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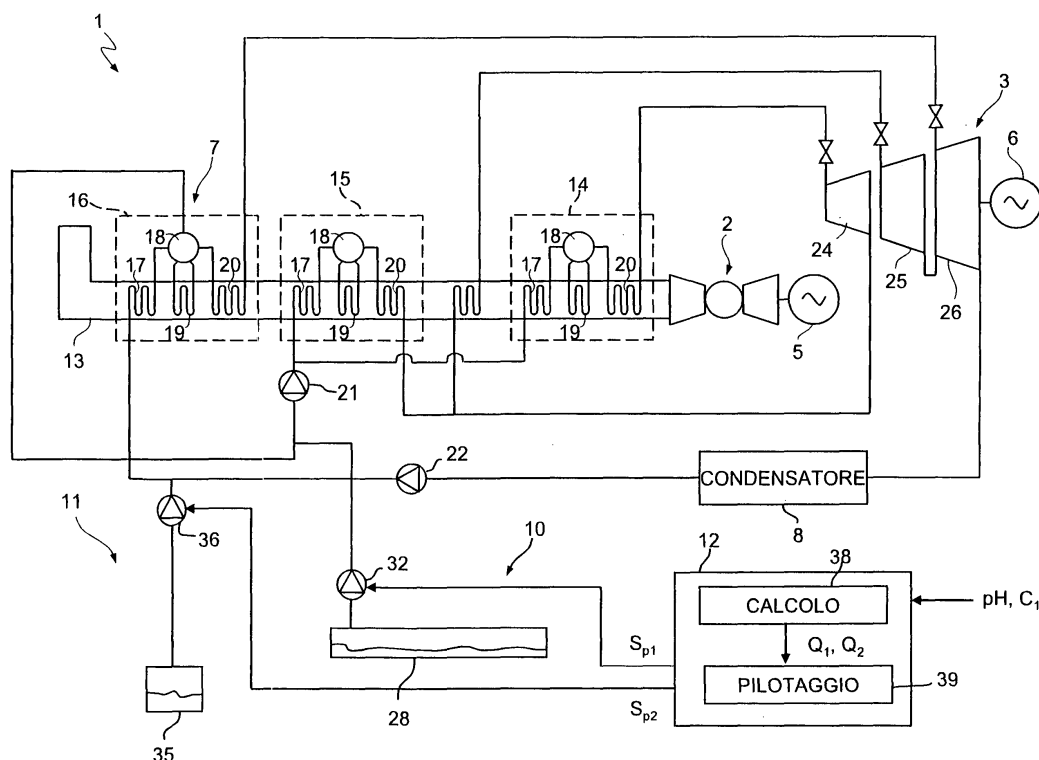
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(54) **Device and method for controlling the injection of an operating fluid and plant for the production of electrical energy said control device**

(57) A device for controlling the injection of at least one operating fluid in an evolving fluid of a plant (1) for the production of electrical energy is provided with: a calculation unit (38) for calculating at least one flowrate (Q_1 , Q_2) of operating fluid to be injected into the evolving fluid on the basis of a detected parameter (C_1 , pH) of the evolving fluid modified by the operating fluid, which is config-

ured for calculating the flowrate (Q_1 , Q_2) of operating fluid to be injected according to a first mode when the detected parameter (C_1 , pH) is lower than a given threshold value (C_{TS} , pH_{TS}) and according to a second mode when the detected parameter (C_1 , pH) is higher than the threshold value (C_{TS} , pH_{TS}); and a driving unit (39) for driving at least one operating fluid injection pump (32, 36) on the basis of the flowrate (Q_1 , Q_2) of operating fluid calculated.



Description

[0001] The present invention relates to a device and a method for controlling the injection of an operating fluid in an evolving fluid of a plant for the production of electrical energy and to a plant for the production of electrical energy comprising said control device. In particular, the present invention relates to a device and to a method for controlling the injection of an operating fluid in an evolving fluid of a combined-cycle electrical energy production plant.

