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(54) **METHOD AND DEVICE FOR REGULATING THE PRODUCTION OF STEAM IN A STEAM PLANT**

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(57) **ABSTRACT**

A method for regulating the production of steam from feed water in an evaporator of a steam plant is provided. A state regulator calculates a plurality of states of a medium in the evaporator by means of an observer and, on the basis thereof, determines a feed water mass flow rate as a regulating variable. In order to obtain a stable and precise regulation of the temperature of the steam, the state regulator is a linear-quadratic regulator.

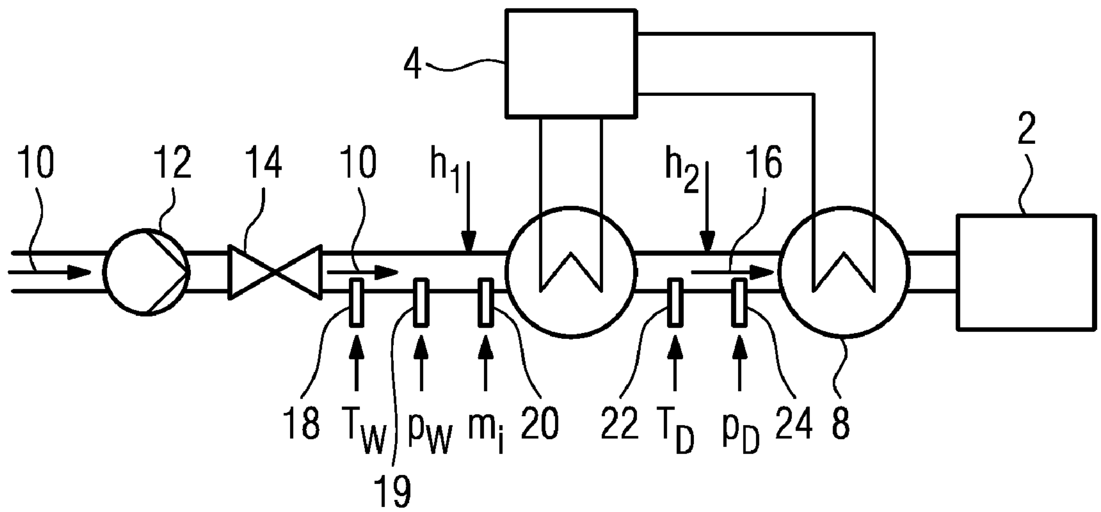

FIG 1

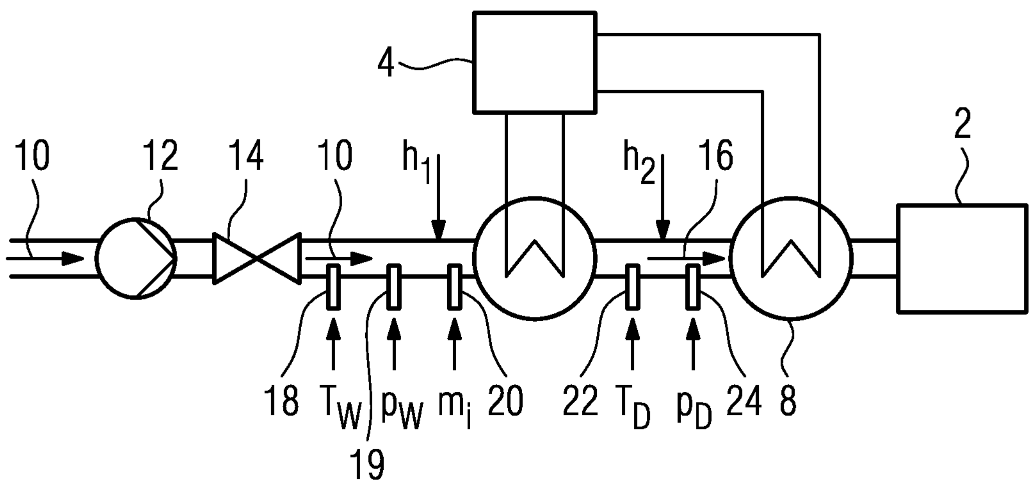
4
2
10
12
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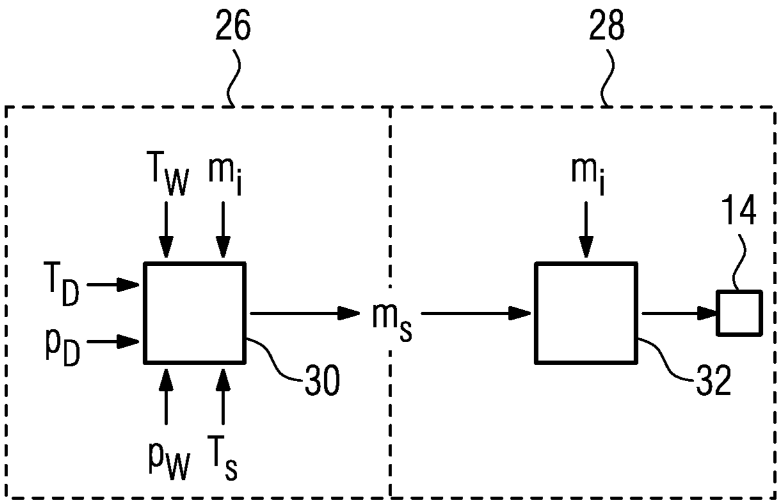
FIG 2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28
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FIG 3

