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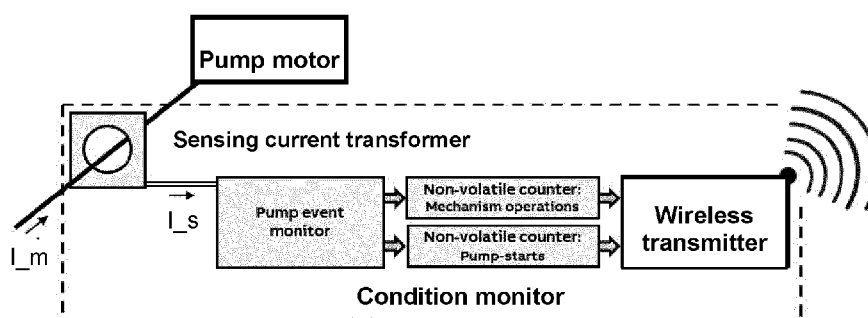


Fig. 4

(57) Abstract: The present disclosure relates to a device for monitoring a condition of switchgear, wherein the device comprises attachment means for attaching the device to switchgear and measurement means for measuring at least one parameter of the switchgear. The measurement is performed non-invasively. Transmission means transmit the at least one measured parameter. The device comprises or is attached to a controller for processing the at least one measured parameter.

MONITOR FOR SWITCHGEAR OR CIRCUIT BREAKERS

The present invention relates to a monitor for switchgear or circuit breakers and a corresponding method. The system and method may particularly be employed for a hydro-mechanical operating mechanism for (high voltage) switchgear.

Circuit breakers or switchgear and particularly hydro-mechanical circuit breakers are used in electrical grids in order to control, protect and isolate electrical equipment. High-voltage switchgear may operate hydro-mechanically, i.e. by a combination of hydraulic pressure and mechanical, e.g. spring, pressure. Details on the working principle will be given below.

Switchgear condition monitoring according to the state-of-the-art varies according to the particular substation and operator from having no monitoring at all, employing warning lamps or installing hardwired systems which are capable of monitoring multiple parameters. However, these advanced hardwired monitoring systems are cumbersome to retrofit since in some cases the entire control cabinet has to be rewired according to customer specification. During this time, the switchgear has to be taken off the grid and thus leads to a costly outage.

It is, however, important to monitor certain switchgear parameters which may be indicative of possible faults such as leakage of a hydraulic system inside the switchgear in order to optimise maintenance and reduce downtime of the system.

It is therefore an object of the present invention to provide a non-invasive, retrofittable device for efficiently reliably monitoring switchgear parameters.

This problem is solved by the independent claims defining the invention. The dependent claims describe preferred embodiments.

In particular, the present disclosure relates to a device for monitoring a condition of switchgear, wherein the device comprises attachment means for attaching the device to switchgear and measurement means for measuring at least one parameter of the switchgear. The measurement

is performed non-invasively. Transmission means transmit the at least one measured parameter. In addition or as an alternative to the transmitted at least one measured parameter, an operational state and/or maintenance state may be transmitted by the transmission means. The device comprises or is attached to a controller for processing the at least one measured parameter. The device may alternatively be connected to the controller.

Various embodiments may preferably implement the following features:

Preferably, the measurement means is a sensor. Preferably, the sensor is configured to measure at least one pump parameter of hydro-mechanical switchgear. Preferably, the sensor is configured to measure at least one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts or magnetic field of the pump as the pump parameter. Preferably, the sensor is configured to measure the current inductively.

Preferably, the measurement means is configured to measure at least one pump parameter of hydro-mechanical switchgear.

Preferably, the measurement means is configured to measure at least one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts or magnetic field of the pump as the pump parameter.

Preferably, the measurement means is configured to measure the current inductively.

Preferably, the at least one measured parameter is periodically transmitted.

Preferably, the transmission means is a transmitter or a transceiver. The transmitter or transceiver may preferably be configured to wirelessly transmit the at least one measured parameter using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

The transmission means may preferably be configured to wirelessly transmit the at least one measured parameter using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

The attachment means may be a fastener and/or a joint. The fastener and/or a joint may preferably be configured to retrofittably attach the device to the switchgear. The fastener and/or a joint may preferably be a magnet, screws, nut and bolt mechanism, a belt or the like.

- 5 The attachment means may preferably be formed as any means suitable for retrofittably attaching the device to the switchgear. The attachment means may preferably be a magnet, screws, a belt or any other means.

- 10 The controller is preferably configured to process the at least one measured pump parameter to generate or determine an operational state and/or maintenance state of the hydro-mechanical switchgear. The controller may preferably be part of the device or a system comprising the device and the controller. The controller may preferably be wirelessly connected to the device. The transmission means may be configured to transmit the at least one measured parameter to the controller or to transmission means, a transmitter and/or transceiver, connected to the
15 controller.

- Preferably, the operational state and/or maintenance state comprises information on at least one of system pressure, leakage detection, sealing state, piston state, pump state, or electrical connection state.

- 20 Preferably, the transmission means is configured to wirelessly transmit the operational state and/or maintenance state using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

- 25 Preferably, the controller is configured to distinguish between an operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter.

- 30 Preferably, the measurement means is configured to measure a number of pump starts and the controller is configured to distinguish between an operational state and a maintenance state based on the number of pump starts. The number of pump starts preferably correlates with particles affecting operation of the switchgear.

Preferably, the controller is configured to determine that the switchgear is in the normal operation if the number of pump starts is below a first threshold and in the maintenance state if the number of pump starts is higher than the first threshold.

- 5 Preferably, the maintenance state is either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time.

- 10 Preferably, the measurement means is configured to measure a number of pump starts and the controller is configured to distinguish between the maintenance state which requires immediate service and/or maintenance of the pump and/or the switch gear and the maintenance state which requires service and/or maintenance within a set period of time based on the number of pump starts. Preferably, the controller is configured to determine that the switchgear is in the state which requires immediate service and/or maintenance of the pump and/or the switchgear if the
15 number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and to the controller is preferably configured to determine that the switchgear is in the state which requires service and/or maintenance within a set period of time if the number of pump starts is higher than the first threshold and lower than the second threshold. The number of pump starts preferably correlates with particles affecting operation of
20 the switchgear.

