

POWER GENERATION SYSTEM AND CO₂ CAPTURE SYSTEM

Field of the invention

[0001] The present invention relates to the field of power. In particular, the invention relates to the field of power generation and gas emissions.

[0002] In particular, this invention relates to a power generation system and a CO₂ capture system.

Description of Related Art

[0003] Below, the known prior art from which the invention has been developed is described.

[0004] The climate emergency makes it essential to change the current energy model, which needs to be refocused around energy efficiency and the reduction of greenhouse gases.

[0005] Indeed, at present, the generation of energy or power passes in particular through installations such as fossil-fueled power plants for producing energy. However, these installations are large producers of greenhouse gases.

[0006] Carbon dioxide (CO₂) is considered to be responsible for 81% of greenhouse gas or "GHG" emissions in Europe according to the data published by the *Commissariat Général au Développement Durable* [General Commission for Sustainable Development] of the French government in "*Chiffres clés du climat France, Europe et Monde*" [Key Climate Figures in France, Europe and the World], 2022 edition. The main greenhouse gas, and partly responsible for global warming, carbon dioxide is, for example, rejected through gaseous effluents such as industrial gaseous effluents, in particular when fossil fuels are burned in order to supply electricity and heat. These industrial processes include, for example, plants for producing energy from fossil energy. The increase in the atmospheric concentration of GHG through anthropogenic emissions increases the emission of energy towards the ground, leading to an imbalance in the energy balance of the Earth and causing the rise of its surface temperature. Hence, prevention of the emission of GHG such as CO₂ is an essential issue for society and in particular in the generation of power.

[0007] Offshore and/or onshore oil and/or gas installations are among the greenhouse gas

emitting industrial processes. Indeed, in operation, these installations can generate carbon dioxide (CO₂), in particular during activities related to the generation of power (electrical and/or thermal and/or mechanical).

[0008] However, the need for energy continues to grow and the demand for energy resources continues to increase in parallel. There is a problem of international scope between the need for energy and the reduction of greenhouse gases. Nevertheless, natural gas and hydrocarbons are a major source of fuel for the production of electricity and heat.

[0009] Several techniques exist for the production of power and/or the capture of CO₂, using in particular so-called open (simple) or combined cycles.

[0010] Open cycle usually runs as open Brayton thermodynamic cycle and consists only of a gas turbine including a compressor to compress the working fluid, a combustor system to heat the working fluid, and an expansion turbine section to expand the working fluid and produce mechanical power, first to drive the compressor, and second to produce electrical power with a generator. The energy of the exhaust gas is wasted.

[0011] A combined cycle is a set of heat engines operating in tandem from the same source of heat. The principle is that after completing its cycle in the first engine, the exhaust gas is still hot enough for a subsequent second heat engine to extract energy from the heat of the exhaust. Between the two engines, the exhaust gas passes through a heat exchanger so that the two engines can use different working fluids at different pressures.

[0012] Due to the presence of an additional engine, a combined cycle makes possible to increase the power generated compared to an open cycle with the same heat input. However, combined cycles are poorly suited to offshore installations. Because of the additional heat exchanger and engine, the weight and size ratio of the combined cycle relative to power are much greater than the ratio observed in open cycle.

[0013] The combined cycles without capture proposed today for offshore remain quite heavy and bulky, and raise some questions for their conversion into a solution with capture, in particular for steam extraction. It is therefore not at all certain that such cycles associated with capture ultimately offer relevant efficiency in power generation and CO₂ capture, while their weight and size are not negligible.

[0014] It is technically possible to implement a CO₂ capture installation on an offshore open cycle installation (fixed or floating) comprising for example two gas turbines of 30 MW each, producing 60 MW total power. The CO₂ capture unit is made up of different pieces of

equipment such as heat recovery unit on exhaust gases, direct contact cooler, absorber etc. The impact of these different capture pieces of equipment reduces the net power available by approximately 15% (9 MW) down to 51 MW, forcing the load on the turbines to be increased if possible, or even to put an additional unit into service to recover initial 60 MW load. The efficiency of the installation is therefore reduced by approximately 6 points (typically 31% against 37% without capture). The large size and weight of this equipment have a direct impact on the design and cost of the fixed or floating installation, which constitutes an obstacle to the implementation of CO₂ capture projects on offshore installations.

[0015] It is also technically possible to implement a similar CO₂ capture installation on a combined cycle for offshore, comprising, for example 2 gas turbines (typically 2x300 tons for 2x30 MW), 2 recovery boilers (typically 2x260 tons and 25 m high), for steam production (typically 2x10 kg/s of steam at 43 bar / 450°C) and located above the turbine exhaust, and 1 condensing steam turbine with its "vacuum" condenser cooled with sea water (typically 1x230 tons for 1x20 MW). This combined cycle makes it possible to produce approximately 1/3 (20 MW) of additional power compared to the "open cycle", and this for the same quantity of fuel consumed, therefore efficiency without capture improved by 12 points to approximately 49%, and potentially the same capture installation, but with an additional weight of 750 tons for the bottoming cycle, i.e. nearly 4 times the weight/power ratio of the open cycle (37.5 t/MW for the 20 additional MW against 10 t/MW for the 60 MW gas turbines, without taking into account the impact on the structure). It should be noted that an installation optimized for onshore would certainly be even more powerful and more efficient (up to 4-5 additional MW on the steam turbine and 2-3 points of additional efficiency gain), but much more complex, heavy and bulky by a factor of around 1.5 to 2, and totally unsuitable for offshore.

[0016] The CO₂ capture unit may also comprise a steam extraction on the steam turbine to supply the regenerator with heat. This extraction at intermediate pressure is very large, varying from 50% to 75% or even more depending on the energy efficiency of the capture process (between 2.5 and 3.5 GJ/t CO₂, i.e. 10 to 15 kg/s of steam at about 4-6 bar to extract 30 t/h of CO₂ from the fumes of the 2 gas turbines). This extraction reduces the power of the steam turbine by 25% to 33% (5 to 7 MW), which finally gives a net power with the capture of 64 to 66 MW, increased by 25 to 30% (13 to 15 MW) compared to the "open cycle" case with capture (51 MW). The additional weight of the complete plant will be reduced by about 100 t (weight of the heat recovery unit of "open cycle" capture plant, replaced by the boilers), i.e. about 650 t, which represents about 40 to 50 t/MW net

excluding structure. This value is apparently slightly better than that of the complete "open cycle" plant with capture (2900 t, or 57 t/MW), but the adaptation of the capture system to combined cycle operation may increase its weight because of optimized heat consumption. The efficiency penalty due to capture is about 8-9 points (40-41% net).

[0017] The adaptation of the capture system to combined cycle operation leads to an increase of its weight in order to optimize heat consumption.

[0018] Moreover, the very significant extraction of steam poses very strong constructive and operational difficulties for the steam turbine, which sees its exhaust flow rate reduced by more than half in capture. It is generally mitigated by modifying the steam cycle with the addition of a second pressure to the boiler to produce more "low pressure" steam, as well as the use of additional fire. However, these arrangements have an impact on the weight and complexity of the installation and will likely deteriorate the overall weight/power ratio. Overall, the optimization of weight/power/yield/residual CO₂ emissions of a combined cycle offshore installation with capture raises a large number of questions.

[0019] In addition, the operation of a CO₂ capture installation associated with a power generation installation leads to a very significant drop in the overall efficiency of the power generation installation. Indeed, the consumption of heat and of the power necessary to operate the CO₂ capture installation increases in particular due to the presence of the auxiliaries of the CO₂ capture installation.

[0020] The combined cycle with capture by absorption is a common solution today for onshore installations, but the weight criterion is not as critical as for offshore, and the impact of the cooling system on the size of the installation makes a lot less relevant the search for a solution for reduced dimensions such as offshore installations. The boilers used are usually heavier, the steam cycle has two pressures to increase efficiency and mitigate the difficulties related to the steam turbine mentioned above.

[0021] The extensive decarbonization of "open cycle" offshore gas turbine power generation installations involves the addition of large and heavy flue gas cooling and CO₂ capture systems by absorption. These systems will also degrade the power and net efficiency of the installation, and sometimes require the addition of power units or the use of more powerful gas turbines.

[0022] To increase the efficiency of the installation and reduce the size of the capture installation, one naturally thinks of using the exhaust heat in a "combined cycle". However,

combined cycle solutions with CO₂ capture used on shore are extremely bulky and heavy (in particular due to the size of the recovery boilers, of the steam turbine and of the condenser), because they aim above all to maximize yield and are not well suited to the constraints of offshore. In addition, the "light" combined cycles without capture proposed today for the offshore remain rather heavy and bulky, and raise some questions for their conversion into a solution with capture, in particular for the impact of the consequent extraction of steam, necessary for the CO₂ capture process, on the design and operation. Thus, it is not at all certain that such cycles with capture will ultimately offer better performance while their weight and footprint will be much greater.

[0023] In addition, the decarbonization of power generation installation also poses the problem of optimizing production and investment costs. The combined cycle with absorption capture is a common solution today, but the weight criterion is not as critical as for offshore, and the impact of the cooling system, usually air, on the size of the installation makes the search less relevant. The boilers used are usually heavier, the steam cycle at 2 pressures to increase efficiency and mitigate the difficulties related to the steam turbine mentioned above, and the cost constraints are little or not optimized with regard to the production need.

[0024] Hence, there is a need for solutions capable of generating power while reducing greenhouse gas emissions and which are suitable for small-scale installations without compromising their efficiency, and while reducing the costs associated with these installations.

Summary of the invention

[0025] The following sets forth a simplified summary of selected aspects, embodiments and examples of the present invention for the purpose of providing a basic understanding of the invention. However, the summary does not constitute an extensive overview of all the aspects, embodiments and examples of the invention. The sole purpose of the summary is to present selected aspects, embodiments and examples of the invention in a concise form as an introduction to the more detailed description of the aspects, embodiments and examples of the invention that follow the summary.

[0026] The invention aims to overcome the disadvantages of the prior art. In particular, the invention proposes **a system for generating power** with a combined cycle for an installation comprising:

- at least one supply pipe configured to supply a working fluid to at least one gas turbine,
- at least one transport pipe configured to guide an exhaust gas from a proximal end to a distal end of the at least one transport pipe, said proximal end being configured to cooperate fluidically with the at least one gas turbine and the distal end being configured to cooperate fluidically with at least one compact heat recovery steam generator, said distal end being at a height less than or equal to a height of the proximal end relative to a base of said installation, and
- at least one conveying pipe configured to direct a steam from the at least one compact heat recovery steam generator to at least one back-pressure steam turbine configured to generate power from the steam.

[0027] The advantage of this system is that it improves overall efficiency, which reduces fuel costs. The system allows improving the weight/power ratio and thus to increase the efficiency of the installation. In addition, the system is compact and allows to be adapted to the installation with reduced space.

[0028] Hence, the invention allows a significant increase in efficiency compared to "open cycle" operation, and therefore a reduction in fuel consumption while minimizing the amount of space and materials required for power generation. The layout and arrangement of each system element is considered to facilitate its implementation and to improve the performance of the installation.

[0029] The invention thus allows for a reduction in costs, an increase in efficiency, a reduction in fuel consumption, in particular compared to a direct capture installation, and thus an improvement in the overall size of the installation.

[0030] In addition, the invention allows to be adaptable to several types of installations.

[0031] According to other optional features of the system according to the invention, it can optionally include one or more of the following characteristics alone or in combination:

- the generated power is an electric, thermal power and/or mechanical power,
- the installation is an onshore installation or an offshore installation,
- the at least one gas turbine comprises an exhaust gas recirculation means,
- the system and/or the at least one compact heat recovery steam generator comprise at least one duct firing,

- the at least one compact heat recovery steam generator comprises a one through steam generator,
- the at least one compact heat recovery steam generator comprises straight and/or finned tubing, circular and/or spiral finned, with solid or serrated fins, preferably finned tubing,
- the at least one compact heat recovery steam generator comprises tubing with an external diameter between 9.00 and 50.00 mm,
- the at least one compact heat recovery steam generator is configured to be arranged below the gas turbine,
- the at least one compact heat recovery steam generator is an inverted vertical compact heat recovery steam generator, preferably inverted may correspond to a vertical downflow, more preferably an inverted vertical compact HRSG,
- the at least one compact heat recovery steam generator is configured to present a horizontal flow or a vertical downflow or vertical upward flow, preferably a horizontal exhaust gas flow or vertical exhaust gas downflow or a vertical exhaust gas upward flow,
- the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an inlet of the at least one compact heat recovery steam generator relative to a base of the installation,
- the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an outlet of the at least one compact heat recovery steam generator relative to a base of the installation,
- the at least one transport pipe comprises a by-pass,
- the system comprises at least one fan,
- it comprises at least one condenser,
- it comprises at least one condensate pump, an extraction pump and/or a feed pump,
- it comprises at least one feed water tank.

