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(54) **METHOD AND DEVICE FOR CONTROLLING A STEAM TURBINE**

(57) A method and device for controlling a steam turbine, in which the steam turbine is controlled via a primary servo valve system as a main control circuit and a secondary servo valve system as a backup control circuit, the servo piston of the secondary servo valve system being kept in constant motion.

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Description

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to a method and a device for controlling a steam turbine, in which the steam turbine is controlled via a primary servo valve system as a main control circuit and a secondary servo valve system as a backup control circuit, the servo piston of the secondary servo valve system being kept in constant motion.

BACKGROUND OF THE DISCLOSURE

[0002] Turbo-compressors are generally used when large gas volume flows have to be compressed, for example in compression installations for increasing the pressure in gas pipelines, as blowers in blast furnaces or steel mills, in air or gas liquefaction plants, as air or nitrous gas compressors in nitric acid plants, in petrochemical plants and refineries or as vacuum blowers in the paper industry. The choice of the drive unit for the turbo-compressor depends on the application. Whilst gas turbines are employed in gas pipeline and offshore applications, electric motors with frequency inverters are mostly used as a drive for small and medium power requirements. In plants in which sufficient and reliable amounts of steam is available, as is generally the case in chemical plants, steel mills or ironworks, a steam turbine is preferably used as the drive.

[0003] Generally, the steam turbine is controlled by using a steam control valve to regulate the amount of steam supplied to the turbine, so as to guarantee the rotational speed of the turbo-compressor necessary for the production process.

[0004] The steam control valves are mostly equipped with a hydraulic control system, in which the steam flow, and thus the rotational speed of the turbo-compressor, are controlled by varying the flow rate of the hydraulic liquid. Oil is often used as the hydraulic liquid.

[0005] Such control systems are described in various references.

[0006] CN105545842 describes a control system and a control method for synchronizing a static TRT blade actuator, the synchronization being achieved with the use of two servo valves, a manual reversing valve and an electromagnetic reversing valve.

[0007] CN 109268347 discloses a steam turbine interruption early warning system for a set of generators, which system comprises a main oil pump, a servo switch valve, a cartridge valve, a pilot valve, a hydraulic pressure controller, a DCS control and an oil drive. The early warning system is to early detect interruptions, for example due to an oil leak.

[0008] JP2022027090 relates to a method for monitoring the opening of a steam control valve for increasing or reducing the amount of steam supplied to a turbine, wherein a first alarm is triggered, if a difference between

the opening of the steam control valve and a target opening is detected, and a second alarm is triggered, if the deflection of a hydraulic actuator does not match a pre-defined target value.

[0009] It is the object of JP 2019031941 to provide a steam valve drive device and a stem valve that can be operated continuously, even if a non-conformity occurs in the control valve. This object is intended to be achieved by the steam valve drive device comprising a control device, a first control valve for controlling an amount of working fluid, a second control valve arranged parallel to the first control valve, a first and a third stop valve for interrupting the supply of a working fluid to the control valve and for discharging the working fluid from the control valve, a second and a fourth stop valve for interrupting the supply of the working fluid to a hydraulic cylinder device from the control valve and for discharging the working fluid to the control valve from the hydraulic cylinder device, and a bypass flow channel. The steam valve drive device continually controls the steam valve through the second control valve on the basis of a signal from the control device, closes the first and second stop valves and discharges the working fluid in the first control valve between the first and second stop valves and the first control valve via a bypass flow channel, if a malfunction occurs in the first control valve. However, the system described has the drawback that the amount of steam has to be reduced significantly during the inspection. The instabilities and fluctuations caused thereby are a problem and may have adverse effects on the process.

[0010] It is a further problem with such control systems that the control and lubricating oil circuits of the turbo-compressor and of the steam turbine receive the oil from the same reservoir so that a mixing of the oil flows from the two applications occurs. Due to thermal stress and contact with process media, the oil ages, forming solid particles in the process. These contaminations may cause an obstruction of the valves, in particular of the sensitive servo valves, which in the worst case may result in a failure of the installation. This problem is exacerbated in the components in which there is no constant flow or in which the flow rate is low, as for example in emergency systems which are intended to take over control of the steam turbine in case of a malfunction or a failure of the main control system. Thus, there is a risk that the emergency system does not operate and the installation comes to a standstill which generally comes with a great financial loss.

