



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.03.2016 Bulletin 2016/09

(51) Int Cl.:
F04D 27/00 (2006.01)

(21) Application number: **14182670.1**

(22) Date of filing: **28.08.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
 Designated Extension States:
BA ME

(71) Applicant: **Siemens Aktiengesellschaft**
80333 München (DE)

(72) Inventor: **Midtgaard, Christian**
3000 Helsingor (DK)

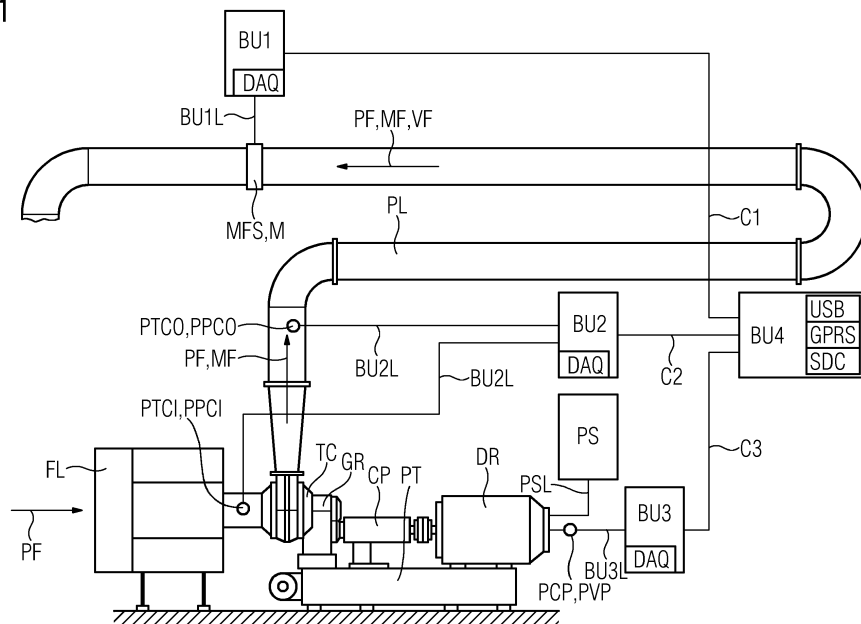
(54) **Compressor monitoring system with sensor modules in wireless communication with a controller**

(57) The invention relates to a measurement system (MS) for compressor (TC) performance monitoring and to a respective measurement method. To most efficiently evaluate the operational performance the invention proposes said measurement system (MS) comprising at least four boxed units (BU) wherein a first boxed unit (BU1) is connected to or comprises sensors (MFS) to directly or indirectly measure a mass flow (MF) or volume flow (VF) being compressed by the compressor (TC), wherein a second boxed unit (BU2) is connected to or comprises sensors (CS) to directly or indirectly measure
 a) a compressor inlet temperature (TCI),
 b) a compressor outlet temperature (TCO),
 c) a compressor inlet pressure (PCI),
 d) a compressor outlet pressure (PCO),

wherein a third boxed unit (BU3) is connected to or comprises sensors (PS) to directly or indirectly measure
 a) current (CP) of the power supplied to a drive motor (DM) of said compressor (TC),
 b) voltage (VP) of the power supplied to the drive motor (DM),

wherein a fourth boxed unit (BU4) is signal transmitting connected by a connection (C1 - C4) to said boxed units (BU1 - BU3) and comprises a storage (SDC) to store collected measurement data from said boxed units (BU1 - BU3) into said storage (SDC). Further a measurement method is proposed.

FIG 1



Description

[0001] The invention relates to a measurement system and a measurement method for compressor performance monitoring.

[0002] One of the most important aspects in the field of fluid energy machines, especially in the field of turbo machines and compressors is the operational verification of the design implemented in machines running under real working conditions. The operational verification traditionally in this field of technology is the most important customer criteria to decide for a specific product. Further, the operational verification is the final and most important proof of design changes and is needed as soon as possible to correct design mistakes or align product development strategies. One of the most important aspects of this operational monitoring is the evaluation of the performance data of the machines under real operation conditions. The operational verification on real installed compressors therefore becomes the most important criteria to judge if a turbo machine design is successful or not.

