

Description

Method and apparatus for quickly controlling the output of a power station facility

The invention relates to a method for quickly
5 controlling the output of a power station facility which
has a turbo-generator set having a steam turbine and a
generator, energy stores present during the facility
process being activated in order to set an additional
generator output. It further relates to an apparatus for
10 carrying out the method.

Reliable power supply in an electric power supply
system presupposes careful tuning between the generation
of electric power by a number of power units and the
tapping of this energy by a number of consumers in an
15 electricity distribution system. If the generation and
tapping of the electric power are equal, the system
frequency, which is an essential parameter in an electrical
system, is constant. Its nominal value is, for
example, 50 Hz in the European interconnected system. A
20 frequency deviation which occurs, for example, owing to
the failure of a power unit or to the connection or
disconnection of a consumer, can be regarded as a measure
of an increase or drop in the generator output. A further
task in addition to correcting frequency deviations
25 within a power supply system consists in maintaining a
prescribed interchange power at coupling points to
subsystems from which the distribution system (interconnected
system or separate network) is composed. One
requirement therefore consists in the availability of a
30 quick increase in output of a power unit within seconds.

Possibilities for quickly controlling the output
and providing frequency back-up control are described in
printed publication "VGB Kraftwerkstechnik", No. 1,
January 1980, pages 18 to 23. Whereas

a plurality of intervention possibilities which can be carried out simultaneously or alternatively exist for quickly changing the output within the range of seconds (seconds reserve), a change in the fuel supply is required for a permanent change in the output of a power unit. In a fossil-fuel-fired power station, control valves of the steam turbine which are held in advance in the throttled position are therefore opened within the first seconds for the purpose of bridging delay times, and available steam accumulators are thereby activated and discharged virtually without delay.

In addition to an increase in output owing to the cancellation of the throttling of control valves of the steam turbine, preheaters which are provided in the water-steam circuit of the steam turbine and are heated by means of extraction steam from the steam turbine are disconnected. A condenser flow simultaneously passed through the low-pressure preheater can be stopped and increased again within a few seconds. This measure for quickly controlling the output in fossil-fuel-fired power units by disconnecting the preheaters with a condensate stop is also described, for example, in German Patent Specification DE-C 33 04 292.

In order to regulate and/or control the quick seconds reserve, that is to say for the purpose of a controlled loading of steam flows to regenerative preheaters and/or heating condensers, as well as of the process steam and the condensate in the water-steam circuit of the steam turbine of a power unit, it is therefore customary to make use of a control device. For the purpose of quickly controlling the output, that is to say of activating the seconds reserve, said control device throttles the supply of steam to preheaters, throttles the process steam and/or throttles the condensate. In this case, desired setting values for control valves at turbine extraction points and for control elements for setting condensate are formed in such a way that a required additional generator output is achieved. A disadvantage of this, however, is that it is extraordi-

narily difficult to coordinate the required rate of
change in output

and the output amplitude with other process variables, in particular with temperature changes in preheating trains and/or heating condensers, as well as with discharging the drains. Moreover, the priorities of the use of the individual measures for quickly controlling the output are not taken into account. In addition, because of the usually nonlinear control system control quality has not been particularly high to date.

It is therefore the object of the invention to specify a method for quickly making output available in a power station facility, by means of which method a particularly effective control is achieved. The aim is to achieve this with simple means using an apparatus which is particularly suitable for carrying out the method.

With reference to the method, this object is achieved according to the invention by using fuzzy logic for the controlled activation of the energy stores, fuzzy-logic rules from experience at the facility being used.

The invention proceeds here from the idea of evaluating a multiplicity of process values or process variables of the facility process. The aim here is to analyze in their entirety the process variables which are relevant for the process to be controlled. It is then possible using fuzzy logic to introduce experience at the facility (expert knowledge) into the evaluation and to take account of it during the subsequent formation of desired setting values.

In an advantageous development, the priority of the use of the individual energy stores is taken into account in implementing the fuzzy-logic rules required. Moreover, it is advantageous, in the case of evaluating process variables or process data in order to determine desired setting values or manipulated variables for the individual energy stores, to take into account information

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concerning their readiness and/or their temporary restriction.

With reference to the apparatus, the said object is achieved according to the invention by means of a fuzzy-logic system whose inputs include the additional generator output and the energy situation of the activatable stores, and whose outputs specify the degree of activation of the individual energy stores.

