

METHOD FOR OPERATING A POWER PLANT

TECHNICAL FIELD

The present invention relates to a method for
5 operating a power plant. In particular in the following
reference to combined power plants is made.

BACKGROUND

Traditionally, power plants such as combined power
10 plants (i.e. power plants including gas and steam turbines)
produce the base electric power that is supplied to the
grid.

With the deregulation of the energy market, increased
fuel prices and diffusion of renewable energies, combined
15 power plants are more and more used to comply with peak
power requests.

In order to comply with peak power requests, combined
power plants are required to adapt their operation (in
particular the power supplied to the grid) very fast; in
20 other words they must be able to operate with great
flexibility. For example, when the energy required by the
grid is low they must be able to reduce the power supplied
to the grid up to zero and when the grid requires power
again they must be able to provide it very quickly (in some
25 cases they must be able to provide tens of megawatt in
seconds).

EP 2 056 421 discloses a method to connect a combined power plant (with gas turbine and steam turbine) to a grid; this method includes the following steps:

- in a first step the gas turbine has full speed but
5 does not supply any power to the grid (in addition the breaker is open). During this step the steam turbine loads up;
- in a second step the breaker is closed. During this step the steam turbine further loads up;
- 10 - in a third step the power plant energises the grid. Also during this step the steam turbine loads up;
- in a fourth step the power plant supplies power to the grid. During this step the steam turbine further loads up.

15 It is thus apparent that during the first through fourth steps the steam turbine does not supply any power to the grid, namely the steam turbine is in a transient, loading up operation.

For this reason the method above could have some
20 drawbacks.

In fact, when the steam turbine is in transient operation, it is not able to supply any power to the grid; the power plant could thus not be able to satisfy a sudden power request from the grid. For example, in some cases
25 sudden power requests from the grid can be so large as 50 MW/s or more.

SUMMARY

An aspect of the present invention is thus to provide a method by which a combined power plant is able to comply
5 with large, sudden power requests from the grid.

This and further aspects are attained according to the invention by providing methods in accordance with the accompanying claims.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will be more apparent from the description of a preferred but non-exclusive embodiment of the method, illustrated by way of non-limiting example in the
15 accompanying drawings, in which:

Figures 1 and 2 are schematic views of combined power plants that can be used to implement the method;

Figures 3 and 4 show two embodiments of the method;

Figures 5 and 6 show embodiments of a start up of the
20 power plant, to bring it to a condition in which it is connected to the grid (with either breaker open or not) but without supplying any power to it; and

Figures 7 and 8 show embodiments of unload of the power plant, to bring it to a condition in which it is
25 connected to the grid (with either breaker open or not) but without supplying any power to it.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The method can be implemented in a power plant schematically described in figure 1.

5 The power plant 1 includes a gas turbine 2 having a compressor 3, a combustion chamber 4 and a turbine 5. The combustion chamber 4 is fed with fuel 6 and oxidiser 7 (usually air compressed in the compressor 3); fuel 6 and oxidiser 7 are combusted to generate hot gases that are
10 expanded in the turbine 5 to gather mechanical power.

 The turbine 5 discharges exhaust flue gases 8 that are then supplied to a steam power generation system 10; the steam power generation system 10 has a boiler 11 (also called Heat Recovery Steam Generator HRSG) that receives
15 the flue gases 8 from the gas turbine 2 and produces steam that is expanded in a steam turbine 12. As usual, also a condenser 13 and a pump 14 are provided.

 The gas turbine 2 and steam power generation system 10 activate an electric generator 20 connected to an electric
20 grid 21 via line 22.

 Figure 2 shows an example of a different power plant; in this figure same numbers indicate same or similar components to those already described.

 In the power plant of figure 2 each of the gas turbine
25 2 and steam power generation system 10 activates one electric generator 20a, 20b; the generators 20a and 20b are

in turn connected to the electric grid 21 via the lines 22 and are connected with each other via a line 23.

Other different schemes are anyhow possible.

The method for operating a power plant is described
5 with reference to figure 1 and 3.

According to the method, in a steady operation of the power plant 1 the gas turbine 2 generates a first output power 30 greater than zero, the steam power generation system 10 generates a second output power 31 greater than
10 zero, and the total generated power 32 (the total generated power 32 being the sum of the first and second output power 30, 31) is substantially equal to a house load 33 of the power plant 1.

The house load 33 corresponds to that power that must
15 be provided to or produced by the power plant 1 to supply the auxiliaries and for its internal use. Thus, when operating at the house load 33, the power plant produces power for its internal use but it is not able to substantially supply any power to the grid 21. In this
20 respect, reference 32 indicates that the power supplied to the grid is zero.

Preferably, during this operation at steady state the electric generator 20 is connected to the grid 21 (i.e. the breaker is closed); therefore the generator 20 energises
25 the grid 21 but does not provide any power to it. Alternatively the electric generator 20 can also be not

connected to the grid 21 (i.e. the breaker is open).

In the example shown in figure 3 the output power 31 is almost twice as large as the output power 30; it is anyhow clear that this is only one of the numerous possibilities and in general the output power 30 and 31 can be equal or different.

