(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 256 207 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
16.07.2025 Bulletin 2025/29

(21) Application number: **21835585.7**

(22) Date of filing: **01.12.2021**

(51) International Patent Classification (IPC):
F04D 27/00 *(2006.01)* ***F04D 27/02*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04D 27/001; F04D 27/0284

(86) International application number:
PCT/EP2021/083688

(87) International publication number:
WO 2022/117607 (09.06.2022 Gazette 2022/23)

(54) PUMP SYSTEM

PUMPENSYSTEM

SYSTÈME DE POMPE

(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

(30) Priority: **01.12.2020 GB 202018903**

(43) Date of publication of application:
11.10.2023 Bulletin 2023/41

(73) Proprietor: **Leybold GmbH**
50968 Köln (DE)

(72) Inventors:
- **PAJONK, Michael**
  50968 Köln (DE)
- **COECKELBERGS, Joeri**
  50968 Köln (DE)

(74) Representative: **Arnold, Emily Anne**
Edwards Limited
Innovation Drive
Burgess Hill, West Sussex RH15 9TW (GB)

(56) References cited:
EP-A2- 1 450 328
US-A1- 2012 136 502
US-A1- 2017 369 061
US-A1- 2018 180 340

EP 4 256 207 B1

Description

[0001] The present application provides a pump system with at least one pump, in particular a vacuum pump or a compressor.

[0002] A pump built as vacuum pump or compressor is a motor driven apparatus in order to convey a gaseous medium from the inlet of the pump to the outlet. Therein, in common pump systems, more than one pump act together in order to provide a vacuum or a compressed fluid to any kind of application. Thus, it is desirable to provide a common control to several pumps within one pump system in order to be operated more efficiently.

[0003] Further, it is desired to collect data from each of the pumps in a pump system for either the customer to have an overview over the pump condition of each pump not only in one particular pump system but in the complete pump fleet, i. e. all employed pumps even at different locations around the world, or by the manufacturer in order to plan service intervals or monitor quality or products or the like. Thus, more pumps are able to be connected to computer networks, in particular the internet, to share data with each other or collect data for example in a cloud service or at a server of the customer or the manufacturer of the pump. However, due to accessibility of the pumps via the internet, a security risk arises, and the pumps may be subject of manipulation from outside or corruption of data, like processing data regarding the specific task delivered by the pump system.

[0004] Thus, it is an object of the present invention to provide a pump system with increased security and reliability of operation.

[0005] EP1450328 describes a known system for remote monitoring of machines.

[0006] The pump system according to the present invention comprises at least one pump which may be built as vacuum pump or compressor. In particular, the pump system may comprise more than one vacuum pump or compressor in order to provide a vacuum or a compressed fluid to a specific application.

[0007] Further, the pump system comprises a controller connected to the at least one pump. Preferably the controller is connected to each of the pumps of the pump system to provide a common control to the pumps of the pump system. Therein, the controller comprises a first processing unit directly connected to the at least one pump for providing low level services to the at least one pump and a second processing unit connected to the first processing unit to provide high level services to the pump system. Therein, preferably only one first processing unit providing low lever services is employed as common first processing unit for each of the pumps in the pump system together. Alternatively, for each of the pumps in the pump system an individual first processing unit is employed providing low level services to each of the pumps of the pump system individually. In any case, the controller comprises only one second processing unit connected to each of the first processing unit if more than one first processing unit employed in the controller. Thus, in accordance to the present invention, the first processing unit provides low level services and separate from the first processing unit, a second processing unit is employed in the controller providing high level services to the pump system. Thus, for specific tasks of the low level services and the high level services, the first processing unit and the second processing unit are foreseen which can be tailored to the computational demands of the low level services and the high level services. Further, in accordance to the invention the second processing unit is connectable to an external network for example the internet. Thus, by the second processing unit data can be exchanged via the external network for example with a cloud server or a central data processing system. However, there is no direct connection between the external network and the first processing unit. Thus, direct access to the first processing unit providing the low level services to the at least one pump is not enabled. Thereby security is enhanced. Further by the first processing unit and the second processing unit a certain redundancy is introduced into the pump system increasing the reliability of operation of the pump system.

[0008] Preferably, the second processing unit is not directly connected to the at least one pump. In other words, the first processing unit is only connected with the at least one pump via the first processing unit. Likewise, the first processing unit is not directly connectable to the external network or, in other words, only connectable to the external network via the second processing unit. Thus, separation between the at least one pump and the external network via the first processing unit and the second processing unit is ensured.

