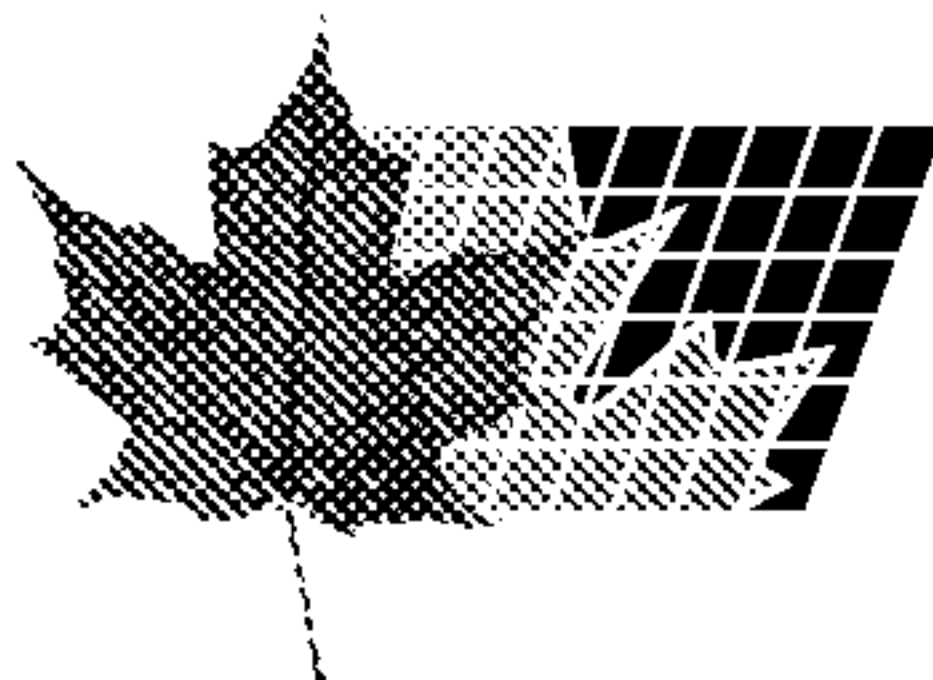




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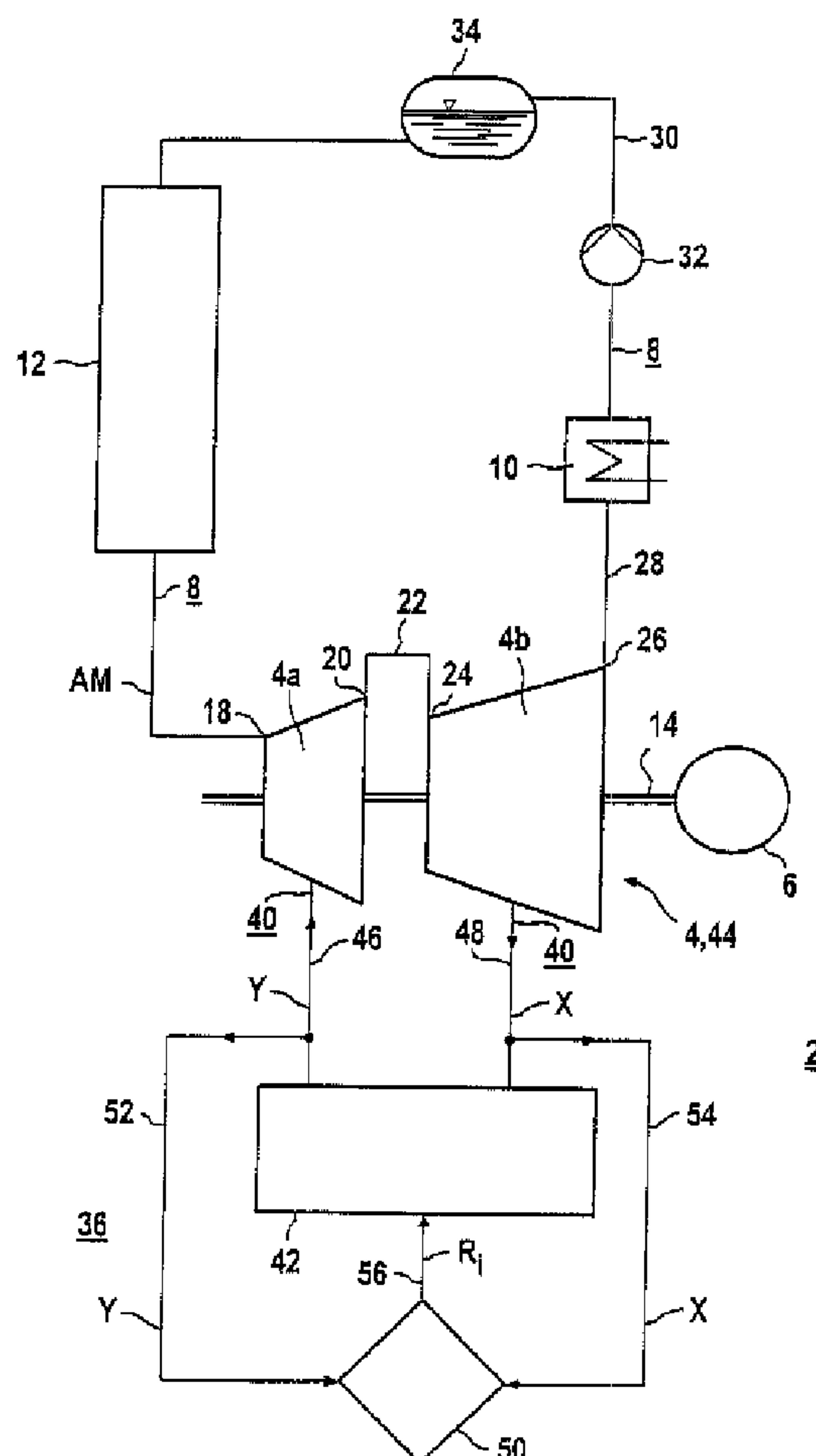
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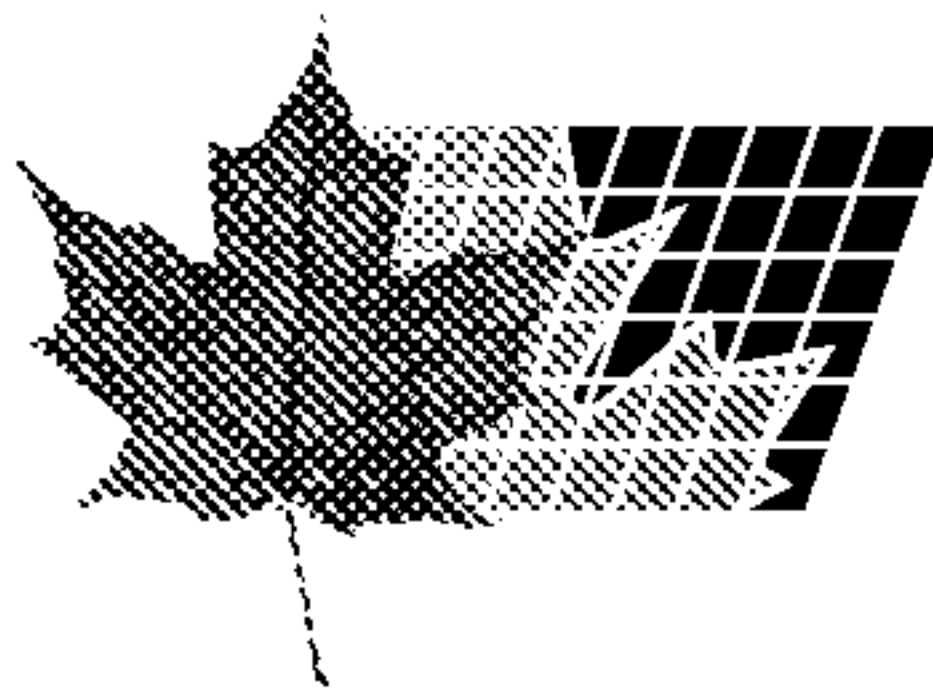
(54) **PROCEDE POUR ACTIONNER UN SYSTEME DE
REGULATION ET DISPOSITIF POUR METTRE LEDIT
PROCEDE EN OEUVRE**

(54) **METHOD FOR OPERATING A CONTROL SYSTEM AND
DEVICE FOR CARRYING OUT SAID METHOD**



(57) L'invention concerne un système de régulation (36) comportant un régulateur (42) qui agit sur un système asservi (44) en fonction d'une variable réglante (Y) et d'un nombre de paramètres du régulateur (R_i), dont le

