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- (71) **Applicant:** ABB S.P.A. [IT/IT]; Via Vittor Pisani, 16, I-20124 Milano (IT).
- (72) **Inventors:** CALAMANI, Dario; Piazzale dei Glicini 2/26, I-16156 Genova (IT). MALACARNE, Fabrizio; Via Albini 1/30, I-16149 Genova (IT).
- (74) **Agent:** DE SANTIS, Giovanni; ABB S.p.A., Via L. Lama, 33, 20099 Sesto San Giovanni (MI) (IT).
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(54) **Title:** POWER GENERATION PLANT MONITORING APPARATUS AND MONITORING SYSTEM

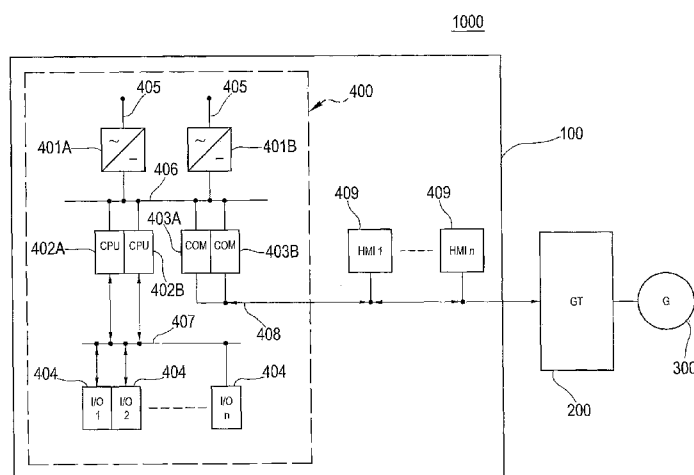


FIG.1

(57) **Abstract:** It is described a power generation plant monitoring apparatus (502) comprising: a supply voltage device (503) structured to generate an electrical voltage (Vcc); a sensor status decision module (504) to be fed by the electrical voltage (Vcc) and configured to determine the status of an external sensor (501) configured to monitor the power generation plant; a voltage monitoring module (505) configured to monitor the operation of the supply voltage device (503) and generate a voltage monitoring signal (S_v), a test module (506) connected to the supply voltage device (503) and the voltage monitoring module (505) and activable by a test signal (S_{TS}) to simulate a malfunction of the supply voltage device (503); a managing module (507) configured to generate said test signal (S_{TS}) and sense the voltage monitoring signal (S_v) to detect anomalies of the voltage monitoring module (505).

**POWER GENERATION PLANT MONITORING APPARATUS AND
MONITORING SYSTEM**

BACKGROUND

Technical Field

5 The present invention relates to monitoring systems of power generation plants.

Description of the Related Art

 In electrical power generation plants several sensors are used to detect and monitor physical
10 parameters (e.g. temperature, pressure) or general conditions of the plants area (e.g. presence of fires).

 Particularly, are known fire sensors employed electrical power generation plants, such as the ones provided with gas turbines, which drive a normally
15 opened electrical switch connected to an electronic control card. The electronic card reads an electrical current which flows as a consequence of the switch closure and generates an alarm signal indicating the presence of fire.

20 The criticality of power generation plants requires a high reliability of the employed monitoring devices in order to guarantee an efficient detection of the plant parameters and the launch of suitable safety procedures. Malfunctions or anomaly behaviours of the

monitoring apparatuses could cause dangerous situations or reduce the availability of the power plant.

SUMMARY

The Applicant has noticed that improvements in the
5 reliability of the monitoring apparatuses associated with the parameter sensors could reduce risk and disruptions.

According to an embodiment of the invention, a power generation plant monitoring apparatus is provided
10 as depicted by the appended claim 1. Further embodiments of the apparatus are described by the dependent claims 2-9.

