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(54) **FUEL CELL SYSTEM**

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(57) **ABSTRACT**

The fuel cell system includes a plurality of fuel cell stacks, an oxidant gas supply unit having a turbo compressor that supplies oxidant gas to each of the fuel cell stacks, and a control device that determines a required operation number for the fuel cell stacks and a target supply pressure and a target supply flow rate of oxidant gas to be commanded to the oxidant gas supply unit according to a required output. The oxidant gas supply unit has an adjustment mechanism that adjusts a supply rate, which is a ratio of a supply flow rate supplied to the plurality of fuel cell stacks, with respect to a discharge flow rate of the turbo compressor. The control device monitors the pressure ratio in the turbo compressor and controls the adjustment mechanism to reduce the supply rate when the pressure ratio exceeds a predetermined threshold.

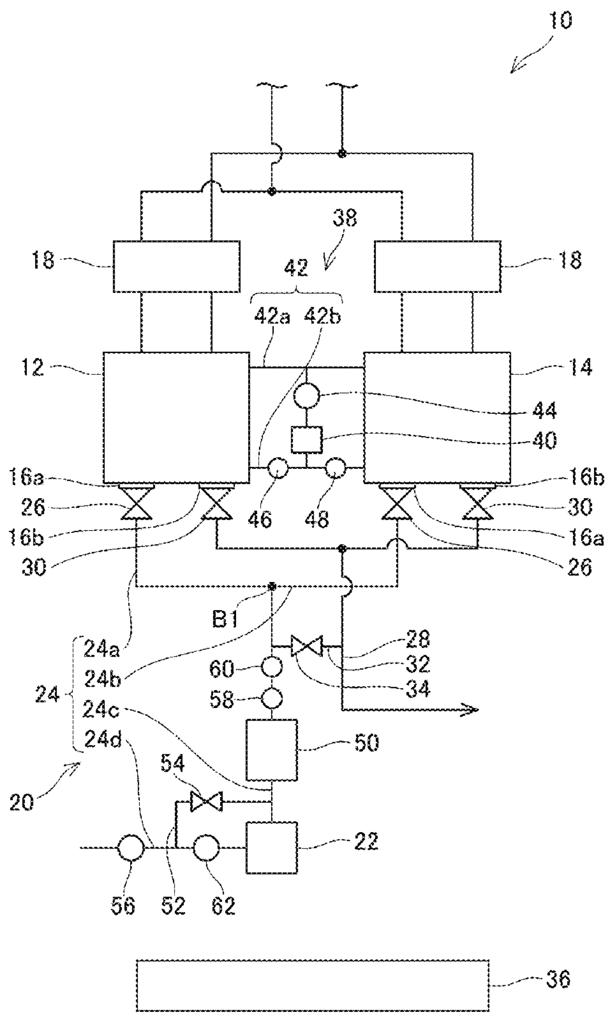


FIG. 1

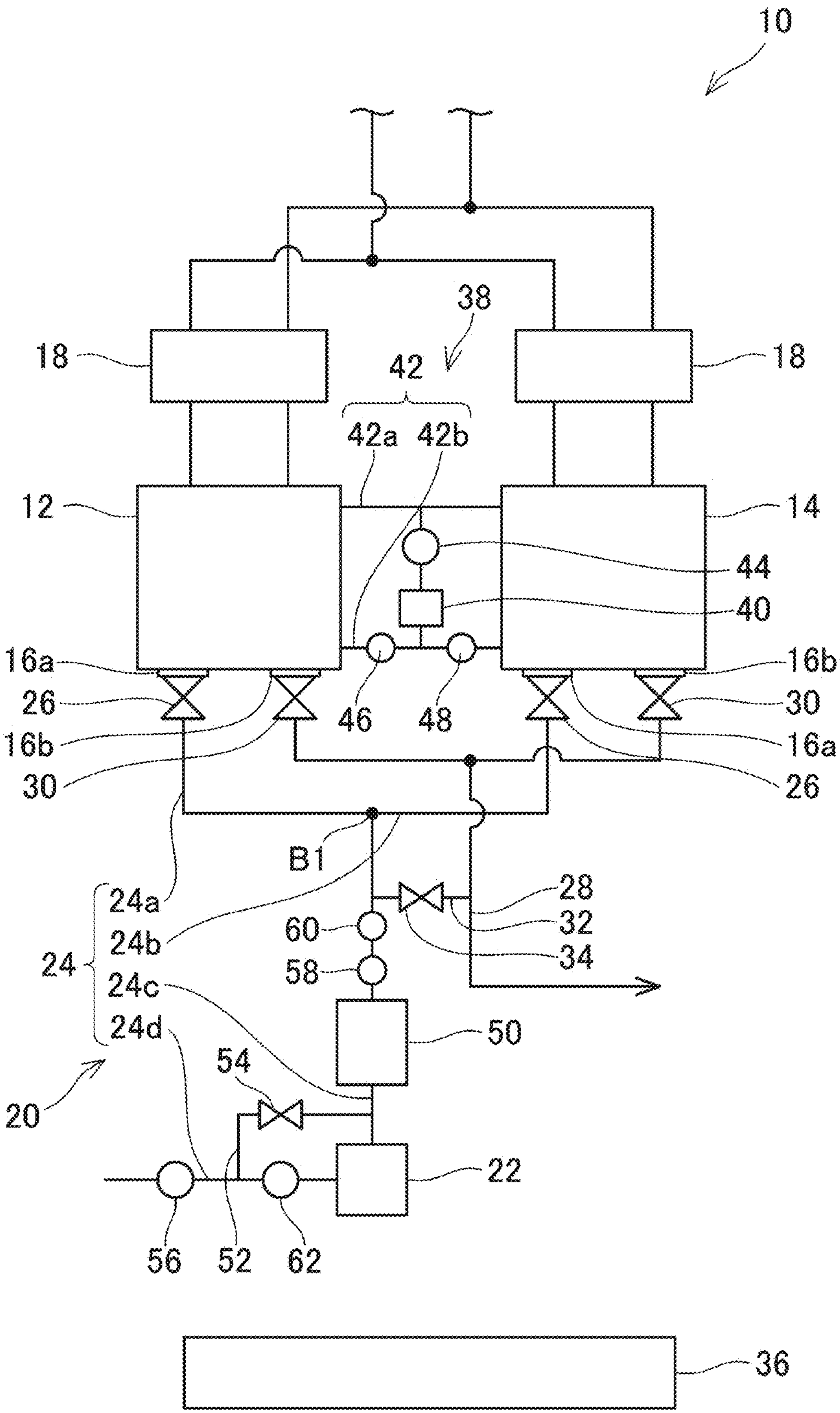

10
38
18
42
18
42a 42b
12
14
44
40
16a
16b
26
30
46
48
16b
16a
30
26
B1
24a
28
24b
32
60
34
24
58
24c
50
24d
54
20
22
56
52
62
36

