

METHOD FOR OPERATING A GAS TURBINE WITH CO₂ SEPARATION

DESCRIPTION

5 [0001] The invention relates to a method for operating a gas turbine.

BACKGROUND

10 [0002] Gas turbines are typically powered by fossil fuels, such as natural gas, and ambient air from the Earth's atmosphere. This produces an exhaust gas that usually contains approximately 2 to 4 mole percent carbon dioxide (CO₂) and 12 to 15 mole percent oxygen, as well as other air components, mainly nitrogen. Typically, the exhaust gas is released into the atmosphere at a pressure of less than 150 kPa.

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[0003] US 2010/0058801 A1 describes a gas turbine in an installation for liquefying natural gas. US 8,671,659 B2 describes a possibility for generating electric power by means of a gas turbine.

20 [0004] Because of the major impact of CO₂ on climate change, it is becoming increasingly important to reduce or completely avoid CO₂ emissions. In this context, EP 2 435 540 B1 and WO 2013/000953 A2 describe how CO₂ can be removed from a gas stream by means of absorption, in particular, amine scrubbing.

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DISCLOSURE OF THE INVENTION

30 [0005] Against this background, methods and installations having the features of the respective independent claims are proposed. Advantageous embodiments and further aspects of the invention are the subject matter of the dependent claims and of the following description.

[0006] The invention makes use of the measure of subjecting a first process stream, which is produced by combustion of an oxidant stream with a fuel stream, downstream of a gas turbine for which it is used to drive, to a compression and subsequent CO₂ separation, and of recirculating it—together
5 with additional oxygen—to the combustion. This results in a higher CO₂ concentration in the exhaust gas compared to conventional methods, and enables a more efficient CO₂ separation.

[0007] In particular, the invention comprises a method for operating a gas
10 turbine, wherein a fuel stream containing at least one combustible component is subjected to combustion together with a compressed oxidant stream containing at least oxygen, to obtain a first process gas. The first process gas is used to drive the gas turbine after at least partial cooling and is at least partially compressed downstream of the gas turbine. Downstream of the
15 compression, the first part of the process gas is subjected to a first CO₂ separation, to obtain a second process gas enriched with CO₂ and an installation exhaust gas depleted of CO₂. A second part of the first process gas is at least partially cooled and then used to form the compressed oxidant stream. An oxygen-containing gas stream is added to the first process gas
20 and/or the second part of the first process gas.

[0008] In some embodiments, the oxygen-containing gas stream contains between 10 and a maximum of 50 mole percent oxygen and is mixed with the first process gas upstream of the compression. For example, ambient air can
25 be used as the oxygen-containing gas stream. This means that only one compressor is needed to compress the oxygen required for the combustion.

[0009] Alternatively, the oxygen-containing gas stream may contain at least 50 to a maximum of 100 mole percent oxygen and be mixed with the second part
30 of the first process gas upstream of the combustion. Thus, fresh oxygen does not need to be treated in the CO₂ separation, so that it can be provided with a lower volume capacity than in cases where the oxygen-containing gas stream

is fed upstream of the CO₂ separation. In addition, this reduces the throughput of essentially inert components of the oxygen-containing gas stream, such as nitrogen and/or noble gases contained in the natural atmosphere. Such an oxygen-rich stream may, for example, originate from an air separation unit, particularly if the gas turbine is used to drive such an air separation unit, or may also arise as a by-product or waste product of electrolysis, e.g., water and/or CO₂ electrolysis.

[0010] The method is preferably operated in such a way that a volume-related concentration of CO₂ of more than 3%, more than 5%, or more than 7% is established in the first process gas immediately upstream of the CO₂ separation. This allows CO₂ separation to be carried out particularly efficiently. In particular, a recirculation rate of the first process gas to the gas turbine (e.g., a quantity ratio of the second part of the first process gas to the first part of the first process gas) can be adjusted depending on the CO₂ concentration upstream of the CO₂ separation.

[0011] The CO₂ separation comprises, in particular, a membrane separation and/or scrubbing with an absorbent, in particular, an amine scrubbing, as described, for example, in DE 10 2008 025 224 A1, and/or an adsorption separation using an adsorber. These are particularly relevant methods for CO₂ removal from a gas mixture.

[0012] In some embodiments of the invention, the first process gas is subjected to a heat exchange upstream of the compression and/or downstream of the compression while cooling, in particular wherein the heat released in the heat exchange is used for regeneration of the absorbent and/or the adsorber, if these are used for the CO₂ separation. This means that the entire method can be carried out in a particularly energy-efficient manner.