In accordance with another embodiment of the invention a power plant control system is defined by
15 the independent claim 10; particular embodiments of the control system are described by the dependent claims 11-13.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages will be
20 more apparent from the following description of preferred embodiment and of its alternatives given as a way of an example with reference to the enclosed drawings in which:

FIG. 1 schematically shows an electrical power
25 generation plant comprising a control and monitoring

system, a gas turbine and an electrical power generator;

FIG. 2 shows a plant control system implementable in said electrical power generation plant;

5 **DETAILED DESCRIPTION**

FIG. 1 shows schematically an example of an electrical power generation plant 1000 comprising a control and monitoring system 100, a gas turbine 200 (GT) and an electrical generator 300 (G).

10 Particularly, the control and monitoring system 100 can be structured to perform automation, control and protection of the gas turbine 200. The control and monitoring system 100 shown in FIG. 1 comprises at least one control unit 400 including: a first power supply
15 module 401A, a first processing and control apparatus 402A (CPU), a first communication module 403A (COM) and one or more input/output electronic modules 404 (I/O).

The first supply module 401A is, as an example, a AC/DC converter connected to an input AC power supply
20 line 405 (e.g. at 230 V) and to an output DC supply bus 406 (e.g. at 24 V).

The first processing and control apparatus 402A includes, as an example, a control and processing unit, and is electrically fed by the output DC supply bus
25 406. Moreover, the first processing and control

apparatus 402A is connected to the input/output electronic modules 404 for exchanging data or control signals via an input/output communication bus 407. The input/output electronic modules 404 can be electronic cards connected to sensor devices associated with the gas turbine 200 or to the electrical power generator 300.

The first communication module 403A (COM) is electrically fed by the output DC supply bus 406 and is configured to allow communications, via a communication bus 408, between the first processing and control apparatus 402A and other processing and control apparatuses (not shown) and/or at least one Human Machine interfaces 409, such as computer and display devices.

It is observed that the control and monitoring system 1000 shown in FIG.1 can be designed with redundancy so duplicating critical components to increase reliability. Accordingly, the control unit 400 can also include: a second power supply module 401B, a second processing and control apparatus 402B and a second communication module 403B.

The gas turbine 200, which can be a known apparatus, is provided with a combustion chamber or flame holder wherein air is fed by a compression system.

A flame obtained by a combustor then heats this air at constant pressure. After heating, air passes from the combustion chamber to the turbine.

The control unit 400 is configured to monitor anomalies that can occur in the electrical power generation plant 1000 and implement a safety policy in case that an anomaly is detected. The anomalies can be faults, malfunctions or dangerous situations occurred in the electrical power generation plant 1000. As an example, the anomaly can be associated with a fire in the electrical power generation plant 1000 or with the absence of the flame in the combustion chamber

FIG. 2 schematically shows a plant control system 500 implementable in the electrical power generation plant 1000 and configured to monitor and manage the anomaly detections. Particularly, the plant control system 500 refers to the fire detection.

The plant control system 500 includes a fire sensor device 501 and a plant monitor apparatus 502 comprising: a voltage supply module 503, a sensor status decision apparatus 504, a voltage monitoring module 505, a test module 506 and a managing module 507.

The voltage supply module 503 comprises a supply terminal T_{s1} for receiving a voltage V_{cc} (generated by

a voltage source not shown) connected to a first supply line L1 and a ground terminal GND connected to a second supply line L2. As an example, the voltage Vcc is 24V. Preferably, the voltage supply module 503 also includes
5 a protection device 2, such as a fuse, placed along the first supply line L1.

In accordance with the shown example, the first line L1 is connected by node N_T to a first terminal T1 of the fire sensor device 501 and to an first switch
10 terminal P1 of the test module 506. The second line L2 is connected to the status decision module 504 and the voltage monitoring module 505.

The fire sensor device 501 can be a device known to the skilled in the art and comprising, as an example,
15 one or more sensing elements (not shown) adapted to detect the presence of a fire in an area of the electrical power generation plant 1000. As an example, the sensing element included into the fire sensor device 501 can be a smog and/or a gas sensor and/or a
20 temperature sensor.

Moreover, the fire sensor device 501 is provided with a processing module (not shown) configured to recognize the presence or the absence of a fire in the electrical power generation plant 1000 from signals
25 provided by the sensing element.

