

Description

The present invention relates to a negative feedback power supply apparatus for a load. For example, the present invention is applied to an apparatus for testing the AC magnetization characteristics of a toroidal core or cut-core type core.

In order to carry out a testing of the AC magnetization characteristics of a large number of toroidal cores, such as exciting currents, and a core loss such as a vortex current loss and a hysteresis loss it is necessary to wind windings on a core for every test.

An example of such test apparatus is that described in PROC. IEE, Volume 121, No. 11, November 1974, pages 1419, 1420. This document describes an arrangement for investigating the flux distribution and core losses in the corner joints of large power transformers. The core to be tested is energised by a distributed winding and the core flux is sensed by a second flux detection winding. The output of the second winding can be integrated with respect to time to give an accurate representation of the core flux. Feedback circuitry is used to ensure that the flux is sinusoidal. In the absence of the feedback circuitry the flux would not be quite sinusoidal as a result of distortion of the current waveform due to the resistance of the windings. Alternatively the feedback circuitry can be used to ensure that the energising coil voltage or current are maintained sinusoidal at the expense of the flux-detecting coil voltage.

It is an object of the present invention to provide a power supply apparatus for testing a core, whereby a winding operation is unnecessary.

According to the present invention there is provided an apparatus for testing a core, comprising a primary winding and a secondary winding, means connected to said primary winding for supplying input current for said primary winding and means connected to said secondary winding for detecting an output voltage induced in said secondary winding, and negative feedback means connected to said means for supplying an input current, the negative feedback means providing negative feedback to said primary winding in accordance with said output voltage characterised in that each of said primary and secondary windings has only one connector-type contact per one turn thereof to enable the windings to be mounted on the core to be tested.

Provision of the connector type contacts allows windings to be formed on the coil without the need to perform a winding operation.

Through use of the negative feedback circuitry adjustment of the input voltage is unnecessary even when the DC resistance and the equivalent AC and DC resistances of the primary winding are

changed by the contacts, and no distortion is generated in the magnetic flux density of the core, thereby enabling a correct and stable measurement.

The present invention will be more clearly understood from the description as set forth below with reference to the accompanying drawings, wherein:

Fig. 1 is a diagram showing suggested examples of tests of windings;

Fig. 2 is a circuit diagram illustrating a suggested apparatus for testing a toroidal core;

Figs. 3A and 3B are equivalent circuit diagrams of the apparatus of Fig. 2;

Fig. 4 is a diagram showing the output characteristics of the apparatus of Fig. 2;

Fig. 5 is a circuit diagram illustrating an embodiment of the power supply apparatus according to the present invention;

Fig. 6 is an equivalent circuit diagram of the apparatus of Fig. 5; and

Fig. 7 is a diagram showing an oscillation phenomenon generated in the apparatus of Fig. 5.

First a suggested apparatus for testing a toroidal core comprising the connector-type contacts but not the feedback circuitry will be explained.

As illustrated in Fig. 1, to test a toroidal core 1, test windings W_1 and W_2 may be wound on the core 1. In this case, in order to simplify the winding operation, connector-type contacts CW_1 and CW_2 are provided to reduce the desorption of the windings W_1 and W_2 . In the actual design of transformers and the like, since the thickness of the windings is as large as possible, to reduce the resistance value thereof, and the number of turns of windings is as large as possible, a current flowing therethrough is small and the reduction in potential and heat generation by the resistance component of the windings is also small. In Fig. 1, however, since the space for installing the connector-type contacts CW_1 and CW_2 is restricted, the thickness of the windings is small and the number of turns of the windings is small. As a result, it is necessary to increase an exciting current or testing supplied to the primary winding W_1 , and in addition, such a current is affected by the resistances of the windings W_1 and W_2 and the contacts CW_1 and CW_2 . In Fig. 1, note that upper and lower contacts of the connector-type connectors CW_1 and CW_2 are separated from each other when the core 1 is inserted therein, and are connected when a testing (measuring) operation is carried out, and thus a winding operation of the windings W_1 and W_2 is unnecessary.

