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(71) Applicant: **Anest Iwata Corporation**
Yokohama-shi
Kanagawa 223-8501 (JP)

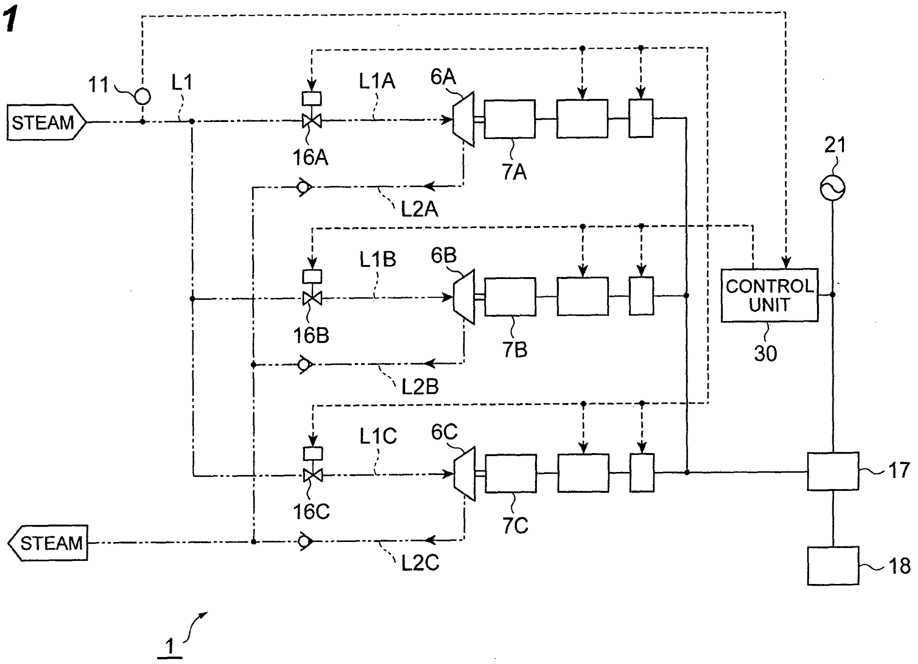
(72) Inventors:
- **Fujioka, Tamotsu**
  Kanagawa, 223-8501 (JP)
- **Unami, Atsushi**
  Kanagawa, 223-8501 (JP)
- **Izumi, Takaaki**
  Kanagawa, 223-8501 (JP)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(54) POWER GENERATION SYSTEM AND POWER GENERATION METHOD

(57) A power generation system (1) includes a plurality of displacement type expanders (6A-6C), and a plurality of power generators (7A-7C) connected to each of the displacement type expanders(6A-6C), and generating power by expansion of steam at least at one of the displacement type expanders (6A-6C). The power generation system (1) includes a suppression means (16A-16C) that is capable of suppressing circulation of the steam for each of the displacement type expanders (6A-6C), and a control unit (30) that controls a load ratio for each of the displacement type expanders (6A-6C) by controlling the suppression means (16A-16C) based on information on the heat amount of the steam.

Fig.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a power generation system and a power generation method.

BACKGROUND

[0002] Conventionally, a device is known which generates power by expanding steam in an expander. For example, in a device described in Patent Document 1 (Japanese Unexamined Patent Publication No. 2012-202262), an evaporator, an expander, and a condenser constitute one power generation cycle, and a plurality of such power generation cycles are provided. In addition, a heating medium cutoff valve and a cooling medium cutoff valve are provided in the device. In the device, a power generation amount is detected, and the heating medium cutoff valve and the cooling medium cutoff are opened and closed according to the detected value of the power generation amount and a heating medium discharge temperature.

SUMMARY

[0003] As in the above device, it is possible to deal with a great amount of heat by providing a plurality of power generation cycles. However, there has not been a power generation system so far which can deal with a fluctuation in heat amount. For example, in a turbine designed to be targeted at the heat amount of 100%, in a case where the heat amount is decreased to 50%, torque for operating a power generator cannot be obtained and a relative mechanical loss becomes great. In this case, a power generation amount significantly decreases.

[0004] An object of the present invention is to provide a power generation system and a power generation method whereby sufficient power can be generated without reductions in the overall efficiency even when an input heat amount fluctuates.

