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DEVELOPMENT OF ADVANCED CONTROL STATE TECHNOLOGY OF TRANSFORMER AND ELECTRIC MOTOR WINDINGS BASED ON PULSED METHOD

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Abstract- Power transformer's park is rapidly aging around the world. Delayed and inaccurate diagnosis of transformer state leads to electrical energy system accidents with severe consequences. At the present day no one famous technique can supply exact transformer winding diagnostic. FRA method is popular enough in American and European electrical systems, but important diagnostic frequency range of it is restricted by 2 MHz. As result, diagnostic mistake by FRA take place despite progress in this technology. As for electric motor windings, it is no one real control state technology except its resistance measurement. New approach to transformer and electric motor winding state control technology is described. Proposed method is based on rectangular pulse of nanosecond (350-400 ns) duration using. It is shown that smaller probe pulse duration allows making a winding state control and increasing a precision of winding diagnostic. Method was experimentally used on real power transformer 63 MVA and AC electric motors.

Keywords: Power Transformer Winding State, Probe Pulse of Nanosecond Duration, Response Pulse Analysis, Increased Accuracy in Diagnosis, Capacitive Elements.

I. INTRODUCTION

Power transformers are key components of the electrical power systems. A big amount of the power transformer population all over the world being in service at the moment, have been reached an age of 30-40 years and more. Those transformers might be close to their end of life. Any next short circuit regime could cause emergency situation. Thus, active part diagnostics of power transformers is an important part of a modern power equipment maintenance strategy. Traditional diagnostic methods such as, winding checking by mega ohmmeter, chromatographic analysis of oil, transformer oil breakdown in standard test apparatus are not effective in most of cases. FRA technology is used in European and American electric energy systems, but accuracy and reliability are not enough sometimes. Mistakes in winding diagnosis took place at the using FRA technique. As for winding of electrical drives, it is no control technology at all. New winding control technology development is actual scientific and engineering task.

II. BASIC FUNDAMENTALS OF WINDING DIAGNOSTICS BY RECTANGULAR PULSES

Low-voltage pulsed method (LVPM) is most progressive winding control technology among using in electric energy systems. This technology was researched and engineered by Polish electrical engineers V. Lekh and L. Tyminskiy in 1966 [1]. The method is recognized in transformer's world as reliable and sensitive technology to determine mechanical deformations more than 45 years [2]. In many countries, including Russia, LVPM is included in national standards of power transformer test methods to electrodynamic firmness of winding control [3].

The crux of matter is in rectangular pulse of low-voltage supply to one of winding of transformer; at the same time transient current is registered on the other. Transient current is reaction of the winding to rectangular probe pulse [4]. Comparative analysis of differences in pulsed transient current curves before and after electrodynamic impact is basic fundamentals [5]. Analysis is comparison of normogram (signal from normal working state winding) and defectogram (signal from damaged or out of order winding). It is necessary to note that, many types of power transformers have no normograms at all. This fact makes diagnostics procedure very difficult and impossible in some cases. In such cases analogical phase normograms of similar transformer types are used, but diagnostics accuracy are not reliable at such approach [6].

We tried to advance abovementioned pulsed method and extend it for electrical machine winding control. Duration of rectangular pulse in standard method is 1 microsecond. We propose to use probe pulse duration no more than 500 nanosecond and less. Pulse front is several units of nanosecond. Decrease of pulse and front duration up to nanosecond range leads to much more exact fixing of transient process in comparison with standard LVPM. Diminished probe pulse duration allows increasing a sensitivity method due to response signal formation in capacitive elements only [7-8].

As result oscillations are excited with bigger intrinsic frequency than in LVPM. Any changes of winding geometry changes, even most negligible are caused by radial or axial deformations, unpressing, lodging conductors, turn to turn short circuit and other factors lead to considerable changes of longitudinal and cross winding capacities. Reaction of windings is changed seriously at the same time and provides more exact measurement result. To realize our approach, special test generator "Nanotest-1" was designed and engineered. Test generator parameters are following: pulse amplitude is 350 V, pulse duration is 350 ns, front of pulse on the matched load is no more than 10 ns. Probe pulse is supply on one of investigating windings, response signal which is transient process result is fixed on another winding.

