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Research Article

DGA, HMM & WAVELET CONCEPTS FOR POWER TRANSFORMER FAILURE ANALYSIS

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ABSTRACT
In the proposed paper, we have demonstrated three different methods for the failure analysis of power transformers. These methods can help in monitoring the transformer condition. The three methods are Dissolved Gas Analysis, Hidden Markov models concept and Wavelet technology. Dissolved Gas Analysis analyzes power transformer failure by considering the concentrations of dissolved gases in the transformer oil samples. A computer program was developed for the Hidden Markov model which helped in finding out the fault probability of the power transformer. Wavelet technology was utilized by developing another program to get the present condition of power transformer taking the temperature variations into account. Here, we demonstrate the application of these three methods on oil samples of power transformers from three different substations spread across the states of Telangana and Andhra Pradesh, India.

Keywords: *Power Transformers, Dissolved Gas Analysis, Hidden Markov Models, Wavelet Technology, MATLAB*

INTRODUCTION
Power transformers are key players ensuring smooth power flow in large power systems. But, various power transformer failures in the recent past due to various reasons led to opt for advanced preventive, predictive and spontaneous repair techniques to nullify them. In this paper, we try to go a little ahead from the present techniques being adopted for saving power transformers from undesirable failures. Three different procedures have been explained in this paper besides implementing them on three power transformers taken as case studies.
The first one is Dissolved Gas Analysis wherein the transformer oil sample is collected to get the composition of dissolved gases which enables the analysis of transformer condition. The second one is Hidden Markov Model concept, which requires MATLAB coding, the output of which provides failure probability of the given power transformer.
In the third procedure, the temperature variations at power transformer location are monitored by visualizing them through a software program which collects the temperature data using wireless or wired transmission from transformer location.

MATERIALS AND METHODS
Dissolved Gas Analysis
The oil sample is composed of various gases which are significant in deciding the transformer behavior. These gases are to be isolated from the sample and analyzed quantitatively using gas chromatography process. This technique enables proper diagnosis of the transformer condition in service and can also suggest preventive measures.
The quantities of gases generated from the transformer oil and their relative levels help in identifying the various fault conditions.
The main gases that are collected include: a) Hydrogen b) Methane c) Ethane d) Acetylene and e) Ethylene. Relative quantities of these gases give the oil decomposition energy during a particular fault. Each fault has its own characteristic amount of energy. Elevated concentrations of gases may signal corona, discharge, overheating, and arcing or cellulose insulation pyrolysis.

Hidden Markov Model

Markov Model is the one wherein state is directly visible to the user and the state transition probabilities are the only parameters. However, a Hidden Markov Model has state not directly visible i.e., the state is hidden and the output which is dependent on the state is visible. The state sequence through which the model passes is hidden and not the parameters of the model. In fact, even when the parameters are exactly known, the model is still hidden.

Hidden Markov Model Fault Diagnosis

This is used for classification. Different fault characteristic patterns should build HMM and the characteristic gas observable value can be used to quantify the sequence at fault classification. The probability '$P(O|\lambda)$' is calculated and reasoned by the forward- backward algorithm or Viterbi algorithm, then the probability output result is compared and the decision is made by the maximal output. For example, if 'λ_i' (output probability) is at its highest level, the fault pattern ω_i' will be judged. The quantification sequence for the characteristic gases observable vector quantity given by

$X = [H_2, CH_4, C_2H_6, C_2H_4, C_2H_2, CO, CO_2]$

This is used as the input vector quantity and the fault is classified by the built-in HMM. There are two types of outputs for HMM classification. The first one is HMM export logarithmic likelihood probability computation result. Another is the fault possibility corresponding to each of fault modes.

Wavelet Technology Application on Power Transformer Fault Analysis

In the proposed paper, temperature sensors were provided at the power transformer location (on the equipment body). This ensured temperature analysis at the control center through a wired communication which can also be replaced by wireless mode like GSM, Zigbee etc., for advanced application. The receiver unit at the control center was connected through software (MATLAB in our case) which displayed the exact and minute simultaneous temperature variations at the power transformer location, in the form of wavelets.

RESULTS AND DISCUSSION

Oil samples of power transformers located at three different substations across Telangana and Andhra Pradesh states (India) were collected and above described procedures were applied on the samples.