In Fig. 2, a testing apparatus for the toroidal core 1 having the test windings W_1 and W_2 are illustrated. In Fig. 2, reference numeral 2 des-

ignates an input AC power supply, 3 an AC current meter, 4 an AC voltage meter, P_1 and P_2 terminals for the connection of the primary winding W_1 , and S_1 and S_2 terminals for the connection of the secondary winding W_2 . According to this circuit, a measurement of a primary current I_p and a measurement of core loss are carried out at the periphery of a saturated magnetic flux of the core 1, which is one of the tests of AC magnetization characteristics. Note that the measurement of core loss is made by a power meter W .

In order to easily understand the circuit of Fig. 2, an equivalent circuit thereof is illustrated in Fig. 3A, and a simplified equivalent circuit is illustrated in Fig. 3B. Note that the power meter W is omitted from Figs. 3A and 3B. In Fig. 3A, reference T designates an ideal transformer, R_p an equivalent DC resistance of the primary winding W_1 , R_c an equivalent contact DC resistance of the connector contact CW_1 , and R_{zp} an equivalent AC resistance of the primary winding W_1 . Note that the resistances of the secondary winding W_2 and the contact CW_2 are negligible. For example, the equivalent DC resistance R_p and the equivalent DC resistance R_c are unstable. That is, the resistance R_p fluctuates from 1 to 1.2 Ω due to the generation of heat by the exciting current I_p , and the contact DC resistance R_c fluctuates from 0 to 0.8 Ω due to the state of the contact CW_1 . Also, the equivalent AC resistance R_{zp} fluctuates from ∞ to 0.5 Ω due to the saturation characteristics of the core 1. Therefore, if the voltage of the AC power supply 2 is 1 V, and an exciting current I_p is supplied to the primary winding W_1 , the output voltage E_s of the secondary winding W_2 is 1 V where $R_p = 1 \Omega$, $R_c = 0 \Omega$ and $R_{zp} = \infty \Omega$, and 0.2 V where $R_p = 1.2 \Omega$, $R_c = 0.8 \Omega$, and $R_{zp} = 0.5 \Omega$, which means that the fluctuation of the output voltage E_s is large. Further, at the periphery of a saturated magnetic flux density of the core 1, an extraordinary current generated locally at one cycle of the AC current invites a spontaneous reduction in the equivalent AC resistance R_{zp} , and as a result, the waveform of the output voltage E_s generated at the secondary winding W_2 is greatly distorted. This large fluctuation and distortion leads to the generation of a large fluctuation and distortion in the magnetic flux of the core 1, which is very disadvantageous in view of the need to obtain a definite AC magnetic flux. Accordingly, to make the output voltage E_s constant, when the voltage of the AC power supply 1 is adjusted so as to correct the voltage E_s generated in the secondary winding W_2 , the distortion of the magnetic flux waveform, i.e., the distortion of the output voltage E_s , remains as illustrated in Fig. 4, and simultaneously, the peak current portion of the exciting current I_p is suppressed. Therefore, it is impossible to carry out a

correct measurement.

In Fig. 5, which illustrates an embodiment of the present invention applied to a testing apparatus for a toroidal core, an analog negative feedback loop circuit is added to the elements of Fig. 2. That is, an amplifier 5, a feedback resistor 6, and a phase adjusting circuit 7 formed by a capacitor 71 and a resistor 72 are added to the elements of Fig. 2. Note that Fig. 6 is an equivalent circuit diagram of the apparatus of Fig. 5.

