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(54) **Method and device for detecting failure of a vacuum interrupter of an on load tap changer**

(57) A method for detecting failure of a vacuum interrupter in an on load tap changer, wherein the tap changer comprises; an oil filled housing, a diverter switch including a movable contact (MC, RC), and at least one vacuum interrupter (MVI, RVI) arranged to interrupt a cur-

rent through the movable contact of the diverter switch, The method comprises; repeatedly,
 - measuring a hydrogen content in the oil, and
 - determining whether there is a failure in the vacuum interrupter (MVI, RVI) based on the measurement of hydrogen content in the oil.

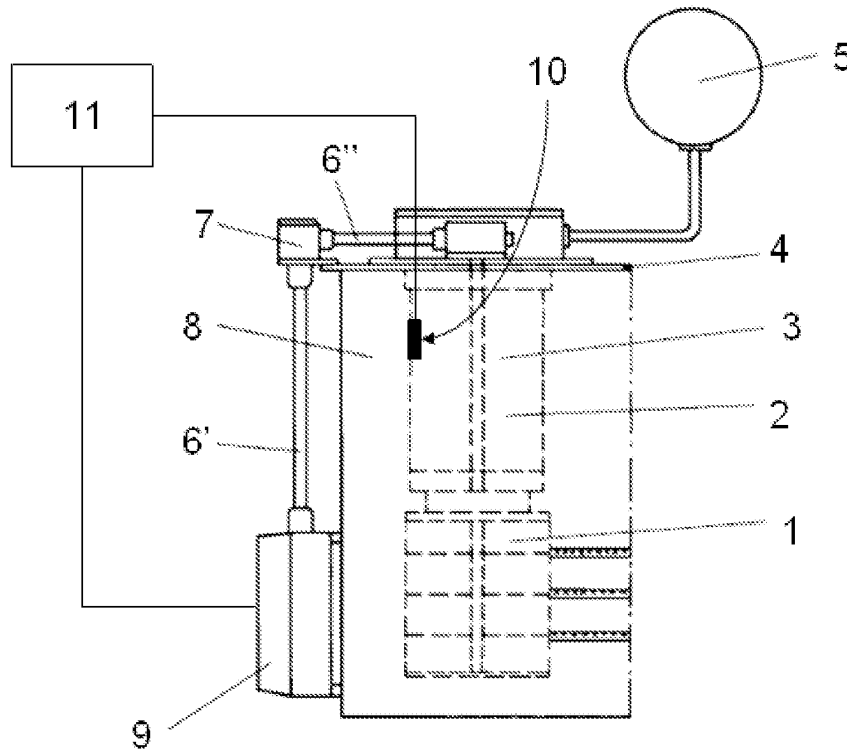


Figure 1

Description

TECHNICAL AREA

5 **[0001]** The invention relates to a method and device for detecting failure of a vacuum interrupter in an on-load tap-changer, wherein the tap changer comprises; an oil filled housing, a diverter switch (3) including a movable contact (MC, RC), and at least one vacuum interrupter (MVI, RVI) arranged to interrupt a current through the movable contact of the diverter switch.

10 TECHNICAL BACKGROUND

[0002] A tap changer is a device used with transformers for regulation of the voltage levels. This is achieved by having the tap changer altering the number of turns in a winding of the transformer.

15 **[0003]** On load tap changers (OLTC) generally comprises of a diverter switch and a tap selector switch operating as a unit to effect transfer current from one voltage tap to the next.

[0004] The diverter switch does the entire on load making and breaking of currents, whereas the tap selector pre-selects the tap to which the diverter switch will transfer the load current. The tap selector operates off load. When the power output from a transformer is to be changed from one voltage level to another, this occurs by first connecting the selector to that tapping point of the transformer winding which corresponds to the new voltage level while the diverter switch is still feeding from the existing voltage level.

20 **[0005]** The connection of the selector thus takes place without current load. When the selector is connected to the tap for the new voltage level, a switching operation then takes with the aid of the diverter switch such that output current is taken out from the new tapping point of the transformer. When a transformer has a plurality of tapping points, switching normally only occurs between two tapping points which are close to each other in terms of voltage. If an adjustment to a more distant location should be required, this takes place step by step. A diverter switch of the kind referred to here is normally used for control of power or distribution transformers. The OLTC may also advantageously be used for control of other types of electrical devices, such as, power transmission or distribution products, such as reactors, industrial transformers, phase shifters, capacitors or the like.

25 **[0006]** The operation of the diverter switch involves commutation from one circuit to another with ensuing occurrence of an electric arc. The diverter switch together with all subsystems is placed in a tank and submerged in oil. The on-load tap changer comprises the tank together with oil, diverter switches and subsystems.

30 **[0007]** The oil in the tank acts as electric insulator and as a coolant to remove the generated heat in the OLTC. The oil will also quench the arcs generated during switching. The arcing during the operation of the OLTC will pollute the insulating oil and wear the switch contacts.

35 **[0008]** To overcome the arcing in oil is previously known to use vacuum switches or vacuum interrupters for those switching operations where an arc arises. The electrical contact wear and arcs will then only arise in the vacuum switch. For an appropriate procedure from an electrical point of view, a diverter switch of this kind is provided with at least one main branch and one resistance branch each with a vacuum interrupter.

40 **[0009]** A diverter switch of the above kind is previously known from, for example, US 5,786,552. The diverter switch described therein thus has one main branch and one resistance branch, in the steady state connected in parallel and connected to an output line. Each branch is provided with a vacuum switch and a contact connected in series therewith. These are operated in a definite sequence when diverter switching is to take place, in which case it is important to ensure that the main branch is operated before the resistance branch for the OLTC but for some load interrupters the main branch is not operated before the resistance branch. In this way, the vacuum switch of the main branch may be dimensioned for breaking of the load current only and the vacuum switch of the resistance branch for the circulating current that arises. In case of the reverse sequence, the vacuum switch of the main branch would be forced to break the sum of these currents and thus be dimensioned therefore.

