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AC Test of Power Frequency with NDDI Method

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Abstract
Cable is used while transmitting power in an electrical system. High tension cable plays a vital role in electrical power systems. This paper puts forward an AC test of power frequency withstand voltage test of the insulation of the high tension cable. Pin to surface type electrode is used while performing the test. Power frequency withstand voltage test is performed at 11KV & 27KV voltages without the time and with time. Readings are taken at four-electrode distance at 11KV and 27KV voltage. The newton divided interpolation method is used to estimate breakdown voltage at unknown distances. The absolute error is calculated with known breakdown value at known distance with newton divided difference interpolation method at each vale of breakdown voltage at a known distance. The mathematical function is generated at 11KV & 27KV voltage and the mathematical function is plotted with the help of MATLAB software.
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Index Terms: Power frequency withstands voltage test, newton divided difference interpolation method, high voltage test

Introduction

Cable use is increasing in our daily life. Generation, transmission and utilization are the major part of power systems. Cable is used in all major parts of power systems. It is important to monitor the condition of the cable for reliable operation. There are many types of cable depending on their use. Some cables are large in their diameter and some of them are small. The cable can damage due to any reason. The main reason that makes a cable burn is due to its increase in its mechanical stress. Many tests can be performed. Some of them are related to its mechanical stress and some of them are related to its electrical stress. Power frequency withstand voltage test is one of the tests that is applied to check the breakdown of the cable and this test was discussed in this research. Many researches are related to cable testing and power frequency withstand voltage test is the part of some researches. Power frequency withstand voltage test is applied in this research with time reference and without time reference. The time reference was taken as 10 minutes [2-9]. Four samples are taken at four electrode distances for check the cable with time reference and without reference. The equation of these results is generated with the help of the newton divided difference interpolation method [11]. These equations were plotted with the help of MATLAB software. There is a need to find unknown breakdown values at unknown electrode distances. The unknown values of breakdown voltages

are estimated with the help of mathematical quations.

Problem Formulation

In this paper, power frequency withstand voltage test was applied to the high voltage cable insulation of the transformer. The breakdown values of the voltage are obtained with time reference and without time reference. The experiment was performed with 27KV voltage [6]. The objective functions were generated with the help of the newton divided difference interpolation method. The electrode difference is the function of the breakdown voltage. The breakdown voltage value can be obtained for every electrode distance value.

Power Frequency Withstand Voltage Test

Power frequency withstand voltage test is one of the tests that was applied on the insulation of the cable. This test is mostly used in cable. This test is used to check the breakdown of the cable [4-9]. Four samples of the insulation of the cable was used without time reference and with time reference. The time reference was taken as 10 minutes for checking the breakdown of insulation.

Newton Divided Difference Interpolation Method

Newton divided difference interpolation method is used when there is a need to calculate the coefficients of a polynomial and the inventor of this algorithm is Isaac Newton. This method is mostly used in engineering applications and crucial role in the field of mathematics in linear algebra. This algorithm is applied in a problem when the interval difference is not equal in all sequences of values. This algorithm is a natural difference version of Taylor's polynomial [11].

Table 1: Newton Divided Difference Method Calculation Explanation

x	f(x)	1st Div. Diff.	2nd Div. Diff.	
x_0	$f[x_0]$			
		$f[x_0,x_1]=\frac{f[x_1]-f[x_0]}{x_1-x_0}$		
x_1	$f[x_1]$		$f[x_0,x_1,x_2]=\frac{f[x_1,x_2]-f[x_0,x_1]}{x_2-x_0}$	
		$f[x_1,x_2]=\frac{f[x_2]-f[x_1]}{x_2-x_1}$		
x_2	$f[x_2]$		$f[x_1,x_2,x_3]=\frac{f[x_2,x_3]-f[x_1,x_2]}{x_3-x_1}$	...
		$f[x_2,x_3]=\frac{f[x_3]-f[x_2]}{x_3-x_2}$		
x_3	$f[x_3]$		$f[x_2,x_3,x_4]=\frac{f[x_3,x_4]-f[x_2,x_3]}{x_4-x_2}$	
		$f[x_3,x_4]=\frac{f[x_4]-f[x_3]}{x_4-x_3}$		
x_4	$f[x_4]$		$f[x_3,x_4,x_5]=\frac{f[x_4,x_5]-f[x_3,x_4]}{x_5-x_3}$	
		$f[x_4,x_5]=\frac{f[x_5]-f[x_4]}{x_5-x_4}$		
x_5	$f[x_5]$			

Table I shows the calculation process of the newton divided difference interpolation method. The calculation procedure becomes easier by using the above arrangements. $f[x_0,x_1]$ is calculated by calculating the difference of $f[x_1]$ and $f[x_0]$ divided by the difference of x_0 and x_1. $f[x_0,x_1,x_2]$ is calculated by calculating the difference of $f[x_1,x_2]$ and $f[x_0,x_1]$ divided by the difference of x_2 and x_0. same as calculating other values and inserting these values in to the formula.

