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(54) **Device for regulating the intercept valves of a steam-turbine plant**

(57) A device (4) for regulating the intercept valves (22) of a steam-turbine plant (2) supplied with a boiler (10) with low capacity of thermal modulation has: a hydraulic circuit (26), designed to supply a linear hydraulic actuator (34) for actuation of a system of levers (37) for opening and closing the intercept valves (22) simultaneously; a hydraulic power distributor (33), designed to supply the linear hydraulic actuator (34) selectively; and a control device (32), designed to control the hydraulic power distributor (33) as a function of a signal (SM) correlated to the mode of operation of the steam-turbine plant (2) for partializing without solution of continuity opening of the intercept valves (22) between a position of complete closing and a position of maximum opening.

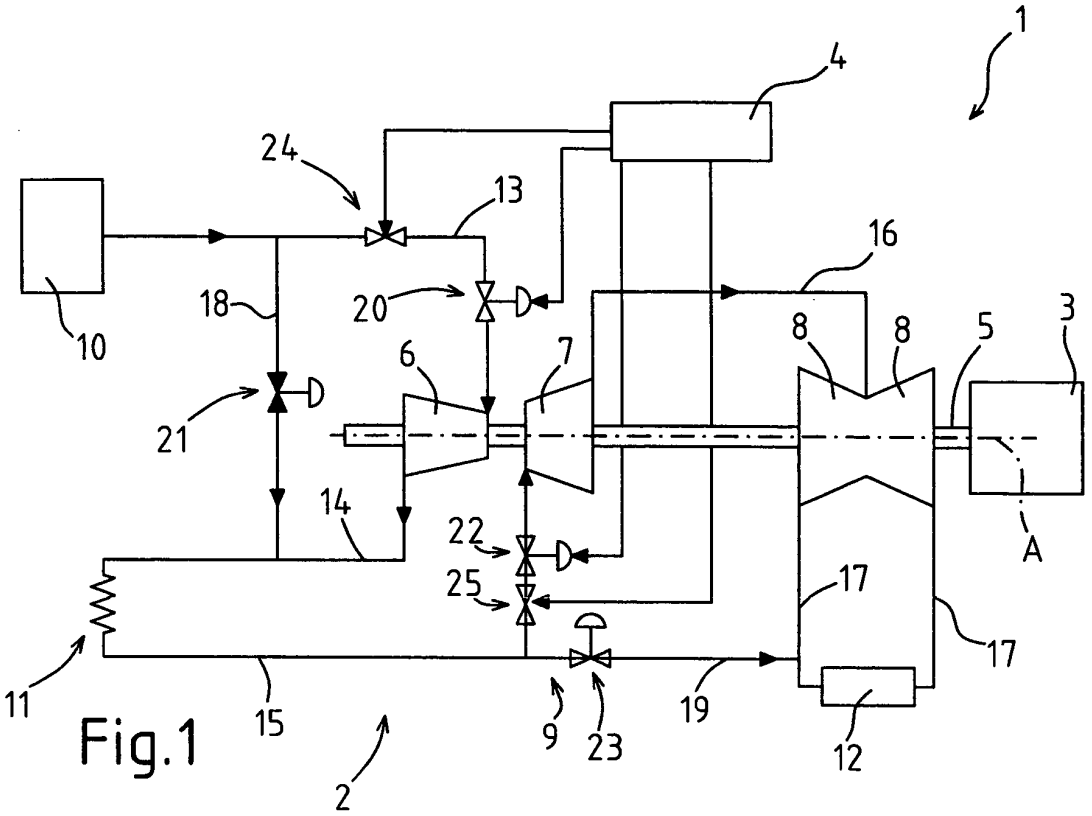

Fig.1

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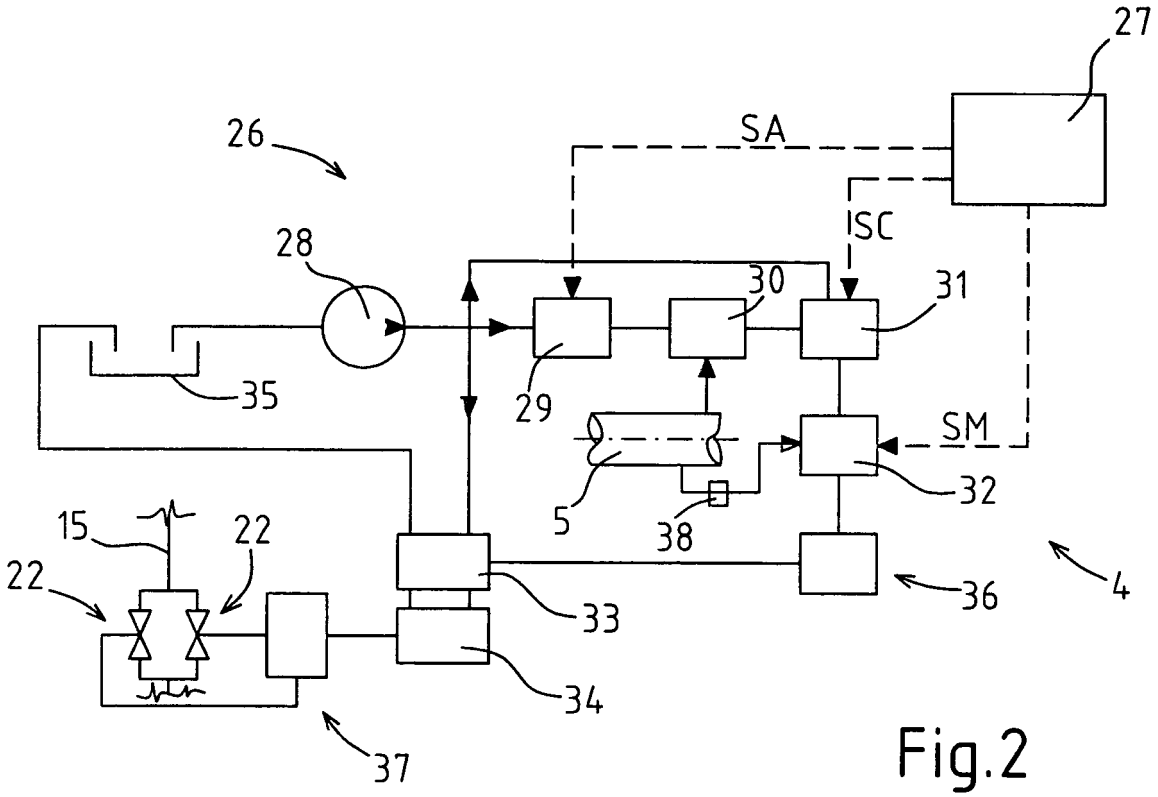

Fig.2

Description

[0001] The present invention relates to a device for regulating the intercept valves of a steam-turbine plant.

[0002] In particular, the present invention relates to a device for regulating the intercept valves of a steam-turbine plant connected to a high-power turbogenerator for the production of electric power.

[0003] Generally, a steam-turbine plant comprises: a boiler for the production of superheated steam; a high-pressure turbine; a medium-pressure turbine; at least one low-pressure turbine; a circuit for supplying steam comprising a first connection branch between the boiler and the high-pressure turbine, a second connection branch between the high-pressure turbine and the medium-pressure turbine; control valves arranged along the first branch; and intercept valves arranged along the second branch.

[0004] A steam-turbine plant of the type described above is supplied with superheated steam and can be equipped with a boiler with a high capacity of thermal modulation, for example a gas boiler, or else with a boiler with a low capacity of thermal modulation, such as for example a fluid-bed boiler designed to burn solid fuel characterized by a low calorific value and by a slow combustion that determines long stay times of the solid fuel in the boiler.