In an advantageous embodiment, the fuzzy-logic system comprises a first fuzzy-logic controller whose inputs include the energy situation of the activatable stores, and whose output specifies a strategy of use for measures to be carried out as well as temporary restrictions of the individual activatable stores. The first fuzzy-logic controller preferably additionally has an input for the degree of throttling of at least one control element connected to the steam turbine on the inlet side.

The fuzzy-logic system expediently further comprises a second fuzzy-logic controller whose inputs include the desired output value and an actual additional output value of the generator as well as the strategy of use and the restrictions, and whose outputs specify desired setting values for steam control elements.

The fuzzy-logic system further expediently comprises a third fuzzy-logic controller, whose inputs include the actual setting value of at least one steam control element and the actual temperature value and/or actual pressure value of feedwater stored in the water-steam circuit, and whose outputs specify desired setting values for condensate control elements. In this case, one input of the third fuzzy-logic controller preferably includes a value for the damper response of at least one steam control element.

The fuzzy-logic system expediently also comprises a fourth fuzzy-logic controller whose input includes an actual value for the level in at least one intermediate store connected in the water/steam circuit,

and whose output specifies a desired setting value for entering condensate into, or extracting it from, a condensate store.

5 The advantages achieved by means of the invention consist, in particular, in that the use of fuzzy logic in conjunction with experience at the facility results in controlled activation of the energy stores present during the facility process. In this case, the priorities of the use of individual measures can be taken into account.
10 Moreover, a gentle running procedure is ensured at the same time as particularly effective use of available energy stores. In particular, quick, high-quality control of output is achieved.

15 An exemplary embodiment of the invention is explained in more detail with the aid of a drawing, in which:

FIGURE 1 shows a block diagram of a turbo-generator as a process section of a power unit, and

20 FIGURE 2 shows a block diagram of a fuzzy-logic system as a control apparatus of a process section in accordance with Figure 1.

Figure 1 shows a basic block diagram of a process section of a power unit having a turbo-generator set, which is composed of a high-pressure component turbine 2, 25 an intermediate-pressure component turbine 4 and a low-pressure component turbine 6, as well as a generator 8. During operation of the turbo-generator set, the main steam FD is introduced into the high-pressure component turbine 2 via a main-steam control valve 10. A first 30 partial flow FD_1 and a second partial flow FD_2 , which can be set by means of a control valve 12 is [sic] extracted from the high-pressure component turbine 2 for a high-pressure preheating train 14. A third partial flow FD_3 , which can be set by means of a further control valve 16, 35 is extracted from the high-pressure component turbine 2 for a feedwater tank 18. The exhaust steam FD' from the high-pressure component turbine 2

is fed to the intermediate-pressure component turbine 2 via a reheater 20.

A further extraction of steam is performed from the intermediate-pressure component turbine 2. For this purpose, a control valve 22 is used to extract a settable first partial flow MD_1 for a low-pressure preheating train 24. A further extraction is performed via a second partial flow MD_2 , which can be set by means of a control valve 26, for a heating condenser 28. Furthermore, an extraction is performed as process steam PD via a third partial flow MD_3 , which can be set by means of a control valve 30. The exhaust steam MD' of the intermediate-pressure component turbine 4 is fed to the low-pressure component turbine 6 via a pressure-relief damper 32.

Steam is likewise extracted from the low-pressure component turbine 6 for the low-pressure preheating train 24 and for the heating condenser 28. For this purpose, the low-pressure preheating train 24 is fed a first partial flow ND_1 directly and a second partial flow ND_2 via a control valve 34. The heating condenser 28 is likewise fed a third partial flow ND_3 directly and a fourth partial flow ND_4 via a control valve 36. The exhaust steam ND' from the low-pressure component turbine 6 condenses in a condenser 40.

The main condensate K is conveyed from the hotwell 42 of the condenser into the feedwater tank 18 via the low-pressure preheating train 24 by means of a condensate pump 44. Feedwater S is conveyed from the feedwater tank 18 via the high-pressure preheating train 14 by means of a feedwater pump 46. Drains NK_1 from the high-pressure preheating train 14 are conveyed into the feedwater tank 18 via a drains pump 48. Drains NK_2 are likewise conveyed from the low-pressure preheating train 24 via a drains pump 50 into the condenser 40, that is to say into the hotwell 42 thereof. In addition, drains NK_3 are conveyed from the heating condenser 28 into the hotwell 42 of the condenser 40 by means of a drains pump 52.