[0009] Preferably, the first processing unit is configured to provide low level services by exchanging control signals with the at least one pump. Thus, low level services relate to control functionalities of the pump which are crucial for operating the pump. Therein, the control signals are determined according to the specific application and may encompass parameters such as operation current, running speed, or may relate to valve position signals in the pump systems.

[0010] According to the subject matter of claim 1, the first processing unit is configured as deterministic processing unit providing responses between 90ms and 110ms and preferably between 99ms and 101 ms and most preferably 100ms. Since the first processing unit is configured to carry out low level services in order to control the pump in the pump system fast exchange of control signals and reactions of changes within the application connected to the pump system are necessary in a reliable and deterministic manner. Delay in providing proper control signals to the at least one pump would lead to improper functionality of the application or even damage the pump system or the application and further lead to failure in products.

[0011] According to the subject matter of claim 1, the second processing unit is configured to provide high level

services such as one or more of data exchange with a cloud server or central data processing unit, user interface for controlling the pump system, preferably built as web access interface, security access to the control of the first processing unit in term of gated access, complex optimization calculation for operating of the pump system in terms of pump system condition prediction for example by artificial intelligence, i. e. pattern recognition, update handling for the first processing unit as well as the second processing unit and the like. Thus, as high level services accessibility, usability and more complex tasks are carried out by the second processing unit. Further, by the second processing unit security access to the pump system is provided.

[0012] Preferably, the first processing unit is configured to reboot the second processing unit in case of failure of the second processing unit. Thus, the first processing unit is acting as watchdog over the second processing unit. Since, all crucial or mandatory processes are carried out the by the first processing unit, failure of the second processing unit and subsequent reboot of the second processing unit initiated by the first processing unit does not interrupt operating of the pump system. Thus, redundancy is introduced into the pump system increasing the reliability of operation of the pump system.

[0013] Preferably the second processing unit is configured to reboot the first processing unit in case of failure of the first processing unit. Thus, the second processing unit is acting as watchdog over the first processing unit. Thereby, fast recovery after system failure of the first processing unit is achieved. Thus, redundancy is introduced into the pump system increasing the reliability of operation of the pump system.

[0014] Preferably, at least one pump comprises a sensor wherein the sensor is directly connected to the first processing unit to transmit sensor data to the first processing unit. In particular, if the sensor data is crucial for operating the specific pump or pump system, this data can be directly handled by the first processing unit. Upon failure of the second processing unit, this sensor data is still available for the first processing unit ensuring reliable operation of the pump system. In particular, since the first processing unit is built as deterministic processing unit, fast reception of sensor data is ensured being able to handle future amount of sensor data in short time. In particular, all sensors are directly connected to the first processing unit for simplified structure.

[0015] Preferably, at least one pump comprises a sensor wherein the sensor is directly connected to the second processing unit to transmit sensor data to the second processing unit. This sensor data may be used either for monitoring operation of the pump system or might be exchanged with a central data processing unit via the external network and stored for monitoring by the manufacturer or customer. If this sensor data is necessary for operating the at least pump of the pump system and the sensor data is handed over from the second processing unit to the first processing unit or may be further evaluated by the second processing unit it term of intelligent control and handed over as instruction from the second processing unit to the first processing unit. In particular, all sensors are directly connected to the second processing unit for simplified structure.

[0016] Preferably, the controller comprises a fieldbus unit disposed between the first processing unit and the at least one pump. Thus, if the sensors in the pump system are all connected directly to the first processing unit, the fieldbus unit is disposed between the first processing unit and the at least one pump to provide fieldbus communication with the pump and the sensors. As a consequence, no direct communication between the second processing unit and the fieldbus unit is possible. Alternatively, if the sensors are directly connected to the second processing unit, the fieldbus unit is disposed between the second processing unit and the sensors.

[0017] In the following the present invention is described in more detail with reference to the accompanied drawing.

[0018] It is shown:

Figure an exemplified structure of the pump system in accordance with the present invention.