[0005] An aspect of the present invention is a power generation system including a plurality of displacement type expanders and a plurality of power generators connected to each of the plurality of displacement type expanders, and generating power by expansion of steam at least at one of the displacement type expanders, the system including a suppression means that is capable of suppressing circulation of the steam for each of the displacement type expanders, and a control unit that controls a load ratio per the displacement type expander by controlling the suppression means based on information on a heat amount of the steam.

[0006] Another aspect of the present invention is a power generation method where power is generated, using a power generation system including a plurality of displacement type expanders, and a plurality of power generators connected to each of the plurality of displacement type expanders, by expansion of steam at least at one of the displacement type expanders, and the method includes adjusting a load ratio per the displacement type expander based on information on a heat amount of the steam.

[0007] With these power generation system and power generation method, a plurality of displacement type expanders to each of which a power generator is connected are provided. A load ratio per one displacement type expander is adjusted based on information on the heat amount of steam. For example, in a case where an input heat amount decreases, it is possible to efficiently control power generation by increasing the load ratio per one displacement type expander. In addition, in a case where the input heat amount increases, it is possible to efficiently control power generation by decreasing the load ratio per one displacement type expander. Therefore, even when the input heat amount fluctuates, sufficient power can be generated by as many displacement type expanders as necessary without reduces in the overall efficiency.

[0008] In the above power generation system, the numbers of the displacement type expanders are N units. The control unit stores at least (N - 1) different thresholds for the information on the heat amount of steam, and may put (a + 1) units of the displacement type expanders into operation when detecting the information on the heat amount of steam and evaluating that the detected information has exceeded an a-th (a is any integer from 1 to (N - 1)) smallest threshold of the (N - 1) thresholds.

[0009] With this configuration, the number of units to be operated is changed gradually with (N - 1) different thresholds as boundaries. Therefore, more efficient power generation can be achieved by simplified determining processing.

[0010] According to the present invention, even when the input heat amount fluctuates, sufficient power can be generated by as many displacement type expanders as necessary without reduces in the overall efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a diagram illustrating a schematic configuration of a power generation system according to an embodiment of the present invention.

FIG. 2 is a diagram illustrating an operation state of each power generator in accordance with an input heat amount.

DETAILED DESCRIPTION

[0012] Embodiments of the present invention will be described below with reference to the drawings. In descriptions of the drawings, identical elements bear identical signs and overlapping descriptions will be eliminated.

[0013] Firstly, a steam power generation system 1 according to the present embodiment will be described with reference to FIG 1. In FIG 1, solid lines indicate electric circuits. Two-dot chain lines indicate steam circuits. The broken lines illustrated so as to be connected to a control unit 30 indicate control circuits. In the present embodiment, an example of steam is water vapor.

[0014] As illustrated in FIG 1, the steam power generation system 1 is a power generation system which generates power using high-temperature steam (for example, about 170 to 180°C at a pressure of 0.7 to 0.8 MPa) as a heat source. The steam power generation system 1 includes a first scroll expander 6A, a second scroll expander 6B, and a third scroll expander 6C. In addition, the steam power generation system 1 includes a first power generator 7A, a second power generator 7B, and a third power generator 7C connected to the three (that is, N=3) expanders, the first to third scroll expanders 6A to 6C, respectively.

[0015] At the first scroll expander 6A and the first power generator 7A, expansion of steam at the first scroll expander 6A rotates an output shaft thereof, and power is generated by the first power generator 7A. At the second scroll expander 6B and the second power generator 7B, expansion of steam at the second scroll expander 6B rotates an output shaft thereof, and power is generated by the second power generator 7B. At the third scroll expander 6C and the third power generator 7C, expansion of steam at the third scroll expander 6C rotates an output shaft thereof, and power is generated by the third power generator 7C.

[0016] A steam line L1 is provided in the steam power generation system 1, and steam at a predetermined pressure is supplied through the steam line L1. The steam line L1 is provided with an inlet detector 11 for detecting information on the heat amount of steam. The information on the heat amount of steam means any one, or two or more pieces of information on flow rates, temperatures, and pressures of the steam. The inlet detector 11 detects the information on steam supplied to the first to third scroll expanders 6A to 6C. The "line" means a pipe through which a fluid flows.

