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(54) Power plant and method of operating a power plant

(57) A fossil fuel fired power plant (PP) can provide an improved dynamic response by means of condensate stop and optionally with indirect firing. The power plant (PP) having a water steam cycle comprises six condensate preheaters (21-26) arranged in series for the preheating by heat exchange with steam extracted from the steam turbines (7-10). Steam extraction lines (23'-26') have a quick-action valve (23"-26") able to stop the extraction steam flow, whereby the additional steam flowing through the turbines enables a large load increase up to 10% within a short time of 10 seconds. In case of a coal-fired power plant (PP), the power plant (PP) comprises a supply silo (45) for pulverized coal that enables a quick increase in supply rate of coal to the boiler (1) and of the firing rate. This allows the load increase to be maintained over a longer time period.

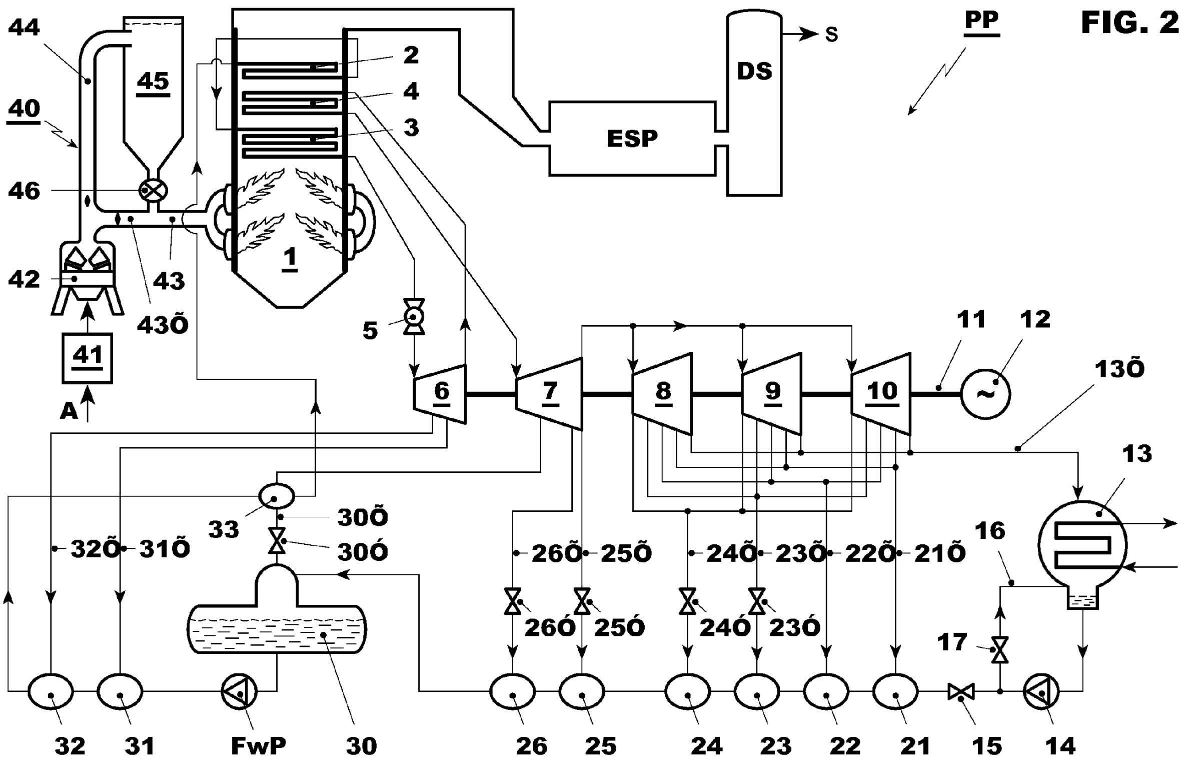

FIG. 2

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Description

Technical Field

[0001] The present invention pertains to a power plant comprising a steam production unit, a steam turbine and water steam cycle, and in particular to a power plant of this type that is designed for dynamic response. The invention pertains furthermore to a method of operating such power plant.

Background Art

[0002] Power plants are operated and regulated such that they can provide power corresponding to the demand in electrical energy in the grid. Variations in the magnitude of the demand can occur for example when a large user is added or stopped, a large electricity producer trips, or a transmission line fails due to overload, disruption, or short circuit. Large variations in demand or supply of electricity typically result in a variation of the AC-frequency. In order to compensate for this frequency variation, power plants are designed to provide a dynamic response, which is the ability to respond to changes in the demand of electrical energy upon detection of the frequency variations and maintain a balance between the electrical energy drawn and electrical energy provided.

[0003] Variations in the energy drawn from the grid can be both large in magnitude as well as rapid, that is within a time span as short as a few seconds. They can occur when a number of large users alter their demand or other providers connected to the same grid decrease or stop their service. A dynamic response must be able to react to frequency changes by providing a load change of the power plants still connected to the grid within a short time.

[0004] In several countries grid codes are established by requiring that power plants be able to generate a minimum load response within a certain time frame when rapid frequency variations occur.

Such grid code is given for example for the national grid in Great Britain. As documented in "The Grid Code", Issue 4, by the National Grid Electricity Transmission plc, it requires that a power plant operating between 65 and 90% of its nominal power be able to increase the power generated by 10% of its nominal power within 10 seconds. However, many power plants cannot fulfill such requirements because their system reaction times are too long and/or their load changes are too small in amplitude.

[0005] Several methods providing frequency response by means of load changes are conventionally known.

For example, the live steam injected into the turbines is regulated by means of valves in the high-pressure steam inlet together with a control wheel. This method allows partial steam injection enabling optimization of plant efficiency during part-load operation. It has proven successful up to certain power levels of the power plant. Above these power levels control wheels are no longer reliable. Power plants of greater power require a larger control wheel. However, the length of the blades of a control wheel is limited due to fatigue stresses, which can occur at super critical pressures.

In further methods the steam flow through the turbines is increased thereby providing a load increase.

In a first method, opening a high-pressure throttle valve increases the live steam flow entering the high-pressure turbine. However, the steam flow characteristics at the intermediate-pressure stage, i.e. the temperature and pressure, adjust only after a full minute following the opening of the high-pressure throttle. Large load changes can therefore not be accommodated by this method within a short time.

