core section receiving a core fluid flow, the core section comprising one or more compressors and at least one turbine that both rotate about a longitudinal axis of the turbine engine; a core vane assembly coupled to the core section, wherein the core vane assembly comprises a plurality of core vanes configured to modify the core fluid flow; a fan connected to the core section and configured to be rotated by the at least one turbine, rotation of the fan providing thrust to a vehicle that includes the turbine engine; a splitter ring that bifurcates a flow from the fan into the core fluid flow and a bypass airflow that passes into a bypass duct; and an electrical generator integrated into the core vane assembly and positioned in the core section aft of the fan and fore of a most upstream stage of all the one or more compressors, the electrical generator having an upstream end fore of the splitter ring and a downstream end aft of the plurality of core vanes, wherein the electrical generator is not axially overlapping with any of the one or more compressors, and wherein the electrical generator comprises: a rotor including an armature mechanically rotated via the fan by a linkage, the linkage having a first end fixed to the armature at the upstream end of the electrical generator and a second end fixed to the fan, wherein the rotor rotates about the longitudinal axis at a same rate as the fan; and a stator including a frame extending to the upstream end of the electrical generator and formed by an inner hub of the core vane assembly, the plurality of core vanes extending from the frame.