Description

Method for operating a gas-turbine and steam-turbine plant and plant working accordingly

The invention relates to a gas-turbine and steam-turbine plant with a waste-heat steam generator which is located downstream of the gas turbine on the exhaust-gas side and the high-pressure preheater of which is connected into the water/steam circuit of the steam turbine having a low-pressure part. It is further directed at a plant operated according to this method.

In a gas-turbine and steam-turbine plant, the heat contained in the expanded working medium from the gas turbine is utilized for generating steam for the steam turbine. The heat is transmitted by means of a number of heating surfaces which are arranged in the form of tubes or tube bundles in a waste-heat steam generator located downstream of the gas turbine on the exhaust-gas side. These heating surfaces are themselves connected into the water/steam circuit of the steam turbine. The water/steam circuit comprises a plurality of, for example two or three, pressure stages, each pressure stage having a preheater, an evaporator and a superheater.

In order to achieve as high a plant efficiency as possible during the transmission of heat, the arrangement of the heating surfaces within the waste-heat steam generator is adapted to the temperature trend of the exhaust gas. Thus, in a three-pressure process with intermediate superheating, the so-called three-pressure IS process, for a predetermined gas-turbine power an especially high steam-turbine power and consequently an especially high overall efficiency of the plant are achieved. A gas-turbine and steam-turbine plant working according to the three-pressure IS process is known from EP0,436,536 B1. Even in this known plant, however, the overall efficiency is limited to about 55%.

The object on which the invention is based is, therefore, to develop a gas-turbine and steam-turbine plant as well as a method for operating the latter, in such a way that an increase in the plant efficiency is achieved as a result of a further increase in the utilization of the heat content in the exhaust gas of the gas turbine.

As regards the plant, this object is achieved by means of a heat exchanger which is arranged outside the waste-heat steam generator and of which the primary-side inlet is connected to the outlet of the high-pressure preheater and of which the primary-side outlet is connected to the inlet of the high-pressure preheater and which is connected on the secondary side to an overflow conduit opening into the high-pressure part of the steam turbine.

In an expedient development, a circulating pump and a regulating valve are located downstream of the heat exchanger on the primary side.

A controller module is expediently provided for adjusting the quantity of feed water supplied per unit time to the heat exchanger on the primary side. The controller module serves for approximating the temperature of the feed water returned to the high-pressure preheater via the heat exchanger to the temperature of the feed water supplied directly to the high-pressure preheater, with the aim of ensuring that the temperatures at the mixing point of the high-pressure preheater are at least approximately equal. For this purpose, a first temperature sensor for recording the temperature of the feed water flowing off from the heat exchanger on the secondary side is connected to the controller module. A second temperature sensor connected to the controller module serves for recording the temperature of the feed water supplied to the high-pressure preheater.

An especially effective adaptation of the heating surface of the high-pressure preheater to the temperature trend of the exhaust gas from the gas turbine within the

waste-heat steam generator is achieved in that the high-pressure preheater has a two-stage design. Consequently, in a further advantageous embodiment,

the high-pressure preheater is a second high-pressure preheater which is located downstream of a first high-pressure preheater on the feed-water side and which is arranged upstream of the first high-pressure preheater in the waste-heat steam generator on the exhaust-gas side.

In a water/steam circuit composed of three pressure stages, this principle can be developed by providing, in addition to the intermediate superheater present in a three-pressure IS process, a medium-pressure superheater which is connected to the latter on the feed-water side and which is arranged upstream of the intermediate superheater in the waste-heat steam generator on the exhaust-gas side. Furthermore, to develop this principle, a low-pressure superheater, which is arranged in the waste-heat steam generator and which is connected to the secondary-side inlet of the heat exchanger on the outlet side, can be provided.

As regards the method, the said object is achieved in that low-pressure steam flowing into the steam turbine is superheated as a result of indirect heat exchange with a part stream of preheated feed water, the said part stream being extracted from the high-pressure preheater.