[0019] In the embodiment of the present invention, the pump system comprises pumps 12 which can be built as vacuum pumps or compressors. In the example of the present embodiment, the pump system comprises three vacuum pumps 12. However, the number of pumps is not limited and can be adapted to the specific task to be performed by the pump system. All pumps 12 are connected to the common controller 14. The controller comprises a first processing unit 16 and a second processing unit 18. Therein, the first processing unit 16 is directly connected to the pumps 12 wherein between the pumps 12 and the first processing unit a fieldbus unit 20 may be disposed in order to handle and provide fieldbus communication between the pumps 12 and the first processing unit 16. Therein one fieldbus unit 20 can be provided for each of the pumps 12 individually or a common fieldbus unit 20 can be provided for all pumps 12 in the pump system.

[0020] Therein, the first processing unit 16 is configured to provide low level services to the pumps 12 including but not limited to controlling of operation of the pumps 12 by exchange of control signals between the first processing unit and the pumps 12 or by controlling actuators of valves or the like. Therein, the first processing unit takes care of all critical, low level talks, which are mandatory for operating the pump system.

[0021] The second processing unit 18 provides high level services to the pump system. Therein, the processing unit is connectable to an external network 23, for example the internet, in order to facilitate data exchange with cloud servers or central data processing units of the customer or manufacturer. Therein, the high level services provided by the second processing unit 18 are for example data exchange with a cloud server 24 in order to

monitor operation of each of the pumps 12 of the pump system by the customer or manufacturer of the pumps 12 for monitoring quality of operation or the like. Further, by the second processing unit 18 an interface may be provided in particular as web interface for external control of the pump system or more convenient visualization of the operation and condition of the pump system. Further, the second processing unit may provide security access and certificate handling between the external user for external data access. Thus, access verification of a user is enabled in order to control the operation of the pump system. Further, by the second processing unit 18 updated handling can be provided either for updating the first processing unit 16 by receiving an update from an update server 26 from the manufacturer and installing this update on the first processing unit or by receiving an update from an update server 26 and installing this update on the second processing unit. Therein, the update alternatively can be provided from the provider of a third party application installed on the second processor unit. Furthermore, by providing a second processing unit 18 complex analytic algorithms and pattern recognition can be carried out on the basis of sensor data collected from the pump system in order to optimize operation of the pump system.

[0022] Therein the first processing unit 16 is built as deterministic processing unit providing reliable and deterministic handling of data with response times between 90ms and 110ms and preferably between 99ms and 101ms in order to be able to quickly react and reliably control the pumps 12 of the pump system. On the contrary, the complexity of the tasks carried out by the first processing unit 16 is relatively low compared to the complexity of the tasks carried out by the second processing unit 18. Consequently, the demands on the first processing unit 16 are fast and efficient processing of less complex data crucial for operating the pumps 12 in the pump system. Contrary, the tasks of the second processing unit 18 are not time critical but have an increased complexity. By separating the different tasks into the first processing unit 16 and the second processing unit 18, it is not necessary to provide a processing unit being able to handle high demands on the complexity of the task within almost real time in a reliable and deterministic manner. By the solution of the present invention, time critical and crucial tasks with low complexity are carried out by the first processing unit while other tasks are carried out by the second processing unit, thereby reducing the overall demands on each of the first processing unit and the second processing unit.

[0023] Further, due to having two processing units within the controller 14, the reliability is enhanced due to the given redundancy. In this regard, the first processing unit 16 acts as a watchdog over the functionality of the second processing unit 18. In case of failure of the second processing unit 18, the first processing unit 16 is configured to initiate reboot of the second processing unit 18. Similar, the second processing unit 18 acts as watchdog over the correct operation of the first processing unit 16 and in case of failure may initiate reboot of the first processing unit 16. Thereby, in case of failure of the second processing unit 18, operation of the pumps 12 in the pump system may not be interrupted since all crucial processes in order to operate the pump system are carried out by the first processing unit 16. After reboot of the second processing unit 18 high level services provided by the second processing unit 18 are again accessible.

[0024] In particular, applications from third parties may be installed on the second processing unit 18. However, for the manufacturer of the controller 14 there is no possibility to ensure complete reliability of these third party applications. Thus, by separating the third party applications from the crucial process in order to operate the pump system by the first processing unit 16, the reliability of the controller is enhanced. Upon failure of the third party applications installed on the second processing unit 18, operation of the pump system can be ensured by the first processing unit 16. Simultaneously, updates of the third party applications on the second processing unit 18 provided by an update server 26 can be installed on the second processing unit 18 without interrupting operation of the pumps system.