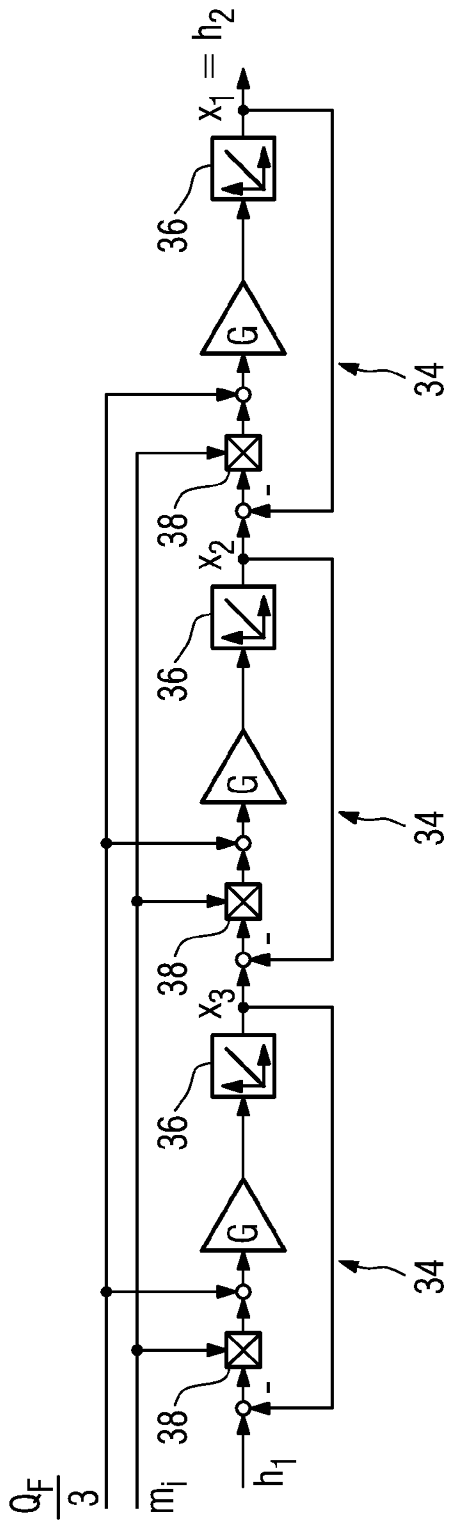


FIG 4

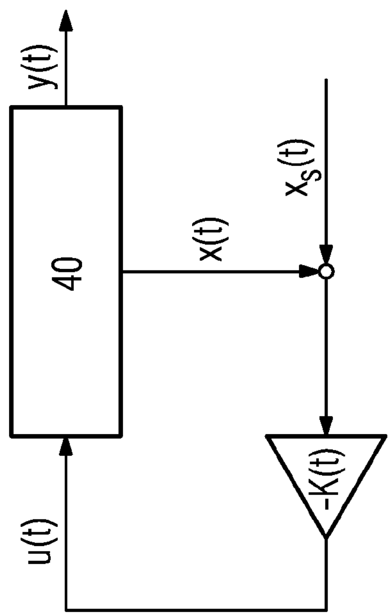


FIG 5

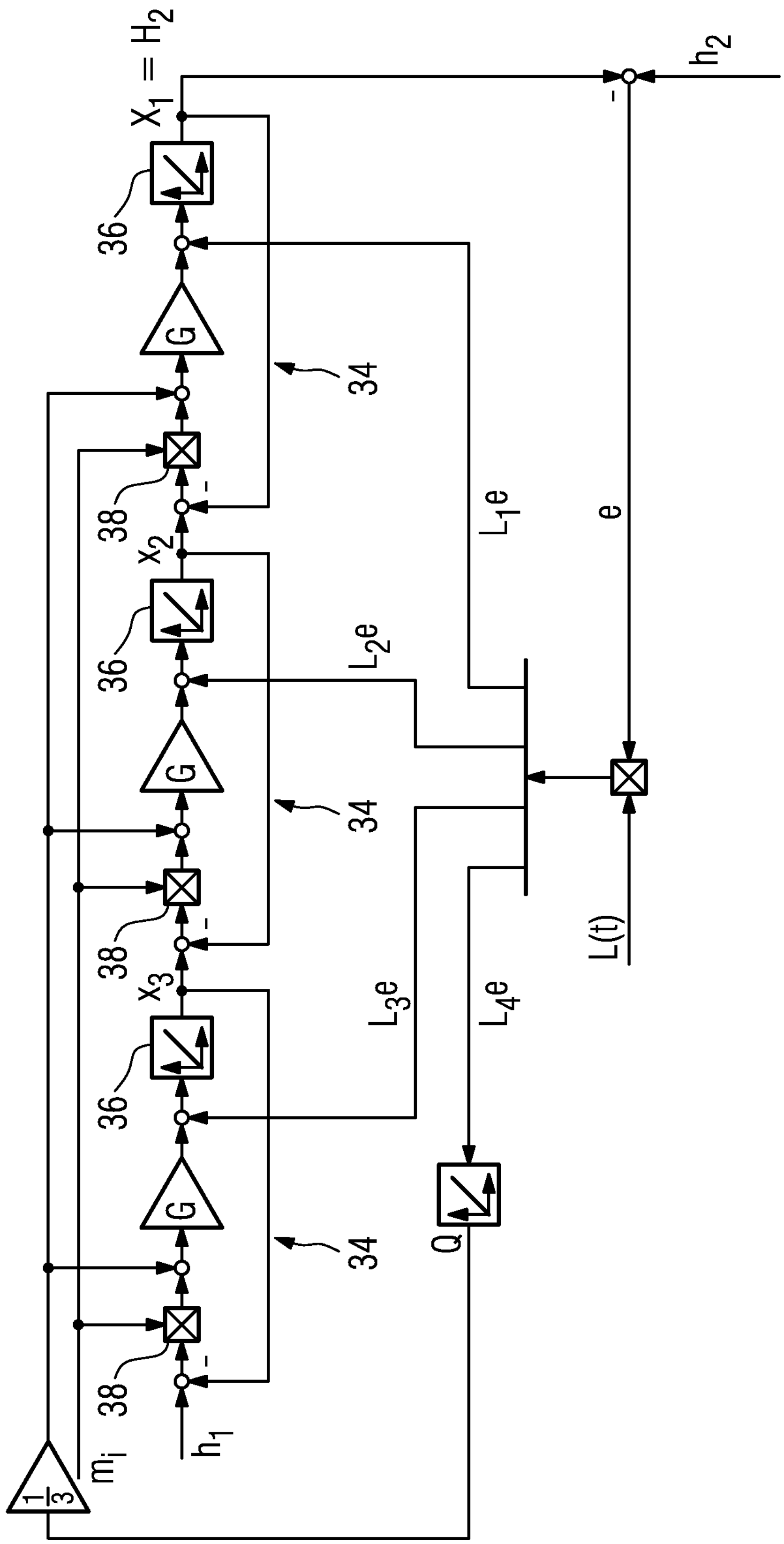
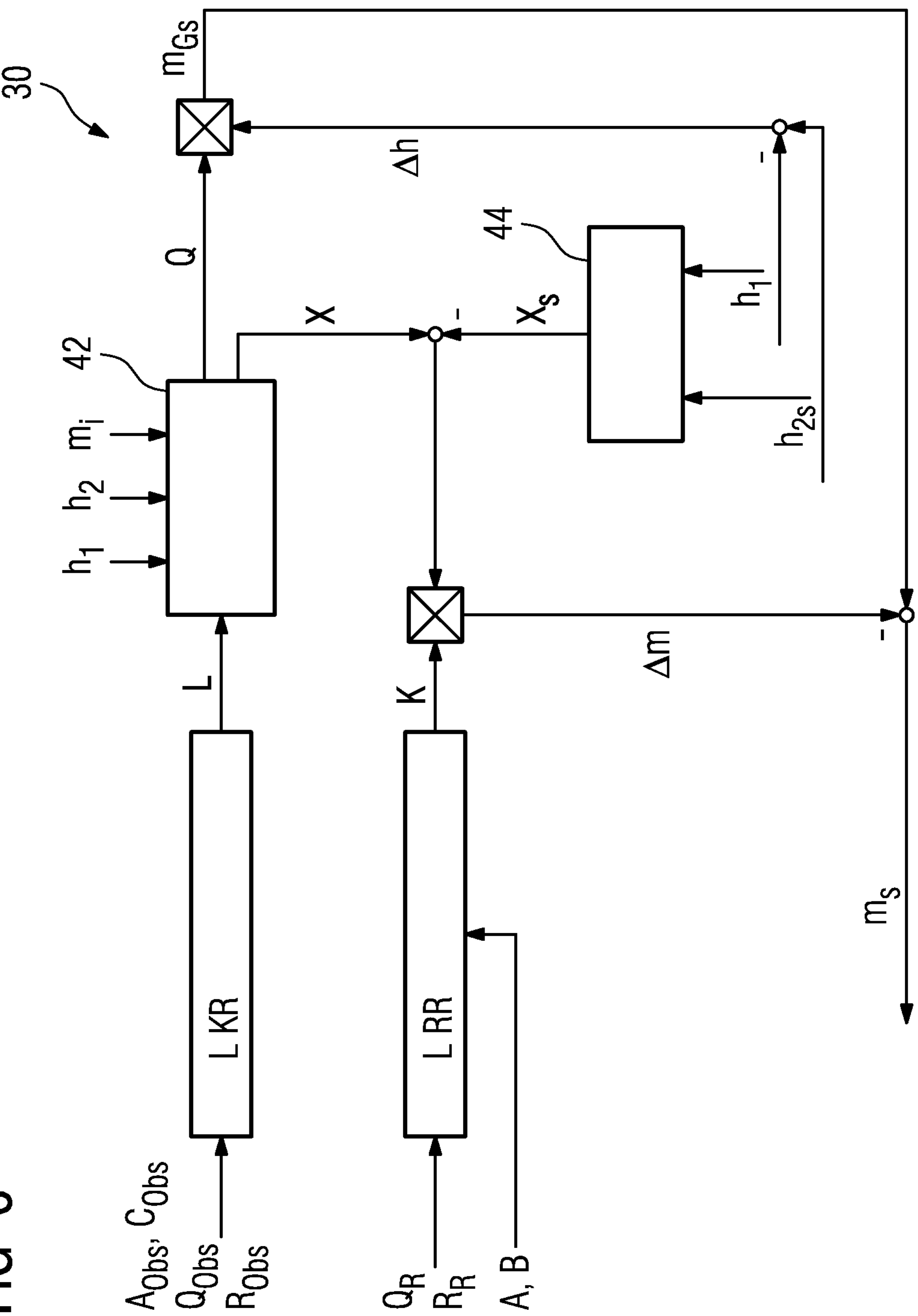