FIG. 2

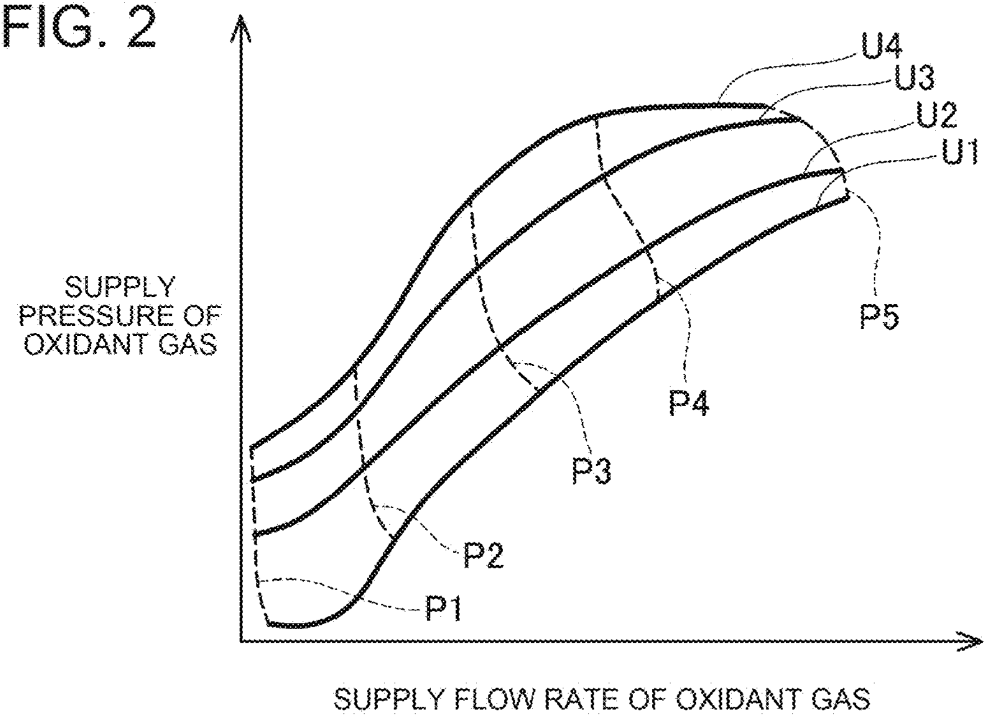

U4
U3
U2
U1
SUPPLY PRESSURE OF OXIDANT GAS
P5
P4
P3
P2
P1
SUPPLY FLOW RATE OF OXIDANT GAS

FIG. 3

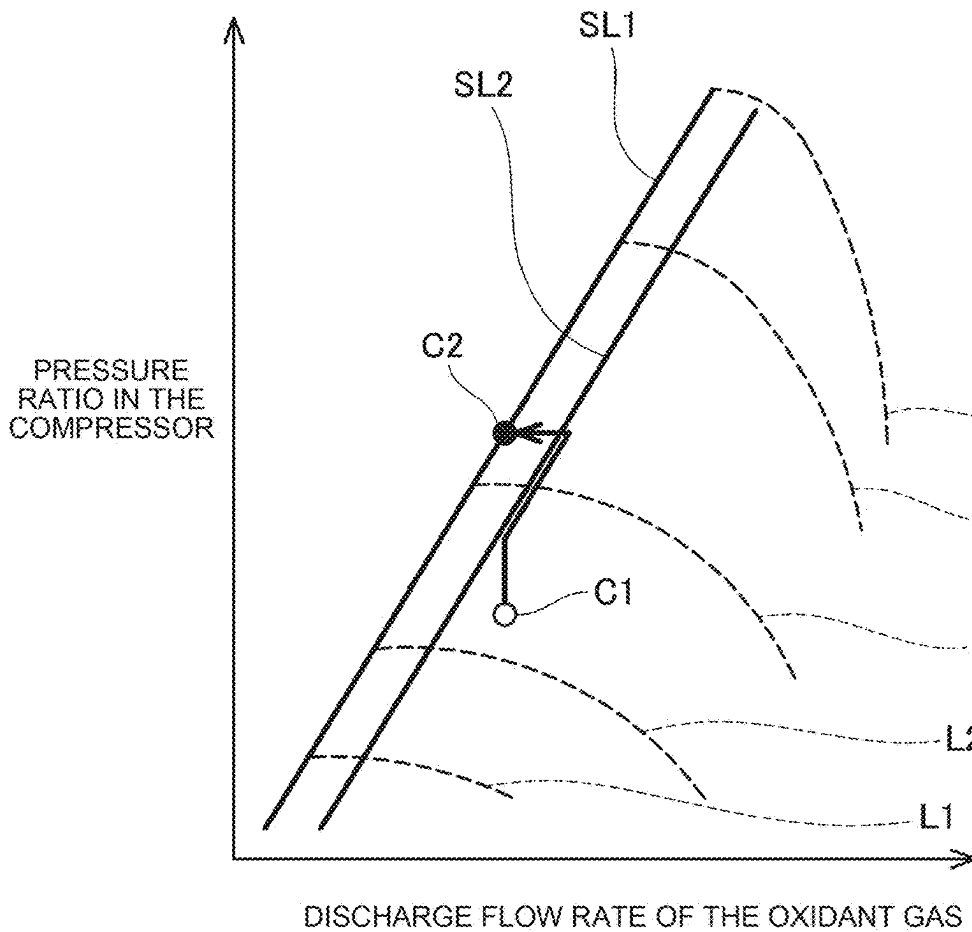

SL1
SL2
C2
PRESSURE RATIO IN THE COMPRESSOR
L5
L4
C1
L3
L2
L1
DISCHARGE FLOW RATE OF THE OXIDANT GAS

FIG. 4

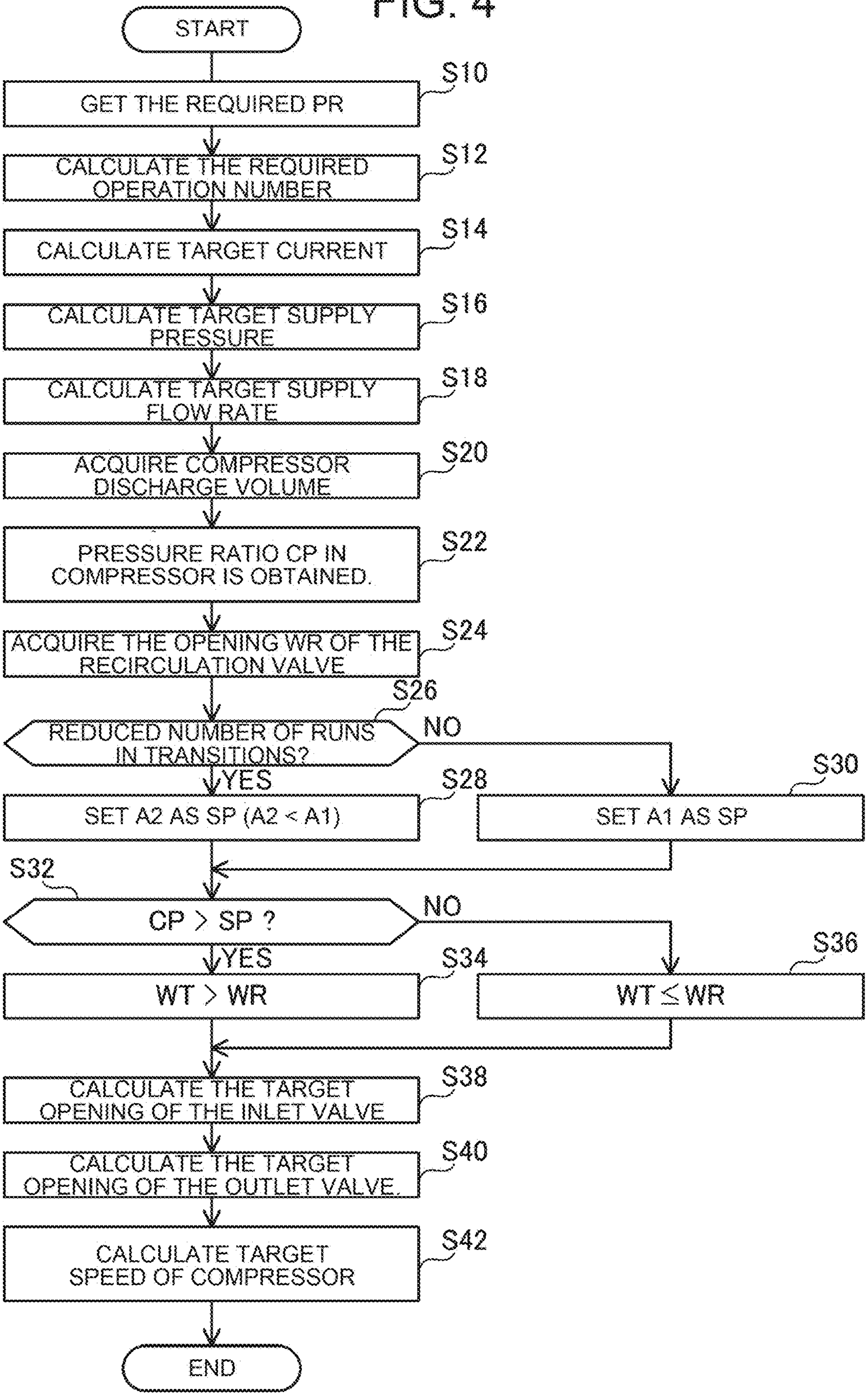

START
GET THE REQUIRED PR
S10
CALCULATE THE REQUIRED OPERATION NUMBER
S12
CALCULATE TARGET CURRENT
S14
CALCULATE TARGET SUPPLY PRESSURE
S16
CALCULATE TARGET SUPPLY FLOW RATE
S18
ACQUIRE COMPRESSOR DISCHARGE VOLUME
S20
PRESSURE RATIO CP IN COMPRESSOR IS OBTAINED.
S22
ACQUIRE THE OPENING WR OF THE RECIRCULATION VALVE
S24
REDUCED NUMBER OF RUNS IN TRANSITIONS?
S26
NO
YES
SET A2 AS SP (A2 < A1)
S28
SET A1 AS SP
S30
CP > SP ?
S32
NO
YES
WT > WR
S34
WT ≤ WR
S36
CALCULATE THE TARGET OPENING OF THE INLET VALVE
S38
CALCULATE THE TARGET OPENING OF THE OUTLET VALVE.
S40
CALCULATE TARGET SPEED OF COMPRESSOR
S42
END