The cooled part stream is admixed again, preferably at the inlet of the high-pressure preheater, with the feed water to be preheated, an approximation of the temperature of the part stream to the feed water to be preheated being carried out by an adjustment of the part stream.

In a water/steam circuit composed of three pressure stages, low-pressure steam superheated in the waste-heat steam generator is further superheated, in that the low-pressure steam is admixed with the low-pressure steam to be superheated by indirect heat exchange.

The advantages achieved by means of the invention are, in particular, that, on the one hand, as a result of the superheating of the low-pressure steam by indirect heat exchange outside the waste-heat

steam generator with feed water preheated in the high-pressure preheater, heat from the exhaust gas of the gas turbine can be utilized for superheating, and that, on the other hand, on account of the indirect heat exchange, an additional degree of freedom in comparison with direct heat exchange with the exhaust gas is afforded. By virtue of this additional degree of freedom, the heat transfer can be adapted in an especially favourable way to the particular operationally prevailing state of the low-pressure steam from the steam turbine. An especially favourable utilization of the heat content in the exhaust gas from the gas turbine is thereby possible, even in the case of alternating load states. However, in addition to the increase in efficiency of the gas-turbine and steam-turbine plant thus attainable, the invention also makes it possible to increase the generator terminal output of the steam turbine.

An exemplary embodiment of the invention is explained in more detail by means of a drawing. In this, the figure shows diagrammatically a gas-turbine and steam-turbine plant with a separate heat exchanger for the heating of low-pressure steam.

The gas-turbine and steam-turbine plant according to the figure comprises a gas turbine 2 and a steam turbine 4 as well as a waste-heat steam generator 6, through which the hot exhaust gas AG from the gas turbine 2 flows. The steam turbine 4 comprises a high-pressure part 4a and a medium-pressure part 4b as well as a low-pressure part 4c. The waste-heat steam generator 6 serves for steam generation, its heating surfaces being connected into a water/steam circuit 8 of the steam turbine 4.

For this purpose, the waste-heat steam generator 6 has a condensate preheater 12 which is connected to a condensate conduit 10 and which is connected on the inlet side, via a condensate pump 14, to a condenser 16 located downstream of the steam turbine 4. The condensate preheater 12 is connected on the outlet side to its inlet via a circulating pump 18. Moreover, on the outlet side, the condensate preheater 12 is connected to a feed-water

tank 22 via a feed conduit 20.

The feed-water tank 22 is connected on the outlet side to a low-pressure drum 28 via a feed-water conduit 24, into which a pump 26 is connected. An evaporator is connected to the low-pressure drum 28 via a circulating pump 30. The low-pressure drum 28 is connected on the steam side to a low-pressure superheater 34 which is connected via a steam conduit 36 to an overflow conduit 38 from the medium-pressure part 4b to the low-pressure part 4c of the steam turbine 4. The low-pressure drum 28 and the low-pressure evaporator 32 form, together with the low-pressure superheater 34 and the low-pressure part 4c, a low-pressure stage of the water/steam circuit 8.

Moreover, the feed-water tank 22 is connected on the outlet side, via a feed-water conduit 40, into which a pump 42 is connected, to a first high-pressure preheater 44 which is connected via a connecting conduit 46 to the inlet of a second high-pressure preheater 48. Connected via a conduit 50 to the connecting conduit 46 is a medium-pressure drum 52, to which a medium-pressure evaporator 56 is connected, in turn, via a circulating pump 54. The medium-pressure drum 52 is connected on the steam side to a medium-pressure superheater 56 which is connected on the outlet side to the inlet of an intermediate superheater 58. The intermediate superheater 58 is connected on the inlet side to the high-pressure part 4a and on the outlet side to the medium-pressure part 4b of the steam turbine 4. The medium-pressure drum 52 and the medium-pressure evaporator 56 as well as the medium-pressure superheater 57 form, together with the intermediate superheater 58 and the medium-pressure part 4b of the steam turbine 4, a medium-pressure stage of the water/steam circuit 8.