45 **[0010]** In case of a vacuum interrupter failure, the auxiliary contact system in the OLTC is capable to break the current a limit number of operations, dependent of OLTC type and load, possibly between 10 to 500 times.

50 **[0011]** If the auxiliary contact system have to break the current more than the limit number of times, the wear of the auxiliary contacts by arcs lead to that the contacts no longer can connect and lead current. If auxiliary main contacts can not connect two things can happen:

55 1. The main circuit is interrupted and the load is carried over the resistance circuit. With the continuous full load on the transition resistor, the resistor will eventually melt and break with a growing arc inside the OLTC as a result. This arc will hopefully be detected and should result in an immediate emergency shut-down of the OLTC-transformer system. A long repair or exchange of the diverter switch will be the result and during the repair time the transformer will be off-line.

2. A standing arc appear over auxiliary contacts which could lead to a short circuit between two phases which will lead to a catastrophic failure e.g. explosion or fire. If one is lucky the standing arc is quenched and one is back to point 1.

5 **[0012]** Therefore, it is important to monitor the operation of the vacuum interrupters to prevent the possible failures above. There is currently no simple and reliable way of detecting if a vacuum interrupter in a tap changer fails.

SUMMARY OF THE INVENTION

10 **[0013]** One object of the present invention is to provide a method for detecting failure of vacuum interrupters of a On-Load Tap-Changer (OLTC).

[0014] This object is achieved by the method as defined in claim 1.

[0015] The method comprises repeatedly measuring a hydrogen content in the oil of the housing, and determining whether there is a failure in the vacuum interrupter based on the measurement of hydrogen content in the oil.

15 **[0016]** Another object of the present invention is to provide a device for detecting failure of vacuum interrupters of a tap changer.

[0017] This object is achieved by the device as defined in claim 10.

[0018] The device comprises an oil filled housing arranged with a sensor 10 for repeatedly measuring the content of hydrogen in oil, and a computing unit is configured to analyze the measurements of hydrogen content in the oil and to determine if there is a failure in the vacuum interrupters (MVI, RVI).

20 **[0019]** The object of the invention is solved by realizing that if the vacuum interrupter fails, current is no longer interrupted by the vacuum interrupters but the auxiliary contact system. The auxiliary contact has to break the current, thus creating arcs in the oil. These arcs combined with the known fact that arcs in insulation oil increase the amount of hydrogen in the insulating oil. With a hydrogen sensor, detecting the absolute amount of hydrogen in oil or the rate of change of hydrogen in oil, it is possible to detect that the vacuum interrupter has not been capable to break the current and thus
25 allows the detection of vacuum interrupter failure.

[0020] In another embodiment of the present invention, the method further comprises the step of;

- storing the measurement of hydrogen content in the oil, and
- determining whether there is a failure in the vacuum interrupter (MVI, RVI) based on the measurement of hydrogen
30 content in the oil and at least one stored measurement of hydrogen content in the oil.

[0021] The determination whether there is a failure in the vacuum interrupter can be done by comparing the measured level of hydrogen in oil with a fixed maximum allowed hydrogen level and/or by comparing the increase of hydrogen in oil over time by using stored previous measurements of hydrogen in oil.

35 **[0022]** In another embodiment of the present invention, the method further comprises the step of;

- executing an action if a failure is determined in vacuum interrupter.

40 **[0023]** The action can be to send a warning to the control system of the tap changer or transformer. The warning could also be sent to a plant wide control system. The action can also be to only allow a limited number of critical operations without overload of the diverter switch. The action can also be to stop the diverter switch from moving at all. The selected action can depend on the level of hydrogen in oil or the rate of increase of the level of hydrogen in oil.

[0024] When a serious vacuum interrupter failure has been detected the OLTC have to immediately stop maneuvering or only make a limited number of critical operations without overload if these are considered critical for the operation of
45 the system it serves. The limited number of operations of the diverter switch can be less than 200 or even less that 20 until the OLTC have been checked by maintenance personnel.

[0025] When the OLTC stops maneuvering the transformer can still be used but the voltage level is no longer controllable but this is a preferred state to the case when the error is undetected and the OLTC undergoes a catastrophic failure.

50 **[0026]** In another embodiment of the present invention, the step determining whether there is a failure in the vacuum interrupter comprises the steps of repeatedly;

- receiving data of the operation of the tap changer
- calculating an expected change in hydrogen content based on a mathematical model of the tap changer and said
55 data of the operation of the tap changer, and
- determining if there is a failure of the vacuum interrupter based on the calculated expected change in hydrogen content and least two of the hydrogen content measurements.

[0027] To repeatedly perform the steps means that they are performed almost continuously or in discrete time steps

with seconds between or with longer time steps with several minutes between. The operation of the tap changer is the timing of switching moves of the diverter switch and load current at the time of the switching moves. The model could be a physical model to project the hydrogen release based on the number of switches and the load current or the model could be a look-up model based on measurements and/or past data where the average hydrogen release is calculated based on the number of switches and the load current.

[0028] The level of hydrogen in the tap changer oil will naturally vary dependent on how the tap changer is operated i.e. how often the taps are performed and what load currents have to be interrupted. This model based determination of vacuum interrupter failure is much less likely to make errors in determining failures than a system that only compares the measured hydrogen level in oil with an absolute hydrogen level. To make a faulty determination of vacuum interrupter failure could lead to an unnecessary shut down of the transformer - tap changer system. This unnecessary shut down would lead to a potential power loss of all connected systems e.g. industrial installation or residential housing which would be very expensive.

[0029] In another embodiment of the present invention, the determination if there is a failure of the vacuum interrupter is based on if

$$[H_2^{\text{mes}}(\text{new}) - H_2^{\text{mes}}(\text{old})] - \Delta H_2^{\text{est}} > \text{eps}$$

is true.

[0030] $H_2^{\text{mes}}(\text{new})$ is a parameter describing the current measured hydrogen content in oil, this can be a single measurement or a some mean or average of a number of measurements.

[0031] $H_2^{\text{mes}}(\text{old})$ is a parameter describing the previously measured hydrogen content in oil, this can be a single measurement or a some mean or average of a number of previous measurements.

