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Neural Network Approach For Condition Monitoring of Traction Transformer oil

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Abstract

As the development of high speed railway, it call for higher reliability of traction power supply system and traction transformer. However compared with power transformer, the running condition of traction transformer, on which the impulse load caused by sort circuit is continually applied, is ever worse. This bring 'Cumulative effect' which will give rise to different kind of transformer faults including heat faults and discharged faults.. Hydro carbon gases and water are created in this course. By implementing correct operational and maintenance strategies the insulation aging/degradation process can be controlled and the traction transformer life can be extended effectively .A new approach has been presented in this paper based on an index which could be computed online to monitor the status of traction transformer.

Keywords: Condition Monitoring, DGA, Traction Transformer.

1. INTRODUCTION

As the development of high speed railway, it calls for higher reliability of traction power supply system and traction transformer power supply system and traction transformer. However compared with power transformer, the running condition of traction transformer, on which the impulse load caused by sort circuit is continually applied, is ever worse. This brings 'Cumulative effect' which will give rise to different kind of transformer faults including heat faults and discharged faults. [1]. Hydro carbon gases and water are created in this course. Transformers inner part, gases including H_2, CH_4, C_2H_6, C_2H_4, C_2H_2, Co and Co_2 Will appear along with insulation materials aging and decoration. As these gases appearance are accompany with all kinds of transformer faults, monitoring of gas concentrations is very helpful to identify transformers running state. [2]-[5].

Transforms can be considered from the most important equipments in the distribution system. As any transform outage affect the system as a whole. One method for predicting the transformers major faults and increasing life time is the use of condition monitoring (CM) techniques. CM concerns the application and development of special purpose equipments that have the function of acquiring the data and the development of new techniques to analyse these data to predict the trend of the monitored equipment and evaluate its current operating status. [6].

CM is the technique served for condition-Basic Maintenance (CBM). Traditionally, time based maintenance had been the main maintenance strategy for a long time. Time based maintenance may prevent many failures CBM will let operators know more about the traction transformer and indicate clearly when and what maintenance in needed clearly when and what maintenance in needed so that money and manpower could be saved and shutdown can be reduced [7].

Transformers are generally reliable pieces of the system. However, the faults are often difficult to diagnose or locate in the transformer due to complicated winding structures, but a multipara meter CM approach gives valuable data to diagnose the fault and suggest its location CM can prevent transformer unplanned outages and catastrophic failures cause by faults. It allows aging of the system to the monitored and therefore controlled and predicted and extended [5].

Accounting to old and recent research in the field of transformer condition monitoring, it can be divided into five main categories-

(1) Thermal Analysis

(2) Vibration Analysis

(3) Dissolved gas Analysis (DGA)

(4) PD Analysis

(5) Frequency response analysis (FRA)

The insulting of power transformers is generally very reliable. Insulation aging is transformers are most commonly associated with long term effect of the operating temperature, moistures and air. Since a significant proportion of transformers on the distribution network is old, it is necessary to assess the "Chemical" age of their insulations, and, if possible, to predict their rates of ageing relative to their present and future loading conditions. Dissolved Gas Analysis (DGA) researchers sees that electrical measurements (Partial discharge, dielectric loss, dc resistance, dielectric strength) have no clear and strong correlation between electrical properties and the physical and chemical states of the oil-paper insulation [8], [9]. The thermal degradation of oil results in the production of hydrogen methane, ethane, ethylene, acetylene, Co, Co_2 and other products on oil breakdown include alcohols, organic acids, aldehydes, peroxides etc.