[0005] A steam-turbine plant with boiler with low capacity of modulation of the thermal power must necessarily comprise a hydraulic circuit having: a first by-pass branch, which is provided with a first by-pass valve, designed to exclude totally or in part the supply of steam to the high-pressure turbine; and a second by-pass branch, which is provided with a second by-pass valve designed to exclude totally or at least in part the supply of steam to the medium-pressure and low-pressure turbines. In other words, modulation is obtained via partialization of the control valves, with simultaneous partialization (complementary to the partialization of the control valves) of the first by-pass valve, and partialization of the intercept valves, with simultaneous partialization (complementary to the partialization of the control valves) of the second by-pass valve.

[0006] In a steam-turbine plant equipped with a boiler with high capacity of modulation of the thermal power, the first and second by-pass branches and the respective first and second by-pass valves are not necessary, and the intercept valves are valves of an on-off type because, both in the stage of startup and in steady-state conditions, the regulation of just the control valves enables control of the entire steam-turbine plant. In the stage of startup of the steam-turbine plant, the intercept valves are opened practically instantaneously, whilst the progressive increase of the flow rate of steam is regulated via the modulation of the boiler and the partialization of the control valves.

[0007] When, for reasons substantially linked to the fuel market, a steam-turbine plant equipped with a boiler with high capacity of modulation of the thermal power is converted into a steam-turbine plant equipped with a boiler with low capacity of modulation of the thermal power, it is necessary to make structural modifications to the steam-turbine plant, such as insertion of the first and second by-pass branches with the respective first and second by-pass valves, and modification of the existing regulating device, with the replacement of the intercept valves, which are typically hydraulically controlled mechanical valves with electro-hydraulic intercept valves.

[0008] However, the replacement of traditional intercept valves with electro-hydraulic intercept valves is an operation that requires time and is particularly burdensome.

[0009] The aim of the present invention is to provide a device for regulating the intercept valves of a steam-turbine plant that is free from the drawbacks of the known art.