Table 1: Dissolved gas analysis test results

		Reference standard			**Result (ppm)**			
Sl. No.	**Name of the gas**	**Up to 4 years**	**4 to 10 years**	**Above 10 years**	**Up to 4 years**	**4 to 10 years**	**Above 10 years**	**Remarks**
1.	Hydrogen (H_2)	100/ 150	200/ 300	200/ 300	NA	3.96	NA	Satisfactory
2.	Methane (CH_4)	50/ 70	100/ 150	200/ 300	NA	1.52	NA	Satisfactory
3.	Ethylene (C_2H_4)	100/ 150	150/ 200	200/ 400	NA	8.57	NA	Satisfactory
4.	Ethane (C_2H_6)	30/ 50	100/ 150	800/ 1000	NA	0.47	NA	Satisfactory
5.	Acetylene (C_2H_2)	20/ 30	30/50	100/ 150	NA	0.43	NA	Satisfactory
6.	Carbon monoxide (CO)	200/ 300	400/ 500	600/ 700	NA	279.43	NA	Satisfactory
7.	Carbon dioxide (CO_2)	3000/ 3500	4000/ 5000	9000/ 12000	NA	288.27	NA	Satisfactory

ND: Not Determined NA: Not Applicable

The results from the above described methods of analyzing the power transformer failures are described in the following Tables and Figures. For the power transformers, the Dissolved Gas Analysis test results are shown in the Tables – 1, 3 and 5 while the respective Hidden Markov Model outputs are given in Tables- 2, 4 and 6. The corresponding Wavelet program visible outputs are shown in Figures- 1, 2 and 3.

Power Transformer Oil Sample Test Results under Healthy Condition

The results for the power transformer located at Vijayawada substation are shown in the Tables- 1 and 2 and Figure 1.

The Dissolved Gas Analysis results are shown in the Table 1 given above.

As per the above table, results are within limits i.e., the transformer is healthy.

The Hidden Markov Models concept results are shown in the Table 2 given below.

Table 2: Hidden Markov Models output results

Output	Normal	Overheat under moderate/low temperature	Overheat under high temperature	Discharge under low energy	Discharge under high energy
Logarithmic likelihood probability	-Infinity	-6.9386e-001	3.4370e+001	1.572e+001	2.515e+000
Fault possibility (%)	8.032e+000	6.3113e+000	**5.2323 e+001**	5.946 e+001	1.046 e+002

*Remarks: The identification results are overheat under high temperature (i.e., the thermal fault), and the fault occurrence probability is '**52.32%**'*

The visible output on screen for the corresponding variations in temperature is as given in the Figure 1 below.

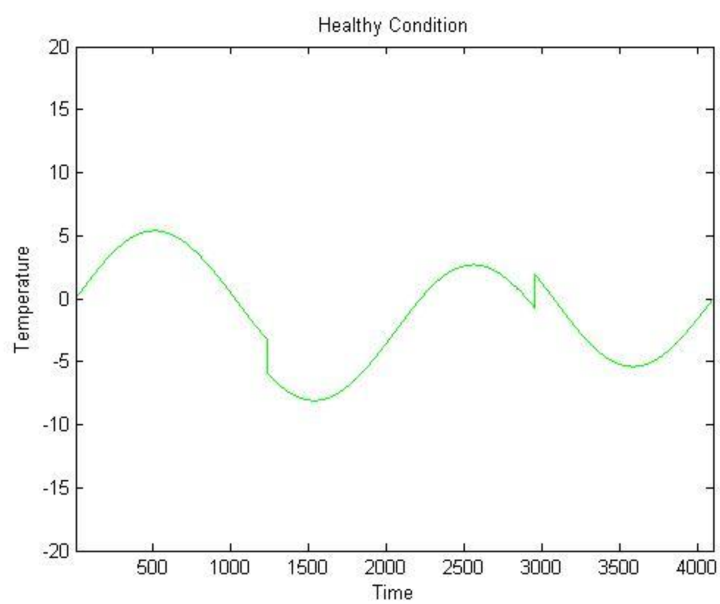

Figure 1: Wavelet Analysis Output for the transformer under healthy condition

As per the above figure, temperature-related faults are within limits i.e., the transformer is healthy.