[0017] The steam line L1 is branched into three lines. A first steam supply line L1A is connected to the first scroll expander 6A, a second steam supply line L1B is connected to the second scroll expander 6B, and a third steam supply line L1C is connected to the third scroll expander 6C. These first to third steam supply lines L1A to L1C are provided with a first to third electromagnetic valves 16A to 16C for stopping (blocking) or suppressing circulation of steam in each line. That is, each of the first to third electromagnetic valves 16A to 16C can suppress circulation of steam by adjustment of the opening therof. In addition, each of the first to third electromagnetic valves 16A to 16C can stop circulation of steam by fully closing. The first to third electromagnetic valves 16A to 16C correspond to suppression means capable of suppressing circulation of steam into the first to third scroll expanders 6A to 6C, respectively.

[0018] A first steam emission line L2A connected to a steam outlet of the first scroll expander 6A, a second steam emission line L2B connected to a steam outlet of the second scroll expander 6B, and a third steam emission line L2C connected to a steam outlet of the third scroll expander 6C are joined into one line, and steam is released to the atmosphere.

[0019] Each of the first to third power generators 7A to 7C is connected to an inverter 17 via a ground detector, an electromagnetic contactor, and the like. The inverter 17 is connected to a three-phase alternate current (for example, 200 V) commercial power source 21. A load 18 such as an electric motor is connected to the inverter 17.

[0020] The steam power generation system 1 includes a control unit 30 that adjusts a load ratio for each of the first to third scroll expanders 6A to 6C by controlling the above suppression means based on the information on the heat amount of steam. The control unit 30 is a computer including hardware such as a central processing unit (CPU), a read only memory (ROM), and a random access memory (RAM) and software such as programs stored in the ROM. Once detecting the information on the heat amount of steam, the above-described inlet detector 11 sequentially transmits the detected information to the control unit 30. The control unit 30 acquires the information on the heat amount of steam and controls, based on the acquired information, opening and closing of the first to third electromagnetic valves 16A to 16C. By the opening and closing control of the first to third electromagnetic valves 16A to 16C, the load ratio for each of the first to third scroll expanders 6A to 6C can be adjusted. In addition, by the full opening and full closing control of the first to third electromagnetic valves 16A to 16C, the number of first to third scroll expanders 6A to 6C to be operated can be controlled. As described, in the steam power generation system 1, it is possible to narrow down the number of displacement type expanders to be operated.

[0021] The control unit 30 stores at least two (N-1) different thresholds for the information on the heat amount of steam. For example, the control unit 30 stores two thresholds (here, for example, a first threshold of 40%, and a second threshold of 70%) for the input heat amount (%) calculated based on the detection results at the inlet detector 11. The input heat amount (%) means a ratio of the actual heat amount of steam to a rated heat amount of three series as a whole. The control unit 30 uses these thresholds for adjusting and controlling the load ratios of the first to third scroll expanders 6A to 6C or the numbers of first to third scroll expanders 6A to 6C to be operated.

[0022] Next, a method for operating the steam power generation system 1 (power generation method using the steam power generation system 1) will be described with reference to FIG. 2. The control unit 30 calculates values corresponding to the above thresholds (values at the same level as the thresholds) based on the information on the heat amount of steam sent from the inlet detector 11 while the steam power generation system 1 is in operation. At the stage above, the control unit 30 calculates a present input heat amount based on the information from the inlet detector 11.

[0023] The control unit 30 evaluates whether the calculated input heat amount has exceeded the first and second thresholds described above. Once evaluating that the input heat amount has been less than or equal to the first threshold, the control unit 30 opens only the first electromagnetic valve 16A and closes the other electromagnetic valves. This puts only the first scroll expander 6A that forms a first series into operation. Once evaluating that the input heat amount has exceeded the first threshold, the control unit 30 opens the second electromagnetic valve 16B. This puts the second scroll expander 6B that forms a second series into operation, resulting in a total of two series put into operation. Once evaluating that the input heat amount has exceeded even the second threshold, the control unit 30 further opens the third electromagnetic valve 16C. This puts the third scroll expander 6C that forms a third series into operation, resulting in a total of three series put into operation.

[0024] As illustrated in FIG 2, the number of units to be operated is switched with the first threshold of 40% and the second threshold of 70% as boundaries. The heat amounts of the steam distributed to a plurality of scroll expanders simultaneously in operation are set equal. Therefore, rotation speeds at the scroll expanders are equal. (The figure shows that the rotation speeds at the scroll expanders are equal (lines are overlapped) by differentiating line types.) In the operating system illustrated in FIG. 2, the rotation speed at each scroll expander is changed gradually with each change by 10% in input heat amount.

