Proceedings of the 14th
KACC, Octorber 1999

Static and Dynamic Testing Technique of Inductor Short Turn

W. Piyarat** ,V. Tipsuwanporn*, C. Tarasantisuk*, S. Kummool* and T.Sum-Im**

*Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.
Tel: (66-2) 326-7346 :Ext. 102, E-mail: ktvittay@kmitl.ac.th
** Dept. of Electrical Engineering, Faculty of Engineering, Srinakharinwirot University,
Nakornnayok, Thailand. Tel: (66-2) 37-322605, E-mail: waksin@psm.swu.ac.th

Abstract

This topic presents an inductor short turn testing. From the rudimentary principles, the quality factor(Q) decreases due to inductor short turn. Frequency response varies because of the variation of circuit inductance and resistance. In general , short turn circuit testing is performed by comparing the ratio of an inductance and resistance of inductor in that particular circuit. An alternative method can be done by considering the response of second order circuit which can give both dynamic and static testing,whereas static testing give an error results not more than 2 turns. For dynamic testing, the result is more accurate, which can test for the short turn number form 1 turn onward.

1. Introduction

It is frequently found that inductance short turn usually occurs in multiturn inductor. If turn number is less or many short turns occur , it is easy to detect by merely measure the inductance or resistance. In case of mumerous turns inductor, but just few turn are shorted , it is not easy to detect the defected element because of minute changing of inductance or resistance. Even though one turn is shorted , it really affects the quality factor (Q) of the circuit and the circuit characteristic changes. The advantage of this technique is the specific merit that it can detect the inductor short turn from number of turns or as less as single turn.

2. Theory and static testing principle

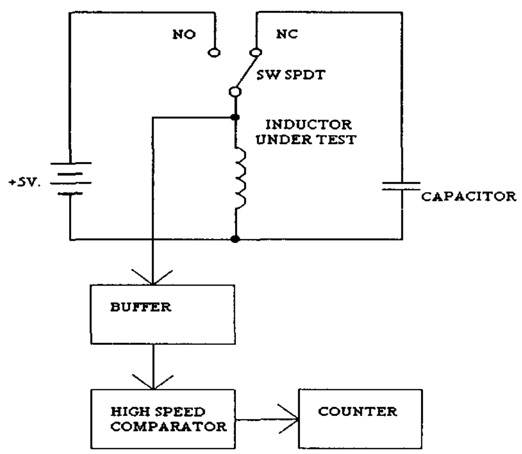

Fig.1. Block diagram shows the static testing technique.

Fig.1 shows block diagram of working principle. Switch SW is moved to position NO for inductor energy storage. The switch is thrown back to position NC instantly. It makes RC in parallel position of underdamped condition as in equation 1[2]. The energy stored will transfer back and forth between L and C, while oscillation occurs, the amplitude dies down because of loss in resistance. Equation 1[2] shows the current oscillation.

$$i_L = Ke^{-\alpha t}\cos(\omega_d t - \theta) \qquad (1)$$

When it is short circuited. The amplitude of oscillation decreases very fast because of energy losses in an inductor is high.

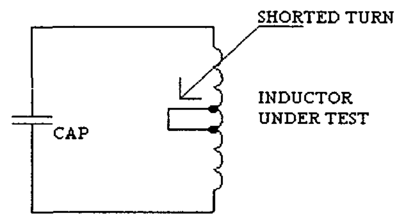

Fig .2 a. Inductor short circuited.

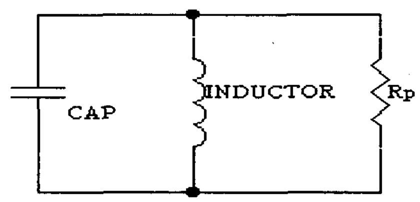

Fig .2 b. Equivalent circuit.

We can compare short turn circuited as the transformer secondary winding is shorted which absorbed energy from primary winding in the form of induce current, and energy level decreases as the quality factor (Q) in equation 2[2] decreases.

$$Q = 2\pi\frac{E_m}{E_l} \quad ; Q = R_p\sqrt{\frac{C}{L}} \qquad (2)$$

E_m = maximum energy store.
E_l = dissipated energy per cycle.

Self inductances (L_i) and mutual inductance ($L_{12} = L_{21}$) in Fig.2 b are shown in equation 3[4] and 4[4] respectively.

$$L_i = \frac{N_i^2}{\Re_i} \qquad (3)$$

$$L_{12} = L_{21} = \frac{N_1 N_2}{\Re_{12}} \qquad (4)$$

N is number of turns , $\Re$ is the Reluctance.

For inductance short circuited equivalent circuit, R, L and C are shown in parallel, R_p is taken into account to indicate the losses which resulted in energy decreasing which affected value of Q as in equation 2[4].

