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Analysis of Transformer Bushing Failure Based on Frequency Response Analysis (FRA)

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Abstract: ***Frequency Response Analysis (FRA) is the most reliable technique for detecting any failure within electrical power transformers. In this paper the FRA technique to identify non-mechanical faults such as transformer bushing failures. The transformer failure on the mark of the FRA strategy has been explored, no standard code has been broadly received. Moreover, the FRA technique is ineligible in identifying minor levels of energy transformer fault that declines the transformer's capacity to withstand any further electrical, thermal and mechanical stresses. The FRA technique properly, the base discovery of transformer issues ought to be evaluated. This paper expects to recognize the effect of the base level of transformer bushing failure on the FRA signature that can be outwardly identified. A 3-phase control transformer is recreated (in light of the Finite Element Analysis (FEA) technique) to mirror its genuine operation amid both solid and broken conditions. The effect FRA marks (in light of FEA) for different bushing failure levels was acquired and afterward contrasted with the solid mark, and varieties are distinguished in the event that they exist. Results demonstrate that the transformer bushing failure has a base level that can be outwardly recognized utilizing the FRA technique.***
Keywords: Power transformer, Transformer bushing failure, Frequency response analysis.

I. INTRODUCTION

The substantial power transformers have a place with the most costly and deliberately imperative segments of any generation and transmission system. A genuine failure of a large power transformer because of insulation breakdown can produce generous expenses for repair and money related misfortunes because of influence blackout. Subsequently, utilities have clear motivator to evaluate the genuine state of their transformer, specifically the state of the HV insulation framework, with the plan to limit the danger of disappointments and to stay away from constrained blackouts of deliberately imperative units. Appraisal of insulation quality in expansive H.V. control hardware anytime, additionally called 'Condition Monitoring' is a territory of work presently being sought after by numerous research facilities and utilities. A few systems are accessible for observing of a few parameters, which could show the condition on the insulation. From the writings and in addition field information it has been set up that bushings are one of the real purposes behind transformer disappointment. With this foundation, it has been the subject of this examination work to build up an on-line molding observing system to screen the status of a bushing.

II. TRANSFORMER BUSHING DESIGN

The power transformer bushing is a sort of porcelain or ebonite post encasing put on the best or side of the transformer tank through which associations are made to the outer circuit. The general constructional points of interest are appeared in Fig.1. The dynamic piece of the bushing comprises of oil Impregnated Paper (OIP) center made from unrivaled review Kraft protecting paper with condenser evaluated layers for field control twisted under strain on focal tube/conductor. The deepest condenser layer is electrically associated with the settling rib through a test tap . The center is dried under warmth and vacuum and afterward impregnated with prevalent review of protecting oil. Porcelain covers on the upper and lower sides of the bushing, oil insulation brilliant elastic gaskets and 'O' rings are held together with the focal tube by methods for an arrangement of intense springs. The settling rib is given a test tap for the estimation of Capacitance and Tan delta, air discharging screw to discharge the air caught in the transformer amid fixing up of oil or can be associated with Buchholz transfer, name plate giving the item points of interest, handle/eyebolt for lifting and space for ring sort CT's on the oil end of the bushing. At the oil end, an epoxy covered anxiety shield or base plate is given to control the high worries in oil inside the transformer. A separable base circular segment shield is accommodated bushing evaluated 245 KV or more. The interceding space between the center of the transformer and the porcelain covers is loaded with uncommonly treated mineral oil under vacuum. A kaleidoscopic (upto 300KV)or attractive (upto 400 KV) oil locate glass is given on the

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development bowl . A best terminal is given to interface with the over head line. Arcing horns are given on ask for in the middle of best shield and base plate.