In accordance with the described example, the fire sensor device 501 is provided with the first terminal T1, connected to the first supply line L1, and a second terminal T2 connected to a first node N1 which is also
5 connected to the status decision apparatus 504.

Particularly, the fire sensor device 501 is configured to selectively assume a detected anomaly status (in presence of a fire) and detected no-anomaly status (in absence of a fire). In the detected anomaly
10 status, the fire sensor device 501 is structured to generate a fire alarm signal S_{ON} at the second terminal T2 connected to the first node N1. In the detected no-anomaly status, the fire sensor device 501 is structured to generate a fire absence signal S_{OFF} on the
15 second terminal T1.

With reference to the example of FIG. 2, the fire sensor device 501 includes a sensor switch SW provided with a first movable contact C1 which can connect/disconnect the first terminal T1 to/from the
20 second terminal T2. Particularly, in the detected anomaly status the sensor switch SW is closed and in the detected no-anomaly status the sensor switch is opened.

Particularly, the fire absence signal S_{OFF}
25 corresponds to the lack of electrical current flowing

between the first terminal T1 and the second terminal T2 while the fire alarm signal S_{ON} corresponds to an electrical current circulating between the first and second terminals T1 and T2.

5 The sensor status decision apparatus 504 comprises a first sensor status decision module 508 configured to detect the status of the fire sensor device 501 by sensing the electrical current, produced when the sensor switch SW is closed, and the current
10 interruption produced when the sensor switch SW is opened.

Particularly, the first sensor status decision module 508 comprises a first sensing terminal ST1, connected to the first node N1, and a second sensing
15 terminal ST2 connected to the second supply line L2 by a second node N2. The first status decision module 508 can be an electronic card including hardware and/or software modules, such as a printed circuit board carrying an integrated circuit. Particularly, the first
20 status decision module 508 can be one of the input/output electronic modules 404 shown in FIG. 1.

Moreover, the first sensor status decision module 508 is configured to recognise the status of the sensor switch SW and produce a corresponding first fire signal
25 S_{DET1} on a first output terminal OU1. An example, the

first fire signal S_{DET1} is a digital signal representing the presence or the absence of the fire.

According to a particular embodiment, the sensor status decision apparatus 504 comprises a second status
5 decision module 509 which is substantially identical to the first sensor status decision module 508. The second status decision module 509 ensures high reliability since allows to implement a redundancy of the fire sensor monitoring.

10 Particularly, the second sensor status decision module 509 comprises a third sensing terminal ST3 connected to the first node N1 and a fourth sensing terminal ST4 connected to the second supply line L2 by a third node N3. The second status decision module 509
15 and the first sensor status decision module 508 are connected to the voltage supply module 503 in an electrical parallel configuration.

Particularly, the use of two sensor status decision modules 508 and 509 requires that such modules
20 were electrically fed by a voltage supply device (i.e. the voltage supply module 503) which is external with respect the two sensor status decision modules 508 and 509.

In accordance with this example, the second sensor
25 status decision module 509 is configured to sense the

presence of an electrical current flowing between the third sensing terminal ST3 and the fourth sensing terminal ST4 to recognise the status of the sensor switch SW and produce a second fire signal S_{DET2} on a
5 second output terminal OU2.

The voltage monitoring module 505 is configured to monitor the presence of the supply voltage V_{cc} between the first and second supply lines L1 and L2 and generate a voltage monitoring signal S_v (on a third output
10 terminal OU3) representing the voltage conditions, such as the presence or the absence of the supply voltage. The voltage monitoring module 505 comprises a fifth sensing terminal ST5 connected to the second supply line L2 and a sixth sensing terminal ST6.

15 Moreover, the voltage monitoring module 505 includes a voltage sensing element and a logic digital circuit or a microprocessor (not shown). Particularly, the voltage monitoring module 505 can be an electronic card including hardware and/or software modules, such
20 as a printed circuit board carrying an integrated circuit. More particularly, the voltage monitoring module 505 can be one of the input/output electronic modules 404 shown in FIG. 1.

