

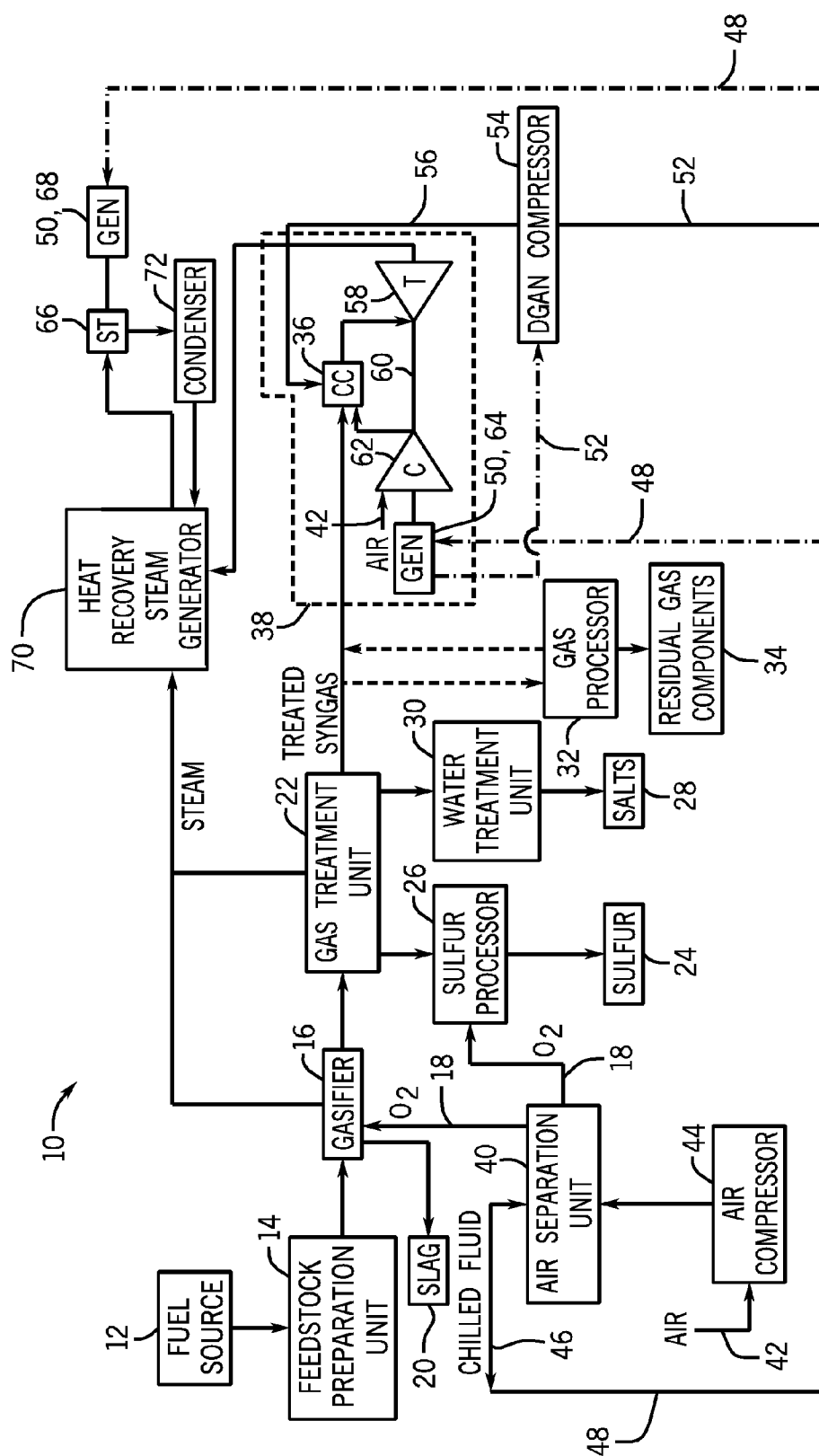
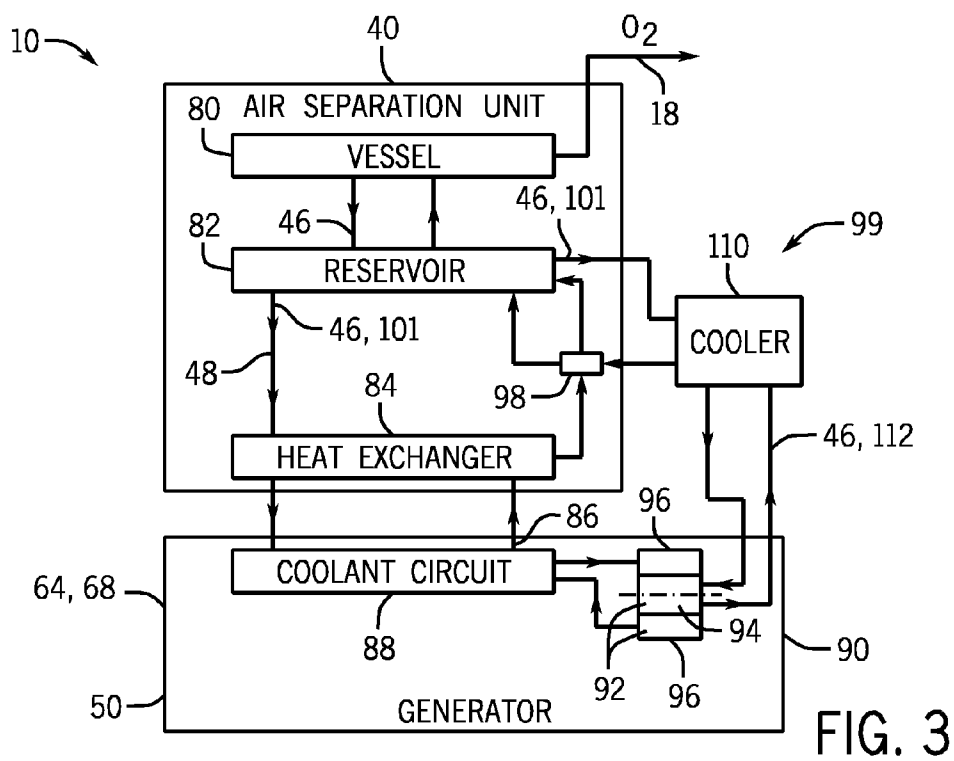
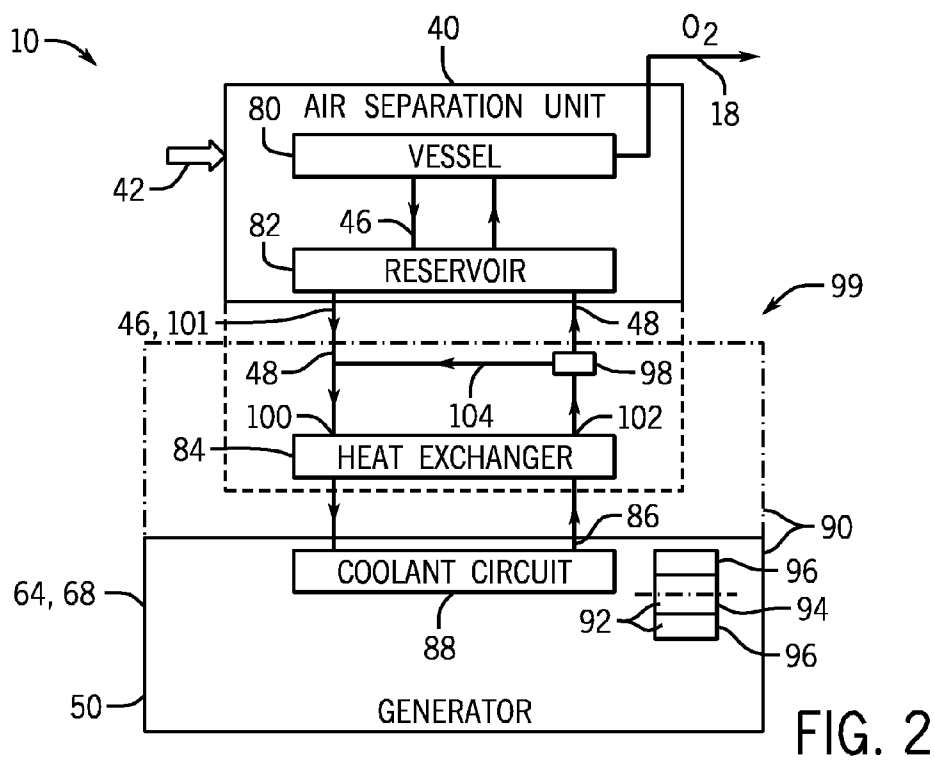