Whereas the main condensate K and the feedwater S are conveyed via a level control L_K/L_{SWB} , the conveyance of the drains $NK_{1,2,3}$ is set via separate level controls NKR_1 , NKR_2 and NKR_3 . The latter can be fed a common
5 desired setting value Y_{NKR} . A cold condensate store 54 which is connected via a condensate pump 48 to the hotwell 42 of the condenser 40 serves in this case the purpose of entering a portion of the main condensate K into the store, or extracting it therefrom.

10 The device for quickly controlling the output is represented in Figure 2. It comprises a fuzzy-logic system 60 having four fuzzy-logic controllers 62, 64, 66 and 68. The fuzzy-logic system 60 receives as input variables a frequency-corrected desired output value P_s
15 and the actual additional output value P_i of the generator 8. The actual additional output value P_i is measured by means of a measuring device 70 on the generator 8 (Figure 1). Further input variables of the fuzzy-logic system 60 are the temperature T_{sw} and the pressure p_{sw} of
20 the feedwater S, which are measured by means of a measuring device 72 in the feedwater tank 18 (Figure 1). Furthermore, the condensate level L_K measured in the hotwell 42 of the condenser 40 and the feedwater level L_{SWB} measured in the feedwater tank 18 are fed to the
25 fuzzy-logic system 60 as input variables. Information concerning the degrees of throttling D_{10} , D_{32} of the main steam control valve 10 or of the pressure relief damper 32 and data on the priorities of use EP, technical readiness TB and load capability KL of the power station,
30 as well as further process variables P, are fed to the fuzzy-logic system 60 as further input variables $e_1 \dots e_n$.

The inputs $e_1 \dots e_n$ belong to the first fuzzy-logic controller 62 of the fuzzy-logic system 60. They take
account of the process variables D_{10} , D_{32} , EP, TB, KL and
35 P which are relevant for the process section to be controlled. With the aid of fuzzy-logic rules FR_1 from experience at the facility (expert knowledge) which are stored in the first fuzzy-logic controller 62, a strategy of use is determined for the measures required for

quickly controlling the output of the power unit. Furthermore, temporary restrictions on energy stores to be activated in the process

section are determined there. This strategy of use, that is to say the staggering of measures and restrictions form the output variable f of the first fuzzy-logic controller 62.

5 This output variable f is simultaneously the input variable of the second fuzzy-logic controller 64. Further input variables a and b of the second fuzzy-logic controller 64 are the frequency-corrected desired output value P_s and the actual additional output value P_i . In the
10 second fuzzy-logic controller 64, output variables g to k are determined from these input variables a , b and f with the aid of fuzzy-logic rules FR_2 . While the output variables g to j are desired setting values, the output variable k is an estimated damper response dY_m/dt of the
15 or of each control element 10, 12, 16, 22, 26, 32, 34 and 36 provided in the process section in accordance with Figure 1. The output variable g of the second fuzzy-logic controller 64 specifies desired setting values Y_{sx} for the hot-condensate control valves 26 and 36. The output
20 variable h specifies desired setting values Y_{pd} , Y_{ux} for the main steam control valve 10 or the pressure relief damper 32. The output variable i specifies a desired setting value Y_{pd} for the control valve 30 which sets the quantity of process steam PD to be coupled out per unit
25 time. The output variable j specifies desired setting values Y_{Kx} for the extraction-steam control valves 12, 16, 22 and 34.

 The output variables j and k of the second fuzzy-logic controller 64 are simultaneously input variables of
30 the third fuzzy-logic controller 66. The third fuzzy-logic controller 66 is fed the temperature T_{sw} and the pressure p_{sw} of the feedwater S in the feedwater tank 18 as further input variables c . Desired setting values Y_{Kx} , Y_{NKR} for the condensate controller or drains controller
35 $NKR_{1,2,3}$ are formed from these input variables j , k and c with the aid of fuzzy-logic rules FR_3 as output variables l and o .

 In the fourth fuzzy-logic controller 68 of the fuzzy-logic system 60, a desired setting value Y_{Kx} is

formed as output variable q for the quantity of condensate K to be entered into, or extracted out of, the cold-condensate store 54.