FIG 6


30
m_{Gs}
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m_S
L KR
L RR
A_{Obs}, C_{Obs}
Q_{Obs}
R_{Obs}
Q_R
R_R
A, B

METHOD AND DEVICE FOR REGULATING THE PRODUCTION OF STEAM IN A STEAM PLANT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the US National Stage of International Application No. PCT/EP2010/064376, filed Sep. 28, 2010 and claims the benefit thereof. The International Application claims the benefits of German application No. 10 2009 047 652.0 DE filed Dec. 8, 2009. All of the applications are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[0002] The invention refers to a method for regulating the production of steam from feed water in an evaporator of a steam power plant, in which in a first control system a state controller calculates a plurality of medium states in the evaporator by means of an observer and determines therefrom a feed-water mass flow as a manipulated variable of the first control system.

BACKGROUND OF INVENTION

[0003] The efficiency of a steam power plant increases with the temperature of the steam which is produced in the power plant boiler and with the constancy of the quality of the steam which is provided downstream of the evaporator unit. The production of steam is carried out in a steam power plant as a rule from feed water which is preheated in a high-pressure preheater, also referred to as an economizer, and is then evaporated in an evaporator. During this, the feed water is brought to a high pressure upstream of the high-pressure preheater by means of a feed water pump and is pushed through the high-pressure preheater and evaporator.

[0004] The controlling of the steam temperature downstream of the evaporator is carried out by setting a mass flow of the feed water as a manipulated variable which is introduced into the evaporator. The dynamic response of the steam temperature with this manipulated variable is very sluggish so that an adjustment of the feed-water mass flow to the temperature which is to be controlled comes into effect only after several minutes. In addition, the temperature to be controlled is greatly influenced by numerous disturbances, such as load changes, sootblowing in the boiler, changes of fuel, etc. An accurate temperature control is very difficult to achieve for these reasons.

SUMMARY OF INVENTION

[0005] It is an object of the invention to disclose a method with which the steam temperature can be both accurately and stably controlled.

[0006] This object is achieved by the state controller being a linear-quadratic controller according to the invention. Such a linear-quadratic controller (LQR) can include a linear-quadratic optimum state feedback. In this case, its parameters can be determined in such a way that an effectiveness criterion for the controlling quality can be optimized. As a result of this, a both accurate and stable control can be achieved.

[0007] In this case, the invention is based on the consideration that during state controlling a plurality—which are partially not measurable—of states for determining the manipulated variable, or the controller actuating signal, are fed back. For the present application case, this means that states, such as a temperature, a pressure, an enthalpy or another state variable, at a plurality of points along the evaporator can be used in the algorithm. Since these states, however, are not measurable, there is a requirement for a so-called observer circuit by means of which the required states, which can be characterized by state variables, can be estimated or calculated. The terms "estimate", "calculate" and "determine" are used as synonyms in the following text. The advantage of this concept is that disturbances which act upon the evaporator can be reacted to very quickly and accurately.

