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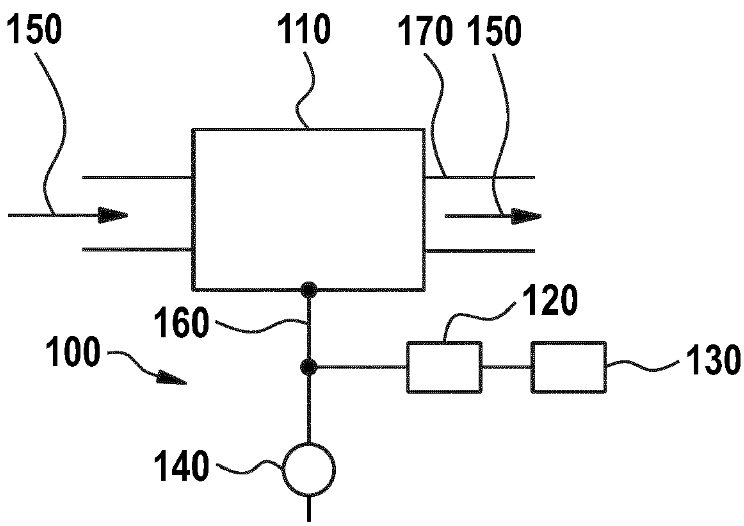
(54) **METHOD OF OPERATING A TRANSFORMER AND APPARATUS FOR A TRANSFORMER**

(57) The present disclosure provides a method of operating a transformer (200), wherein the transformer (200) generates heat when being operated, and wherein the transformer (200) includes a cooling unit (110) for forced cooling of the transformer (200). The method includes generating by the cooling unit a flow (150) of a coolant along a cooling path (170) for forced cooling of the transformer (200), measuring a true power value supplied to the cooling unit (110), and comparing the detected true power value with a predetermined true power threshold value.

Fig. 1



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Description

FIELD

[0001] Embodiments of the present disclosure relate to a method of operating a transformer. In particular, embodiments of the present disclosure relate to a transformer having a cooling system with a cooling unit for actively cooling the transformer.

BACKGROUND

[0002] A transformer transfers electrical energy between two or more circuits. When a load is applied to a transformer, heat is typically generated by the currents drawn from and conducted through the transformer. Increased temperatures during operation can deteriorate the performance and the life expectancy of a transformer. Thus, it can be important to maintain the temperature of a transformer below a certain temperature value, as elevated temperatures may lead to reduced reliability or even to premature failure of the transformer.

[0003] For cooling the transformer and for dissipation of the heat, transformers may include cooling systems such as active cooling systems for actively dissipating the heat generated by the transformer or passive cooling systems for dissipating the heat by natural convection. Active cooling systems typically generate a flow of a coolant for forced cooling of the transformer. Typical coolants used for cooling of a transformer may include, for example, air, oil, in particular transformer oil, such as for example: mineral oil, silicon oil, or natural esters and synthetic esters.

[0004] Monitoring a cooling system in order to provide a sufficient flow of a coolant may require a mechanical sensor, such as for example a mechanical flow meter. Mechanical sensors are typically in direct contact with the coolant for measuring the coolant flow. For example, a mechanical sensor can include a mechanical indicator, such as a paddle, that measures the force exerted thereon by the coolant flow. Typically, the aim of such mechanical sensors is to detect whether an oil flow is present. A paddle may move relatively to the coolant flow. The movement may for example actuate a microswitch. However, mechanical parts of the mechanical sensor may age, e.g. corrode, which may deteriorate flow detection. Mechanical parts, such as for example metallic parts, may also become loose. For example, mechanical parts may drop into the coolant. Therefore, loose mechanical parts may further impose a risk on proper operation of the transformer.

[0005] If a failure of the mechanical flow sensor leads to an undetected insufficient coolant flow, the temperatures of the transformer can rise quickly. For example, the temperature of the coils may rise quickly and may deteriorate the windings of the coils. In particular, the rise of the temperature may happen faster than the detection of the sudden temperature rise by a temperature sensor installed on or inside the transformer.

[0006] If, however, a deteriorated flow detection of the mechanical flow sensor indicates a fault signal despite of the presence of a sufficient coolant flow, operating the transformer may have to be halted. Consequently, the transformer stops providing power to electrical connected equipment, such as, for example, an electrical motor. This may lead to increased operating costs of the transformer and/or the equipment operated by the transformer For example, if a mechanical flow sensor for a traction transformer indicates a false error, the train may have to be stopped.

[0007] Accordingly, it would be beneficial to reduce the risk of an insufficient coolant flow, which may lead to damaging the transformer due to overheating. It would further be beneficial to provide a coolant flow detection that is more reliable. Furthermore, it would be beneficial to provide a coolant flow detection that may reduce or even avoid the risk of coolant leakage.

SUMMARY

[0008] In light of the above, a method of operating a transformer and a coolant flow detecting device for a transformer are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0009] According to one aspect of the present disclosure, a method of operating a transformer is provided, wherein the transformer generates heat when being operated and wherein the transformer includes a cooling unit for forced cooling of the transformer. The method includes generating by the cooling unit a flow of a coolant along a cooling path for forced cooling of the transformer. The method further includes measuring a true power value supplied to the cooling unit. Further, the method includes comparing the detected true power value with a predetermined true power threshold value.