(57) A control system (36), comprising a controller (42) that acts upon a controlled system (44) according to a manipulated variable (Y) and a number of controller parameters (R_i), guaranteeing a predetermined control



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but est de garantir un comportement prédéterminable en régulation dans tous les états de fonctionnement du système asservi (44). A cet effet, lorsque le régulateur (42) est en marche, le comportement en transmission du système asservi (44) est déterminé par comparaison entre une transformation par ondelettes du comportement temporel de la variable réglante (Y) et une transformation par ondelettes du comportement temporel d'une variable réglante (X) du régulateur (42) du système asservi (44), dans une fenêtre temporelle prédéterminable. Un moment associé à chaque transformation par ondelettes est détecté et tel ou tel paramètre du régulateur (R_i) est ajusté, en fonction du comportement en transmission déterminé.

quality and a predetermined control response during all operational states of said controlled system (44). When the controller (42) is operated, the response characteristic of the controlled system (44) is determined by comparing the wavelet transformation of the time response of the manipulated variable (Y) with a wavelet transformation of the time response of a controlled variable (X) of the controller (42) of the controlled system (44) in a predetermined time slot, whereby a moment in time associated with each wavelet transformation is detected and the respective controller parameter (R_i) is adjusted according to the response characteristic thus determined.

Abstract

Method for Operating a Control System and an Apparatus for

Using this Method

A control system (36) with a controller (42) is intended to ensure a specified control quality and a specified control behaviour for all the operating states of the controlled system (44) as a function of a manipulated variable (Y) and a number of control parameters (R_i). To this end, when the controller (42) is operating, the transmission behaviour of the controlled system (44) is determined by a comparison of a wavelet transformation of the behaviour over time of the manipulated variable (Y) with a wavelet transformation of the behaviour over time of a control parameter (X) of the controller (42) of the controlled system (44) in a specified window of time, a point in time that is associated with the particular wavelet transformation is identified, and the or each control parameter (R_i) is adjusted as a function of the transmission behaviour that has been identified.

Method for Operating a Control System and an Apparatus for
Using this Method

The present invention relates to a method for operating a control system with a controller, which operates with a manipulated variable on a controlled system as a function of a number of control parameters. The present invention also relates to a control system for use with this method.

In the normal course of events, a technical facility incorporates a number of control systems that are intended to ensure that operation of the facility is as far as possible uninterrupted. Such a control system usually operates on an associated controlled system so that a closed control loop is formed. For example, a sensing device measures the control parameter that is to be observed. In the event that this deviates from a predetermined set point as the result of interference, the controller of the control system acts with its manipulated variable on an actuator that is associated with the controlled system. In addition to the deviation of the measured control parameter from the predetermined nominal value,

the manipulated variable that is supplied from the controller depends on a number of control parameters by which, for example, reaction speed and/or the precision with which the controller can be adjusted.

Because of a lack of system information about the actual dynamic behaviour of the controlled system, adjustment of the control parameters-the so-called parametrization-of such a controller is usually based on empirical data that is obtained, for example, when the facility is started up. The control parameters for the particular controller are determined on the basis of these data, and these are preserved unchanged during further operation. However, in such a control system, a change in the characteristics of the controlled system can result in impairment of the quality of control, and in particular in impairment of the precision of adjustment and/or the reaction speed of the controller. Changes in the characteristics of the controlled system can occur, in particular, as a result of changes to the load point or as a result of changes to the machine characteristics, such as those occasioned by modification or dirt.

O. Vollinger, *Regelungstechnik* [Control Technology], 6th Ed., Hüttich Buchverlag, Heidelberg, 1990, Chapter 1.6, pp.

14 - 20, describes an adaptive control method in which the variable system behaviour brought about by varying parameters is first identified in a suitable manner, after which the control parameters are fixed with the assistance of the information so obtained. In addition, US 6,610,843 describes the use of wavelet transformations to describe controlled systems; this is also done in JP 09120303. DE 34 45 791 also describes a steam-turbine generator system in which the steam pressure and steam temperature can be controlled.

The article titled "Self-tuning control of nonlinear systems using neural network adaptive frame wavelets," which appeared in the *1997 International Conference on Systems man [sic] and cybernetics*, Vol. 2, 12 October 1997, pp. 1017 - 1022, describes a special neural network by which a dynamically changing system operation can be controlled. According to the mathematical model that is presented in this paper, a wavelet transformation of an input function is performed for the process.