For any given oil sample, the absolute and relative concentrations of fault gas can be used to indicate the type, intensity and location of the fault. A variety of methods are available to achieves this, laboratories may rely upon defined critical levels of gases, rates increase in gas level (on a year by year basis), or one of the various methodologies associated with Rogers, Davd or Domberg. The recommended practice for oil sampling extraction of gases and methods of analyst's are detailed in IEC 567 [10] After analysing the gas concentrations and using the gases with the defect. Some artificial intelligent agents can be trained on the DGA ratio codes to classify some incipient faults with have some irregular gas ratios that can't be interpreted [11, 12]

However in the recent years consistent methods have been developed in DGA interpretation based on a large number of expert systems, data and failure history of transformers. DGA data could be used along with fuzzy logic and to design an expert system [13]. Transformer Diagnostic Monitoring (TDM) system is used for continuous monitoring and analysis of power transformers technical condition [14].

Frequency response analysis method is one of the most frequently used diagnostic tools for investing transformer coil deformation A new technique for on-line transfer function monitoring through its bushing taps or capacitive sensors installed on the surface is presented [16] via transfer functions. For condition assessment of power transformer, it is recommendable to use a modern monitoring system. With such a system, a more safe, reliable and cost optimized operation of the transformer is possible. State of the art monitoring systems feature supervision of all main components of traction transformers. Condition Monitoring involves monitoring of certain parameters of traction transformer. Based on the prescribed parameter values certain maintenance can be decided and carried out.

Normally, any equipment is maintained in three ways viz.

(a) Routine Maintenance

(b) Periodic Maintenance

(c) Condition based Maintenance.

In Routine maintenance, activities involved which are essential for day-to-day working like checking of oil level, colour of silica Gel in Breather etc.

In Periodic maintenance, activities involved are that type of maintenance activities which are not necessary to be done so frequently and ensures the working of the transformer over a longer period such as oil testing, measuring IR value etc.

It is established that over maintenance of any equipment leads to more number of failures. Hence the present trend is to minimize the maintenance, which can be achieved through condition based monitoring. Failure of a transformer leads to lot of inconvenience and anxiety which can be avoided if proper measures are taken before its failure takes place. A transformer never fails all of a sudden except due to short circuit or lighting surges. Always a fault is developed gradually and may lead to its failure and consequently to be shut down for repairs if not detected in its incipient stage. Such faults can be of following nature.

(i) A local fault developing over days and weeks.

(ii) Deterioration of insulation comparatively over a longer period.

When such faults are detected and diagnosed at the early stage, necessary steps can be taken to plan the shutdown of the transformer conveniently for its repairs and procurement of the necessary spares.

2. Methodology

The reliability of the ANN will be is tested on standard 70 samples for different gage as shown in appendix 1. Block diagram of the methodology adopted is given in following figure.

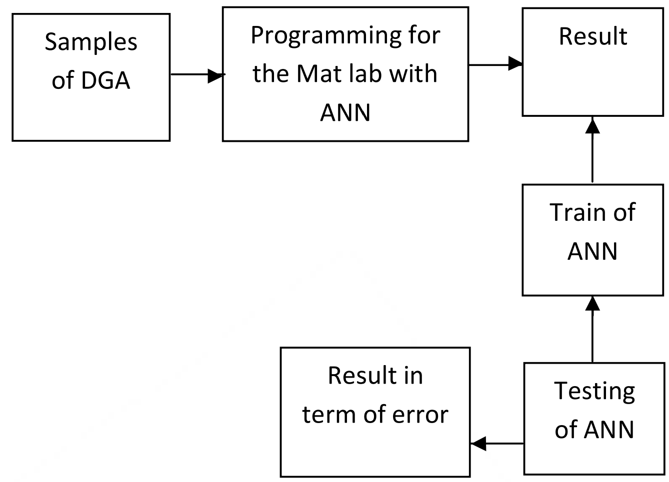

Fig 5.1 Block diagram of the methodology adopted

Transformer of gases takes place in oil filled transformer due to the following reasons-

1. Oxidation

2. Vaporization

3. Insulation Decomposition

4. Oil Breakdown

5. Electrolytic Action

For DGA, generally Roger's method is used which analyses proportion of one gas w.r.t. the other gas. The gases involved are:

1. Methane (CH_4) } at 120º

2. Ethane (C_2H_6) } at 120º

3. Ethylene (C_2H_4) } at 150º

4. Acetylene (C_2H_2) } at very high temp.

The absolute condition of the fault gases gives the status of the transformer insulation whereas the relative concentration these gases provide an idea of the type of the fault. The concentrations of fault gases are measured in ppm. Normal gas levels considering the aging effect are as shown below in Table 1. Based on statistical data; one indicator is proposed for the insulation status of the transformer. The Insulation Deterioration Index (IDI) is expressed as-

$$\frac{\sqrt{\begin{matrix}0.2(H_2-20)^2+0.8(CH_4-10)^2+0.7(C_2H_6-10)^2+0.8(C_2H_4-10)^2+0.8(C_2H_2-10)^2\\+0.01(CO_2-3000)^2+0.1(CO-200)^2\end{matrix}}}{Total\ Gas\ Concentration}$$

Where $H_2, CH_4, C_2H_6, C_2H_4, C_2H_2, CO_2$ & CO in this formula indicates the concentration in ppm of respective gases dissolved in the transformer oil.

IDI is based on the square root deviations from the normal concentration of respective gases. If in a sample of transformer oil,

H_2 = 20 ppm

CH_4 = 10 ppm

C_2H_6 = 10 ppm

C_2H_4 = 10 ppm

C_2H_2 = 10 ppm

CO_2 =3000 ppm

Co = 200 ppm

Then the IDI will be zero, which indicates an absolute sound insulation condition.

As stated earlier, the relative concentration provides a clue to type of fault.

1. If CH_4/H_2 = 1, transformer has slight overheating below 150ºC
2. If CH_4/H_2= C_2H_6/CH_4 = 1, Overheating between (150-200ºC)
3. If C_2H_6/CH_4= 1, Overheating between 200-300ºC
4. If C_2H_4/C_2H_6= 1, Conducter overheating
5. If CH_4/H_2= C_2H_4/CH_4= 1, Circulating currents or overhead joints
6. If C_2H_2/C_2H_4= 1, Flashover without power follow through
7. If C_2H_4/CH_4= C_2H_2/C_2H_4= 1, Persistent arcing

Hence DGA is a very powerful tool for condition monitoring of traction transformers. In this dissertation; an algorithm is proposed for a comprehensive condition monitoring of traction transformer as given below:

The Insulation Deterioration Index (IDI) as proposed is calculated based on the data of DGA for various samples. The condition of the transformer and assessment of the fault type is done as per the algorithm proposed.

3. Implementation and Results

Sample No.	*Concentration in ppm*							*TGC*	*IDI*	*Condition*
	CH_4	**C_2H_6**	**C_2H_4**	**C_2H_2**	**CO_2**	**CO**	**H_2**			
1	40	40	40	18	4000	210	100	4448	0.026	Sound
2	550	20	50	20	3000	300	40	8428	0.0576	
3	80	80	30	40	3000	400	60	3690	0.0598	
4	50	70	35	35	3720	500	50	4460	0.0315	Gradual Overheating
5	50	50	52	19.2	3672	552	50	4445.2	0.4716	Gradual O/H (200-300ºC)
6	172	75	75	38.7	5223	372	72	6027.7	0.0471	Conductor overheating
7	110	97	110	37.8	4228	421	110	5113.2	0.0407	Circulating Current or Joint Heating
8	197	60	192	196	3212	614	52	4523	0.0705	Persistent Arcing
9	82	97.2	86	32.4	3220	256	55	3828.6	0.0325	