[0002] Energy-production plants, and in particular combined-cycle energy-production plants, usually comprise a device for controlling the injection of an operating fluid into the fluid evolving in the plant. In the case of the combined-cycle plant, the evolving fluid is initially water, then vapour, and finally condensate.

[0003] The operating fluid is injected into the evolving fluid in different portions of the plant in order to protect from electrochemical corrosion and from the deposition of encrusting salts the circuit of the plant within which the evolving fluid flows.

[0004] Known devices for controlling the injection of the operating fluid substantially comprise means for calculation of a flowrate of operating fluid to be injected, and means for driving at least one pump for injection of the operating fluid on the basis of the flowrate of operating fluid calculated. In particular, the calculation means are configured for calculating the flowrate of operating fluid to be injected on the basis of the difference between a value of a detected parameter of the evolving fluid modified by the operating fluid and a reference value set beforehand.

[0005] Said control devices generally use a PID (proportional integral derivative) control mode, which requires identification of appropriate control constants.

[0006] However, the identification of the control constants is particularly problematical, in so far as it is very difficult to identify control constants such as to determine a control of the injection that is precise, stable, and fast. The choice of the control constants has repercussions on the stability of the control of the injection above all in emergency situations, such as, for example, pollution of the condensate, where it is necessary to intervene rapidly maintaining the stability of the control.

[0007] Frequently, it is necessary to entrust control of the injection of the operating fluid to an operator, who, on the basis of the measurements of the detected parameter of the evolving fluid, regulates directly the pumps for injection of the operating fluid.

[0008] An aim of the present invention is to provide a device for controlling the injection of an operating fluid that is free from the drawbacks highlighted of the known art. In particular, an aim of the invention is to provide a device for controlling the injection of an operating fluid that is reliable and simple to use.

[0009] In accordance with said aims, the present invention relates to a device for controlling the injection of at least one operating fluid in an evolving fluid of a plant for the production of electrical energy, said device comprising: calculation means for calculating at least one flowrate of operating fluid to be injected into the evolving fluid on the basis of a detected parameter of the evolving fluid modified by the operating fluid;

the device being **characterized in that** the calculation means are configured for calculating the flowrate of operating fluid to be injected according to a first mode when the detected parameter is lower than a given threshold value and according to a second mode when the detected parameter is higher than said threshold value.

[0010] The present invention moreover relates to a method for controlling the injection of at least one operating fluid in an evolving fluid of a plant for the production of electrical energy. In accordance with said purposes, the present invention relates to a method for controlling the injection of at least one operating fluid in an evolving fluid of a plant for the production of electrical energy comprising the step of calculating at least one flowrate of operating fluid to be injected into the evolving fluid on the basis of a detected parameter of the evolving fluid modified by the operating fluid; the method being **characterized in that** the flowrate of operating fluid to be injected is calculated according to a first mode when the detected parameter is lower than a given threshold value and according to a second mode when the detected parameter is higher than said threshold value.

[0011] The present invention moreover relates to a plant for the production of electrical energy. In accordance with said aims the present invention relates to an electrical energy production plant comprising at least one steam-turbine unit flowing within which is an evolving fluid; the plant being characterized by comprising a device for controlling the injection of at least one operating fluid into the evolving fluid as claimed in any one of Claims 1 to 18.

[0012] Further characteristics and advantages of the present invention will be clear from the following description of a non-limiting example of embodiment thereof, with reference to the attached figure, which is a schematic representation of a plant for the production of energy according to the present invention.

[0013] In Figure 1 designated by the reference number 1 is a plant for the production of energy. In the non-limiting example described and illustrated herein, the plant 1 is a plant for the combined-cycle production of electrical energy and comprises a gas-turbine unit 2, a steam-turbine unit 3, two alternators 5, 6, respectively coupled to the gas-turbine unit 2 and to the steam-turbine unit 3 and connected to a distribution network (not illustrated), a steam generator 7, a condenser 8, an assembly for injection of a first operating fluid 10, an assembly for injection of a second operating fluid 11, and an operating fluid injection control device 12. Alternatively, the plant comprises a gas-turbine unit, a steam-

turbine unit, and an alternator all set on one and the same axis.