This wavelet transformation is the basis for estimating an output function. By comparing the estimated output function with a measured output function, the iteration steps of the estimated output function are optimized so as to permit appropriate control of the facility.

Thus, it is the objective of the present invention to describe a method for operating a control system of the type described heretofore, in which the quality of control and the control behaviour of the control loop are preserved even if the characteristics of the controlled system are modified. In addition, a control system for implementing this method will also be described.

With reference to the method, according to the present invention, this has been achieved in that, during operation of the controller, the transmission behaviour of the controlled system is determined by comparing a wavelet transformation of the behaviour over time of the manipulated variable with a wavelet transformation of the behaviour over time of a control parameter of the controller of the controlled system within a predetermined time window, a point in time associated with the particular wavelet transformation being identified, each controller parameter being adjusted as a function of the transmission behaviour that has been identified.

The present invention proceeds from the idea that, given a change in the characteristics of the controlled system, the quality of control and control behaviour of the control loop will be preserved if the change in behaviour of the controlled

system is identified and used to adapt the control parameters. Its transmission behaviour is particularly well-suited for describing the controlled system. A change in the transmission behaviour of the controlled system is intended to have an effect on the control parameters. In order to avoid any impairment of the functionality of the controlled system, when this is done the control parameter(s) is/are readjusted as a function of the transmission behaviour of the controlled system that has been identified, this being effected in the manner of an online intervention during operation of the controller.

Identification of the transmission behaviour of the controlled system during operation of the control system is effected by means of a wavelet transformation. When this is done, the progress over time of the manipulated variable and of a control variable of the controller of the controlled system are analyzed in the same way in a predetermined window of time, using a wavelet transformation. The method of wavelet transformation is described, for example, in *Automatisierungstechnik* [Automation Technology], Issue No. 2, 1996, R. Oldenbourg Verlag, pp. 64 - 66. Using this analysis, it is possible to establish whether or not a specified component of the manipulated variable is contained in the control parameter. This is done by breaking down the manipulated variable or the control parameter into

components of a so-called wavelet family in a predetermined time window at a specific time. A wavelet family is a family of mathematical functions that are generated from a single output function by mathematical extension and/or displacement. The mathematical extension and/or displacement of the functions signifies adaptation to different frequency and amplitude elements of the signal that is to be examined. When this is done, based on the presence of specified wavelet components in the framework of the specified time window, it is possible to determine the time at which the value to be examined has specific properties.

The transmission behaviour of the controlled system is determined by comparison of the wavelet transformation of the behaviour over time of the manipulated variable with the wavelet transformation of the behaviour over time of the control parameter. To this end, the results of analysis of the manipulated variable and of the control parameter are passed to a differential equation system. The construction of the differential equation system serves to determine a mathematical function that characterizes the transmission behaviour of the controlled system.

With every determination of the transmission behaviour, a point in time that is associated with the wavelet transformation is identified. This means that changes in the transmission behaviour of the controlled system can be documented. In this way, the control system can be adapted very simply to specified operating states of the controlled system that occur again and again when the controlled system is operating.

The method can be used to advantage for a control system that is part of a steam-turbine plant. The controller of the control loops of a steam-turbine plant are usually parametrized on the basis of data that are obtained empirically.

Because of the lack of system information about the actual dynamic behaviour of the particular steam-turbine plant, this results in long commissioning times. In addition, there is, as a rule, no adaptation of the control parameters to different operating states of the steam-turbine plant when the steam-turbine plant is operated. To an especial degree, follow-up of the control parameters of the or each controller of the steam-turbine plant when the steam-turbine plant is operated ensures the consistent control quality and consistent control performance of the or every control loop.

It is advantageous that the manipulated variable of the controller is a turbine-wheel chamber pressure value or a steam-consumption value for the steam turbine. In one advantageous version, the control variable of the control loop is a performance figure, a speed [rpm] value, or a pressure value for the operating medium of the steam turbine.

With respect to the apparatus, the objective has been achieved with a controller adaptation device that determines the transmission behaviour of the controlled system during operation of the controller and adjusts the or each control parameter as a function of the current transmission behaviour of the controlled system.

The advantages achieved with the present invention comprise, in particular, the fact that a follow-up of the control parameters when the controller is operating ensures a specified control quality during all operating states of the controlled system. This is done without any interruption in the operation of the control system. In addition, technical facilities that include the control system and that use the method have particularly short commissioning times. In addition, control systems that are operated with the method can be adapted very simply to different operating states of the controlled system.