[0025] Thus, the control unit 30 puts two units of displacement type expanders into operation when detecting the information on the heat amount of steam and evaluating that the detected information has exceeded the first threshold (the smallest threshold) of two (N-1) thresholds. The control unit 30 puts three units of displacement type expanders into operation when evaluating that the information on the detected heat amount has exceeded the second threshold (the second smallest threshold) of two (N-1) thresholds.

[0026] With the above-described steam power generation system 1 and power generation method using the same, the plurality of displacement type expanders 6A to 6C to which the first to third power generators 7A to 7C are connected, respectively, is provided. Opening and closing of the first to third electromagnetic valves 16A to 16C are controlled by the control unit 30 based on the information on the heat amount of steam. This adjusts the load ratio for each of the displacement type expanders 6A to 6C. For example, in a case where an input heat amount decreases, it is possible to efficiently control power generation by increasing the load ratio per one displacement type expander. In addition, in a case where the input heat amount increases, it is possible to efficiently control power generation by decreasing the load ratio per one displacement type expander. Therefore, even when the input heat amount fluctuates, sufficient power can be generated by as many displacement type expanders 6A to 6C as necessary without reductions in the overall efficiency.

[0027] Especially, the steam power generation system 1 can deal with a wide range of heat amounts, from a small heat amount to a great heat amount, and is especially advantageous in a fluctuation where a fluctuation in heat amount is large. Conventionally, there are not many small power generation systems using steam as a heat source; however, the steam power generation system 1 in which a plurality of displacement type expanders and a plurality of power generators are arranged side-by-side is adaptable to a wide variety of scales, from small to large.

[0028] The control unit 30 puts (a + 1) units of displacement type expanders into operation when detecting the information on the heat amount of steam, which is a heat source medium, and evaluating that the detected information has exceeded an a-th (a is any integer between 1 and 2) smallest threshold of two thresholds. With this configuration, the number of units to be operated is changed gradually with two different thresholds as boundaries. Therefore, more efficient power generation can be achieved by simplified determining processing.

[0029] The embodiments of the present invention has been described above; however, the present invention is not limited to the above embodiments. For example, the number of series (number of units) of displacement type expanders may be 4 or more. Even when a number of series are provided, the control of the present invention can generate power simply and efficiently with the most appropriate number of units to be operated in accordance with the heat amount of steam as a heat source medium.

[0030] The number of thresholds stored by the control unit 30 is not limited to that less than the number of series by 1. The number of thresholds may be more or less than that. A suppression means is not limited to the electromagnetic valve. A pump may be independently provided to each series, and circulation may be suppressed/stopped by flow rate adjustment and on-off operation of the pump. A three-way valve may be used at a branch point.

[0031] The displacement type expanders are not limited to the scroll expanders. Instead of the first to third scroll expanders 6A to 6C, other displacement type expanders may be used. For example, various types of expanders such as screw expanders, claw expanders, reciprocating expanders, and root expanders may be used. Steam other than water vapor may be used.

Claims

1. A power generation system (1) comprising a plurality of displacement type expanders (6A-6C) and a plurality of power generators (7A-7C) connected to each

of the plurality of displacement type expanders (6A-6C), and generating power by expansion of steam at least at one of the displacement type expanders (6A-6C), the system comprising:

a suppression means (16A-16C) that is capable of suppressing circulation of the steam for each of the displacement type expanders (6A-6C); and
a control unit (30) that controls a load ratio per the displacement type expander (6A-6C) by controlling the suppression means (16A-16C) based on information on a heat amount of the steam.

2. The power generation system (1) according to claim 1, wherein
the numbers of the displacement type expanders (6A-6C) are N units,
the control unit (30) stores at least (N - 1) different thresholds for the information on the heat amount of the steam, and
the control unit (30) puts (a + 1) units of the displacement type expanders (6A-6C) into operation when detecting the information on the heat amount of the steam and evaluating that the detected information has exceeded an a-th (a is any integer from 1 to (N - 1)) smallest threshold of the (N - 1) thresholds.

3. A power generation method where power is generated, using a power generation system (1) including a plurality of displacement type expanders (6A-6C), and a plurality of power generators (7A-7C) connected to each of the displacement type expanders (6A-6C), by expansion of steam at least at one of the displacement type expanders (6A-6C), and the method comprising
adjusting a load ratio per the displacement type expander (6A-6C) based on information on a heat amount of the steam.