[0014] The exhaust fumes of the gas-turbine unit 2 are channelled along a duct 13 and provide a source of heat for the steam generator 7.

[0015] The steam generator 7 comprises a high-pressure element 14, a medium-pressure element 15 and a low-pressure element 16, each of which comprises an economizer 17, a cylindrical body ("drum") 18, an evaporator 19 and a super-heater 20, operation of which is known and will not be discussed in detail.

[0016] The economizers 17 of the high-pressure element 14 and of the medium-pressure element 15 receive water from the low-pressure drum 18 by means of a supply pump 21, whilst the economizer 17 of the low-pressure element 16 receives water from a collection tank of the condenser 8, by means of an extraction pump 22.

[0017] The steam-turbine unit 3 comprises a high-pressure section 24, a medium-pressure section 25, and a low-pressure section 26 circulating within which is steam coming, respectively, from the high-pressure element 14, the medium-pressure element 15, and the low-pressure element 16. In a different embodiment (not illustrated) the steam turbine comprises the high-pressure section and a medium-low-pressure section.

[0018] Basically, within the plant 1 an evolving fluid flows, which is initially water supplied by the pump 21, becomes vapour (steam) within the steam generator 7, and is transformed into condensate after the expansion in the low-pressure section 26 of the steam-turbine unit 3.

[0019] The injection assembly 10 of the first operating fluid comprises a tank 28 containing the first operating fluid, and an injection pump 32 for injecting the first operating fluid. The injection pump 32 injects the first operating fluid into the evolving fluid upstream of the supply pump 21 under the control of the control device 12 as will be described in detail hereinafter. The evolving fluid, in this situation, is water coming from the low-pressure drum 18.

[0020] The first operating fluid comprises a de-oxygenating fluid diluted in water, for example, an amine-based de-oxygenating organic fluid.

[0021] The de-oxygenating fluid has a given concentration of active principle, commonly referred to as de-oxygenating power P_{deox} .

[0022] The assembly 11 for injection of the second operating fluid comprises a tank 35 containing the second operating fluid, and an injection pump 36 for injection of the second operating fluid. The injection pump 36 injects the second operating fluid into the evolving fluid downstream of the pump 22 for extraction of the condensate under the control of the control device 12 as will be described in greater detail hereinafter. The evolving fluid, in this situation, is condensate coming from the condenser 8.

[0023] The second operating fluid comprises an alkalinizing fluid diluted in water, for example an amine-based or ammoniac-based alkalinizing fluid, to maintain the pH of the evolving fluid in the limits set by the standards.

[0024] The alkalinizing fluid has a given concentration of alkalinizing agent C_{flop} .

[0025] The control device 12 comprises a calculation module 38 for calculating the flowrates Q_1 , Q_2 of operating fluid to be injected into the fluid evolving in the plant 1 and a driving module 39 for driving the injection pumps 32 and 36 on the basis of the calculated flowrates Q_1 , Q_2 of operating fluid.

[0026] The calculation module 38 is configured for calculating the flowrate Q_1 of the first operating fluid to be injected into the evolving fluid upstream of the supply pump 21 on the basis of a detected parameter of the evolving fluid modified by the first operating fluid. In the example described and illustrated herein, the detected parameter of the evolving fluid modified by the first operating fluid is the concentration of oxygen C_1 in the evolving fluid detected in the portion of plant 1 into which the operating fluid is injected, in particular upstream of the supply pump 32.

[0027] In particular, the calculation module 38 is configured for calculating the flowrate Q_1 of the first operating fluid to be injected according to a first mode when the concentration of oxygen C_1 is lower than a given threshold value C_{TS} and according to a second mode when the concentration of oxygen C_1 is higher than said threshold value C_{TS} .

[0028] The threshold value C_{TS} of the detected parameter of the evolving fluid modified by the first operating fluid defines the type of treatment that it is intended to adopt. In the case where it is intended to adopt a reducing type treatment, the threshold value C_{TS} is comprised between 4 and 6 ppb, preferably 5 ppb. In the case where it is desired to adopt an oxidizing type treatment, the threshold value C_{TS} is comprised between 19 and 20 ppb, preferably 20 ppb.