FIG. 1



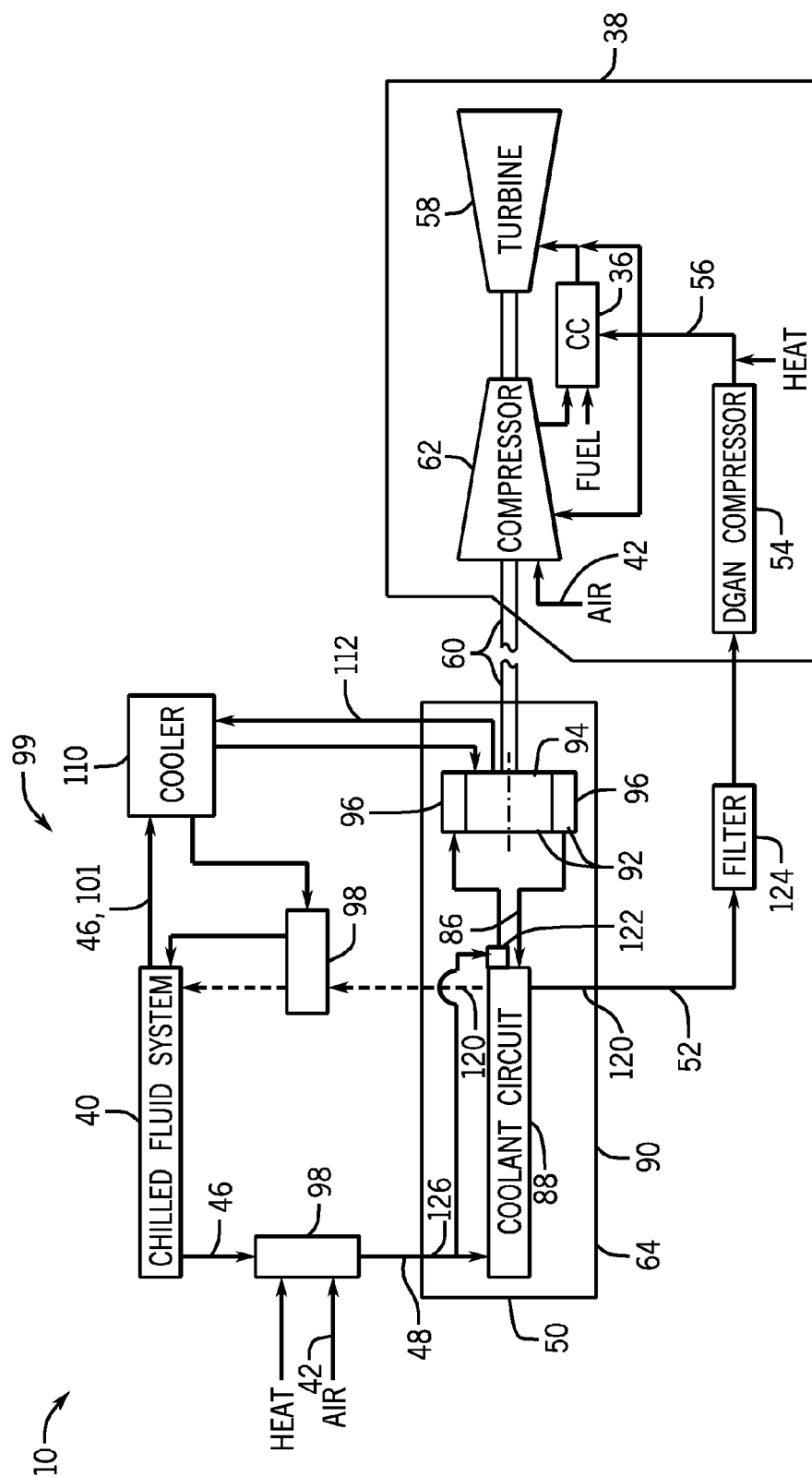


FIG. 4

SYSTEM AND METHOD FOR USING A CHILLED FLUID TO COOL AN ELECTROMECHANICAL MACHINE

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to relates to industrial plants, and more specifically, to systems and methods to use a chilled fluid of the industrial plant to cool a portion of the industrial plant.

[0002] In general, an integrated gasification combined cycle (IGCC) power plant converts a fuel source into syngas through the use of a gasifier. A typical IGCC gasifier may combine a fuel source (e.g., a coal slurry) with steam and oxygen to produce the syngas. The product syngas may be provided to a combustor to combust the syngas with oxygen in order to drive one or more gas turbines. Heat from the IGCC power plant may also be used to drive one or more steam turbines. The one or more turbines may drive generators to produce electricity. A generator may warm due to electrical losses such as resistive heating from electrical current flowing through coils or due to other heat sources within the generator or IGCC power plant. High generator temperatures may decrease the operational life of the generator and limit the output or efficiency of the generator.

BRIEF DESCRIPTION OF THE INVENTION

[0003] Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0004] In a first embodiment, a system includes an air separation unit configured to generate a chilled fluid. The system also includes an electromechanical machine configured to be cooled via heat exchange with the chilled fluid.

[0005] In a second embodiment, a system includes an electromechanical machine temperature controller configured to control a heat exchange system to maintain a temperature of an electromechanical machine below a threshold temperature. The heat exchange system includes a chilled fluid circuit configured to remove heat from the electromechanical machine via heat exchange with a heat transfer fluid and a chilled fluid. The chilled fluid is generated by an air separation unit fluidly coupled to the heat exchange system.

[0006] In a third embodiment, a method includes generating a chilled fluid using an air separation unit, removing heat from an electromechanical machine via heat exchange with the chilled fluid, and controlling the heat exchange to maintain a temperature of the electromechanical machine below a threshold temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. 1 illustrates a block diagram of an embodiment of an integrated gasification combined cycle (IGCC) power plant having a chilled fluid cooling conduit;

[0009] FIG. 2 illustrates a block diagram of an embodiment of the chilled fluid cooling conduit having a heat exchanger coupled to a chilled fluid system and a generator;

[0010] FIG. 3 illustrates a block diagram of an embodiment of the chilled fluid cooling conduit having a cooler coupled to a chilled fluid system and a component of the generator; and

[0011] FIG. 4 illustrates a block diagram of an embodiment of the chilled fluid system coupled to a gas turbine engine.