[0010] In accordance with said aim, the present invention relates to a device for regulating the intercept valves of a steam plant, the regulating device comprising: a hydraulic circuit designed to supply a linear hydraulic actuator for actuating a first mechanical system of levers for simultaneously opening and closing the intercept valves; and a hydraulic power distributor designed to supply the linear hydraulic actuator selectively; the regulating device being characterized in that it comprises a control device, designed to control the hydraulic power distributor as a function of a signal correlated to the modes of operation of the steam-turbine plant so as to partialize, without solution of continuity, opening of the intercept valves between a position of complete closing and a position of maximum opening.

[0011] In this way, the modification of the regulating device is only slight and does not entail replacement of intercept valves of a mechanical type with electro-hydraulic valves, with a consequent considerable reduction of the costs and of the time of intervention.

[0012] Further characteristics and advantages of the present invention will emerge clearly from the ensuing description of a non-limiting example of embodiment, with reference to the figures of the annexed plate of drawings, wherein:

- Figure 1 is a schematic view, with parts removed for reasons of clarity, of a steam-turbine plant, which forms part of an installation for the production of electric power and is equipped with a regulating device built according to the present invention;
- Figure 2 is a schematic view, with parts removed for clarity, of the regulating device forming the subject of the present invention;
- Figure 3 is a cross-sectional view, with parts removed for clarity and parts indicated schematically, of a detail of the regulating device of Figure 2; and
- Figure 4 is a diagram of the percentage of opening of the control valves and of the intercept valves of the steam-turbine plant of Figure 1 as a function of time.

[0013] With reference to Figure 1, the reference numeral 1 designates as a whole an installation for the production of electric power. The installation 1 comprises: a steam-turbine plant 2; a high-power turbogenerator 3; and a regulating device 4, designed to manage the steps of startup and of arrest of the plant 2 and to regulate the plant 2 during operation in steady-state conditions.

[0014] The steam-turbine plant 2 comprises: a shaft 5, which can turn about an axis A; a high-pressure turbine 6, a medium-pressure turbine 7, and two low-pressure turbines 8; a circuit 9 for circulation of the steam; a boiler 10 for generation of steam; a heater 11 for heating the steam at output from the high-pressure turbine 6; and a condenser 12 for condensing the steam at output from the low-pressure turbines 8.

[0015] The shaft 5 is common to the high-pressure turbine 6, to the medium-pressure turbine 7, to the low-pressure turbines 8, as well as to the rotor (not illustrated in the attached figures) of the turbogenerator 3.

[0016] The circuit 9 comprises: a branch 13 for connection between the boiler 10 and the high-pressure turbine 6 for supplying superheated steam (designated by SH) at a pressure of approximately 150 bar; a branch 14 for connection between the high-pressure turbine 6 and the heater 11 for supplying steam at a pressure of approximately 10 bar to the heater 11; a branch 15 for connection between the heater 11 and the medium-pressure turbine 7 for supplying reheated steam (designated by RH) at a pressure of approximately 10 bar; a branch 16 for connection between the medium-pressure turbine 7 and the common inlet to the two low-pressure turbines 8 at a pressure of approximately 4 bar; and two branches 17 for connection between the low-pressure turbines 8 and the condenser 12.

[0017] The circuit 9 comprises a by-pass branch 18 for connecting the branch 13 directly to the branch 14 and excluding totally or in part the supply of steam to the high-pressure turbine 6, and a by-pass branch 19 for connecting the branch 15 directly to at least one of the branches 17 so as to exclude totally or in part the supply of steam to the medium-pressure turbine 7, and to the low-pressure turbines 8.

[0018] The circuit 9 comprises: control valves 20, which are commonly referred to as CVs and are arranged in parallel along the branch 13 for regulating the flow of steam to the high-pressure turbine 6; a by-pass valve 21 set along the by-pass branch 18; intercept valves 22, which are commonly referred to as IVs and are arranged in parallel along the branch 15 for regulating the flow of steam to the medium-pressure turbine 7 and to the low-pressure turbines 8; and a by-pass valve 23 along the by-pass branch 19. The circuit 9 also comprises an emergency valve 24 of an on-off type, set along the branch 13 upstream of the control valves 20, and an emergency valve 25 of an on-off type, set along the branch 15 upstream of the intercept valves 22.

[0019] In Figure 1, the control valves 20 are illustrated as a single valve; however, the control valves 20 are generally eight in number and are arranged in parallel along the branch 13. In a similar way, in Figure 1 the intercept valves 22 are illustrated as a single valve; however, the intercept valves 22 are generally two in number and are arranged in parallel along the branch 15 according to what is illustrated in greater detail in Figure 2.

[0020] With reference to Figure 1, the boiler 10 is of the fluid-bed type and is designed to be supplied with solid fuels characterized by a low calorific value and by a long stay in the boiler. Consequently, the thermal power supplied by the boiler 10 can be varied over times that are very long and certainly inadequate for the needs of regulation of the plant 2.