[0032] ΔH_2^{est} is an expected change in hydrogen content in oil based on operation of the tap changer. The operation of the tap changer is the timing of switching moves of the diverter switch and load current at the time of the switching moves.

[0033] eps is a safety parameter that will ensure that a failure of the vacuum interrupter is not determined unless the measured increase in hydrogen is above eps. eps can be in the order of a few ppm up to several hundred ppm of hydrogen in oil, depending on type of tap-changer, load, age of oil and risk of a false alarm.

[0034] The hydrogen detection in the tap changer has additional advantages in that it could also be used to detect:

- commutation sparks - which will generate much less hydrogen in oil than an full arc,
- partial discharges - will generate a constant, low increase of hydrogen in oil, a different hydrogen signal than the hydrogen signal for an arc,
- serious overheating with associated arcs will generate a different hydrogen signal than the hydrogen signal for an tap changing arc.

[0035] In another embodiment of the present invention, the computing unit is configured to send a warning to the control system if a failure of the vacuum interrupters (MVI, RVI) is detected.

[0036] In another embodiment of the present invention, the computing unit is configured to send a signal to the control system to stop or limit movement of the diverter switch if a failure of the vacuum interrupters (MVI, RVI) is detected.

[0037] In another embodiment of the present invention, the computing unit is configured to receive data of the operation of the tap changer and said computing unit is configured to calculate an expected change in hydrogen content and compare the expected change in hydrogen content with the analyzed measurements of hydrogen content in the oil to determine failure in the vacuum interrupters (MVI, RVI).

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The drawings constitute a part of this specification and include exemplary embodiments to the invention, which may be embodied in various forms.

Fig 1. Shows schematically an on-load tap-changer in a transformer with an embodiment of the present invention

Figures 2a-2e shows schematically the switching of an on load tap changer without vacuum interrupters.

Figures 3a-3g shows schematically the switching of an on load tap changer with vacuum interrupters.

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Figure 4 shows one situation where there would be arcing in the auxiliary switches in an on-load tap-changer with vacuum interrupters.

Fig 5 is a schematic view of an on-load tap changer.

Fig 6-8 is a schematic view the development of hydrogen content in oil over time in the tap changer as well as different warning or alarm levels.

DETAILED DESCRIPTION OF THE DRAWINGS

[0039] Detailed descriptions of the preferred embodiment are provided herein. It is to be understood, however, that the present invention may be embodied in various forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but rather as a basis for the claims and as a representative basis for teaching one skilled in the art to employ the present invention in virtually any appropriately detailed system, structure or manner.

[0040] Figure 1. shows schematically an on-load tap-changer 2 in a transformer 8 with an embodiment of the present invention. The tap-selector 1 is mounted beneath the diverter switch 3. The movements of the OLTC get the energy from a motor drive mechanism 9, here mounted on the wall of the transformer 8. The movements from the motor 9 are transferred by shafts 6', 6" and a bevel gear 7. An oil conservator 5 ensures that there is enough of oil in the OLTC at all temperatures. A hydrogen sensor device 10 is immersed in the oil, the placement in the drawing is only indicative it can be arranged anywhere in the housing. The hydrogen sensor device 10 signals to a drive control unit 11 which control the movements of the motor 9 driving the diverter switch 3. The transformer 8 and the OLTC 2 are both oil filled but have different housings and the oil in the OLTC and the oil in the transformer are never in contact. It is also possible to arrange the OLTC outside the transformer tank.

[0041] Figures 2a-2e shows schematically the switching sequence of the on-load tap-changer from position 6 to position 5 on the transformer winding.

[0042] The dominant electrical flows are indicated by the grey arrows.

[0043] The sequence is designated the symmetrical flag cycle. This means that the main switching contact of the diverter switch breaks before the transition resistors are connected across the regulating step. This ensures maximum reliability when the switch operates with overloads.

[0044] At rated load the breaking takes place at the first current zero after contact separation, which means an average arcing time of approximately 4-6 ms. The total time for a complete sequence is approximately 50 milliseconds. The tap change operation time of the motor-drive mechanism is approximately 5 s/step.

Fig 2a: Selector contact V connects tap 6 and selector contact H on tap 5. The main contact x carries the load current.

Fig 2b: The main contact x has opened. The load current passes through the resistor Ry and the resistor contact y.

Fig 2c: The resistor contact u has closed. The load current is shared between Ry and Ru. The circulating current is limited by the resistance of Ry plus Ru.

Fig 2d: The resistor contact y has opened. The load current passes through Ru and contact u.

Fig 2e: The main contact v has closed, resistor Ru is bypassed and the load current passes through the main contact v. The on-load tap-changer is now in position 5.

[0045] Arcs occur in any of the movements where a contact is opened.

Figures 3a-3g shows schematically the switching of an on load tap changer with vacuum interrupters. By using an auxiliary contact system (MC, RC) in combination with the vacuum interrupters (MVI, RVI) only two vacuum interrupters are required per phase.

Fig. 3a shows the current path during normal operation, from x to the star point (could also be to the next phase). The main electrical path is indicated by grey arrows.

When commuting the load from x to v, the steps of the operation sequence are;

Fig 3b - open the main vacuum interrupter (MVI) and hence let the current flow through the transition resistor (TR).

Fig 3c, 3d - the main contact (MC) is then rotated in order to connect to v.

Fig 3e - the main vacuum interrupter then closes, meaning that the new tap is connected, leading to an associated circulating current driven by the difference in voltage potential.

Fig 3f - the transition resistor is disconnected when opening the resistor vacuum interrupters (RVI). The load current is now via the normal path from v to the star point.

Fig 3g - the resistor contact (RC) is then rotated and put in position.

Fig 3h - finally, the sequence is completed and next service position is reached when the resistor vacuum interrupter is closed.