[0008] The steam power plant is a plant operated by steam power. It can be, or comprise, a steam turbine, a steam processing plant or any other plant which is operated by the energy of steam. Any system in which water is evaporated can be understood as an evaporator in the following text, wherein a preheater, especially a high-pressure preheater, can be included. The medium can be feed water, steam or a mixture of feed water and steam. A medium state—also referred to as state for simplicity in the following text—can be an energy, a temperature, a pressure, an enthalpy or another state of the medium.

[0009] A control loop, which controls the controlled variable on the basis of an estimated state, for example in the form of a state space representation, can be understood as a state controller in the following text. In this case, a state, or a plurality of states, within the controlled system can be estimated by means of an observer and fed again, that is to say fed back, to the controlled system, or to the controller. The feedback, which together with the controlled system forms the control loop, can take place by means of the observer, which therefore can replace a measuring device. The observer calculates or estimates the states of the system, in this case of the medium in the evaporator, and can include a state differential equation, an output equation and an observer vector. The output of the observer can be compared with the output of the controlled system. The difference can have an effect upon the state differential equation via the observer vector. Furthermore, it is advantageous if the observer works independently of the state controller.

[0010] The state controller expediently uses a state of the steam leaving the evaporator as a controlled variable, such as the steam temperature or the enthalpy of the steam. The feed-water mass flow is advantageously used as a manipulated variable.

[0011] In an advantageous embodiment of the invention, a setpoint value for the feed-water mass flow at a controller of a second control system is transmitted for controlling the feed-water mass flow. This can use the setpoint value as a controlled variable. As a manipulated variable of the second control system, the rotational speed of a feed-water pump, the position of a valve, e.g. in the feed-water line, or another parameter which is suitable for adjusting the feed-water mass flow can be directly or indirectly used.

[0012] It is also advantageous if an enthalpy of the medium is used as a state variable for calculating the medium states. A plurality of states and, as a result of it, a plurality of enthalpies are expediently used. The steam parameters, such as enthalpy and/or pressure and temperature, depending upon the load case, are to be kept at desired values and correspondingly controlled in the case of load changes. The advantages of an enthalpy-state control, that is to say a use of an enthalpy or a product from enthalpy and another variable, such as a water mass flow, as a state, are that state controls achieve a greater control effectiveness and controlling becomes quicker. Also, advantages arise in respect to process engineering: The process is expediently designed so that slightly superheated steam, which lies close to the saturation steam limit, issues at the evaporator exit. With changing pressure, e.g. during variable-pressure operation, the evaporation end point or the saturation steam point changes, which, in consideration of temperature, can lead to wet steam being produced. When the enthalpy is being used as a state variable, the pressure does not have to be explicitly taken into consideration along with it since the enthalpy combines both temperature and pressure in a variable.

[0013] Deviations of the absolute enthalpies from enthalpy setpoint values are advantageously used as state variables. As a result of this, controlling can be carried out at equilibrium at zero and the mathematical problem can be simplified.

[0014] The LQR process relates to linear controlling problems. By converting temperature measured values and temperature setpoint values to enthalpies the mathematical controller problems when using enthalpy states can be linearized and as a result access can be made to a simpler calculation because a linear relationship exist between input and output enthalpies. The conversion is expediently carried out by means of corresponding water/steam table relationships, using, for example, the measured steam pressure.

[0015] When the evaporation system is being controlled by means of state control, there is the problem, however, that the state at the evaporator inlet can certainly be specified by means of an enthalpy, but the enthalpy at the evaporator inlet cannot be adjusted since pressure and temperature of the feed water can be altered to only an insignificant degree and are unsuitable as a manipulated variable. Therefore, the feed-water mass flow is expediently used as a manipulated variable and during the calculation of the states is multiplied by these.

[0016] The feed-water flow, however, acts upon the controlled variable enthalpy at the evaporator inlet and outlet in a non-linear manner so that the controller problem, despite using enthalpies, is non-linear. For solving this problem, a linearization is expediently used when calculating the states. In the present case, it is advantageously assumed that the states move only around a deviation band around an operating point. In these deviation bands, which are expediently predetermined, the system can be assumed as being linear.

[0017] This linearization is practical for a state only for the operating point and the deviation band lying around this. If the actual state migrates from the deviation band then the linearization leads to unfavorable results. It is therefore advantageous to actualize the operating point. This expediently takes place by the operating point being actualized by the inputting of measured values. The measured values are expediently current measured values which were recorded by measuring a currently existing medium parameter, such as pressure, temperature, and the like. The operating point which is taken as a basis for the state calculation can be adapted to a current medium state. Use can be made of a non-linear control system which is linearized by inputting current measured values. As a result of the linearization, a very robust dynamic response is achieved, i.e. the control quality no longer depends upon the current operating point of the plant.

[0018] A further advantageous embodiment of the invention provides that the control system of the state controller includes a matrix equation, for example in the form of a feedback matrix, for the calculation of which measured medium values are used during the steam production. Therefore, the state feedback can be carried out via a matrix equation, for example, the parameters of which are determined at least partially by using current measured values. By using current measured values, for example in an online calculation of the feedback matrix, the controller can be continuously adapted to the actual operating conditions. As a result of this, a load-dependent change of the dynamic evaporator behavior can be automatically taken into consideration. Also, as a result of this step, an increase of the robustness of the control algorithm can be achieved. Due to the fact that the control algorithm is very robust, only very few parameters have to be set when putting into service. The time and cost for putting into service is therefore considerably reduced compared with all previously known methods.

[0019] The matrix equation is advantageously calculated by means of an instrumentation and control technique of the steam power plant. The instrumentation and control technique can be an open-loop control system in this case which controls the steam power plant during its normal operation. In order to keep the mathematical modules of the instrumentation and control technique simple, it is advantageous if the matrix equation is converted into a set of scalar differential equations. A relatively simple integration of the matrix equation can be achieved by means of an integration backward over time. Since in the actual case no information from the future is available, an integration which is equivalent to a backward integration can be achieved if the set of scalar differential equations is integrated with inverse signs, which stably leads to the same steady-state solution.

[0020] In an advantageous embodiment of the invention, the observer is a Kalman filter, which is designed for the linear-quadratic state feedback. The interaction of the linear-quadratic controller with the Kalman filter is referred to as an LQG (Linear-Quadratic-Gaussian) controller or LQG algorithm.