3. Experimental results

3.1 Operation and circuit principle

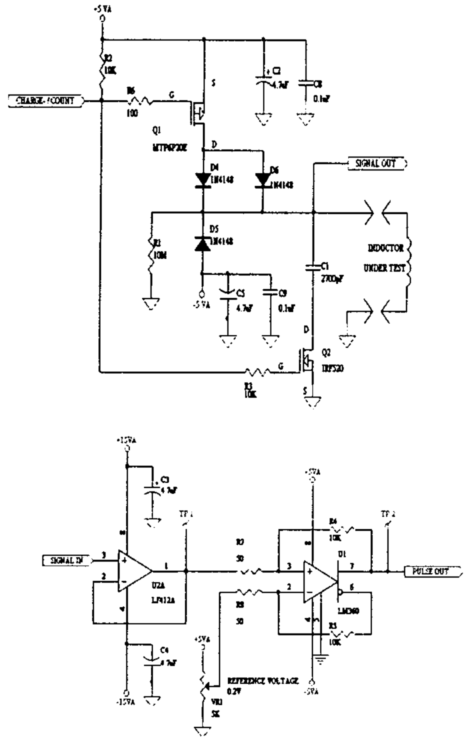

Fig. 3. Static operate circuit.

Fig. 3 shows the practical circuit, Q_1 and Q_2 function as switch , where Q_1 will be active at logic "O" , and Q_2 at logic "1" respectively.To operate,logic "O" is transmitted to circuit control at the charge-/count terminals , and Q_1 will be "ON". Current from +5V supply flow through Q_1 to energize the under test inductor. After inductor absorbed energy, control circuit changes the logic level to "1" in order to make Q_1 "OFF" and Q_2 "ON" , C_1 will be in parallel position with inductor , thus, oscillation occurs. From Fig. 1 oscillation signal flow through buffer circuit U_2 to comparator U_1. Pulses output from U_1 are transmitted to counter.

3.2 Experimental results

From Fig.3 shows an experimental results, inductance of different values are tested. The outputs at TP. 1 and TP.2 are measured, the results are shown in table 1.

Inductor Type & Condition	Test Parameter		
	Resistance	Inductance	Pulse cycle
Air core inductor			
Good	8.3 Ohm	1.534 mH	31
2 turn shorted	8.3 Ohm	1.505 mH	4
Good coil close to metal	8.3 Ohm	1.406 mH	8
Ferrite core inductor			
Good	1.2 Ohm	385 µH	29
2 turn shorted	1.2 Ohm	383 µH	0
Ferromagnetic inductor			
Good	0.4 Ohm	119.7 µH	11
2 turn shorted	0.4 Ohm	118.8 µH	0
Iron core inductor			
Good	17.3 Ohm	630 mH	4

Table 1 Typical inductance values of different inductors.

Detail of signals from different core types can be considered from Fig. 4 to Fig. 9.

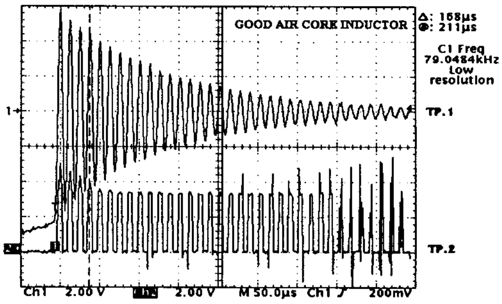

Fig. 4. Signals from undefected air core inductor.

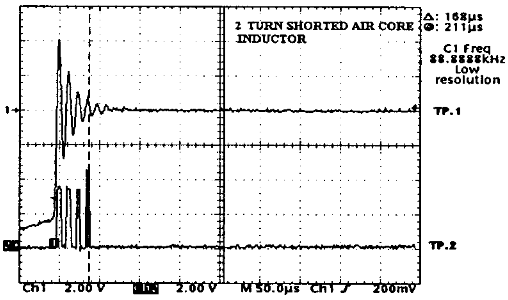

Fig. 5.Signals from air core inductor with 2 turns short circuited.

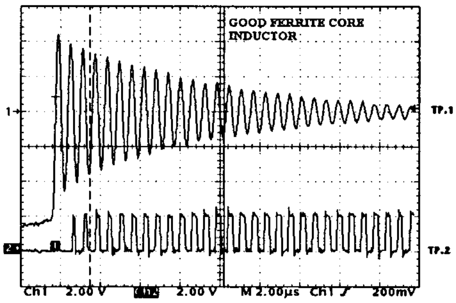

Fig. 6. Signals from undefected ferromagnetic core inductor.

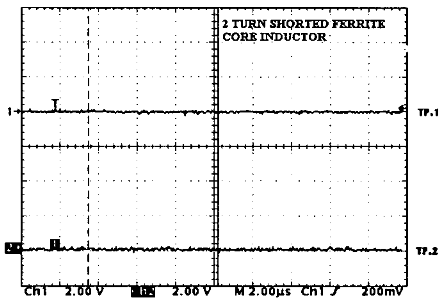

Fig. 7. Signals from 2 turns short circuited ferromagnetic core.

