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(57) **ABSTRACT**

A steam power plant including a number of partial turbines is provided. Each partial turbine is permeated by steam, an overflow line disposed between a first partial turbine and a second partial turbine and an intermediate superheater in the overflow line. A bleeder line for extracting steam is thereby fluidically connected to the first partial turbine after the expansion stage, prior to the intermediate superheater. An expansion device is further provided, into which the bleeder line opens, and a consumer is connected via a process steam line of the expansion device.

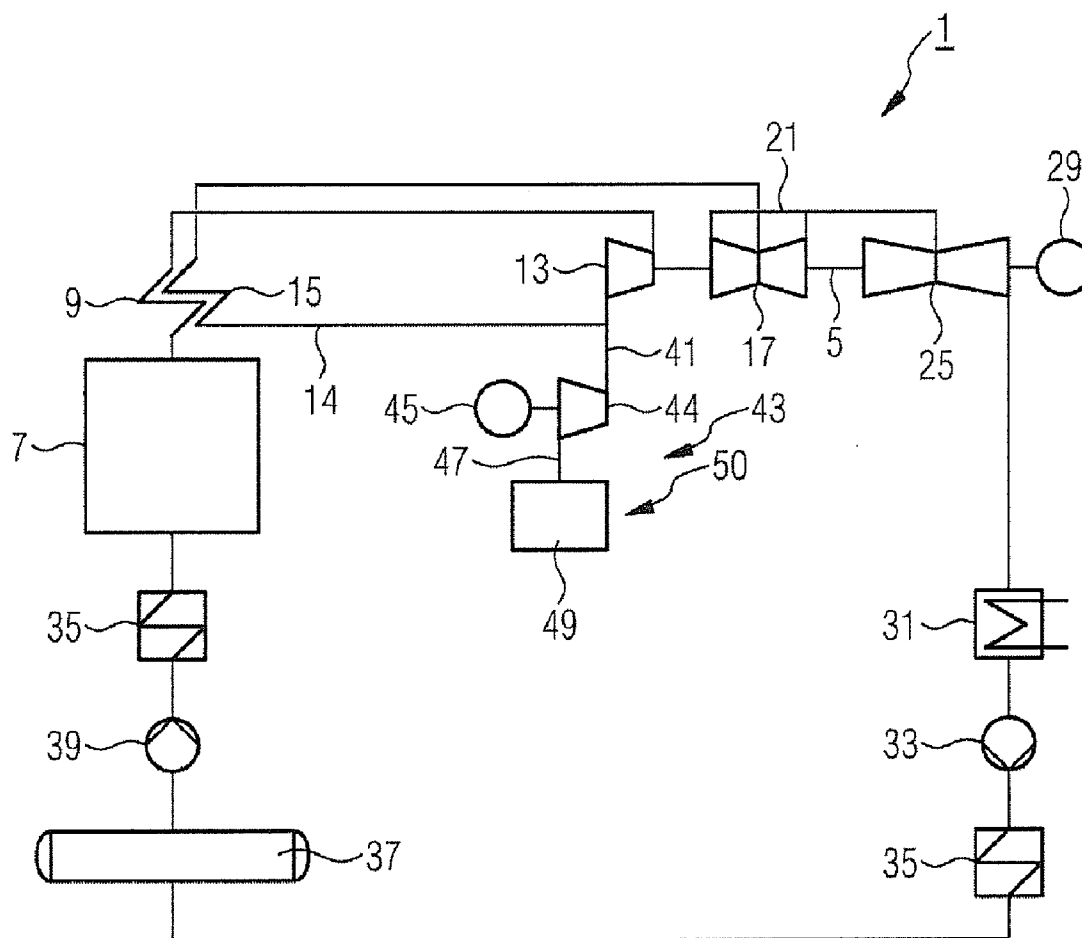


FIG 1

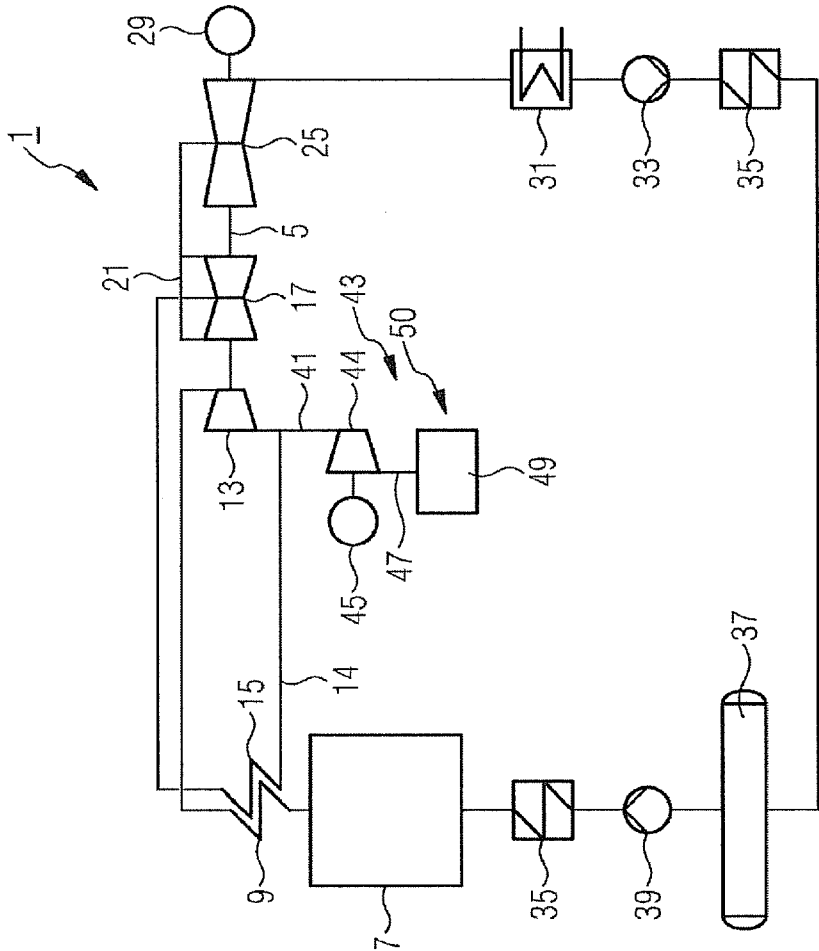


FIG 2

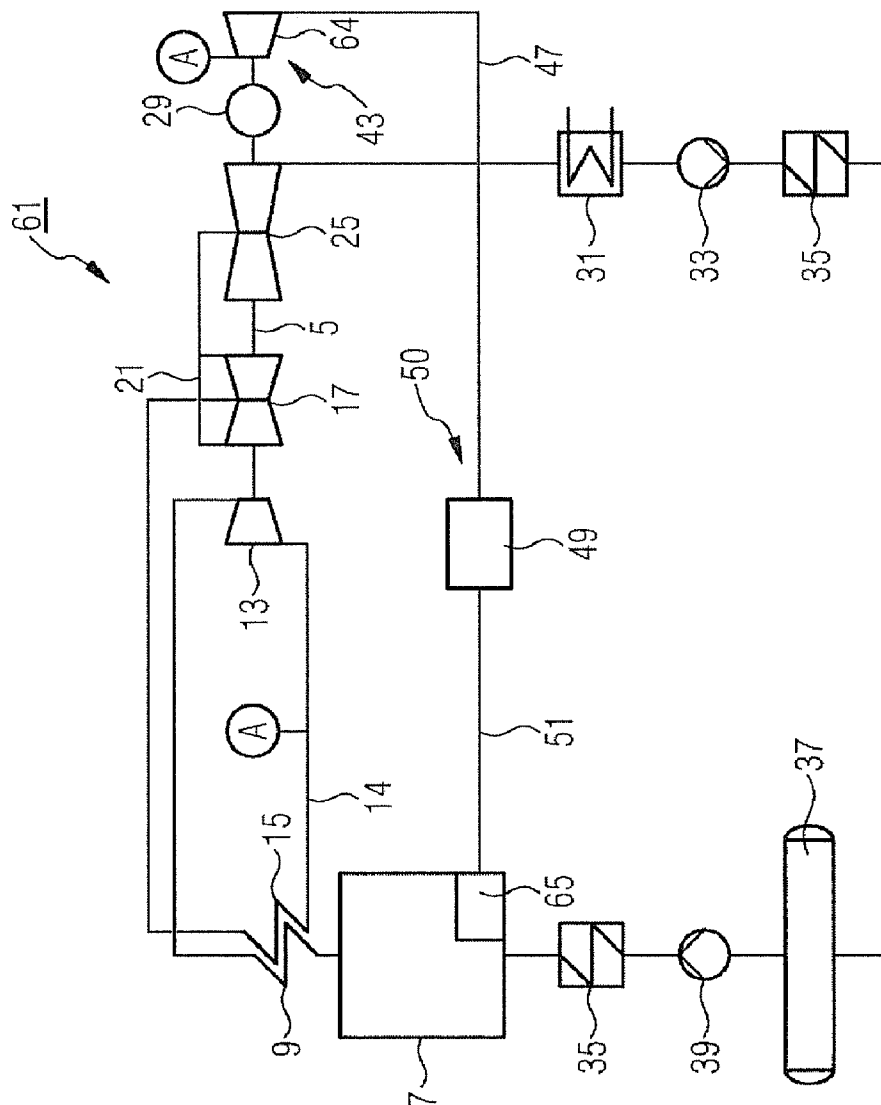