[0021] The observer advantageously calculates the heat which is yielded to the medium in the evaporator. This can be defined as a disturbance variable and used in the control algorithm. In this case, not only the enthalpies, or a parameter along the evaporator derived therefrom, but the disturbance variable can additionally be defined as a state and estimated or determined especially by means of the observer. Disturbances, which directly have an effect upon the evaporator, are expressed by the temperature rise in the evaporator changing. By means of such observing of the disturbance variables, a very fast, accurate, but at the same time robust, reaction to corresponding disturbances is possible.

[0022] The invention also refers to a device for regulating the production of steam from feed water in an evaporator of a steam power plant, having a control system which comprises an observer and a state controller which is configured for calculating a plurality of medium states in the evaporator by means of an observer and for determining therefrom a feed-water mass flow as a manipulated variable of the first control system.

[0023] It is proposed that the state controller is a linear-quadratic controller. An accurate and stable control can be achieved.

[0024] The device is advantageously designed for executing one, a plurality, or all of the method steps proposed above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The invention is explained in more detail based on exemplary embodiments which are depicted in the drawings.

[0026] In the drawing:

[0027] FIG. **1** shows a detail from a steam power plant with an evaporator,

[0028] FIG. **2** shows a schematic arrangement of a control cascade,

[0029] FIG. **3** shows a model of the evaporator,

[0030] FIG. **4** shows a linear system model as a basis for a controller design,

[0031] FIG. **5** shows a structure of an observer and

[0032] FIG. **6** shows an overview of a controller construction.

DETAILED DESCRIPTION OF INVENTION

[0033] FIG. **1** shows a schematic view of a detail from a steam power plant with a steam power plant which comprises a steam turbine **2**, a boiler **4**, and evaporator **6** and a superheater **8**. The boiler **4** gives off heat to the evaporator **6**, into which flows feed water **10** which is pumped by a feed-water pump **12** to the evaporator **6** and which absorbs the heat. By means of a valve **14**, the feed-water flow can be controlled.

[0034] As a result of the absorption of heat, the feed water **10** is evaporated in the evaporator **6**, and the resulting steam **16** flows on to the superheater **8** in order to be superheated there to form live steam and then to be fed to the steam turbine **2**. For controlling the temperature of the steam **16**, the feed-water flow is controlled by means of the valve **14** and/or the feed-water pump **12**, wherein a setpoint flow of the feed water **10** upstream of the evaporator **6** is the controlled variable and a valve position and/or a pump output is the manipulated variable.

[0035] A temperature sensor **18** and a pressure sensor **19** measure the temperature T_w and the pressure p_w respectively of the feed water **10** and a sensor **20** measures the actual feed-water flow m_i upstream of the evaporator **6**.

[0036] A temperature sensor **22** and a pressure sensor **24** measure the temperature T_D and the pressure p_D respectively of the steam **16** downstream of the evaporator **6**.

[0037] The evaporator **6** can include a preheater, which is not shown. This, however, is insignificant for the invention and in the following text a system consisting of an evaporator having a preheater is also understood by the term "evaporator".

[0038] The evaporator **6** is a once-through steam generator, in which the passage of water or steam flow is forced by the feed pump **12**. The feed water **10** in this case can flow consecutively through a feed-water preheater and the evaporation system, especially also the superheater **8**, so that the heating of the feed water **10** up to saturation steam temperature, the evaporating and the superheating are carried out continuously in one pass. No drum is required in this case. The evaporator **6** is especially part of a Benson boiler. This can be operated in the supercritical range, wherein the feed water **10** can be brought to a pressure of over **230** bar by the feed-water pump **12**. The feed-water mass flow can be controlled in dependence upon load.

[0039] In FIG. **2**, a control cascade with a first or external control system **26** and a second or internal control system **28** is schematically shown. The external control system **26** comprises a linear-quadratic controller **30**, especially an LQG controller. The measured actual feed-water flow m_i, the measured temperature T_w of the feed water **10**, the measured temperature T_D and the measured pressure p_D of the steam **16** and also the setpoint temperature T_S of the steam **16** downstream of the evaporator **6** are fed to this controlled as input variables. The setpoint temperature T_S of the steam **16** is the controlled variable of the controller **30**. The setpoint mass flow m_S of the feed water **10** is issued by the controller **30** as a manipulated variable.

[0040] This setpoint mass flow m_S is passed to a control loop **32** of the internal control system **28** as a setpoint value for the controlled variable.

[0041] The measured feed-water flow m_i is the controlled variable of the control loop **32**. The control loop **32** has a position of the control valve **14** and/or an output of the feed-water pump **12** as a manipulated variable.

[0042] The controller **30** does not directly influence the process via an actuating element, but transmits the setpoint value m_S for feed-water mass flow to the subordinated control loop **32**, with which it therefore forms a cascade consisting of an external control system **26** and an internal control system **28**. The measured temperature T_W and the pressure p_W of the feed water **10** upstream of the evaporator **6** are required by the controller **30** as additional information in order to determine the specific enthalpy h_i of the feed water **10** upstream of the evaporator **6**. The enthalpy h_i can be determined via the water-steam table. From the steam pressure p_D and the steam temperature T_D, the specific enthalpy h_2 of the steam **16** downstream of the evaporator **6** is calculated.

[0043] FIG. **3** shows a model of the evaporation system in the evaporator **6** which is split into three delay elements **34** of the first order so that a delaying behavior of the third order is created in its series connection. The three delay elements can be PT_1 elements in each case which are realized by means of a negatively back-feeding integrator **36**. The time constants of these delay elements are dependent upon load and become larger with falling load, and vice versa. Depending upon each delay element **34**, a state x_i is specified, with i=1, 2, 3, wherein the state x_1 specifies the output enthalpy h_2. An input state is characterized by the input enthalpy h_1 of the evaporation system. The two mean states x_2, x_3 are calculated and not measurable states, which are estimated by means of the observer. All the states x_i are time-dependent variables.

[0044] Feed water **10** with the enthalpy h_1 flows into the evaporation system. In principle, this enthalpy h_1 could be used as a manipulated variable of the first or external control system **26** since with enthalpies instead of temperatures the assumption of a linear behavior of the evaporation system is justified. However, the enthalpy h_1 can hardly be adjusted since the pressure p_W and the temperature T_W of the feed water are hardly adjustable in sufficient measure and fast enough in order to be able to serve as a manipulated variable.