[0025] In particular the second processing unit has a Docker engine running for the containerization of the high level services. Therein all communication between the containers happen through a medium broker which acts as a publish/subscribe elements server which might be provided by the MQTTS-protocol.

[0026] Further, one or more of the pumps 12 may comprise sensors 28. As depicted in the figure, the sensor 28 is directly connected to the first processing unit 16. Between the sensor 28 and the first processing unit 16 the fieldbus unit is positioned in order to enable fieldbus communication between the first processing unit 16 and the sensor 28. In particular, all sensors of the pump system may be directly connected to the first processing unit 16. Since the first processing unit 16 is built as deterministic processing unit, fast and reliable handling of the acquired sensor data is enabled. Therein, the fieldbus may provide communication via one of the known fieldbuses, such as CANopen, Modbus, EtherCAT, PROFINET, EtherNet/IP, OPC UA or the like.

[0027] Thus, by the present invention certain tasks in order to proper operate a pump system are separated and carried out by specific processing units. Therein, a first processing unit is 16 provided for low level services, i. e. direct control of the pumps in the pump system and handling sensor data from sensors 28. Additionally, higher level services are provided by a second processing unit 18 enabling further services for the customer or manufacturer of the pumps such as data exchange via an external network, update handling and other security features. Therein, there is no direct communication between the second processing unit providing the higher level services and the pumps 12 in the pump system.

Communication is enabled only via the first processing unit. Thus, the second processing unit acts as a security gate for access for control of the pumps 12 in the pump system from the outside. Simultaneously, due to the two processing units in the controller 14 of the pump system, reliability of operation is enhanced due to redundancy.

Claims

1. Pump system with at least one pump (12), in particular a vacuum pump or a compressor,

   a controller (14) connected to the at least one pump (12), wherein the controller (14) comprises: a first processing unit (16) directly connected to the at least one pump (12) for providing low level services to the at least one pump (12), and a second processing unit (18) connected to the first processing unit (16) to provide high level services to the pump system, wherein the second processing unit (18) is connectable to an external network (22),
   characterized in that
   the first processing unit (16) is configured as deterministic processing unit, providing responses between 90ms and 110ms and the second processing unit (18) is configured to provide one or more of data exchange with a cloud, an interface for controlling the pump system, security access, optimization calculation, update handling of the first processing unit (16) as well as the second processing unit (18) as high level services.

2. Pump system according to claim 1, **characterized in that** the second processing unit (18) not directly connected to the at least one pump (12) and the first processing unit (16) is not directly connectable to the external network (22).

3. Pump system according to claim 1 or 2, **characterized in that** the first processing unit (16) is configured to provide low level services by exchanging control signals with the at least one pump (12).

4. Pump system according to any of claims 1 to 3, **characterized in that** the deterministic processing unit, provides responses between 99ms and 101ms and preferably 100ms.

5. Pump system according to any of claims 1 to 4, **characterized in that** the first processing unit (16) is configured to reboot the second processing unit (18) in case of failure of the second processing unit (18).

6. Pump system according to any of claims 1 to 5, **characterized in that** the second processing unit (18) is configured to reboot the first processing unit (16) in case of failure of the first processing unit (16).

7. Pump system according to any of claims 1 to 6, **characterized in that** the at least one pump (12) comprises a sensor (28), wherein the sensor (28) is directly connected to the first processing unit (16) to transmit sensor data to the first processing unit (16).

8. Pump system according to any of claims 1 to 7, **characterized in that** the at least one pump (12) comprises a sensor (28), wherein the sensor (28) is directly connected to the second processing unit (18) to transmit sensor data to the second processing unit (18).

9. Pump system according to any of claims 1 to 8, **characterized by** a fieldbus unit (20) connected to the first processing unit (16) or the second processing unit (18) to provide fieldbus communication.