DETAILED DESCRIPTION OF THE INVENTION

[0012] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0013] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. The term "cryogenic" is intended to mean at a temperature below approximately -150°C . (-238°F). The term "chilled fluid" is intended to be inclusive of fluids at temperatures below approximately 22°C . (70°F), 10°C . (50°F), 0°C . (32°F), or -10°C . (14°F) and fluids at cryogenic temperatures (i.e., cryogenic fluids). Additionally, the term "chilled fluid" is intended to be inclusive of liquids, gases, slurries, and fluid-like mixtures.

[0014] Presently contemplated embodiments of an industrial plant, such as a hydroelectric power plant, a chemical plant, or an integrated combined cycle (IGCC) plant system include a chilled fluid system configured to generate a chilled fluid to cool components (e.g., electromechanical machines) of the plant system, such as one or more generators. The chilled fluid system may be an air separation unit configured to generate one or more chilled fluids by compressing and separating component gases (e.g., oxygen, nitrogen, or argon) from air. These chilled fluids may be cryogenic fluids. Oxygen may be used for reactions within the plant system (e.g., for gasification, combustion, etc.) whereas chilled nitrogen (i.e., a substantially inert gas) and other chilled fluids may be byproducts. As described below, the chilled fluids may be used to directly or indirectly cool a generator within the IGCC system, such as a generator driven by a gas turbine, steam turbine, hydro turbine, or other engine. Using chilled fluids may increase the efficiency of the system by utilizing the energy expended to generate the chilled fluids to cool the generator or other component within the system. The chilled fluids may be produced on site, reducing or eliminating transportation costs associated with some cooling systems. Moreover, some chilled fluids are substantially nonreactive with the cooled component (e.g., generator), enabling lower tolerances for fittings within the chilled fluid system. A working

fluid may absorb heat from windings of the generator and circulate through a heat exchanger to transfer heat to the chilled fluid. In some embodiments, the working fluid may transfer heat to an intermediate fluid, and the intermediate fluid may transfer heat to the chilled fluid to protect the working fluid from freezing. The working fluid and/or intermediate fluid may be a liquid or a gas, such as air, hydrogen, water, deionized water, glycol solution, oil, refrigerant, and so forth. The working fluid and/or intermediate fluid may protect the generator from undesirable temperatures. The heat exchanger may be within the chilled fluid system or the generator. Alternatively, the heat exchanger may be external to both. In some embodiments, the chilled fluid may circulate through a first heat exchanger and a second heat exchanger (e.g., cooler) to further cool the rotor and stator of the generator. An electromechanical machine temperature controller may control the flow of the chilled fluid through the one or more heat exchangers to maintain a temperature of the electromechanical machine (e.g., generator) below a threshold temperature. In some embodiments, the electromechanical machine temperature controller may control the chilled fluid to cool the generator and to be used as a diluent in a gas turbine engine. The electromechanical machine temperature controller may be configured to warm the chilled fluid by adding heat and/or moderating the chilled fluid with ambient air. The chilled fluid may also be used as a prewarmed diluent in a gas turbine engine, gasifier, or other reactor.

[0015] With the foregoing in mind, it may be beneficial to describe an embodiment of a chilled fluid system that may incorporate the components disclosed herein, that may be used, for example, in a power production plant. FIG. 1 is a diagram of an embodiment of an integrated gasification combined IGCC plant system 10 that may produce and burn a synthetic gas, i.e., syngas to produce electricity through a generator 64 or 68 cooled by a chilled fluid, such as a chilled fluid from a chilled fluid system 40. Elements of the IGCC plant system 10 may include a fuel source 12, such as a solid feed, that may be utilized as a source of energy for the IGCC plant system 10. The fuel source 12 may include coal, petroleum coke, biomass, wood-based materials, agricultural wastes, tars, coke oven gas, asphalt, heavy residues from a refinery, or other carbon containing items. The solid fuel of the fuel source 12 may be passed to a feedstock preparation unit 14. The feedstock preparation unit 14 may, for example, resize or reshape the fuel source 12 by chopping, milling, grinding, shredding, pulverizing, briquetting, or pelletizing the fuel source 12 to generate feedstock. Additionally, water, or other suitable liquids may be added to the fuel source 12 in the feedstock preparation unit 14 to create slurry feedstock. In other embodiments, no liquid is added to the fuel source, thus yielding dry feedstock.

[0016] The feedstock prepared by the feedstock preparation unit 14 may be passed to a gasifier 16. The gasifier 16 may convert the prepared fuel into syngas, (e.g., a combination of carbon monoxide and hydrogen). This conversion may be accomplished by subjecting the feedstock to a controlled amount of any moderator (e.g., liquid water, carbon dioxide, nitrogen, and so forth) at elevated pressures (e.g., from approximately 2 MPa to approximately 8.5 MPa) and temperatures (e.g., approximately 700° C. to approximately 1600° C.), depending on the type of gasifier 16 utilized. The heating of the feedstock during a pyrolysis process may generate a solid (e.g., char) and residue gases (e.g., carbon monoxide, hydrogen, and nitrogen). The char remaining from the

feedstock from the pyrolysis process may only weigh up to approximately 30% of the weight of the original feedstocks.

[0017] The combustion reaction in the gasifier 16 may include introducing oxygen 18 to the char and residue gases. The char and residue gases may react with the oxygen 18 to form carbon dioxide and carbon monoxide, which provides heat for the subsequent gasification reactions. The temperatures during the combustion process may range from approximately 700° C. to approximately 1600° C. In addition, steam may be introduced into the gasifier 16. In essence, the gasifier utilizes steam and oxygen 18 to allow some of the feedstock to be burned to produce carbon monoxide and energy, which may drive a second reaction that converts further feedstock to hydrogen and additional carbon dioxide.

[0018] In this way, a resultant gas may be manufactured by the gasifier 16. The resultant gas may include approximately 85% of carbon monoxide and hydrogen, as well as CH₄, HCl, HF, COS, NH₃, HCN, and H₂S (based on the sulfur content of the feedstock). This resultant gas may be termed “untreated syngas.” The gasifier 16 may also generate waste, such as slag 20, which may be a wet ash material. As described in greater detail below, a gas treatment unit 22 may be utilized to treat the untreated syngas. The gas treatment unit 22 may scrub the untreated syngas to remove the HCl, HF, COS, HCN, and H₂S from the untreated syngas, which may include separation of sulfur 24 in a sulfur processor 26 by, for example, an acid gas removal process in the sulfur processor 26. Furthermore, the gas treatment unit 22 may separate salts and fine particulates 28 from the untreated syngas via a water treatment unit 30, which may utilize water purification techniques to generate usable salts and fine particulates 28 from the untreated syngas. An optional water-gas shift reaction may increase the hydrogen concentration of the syngas. Subsequently, a treated syngas may be generated from the gas treatment unit 22.

[0019] A gas processor 32 may be utilized to remove residual gas components 34 from the treated syngas, such as ammonia and methane, as well as methanol or other residual chemicals. However, removal of residual gas components 34 from the treated syngas is optional since the treated syngas may be utilized as a fuel even when containing the residual gas components 34 (e.g., tail gas). At this point, the treated syngas may include approximately 3% CO, approximately 55% H₂, and approximately 40% CO₂, and may be substantially stripped of H₂S. This treated syngas may be directed into a combustor 36 (e.g., a combustion chamber) of a gas turbine engine 38 as combustible fuel, such that the turbine engine 38 can drive the generator 64 cooled by the chilled fluid (e.g., nitrogen, argon, or other inert gases cooled by the chilled fluid system 40).