[0006] In another method, frequently referred to as condensate stop, a steam extraction from the steam turbines is stopped and the condensate flow extracted by the condensate pump is recirculated back to the condensate well. By this measure, the total amount of steam passing through the steam turbines is immediately increased and the power output of the generator is increased proportionally. The recirculation of the condensate flow and therefore shutdown of the condensate flow through the condensate preheaters prevents a drop in the temperature of the feedwater in the feedwater tank. The temperature at the boiler inlet is therefore maintained. A condensate stop can be maintained as long as the level in the feedwater tank remains above a critical level necessary to prevent a tripping of the boiler.

Condensate stop is an effective method to generate a load jump. However, known condensate stop in power plants operating today is effective only over a short time period, that is on the order of a few minutes. This is due to the diminished steam extraction resulting in a drop in the feedwater tank level and an increase in condensate level in the condenser well. A condensate stop can only be maintained until certain critical levels are reached in the feedwater tank and condenser well.

Presently operating power plants equipped for a condensate stop have several preheaters for the preheating of condensate and feedwater, where the feedwater tank is arranged following five condensate preheaters in series and prior to three feedwater preheaters. Such power plants are able to provide a load jump by means of a condensate stop of up to 7% load increase and are able to maintain the increased power output for 6-8 minutes. Such power plant design is based on thermodynamic and cost considerations, in particular the cost of fabrication and mounting of the feedwater tank. The design is furthermore based on considerations of the grid code requirements at the time of their construction.

[0007] DE 4344118 discloses a method of operating a power plant including condensate stop together with a control of the power reserve in order provide a primary frequency response.

[0008] In a further method, as disclosed for example EP1368555, the amount of high-pressure steam extracted for the preheating of feedwater is reduced or shut-off and a load increase is effected by the resulting increase of the high-pressure steam flowing through the high-pressure turbine.

[0009] A high-pressure preheater bypass can cause a drop in the feedwater temperature, which in turn can cause thermal stresses in the boiler. A change in the feedwater temperature can be avoided by slow regulation of the throttle, which however causes the whole system to react only very slowly causing dead times until the frequency response takes effect. The method is therefore suitable for slow frequency response only taking effect after many minutes.

[0010] A further method to provide a load jump is additional direct firing in the boiler itself. This can be done quickly when fossil fuels such as oil or gas are used. For coal fired power plants, additionally direct firing is not suitable to generate a rapid load jump because coal milling facilities provide pulverized coal of given coal particle sizes only at a slow rate. Furthermore, coal mills can vary their milling speed only at a slow rate.

Summary of Invention

[0011] In view of the described background art it is an object of the invention to provide a power plant comprising a boiler and steam turbines with a water steam cycle designed to enable a high degree of dynamic response, that is to enable a rapid response to frequency variations in the grid by an appropriate load response.

[0012] It is a further object of the invention to provide a method of operating such power plant with a boiler, steam turbines, and water steam cycle enabling a rapid frequency response.

[0013] A fossil fuel fired power plant having a water steam cycle comprises a boiler, one or more steam turbines, and low- and intermediate-pressure preheaters arranged in series for the preheating of condensate from the steam turbine condenser by means of steam extracted from the steam turbines. According to the invention, six preheaters for the preheating of condensate are arranged in series following a condensate extraction pump, where lines for directing the steam extracted from the steam turbines to the preheaters are configured with quick-action valves.

[0014] The preheaters are operatable by means of heat exchange with low- and intermediate-pressure steam extracted from low- and intermediate-pressure stages of the one or more steam turbines. All of the steam extraction lines or less than six of the steam extraction lines to the preheaters are configured with valves allowing quick closure of the steam flow when a condensate stop is to be activated.

[0015] In particular, at least four steam extraction lines lead from the low- and intermediate-pressure turbine stages to two intermediate-pressure preheaters and to two low-pressure preheaters, which are arranged prior to the intermediate-pressure preheaters. Each of these four extraction lines is configured with a quick-acting valve. In case of a frequency variation, a condensate stop can be activated by closure of the quick-acting valves and stoppage of the extraction steam flow leading to the preheaters. By this measure a greater steam flow is available to drive the steam turbines enabling an immediate and large load increase.

[0016] In order to stop the flow of the condensate through the preheaters, the power plant comprises a stop valve in the condensate extraction line leading away from the condensate extraction pump and a line for recirculating the condensate extracted from the condenser by a condensate extraction pump back into the condenser well. When the extraction steam lines to the preheaters are closed, the preheaters no longer provide preheating of the condensate. If condensate from the condenser well continued to flow through the preheaters, the temperature of the feedwater would gradually drop. The power plant according to the invention allows a stoppage of the condensate flow through the preheaters and an opening of the condensate recirculation line from the condensate extraction pump to the condenser well. Thereby the load increase operation by means of condensate stop has no effect on the feedwater temperature in the boiler feedwater tank, and a drop in temperature of the water to the boiler is avoided.

[0017] Compared to conventional power plants, this power plant has increased load jump capacity due to a condensate stop operation. Due to the large number of low- and intermediate-pressure preheaters and associated steam extraction lines, the power plant has an increased extraction steam flow. When this is closed off during a condensate stop operation, the extraction steam flow is stopped within a very short time. Instead, it flows through the steam turbines and effects a load increase. In other words, the power plant according to the invention has an increased steam reserve available when a frequency variation occurs and the condensate stop is activated. Consequently, a greater load jump can be realized. Compared to conventional power plants, the percentage increase in power output due to condensate stop can be increased in a power plant according to the invention, for example from a 6.5% to about 10% increase in power output.

[0018] In a particular embodiment of the power plant, two high-pressure heaters are arranged in series following the feedwater tank and configured for the preheating of feedwater by means of steam extracted from a high-pressure steam turbine.

[0019] Due to the greater number of low- or intermediate-pressure preheaters for the preheating of condensate, the number of high-pressure preheaters for the preheating of the feedwater following the feedwater tank can be reduced to two. This power plant can be realized with greater cost efficiency compared to a power plant with three high-pressure preheaters.

[0020] In an embodiment of the power plant, four or more extraction lines lead from the intermediate-pressure turbine stages and from the low-pressure turbine stages to the preheaters, where the low-pressure turbine stages are the turbine stages immediately following the intermediate-pressure turbine stages. Two more steam extraction lines lead from the low-pressure turbine stages of the lowest pressure level in the turbine train to the first low-pressure preheaters in the series of condensate preheaters.

In a first variant, the two steam extraction lines extend from the condenser neck of the steam turbine condenser. They can be configured without quick-acting valves. In a further variant, the two steam extraction lines extend from the low-pressure steam turbines. One or both lines can be configured with a quick-action valve.