Patentansprüche

1. Pumpensystem mit mindestens einer Pumpe (12), insbesondere einer Vakuumpumpe oder einem Verdichter,

   einer Steuerung (14), verbunden mit der mindestens einen Pumpe (12), wobei die Steuerung (14) Folgendes umfasst: eine erste Verarbeitungseinheit (16), direkt verbunden mit der mindestens einen Pumpe (12), um der mindestens einen Pumpe (12) Low-Level-Services bereitzustellen, und eine zweite Verarbeitungseinheit (18), verbunden mit der ersten Verarbeitungseinheit (16), um dem Pumpensystem High-Level-Services bereitzustellen, wobei die zweite Verarbeitungseinheit (18) mit einem externen Netzwerk (22) verbindbar ist, **dadurch gekennzeichnet, dass**
   die erste Verarbeitungseinheit (16) als deterministische Verarbeitungseinheit konfiguriert ist, die Reaktionen zwischen 90 ms und 110 ms bereitstellt, und die zweite Verarbeitungseinheit (18) dazu konfiguriert ist, Datenaustausch mit einer Cloud, eine Schnittstelle zum Steuern des Pumpensystems, Sicherheitszugriff, Optimierungsberechnung und/oder Update-Handling durch die erste Verarbeitungseinheit (16) und die zweite Verarbeitungseinheit (18) als High-Level-Services bereitzustellen.

2. Pumpensystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die zweite Verarbeitungseinheit (18) nicht direkt mit der mindestens einen Pumpe (12) verbunden ist und die erste Verarbeitungs-

einheit (16) nicht direkt mit dem externen Netzwerk (22) verbindbar ist.

3. Pumpensystem nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die erste Verarbeitungseinheit (16) dazu konfiguriert ist, durch Austauschen von Steuersignalen mit der mindestens einen Pumpe (12) Low-Level-Services bereitzustellen.

4. Pumpensystem nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** die deterministische Verarbeitungseinheit Reaktionen zwischen 99 ms und 101 ms und vorzugsweise 100 ms bereitstellt.

5. Pumpensystem nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** die erste Verarbeitungseinheit (16) dazu konfiguriert ist, im Fall eines Defekts der zweiten Verarbeitungseinheit (18) die zweite Verarbeitungseinheit (18) neu zu starten.

6. Pumpensystem nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** die zweite Verarbeitungseinheit (18) dazu konfiguriert ist, im Fall eines Defekts der ersten Verarbeitungseinheit (16) die erste Verarbeitungseinheit (16) neu zu starten.

7. Pumpensystem nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet, dass** die mindestens eine Pumpe (12) einen Sensor (28) umfasst, wobei der Sensor (28) direkt mit der ersten Verarbeitungseinheit (16) verbunden ist, um Sensordaten an die erste Verarbeitungseinheit (16) zu übertragen.

8. Pumpensystem nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass** die mindestens eine Pumpe (12) einen Sensor (28) umfasst, wobei der Sensor (28) direkt mit der zweiten Verarbeitungseinheit (18) verbunden ist, um Sensordaten an die zweite Verarbeitungseinheit (18) zu übertragen.

9. Pumpensystem nach einem der Ansprüche 1 bis 8, **gekennzeichnet durch** eine Feldbuseinheit (20), verbunden mit der ersten Verarbeitungseinheit (16) oder der zweiten Verarbeitungseinheit (18), um Feldbuskommunikation bereitzustellen.

Revendications

1. Système de pompe avec au moins une pompe (12), en particulier une pompe à vide ou un compresseur, un système de commande (14) relié à l'au moins une pompe (12), dans lequel le système de commande (14) comprend : une première unité de traitement (16) directement reliée à l'au moins une pompe (12) afin de fournir des services de bas niveau à l'au moins une pompe (12), et une deuxième unité de traitement (18) reliée à la première unité de traitement (16) afin de fournir des services de haut niveau au système de pompe, dans lequel la deuxième unité de traitement (18) peut être reliée à un réseau externe (22), **caractérisé en ce que** la première unité de traitement (16) est configurée comme une unité de traitement déterministe qui fournit des réponses entre 90 ms et 110 ms, et la deuxième unité de traitement (18) est configurée pour assurer une ou plusieurs fonctions parmi échanger des données avec un nuage informatique, interface pour piloter le système de pompe, assurer la sécurité d'accès, optimiser les calculs et gérer la mise à jour de la première unité de traitement (16) et de la deuxième unité de traitement (18), en guise de services de haut niveau.

2. Système de pompe selon la revendication 1, **caractérisé en ce que** la deuxième unité de traitement (18) n'est pas directement reliée à l'au moins une pompe (12) et la première unité de traitement (16) ne peut pas être directement reliée au réseau externe (22).

3. Système de pompe selon la revendication 1 ou 2, **caractérisé en ce que** la première unité de traitement (16) est configurée pour fournir des services de bas niveau en échangeant des signaux de commande avec l'au moins une pompe (12).

4. Système de pompe selon l'une quelconque des revendications 1 à 3, **caractérisé en ce que** l'unité de traitement déterministe fournit des réponses entre 99 ms et 101 ms, et de préférence de 100 ms.