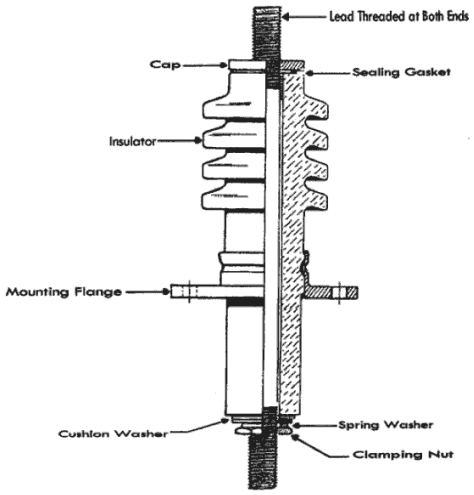


Fig.1. The general constructional diagram of bushing

III. BUSHING CIRCUIT MODELING

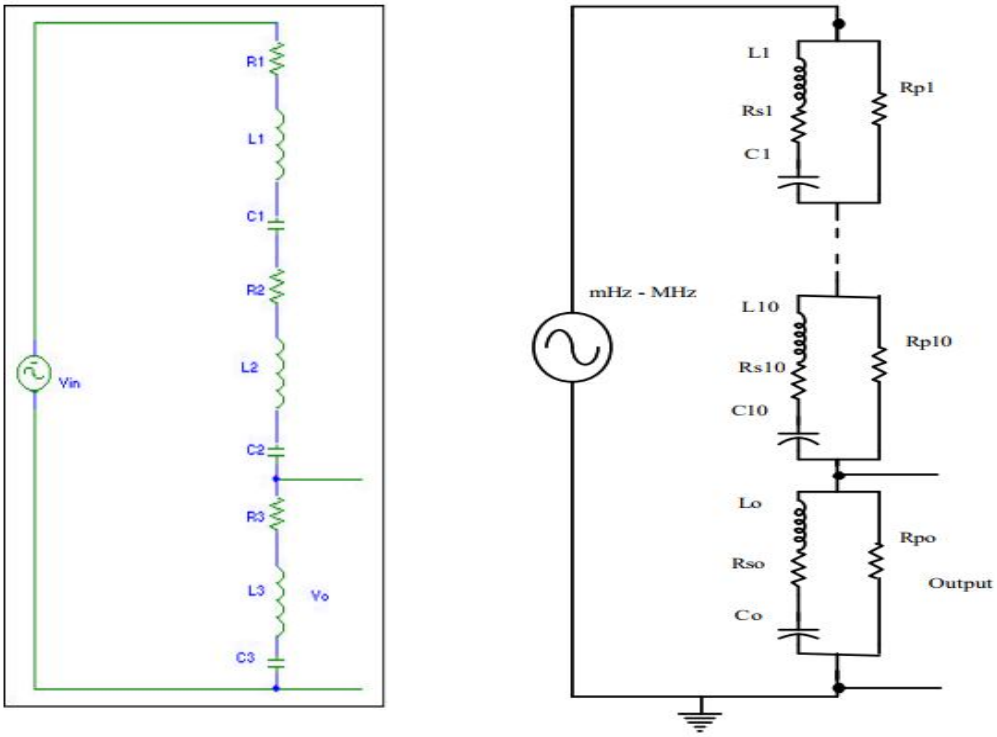


Fig.2. Equivalent Circuit model of bushing

To set up the attainability of utilizing TFA/FRA for fault location in bushings a bushing proportional circuit display is considered. Despite the fact that when all is said in done bushings are considered as non-inductive capacitor and resistive component organize, in the present examination the leftover (self) inductance is additionally considered to think about the impact of this inductance on the affectability of the method. The aggregate misfortunes in the bushing can be either spoken to as a proportional arrangement or parallel insulation. In the models considered both arrangement and parallel portrayals are considered alongside some conceivable

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mixes of both arrangement and parallel resistors (eight combinational circuits were dissected). This has been done to build up the affectability of the method to equal circuit portrayal and comprehend the physical wonders.

IV. FREQUENCY RESPONSE ANALYSIS

The frequency response of the built bushing model is contemplated by systematic technique. Analytical technique is utilized as this fits consider the varieties in parameters rapidly for a given proportionate circuit portrayal. In investigative technique scientific models are created in light of the identical circuit parameters and these are utilized to determine the yield capacities for any given info flag. The yield flag is determined over the last area of the identical circuit and the info is connected over the whole series of arrangement areas. The yield is examined for different conditions like no fault, 3 % and 10% change in insulation and capacitance. The explanatory models are of the form

$$VI = I (Z1+ Z2 +…..+Z10+ Zo) \text{ and } Vo= IZo$$

$$\text{Transfer function } = Vo(s) / Vi(s)$$

$$= Zo / (Z1 + Z2 +Z3 +….Z10 + Zo)$$

The FRA technique is directed on the 40MVA transformer to get a solid FRA magnitude signature by infusing a variable frequency low amplitude AC voltage (vin) at one terminal of the HV winding, and measuring the reaction signal over another terminal of HV winding (vout). The FRA mark of the 40MVA transformer HV winding is plotted as a transfer function work for the three phases (A, B and C) shown in Figure