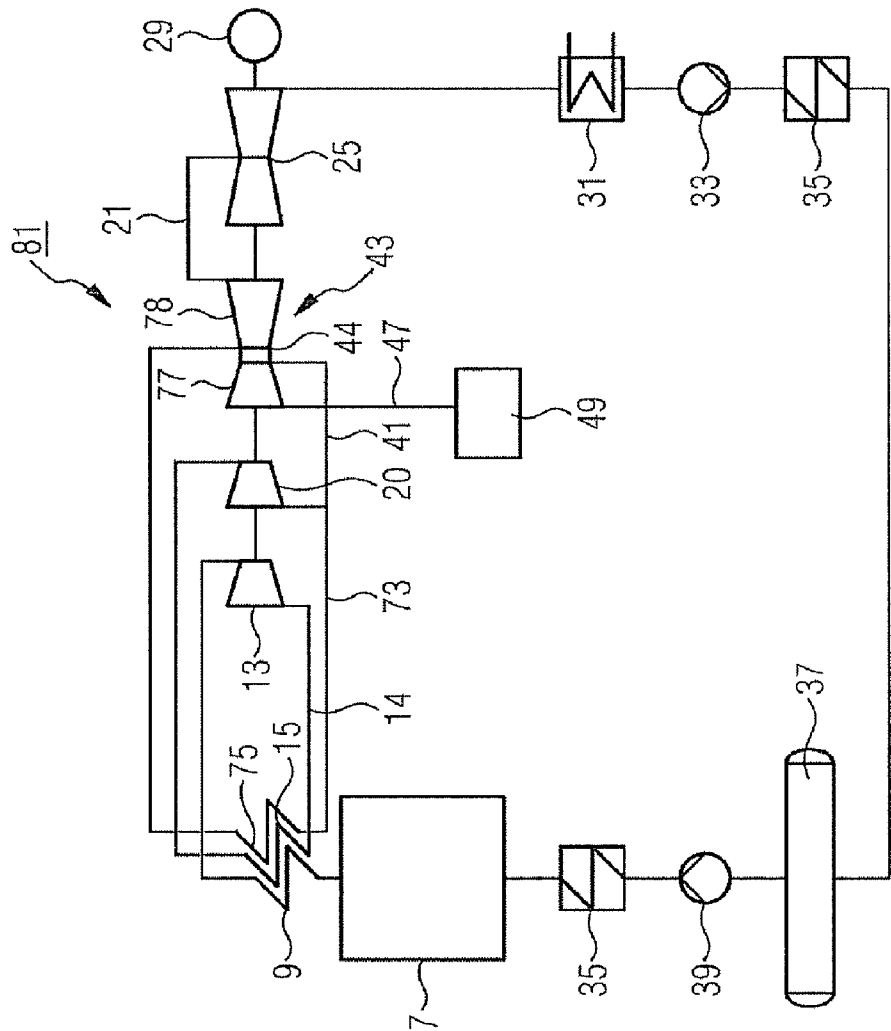


FIG 4



STEAM POWER PLANT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the US National Stage of International Application No. PCT/EP2010/063661, filed Sep. 17, 2010 and claims the benefit thereof. The International Application claims the benefits of European Patent Office application No. 09171049.1 EP filed Sep. 23, 2009. All of the applications are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[0002] The invention refers to a steam power plant, comprising a number of turbine sections, through which steam can flow in each case, a crossover line, which is arranged between a first turbine section and a second turbine section, and a reheater in the crossover line.

BACKGROUND OF INVENTION

[0003] A steam power plant of the type referred to in the introduction is to be gathered from EP 1 744 032 A1, for example. The steam power plant, in this case designed as a combined gas and steam power plant (CCPP), comprises a number of turbine sections which are designed for different pressures and through which steam flows. The steam, for example after exiting from a turbine section which is designed as a high-pressure turbine, is directed via a crossover line into a reheater. A further crossover line is arranged between an intermediate-pressure turbine and a low-pressure turbine. This crossover line is equipped with a valve for the extraction of heating steam and process steam. The process steam is fed via a steam line to an engineering plant or to an industrial operation.