Power Transformer Oil Sample Test Results under Moderately Deteriorated Condition

The results for the power transformer located at Vijayawada substation are shown in the Tables- 3 and 4 and Figure 2.

The Dissolved Gas Analysis results are shown in the Table 3 given below.

Table 3: Dissolved gas analysis test results

Sl. No.	Name of the gas	Reference standard Up to 4 years	4 to 10 years	Above 10 years	Result (ppm) Up to 4 years	4 to 10 years	Above 10 years	Remarks
1.	Hydrogen (H_2)	100/ 150	200/ 300	200/ 300	NA	42.54	NA	Satisfactory
2.	Methane (CH_4)	50/ 70	100/ 150	200/ 300	NA	12.62	NA	Satisfactory
3.	Ethylene (C_2H_4)	100/ 150	150/ 200	200/ 400	NA	10.17	NA	Satisfactory
4.	Ethane (C_2H_6)	30/ 50	100/ 150	800/ 1000	NA	2.85	NA	Satisfactory
5.	Acetylene (C_2H_2)	20/ 30	30/50	100/ 150	NA	25.63	NA	Satisfactory
6.	Carbon monoxide (CO)	200/ 300	400/ 500	600/ 700	NA	30.58	NA	Satisfactory
7.	Carbon dioxide (CO_2)	3000/ 3500	4000/ 5000	9000/ 12000	NA	46.3	NA	Satisfactory

ND: Not Determined NA: Not Applicable

As per the above table, H_2 and C_2H_2 gases are very high. As per IEC 60599, discharge of low energy is suspected in the transformer.
The Hidden Markov Models concept results are shown in the Table 4 given below.

Table 4: Hidden Markov Models output results

Output	Normal	Overheat under moderate/low temperature	Overheat under high temperature	Discharge under low energy	Discharge under high energy
Logarithmic likelihood probability	-Infinity	1.1659e+002	5.9730e+001	3.457e+001	6.6319e+002
Fault possibility (%)	8.6e+001	5.1340e+001	**6.2059e+001**	2.525e+001	3.6025e+002

*Remarks: The identification results are overheat under high temperature (i.e., the thermal fault), and the fault occurrence probability is '**62.059%**'*

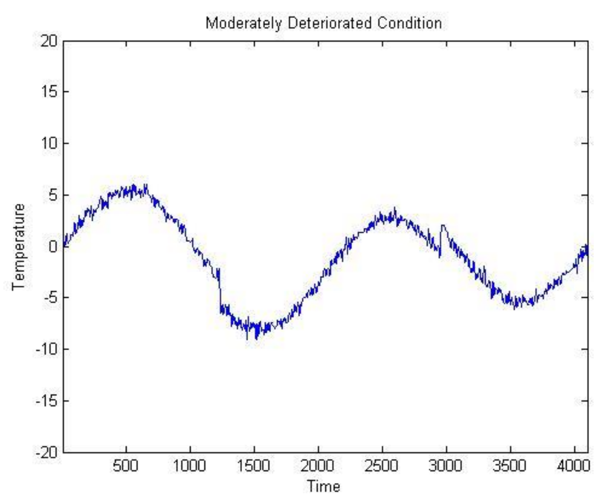

Figure 2: Wavelet Analysis Output for the transformer under moderately deteriorated condition

For the Wavelet analysis, the visible waveforms on screen for the corresponding variations in temperature are shown in Figure 2 above.

As per the above Figure, temperature-related faults appear to be bordering the alarming level i.e., the transformer is partially deteriorated.

Power Transformer Oil Sample Test Results under Extensively Deteriorated Condition:

The results for the power transformer located at Vijayawada substation are shown in the Tables- 5 and 6 and Figure 3.

The Dissolved Gas Analysis results are shown in the Table 5 given below.