FIG. 5

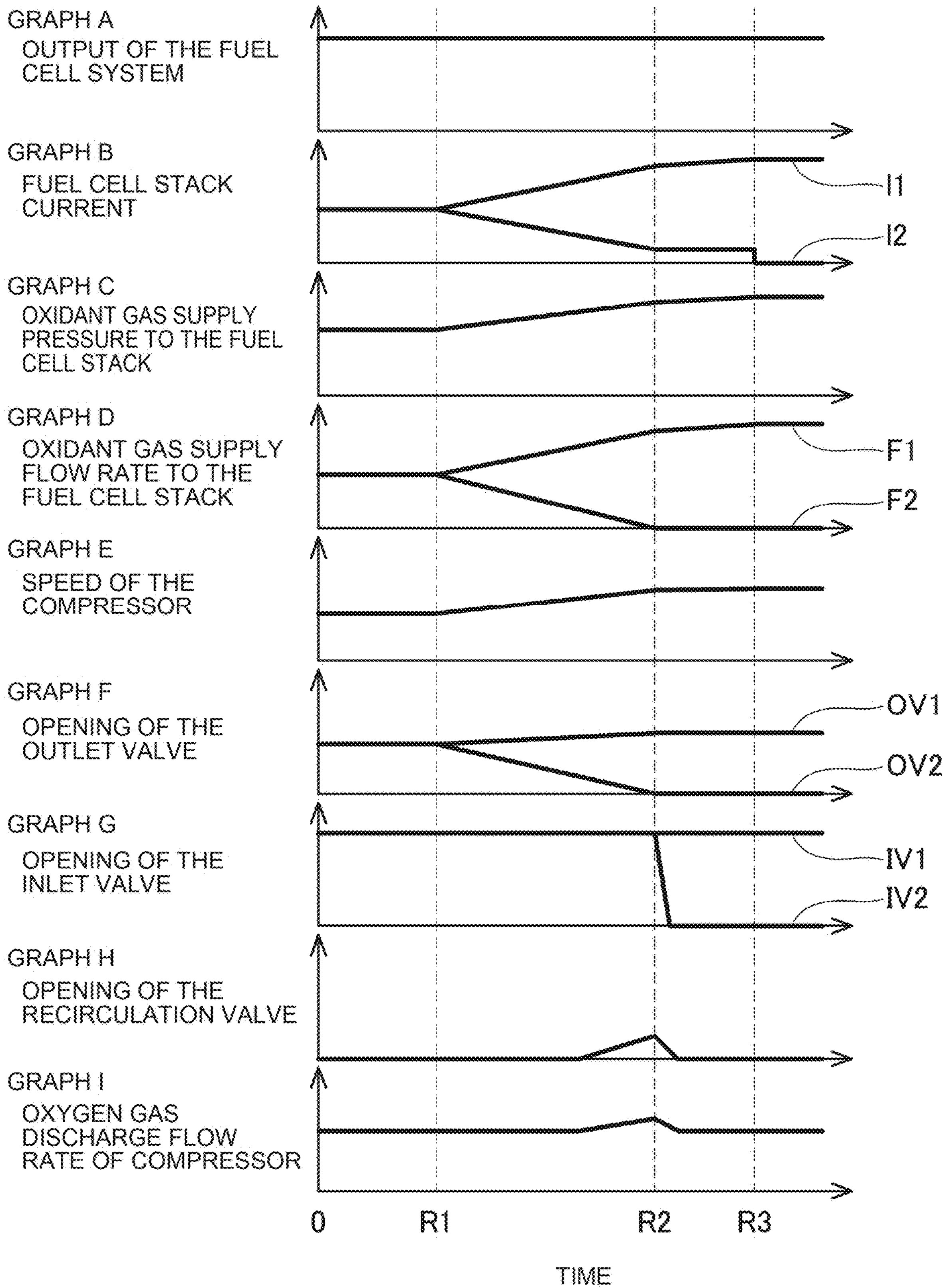

GRAPH A
OUTPUT OF THE FUEL CELL SYSTEM
GRAPH B
FUEL CELL STACK CURRENT
I1
I2
GRAPH C
OXIDANT GAS SUPPLY PRESSURE TO THE FUEL CELL STACK
GRAPH D
OXIDANT GAS SUPPLY FLOW RATE TO THE FUEL CELL STACK
F1
F2
GRAPH E
SPEED OF THE COMPRESSOR
GRAPH F
OPENING OF THE OUTLET VALVE
OV1
OV2
GRAPH G
OPENING OF THE INLET VALVE
IV1
IV2
GRAPH H
OPENING OF THE RECIRCULATION VALVE
GRAPH I
OXYGEN GAS DISCHARGE FLOW RATE OF COMPRESSOR
0
R1
R2
R3
TIME

FIG. 6

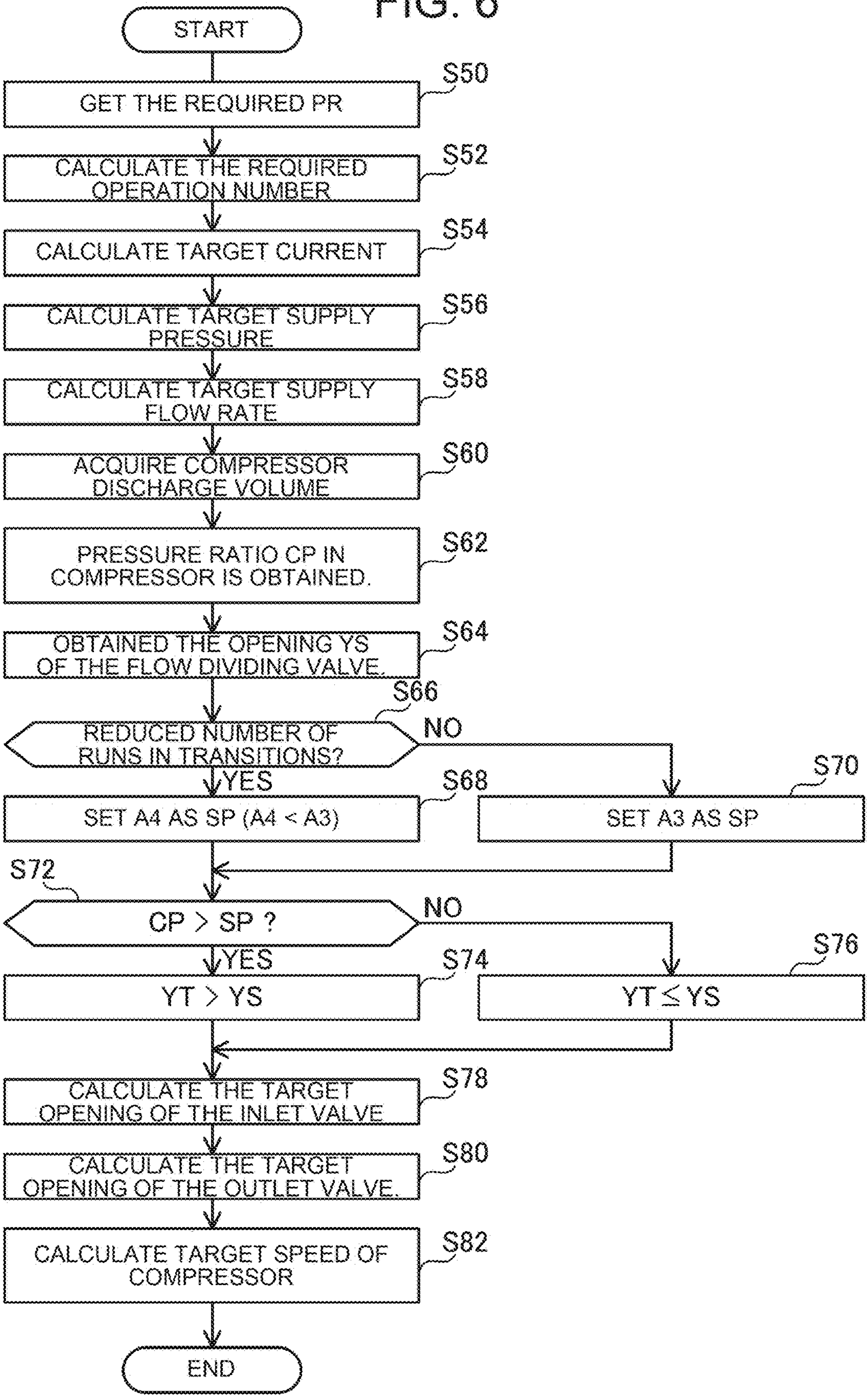

START
S50
GET THE REQUIRED PR
S52
CALCULATE THE REQUIRED OPERATION NUMBER
S54
CALCULATE TARGET CURRENT
S56
CALCULATE TARGET SUPPLY PRESSURE
S58
CALCULATE TARGET SUPPLY FLOW RATE
S60
ACQUIRE COMPRESSOR DISCHARGE VOLUME
S62
PRESSURE RATIO CP IN COMPRESSOR IS OBTAINED.
S64
OBTAINED THE OPENING YS OF THE FLOW DIVIDING VALVE.
S66
REDUCED NUMBER OF RUNS IN TRANSITIONS?
NO
YES
S68
SET A4 AS SP (A4 < A3)
S70
SET A3 AS SP
S72
CP > SP ?
NO
YES
S74
YT > YS
S76
YT ≤ YS
S78
CALCULATE THE TARGET OPENING OF THE INLET VALVE
S80
CALCULATE THE TARGET OPENING OF THE OUTLET VALVE.
S82
CALCULATE TARGET SPEED OF COMPRESSOR
END