[0010] According to another aspect of the present disclosure, a coolant flow detecting device for a transformer, wherein the transformer generates heat when being operated and wherein the transformer includes a cooling unit for forced cooling of the transformer is provided. The coolant flow detecting device includes a detector for measuring a true power value supplied to the cooling unit, wherein the cooling unit is adapted to generate a flow of a coolant along a cooling path for forced cooling of the transformer. The coolant flow detecting device further includes a controller for comparing the detected true power value with a predetermined true power threshold value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, is given by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

Fig. 1 schematically shows a coolant flow detecting device according to embodiments described herein;

Fig. 2 schematically shows a cross-sectional view of a transformer including a coolant flow detecting device according to embodiments described herein;

Fig. 3 shows a graph illustrating true power as a function of temperature; and

Fig. 4 shows a schematic chart illustrating a method of operating a transformer according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0012] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0013] Although the following description is given with respect to a cooling system for a transformer, and particularly with respect to coolant flow detection of a coolant flow generated by a cooling unit for a transformer, it is to be understood that the embodiments of the present disclosure are not limited thereto. Instead, the present embodiments could be applied anywhere, where a coolant flow detection of a coolant flow for cooling of a conductor, such as a liquid-cooled inductor, is needed.

[0014] According to some embodiments, which can be combined with embodiments described herein, a method of operating a transformer is provided, wherein the transformer generates heat when being operated and wherein the transformer includes a cooling unit for forced cooling of the transformer. The method includes generating by the cooling unit a flow of a coolant along a cooling path for forced cooling of the transformer. The method further includes measuring a true power value supplied to the cooling unit. Further, the method includes comparing the detected true power value with a predetermined true power threshold value.

[0015] As mentioned above, it can be beneficial to detect whether a coolant flow is sufficient to cool the transformer. However, mechanical coolant flow sensors provided for the transformer or for the transformer cooling circuit can be subject to corrosion or mechanical agingm which may affect the reliability of the mechanical coolant flow sensor. Thus, particularly over time, the flow detection of the mechanical coolant flow sensor may become deteriorated. The flow detection may then become unreliable. For example, the transformer may get damaged due to overheating when an insufficient coolant flow is not reliably detected. Yet, an unreliable flow detection or a failure of the mechanical coolant flow sensor may also lead to a false error signal indicating erroneously an insufficient coolant flow.

[0016] The present embodiments overcome this problem by measuring a true power value supplied to the cooling unit. The detected true power value is compared with a predetermined true power threshold value. In other words, the coolant flow is detected based on the true power value supplied by, for example, a power supply, to the cooling unit. True power may also be referred to as real power. The supplied true power value to the cooling unit may differ from the rated power value of the cooling unit or the apparent power. In embodiments, the apparent power value is defined as the product of the root-mean-square values of voltage and current.

[0017] In contrast, true power may be defined by equation (1),

$$P = |S| \times PF \qquad (1)$$

wherein P is the real power |*S*| is the apparent power, which is the magnitude of the complex power *S*, and *PF* is the power factor. The power factor *PF* is defined as the cosine of the angle of the phase difference between the current waveform and the voltage waveform. Accordingly, true power differs from the apparent power due to a phase difference between the voltage and the current. True power measurement may be performed by a Wattmeter suitable for AC applications.

[0018] Measuring the true power value can, for example, be performed by averaging or integrating the products of voltage and current measured simultaneously over a certain period of time, as shown below in equation (2),

$$P = \frac{1}{T}\int_0^T v(t) \times i(t) \times dt \qquad (2),$$

wherein T is the selected period of time to be measured, *v(t)* is the voltage value at time *t,* and *i(t)* is the current value at time *t,* and x denotes multiplication. However, it is to be understood that embodiments of the present disclosure are not limited to measuring the true power value as described above, and there are several ways of measuring the true power value. For example, the true power value may be derived by measuring the apparent power, that is to say the root-mean-square values of voltage and current, and measuring, for example with an oscilloscope, the phase difference between the voltage and the current waveform.

[0019] The inventors of the present disclosure have found that by measuring a true power value, supplied to the cooling unit, and by comparing the measured or detected true power value with a predetermined true power threshold value, it can be determined, whether a sufficient coolant flow is present. For instance, a measured true power value that is lower than a true power threshold value may be related to a malfunction of the cooling unit, such that a sufficient coolant flow may no longer be provided by the cooling unit. That is to say, that an insufficient coolant flow can be linked to a detected true power value that is provided to the cooling unit. For example, failure of the cooling unit will be detectable by observing the value of the true power measurement.

[0020] According to embodiments described herein, the cooling of the transformer by the cooling unit may be monitored by detecting a true power value supplied to the cooling unit. In particular, embodiments described herein may monitor whether a sufficient coolant flow is provided by the cooling unit.