- The present disclosure further relates to a method for monitoring a condition of switchgear, the method comprising attaching a device for monitoring a condition of switchgear to a switchgear, measuring at least one parameter of the switchgear, wherein the measuring is performed non-
25 invasively, transmitting the at least one measured parameter, and processing the at least one measured parameter. In addition or as an alternative, an operational state and/or maintenance state may be transmitted.

- Various embodiments may preferably implement the following features.
30

Preferably, the at least one parameter of a hydro-mechanical switchgear is measured non-invasively.

Preferably, one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts or magnetic field of the pump is measured.

- 5 Preferably, the at least one measured parameter is transmitted periodically.

Preferably, wireless transmission of the at least one measured parameter is performed using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

- 10 Preferably, the at least one measured pump parameter is processed to generate or determine an operational state and/or maintenance state of the hydro-mechanical switchgear.

- 15 Preferably, the operational state and/or maintenance state comprises information on at least one of system pressure, leakage detection, sealing state, piston state, pump state, or electrical connection state.

Preferably, wirelessly transmitting the operational state and/or maintenance state is performed using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

- 20 Preferably, the method comprises distinguishing between a normal operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter.

- 25 Preferably, the measuring comprises measuring a number of pump starts and the method comprises distinguishing between an operational state and a maintenance state based on the number of pump starts. The number of pump starts preferably correlates with particles affecting operation of the switchgear.

- 30 Preferably, the method comprises determining the operational state if the number of pump starts is below a first threshold and the maintenance state if the number of pump starts is higher than the first threshold.

Preferably, the maintenance state is either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time.

- 5 Preferably, the measuring comprises measuring a number of pump starts and the method comprises distinguishing between the maintenance state which requires immediate service and/or maintenance of the pump and/or the switch gear and the maintenance state which requires service and/or maintenance within a set period of time based on the number of pump starts. The number of pump starts preferably correlates with particles affecting operation of the
10 switchgear.

- Preferably, the state which requires immediate service and/or maintenance of the pump and/or the switchgear is determined if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and the state which requires
15 service and/or maintenance within a set period of time is determined if the number of pump starts is higher than the first threshold and lower than the second threshold.

- The invention is further described with reference to the figures. Therein,
Fig. 1a to 1c show the working principle of a hydro-mechanical switchgear,
20 Fig. 2 shows an exemplary graph depicting a correlation between pump starts and maintenance, and
Figs. 3 to 5 show examples according to the present disclosure.

- The present disclosure is described using the example of a hydromechanical operating
25 mechanism for a (high voltage) switchgear which may also be referred to as hydro-mechanical switchgear. However, the disclosure may be employed for various types of switchgear or circuit breakers. The working principle and operational states of a hydro-mechanical switchgear are described with reference to Figures 1a - 1c. This hydro-mechanical switchgear depicted in the figures is, however, only exemplary and should not be construed as limiting the scope of the
30 disclosure.

A hydro-mechanical operating mechanism combines a hydraulic operating mechanism with a spring mechanism. In a nutshell, energy is transferred from a hydraulic system to a mechanical

system, where it is stored as spring force. Via a release mechanism, the energy stored in the spring may be released to open or close the circuit breaker.

Fig. 1a shows a hydro-mechanical system which is in an open position, i.e. the switch is opened, and where the springs 1 are not charged. The system may comprise a controlling link 2 which may also be referred to as a spring travel switch. A hydraulic pump 3 is provided in order to provide pressure to the hydraulic system. Furthermore, the pump 3 may compensate for slight internal pressure losses by incidental recharging. This may ensure a stable internal pressure. Fig. 1b depicts a state, in which the hydraulic pump 3 is working and charges the springs 1 by compressing the piston 6 through hydraulic pressure. This is indicated by the movement to the right of the piston 6 when compared to Fig. 1a. Furthermore, operation of the pump 3 applies pressure to the operating piston 4, thereby maintaining it in an open state. A changeover valve 5 is provided to separate the high-pressure region, which pressurises the operating piston 4 and the piston 6, from the low-pressure region. As mentioned above, the hydraulic pump 3 may be operated in certain intervals in order to maintain the internal pressure.

After the system is pressurised, the switch may be transferred into a closed position as depicted in Fig. 1c. This is achieved by operating the changeover valve 5 in a fast movement to apply pressure to the operating piston 4 from below, thereby pushing the operating piston 4 in a vertical direction and closing the switch. Thus, the operating mechanism is in a closed position while the springs 1 are still charged. As long as the high-pressure is applied on the area beneath the operating piston 4, it remains in a closed position. This may constitute the idle position with charged springs and an open switch.

In case the circuit breaker shall be activated in order to open the circuit, the changeover valve 5 is switched to its original position (cf. Figs. 1a and 1b) by activating an opening magnet. Thereby, the pressure applied from below and maintaining the operating piston 4 in the closed position is released, while the springs 1 urge the piston 6 in the left direction. Thus, the operating piston 4 is pressurised from above and the switch is transferred to the open position. The system is then in a state according to Fig. 1a where the operating mechanism is open and the springs are not charged.

As evident from the above description, it is crucial for operation of the hydro-mechanical system to maintain the pressure in the high-pressure regions and detect leakage or faults in good time.

5 When the system is in its idle state, waiting for the command to operate the circuit breaker, the springs are charged causing a high hydraulic pressure inside the system. In a highly pressurized hydraulic system, however, some internal leakage may occur from high pressure to low pressure regions. This is compensated by operating the pump 3 at a hydraulic pressure slightly below the nominal state. Typically, the pump 3 may be operated 1-5 times in a 24h period and such
10 information relating to pump operation information can provide operational and/or maintenance states.

Internal leakage is also the most common failure cause, indicating either component or sealing failure. Typically, such failure occurs slowly, increasing the number of pump starts and help in
15 determination of maintenance state.