5. Système de pompe selon l'une quelconque des revendications 1 à 4, **caractérisé en ce que** la première unité de traitement (16) est configurée pour redémarrer la deuxième unité de traitement (18) en cas de défaillance de la deuxième unité de traitement (18).

6. Système de pompe selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** la deuxième unité de traitement (18) est configurée pour redémarrer la première unité de traitement (16) en cas de défaillance de la première unité de traitement (16).

7. Système de pompe selon l'une quelconque des revendications 1 à 6, **caractérisé en ce que** l'au moins une pompe (12) comprend un capteur (28), dans lequel le capteur (28) est directement relié à la première unité de traitement (16) afin de transmettre des données de capteur à la première unité de traitement (16).

8. Système de pompe selon l'une quelconque des

revendications 1 à 7, **caractérisé en ce que** l'au moins une pompe (12) comprend un capteur (28), dans lequel le capteur (28) est directement relié à la deuxième unité de traitement (18) afin de transmettre des données de capteur à la deuxième unité de traitement (18).

9. Système de pompe selon l'une quelconque des revendications 1 à 8, **caractérisé par** une unité de bus de terrain (20) reliée à la première unité de traitement (16) ou à la deuxième unité de traitement (18) afin d'assurer une communication de bus de terrain.

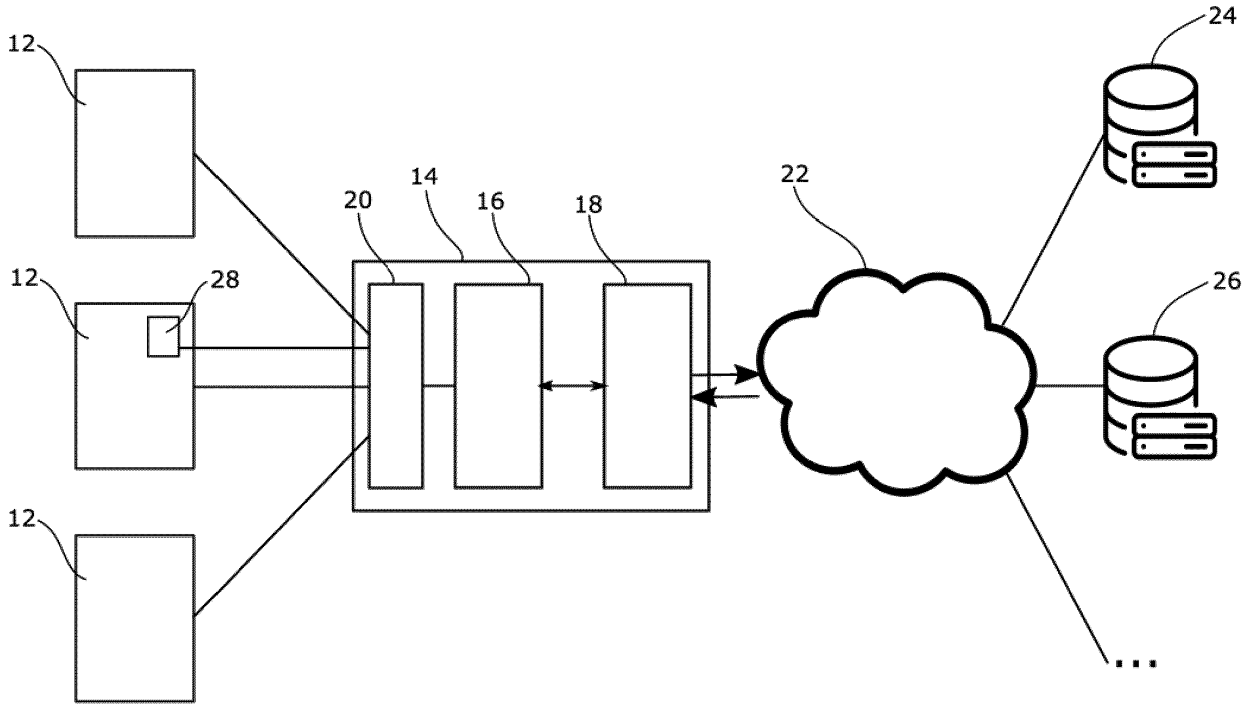

Figure 1

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

- EP 1450328 A **[0005]**