[0004] Especially in the case of steam power plants with very high efficiency requirements, suitable ways are sought of suitably extracting large volumes of steam. Large volumes of steam are required for example for district heat extraction, for the treatment of fuel, particularly such as brown coal drying, or for flue gas scrubbing, particularly such as CO₂ separation. These consumers, in addition to the large volumes of steam which can be up to half the volume of steam fed to a low-pressure turbine section in a conventional steam power plant, require the steam, moreover, at a relatively low temperature level of 100° C. to 150° C. close to the condensation temperature.

[0005] According to EP 1 744 032 A1, steam extraction is carried out from a crossover line between two turbine sections, especially between an intermediate-pressure steam turbine and a low-pressure steam turbine. In this case, to remove large volumes of steam would, however, seriously reduce the efficiency of the steam power plant in an undesirable way.

SUMMARY OF INVENTION

[0006] For a steam power plant, it is the object of the invention to disclose a steam treatment for a specific consumer with high steam requirement, wherein with costs which are as low as possible the overall efficiency remains as high as possible.

[0007] This object of the invention is achieved according to the invention by means of a steam power plant with the feature combination according to the claims.

[0008] Therefore, the steam power plant comprises a number of turbine sections, through which steam can flow in each case, a crossover line, which is arranged between a first tur-

bine section and a second turbine section, and a reheater in the crossover line. In this case, a bleed line for steam extraction is connected to the first turbine section downstream of the expansion stage, fluidically upstream of the reheater. Provision is made for an expansion device into which leads the bleed line, and for a consumer which is connected via a process steam line to the expansion device.

[0009] In a first step, the invention is based on the fact that previously a volume of steam was customarily extracted from crossover lines downstream of a reheater. Superheated steam, however, provides higher temperatures than are necessary for the mentioned consumers, particularly such as a flue gas scrubber or for a fuel treatment facility, and therefore provides an exergy surplus. The surplus of exergy, therefore, is lost without being utilized, as a result of which the efficiency of the steam power plant is reduced.

[0010] The invention solves this problem by the steam being extracted upstream of the reheater via a bleed line. Such steam has a usable temperature level for connected consumers. Since the extracted steam leaves the steam power plant without unnecessary exergy losses, the overall efficiency of the steam power plant can be maintained at a higher level compared with the previously known solution. In other words, the invention makes provision for extracting the steam upstream of, or from, the so-called cold reheat line, this being the feed line to the reheater. In this case, the invention is also to comprise such developments in which the required steam is essentially or predominantly extracted from the crossover line upstream of the reheater, and wherein a further, smaller, proportion of steam is taken, for example, from the crossover line downstream of the reheater. This can be altogether more cost-effective for a specific consumer, taking into consideration the overall system, or, in a given case, can lead to higher overall efficiency.

[0011] In a further step, the invention makes provision for an expansion device, by means of which the extracted steam is expanded to a corresponding pressure level upstream of the forwarding line to a consumer. As a result of the expansion, the temperature of the steam is also reduced and the conditions which are required for a consumer can be specifically established. The steam can especially be set exactly to the level which is usable by the consumer, performing work. An expansion device therefore offers the additional advantage of improving the overall efficiency of the steam power plant as a result of the expansion of the steam, performing work for the overall system.

[0012] A steam power plant is the predominant type of construction of a power plant for the conventional generation of electric energy from fossil fuels, in which the thermal energy from steam is utilized in a steam turbine. For operating a steam turbine, steam is heated in a steam boiler and introduced into the steam turbine. There, the steam is expanded. The work which is released during the expansion is delivered to a generator, for example, which is connected to the turbine. The steam boiler is fired with conventional fuels, such as natural gas or coal. In the case of a combined gas and steam plant (CCPP), the exhaust gas of the gas turbine is fed to a waste heat steam boiler for steam preparation. By utilizing the residual heat which is contained within the exhaust gas flow of the gas turbine, a particularly high level of overall efficiency can be achieved in such a combined gas and steam power plant, and therefore a saving in fuel can also be made. This is of great interest with regard to the issues of protection of the environment.