[0021] The heater 11 is designed to heat the steam at output from the high-pressure turbine 6 prior to supply of the steam to the medium-pressure turbine 7.

[0022] The regulating device 4 has the functions of: regulating the flow rate of the steam; preventing the shaft 5 from exceeding a given threshold of angular velocity; and modulating the flow of steam during startup of the installation 1. In the case in point, the regulating device controls the control valves 20, the intercept valves 22, the by-pass valves 21, 23, and the emergency valves 24 and 25.

[0023] With reference to Figure 2, the regulating device 4 comprises a hydraulic circuit 26 and a control unit 27. The by-pass valves 21 and 23 are actuated by a pneumatic circuit (not illustrated in the attached figures) and are controlled by the control unit 27.

[0024] The ensuing description will make specific reference to the regulation of the intercept valves 22, the modes of regulation of the control valves 20 and of the emergency valves 24 and 25 being known.

[0025] The hydraulic circuit 26 comprises: a pump 28 that supplies oil under pressure to a valve 29 of an on-off type, referred to as "safety block"; a valve 30 of an on-off type, referred to as "mechanical overspeed trip device" and connected in series to the valve 29; a load limiter 31; a control device 32 for controlling the intercept valves 22; a hydraulic power distributor 33; a hydraulic power actuator 34; and a tank 35 for collecting the oil.

[0026] The regulating device 4 comprises: a mechanical system of levers 36, which is actuated by the control device 32 and is designed to actuate the hydraulic power distributor 33 that modulates the supply of the oil coming from the pump 28 to the hydraulic actuator 34; and a mechanical system of levers 37 that is connected to the hydraulic actuator 34 and is able to actuate simultaneously the two intercept valves 22 arranged in parallel.

[0027] The regulating device 4 interacts mechanically with the shaft 5 through the valve 30 and the control device 32. In particular, the mechanical overspeed trip valve 30 is actuated mechanically as a function of the velocity of the shaft 5. In the case in point, when the velocity of the shaft 5 exceeds the velocity corresponding to the 110% of the nominal velocity (3000 r.p.m.), a mechanical trip, of a known type and not illustrated in the attached figures, closes the valve 30 and controls closing of the

emergency valves 24 and 25 according to modalities that are known and not illustrated in the attached figures. The regulating device 32 is controlled by: a tachometric member 38, sensitive to the angular velocity of the shaft 5; the oil at output from the load limiter 31; and the control unit 27.

[0028] The load limiter 31 is a device of a known type, which is able to regulate the pressure of the oil of the hydraulic circuit 26 downstream of the load limiter 31 itself between zero and a maximum value as a function of values at the point of delivery.

[0029] The control unit 27, via a signal SA, controls the state of the "safety block" valve 29, which is normally open and is closed only in the case of faulty operation (pressure, temperature of the steam, etc. outside ranges of acceptability). The control unit 27, via the signal SC, controls the load limiter 31 as a function of the control set by the operator, and via the signal SM controls the control device 32 of the intercept valves 22. The signal SM is a signal correlated to the modes of operation of the plant 2: the startup stage, the steady-state stage, the arrest stage; and to other parameters of operation of the plant 2, such as, for example, the commissioning of the plant 2.

[0030] The regulating device 4 differs from a known regulating device as regards the presence of the control device 32 that enables modulation of the intercept valves 22, which otherwise would follow a law of opening of an on-off type.

[0031] With reference to Figure 3, the control device 32 comprises: a frame F; a regulating hydraulic distributor 39, co-operating with the tachometric member 38; a hydraulic cylinder 40, which is actuated by the hydraulic distributor 39 and is connected to the mechanical system of levers 36; and a linear electrical actuator 41, which is driven by the signal SM and is connected to the regulating hydraulic distributor 39 and to the mechanical system of levers 36.

[0032] The hydraulic distributor 39 is a three-way distributor comprising a liner 42 fixed to the frame F, a slide valve 43, which can slide in a direction D1 within the liner 42 and a slide valve 44, which can slide in the direction D1 within the slide valve 43. The slide valve 43 is actuated by the linear electrical actuator 41 and, in feedback, by the mechanical system of levers 36, whilst the slide valve 44 is actuated by the tachometric member 38 as a function of the velocity of the shaft 5. The slide valve 43 is mobile between two end positions, namely, a position of closing of supply (illustrated in Figure 3) and a position of supply, and between a plurality of intermediate positions, which are able to partialize the flow of oil to the hydraulic cylinder 40.

[0033] The slide valve 44 is coaxial to the slide valve 43 and to the liner 42 and is able to perform slight displacements in the direction D1 with respect to a position of equilibrium so as to supply and discharge the hydraulic cylinder 40 in a selective way.

[0034] The hydraulic cylinder 40 is a single-acting cylinder fixed to the frame F that comprises a piston 45 fixed to a stem 46 and a spring 47 for counteracting the displacement of the piston 45 caused by the inflow of oil into the hydraulic cylinder 40. The stem 46 is connected to the mechanical system of levers 37, along which is set a damper 48. The piston 45 and the stem 46 are mobile in the direction D1.