[0032] According to **another aspect**, the invention can also relate to a **system for capturing CO₂** from exhaust gas comprising:

- At least one power generation system according to the invention,
- At least one cooling module configured to cool the exhaust gas from the at least one compact HRSG,
- At least one absorption module configured to contact cooled exhaust gas with a lean solvent capable of absorbing CO₂ from the exhaust gas to generate an enriched solvent, and
- At least one solvent regeneration module fluidically coupled to at least one reboiler, said solvent regeneration module being configured to treat the enriched solvent to release absorbed CO₂ and form a lean solvent, and
- wherein the back pressure steam turbine is configured to supply steam to the reboiler of the solvent regeneration module.

[0033] The invention allows increasing efficiency compared to "open cycle" operation, and thus reduced fuel consumption and residual CO₂ emissions, while minimizing the space and amount of material required to provide CO₂ capture by absorption on a power generation installation and thus reducing CO₂ emissions.

[0034] The invention allows a power generation system with a specific layout and arrangement to be judiciously combined with a CO₂ capture system also having a particular layout and arrangement in order to improve and decrease the weight/power ratio of the installation and to adapt to space constraints.

[0035] The invention also allows for a reduction in the cost of implementing CO₂ capture on an installation with an increase in efficiency, reduction in fuel consumption and CO₂ emissions compared to, for example, a direct capture installation, and thus in the overall size of the installation. This invention allows the implementation of capture on a power generation installation at a significantly lower overall cost than that of an "open cycle" installation with direct capture, or of a "combined cycle" installation, lightened or not with capture. Moreover, the invention can be adapted to installations with a reduced footprint.

[0036] In addition, the invention allows to be adaptable to several types of installations.

[0037] According to other optional features of the system according to the invention, it can optionally include one or more of the following characteristics alone or in combination:

- it comprises an auxiliary water extraction and re-injection system,

- it comprises a water storage means,
- it comprises a collector, preferably configured to be arranged downstream of the at least one compact heat recovery steam generator,
- the cooling module comprises a cooling fluid, said cooling module being configured to bring the exhaust gas and the cooling fluid into contact, said contact being direct or indirect,
- the cooling module and the absorption module are configured to be arranged in the lower part of the installation,
- the cooling module is configured to cooperate fluidically with the at least one compact heat recovery steam generator,
- it comprises a fan,
- the absorption module is configured to enable a counter-current flow absorption,
- the absorption module is configured to enable a crossflow absorption.

[0038] The invention can also relate to **a method for capturing CO₂** comprising at least one system for capturing CO₂ according to the invention wherein the said method comprises a step of setting the at least one compact heat recovery steam generator to an inlet exhaust gas temperature ranging from 400 °C to 650 °C.

[0039] The invention allows for increased efficiency over "open cycle" operation, thus reducing fuel consumption and residual CO₂ emissions, while minimizing the space and amount of material required to provide CO₂ capture by absorption on an installation. The invention allows an optimization of the system parameters allowing an excellent compromise between performance and compactness, while allowing a thorough integration of the whole "power generation" and "CO₂ capture" functions in an optimized installation.

[0040] In addition, the invention allows to be adaptable to several types of installations.

[0041] According to other optional features of the method according to the invention, it can optionally include one or more of the following characteristics alone or in combination:

- It comprises a step of setting the at least one compact heat recovery steam generator to an outlet exhaust gas temperature ranging from 70 °C to 250 °C,

- It comprises a step of setting the at least one compact heat recovery steam generator to a steam outlet temperature ranging from 400 °C to 565°C,
- It comprises a step of setting the at least one compact heat recovery steam generator to a steam outlet pressure ranging from 25 bar to 170 bar,
- It comprises a step of setting the back pressure steam turbine to an inlet steam pressure ranging from 25 to 170 bar,
- It comprises a step of setting the back pressure steam turbine to an outlet steam pressure ranging from 1 to 20 bar,
- It comprises a step of setting the back pressure steam turbine to a steam inlet temperature ranging from 400 to 565 °C,
- It comprises a step of setting the back pressure steam turbine to a steam outlet temperature ranging from a saturation temperature to at most 50 °C superheating,
- It comprises a step of setting the reboiler to a steam inlet pressure in a range from 2 bar to 6 bar,
- It comprises a step of setting the reboiler to a steam inlet temperature in a range from 120 °C to 200 °C,
- It comprises a step of setting the reboiler to a steam outlet pressure in a range from 2 bar to 6 bar,
- It comprises a step of setting the reboiler to a steam outlet temperature in a range from 120 °C to 160 °C.

[0042] According to **another aspect**, the present invention can also relate to a use of a CO₂ capture system according to the invention in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport.

[0043] The use of such a system allows to reduce CO₂ emissions, to optimize costs while being compatible with multiple installations and platform activities.

[0044] According to **another aspect** of the present invention, it is provided a use of a power generation system according to the invention in the capture of CO₂, in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport.

[0045] The use of such a system allows generating power, to optimize costs while being compatible with multiple installations and platform activities.

[0046] According to **another aspect**, the present invention can also relate to an offshore installation comprising a power generation system according to the invention.

[0047] According to **another aspect**, the present invention can also relate to an onshore installation comprising a power generation system according to the invention.

[0048] According to **another aspect**, the present invention can also relate to an offshore installation comprising a system for capturing CO₂ according to the invention.

[0049] According to **another aspect**, the present invention can also relate to an onshore installation comprising a system for capturing CO₂ according to the invention.

Brief description of the drawings

[0050] Other features and advantages of the invention will be better understood by reading the following description with reference to the attached drawings, given for illustrative purposes and in no way limiting:

FIG. 1 is a schematic diagram of a power generation system according to an embodiment of the invention.

FIG. 2 is a schematic view of a power generation system according to an embodiment of the invention.

FIG. 3 is a schematic diagram of an arrangement of the compact HRSG and the GT and in particular the flow between the compact HRSG and the GT according to several embodiments of the invention, FIG.3A is a schematic diagram of a horizontal flow, FIG. 3B and FIG. 3C are a schematic diagram of a vertical

downflow FIG. 3D is a schematic diagram of a vertical upward flow.

FIG. 4 is a schematic diagram of a system for capturing CO₂ according to an embodiment of the invention.

FIG. 5 is a schematic view of a system for capturing CO₂ according to an embodiment of the invention.

FIG. 6 is a schematic view of a system for capturing CO₂ according to an embodiment of the invention.

[0051] Several aspects of the present invention are disclosed with reference to diagrams and/or block diagrams according to embodiments of the invention.

[0052] On the figures, the diagrams and/or block diagrams show the architecture, the functionality and possible implementation of devices or systems or methods according to several embodiments of the invention.

[0053] In some implementations, the functions associated with the box may appear in a different order than indicated in the drawings.

[0054] For example, two boxes successively shown, may be arranged substantially simultaneously, or boxes may sometimes be arranged in the reverse order, depending on the functionality involved.

[0055] Each box of diagrams and combinations of boxes in diagrams may be implemented by special systems that perform the specified functions or actions or perform combinations of special equipment.

Detailed description

[0056] Below, a summary of the invention and the associated vocabulary is described, before presenting the disadvantages of the prior art, and finally showing in more detail how the invention overcomes these.

[0057] In the following description, “**power**” may mean energy such as electrical and/or thermal and/or mechanical.

[0058] The term “**pipe**” may mean, within the meaning of the invention, to a conduit, a channel, a line, a tube or a duct enabling the flow of a fluid (liquid or gas), and/or the transport and/or the conveying of a fluid.

[0059] By “**fluid**” in the meaning of the invention may correspond to a gas or a liquid or a steam or a mixture of gas and liquid or gas and steam or liquid and steam or gas, liquid and steam.

[0060] The terms or expressions “**cooperate**” may mean that two elements are connected directly or indirectly with one or more intermediate elements to participate, contribute to a flow (gas and/or steam). Two elements may cooperate mechanically, electrically, fluidically or by a communication channel

[0061] By “**coupled**” within the meaning of the invention may mean connected, directly or indirectly, with one or more intermediate elements. Two elements may be coupled mechanically, electrically, fluidically or linked by a communication channel.

[0062] The expression “**offshore facility**” or “**offshore installation**” may correspond, within the meaning of the invention, to fixed or floating, platform, barge or gravity structures. An installation can be a platform. In the rest of the description, the expression may correspond to a fixed or floating installation and also may or may not be mobile. An offshore installation can be at sea, close to the coast or even on a stretch of water such as a lake.

[0063] The expression “**onshore facility**” or “**onshore installation**” may refer, within the meaning of the invention to facilities, areas or operations for land-based exploration or exploitation (as opposed to offshore).

[0064] The expression “**open cycle**” may refer to an open cycle or a simple cycle.

[0065] The term “**about**” as used herein can allow for a degree of variability in a value or range, for example, within 10%, within 5%, or within 1% of a stated value or of a stated limit of a range.

[0066] In the remainder of the description, when ranges or spreads are used, the limits are included.

[0067] As mentioned, the need for power is constantly increasing, to the detriment of global warming. It is therefore necessary and urgent to be able to produce power in a more efficient way with optimized or even improved yields and in particular by comparison between simple cycle and combined cycle and for all types of installations and preferably for installations in reduced locations (with reduced space requirements) in order to be able to ensure improved power outputs. At the same time, it is also necessary to be able to produce (improve yields) without increasing greenhouse gas emissions, especially CO₂. Also, it is becoming just as

important to find solutions to ensure the generation of energy in a "decarbonized" way. Finally, it is equally important to ensure the reduction of energy loss in existing or future installations. It would be even more relevant for the industry if this solution could also reduce costs (operating, production, etc.).

[0068] The present invention proposes to take into consideration, on the one hand, the energy requirement, the costs and the facilities and, on the other hand, the CO₂ emissions. In particular, the invention proposes to optimize the yields without affecting the constraints related to the installation site and to the exercise of their activity, while minimizing the costs and the use of bulky and expensive materials.

[0069] To this end, the invention proposes according to **a first aspect** a combined cycle power generation system for an installation. Such system may be illustrated in accordance with the **figure 1 or figure 2**.

[0070] As shown in **figure 1 or in figure 2**, a system 1 for generating power with a combined cycle for an installation according to the invention comprises at least one supply pipe 2, at least one gas turbine (GT) 3, at least one transport pipe 4, at least one compact heat recovery steam generator (HRSG) 5, at least one conveying pipe 6, at least one back pressure steam turbine (BPST) 7.

[0071] **The installation** may be an onshore installation or an offshore installation.

[0072] An onshore installation may be an independent power plant connected to an electrical grid, with supply of heat for industrial process or district heating, or a power generation system part of an industrial facility, providing heat and power to this facility.

[0073] An offshore installation may be fixed or floating. For example, an offshore installation may be a barge, a gravity structure made of concrete (GBS for Gravity Based Structure) or a gravity structure made of concrete (CBS for Concrete Based Structure), or a gravity structure made of concrete (CGBS for Concrete Gravity Based Structure) or a gravity structure made of steel (SGBS for Steel Gravity Based Structure) or a gravity structure made of steel (SGS for Steel Gravity Structure). A marine structure may correspond, for example, to a floating production storage and offloading unit (FPSO), a floating production unit (FPU), a floating liquefied natural gas unit (FLNG), a floating storage and offloading unit (FSO), a floating power generation unit (FPGU), a floating storage and regasification unit (FSRU) for liquefied natural gas, a floating storage and regasification of liquefied natural gas barge with power generation (FSRP), or any other semi-submersible floating unit, a

single-point anchor reservoir (SPAR) structure or tension leg platform (TLP).

[0074] In a preferred embodiment, the system 1 may be intended for an installation with a small footprint, i.e., having a constraint in terms of space and/or congestion and/or installation weight.