[0021] Fig. 1 illustrates a schematic view of a coolant flow detecting device 100 for a transformer according to embodiments described herein. According to typical embodiments, the coolant flow detecting device 100 is configured to perform the method described above and also described later with reference to Fig. 2 to Fig. 4.

[0022] For forced cooling of the transformer, the transformer can include a cooling unit 110. The cooling unit 110 can be, for example, a pump, such as a circulating pump, or an oil pump. The cooling unit 110 can have a coolant intake and a coolant exhaust.

[0023] According to embodiments described herein, the cooling unit 110 is adapted to generate a flow of a coolant. Reference numeral 150 figuratively illustrates the flow of a coolant. In particular, the flow 150 of the coolant may be provided along a cooling path 170, as shown in Fig. 1.

[0024] According to embodiments described herein, the cooling unit 110 can be supplied with power by a power supply 140. The power supply 140 can be connected to the cooling unit 110 by a power supply line 160. Cooling units according to embodiments described herein are typically supplied with an electric power by an electrical power supply. Accordingly, the power supply line 160 may electrically connect the cooling unit 110 and the power supply 140. According to embodiments described herein, the power supply is an AC power supply. The power supply 140 may be provided outside of the transformer and could be connected to the cooling unit 110 arranged outside or inside of the transformer. Alternatively, the power supply 140 may be an auxiliary transformer of the transformer.

[0025] According to embodiments described herein, the cooling path 170 can be a closed cooling circuit. A closed cooling circuit could be understood as a closed cooling system providing a circulating coolant within. The closed cooling system may, for example, include one or more pipings.

[0026] According to some embodiments described herein, the cooling unit 110 could be a fan, e.g. a mechanical fan. The fan may generate a flow of coolant, which may be a gas such as air.

[0027] According to some embodiments described herein, the cooling path 170 may be an open cooling circuit. For example, a fan may be described as a cooling unit having an open cooling circuit. In an open cooling circuit, an emitted flow of a coolant at the coolant exhaust of the cooling unit 110 is not necessarily fed back to the coolant intake of the cooling unit 110. Instead, the coolant intake of the cooling unit 110 may be supplied by a reservoir of a coolant, such as the air surrounding a fan cooling unit.

[0028] In Fig. 1, the coolant flow detecting device 100 includes a detector 120 for measuring a true power value supplied to the cooling unit 110. According to embodiments described herein, the detector 120 is configured to detect the true power value supplied to the cooling unit 110 by the power supply 140. For example, the detector 120 may be configured to measure an instantaneous voltage value and an instantaneous current value. The detector 120 may then derive the true power value.

[0029] The detector 120 may use different ways of measuring the true power value, such as measuring the true power value by implementing various definitions of true power as, for example, the definitions described herein. In particular, the detector 120 can include a wattmeter suitable for AC measurements. Alternatively or additionally, the detector 120 may also include a digital oscilloscope for measuring the true power value.

[0030] According to some embodiments, which can be combined with embodiments described herein, measuring the true power value supplied to the cooling unit 110 includes performing a measurement on-line of the power supply line 160 of the cooling unit 110. For instance, the detector 120 can be arranged between an electrical connection of the cooling unit 110 and the power supply 140. The arrangement of the detector 110 may be such that a voltage and a current could be measured, in particular, substantially at the same time.

[0031] According to some embodiments, which could be combined with embodiments described herein, measuring the true power value includes measuring a value selected from a group comprising of: a voltage, a current, a time, a phase difference, and combinations thereof. For instance, several voltage values and current values may be measured successively and integrated over a period of time. The true power value may be then determined by averaging the integrated value. By measuring the true power value, the power consumed by the cooling unit 110 can be determined.

[0032] According to some embodiments, which can be combined with embodiments described herein, the coolant flow detecting device includes a controller 130 for comparing the detected true power value with a predetermined true power threshold value. The detector 120 is typically in communication (i.e. signal or data communication) with the controller 130. As exemplarily shown in Fig. 1, the controller 130 may be connected to the detector 120, such that the measured true power value is received by the controller 130 from the detector 120. For example, the connection may be an electrical signaling line.

[0033] By comparing the detected true value with a predetermined true power threshold value, the coolant flow detecting device can detect, if a sufficient flow of coolant is provided by the cooling unit 110, as also described in more detail hereafter. This has the benefit that no mechanical parts may have to be exposed in the coolant for detecting the flow of the coolant. Thus, embodiments of the present disclosure may provide a more reliable operation of a cooling unit for a transformer, as the risk of ageing of mechanical parts or even loosing mechanical parts in the coolant may be decreased. Furthermore, embodiments of the present disclosure can reduce the risk of coolant leakage.

[0034] Fig. 2 schematically illustrates a cross-sectional view of a transformer 200 including a coolant flow detecting device 100. The coolant flow detecting device 100 may be similar to the coolant flow detecting device depicted in Fig. 1, so that reference can be made to the above explanations.

[0035] The transformer 200 includes windings 240 disposed in the transformer housing. A transformer tank 250 is provided within the transformer housing. In embodiments, the transformer tank 250 is configured to enclose a coolant, e.g. a fluid coolant. A fluid coolant may be, for example, oil, in particular, transformer oil having electrical insulating properties. The coolant can flow past the windings 240 and can absorb heat generated by currents drawn through the windings 240.