Here, assume that there is no negative feedback circuit, the amplification factor F of the amplifier 5 having an output impedance O is 100, and the voltage of the AC power supply 2 is 1 V $\times$ $1/100 = 0.01$ V. Then, the circuit of Fig. 5 is substantially the same as that of Fig. 2, and therefore, if the values of the equivalent DC resistance R_p , the equivalent contact resistance R_c , and the equivalent AC resistance R_{zp} are the same as in Fig. 3A, the output voltage E_s is also changed from 1 to 0.2 V. That is, if a total amplification factor A' is determined by the ratio of the input voltage (= 0.01 V) of the AC power supply 2 to the output voltage E_s , the factor A' is fluctuated by

$$A' = 100 \sim 20.$$

Next, consider the presence of the negative feedback circuit according to the present invention. Here, the feedback ratio F is made 0.99 by the feedback resistor 6, the output voltage E_s can be represented by

$$E_s = \frac{A'}{1 + A' \cdot F} \times E_1$$

where E_1 is the output voltage of the AC power supply 2 and is, in this case, 1 V. Therefore, the maximum of the output voltage E_s

$$\begin{aligned} &= \frac{20}{1 + 0.99 \times 100} \times 1 \text{ V} \\ &= 1.00 \text{ V,} \end{aligned}$$

and the minimum of the output voltage E_s

$$\begin{aligned} &= \frac{20}{1 + 0.99 \times 20} \times 1 \text{ V} \\ &= 0.96 \text{ V.} \end{aligned}$$

Thus, the fluctuation of the output voltage E_s is reduced compared with the case of Fig. 3A (Fig. 3B). Therefore, even when the DC resistance by

the contacts, and the equivalent AC and DC resistances of the primary winding W_1 are fluctuated, a substantial adjustment of the input voltage is unnecessary, and as a result, the distortion of the magnetic flux waveform in the core 1, i.e., the distortion of the output voltage E_s , is reduced. Note that, if the amplification factor of the amplifier 5 is increased to increase the feedback factor F , the stability of the output voltage E_s can be improved. However, when the feedback factor F is increased, an oscillation phenomenon may occur due to the leak reactances of the windings. Such an oscillation phenomenon can be suppressed by adjusting the resistor 71 and/or the capacitor 72 of the phase adjusting circuit 7, to a certain extent.

In the circuit of Fig. 5 having an analog negative feedback circuit, an accurate measurement can be obtained for a directional silicon steel core having a magnetic flux density of about 17000 gauss. Also, when an extremely distorted exciting current I_p is supplied to the primary winding W_1 thereby generating a saturated magnetic flux density of about 18000 to 20000 gauss in the core 1, both the feedback factor F and the amplification factor A' must be increased to obtain a highly accurate and stable measurement. In this case, however, an oscillation phenomenon always occurs. That is, when the amplification factor A' is larger than 1 and a phase shift amount in the negative feedback loop circuit is larger than 180° , the oscillation conditions may be satisfied. Such a phase shift amount is commonly generated by the capacitance component in the negative feedback loop circuit in a relatively high frequency region, and in addition, it is difficult to completely adjust such a phase shift amount by the phase adjusting circuit 7. It is also difficult to adjust this phase shift amount when an inductance component due to the windings and the leak inductances therebetween is added to the negative feedback loop circuit.

Thus, in the core 1 having a relatively high magnetic flux density, even if an analog negative feedback loop circuit is used, the output voltage E_s of the secondary winding W_2 is still distorted and unstable. That is, in the circuit of Fig. 5, after the oscillation conditions are satisfied in the analog negative feedback loop circuit, a positive feedback control at a specific frequency of about 10 KHz to 1 MHz is triggered by differential noise or the like, and as a result, the amplitude of the input voltage applied to the core 1 is rapidly increased as illustrated in Fig. 7.

Claims

1. An apparatus for testing a core (1), comprising a primary winding (W_1) and a secondary winding (W_2), means connected to said pri-

mary winding (W_1) for supplying input current (I_p) for said primary winding (W_1) and means connected to said secondary winding (W_2) for detecting an output voltage (E_s) induced in said secondary winding (W_2), and negative feedback means (5,6,7) connected to said means for supplying an input current, the negative feedback means (5,6,7) providing negative feedback to said primary winding (W_1) in accordance with said output voltage (E_s) characterised in that each of said primary and secondary windings (W_1 , W_2) has only one connector-type contact (CW_1 , CW_2) per one turn thereof to enable the windings (W_1 , W_2) to be mounted on the core (1) to be tested.