[0029] In the case where the reducing treatment is chosen, the calculation module 38 calculates the flowrate Q_1 according to a formula independent of the concentration of oxygen C_1 in the first mode, whilst in the second mode adds to the independent term calculated in the first mode, a term depending upon the concentrations of oxygen C_1 .

[0030] In particular, in the first mode, i.e., when the value of the concentration of oxygen C_1 is lower than the threshold value C_{TS} , the calculation module 38 calculates the flowrate Q_1 of the first operating fluid according to the following formula:

$$(1) Q_1 = \frac{K_1 \cdot Q_{flev1} (Dose_{Rif})}{D_{flop}}$$

where:

K_1 is a conversion factor depending upon the measure units used;
 Q_{flev1} is the flowrate of evolving fluid upstream of the supply pump 21;
 D_{flop} is the dilution in water of the de-oxygenating fluid in the tank 28; and
 $Dose_{Rif}$ is a reference dose of the operating fluid established beforehand and such as to maintain the concentration of oxygen C_1 below the threshold value C_{TS} .

[0031] In the second mode, i.e., when the value of the concentration of oxygen C_1 is higher than the threshold value C_{TS} , the calculation module 38 calculates the flowrate Q_1 of first operating fluid according to the following formula:

$$(2) Q_1 = \frac{K_1 \cdot Q_{flev1} (Dose_{Rif})}{D_{flop}} + \frac{C_1 \cdot Q_{flev1} \cdot K_2 \cdot P_{deox}}{D_{flop}}$$

where:

K_1 and K_2 are conversion factors depending upon the measure units used;
 Q_{flev1} is the flowrate of evolving fluid upstream of the supply pump 21;
 D_{flop} is the dilution in water of the de-oxygenating fluid in the tank 28;
 $Dose_{Rif}$ is a reference dose of the operating fluid established beforehand and such as to maintain the concentration of oxygen C_1 below the threshold value C_{TS} ;
 C_1 is the concentration of oxygen detected upstream of the supply pump 21; and
 P_{deox} is the de-oxygenating power of the de-oxygenating fluid.

[0032] In the case where the oxidizing treatment is chosen, in the first mode, the calculation module 38 determines a zero value of the flowrate Q_1 . In the second mode, i.e., only when the value of the concentration C_1 is higher than the threshold value C_{TS} , the calculation module 38 calculates the flowrate Q_1 in accordance with Eq. (2) indicated above.

[0033] The calculation module 38 is moreover configured for calculating the flowrate Q_2 of second operating fluid to be supplied downstream of the pump 22 for intake of the condensate on the basis of a detected parameter of the evolving fluid modified by the second operating fluid. In the example described and illustrated herein, said parameter is the pH of the evolving fluid detected in a portion of the plant in which the operating fluid is injected, in particular downstream of the suction pump 22.

[0034] In particular, the calculation module 38 is configured for calculating the flowrate Q_2 of the second operating fluid to be injected according to a first mode when the pH of the evolving fluid downstream of the suction pump 22 is lower than a given threshold value pH_{TS} and a second mode when the pH of the evolving fluid downstream of the suction pump 22 is higher than said threshold value pH_{TS} .

[0035] The threshold value pH_{TS} is comprised between 9 and 10, in particular the threshold value pH_{TS} is preferably 9.55 in the case where an amine-based operating fluid is used, whilst it is preferably 9.85 in the case where an ammoniac-based operating fluid will be used.