[0013] A steam power plant usually comprises a plurality of turbine sections which are designed in each case for different pressures. In this case, for example high-pressure (HP) turbine sections, intermediate-pressure (IP) turbine sections and low-pressure (LP) turbine sections connected in series are customary. It is also possible that a steam turbine has a plurality of turbine sections which are designed for the same pressures.

[0014] Inside a steam turbine, the steam from a turbine section at high pressure (for example an HP turbine section) is expanded in the direction of a turbine section with the lowest pressure (for example an LP turbine section). The number of expansion stages, that is to say the number of series-connected turbine sections, can be different in this case, depending upon application and upon the connected consumer. The individual turbine sections can be of single-flow or multifold design.

[0015] The steam power plant disclosed here comprises a crossover line, having a reheater, which is arranged between a first turbine section and a second turbine section. Via such a crossover line, for example the steam expanded in a high-pressure turbine section is directed into an intermediate-pressure turbine section in order to be further expanded there.

[0016] In the process, the reheater superheats again the previously expanded steam which discharges from the first turbine section. The superheated steam is finally directed into the second turbine section with a lower pressure level. The steam is again expanded there. It is possible to provide a plurality of reheaters in a steam power plant. A steam power plant can be designed with one reheater, or with a plurality of reheaters, depending upon the number of turbine sections.

[0017] The bleed line is connected to the first turbine section downstream of the expansion stage, in fact fluidically upstream of the reheater. By means of the bleed line, process steam can be extracted from the turbine system. The bleed line can basically be connected directly to the turbine or can be branched from the feed line to the reheater.

[0018] The expansion device is connected on the outlet side, via a process steam line, to the consumer. The process steam expanded in the expansion device, and therefore set at the required level, is directed via the process steam directly to the consumer. The expansion device is preferably designed to deliver the essentially total required volume of steam to the consumer.

[0019] In accordance with the aforesaid specific consumers, which require enormously large volumes of steam at a relatively low temperature level, the expansion device is especially designed for expanding large volumes of steam from the delivered pressure level from the cold reheat line to pressures of between about 1.5 and 5 bar at a temperature level of between about 100° C. and 150° C. For example, a flue gas scrubber, especially for CO₂ separation, requires a pressure of about 2 bar at such a temperature level. A fuel treatment facility, especially a brown coal drier, requires pressures of between 3 bar and 5 bar.

[0020] In the case of the design of the consumer as a flue gas scrubber, exhaust gas, also referred to as flue gas, for example from the firing system of the steam boiler, is directed through a corresponding fluid, wherein a gas component which is to be separated goes into solution. The residual gas is directed into the exhaust air by means of the flue gas scrubber. The gas component, which is in solution, is thermally driven out of the fluid and, for example, fed to a storage facility or the like or permanently integrated elsewhere. For the thermal removal of

the dissolved gas component, the process steam is required. The flue gas scrubber is especially designed for separating CO₂ from the flue gas. The separated CO₂ is fed to a place of storage, for example in underground storage facilities.

[0021] For separating CO₂ and other acidic gas components from the flue gas, a so-called amine scrubber, for example, is used, wherein the flue gas is directed through an aqueous amine solution. In the process, the acidic components, especially CO₂, go into solution. The residual components are directed into the exhaust air. The solution is subsequently heated by means of the process steam to between 100° C. and 150° C., as a result of which the CO₂ emerges again from the solution. The residual gases possibly remain in the solution. The CO₂ can subsequently be compressed and then, for example, pumped into storage facilities in the ground.

[0022] The flue gas scrubber is designed especially to extract the required heat, for expelling the CO₂, from the supplied process steam, which discharges this possibly by condensing. The steam condensate is fed back into the steam cycle.

[0023] The high cost for separating CO₂ from the exhaust gases of a power plant, especially of a steam power plant—wherein large volumes of steam are extracted, reducing the efficiency,—is necessary taking into consideration overall environmentally relevant effects. A steam power plant equipped in such a way, compared with conventional plants, fulfills the stipulated emissions requirements, which are becoming more stringent, in relation to this.

[0024] In the case of the design of the consumer as a flue gas scrubber, the steam power plant comprises an exhaust gas line which leads into the consumer. By means of such an exhaust gas line, the exhaust gas is fed to the consumer, for example directly from the firing system of the steam boiler, or as exhaust gas of a gas turbine from a waste heat steam boiler.

[0025] In another development, the consumer of large volumes of steam is constructed as a fuel treatment facility. In this case, the heat of the process steam is used for removal of residual moisture from brown coal, for example.