[0021] In a further embodiment, the power plant comprises additionally a steam extraction line leading from an intermediate-pressure turbine stage to the feedwater tank, where this extraction line is configured with a quick-acting valve. This can be closed in case of a condensate stop operation.

[0022] The power plant configuration according to the present invention may be applied to any power plant with a boiler that is fired by any fossil fuel such as coal, oil, gas, biomass, etc.

[0023] In a particular embodiment of the invention the power plant is a coal-fired power plant and comprises a combination of features enabling an improved dynamic response. The coal-fired power plant is configured as described above to enable a large and fast load jump by means of condensate stop. Additionally, this power plant having a boiler with coal milling facilities, where at least one of the facilities comprises a coal supply container for receiving, storing, and dispensing a supply of pulverized coal that is already milled and pulverized to a given particle size and ready for combustion.

This power plant with supply container of pulverized coal allows an improved dynamic response of the power plant in that the firing rate in the boiler can be rapidly adjusted. Thus a rapidly increased load level can be maintained over a long period of time, for example up to 30 minutes or more. Such time period for maintaining an increased load level is significantly longer than presently possible with power plants of the state of the art.

A condensate stop activated by means of closing the extraction lines to the low-pressure preheaters can be maintained for a period of time of several minutes. After a certain time, the level of feedwater in the feedwater tank drops while the level in the condensate well rises.

The supply container of pulverized coal, which can be in the shape of a silo for example, provides a buffer source of coal ready for combustion such that the supply rate of coal to the boiler and thus also the firing rate of the boiler can be rapidly increased. In coal-fired boilers of the prior art, the supply rate is limited by the milling speed of the coal mill. A buffer silo of already pulverized coal on the other hand, allows a higher rate of providing coal to the boiler for combustion.

[0024] In the case of condensate stop, the supply container of coal allows a rapid adjustment of the firing rate in the boiler and of the boiler steam production. The rapidly adjusted firing rate can thereby support a load jump effected by a condensate stop.

Furthermore, the consumption of the feedwater from the tank can be adjusted and the water level in the feedwater tank can be maintained at a suitable level for a longer period of time. A drop of the feedwater level below a critical level, which could trip the boiler, can be avoided.

[0025] As soon as steam production begins to increase as a result of increased firing rate in the boiler, the valves in the steam extraction lines used for condensate stop are slowly opened again. Concurrently, the recirculation line for directing the condensate back into the condenser well is closed. Thus, feedwater is again slowly supplied to the feedwater tank, the level in the condenser well will slowly decrease and the level in the feedwater tank will increase.

[0026] Another possibility of maintaining a minimum level in the feedwater tank during condensate stop would be to provide a larger feedwater tank as well as a larger condensate well. With the arrangement of the preheaters according to the invention together with the buffer coal supply this is not necessary. The feedwater tank as well as condensate well can be maintained with present volumes and wall thicknesses, which further supports cost efficiency of the power plant.

[0027] The power plant according to the invention has particular advantages in the case that it provides electrical energy to a grid, which is connected to a variety of renewable electrical energy sources such as wind, solar, tidal etc. These energy sources are non-permanent energy sources, which means they provide energy depending on the weather conditions as well as day or night and rapid and large changes in the amount of energy provided can occur. Such changes can be compensated by the increased dynamic response of a power plant as presented, and a grid provided by such power plant can reach greater stability.

[0028] The implementation of a buffer silo for pulverized coal allows an indirect coal-firing of the boiler, that is a firing of the boiler using pre-milled and pulverized coal, as opposed to a direct coal-firing by means of coal that is pulverized in the mill and immediately supplied to the boiler. In a further specific embodiment of the power plant, the power plant comprises a buffer silo of pulverized coal for some of its coal mills, for example half of the coal mills, while the other coal mills are operatable by conventional supply only. Such arrangement allows a partial indirect firing, i.e. an indirect firing for some of the boiler units only, which enables sufficient dynamic response of the power plant, but where the cost for the silos is kept at a minimum.

[0029] A method to operate a fossil fuel fired power plant as presented according to the invention comprises at the occurrence of a frequency variation in the grid, activating a condensate stop process by closing quick-action valves in lines leading from extraction points at low- and intermediate-pressure steam turbine stages to low- and intermediate-pressure preheaters.

[0030] A particular method further comprises closing a quick-action valve in a line from the condensate extraction pump to the preheaters and opening a recirculation line from the condensate extraction pump to the condenser well of the steam turbine condenser.

[0031] In a further method to operate the power plant presented, a condensate stop is activated and, in addition, pulverized coal ready for combustion from a coal supply container is fed to the boiler.

As soon as steam production begins to increase as a result of increased pulverized coal supply to the boiler, valves in the steam extraction lines to the condensate preheaters are opened.

[0032] In a further method to operate the power plant, in addition to activating the condensate stop and the indirect firing, a high-pressure throttle valve for the regulation of the live-steam flow to the steam turbines is operated. This high-pressure throttling allows supplementing and completing a load increase in case of a frequency variation in the grid by regulation or fine-tuning of the load increase.

Brief Description of the Drawings

[0033]

Figure 1 shows a schematic of a power plant having an arrangement according to the invention with six intermediate- and low-pressure steam extraction lines in the water steam cycle.

Figure 2 shows a schematic of a further power plant having an arrangement according to the invention of six intermediate- and low-pressure steam extraction lines combined with a supply buffer silo for pulverized coal.

Figure 3a)-3e) show various plots illustrating the dynamic response of a power plant according to the invention as a function of time.

Specifically, figure 3a) shows the power output of a power plant according to the invention over a first immediate time period following a frequency variation of the grid.

Figure 3b) shows the power output of a power plant according to the invention over a longer time period following a frequency variation of the grid.

Figure 3c) shows a comparison of the live steam production in a coal-fired boiler in a power plant with conventional direct firing with that in a coal-fired boiler in a power plant according to the invention with indirect firing.

Figure 3d) shows the pulverized coal level in a coal buffer silo of a power plant according to the invention and the live steam flow during a 10% load increase.

Figure 3e) shows the development of the feedwater level in the boiler feedwater tank and of the condensate level in the condenser well following a frequency variation in the grid.

[0034] Same numerals indicate same elements in the various figures.