[0036] In some embodiments, the transformer 200 includes a cooling circuit 220 as a cooling path. The cooling circuit 220 may for example include a heat exchanger. The heat exchanger may be in fluid connection to the transformer tank 250. In particular, the heat exchanger may be positioned such that at least an area of a surface is exposed on the outside of the transformer. Thus, the heat exchanger may take up heat from one coolant and releases the heat to another coolant provided outside of the transformer.

[0037] According to embodiments described herein, a cooling unit 110 is provided for the transformer 200. The cooling unit 110 may be arranged within a portion of the cooling circuit 220, as exemplarily shown in Fig. 2. In particular, a coolant is moved by the cooling unit 110, which results in a flow 150 of the coolant from the coolant intake to the coolant exhaust of the cooling unit 110. Accordingly, the cooling unit 110 can provide a flow 150 of a coolant inside the cooling circuit 220. The coolant may take up heat from a first portion of the transformer and release the heat to a second portion of the transformer. For instance, the heat may be taken up from the windings 240 of the transformer. The heat may be then released at a heat exchanger of the transformer.

[0038] In Fig. 2, the cooling unit 110 is connected to an external power supply 140 by a power supply line 160. A detector 120 for measuring a true power value supplied to the cooling unit 110 is connected to the cooling unit 110. According to the embodiment shown in Fig. 2, the detector 120 is arranged within the power supply line 160. A controller 130 is further connected to the detector 120.

[0039] The coolant flow detecting device 100 according to embodiments described herein, may be provided for a cooling unit 110 including a circulating pump. As exemplarily shown in Fig. 2, the cooling unit 110 is designed as a circulating pump and can be adapted to provide a flow 150 of a transformer cooling fluid circulating in a cooling circuit 220 of the transformer 200.

[0040] According to some embodiments, which can be combined with embodiments described herein, it is detected, based on the comparison of the detected true power value and the predetermined true power threshold value, whether the cooling unit 110 is in a desired operational condition. A desired operational condition can be, for example, an operational condition in which a sufficient flow of a coolant is provided, such that the transformer is not exceeding a temperature value that may damage the transformer or parts of the transformer. In other words, in a desired operational conditions, the transformer is cooled sufficiently.

[0041] According to some embodiments, which can be combined with embodiments described herein, a signal can be emitted, if the cooling unit 110 is not in a desired operational condition. The signal may be selected from the group consisting of: an electrical signal, an acoustic signal, a visual or optical signal, a mechanical signal, and combinations thereof. This may have the beneficial effect of an early fault detection. In particular, the fault may be detected at an early stage of emerging insufficient flow of coolant before temperature rises to unbeneficial elevated values.

[0042] According to some embodiments, which could be combined with embodiments described herein, the coolant flow detecting device 100 may include a controller 130 connectable to a signaling unit for emitting a signal selected from the group consisting of: an electrical signal, an acoustic signal, a visual or optical signal, a mechanical signal, and combinations thereof

[0043] According to some embodiments, which may be combined with embodiments described herein, the coolant flow detecting device 100 can include a temperature sensor 210 for measuring a temperature of a portion of the transformer 200, as exemplarily shown in Fig. 2. The temperature sensor 210 may, for example, be arranged within welded thermowells of the transformer 200. The temperature sensor 210 could also be disposed directly on the outer surface of the transformer tank 250. This can have the benefit that the temperature sensor 210 is not in direct contact with the coolant and becomes easily accessible, e.g. for maintenance.

[0044] In embodiments described herein, the flow of the coolant generated by the cooling unit depends on the true power value supplied to the cooling unit. According to some embodiments, which can be combined with other embodiments described herein, the predetermined true power threshold value can be a function of temperature.

[0045] The predetermined true power threshold value can depend on parameters such as the characteristics of the cooling unit including the type of the cooling unit, the rated power value of the cooling unit, the type of coolant used, the viscosity of the coolant, or the temperature of the coolant. For example, different cooling units may have different performance specifications. Moreover, the viscosity of the coolant may be temperature dependent. Thus, the viscosity may become lower with increased temperature. The temperature for adjusting the predetermined threshold value may be chosen in embodiments to be more than -40°C. In embodiments, the temperature may be chosen to be less than 140°C.

[0046] A cooling unit may consume less true power when providing a coolant flow of a coolant having a lower viscosity, compared to a coolant having a higher viscosity. The predetermined true power threshold value may then be adjusted according to the temperature of the coolant. Typically, the predetermined true power threshold value are smaller for higher temperature values, as also shown hereinafter in Fig. 3. Typically, the temperature of the coolant can be measured indirectly by measuring the temperature of the transformer, e.g. the temperature of the outer wall of the transformer tank or by measuring inside welded thermowells.

[0047] In some embodiments, the controller 130 has access to a data storage. The data storage may, for example, be included in the controller 130. The controller 130 may also be connected to a data storage provided outside of the controller 130. The information of the predetermined true power threshold value may be stored on the data storage. The controller 130 can, for example, compare the detected true power value with a predetermined true power threshold value by using the information stored on the data storage.