[0020] The IGCC plant system 10 may further include the chilled fluid system 40 (e.g., an air separation unit (ASU)). The chilled fluid system 40 may separate air into component gases using, for example, cryogenic distillation techniques. The chilled fluid system 40 may separate oxygen 18 from the air 42 supplied to it from a supplemental air compressor 44 and may transfer the separated oxygen 18 to the gasifier 16, sulfur processor 26, or other components of the IGCC plant system 10 (e.g., furnace, reactor, combustion engine, etc.). The chilled fluid system 40 may separate the oxygen 18 from a chilled fluid 46 (e.g., nitrogen, argon, and/or other inert gases). The chilled fluid system 40 may direct the separated chilled fluid 46 to a chilled fluid conduit 48. The chilled fluid 46 may be used to cool components 50 of the IGCC plant

system 10. The components 50 may include electromechanical machines, such as generators (e.g., electrical generators 64 and 68), motors, power transformers, high voltage bushings, or circuit breakers, or combinations thereof. As discussed in detail below, the chilled fluid 46 may be configured to cool components 50 directly through contact with the components 50 or indirectly through heat exchange with a working fluid. In some embodiments, the chilled fluid 46 may be configured to circulate through the chilled fluid conduit 48 and components 50 back to the air separation unit 40. In other embodiments, the chilled fluid 46 may be configured to flow through the chilled fluid conduit 48 to one or more components 50 of the IGCC plant system 10 without returning to the chilled fluid system 40. For example, the chilled fluid 46 may be used as a diluent, a purge gas, a coolant gas, and/or a shielding gas for the gas turbine engine 38, the gasifier 16, the gas treatment unit 22, or other IGCC components. Specifically, the chilled fluid 46 may be warmed (e.g., by having absorbed heat from components 50) and directed along a diluent conduit 52 to a diluent gas (DGAN) compressor 54. The DGAN compressor 54 may process (e.g., warm and compress) the chilled fluid 46 received from the chilled fluid system 40 to produce a diluent gas 56. The diluent gas 56 may be compressed at least to a pressure level equal to the combustor 36 and warmed to a sufficient temperature so as to not interfere with proper combustion of the syngas. The DGAN compressor 54 may direct the diluent gas 56 to the combustor 36 or other parts of the gas turbine engine 38. As described below, in some embodiments the chilled fluid 46 may flow from a component 50 to the diluent conduit 52 rather than back to the chilled fluid system 40.

[0021] The gas turbine engine 38, which drives the generator 64, includes a turbine 58, a drive shaft 60, and a compressor 62, as well as the combustor 36. The combustor 36 may receive compressed air and fuel, such as the syngas, which may be injected under pressure from fuel nozzles. This fuel may be mixed with diluent gas 56 from the DGAN compressor 54. In some embodiments, the combustor 36 may combust with oxygen 18 from the chilled fluid system 40 and/or oxygen in compressed air from the compressor 62. The combustion creates hot pressurized exhaust gases directed towards an exhaust outlet of the turbine 58. As the exhaust gases from the combustor 36 pass through the turbine 58, the exhaust gases may force turbine blades in the turbine 58 to rotate the drive shaft 60 along an axis of the gas turbine engine 38. As illustrated, the drive shaft 60 may be connected to various components of the gas turbine engine 38, including a compressor 62.

[0022] The drive shaft 60 may connect the turbine 58 to the compressor 62, and the compressor 62 may include blades coupled to the drive shaft 60. Thus, rotation of turbine blades in the turbine 58 may cause the drive shaft 60 connecting the turbine 58 to the compressor 62 to rotate blades within the compressor 62. The rotation of blades in the compressor 62 causes the compressor 62 to compress air 42 received via an air intake in the compressor 62. The compressed air may then be fed to the combustor 36 and mixed with fuel (e.g., syngas) in a fuel-air mixture. In some embodiments, the fuel-air mixture may be mixed with the compressed diluent gas 56 to allow for higher efficiency combustion. The drive shaft 60 may also be connected to the component 50, which may be a load, such as the generator 64 cooled by the chilled fluid from the chilled fluid system 40, for producing electrical power in

the IGCC plant system 10. Indeed, the component 50 may be any suitable device that is powered by the rotational output of the gas turbine engine 38.

[0023] The IGCC plant system 10 also may include a steam turbine engine 66 and a heat recovery steam generation (HRSG) system 70. The steam turbine engine 66 may drive a component 50, which may be a stationary load cooled by the chilled fluid from the chilled fluid system 40, such as the second generator 68 for generating electrical power. However, the component 50 may be any suitable device that is powered by the rotational output of the steam turbine engine 66. In addition, although the gas turbine engine 38 and the steam turbine engine 66 may drive separate components 50 as shown in the illustrated embodiment, the gas turbine engine 38 and the steam turbine engine 66 may also be utilized in tandem to drive a single component 50 (e.g., generator 68) via a single shaft. Additionally, the chilled fluid conduit 48 may be configured to cool any component 50 as described in detail below. The specific configuration of the steam turbine engine 66, as well as the gas turbine engine 38, may be implementation-specific and may include any combination of sections.

[0024] Heated exhaust gas from the gas turbine engine 38 may be directed into the HRSG 70 and used to heat water and produce steam used to power the steam turbine engine 66. Exhaust from the steam turbine engine 66 may be directed into a condenser 72. Condensate from the condenser 72 may, in turn, be directed into the HRSG 70. Again, exhaust from the gas turbine engine 38 may also be directed into the HRSG 70 to heat the water from the condenser 72 and produce steam.

[0025] As such, in combined cycle systems such as the IGCC plant system 10, hot exhaust may flow through the gas turbine engine 38 to drive the second generator 68 through the HRSG 70. Heat from the gas turbine engine 38, gasifier 16, and gas treatment unit 22 may be directed to the HRSG 70, where it may be used to generate high-pressure, high-temperature steam that flows through the steam turbine engine 66 to drive the component 50 (e.g., second generator 68) coupled to the steam turbine engine 66 or different components 50 coupled to other equipment of the IGCC plant system 10. The components 50, such as the electrical generators 64 and/or 68 may warm during operation. The chilled fluid system 40 produces oxygen 18 for use in the IGCC plant system 10 and chilled fluid 46 as a byproduct. The IGCC plant system 10 may be configured to use the oxygen 18 for reactions and the chilled fluid 46 for cooling components 50, thus utilizing both products of the chilled fluid system 40 (e.g., air separation unit). Presently disclosed embodiments integrate chilled fluid 46 of the chilled fluid system 40 with the components 50 (e.g., electrical generators 64 and/or 68) to increase the efficiency of the IGCC plant system 10. Cooling the components 50 with the chilled fluid 46 enables the recovery of at least some of the energy used by the chilled fluid system 40 to compress and cool the chilled fluid 46. In this way, the chilled fluid 46 may be configured to cool the components 50 without significant additional energy input, thus utilizing the available heat absorption capacity of the chilled fluid 46. For example, the chilled fluid 46 may cool the components 50 more effectively than ambient air 42 that is warmer than the chilled fluid 46. Also, the chilled fluid may be substantially inert and reduce or eliminate corrosion and maintenance of the components 50.