[0035] In greater detail, the tachometric member 38 comprises: a shaft 49, which can turn about its own axis A1, parallel to the direction D1, with respect to the frame F; two eccentric rotating masses 50, which are hinged to an extension to the shaft 49; a spring 51, connected to the two rotating masses 50; and two levers 52, fixed to the masses 50. The shaft 49 is connected, via a motor reducer (not illustrated in the attached figures), to the shaft 5. When the velocity of the shaft 5 exceeds a given value of angular velocity, the masses 50 move away from one another, overcoming the resistance of the spring 51 as a result of the centrifugal force, and the levers 52 are lowered. Since the slide valve 44 rests on the levers 52, the exceeding of the aforementioned threshold of angular velocity brings about a lowering (sliding) of the slide valve 44 with respect to the slide valve 43, with opening of the discharge of the distributor 39 and lowering of the piston 45 of the cylinder 40. This displacement results in the partial closing of the intercept valves 22. The spring 51 is calibrated to operate in a given range of velocities of around 3000 r.p.m., which is the theoretical value imposed on the rotation of the rotor (not illustrated) of the turbogenerator 3.

[0036] The linear electrical actuator 41 is coupled to a rod 53 parallel to the direction D1 and mobile in the direction D1. The mechanical system of levers 36 comprises two stems 54 and 55, between which is set the damper 48. The stem 55 actuates the hydraulic power distributor 33 directly, whilst the stem 54 is hinged to a lever 56, which is transverse to the direction D1 and is in turn hinged to the stem 46, to a rod 57 parallel to the direction D1,

[0037] Pivoted at the top end (Figure 3) of the rod 57 is a lever 58, which is transverse to the direction D1 and hinged to which are hinged two rods 59 and 60 parallel to the direction D1. The rod 60 is in turn hinged to a bracket 61 fixed to the frame F, whilst the rod 59 is hinged to a lever 62, transverse to the direction D1.

[0038] The lever 62 is hinged to the rod 53, in an end area, and to the slide valve 43, in a median area.

[0039] The mechanical system of levers 36 brings about actuation of the linear hydraulic power distributor 33 as a function of the position assumed by the piston 45 of the cylinder 40 and determines the position of the slide valve 43 as a function of the position assumed by the rod 53 following upon actuation of the linear hydraulic actuator 41 and of the position assumed by the stem 54. Basically, each displacement of the piston 45 in a given direction brings about a displacement of the slide valve 43 aimed at limiting the displacement of the piston 45 itself.

[0040] In steady-state operating conditions, the linear electrical actuator 41 is in a fixed position. If the velocity of the shaft 5 exceeds a threshold value, the tachometric member 38 brings about a displacement of the slide valve 44 in the direction opposite to the direction D1, which sends into discharge part of the oil contained in the cylinder 40. Consequently, also the stems 54 and 55 shift in the direction opposite to the direction D1, so causing a partial choking of the intercept valves 22 (not illustrated in Figure 3) and the slowing-down of the shaft 5. In this step, the mechanical system of levers 36 brings about a displacement of the rod 59 in the direction opposite to the direction D1 and a displacement in the direction opposite to the direction D1 of the slide valve 43, with partial or total closing of the discharge of the oil from the cylinder 40. The displacement of the slide valve 43 can be such as to set the hydraulic distributor 39 in a position of supply of oil to the cylinder 40. This feedback system enables rapid restoration of the velocity of the shaft 5 that has been set.

[0041] The control device 32 is driven, via the electrical signal SM, by the oil at a modulated pressure supplied by the load limiter 31 and by the tachometric member 38 sensitive to the velocity, which is of no effect in the stage of startup of the steam-turbine plant 2.

[0042] Precisely in the startup stage, the linear hydraulic actuator 41 is actuated for displacing the slide valve 43 in the direction opposite to the direction D1 so as to supply the cylinder 40 and bring about a displacement of the stems 46, 54 and 55 in the direction D1 and consequent opening of the valves. Also in this case, the mechanical system of levers 36 brings about a displacement of the slide valve 43 in the direction D1, with the tendency to shut off supply of the oil to the cylinder 40. The mechanical system of levers 46 guarantees in this way a progressive supply of oil to the cylinder 40 in combination with the signal SM for controlling the linear electrical actuator 41.

[0043] The control device 32 enables, in the stage of startup of the steam-turbine plant 2, a progressive opening of the intercept valves 22 according to what is illustrated in the diagram of Figure 4, which gives on the ordinate the percentage of opening as a function of time T. The curve IV (dashed line) shows a preferred law of opening of the intercept valves 22, whilst the curve CV shows a preferred law of opening of the control valves 20. The time T1 is the instant at which the switch of the turbogenerator 3 is set in the closed condition.