Fig. 2 is an exemplary graph showing the pump starts per day on the y-axis, wherein the x-axis is the time axis in days. In this example according to Fig. 2, less than 10 starts per day is normal, i.e. no action is required. 10-20 starts per day leads to observing the mechanism and planning
20 maintenance, and if more than 20 starts per day are noticed, service will be notified and the breaker may possibly be taken out of service. Furthermore, Fig. 2 shows exemplary faults such as an increase in pump starts e.g. caused by a particle in a valve, indicated by the reference sign (A), and a corresponding decrease in pump starts e.g. due to removal of the particle by a switching operation (B). The increase in pump starts at time (C) may indicate a more extensive
25 failure, e.g. caused by severe internal leakage. Such behaviours can be observed with help of data collected by the monitoring device described in the invention and accordingly help in diagnosis and plan maintenance/service schedules and activities.

A controller may be configured to generate or determine an operational state and/or
30 maintenance state of the switchgear, in particular the pump. The controller may be configured to distinguish between a normal operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter. In particular, the operational state and a maintenance state may be determined based on the number of pump starts. Thus, a first threshold may be set. If the number

of pump starts is below the first threshold, the switch gear may be determined to be in the normal operation and the switchgear may be determined to be in the maintenance state if the number of pump starts is higher than the first threshold. The maintenance state may be either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time. This determination may also be performed based on the number of pump starts. It may be determined that the switchgear is in the state which requires immediate service and/or maintenance of the pump and/or the switchgear if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and it may be determined that the switchgear is in the state which requires service and/or maintenance within a set period of time if the number of pump starts is higher than the first threshold and lower than the second threshold. Referring to the example above, the first threshold may be 10 pump starts per day and the second threshold may be 20 pump starts per day.

An increase of pump starts may thus also be due to particles blocking movement of the piston or preventing a sealing from effectively sealing a pressurised region of the system. This may be resolved e.g. by switching operation which removes the blocking particle or contamination from the affected region. In other words, the number of pump starts may correlate with particles affecting operation of the switchgear. I.e., the number of pump starts may be dependent on a number of particles affecting operation of the switchgear, e.g. by blocking movement of the piston or preventing a sealing from effectively sealing a pressurised region of the system.

In addition, if no pump start is detected at all, this could also be a trigger for alarm, possibly indicating pump motor or electrical connection failure. This mechanism would allow enough time to react before the system would reach a critical condition.

Thus, the number of pump starts and duration of pump activity may be an indication of the state of the system, in particular leakages or internal contamination of the hydraulic system. The present disclosure provides a device for monitoring a condition of switchgear which is able to non-invasively monitor parameters of the switchgear and may be retrofitted to any suitable system comprising switchgear.

Referring to Fig. 3, the disclosure thus relates to a system comprising switchgear 11 and a device 12 for monitoring a condition of switchgear. The device 12 comprises attachment means

13 for attaching the device to switchgear 11. The attachment means 13 may be formed as any means suitable for retrofittably attaching the device 12 to the switchgear. The attachment means 13 may be a magnet, screws, a belt or any other means. The device 12 further comprises measurement means 14 for measuring at least one parameter of the switchgear 11, wherein the
5 measurement is performed non-invasively. Transmission means 15 are provided for transmitting the at least one measured parameter.

The system 10 may particularly be configured to measure at least one pump parameter of hydro-mechanical switchgear. Therefore, the device 12 may be attached close to a hydraulic pump 3
10 of the switchgear 11. The at least one measured pump parameter may be one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts and magnetic field of the pump. A plurality of the enumerated pump parameters may be simultaneously acquired.

15 The current flowing through the pump, the vibration of the pump and/or the magnetic field of the pump may also be used to compute the frequency of operation, the number of pump starts in a certain amount of time or the duration of pump operation.

The measurement means 14 may particularly be configured to inductively measure a current
20 flowing through the hydraulic pump 3.

The transmission means 15 may be configured to wirelessly transmit the at least one measured parameter using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol. The at least one measured parameter may e.g. be periodically transmitted. The transmitted data
25 may for example be centrally acquired and evaluated in order to improve the maintenance data and data on the state of the system. The data may also be anonymously shared. Alternatively, the data may also be evaluated only on a facility or substation level.

The device may also comprise a controller or computing device to process the at least one
30 measured pump parameter. As an alternative, the controller and the device are or form part of a system. In particular, the controller may be configured to generate or determine an operational state and/or maintenance state of the hydro-mechanical switchgear. The operational state and/or maintenance state may be generated or determined by processing the at least one measured pump parameter. The operational state and/or maintenance state may e.g. comprise information

on at least one of operation related parameters of the circuit breaker e.g. electrical connection state, system pressure, leakage detection, sealing state, piston state, pump state or conditions/states of other components relating to the circuit breaker. As explained above, information relating to operational state and/or maintenance state may be correlated to the pump data such as flow through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts and magnetic field of the pump. Such correlation is also useful for consistency checks relating to determination of operational and/or maintenance state. The operational state and/or maintenance state may also be transmitted by the transmission means 15.

The controller may be configured to distinguish between a normal operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter. In particular, the operational state and a maintenance state may be determined based on the number of pump starts. Thus, a first threshold may be set. The number of pump starts may correlate with particles affecting operation of the switchgear. If the number of pump starts is below the first threshold, the switch gear may be determined to be in the normal operation and the switchgear may be determined to be in the maintenance state if the number of pump starts is higher than the first threshold. The maintenance state may be either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time. This determination may also be performed based on the number of pump starts. The number of pump starts may correlate with particles affecting operation of the switchgear. It may be determined that the switchgear is in the state which requires immediate service and/or maintenance of the pump and/or the switchgear if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and it may be determined that the switchgear is in the state which requires service and/or maintenance within a set period of time if the number of pump starts is higher than the first threshold and lower than the second threshold.

The controller having a functionality as described above may also be connected to the device. That is, the controller may be provided external from the device. One or more devices may be connected to the controller and the controller may thus process the at least one measured pump parameter for one switchgear or a plurality of switchgears, e.g. per substation.

The controller may also be provided in a cloud or central storage or processing facility to centrally process the gathered data. In any case, the processing may be performed for one device or a plurality of devices and accordingly per device, per substation or for a plurality of substations/facilities to monitor a fleet of switchgears. The controller provided centrally or in a cloud may also receive and process data from adjacent switchgear, other devices (e.g. drives) or other electrical equipment in the substation and correlate received information with the information relating to operational and/or maintenance state by observing specific behaviours and determine corresponding service or maintenance activities for the switchgear connected with the device 12. Further, the controller for observing/predicting/diagnosing behaviours associated with the switchgear connected with the device 12 may also correlate data transmitted by a device 12 and the processed information relating to operational and/or maintenance state determined for the switchgear with information such as electrical load, ambient conditions (temperature, pressure) at the site and observed behaviour information relating to one or more switchgears in a fleet of switchgears installed in one or more substations.