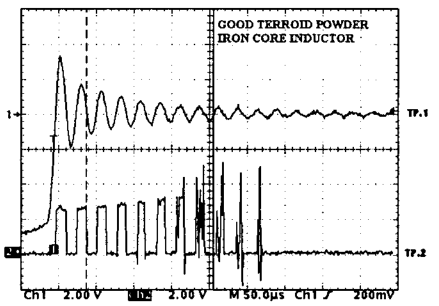

Fig. 8. Signals from undefected ferrite core.

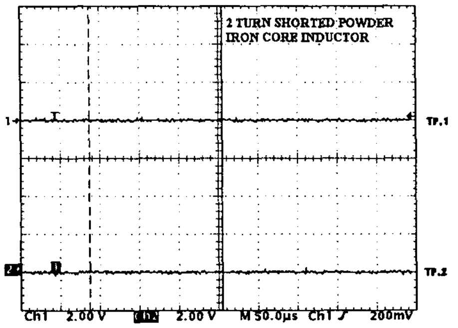

Fig. 9. Signals from 2 turns short circuited ferrite core.

From table 1, and Fig.4 to Fig. 9. It can be concluded that.

1. When there are only 2 turns short circuited, the inductance decrement values do not alter so greatly compared to many turns inductor.
2. Air core and Ferrite inductor give maximum pulse (more than 20) because of low losses. For inductor with 2 turns short circuited gives output less than 10 pulses (see Fig.4,5,6,7).
3. Ferrite core inductor without short turn gives amount of pulse output less than air core and ferromagnetic core because more losses in an inductor. For the 2 turn short circuited the output may be as low as zero (see Fig. 8 and 9).

4. Dynamic testing

4.1 principle and theory

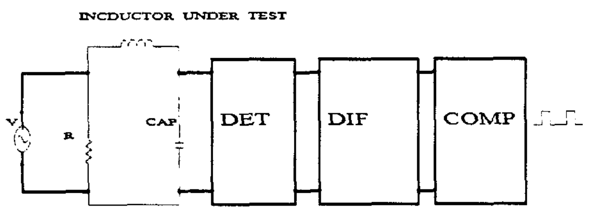

Fig. 10. Block diagram of dynamic test.

Fig.10 shows the principle of dynamic testing[5]. Sine wave signal is fed into lossless RLC circuit. Output U_C is a modulated signal as in equation 5[2]. After signals passing through detector circuit, every cycle, the output look like an arc shape. Then the output signals pass through differential amplifier and comparator give pulses of width τ. From test results, it is found that, pulse of short circuited inductor, the frequency will be more compare to undefected inductor short circuited,and less than 2 turns can also be detected.

$$V_C = A\sin\omega t * K\sin\omega_d t \quad (5\ a)$$

$$\omega_d^2 = 1/LC \quad (5\ b)$$

4.2 Experimental results

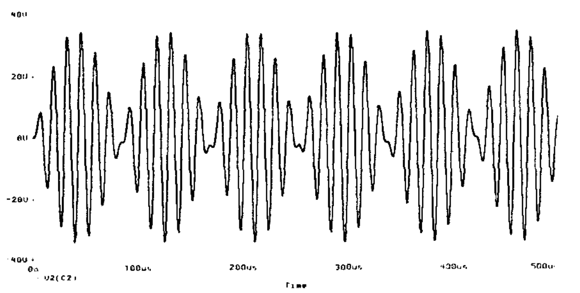

Fig .11. Dynamic testing results simulation.

Inductor Condition	Test Parameter		
	Resistance	Inductance	Pulse cycle
Good	8.3 Ohm	1.534 mH	26
3 turn shorted	8.3 Ohm	1.519 mH	27
2 turn shorted	8.3 Ohm	1.505mH	28
1 turn shorted	8.3 Ohm	1.491mH	29

Table 2 Output from simulation different inductance values.

From Fig. 11 and Table 2 shows the output of capacitor, the short circuited inductors have less inductance, pulse increases. Dynamic test gives more details.

5. Conclusions

The static test principle gives results of high accurate value, it can be used to test up to number of inductor less than 2 turns. The test results can be seen clearly when compare to undefected inductors. If we test by measurement of inductance and resistance, it can not identify the defected value easily and difficult to determine. From repeatition of testing, it shows undefected inductor gives pulse more than 10, but for short circuited pulse gives less than 10. We can apply the results to standardize the Pass/Fail inductors as the reference values in case of mass production of inductors. Incase of static test, 2 turns shorted circuit is supposed to be crude value, if we need more detail and fine values we have to switch to dynamic testing technique.

References

[1] C. Bowick "RF circuit Design" SAMS; A division of Prentice Hall Computer publishing, 1992.

[2] D. E. Johnson,J. R. Johnson,J. L. Hilburn, "Electric Circuit Analysis"Prentice Hall International,Inc., 1997.

[3] P. Horowitz, W. Hill "The Art of Electronics" Cambridge University Press, 1989.

[4] M. A. Moser "Shorted Turn Effects in Rotary Voice Coil Actuators" IEEE Trans. Magnetics, Vol.32, No.3, 1996.

[5] V. Popovic "An Automatic Digital Q-Meter" IEEE. Trans. Instrument and measurment Vol. 27 No. 2 pp.169-171 June 1978.