III. WINDING DIAGNOSTICS OF POWER TRANSFORMER 110/10 KV, 63 MVA

We have applied our research results to control mechanical state of winding transformers in real electric energy system. Type of transformer is TRDTSN - 63000/110 - U1 (Russian Federation Government Standard 12965-74). There are four transformers of same type, produced by transformer's plant in Tol'yatti, Russia in 1980. Diagnostics procedure is following: probe pulse has been put in one of winding, response signal have been fixed at the windings. The oscillogram on entrance of high voltage winding 110 kV is shown in Figure 1.

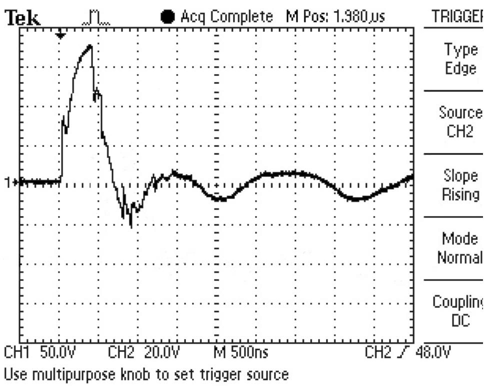


Figure 1. Signal view at the entrance of transformer winding

Analogical signal was fixed on the entrance of low voltage winding 6kV. This fact is evidence that input resistances of both windings are practically the same and have capacitive character for frequency range of probe pulse. This signal is not enough to make conclusion about winding element state. Response signals from other windings are more sensitive to different geometrical changes of turns. Responses from all windings have individual character at the probe pulse putting in the one of those. This is confirmation of high sensitivity of "nanosecond pulse diagnostics". Signals from high voltage windings of phases A and C at the probe pulse putting on high voltage winding B are shown on the Figure 2. Winding similarity is confirmed by signal forms when probe pulse and response-pulse are changed by places. Figure 3(a) illustrates response-pulse from at the high voltage winding A at the probe pulse putting on the high voltage winding B. In turn, Figure 3(b) demonstrates response-pulse from the winding B at the probe pulse putting on the high voltage winding A. It is seen that, response-pulse forms are equal. This is evidence of good correspondence of mutual geometrical placement of windings A and B between each other.

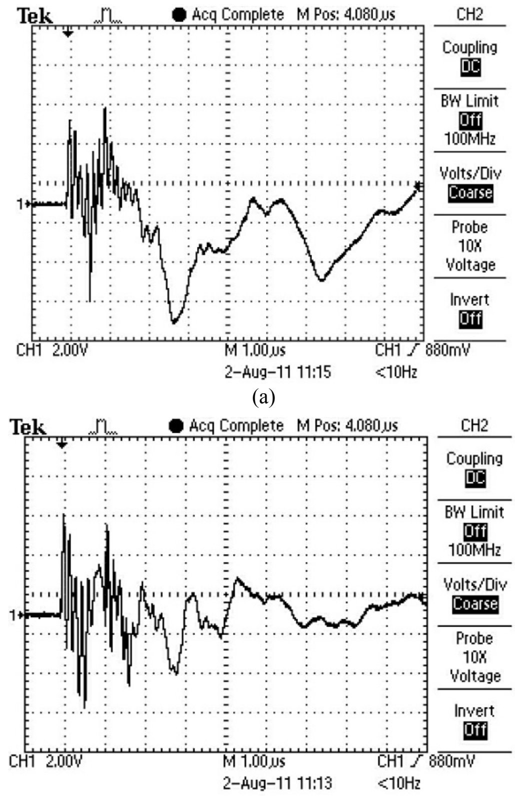
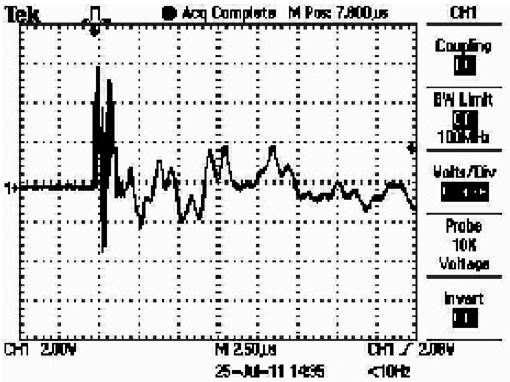