[0075] The system can be adapted to all types of installations and available surfaces (i.e., space and, preferably, in small/confined spaces) and even for offshore installations.

[0076] The system 1 according to the invention may comprise **at least one supply pipe 2**.

[0077] A supply pipe 2 is configured to supply a working fluid to at least one GT 3.

[0078] The invention is not limited by the shape, length or materials of the supply pipe. However, it is preferred that the supply pipe corresponds to the requirements and constraints of the power generation installation.

[0079] A supply pipe allows to supply a GT with a working fluid. Working fluid may be defined as air or a mixture of air and recirculated exhaust gases or air and selectively recirculated exhaust gases preferably with CO₂.

[0080] Moreover, the at least one supply pipe is configured to cooperate intimately with the at least one GT. The cooperation can be mechanical and/or fluidic.

[0081] According to a particular but non-limiting embodiment of the invention, the system can comprise several supply pipes identical or different from each other and, preferably the number of supply pipes is function of the number of GT's.

[0082] The system according to the invention comprises **at least one GT 3**.

[0083] A GT allows to produce a first power and preferably an electrical power and/or mechanical power. A mechanical power can be for example a mechanical drive. Advantageously, the electrical energy generated by the GT can be used in the system 1 and/or in the installation allowing to produce a first part of the electricity needs of the system/installation. Indeed, the system includes a combined cycle which allows to produce additional power in addition to the power generated by the GT and to improve the efficiency of the installation. Advantageously, the mechanical power and preferably the mechanical drive may be used in the system 1.

[0084] The at least one GT may correspond to a GT as known in the art, with its components

also known in the art such as a compressor to compress the working fluid, a combustor system to heat the working fluid, and an expansion turbine section to expand the working fluid and produce mechanical power, first to drive the compressor, and second to produce useful power. This useful power can be electrical power with the drive of a generator, or mechanical power with the drive of another compressor (not part of GT).

[0085] A GT also allows to generate exhaust gas. Preferably, exhaust gas comprises combustion products. These exhaust gases are generally loaded with CO₂, but also comprise other components such as nitrogen, oxygen, water, argon, sulphur oxides, carbon oxide, , unburned hydrocarbons, and nitrogen oxides. In addition, the CO₂ is very diluted, for example in a volume of exhaust gas, the CO₂ may represent only 3% to 5% without recirculation of exhaust gas and up to 9% with recirculation of exhaust gas.

[0086] Thus, according to an embodiment of the invention, but not limited to, the at least one GT may be designed to have an EGR (for exhaust gas recirculation in Anglo-Saxon terminology) or a SEGR (for selective exhaust gas recirculation in Anglo-Saxon terminology). Optionally, the at least one gas turbine can comprise a duct for recirculation of exhaust gas, arranged at the at least one gas turbine inlet. The recirculation allows to feed the at least one GT with combustion products mixed with air and thus to increase the CO₂ content in exhaust gases at the exit of the at least one GT, this participating to the optimization of the power production, preferably with a CO₂ capture system disclosed below.

[0087] According to an embodiment, the at least one GT may comprise a cold end drive or a hot end drive, preferably a cold end drive. According to an embodiment, the at least one GT may comprise an axial exhaust or vertical exhaust (-up and/or -down) or lateral exhaust and preferably an axial exhaust or a vertical exhaust (-up and -down), and more preferably an axial exhaust. According to an embodiment, the at least one GT may comprise a plenum or a bend to guide exhaust gas, for example.

[0088] According to an embodiment, the system may comprise at least 1 GT preferably at least 2 GT's. The system according to the invention may comprise at most 10 GT's, at most 9 GT's, at most 7 GT's, preferably at most 6 GT's and more preferably at most 5 GT's and even more preferably at most 4 GT's.

[0089] A system according to the invention may comprise between 1 and 10 GT's, between 2 and 9, between 2 and 8 between 2 and 7, preferably between 2 and 6 GT's, more preferably between 2 and 5 GT's and even more preferably between 2 and 4 GT's. Each GT can be identical or different between them. According to an embodiment of the invention,

the system may comprise at least one GT for the mechanical power and at least one GT for the electrical power. According to another embodiment, the system may comprise at least one GT for both electrical and mechanical power.

[0090] Preferably the number of GT is function of the installation such as the footprint but also according to the need of power and/or the power rating of the selected GT. Advantageously the system according to the invention is adaptable. The system according to the invention allows a compromise between power generation and equipment for example in terms of weight and/or size. Indeed, this allows to contribute to the improvement and optimization of the power output of an installation.

[0091] The system according to the invention may comprise **at least one transport pipe 4**.

[0092] The at least one transport pipe comprises preferably a proximal end 4.1 and a distal end 4.2. The at least one transport pipe 4 is configured to guide exhaust gas. Indeed, said proximal end of the at least one transport pipe is configured to cooperate and preferably cooperate fluidically with the at least one gas turbine 3 and preferably with an outlet (for example exhaust) of the at least one gas turbine.

[0093] The invention is not limited by the shape, length or materials of the transport pipe. However, it is preferred that the transport pipe corresponds to the requirements and constraints of the power generation installation.

[0094] According to a particular but non-limiting embodiment of the invention, the system can comprise several transport pipes identical or different from each other and, preferably the number of transport pipes is a function of the number of GT.

[0095] The at least one transport pipe therefore makes it possible to transport exhaust gas loaded with CO₂, and preferably to transport the exhaust gas to at least one compact HRSG. Indeed, the distal end of the transport pipe is configured to cooperate and preferably cooperate fluidically with at least one compact HRSG 5, and more preferably with an inlet of the compact HRSG.

[0096] The at least one transport pipe is configured to guide exhaust gas from a proximal end to a distal end of the at least one transport pipe.

[0097] According to a preferred embodiment, the distal end of the transport pipe is configured to be at a height less than or equal to a height of the proximal end relative to a

base of the installation. For example, if the installation is an onshore installation, the base may be the earth or the soil. If the installation is an offshore installation, the base may be sea water level and/or seabed level. This arrangement reduces the number of pipes and connections, especially between the gas turbine and the compact HRSG and in particular to the transport of exhaust gas, and thus reduces the weight of the system and cost. Consequently, this arrangement allows to increase power efficiency of the system. Indeed, the exhaust gases do not need to be brought up and then brought down again as in conventional arrangements and therefore do not require the equipment necessary for their circulation. In the present invention, it is advantageous to take into account the layout and the constraints of the equipment and the installations in order to improve and optimize the transport of the exhaust gases and thus to improve the routing of the exhaust gases allowing to reduce the use of pipe, fan, damper, by-pass and others which allows to reduce the weight, to reduce the losses (distances of travel of the exhaust gas reduced and optimized) , to reduce the cost and to improve the ratio weight power of the installation.

[0098] According to another embodiment, the distal end of the transport pipe is configured to be at a height less than or equal to a height of an inlet of the compact HRSG relative to a base of the installation. Examples are illustrated in connection with **figure 3D**. Alternatively, and in a preferred but non-limiting embodiment, in order to more optimize the power efficiency and the weight of the system and cost, the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an inlet of the compact HRSG relative to a base of the installation. Examples are illustrated in connection with **figure 3 (3A to 3C)**.

[0099] According to an embodiment, and in order to further optimize the power efficiency and the weight of the system and cost, the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an outlet of the compact HRSG relative to a base of the installation. Examples are illustrated in connection with **figure 3A, 3B and 3C**.

[0100] The system according to the invention may comprise **at least one compact HRSG 5**.

[0101] The at least one compact HRSG allows to generate steam utilizing the energy of exhaust gas from the at least one GT. In addition, compact HRSG allows to produce a power and preferably a thermal power. Advantageously, the thermal energy generated by the at least one compact HRSG can be used in the system 1 and/or in the installation allowing to

produce a part of the power needs of the system/installation while participating to the increase of the installation efficiency. Indeed, the system includes a combined cycle which allows to improve the efficiency of the installation.

[0102] According to an embodiment, the at least one compact HRSG may be a horizontal flow (exhaust gas) as illustrated for example in **figure 3A**, a vertical downflow as illustrated for example in **figure 3B** or in **figure 3C** or vertical upward flow as illustrated for example in **figure 3D**. Preferably arrangement of the figure 3A to 3C. More preferably arrangement of figures 3B or 3C. In a preferred but non limiting embodiment, the at least one compact HRSG is a vertical downflow compact HRSG. These arrangements allow to reduce the number of pipes and their size/length and even more it allows a better organization of the pipes and the equipment of the installation. Consequently, these arrangements allow to increase and/or optimize the power generated by the installation and to reduce the weight of the installation. According to an embodiment, the at least one compact HRSG may be a vertical compact HRSG, preferably an inverted vertical compact HRSG.

[0103] According to a preferred but not limiting embodiment, the at least one compact HRSG is configured to be arranged below to the at least one GT. Indeed, this arrangement allows to improve (i.e. decrease) the weight/power ratio or even volume/power ratio of the installation and therefore improve the net power of the installation.

[0104] According to another preferred but not limiting embodiment, the at least one GT and the at least one compact HRSG are arranged in the top side of the installation.

[0105] The at least one compact HRSG according to the invention may comprise at least one superheater. Preferably the at least one compact HRSG comprises at least one superheater and at least one evaporator, and more preferably the compact HRSG may comprise at least one superheater and at least one evaporator and at least one economizer. Preferably, the compact HRSG comprises a steam outlet and a water inlet.

[0106] The at least one compact HRSG may comprise at least one burner, at least one cooled exhaust gas outlet, at least one by-pass and/or at least one tube. Preferably, the at least one compact HRSG may comprise a by-pass 8. A by-pass may be configured to cooperate with the at least one HRSG. Alternatively, the by-pass may be configured to be arranged upstream or downstream of the at least one compact HRSG, preferably upstream of the at least one compact HRSG for example the at least one transport pipe 4 may comprise a by-pass. The by-pass may be configured to cooperate with the at least one transport pipe. The at least one by-pass may comprise at least one diverter and/or at least

one damper. Indeed, a by-pass allows for example to reduce costs and avoid the use of nickel alloy tubes for example because of the hot gases.

[0107] The at least one compact HRSG may comprise at least one duct firing. Indeed, according to an embodiment, a duct section upstream of the compact HRSG can be equipped with a burner manifold with a minimum distance to the superheater. This section can be part of the compact HRSG or separate from the compact HRSG.

[0108] As disclosed, the at least one compact HRSG may comprise at least one tube and preferably at least one heat exchanger tube. The at least one compact HRSG may comprise at most 8000 tubes. The at least one compact HRSG may comprise between 1 and 8000 tubes. In an embodiment, the at least one compact HRSG may comprise tubing with an external diameter between 9.00 mm and 50.00 mm, preferably between 9.00 mm and 30.00 mm. The invention is not limited by the shape of the at least one tube. For example, the at least one tube may comprise straight portion and/or bent portion. Preferably, the at least one compact HRSG comprises straight and/or finned tubing, circular and/or spiral finned, with solid or serrated fins, preferably finned tubing. However, it is preferred that the at least one tube corresponds to the requirements and constraints of the power generation installation and preferably of the HRSG. The at least one tube may allow to form a complete circuit from the water inlet to the steam outlet. The invention is not limited by the number of circuits. For example, the invention may comprise several circuits, preferably in parallel. By several, it means at least 2 and at most 2000, preferably at least 100 and at most 800. According to a particular but non-limiting embodiment of the invention, the at least one compact HRSG can comprise several tubes identical or different from each other, in addition tubes may be identical or different from each other depending on the place in the at least one HRSG (for example at least one superheater, at least one evaporator, at least one economizer).