One embodiment of the present invention will be described in greater detail below on the basis of the drawings appended hereto. These drawings show the following:

Figure 1: a diagram of a steam-turbine plant with a control system;

Figure 2: a diagram showing the control system as in Figure 1.

Identical parts in these figures bear identical reference numbers.

The steam-turbine plant 2 that is illustrated in Figure 1 comprises a steam-turbine 4 that is coupled to a generator 6 and a condenser 10 that follows the steam-turbine 4 in a water-steam circulatory system, as well as a steam generator 12. The steam turbine itself comprises a first pressure stage or high-pressure stage 4a and a second stage, a medium- and low-pressure stage 4b that drive the generator 6 through a shaft 14.

On the steam-outlet side, the steam generator 12 is connected to the steam inlet 18 from the high-pressure stage 4a of the steam turbine 4 in order to supply working medium AM to the steam turbine. The steam-outlet 20 of the high-pressure

stage 4a of the steam turbine 4 is connected to the steam inlet 24 of the medium- and low-pressure stage 4b of the steam turbine through a transfer line 22. The steam-outlet 26 from the medium- and low-pressure stage 4b of the steam turbine 4 is connected to the condenser 10 through a steam line 28. This condenser 10 is connected to the steam generator 12 through a feed-water line 30, which includes the feed-water pump 32 and a feed-water reservoir 34, so as to form a closed water-steam loop 8.

A control system 36 is associated with the steam-turbine plant 2 so as to control a power-output value P , a speed [rpm] value N and/or a pressure value W of the working medium AM for the steam turbine 4. The control system 36 is part of a control loop 40, and includes a controller 42. This is connected to a controlled system 44 in order to form the control loop 40. The control system 44 that is associated with the controller 42 includes the steam turbine 4. The controller 42 is connected through a manipulated-variable line 46 to its associated controlled system 44 so as to supply a manipulated variable Y . An actuator, not shown in greater detail herein, which is associated with the controlled system 44, results in a specific setting of the controlled system 44 as a function of the manipulated variable Y . The control parameter X can be passed to

the controller 42 on the control-parameter line 48, so that a closed control loop 40 is formed.

The controller 42 is so designed that in the event that the control parameter X departs from a specified set point it can change the manipulated variable Y that is to be passed to the controlled system 44 proportionally, integrally, and/or differentially. The manipulated variable that is passed from the controller thus depends on a number of control parameters R_i ($i = 1, 2, \dots, n$). The setting of the control parameter is the so-called parameterization of the controller 42.

In order to ensure that a particularly favourable parametrization of the controller 42 is arrived at for all operating states of the steam-turbine plant 2, the control system 36 has a controller adaptation system 50 for determining the control parameters R_i . To this end, the manipulated variable Y can be passed to the controller adaptation system 50 by way of the connector line 52 that branches off from the manipulated variable line 46, and the control parameter X can be passed to the controller adaptation system 50 by way of the connector line 54 that branches off from the control parameter line 48. The controller adaptation system 50 is connected to its associated controller 42 through the controller line 56 in order to supply

the control parameters R_i that have been determined in the controller adaptation system 50.

As is shown in additional detail in Figure 2, the controller adaptation system 50 is connected to the control loop 40 through the connector lines 52 or 54 that branch off from the manipulated-variable line 46 and from the control parameter line 48, respectively. The controller adaptation system 50 comprises a transformation module 60 to analyze the manipulated variable Y , a transformation module 62 to analyze the control parameter X , a computation module 64 to determine the transmission function of the controlled system 44, and a parametrization module 66 to determine the control parameters R_i . The transformation module 60 is connected to the connector line 52, and the transformation module 62 is connected to the connector line 54. The transformation modules 60 and 62 are in their turn connected to the computation module 64 as data lines, and the computation module is in its turn connected by data line to the parametrization module 66. The control parameters R_i that are determined in the parametrization module 66 can be passed to the controller 42 by way of the controller line 56.

When the steam-turbine plant is running, the steam turbine is operated with the assistance of the control system 36.