2. An apparatus according to claim 1, wherein when the connector-type contacts (CW_1 , CW_2) are connected with the windings (W_1 , W_2) extending around the core (1), the contacts (CW_1 , CW_2) are located within an aperture defined by the core (1).
3. An apparatus according to claim 1 or 2, wherein said negative feedback means (5,6,7) comprises; means for generating a basic sine-wave voltage, and means connected to said basic sine-wave voltage generating means and said output voltage detecting means for detecting a voltage difference between said basic sine-wave voltage and said output voltage, thereby supplying said input current to said core (1).
4. An apparatus according to claim 3, wherein said negative feedback means comprises a phase adjusting circuit (7) connected between said output voltage detecting means and said voltage difference detecting means.

Patentansprüche

1. Vorrichtung zum Testen eines Kernes (1) mit einer Primärwicklung (W_1) und einer Sekundärwicklung (W_2), an die Primärwicklung (W_1) angeschlossenen Einrichtungen zum Anlegen eines Eingangsstromes (I_p) für die Primärwicklung (W_1) und an die Sekundärwicklung (W_2) angeschlossenen Einrichtungen zum Detektieren einer in der Sekundärwicklung (W_2) induzierten Ausgangsspannung (E_s) sowie an die Einrichtungen zum Anlegen eines Eingangsstromes angeschlossenen negativen Rückkopplungseinrichtungen (5, 6, 7), die in Abhängigkeit von der Ausgangsspannung (E_s) für die Primärwicklung (W_1) eine negative Rückkopplung vorsehen, dadurch gekenn-

the contacts, and the equivalent AC and DC resistances of the primary winding W_1 are fluctuated, a substantial adjustment of the input voltage is unnecessary, and as a result, the distortion of the magnetic flux waveform in the core 1, i.e., the distortion of the output voltage E_s , is reduced. Note that, if the amplification factor of the amplifier 5 is increased to increase the feedback factor F , the stability of the output voltage E_s can be improved. However, when the feedback factor F is increased, an oscillation phenomenon may occur due to the leak reactances of the windings. Such an oscillation phenomenon can be suppressed by adjusting the resistor 71 and/or the capacitor 72 of the phase adjusting circuit 7, to a certain extent.

In the circuit of Fig. 5 having an analog negative feedback circuit, an accurate measurement can be obtained for a directional silicon steel core having a magnetic flux density of about 17000 Gs. Also, when an extremely distorted exciting current I_p is supplied to the primary winding W_1 , thereby generating a saturated magnetic flux density of about 18000 to 20000 gauss in the core 1, both the feedback factor F and the amplification factor A' must be increased to obtain a highly accurate and stable measurement. In this case, however, an oscillation phenomenon always occurs. That is, when the amplification factor A' is larger than 1 and a phase shift amount in the negative feedback loop circuit is larger than 180° , the oscillation conditions may be satisfied. Such a phase shift amount is commonly generated by the capacitance component in the negative feedback loop circuit in a relatively high frequency region, and in addition, it is difficult to completely adjust such a phase shift amount by the phase adjusting circuit 7. It is also difficult to adjust this phase shift amount when an inductance component due to the windings and the leak inductances therebetween is added to the negative feedback loop circuit.

Thus, in the core 1 having a relatively high magnetic flux density, even if an analog negative feedback loop circuit is used, the output voltage E_s of the secondary winding W_2 is still distorted and unstable. That is, in the circuit of Fig. 5, after the oscillation conditions are satisfied in the analog negative feedback loop circuit, a positive feedback control at a specific frequency of about 10 KHz to 1 MHz is triggered by differential noise or the like, and as a result, the amplitude of the input voltage applied to the core 1 is rapidly increased as illustrated in Fig. 7.