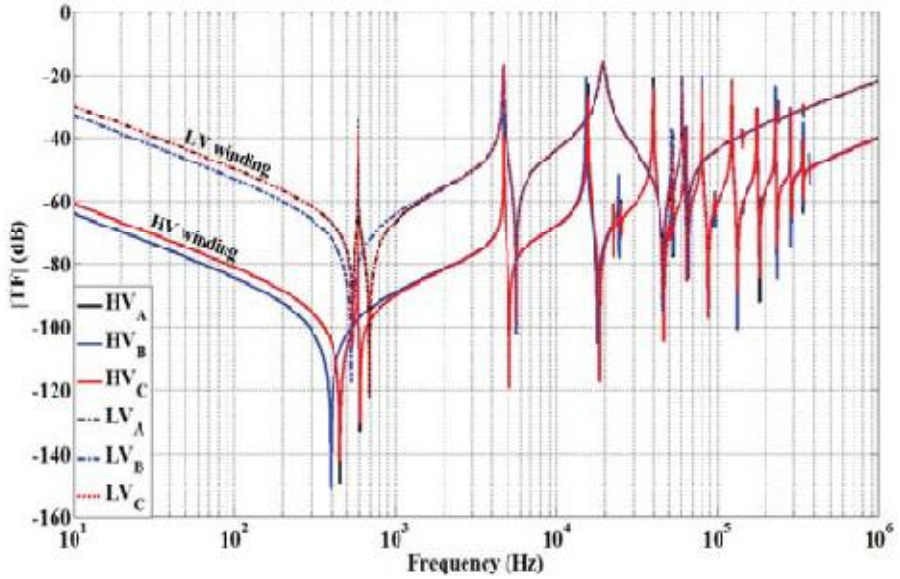


Fig.3. HV and LV windings FRA analysis.

As can be found in Fig.3, the marks are characterized by resonances and anti-resonances frequencies over the whole frequency. As the frequency expands, more space harmonics are developed in the winding. At a low frequency range, resonances and anti-resonances frequencies are influenced by the inductive segments while the impact of capacitive segments is appeared in the high frequency run. Further, the FRA marks of the three phases are practically indistinguishable aside from the center (phase B). This variety can be ascribed to the slight contrast of the attractive motion amid phase B (contrasted with phases A and C).

V. FRA IMPACT OF TRANSFORMER BUSHING FAILURE

The key factor of degradation inside transformer bushing insulation material is an expansion in the dampness content. This can be recreated by expanding the dielectric factors (complex permittivity and electrical conductivity) to speak to bushing disappointment. The failure of transformer bushing is executed utilizing FEA by changing the perplexing permittivity and electrical conductivity, so as to acquire the connection between's dielectric factors changing and bushing capacitive segments (C1 and C2) as recorded in Table1. In this table, an expansion of transformer bushing dielectric factors (complex permittivity and electrical conductivity) variety prompts an increment in the estimation of variety inside the bushing capacitive parts (C1 and C2). It is worth to specify that the variety of the C1 esteem is higher than the C2 esteem as can be seen in Table 1.

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TABLE I
Correlation between bushing dielectric factors and capacitive components.

Dielectric factors variation (%)	Bushing capacitances variation (%)	
	C1[pf]	C2[pf]
1%	1.06	0.16
5%	4.43	0.65
10%	10.28	0.97

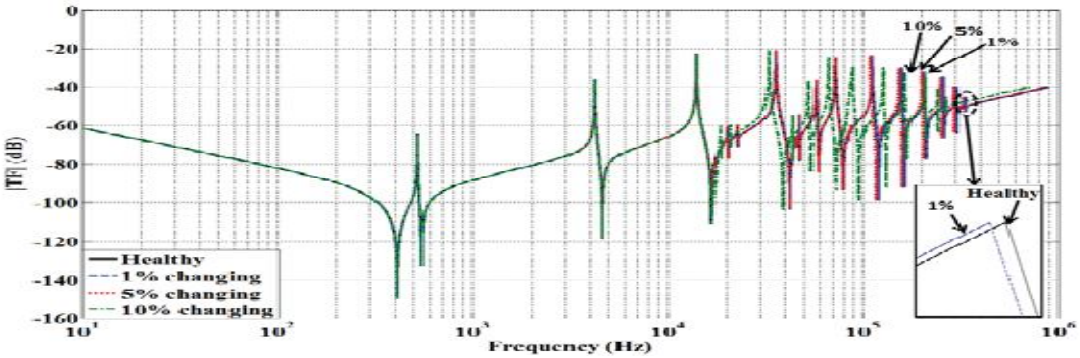


Fig.5. The failure levels of transformer bushing of 40MVA transformer HV winding on FRA signature.

As appeared in Figure 5, the effect of a 1% transformer bushing failure (changing the dielectric elements of transformer bushing by 1%) on the 40MVA transformer HV winding stage A FRA mark is gotten and contrasted with a sound mark. As uncovered Figure5, the sound and broken marks are practically indistinguishable, and it is hard to recognize any variety. A slight variety however can be outwardly recognized in the high recurrence go (50 kHz) when the transformer bushing failure increments to 5% (as appeared in Figure 5) that movements resonances and hostile to resonances frequencies in the high recurrence range to one side. The effect of the transformer bushing failure on the FRA signature turns out to be more articulated when the bushing failure level is expanded by 10% as appeared in Figure 5.