Fig. 4 shows an example according to the present disclosure. In particular, the device 12, i.e. the condition monitor, is attached to the switchgear 11 and is in particular able to monitor activity of the pump or pump motor 3. The device 12 may further comprise a sensing current transformer which feeds an input current to a pump event monitor. Therein, I_m may denote the motor current and I_s may denote the sensing current. The device 12 may also comprise at least one non-volatile counter for counting mechanism operations and pump starts, respectively. The data from the counter or counters may then be transferred to a wireless transmitter, e. g. a long-range wireless transmitter, which wirelessly transmits the data to a recipient. Any form of wireless transmitter or, alternatively, a tethered transmission may be used with the present disclosure.

Fig. 5 shows an exemplary configuration of data transfer and evaluation. The condition monitor may correspond to the one depicted in Fig. 4. The data is transmitted in a 24-hour interval to a mobile operator wireless gateway which is connected to a mobile operator cloud. Data may also be transferred to a cloud, where general analytics or customer specific analytics are performed.

The disclosure further relates to a corresponding method as depicted in Fig. 6. In particular, the method comprises attaching a device for monitoring a condition of switchgear to a switchgear

and non-invasively measuring at least one parameter of the switchgear. The at least one measured parameter is then transmitted.

The method may be employed for non-invasively measuring at least one parameter of a hydro-mechanical switchgear. The method may further comprise measuring one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts and magnetic field of the pump.

The at least one measured parameter may be transmitted periodically. The at least one measured parameter may be wirelessly transmitted using, e.g., Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

The method may further comprise processing the at least one measured pump parameter to generate or determine an operational state and/or maintenance state of the hydro-mechanical switchgear. The operational state and/or maintenance state may comprise information on at least one of system pressure, leakage detection, sealing state, piston state, pump state or electrical connection state. The operational state and/or maintenance state may also be wirelessly transmitted using, e.g., Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

The method may comprise distinguishing between a normal operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter. The measuring may comprise measuring a number of pump starts and the method may comprise distinguishing between an operational state and a maintenance state based on the number of pump starts. The number of pump starts may correlate with particles affecting operation of the switchgear. It may be determined that the switchgear is in the normal operation if the number of pump starts is below a first threshold and in the maintenance state if the number of pump starts is higher than the first threshold.

The maintenance state may be either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time. The measuring may comprise measuring a number of pump starts and the method may comprise distinguishing between the maintenance state which requires immediate service and/or maintenance of the pump and/or the switch gear and the

maintenance state which requires service and/or maintenance within a set period of time based on the number of pump starts. The number of pump starts may correlate with particles affecting operation of the switchgear.

- 5 It may be determined that the switchgear is in the state which requires immediate service and/or maintenance of the pump and/or the switchgear if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and in the state which requires service and/or maintenance within a set period of time if the number of pump starts is higher than the first threshold and lower than the second threshold.

10

The present disclosure may further relate to a program carried out by a computer implementing the above described method.

15

The present disclosure hence provides a simple and reliable system, device and method for monitoring a condition of switchgear. The device can be attached to a variety of switchgear and can particularly be used to monitor e.g. a frequency and duration of operation of a hydro-mechanical switchgear pump. This solution can be retrofitted and easily employed in switchgear irrespective of the internal structure. No circuitry or internal wiring has to be adapted and the system must not be taken off the grid to install the monitoring device. The gathered data can be indicative of the state of the system such as internal leakage, system pressure, sealing state, piston state, pump state and electrical connection state and thus facilitate maintenance and avoid downtime or even system failure of the system.

20

- Other aspects, features, and advantages will be apparent from the summary above, as well as from the description that follows, including the figures and the claims.

25

- While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. It will be understood that changes and modifications may be made by those of ordinary skill within the scope of the following claims. In particular, the present invention covers further embodiments with any combination of features from different embodiments described above and below.

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Furthermore, in the claims the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single unit may fulfil the functions of several features recited in the claims. The terms "essentially", "about", "approximately" and the like in connection with an attribute or a value particularly also define
5 exactly the attribute or exactly the value, respectively. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS

1. A device for monitoring a condition of switchgear, wherein the device comprises:
attachment means for attaching the device to hydro-mechanical switchgear;
5 measurement means for measuring at least one parameter of the switchgear, wherein the measurement is performed non-invasively;
transmission means for transmitting the at least one measured parameter;
wherein the device comprises or is attached to or is connected to a controller for processing the at least one measured parameter,
10 wherein the measurement means is configured to measure at least one pump parameter of the switchgear, and
wherein the controller is configured to process the at least one measured pump parameter to generate or determine an operational state and/or maintenance state of the switchgear.

15 2. The device according to claim 1, wherein the measurement means is configured to measure at least one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts or magnetic field of the pump as the pump parameter.

20 3. The device according to claim 2, wherein the measurement means is configured to measure the current inductively.

25 4. The device according to any one of the preceding claims, wherein the at least one measured parameter is periodically transmitted.

30 5. The device according to any one of the preceding claims, wherein the transmission means is configured to wirelessly transmit the at least one measured parameter using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.

6. The device according to any one of claims 1 to 5,

wherein the operational state and/or maintenance state comprises information on at least one of system pressure, leakage detection, sealing state, piston state, pump state, or electrical connection state.

- 5 7. The device according to any one of claims 1 to 6, wherein the transmission means is configured to wirelessly transmit the operational state and/or maintenance state using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.
- 10 8. The device according to any one of claims 1 to 7, wherein the controller is configured to distinguish between an operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter.
- 15 9. The device according to any one of claims 1 to 8, wherein the measurement means is configured to measure a number of pump starts and wherein the controller is configured to distinguish between an operational state and a maintenance state based on the number of pump starts.
- 20 10. The device according to claim 9, wherein the number of pump starts correlates with particles affecting operation of the switchgear.
- 25 11. The device according to claim 9 or 10, wherein the controller is configured to determine that the switchgear is in the normal operation if the number of pump starts is below a first threshold and in the maintenance state if the number of pump starts is higher than the first threshold.
- 30 12. The device according to any one of claims 1 to 11, wherein the maintenance state is either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time.
13. The device according to claim 12, wherein the measurement means is configured to measure a number of pump starts and wherein the controller is configured to distinguish between the maintenance state which requires immediate service and/or maintenance of the

pump and/or the switch gear and the maintenance state which requires service and/or maintenance within a set period of time based on the number of pump starts.