Best Modes for Carrying out the Invention

[0035] Figure 1 shows a power plant PP with a fossil fueled boiler 1 comprising an economizer 2, a superheater 3, and a reheater 4, and several steam turbines 6-10 including a high-pressure turbine stage 6, to which live steam is led via a line with throttling valve 5, an intermediated-pressure turbine stage 7 and low-pressure turbine stages 8-10. Steam expanded in the high-pressure turbine stage 6 is reheated in reheater 4 and led into intermediate-pressure turbine stage 7. The steam is further expanded in the low-pressure turbines 8-10. All turbines are mounted on a shaft 11 driving a generator 12. Exhaust steam is led from the low-pressure turbines 8-10 via line 13' to a condenser 13, where resulting condensate collects in a condensate well of the condenser. A condensate extraction pump 14 pumps the condensate through a series of condensate preheaters 21-26, which are each operated by steam as a heat exchange medium, which is extracted from the low- and intermediate-pressure steam turbines 7-10 and led to the preheaters 21-26 via six individual extraction lines 21'-26', respectively. The extraction lines leading to the intermediate-pressure preheaters 25 and 26 and to the two low-pressure preheaters 23 and 24 arranged prior to the intermediate-pressure preheaters are configured with a quick-action stop valve 23''- 26'', respectively. Extraction lines 21'-24' lead steam extracted from all of the low-pressure steam turbines 8-10 to the preheaters 21-24. The extraction lines 21 and 22 can be arranged within the steam condenser neck and can be configured without valves. In order to activate the condensate stop process, the four quick-action valves 23''-26'' in the low- and intermediate-pressure extraction lines are closed. The two lowest-pressure steam extraction lines 21' and 22' can be left untouched because their contribution to the condensate stop and load increase is limited compared to that of the four other extraction lines.

[0036] The steam flow in lines 21' and 22' is proportional to the temperature difference between the piping in the preheaters 21 and 22 and the extracted steam. As the flow of condensate to the preheaters is stopped by closing valve 15 and opening valve 17 and recirculation line 16, a thermal equilibrium in the preheaters 21 and 22 is reached. Then, no more steam condenses on the piping of the preheaters 21 and 22 and the extraction of steam through these lines comes to a halt due to a zero pressure difference. This complete process can take about 1 minute and 30 seconds.

[0037] The line leading from the condensate extraction pump 14 to the first preheater 21 contains a quick-acting valve 15 allowing to close this line at the time of closure of the extraction lines. The recirculation line 16 with a quick-acting valve 17 allows the recirculation of the condensate discharged by the extraction pump 14 back into the condenser 13. The stoppage of the condensate flow through the preheaters prevents a drop in the feedwater temperature. It also allows to maintain the temperature of the preheaters 21-26, which avoids massive condensation and thereby allows an easier restarting of their operation after the condensate stop and load increase. The recirculation of the condensate however, also results in an increase of the level in the condensate well.

[0038] During normal operation of the water-steam cycle, the condensate preheated in the low-pressure preheaters 21-26 is collected in the boiler feedwater tank 30. Additional heat is provided to the feedwater tank 30 via steam extraction line 30' extracting steam from the intermediate-pressure turbine stage 7, which is used for preheating in a preheater 33.

As an additional optional measure of the method operating the power plant following a frequency variation, the quick-acting valve 30" in the intermediate-pressure steam extraction line 30' is closed. Thereby the additional steam made available to drive the turbines further supports the load increase.

[0039] Feedwater pump FWP directs the feedwater through high-pressure preheaters 31 and 32. Following the preheaters 31 and 32, the feedwater is led through a further preheater 33 and finally to the boiler 2 completing the water steam cycle of the power plant PP.

[0040] In case of a large frequency variation in the grid, the power plant PP will be operated in order to compensate for the variation by increasing its load within a short time period. For this, a condensate stop is activated by closing the stop valves 23" to 26" in the extraction lines 23'-26'.

Due to the fact that four extraction lines are available for the condensate stop that significantly contribute to a load increase, an increased amount of steam is available compared to in conventional power plants to drive the turbines.

[0041] For example, compared to a steam power plant having five intermediate- and low-pressure steam extractions, a steam power plant with six intermediate- and low-pressure steam extractions is able to provide a load jump as great as about 10% corresponding to a 50% increase over the possible load jump in a conventional power plant.

[0042] Figure 2 shows the same power plant as in figure 1. The figure illustrates the steam production unit of the power plant PP comprising a coal milling facility 40, a boiler 1 including an economizer 2, a superheater 3 and a reheater 4. The flue gases of the boiler 1 are led through an electrostatic precipitator ESP and a desulphurization unit DS before they are emitted through the stack S. The coal milling facility 40 comprises an air preheater 41, through which air A is directed before it is led to the mill 42, to which raw coal of large size is fed. The coal mill reduces the raw coal to powder with particle sizes in a given range suitable for combustion. Compared to a conventional coal milling facility, the present facility comprises a coal buffer silo 45 and a duct 44 by which the pulverized coal is transported from the coal mill 44 to the silo 45, where the pulverized coal is stored ready for combustion. A feeding device 46 leads from the silo 45 directly to a duct 43, which leads into the boiler. The store 45 of pulverized coal allows a quick release of coal to the boiler at a faster rate than can be provided directly by the coal mill. The feeding device 46 allows the supply of pulverized coal to the boiler at a given rate. It also allows a steady release of the pulverized coal into the duct 43 such that the formation of hollow spaces at the bottom of the silo is avoided. An additional duct 43' leading from the coal mill 43 directly to the duct 43 is intended for emergency coal supply only.

[0043] During normal steady state operation of the power plant, that is during frequency stability of the grid, the coal facility for indirect firing according to the invention operates in that coal is milled and provided to the buffer silo 45 and fed by means of the feeding device 46 to the duct 43 for combustion. It is supplied to the boiler at a rate given by the steam demand or boiler load rate. During this normal steady state operation of the power plant, the coal milling rate is set such that the supply silo 45 is gradually filled. The filling of the buffer silo 45 generates readiness for a high degree of dynamic response with increased firing rate in case a frequency instability occurs in the grid.

The milling time is long to produce coal particles of the required size, especially in the case of hard coal. Also, the coal mill can change speed only at a slow rate and is therefore not able to rapidly change the supply rate of pulverized coal to the boiler.

When a large frequency variation occurs, a condensate stop is activated and an increased firing rate is initiated by the indirect firing system supplying pulverized coal to the boiler from the buffer silo 45 at rate that is higher than during normal steady state as described above or with direct firing system having no pulverized coal supply silo. Thereby an increase in steam production can be assured within seconds. During this period of dynamic response, the level of pulverized coal in the buffer silo 45 decreases steadily as the rate of pulverized coal consumption is increased.