The second high-pressure preheater 48 is connected on the outlet side, via a connecting conduit 60 and a valve 62, to a high-pressure drum 64, to which a high-pressure evaporator 68 is connected via a circulating pump 66. The high-pressure drum

64 is connected on the steam side, via a high-pressure superheater 70, to the high-pressure part 4a of the steam turbine 4. The high-pressure preheaters 44, 48 and the high-pressure drum 64 as well as the high-pressure evaporator 68 and the high-pressure superheater 70 form, together with the high-pressure part 4a of the steam turbine 4, a high-pressure stage of the water/steam circuit 8.

The secondary side of a heat exchanger 72 is connected into the overflow conduit 38 between the medium-pressure part 4b and the low-pressure part 4c of the steam turbine 4. On the primary side, the heat exchanger 72 is connected on the inlet side, via a conduit 74, to the conduit 60 and is thus connected to the outlet of the second high-pressure preheater 48. The primary-side outlet of the heat exchanger 72 is connected to the inlet of the second high-pressure preheater 48 via a conduit 76, into which a pump 78 and a regulating valve 80 are connected. In this case, the conduit 76 opens at a mixing point 82 into the conduit 46 connecting the two high-pressure preheaters 44 and 48.

When the gas-turbine and steam-turbine plant is in operation, condenser [sic] K from the condenser 16 is supplied to the condensate preheater 12 via the pump 14 and the condensate conduit 10. In this case, the condensate preheater 12 may be bypassed completely or partially. The condensate K is heated in the condensate preheater 12 and, for this purpose, is circulated at least partially via the circulating pump 18. The heated condensate K is guided via the conduit 20 into the feedwater tank 22, a heating of the feed water taking place there by means of bled steam from the steam turbine 4 in a way not shown in more detail. The heated feed water S is supplied, on the one hand, to the low-pressure drum 28 and, on the other hand, via the first high-pressure preheater 44 to the medium-pressure drum 52 and via the second high-pressure preheater 48 to the high-pressure drum 64. The feed water S supplied to the low-pressure stage is evaporated at low pressure in the low-pressure

evaporator 32, the low-pressure steam ND separated in the low-pressure drum 28 being

supplied to the low-pressure superheater 34. The low-pressure steam ND superheated there is guided into the overflow conduit 38 upstream of the heat exchanger 72.

The feed water S guided into the medium-pressure drum 52 is likewise evaporated in the medium-pressure evaporator 56. The steam, which is separated in the medium-pressure drum 52 and which is under medium pressure, is guided via the medium-pressure superheater 57 and is supplied as superheated medium-pressure steam MD to the medium-pressure part 4b of the steam turbine 4. In a similar way, the feed water S preheated in the second high-pressure preheater or high-pressure economizer 48 is evaporated under high pressure in the high-pressure evaporator 68, the high-pressure steam HD separated in the high-pressure drum 64 being superheated in the high-pressure superheater 70 and being guided in the superheated state into the high-pressure part 4a of the steam turbine 4. The steam expanded in the high-pressure part 4a is superheated once more in the intermediate superheater 58 and is supplied in the superheated state, together with the medium-pressure steam MD superheated in the medium-pressure superheater 56, to the medium-pressure part 4b of the steam turbine 4.

The steam, which is expanded in the medium-pressure part 4b of the steam turbine 4 and which is under low pressure, is guided via the overflow conduit 38 and is superheated in the heat exchanger 72 by indirect heat exchange with a part stream t_s of the feed water S preheated in the high-pressure preheater 48, the said part stream being guided via the conduit 74. At the same time, the low-pressure steam ND superheated in the low-pressure superheater 34 is admixed, upstream of the heat exchanger 72, with the steam flowing off from the medium-pressure part 4b. The low-pressure steam ND superheated in the heat exchanger 72 is expanded in the low-pressure part 4c of the steam turbine 4 and is supplied to the condenser 16 for condensation.