[0003] From the US 7,596,959 B2 a compressor monitoring system to observe the performance of a refrigeration system is known. The system described in this patent needs to be fully integrated into the refrigeration compressor system or to be applied under laboratory conditions which both is not cost efficient especially when it is to be installed on running fluid energy machine equipment. The system described in the prior art is not flexible enough to enable the equipment of a compressor fleet to collect masses of data to verify successful operation especially for many compressors.

[0004] It is therefore one task of the current invention to enable mass data collection of compressors being operated in field without expensive installation effort in a cost effective manner.

[0005] To meet these requirements the invention proposes a measurement system of the incipiently defined type with the additional features of the characterizing portion of claim 1. Further the invention proposes a method according to the independent method claim. The respectively dependent claims relate to preferred embodiments of the invention.

[0006] A boxed unit according to the wording of this document has the features which are normally connected with the term "black box". Further the boxed unit has indeed an outer shell protecting the inside of the boxed unit from mechanical impact. Further the boxed unit can be connected in a signal transmitting way to other boxed units either by cable or wirelessly. In addition the boxed unit according to the invention has at least its own power supply or a power input to be connected by a plug-in cable to an external power supply. Preferably the boxed unit is sealed against the outside against dust and/or humidity and/or water.

[0007] One advantage of the boxed unit according to the invention is the flexibility to arrange a measurement network by setting up several boxed units measuring

mass flow or volume flow, pressure and temperature and current or voltage or both and connecting these three types of boxed units to at least one forth boxed unit receiving the measurement results by the signal transmitting connection by wire or in a wireless way. Preferably respectively several of the three types of boxed units can be connected to one forth boxed unit receiving all the measurement results. For example several compressors can be measured with regard to the electrical power consumption by monitoring the current and voltage received by these compressors by several respective third boxed units, wherein all these third boxed units transmit these measurement results to only one single forth boxed unit. Most preferred this forth boxed unit is connected to the other boxed units by a wireless signal transmitting connection.

[0008] One preferred embodiment of the invention provides a measurement system according to the invention, wherein said forth boxed unit comprises a data acquisition device, wherein data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values.

[0009] Preferably at least one of the first, second or third boxed unit comprises a data acquisition device converting the measured analog signals into digital numeric values. Most preferred all boxed units, namely the first, second or third boxed unit, measuring real world physical parameters comprise a data acquisition device converting these parameters into digital numeric values. These digital numbers are suitable to be transferred by a wireless local area network (LAN) connection from at least one of the first, second or third boxed unit to the forth boxed unit receiving digital values as measurement results. To have the most functional and cost effective setup it is preferred to provide said storage to the forth boxed unit as a flash EEPROM especially made as a SD card (secure digital memory card).

[0010] Another preferred embodiment provides said forth boxed unit comprising a general package radio service modem (GPRS).

[0011] Another preferred embodiment of the invention provides the boxed units being connected by a wireless local area network. For this purpose it is useful that each boxed unit is part of that network and is a suitable equipped to be a wireless LAN station. Preferably the forth boxed unit is a wireless access point, being a wireless router and working as a base station for at least one of a first boxed unit, a second boxed unit and/or the third boxed unit. In a field comprising several compressors several first boxed units, second boxed units and third boxed units might be connected to the forth boxed unit being the wireless access point. One preferred embodiment is given by a compressor field comprising several compressors wherein one selected compressor is a reference compressor being equipped with a first boxed unit, a second boxed unit and a third boxed unit and the other compressors are only equipped with a third boxed

unit, wherein all these boxed units are connected to one forth boxed unit preferably wirelessly, wherein said forth boxed unit is the wireless access point and the other boxed units are clients.

[0012] Another preferred embodiment is given by the forth boxed unit comprising a USB-interface enabling data transmitting connection to other USB-interface devices. It is further preferred that said forth boxed unit can be connected in a wireless way to other computer-like devices like mobile phones, laptops or similar equipment. These devices may be beneficially used to visualize the operating parameters of the compressor plant to give the operator a quick possibility to observe the condition of the plant.