[0044] Basically, the controlled opening of the intercept valves 22 and the control in steady-state conditions of the intercept valves 22 themselves are rendered possible thanks to the insertion of the control device 32 in a known regulating device 4, without requiring the replacement of the intercept valves 22.

Claims

1. A device for regulating the intercept valves (22) of a steam-turbine plant (2), the regulating device (4) comprising: a hydraulic circuit (26), designed to supply a linear hydraulic actuator (34) for actuating a first mechanical system of levers (37) for opening and closing the intercept valves (22) simultaneously; and a hydraulic power distributor (33), designed to supply selectively the linear hydraulic actuator (34); the regulating device (4) being **characterized in that** it comprises a control device (32), designed to control the hydraulic power distributor (33) as a function of a signal (SM) correlated to the modes of operation of the steam-turbine plant (2) for partializing, without solution of continuity, opening of the intercept valves (22) between a position of complete closing and a position of maximum opening.

2. The device according to Claim 1, **characterized in that** the control device (32) comprises: a hydraulic distributor (39); a hydraulic cylinder (40); and a second mechanical system of levers (36); the hydraulic cylinder (40) being selectively supplied by the hydraulic distributor (39) and connected to the hydraulic power distributor (33) by the second mechanical system of levers (36).

3. The device according to Claim 2, in which the intercept valves (22) are arranged in parallel along a connection branch (15) between a high-pressure turbine (6) and a low-pressure turbine (7), and are actuated by the first mechanical system of levers (37); the regulating device (4) being **characterized in that** it comprises a load limiter (31), which is designed to modulate the pressure of the oil and is connected to the hydraulic distributor (39) for supplying the oil modulated in pressure to the hydraulic distributor (39) and to the cylinder (40); the hydraulic power distributor (33) and the linear hydraulic actuator (34) being supplied with non-modulated oil.

4. The device according to Claim 3, **characterized in that** it comprises a linear electrical actuator (41), designed to actuate the hydraulic distributor (39) as a function of said signal (SM).

5. The device according to Claim 4, **characterized in that** the hydraulic distributor (39) comprises a liner (42) and a first slide valve (43) that is mobile with respect to the liner (42); said first slide valve (43) being connected to said linear electrical actuator (41) for determining the travel of the first distributing slide valve (43) with respect to the liner (42).

6. The device according to Claim 5, **characterized in that** the second mechanical system of levers (36) is connected to the first slide valve (43) so that, when

the linear electrical actuator (41) brings about a displacement of the first slide valve (43) in a first direction, the movement induced on the second mechanical system of levers (36) by the hydraulic cylinder (40) brings about a displacement of the slide valve (43) in a second direction opposite to the first direction.

7. The device according to Claim 5 or Claim 6, **characterized in that** the hydraulic regulating distributor (39) comprises a second distributing slide valve (44), slidably mounted within the first distributing slide valve (43), which is designed to supply and discharge selectively the hydraulic cylinder (40).

8. The device according to Claim 7, in which the steam-turbine plant (2) comprises a shaft (5), which can turn about the axis (A), the regulating device (4) being **characterized in that** it comprises a tachometric member (38), which is sensitive to the angular velocity of the shaft (5), is connected to the shaft (5), and is connected to the second distributing slide valve (44) for displacing the second slide valve (44) as a function of the velocity of the shaft (5).

9. A steam-turbine plant comprising a regulating device according to any one of Claims 1 to 8, **characterized in that** it comprises a steam circuit (9) and a boiler (10) for generation of the steam with low capacity of thermal modulation, in particular a fluid-bed boiler.

10. An installation for the production of electric power comprising a steam-turbine plant according to Claim 9, **characterized in that** it comprises a turbogenerator (3) actuated by the steam-turbine plant (2).