[0048] In general, the detected true power value is compared with a predetermined true power threshold value. In embodiments, the value of the predetermined true power threshold value is in relation to a desired operational condition of the transformer. For example, if the detected true power value is lower than the predetermined true power threshold value, it could be considered that the transformer is not in a desired operational condition. For example, the cooling unit may have a malfunction. Also, a part of the cooling circuit may not be in an operational state such as, for example, a valve of the cooling circuit being closed. The flow of the coolant may then be considered as not sufficient for cooling the transformer. If the detected true power value is above the predetermined true power threshold value, it could be considered that the flow of the coolant is sufficient for cooling the transformer.

[0049] In some embodiments, the predetermined true power threshold value is provided as a lookup table. This can be understood as a lookup table having a plurality of predetermined true power threshold values, wherein the plurality of predetermined threshold values have at least one additional parameter, such as, for example, the measured temperature of the transformer, the type of cooling unit, the coolant type used therein, or combinations thereof Accordingly, the predetermined true power threshold value used for comparison with the detected true power value is selected based on the at least one parameter.

[0050] Alternatively, in a further embodiment, the predetermined true power threshold value may be a true power value for which the transformer is considered to be in a desired operational condition. In particular, in this case, the cooling unit, is considered to be in a desired operational condition, if a measured true power has the value of the predetermined true power threshold value.

[0051] In particular, the inventors have found that from a power consumption point of view, it can be detected whether a cooling unit such as, for example, a pump, is working abnormally and thus is not providing a sufficient flow of a coolant such as, for example, an oil flow. In general, the power consumption is related to the supplied true power value. For example, the operational state of components of the cooling unit, e.g. an electric motor, may have an influence on the phase difference of the cooling unit. The phase difference may typically affect the power factor. To stay with this example, impairments of the motor windings may alter the power factor of the cooling unit and affect the true power value of the cooling unit. An obstruction inside the cooling circuit interfering with the coolant flow, such as, for example, a closed valve, may also alter the true power value of the cooling unit. This may be caused, for example, by an impeded rotating mechanism of the cooling unit.

[0052] Fig. 3 shows a graph illustrating the effect on the true power value. In particular, the graph shows the true power value as a function of temperature. The graph has an axis 310 for the value of the true power and an axis 320 for the temperature value. Fig. 3 displays a first graph 330 and a second graph 340. Here, the first graph 330 has a lower true power value over the shown temperature range than the second graph 340. Accordingly, the true power value of the second graph 340 is higher than the true power value of the first graph 330 independently of the temperature value. In other words, the first graph 330 and the second graph 340 do not intersect one another over a certain temperature range, in particular, at least over a certain temperature range relevant for operating transformers.

[0053] According to some embodiments, which can be combined with embodiments described herein, a temperature of the transformer is detected. The predetermined true power threshold value can be temperature-adjusted based on the detected temperature of the transformer.

[0054] Embodiments of the present disclosure are now described exemplarily using Fig. 2 and Fig. 3. In a first example case, the detector 120 measures the true power value supplied to the cooling unit 110. The second graph 340 of Fig. 3 shows the measured true power values at different temperatures. In this first example case, the first graph 330 represents the predetermined true power threshold value. Here, the predetermined true power threshold value is temperature dependent, e.g. the value of the first graph 330 becomes lower with increasing temperature. For a given temperature, in particular, for a measured temperature measured by the temperature sensor 210, the detected true power value has a higher value than the predetermined true power threshold value. Therefore, in this first example case, it is considered that the cooling unit provides a sufficient flow of coolant for cooling the transformer.

[0055] In a second example case, the first graph 330 represents the detected true power, while the second graph 340 represents the predetermined true power threshold value. Accordingly, for a given temperature, in particular, for a measured temperature measured by the temperature sensor 210, the detected true power value has in this second example case a lower value than the predetermined true power threshold value. Therefore, in this second example case, it is considered that the coolant flow is not sufficient to cool the transformer.

[0056] As shown in Fig. 2, the temperature sensor 210 arranged within welded thermowells can measure the temperature of the transformer 200. The temperature sensor 210 is typically in communication (i.e. signal or data communication) with the controller 130 (and vice versa). For example, the temperature sensor 210 is connected by a signaling line 230 for transmitting the measured temperature data. Accordingly, the temperature sensor 210 can have an analog or a digital output for sending data to the controller 130.

[0057] The controller 130 in communication with the temperature sensor 210 receives from the temperature sensor 210 the measured temperature of the transformer 200. According to some embodiments, which can be combined with embodiments described herein, comparing the detected true power threshold value includes measuring the true power value supplied to the cooling unit such as, for example, a true power consumed by an oil pump, wherein the comparison is coupled with a temperature measure. Hence, it could be detected whether a minimum flow of a coolant such as, for example, an oil flow, is provided.