[0026] The expansion device can especially be designed separately for the turbine sections. In this case, the possibility exists of retrofitting an existing steam turbine or an existing steam power plant. The expansion device, however, is advantageously an integrated component part of the turbine generator set of the steam power plant. This solution is especially ideal in the case of a new design of a steam power plant since less space is required overall, and such an arrangement can possibly contribute positively to the overall efficiency. However, a separate solution also offers the great advantage that the system parts downstream of the steam bleed point can be designed more cost effectively. Since a substantial proportion of steam is extracted for the said consumer, pipelines downstream of the bleed point, especially for a crossover line between an intermediate-pressure turbine section and a low-pressure turbine section, can be designed with a smaller cross section than normal, as a result of which considerable cost advantages ensue. In the same way, heating surfaces downstream of the bleed point can be designed smaller than in the case of conventional types of construction, which again is associated with cost advantages.

[0027] The expansion device is preferably designed as an expansion turbine. As a result of such a design, it becomes easily possible to still utilize existing energy surplus for the performing of work for the overall system. Via the expansion

of the extracted steam, a shaft in particular, which can be connected to a generator, is driven.

[0028] The expansion turbine is preferably operated in back-pressure mode. The expansion end downstream of the expansion turbine then corresponds to the required process steam pressure. Therefore, the required pressure level and temperature level can ideally be provided for the consumer.

[0029] If the expansion turbine in an advantageous development is not constructed as a separate turbine, but is arranged on a common shaft with the turbine sections, then the work produced is delivered directly to the overall system.

[0030] The design of the expansion device as an expansion turbine furthermore offers the great advantage that the pressure level for the consumer can ideally be set by control of the turbine, in fact within broad limits regardless of the pressure level of the inflowing steam. In particular, pressure fluctuations of the inflowing steam can also easily be compensated by corresponding control of the turbine.

[0031] The expansion turbine expediently has additional bleed points. For example, a regenerative feed-water preheater, or a plurality of feed-water preheaters, can be fed as a result of this.

[0032] A high-pressure turbine section and an intermediate-pressure turbine section are advantageously included and interconnected via the crossover line having reheaters, wherein the bleed line is connected to the high-pressure turbine section, especially via the crossover line. In this case, the extracted steam is expanded downstream of the high-pressure turbine section in a separate expansion step to the corresponding pressure level of a connected consumer. The process steam is not directed via a reheater upstream of the extraction. The downstream system parts are designed more cost-effectively corresponding to the reduced volume of steam.

[0033] In a further advantageous development, a high-pressure turbine section, a first intermediate-pressure turbine section, a second intermediate-pressure turbine section and, if necessary, a low-pressure turbine section, or a plurality of low-pressure turbine sections, are included, wherein the first intermediate-pressure turbine section and the second intermediate-pressure turbine section are interconnected via the crossover line having a second reheater, and wherein the bleed line is connected to the first intermediate-pressure turbine section, especially via the crossover line. In this case, the volume of steam which is required for a CO₂ separation facility, for example, can be extracted downstream of the first intermediate-pressure turbine section and be expanded especially in an expansion turbine to the desired pressure level.

[0034] Preferably included is a steam boiler, which is connected on the exhaust gas side, via the exhaust gas line, to the consumer. The steam boiler provides exhaust gases from the combustion system which are fed to a CO₂ separation facility. As a result of the connection between the steam boiler and the consumer, the possibility is presented of clearing the exhaust gas of CO₂ before being emitted into the atmosphere. Such a treatment of the exhaust gas offers the possibility of designing a steam power plant in an especially environmentally caring and energy efficient manner. In a further development, the exhaust gas of a gas turbine is ducted for heating steam in a waste heat steam boiler and is directed from there to the consumer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] Exemplary embodiments of the invention are explained in more detail in the following text with reference to a drawing. In this case, in the drawing

[0036] FIG. 1 schematically shows a steam power plant with a number of turbine sections and a bleed line downstream of the high-pressure (HP) expansion stage, wherein extracted steam is expanded in a separate expansion turbine,

[0037] FIG. 2 schematically shows a steam power plant with a number of turbine sections and a bleed line downstream of a high-pressure (HP) expansion stage, wherein extracted steam is expanded in an expansion turbine which is integrated in the turbine generator set,

[0038] FIG. 3 schematically shows a steam power plant with a number of turbine sections and a bleed line downstream of a first intermediate-pressure (IP) expansion stage, wherein extracted steam is expanded in a separate expansion turbine, and

[0039] FIG. 4 schematically shows a steam power plant with a number of turbine sections and a bleed line downstream of a first intermediate-pressure (IP) expansion stage, wherein extracted steam is expanded in a double-flow expansion turbine which is integrated in the turbine generator set.