In a different example (figure 4), the gas turbine 2 can produce a negative power or, in other words, can require power to operate (mainly to operate the compressor); in this case the power needed for the gas turbine operation is provided by the steam power generation system 10.

In this respect figure 4 shows that the steam power generation system 10 generates an output power 31 larger than the house load 33 and the gas turbine 2 requires power (because the output power 30 is negative). Since the positive output power 31 compensate for the negative output power 30, the total generated power 32 (that is supplied to the grid 21) is zero.

When operating under these conditions, the power plant 1 is ready to provide large power to the grid 21 in very short time periods, because both the gas turbine 2 and the steam power generation system 10 are already in working conditions (either connected to the grid 21 or not). In addition these conditions can be maintained for long periods, such that the power plant 1 can be continuously

connected to the grid without providing any power to the grid, to only provide power to the grid when requested. The power plant 1 can thus operate to comply with peak power requests for example together with renewable power plants.

5 The steady operation described above can be reached from a switched off condition (thus the power plant must be started up) or from a normal operation during which the power plant supply electric power to the grid 21 (thus the power plant must be unloaded).

10

START UP

The start up is described with reference to figure 5, that shows the output power 30 of the gas turbine 2, the output power 31 of the steam power generation system 10 and
15 the total generated power 32 (equal to the sum of the output power 30 and 31).

In order to start up the power plant 1 the gas turbine 2 is started up and loaded up in a step 45 up to the house load 33 and is then maintained at the house load 33 (step
20 46).

In addition, during the step 46 the steam power generation system 10 is started up (i.e. it is accelerated up to the synchronism speed) and is then loaded up in a step 47; in these conditions the steam power generation
25 system 10 generates a second output power 31 greater than zero.

While the steam power generation system 10 is loaded up (i.e. during the step 47) the output power 30 of the gas turbine 2 is decreased.

5 The total generated power 32 (being the sum of the first and second output power 30, 31) is substantially equal to the house load 33 of the power plant 1.

Figure 6 shows an additional example in which during the step 47 the gas turbine output power 30 is reduced down to below zero, i.e. the gas turbine 2 requires power to
10 operate; as already explained, in this case the power required by the gas turbine 2 can be provided by the steam power generation system 10 that can generate an output power 31 greater than the house load 33, such that the power 31 compensates for the power 30 and the total
15 generated power 32 is substantially zero.

The plant 1 is then maintained in a steady operation with the total generated power 32 substantially equal to the house load 33 (i.e. no power is supplied to the grid 21).

20 Advantageously, the electric generator 20 is connected to the grid 21; in this condition, since the power plant 1 only produces a power equal to the house load 33, the power plant 1 does not provide any power to the grid 21.

25 Within the boiler 11 steam is generated that is then expanded in the steam turbine 12; in addition the turbine 12 has a stator 12a and a rotor 12b. Preferably while the

output power 30 of the gas turbine 2 is decreased during step 47, the gas turbine 2 is regulated to get a steam minimum temperature compatible with the rotor 12b. In other words, since the steam exchanges heat with the rotor 12b the steam temperature cannot be too different from the temperature of the same rotor 12b, because it can cause high stress. For this reason the temperature of the steam should preferably be close to the temperature of the rotor 12b.

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UNLOAD

The reduction of output power to bring a power plant 1 from a condition in which it supplies power to the grid 21 to a condition in which it is connected to the grid 21 but does not supply any power to it is described with reference to figure 7.

Figure 7 shows the first output power 30 of the gas turbine 2, the second output power 31 of the steam power generation system 10, the total generated power 32 (corresponding to the power supplied to the grid 21) and the house load 33.

Starting from a steady operation 54 with the power plant 1 that supplies power to the grid 21, the method comprises a step 55 of decreasing the first output power 30 of the gas turbine 2. In a preferred embodiment of the method, the first output power is decreased up to achieve a

minimum steam temperature compatible with the rotor 12b.

During this phase the second output power 31 of steam power generation system 10 is also reduced due to the less heat provided by the gas turbine exhaust gases to the boiler 11 that causes less steam generation in the boiler 11.

Then, in a step 56, the second output power 31 of the steam power generation system 10 is decreased to a stable operation (while the first output power 30 of the gas turbine 2 is maintained substantially constant) and in a subsequent step 57 the first output power 30 of the gas turbine 2 is further decreased, such that the total generated power 32, i.e. the sum of the first and second output power 30, 31 produced by the gas turbine 2 and steam power generation system 10 is substantially equal to the house load 33 of the power plant 1.

Figure 7 shows an example in which both the gas turbine 2 and the steam power generation system 10 generate a positive first power output 30 and second power output 31.

Figure 8 shows an example in which the output power 30 of the gas turbine 2 is reduced up to below zero. In this case the gas turbine 2 requires power to operate, this power is supplied by the steam power generation system 10.

Thus the power plant is maintained in a steady operation (step 58), with the total generated power 32

substantially equal to a house load 33 of the power plant 1.