The quantity of the part stream t_s, supplied per unit time to the heat exchanger 72, of the feed water S

preheated in the second high-pressure preheater 48 is adjusted by means of the regulating valve 80. In this case, adjustment is carried out in such a way that the

temperature T_1 of the part stream t_s and the temperature T_2 of the feed water S to be preheated are approximated to one another, preferably equal to one another, at the mixing point 82. For this purpose, a controller module 84 is connected to the regulating valve 80 via a control line 85. Moreover, for this purpose, the controller module 84 is connected via a control line 86 to a first temperature sensor 87 for recording the temperature T_1 and via a control line 88 to a second temperature sensor 89 for recording the temperature T_2.

By connecting the heat exchanger 72 into the overflow conduit 38 for superheating the low-pressure steam ND by means of the part stream t_s extracted from the high-pressure preheater 48, the terminal output capable of being extracted at a steam-turbine generator (not shown) is increased by 1.3% to 2%. If the entire low-pressure steam quantity is superheated correspondingly in a two-pressure process, the increase thus achieved in the steam-turbine power is more than 2.6%.



Patent Claims

1. Gas-turbine and steam-turbine plant with a waste-heat steam generator (6) which is located downstream of the gas turbine (2) on the exhaust-gas side and the high-pressure preheater (48) of which is connected into the water/steam circuit (8) of the steam turbine (4) having a low-pressure part (4c), characterized by a heat exchanger (72) which is arranged outside the waste-heat steam generator (6) and of which the primary-side inlet is connected to the outlet of the high-pressure preheater (48) and of which the primary-side outlet is connected to the inlet of the high-pressure preheater (48) and which is connected on the secondary side into an overflow conduit (38) opening into the low-pressure part (4c) of the steam turbine (4).

2. Plant according to Claim 1, characterized in that a circulating pump (78) and a regulating valve (80) are located downstream of the heat exchanger (72) on the primary side.

3. Plant according to Claim 1 or 2, characterized by a controller module (84) for adjusting the quantity of feed water (t_s) supplied per unit time to the heat exchanger (72) on the primary side.

4. Plant according to Claim 3, characterized by a first temperature sensor (87), connected to the controller module (84), for recording the temperature (T_1) of the feed water (t_s) flowing off from the heat exchanger (72) on the secondary side and by a second temperature sensor (89), connected to the controller module (84), for recording the temperature (T_2) of the feed water (S) supplied to the high-pressure preheater (48).

5. Plant according to one of Claims 1 to 4, characterized in that the high-pressure preheater (48) is a second high-pressure preheater which is located downstream of a first high-pressure preheater

(44) on the feed-water side and which is arranged upstream of the first high-pressure preheater (44) in the waste-heat steam generator (6) on the exhaust-gas side.

6. Plant according to one of Claims 1 to 5, characterized by a low-pressure superheater (34) which is arranged in the waste-heat steam generator (6) and which is connected on the outlet side to the secondary-side inlet of the heat exchanger (72).

7. Method for operating a gas-turbine and steam-turbine plant, in which heat contained in the expanded working medium (AG) from the gas turbine (2) is utilized for generating steam for the steam turbine (4) connected into a water/steam circuit (8) composed of at least two pressure stages, feed water (S) which flows in the water/steam circuit (8) being preheated in a high-pressure preheater (48) arranged in the waste-heat steam generator (6), characterized in that low-pressure steam (ND) flowing into the steam turbine (4) is superheated as a result of indirect heat exchange with a part stream (t_s) of preheated feed water (S), the said part stream being extracted from the high-pressure preheater (48).

8. Method according to Claim 7, characterized in that the cooled part stream (t_s) is admixed with the feed water (S) to be preheated, the temperature (T_1) of the part stream (t_s) and the temperature (T_2) of the feed water (S) to be preheated being approximated to one another.

9. Method according to Claim 8, characterized in that the temperature approximation is carried out by adjusting the part stream (t_s).

10. Method according to one of Claims 7 to 9, with a water/steam circuit (8) composed of three pressure stages, characterized in that low-pressure steam (ND) superheated in the waste-heat steam generator (6) is admixed with the low-pressure steam (ND) to be superheated by indirect heat exchange.