[0026] FIG. 2 illustrates an embodiment of a chilled fluid system 40 coupled to the component 50, which both may be part of the IGCC plant system 10. The component 50 may include one or more generators 64 and 68 of FIG. 1 or other

components 50. While the generator 64 is referred to as the component 50 of the embodiments discussed below, the disclosed embodiments are not limited to the generator 64. For example, the chilled fluid system 40 may be coupled to other components 50, such as the generator 64, the second generator 68, a motor, a power transformer, a high voltage bushing, or a circuit breaker, or combinations thereof.

[0027] The chilled fluid system 40 may be configured to generate the chilled fluid 46 (e.g., nitrogen and/or argon). In some embodiments, the chilled fluid system 40 is an air separation unit configured to separate air 42 into oxygen 18, nitrogen, and other gases, wherein the inert gases (e.g., nitrogen, argon, etc.) may be used as the chilled fluid 46. The chilled fluid system 40 may generate the chilled fluid 46 from the air 42 in a vessel 80 (e.g., distillation column). The chilled fluid 46 may be directed to a reservoir 82. The reservoir 82 may store the chilled fluid 46 used to directly or indirectly cool the generator 64. In some embodiments, the reservoir 82 is configured to circulate at least some of the chilled fluid 46 with the vessel 80. The chilled fluid 46 may be at cryogenic temperatures (e.g., below approximately -196°C.) within the reservoir 82. Alternatively, the reservoir 82 may be configured to warm the chilled fluid 46 to a suitable temperature (e.g., between approximately -20°C. to 20°C.) to cool the generator 64 within an operational temperature range. The operational temperature range may be between approximately -10°C. to 200°C.

[0028] The chilled fluid 46 may be directed from the reservoir 82 to a first heat exchanger 84 to cool a working fluid 86 from the generator 64. The working fluid 86 may circulate through a coolant circuit 88 to absorb heat from within the generator casing 90, such as heat from windings 92. The windings 92 may be a component of a rotor 94, a stator 96, and/or other parts that generate electricity or a field. The windings 92 may warm by resistive heating during operation of the generator 64. The coolant circuit 88 may include fans or pumps configured to direct the working fluid 86 to the first heat exchanger 84. The absorbed heat of the working fluid 86 may be transferred to the chilled fluid 46 within the first heat exchanger 84. In this way, the chilled fluid 46 directly cools the working fluid 86 and indirectly cools the winding 92 within the generator 64 as the working fluid 86 circulates through the coolant circuit 88. As a result of the heat exchange with the chilled fluid 46, the working fluid 86 may reenter the coolant circuit 88 at a lower temperature than the temperature at which the working fluid 86 left the coolant circuit 88. The working fluid 86 (i.e., first heat transfer fluid) may be a gas or liquid, such as air, hydrogen, water, deionized water, glycol solution, oil, refrigerant, and so forth. In some embodiments, the coolant circuit 88 may be a gas ventilation circuit configured to cool the rotor 94 and stator 96 substantially by convection. For example, the working fluid 86 may be air that flows about the chilled fluid conduit 48 in the first heat exchanger 84 and about the rotor 94 and stator 96. In some embodiments, chilled fluid 46 may directly cool the stator 96 without the working fluid 86.

[0029] The first heat exchanger 84 may be disposed in different configurations to facilitate heat exchange between the chilled fluid 46 and working fluid 86. In some embodiments, the first heat exchanger 84 may include, but is not limited to a shell and tube, plate, plate and shell, or spiral heat exchanger. Additionally, the chilled fluid 46 and working fluid 86 may flow through the first heat exchanger 84 in a parallel or counter-current direction. The chilled fluid 46 may

flow through the first heat exchanger 84 in either a liquid or gaseous state. The temperature of the chilled fluid 46 may be a cryogenic temperature (e.g., the boiling point of liquid nitrogen at atmospheric pressure: -196°C. ; or the boiling point of liquid argon at atmospheric pressure: -185°C.), or a temperature below approximately -100°C. , -50°C. , -15°C. , 0°C. , 10°C. , 20°C. , or an ambient temperature.

[0030] In some embodiments, an electromechanical machine temperature controller 98 may be configured to control a heat exchange system 99 that includes the chilled fluid system 40 and first heat exchanger 84. The electromechanical machine temperature controller 98 may include one or more valves, memory, and a processor. The memory may be a machine readable media configured to store code or instructions to be used by the processor to control the one or more valves. The one or more valves may be configured to adjust the flow rates of the chilled fluid 46, working fluid 86, other fluids (e.g., intermediate fluids) used within the heat exchange system 99, or combinations thereof. In some embodiments, the electromechanical machine temperature controller 98 includes one or more sensors to monitor the temperature of the chilled fluid 46 and/or working fluid 86. The electromechanical machine temperature controller 98 may be configured to control the heat exchange system 99 by adjusting the one or more valves based at least in part on the sensed temperatures received by the electromechanical machine temperature controller 98.

[0031] The electromechanical machine temperature controller 98 may be configured to circulate the chilled fluid 46 directly through the first heat exchanger 84. However, extremely low temperatures may reduce the performance of the generator 64. For example, extremely low temperatures may reduce the ductility of a material, increase the viscosity of lubricants or the working fluid 86, or freeze the working fluid 86, or combinations thereof. A ductile-brittle transition temperature (DBTT) of a metal indicates a low temperature at which the metal has a pre-determined brittleness. In some embodiments, the electromechanical machine temperature controller 98 is configured to circulate the chilled fluid 46 at temperatures above the DBTT (e.g., -10°C.) through the first heat exchanger 84. The electromechanical machine temperature controller 98 may be configured to adjust the flow rate of the chilled fluid 46 to control the temperature of the working fluid 86 (e.g., primary coolant). The chilled fluid 46 may exchange heat with the warmer working fluid 86 (i.e., primary coolant), which absorbs heat from the generator 92 through the coolant circuit 88. In some embodiments, the chilled fluid 46 has a lesser heat capacity than the working fluid 86. In some embodiments, the electromechanical machine temperature controller 98 may circulate an intermediate fluid 101 through the reservoir 82 and first heat exchanger 84 to protect the materials of the first heat exchanger 84 and generator 64 from exposure to temperatures near or below the DBTT. In some embodiments, the working fluid 86 is configured to absorb heat from the generator 92 through the cooling circuit 88, the intermediate fluid 101 is configured to absorb heat from the working fluid 86 in the first heat exchanger 84, and the chilled fluid 46 is configured to absorb heat from the intermediate fluid 101 in the reservoir 82. Using the intermediate fluid 101 may also enable the maintenance of lubricants at desirable viscosity levels and protect the working fluid 86 from freezing and/or increasing beyond a threshold viscosity. The intermediate fluid 101 (i.e., second heat transfer fluid)

may be a gas or liquid, such as air, hydrogen, water, deionized water, glycol solution, oil, refrigerant, and so forth.

[0032] In some embodiments, the first heat exchanger **84** may be disposed within the chilled fluid system **40** as shown by the dashed lines (---). In some embodiments, the reservoir **82** may include part of the first heat exchanger **84**. For example, the reservoir **82** may be a pool of the chilled fluid **46** and the working fluid **86** may circulate through pipes of the first heat exchanger **84** immersed in the chilled fluid **46**. Disposing the first heat exchanger **84** within the chilled fluid system **40** may enable the same size winding **92** to be disposed within a smaller generator casing **90** or larger windings **92** to be disposed within the same size generator casing **90**. The size of the windings **92** may be related to the electrical output capacity. For example, large windings **92** may be capable of producing a greater electrical output than small windings **92**.