10	62	48.2	40	19	3000	250	35	3454.2	0.0189	
11	87	80	44	25	3227	270	47	3780	0.0295	
12	41	57	62	32	3332	215	50	3789	0.0204	
13	47	50	57	27	4200	218	56	4485	0.268	
14	52.4	63	42	19	3100	215	25	3553.4	0.0216	
15	55.4	42	30	16	3200	250	27	3620.4	0.0160	
16	47.8	60	35	19	3710	220	20	4111.8	0.0333	
17	42	48	52	25	4130	210	40	45.47	0.0280	

Table1: DGA data of oil samples for Traction Transformer

With these results, it is observed that the value of IDI could be a better index as compared with the individual gas concentration observations. It also gives comprehensive information about the aging of transformer oil. Samples 4, 5, 6, 7 & 8 indicate typical faults that are developing inside the tank. Whereas some samples have low values of IDI which reflect sound conditions of traction transformer.

Transformer oil also deteriorates with aging. Following observations are illustrated from the test data's available to check the behaviour of the proposed index. The effect of aging on a sample of transformer is as shown in Table 4:

Year of service	**CH_4**	**$C2H_6$**	**C_2H_4**	**C_2H_2**	**CO_2**	**CO**	**H_2**	**TGC**	**IDI**
Fresh	12	10	14	11	3000	210	20	3277	$1.57*10^{-3}$
1	14	13	17	12	3130	220	50	3456	$6.14*10^{-3}$
2	18	19	21	14	3424	260	80	3836	0.0145

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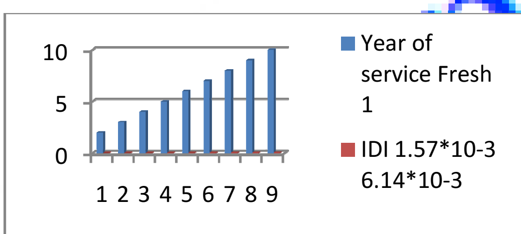
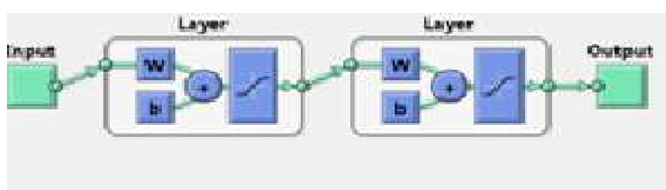
3	24	26	24	15	3700	280	120	4189	0.02142
4	30	28	27	16	4000	300	150	4551	0.02707
5	50	40	40	20	5000	370	200	5720	0.0398
6	80	60	65	25	6000	410	240	7530	0.0445
7	98	75	82	30	7000	500	290	8075	0.05499
8	102	82	110	32	8000	582	340	9248	0.0653
9	119	99	130	38	9000	635	418	10439	0.06338
10	130	110	150	40	10000	700	500	11630	0.0663

4. Graph of Year v/s IDI



The results clearly reflect the variation of Insulation Deterioration Index with aging and the typical values over 10 year of service of transformer oil. As discussed in chapter 4, ANN is a powerful tool for predicting the output with the given set of inputs. Hence in this part, feed forward neural network with seven input neurons and one output neuron is selected. The idea behind this is to get clear cut information about the existing insulating properties of transformer oil in service with the help of artificial intelligence. The output of the proposed ANN model is IDI as defined previously and the inputs are gas concentration.

MATLAB 7.0 is used for the purpose which provides platform for the proposed ANN Model.



As discussed earlier ANN is a powerful tool for simulation of Nonlinear problems as the case presented. Gas concentrations obtained in ppm are selected as inputs. ANN model gives output IDI. Back propagation algorithm is used to train the network. Feed forward neural network has been selected with seven input neurons, three hidden layer neurons and one output neurons. The training data for the ANN were selected as follows:

Sample No.	Concentration in ppm							IDI
	CH4	C2H6	C2H4	C2H2	CO2	CO	H2	
1	30	30	30	8	3000	110	50	0.0288
2	275	10	25	10	1500	150	20	0.0299
3	40	40	15	20	1500	200	30	0.01575
4	25	35	17.5	17.5	1860	250	25	0.2358
5	25	25	26	9.6	1836	276	25	0.02355
6	86	37.5	37.5	19.35	2611.5	186	36	0.02035
7	55	48.5	55	18.9	2114	210.5	55	0.03525
8	98.5	30	96	98	1606	307	26	0.6125
9	41	48.6	43	16.2	1610	128	27.5	0.00945
10	31	24.1	20	9.5	1500	125	17.5	0.01475
11	43.5	40	22	12.5	1663.5	135	23.5	0.0102
12	20.5	28.5	31	16	1666	107.5	25	0.134
13	23.5	25	28.5	13.5	2100	109	28	0.0108
14	26.2	31.5	21	9.5	1550	107.5	12.5	0.008
15	27.7	21	15	8	1600	125	13.5	0.01665
16	23.9	30	17.5	9.5	1855	110	10	0.014

17	21	24	26	12.5	2065	105	20	0.013
18	20	20	20	9	2000	105	50	0.0192
19	173.33	6.66	16.666	6.66	1000	100	13.333	0.01993
20	26.66	26.66	10	13.333	1000	133.333	20	0.0105
21	16.666	23.33	11.666	11.666	1240	166.66	16.666	0.1572
22	16.666	16.666	17.333	6.4	1224	184	16.33	0.0157
23	57.333	25	25	12.9	1741	124	24	0.01356
24	36.666	32.333	36.67	12.6	1409.33	140.333	36.67	0.0235
25	65.666	20	64	65.333	1070.66	204.666	17.333	0.01083
26	17.333	32.4	28.666	10.8	1073.33	85.33	18.333	0.0063
27	20.66	16.066	13.333	6.333	1000	83.333	11.6666	0.00983
28	29	26.666	14.666	8.333	1075.66	90	15.666	0.0068
29	13.66	19	20.666	10.66	1110.67	71.666	16.666	0.0893
30	15.6666	16.666	19	9	1400	72.666	18.666	0.0072
31	17.466	21	14	6.333	1033.33	71.666	8.333	0.0072
32	18.466	14	10	5.333	1066.67	71.666	8.333	0.0111
33	15.93	20	11.666	6.333	1236.66	73.333	6.666	0.00933
34	14	16	17.333	8.333	1376.66	70	13.333	0.063
35	110	140	70	70	7440	1000	100	0.056
36	84	96	104	50	8260	420	80	0.0378

37	124	96.4	80	38	6000	500	70	0.0814
38	220	194	220	75.66	8456	842	220	0.0814
39	275	10	25	10	1500	150	20	0.0288
40	40	40	15	20	1500	200	30	0.0299
41	25	35	17.5	17.5	1860	250	25	0.01575
42	25	25	26	9.6	1836	276	25	0.2358
43	86	37.5	37.5	19.35	2611.5	186	36	0.02355
44	55	48.5	55	18.9	2114	210.5	55	0.02035
45	98.5	30	96	98	1606	307	26	0.03525
46	41	48.6	43	16.2	1610	128	27.5	0.6125
47	31	24.1	20	9.5	1500	125	17.5	0.00945
48	43.5	40	22	12.5	1663.5	135	23.5	0.01475
49	20.5	28.5	31	16	1666	107.5	25	0.0102
50	23.5	25	28.5	13.5	2100	109	28	0.134
51	26.2	31.5	21	9.5	1550	107.5	12.5	0.0108
52	27.7	21	15	8	1600	125	13.5	0.008
53	23.9	30	17.5	9.5	1855	110	10	0.01665
54	21	24	26	12.5	2065	105	20	0.014
55	20	20	20	9	2000	105	50	0.013
56	173.33	6.66	16.666	6.66	1000	100	13.333	0.0192