[0044] Figure 3a) shows the development of a grid frequency over time Gf(Hz) including a typical frequency variation with a sharp decrease from 50 Hz to 49.5 Hz. On the same time scale, the development of the demanded load Ld and that of the actual measured load Lm of a power plant according to the invention is shown, where the power plant is equipped with six condensate preheaters and two feedwater preheaters and an indirect firing facility with a coal buffer silo. At the detection of the frequency variation, an immediate dynamic response is activated within the time frame of a few seconds from the onset of the frequency drop. In this case, well within 10 seconds after the beginning of the frequency variation the full frequency response is completed in that the effective power load Lm of the power plant has reached the demanded load Ld.

[0045] Figure 3b) shows for the same power plant the development of grid frequency Gf and demanded and measured load Ld and Lm respectively over a longer time frame of 30 minutes following the onset of a frequency variation. The curves show that the power plant according to the invention is able to maintain the dynamic response by load increase over the full 30 minutes.

[0046] Figure 3c) shows as a function of time following a rapid frequency drop, the production of live steam flow by a coal-fired boiler with and without a coal buffer silo. Curve A shows the live steam production in a conventional plant having no coal silo, where pulverized coal is provided to the boiler at the rate that the mill is able to produce the coal particles. Curve B in contrast, shows the production of live steam by means of additional coal already pulverized and provided at a greater rate by the coal silo. Compared to curve A, the rate of increase in steam production is much greater.

[0047] Figure 3d) shows the production of live steam flow LSF as the quantity of pulverized coal CS in the buffer silo is diminished over time. It shows that even if the pulverized coal is supplied almost steadily, the boiler firing rate can be increased. The resulting quick increase in live steam flow enables the support of a load jump within a short time and its maintenance over a long time period, for example up to 30 minutes.

[0048] Figure 3e) shows following the variation of the grid frequency Gf, the development of the condensate level in the condensate well Cwl and the feedwater level in the feedwater tank Fwl. Initiated by the frequency, the condensate well level rises as a result of the condensate stop and stoppage of the condensate extraction flow variation. On the same time scale, as the condensate flow is stopped and the feedwater pump continues to operated, the level of the feedwater in the feedwater tank begins to drop. With the onset of indirect firing and the increase of the firing rate by means of pulverized coal from the buffer silo 45, the quick-action valves 23"-26" and 30" in the intermediate- and low-pressure steam extraction lines 23'-26 and 30' are slowly opened again and the condensate is no longer recirculated but instead is again allowed to flow through the preheaters 21-26. As a result, the feedwater level in the boiler feedwater tank begins to rise again and the feedwater flow rate is given by the steam flow production rate, which is a function of the firing rate.

Terms used in Figures

[0049]

1	boiler
2	economizer
3	superheater
4	reheater
5	throttling valve
6	high-pressure steam turbine
7	intermediate-pressure steam turbine
8, 9, 10	low-pressure steam turbines
11	shaft
12	generator
13	condenser
13'	line to condenser
14	condensate extraction pump
15	stop valve
16	recirculation valve
17	valve
21-26	condensate preheaters
21'-26'	steam extraction lines from low- and intermediate pressure steam turbines
to	condensate preheaters
23"-26"	quick-action valves
30	feedwater tank
30'	line to feedwater tank
31 "	quick-action valve
31-32	feedwater preheaters
31', 32'	steam extraction lines from high-pressure steam turbines to feedwater preheaters
33	preheater
40	coal milling facility
41	air preheater

42	coal mill
43	coal duct
43'	emergency coal duct
44	coal duct
45	coal buffer silo
46	feeding device
PP	power plant
FWP	feedwater pump
A	air
ESP	electrostatic precipitator
DS	desulphurization unit
S	stack

Claims

1. Fossil fuel fired power plant (PP) having a water steam cycle comprising a boiler (1), one or more steam turbines (7-10), one or more preheaters (21-26) for the preheating of condensate by means of steam extracted from the steam turbines
characterized by
the arrangement of six low- and intermediate pressure preheaters (21-26) for the preheating of condensate arranged in series following a condensate extraction pump (14), and steam extraction lines (21'-26') directing steam from the one or more steam turbines (7-10) to the six preheaters (21-26), where all of the steam extraction lines or less than six of the steam extraction lines to the preheaters are configured with quick-action valves (23"-26").

2. Fossil fuel fired power plant (PP) according to claim 1
characterized by
at least four steam extraction lines (23'-26') leading from the low- and intermediate-pressure turbine stages (7-10) to two intermediate-pressure preheaters (25, 26) and to two low-pressure preheaters (23, 24) arranged prior to the intermediate-pressure preheaters, and a quick-acting valve (23"-26") arranged in each of the four steam extraction lines (23'-26').

3. Fossil fuel fired power plant (PP) according to claim 1 or 2
characterized by
a line (16) for recirculating condensate extracted by the condensate extraction pump (14) back into a condenser (13) of the steam turbines.

4. Fossil fuel fired power plant (PP) according to claim 3
characterized by
a quick-action valve (15) arranged following the condensate extraction pump (14) to stop the flow of condensate to the preheaters (21-26) and a quick-action valve (17) arranged in the line (16) for recirculating the condensate to the condenser (13) of the steam turbines.

5. Fossil fuel fired power plant (PP) according to claim 1 or 2
characterized by
a feedwater tank (30) arranged following the preheaters for preheating the condensate (21-26) and two high-pressure feedwater preheaters (31-32) arranged in series following the feedwater tank (30).

6. Fossil fuel fired power plant (PP) according to claim 1 or 2
characterized by
two steam extraction lines (21', 22') leading from the condenser neck of the steam turbine condenser (13) to the first low-pressure preheaters (21, 22) in the series of condensate preheaters.

7. Fossil fuel fired power plant (PP) according to claim 4
characterized by
a steam extraction line (30') leading from an intermediate-pressure turbine stage (7) to the feedwater tank (30), where the extraction line is configured with a quick-acting valve (30").

8. Fossil fuel fired power plant (PP) according to claim 1
characterized in that
the power plant is fueled by coal, oil, or biomass.

9. Fossil fuel fired power plant (PP) according to one of the foregoing claims
characterized in that
the power plant (PP) is a coal-fired power plant and comprises at least one coal milling facility (40) having a supply container for pulverized coal (45) to hold coal milled and pulverized ready for combustion in the boiler (1).

10. Fossil fuel fired power plant (PP) according to claim 9
characterized in that
the supply container is a silo (45).

11. Fossil fuel fired power plant (PP) according to claim 9
characterized in that
the coal milling facility (40) comprises a feeding device (46) to supply pulverized coal to the boiler (1) at a given rate.