[0033] In some embodiments, the first heat exchanger **84** may be disposed within the generator casing **90** as shown by the dash-dot lines (-.-.-). This may enable the chilled fluid system **40** to readily replace a previously coupled cooling system or to improve an existing first heat exchanger **84**. The chilled fluid system **40** coupled to an existing generator **64** may be configured to increase the efficiency and/or output of the existing generator **64** by decreasing the temperature of the circulated working fluid **86** due to the low temperature of the chilled fluid **46** of the chilled fluid system **40**. In this manner, the efficiency and/or output of the existing generator may be increased without substantially altering the first heat exchanger **84** or generator **64**. The low temperature of the chilled fluid **46** may enable the working fluid **86** to transfer more heat to the chilled fluid **46** compared to an air cooled system at ambient temperature.

[0034] The first heat exchanger **84** of some embodiments may be disposed external to both the chilled fluid system **40** and the generator **64**. Disposing the first heat exchanger **84** externally may increase the flexibility of the IGCC plant system **10** by enabling the heat exchanger **84** to be readily replaced, modified, or maintained. An externally disposed first heat exchanger **84** may be readily used for multiple purposes within the IGCC plant system **10**. An external heat exchanger **84** may also increase the modularity of components within the IGCC plant system **10**.

[0035] As discussed above, the electromechanical machine temperature controller **98** along the chilled fluid conduit **48** may be configured to circulate the chilled fluid **46** or an intermediate fluid **101** between the reservoir **82** and the first heat exchanger **84**. The electromechanical machine temperature controller **98** may be disposed along the chilled fluid conduit **48** at a first inlet **100** or a first outlet **102** of the first heat exchanger **84**. Like the first heat exchanger **84**, the electromechanical machine temperature controller **98** may be disposed within the chilled fluid system **40**, the generator **64**, the first heat exchanger **84**, or external to these systems of the IGCC plant system **10**. The electromechanical machine temperature controller **98** may be configured to control the heat exchange between the chilled fluid **46** and the working fluid **86** to maintain a temperature of the generator **64** below a threshold temperature (e.g., 100° C. to 200° C.). In some embodiments, electromechanical machine temperature controller **98** is configured to maintain the temperature of the rotor **94**, stator **96**, or the windings **92** below a threshold temperature. The windings **92** may warm due to resistance heating from the produced current through the windings **92**.

Resistance may increase with temperature such that warmer windings **92** may have greater resistance than cooler windings **92**. Cooling the windings **92** may lower the temperature and resistance within the windings **92** so that less of the output of the generator **64** is lost due to resistance heating, thus increasing the efficiency. Cooling the windings **92** may also extend or improve the thermal capability of the windings **92**. A thermal capability may be an amount of heat generated within the windings **92** to reach a threshold temperature. For example, the generator **64** producing a first output without heat exchange with the chilled fluid may have windings **92** with a first thermal capability. Cooling the generator **64** with the chilled fluid may extend the thermal capability of the windings **92** to a second thermal capability so that the generator **64** may produce a second output greater than the first output and the windings **92** may absorb additional heat without exceeding the threshold temperature.

[0036] The electromechanical machine temperature controller **98** may control the heat exchange of the heat exchange system **99** at least by adjusting the flow rate of the chilled fluid **46**, the temperature of the chilled fluid **46**, or combinations thereof. The electromechanical machine temperature controller **98** may restrict the flow rate and/or warm the chilled fluid **46** to decrease the heat exchange between the chilled fluid **46** and working fluid **86**. Likewise, the electromechanical machine temperature controller **98** may increase the flow rate of the chilled fluid **46** to increase the heat exchange. In some embodiments, the electromechanical machine temperature controller **98** may be configured to warm the chilled fluid **46** by inductive heating, convection, or other heat transfer. The electromechanical machine temperature controller **98** may direct the chilled fluid **46** near a warm component **50** (e.g., generators **64**, **68**) for purposes of cooling, resulting in heat transfer to the chilled fluid **46**.

[0037] In some embodiments, due to the low (e.g., cryogenic) temperature of the chilled fluid **46** in the reservoir **82**, a bypass conduit **104** may be fluidly coupled between the first inlet **100** and the first outlet **102** to bypass the reservoir **82**. The electromechanical machine temperature controller **98** may be configured to recirculate some of the chilled fluid **46** or intermediate fluid **101** from the first outlet **102** to the first inlet **100** along the bypass conduit **104** rather than through the reservoir **82**. The recirculated chilled fluid **46** may warm the chilled fluid **46** directed to the first heat exchanger **84**. In this way, the electromechanical machine temperature controller **98** may be configured to maintain a temperature of the generator **64** at an operational temperature between a threshold (e.g., maximum) temperature (e.g., 200° C.) and the ductile-brittle transition temperature (e.g., -10° C.). For example, recirculating at least some of the chilled fluid **46** through the bypass conduit **104** may raise the temperature of the chilled fluid **46** flowing through the first heat exchanger **84** from approximately -196° C. to approximately 5° C. or higher.

[0038] In some embodiments as illustrated in FIG. 3, the chilled fluid system **40** may be configured to cool a component **50** (e.g., the generator **64**, **68**) via heat exchange with the first heat exchanger **84** as discussed above with FIG. 1 and with a second heat exchanger (e.g., cooler **110**). For example, the first heat exchanger **84** and coolant circuit **88** may be configured to cool the rotor **94** and the cooler **110** may be configured to cool the stator **96**. Alternatively, only the cooler **110** may be configured to cool the generator **64**, **68**. The cooler **110** may be coupled between the chilled fluid system **40** and generator **64**, **68** in various configurations. The cooler

110 may be disposed within the chilled fluid system 40, within the generator casing 90, or external to both. In some embodiments, the cooler 110 may include, but is not limited to an evaporative cooler (e.g., cooling tower), shell and tube heat exchanger, plate and/or shell heat exchanger, or spiral heat exchanger. Additionally, the chilled fluid 46 and a second working fluid 112 may flow through the second heat exchanger in a parallel or counter-current direction. The chilled fluid 46 may flow to the cooler 110 in either a liquid or gaseous state.

[0039] The heat exchange system 99 controlled by the electromechanical machine temperature controller 98 may include the cooler 110 and/or the first heat exchanger 84. The electromechanical machine temperature controller 98 may be configured to circulate the chilled fluid 46 from the reservoir 82 to a cooler 110 fluidly coupled to the stator 96. In some embodiments, the chilled fluid 46 and the second working fluid 112 may exchange heat within the cooler 110, and the cooler 110 may circulate the second working fluid 112 to indirectly cool the stator 96. The chilled fluid 46 may be configured to circulate back to the reservoir 82. In other embodiments, the cooler 110 may circulate the chilled fluid 46 to directly cool (e.g., contact) the stator 96 without using the second working fluid 112. The stator winding 92 may be electrically insulated and coiled about a core. The cooler 110 may direct the chilled or second working fluids 46 or 112 through the core or through hollow strands of the stator winding 92. The second working fluid 112 (e.g., third heat transfer fluid) may be a gas or liquid, such as air, hydrogen, water, deionized water, glycol solution, oil, refrigerant, and so forth. Presently contemplated embodiments include a deionized water cooler 110 configured to circulate deionized water, (e.g., second working fluid 112) through the stator winding 92 to absorb heat from the stator winding 92. The chilled fluid 46 may be configured to be a heat sink within the deionized water cooler 110 to absorb the heat from the deionized water so that the deionized water may circulate through the stator winding 92 to absorb additional heat.