The power plant 1 of figure 1 has the turbine 5, steam turbine 12 and generator 20 connected through one single shaft. It is apparent that the same method can also be implemented with a power plant 1 having more than one shaft, such as for example the power plant of figure 2.

In this case the gas turbine 2 (or each gas turbine 2 if more than one gas turbine is provided) and the steam power generation system 10 (or each steam power generation system 10 if more of them are provided) are connected to generators 20a, 20b that are connected to the grid 21. The power transfer from the steam power generation system 10 to the gas turbine 2 (when this is needed) can occur via the grid 21. In other words the steam power generation system 10 can provide power to the grid 21 and the gas turbine 2 can adsorb power from the grid 21 (its generator 20b works as a motor) such that the total generated power (that is supplied to the grid 21 and being the difference between the power supplied by the steam power generation system 10 and the power adsorbed by the gas turbine 2) is zero.

In addition or alternatively the power can be transferred directly between the generators 20a, 20b via the line 23.

Additionally, it is also possible disconnecting the power plant 1 from the grid 21.

Naturally the features described may be independently provided from one another.

In practice materials and dimensions can be chosen at will according to requirements and to the state of the art.

REFERENCE NUMBERS

- 1 power plant
- 2 gas turbine
- 3 compressor
- 5 4 combustion chamber
- 5 turbine
- 6 fuel
- 7 oxidiser
- 8 flue gases
- 10 10 steam power generation system
- 11 boiler
- 12 turbine
- 12a stator
- 12b rotor
- 15 13 condenser
- 14 pump
- 20, 20a, 20b electric generator
- 21 grid
- 22 line
- 20 23 line
- 30 (30a) first output power from 2
- 31 (31a) second output power from 12
- 32 total generated power (30+31)
- 33 house load
- 25 45, 46, 47, steps
- 54, 55, 56, 57 steps

t time

CLAIMS

1. Method for operating a power plant (1) comprising a gas turbine (2) and a steam power generation system (10) that activate at least one electric generator (20), wherein the gas turbine (2) produces flue gases (8) that are supplied into a boiler (11) of the steam power generation system (10), characterised in that in a steady operation the gas turbine (2) generates a first output power (30) greater or less than zero, the steam power generation system (10) generates a second output power (31) greater than zero, and the total generated power (32) being the sum of the first and second output power (30, 31) is substantially equal to a house load (33) of the power plant (1).
2. Method according to claim 1, characterised in that the steam power generation system (10) generates a second output power (31) larger than the house load (33), and in that the power generated by the steam power generation system (10) in excess of the house load (33) is used to drive the gas turbine (2).
3. Method according to claim 1, characterised in that the electric generator (20) is connected to a grid (21).
4. Method for starting up a power plant (1) comprising a gas turbine (2) and a steam power generation system (10) that activate at least one electric generator

(20), wherein the gas turbine (2) produces flue gases (8) that are supplied into a boiler (11) of the steam power generation system (10), characterised by:

- 5 - starting up and loading up the gas turbine (2) for it to generate a first output power (30) greater than zero and substantially equal to house load, then
- 10 - starting up and loading up the steam power generation system (10) for it to generate a second output power (31) greater than zero,
- 15 - while the steam power generation system (10) is loaded up, decreasing the first output power (30) while the total generated power (32) being the sum of the first and second output power (30, 31) is substantially equal to a house load (33) of the power plant (1), then
- 20 - maintaining the power plant (1) in a steady operation with the total generated power (32) substantially equal to a house load (33) of the power plant (1).

5. Method according to claim 4, characterised by connecting the electric generator (20) to a grid (21).

6. Method according to claim 4, characterised in that:

- 25 - within the boiler (11) steam is generated that is then expanded in one or more turbines (12) of the

steam power generation system (10),

- the turbine (12) has a stator (12a) and a rotor (12b),

- while decreasing the first output power (30), the gas turbine (2) is regulated to get a steam minimum temperature compatible with the rotor (12b).

7. Method for reducing the power of power plant (1) comprising a gas turbine (2) and a steam power generation system (10) that activate at least one electric generator (20), wherein the gas turbine (2) produces flue gases (8) that are supplied into a boiler (11) of the steam power generation system (10), wherein within the boiler (11) steam is generated that is then expanded in a turbine (12) of the steam power generation system (10), and wherein the turbine (12) has a stator (12a) and a rotor (12b), the method comprising:

- decreasing a first output power (30) of the gas turbine (2), then

- decreasing a second output power (31) of the steam power generation system (10), then

- further decreasing the first output power (30) of the gas turbine (2), such that the total generated power (32) being sum of the first and second output power (30, 31) is substantially equal to a house load (33) of the power plant (1), then

- maintaining the power plant (1) in a steady operation with the total generated power (32) substantially equal to a house load (33) of the power plant (1).

5 8. Method according to claim 7, characterised in that during the first decreasing of the first output power (30), the first output power (30) is decreased up to achieve a minimum steam temperature compatible with the rotor (12b).

10 9. Method according to claim 7, characterised by the disconnecting the power plant (1) from the grid (21).