[0011] Against this backdrop, there is thus a need to provide a method that enables a reliable control of a steam turbine.

SUMMARY OF THE DISCLOSURE

[0012] The present disclosure provides a method, in which a primary servo valve system is provided as a main control circuit and a secondary servo valve system is provided as a backup control circuit for controlling a

steam turbine, and in which the secondary servo valve system is continually kept in motion and flown through.

[0013] Therefore, a first subject matter of the present disclosure relates to a method for controlling a steam turbine, the method comprising the following steps:

i) providing a primary servo valve system as a main control circuit for controlling the steam flow entering the steam turbine;

ii) providing a secondary servo valve system as a backup control circuit for controlling the steam flow entering the steam turbine;

wherein the servo piston of the secondary servo valve system is freely movable between a first position and a second position;

iii) generating a control oil return flow from the secondary servo valve system;

iv) cyclically moving the servo piston between the first position and the second position within a period t_x and simultaneously sensing the pressure in the control oil return flow;

v) recording the sensed pressure values while forming a maximum and a minimum pressure value;

vi) triggering an alarm signal, if the measured pressure fails to reach a minimum and/or maximum target pressure.

[0014] The method of the present disclosure keeps the secondary servo valve system, which serves as a backup in case of a failure of the primary servo valve system, is kept in motion and is constantly flown through by the control oil flow, so that a seizure of the servo piston is prevented. Thus, it is ensured that also the secondary servo valve system is always operational and can take over the control of the steam turbine should the primary servo valve system fail. Costly failures of the installation and an associated production stop can be avoided in this manner.

[0015] In some embodiments, the first position is a discharge position of the secondary servo valve system and the second position is a supply position of the secondary servo valve system.

[0016] In some embodiments, the servo piston of the secondary servo valve system is continuously moved between the first position and the second position.

[0017] In some embodiments, the servo piston is moved from the first position to the second position within a first period t_1 .

[0018] In some embodiments, the servo piston is moved from the second position to the first position within a second period t_2 .

[0019] In some embodiments, t_x may be $t_1 + t_2$. Addi-

tionally or alternatively t_1 and t_2 may be equal.

[0020] In some embodiments, a primary control oil flow may be supplied to the primary servo valve system from an oil receptacle and may be supplied from there to an actuator via a magnetic switch valve, which actuator controls the steam supply to the steam turbine. Furthermore, a secondary control oil flow may be supplied to the secondary servo valve system from an oil receptacle and is returned into the oil receptacle via the magnetic switch valve, wherein the magnetic switch valve is controlled such that the control oil flow from the secondary servo valve system is supplied to the actuator if the primary servo valve system fails.

[0021] In some embodiments, the alarm is triggered if the pressure in the control oil return flow does not reach the minimum and/or the maximum pressure value within a period t_z , wherein t_z is equal to the sum of t_1 and x and/or t_z is equal to t_2 and x , with x representing a freely selectable waiting period.

[0022] In some embodiments, the steam turbine drives a turbo-compressor in a petrochemical installation, in particular a cracker, or a generator in a power plant.

[0023] A further subject matter of the present disclosure relates to a device for controlling a steam turbine, comprising

i) an oil tank containing a control oil;

ii) a primary control circuit comprising a primary servo valve system;

iii) a secondary control circuit comprising a secondary servo valve system;

iv) a magnetic switch valve;

v) a control unit for controlling the steam flow to the steam turbine and

vi) an alarm system,

wherein the primary control circuit and the secondary control circuit are connected to the oil tank,

wherein the primary servo valve system and the secondary servo valve system are configured to guide the control oil flow to the magnetic switch valve,

wherein the magnetic switch valve is controlled such that it switches from the primary servo valve system to the secondary servo valve system if the primary servo valve system is not operational;

wherein the secondary control circuit comprises a limiting orifice, a valve and a measuring unit that are arranged between the oil tank and the secondary servo valve system;

wherein the measuring unit is designed to measure a minimum pressure value and/or a maximum pressure value in the control oil flow, which is generated by cyclically moving a servo piston in the secondary servo valve system between a first position and a second position,

wherein the alarm system is configured such that an alarm signal is triggered if the measured pressure value does not reach a maximum target pressure value and/or a minimum target pressure value.