[0013] The above mentioned attributes and other features and advantages of this invention and the manner of attaining them will become more apparent and the invention itself will be better understood by reference to the following description of the currently best mode of carrying out the invention taken in conjunction with the accompanying drawings, wherein:

Figure 1: shows a schematic depiction of a single compressor being equipped with the measurement system according to the invention and being monitored by the method according to the invention,

Figure 2: shows a schematic depiction of a compressor plant being equipped with the measurement system according to the invention and being monitored by the method according to the invention.

[0014] Figure 1 shows schematically a single compressor setup comprising the measurement system according to the invention and being monitored by the method according to the invention.

[0015] A turbo compressor TC is driven by an electric drive DR being connected by a coupling CP to a gear GR transferring the speed of the drive DR to at least one impeller of said turbo compressor TC. This setup is mounted to a platform PT and fixed to the ground by said platform PT. The electric drive DR is supplied with electrical power by a power supply PS by means of three phase electricity, wherein said motor drive DR is a variable speed drive and said power supply PS is designed such that a variable frequency output enables speed control of said drive DR.

[0016] Said turbo compressor TC sucks a process fluid respectively ambient air through a filter FL and delivers said process fluid PF into a pressure line PL.

[0017] The first boxed unit BU1 comprising a data acquisition device DAQ is connected by a first signal line BU1L to a flow meter placed in pressure line PL. Said flow meter MFS measures the volume flow VF or the mass flow MF.

[0018] A second boxed unit BU2 comprises a data ac-

quisition device DAQ and is connected by second signal lines BU2L respectively to sensors in the compressor inlet and the compressor outlet. The sensors in the compressor inlet are an inlet temperature sensor PTCI and an inlet pressure sensor PPCI. The sensors in the outlet are an outlet temperature sensor PTCO and an outlet pressure sensor PPCO. The measured data is received by the second boxed unit BU2 and converted by said data acquisition device DAQ from analog data into digital data.

[0019] A third boxed unit BU3 comprising a data acquisition device DAQ is connected to sensors located in the power supply line PSL between the power supply PS and the electric drive DR. A current sensor PCP and a voltage sensor PVP measure the power transmitted through the three phase power supply line PSL from the power supply PS to the electric drive DR. This analog information is transmitted by a third signal line BU3L to the data acquisition device DAQ of the third boxed unit which transforms the analog data into digital data.

[0020] The first boxed unit BU1, the second boxed unit BU2 and the third boxed unit BU3 are connected respectively preferably wirelessly by a first connection C1, a second connection C2 and a third connection C3 to the forth boxed unit BU4 collecting the digital data resulting from the measurement installing this data in a storage SDC. The forth boxed unit comprises a USB-interface to be connected to other USB compatible devices. A GPRS-modem of the forth boxed unit enables wireless access to the storage of the forth boxed unit.

[0021] Figure 2 shows a compressor plant being monitored according to the method of the invention by a measurement system according to the invention. The compressor plant comprises a first compressor TC1, a second compressor TC2, a third compressor TC3 and a forth compressor TC4. The first compressor TC1 is a reference compressor being equipped with a first boxed unit BU1, a second boxed unit BU2 and a third boxed unit BU3. The remaining compressors TC2, TC3, TC4 are equipped with a third boxed unit BU3 only monitoring the power consumption. All these boxed units BU1, BU2, BU3 are connected wirelessly to one single forth boxed unit BU4 collecting all the data and storing this data in said storage SDC.