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Fig 4 is the same position as in fig 3c but with the difference that the main vacuum interrupter (MVI) has failed to open or failed break the current in the main auxiliary contact (MC). When main contact (MC) is rotated in order to connect to v, the current is broken by the movement in the main auxiliary contact (MC). The appearing arc is quenched by oil but as the auxiliary contacts are not designed to take repeated arcs some damage will occur. If this happens more than 10-500 times, dependent on the load current, there is a risk that the auxiliary contacts will fail and the OLTC will experience a catastrophic break-down. If the current is interrupted by auxiliary contacts and quenched by oil the hydrogen concentration in will increase rapidly in the oil and detecting this will be a sure way of indicating this error state.

Fig 5 is a schematic view of an on-load tap changer, which is used with embodiments of the present invention. The illustrated tap changer 12 is formed of two main parts, a diverter switch 24 and a tap selector 26, interrelated by connections 30. The diverter switch 24 may include a conventional top housing 28.

Fig 6 shows a schematic view of a possible development of hydrogen content/concentration 46 in oil over time in the tap changer. The hydrogen detector measures the hydrogen content/concentration 46 in oil and the analysis of the measurement compares the measured data with different warning or alarm levels, for example, a warning level 40, first alarm level 41 and second alarm level 42.

[0046] Each level can be associated with different actions. For example, when the hydrogen concentration goes above 43 warning level 40, the control system alerts the monitoring system for the transformer or a plant wide control system alerting operators that something might not be OK with the tap changer. When the hydrogen concentration goes above 44 first alarm level 41, the control system alerts the monitoring system for the transformer or a plant wide control system alerting operators and will only perform the most necessary tap changes. When the hydrogen concentration goes above 45 second alarm level 42, the control system alerts the monitoring system for the transformer or a plant wide control system and alerting operators and stops all tap changes.

[0047] Fig 7 shows a schematic view of a possible development of hydrogen content/concentration 46 in oil over time in the tap changer. The hydrogen detector measures the hydrogen concentration 46 in oil and the analysis of the measurement compares the measured hydrogen concentration data series with different warning or alarm levels of increase of hydrogen concentration.

[0048] At 52 the rate of increase of measured hydrogen concentration is larger than a possible warning increase 50. At 53 the rate of increase of measured hydrogen concentration is larger than a possible alarm increase 51. The analysis of the data series 46 might include smoothing or filtering of the measured values.

[0049] Fig 8 shows a schematic view of a possible development of hydrogen content/concentration 46 in oil over time in the tap changer where each tap change is associated with a up-tic of the concentration of hydrogen. This is to illustrate that the analysis system also have to include the frequency of tap changes or the time between taps. A large number of tap changes 51 might generate a larger increase of hydrogen than on with much fewer taps 50. But the increase of the curve 50 with few taps might indicate a problem. The system have to be able to separate the two cases 50, 51 and might give a warning/alarm for 50 but not for 51. The relative size of the curves and alarm levels in figures 6-8 are only for illustration.

[0050] It is known that arcs in insulating oil generate hydrogen in the oil. This effect is sometimes used to monitor the operation of a transformer. It has not been used to monitor OLTC without vacuum interrupters since arcs in oil occur in normal operation.

[0051] With the introduction of OLTCs with vacuum interrupters, the normal arcs in oil have been removed and during normal operation, all arcs occur in the vacuum interrupters. If an arc in oil do appear in a OLTC with vacuum interrupters, this is an indication of something is seriously wrong.

[0052] For a conventional OLTC with arc quenching in oil operating according to the flag cycle principle as can be seen in figures 2, there are two interruptions with arcs occurring for every tap operation. One arc occurs when breaking the main contact (i.e. between fig 2a and fig 2b) and one arc when breaking the transition contacts (i.e. between fig 2c and fig 2d).

[0053] The arc in the main contacts has a current equal to the load current while the current in the transition contacts is composed by half the load current and the circulation current. The circulation current is dependent of the step voltage and the resistance of the transition resistor and is thus load independent.

[0054] Each of these arcs lasts normally for max half a period and the average will be half a period that is 5 ms for 50 Hz. The energy in these arcs determines the amount of gas that is generated. The gas generation can be estimated to be linear with the energy dissipation of the arcs.

[0055] The primary goal for an OLTC with arc quenching in vacuum interrupters is to prevent arcs in oil. The arcing in the oil gives several disadvantages such as higher erosion of the contact material in the breaking contacts and deterioration of the oil due to the high temperatures in the arcs. The deterioration of the oil generates substances that reduces the dielectric withstand of the oil, especially in the presence of moisture, as well as increases the wear of the mechanism.

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[0056] The diverter switch breaks the current from one tap before it connects the other one. In order not to generate interruptions in the circuit, the load current goes through the transition contacts during the time it takes for the main contacts to safely break the current from tap 1 until tap 2 is connected.

[0057] If the breaking of load in an OLTC should fail, for example, due to a faulty vacuum interrupter, there is a risk for connecting tap 2 before tap 1 is disconnected. Due to the electrical properties of the transformer, a short circuit of one regulating step, results in huge currents that destroys not only the OLTC but also the transformer winding/windings. There will also be a severe risk for even larger damages due to fire, explosions, etc.

[0058] By designing such that the commutation of the currents is carried out by the vacuum interrupters these become critical components. If they fail to break the serious faults earlier described might happen.

[0059] By designing the auxiliary contact such that they can break the load current or circulating current in case a vacuum interrupter fails, a much larger safety margin against such serious failures is obtained.

[0060] Since the auxiliary contacts are made primarily for conducting current the materials are selected for low resistance and not for good arc resistance. The goal is that they should be able to make half a cycle of operation while breaking maximum the rated load current with maintained function both as current conductor and as breaking contact.

[0061] Thus, some supervisory device must give alarm before the contacts are destroyed so much by the arcs that they not fulfils their functions. The aim is to give alarm not to trip the transformer. Since several operations are possible it does not need to trip the transformer. A number of detections methods are possible such as pressure detection, oil flow detection (in the tube to the oil conservator), light detection, radio emission detection, etc.

[0062] This invention deals with the possibility to use hydrogen concentration changes in the insulating oil as a parameter for detection of arcs in the oil.