For this purpose, the condensate level and feedwater level L_k and L_{swb} , respectively, are fed to the fuzzy-logic controller 68 as input variable d . The desired setting value Y_{kp} is likewise formed with the aid of fuzzy-logic rules FR_4 .

The knowledge of process engineering used in the fuzzy-logic system 60 ensures both a gentle running procedure of the power station facility or the power unit in the case of quick changes in output, and a particularly effective utilization of the available energy stores. The knowledge of process engineering is incorporated in this case into the fuzzy-logic rules FR_1 to FR_4 of the individual fuzzy-logic controllers 62 to 68. In particular, the priority of the use of the individual energy stores is taken into account in order to implement the fuzzy-logic rules FR_1 of the first fuzzy-logic controller 62. The energy stores are activated by throttling the steam supply to the preheating trains 14 and 24 and/or by throttling the process steam PD, as well as by throttling the condensate K and/or the drains $NK_{1,2,3}$. The formation of appropriate desired setting values Y for the control valves or regulating valves at the turbine extraction points and for condensate regulation is performed in this case with regard to the setting of a required additional generator output P_g .



Patent Claims

1. Method for quickly controlling the output of a power station facility which has a turbo-generator set having a steam turbine (2, 4, 6) and a generator (8),
5 energy stores present during the facility process being activated in order to set an additional generator output (P_s), characterized in that fuzzy logic is used for the controlled activation of the energy stores, fuzzy-logic rules ($FR_{1...4}$) from experience at the facility being used.
- 10 2. Method according to Claim 1, characterized in that the priority (EP) of the use of the individual energy stores is taken into account in implementing the fuzzy-logic rules (FR_1).
3. Method according to Claim 1 or 2, characterized
15 in that in order to determine desired setting values (Y) for the individual energy stores, information (TB) concerning their readiness is taken into account.
4. Apparatus for quickly controlling the output of a power station facility which has a turbo-generator set
20 having a steam turbine and [sic] (2, 4, 6) and a generator (8), energy stores present during the facility process being activatable in order to set an additional generator output (P_s), characterized by a fuzzy-logic system (60) whose inputs (a to e) include the additional
25 generator output (P_s) and the energy situation of the activatable stores, and whose outputs (g to j, l, o, q) specify the degree of activation of the individual energy stores.

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5. Apparatus according to Claim 4, characterized in that the fuzzy-logic system (60) comprises a first fuzzy-logic controller (62) whose inputs ($e_1 \dots e_n$) include the energy situation of the activatable stores, and whose output (f) specifies a strategy of use for measures to be carried out as well as for temporary restrictions of the or of each activatable store.
6. Apparatus according to Claim 5, characterized in that the first fuzzy-logic controller (62) has an input (e) for the degree of throttling (D_{FD} , D_{UK}) of at least one control element (10, 32) connected to the steam turbine (2, 4, 6) on the inlet side.
7. Apparatus according to one of Claims 4 to 6, characterized by a second fuzzy-logic controller (64) whose inputs (a, b, f) include the desired output value (P_s) and an actual additional output value (P_i) of the generator (8) as well as the strategy of use and the restrictions, and whose outputs (g to k) specify desired setting values (Y) for control elements (10, 12, 16, 22, 26, 30, 32, 34, 36).
8. Apparatus according to one of Claims 4 to 7, characterized by a third fuzzy-logic controller (66), whose inputs (c, j, k) include the desired setting value (Y_{KL}) of at least one extraction steam control element (12, 16, 22, 34) and the actual temperature value (T_{SW}) and/or actual pressure value (P_{SW}) of stored feedwater (S), and whose outputs (l, o) specify desired setting values (Y_{KP} , Y_{MKR}) for condensate control elements (44, 48, 50, 52).
9. Apparatus according to Claim 8, characterized in that one input (k) of the third fuzzy-logic controller (66) includes a value for the damper response (dY_x/dt) of at least one control element.



10. Apparatus according to one of Claims 4 to 9, characterized by a fourth fuzzy-logic controller (68) whose input (d) includes a value (L_K , L_{SVB}) for the level in at least one intermediate store (18, 42), and whose
5 output (q) specifies a desired setting value (Y_{KTP}) for entering condensate K into, or extracting it from, a condensate store (54).