[0036] In the first mode, the calculation module 38 calculates the flowrate Q_2 according to a formula depending upon the pH detected, whilst in the second mode the calculation module 38 calculates a zero flowrate Q_2 . In detail, the formula for calculation of the flowrate Q_2 in the first mode is the following:

$$(3) Q_2 = \frac{PM \cdot Q_{flev2} \cdot \left[10^{(pH_{TS}-14)} - \left(\frac{10^{-14}}{10^{-pH}} \right) \right]}{C_{flop} \cdot D_{flop}}$$

where:

PM is the molecular weight of the alkalinizing agent contained in the operating fluid;
 Q_{flev2} is the flowrate of evolving fluid downstream of the extraction pump 22;

C_{flop} is the concentration of the alkalinizing agent in the second alkalinizing fluid;
 D_{flop} is the dilution in water of the alkalinizing fluid in the tank 35;
 pH is the value of the pH detected downstream of the pump 22 for extraction of the condensate;
 pH_{TS} is the threshold value of the pH parameter detected.

[0037] The driving module 39, on the basis of the flowrates Q_1 , Q_2 of operating fluids calculated by the calculation module 38, sends to the injection pumps 32 and 36 respective driving signals Sp_1 Sp_2 designed to drive the stroke of the pump in such a way as to determine an injection of a flowrate of operating fluid equal to the flowrate calculated by the calculation module 38.

[0038] Finally, it is evident that modifications and variations may be made to the device, the method and the plant described herein without departing from the scope of the annexed claims.

Claims

1. A device for controlling the injection of at least one operating fluid in an evolving fluid of a plant (1) for the production of electrical energy comprising:

calculation means (38) for calculating at least one flowrate (Q_1 , Q_2) of operating fluid to be injected into the evolving fluid on the basis of a detected parameter (C_1 , pH) of the evolving fluid modified by the operating fluid; the device (12) being **characterized in that** the calculation means (38) are configured for calculating the flowrate (Q_1 , Q_2) of operating fluid to be injected according to a first mode when the detected parameter (C_1 , pH) is lower than a given threshold value (C_{TS} , pH_{TS}) and according to a second mode when the detected parameter (C_1 , pH) is higher than said threshold value (C_{TS} , pH_{TS}).

2. A device according to Claim 1, **characterized by** comprising driving means (39) for driving at least one operating fluid injection pump (32, 36) on the basis of the calculated flowrate (Q_1 , Q_2) of operating fluid.

3. A device according to Claim 1 or Claim 2, **characterized in that** the operating fluid contains an alkalinizing fluid; the detected parameter of the evolving fluid modified by the operating fluid being the pH.

4. A device according to Claim 3, **characterized in that** the evolving fluid in which the operating fluid is injected is condensed vapour.

5. A device according to Claim 3 or Claim 4, **characterized in that** the threshold value (pH_{TS}) is comprised between 9 and 10.

6. A device according to any one of Claims 3 to 5, **characterized in that** in the first mode the calculation means (38) are configured for calculating a flowrate (Q_2) of operating fluid as a function of the pH detected.

7. A device according to Claim 6, **characterized in that** in the first mode the calculation means (38) are configured for calculating a flowrate (Q_2) of operating fluid as follows:

$$Q_2 = \frac{PM \cdot Q_{flev2} \cdot \left[10^{(pH_{TS}-14)} - \left(\frac{10^{-14}}{10^{-pH}} \right) \right]}{C_{flop} \cdot D_{flop}}$$

where:

PM is the molecular weight of the alkalinizing agent contained in the operating fluid;
 Q_{flev2} is the flowrate of evolving fluid in the portion of plant in which the operating fluid is injected;
 C_{flop} is the concentration of the alkalinizing agent in the alkalinizing fluid;

D_{flop} is the dilution in water of the alkalizing fluid;
 pH is the value of the pH detected in the portion of plant in which the operating fluid is injected; and
 pH_{TS} is the threshold value of the pH parameter detected.