FIG. 7

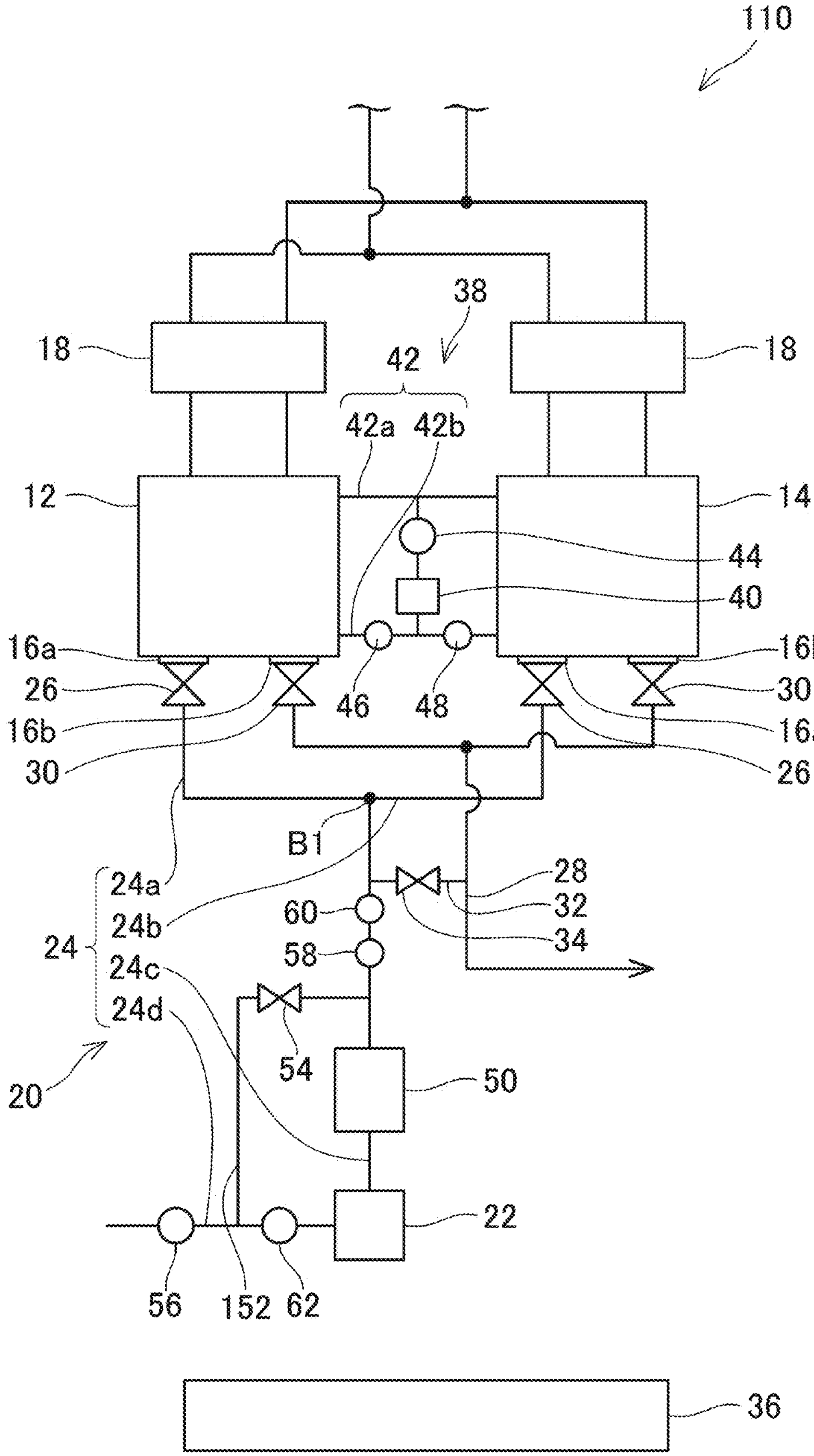
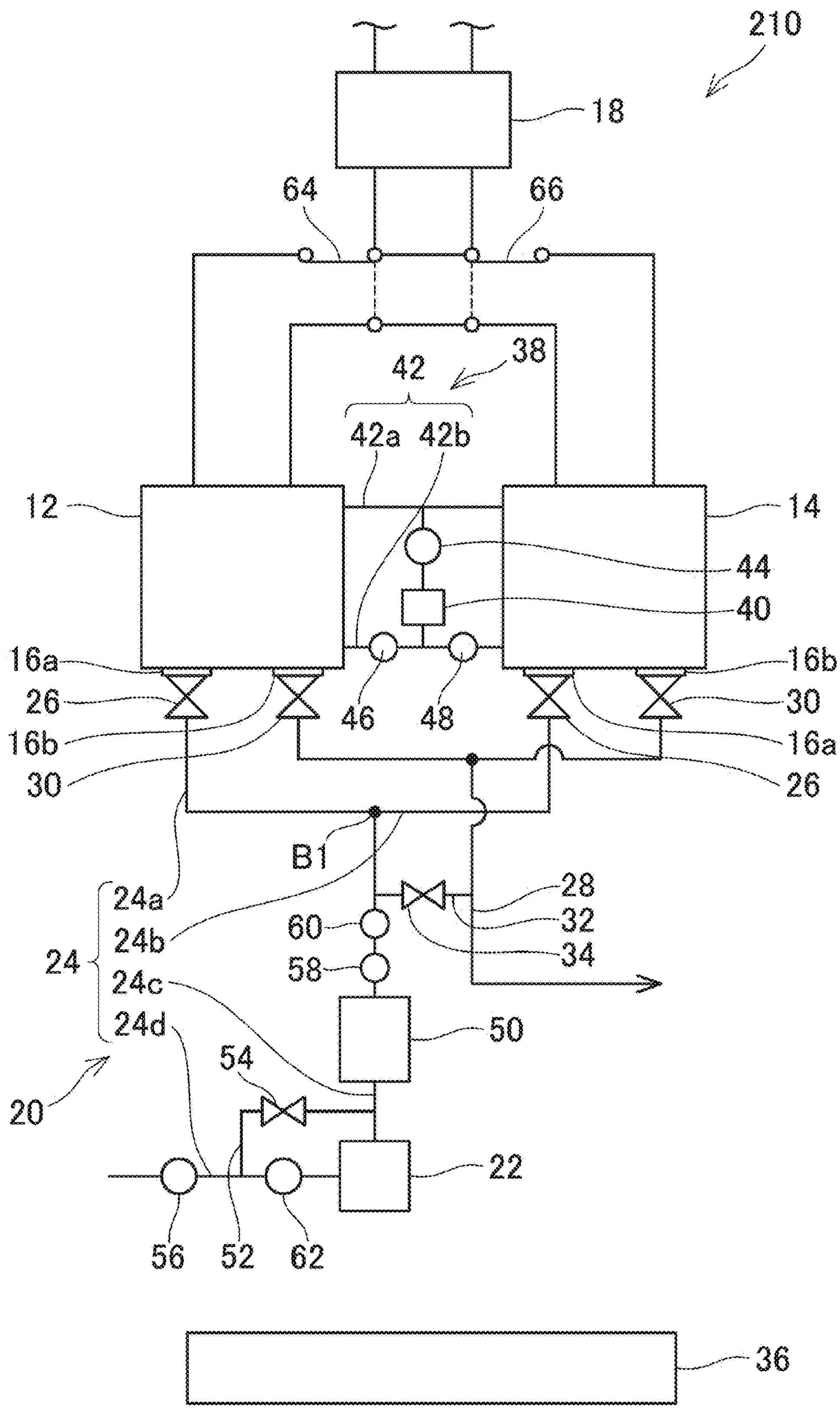

110
38
42
42a 42b
18
18
12
14
44
40
16a
16b
26
30
16b
16a
46
48
30
26
B1
24a
24b
24c
24d
24
28
32
34
60
58
54
50
20
22
56
152
62
36

FIG. 8


210
18
64
66
42
38
42a
42b
12
14
44
40
16a
16b
26
30
16b
46
48
16a
30
26
B1
24a
28
32
24b
60
34
24
58
24c
50
24d
54
20
22
56
52
62
36

FUEL CELL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-018828 filed on Feb. 9, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The technology disclosed by the present specification relates to a fuel cell system.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2022-156906 (JP 2022-156906 A) describes a fuel cell system. The fuel cell system includes a plurality of fuel cell stacks, an oxidant gas supply unit that supplies an oxidant gas to each of the fuel cell stacks, a cooling unit that supplies a refrigerant for cooling each of the fuel cell stacks, and a control device that determines a target supply flow rate of the oxidant gas to be commanded to the oxidant gas supply unit and a target supply flow rate of the refrigerant to be commanded to the cooling unit.

SUMMARY

[0004] In the fuel cell stack, a supply pressure and a supply flow rate of the oxidant gas to be supplied to the fuel cell stack are determined in accordance with a required output (namely, generated power) and the temperature of the fuel cell stack. For example, if the temperature of the fuel cell stack is constant, it is necessary to increase the supply pressure and the supply flow rate of the oxidant gas as the required output for the fuel cell stack increases. At this time, if a turbo compressor is adopted for a supply of the oxidant gas, there is a fear that surging occurs due to a pressure ratio in the compressor increasing. In particular, in a fuel cell system that includes a plurality of fuel cell stacks, the number of fuel cell stacks to be operated may be reduced, in accordance with a required output for the entire system. In this case, in a fuel cell stack that continues an operation, since the required output rapidly increases, there is a high risk that surging occurs.