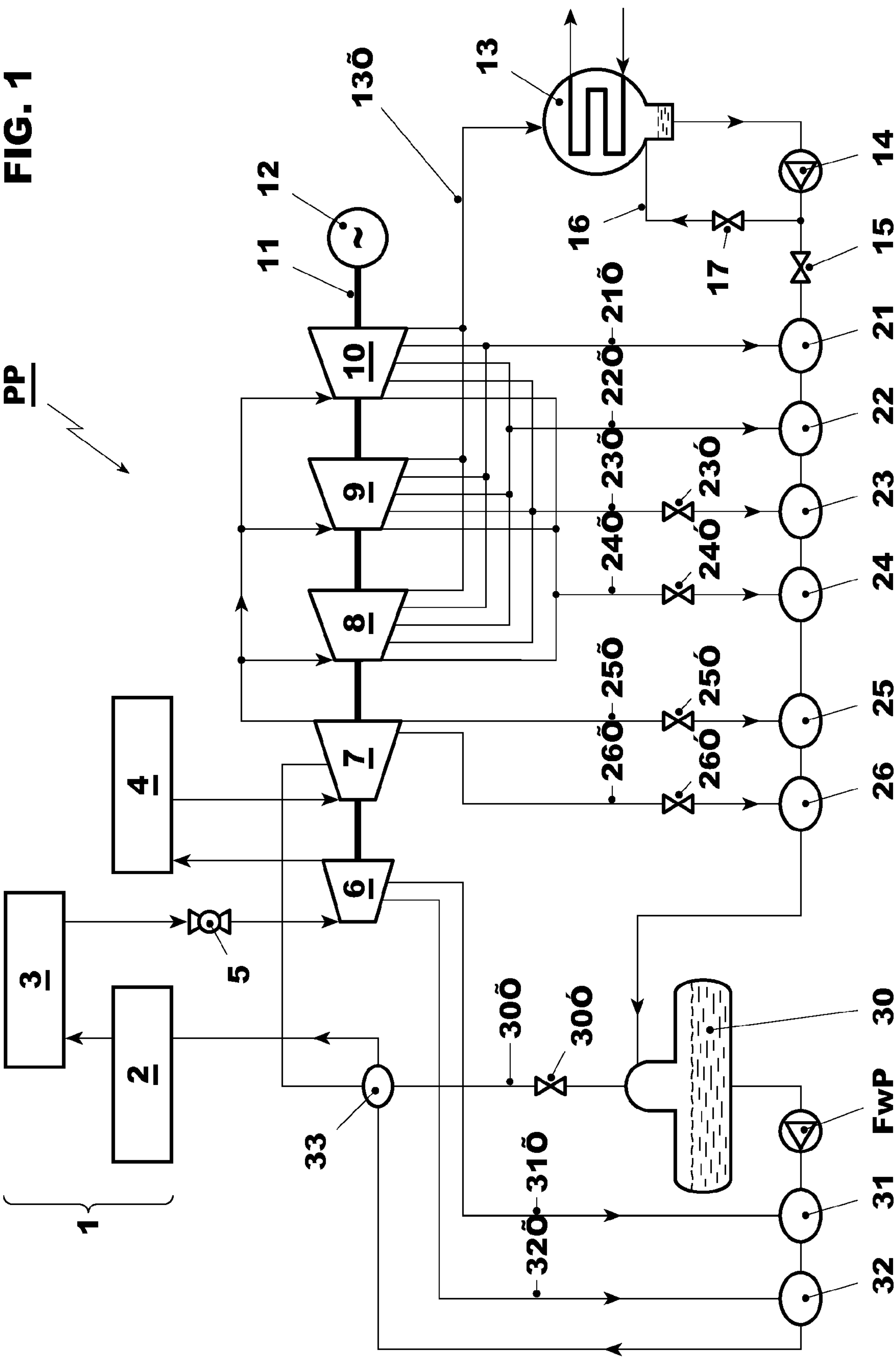
12. A method to operate a fossil fuel fired power plant

(PP) according to one of the foregoing claims 1-11 **characterized by** when a frequency variation occurs in the grid, to which the power plant (PP) provides electrical energy, activating a condensate stop process by closing quick-action valves (23"-26") in at least four steam extraction lines (23'-26') leading from extraction points at low- and intermediate-pressure steam turbines (8-10) to two low-pressure preheaters (23, 24) and to two intermediate-pressure preheaters (25, 26).

13. Method according to claim 12 **characterized by** closing a valve (15) in a line from a condensate extraction pump (14) to the preheaters (21-26) and opening a line (16) to recirculated condensate extracted by the condensate extraction pump (14) to the condenser (13).

14. Method according to claim 12 **characterized by** feeding pulverized coal from a coal supply container (45) to the boiler (1).

15. Method according to claim 14 **characterized by** when steam production in the boiler (1) increases, opening the quick-acting valves (23"-26") in the steam extraction lines (23'-26') to the preheaters (23-26) for preheating the condensate and closing the line (16) for recirculating the condensate and opening the valve (15) in the line for condensate extracted by the condensate extraction pump (14).