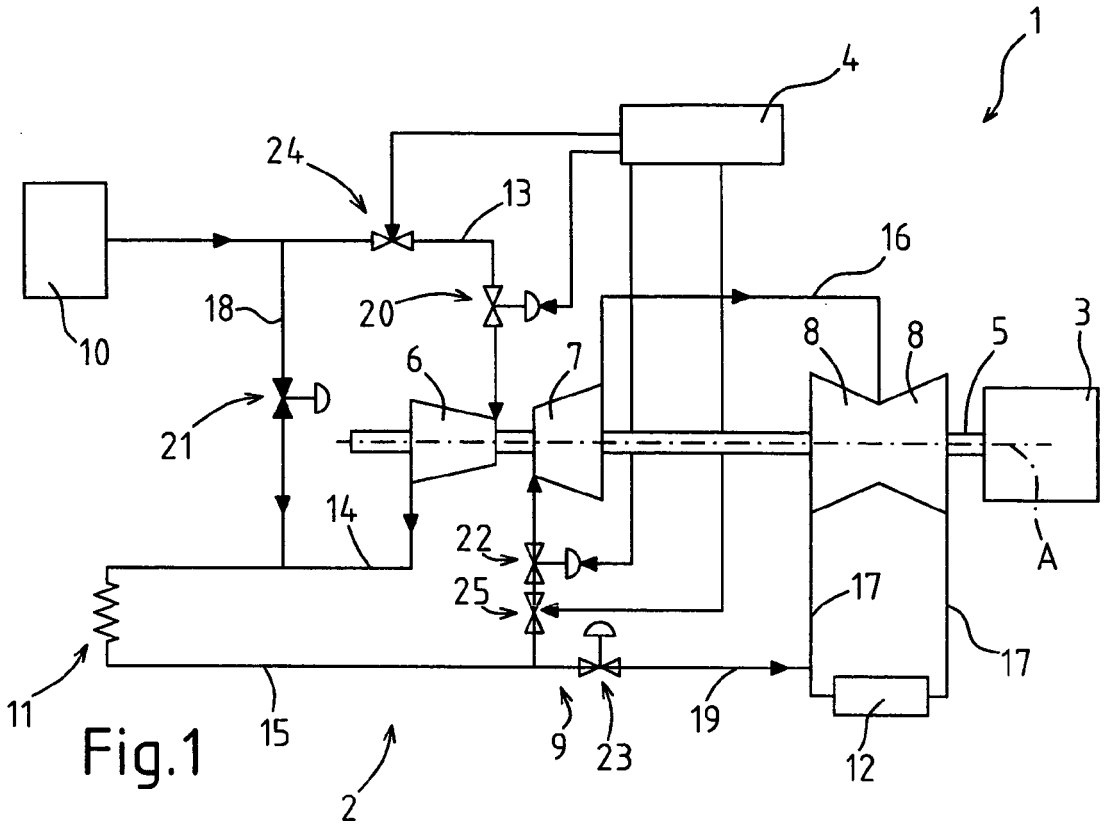
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Fig.1

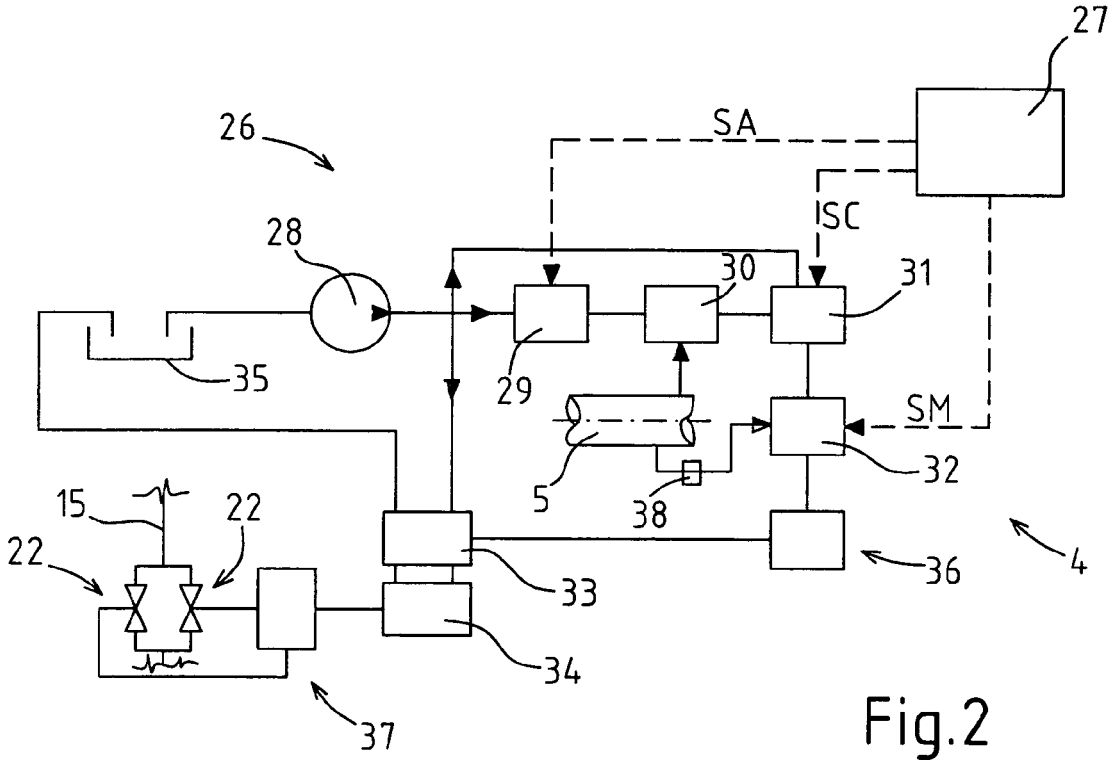
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Fig.2