[0045] For solving this problem, the actual mass flow m_i of the feed water **10** is multiplied by the enthalpy h_1 so that an output is created from the product. This is simply adjustable by means of the feed-water pump **12** and/or by the valve **14** and can therefore be used as a manipulated variable. Since the enthalpy h_1 is basically constant, the actual mass flow m_i of the feed water **10** alone can be used as a manipulated variable.

[0046] Accordingly, in the dynamic model, which is shown in FIG. **3**, m_i is multiplied by the present enthalpy in each case in each delay element **34**, as is shown by multipliers **38**, so that an output is formed as a variable. Added to these outputs, in each of the three delay stages **34**, is ⅓ of an assumed firing output Q_F in each case so that the overall firing output Q_F is introduced into the dynamic model of the overall evaporation system.

[0047] This output sum is multiplied by a time function element G which includes a delaying time constant in the denominator, e.g. the delaying time constant t of a PT_1 element at full load. Also, $G=(mt)^{-1}$ includes a feed-water mass flow m in the denominator, e.g. that at full load, so that according to the time function element G a specific enthalpy per time is available. This is integrated in each delay element **34** by means of the integrators **36** in each case so that an enthalpy is available as a result. This is subtracted from the input enthalpy of the respective delay element **34**. It is produced as equations for the states x_i according to the three delay elements **34**:

$$\dot{x}_1 = \frac{1}{mt}\left(\frac{Q_F}{3} + m_1(x_2 - x_1)\right)$$

$$\dot{x}_2 = \frac{1}{mt}\left(\frac{Q_F}{3} + m_2(x_3 - x_2)\right)$$

$$\dot{x}_3 = \frac{1}{mt}\left(\frac{Q_F}{3} + m_3(h_1 - x_3)\right).$$

[0048] The state x_1 is the output enthalpy h_2. It is to be seen that a state x is constant, that is to say its derivative is zero, if the enthalpy difference across a delay element **34** multiplied by the feed-water flow m_i in addition to the third of the firing output Q_F is zero, i.e. is inversely proportional to the enthalpy difference times feed-water mass flow m_i and $Q_F/3$. In this case, the system is in a steady state and therefore in equilibrium of feed water supply and heating.

[0049] These three equations are not linear since the states x_i are multiplied by the feed-water flow m_i. This is correct since the changeable yield of firing heat is to be produced non-linearly. This non-linearity of the firing heat is simulated in the state model—more precisely in the observer which is described in more detail in FIG. **5**—by the multiplication of states x_i with the feed-water flow m_i. As a result of this, the change of the feed-water flow m_i stands as a corresponding variable for compensation of the changeable firing power (Q_F). Consequently, the feed-water flow m_i is used as a manipulated variable of the first control system **26**.

[0050] In order to be able to use an LQ regulator or an LQG controller, this non-linear equation system must be converted by means of linearization into a linear system. To this end, the states and the input are first expressed as a sum of steady-state values and the deviations around these steady-state values. The stable states result from the non-linear system equations by the time derivates of the states being set to zero. This means that any time change of the states in the system no longer takes place and these are in a steady-state neutral position. The stable state is additionally defined as a setpoint state.

[0051] Correspondingly applicable to the stable state is:

$$h_2 = h_1 + \frac{Q_F}{m_s},$$

[0052] wherein m_s is the desired feed-water mass flow with which the stable state is achieved, in which state the feed-water flow is just large enough for it to absorb the heat feed Q_F with constant output enthalpy h_2 downstream of the evaporator. By conversion, the manipulated value m_s of the first control system is obtained:

$$m_s = \frac{Q_F}{h_2 - h_1}.$$

[0053] It is then further assumed for the linearization that the states and the input move only around a deviation band around an operating point. Therefore, the system can be assumed as being linear at this operating point. As operating points, setpoint states are selected, with u representing the input of the system:

$$x_i = x_{i,soll} + \Delta x_i$$

$$u = m_s + \Delta u.$$

[0054] Under the assumption that the products of the deviations, that is to say $\Delta u \cdot \Delta x_i$, are very small and can be disregarded, the following linearized state equation is produced:

$$\Delta\dot{x}_1 = \frac{1}{m \cdot T}\left(\frac{Q_F}{h_{2s} - h_1} \cdot (\Delta x_2 - x_1) - \frac{h_{2s} - h_1}{3} \cdot \Delta u\right)$$

$$\Delta\dot{x}_2 = \frac{1}{m \cdot T}\left(\frac{Q_F}{h_{2s} - h_1} \cdot (\Delta x_3 - x_2) - \frac{h_{2s} - h_1}{3} \cdot \Delta u\right)$$

$$\Delta\dot{x}_3 = \frac{1}{m \cdot T}\left(\frac{Q_F}{h_{2s} - h_1} \cdot (\Delta x_3) - \frac{h_{2s} - h_1}{3} \cdot \Delta u\right)$$

$$y = x_{1s} + \Delta x$$

[0055] Therefore, an output offset x_{1s} remains and is added directly to the output.

[0056] Consideration is to be given to the fact that the differential equations apply only to small deviations around the operating point. The operating point is defined in this case by the load-dependent setpoint enthalpy downstream of the evaporator $h_{2S}=x_{1S}$. The operating points are therefore to be adjusted based on current measurements. This is effected by variables in matrices A and B, which result from the basic equations of the linearized model:

$$\dot{x}(t) = A(t) \cdot x(t) + B(t) \cdot u(t)$$

$$y(t) = C(t) \cdot x(t) + D(t) \cdot u(t),$$

[0057] wherein the input u(t) in many cases does not have a direct effect upon the output y(t) and therefore D(t) is zero. In this way, the matrices A and B change with the load or with the current setpoint value of the enthalpy h_{2S} downstream of the evaporator **6**. This means that the dynamics are adapted to the current load case and the process is therefore adjusted over the entire load range.

[0058] FIG. **4** shows a basic schematic diagram of a state controller. A state controller is a linear controller in which actual states of a process **40** are compared with the corresponding setpoint states and the resulting difference multiplied by a factor is applied to the process. If applied specifically to the evaporation system, the calculated actual states x(t) are compared with predetermined setpoint states $x_{soll}(t)$. Indicated here, and in the following text, by the bold lettering is a vector or a matrix which in the present case includes the three states x_1, x_2, x_3 and Q_F as a fourth variable or the corresponding setpoint variables. As a factor, a feedback vector K(t) with the variables K_1, K_2, K_3 can be used. u(t) is the manipulated variable and y(t) is the output variable of the process.