[0024] In some embodiments, the alarm system is triggered if the measured pressure value does not reach a maximum target pressure value and/or a minimum target pressure value.

[0025] In some embodiments the alarm system is configured such that an alarm is triggered if the maximum target pressure value and/or the minimum target pressure value is not reached within a time period t_z .

[0026] In some embodiments, the device is operated in a petrochemical installation. In particular, the device may be operated in a cracker or in a power plant.

[0027] The present disclosure is illustrated with reference to the following Figures which should by no means be understood as limiting the idea of the disclosure.

[0028] The combination of features shown and described in the individual exemplary embodiments serves solely the purposes of explanation. According to the statements above, it is possible to dispense with a feature of an exemplary embodiment if its technical effect is of no importance in a particular application. Conversely, according to the above statements, a further feature can be added in an exemplary embodiment if its technical effect is meant to be advantageous or necessary for a particular application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

Figure 1 shows an exemplary pressure recording of the control oil return flow within the scope of the method according to the disclosure, wherein the recording shows the pressure buildup and the pressure drop which are generated by the cyclical movement of the servo piston in the secondary servo valve system.

Figure 2 shows a schematic structure of the system according to the disclosure comprising

1. oil reservoir
2. limiting orifice and adjusting valve
3. bearing lubrication and sealing oil system of the steam turbine and the crude gas turbo-compressor

4. pressure measurement secondary servo valve system

5. primary servo valve system

6. secondary servo valve system

7. switch valve

8. steam supply

9. steam control valve

10. steam turbine

DETAILED DESCRIPTION OF THE DISCLOSURE

[0030] A first subject matter of the present disclosure relates to a method for controlling a steam turbine, the method comprising the following steps:

i) providing a primary servo valve system as a main control circuit for controlling the steam flow entering the steam turbine;

ii) providing a secondary servo valve system as a backup control circuit for controlling the steam flow entering the steam turbine;

wherein the servo piston of the secondary servo valve system is freely movable between a first position and a second position;

iii) generating a control oil return flow from the secondary servo valve system;

iv) cyclically moving the servo piston between the first position and the second position within a period t_x and simultaneously sensing the pressure in the control oil return flow;

v) recording the sensed pressure values while forming a maximum and a minimum pressure value;

vi) triggering an alarm signal, if the measured pressure fails to reach a minimum and/or maximum target pressure.

[0031] The method of the present disclosure keeps the secondary servo valve system, which serves as a backup in case of a failure of the primary servo valve system, is kept in motion and is constantly flown through by the control oil flow, so that a seizure of the servo piston is prevented. Thus, it is ensured that also the secondary servo valve system is always operational and can take over the control of the steam turbine should the primary servo valve system fail. Costly failures of the installation and an associated production stop can be avoided in this

manner.

[0032] In some embodiments of the method according to the disclosure a primary control oil flow is supplied from an oil receptacle to the primary servo valve system from which the control oil flow is supplied on through a magnetic switch valve to an actuator that controls the steam supply to the steam turbine. A secondary control oil flow is supplied from the oil receptacle to the secondary servo valve system and is returned into the oil receptacle. In a further embodiment, the magnetic valve is controlled such that the control oil flow is supplied from the secondary servo valve system to the actuator if the primary servo valve system fails.

[0033] In conventional installations, a combined lubrication oil and control oil system is used, whereby obstructions of the control valve can occur, for example due to abraded material accumulated in the oil. According to the method of the disclosure, the control oil flow is returned from an oil receptacle back into the oil receptacle through the secondary servo valve system, if the secondary servo valve system is in the backup mode. The regular flushing of the secondary servo valve system creates a flushing effect, by which small contaminations that would otherwise accumulate in the valve are flushed away. Furthermore, the accretion of solids is prevented by the continuous movement of the servo piston. Thus, upon a failure of the main control circuit, the secondary servo valve system can be used without delay to control the steam turbine, in which the control oil flow is then supplied by the secondary servo valve system to the actuator which controls the steam supply to the steam turbine. Moreover, a negative impact on the steam flow in regular operation, which is partly common in conventional methods, is prevented. In some embodiments, as part of the method of the method of the disclosure, control oil and lubricating oil are taken from the same oil tank.