Figure 2. Pulsed responses from high voltage windings A and C at the probe pulse putting on the phase B, (a) response signal from winding A, (b) response signal from winding C

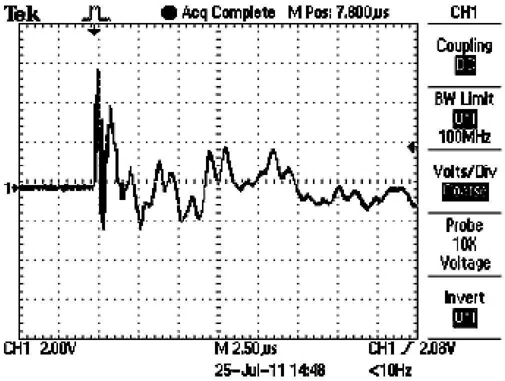
The same way is used to check how identical windings are made which are placed on different transformer rods. On the figure 4 are shown the response-pulses from winding A_2B_2 at the probe pulses putting to windings A_1B_1 and, B_2C_2-B_1C_1, respectively. It is seen that, all response forms are equal. So, this is good evidence of good geometrical correspondence of windings, placed on the different rods between each other. The results confirm high sensitivity of nanosecond pulse technology (NNPT). In this connection proposed approach could be prospect and successful at the mechanical state control of transformer winding.

IV. DIAGNOSTICS OF AC MOTOR WINDINGS

Proposed NNPT was applied to control AC electric motor windings. It was researched result of nanosecond probe pulse influence to AC electric motor windings at thermal power station of engineering plant, Urga, Kuzbass. Main goal of these nature experiments was the same like for transformer windings written above. Nanosecond probe pulse is applied to one of phase of electrical drive, response pulse was registered from other ones. Measurements of all signals were fulfilled by oscilloscopes "Tektronix TDS 2012". Measurements were fulfilled for two electrical motors - new AC motor and damaged electrical motor with failed windings. Motors are identical for type and construction. Figure 5(a) illustrates probe and response oscillograms for motor in normal state. Probe pulse was applied to contact pair "phase C-neutral", response pulse was registered at the pair "phase A-neutral".

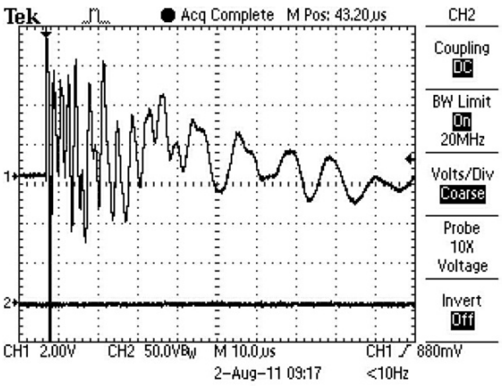


(a)

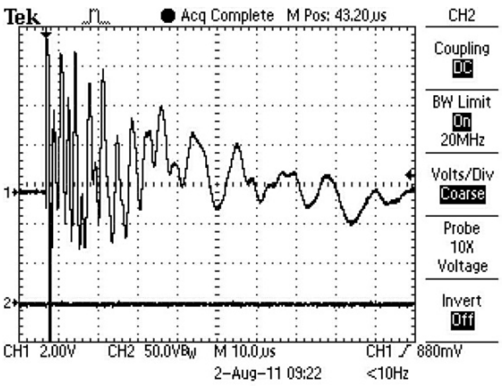


(b)

Figure 3. Response signals: (a) at the winding A, probe pulse on the winding B; (b) at the winding B, probe pulse on the winding A and on the winding B.