[0109] The number of tube stages can be between 10 and 60. Alternatively, the number of stages may be between 14 and 52, preferably between 16 and 48 more preferably between 20 and 44 and even more preferably between 24 and 38. It should be noted that the number of stages depends on the external diameter of the tubes. Thus, the larger the external diameter of a tube (for example between 30 mm and 50 mm), the larger the number of stages (for example between 26 and 60). For example, the minimum number of stages is between 10 and 40 preferably for a low pressure drop below 12 hPa, preferably between 12 and 36 more preferably between 14 and 32 and even more preferably between 16 and 26. In another example, the maximum number of stages is between 18 and 60, preferably

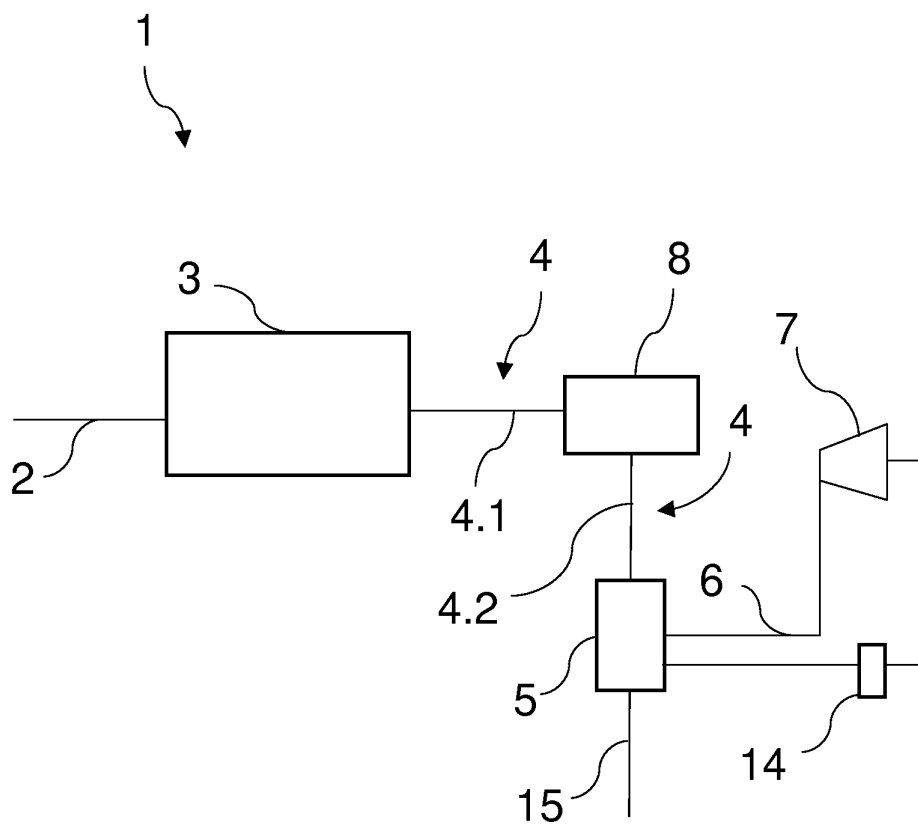


FIG. 1

preferably between 3300 mm and 17100 mm and even more preferably between 3600 mm and 15300 mm.

[0117] The at least one compact HRSG according to the invention may have a length at a minimum number of stages between 3300 mm and 24300 mm, preferably between 3600 mm and 17100 mm.

[0118] The at least one compact HRSG according to the invention may have a length at a maximum number of stages between 2500 mm and 18700 mm, preferably between 2700 mm and 15300 mm.

[0119] The at least one compact HRSG according to the invention may have a width between 2000 mm and 19800 mm, between 2300 mm and 19800 mm, preferably between 2400 mm and 17100 mm, more preferably between 2800 mm and 14000 mm and even more preferably between 3000 mm and 12300 mm.

[0120] The at least one compact HRSG according to the invention may have a width at a minimum number of stages between 2800 mm and 19800 mm, preferably between 3000 mm and 17100 mm.

[0121] The at least one compact HRSG according to the invention may have a width at a maximum number of stages between 2300 mm and 14000 mm, preferably between 2400 mm and 12300 mm.

[0122] The at least one compact HRSG according to an embodiment of the invention may have a height between 5500 mm and 20125 mm, preferably between 6000 mm and 19500 mm, more preferably between 6300 mm and 16300 mm and even more preferably between 7400 mm and 15300 mm.

[0123] The at least one compact HRSG according to the invention may have a height at a minimum number of stages between 6300 mm and 20125 mm, preferably between 7400 mm and 15300 mm.

[0124] The at least one compact HRSG according to the invention may have a height at a maximum number of stages between 5500 mm and 19500 mm, preferably between 6000 mm and 16300 mm.

[0125] It should be noted that the size (volume and/or weight) of the at least one compact HRSG may vary by a factor of 4 or 5 between the GT power (i.e. from 30 MW to 140 MW).

[0126] The at least one compact HRSG according to the invention may have a mass between 25 tons and 1100 tons, preferably between 30 tons and 940 tons, more preferably between 40 tons and 500 tons and even more preferably between 41 tons and 400 tons. The mass of the at least one compact HRSG may depend on GT power, on tube diameter and/or aeraulic pressure drop. For example, the at least one compact HRSG may have a mass about 380 tons or 110 tons depending on the diameter of tube, for a given GT power and aeraulic pressure drop. In an embodiment with a GT of 126 MW the at least one compact HRSG may have a mass about 380 tons for a medium size tube diameter of 31.8 mm and a high aeraulic pressure drop above 30 hPa. In an embodiment with a GT of 126 MW, the at least one compact HRSG may have a mass about 110 tons for very small size tube diameter of 9.5 mm and a high aeraulic pressure drop above 30 hPa. In comparison for a GT of 30 MW the at least one compact HRSG may have a mass about 105 tons for a medium size tube diameter of 31.8 mm and a high aeraulic pressure drop above 30 hPa. For a GT of 30 MW the at least one compact HRSG may have a mass about 30 tons for a very small size tube diameter of 9.5 mm and a high aeraulic pressure drop above 30 hPa.

[0127] The at least one compact HRSG according to the invention may have a minimum stage weight of between 40 tons and 1100 tons, preferably between 50 tons and 940 tons.

[0128] The at least one compact HRSG according to the invention may have a maximum stage weight of between 25 tons and 820 tons, preferably between 35 tons and 700 tons.

[0129] These dimensions make it possible to contribute to a compact dimensioning of the HRSG. Indeed, compared to a conventional HRSG, a compact HRSG according to the invention is about 1.5 times less long and about 3 times less high while recovering as much or more heat and producing as much or more steam (parameters disclosed hereafter) with an improved operation. According to a specific embodiment of the preferred but non-limiting embodiment, the term compact may mean reduce in weight and/or in size and preferably adaptable to small footprint. Small footprint can be understood as a footprint is less than a conventional HRSG. A conventional HRSG may for example be about 8 m long, 5 m wide, and 20 m high for a 30 MW Gas Turbine.

[0130] In addition, a compact HRSG according to the invention allows to optimize weight/power ratio for an installation and to decrease the construction costs. It is noted that compact means a reduced weight and/or size, preferably a reduced weight and size.

[0131] The skill in the art knows that a variation of parameter for example temperature / pressure, the dimensions can vary. However, the at least one compact HRSG according to

the invention has dimensions to be preferably compact in weight and/or size compared to a conventional HRSG.

[0132] In a preferred embodiment, the at least one compact HRSG may comprise at least one OTSG (Once Through Steam Generator in Anglo-Saxon terminology), preferably may be at least one OTSG.

[0133] According to an embodiment, the system according to the invention may comprise at least one compact HRSG and at most 10 compact HRSG. Each compact HRSG may be identical or different from each other.

[0134] According to an embodiment, the system according to the invention may comprise **a pipe 15** which may be configured to transport exhaust gas from the compact HRSG. A pipe 15 may be configured to cooperate, preferably mechanically and/or fluidically with the at least one compact HRSG and preferably with an outlet of the at least one compact HRSG.

[0135] The system according to the invention comprises **at least one conveying pipe 6**.

[0136] A conveying pipe is configured to direct a steam from the at least one compact HRSG to at least one back-pressure steam turbine 7 (BPST).

[0137] The invention is not limited by the shape, length or materials of the conveying pipe. However, it is preferred that the conveying pipe corresponds to the requirements and constraints of the power generation installation.

[0138] A conveying pipe allows to supply steam to a back pressure steam turbine.

[0139] Moreover, the at least one conveying pipe is configured to cooperate, preferably intimately, with the at least one compact HRSG, and preferably an outlet of the compact HRSG, and to the at least one BPST, and preferably to an inlet of the BPST, so as to limit the pressure drop.

[0140] According to a particular but non-limiting embodiment of the invention, the system can comprise several conveying pipes identical or different from each other and, preferably the number of conveying pipes is a function of the number of back pressure steam turbines and/or HRSGs.

[0141] According to a preferred but non-limiting embodiment, the length of the conveying pipe is reduced in order to limit the distance between the compact HRSG and the BPST. This not only improves the power to weight ratio but also reduces costs.

[0142] The system according to the invention comprises **at least one back pressure steam turbine 7 (BPST)**.

[0143] The at least one back pressure steam turbine is configured to generate power from the steam and preferably electrical power and/or mechanical power.

[0144] The at least one BPST allows to produce a second power and preferably an electrical power. Advantageously, the electrical energy generated by the BPST can be used in the system 1 and/or in the installation allowing to produce a second part of the electricity needs of the system/installation and to reduce the electricity capacity of the gas turbines of the system/installation by comparison with an open cycle while participating to the increase of the installation efficiency. Moreover, the at least one BPST allows to downsize the electrical power provide by the at least one GT allowing to reduce the weight associated. Indeed, as explained the system comprises power from the GT and from the BPST.

[0145] In addition, the at least one BPST allows to produce a mechanical power which can be for example a mechanical drive. Advantageously, the mechanical power and preferably the mechanical drive may be used in the system 1.

[0146] The at least one BPST may correspond to a BPST as known in the art with its components also known in the art such as inlet valve, turbine rotor and stator, exhaust casing, bearings. The BPST may drive a generator and/or a compressor and/or any other mechanical load.

[0147] Advantageously, the system comprises at least one BPST which is more compact than conventional steam turbine usually used in combined cycle such as condensing steam turbine. This is particularly advantageous because it reduces the weight of the system and therefore improves the power-to-weight ratio. In addition, a BPST is more compact and therefore requires less space and can be adapted to smaller spaces on land or at sea.

[0148] The at least one BPST may comprise at least one high-pressure casing. Alternatively, the at least one BPST may comprise at least one high-pressure casing and at least one medium pressure casing. The at least one BPST may present several stages (several means at least two). In an embodiment of the invention, the at least one BPST does not comprise a low-pressure casing, this allows to reduce the weight and consequently as explained to improve the weight-power ratio.

[0149] The at least one BPST may be arranged near to the at least one compact HRSG. For example, the at least one compact HRSG and the at least one BPST are configured to

be arranged on the top side of the installation. Preferably, the at least one GT, the at least one compact HRSG and the at least one BPST are configured to be arranged on the top side of the installation.

[0150] According to an embodiment, the system may comprise at least 2 BPST's preferably at least 3 BPST's and more preferably at least 4 BPST's. The system according to the invention may comprise at most 10 BPST's, preferably at most 9 BPST's and more preferably at most 8 BPST and even more preferably at most 7 BPST's.

[0151] A system according to the invention may comprise between 1 and 10 BPST's, preferably between 2 and 9 BPST's, more preferably between 2 and 8 BPST's and even more preferably between 2 and 7 BPST's. Each BPST can be identical or different between them.

[0152] According to a preferred but non-limiting embodiment, the system may comprise at least one BPST according to the number of GT. For example, the system may comprise one BPST for 1 to 4 GT's, preferably for 2 to 4 GT's. According to another example, the system may comprise two BPST's for 1 to 8 GTs, preferably 2 to 4 GT's. Another example may be three BPST's for 9 to 10 GT's.

[0153] According to another embodiment of the invention, the system may comprise one BPST by GT allowing so-called "single shaft" BPST and GT arrangements in tandem with a common generator.

[0154] Preferably the number of BPST is function of the installation such as the footprint but also according to the need of power. Advantageously the system according to the invention is adaptable. The system according to the invention allows a compromise between power generation and equipment for example in terms of weight and/or size. Indeed, this allows to contribute to the improvement and optimization of the power output of an installation.

[0155] The system according to the invention may comprise at least one fan. A fan allows to improve the circulation of the exhaust gas. A fan can be configured to be arranged downstream of the at least one compact HRSG.

[0156] The system according to the invention may comprise **a condenser 14**.

[0157] A condenser is configured to condense water vapor. Preferably the condenser is configured to be coupled to the at least one compact HRSG and more preferably indirectly

coupled. For example, a condenser may be configured to be coupled to at least one extraction pump and/or feed pump and/or condensation pump. This allows the pressure to be increased. Advantageously, the system may comprise a feed water tank that can be configured to ensure water/steam volume variations.