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mary winding (W_1) for supplying input current (I_p) for said primary winding (W_1) and means connected to said secondary winding (W_2) for detecting an output voltage (E_s) induced in said secondary winding (W_2), and negative feedback means (5,6,7) connected to said means for supplying an input current, the negative feedback means (5,6,7) providing negative feedback to said primary winding (W_1) in accordance with said output voltage (E_s) characterised in that each of said primary and secondary windings (W_1 , W_2) has only one connector-type contact (CW_1 , CW_2) per one turn thereof to enable the windings (W_1 , W_2) to be mounted on the core (1) to be tested.

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zeichnet, daß die Primärwicklung und Sekundärwicklung (W_1 , W_2) zur Montage der Wicklungen (W_1 , W_2) am zu testenden Kern (1) jeweils nur einen Verbindungsklemmenkontakt (CW_1 , CW_2) pro Windung aufweisen.

2. Vorrichtung nach Anspruch 1, bei der sich die Verbindungsklemmenkontakte (CW_1 , CW_2) innerhalb einer vom Kern (1) gebildeten Öffnung befinden, wenn die Kontakte (CW_1 , CW_2) an die sich um den Kern (1) erstreckenden Wicklungen (W_1 , W_2) angeschlossen sind.

3. Vorrichtung nach Anspruch 1 oder 2, bei der die negativen Rückkopplungseinrichtungen (5, 6, 7) Einrichtungen zur Erzeugung einer Basissinuswellenspannung und Einrichtungen umfassen, die an die Erzeugungseinrichtungen für die Basissinuswellenspannung und die Ausgangsspannungsdetektionseinrichtungen angeschlossen sind, um eine Spannungsdifferenz zwischen der Basissinuswellenspannung und der Ausgangsspannung zu detektieren und auf diese Weise den Eingangsstrom an den Kern (1) zu legen.

4. Vorrichtung nach Anspruch 3, bei der die negativen Rückkopplungseinrichtungen eine Phaseneinstellschaltung (7) umfassen, die zwischen die Ausgangsspannungsdetektionseinrichtungen und die Spannungsdifferenz der Detektionseinrichtungen geschaltet ist.

Revendications

1. Appareil pour essayer un noyau (1), comprenant un enroulement primaire (W_1) et un enroulement secondaire (W_2) pour fournir un courant d'entrée (I_p) audit enroulement primaire (W_1) et des moyens reliés audit enroulement secondaire (W_2) pour détecter une tension de sortie (E_s) induite dans ledit enroulement secondaire (W_2), et des moyens de contre-réaction (5, 6, 7) reliés auxdits moyens pour fournir un courant d'entrée, lesdits moyens de contre-réaction (5, 6, 7) fournissant une contre-réaction audit enroulement primaire (W_1) selon ladite tension de sortie (E_s), caractérisé en ce que chacun desdits enroulements primaire et secondaire (W_1 , W_2) a un seul contact du type connecteur par tour de celui-ci pour permettre aux enroulements (W_1 , W_2) d'être montés sur le noyau (1) à essayer.

2. Appareil selon la revendication 1, dans lequel les contacts du type connecteur (CW_1), (CW_2) sont connectés aux enroulements (W_1 ,

W_2) s'étendant autour d'un noyau (1), les contacts (CW_1 , CW_2) étant situés dans une ouverture définie par le noyau (1).

3. Appareil selon la revendication 1 ou 2, dans lequel lesdits moyens de contre-réaction (5, 6, 7) comprennent des moyens pour produire une tension sinusoïdale de référence et des moyens reliés auxdits moyens pour produire une tension sinusoïdale de référence et auxdits moyens de détection d'une tension de sortie pour détecter une différence de tension entre ladite tension sinusoïdale de référence et ladite tension de sortie, en fournissant par ce moyen ledit courant d'entrée audit noyau (1).

4. Appareil selon la revendication 3, dans lequel lesdits moyens de contre-réaction comprennent un circuit de réglage de phase (7) monté entre lesdits moyens de détection d'une tension de sortie et lesdits moyens pour détecter une différence de tension.