[0058] Fig. 4 shows a chart illustrating a method 400 of operating a transformer 200 according to embodiments described herein. A flow of a coolant along a cooling path 170 is generated by the cooling unit 110 (box 410). In particular, flow of the coolant is generated by the cooling unit 110 for forced cooling of the transformer 200. In step 420, a true power value supplied to the cooling 110 is measured. The detected true power value is compared with a predetermined true power threshold value in step 430. According to some embodiments, the method further includes detecting, based on the comparison of the detected true power value and the predetermined true power threshold value, whether the cooling unit 110 is in a desired operational condition (box 440).

[0059] In further embodiments, the predetermined true power threshold value may be a function of temperature. The predetermined threshold value may be then adjusted based on the detected temperature of the transformer. Accordingly, the method according to embodiments described herein can further include comparing the detected true power value with a temperature adjusted predetermined true power threshold value (box 450).

[0060] According to some embodiments, which can be combined with embodiments described herein, the cooling unit 110 can be a circulating pump adapted to generate a flow 150 of a transformer cooling fluid circulating in a cooling circuit 220 of the transformer 200, as exemplarily shown in Fig. 2.

[0061] According to some embodiments, which can be combined with embodiments described herein, the transformer may include a second cooling unit for forced cooling of the transformer. The second cooling unit may be adapted to generate a second flow of a coolant along a second cooling path for forced cooling of the transformer. According to some embodiments, a second true power value supplied to the second cooling unit may be measured. The detected second true power value may be then compared with a predetermined second true power threshold value. In particular, the second cooling unit can be a cooling fan generating an air flow for forced air cooling of the transformer.

[0062] Embodiments of the present disclosure may be used for transformers such as, for example, 3-phase transformers, e.g. for distribution or the like, single-phase transformers, in particular single phase traction transformers, measurement transformers, insulation transformers for traction, auxiliary, double insulation or the like, or for transformers integrated in power electronic converters, such as, for example, a power-electronic traction transformer. Embodiments of the present disclosure may also be used for liquid-cooled inductors.

[0063] According to some embodiments, which can be combined with embodiments described herein, the coolant flow detecting device 100 may further include a network interface for connecting the device to a data network, in particular a global data network. The data network may be a TCP/IP network such as Internet. The controller 130 of the coolant flow detecting device 100 may be operatively connected to the network interface for carrying out commands received from the data network. The commands may include a control command for controlling the transformer, the cooling unit 110, or for performing tasks such as, for example, monitoring the coolant flow 150 by measuring the true power value supplied to the cooling unit 110, receiving data from the controller 130, sending data to the controller 130.

[0064] In some embodiments, the controller 130 is adapted for carrying out the task in response to the control command received from the data network. The commands may include a status request. In response to the status request, or without prior status request, the controller 130 may be adapted for sending a status information to the network interface, and the network interface is then adapted for sending the status information over the network. The commands may include an update command including update data. In this case, the controller 130 is adapted for initiating an update in response to the update command and using the update data.

[0065] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

1. A method of operating a transformer (200), wherein the transformer generates heat when being operated and wherein the transformer includes a cooling unit (110) for forced cooling of the transformer, the method comprising:

generating by the cooling unit a flow (150) of a coolant along a cooling path (170) for forced cooling of the transformer;
measuring a true power value supplied to the cooling unit (110); and
comparing the detected true power value with a predetermined true power threshold value.

2. The method according to claim 1, wherein the predetermined true power threshold value is a function of temperature.

3. The method according to claim 2, further comprising: detecting a temperature of the transformer (200), wherein the predetermined true power threshold value is temperature-adjusted based on the detected temperature of the transformer.

4. The method according to any one of the preceding claims 1 to 3, further comprising: detecting, based on the comparison of the detected true power value and the predetermined true power threshold value, whether the cooling unit (110) is in a desired operational condition.

5. The method according to claim 4, wherein a signal is emitted, if the cooling unit (110) is not in a desired operational condition, wherein the signal is selected from the group consisting of: an electrical signal, an acoustic signal, a visual or optical signal, a mechanical signal, and a combination thereof.

6. The method according to any one of the preceding claims 1 to 5, wherein the cooling unit (110) is or comprises a circulating pump adapted to generate a flow (150) of a transformer cooling fluid circulating in a cooling circuit (220) of the transformer (200).

7. The method according to any one of the preceding claims 1 to 6, wherein the transformer includes a second cooling unit for forced cooling of the transformer by generating, by the second cooling unit, a second flow of a coolant along a second cooling path for forced cooling of the transformer, wherein the method further comprises:

measuring a second true power value supplied to the second cooling unit; and
comparing the detected second true power value with a predetermined second true power threshold value, wherein
the second cooling unit is a cooling fan generating an air flow for forced air cooling of the transformer.

8. The method according to any one of the preceding claims 1 to 7, wherein measuring the true power value supplied to the cooling unit (110) includes performing a measurement on-line of a power supply line (160) of the cooling unit (110).

9. The method according to any of the preceding claims 1 to 8, wherein measuring the true power value includes measuring a value selected from the group consisting of:

a voltage, a current, a time, a phase difference, and combinations thereof.