14. The device according to claim 13, wherein the number of pump starts correlates with particles affecting operation of the switchgear.

15. The device according to claim 13 or 14, wherein the controller is configured to determine that the switchgear is in the state which requires immediate service and/or maintenance of the pump and/or the switchgear if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and to determine that the switchgear is in the state which requires service and/or maintenance within a set period of time if the number of pump starts is higher than the first threshold and lower than the second threshold.

16. Method for monitoring a condition of switchgear, the method comprising:
attaching a device for monitoring a condition of switchgear to a hydro-mechanical switchgear,
measuring at least one parameter of the switchgear, wherein the measuring is performed non-invasively;
transmitting the at least one measured parameter;
processing the at least one measured parameter;
non-invasively measuring at least one pump parameter of a hydro-mechanical switchgear; and
processing the at least one measured pump parameter to generate or determine an operational state and/or maintenance state of the switchgear.

17. Method according to claim 16, further comprising
measuring one of current flowing through the pump, duration of pump operation, frequency of pump operation, vibration of the pump, number of pump starts or magnetic field of the pump.

18. Method according to any one of claims 16 or 17, further comprising periodically transmitting the at least one measured parameter.

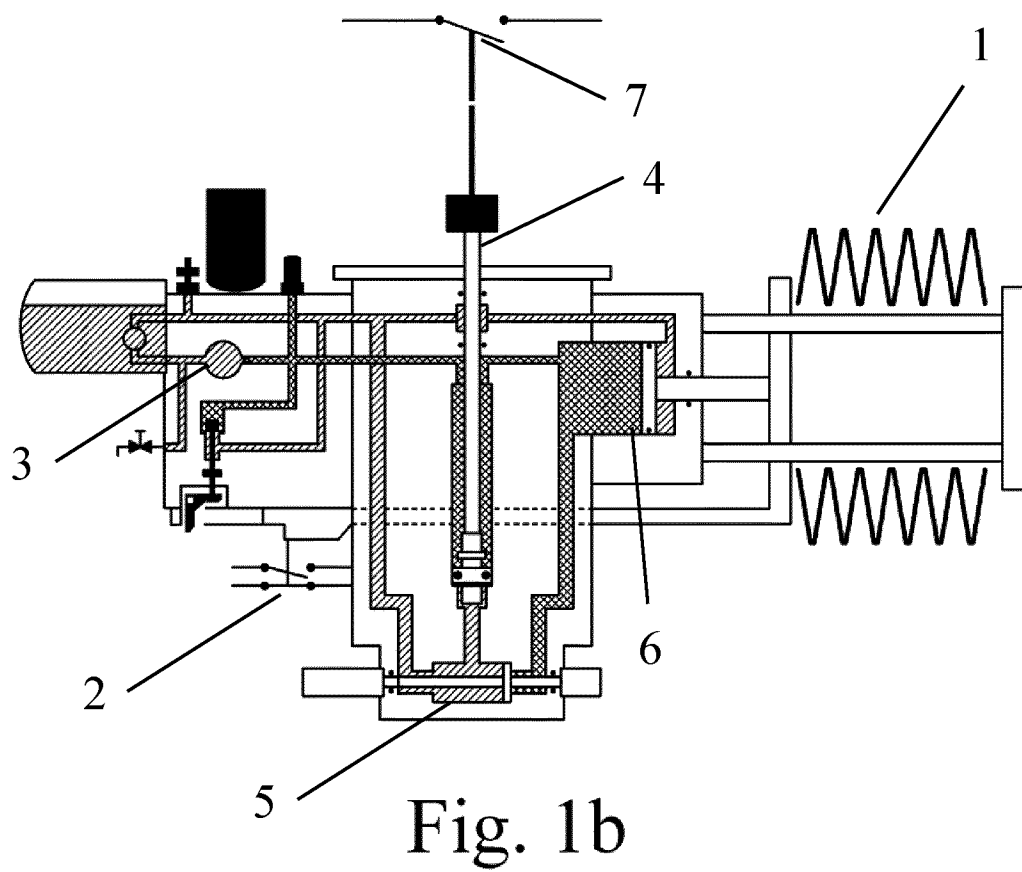
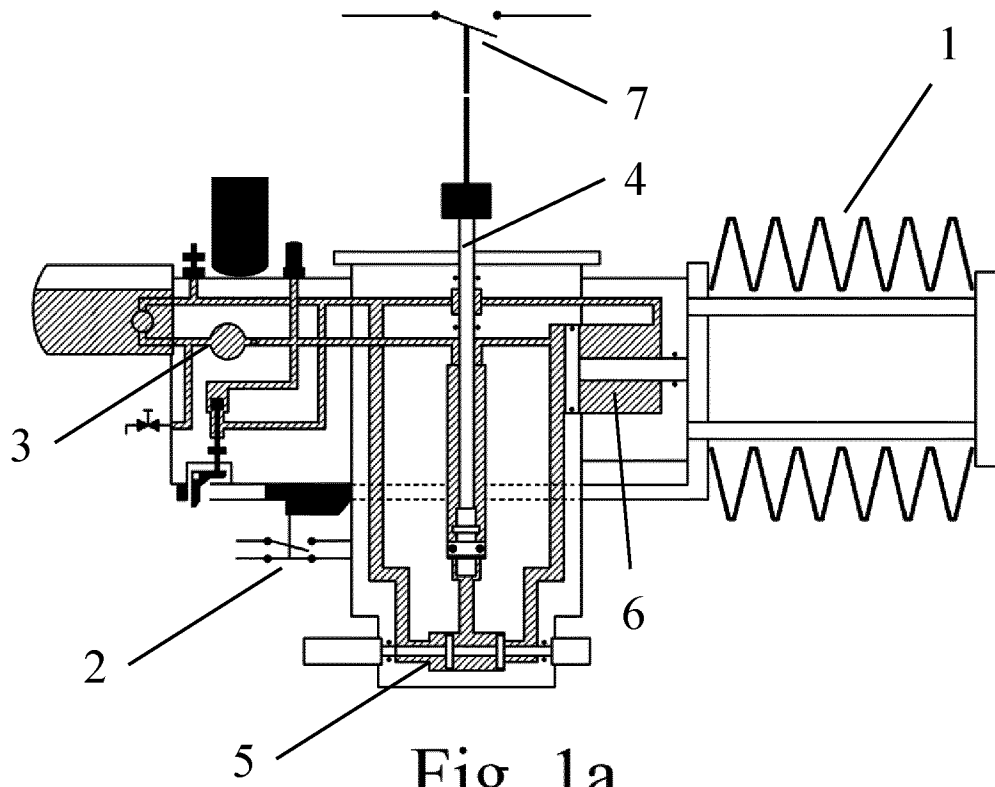
19. Method according to any one of claims 16 to 18, further comprising wirelessly transmitting the at least one measured parameter using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.
- 5 20. Method according to any one of claims 16 to 19,
wherein the operational state and/or maintenance state comprises information on at least one of system pressure, leakage detection, sealing state, piston state, pump state, electrical connection state.
- 10 21. Method according to any one of claims 16 to 20, further comprising wirelessly transmitting the operational state and/or maintenance state using Long Range Wireless Transmitter or Bluetooth or a 5G transmission protocol.
- 15 22. Method according to any one of claims 16 to 21, wherein the method comprises distinguishing between a normal operational state indicating a normal operation and a maintenance state requiring service and/or maintenance based on the processed at least one measured pump parameter.
- 20 23. Method according to any one of claims 16 to 22, wherein the measuring comprises measuring a number of pump starts and wherein the method comprises distinguishing between an operational state and a maintenance state based on the number of pump starts.
- 25 24. Method according to claim 23, wherein the number of pump starts correlates with particles affecting operation of the switchgear.
- 25 25. Method according to claim 23 or 24, wherein the method comprises determining the operational state if the number of pump starts is below a first threshold and the maintenance state if the number of pump starts is higher than the first threshold.
- 30 26. Method according to any one of claims 16 to 25, wherein the maintenance state is either a state which requires immediate service and/or maintenance of the pump and/or the switch gear or a state which requires service and/or maintenance within a set period of time.