[0005] In view of the circumstances, the present specification provides technology to avoid surging of a turbo compressor.

[0006] As described, when the required output for a fuel cell stack increases, it is necessary to increase the supply pressure and the supply flow rate of the oxidant gas to the fuel cell stack. Accordingly, in the turbo compressor, it is necessary to increase a pressure ratio and a discharge flow rate of the oxidant gas. In relation to this point, in a turbo compressor, there is a high risk that surging occurs by having the pressure ratio exceed a certain upper limit value. However, the upper limit value is not constant, and the upper limit value increases as the discharge flow rate of the turbo compressor increases. Therefore, when the pressure ratio in the turbo compressor increases, surging of the compressor can be avoided if the discharge flow rate of the oxidant gas in the turbo compressor can also be increased. Also, oxidant gas of an appropriate amount can be supplied to the fuel cell stack if a ratio of the supply flow rate supplied to the fuel cell stack with respect to the discharge flow rate of the oxidant gas in the compressor can be adjusted.

[0007] Based on the findings, the technology disclosed in the present specification is embodied in a fuel cell system. In a first aspect,

[0008] a fuel cell system includes

[0009] a plurality of fuel cell stacks,

[0010] an oxidant gas supply unit having a turbo compressor that supplies an oxidant gas to each of the fuel cell stacks, and

[0011] a control device that determines a required operation number for the fuel cell stacks and a target supply pressure and target supply flow rate of the oxidant gas to be commanded to the oxidant gas supply unit in accordance with a required output, in which

[0012] the oxidant gas supply unit has an adjustment mechanism that adjusts a supply rate being a ratio of a supply flow rate supplied to the fuel cell stacks with respect to a discharge flow rate of the turbo compressor.

[0013] The control device monitors a pressure ratio in the turbo compressor, and reduces the supply rate by controlling the adjustment mechanism when the pressure ratio exceeds a predetermined threshold.

[0014] According to the configuration, by reducing the number of fuel cell stacks to be operated (namely, to generate electricity), for example, the discharge flow rate of the oxidant gas in the turbo compressor can be preferentially increased, when the pressure ratio in the turbo compressor increases. As a result, surging of the turbo compressor can be avoided.

[0015] In a second aspect, in the first aspect,

[0016] the adjustment mechanism may include

[0017] a recirculation path that connects a discharge side and a suction side of the turbo compressor to each other, and

[0018] a flow rate adjustment valve provided in the recirculation path.

[0019] According to the configuration, the oxidant gas can be sent from the discharge side to the suction side via the recirculation path, and the discharge flow rate of the oxidant gas in the turbo compressor can be preferentially increased.

[0020] In a third aspect, in the first or second aspect,

[0021] the oxidant gas supply unit may further include an intercooler that cools the oxidant gas discharged from the turbo compressor.

[0022] In this case, the recirculation path may connect the discharge side and the suction side of the turbo compressor to each other on an upstream side of the intercooler.

[0023] According to the configuration, since the oxidant gas sent from the discharge side to the suction side does not pass through the intercooler, only the oxidant gas supplied to the fuel cell stack can be cooled by the intercooler.

[0024] In a fourth aspect, in the first or second aspect,

[0025] the oxidant gas supply unit may further include an intercooler that cools the oxidant gas discharged from the turbo compressor.

[0026] In this case, the recirculation path may connect the discharge side and the suction side of the turbo compressor to each other on a downstream side of the intercooler.

[0027] According to the configuration, the temperature of the oxidant gas sucked in by the turbo compressor is lowered, and energy required for realizing a predetermined pressure ratio in the compressor can be reduced.

[0028] In a fifth aspect, in any one of the first to fourth aspects,

[0029] the oxidant gas supply unit may include an oxidant gas supply path that supplies the oxidant gas from the turbo compressor to the fuel cell stacks, and

[0030] an off-gas discharge path that discharges an off-gas of the oxidant gas from the fuel cell stacks.

[0031] In this case, the adjustment mechanism may include a flow dividing path that connects the oxidant gas supply path and the off-gas discharge path to each other, and a flow rate adjustment valve provided in the flow dividing path.

[0032] According to the configuration, the oxidant gas can be discharged from the oxidant gas supply path to the off-gas discharge path via the flow dividing path, and the discharge flow rate of the oxidant gas in the turbo compressor can be preferentially increased.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0034] FIG. **1** is a diagram schematically illustrating a configuration of a fuel cell system **10** according to a first embodiment;

[0035] FIG. **2** is a diagram illustrating a relationship between a target supply pressure and a target supply flow rate of the oxidant gas that the control device **36** instructs the oxidant gas supply unit **20** in accordance with the output required for the fuel cell stacks **12** and **14**;

[0036] FIG. **3** shows a surging restriction line SL of the compressor **22**;

[0037] FIG. **4** is a flowchart showing a first process executed by the control device **36**;

[0038] FIG. **5** shows changes over time of various parameters in the first process shown in FIG. **4**;

[0039] FIG. **6** is a flowchart showing a second process executed by the control device **36**;

[0040] FIG. **7** is a diagram schematically illustrating a configuration of a fuel cell system **110** according to a second embodiment; and

[0041] FIG. **8** is a diagram schematically illustrating a configuration of a fuel cell system **210** according to a third embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Example 1

[0042] The fuel cell system **10** of the present embodiment will be described with reference to the drawings. The fuel cell system **10** is a power generation system that is mounted on a moving object (for example, an automobile, a bus, a truck, a train, a ship, an airplane), a stationary fuel cell device, or the like, and outputs electric power in response to an output requested from the outside.

[0043] As shown in FIG. **1**, the fuel cell system **10** includes a plurality of fuel cell stacks **12** and **14**. Each of the fuel cell stacks **12** and **14** has a structure in which a plurality of fuel cell cells is stacked. The fuel cell stacks **12** and **14** include an anode-side supply port (not shown), a cathode-side supply port **16***a*, an anode-side discharge port (not shown), and a cathode-side discharge port **16***b*. The anode-side supply port and the cathode-side supply port **16***a* of the fuel cell stacks **12** and **14** are connected to each of the plurality of fuel cell cells in the fuel cell stacks **12** and **14**. The fuel cell stacks **12** and **14** generate electric power by chemically reacting the fuel gas taken in from the anode-side supply port and the oxidant gas taken in from the cathode-side supply port **16***a* in the plurality of fuel cell cells. Gases (i.e., off-gas) that have passed through the plurality of fuel cell stacks **12** and **14** are discharged to the outside from the anode-side discharge port and the cathode-side discharge port **16***b*.

[0044] The plurality of fuel cell stacks **12**, **14** includes a first fuel cell stack **12** and a second fuel cell stack **14**. In the present embodiment, the first fuel cell stack **12** is electrically connected in parallel to the second fuel cell stack **14**. However, the number of the plurality of fuel cell stacks **12** and **14** is not particularly limited, and may be two or more. In the fuel cell system **10** of the present embodiment, hydrogen gas is used as the fuel gas, and air is used as the oxidant gas. The air contains oxygen as an oxidizing agent.

[0045] As shown in FIG. **1**, the fuel cell system **10** further includes a plurality of power control units **18**. In the present embodiment, the power control unit **18** includes a step-up converter. The power control unit **18** is electrically connected to each fuel cell stack **12**, **14**. The power control unit **18** can boost the generated power from the fuel cell stacks **12** and **14** and output the boosted power to the outside. Although not particularly limited, the power control unit **18** may further include an inverter in addition to the step-up converter.

[0046] As illustrated in FIG. **1**, the fuel cell system **10** further includes an oxidant gas supply unit **20** and a control device **36**. The oxidant gas supply unit **20** is a unit for supplying oxidant gas (air) to each of the plurality of fuel cell stacks **12** and **14**. The oxidant gas supply unit **20** includes a compressor **22**, an intercooler **50**, an oxidant gas supply path **24**, a plurality of inlet valves **26**, an off-gas discharge path **28**, a plurality of outlet valves **30**, a flow dividing path **32**, and a flow dividing valve **34**. The control device **36** can start and stop the operation of the fuel cell stacks **12**, **14**.

[0047] The compressor **22** is a turbo compressor. The compressor **22** is provided in the oxidant gas supply path **24**, and compresses air taken from the outside and supplies the compressed air to the plurality of fuel cell stacks **12** and **14**. The oxidant gas supply path **24** is a path for supplying the oxidant gas discharged from the compressor **22** to the plurality of fuel cell stacks **12** and **14**. The oxidant gas supply path **24** includes a first oxidant gas supply path **24***a* and a second oxidant gas supply path **24***b*. The first oxidant gas supply path **24***a* is connected to the cathode-side supply port **16***a* of the first fuel cell stack **12**, and supplies the oxidant gas from the compressor **22** to the first fuel cell stack **12**. The second oxidant gas supply path **24***b* is connected to the cathode-side supply port **16***a* of the second fuel cell stack **14**, and supplies the oxidant gas from the compressor **22** to the second fuel cell stack **14**. The first oxidant gas supply path **24***a* and the second oxidant gas supply path **24***b* are connected to each other at a branch point B**1**.