[0034] In some embodiments, the servo piston of the secondary servo valve system is continually moved between the first position and the second position. This continuous movement of the servo piston causes a cleaning effect on the running surfaces of the cylinder and the piston, so that an accumulation of an accretion that would cause a blocking of the cylinder is prevented. Surprisingly, it has been observed that the cyclical and continuous movement of the piston causes a certain heat input that prevents oil in the system from cooling, which would cause flocculation in the oil and would again result in a blocking of the system.

[0035] The continuous movement of the servo piston causes a rising and falling pressure in the control oil return flow, which pressure can be used as a control function of the system. If specific target values, such as a maximum pressure value and a minimum pressure value, are not reached, one can conclude on a malfunction of the system and an alarm is triggered. In some embodiments of the method according to the disclosure, the servo piston is moved from the first position to the second position within a first period t_1 , and thereby a pressure

change is caused in the control oil return flow. This pressure change may in an exemplary embodiment be monitored based on target values defined in advance.

[0036] In a further exemplary embodiment, the servo piston is moved from the second position to the first position within a second period t_2 , and thereby a pressure change is caused in the control oil return flow. The pressure change thus caused can be monitored on the basis of target values defined in advance, and thus the correct functioning of the secondary servo valve system can be monitored and maintained.

[0037] In some embodiments of the method according to the disclosure, the servo piston of the secondary servo valve system may be moved cyclically from the first position to the second position and back within a period t_x . In a further exemplary embodiment t_x may be characterized by the following relationship:

$$t_x = t_1 + t_2.$$

[0038] The time intervals t_1 and t_2 can be chosen freely and can be adjusted depending on the application. In an exemplary embodiment, it further holds that $t_1 = t_2$.

[0039] The method according to the disclosure provides that an alarm is triggered if the pressure in the control oil return flow does not reach the defined target values. This alarm can be triggered with a delay in time, so that an embodiment is in which the alarm is triggered if the pressure in the control oil return flow has not reached the minimum and/or the maximum pressure value within a period t_z . In this manner, false alarms can be prevented that may be triggered by slight pressure variations in the control oil return flow. The time interval t_z can be chosen freely and can be adjusted. In one embodiment, it holds that:

$t_z = t_1 + x$ and/or $t_z = t_2 + x$, where x is a freely selectable waiting period. More preferably, it holds that: 60 seconds $\leq t_z \leq$ 600 seconds, more preferably 120 seconds $\leq t_z \leq$ 300 seconds.

[0040] For the time that the main control circuit comprising the primary servo valve system operates properly, no interference by the backup control circuit has to be provided and its influence on the operation of the steam turbine should be kept as little as possible. In an exemplary embodiment, the control oil flow is therefore returned into the oil receptacle when the servo piston of the secondary servo valve system is in the first position or between the first position and the second position. In addition, a regular flushing of the secondary servo valve system is achieved by this guiding of the control oil flow, so that a clogging of the valve is prevented.

[0041] The control method according to the disclosure is characterized in particular in that it provides for an instantaneous operational readiness of the backup control circuit if the main control circuit should fail. In the context of this protective function, an embodiment is envisioned in which in case of a failure of the primary servo valve

system, the control oil flow is supplied by the secondary servo valve system to an actuator, for example a hydraulic main steam valve, which controls the steam flow to the steam turbine. In this manner, the secondary control circuit can assume the control of the steam turbine, without a failure of the installation occurring.

[0042] The control system of a steam turbine generally comprises a number of control and actuation units that control the steam flow supplied to the turbine. In an exemplary embodiment of the method according to the disclosure, the servo valve systems supply the control oil flow to an actuator via a magnetic switch valve, the actuator operating a valve that controls the supply of the steam flow to the steam turbine. Should the primary servo valve system fail, the control oil flow can be supplied to the actuator from the secondary servo valve system via the magnetic switch valve and the control oil flow can thus be maintained.

[0043] The method according to the disclosure can be used to control any optional steam turbine. In one embodiment, the steam turbine drives a turbo-compressor, particularly one used in a petrochemical plant, such as a cracker. In an alternative embodiment, the steam turbine drives a generator in a power plant.