[0158] A condenser may be configured to be coupled to at least one back pressure steam turbine, preferably indirectly. For example, a condenser may be coupled to an additional equipment capable of recovering heat preferably for a later use.

[0159] In another example, a condenser can be configured to be coupled with a subcooling exchanger separated by or coupled via a feed water tank. In this particular embodiment, water can be stored in the bottom of the condenser at a certain temperature and then extracted from the bottom of the condenser for the subcooling exchanger. Thus, it allows both condensation and storage.

[0160] Advantageously, a condenser is preferably compact. This means that a condenser according to the invention can be half the size of a condenser usual power generation systems and more preferably compared to a condensing turbine condenser of equivalent power. This makes it possible to promote the weight/power ratio and the efficiency of the installation.

[0161] The condenser can be configured as a function of the water temperature of the at least one compact HRSG and preferably of the input of the at least one compact HRSG.

[0162] With pump-type auxiliaries, the system includes at least one pump configured to pump the condensate to the at least one compact HRSG. Thanks to the at least one compact HRSG according to the invention, which is compact and preferably inverted and even more preferably with finned tubes of minimum diameter, the at least one compact HRSG is configured to cool the exhaust gases leaving the gas turbine and to produce superheated steam which is then, thanks to the at least one BPST, configured to produce power.

[0163] As explained the system according to the invention is more compact than conventional combined cycle in installation. According to an embodiment, the system according to the invention may present a mass between 550 tons and 3800 tons (equipment only, excluding "bulks"), preferably between 700 tons and 3600 tons (dry weight). For example, the system according to the invention may present a mass between 760 tons and 960 tons (dry weight) for 2 GT's at 30 MW each (2x300 tons including generator,

accessories, inlet and exhaust system), 2 compact HRSG's (2x30 tons to 2x130 tons), one BPST at 15 MW (1x100 tons including condenser and accessories) in comparison to the prior art at 1350 tons for 2 GT's at 30 MW each (i.e. 2x300 tons), 2 HRSG's (2x260 tons), one condensing steam turbine at 20 MW (1x230 tons) to which are added the mass of the "bulks" (pipes and other) (about + 30% on equipment's mass). Thanks to the invention, the mass of the "bulks" is reduced (of the order of 5 % to 20 %, preferably of the order 10 to 15% instead of 30 %). Furthermore, thanks to the invention and to the at least one compact HRSG, the mass of the system is more reduced (760 tons for 2 GT's at 30 MW instead of 1350 tons for 2 GT's at 30 MW in comparison).

[0164] The system according to the invention allows the reduction of costs in the generation of power on an installation, through the increase of the output and the efficiency, the reduction of the fuel consumption compared to an installation of direct capture (without combined cycle) in particular, and thus of the global size of the installation. The system allows to consume less working gas for same power and therefore increase the efficiency and performance of the installation. Moreover, thanks to the arrangement of the system and the layout of the system, it is less complex to implement while being less expensive, which is particularly advantageous in this field. In particular, thanks to the arrangement, less "bulks" are used. Thus, the system is particularly well suited and optimal for power generation installations and in particular for installations with space constraints or with limited space.

[0165] According to another aspect, the invention concerns **a system for capturing CO₂**.

[0166] A system for capturing CO₂ may be illustrated in **figure 4** or in **figure 5** or in **figure 6**.

[0167] The applicant has developed a system capable of reducing CO₂ emissions in power generation installations, preferably from exhaust gas. The applicant has developed a system capable to produce power while capturing CO₂.

[0168] A system 20 for capturing CO₂ according to the invention can comprise **at least one combined cycle power generation system 1**, preferably according to the invention and more preferably according to the above disclosure. Indeed, a power generation system with a combined cycle according to the invention allows the production of both thermal and electrical energy and even mechanical power. The heat supplied by the exhaust of the steam turbine is used and preferably prioritized to operate the CO₂ capture system. This heat supplied through the steam turbine, preferably from back pressure exhaust, is thus

able to distribute heat to the CO₂ capture system. It should be noted that the surplus heat available to the steam turbine can be converted into electricity to improve the overall efficiency of the installation (cumulation with the gas turbine). In addition, the cold exhaust gas from cooling module can be recirculated to the gas turbine inlet to obtain a higher plant efficiency by minimizing the energy requirements of the CO₂ capture system. Indeed, as explained, an EGR makes it possible to reduce the CAPEX of the capture system, and also to reduce NO_x, for example. Also, EGR can improve part-load performance. The whole system thus allows to find an excellent efficiency while offering a very strong decarbonization of the produced energy.

[0169] According to an embodiment, the compact HRSG may be in contact with **a pipe 15** which may be configured to transport exhaust gas from the compact HRSG to a cooling module 10. Preferably, the said pipe 15 is configured to transport exhaust gas from an outlet of the compact HRSG to an inlet of the cooling module. The said pipe may comprise a fan 16 in order to facilitate the flow and routing of exhaust gas. The exhaust gases produced are then transported to various modules via the at least one pipe 15 in order to be able to treat the gas of interest and to enable the capture of CO₂. The at least one pipe 15 therefore makes it possible to transport exhaust gas loaded with CO₂, and preferably to transport the exhaust gas to at least one module of the CO₂ capture system 20 and preferably to a cooling module 10.

[0170] The invention is not limited by the shape, length or materials of the pipe. However, it is preferred that the pipe corresponds to the requirements and constraints of the power generation installation and capture CO₂.

[0171] Moreover, the at least one pipe is configured to cooperate intimately with the at least one compact HRSG and to the at least one cooling module so as to limit pressure drop.

[0172] According to a particular but non-limiting embodiment of the invention, the system can comprise several pipes identical or different from each other and, preferably the number of pipes is a function of the number of compact HRSG and/or cooling modules.

[0173] According to a preferred, but non-limiting embodiment, the pipe is configured to pass through the top side shell of the installation. The capture unit being generally within the shell of the installation. Again, the system has a functional architecture and is optimized to facilitate and reduce cost and promote power-to-weight ratio.

[0174] The system for capturing CO₂ may comprise **at least one collector 9**. Preferably

the collector is configured to be arranged downstream of the at least one compact HRSG and preferably at the at least one compact HRSG outlet. A collector allows to collect the exhaust gas. Preferably the at least one collector may comprise a flue gas header, and more preferably may be at least one flue gas header. According to an embodiment, the at least one collector allows to collect the exhaust gases from the various HRSG's. In addition, a collector may redistribute exhaust gases, for example and as disclosed subsequently, to at least one cooling module and/or to at least one absorption column.

[0175] The system for capturing CO₂ may comprise **at least one cooling module 10**.

[0176] A cooling module is configured to cool the exhaust gas from the at least one compact HRSG. It should be noted that advantageously, a module can comprise one or more internal volumes or at least two modules can have a same internal volume. In these embodiments, the internal volume or volumes correspond to a volume in which the actions necessary for the purpose of the module take place.

[0177] Preferably, the cooling module is configured to be in contact with the at least one compact HRSG and more preferably to cooperate fluidically with the at least one compact HRSG through a pipe, for example a pipe 15 as disclosed.

[0178] A cooling module may comprise a Direct Contact Cooler (DCC), preferably may be a DCC.

[0179] According to an embodiment of the invention, the cooling module may include a cooling fluid. The cooling fluid may be water, seawater, air, demineralized water.

[0180] According to an embodiment of the invention, the cooling module is configured to allow cooling of exhaust gas comprising CO₂ with the cooling fluid. The cooling may, for example, correspond to bringing the exhaust gas and the fluid into contact. The contacting may be by direct contact or by indirect contact.

[0181] For example, in a non-limiting embodiment of the invention, the cooling module may be in contact with an indirect cooling loop. The exhaust gases are then brought into contact with the fluid which is cooled by a water-filled cooling loop coupled to at least one recovery unit.

[0182] Alternatively, a cooling module can be coupled to a direct cooling loop.

[0183] According to another embodiment, the cooling module can be in contact with a direct

air cooling system (air cooler).

[0184] The exhaust gases can also be in direct contact with water in the cooling module.

[0185] This allows the exhaust gases to be cooled. Advantageously, the cooling module can also allow an at least partial reduction of the concentration of other compounds present in the exhaust gases, in particular sulfur and nitrogen oxides.

[0186] The system for capturing CO₂ according to the invention may comprise **at least one absorption module 11**.

[0187] The absorption module is configured to enable the cooled exhaust gas to encounter a lean solvent capable of absorbing CO₂ from exhaust gas in order to generate an enriched solvent. By way of example, a solvent may for example be an amine-based solvent.

[0188] According to an embodiment, the absorption module may be formed by at least one column.

[0189] According to an embodiment, the absorption module may be formed by at least two columns, each column may be identical or different from each other.

[0190] Preferably, the absorption module according to the invention comprises at most 3 columns.

[0191] According to an embodiment, the absorption module is configured to enable a cross-flow absorption.

[0192] Advantageously, the use of cross-flow absorption can limit the effects of motion and/or tilting constraints, due for example to the swell on the floating structure and which can impact the performance of chemical absorption of CO₂ by a solvent. Indeed, the motion of the installation when this one is an offshore installation can disturb the homogeneity of the distribution of the solvent by one or more distributor(s), especially since the height of the counter-current flow absorption module is large and the number of solvent dispensers is low, which reduces the performance of the CO₂ capture system. Further, due to a cross-flow absorption module, the phenomenon described above is reduced, which preserves the performance of the CO₂ capture system despite the motion undergone. Such a layout is therefore particularly advantageous in a system according to the invention.

[0193] In a particular but non-limiting embodiment of the cross-flow embodiment, the CO₂ capture system can comprise at least one absorption module comprising at least one

absorption internal volume, and at least one washing module comprising at least one washing internal volume or at least one internal volume of the absorption module and at least one internal volume of the washing module within the same absorption module.

[0194] Furthermore, the one or more absorption modules can include at least one absorption stage or a plurality of absorption stages. Each stage can be delimited by partial bulkheads. These bulkheads can optimize the distribution of fluids and the recovery of solvent so as to reduce the required flow of solvent.

[0195] Cross-flow absorption is particularly advantageous in the case of a limited structure height. For example, the CO₂ capture system according to the invention can horizontally incorporate one or more absorption columns and/or one or more cross-flow washing columns for example.

[0196] Hence, the use of cross-flow absorption makes it possible to dispense with height-limitation constraints of the installation. Furthermore, cross-flow technology enables an operation with low gas flow compared with a counter-current absorber requiring a higher minimum flow. Finally, the pressure drop is also lower through a cross-flow absorber than in a counter-current absorber, which can minimise the electrical power consumed by the CO₂ capture system.

[0197] According to an embodiment, the absorption module is configured to enable a counter-current flow absorption.

[0198] According to a preferred embodiment, the absorption module may be coupled to at **least one washing module**. A washing module is configured to enable placing CO₂ depleted exhaust gas in contact with water, preferably demineralised water, in order to reduce the potential entrainment of solvent present in the exhaust gas.

[0199] According to the embodiment wherein the absorption module is configured to enable cross-flow absorption, the CO₂ capture system may comprise at least one absorption module directly coupled to the at least one washing module.

[0200] Furthermore, the one or more washing modules can include at least one washing stage or a plurality of washing stages so as to reduce the entrainment and/or loss of solvent. Each stage can be delimited by partial bulkheads.

[0201] Furthermore, the CO₂ capture system according to the invention can also be designed in order to allow a horizontal and/or vertical and/or radial fluid flow.

[0202] The CO₂ capture system according to the invention therefore makes it possible to minimise the quantity of materials required in order to ensure CO₂ capture and therefore also reduces the costs.

[0203] According to a preferred embodiment, the at least one cooling module and the at least one absorption module are configured to be arranged in the lower part of the installation.

[0204] The system for capturing CO₂ may comprise **at least one solvent regeneration module 12**.

[0205] A solvent regeneration module is configured to enable the treatment of the enriched solvent so as to release the absorbed CO₂ and form a lean solvent.

[0206] In a particular and preferred but non-limiting embodiment, the at least one solvent regeneration module is configured to be fluidly coupled to **at least one reboiler 13**. The coupling can be a direct or indirect coupling, preferably direct.