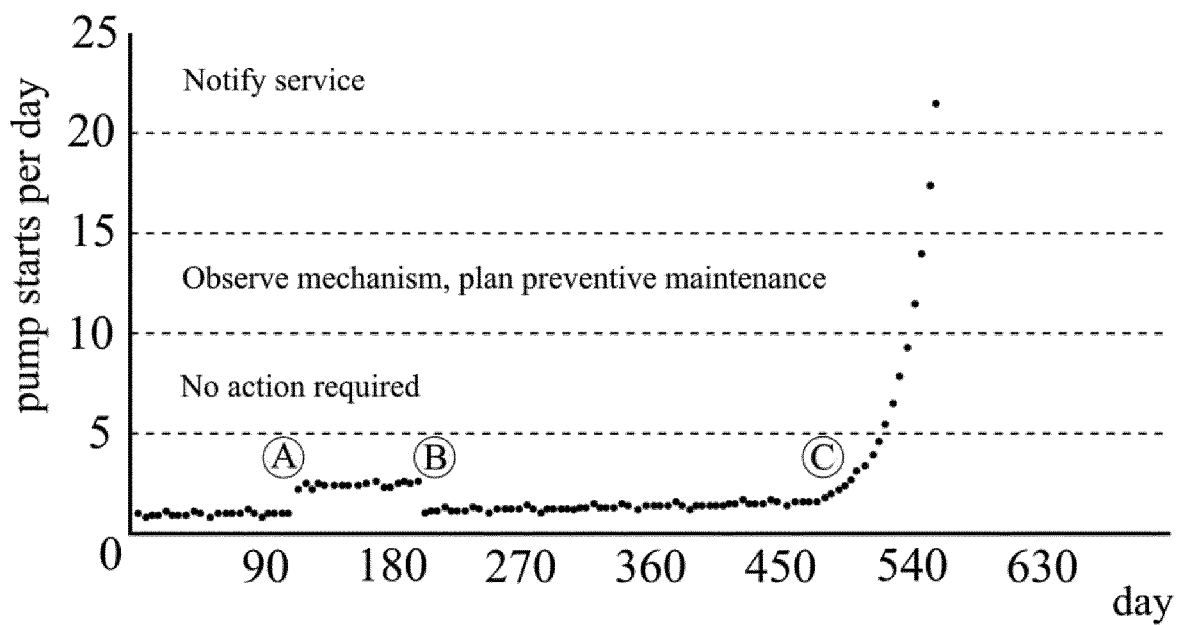
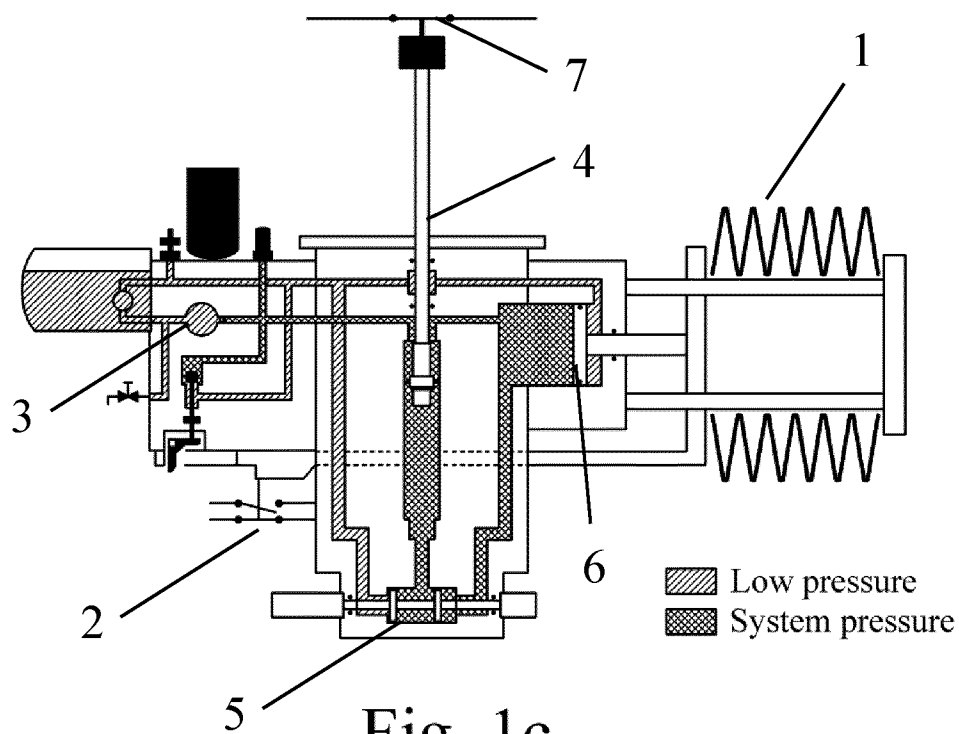
27. Method according to claim 26, wherein the measuring comprises measuring a number of pump starts and wherein the method comprises distinguishing between the maintenance state which requires immediate service and/or maintenance of the pump and/or the switch gear and the maintenance state which requires service and/or maintenance within a set period of time