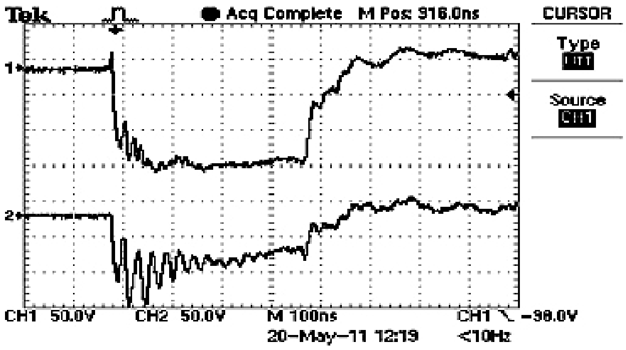


(a)

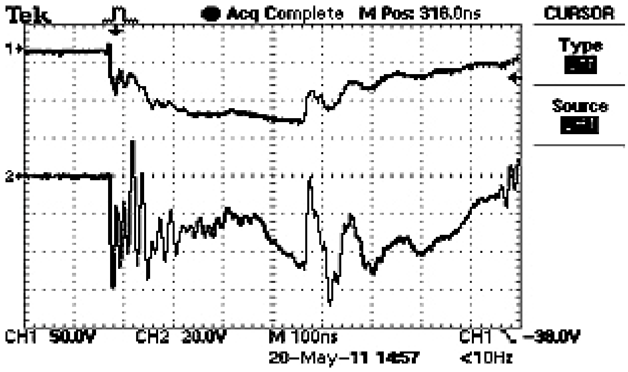


(b)

Figure 4. Response pulses from the low voltage windings: (a) A_2B_2 at the probe pulse putting to the A_1B_1, (b) B_2C_2 at the probe pulse putting to the winding B_1C_1



(a)



(b)

Figure 5. Response signals at the winding C and at the winding A during probe pulse putting to pair "phase C-neutral": (a) motor at the normal state, (b) out of order motor

Figure 5(b) shows the same oscillograms, but for damaged motor case. It is seen that, at first, the probe pulse is depend on winding state, at second, response pulse has a lot of changes at the defect presence in the winding which probe pulse is applied. Thus, NNPT is sensitive enough for winding state diagnostics of electrical motors.

If neutral of drive winding is not available for some reasons, proposed method could be used applying probe pulse to pair "winding-ground". Oscillograms on the figures 6 are confirmation of workability of NNPT for motor winding case. Figure 6(a) shows probe pulse "phase A-ground" and response pulse "phase B-ground" for working motor. Figure 6(b) illustrates the same situation for damaged motor.

Comparison forms of response pulses for 'healthy" and damaged cases shown that pulse distortion takes place in both cases. Specific related pulse form changes allow determining defect winding state with good accuracy. No any normograms were used. This fact allows concluding that NNPT could be successfully applied to electric motor winding diagnostics.

In this case NNPT is even more effective than for transformers so as both signal form changes-probe and response – are used for analysis. Fourier series expansion is not used in our analysis. Specific response form is good winding state evidence without ones.

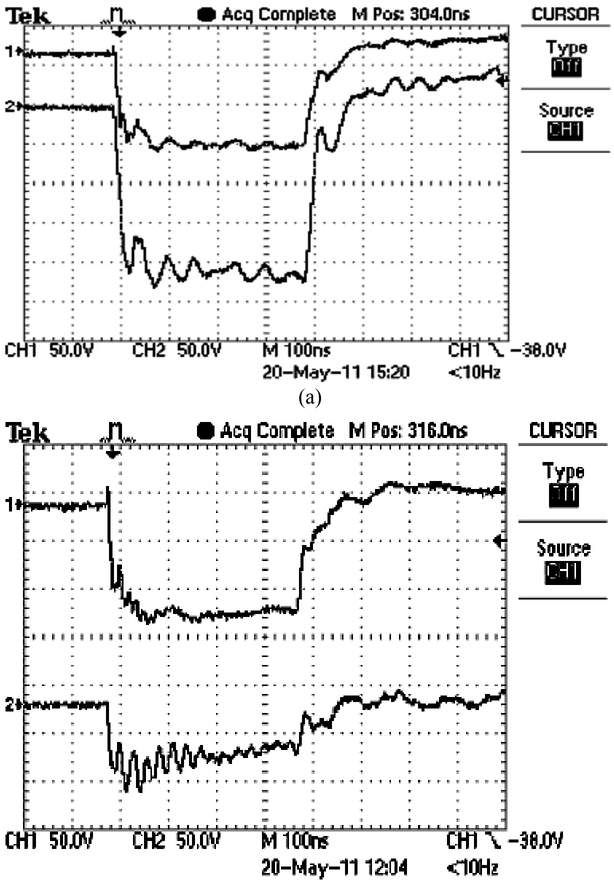


Figure 6. Signals for case where probe pulse is applied to "phase A-ground" and response pulse to "phase B-ground":
(a) normal state motor, (b) winding A is damaged