[0044] A further subject matter of the present disclosure relates to a device for controlling a steam turbine, comprising

- i) an oil tank containing a control oil;
- ii) a primary control circuit comprising a primary servo valve system;
- iii) a secondary control circuit comprising a secondary servo valve system;
- iv) a magnetic switch valve;
- v) an actuator for controlling the steam flow to the steam turbine and
- vi) an alarm system,

wherein the primary control circuit and the secondary control circuit are connected to the oil tank,

wherein the primary servo valve system and the secondary servo valve system are configured to guide the control oil flow to the magnetic switch valve,

wherein the magnetic switch valve is controlled such that it switches from the primary servo valve system to the secondary servo valve system if the primary servo valve system is not operational;

wherein the secondary control circuit comprises a limiting orifice, a valve and a measuring unit that are arranged between the oil tank and the secondary

servo valve system;

wherein the measuring unit is designed to measure a minimum pressure value and/or a maximum pressure value in the control oil flow, which is generated by cyclically moving a servo piston in the secondary servo valve system between a first position and a second position,

wherein the alarm system is configured such that an alarm signal is triggered if the measured pressure value does not reach a maximum target pressure value and/or a minimum target pressure value.

[0045] In an exemplary embodiment, the alarm system is configured such that an alarm is triggered if the maximum target pressure value and/or the minimum target pressure value is not reached within a period t_z . In this manner, it is provided that false alarms are caused due to noncritical delays during pressure adjustment.

[0046] In some embodiments, the actuator is the main steam control valve that controls the steam flow supplied to the steam turbine.

[0047] In some embodiment, the device according to the present disclosure is operated in a petrochemical installation, preferably a cracker, or in a power plant.

[0048] A control oil flow is directed from a reservoir (1), from which also the oil for the bearing lubrication and the sealing oil system of the steam turbine and the crude gas turbo-compressor (3) is taken, into the control system comprising a primary servo valve system (5) and a secondary servo valve system (6). In regular operation, after passing the secondary servo valve system (6), a first part of the control oil flow is returned into the oil reservoir (1) via the switch valve (7), wherein the pressure in this return flow is monitored using a limiting orifice and an adjusting valve (2) as well as a pressure gauge (4). Should the pressure in the secondary servo valve system (6) not reach the predetermined target values within a defined period, an alarm will be triggered.

[0049] After passing the primary servo valve system (5), a second part of the control oil flow is supplied via the switch valve (7) to the steam control valve (9) which controls the steam supply (8) to the steam turbine (10). Should the primary servo valve system (5) fail, the control oil flow of the secondary servo valve system (6) can be supplied to the steam control valve (9) via the switch valve (7) and assume the control of the steam flow (8).

Claims

1. A method for controlling a steam turbine (10), the method comprising:

- i) providing a primary servo valve system (5) as a main control circuit for controlling the steam flow (8) entering the steam turbine (10);

ii) providing a secondary servo valve system (6) as a backup control circuit for controlling the steam flow (8) entering the steam turbine (10);

wherein the secondary servo valve system (6) comprises a servo piston that is freely movable between a first position and a second position;

iii) generating a control oil return flow from the secondary servo valve system (6);

iv) cyclically moving the servo piston between the first position and the second position within a period t_x and simultaneously sensing the pressure in the control oil return flow (4);

v) recording the sensed pressure values while forming a maximum and a minimum pressure value;

vi) triggering an alarm signal, if the measured pressure fails to reach a minimum and/or maximum target pressure.

2. The method according to claim 1, **characterized in that** the first position is a discharge position and the second position is a supply position.

3. The method according to at least one of the preceding claims, **characterized in that** the servo piston of the secondary servo valve system (6) is continuously moved between the first position and the second position.

4. The method according to at least one of the preceding claims, **characterized in that** the servo piston is moved from the first position to the second position within a first period t_1 .

5. The method according to at least one of the preceding claims, **characterized in that** the servo piston is moved from the second position to the first position within a second period t_2 .

6. The method according to at least one of the preceding claims, **characterized in that** $t_x = t_1 + t_2$ and/or $t_1 = t_2$.

7. The method according to at least one of the preceding claims, **characterized in that** a primary control oil flow is supplied to the primary servo valve system (5) from an oil receptacle (1) and is supplied from there to an actuator (9) via a magnetic switch valve (7), which actuator controls the steam supply (8) to the steam turbine (10), and a secondary control oil flow is supplied to the secondary servo valve system (6) from an oil receptacle (1) and is returned into the oil receptacle (1) via the magnetic switch valve (7), wherein the magnetic switch valve (7) is optionally controlled such that the control oil flow from the secondary servo valve system (6) is supplied to the ac-

tuator (9) if the primary servo valve system (5) fails.