PP
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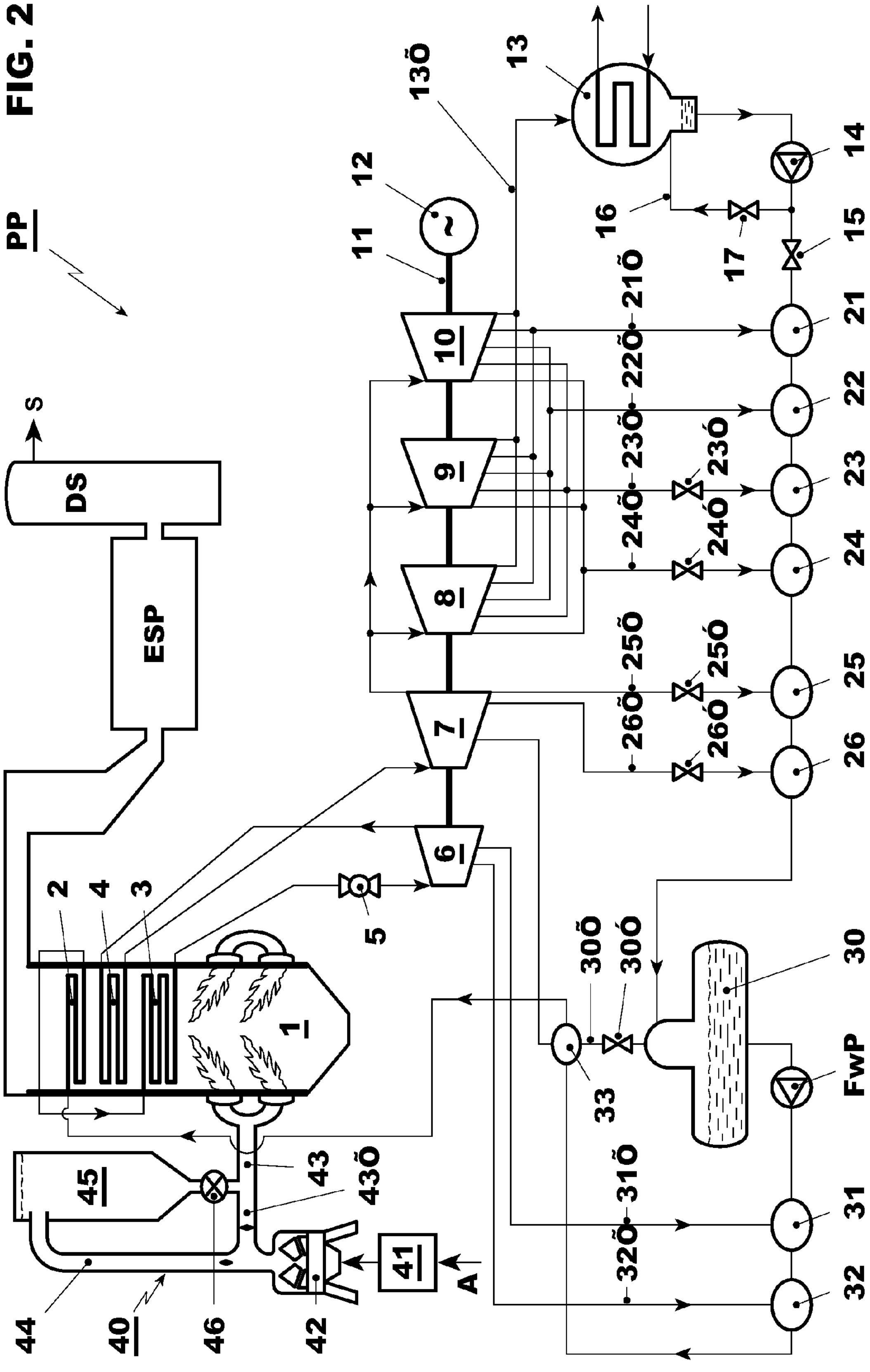
33
FwP

FIG. 1

FIG. 2


PP
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46
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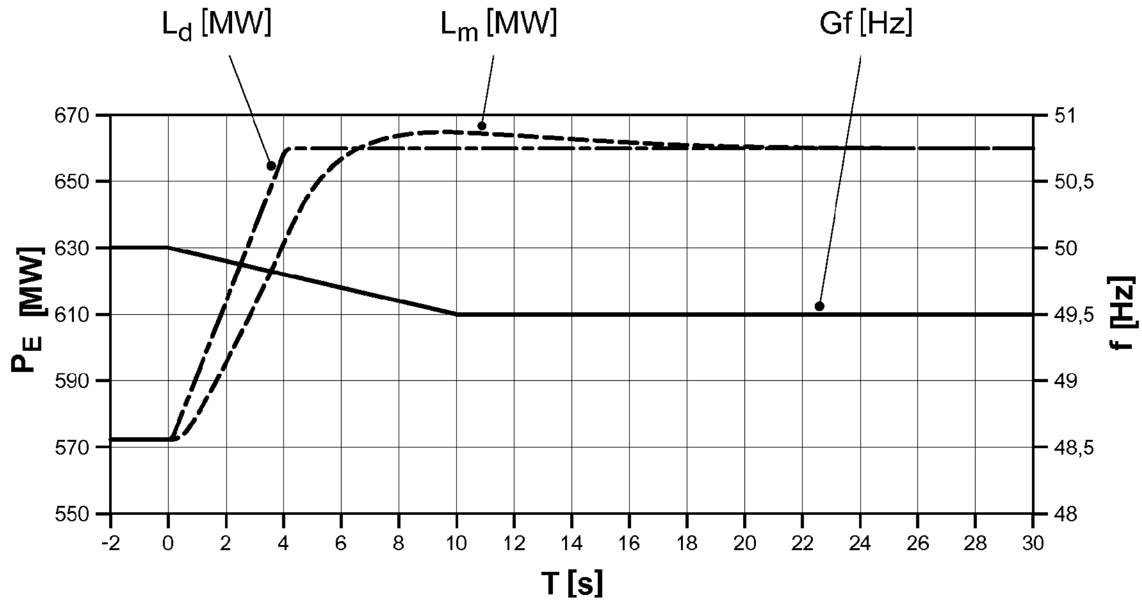
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Gf [Hz]
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650
630
610
590
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P_E [MW]
51
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50
49,5
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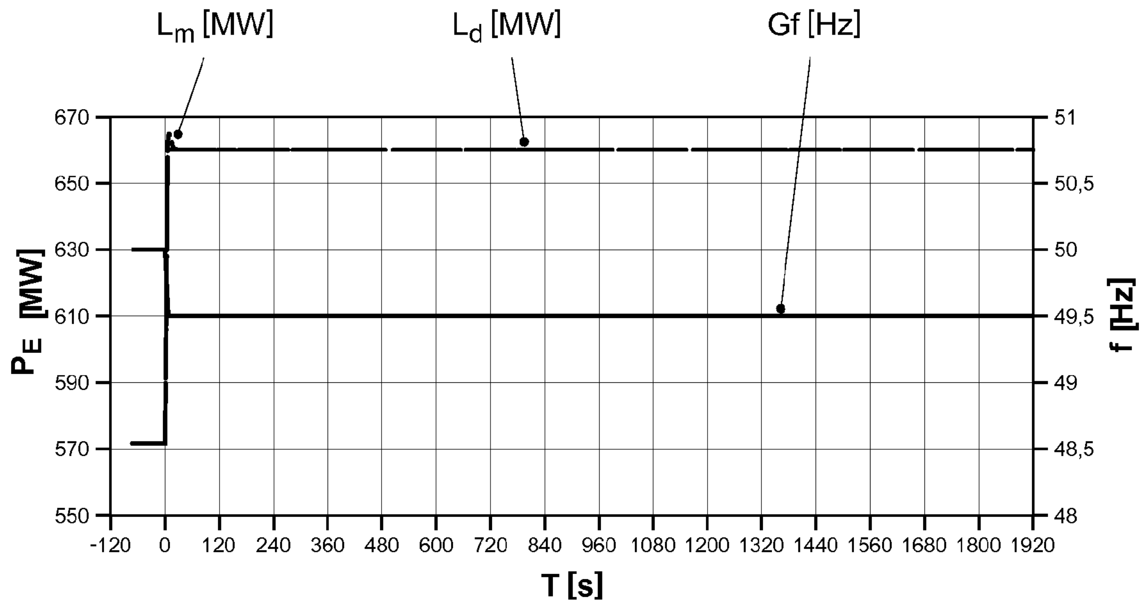
48,5
48
f [Hz]
-2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
T [s]