Results of NNPT applying for electrical motor winding state control could be summarized as following:
1. Improved low-voltage pulse method with nanosecond probe pulse duration could be applied for diagnostics of asynchronous electrical motor winding state.
2. Decreasing of probe pulse duration up to 400 ns allows upgrading the method sensitivity.
3. Basic of proposed approach includes form signal analysis for both pulses probe and response. Specific form changes allow making a conclusion about winding state.
4. Fourier series expansion is not necessary to use in this case. This fact makes our approach simpler.
5. No necessity a normograms using to analyze possible defects presence.

V. CONCLUSIONS

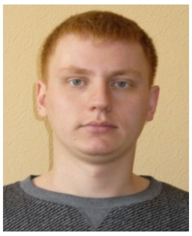
To improve famous low voltage pulse method to control winding state a nanosecond probe pulse duration was used. This approach was called 'nanosecond pulse technology" and successfully applied to transformer and electrical motor winding diagnostics. Power transformer 63 MVA survey has shown principal possibility to use NNPT with good efficiency. Proposed technology is simply, possesses high sensitivity to different winding defects. There is reasoned opinion to suppose that at the more detailed research and engineering the technology it would be make diagnostic procedure without normograms using. Experiments with AC electrical motor windings have shown principal possibility to control winding state. This is prospect area in modern electrical engineering also.

REFERENCES

[1] V. Lekh, L. Tyminskiy, "New Method of Damage Detection at the Transformer Test for Electrodynamic Strength", Electrichestvo, No. 1, 1966.
[2] V. Avetisov, E. Levitsckaya, B. Popov, "Pulsed Defect Detection of Transformers at the Tests for Electrodynamic Strength", Electrotechnika. No. 4, 1978.
[3] S. Alikin, A. Drobyshevskiy, E. Levitsckaya, M. Filatova, "Quantitative Estimation of Pulsed Defect Detection Results of Power Transformer Windings", Electrotechnika, No. 5, 1990.
[4] V. Sokolov, S. Tscurnal, Yu. Kolov, V. Korolenko, "Deformation Detection of Power Transformers", Electricheskie Stantscii, No. 6, 1988.
[5] Yu. Kolov, V. Korolenko, V. Fedorova, "Damage Detection of Transformers at the Short Circuits", Electricheskie Stantscii, No. 7, 1980.
[6] A. Lurie, O. Schlegel, "Increasing of Measurement Accuracy of Inductive Resistance Deviation at the Electrodynamic Strength Tests of Transformers", Electrotechnika, No. 12, 1991.
[7] A. Mamizadeh, I. Iskender, "Winding Thermal Analyzing of Dry Type Transformers", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 5, Vol. 2, No. 4, pp. 80-84, December 2010.
[8] Y. Najafi Sarem, E. Hashemzadeh, M.A. Layegh, "Transformers Fault Detection Using Wavelet Transform", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 10, Vol. 4, No. 1, pp. 17-26, March 2012.

BIOGRAPHIES

Valeriy A. Lavrinovich was born on 7 November 1948. He received the Ph.D. degree in 1985 from High Current Electronics Institute of Russian Academy of Sciences (Tomsk, Russia) and Doctor of Science degree in 2005 from the Tomsk Polytechnic University (Tomsk, Russia). Both dissertations are dedicated to investigation and elaboration of high voltage vacuum spark gaps and commutators. He was director of Russian Research Institute of Electrotechnical Industry, Russia from 1989 to 1998. Now he is the Professor of Department of Electrical Power Engineering Systems and High Voltage Engineering. He is laureate of Russia Government Prize in area of Science and Technology. He published more than 90 scientific articles. His areas of interest include pulsed power and electrical power engineering systems.



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