[0040] As discussed above, the chilled fluid 46 from the vessel 80 or in the reservoir 82 may be at cryogenic temperatures. The chilled fluid 46 may be a liquid or a gas that may be warmed before exchanging heat with the second working fluid 112 or generator 64, 68 to protect materials from undesirably low temperatures that may affect properties of the generator 64, such as the ductility of metals or the viscosity of fluids. The electromechanical machine temperature controller 98 may be configured to warm the chilled fluid 46 directed to the cooler 110. The electromechanical machine temperature controller 98 may direct the chilled fluid 46 to be warmed by absorbing some heat from a system (e.g., gas treatment unit 22 of FIG. 1) within the IGCC plant system 10. In some embodiments, the electromechanical machine temperature controller 98 may circulate an intermediate fluid 101 between the reservoir 82 and the cooler 110 where the intermediate fluid 101 is at an intermediate temperature between the temperature of the chilled fluid 46 and the temperature of the second working fluid 112. The electromechanical machine temperature controller 98 is configured to control the flow rate of the chilled fluid 46 and/or the intermediate fluid 101 to control the temperature of the fluid (e.g., chilled fluid 46 or second working fluid 112), which is circulated by the cooler 110 circulates through the generator 64.

[0041] In some embodiments, the electromechanical machine temperature controller 98 may be configured to cir-

culate the chilled fluid 46 directly through the generator 64, 68 without a working fluid 86 or second working fluid 112. Circulating the chilled fluid 46 directly through the generator 64, 68 may reduce maintenance costs of the generator 64, 68. For example, argon and nitrogen are generally chemically inactive at operating temperatures of the generator 64, 68, thus an argon chilled fluid 46 or a nitrogen chilled fluid 46 may not react with the parts within the generator 64, 68. Additionally, argon and nitrogen may displace reactive fluids such as oxygen, hydrogen, and water within the generator 64, 68 and generator casing 90 to reduce reactions with the reactive fluids. The use of generally inert chilled fluids 46 may decrease maintenance costs due to corrosion and oxidation.

[0042] The rated power output of the generator (e.g., generator 64, 68) is typically based on the size of the generator. For example, a large generator may have a greater rated output than a small generator. A heat exchange system 99 for the generator may vary based at least in part on the rated output and size of the generator. Several types of heat exchange systems use one or more heat exchangers and working fluids. Each type of heat exchange system may have a base capacity and efficiency. In a first heat exchange system, a low rated output generator may be cooled by circulating air forced through ducts and the rotor 94. The stator winding 92 may be electrically insulated and coiled about a ducted core. The stator winding 92 may be cooled by conduction through the insulation to the air and the ducted core. In a second heat exchange system, a larger rated output generator may be cooled by circulating pressurized hydrogen through cooling passages in the stator 96 and rotor 94. The generator may be sealed to prevent leaks that may generally cause loss of coolant, corrosion, or oxidation. The second heat exchange system may enable more heat to be removed from the generator than the first heat exchange system alone. In a third heat exchange system, a larger rated output generator may cool the stator 96 by an additional system, such as the cooler 110 to circulate a liquid (e.g., de-ionized water) through the ducts and/or hollow conduits within the stator winding 92. The third heat exchange system may enable more heat to be removed from the generator 64 than the second heat exchange system. Additionally, the third heat exchange system may be used together with the first or second heat exchange system. The third heat exchange system may be larger than the first or second heat exchange system. In some embodiments, circulating the chilled fluid 46 through the first heat exchanger 84 rather than air may increase the heat removed via heat exchange, so that the first heat exchange system may replace a second or third heat exchange system. Similarly, using the chilled fluid 46 rather than the pressurized hydrogen in the second heat exchange system may enable the second heat exchange system to replace a third heat exchange system. In this way, integrating the chilled fluid system 40 may decrease the size and/or complexity of the heat exchange system 99 used to remove heat from the generator 64, 68. This may also reduce maintenance and installation costs associated with the generator 64, 68.

[0043] FIG. 4 illustrates an embodiment having the electromechanical machine temperature controller 98 configured to control the heat exchange system 99 and use chilled fluid 46 from the chilled fluid system 40 for other purposes. After absorbing heat from the coolant circuit 88, the chilled fluid 46 exits the coolant circuit 88 as a warmed fluid 120. In some embodiments, the electromechanical machine temperature controller 98 may circulate the warmed fluid 120 back to the

chilled fluid system 40 as shown by the dashed lines. Alternatively, the electromechanical machine temperature controller 98 may direct the warmed fluid 120 elsewhere in the IGCC plant system 10. In some embodiments, the chilled fluid 46 may be bled at the bleed inlet 122 into air used as the working fluid 86. The chilled fluid 46 may cool the working fluid 86 directly. In some embodiments, the chilled fluid 46 may pre-cool the working fluid 86 before the working fluid 86 enters the coolant circuit 88 and/or stator winding 92. Bleeding the chilled fluid 46 into the bleed inlet 122 may also provide a clean and dry ventilation source. Bleeding a substantially inert chilled fluid 46 (e.g., nitrogen, argon) into the bleed inlet 122 may displace oxygen, hydrogen, and/or water and reduce maintenance costs of the coolant circuit 88 due to corrosion and oxidation.

[0044] In another example, the electromechanical machine temperature controller 99 may direct the warmed fluid 120 through a diluent conduit 52 to be directed to the gas turbine engine 38 as a diluent gas 56. In some embodiments, the diluent gas 56 may be directed to the compressor 62 to dilute the air sent to the combustor 36. In some embodiments, the diluent gas 56 may be directed to the combustor 36 and/or turbine 58 to dilute emissions, cool the exhaust gases, cool components, and/or purge fuel lines. The diluent gas 56 may flow through a filter 124 to remove particulates or contamination from the diluent gas 56 and protect the gas turbine engine 38. The diluent gas (DGAN) compressor 54 pressurizes the diluent gas 56 to approximately the same pressure as the combustor 36 or turbine 58. In some embodiments, heat may be added to the diluent gas 56, so that the diluent gas is approximately the temperature of the compressed air and fuel injected into the combustor 36. However, the relative quantity of heat added to the diluent gas 56 may be small, because the chilled fluid 46 has absorbed heat from the generator 64 prior to entering the diluent conduit 52 as the warmed fluid 120. In some embodiments, the drive shaft 60 coupled to the turbine 58 may drive the compressor 62 and the component 50 (e.g., generator 64). In other embodiments, the component 50 (e.g., second generator 68) may be driven by another turbine (e.g., steam turbine 66 of FIG. 1).