When this is done, a wheel-chamber pressure value R or a steam-consumption value D serve as manipulated variables for the steam turbine 4. The associated control parameters are a power output value P , a speed [rpm] value N , or a pressure value W for the steam turbine 4. The power-output value P of the steam turbine can be controlled, for example, by appropriate adjustment of the wheel-chamber pressure value R . To this end, a specified set point of the power-output value is applied to the controller 42 in a manner not described in greater detail herein. In its turn, with the assistance of the control parameters R_i , the controller 42 passes a wheel-chamber pressure value R as a manipulated variable Y to the actuator (not shown in greater detail herein) by way of the manipulated-variable line 46. This then makes a change to the behaviour of the controlled system 44 with the controller 42. The feedback value of the power-output value P of the controlled system 44 is passed on to the controller 42 as control parameter X by way of the control-parameter line 48.

In order to be able to ensure a specified control quality of the controlled system for all the operating states of the steam-turbine plant 2, changes in the behaviour of the controlled system are identified and used to adapt the control parameters R_i . This is done by determining the transmission behaviour of the controlled system 44 during operation of the

controller 42. The actualization of the or each control parameter R_i then takes place as a function of the transmission behaviour of the controlled system 44 that has been identified during operation of the controller 42.

To this end, the manipulated variable Y is also passed by way of the connector line 52 to the transformation module 60 of the controller adaptation system 50. At the same time, the control parameter X is passed to the transformation module 62 of the controller adaptation system by way of the connector line 54.

The transformation module 60 breaks down the manipulated variable Y that has been passed to the controlled system 42 in a predetermined time window, at a specific point in time, with the assistance of a wavelet transformation into signal parts of a amplitude spectrum of a specific frequency band, which are also referred to as wavelet components. This occurs with a family of wavelets. A family of wavelets is a family of mathematical functions that can be generated from a single starting function by mathematical extension and/or displacement. The analysis of the variation in time of the signal is performed in a specified time window. By this means, it is possible to determine the point in time when the signal displayed a specific property that is filtered out by the wavelet transformation. So, by using this method, it can be established whether or not a specified

component of the signal is contained in the signal at a specific point in time.

In the same way as the transformation module analyzes the manipulated variable Y, the transformation module 62 analyzes the way the control variable X behaves over time. In this way, it can be determined whether or not a specified component of the manipulated variable Y is to be found once again in the control parameter X. When this is done, it is possible to localize the point in time when the manipulated variable Y or the control parameter X had a specific component. Thus, it is possible to sequence changes to the manipulated variable Y and/or to the control parameter X by time.

In addition, a point in time is associated with the particular wavelet transformation, so that changes in the behaviour of the controlled system 44 can be fixed. In the case of repeating states of the steam turbine 4, specific control parameters R_i that have been found to be particularly favourable can then be set up.

The results of the wavelet transformation of the manipulated variable Y and the control parameter X are passed to the computation module 64, where they are used to construct a

system of differential equations. The determination of the differential-equation system that is carried out in the computation module 64 leads to the establishment of the transmission function of the controlled system 44. The transmission function of the controlled system 44 is passed to the parametrization module 66 where, if needed, new parameters R_i are computed. For a new adjustment of the control parameters R_i of the controller 42, these are passed to this by way of the controller line 56 when the controller 42 is in operation.

The transmission behaviour of the controlled system 44 is determined with the control system 36 of the steam-turbine plant 2 when the controller 42 is operating. Then the or each control parameter R_i is adjusted in the manner of an on-line intervention as a function of the transmission behaviour of the controlled system 44 that has been identified. This ensures a specified control quality and a specified control behaviour of the control system 36 for all operating states of the steam-turbine plant 2.