8. A device according to one of Claims 3 to 7, **characterized in that** in the second mode the calculation means (38) are configured for calculating a zero flowrate (Q_2) of operating fluid.
9. A device according to Claim 1 or Claim 2, **characterized in that** the operating fluid contains a de-oxygenating fluid; the detected parameter of the evolving fluid modified by the operating fluid being a concentration of oxygen (C_1).
10. A device according to Claim 9, **characterized in that** the evolving fluid into which the operating fluid is injected is water.
11. A device according to Claim 9 or Claim 10, **characterized in that** the threshold value (C_{TS}) is comprised between 4 and 6 ppb.
12. A device according to one of Claims 9 to 11, **characterized in that** in the first mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid independent of the concentration of oxygen (C_1).
13. A device according to Claim 12, **characterized in that** in the first mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid as follows:

$$Q_1 = \frac{K_1 \cdot Q_{flev1} (Dose_{Rif})}{D_{flop}}$$

where:

K_1 is a conversion factor depending upon the measure units used;
 Q_{flev1} is the flowrate of evolving fluid in the portion of plant in which the operating fluid is injected;
 D_{flop} is the dilution in water of the de-oxygenating fluid; and
 $Dose_{Rif}$ is a reference dose of the operating fluid established beforehand and such as to maintain the concentration of oxygen (C_1) below the threshold value (C_{TS}).

14. A device according to one of Claims 9 to 13, **characterized in that** in the second mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid as a function of the concentration of oxygen (C_1).
15. A device according to Claim 14, **characterized in that** in the second mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid as follows:

$$Q_1 = \frac{K_1 \cdot Q_{flev1} (Dose_{Rif})}{D_{flop}} + \frac{C_1 \cdot Q_{flev1} \cdot K_2 \cdot P_{deox}}{D_{flop}}$$

where:

K_1 and K_2 are conversion factors depending upon the measure units used;
 Q_{flev1} is the flowrate of evolving fluid in the portion of plant in which the operating fluid is injected;
 D_{flop} is the dilution in water of the de-oxygenating fluid;
 $Dose_{Rif}$ is a reference dose of the operating fluid established beforehand and such as to maintain the concentration of oxygen (C_1) below the threshold value (C_{TS});
 C_1 is the concentration of oxygen detected in the portion of plant in which the operating fluid is injected; and
 P_{deox} is the de-oxygenating power of the de-oxygenating fluid.

16. A device according to Claim 9, **characterized in that** the threshold value (C_{TS}) is comprised between 19 and 21 ppb.
17. A device according to Claim 16, **characterized in that** in the first mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid as a function of the concentration of oxygen (C_1).
18. A device according to Claim 17, **characterized in that** in the second mode the calculation means (38) are configured for calculating a flowrate (Q_1) of operating fluid as follows:

$$Q_1 = \frac{K_1 \cdot Q_{flev1} (Dose_{Rif})}{D_{flop}} + \frac{C_1 \cdot Q_{flev1} \cdot K_2 \cdot P_{deox}}{D_{flop}}$$

where:

K_1 and K_2 are conversion factors depending upon the measure units used;
 Q_{flev1} is the flowrate of evolving fluid in the portion of plant in which the operating fluid is injected;
 D_{flop} is the dilution in water of the de-oxygenating fluid;
 $Dose_{Rif}$ is a reference dose of the operating fluid established beforehand and such as to maintain the concentration of oxygen (C_1) below the threshold value (C_{TS});
 C_1 is the concentration of oxygen detected in the portion of plant in which the operating fluid is injected; and
 P_{deox} is the de-oxygenating power of the de-oxygenating fluid.

19. A method for controlling the injection of at least one operating fluid in an evolving fluid of a plant (1) for the production of electrical energy comprising the step of calculating at least one flowrate (Q_1 , Q_2) of operating fluid to be injected into the evolving fluid on the basis of a detected parameter (C_1 , pH) of the evolving fluid modified by the operating fluid; the method being **characterized in that** the flowrate (Q_1 , Q_2) of operating fluid to be injected is calculated according to a first mode when the detected parameter (C_1 , pH) is lower than a given threshold value (C_{TS} , pH_{TS}) and according to a second mode when the detected parameter (C_1 , pH) is higher than said threshold value (C_{TS} , pH_{TS}).
20. An electrical energy production plant comprising at least one steam-turbine unit (3) within which an evolving fluid flows; the plant (1) being **characterized by** comprising a device for controlling (12) the injection of at least one operating fluid into the evolving fluid as claimed in any one of Claims 1 to 18.