[0207] In a particular and preferred but non-limiting embodiment, the at least one reboiler is configured to be fluidly coupled to at least one compact HRSG. The coupling can be configured to be a direct or indirect coupling, preferably indirect. Indeed, the at least one reboiler may be configured to be coupled to the at least one compact HRSG via at least one condenser and/or at least one pump and/or at least one feed water tank.

[0208] In a particular and preferred but non-limiting embodiment, the at least one reboiler may be configured to be fluidly coupled to at least one back pressure steam turbine. Preferably, the at least one reboiler may be configured to be fluidically coupled to the at least one BPST. The coupling can be a direct or indirect coupling, preferably direct. Indeed, the at least one BPST is configured to supply steam to the reboiler.

[0209] In an embodiment of the invention, the system may comprise **a condenser 14**.

[0210] As explained, a condenser is configured to condense water vapor. A condenser is preferably configured to be coupled to a cooling module. A condenser allows, on the one hand, to condense the steam but also to cool and sub-cool the condensates in order to ensure a suitable temperature with the at least one compact HRSG.

[0211] Preferably the condenser is configured to be coupled to the at least one compact HRSG and more preferably indirectly coupled. For example, a condenser may be

configured to be coupled to at least one extraction pump and/or feed pump and/or condensation pump. This allows the pressure to be increased.

[0212] In addition, and particularly advantageously, the system can comprise a water storage means. This allows for water/steam volume variations. Advantageously, a condenser can be configured to ensure these variations. Alternatively, the system may comprise a feed water tank that can be configured to ensure these variations.

[0213] In another alternative, the system can comprise an auxiliary water extraction and re-injection system.

[0214] In another example, a condenser can be configured to be coupled with a subcooling exchanger separated by or coupled via a feed water tank. In this particular embodiment, water can be stored in the bottom of the condenser at a certain temperature and then extracted from the bottom of the condenser for the subcooling exchanger. Thus, it allows both condensation and storage.

[0215] Advantageously, a condenser is preferably compact. This means that a condenser according to the invention can be half the size of a condenser usual in CO₂ capture systems and more preferably compared to a condensing turbine condenser of equivalent power. This makes it possible to promote the weight/power ratio and the efficiency and the output of the installation while participating in the capture of CO₂.

[0216] Thus, a condenser allows on the one hand to condense the steam but also to cool and sub-cool the condensates in order to ensure a suitable temperature with the at least one compact HRSG.

[0217] The condenser can be configured as a function of the temperature of the at least one compact HRSG and preferably of the input of the at least one compact HRSG.

[0218] Thanks to the invention, the water-steam circuit is based on a back pressure turbine. Thus, the CO₂ capture system comprising a power generation system according to the invention allows to send the entire exhaust flow of the at least one BPST into the reboiler of the regeneration column. This also provides the necessary solvent regeneration heat which is particularly important and problematic in terms of consumption in the capture systems. The invention makes it possible to avoid such a need. Moreover, the reboiler is configured to condense said steam, preferably a partial condensation.

[0219] Furthermore, the reboiler is configured to send the water-steam mixture leaving the

reboiler into a condenser, preferably with sea water or on an internal cooling loop. Advantageously, the said condenser is configured to be very compact because of the important temperature difference. This condenser is configured to perform a significant subcooling of the condensates to remove the excess heat and further condense the condensates.

[0220] With pump-type auxiliaries, the system includes at least one pump configured to pump the condensate to the at least one compact HRSG. Thanks to the at least one compact HRSG according to the invention, which is compact and preferably inverted and even more preferably with finned tubes of minimum diameter, the at least one compact HRSG is configured to cool the exhaust gases leaving the gas turbine and to produce superheated steam which is then, thanks to the at least one BPST, configured to produce power.

[0221] The system for capturing CO₂ may comprise **at least one storage module**. A storage module is configured to enable storage of solvent.

[0222] Advantageously, the CO₂ capture system according to the invention includes pipes for transport of the solvent designed to enable the transport of the enriched solvent from the absorption module to the solvent regeneration module or of the lean solvent from the solvent regeneration module to the absorption module. These solvent transport pipe, whether enriched or lean, can be of the type known per se by a person skilled in the art, such as conventional piping in the field.

[0223] Advantageously, the CO₂ capture system according to the invention also includes at least one exhaust gas transport duct configured to enable the transport of exhaust gas to the cooling module, preferably from the power generation system. The exhaust gas transport duct can also be configured to enable the transport of exhaust gas from the cooling module to the absorption module. Optionally, the exhaust gas transport duct can also be configured to enable the transport of exhaust gas from the absorption module to the washing module. The exhaust gas transport duct may also be configured to enable the transport of exhaust gas from the cooling module to the power generation system or in the atmosphere.

[0224] The system for capturing CO₂ may also comprise at least one fan (i.e. blower) 16. A fan allows to improve the displacement of exhaust gases. A fan may be configured to be arranged at an outlet of the at least one compact HRSG, and/or between the cooling module and the absorption module and/or at an outlet of the absorption module. According to its arrangement and sizing the pressure will be positive or negative in the upstream

equipment's, preferably the pressure is positive.

[0225] The CO₂ can then be extracted in parallel with any activity (electrical, mechanical, thermal, storage, gas and/or oil). Hence, the captured CO₂ can be reinjected into the ground from which it comes, which reduces the CO₂ emissions by sequestering it. The CO₂ can also be stored temporarily, preferably in liquid form, for subsequent use, which also enables the reduction of CO₂ emissions. This is particularly advantageous, because the CO₂ is captured, which, on the one hand, reduces CO₂ emissions and, on the other hand, is complementary to any activity.

[0226] According to another aspect, the invention concerns **the use of a CO₂ capture system** according to the invention in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport. Indeed, a CO₂ capture system according to the invention can be incorporated in any activity and therefore enables CO₂ capture in order to reduce CO₂ emissions. Treatment of CO₂ can involve, for example, dehydration, deoxygenation, purification, compression, liquefaction and/or pumping.

[0227] According to another aspect, the invention relates to **the use of a power generation system** according to the invention in the capture of CO₂, in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport.

[0228] According to another aspect, the invention comprises **an offshore installation** comprising a power generation system according to the invention.

[0229] According to another aspect, the invention comprises **an onshore installation** comprising a power generation system according to the invention.

[0230] According to another aspect, the invention comprises **an offshore installation** comprising a system for capturing CO₂ according to the invention.

[0231] According to another aspect, the invention comprises **an onshore installation** comprising a system for capturing CO₂ according to the invention.

[0232] According to another aspect to the invention, said invention concerns **a method for capturing CO₂**, preferably comprising at least one system for capturing CO₂ according to the invention, and more preferably implemented by a system for capturing CO₂ according to the invention.

[0233] The method may comprise a step of setting the BPST to generate an electrical power ranging from 10 MW to 150 MW.

[0234] The BPST can be configured to generate an electrical power ranging from 10 MW to 150 MW, preferably from 20 MW to 100 MW and even more preferably from 25 MW to 60 MW.

[0235] The method may comprise a step of setting the BPST to have an efficiency ranging from 75 % to 95 %.

[0236] The BPST can be configured to have an efficiency ranging from 75 % to 95 % preferably more than 85% and even more preferably more than 90 %.

[0237] The method may comprise a step of setting the GT to generate an electrical power ranging from 15 MW to 140 MW.

[0238] The at least one GT can be configured to generate an electrical power ranging from 15 MW to 140 MW, preferably from 30 MW to 100 MW and even more preferably from 40 MW to 65 MW.

[0239] The method may comprise a step of setting the GT to have an efficiency ranging from 30 % to 45 %.

[0240] The GT can be configured to have an efficiency ranging from 30 % to 45 % preferably from 35 % to 42%.

[0241] The complete steam cycle with BPST achieves an efficiency of about 15 % to 20 % on the heat recovered at the compact HRSG, while on a classic "condensation" cycle, it will be about 25% (1 pressure cycle) to 40% (3-Pressure Reheat cycle) without extraction for CO₂ capture.

[0242] The thermal efficiency of the compact HRSG is around 65% to 85% (Low Heating Value basis, therefore without taking into account the latent heat of condensation of the steam) for a "1 pressure" cycle.

[0243] According to the invention, the system parameters can be set. "Set" can correspond to adjusting, defining the parameters of a system equipment to make it work under given conditions. During operation, the system parameters can be determined/limited according to the components and the requirements to be met.

[0244] For example, according to a method of the invention, the exhaust gas outlet temperature of the gas turbine can be set to be between 400 °C and 650 °C, preferably between 510 °C and 650 °C.

[0245] For example, according to a method of the invention, the exhaust gas flow rate at the gas turbine can be set to be between 35 kg/s and 400 kg/s preferably between 70 kg/s and 250 kg/s.

[0246] Indeed, the gas turbine may work with ambient air, GT may compress it in its compressor, raises its temperature in the combustion chamber where the gas burns to constitute the engine fluid at high temperature (about 1100°C to 1500°C according to the turbines) which is expanded and works in the expansion turbine. Part of the air leaving the compressor is used to cool the turbine blades, before mixing with the engine fluid. The engine fluid exits the expansion turbine and forms the exhaust gas with 3-4% CO₂, 7-10% H₂O, 12-14% O₂ and 73% nitrogen and 1% argon. There may be exhaust gas recirculation systems (called EGR) to recirculate part of the exhaust gas at the inlet to increase the concentration of CO₂ and facilitate capture.

[0247] For example, according to a method of the invention, the compact HRSG may be set.

[0248] According to an embodiment of the invention, the invention does not comprise at least one burner.

[0249] A method of the invention may comprise a compact HRSG whose operating parameters are predetermined to have an inlet exhaust gas temperature ranging from 400 °C to 650 °C preferably from 510 °C to 650 °C.

[0250] A method according to the invention may comprise setting the compact HRSG to an exhaust gas outlet temperature ranging from 70 °C to 250 °C, preferably from 100 °C to 200 °C.

[0251] A method according to the invention may comprise setting the compact HRSG to a steam outlet temperature ranging from 400 °C to 565°C preferably from 450 °C to 540 °C.

[0252] A method according to the invention may comprise setting the compact HRSG to a steam outlet pressure ranging from 25 bar to 170 bar preferably from 40 bar to 140 bar, more preferably from 60 bar to 120 bar.

[0253] A method according to the invention may include adjusting the steam flow rate in a range from 10 t/h to 250 t/h preferably from 20 t/h to 200 t/h more preferably from 40 t/h to 150 t/h.

[0254] It should be noted that the person skilled in the art understands the impact of the system parameters as a whole. Thus, in one example of the method, for thermal processes with a back pressure of 20 bar, the working fluid outlet temperature could even rise to 250 °C. Alternatively, for lower back pressure, the working fluid outlet temperature could be around 70 °C.

[0255] A method of the invention may comprise setting the BPST to an inlet steam pressure ranging from 25 bar to 170 bar preferably from 40 bar to 140 bar, more preferably from 60 bar to 120 bar.

[0256] A method of the invention may comprise setting the BPST to an outlet steam pressure ranging from 1 bar to 20 bar preferably from 2 bar to 15 bar and more preferably from 2 bar to 10 and even more preferably from 2 bar to 7 bar.

[0257] A method according to the invention may comprise setting the BPST to a steam outlet temperature ranging from 100 °C to 262 °C, and preferably from a saturation temperature to at most 50°C superheating. Preferably at less 10 °C superheating.

[0258] A method according to the invention may comprise setting the BPST to a steam inlet temperature ranging from 400 °C to 565 °C preferably from 450 °C to 540 °C.

[0259] A method according to the invention may include adjusting the steam flow rate in a range from 20 t/h to 1000 t/h preferably from 40 t/h and 500t/h and more preferably from 80 t/h to 300 t/h.

[0260] A method according to the invention may comprise setting the feed water temperature in a range from 30 °C to 120 °C preferably from 60 °C to 100 °C.

[0261] According to an embodiment, the invention may comprise at least one burner.

[0262] A method of the invention may comprise a compact HRSG whose operating parameters are predetermined to have an inlet exhaust gas temperature ranging from

650 °C to 871 °C preferably from 700 °C to 800 °C.

[0263] A method according to the invention may comprise setting the compact HRSG to an exhaust gas outlet temperature ranging from 100 °C to 200 °C preferably from 70 °C to 250 °C, preferably from 100 °C to 200 °C.