[0040] The same components in the figures retain the same designations in each case here.

DETAILED DESCRIPTION OF INVENTION

[0041] FIG. 1 shows a steam power plant 1 with a number of turbine sections which are designed for different pressures. The turbine sections are allocated in series to a common shaft 5.

[0042] For operation, water is heated in a steam boiler 7 and steam is produced via a live-steam superheater 9. The superheated steam is introduced as operating steam, via a piping arrangement, into a high-pressure turbine section 13, where the steam is expanded. After expansion in the high-pressure turbine section 13, a portion of the steam is directed, via a first crossover line 14, into a reheater 15, reheated there, and then directed into a double-flow intermediate-pressure turbine section 17.

[0043] Here, the steam expands again to a predetermined, now lower pressure level.

[0044] Following this, the steam, which is expanded in the intermediate-pressure turbine section 17 to the lower pressure level, is directed, via an associated second crossover line 21, into an also double-flow low-pressure turbine section 25.

[0045] A generator 29 is driven via the common shaft 5 for electric power generation. The steam, expanded and cooled, leaving the low-pressure turbine section 25, flows into a condenser 31 where it condenses as a result of heat transfer to the environment and accumulates as liquid water. Via a condensate pump 33 and a preheater 35, the water is temporarily stored in a feed-water tank 37 and then fed again to the steam boiler 7 via a feed-water pump 39.

[0046] Downstream of the expansion stage, a bleed line 41 is connected to the high-pressure turbine section 13 downstream of its expansion stage, in fact fluidically upstream of the reheater 15. Via this bleed line 41, steam which is required for a consumer 49 is extracted from the system downstream of the expansion in the high-pressure turbine section 13.

[0047] The bleed line 41 leads into an expansion device 43 which is therefore connected to the high-pressure turbine section 13. The expansion device 43 is designed as a separate expansion turbine 44 to which is connected a second generator 45. Inside the expansion turbine 44, the extracted steam is expanded ideally to a level (pressure, temperature) desired for the consumer 49, performing work for the overall system.

Instead of the generator, a suitable consumer for mechanical energy can also be arranged or connected.

[0048] From the expansion turbine 44, the expanded process steam is forwarded directly to the consumer 49 via a process steam line 47. This consumer is designed as a fuel treatment facility or as a flue gas treatment facility, for example. The separate expansion turbine 44 is operated in back-pressure mode.

[0049] The expansion end corresponds as far as possible in this case directly to the required process steam pressure so that the expansion turbine 44 ideally provides the required level of pressure and temperature for the connected consumer 49.

[0050] FIG. 2 shows a further development of a steam power plant 61 with a number of turbine sections.

[0051] As also in FIG. 1, the turbine generator set is operated by means of superheated steam from a steam boiler 7. The steam finds its way from the steam boiler 7 into the live-steam superheater 9 and then, via a piping arrangement, into the high-pressure turbine section 13.

[0052] In contrast to FIG. 1, the expansion device 43 of the steam power plant is now, however, not arranged separately from the turbine generator set but allocated to the common shaft 5 as a correspondingly designed expansion turbine 64. Via a bleed point A from the first crossover line 14, extracted steam is fed to the expansion turbine 64 and expanded to the level required by the consumer 49, which is connected on the outlet side via the process steam line 47, performing work for the overall system.

[0053] The consumer 49 in this case is designed as a flue gas scrubber for CO₂ separation from the exhaust gases of the firing system 65 of the steam boiler 7. Correspondingly, an exhaust gas line 51 from the firing system 65 leads into the consumer 49. The resulting CO₂, as described previously, is removed from the exhaust gases and stored.

[0054] In FIG. 3, a third development of a steam power plant 71 is to be seen. The steam power plant 71, as also in FIGS. 1 and 2, is designed as a steam power plant with a number of turbine sections. The operation of the steam power plant 71 can be gathered in accordance with the preceding embodiments.

[0055] As in FIG. 1, the expansion device 43 in the steam power plant 71 is designed as a separate expansion turbine 44. In contrast to FIG. 1, the expansion turbine 44, however, is connected via the bleed line 41 to the first intermediate-pressure turbine section 17 downstream of the expansion stage.