[0048] The oxidant gas supply path **24** further includes a third oxidant gas supply path **24***c* and a fourth oxidant gas supply path **24***d*. The third oxidant gas supply path **24***c* extends between the branch point B**1** and the compressor **22**, and connects the compressor **22** to the first oxidant gas supply path **24***a* and the second oxidant gas supply path **24***b*. The third oxidant gas supply path **24***c* is located on the discharge side of the compressor **22**, and supplies the oxidant gas discharged from the compressor **22** to the first oxidant gas supply path **24***a* and the second oxidant gas supply path **24***b*. The fourth oxidant gas supply path **24***d* is located on the suction side of the compressor **22**, and supplies the air taken from the outside to the compressor **22**. Although not particularly limited, the fuel cell system **10** may further include an air cleaner that removes foreign matters such as dust and dust from the air taken from the outside.

[0049] The off-gas discharge path **28** is a path for discharging the off-gas of the oxidant gas from the plurality of fuel cell stacks **12** and **14**. The off-gas discharge path **28** is connected to the cathode-side discharge port **16***b* in each of the plurality of fuel cell stacks **12** and **14**.

[0050] The intercooler **50** is provided in the third oxidant gas supply path **24***c*. The intercooler **50** cools the oxidant gas discharged from the compressor **22**. Thus, the oxidant gas discharged from the compressor **22** is cooled by the intercooler **50** and then supplied to the plurality of fuel cell stacks **12** and **14**. The intercooler **50** may be water-cooled or air-cooled.

[0051] The plurality of inlet valves **26** are provided in the cathode-side supply port **16***a* in the plurality of fuel cell stacks **12** and **14**, respectively. The plurality of outlet valves **30** are provided on the cathode-side discharge port **16***b* in the plurality of fuel cell stacks **12** and **14**, respectively.

[0052] The flow dividing path **32** connects the oxidant gas supply path **24** and the off-gas discharge path **28** to each other. As an example, the flow dividing path **32** in the present embodiment branches from the third oxidant gas supply path **24***c* and is connected to the off-gas discharge path **28**. A flow dividing valve **34** is provided in the flow dividing path **32**. The inlet valve **26**, the outlet valve **30**, and the flow dividing valve **34** are control valves whose opening degree can be adjusted. The operation (opening degree) of the inlet valve **26**, the outlet valve **30**, and the flow dividing valve **34** is controlled by the control device **36**. The control device **36** may control the operation of the compressor **22**, the inlet valves **26**, the outlet valves **30**, and the flow dividing valve **34** to adjust the supply pressure and the supply flow rate of the oxidant gas supplied to the fuel cell stacks **12** and **14**, respectively.

[0053] As shown in FIG. **1**, the oxidant gas supply unit **20** further includes a recirculation path **52** and a recirculation valve **54**. The recirculation path **52** connects the fourth oxidant gas supply path **24***d* located on the suction side of the compressor **22** and the third oxidant gas supply path **24***c* located on the discharge side of the compressor **22** to each other. A recirculation valve **54** is provided in the recirculation path **52**. The operation (opening degree) of the recirculation valve **54** is controlled by the control device **36**. By controlling the operation of the recirculation valve **54**, the control device **36** can deliver a part of the oxidant gas discharged from the compressor **22** from the third oxidant gas supply path **24***c* to the fourth oxidant gas supply path **24***d*. Thus, the control device **36** can adjust a supply rate (hereinafter, sometimes simply referred to as a supply rate) which is a ratio of a supply flow rate supplied to the plurality of fuel cell stacks **12** and **14** with respect to a discharge flow rate of the compressor **22**.

[0054] Although not shown, the fuel cell system **10** further includes a fuel gas supply unit. The fuel gas supply unit is a unit for supplying fuel gas (hydrogen gas) to the fuel cell stacks **12** and **14**.

[0055] As shown in FIG. **1**, the fuel cell system **10** further includes a cooling unit **38**. The cooling unit **38** is a unit for cooling each of the plurality of fuel cell stacks **12** and **14**. The cooling unit **38** includes a radiator **40**, a circulation path **42**, a pump **44**, and a plurality of temperature sensors **46** and **48**. The radiator **40** discharges heat from the refrigerant circulating in the circulation path **42**. The circulation path **42** includes a forward path **42***a* for supplying the refrigerant from the radiator **40** to the fuel cell stacks **12** and **14**, and a return path **42***b* for returning the refrigerant from the fuel cell stacks **12** and **14** to the radiator **40**. The pumps **44** are provided in the forward path **42***a*.

[0056] The plurality of temperature sensors **46**, **48** includes a first temperature sensor **46** and a second temperature sensor **48**. The first temperature sensor **46** is provided at the outlet of the first fuel cell stack **12** in the return path **42***b*, and detects the temperature of the coolant that has passed through the first fuel cell stack **12**. The second temperature sensor **48** is provided at the outlet of the second fuel cell stack **14** in the return path **42***b*, and detects the temperature of the coolant that has passed through the second fuel cell stack **14**. The refrigerant absorbs heat from the fuel cell when passing through the plurality of fuel cell cells in the fuel cell stacks **12** and **14**. Therefore, the value detected by each temperature sensor **48**, i.e., the temperature of the refrigerant at the outlet of each fuel cell stack **12**, **14**, has a correlation with the actual temperature of the fuel cell stack **12**, **14**. Here, the actual temperature of the fuel cell stacks **12** and **14** means the actual temperature of the fuel cell stacks **12** and **14**.

[0057] The control device **36** determines a target cooling temperature of the fuel cell stacks **12**, **14** that commands the cooling unit **38**. Then, the control device **36** controls the pump **44** based on the values detected by the temperature sensors **46** and **48** to adjust the flow rate of the refrigerant supplied to the fuel cell stacks **12** and **14**. Accordingly, the control device **36** cools the fuel cell stacks **12** and **14** so that the temperature of the fuel cell stacks **12** and **14** becomes the target cooling temperature. In one example, the refrigerant is water. In other embodiments, the fuel cell system **10** may include a separate cooling unit **38** for each fuel cell stack **12**, **14**.

[0058] As shown in FIG. **1**, the fuel cell system **10** further includes a first pressure sensor **56** and a second pressure sensor **58**. The first pressure sensor **56** is provided in the fourth oxidant gas supply path **24***d*, and detects the pressure of the oxidant gas (air) sucked into the compressor **22**. The second pressure sensor **58** is provided in the third oxidant gas supply path **24***c*, and detects the pressure of the oxidant gas (air) discharged from the compressor **22**. The detection value by each pressure sensor **56**, **58** is obtained by the control device **36**. Based on the values detected by the pressure sensors **56** and **58**, the control device **36** calculates and monitors the pressure ratio in the compressor **22**.

[0059] As shown in FIG. **1**, the fuel cell system **10** further includes a third temperature sensor **60** and a flow rate sensor **62**. The third temperature sensor **60** is provided at the outlet of the intercooler **50** in the third oxidant gas supply path **24***c*. Thus, the third temperature sensor **60** detects the temperature of the oxidant gas cooled by the intercooler **50**. The flow rate sensor **62** is provided in the fourth oxidant gas supply path **24***d*, and detects the flow rate of the oxidant gas sucked by the compressor **22**. The values detected by the sensors **60** and **62** are acquired by the control device **36**.

[0060] The control device **36** may change the number of fuel cell stacks **12**, **14** to be operated in response to the output required of the fuel cell system **10**. For example, if the output required of the fuel cell system **10** is relatively small, the control device **36** stops the operation of one of the two fuel cell stacks **12**, **14**. Thus, a decrease in power generation efficiency can be avoided.

[0061] Once the number of fuel cell stacks **12**, **14** to be operated is determined, the required output for each fuel cell stack **12**, **14** is determined. In each fuel cell stack **12**, **14**, the supply pressure and the supply flow rate of the oxidant gas to be supplied to each fuel cell stack **12**, **14** are determined according to the required output (i.e., generated power) and the temperature of the fuel cell stack **12**, **14**. FIG. **2** shows the relationship between the target supply pressure and the target supply flow rate of the oxidant gas that the control device **36** instructs the oxidant gas supply unit **20** in accordance with the output required for the fuel cell stacks **12** and **14**. Each of the solid lines U**1** to U**4** indicates a relation between a supply flow rate of the oxidant gas and a supply pressure of the oxidant gas for different temperatures of the fuel cell stacks **12** and **14**. Each of the dashed lines P**1** to P**5** indicates the relation between the supply flow rate of the oxidant gas and the supply pressure of the oxidant gas for the different currents (i.e., generated electric power) of the fuel cell stacks **12** and **14**. The larger the number, the higher the temperature or the higher the power. As shown in FIG. **2**, for example, when the temperature of the fuel cell stacks **12** and **14** is constant, the supply pressure and the supply flow rate of the oxidant gas need to be increased as the output required for the fuel cell stacks **12** and **14** increases. In particular, when the number of fuel cell stacks **12** and **14** to be operated is reduced, the required output of the fuel cell stack **12** (or **14**) to be operated is rapidly increased, and therefore, the supply pressure and the supply flow rate of the oxidant gas need to be greatly increased.