FIG. 3a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f [Hz]
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T [s]

FIG. 3b

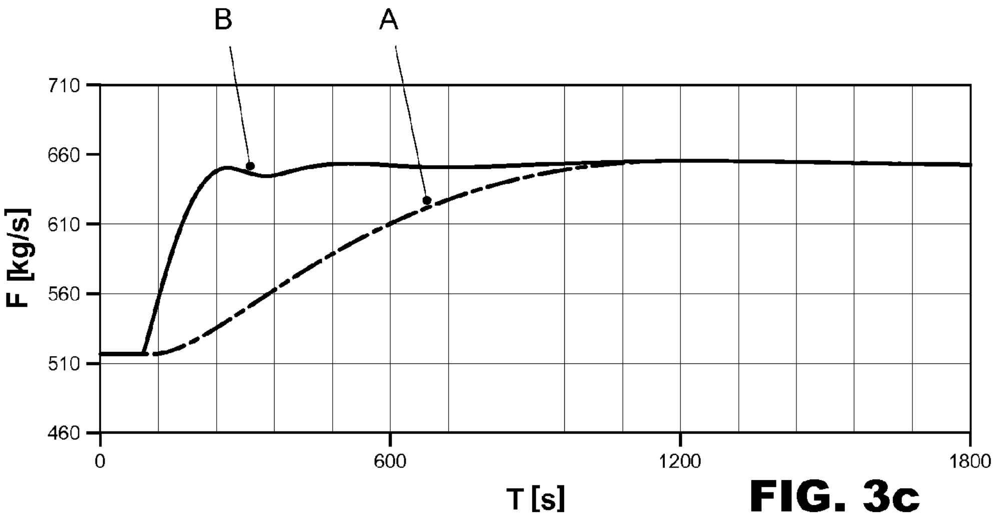

FIG. 3c

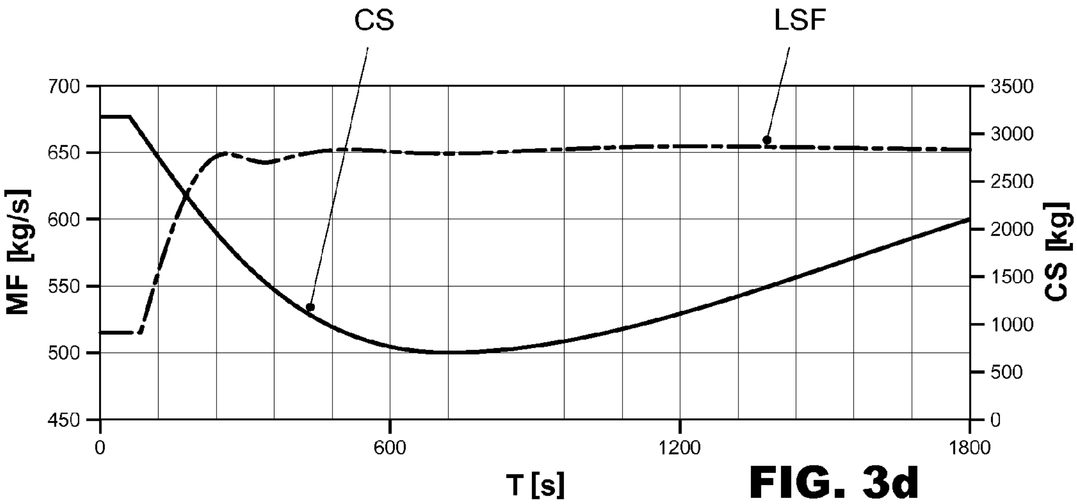

FIG. 3d

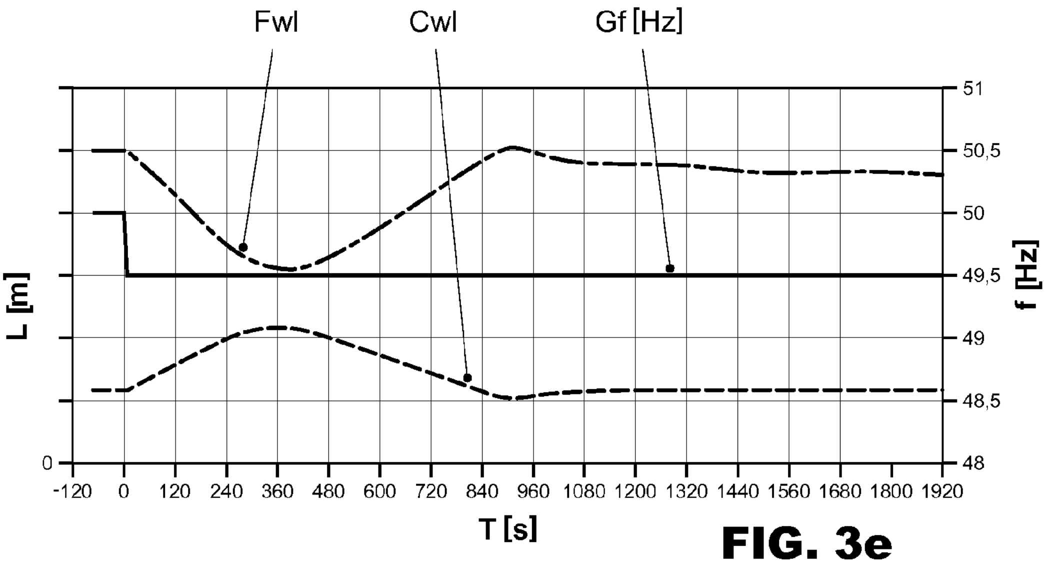

FIG. 3e

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EUROPEAN SEARCH REPORT

Application Number
EP 10 15 0416

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 January 2011	Lepers, Joachim

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2

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The members are as contained in the European Patent Office EDP file on
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03-01-2011

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REFERENCES CITED IN THE DESCRIPTION

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