[0264] A method according to the invention may comprise setting the compact HRSG to a steam outlet temperature ranging from 400 °C to 565°C preferably from 450 °C to 540 °C.

[0265] A method according to the invention may comprise setting the compact HRSG to a steam outlet pressure ranging from 25 bar to 170 bar preferably from 40 bar to 140 bar, more preferably from 60 bar to 120 bar.

[0266] A method according to the invention may comprise setting the feed water temperature in a range from 30 °C to 120 °C preferably from 60 °C to 100 °C.

[0267] A method according to the invention may include adjusting the steam flow rate in a range from 15 t/h to 375 t/h preferably from 30 t/h to 300 t/h more preferably from 60 t/h to 225 t/h.

[0268] A method of the invention may comprise setting the BPST to an inlet steam pressure ranging from 25 bar to 170 bar, preferably from 40 bar to 140 bar, more preferably from 60 bar to 120 bar

[0269] A method of the invention may comprise setting the BPST to an outlet steam pressure ranging from 1 to 20 bar preferably from 2 bar to 15 bar, more preferably from 2 bar to 10 bar and even more preferably from 2 to 7 bar.

[0270] A method according to the invention may comprise setting the BPST to a steam outlet temperature ranging from saturation temperature to at most 50°C superheating. Preferably at less 10 °C superheating.

[0271] A method according to the invention may comprise setting the BPST to a steam inlet temperature ranging from 400 to 565 °C preferably from 450 °C to 540 °C.

[0272] A method according to the invention may include adjusting the steam flow rate in a range from 30 t/h to 1500 t/h preferably from 60 t/h and 750t/h and more preferably from 120 t/h to 450 t/h.

[0273] For operation with burner, efficiency may be degraded, but the power of the BPST

will significantly increase (+50% typically), will easily allow to raise the steam parameters to 540°C or even 565°C, while maintaining or even reducing the size (exchange surface) of compact HRSG up to 30%. This reduction will also compensate for the additional height of the burners.

[0274] According to another embodiment, the method may comprise setting the compact HRSG to a pressure drop in a range from 8 mbar to 50 mbar. According to another embodiment, the method may comprise setting the compact HRSG to a hydraulic pressure loss in a range from 0.2 bar to 30 bar, preferably from 0.5 bar to 25 bar. The number of stages is linked to the pressure drop and will depend little or not on the size of the GT. For the dimensions of length and width of tubes, there is a direct dependence with the size of the GT.

[0275] According to another embodiment, the method may comprise setting the condenser to pressure from 2.5 bar to 6 bar preferably from 3.5 bar to 4.5 bar.

[0276] According to another embodiment, the method may comprise adjusting the condenser to a temperature difference with the cooling fluid of at least 20° C, preferably for the cold side and of at most 110° C preferably for the hot side. Indeed, in a particular but non-limiting embodiment, and more preferably with a direct cooling, on the cold side, the minimum difference will be about 20°C with an assumption of high 40°C cooling water inlet, the maximum difference can reach 75°C with condensates at 100°C and assumption of average 25°C cooling water inlet. On the hot side, the minimum difference will be about 65°C with a low pressure at 3 bar (133°C Temperature of saturation) and cooling water leaving at 70°C for a typical high 40°C cooling water inlet. The maximum difference can reach 110°C with a pressure of 5 bar (152°C Temperature of saturation) and cooling water leaving at 40°C for a typical low 15°C cooling water inlet.

[0277] According to another embodiment, the method may comprise setting the reboiler to a steam inlet pressure in a range from 2 bar to 6 bar preferably from 3 bar to 4 bar.

[0278] According to another embodiment, the method may comprise setting the reboiler to a steam inlet temperature in a range from 120 °C to 200 °C, preferably from 130 °C to 180 °C, more preferably from 140 °C to 170 °C and even more preferably from 150 °C to 160 °C.

[0279] According to another embodiment, the method may comprise setting the reboiler to a steam outlet pressure in a range from 2 bar to 6 bar preferably from 3 bar to 4 bar.

[0280] According to another embodiment, the method may comprise setting the reboiler to a steam outlet temperature in a range from 120 °C to 160 °C preferably from 130 °C to 4 155 °C.

[0281] According to another embodiment, the method may include setting the reboiler to a pressure drop ranging from 0.1 bar to 0.5 bar.

[0282] According to an embodiment of the invention, the method may comprise a setting of the CO₂ capture system comprising a capture rate greater than 80%, preferably greater than 85%, more preferably greater than 90% and even more preferably greater than 95%. The invention allows to capture CO₂ and to reduce emission of CO₂.

[0283] According to an embodiment of the invention, the method may comprise a setting of the CO₂ capture system to an outlet pressure in range from 20 bar to 400 bar, preferably from 40 bar to 300 bar and more preferably from 80 bar to 250 bar preferably at the outlet of the compressor.

[0284] According to an embodiment of the invention, the method may comprise a setting of the CO₂ capture system to an outlet pressure in range from 1 bar to 3 bar, preferably from 1 to 2 bar preferably at the outlet of the column of the solvent regeneration module.

[0285] In addition, the method may comprise a setting of the CO₂ capture system comprising a CO₂ purity greater than 90% and up to 100%. The invention may allow the recovery of CO₂ with a high purity rate.

[0286] Advantageously, the power generated, preferably the gross electrical power generated by the invention can be between 50 MW and 600 MW preferably between 75 MW and 400 MW.

[0287] Advantageously, the power generated, preferably the gross thermal power generated by the invention can be between 24 MWth and 750 MWth preferably between 50 MWth and 600 MWth and more preferably 75 MWth and 400 MWth

[0288] Advantageously, the power generated, preferably the gross mechanical power generated by the invention can be between 75 MW and 600 MW preferably between 75 MW and 400 MW.

[0289] Table 1 Comparison, weight, power and ratio according to different cycle (combined cycle CC or open cycle OC) with capture. Example for 2x30MW Gas

Turbines

Cycle	Net Power (MW)	Weight (ton) - equipment's	Ratio (t/MW)	Efficiency - (%)
OC	51	2900	57	31
Light CC (LCC)	64-66	3800	58-60	39-41
Compact CC (CCC) (invention)	65	3300	51	40
Delta LCC - OC	14	900	60	
Delta CCC - OC	14	400	30	

[0290] The invention allows the implementation of CO₂ capture in a more compact, more efficient and less expensive way.

[0291] Indeed, the invention allows to reduce the costs of implementing CO₂ capture on an installation and preferably an offshore one, through the increase in efficiency (yield), the reduction in fuel consumption and CO₂ emissions compared to a direct capture installation (without combined cycle), and therefore the overall size of the installation. This invention allows the implementation of capture on an offshore power generation installation at a significantly lower overall cost (CAPEX + OPEX) than that of an "open cycle" installation with direct capture, or of a "combined cycle" installation with or without capture.

[0292] For the above example, the backpressure steam turbine power is estimated to be 14 MW, compared to 13-15 MW for the condensing turbine solution, which is assumed to have 7-8 bar extraction. The invention thus allows a BPST power comparable to that of a conventional "light" combined cycle with capture.

[0293] The auxiliary capture power is comparable, about 9 MW in both cases.

[0294] The weight of the capture unit equipment is comparable, estimated at 2300 tons. However, the present invention has a capture rate higher than 90%, against 85% for the unit considered OC or LCC, so this value can be reduced by 5% /100 tons for the invention with comparable capture rate.

[0295] The invention in an installation and in particular in an offshore installation allows a substantial gain on the bulks (interconnection ducts, piping, wiring, valves, etc.) which represent about 30% of the weight of the main equipment's. It can be reasonably estimated that the capture installation according to the invention will be lighter by about 5-10% for this bulks set at the same capture rate, i.e. 200-300 tons out of a total of 3100 tons.

[0296] The bottoming cycle equipment part of the invention will be considerably lighter at about 500 tons instead of 900 tons for a light combined cycle, i.e. 400 tons less.

[0297] The invention allows to supply 14 MW for a delta of 400 t while for the same power the delta is 900 t for a light cycle. Thanks to the invention, there is a net performance without the need for high-pressure extraction.

[0298] The invention makes it possible to offer a performance equivalent to a lightened combined cycle with capture for an additional weight to the "open cycle" solution less than half of the light combined cycle one, with the added benefit of greater operational flexibility.

[0299] As disclosed the invention allows to improve the ratio weight power of an installation, to reduce cost and to reduce the emission of CO₂

[0300] In one specific but non-limiting embodiment and just to illustrate one or several embodiments of the invention, several parameters are disclosed below.

[0301] Cycle parameters are adjusted to minimize equipment sizes and maximize net power recovery at the back pressure steam turbine.

[0302] Back pressure steam turbine

[0303] The BPST is dependent on the capture process and the required reboiler temperature. The value of 4.2 bar has been chosen in this example to ensure a correct temperature difference in the reboiler with lean amines (saturated steam temperature about 145°C - amine outlet temperature about 117°C = 28°C gap). However, this gap could be increased with a higher choice of back pressure, e.g. 5.5 bar (saturation temperature about 155°C, +10°C), but at the expense of the BPST power. The pressure in the regeneration column (about 1.6 bar here for example) and the temperature at the reboiler can vary according to the optimization of the capture process and the nature of the solvent used, in the order of +/- 10°C. It is in the interest to minimize the regeneration pressure and temperature if it is compatible with the weight reduction of the capture system. This pressure will be set mainly by the reboiler which condenses about 60% of the steam, and secondarily

by the condenser which condenses the remaining steam. An adjustable bypass to the condenser will probably be necessary to facilitate the adjustment of thermal power and pressure in partial and transient loads. At part load, the BPST outlet pressure and reboiler temperature should drop very slightly, for example about less than 0.5 bar at 50% of the nominal steam flow. By comparison, a condensing turbine would see its extraction pressure drop almost in proportion to the condenser flow rate, i.e. from about 50% to 50% of the inlet and outlet steam flow. As a minimum reboiler pressure of 3-3.5 bar is required to ensure a sufficient regeneration temperature, this means that an extraction system designed for example for 4 bar at nominal load can no longer be used on a condensing turbine at part load below ~80% steam flow to ensure proper regeneration and capture. It is therefore necessary to either (a) increase the nominal extraction pressure to a higher pressure of the order of 6-7 bar, but will result in a degradation of the steam turbine power at nominal load or (b) provide an alternative extraction upstream in order to be able to ensure typical partial loads of 50% steam flow but will complicate the extraction process and require a steam turbine with 2 steam extractions. This shows that the invention with a back-pressure turbine provides a substantial advantage for CO₂ capture application that requests significant thermal power.

[0304] The BPST inlet pressure may be 80 bar, suitable for a proper BPST operation, and much higher than the usual pressure of "one pressure" condensation cycles (about 43 bar) and of the order of those with 2 pressures. The optimization of the HRSG and the cycle with the exhaust gas data (about 594°C at GT outlet) results in a steam inlet temperature about 410°C to minimize the HRSG weight and to obtain a fairly high steam turbine power. This results in a steam exit temperature at saturation with about 7% moisture, but this can be reduced with modified turbine inlet conditions (increased temperature and decreased pressure). The value of 80 bar can be optimized within a typical range of pressure and temperature of 60 to 120 bar and 400°C to 540°C or more.

[0305] The invention here is therefore characterised by the use of a back pressure steam turbine instead of a condensing turbine, and the associated water-steam cycle at about 80 bar and about 450°C at the inlet, and about 4.2 bar and about 145°C at the outlet (saturation temperature), allowing a doubled power of the steam turbine compared to a 25 bar steam turbine as mentioned in prior art for example.

[0306] Condenser

[0307] The pressure at the condenser is about 3.9 bar, with a very important hot

temperature difference of more than 90°C between saturation temperature (about 143°C) and cooling water (typically 25°C at inlet - 50°C at outlet for a closed loop). The subcooling of the condensate down to about 60°C gives a very comfortable cold temperature difference of about 35°C leading to a more compact condenser. In addition, this 60°C temperature could be optimized in a typical range of -20°C/+40°C (40 to 100°C): the higher this condensate temperature, the lower the condenser load, about -16% (-8 MWth) at 100°C, the smaller its size. At constant steam flow and temperature, this variation in load has direct impact on the HRSG thermal load, which would decrease by the same amount (-8 MWth, -6% boiler load) due to the hotter feed water, resulting in a higher HRSG outlet exhaust gas temperature (28°C) while the economizer surface may be slightly reduced, reducing the weight of the boiler of about 3%. But this may also result in increase of the electrical load of the fan (about +7%) and thermal load of the cooler by direct contact with an increase in the flow of demineralized water of its inlet quench by 33% (+11t/h). On the other hand, the steam flow may be increased to maintain the HRSG outlet temperature. This would lead to a 6% increase of steam flow (hence +1.5 MW BPST power), but a huge 50% increase of HRSG exchange surface and a 40% increase of HRSG weight. This shows the importance of a good optimisation of the condensate return temperature.