[0063] It is based on the fact that arcs in the vacuum interrupter generate no gas in the oil. However, OLTCs with vacuum interrupters for high currents have normally by-pass contacts that are by-passing the vacuum interrupter circuit when the OLTC is in position, to prevent the vacuum interrupters to continuously conduct the current as well as to protect them from short-circuit currents.

[0064] The by-pass contact will generate commutation sparks when the current is commutated from the by-pass path to the vacuum interrupter circuit due to the small inductances in the circuit. These sparks will generate small amounts of hydrogen. The energy released is though only a few percent of that of a real arc in the oil and the gas generation is in relation to that.

[0065] Those OLTCs not having by-pass contacts do still have the auxiliary contacts. These do not commute any current but during switching they are potentially disconnected shortly which give them a voltage that causes minor capacitive discharge sparks. The energy in these are even smaller than that from the commutation sparks in the by-pass contacts but will give rise to small amounts of hydrogen in the oil after a large amount of operations at voltage.

[0066] The compositions of these gases are such that about 75 % is hydrogen (H₂) and about 20 % is acetylene (C₂H₂). For the small capacitive discharge sparks, the composition will be closer to 100 % hydrogen. Acetylene is easily dissolved in oil due to its similarity with the hydrocarbons in oil while hydrogen is not easily dissolved.

[0067] By analyzing the hydrogen content in the oil, cheaper and more reliable measuring devices are available compared to if a hydrocarbons should be analyzed. Continuous measurements of hydrogen in transformer oil are also a well proven method that has been in use for quite a long time.

[0068] Thus, measuring hydrogen in transformer oil is nothing new. The results must be interpreted in a way that gives a reliable supervisory method. The interpretation must work for at least a majority of different applications, at low current, at low operational frequency, when using different breathing system, etc.

[0069] There are two possible ways to interpret the hydrogen measurements:

1. Give an alarm at a certain hydrogen concentration in the oil
2. Evaluate the rate of rise of hydrogen related to the number of operation per unit of time as well as to the load current when switching.

[0070] Interpretation 1. Since there will be a certain amount of hydrogen vanishing to the surrounding atmosphere by time a small generation will soon find a equilibrium between production and vanishing resulting in a low and fairly constant concentration. The alarm level can be set as high as it works for the whole range of load currents since the hydrogen generation for arcs in oil is so much higher. Arcs in oil will give a fast rise in concentration making the alarm level to be passed even at low load currents. This device requires no intelligence and is thus a simple and cheap method.

[0071] Interpretation 2. This method requires some intelligence and availability to information about when operations occur and the load of the transformer. But it gives the advantage of being more sensitive and reacting faster especially in applications with low currents and/or low operation frequency. This method is preferably used in combination with a transformer control and protection system, such as ABB TEC or similar, that already has access to the data needed. It can of course also be made with a separate unit

[0072] The interpretation is made with a special program in the control system. The interpretation is made such that

the change in concentration of hydrogen is related to the spark energy released per unit of time. The load current is available as well as the number of operation per unit of time. The arc energy might thus be easily calculated and the hydrogen concentration is related to that.

[0073] If the load is changed and/or the operation frequency is changed, the method automatically calculates the expected values within a certain tolerance width. This width can be quite large since the difference between the hydrogen generation at normal service and arcs in oil differ so much. Thus, the calculation does not need to be very precise.

Claims

1. Method for detecting failure of a vacuum interrupter in an on load tap changer, wherein the tap changer comprises;
 - an oil filled housing,
 - a diverter switch (3) including a movable contact (MC, RC), and
 - at least one vacuum interrupter (MVI, RVI) arranged to interrupt a current through the movable contact of the diverter switch (3), **characterized in that** the method comprises; repeatedly,
 - measuring a hydrogen content in the oil, and
 - determining whether there is a failure in the vacuum interrupter (MVI, RVI) based on the measurement of hydrogen content in the oil.
2. The method according to claim 1, wherein the method further comprises the step of;
 - storing the measurement of hydrogen content in the oil, and
 - determining whether there is a failure in the vacuum interrupter (MVI, RVI) based on the measurement of hydrogen content in the oil and at least one stored measurement of hydrogen content in the oil.
3. The method according to any of the claims 1-2, wherein the method further comprises the step of;
 - executing an action if a failure is determined in vacuum interrupter.
4. The method according to claim 3, wherein the action comprising
 - generating a warning.
5. The method according to claim 3, wherein the action comprising
 - allowing only a limited number of critical operations without overload of the diverter switch.
6. The method according to claim 3, wherein the action comprising
 - stopping the diverter switch from moving.
7. The method according to any of the claims 1-6, wherein the step determining whether there is a failure in the vacuum interrupter comprises the steps of repeatedly;
 - receiving data of the operation of the tap changer
 - calculating an expected change in hydrogen content based on a mathematical model of the tap changer and said data of the operation of the tap changer, and
 - determining if there is a failure of the vacuum interrupter based on the calculated expected change in hydrogen content and least two of the hydrogen content measurements.
8. The method according to claim 7 wherein said operation data comprises; movements of contacts and load current.
9. The method according to any of the claims 7-8, wherein the determining if there is a failure of the vacuum interrupter is based on if

$$[H_2^{\text{mes}}(\text{new}) - H_2^{\text{mes}}(\text{old})] - \Delta H_2^{\text{est}} > \text{eps}$$

5 is true where,
 $H_2^{\text{mes}}(\text{new})$ - parameter describing the current measured hydrogen content,
 $H_2^{\text{mes}}(\text{old})$ - parameter describing the previously measured hydrogen content,
 ΔH_2^{est} - expected change in hydrogen content based on operational data, and
 eps - safety parameter that will ensure that a failure of the vacuum interrupter is not determined unless the measured
 10 increase in hydrogen is above eps.

10. A device for detecting failure of a vacuum interrupter in an on load tap changer, wherein the tap changer comprises;

- 15 - an oil filled housing with an diverter switch (3) comprising movable contacts (MC, RC) with vacuum interrupters (MVI, RVI) in series arranged to interrupt the current before the contacts (MC, RC) disconnects, and the on-load tap changer is **characterized in that**
- the oil filled housing is arranged with a sensor (10) for repeatedly measuring the content of hydrogen in oil, and
- a computing unit is configured to analyze the measurements of hydrogen content in the oil and to determine if there is a failure in the vacuum interrupters (MVI, RVI).