10. A coolant flow detecting device (100) for a transformer (200), wherein the transformer (200) generates heat when being operated and wherein the transformer (200) includes a cooling unit (110) for forced cooling of the transformer (200), the coolant flow detecting device (100) comprising:

a detector (120) for measuring a true power value supplied to the cooling unit (110), wherein the cooling unit (110) is adapted to generate a flow (150) of a coolant along a cooling path (170) for forced cooling of the transformer (200); and
a controller (130) for comparing the detected true power value with a predetermined true power threshold value.

11. The coolant flow detecting device (100) according to claim 10, wherein the cooling unit (110) is or comprises a circulating pump adapted to provide a flow (150) of a transformer cooling fluid circulating in a cooling circuit (220) of the transformer (200).

12. The coolant flow detecting device (100), according to any one of the claims 10 and 11, wherein the controller (130) is connectable to a signaling unit for emitting a signal selected from the group comprising of: an electrical signal, an acoustic signal, a visual or optical signal, a mechanical signal, and combinations thereof.

13. The coolant flow detecting device (100) according to any one of the claims 10 to 12, further comprising a temperature sensor (210) for measuring a temperature of a portion of the transformer (200).

14. The coolant flow detecting device (100) according to any one of the claims 10 to 13, wherein the controller (130) is in communication with the temperature sensor (210).

15. The coolant flow detecting device (100) according to any one of the claims 10 to 14, further comprising a network interface for connecting the coolant flow detecting device (100) to a data network,
wherein the controller (130) is operatively connected to the network interface for at least one of: carrying out a command received from the data network, and sending status information of the coolant flow detecting device (100) to the data network.