[0013] Mechanical energy provided by the gas turbine can be used, in particular, to compress the first process gas and/or to further compress the (cooled)

second part of the first process gas to generate the compressed oxidant stream and/or to compress a CO₂-rich stream and/or to generate electric power. This creates particularly energy-efficient implementation options.

- 5 [0014] Preferably, the generation of electric power is controlled in such a way that load changes of other consumers are at least partially compensated by mechanical energy provided by the gas turbine. This facilitates the control of the mechanically relatively sluggish gas turbine and increases its efficiency.
- 10 [0015] An installation according to the invention having a gas turbine, at least one compressor, and a device for depleting a gas stream of CO₂, is designed to carry out a method as just described and therefore benefits from its advantages in a corresponding manner.
- 15 [0016] The invention thus provides installations and methods in which a gas turbine, components driven by the gas turbine, exhaust gas compression, and CO₂ separation are highly integrated. All the required mechanical energy can be provided by the gas turbine. This increases overall efficiency by optimizing the conversion of chemical energy contained in the fuel into thermal and
- 20 mechanical energy and its use. At the same time, the number of required components, the space required, and the planning effort are reduced. The invention also provides a possibility for retrofitting existing installations, since the components used here are usually already present in conventional installations, and therefore only an appropriate interconnection (e.g., by means
- 25 of pipes, valves, control systems, etc.) has to be carried out.

EMBODIMENTS OF THE INVENTION

- [0017] The invention will be explained in more detail below with reference to
- 30 the embodiment shown schematically in Figure 1. If reference is made below to a component of a device, this also refers in a corresponding manner to

method steps carried out in this component or by means of this component and/or vice versa. In the figures:

Figure 1 is an embodiment of the invention in a schematic representation as a block diagram.

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[0018] In Figure 1, an embodiment of the invention is shown schematically in the form of a block diagram and is referred to overall as installation 100.

[0019] A central element of the installation 100 is a gas turbine 110, which
10 drives compressors 120, 130 and optionally further consumers 170, 180. The gas turbine 110 is supplied with a fuel stream 1, for example, a fluid stream containing methane, ethane, propane, and/or butane, and with an oxidant stream 6 containing at least oxygen. The fuel stream 1 is at least partially combusted, resulting in a volume expansion, which is ultimately used to drive
15 the turbine and is thus converted into mechanical energy. The turbine exhaust gas (also referred to as first process gas 7) is expanded and partially cooled.

[0020] In the example shown here, the first process gas 7 is fed to the compressor 130 via a waste heat recovery unit 160 and an unspecified heat
20 exchanger (e.g., optional), and is compressed. For example, the expanded first process gas 7 may be present upstream of the compressor 130 at a first pressure level, which essentially corresponds to the natural ambient air pressure, e.g., in the range from 0.9 to 3 bar, and may be compressed in the compressor 130 to a second pressure level, e.g., in a range from 4.5 to 50 bar.
25 For example, a pressure ratio (from downstream to upstream of the compressor 130) may range from 4.5 to 44.5, wherein large power plant turbines are typically operated at a pressure ratio between 13 and 25, and aeroderivative turbines are operated at a pressure ratio of 23 to 44.5. An example of an aeroderivative turbine is the LMS100 model from GE, which can
30 be operated with intercooling at a pressure ratio of up to 44.5. In some embodiments of the installation 100, an oxygen-containing gas stream 2, for example, air, synthetic air, purified air, or another oxygen-containing gas

mixture, can be mixed with the first process gas 7 at the first pressure level upstream of the compressor 130.

5 [0021] The waste heat recovery 160 can, for example, generate steam in one or more heat exchangers in which the turbine exhaust gas 7 is cooled, which steam can be used for further applications inside and/or outside the installation 100. The steam quality (steam pressure) is essentially determined by the temperature level of the turbine exhaust gas (typically between approx. 420°C and approx. 540°C for aeroderivative steam turbines, i.e., turbine designs
10 based on aviation turbines; for power plant or industrial turbines, typically between approx. 540°C and approx. 650°C). In particular, low-pressure steam can be generated in the process. For example, low-pressure steam may be present at a pressure level in the range of 0.5 to 5 bar.