Newton divided difference interpolation formulae is given in equation 1

$$y(x) = y_0 + (x - x_0)f[x_0,x_1] + (x - x_0)(x - x_1)f[x_0,x_1,x_2] + \cdots \quad (1)$$

Equation 1 was used in this research for the estimation of unknown values of breakdown

voltage at electrode distance values.

Results of Power Frequency Test at 11kv Voltage

Table 2: Power Frequency Withstand Voltage Test Without Time & With Time

Distance between Electrodes	Without Time	Time=10 minutes
3mm	27.46KV	NIL
9mm	29.09KV	NIL
18mm	31.11KV	NIL
36mm	35.49KV	NIL

Table II shows that breakdown voltage increased when the distance between electrodes was increased. So, the behavior was nonlinear. From the above results, we can say that the breakdown voltage is increased when the distance between electrodes is increased. There is no breakdown at different distances when 11KV voltage is applied for 10 minutes [2-9].

Without Time Reference At 11KV Voltage

$$f_1(x) = 0.000116598x^3 - 0.00664609x^2 + 0.337778x + 26.5033 \ldots (2)$$

Equation 2 is generated without time reference values above equation is generated using the newton divided difference interpolation method and this equation is plotted with the help of MATLAB software and the plot is figure 1.

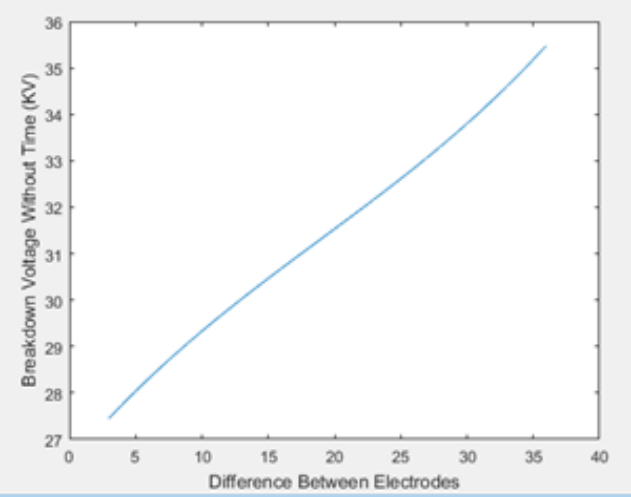

Fig. 1 Plot between difference between electrodes & breakdown voltage without time at voltages above 11KV

Table 3: Breakdown Voltage Value Estimation In Power Frequency Withstand Voltage Test Without Time & With Time At Voltages Above 11kv

Distance between Electrodes	Without Time	Without Time (With NDDI)	Absolute Error (%)
3mm	27.46KV	27.46	0
4mm	-	27.75	-
5mm	-	28.04	-
6mm	-	28.31	-
7mm	-	28.58	-
8mm	-	28.84	-
9mm	29.09KV	29.09	-
10mm	-	29.33	-
11mm	-	29.57	-
12mm	-	29.80	-
13mm	-	30.02	-
14mm	-	30.25	-
15mm	-	30.46	-
16mm	-	30.68	-
17mm	-	30.89	-
18mm	31.11KV	31.11	0
19mm	-	31.32	-
20mm	-	31.53	-
21mm	-	31.74	-
22mm	-	31.95	-
23mm	-	32.17	-
24mm	-	32.39	-
25mm	-	32.61	-
26mm	-	32.84	-
27mm	-	33.07	-
28mm	-	33.31	-
29mm	-	33.55	-
30mm	-	33.80	-

31mm	-	34.06	-
32mm	-	34.32	-
33mm	-	34.60	-
34mm	-	34.88	-
35mm	-	35.18	-
36mm	35.49KV	35.49	0

Table III shows the percentage error between the known values with NDDI method and without NDDI method. The distance between electrodes was taken from 3mm to 36mm. Breakdown voltage at 3mm, 9mm, 18mm and 36mm was known without the newton divided difference interpolation method. Percentage absolute error is 0% at every known value of breakdown voltage.

With Time Reference At 11KV

The equation 3 at breakdown voltages above 11KV with a time reference.

$$f_2(x) = 0 \qquad \ldots(3)$$

Results Of Power Frequency Test At 27kv Voltage

Table 4: Power Frequency Withstand Voltage Test Without Time & With Time At 27kv Voltage

Distance Between Electrodes	Without Time	Time=10 minutes
3mm	27KV	27KV (2 Second)
9mm	31.91KV	NIL
18mm	30.12KV	NIL
36mm	39.04KV	NIL

From the results in Table IV , it is clear that the breakdown voltage was increased when the distance was from 3mm to 9mm and decreased at 18mm and after this, it increased which shows that behavior was non-linear. There was a breakdown at 3mm and at 9mm, 18mm, 36mm there was no breakdown when 27KV voltage was applied for 10 minutes.