Patent Claims

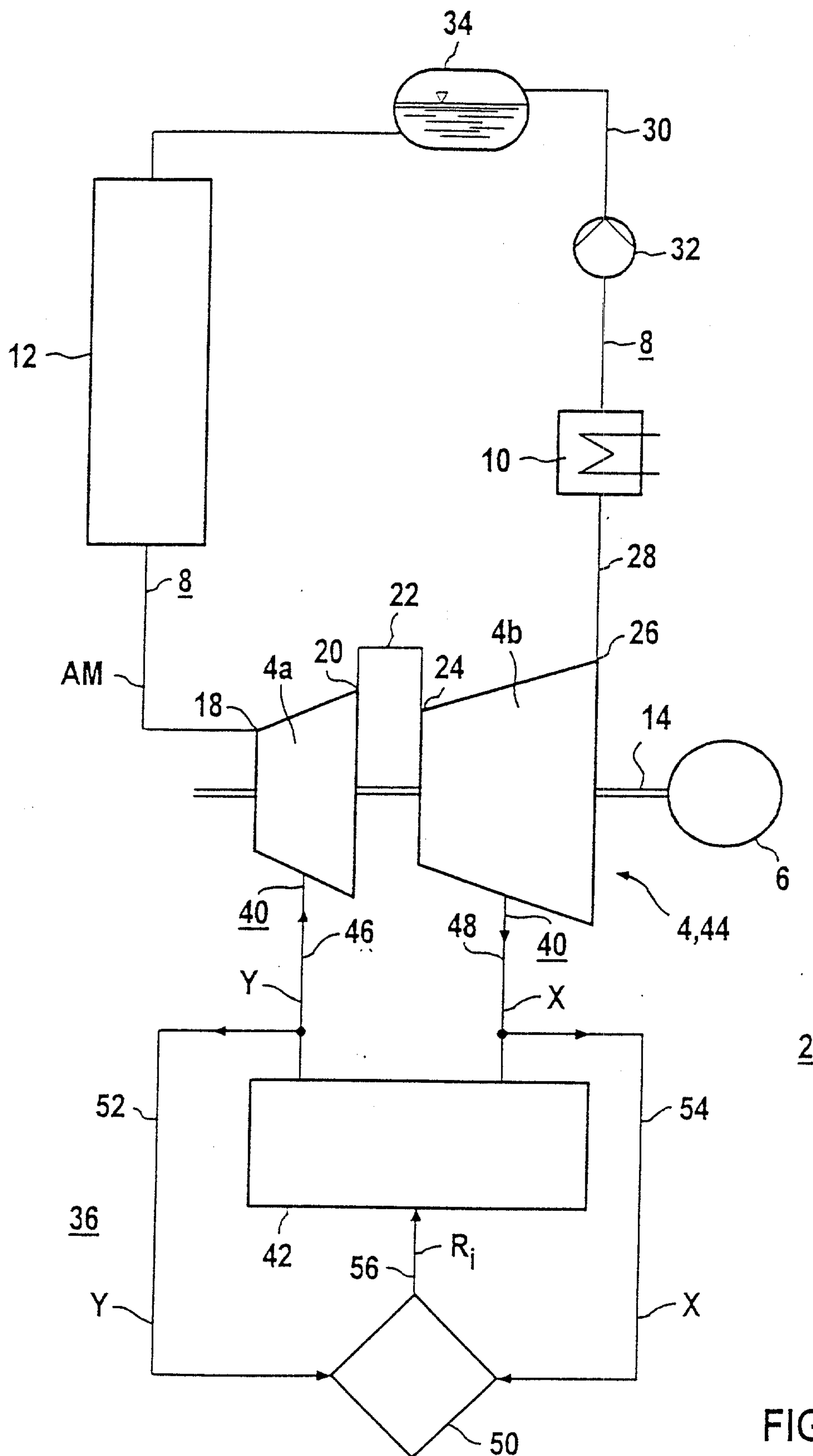
1. Method for operating a control system (36) with a controller (42) that acts with a manipulated variable (Y) on a controlled system (44) as a function of a number of control parameters (R_i), in which, during the operation of the controller (42), the transmission behaviour of the controlled system (44) is determined by comparison of a wavelet transformation of the behaviour over time of the manipulated variable (Y) with a wavelet transformation of the behaviour over time of a control parameter (X) of the controller (42) of the controlled system (44) within a specified window of time, a point in time that is associated with one of the particular wavelet transformations being determined, and the or each control parameter (R_i) being adjusted as a function of the transmission behaviour that has been identified.
2. Method as defined in Claim 1, in which the control system (36) is incorporated in a steam-turbine plant (2).
3. Method as defined in Claim 1 or Claim 2, in which the manipulated variable (Y) is a wheel-chamber pressure value (R) of the steam turbine (4).
4. Method as defined in one of the Claims 1 to 3, in which the manipulated variable (Y) is a steam-consumption value (D) of the steam turbine (4).

5. Method as defined in one of the Claims 1 to 4, in which the control parameter (X) is a power-output value (P) of the steam turbine (4).