8. The method according to at least one of the preceding claims, **characterized in that** the alarm is triggered if the pressure in the control oil return flow does not reach the minimum and/or the maximum pressure value within a period t_z , wherein $t_z = t_1 + x$ and/or $t_2 + x$, with x representing a freely selectable waiting period.

9. The method according to at least one of the preceding claims, **characterized in that** the steam turbine (10) drives a turbo-compressor in a petrochemical installation, particularly a cracker, or a generator in a power plant.

10. A device for controlling a steam turbine (10), comprising:

i) an oil tank (1) containing a control oil;

ii) a primary control circuit comprising a primary servo valve system (5);

iii) a secondary control circuit comprising a secondary servo valve system (6);

iv) a magnetic switch valve (7);

v) a control unit (9) for controlling the steam supply (8) to the steam turbine (10), and

vi) an alarm system,

wherein the primary control circuit and the secondary control circuit are connected to the oil tank (1),

wherein the primary servo valve system (5) and the secondary servo valve system (6) are configured to guide the control oil flow to the magnetic switch valve (7),

wherein the magnetic switch valve (7) is controlled such that it switches from the primary servo valve system (5) to the secondary servo valve system (6) if the primary servo valve system (5) is not operational;

wherein the secondary control circuit comprises a limiting orifice (2), a valve (2) and a measuring unit (4) that are arranged between the oil tank (1) and the secondary servo valve system (6);

wherein the measuring unit (4) is designed to measure a minimum pressure value and/or a maximum pressure value in the control oil flow, which is generated by cyclically moving a servo piston in the secondary servo valve system (6) between a first position and a second position, wherein the alarm system is configured such that an alarm signal is triggered if the measured pressure value does not reach a maximum target pressure value and/or a minimum target pressure value.

11. The device according to claim 10, **characterized in that** the alarm system is configured such that an

alarm is triggered if the maximum target pressure value and/or the minimum target pressure value is not reached within a period t_z .

12. The device according to at least one of claims 10 or 11, **characterized in that** the device is operated in a petrochemical installation, preferably a cracker, or in a power plant.