[0045] As discussed above, the electromechanical machine temperature controller 98 may be configured to warm the chilled fluid 46 by absorbing heat from a system within the IGCC plant system 10. In some embodiments, the electromechanical machine temperature controller 98 may be configured to adjust the temperature of the chilled fluid 46 by moderating the chilled fluid 46 with air 42. Air 42 may be introduced to the chilled fluid 46 to produce a chilled mixture 126. The chilled mixture 126 may be warmer than the chilled fluid 46 and cooler than the generator 64. The electromechanical machine temperature controller 98 may be configured to moderate the chilled fluid 46 with air 42 to protect the coolant circuit 88, winding 92, or other part of the generator 64 from undesirable low temperatures (e.g., cryogenic temperatures). The chilled mixture 126 may flow through the coolant circuit 88 and be directed to the chilled fluid system 40, the bleed inlet 122, or the diluent conduit 52.

[0046] The embodiments of FIG. 4 in which the chilled fluid 46 is used in the IGCC plant system 10 after cooling the generator 64 may be used together with embodiments described above in FIGS. 2 and 3. For example, the chilled fluid system 40 may be configured to cool the generator 64, 68 through any of the configurations of the first heat exchanger 84 of FIG. 2, where some of the warmed fluid 120 may be

directed elsewhere as diluent gas 56 as described above with FIG. 4. As another example, the electromechanical machine temperature controller 98 may direct a part of the chilled fluid 46 from the chilled fluid system 46 through the generator 64, 68 to another system (e.g., gas turbine engine 38) within the IGCC plant system 10 while another part of the chilled fluid 46 is directed to the cooler 110 to cool the stator 96.

[0047] Presently contemplated embodiments include systems and methods for generating a chilled fluid using a chilled fluid system (e.g., air separation unit), removing heat from a generator via heat exchange with the chilled fluid (e.g., inert gas from chilled fluid system), and controlling the heat exchange to maintain a temperature of the generator below a first threshold temperature. As discussed above, the chilled fluid may be a liquid or a gas, such as nitrogen, argon, or helium. The chilled fluid also may be a cryogenic fluid. The first threshold temperature may be approximately 100° C., 125° C., 150° C., 175° C., or 200° C. A working fluid may be configured to exchange heat with the chilled fluid and the generator to remove heat. The method may include circulating the working fluid and chilled fluid through a heat exchange system (e.g., heat exchanger or chiller). In some embodiments, controlling the heat exchange includes directing the working fluid to interface directly with a rotor and/or a stator of the generator. In some embodiments, the method includes using the chilled fluid as a diluent in a gas turbine engine. Moreover, the method may include moderating the chilled fluid with a gas (e.g., ambient air) that is warmer than the chilled fluid. In some embodiments, the method includes warming the chilled fluid to a second threshold temperature prior to removing heat from the generator. The second threshold temperature may be approximately -20° C., -10° C., 0° C., or 10° C. Warming the chilled fluid to the second threshold temperature may protect the generator from temperatures near the DBTT and protect the fluids from freezing or becoming too viscous.

[0048] Technical effects of the invention include integrating a chilled fluid system with components of an IGCC plant system, so that a generated chilled fluid may cool a generator or other components. The chilled fluid system (e.g., air separation unit) may be configured to produce a primary product, such as oxygen, and produce the chilled fluid as a byproduct (e.g., nitrogen, argon, or other inert gas). Using the chilled fluid within the system to cool a component increases the efficiency of the IGCC plant system by utilizing the energy used to generate the chilled fluid to cool a warm component, such as a generator. Cooling the generator may increase the efficiency by lowering the energy lost due to the electrical resistance within the generator. Circulating the chilled fluid may increase the heat removed from the generator to increase the generated output by removing or extending thermal limits in the windings. Using the chilled fluid may enable the generator to be cooled with a smaller and/or less complex heat exchange system. For example, circulating the chilled fluid may increase the rated output for a generator using liquid cooled bushings. Using the chilled fluid from the chilled fluid system within the IGCC plant may reduce the frame size and complexity of the generator, because on-base coolers are no longer used for the generator. Reducing the size of the heat exchange system or using a heat exchanger external to the generator casing, rather than internal, may reduce the size of a generator casing and frame or increase the rated output of a generator with the same casing and frame. Circulating the chilled fluid directly through the generator may reduce main-

tenance costs due to decreased corrosion and oxidation due to water leakage. Directing the chilled fluid from the generator to the gas turbine engine as a diluent gas may decrease the energy used to heat the diluent gas prior to entering the combustor.

[0049] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

1. A system, comprising:
an air separation unit configured to generate a chilled fluid;
and
an electromechanical machine, wherein the electromechanical machine is configured to be cooled via heat exchange with the chilled fluid.
2. The system of claim 1, wherein the air separation unit is configured to generate nitrogen as the chilled fluid.
3. The system of claim 1, comprising an integrated gasification combined cycle (IGCC) power plant comprising the air separation unit and the electromechanical machine.
4. The system of claim 1, wherein the electromechanical machine comprises a generator, wherein the generator comprises a rotor and a stator.
5. The system of claim 4, wherein the rotor and the stator are configured to be cooled via heat exchange with the chilled fluid.
6. The system of claim 1, comprising a heat exchanger configured to receive the chilled fluid, cool a heat transfer fluid via heat exchange with the chilled fluid, and circulate the heat transfer fluid through the electromechanical machine.
7. The system of claim 6, wherein the heat exchanger is disposed in the air separation unit, or the electromechanical machine, or any combination thereof.
8. The system of claim 1, wherein the air separation unit comprises a chilled fluid reservoir configured to store the chilled fluid.
9. The system of claim 1, comprising a controller configured to maintain a temperature of the electromechanical machine below a threshold temperature.
10. A system, comprising:
an electromechanical machine temperature controller configured to control a heat exchange system to maintain a

temperature of an electromechanical machine below a threshold temperature, wherein the heat exchange system comprises a chilled fluid circuit configured to remove heat from the electromechanical machine via heat exchange with a heat transfer fluid and a chilled fluid, and the chilled fluid is generated by an air separation unit fluidly coupled to the heat exchange system.

11. The system of claim 10, comprising the electromechanical machine, wherein the electromechanical machine comprises a generator, the generator comprises a rotor and a stator, and the electromechanical machine temperature controller is configured to control the heat exchange system to remove heat from the rotor and the stator via heat exchange.

12. The system of claim 10, comprising the air separation unit, wherein the air separation unit comprises a heat exchanger and the electromechanical machine temperature controller is configured to control a first flow of the chilled fluid and a second flow of the heat transfer fluid through the heat exchanger.

13. The system of claim 10, comprising an integrated gasification combined cycle (IGCC) power plant comprising the air separation unit, the electromechanical machine, and the heat exchange system.

14. The system of claim 10, comprising a gas turbine, wherein the electromechanical machine controller is configured to direct a first flow of the chilled fluid into the gas turbine as a diluent.

15. A method, comprising:
generating a chilled fluid using an air separation unit;
removing heat from an electromechanical machine via heat exchange with the chilled fluid; and
controlling the heat exchange to maintain a temperature of the electromechanical machine below a threshold temperature.

16. The method of claim 15, wherein removing heat comprises cooling a heat transfer fluid configured to exchange heat with the chilled fluid and the electromechanical machine.

17. The method of claim 16, wherein the electromechanical machine comprises a generator, wherein the generator comprises a rotor and a stator, and controlling the heat exchange comprises directing the heat transfer fluid to come in contact with the rotor, the stator, or both.

18. The method of claim 15, comprising circulating the chilled fluid through a heat exchange system.

19. The method of claim 15, comprising using the chilled fluid as a diluent in a gas turbine.

20. The method of claim 15, comprising moderating a temperature of the chilled fluid with a gas, wherein the gas is warmer than the chilled fluid.

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