Fig.1

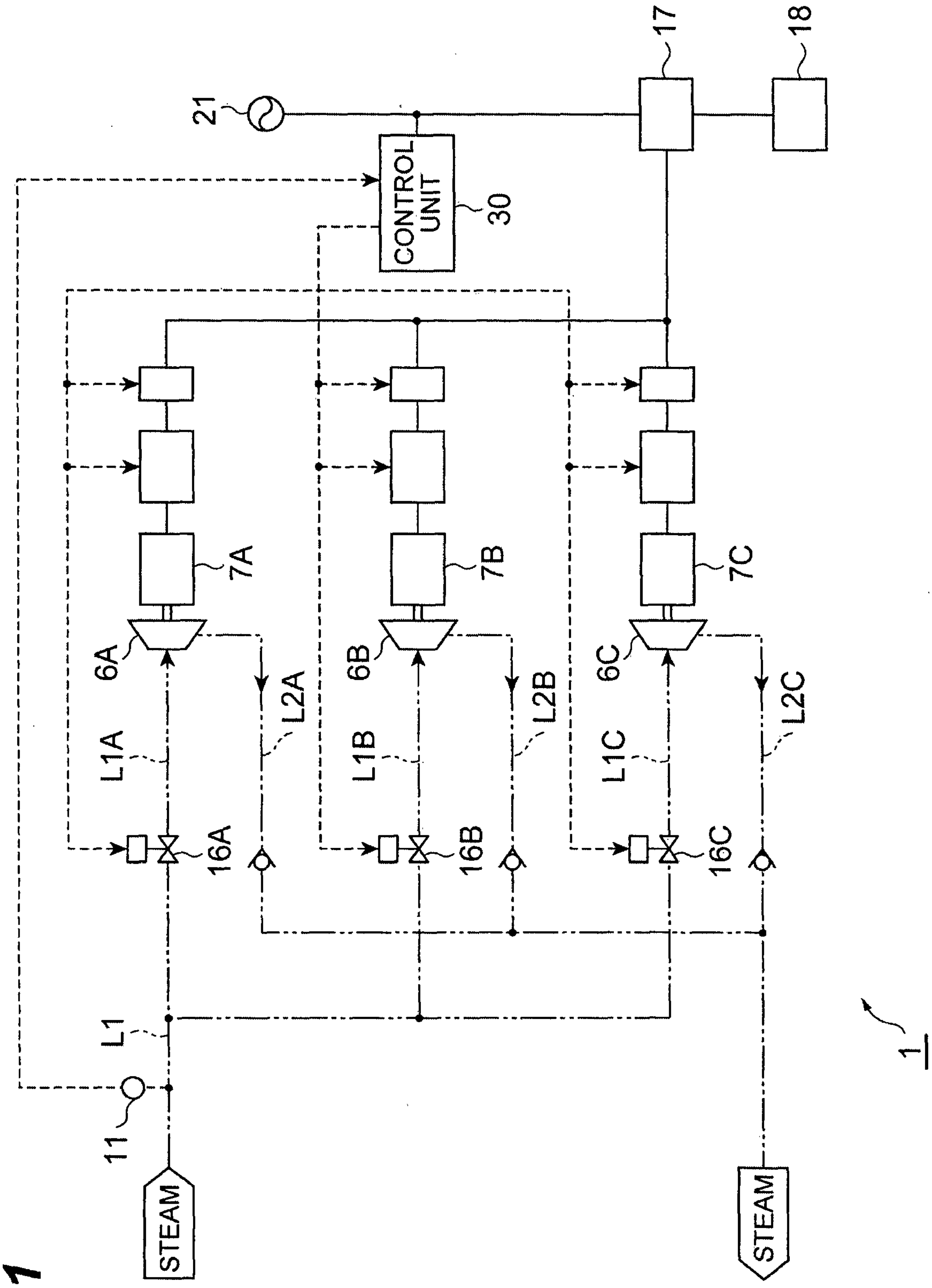
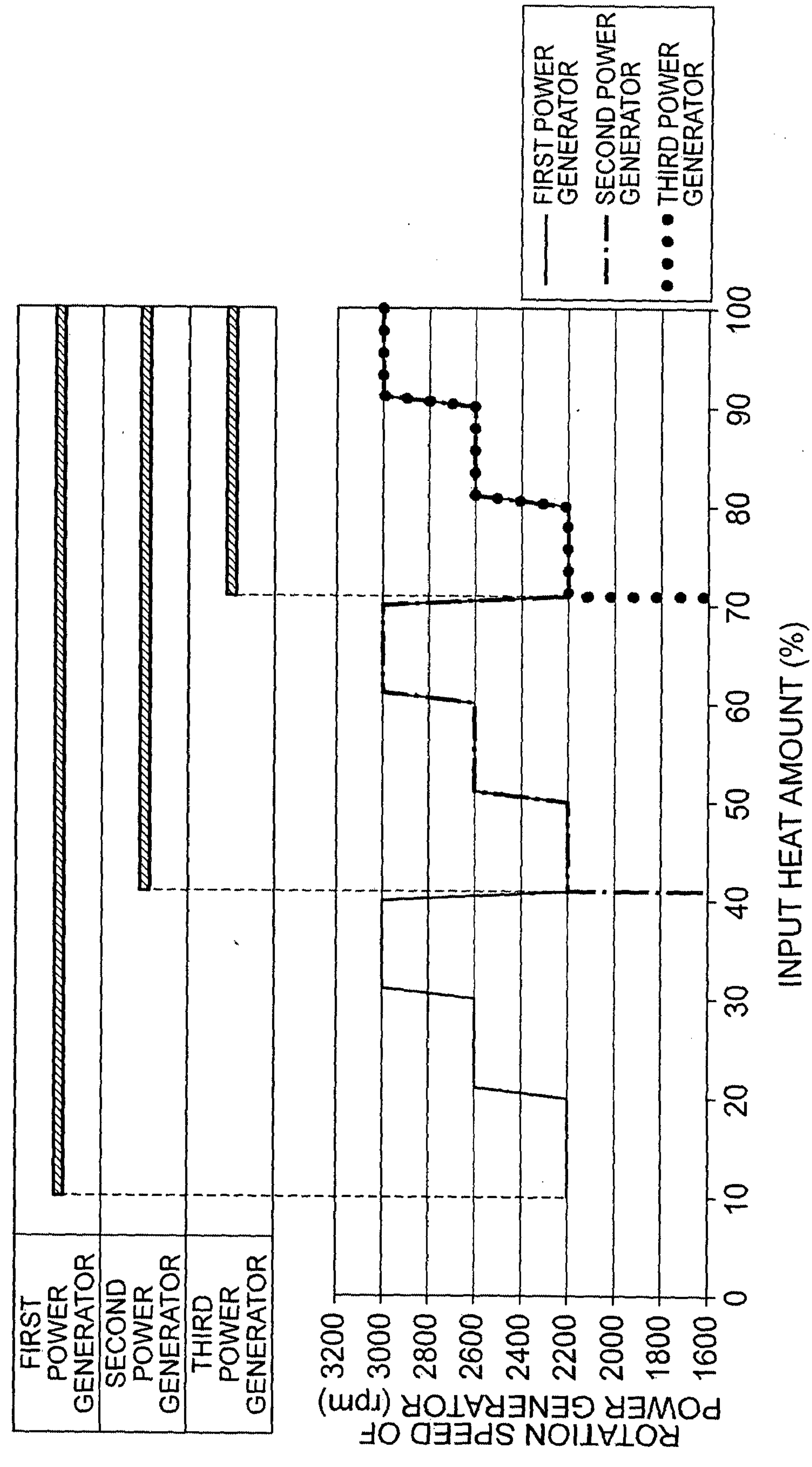

STEAM
STEAM
11
L1
16A
16B
16C
L1A
L1B
L1C
L2A
L2B
L2C
6A
6B
6C
7A
7B
7C
CONTROL UNIT
30
21
17
18
1

Fig.2


FIRST POWER GENERATOR
SECOND POWER GENERATOR
THIRD POWER GENERATOR
ROTATION SPEED OF POWER GENERATOR (rpm)
3200
3000
2800
2600
2400
2200
2000
1800
1600
0
10
20
30
40
50
60
70
80
90
100
INPUT HEAT AMOUNT (%)
FIRST POWER GENERATOR
SECOND POWER GENERATOR
THIRD POWER GENERATOR

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 7137

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F01K

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 November 2016	Röberg, Andreas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 17 7137

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REFERENCES CITED IN THE DESCRIPTION

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