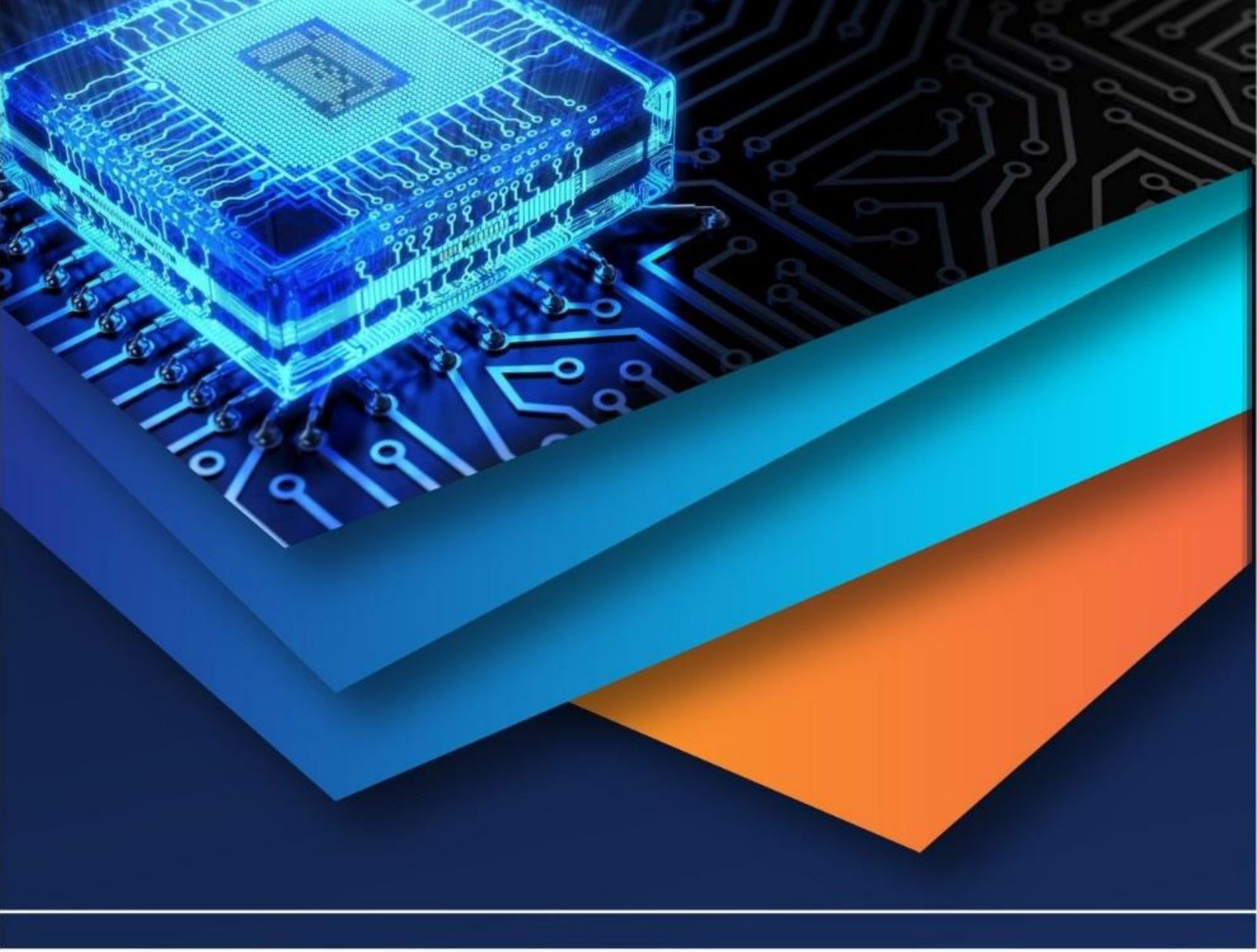
VI. CONCLUSIONS

This paper discussed about in detail the effect of transformer bushing disappointment on the FRA mark to demonstrate the affectability of bushing disappointment on the FRA strategy and recognize the least disappointment levels that can be recognized outwardly. Results uncover that the FRA mark is influenced by bushing disappointment; however a disappointment level under 5% is hard to identify outwardly utilizing the ordinary understanding procedure of the FRA procedure. Disappointment levels higher than 5% has a visual affect on the FRA signature at a high recurrence extend. Studies ought to be proceeded so as to build up a progressed system of recognizable proof and evaluation of such a minor level.

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