Fig. 1

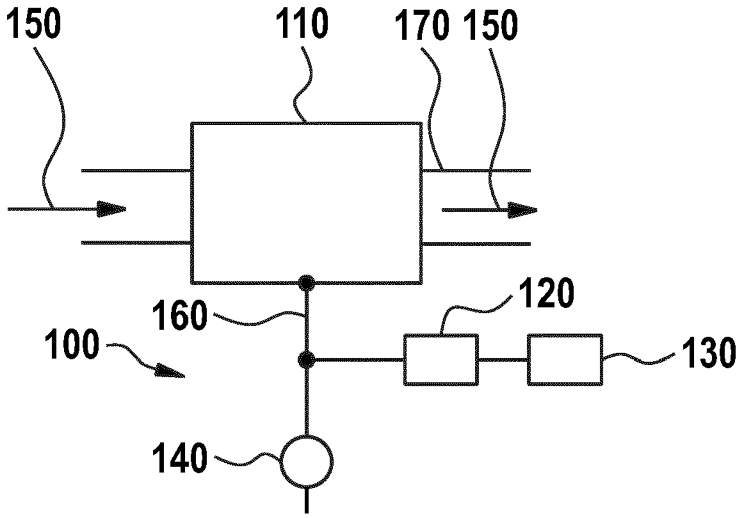

150
110
170
150
120
160
100
130
140

Fig. 2

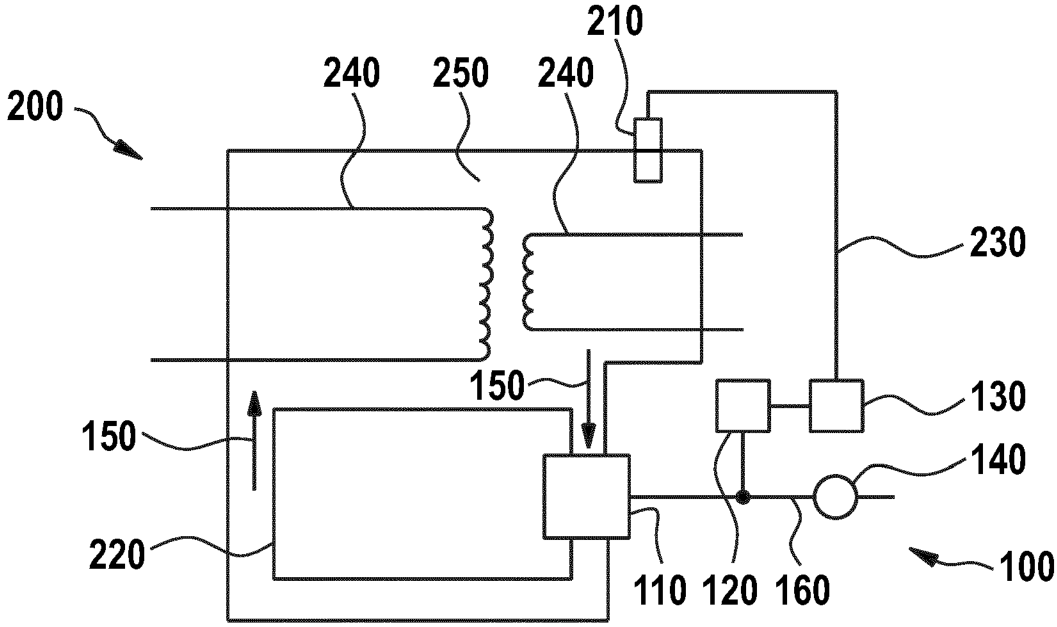

210
240
250
240
200
230
150
130
150
140
220
110
120
160
100

Fig. 3

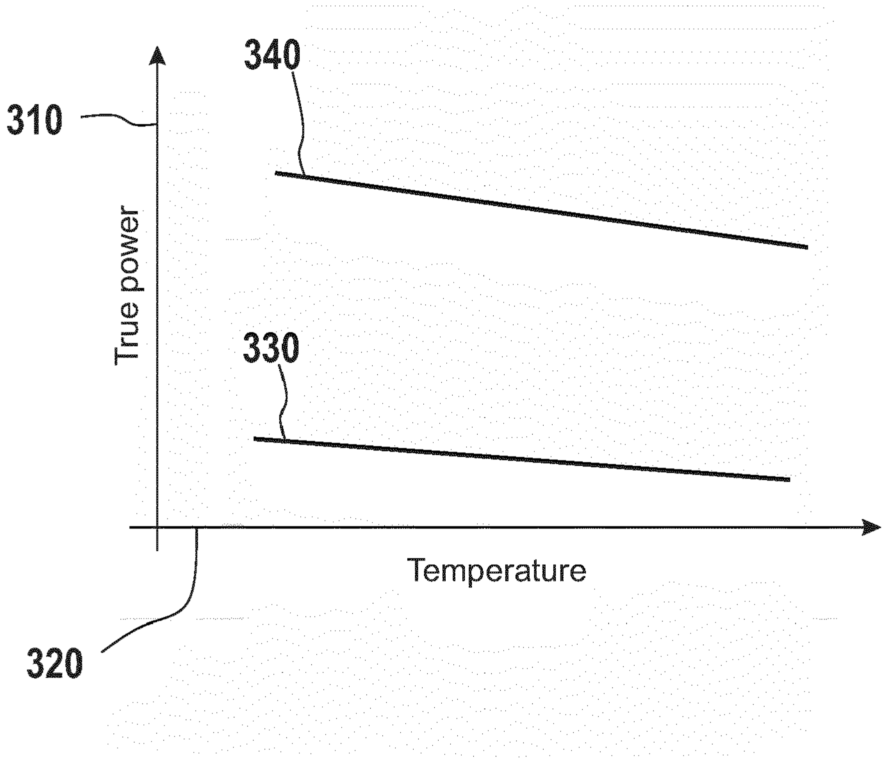
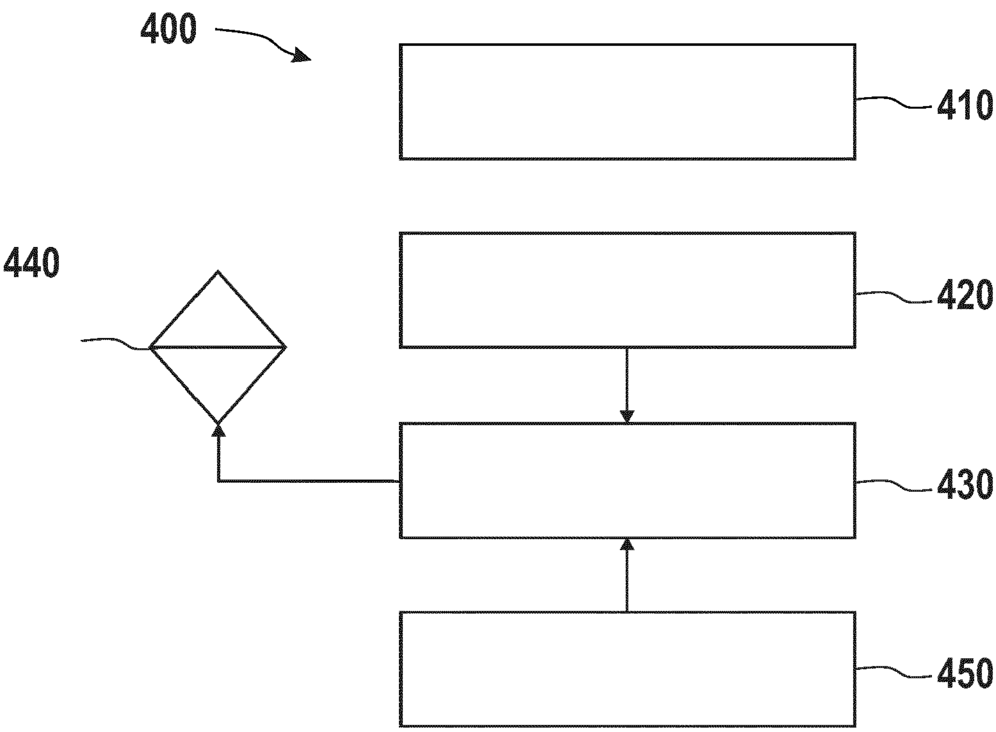

340
310
True power
330
Temperature
320

Fig. 4


400
410
440
420
430
450

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EUROPEAN SEARCH REPORT

Application Number
EP 17 16 8820

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 October 2017	Rouzier, Brice

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EUROPEAN SEARCH REPORT

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1

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