[0056] The operating steam, after expansion in the high-pressure turbine section 13, is directed via a first crossover line 14 and via the first reheater 15 into the first intermediate-pressure turbine section 17 and expanded there. Via the third crossover line 73, the expanded steam is directed downstream of the first intermediate-pressure turbine section 17 through a second reheater 75 and from there is led into a second intermediate-pressure turbine section 19. Via the second crossover line 21, the steam expanded in the second intermediate-pressure turbine section 19 is directed into the double-flow low-pressure turbine section 25. From there, the steam is further processed in accordance with the processes described in FIGS. 1 and 2.

[0057] According to FIG. 3, provision is made to feed the exhaust gases of a gas turbine 53 to the boiler 7 for steam generation. From there, the exhaust gases flow via the exhaust

gas line 51 into the consumer 49 which in the present case is again designed as a flue gas scrubber.

[0058] The steam power plant 81 according to FIG. 4 comprises a single-flow intermediate-pressure turbine section 20, from which discharging, expanded steam is led via the third crossover line 73 and via the second reheater 75 into an expansion turbine 44 which is integrated into the turbine generator set.

[0059] The expansion turbine 44, which is allocated to the common shaft 5, is designed, according to FIG. 4, as an asymmetrical turbine section which has a first expansion section 77 and a second expansion section 78. The second expansion section 78 is designed as an intermediate-pressure turbine. After expansion, the steam flows via the crossover line 21 into the double-flow low-pressure turbine section 25. The first expansion section 77 is connected on the inlet side, via the bleed line 41, to the third crossover line 73. From this, steam is extracted for the consumer 49. The first expansion section 77 expands the extracted steam for the consumer 49 to the required level, performing work for the overall system. The expanded steam is fed via the process steam line 47 to the consumer 49.

[0060] The asymmetrical expansion turbine 44 according to FIG. 4 can also be used as a separate expansion device in isolation from the turbine generator set.

1-10. (canceled)

11. A steam power plant, comprising:

a plurality of turbine sections including a first turbine section and a second turbine section, through which steam flows in each case;

a crossover line, which is arranged between the first turbine section and the second turbine section; and

a reheater in the crossover line,

wherein a bleed line for steam extraction is connected to the first turbine section downstream of an expansion stage, fluidically upstream of the reheater, in that provision is made for the expansion device which is designed as an expansion turbine and into which leads the bleed line,

wherein a consumer is connected via a process steam line to the expansion device, and

wherein the expansion turbine including the plurality of turbine sections is arranged on a common shaft.

12. The steam power plant as claimed in claim 11, wherein the consumer is designed as a flue gas scrubber.

13. The steam power plant as claimed in claim 12, wherein the flue gas scrubber is a CO₂ separator.

14. The steam power plant as claimed in claim 11, wherein the consumer is designed as a fuel treatment facility.

15. The steam power plant as claimed in claim 11, wherein the expansion device is designed to essentially provide the total required volume of steam for the consumer.

16. The steam power plant as claimed in claim 11,

wherein the expansion turbine is of double-flow design with two asymmetrical expansion sections, and

wherein the bleed line leads into a first expansion section and a crossover line from a turbine section, which is routed via a reheater, leads into a second expansion section.

17. The steam power plant as claimed in claim 11, wherein the expansion turbine comprises additional bleed points for process steam.

18. The steam power plant as claimed in claim **11**, wherein a high-pressure turbine section and an intermediate-pressure turbine section are included and are interconnected via the crossover line having reheaters, and wherein the bleed line is connected to the high-pressure turbine section.

19. The steam power plant as claimed in claim **18**, wherein the bleed line is connected to the high-pressure turbine section via the crossover line.

20. The steam power plant as claimed in claim **11**, wherein a high-pressure turbine section, a first intermediate-pressure turbine section, a second intermediate-pressure turbine section are included, wherein the first intermediate-pressure turbine section and the second intermediate-pressure turbine section are interconnected via the crossover line having reheaters, and

wherein the bleed line is connected to the first intermediate-pressure turbine section.

21. The steam power plant as claimed in claim **20**, further comprising a low-pressure turbine section.

22. The steam power plant as claimed in claim **20**, wherein the bleed line is connected to the first intermediate-pressure turbine section via the crossover line.

23. The steam power plant as claimed in claim **11**, further comprising a steam boiler and on the exhaust gas side is connected via an exhaust gas line to the consumer.

24. The steam power plant as claimed in claim **23**, wherein a gas turbine is included and on the exhaust gas side is connected to the steam boiler.

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