[0059] In order to be able to implement this controlling principle of the state feedback, the current values of the actual states x(t) have to be known and made available. Now, however, in actual processes it is not always possible for all the states to be measured. In the present system, the states x_2, x_3 and Q_F, for example, cannot be measured. The reason for this lies in the fact that the accurate point of the two states inside the evaporator cannot be determined. The first two delay elements of the model only reproduce the time dynamic of the process. This, however, says nothing about the local dynamic, which is why a measuring point for the temperature cannot be determined. Furthermore, wet steam is present in the case if the states x_2 and x_3, which makes a determination of its enthalpy additionally more difficult. Therefore, another way must be found in order to determine the states.

[0060] This state determination, or state estimation, can be achieved by means of a state feedback. Controlling per state feedback is a purely proportional control. This means that the states only multiplied by a factor are negatively fed back. This type of feedback can lead to a control deviation, which means that predetermined setpoint values are not achieved. In order to ensure that these setpoint values are achieved, the implementation of an integral-action component is advisable. In a simple embodiment of a state feedback, the implementation of an integral-action component is achieved via a circuit in which the control difference between output value and command value is fed back via an integrator and also applied to the manipulated variable.

[0061] In the present case, however, another way is selected, specifically the implementation of an observer or disturbance-variable observer which is a state estimator. This includes an integral-action component in order to determine the states, as a result of which the remaining control deviation disappears. Furthermore, it has the advantage that a disturbance variable influencing the process can be estimated by it. This allows a faster controlling of the process since the dimension of the disturbance variable becomes directly visible in an estimated state. Without the disturbance-variable observer, the disturbance variable and its influence upon the process can be seen only indirectly via the changes of the individual states.

[0062] In the present system, there two disturbance variables, for which an estimate by means of disturbance-variable observers is a possibility. For one thing, this is the fluctuation of the firing heat output Q_F, which is fed to the evaporator **6**, and for another thing, this is the fluctuation of the enthalpy h_1 upstream of the evaporator **6**. The fluctuation of h_1, however, can be determined via the water-steam table from the measurement of pressure and temperature and therefore does not necessarily have to be estimated.

[0063] A non-measurable disturbance variable is the fluctuation in the firing heat output Q_F, which has a great influence upon the present process. The fluctuation is induced as a result of varying calorific values of the fired primary energy carrier (coal, oil or gas). Therefore, it would make sense to define the firing heat output Q_F as a new estimated state $Q=X_4$. The dynamic is selected for $dX_4/dt=0$. With this information, an extended state-space form can be deduced for the observer.

[0064] Described in the following text is the observer, which is also referred to a disturbance observer or disturbance-variable observer since it observes the disturbance. FIG. **5** shows the structure of the disturbance-variable observer. The model of the evaporation system in the evaporator **6** corresponding to FIG. **3** is to be seen, but with small changes. Thus, the states X_1, X_2 and X_3 stand for the estimated states, wherein the state $X_1=H_2$ also specifies the estimated enthalpy H_2 at the outlet of the evaporator **6** and not the actual and measurable enthalpy h_2. Despite the large letter, a specific enthalpy is indicated by H_2. This estimated enthalpy H_2 is compared with the enthalpy h_2, which is measured via pressure and temperature, and the difference, that is to say the observer error e, is applied to the observed, that is to say calculated, process, but not directly but as a product with an observer correction L, that is with the so-called observer vector. This is a four-dimensional vector, that is to say includes four components, L_1, L_2, L_3 and L_4, which are multiplied in each case by the observer error—by a scalar.

[0065] The reconstruction of the system states is carried out by the calculation of a dynamic system model parallel to the real process. The deviation between measured variables from the process and the corresponding values which are determined by the system model is the observer error e. The individual states of the system model are corrected in each case by the observer error which is weighted by L_i, as a result of which this is stabilized.

[0066] In each of the three delay elements **34**, the corresponding correction component is applied to the observer error with the aim of achieving the balanced state, that is to say the state of equilibrium. The estimated firing output Q—in contrast to the actual firing output Q_F—is used in this case as a fourth component X_4 of the state vector X, and the correction component L_4 with the observer error e is correspondingly applied to the estimated firing output Q.

[0067] The observer correction L, also referred as feedback vector, is to be calculated in this case so that the observer error is corrected, that is to say disappears. The observer can be realized as a non-linear observer since the input variable m_i is measurable. The non-linear system can therefore be transcribed directly into a state space representation. This is generally known under the term of extended Lunenburg observer or extended Kalman filter (EKF). A non-linear model is computed parallel to the process. The feedback vector L(t), which stabilizes the observer error, is, however, produced from a linear model. The linearization is carried out by using the measured feed-water mass flow m_i in each case.

[0068] Controlling, in the first control system **26**, involves a linear-quadratic controller, especially an LQG controller **30**. An LQG controller is a common implementation of a linear-quadratic (LQ) regulator and a Kalman filter. An LQ regulator can be a so-called optimum regulator upon which a quadratic effectiveness criterion is based. With this effectiveness criterion and an algorithm, a feedback vector K(t) of the state control is calculated. A Kalman filter is a special observer or state estimator, in which both measurement inaccuracies at the output (measured noises) and modeling inaccuracies (process noises) can be taken into consideration or modeled together. By means of an algorithm, the additional feedback vector L(t) can be determined for the observer.

[0069] Such an LQG controller is shown in FIG. **6**. Transmitted to the LQG-controller module, as inputs, are the measured enthalpy h_2 downstream of the evaporator **6**, the current feed-water mass flow m_i, the enthalpy h_1 upstream of the evaporator **6** and the setpoint enthalpy h_{2s} downstream of the evaporator **6**, which can be calculated from the setpoint temperature of the steam **16** and its pressure. Also, calculation matrices A, B, A_{Obs}, C_{Obs}, R_{Regler}, Q_{Regler}, R_{Obs} and Q_{Obs} are transmitted.

[0070] A, B, A_{Obs}, C_{Obs} result from the linearized system representation, R_{Regler}, Q_{Regler}, R_{Obs} and Q_{Obs} include weighting factors for adjusting the desired dynamic response (sensitivity, aggressiveness).

[0071] The output is the delivered feed-water mass flow m_s, which is calculated from the difference of the disturbance-variable injection m_{Gs} and the state deviation Δm. In this case, consideration is to be given to the fact that the disturbance-variable injection m_{Gs} is calculated with the estimated firing heat output Q. This disturbance-variable injection In_{Gs} is pre-controlled in other concepts via the coal mass flow, but here it is calculated directly via the estimated firing heat output Q. The state variable Δm, however, is the result of the state control.