[0062] In this regard, in the fuel cell system **10** of the present embodiment, a turbo compressor **22** is employed to supply the oxidant gas. FIG. **3** shows a surging restriction line SL of the compressor **22**. Each of the dotted lines L**1** to L**5** indicates the relation between the discharge flow rate of the oxidant gases and the pressure ratio at the compressor **22** for the different rotational speeds of the compressor **22**. Incidentally, the larger the number, which means that the rotational speed is larger. Increasing the pressure ratio in the compressor **22** to increase the supply pressure of the oxidant gas to the fuel cell stacks **12**, **14** may cause surging of the compressor **22**. Therefore, as shown in FIG. **3**, in the fuel cell system **10**, the surging restriction lines SL**1**, SL**2** are defined for the operating point (combined pressure ratio and discharge flow rate) of the compressor **22**. That is, if the operating point of the compressor **22** exceeds the surging restriction lines SL**1**, SL**2**, surging may occur in the compressor **22**. In particular, when the power required by the fuel cell stack **12** (or **14**) suddenly increases, such as when the number of operating fuel cell stacks **12**, **14** decreases, the operating point of the compressor **22** is more likely to exceed the surging restriction lines SL**1**, SL**2**.

[0063] In order to avoid surging of the compressor **22**, the operating point of the compressor **22** must be maintained at or below the surging restriction line SL**1** (or SL**2**). As indicated by the surging restriction line SL**1** (or SL**2**), in the compressor **22**, surging is more likely to occur when the pressure ratio exceeds a certain upper limit. However, the upper limit value is not constant, and as the discharge flow rate of the compressor **22** increases, the upper limit value also increases. Therefore, if the discharge flow rate of the oxidant gas in the compressor **22** can also be increased when the pressure ratio in the compressor **22** increases, surging of the compressor **22** can be avoided. Even when the discharge flow rate of the oxidant gas in the compressor **22** is increased, an appropriate amount of the oxidant gas can be supplied to the fuel cell stacks **12** and **14** as long as the ratio of the supply flow rate supplied to the fuel cell stacks **12** and **14** can be adjusted with respect to the discharge flow rate.

[0064] Based on this finding, the control device **36** of the present embodiment is configured to be able to repeatedly execute the first process illustrated in FIG. **4**. By repeatedly executing the first process, the control device **36** can adjust the supply rate, which is the ratio of the supply flow rate to be supplied to the plurality of fuel cell stacks **12** and **14**, with respect to the discharge flow rate of the compressor **22**.

[0065] As illustrated in FIG. **4**, the control device **36** acquires an output PR requested from the outside (S**10**). Based on the output PR obtained by S**10**, the control device **36** calculates the required operation number for the fuel cell stacks **12** and **14** (S**12**). Further, the control device **36** calculates a target current (i.e., a target generated power) for the fuel cell stacks **12** and **14** (S**14**). The control device **36** calculates the target supply pressure of the oxidant gas to be instructed to the oxidant gas supply unit **20** in accordance with the target current determined by S**14** (S**16**), and calculates the target supply flow rate of the oxidant gas to be instructed to the oxidant gas supply unit **20** (S**18**). The control device **36** of the present embodiment stores in advance a map describing the relationship (see FIG. **2**) between the target supply pressure and the target supply flow rate of the oxidant gas to be instructed to the oxidant gas supply unit **20**. Therefore, the control device **36** calculates the target supply pressure and the target supply flow rate of the oxidant gas according to the actual operation number based on the relationship described by the map stored in advance. Thereafter, the control device **36** controls each unit according to the calculated value.

[0066] The control device **36** acquires the discharge flow rate of the compressor **22** (S**20**). As described above, the intake flow rate of the oxidant gas sucked into the compressor **22** is detected by the flow rate sensor **62**. For example, when the pressure of the oxidant gas in the third oxidant gas supply path **24***c* increases, the discharge flow rate of the oxidant gas by the compressor **22** decreases. When the oxidant gas in the third oxidant gas supply path **24***c* decreases, the discharge flow rate of the oxidant gas by the compressor **22** increases. Then, the control device **36** can estimate the discharge flow rate of the compressor **22** from the detection value by the second pressure sensor **58** and the detection value by the flow rate sensor **62**. However, as another embodiment, the fuel cell system **10** may further include a flow rate sensor that detects a discharge flow rate of the compressor **22**, and the control device **36** may acquire a detection value by the flow rate sensor.

[0067] The control device **36** acquires the pressure ratio CP at the compressor **22** (S**22**). As described above, the control device **36** calculates and monitors the pressure ratio in the compressor **22** based on the detection values by the pressure sensors **56** and **58**.

[0068] Next, the control device **36** acquires the opening degree WR of the recirculation valve **54** (S**24**). As described above, since the opening degree WR of the recirculation valve **54** is controlled by the control device **36**, the control device **36** can acquire the opening degree WR of the recirculation valve **54**.

[0069] The control device **36** determines whether or not it is during the transition in which the number of operations of the fuel cell stacks **12** and **14** is reduced (S**26**). Here, the transition during which the number of operation of the fuel cell stacks **12** and **14** is reduced refers to a period from a state in which the two fuel cell stacks **12** and **14** are in operation to a state in which only one of the fuel cell stacks **12** and **14** is in operation (that is, a state in which the fuel cell stacks are in independent operation). In this period, as shown in the range from the time R**1** to the time R**3** in FIG. **5**, various parameters such as the discharge flow rate of the oxidant gas by the compressor **22** are greatly varied, and surging of the compressor **22** is relatively likely to occur. Graphs A to I in FIG. **5** show changes over time in various parameters in the first process shown in FIG. **4**. In graph B of FIG. **5**, the curve I**1** indicates the current of the first fuel cell stack **12**, and the curve **12** indicates the current of the second fuel cell stack **14**. In the graph E of FIG. **5**, the curve OV**1** indicates the opening degree of the outlet valve **30** of the first fuel cell stack **12**, and the curve OV**2** indicates the opening degree of the outlet valve **30** of the second fuel cell stack **14**. In the graph F of FIG. **5**, the curve IV**1** indicates the opening degree of the inlet valve **26** of the first fuel cell stack **12**, and the curve IV**2** indicates the opening degree of the inlet valve **26** of the second fuel cell stack **14**.

[0070] If NO in S**26**, the control device **36** sets the first pressure value A**1** as the surging restriction pressure SP (S**30**). In S**30**, the control device **36** first adopts the first surging restriction line SL**1** shown in FIG. **3** as the surging restriction line SL. The control device **36** determines, on the first surging restriction line SL**1**, a pressure value that becomes the discharge flow rate of the compressor **22** acquired by S**20** as the first pressure value A**1**.

[0071] On the other hand, when S**26** is YES, the control device **36** sets the second pressure value A**2** as the surging restriction pressure SP (S**28**). In S**28**, the control device **36** first adopts the second surging restriction line SL**2** as the surging restriction line SL. The control device **36** determines, on the second surging restriction line SL**2**, a pressure value that becomes the discharge flow rate of the compressor **22** acquired by S**20** as the second pressure value A**2**. The second pressure value A**2** is a value smaller than the first pressure value A**1**. As shown in FIG. **3**, the second surging restriction line SL**2** corresponds to the first surging restriction line SL**1** moved downward. Therefore, when the discharge flow rate of the compressor **22** is constant, when the second surging restriction line SL**2** is adopted, the surging restriction pressure SP is set to be smaller than when the first surging restriction line SL**1** is adopted. Thereby, surging of the compressor **22** is more reliably avoided.

[0072] The control device **36** determines whether or not the pressure ratio CP in the compressor **22** acquired by S**22** exceeds the surging restriction pressure SP set by S**28** or S**30** (S**32**). When S**32** is YES, the control device **36** sets the target opening degree WT of the recirculation valve **54** to be larger than the opening degree WR of the recirculation valve **54** acquired by S**24** (S**34**). As a result, the opening degree of the recirculation valve **54** is increased, and the oxidant gas delivered from the third oxidant gas supply path **24***c* to the fourth oxidant gas supply path **24***d* among the oxidant gas discharged from the compressor **22** is increased. That is, the supply rate decreases. When S**32** is NO, the control device **36** sets the target opening degree WT of the recirculation valve **54** to be equal to or less than the opening degree WR of the recirculation valve **54** acquired by S**24** (S**36**).

[0073] The control device **36** calculates a target opening degree to be instructed to the inlet valve **26** of the oxidant gas supply unit **20** (S**38**) and calculates a target opening degree to be instructed to the outlet valve **30** of the oxidant gas supply unit **20** (S**40**). Next, the control device **36** calculates a target rotational speed to be instructed to the compressor **22** (S**42**). The control device **36** controls each unit according to the calculated value, and ends one cycle of the first process illustrated in FIG. **4**.