6. Method as defined in one of the Claims 1 to 5, in which the control parameter (X) is a speed [rpm] value (N) of the steam turbine (4).
7. Method as defined in one of the Claims 1 to 6, in which the control parameter (X) is a pressure value (W) of the working medium of the steam turbine (4).
8. Control system (36) with a controller (42) that acts with a manipulated variable (Y) on a controlled system (44) as a function of a number of control parameters (R_i), and with a controller adaptation system (50) which, during operation of the controller (42), determines the transmission behaviour of the controlled system (44) by comparison of a wavelet transformation of the behaviour over time of the manipulated variable (Y) with a wavelet transformation of the behaviour over time of a control parameter (X) of the controller (42) of the controlled system (44) in a specified window of time, identifies a point in time that is associated with the particular wavelet transformation, and adjusts the or each control parameter (R_i) as a function of the transmission behaviour that has been identified.

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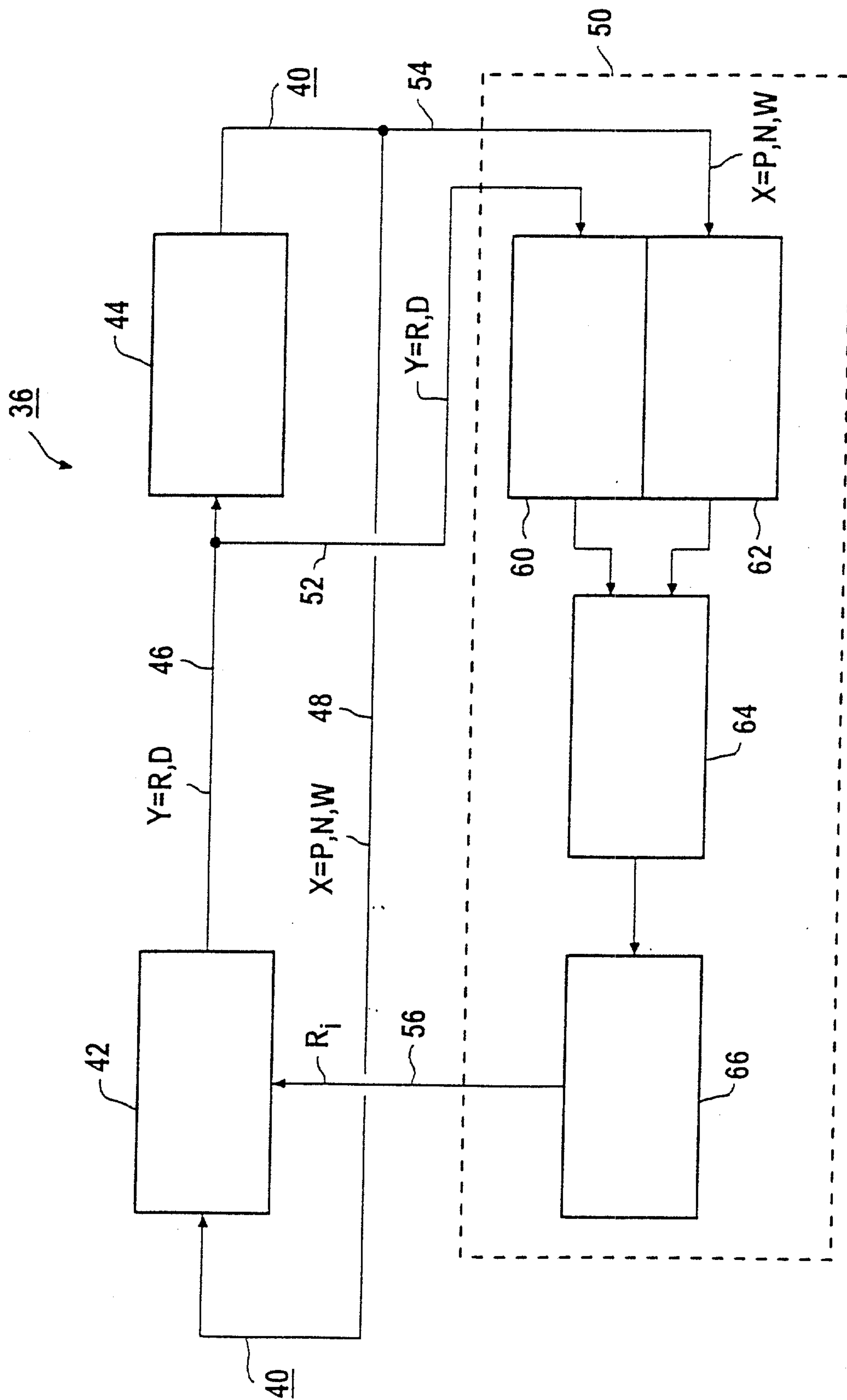


FIG 2