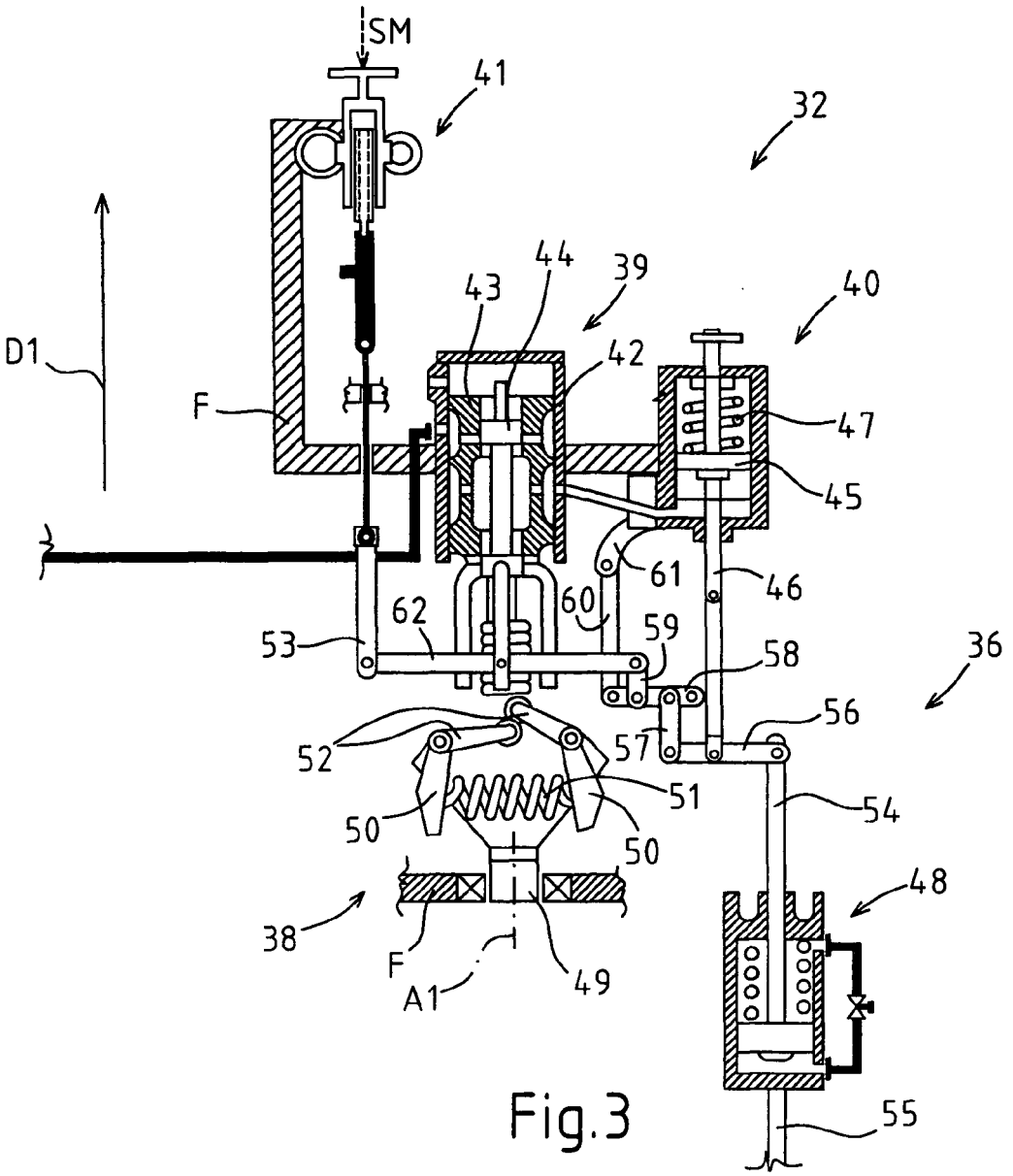
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Fig.3

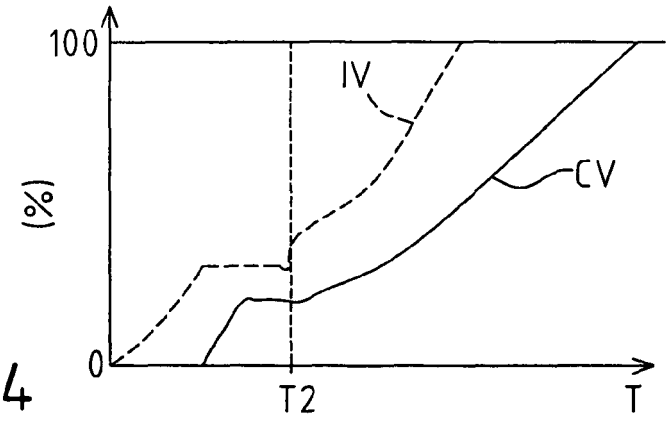
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Fig.4

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EUROPEAN SEARCH REPORT

Application Number
EP 06 42 5509

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	DE 100 42 317 A1 (ALSTOM POWER NV [NL]) 14 March 2002 (2002-03-14) * paragraph [0040] - paragraph [0055]; claims; figure 1 * * abstract * -----	1-10	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 May 2007	Zerf, Georges

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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