Claims

1. Measurement system (MS) for compressor (TC) performance monitoring, comprising at least four boxed units (BU) wherein a first boxed unit (BU1) is connected to or comprises sensors (MFS) to directly or indirectly measure a mass flow (MF) or volume flow (VF) being compressed by the compressor (TC), wherein a second boxed unit (BU2) is connected to or comprises sensors (CS) to directly or indirectly measure

- a) a compressor inlet temperature (TCI),
- b) a compressor outlet temperature (TCO),
- c) a compressor inlet pressure (PCI),
- d) a compressor outlet pressure (PCO),

5

wherein a third boxed unit (BU3) is connected to or comprises sensors (PS) to directly or indirectly measure

- a) current (CP) of the power supplied to a drive motor (DM) of said compressor (TC),
- b) voltage (VP) of the power supplied to the drive motor (DM),

10

wherein a fourth boxed unit (BU4) is signal transmitting connected by a connection (C1 - C4) to said boxed units (BU1-BU3) and comprises a storage (SDC) to store collected measurement data from said boxed units (BU1 - BU3) into said storage (SDC).

15

20

2. Measurement system (MS) according to claim 1, wherein said first, second, third and fourth boxed unit (BU1 - BU4) respectively comprise wireless transmitters and wherein connections (C1 - C4) are wireless.

25

3. Measurement system (MS) according to claim 1 or claim 2, wherein at least one of the first, second or third boxed unit (BU1 - BU3) comprises a data acquisition device (DAQ).

30

4. Measurement system (MS) according to at least one the preceding claims, wherein said storage (SDC) is a flash EEPROM, especially made as a SD card.

35

5. Measurement system (MS) according to at least one of the preceding claims, wherein said fourth boxed unit (BU4) comprises a general packet radio service modem (GPRS).

40

6. Measurement system (MS) according at least one of the preceding claims, wherein said fourth boxed unit (BU4) comprises a USB interface.

45

7. Measurement method, for compressor (TC) performance monitoring, in particular to be applied in combination with a measurement system (MS) according at least one of the preceding claims, comprising the following steps:

50

- i) connecting a first boxed unit (BU1) to sensors (MFS) to directly or indirectly measure a mass flow (MF) or volume flow (VF) being compressed by the compressor (TC),
- ii) connecting a second boxed unit (BU2) to sensors (CS) to directly or indirectly measure

55

- a) a compressor inlet temperature (TCI) and/or
- b) a compressor outlet temperature (TCO) and/or
- c) a compressor inlet pressure (PCI) and/or
- d) a compressor outlet pressure (PCO) and/or

iii) connecting a third boxed unit (BU3) to sensors (PS) to directly or indirectly measure

- a) current of the power supplied to a drive motor (DM) of said compressor (TC) and/or
- b) voltage of the power supplied to the drive motor (DM),

iv) connecting a fourth boxed unit (BU4) in a signal transmitting way by a connection (C1 - C3) to said boxed units (BU1 - BU3), wherein said fourth boxed unit (BU4) comprises a storage (SDC) to store collected measurement data from said boxed units (BU1 - BU3) into said storage (SDC).