Table 5: Dissolved gas analysis test results (extensively deteriorated condition)

		Reference standard			**Result (ppm)**			
Sl. No.	**Name of the gas**	**Up to 4 years**	**4 to 10 years**	**Above 10 years**	**Up to 4 years**	**4 to 10 years**	**Above 10 years**	**Remarks**
1.	Hydrogen (H_2)	100/ 150	200/ 300	200/ 300	NA	235.07	NA	Satisfactory
2.	Methane (CH_4)	50/ 70	100/ 150	200/ 300	NA	49.07	NA	Satisfactory
3.	Ethylene (C_2H_4)	100/ 150	150/ 200	200/ 400	NA	117.4	NA	Satisfactory
4.	Ethane (C_2H_6)	30/ 50	100/ 150	800/ 1000	NA	15.7	NA	Satisfactory
5.	Acetylene (C_2H_2)	20/ 30	30/50	100/ 150	NA	62.9	NA	**Unsatisfactory**
6.	Carbon monoxide (CO)	200/ 300	400/ 500	600/ 700	NA	245.3	NA	Satisfactory
7.	Carbon dioxide (CO_2)	3000/ 3500	4000/ 5000	9000/ 12000	NA	174.09	NA	Satisfactory

ND: Not Determined NA: Not Applicable

As per the above table, the transformer is suspected to have thermal fault due to high concentration of Acetylene.

The Hidden Markov Models concept results are shown in the Table 6 given below.

Table 6: Hidden Markov Models output results

Output	**Normal**	**Overheat under moderate/low temperature**	**Overheat under high temperature**	**Discharge under low energy**	**Discharge under high energy**
Logarithmic likelihood probability	-Infinity	5.6578e+000	2.1030e+001	1.1314e+001	5.7951e+001
Fault possibility (%)	4.8e+001	2.0345e+001	**7. 266e+001**	1.5059e+001	1.6505e+002

*Remarks: The identification results are overheat under high temperature (i.e., the thermal fault), and the fault occurrence probability is '**72.66%**'*

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For the Wavelet analysis, the visible waveforms on screen for the corresponding variations in temperature are as given in the Figure 3 below.

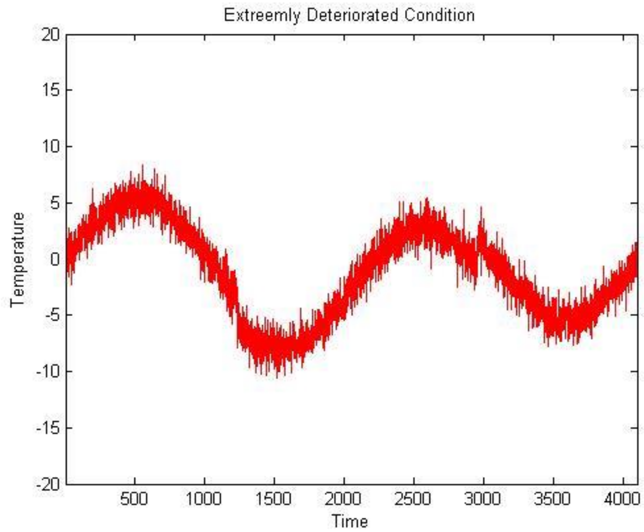

Figure 3: Wavelet Analysis Output for the transformer under extensively deteriorated condition

As per the above Figure, temperature-related faults appear to be clearly at the alarming level i.e., the transformer is severely deteriorated. The equipment may be replaced for repair/overhaul or may be scrapped!

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Conclusion

In the proposed paper, an attempt was made to explain two methods of determining the power transformer failure condition for undertaking maintenance steps as and when needed. The widely used Conventional Oil analysis checks the oil samples for various properties like colour, density, viscosity, resistivity etc. Here, we proposed Wavelet technology application through temperature sensors connected from transformer point to the control center and successfully verified through software coding. Computing method was developed for the Wavelet technology.

As a case study, transformer oil samples from 132kV Port substation (Andhra Pradesh, India) were collected and tested for analyzing the aging effect. Accordingly, the transformer's oil sample was tested for three different conditions namely healthy, moderately deteriorated and extensively deteriorated conditions, as it ages. The above mentioned tests were conducted on these oil samples. From the Oil tests and Wavelet analysis results, it was clearly seen that the transformer deterioration increases as the transformer ages.

REFERENCES

Uzair MAR and Basavaraja B (2015). Oil tests and Wavelet Analysis of Faults in Power Transformers. *International Journal of Applied Engineering and Technology (CIBTech)* **5**(3) 22-30.