The test module 506 is configured to test the
25 operation of the voltage monitoring module 505 by

simulating an interruption of the voltage supply module 503. Particularly, the first switch terminal P1 of the test module 506 is connected to the first supply line L1 via the node N_T while a second switch terminal P2 is
5 connected to the sixth sensing terminal ST6 of the voltage monitoring module 505.

The test module 506 is provided with a switch device SW1 having a second movable contact C2 which can connect/disconnect the first switch terminal P1 to/from
10 the second switch terminal P2.

The switch component SW1 can assume a closed configuration in which the first switch terminal P1 is connected to the second switch terminal P2 and to the sixth sensing terminal ST6, so providing the supply
15 voltage Vcc to the voltage monitoring module 505.

The switch component SW1 can also assume an opened configuration in which the first switch terminal P1 is disconnected from the second switch terminal P2, so to interrupt the feeding of the supply voltage Vcc to the
20 voltage monitoring module 505.

Particularly, the test module 506 can include an electronic driving circuit configured to drive the switch component SW1 under the command of test signal S_{TS} . As an example, the test module 506 can be one of

the input/output electronic modules 404 shown in FIG.

1.

The managing module 507 is configured to generate the test signal S_{TS} , to be provided to a first input terminal IN1 of the test module 506. Particularly, the managing module 507 is configured to manage test operations in order to evaluate the correct or anomalous behaviour of the voltage monitoring module 505.

As will be discussed later, the managing module 507 periodically activates, by means of the test signal S_{TS} , the test module 505 to simulate an interruption of the voltage supply and senses the voltage monitoring signal S_V produced by the voltage monitoring module 505. The managing module 507 is structured to generate an anomaly signal S_{AN} indicating the correct or anomalous behaviour of the voltage monitoring module 505.

The managing module 507 includes hardware and/or software modules and can comprise a control and processing unit, such as a microprocessor, executing a specific software. The functionalities of the managing module 507 can be also implemented by a finite-state machine. According to an example, the managing module 505 is implemented into the first processing and control apparatus 402A of FIG. 1.

With reference to the operation, it has to be observed that the plant control system 500 can operate in a normal mode and in a test mode.

In the normal mode, the test module 506 is not
5 activated and (as indicated in FIG. 2) the switch device SW1 is in the closed configuration. In the above situation the supply terminal T_{s1} of the voltage supply module 503 is connected, via the first supply line L1 and node N_T , to the first switch terminal P1 of the test
10 module 506.

The closed configuration of the switch device SW1 allows the connection of the input terminal P1 with the input terminal P6 and the sixth sensing terminal ST6 of the voltage monitoring module 505. The fifth sensing
15 terminal ST5 of the voltage monitoring module 505 is connected to the ground terminal GND of the voltage supply module 503, via the second supply L2 and the third and second nodes N3 and N2.

In the normal operation mode, the voltage
20 monitoring module 505 can operate to detect possible malfunctions of the voltage supply module 503. With the terms anomalies or malfunctions of the voltage supply module 503 also failures of the electrical conductive paths connecting the voltage monitoring module 505 with
25 the voltage supply module 503 are included.

If there is no electrical current flowing between the fifth sensing terminal ST5 and the sixth sensing terminal ST6, the voltage monitoring module 505 generates the voltage monitoring signal S_v which
5 indicates the detection of the anomaly. In this case, safety procedures can be activated such as an example, substitution of voltage supply module 503 or substitution of the voltage monitoring module 505.

It is observed that if the voltage supply module
10 503 does not operate correctly, the first and second status sensor decision module 508 and 509 are not fed with the necessary electrical power and so they cannot operate to detect the status of the fire sensor device 501.

15 If the voltage supply module 503 operates correctly the first and second status sensor decision module 508 and 509 receives the electrical power necessary to perform the detection of the status of the fire sensor device 501.

20 Particularly, in a condition of absence of any fire, the sensor switch SW is opened and neither the first status sensor decision module 508 nor the second status sensor decision module 509 are fed with electrical power generated by the voltage supply module

503, since the first node N1 is disconnected from the first supply line L1.