15 [0022] In some embodiments of the installation 100, medium-pressure (5 to 25 bar) and/or high-pressure steam (>25 bar) can also be generated in the waste heat recovery 160 and made available for applications inside and/or outside the installation 100. In particular, such steam at medium or high pressure can be used to generate electricity or to drive mechanical units by means of steam
20 turbines.

[0023] In some embodiments, steam streams at different pressure levels can also be generated in the waste heat recovery 160, so that different consumers can be supplied according to their respective requirements.

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[0024] Downstream of the compression 130, a first part 9 of the first process gas 7 (if necessary, together with the oxygen-containing gas stream 2) is fed to a CO₂ separation 140, 150. In the example shown here, this first part 9 of the first process gas 7 is depleted of CO₂ in a CO₂ scrubber 140 (which
30 comprises, for example, an absorber, in particular in the form of an amine scrubber). The absorption medium used for this purpose is regenerated in a regeneration unit 150 (also referred to as CO₂ stripping) (e.g., by adding heat),

whereby a second process gas 4 enriched in CO₂ is obtained. In particular, heat from the waste heat recovery unit 160 can be used for the regeneration 150 of the absorbent. For example, low-pressure steam generated in waste heat recovery can be used to heat (also known as reboiling) the absorbent, for example, an amine solution, and thus to strip the CO₂ absorbed in it. At least a part of the first part 9 of the first process gas 7 treated in the CO₂ scrubber 140 is discharged as installation exhaust gas 5. In particular, the installation exhaust gas contains less than 1%, less than 0.3%, less than 0.1%, or less than 0.03% CO₂.

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[0025] The CO₂ scrubber 140 may, in particular, comprise a medium-pressure scrubber configured to absorb CO₂ from gas streams at a medium pressure level ranging from 5 to 60 bar, and a low-pressure scrubber configured to absorb CO₂ from gas streams at a low pressure level ranging from 1 to 5 bar.

15 In such cases, the regeneration 150 may be configured to strip the absorbed CO₂ from both the absorbent of the medium-pressure scrubber and that of the low-pressure scrubber, wherein separate media circuits (e.g., separate stripping vessels) may be provided for the different absorbents. However, a common media circuit is also possible, especially if the same absorbent is used
20 in the low-pressure scrubber as in the medium-pressure scrubber.

[0026] As mentioned at the beginning, other methods of CO₂ separation may be used alternatively or in addition to the scrubber-based system shown here. Examples of such other methods include membrane separation methods, adsorption separation, and distillation methods, or combinations thereof.
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[0027] A second part 8 of the first process gas 7 is cooled without passing through the CO₂ scrubber 140, and is subsequently used to form the oxidant stream 6. In some embodiments, a (possibly further) oxygen-containing gas stream 3 can additionally be added. The oxygen-containing gas stream 3 is, in particular, a gas stream which has a higher oxygen concentration than the oxygen-containing gas stream 2. Particularly preferably, a gas stream
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consisting of more than 50 mole percent oxygen is used as the oxygen-containing gas stream 3. This is particularly advantageous when such a gas stream is already present in the installation 100 or in its spatial surroundings, for example, when the gas turbine 110 is used to drive an air separation unit
5 (e.g., consumer 170).

[0028] In some embodiments, a part of the gas 9 processed in the CO₂ scrubber 140 may be transferred into the oxidant stream 6, for example, in order to achieve a higher control quality with respect to the composition of the
10 oxidant stream 6 and/or in order to achieve a higher utilization of the residual oxygen contained in the first process gas 2. This is particularly advantageous in cases where a gas stream 3 that is very rich in oxygen is fed in.

[0029] Preferably, the division of the first process gas 7 into its first part 9 and
15 second part 8 is carried out in such a way that a CO₂ concentration of more than 5 mole percent, for example, approximately 7 mole percent, is established in the first process gas. Conventionally (especially without exhaust gas recirculation), the CO₂ concentration is around 3 mole percent. Due to the significantly increased concentration and the pressure increased by means of
20 the compressor, the separation of relevant amounts of CO₂ is made significantly easier, so that the installation components used for this purpose (CO₂ scrubber 140, regeneration 150) can be made considerably smaller and more cost-effective than would conventionally be the case, while maintaining the same separation performance (residual concentration of CO₂ in the
25 installation exhaust gas 5). The gas volumes discharged via the second process gas 4 and the installation exhaust gas 5 are compensated by the feeding of the oxygen-containing gas stream(s) 2, 3.