5 based on the number of pump starts.

28. Method according to claim 27, wherein the number of pump starts correlates with particles affecting operation of the switchgear.

10 29. Method according to claim 27 or 28, wherein the state which requires immediate service and/or maintenance of the pump and/or the switchgear is determined if the number of pump starts is higher than a second threshold, wherein the second threshold is higher than the first threshold, and the state which requires service and/or maintenance within a set period of time is determined if the number of pump starts is higher than the first threshold and lower than the
15 second threshold.





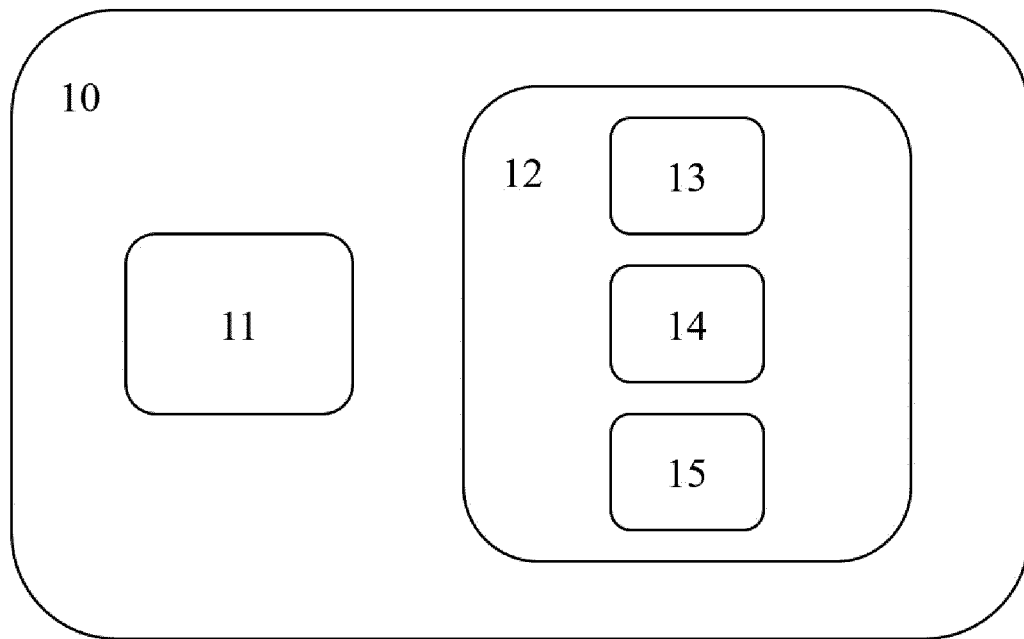


Fig. 3

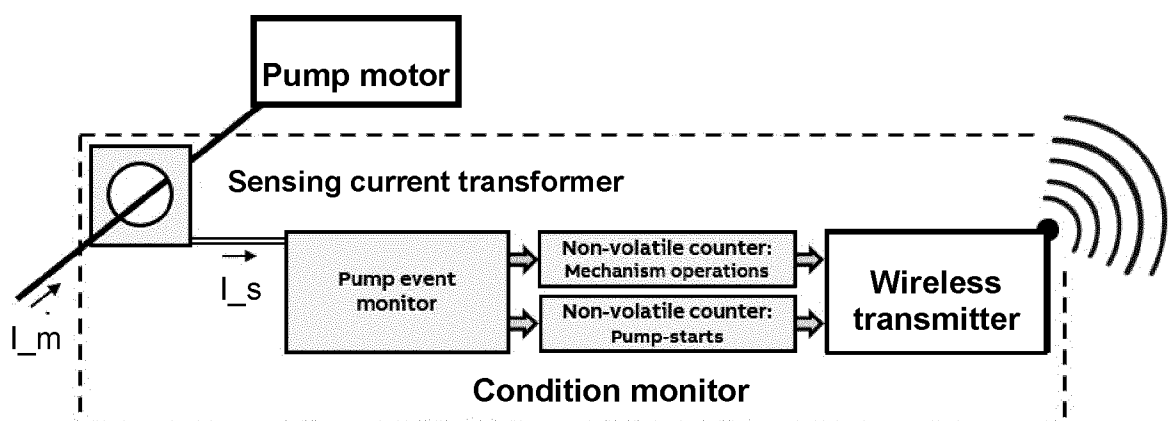


Fig. 4

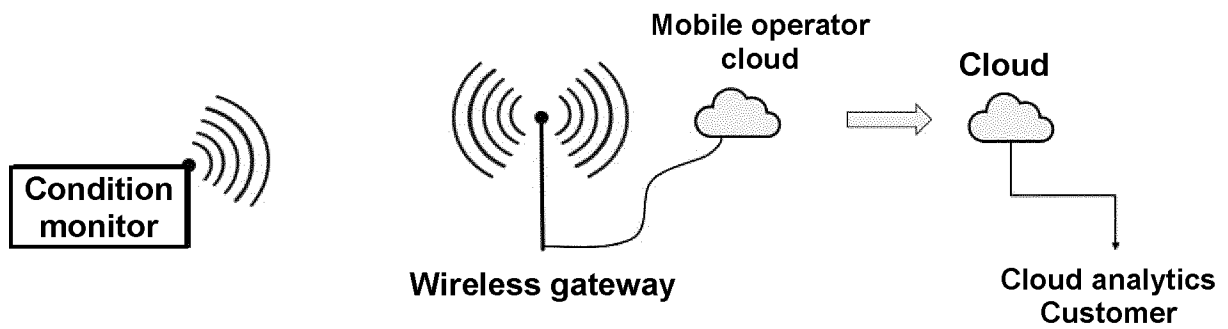


Fig. 5

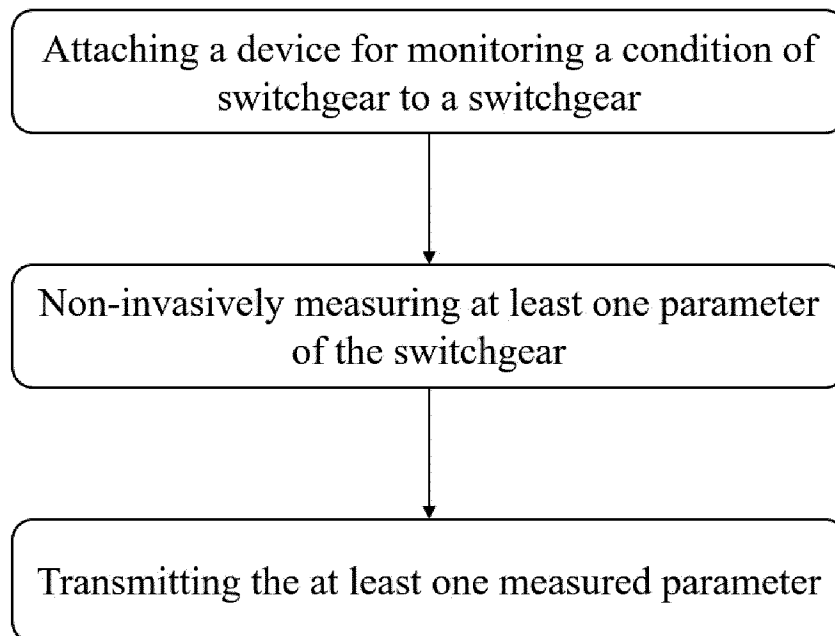


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/083055

A. CLASSIFICATION OF SUBJECT MATTER INV. H01H33/34 H01H33/02 H01H11/00 H01H9/16 G01R31/327 ADD. H01H33/40		
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) H01H G01R		
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.
A	WO 92/01303 A1 (SIEMENS AG [DE]) 23 January 1992 (1992-01-23) page 5, lines 1-25 page 6, lines 11-34 page 8, line 25 - page 9, line 8 claims 4,5; figure 1 -----	1-29
X	EP 3 712 919 A1 (MITSUBISHI ELECTRIC CORP [JP]) 23 September 2020 (2020-09-23)	1, 2, 4, 6, 8, 9, 11, 16-18, 20, 22, 23, 25
Y	paragraphs [0001] - [0002], [0011] - [0024], [0060] - [0064] figures 1, 7, 8 ----- -/--	3, 5, 7, 19, 21
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 7 February 2022		Date of mailing of the international search report 24/02/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Glaman, C

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2021/083055