20 11. The on-load tap changer according to claim 10 wherein the tap changer comprises a control system (11) controls the movement of the diverter switch, and said computing unit is configured to send a warning to the control system if a failure of the vacuum interrupters (MVI, RVI) is detected.

25 12. The on-load tap changer according to claim 10 wherein said computing unit is configured to send a signal to the control system to stop or limit movement of the diverter switch if a failure of the vacuum interrupters (MVI, RVI) is detected.

30 13. The on-load tap changer according to any of the claims 10-12, wherein said computing unit is configured to receive data of the operation of the tap changer and said computing unit is configured to calculate an expected change in hydrogen content and compare the expected change in hydrogen content with the analyzed measurements of hydrogen content in the oil to determine failure in the vacuum interrupters (MVI, RVI).

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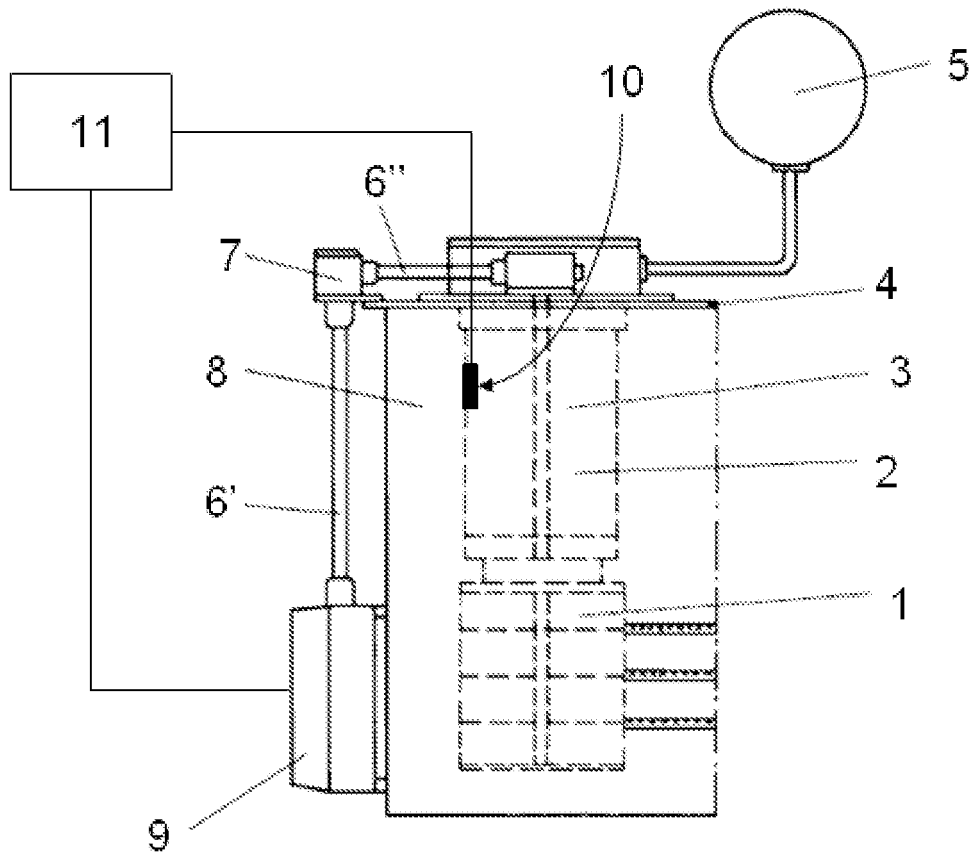