[0072] The LQG controller **30** comprises the observer **42**, which is shown in FIG. **5**, to which are fed, as input variables, the measured input enthalpy h_1, the measured output enthalpy h_2 and the measured feed-water flow m_i. The feedback vector L(t) is additionally fed to the observer for compensating the observer error e. The feedback vector L(t) is calculated by means of a solver L KR of the Kalman-Riccati differential equation, to which are transmitted the calculation matrices A_{Obs}, C_{Obs}, R_{Obs}, and Q_{Obs}.

[0073] As an additional module, the LQG controller **30** comprises a module **44** for calculating the setpoint states X_s which are required for the state feedback. The inputs into the module **44** are the input enthalpy h_1 and the setpoint output enthalpy h_{2s}. For the state feedback, however, the LQG controller **30** does not use the states X(t) directly, but uses the deviation of the states from their operating point, that is to say from the setpoint states $X_s(t)$. As state variables to be additionally used, therefore, deviations of the absolute enthalpies from enthalpy setpoint values are provided. The deviation of each state x_i from its operating point X_{is} becomes zero at the operating point. If the weighted sum $X(t)-X_s(t)=0$, then no controller intervention takes place. Therefore, the states X(t) are compared directly with the setpoint states $X_s(t)$ and the difference is used in addition.

[0074] The LQG controller **30** also comprises a solver L RR for the controller Riccati differential equation which calculates the feedback vector K(t). To this are transmitted the calculation matrices A, B, R_{Regler} and Q_{Regler}. The use of the feedback vector K(t) is similar to that of the feedback vector L(t). Whereas the aim of L(t) is to compensate the observer error e by multiplication and feedback, the feedback vector K(t) is multiplied by a state error and serves for state control, that is to say for a fluctuation correction for compensating the control error of the LQG controller **30**. From the difference of the state vector X(t) with the components X_1, X_2 and X_3 and the also three-dimensional state vector for the setpoint states $X_s(t)$, the dynamic control component of the LQG controller **30** is produced, with which the state control is executed:

$$K_1(X_1-X_{1s})+K_2(X_2-X_{2s})+K_3(X_3-X_{3s})=\Delta m.$$

[0075] The dynamic control component, or the state deviation Δm, is a component of the feed-water mass flow which is compared with the calculated disturbance-variable injection m_{Gs}, that is to say which supplements the disturbance-variable injection. The disturbance-variable injection m_{Gs} is a calculated setpoint mass flow, also referred to as basic setpoint value, which results from the quotient of the estimated firing output Q and the enthalpy difference Δh, resulting therefrom, across the evaporation system.

[0076] The dynamic control component Δm is negatively added to this setpoint mass flow, or basic setpoint value m_{Gs}, so that the setpoint feed-water mass flow m_s is created, being the manipulated variable of the first control system **26**. This setpoint mass flow m_s is transmitted as a manipulated variable to the second control system **28**, which adjusts this setpoint mass flow m_s by means of a suitable component, or a plurality of suitable components, e.g. the feed-water pump **12** and/or the valve **14**.

[0077] The calculation of the two feedback vectors, specifically the observer correction L(t) and the vector K(t) for the control correction, is known to the person skilled in the art who is familiar with thermodynamic state calculations. For this purpose, the filter problem is to be solved with the solver L KR of the Kalman-Riccati differential equation and the Controller problem is to be solved with the solver L RR for the controller Riccati differential equation. The solving of the LQ controller problem is carried out via the matrix-Riccati DGL:

$$\frac{dS(t)}{dt} = A^T(t)\cdot S(t) + S(t)\cdot A(t) - S(t)\cdot B(t)\cdot R_{Regler}^{-1}\cdot B^T(t)\cdot S(t) + Q_{Regler}.$$

[0078] With the solution matrix S(t), the controller feedback matrix K(t) can also be calculated:

$$K(t)=R_{Regler}{}^{-1}\cdot B^T(t)\cdot S(t).$$

[0079] The same applies to the solving of the Kalman filter problem, which is also solved via a matrix-Riccati DGL:

$$\frac{dP(t)}{dt} = A(t)\cdot P(t) + P(t)\cdot A^T(t) - P(t)\cdot C^T(t)\cdot R_{Obs}^{-1}\cdot C(t)\cdot P(t) + Q_{Obs}.$$

[0080] In this case, the observer feedback matrix L(t) can be calculated by means of the solution matrix P(t):

$$L(t)=P(t)\cdot C^T(t)\cdot R_{Obs}{}^{-1}.$$

[0081] P and S are the matrices according to which the matrix-Riccati equations are solved and in this case represent only intermediate variables in order to determine L and K.

1-10. (canceled)

11. A method for regulating the production of steam from feed water in an evaporator of a steam power plant, comprising:

calculating a plurality of medium states in an evaporator by a state controller by means of an observer; and

determining from the plurality of medium states a feed-water mass flow as a manipulated variable,

wherein the state controller is a linear-quadratic controller.

12. The method as claimed in claim **11**,

wherein a setpoint value for the feed-water mass flows is transmitted to an additional controller for controlling the feed-water mass flow.

13. The method as claimed in claim **11**, wherein an enthalpy of the medium is used as a state variable for calculating a medium state.

14. The method as claimed in claim **13**, wherein deviations of the absolute enthalpies from enthalpy setpoint values are used as state variables.

15. The method as claimed in claim **11**,

wherein a non-linear control system is used, and

wherein the control system is linearized within a predetermined deviation band around an operating point.

16. The method as claimed in claim **15**, wherein the operating point is actualized by using measured values.

17. The method as claimed in claim **15**, wherein the control system of the state controller includes a matrix equation, for the calculation of which use is made of medium values which are measured during the steam.

18. The method as claimed in claim **11**, wherein the observer is a Kalman filter which is designed upon a linear-quadratic state feedback.

19. The method as claimed in claim **11**, wherein the observer calculates the heat which is yielded to the medium in the evaporator.

20. A device for regulating the production of steam from feed water in an evaporator of a steam power plant, comprising:

a control system which includes an observer and a state controller which is preconfigured to calculate a plurality of medium states in an evaporator by means of the observer and to determine therefrom a feed-water mass flow as a manipulated variable of the control system,

wherein the state controller is a linear-quadratic controller.

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