FIG 1

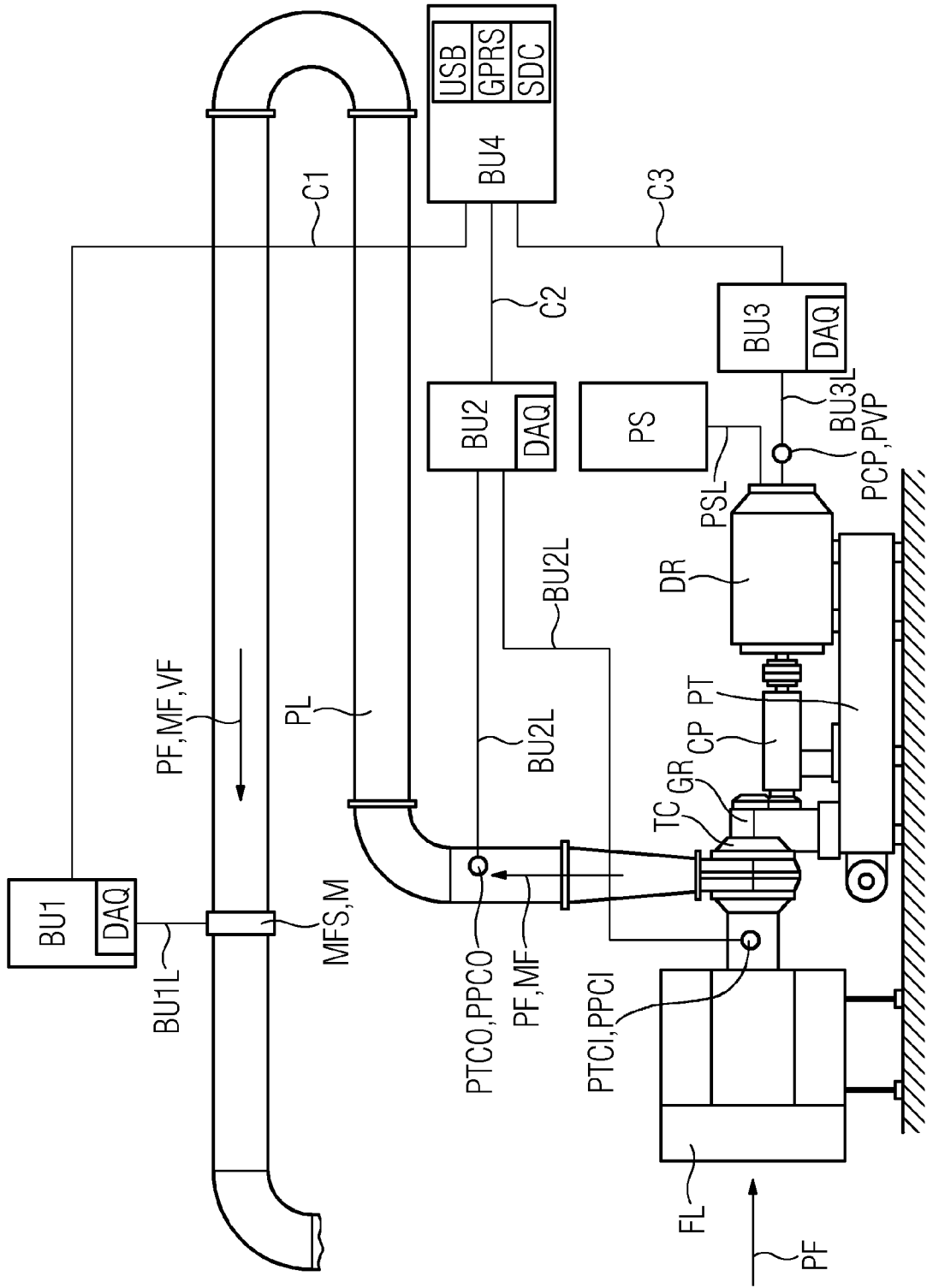
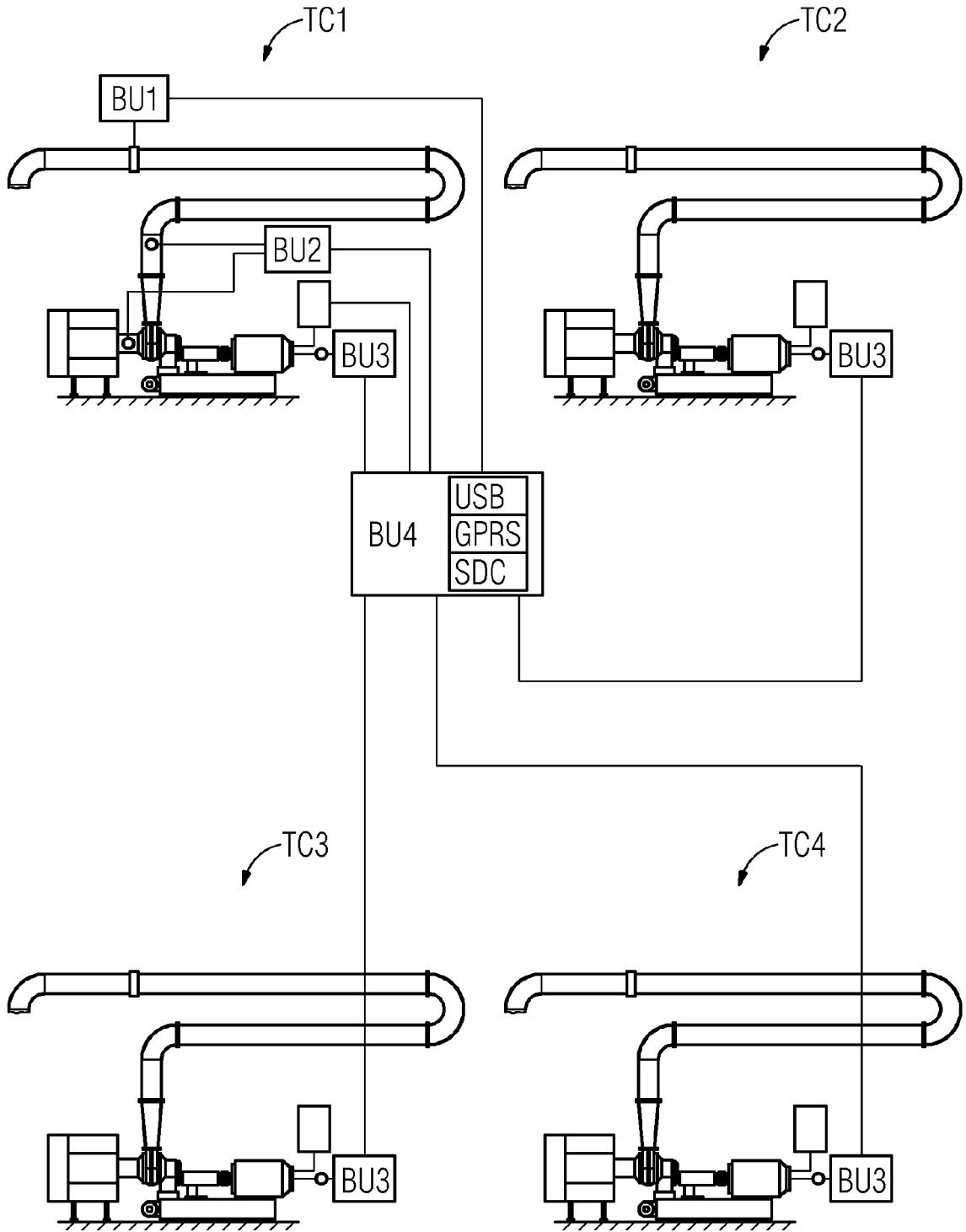