[0074] According to the above-described configuration, by decreasing the number of fuel cell stacks **12** and **14** to be operated (that is, to generate electric power), it is possible to preferentially increase the discharge flow rate of the oxidant gas in the compressor **22** when the pressure ratio in the compressor **22** increases. Thus, surging of the compressor **22** can be avoided. In particular, in the first process shown in FIG. **4**, the oxidant gas can be delivered from the discharge side to the suction side via the recirculation path **52**, whereby the discharge flow rate of the oxidant gas in the compressor **22** can be preferentially increased (see FIG. **5**). Note that the recirculation path **52** and the recirculation valve **54** in the present specification are examples of the adjustment mechanism in the present technology. The first pressure value A**1** and the second pressure value A**2** in the present specification are examples of predetermined thresholds with respect to the pressure ratio in the turbo compressor in the present technology.

[0075] In this embodiment, the oxidant gas supply unit **20** includes an intercooler **50** that cools the oxidant gas discharged from the compressor **22**. The recirculation path **52** connects the fourth oxidant gas supply path **24***d* located on the suction side of the compressor **22** and the third oxidant gas supply path **24***c* located on the discharge side of the compressor **22** to each other. In particular, in the third oxidant gas supply path **24***c,* the recirculation path **52** is connected upstream side of the intercooler **50**. According to such a configuration, since the oxidant gas delivered from the discharge side to the suction side does not pass through the intercooler **50**, only the oxidant gas supplied to the fuel cell stacks **12** and **14** can be cooled by the intercooler **50**.

[0076] In the above-described first process, the threshold value (here, the second pressure value A**2**) with respect to the pressure ratio in the compressor **22** is set to be low during the transition in which the number of operations of the fuel cell stacks **12** and **14** is reduced. During the transition in which the number of operations of the fuel cell stacks **12** and **14** is reduced, the discharge flow rate of the oxidant gas in the compressor **22**, the pressure ratio in the compressor **22**, and the like greatly fluctuate, so that surging is relatively likely to occur. Therefore, according to the above-described configuration, it is possible to more reliably avoid surging of the compressor **22** even during a transition in which the number of operations of the fuel cell stacks **12** and **14** is reduced. In the first process illustrated in FIG. **4**, the control device **36** may omit the process from S**26** to S**30**. That is, in other embodiments, the control device **36** may not set the threshold for the pressure ratio at the compressor **22** low during the transition to reduce the number of fuel cell stacks **12**, **14** operations.

[0077] In addition, based on the same knowledge, the control device **36** of the present embodiment is configured to be able to repeatedly execute the second process illustrated in FIG. **6**. In the second process, the flow dividing path **32** and the flow dividing valve **34** are used instead of the recirculation path **52** and the recirculation valve **54** of the first process shown in FIG. **4**. This makes it possible to adjust the supply rate, which is the ratio of the supply flow rate to be supplied to the plurality of fuel cell stacks **12** and **14**, with respect to the discharge flow rate of the compressor **22**. Each step from S**50** to S**82** in the second process corresponds to each step from S**10** to S**42** in the first process. In the second process, the third pressure value A**3** or the fourth pressure value A**4** is set as the surging restriction pressure SP (S**78**, S**80**), and the fourth pressure value A**4** is a value smaller than the third pressure value A**3**.

[0078] According to such a configuration, by reducing the number of fuel cell stacks **12**, **14** to be operated (i.e., to generate electricity), when the pressure ratio in the compressor **22** increases, the oxidant gas can be discharged from the oxidant gas supply path **24** to the off-gas discharge path **28** via the flow dividing path **32**. Thus, the discharge flow rate of the oxidant gas in the compressor **22** can be preferentially increased. Here, the flow dividing path **32** and the flow dividing valve **34** in the present specification are examples of the adjustment mechanism in the present technology. The third pressure value A**3** and the fourth pressure value A**4** in the present specification are examples of predetermined thresholds with respect to the pressure ratio in the turbo compressor in the present technology.

[0079] Although not particularly limited, in the first process illustrated in FIG. **4**, the control device **36** may preferentially increase the discharge flow rate of the oxidant gas in the compressor **22** by using the flow dividing path **32** and the flow dividing valve **34** in addition to the recirculation path **52** and the recirculation valve **54**.

Example 2

[0080] The fuel cell system **110** of the second embodiment will be described with reference to FIG. **7**. As shown in FIG. **7**, in the fuel cell system **110** of the second embodiment, the position where the recirculation path **152** is provided is changed as compared with the fuel cell system **10** of the first embodiment. The remainder of the configuration is the same as that of the fuel cell system **10** of the first embodiment, and therefore, a repetitive description thereof will be omitted here.

[0081] As shown in FIG. **7**, the recirculation path **152** connects the fourth oxidant gas supply path **24***d* located on the suction side of the compressor **22** and the third oxidant gas supply path **24***c* located on the discharge side of the compressor **22** to each other. In particular, in the third oxidant gas supply path **24***c*, the recirculation path **152** is connected downstream side of the intercooler **50**.

[0082] Also in the above-described configuration, the control device **36** can repeatedly execute the first processing and/or the second processing in the first embodiment. Thus, surging of the compressor **22** can be avoided. In particular, as described above, since the recirculation path **152** is connected downstream side of the intercooler **50**, the temperature of the oxidant gas sucked in by the compressor **22** is lowered. Thus, the energy required to achieve a predetermined pressure ratio in the compressor **22** can be reduced.

Example 3

[0083] Referring to FIG. **8**, a fuel cell system **210** according to a third embodiment will be described. As shown in FIG. **8**, in the fuel cell system **210** of the third embodiment, a plurality of fuel cell stacks **12** and **14** are electrically connected in series as compared with the fuel cell system **10** of the first embodiment. The remainder of the configuration is the same as that of the fuel cell system **10** of the first embodiment, and therefore, a repetitive description thereof will be omitted here.

[0084] As illustrated in FIG. **9**, the fuel cell system **210** further includes a first relay **64** and a second relay **66**. The first relay **64** is provided between one pole of the first fuel cell stack **12** and one pole of the power control unit **18**, and the second relay **66** is provided between the other pole of the second fuel cell stack **14** and the other pole of the power control unit **18**. As shown in FIG. **9**, when the first relay **64** and the second relay **66** are both in the first state, the first fuel cell stack **12** is electrically connected in series with the second fuel cell stack **14**. When the first relay **64** is in the first state and the second relay **66** is in the second state (the position indicated by the dotted line), the fuel cell system **10** supplies only the output from the first fuel cell stack **12** to the outside. When the second relay **66** is in the first state and the first relay **64** is in the second state (the position indicated by the dotted line), the fuel cell system **10** supplies only the output from the second fuel cell stack **14** to the outside.

[0085] Also in the above configuration, the control device **36** can repeatedly execute the first processing and/or the second processing in the first embodiment. Thus, surging of the compressor **22** can be avoided.

[0086] In addition, in the fuel cell system **210** of the third embodiment, the position where the recirculation path **52** is provided can be changed. That is, as another embodiment, a fuel cell system in which a plurality of fuel cell stacks **12** and **14** are electrically connected in series may be employed as compared with the fuel cell system **110** of the second embodiment. Also in this configuration, the control device **36** can repeatedly execute the first processing and/or the second processing in the first embodiment, and can avoid surging of the compressor **22**.

[0087] While several specific examples have been described in detail above, these are merely illustrative and do not limit the scope of the claims. The technique described in the claims includes various modifications and variations of the specific examples exemplified above. The technical elements described in this specification or in the drawings may be used alone or in combination to achieve technical usefulness.

What is claimed is:

1. A fuel cell system comprising:

a plurality of fuel cell stacks;

an oxidant gas supply unit having a turbo compressor that supplies an oxidant gas to each of the fuel cell stacks; and

a control device that determines a required operation number for the fuel cell stacks and a target supply pressure and target supply flow rate of the oxidant gas to be commanded to the oxidant gas supply unit in accordance with a required output, wherein

the oxidant gas supply unit has an adjustment mechanism that adjusts a supply rate being a ratio of a supply flow rate supplied to the fuel cell stacks with respect to a discharge flow rate of the turbo compressor, and

the control device monitors a pressure ratio in the turbo compressor, and reduces the supply rate by controlling the adjustment mechanism when the pressure ratio exceeds a predetermined threshold.

2. The fuel cell system according to claim **1**, wherein the adjustment mechanism includes

a recirculation path that connects a discharge side and a suction side of the turbo compressor to each other, and

a flow rate adjustment valve provided in the recirculation path.

3. The fuel cell system according to claim **2**, wherein:

the oxidant gas supply unit further includes an intercooler that cools the oxidant gas discharged from the turbo compressor; and

the recirculation path connects the discharge side and the suction side of the turbo compressor to each other on an upstream side of the intercooler.

4. The fuel cell system according to claim **2**, wherein:

the oxidant gas supply unit further includes an intercooler that cools the oxidant gas discharged from the turbo compressor; and

the recirculation path connects the discharge side and the suction side of the turbo compressor to each other on a downstream side of the intercooler.

5. The fuel cell system according to claim **1**, wherein:

the oxidant gas supply unit includes

an oxidant gas supply path that supplies the oxidant gas from the turbo compressor to the fuel cell stacks, and

an off-gas discharge path that discharges an off-gas of the oxidant gas from the fuel cell stacks; and

the adjustment mechanism includes a flow dividing path that connects the oxidant gas supply path and the off-gas discharge path to each other, and a flow rate adjustment valve provided in the flow dividing path.

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