Figure 1

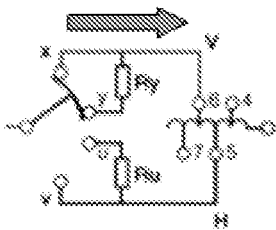


Figure 2a

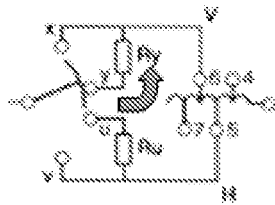


Figure 2b

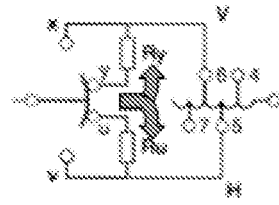


Figure 2c

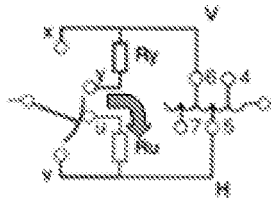


Figure 2d

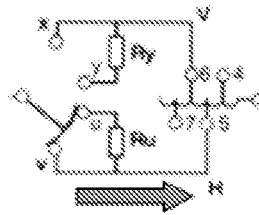


Figure 2e

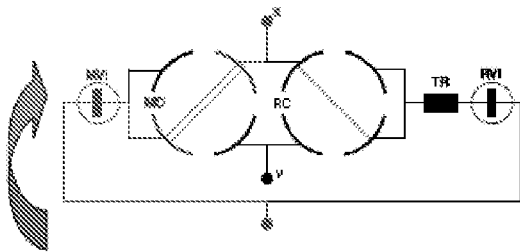


Figure 3a

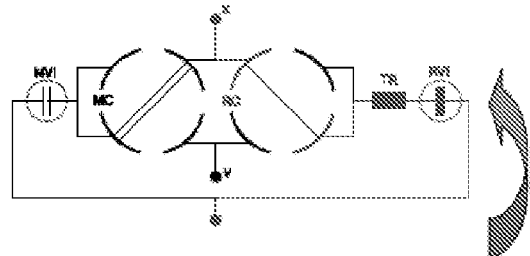


Figure 3b

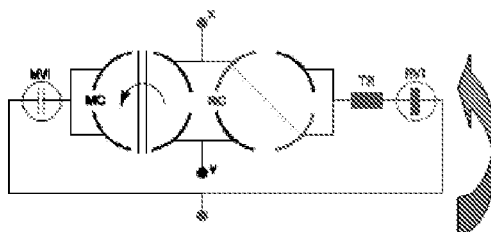


Figure 3c

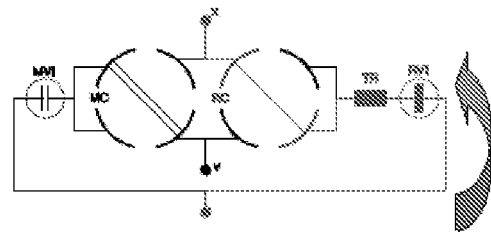


Figure 3d

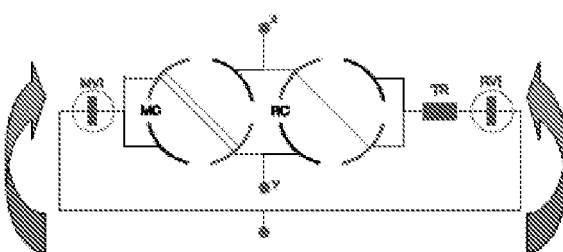


Figure 3e

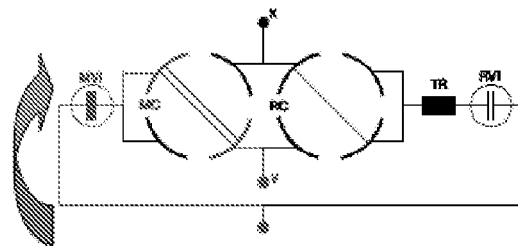


Figure 3f

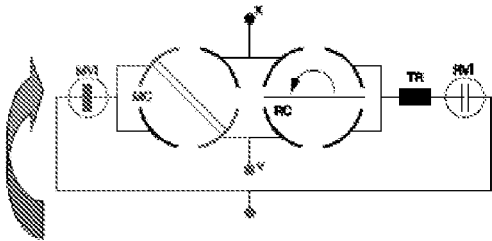


Figure 3g

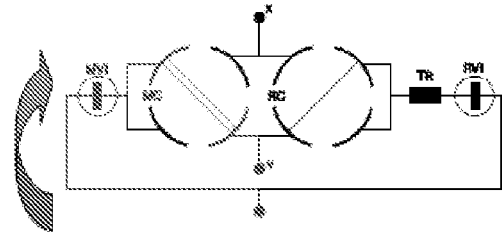


Figure 3h

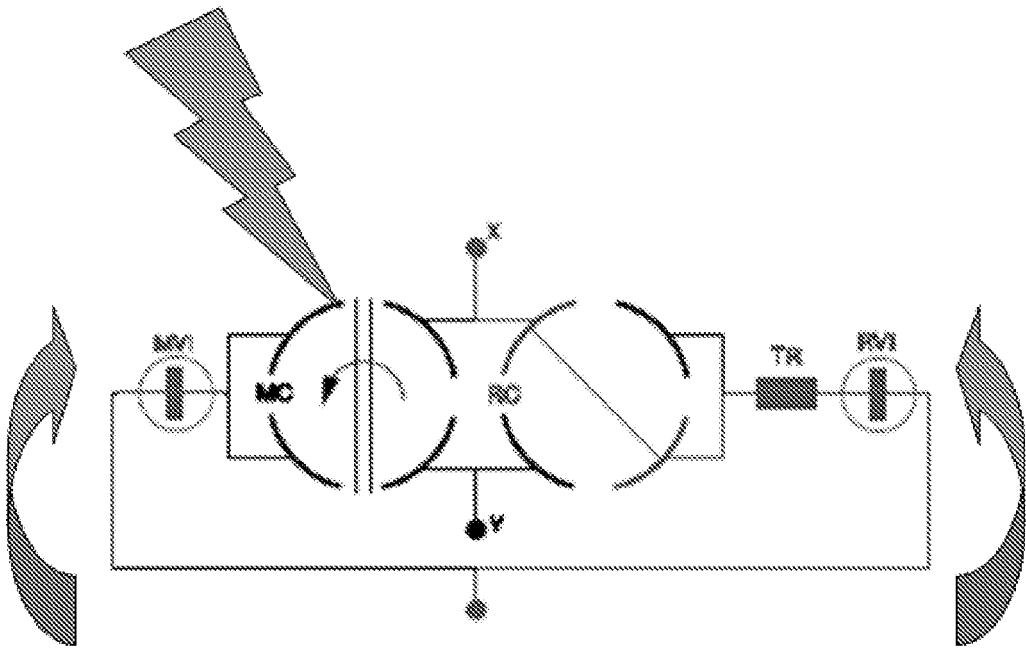


Figure 4

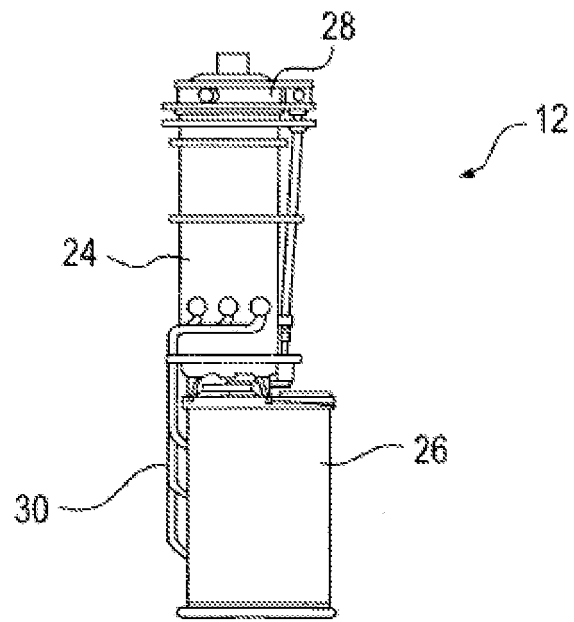


Figure 5

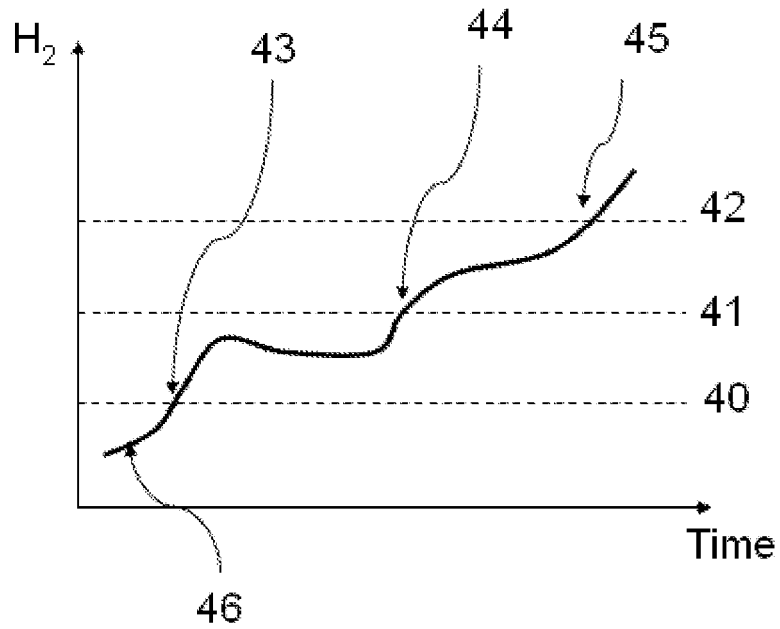


Figure 6

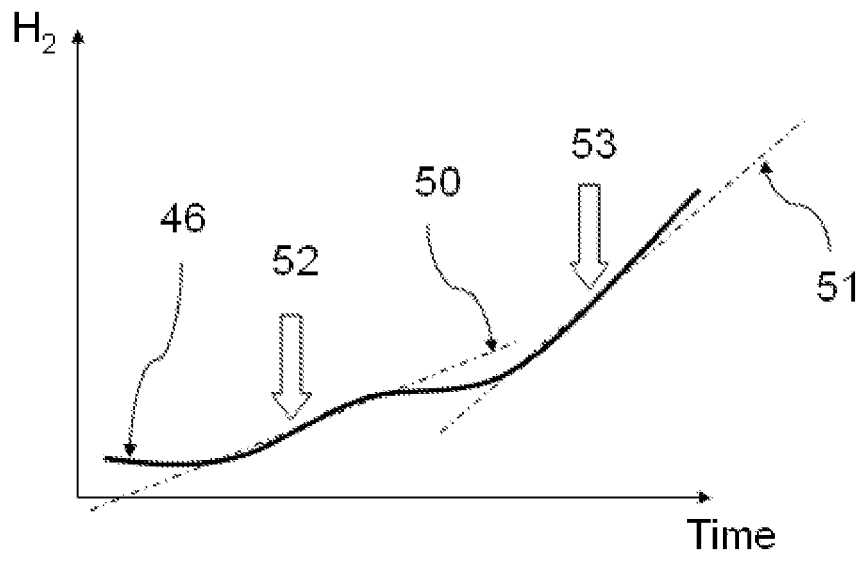


Figure 7

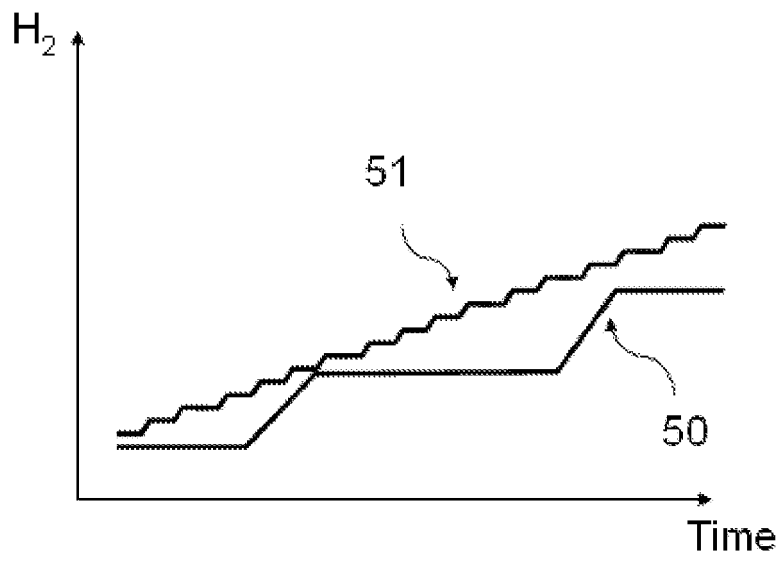


Figure 8



EUROPEAN SEARCH REPORT

Application Number
EP 09 16 3129

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 206 569 A (MCCARTY ORIN P) 14 September 1965 (1965-09-14) * the whole document *	1,10	INV. H01H9/00
A,D	----- US 5 786 552 A (DOHNAL DIETER [DE] ET AL) 28 July 1998 (1998-07-28) -----		
			TECHNICAL FIELDS SEARCHED (IPC)
			H01H
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 24 November 2009	Examiner Socher, Günther
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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ON EUROPEAN PATENT APPLICATION NO.

EP 09 16 3129

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24-11-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3206569	A	14-09-1965	NONE

US 5786552	A	28-07-1998	AT 185442 T 15-10-1999
			AU 2067895 A 25-09-1995
			BG 62224 B1 31-05-1999
			BG 100768 A 31-03-1997
			BR 9507049 A 02-09-1997
			CA 2184371 A1 14-09-1995
			CN 1143426 A 19-02-1997
			WO 9524724 A1 14-09-1995
			EP 0749627 A1 27-12-1996
			HU 75268 A2 28-05-1997
			JP 3847780 B2 22-11-2006
			JP 9510052 T 07-10-1997
			KR 100248253 B1 15-03-2000
			PL 316081 A1 23-12-1996
			RO 117823 B1 30-07-2002
			RU 2133994 C1 27-07-1999

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 5786552 A [0009]