[0030] As already mentioned, the gas turbine 110 supplies consumers 170,
30 180 with mechanical drive energy. In some embodiments of the installation 100, at least one of these consumers 170, 180 may comprise a compressor, for example, a centrifugal compressor, for compressing the CO₂-enriched

second process gas 4. The second process gas 4 may, in particular, contain more than 30%, more than 50%, more than 70%, more than 90%, more than 95%, more than 99%, or more than 99.9% CO₂. Depending on the intended use of the second process gas 4, it may be compressed to an appropriate pressure level. For example, the second process gas 4 may be released as CO₂ product gas, so that compression to a storage or transport pressure level (e.g., 20 to 300 bar) may be provided. However, it may also be provided that the second process gas 4 is used directly for CO₂ injection (also referred to as sequestration) for essentially permanent disposal in underground storage facilities. In such cases, compression directly to an injection pressure level (e.g., 80 to 300 bar) may be provided. In some embodiments, the second process gas stream 4 may also be used as a coolant or refrigerant in an open cooling circuit after its compression and may only be released after being used as a coolant.

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[0031] Alternatively or additionally, at least one of the consumers 170, 180 may comprise one or more refrigerant compressors that compress a refrigerant that may be used in the installation 100 or in its vicinity. Centrifugal compressors are particularly suitable for this purpose.

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[0032] In cases where a generator for generating electricity is driven by the gas turbine 110 (in some embodiments, this may also be a starter motor with reverse running capability), the generator may be used to compensate for load changes of other consumers, in particular of the consumers 170, 180. In this way, the overall efficiency can be increased because the sluggish gas turbine 110 is exposed to fewer strong load changes, and instead a relatively stable output load is flexibly distributed to more easily controllable consumers 170, 180.

Claims

1. A method for operating a gas turbine (110), wherein a fuel stream (1) containing at least one combustible component is subjected to combustion together with a compressed oxidant stream (6) containing at least oxygen, to obtain a first process gas (7), and the first process gas (7) is used to drive the gas turbine (110) with at least partial cooling, **characterized in that** the first process gas (7) is at least partially subjected to a compression (130) downstream of the gas turbine (110), and is subjected to a CO₂ separation (140, 150) downstream of the compression (130) to a first part (9) to obtain a CO₂-enriched second process gas (4) and a CO₂-depleted installation exhaust gas (5), wherein the first process gas (7) is cooled to a second part (8) and then at least partially used to form the compressed oxidant stream (6), and wherein an oxygen-containing gas stream (2, 3) is admixed to the first process gas (7) and/or the second part (8) of the first process gas (7).
2. The method according to claim 1, wherein the oxygen-containing gas stream (2) contains between 10 and a maximum of 50 mole percent oxygen and is mixed with the first process gas (7) upstream of the compression.
3. The method according to claim 1, wherein the oxygen-containing gas stream (3) contains at least 50 to a maximum of 100 mole percent oxygen and is mixed with the second part (8) of the first process gas upstream of the combustion.
4. The method according to any of the preceding claims, wherein the CO₂ separation (140, 150) comprises an adsorption separation using an adsorber and/or scrubbing with an absorbent, in particular amine scrubbing, and/or a membrane separation.
5. The method according to any of the preceding claims, wherein the first process gas (7) upstream of the compression (130) and/or downstream of the

compression (130) is subjected to a heat exchange (160) while cooling, in particular wherein the heat released in the heat exchange (160) is used for regeneration of the absorbent and/or adsorber according to claim 4.

5 6. The method according to any of the preceding claims, wherein a volume-related concentration of CO₂ of more than 3%, more than 5%, or more than 7% is set in the first process gas (7) upstream of the CO₂ separation (140, 150).

7. The method according to any of the preceding claims, wherein
10 mechanical energy provided by the gas turbine (110) is used for the compression (130) of the first process gas (7) and/or for further compression (120) of the second part (8) of the first process gas to generate the compressed oxidant stream (6) and/or for compression (170) of a CO₂-rich stream, in particular the second process gas (4) or a part thereof, and/or for generating
15 electric power (180).

8. The method according to claim 7, wherein generation of electric power (180) is controlled such that load changes in other consumers (170) are at least partially compensated by mechanical energy provided by the gas turbine (110).

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9. An installation (100) with a gas turbine (110) and at least one compressor (120, 130) and a device (140, 150) for depleting a gas stream of CO₂, wherein the installation (100) is designed to carry out a method according to one of the preceding claims.

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