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 750 950 A (NOGAMI TADAHICO [JP] ET AL) 12 May 1998 (1998-05-12)	1, 2, 4, 6, 8, 16-18, 20, 22
Y	column 17, line 48 - column 18, line 25 figure 15	3, 5, 7, 19, 21
Y	----- EP 3 680 925 A1 (SIEMENS NEDERLAND [NL]) 15 July 2020 (2020-07-15)	3, 5, 7, 19, 21
A	paragraphs [0004], [0028] - [0035] figure 1	1, 16
A	----- US 2005/168891 A1 (NILMAN-JOHANSSON KRISTINA [SE] ET AL) 4 August 2005 (2005-08-04) paragraphs [0029] - [0033], [0081] - [0084] figures 1-3	1-29
A	----- WO 2019/197038 A1 (ABB SCHWEIZ AG [CH]) 17 October 2019 (2019-10-17) page 5, lines 16-33 page 6, line 17 - page 7, line 18 figures 1-3	1-29
X	----- US 5 636 134 A (JOHNSON DAVID S [US] ET AL) 3 June 1997 (1997-06-03)	1, 2, 4, 6, 8, 9, 11-13, 15-17, 20, 23, 25-27, 29
Y	column 11, lines 30-50 column 16, lines 27-48 claims 1, 12 figures 3-6	3, 5, 7, 19, 21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2021/083055

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9201303	A1	23-01-1992	DE 4022262 A1	16-01-1992
			EP 0538269 A1	28-04-1993
			WO 9201303 A1	23-01-1992

EP 3712919	A1	23-09-2020	EP 3712919 A1	23-09-2020
			JP 6338806 B1	06-06-2018
			JP WO2019097668 A1	14-11-2019
			US 2020321771 A1	08-10-2020
			WO 2019097668 A1	23-05-2019

US 5750950	A	12-05-1998	CN 1155744 A	30-07-1997
			JP 3183120 B2	03-07-2001
			JP H0992096 A	04-04-1997
			KR 970017750 A	30-04-1997
			US 5750950 A	12-05-1998

EP 3680925	A1	15-07-2020	CN 113302711 A	24-08-2021
			EP 3680925 A1	15-07-2020
			EP 3891771 A1	13-10-2021
			WO 2020144338 A1	16-07-2020

US 2005168891	A1	04-08-2005	CN 1914701 A	14-02-2007
			EP 1719141 A1	08-11-2006
			JP 2007519924 A	19-07-2007
			US 2005168891 A1	04-08-2005
			WO 2005073992 A1	11-08-2005

WO 2019197038	A1	17-10-2019	NONE	

US 5636134	A	03-06-1997	US 5629869 A	13-05-1997
			US 5636134 A	03-06-1997
			US 5638296 A	10-06-1997
			WO 9528025 A1	19-10-1995