In a condition of presence of fire, the sensor switch SW is closed and both the first and second status sensor decision modules 508 and 509 are fed with the electrical power generated by the voltage supply module 503, since the first node N1 is connected to the first supply line L1.

In the above situation, the first status sensor decision module 508 detects the electrical current flowing between the first sensing terminal ST1 (connected to the first supply line L1 via the sensor switch SW) and the second sensing terminal ST2 (connected to the second supply line L2 via the second node N2).

Moreover, the second status sensor decision module 509 detects the electrical current flowing between the third sensing terminal ST3 (connected to the first supply line L1 via the sensor switch SW) and the fourth sensing terminal ST4 (connected to the second supply line L2 via the third node N3).

The detection of the presence of a fire, as an example, by both first and second decision modules 508 and 509, which generate the first and second fire signals S_{DET1} and S_{DET2} , allows to activate the necessary

safety procedures, such as: block of the power generation plant, action of fire-extinguishing system etc.

Reference is now made to the test mode. In the test mode, the managing module 507 generates the test signal S_{TS} which is received by the test module 506. The test module 506 opens the switch device SW1 so disconnecting the first switch terminal P1 from the second switch terminal P2. In this configuration, no electrical power is provided to the voltage monitoring module 505.

If the voltage monitoring module 505 operates correctly, the lack of electrical current flowing between the fifth sensing ST5 and sixth sensing terminal ST6 is detected and a corresponding voltage monitoring signal S_v is generated. The correct operation of the voltage monitoring module 505 is so recognised by the managing module 507.

It is noted that the voltage monitoring module 505 can show malfunctions due, as an example, to a non-detectable failure in its input cards.

If the voltage monitoring module 505 does not operate correctly, in the test mode, the lack of electrical current flowing between the fifth sensing ST5 and sixth sensing terminal ST6 is not detected and

the corresponding voltage monitoring signal S_v indicates erroneously the presence of electrical power.

In the above situation, the managing module 507 receives the voltage monitoring signal S_v and recognises
5 that the voltage monitoring module 505 shows malfunctions so generating a corresponding anomaly signal S_{AN} indicating the anomalous behaviour of the voltage monitoring module 505.

The detection of the malfunction of the voltage
10 monitoring module 505 allows to repair or substitute this module in order to restore the reliability of the plant control system 500.

The managing module 507, after having recognised the correct or anomalous behaviour of the voltage
15 monitoring module 505, commands the closure of the switch device SW1 so starting the normal mode.

It is noticed that, in the test mode, the interruption of the electrical power feeding is performed for the voltage monitoring module 505 but is
20 not performed for the first and second sensor decision modules 508 and 509 which are normally fed with the electrical voltage and can operate as they do in the normal mode.

Particularly, when the switch device SW1 is opened
25 the first and second sensor decision modules 508 and

509 remain connected to the first and second supply line L1 and L2 and can operate as described above.

The plant control system 500 shows the advantage of guarantee a high level of availability of the electrical power generation plant 1000. Particularly,
5 the test made on the voltage monitoring module 505 allows to detect any malfunction so increasing the reliability of such voltage monitoring module together with the efficiency of the sensor status detection.

10 Moreover, the use of two status decision modules (508 and 509) with the external supply voltage device 503 provides reliability of the sensor status detection in accordance with a redundant approach.

The plant control system 500 allows to fulfill the
15 law requirements, such as the ones ruled by European Machinery Directive 2006/42/EC. It is observed that the European Machinery Directive 2006/42/EC refers to the standard ISO 13849-1: this standard deals with the design and integration of Safety-Related Parts of
20 Control Systems (SRP/CS) independently from the technology used.

Moreover, the described plant control system 500 allows to increase the performance level (PL) defined by the standard ISO 13849-1.