Without Time Reference At 27KV

$$f_2(x) = 0.00283439x^3 - 0.152847x^2 + 2.32087x + 21.3365 \ldots(4)$$

Equation 4 was generated using the newton divided difference interpolation method and the graph of that equation was plotted with the help of MATLAB software the plot of the equation 6.

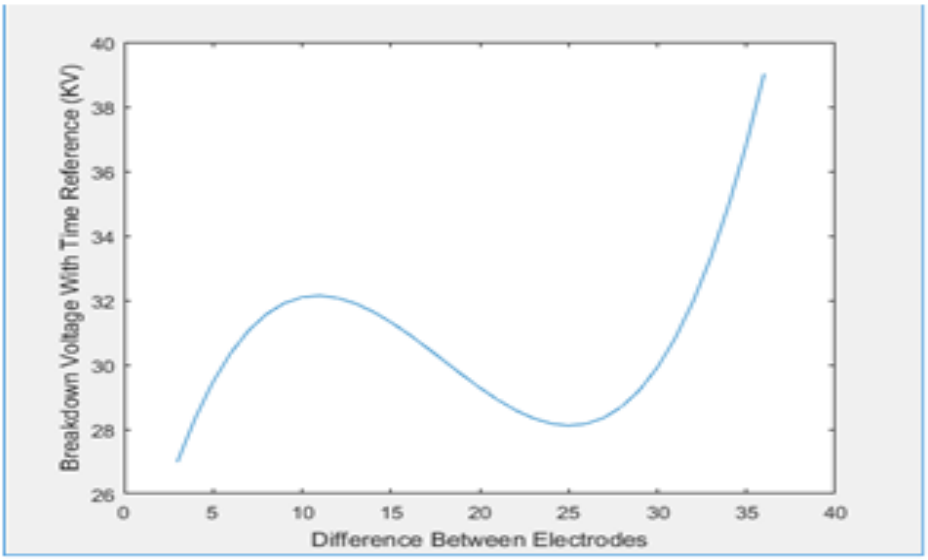

Fig. 2 Plot between difference between electrodes & breakdown voltage without time at voltages above and equal 27KV

The breakdown value at unknown distances was estimated in the table below. The error with and without newton's divided difference interpolation was also given in the table V. There is no absolute error at 3mm to 35mm and 0.025% error at 36mm.

Table 5: Breakdown Voltage Value Estimation In Power Frequency Withstand Voltage Test Without Time & With Time At Voltages Above 27kv

Distance Between Electrodes	Without Time	Without Time (With NDDI)	Absolute Error (%)
3mm	27KV	27.00	0
4mm	-	28.35	-
5mm	-	29.47	-
6mm	-	30.37	-
7mm	-	31.06	-
8mm	-	31.57	-
9mm	31.91KV	31.91	0
10mm	-	32.09	-
11mm	-	32.14	-
12mm	-	32.07	-
13mm	-	31.90	-
14mm	-	31.64	-
15mm	-	31.32	-

16mm	-	30.95	-
17mm	-	30.54	-
18mm	30.12KV	30.12	0
19mm	-	29.69	-
20mm	-	29.29	-
21mm	-	28.91	-
22mm	-	28.59	-
23mm	-	28.34	-
24mm	-	28.18	-
25mm	-	28.11	-
26mm	-	28.17	-
27mm	-	28.36	-
28mm	-	28.70	-
29mm	-	29.22	-
30mm	-	29.92	-
31mm	-	30.83	-
32mm	-	31.96	-
33mm	-	33.33	-
34mm	-	34.95	-
35mm	-	36.85	-
36mm	39.04KV	39.03	0.025

Table V shows the percentage of the error between the known values with the NDDI method and without the NDDI method. The distance between electrodes was taken from 3mm to 36mm. Breakdown voltage at 3mm, 9mm, 18mm and 36mm was known without the newton divided difference interpolation method. 0.025% error at 36mm electrode distance.

With Time Reference At 27KV
The equation 5 at breakdown voltages above 27KV with a time reference.

$$f_2(x) = 0 \qquad \ldots(5)$$

Conclusion
In this paper, the power frequency withstand voltage test on the high tension cable of the transformer is applied. Power frequency withstand voltage test is applied on the insulation of high tension cable. Voltages above and equal 11KV & 27KV applied. This test is carried out with time reference and without time reference. Newton divided difference interpolation

method is used for estimating unknown breakdown values. The mathematical function is generated using the newton divided difference interpolation method.

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