FIG 2





EUROPEAN SEARCH REPORT

Application Number
EP 14 18 2670

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2008/077260 A1 (PORTER MICHAEL RAMEY [US] ET AL) 27 March 2008 (2008-03-27)	1-4,6,7	INV. F04D27/00
Y	* paragraphs [0020], [0023], [0027], [0063], [0064], [0065], [0066], [0067], [0083], [0103]; figures 1,3,4,5 *	5	
Y	----- US 2013/272840 A1 (FUJIOKA TAMOTSU [JP] ET AL) 17 October 2013 (2013-10-17)	5	
A	* paragraph [0057] *	1-4,6,7	
A	----- US 2009/019938 A1 (KLOSINSKI ANDREW JURI [US] KLOSINSKI ANDREW JURLI [US]) 22 January 2009 (2009-01-22)	1,7	
	* paragraphs [0026], [0027], [0030] - [0038]; figures 1,2 *		

The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 30 January 2015	Examiner Brouillet, Bernard
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.02 (F04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 14 18 2670

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

30-01-2015

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008077260 A1	27-03-2008	NONE	

US 2013272840 A1	17-10-2013	CN 103362791 A	23-10-2013
		JP 2013209902 A	10-10-2013
		US 2013272840 A1	17-10-2013

US 2009019938 A1	22-01-2009	CN 101802314 A	11-08-2010
		CN 101802928 A	11-08-2010
		EP 2176470 A1	21-04-2010
		EP 2179422 A1	28-04-2010
		US 2009019938 A1	22-01-2009
		WO 2009014656 A1	29-01-2009
		WO 2009014658 A1	29-01-2009

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 7596959 B2 [0003]