Claims

1. A power generation plant monitoring apparatus (502), comprising:

5 a supply voltage device (503) structured to generate an electrical voltage (Vcc);

a sensor status decision module (504) to be fed by said voltage (Vcc) and configured to determine a status of an external sensor (501) configured to monitor power generation plant conditions;

10 a voltage monitoring module (505) configured to monitor the operation of the supply voltage device (503) and generate a voltage monitoring signal (S_V),

a test module (506) connected to the supply voltage device (503) and the voltage monitoring module (505) and activable by a test signal (S_{TS}) to simulate a malfunction of the supply voltage device (503);

a managing module (507) configured to generate said test signal (S_{TS}) and sense the voltage monitoring signal (S_V) to detect anomalies of the voltage monitoring module (505).

2. The monitoring apparatus of claim 1, wherein the test module (506) is structured to selectively assume:

a normal configuration in which the supply voltage device (503) is connected to the sensor status decision module (504) and the voltage monitoring module (505);

a simulation configuration in which the supply
5 voltage device (503) is connected to the sensor status decision module (504) and is disconnected from the voltage monitoring module (505).

3. The monitoring apparatus of claim 2, wherein said test module (503) includes:

10 a switch (SW1) structured to interrupt the supply of the electrical voltage to the voltage monitoring module (505);

a driving circuit configured to receive the test signal (S_{TS}) and drive said switch (SW1).

15 4. The monitoring apparatus of claim 3, wherein said switch comprises a first movable contact (C2) configured to selectively assume a closed configuration and an opened configuration in which respectively a supply terminal (1) of the supply voltage device (503)
20 is connected/disconnected to/from a sensing terminal (ST6) of the voltage monitoring module (505).

5. The monitoring apparatus of claim 1, wherein the sensor status decision module (504) includes:

a first status decision module (508) configured to determine the status of the external sensor (501) and generate a first detection signal (S_{DET1});

a second status decision module (508) configured
5 to determine the status of the external sensor (501) and generate a second detection signal (S_{DET2}).

6. The monitoring apparatus of claim 1, wherein the managing module (507) is configured to:

periodically generate the test signal (S_{TS}) to
10 start a test on the voltage monitoring module (505);

receive the voltage monitoring signal (S_V); and

generate an anomaly signal (S_{AN}) indicating an anomalous behaviour of voltage monitoring module (505) when the voltage monitoring signal (S_V) lacks to
15 represent a simulated malfunction of the supply voltage device (502).

7. The monitoring apparatus of claim 1, wherein said sensor status decision module (504) is configured to determine the status of an external sensor (501)
20 structured to operate as a fire sensor.

8. The monitoring apparatus of claim 1, wherein said power generation plant is a gas turbine plant.

9. The monitoring apparatus of claim 5, wherein said supply voltage device (503) is external with

respect to the first status decision module (508) and the second status decision module (508).

10. A power plant control system (500) comprising:

5 a sensor device (501) associable with a power plant apparatus (200) and structured to selectively assume an anomaly detection status and a no-anomaly detection status;

a supply voltage device (503) structured to
10 generate an electrical voltage (V_{cc}),

a sensor status decision module (504) to be fed by the electrical voltage (V_{cc}) and configured to determine the status of the sensor device (501);

a voltage monitoring module (505) configured to
15 monitor the operation of the supply voltage device (503) and generate a voltage monitoring signal (S_v),

a test module (506) connected to the supply voltage device (503) and the voltage monitoring module (505) and activable by a test signal (S_{TS}) to simulate a
20 malfunction of the supply voltage device (503);

a managing module (507) configured to generate said test signal (S_{TS}) and sense the voltage monitoring signal (S_v) to detect anomalies of the voltage monitoring module (505).

11. The control system of claim 10, wherein the test module (506) is structured to selectively assume:

a normal configuration in which the supply voltage device (503) is connected to the sensor status decision module (504) and the voltage monitoring module (505);

a simulation configuration in which the supply voltage device (503) is connected to the sensor status decision module (504) and is disconnected from the voltage monitoring module (505).

10 12. The control system of claim 10, wherein said sensor device (501) is a fire sensor.