[0308] HRSG

[0309] The HRSG may deliver steam at about 410°C with exhaust gas entering at about 594°C and leaving at about 150°C against a water inlet temperature about of 60°C. The evaporator pinch is about 38°C. These important values of temperature difference associated with important exchange coefficients thanks to the high working fluid velocities, allowed with an aerodynamic pressure drop of 30 mbar or more (up to 50 mbar), against 12 to 20 mbar usually, allow a compact thermal design of the HRSG.

[0310] The exhaust gas exiting boilers at about 150°C may be gathered in a collector and boosted by a fan whose consumption is a function of the exhaust gas temperature. The exhaust gas leaving the fan at about 164°C and may be cooled and treated in the seawater direct contact cooler (DCC), which will naturally capture SO_x and part of the NO_x like a seawater desulfurizer. Preferably, upstream of the cooler, a quench system may be arranged, preferably for the exhaust gas by spraying demineralized water, in order to reduce the inlet temperature of the seawater cooler itself to about 75°C, to eliminate the possible risks of salt deposits related to this temperature about of 164°C, and to reduce the design temperature of the seawater DCC. The cleaned and cooled exhaust gas at about 31°C (depending on the seawater temperature) are directed into the first absorption column.

[0311] In order to lead the exhaust gas directly into the shell where the CO₂ treatment equipment may be located, without a long descent duct from the compact HRSG outlet usually located above the exhaust, the gas turbine package has been placed in an elevated position, and preferably the compact HRSG below the GT.

[0312] A by-pass at the GT outlet allows the exhaust gas to be sent either to the chimney located above (vertical outlet above the by-pass, axial outlet with elbow), or to the compact HRSG located preferably below (vertical outlet below the by-pass, or axial outlet with elbow). The compact HRSG may be a "once through" type, preferably vertical and more preferably inverted architecture. The compact HRSG is preferably located above the deck, and the cooled exhaust gases pass into the hull for treatment and capture of CO₂. As explained, the steam turbine is preferably located near to the compact HRSG to limit the length and weight of the high-pressure steam pipes.

[0313] In another specific but non-limiting embodiment, the invention may comprise between 2 and 4 GT's in operation (for example 2x30MW or 4x120 MW), and one BPST (for example 15 MW or 120 MW, about 25% of the sum of the GT powers, typical range 20 to 30 % depending on the GT exhaust conditions and steam cycle parameters).

[0314] The CO₂ capture and storage is an interesting way to reduce the CO₂ emission in particular with the power generation installation.

[0315] As explained with a simple cycle, no steam is available. However, the CO₂ capture requires a supply of heat for desorption and regeneration of solvent. The steam at the end of the compact HRSG allows to supply heat in a reboiler, but steam is mandatory in very large quantities and at an acceptable pressure. For example, in a usual technic, between 1.25 and 1.3 tons of steam are necessary per ton of CO₂.

[0316] A back pressure steam turbine allows to supply all steam and power necessary in the capture and storage but also allows to strongly improve the weight/power ratio of power generation installations. The BPST instead of conventional condensation steam turbine allow to send all the steam from BPST output to the reboiler for regeneration before final condensation.

[0317] The invention allows to adapt parameters and equipment to water-steam cycle to optimize/maximize BPST power and minimize equipment size (particularly HRSG size but also condenser and direct contact cooler (exhaust gas treatment)).

[0318] The invention allows to integrate equipment in a compact architecture, with a gas

turbines in a « upper » position. The exhaust piping goes through a vertical, and preferably « inverted » compact HRSG placed at GT exhaust, and then directly send to exhaust gas treatment with cooling and CO₂ absorption positioned below (usually in the hull).

[0319] Advantageously, the invention allows an easiest implementation of CO₂ capture in area with space and weight constraints (in particular for offshore applications), a gain in term of pipe and bulk length/weight because of a smart and compact integration which minimize their utilization, weight reduction compared to conventional Combined Cycle, efficiency (yield) comparable to ultra-light or light combined cycle with carbon capture and weight reduction compared to an open cycle (only GTs) and better operational flexibility, and a cost reduction for CO₂ capture in offshore environment (higher efficiency compared to open cycle, volume and weight reduction (compared to conventional CC)).

[0320] The invention can be the subject of numerous variants and applications other than those described above. In particular, unless otherwise indicated, the different structural and functional characteristics of each of the implementations described above should not be considered as combined and / or closely and / or inextricably linked to each other, but on the contrary as simple juxtapositions. In addition, the structural and / or functional characteristics of the various embodiments described above may be the subject in whole or in part of any different juxtaposition or any different combination.

Claims

1. System (1) for generating power with a combined cycle for an installation comprising:
 - at least one supply pipe (2) configured to supply a working fluid to at least one gas turbine (3),
 - at least one transport pipe (4) configured to guide an exhaust gas from a proximal end (4.1) to a distal end (4.2) of the at least one transport pipe, said proximal end (4.1) being configured to cooperate fluidically with the at least one gas turbine (3) and the distal end (4.2) being configured to cooperate fluidically with at least one compact heat recovery steam generator (5), said distal end being at a height less than or equal to a height of the proximal end relative to a base of said installation, and
 - at least one conveying pipe (6) configured to direct a steam from the at least one compact heat recovery steam generator (5) to at least one back-pressure steam turbine (7) configured to generate power from the steam.
2. System (1) for generating power according to the claim 1 wherein the generated power is an electric, thermal power and/or mechanical power.
3. System (1) for generating power according to the claim 1 or 2 wherein the installation is an onshore installation or an offshore installation.
4. System (1) for generating power according to any one of the preceding claims, wherein the at least one gas turbine comprises an exhaust gas recirculation means.
5. System (1) for generating power according to any one of the preceding claims, wherein the system and/or the at least one compact heat recovery steam generator comprise at least one duct firing.
6. System (1) for generating power according to any one of the preceding claims, wherein the at least one compact heat recovery steam generator comprises a one through steam generator.
7. System (1) for generating power according to any one of the preceding claims, wherein the at least one compact heat recovery steam generator comprises straight and/or finned tubing, circular and/or spiral finned, with solid or serrated fins, preferably finned tubing.

8. System (1) for generating power according to any one of the preceding claims, wherein the at least one compact heat recovery steam generator comprises tubing with an external diameter between 9.00 mm and 50.00 mm.
9. System (1) for generating power according to any one of the preceding claims, wherein the at least one compact heat recovery steam generator is an inverted vertical compact heat recovery steam generator.
10. System (1) for generating power according to claims 1 to 8, wherein the at least one compact heat recovery steam generator is configured to present a horizontal flow or a vertical downflow or vertical upward flow.
11. System (1) for generating power according to claims 1 to 8, wherein the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an inlet of the at least one compact heat recovery steam generator relative to a base of the installation.
12. System (1) for generating power according to claims 1 to 8, wherein the distal end of the transport pipe is configured to be at a height greater than or equal to a height of an outlet of the at least one compact heat recovery steam generator relative to a base of the installation.
13. System (1) for generating power according to claims 1 to 8, wherein the at least one compact heat recovery steam generator is configured to be arranged below the gas turbine.
14. System (1) for generating power according to any one of the preceding claims, wherein the at least one transport pipe comprises a by-pass (8)
15. System (1) for generating power according to any one of the preceding claims, wherein the system comprises at least one fan.
16. System (1) for generating power according to any one of the preceding claims, wherein said system (1) comprises at least one condenser (14).
17. System (1) for generating power according to the claim 16, wherein said system (1) comprises at least one condensate pump, an extraction pump and/or a feed pump.
18. System (1) for generating power according to the claim 16, wherein said system (1) comprises at least one feed water tank.

19. System (20) for capturing CO₂ from exhaust gas comprising:
 - At least one power generation system according to the claim 1,
 - At least one cooling module (10) configured to cool the exhaust gas from the at least one compact heat recovery steam generator (5),
 - At least one absorption module (11) configured to contact cooled exhaust gas with a lean solvent capable of absorbing CO₂ from the exhaust gas to generate an enriched solvent, and
 - At least one solvent regeneration module (12) fluidically coupled to at least one reboiler (13), said solvent regeneration module (12) being configured to treat the enriched solvent to release absorbed CO₂ and form a lean solvent, and
 - wherein the back pressure steam turbine (7) is configured to supply steam to the reboiler (13) of the solvent regeneration module (12).
20. System (20) for capturing CO₂ according to the claim 19, wherein said system (20) for capturing CO₂ comprises an auxiliary water extraction and re-injection system.
21. System (20) for capturing CO₂ according to the claim 19, wherein said system (20) for capturing CO₂ comprises a water storage means.
22. System (20) for capturing CO₂ according to the claim 19, wherein said system (20) for capturing CO₂ comprises a collector (9), preferably configured to be arranged downstream of the at least one compact heat recovery steam generator (5).
23. System (20) for capturing CO₂ according to the claim 19, wherein the cooling module comprises a cooling fluid, said cooling module being configured to bring the exhaust gas and the cooling fluid into contact, said contact being direct or indirect.
24. System (20) for capturing CO₂ according to the claim 19, wherein the cooling module and the absorption module are configured to be arranged in the lower part of the installation.
25. System (20) for capturing CO₂ according to the claim 19, wherein the cooling module is configured to cooperate fluidically with the at least one compact heat recovery steam generator (5).
26. System (20) for capturing CO₂ according to the claim 19, wherein said system for capturing CO₂ comprises a fan (16).

27. System (20) for capturing CO₂ according to the claim 19 wherein the absorption module is configured to enable a counter-current flow absorption.
28. System (20) for capturing CO₂ according to the claim 19 wherein the absorption module is configured to enable a crossflow absorption.
29. Method for capturing CO₂ comprising at least one system for capturing CO₂ according to the claim 19 wherein the said method comprises a step of setting the at least one compact heat recovery steam generator to an inlet exhaust gas temperature ranging from 400 °C to 650 °C.
30. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the at least one compact heat recovery steam generator to an outlet exhaust gas temperature ranging from 70 °C to 250 °C.
31. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the at least one compact heat recovery steam generator to a steam outlet temperature ranging from 400 °C to 565 °C.
32. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the at least one compact heat recovery steam generator to a steam outlet pressure ranging from 25 bar to 170 bar.
33. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the back pressure steam turbine to an inlet steam pressure ranging from 25 to 170 bar.
34. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the back pressure steam turbine to an outlet steam pressure ranging from 1 to 20 bar.
35. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the back pressure steam turbine to a steam inlet temperature ranging from 400 to 565 °C.
36. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the back pressure steam turbine to a steam outlet temperature ranging from a saturation temperature to at most 50 °C superheating.

37. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the reboiler to a steam inlet pressure in a range from 2 bar to 6 bar.
38. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the reboiler to a steam inlet temperature in a range from 120 °C to 200 °C.
39. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the reboiler to a steam outlet pressure in a range from 2 bar to 6 bar.
40. Method for capturing CO₂ according to the claim 29 wherein the said method comprises a step of setting the reboiler to a steam outlet temperature in a range from 120 °C to 160 °C.
41. Use of a CO₂ capture system according to the claim 19 in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport.
42. Use of a power generation system according to claim 1 in the capture of CO₂, in electricity production, steam production, mechanical power production, thermal power production, in the treatment of CO₂, in the conditioning of CO₂, in the transport of CO₂, in the storage of CO₂, in the recovery of exhaust flue gas, in the treatment of exhaust flue gas, in gas production, in oil production and/or in marine transport.
43. Offshore installation comprising a power generation system according to the claim 1.
44. Onshore installation comprising a power generation system according to the claim 1.
45. Offshore installation comprising a system for capturing CO₂ according to the claim 19.
46. Onshore installation comprising a system for capturing CO₂ according to the claim 19.