57	26.66	26.66	10	13.333	1000	133.333	20	0.01993
58	16.666	23.33	11.666	11.666	1240	166.66	16.666	0.0105
59	16.666	16.666	17.333	6.4	1224	184	16.33	0.1572
60	57.333	25	25	12.9	1741	124	24	0.0157
61	36.666	32.333	36.67	12.6	1409.33	140.333	36.67	0.01356
62	65.666	20	64	65.333	1070.66	204.666	17.333	0.0235
63	17.333	32.4	28.666	10.8	1073.33	85.33	18.333	0.01083
64	20.66	16.066	13.333	6.333	1000	83.333	11.6666	0.0063
65	29	26.666	14.666	8.333	1075.66	90	15.666	0.00983
66	13.66	19	20.666	10.66	1110.67	71.666	16.666	0.0068
67	15.6666	16.666	19	9	1400	72.666	18.666	0.0893
68	17.466	21	14	6.333	1033.33	71.666	8.333	0.0072
69	18.466	14	10	5.333	1066.67	71.666	8.333	0.0072
70	15.93	20	11.666	6.333	1236.66	73.333	6.666	0.0111
71	14	16	17.333	8.333	1376.66	70	13.333	0.00933
72	110	140	70	70	7440	1000	100	0.063
73	84	96	104	50	8260	420	80	0.056
74	124	96.4	80	38	6000	500	70	0.0378
75	220	194	220	75.66	8456	842	220	0.0814

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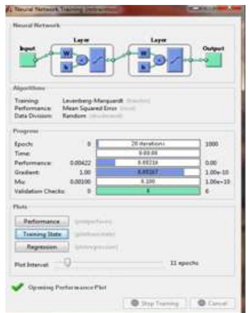
Back Propagation Algorithm has been used to train the network. The network has been trained in 24 epoch.



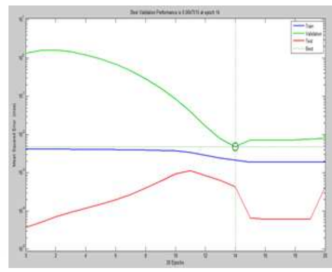


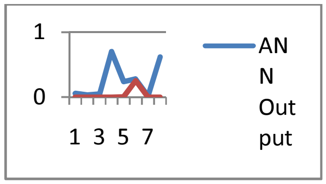
Fig (a) and (b) output of ANN

After successful training, the network has been tested for the following inputs. The deviation (error) obtained with the ANN output indicates that the training was successful.

The test data's are as follows:

S.No.	CH4	C2H6	C2H4	C2H2	CO2	CO	H2	IDI	ANN Output	Error
1	550	20	50	20	3000	300	40	0.0576	0.0572	0.0004
2	50	70	35	35	3720	500	50	0.0315	0.0314	0.0001
3	172	75	75	38.7	5223	372	72	0.0471	0.0474	0.0002
4	197	60	192	196	3212	61`4	52	0.0707	0.702	0.0003
5	41	57	62	32	3332	215	50	0.02042	0.238	0.003
6	42	48	52	25	4130	210	40	0.02806	0.281	0.252
7	18	19	21	14	3424	260	80	0.0145	0.0142	0.0003
8	119	99	130	38	9000	635	418	0.06338	0.62	0.001

The graph of error v/s output as obtained from MATLAB is as shown in fig.



5. Conclusion

Dissolved gas analysis is a very powerful tool to monitor the conditions inside the traction transformer. The knowledge of absolute concentration of fault gas indicates status of insulation whereas relative concentration provides a clue to the type of fault. Results show that the proposed index IDI gives a fearsome idea about the insulating property of transformer oil. The relative concentration of fault gases gives the clue about the characteristics of the fault that is developing inside the tank. Another important feature of IDI is that it can give an idea about the aging of insulating oil. Table4 shows the variation of IDI with aging.

Artificial Neural Network can be trained for the various conditions from the gas concentrations to access directly the insulating quality in terms of IDI. Once trained, a numeric relay could be used for alarming conditions based on IDI.

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