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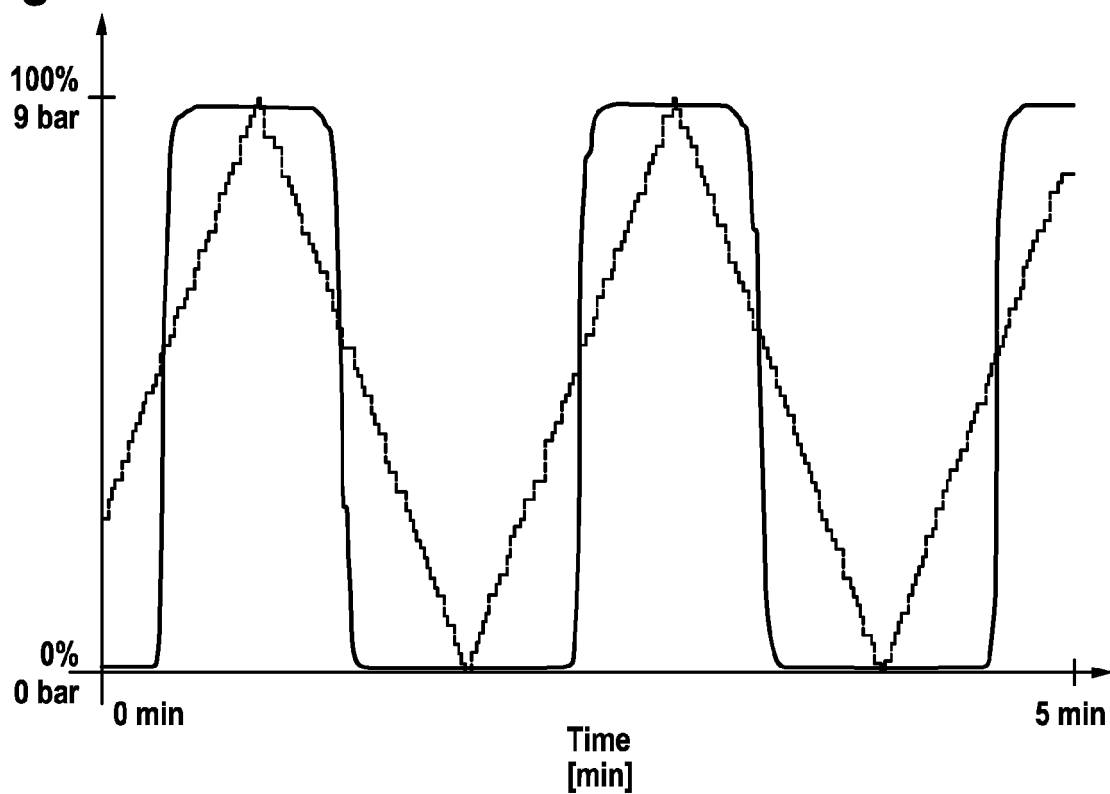
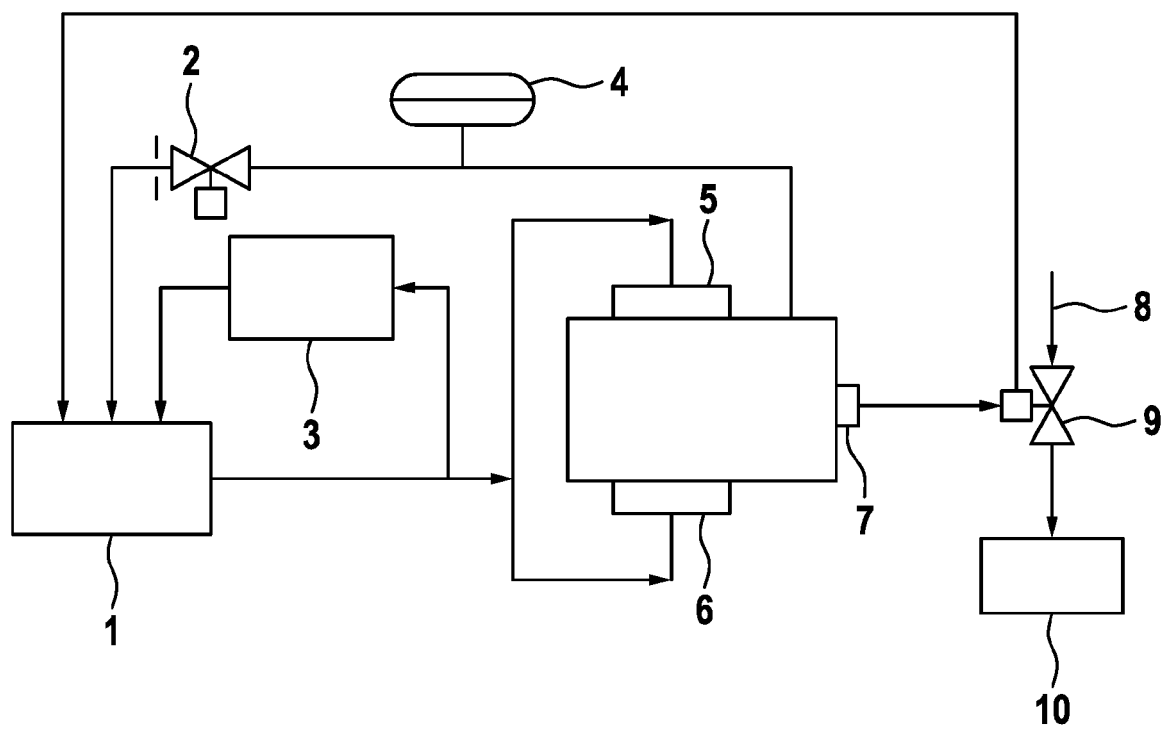
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Fig. 1**Fig. 2**



EUROPEAN SEARCH REPORT

Application Number

EP 22 17 6496

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A, D	JP 2019 031941 A (TOSHIBA CORP; TOSHIBA ENERGY SYSTEM & SOLUTION CORP) 28 February 2019 (2019-02-28) * paragraphs [0022] - [0033]; figures 1-3 *	1-12	INV. F01K7/16
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			TECHNICAL FIELDS SEARCHED (IPC)
			F01K
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		23 November 2022	Röberg, Andreas
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 22 17 6496

5 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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