13. The control system of claim 10, wherein a power plant apparatus (200) is a gas turbine.

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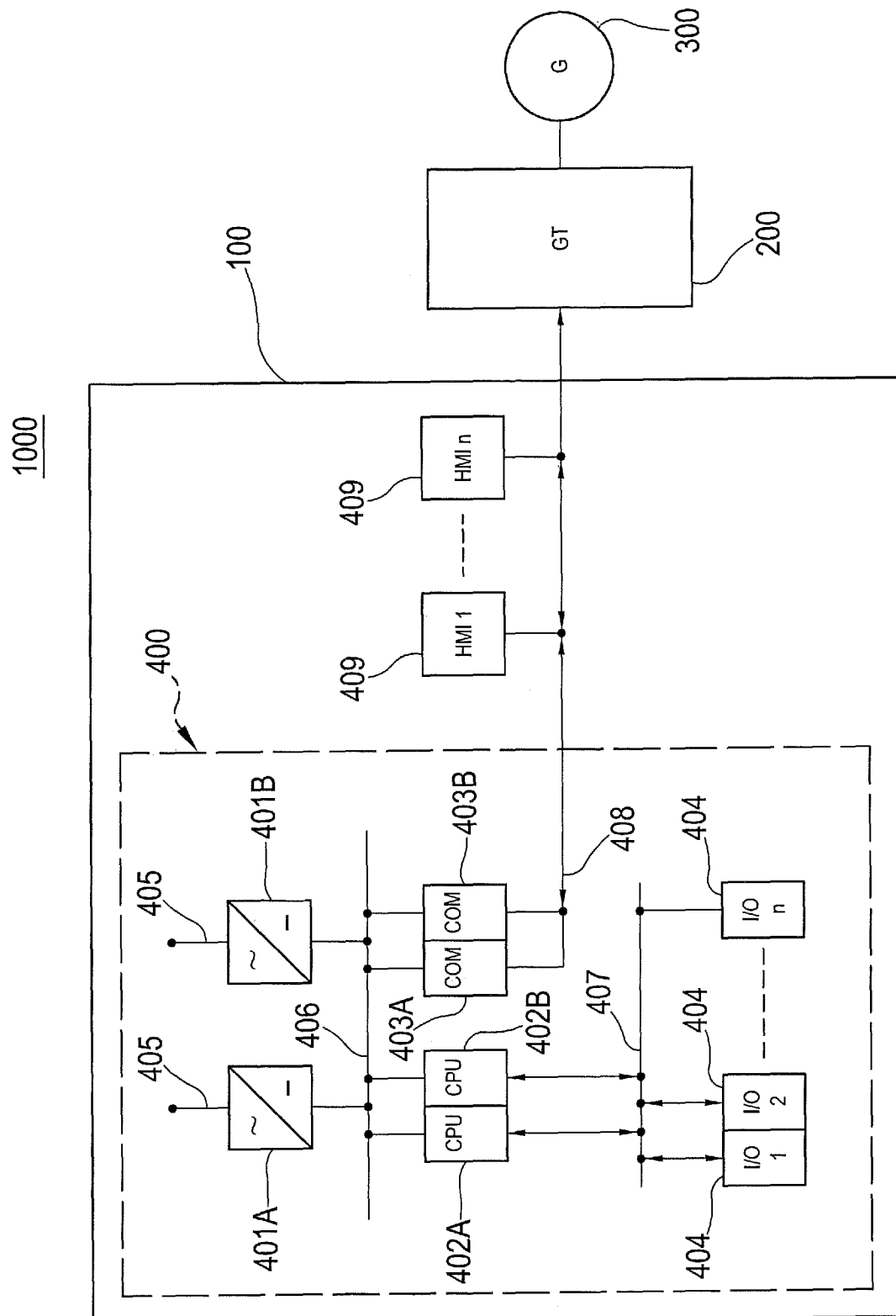
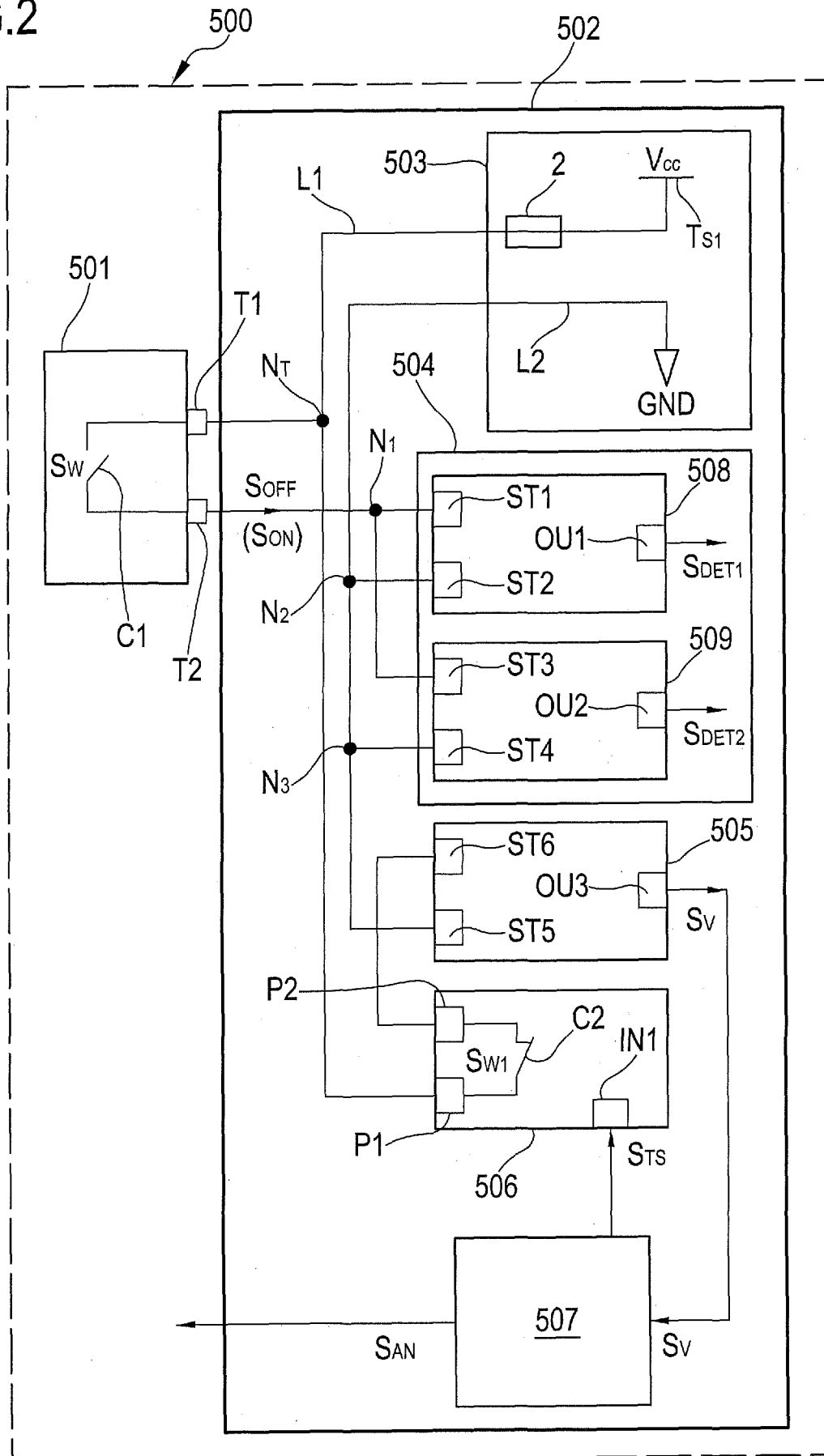


FIG. 1

2/2

FIG.2



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/063644

A. CLASSIFICATION OF SUBJECT MATTER

INV. G05B9/02 G05B23/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015/002185 A1 (MCGUIRE CHAD MICHAEL [US] ET AL) 1 January 2015 (2015-01-01) paragraph [0022] - paragraph [0023] paragraph [0049] - paragraph [0050] -----	1,2,5, 7-13
Y	US 2011/167289 A1 (THOMPSON PAUL M [US] ET AL) 7 July 2011 (2011-07-07) paragraph [0038] - paragraph [0043] -----	1,2,5, 7-13



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kelperis, K

INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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