TRANSFORMER'S FITNESS INDEX JUDGMENT USING GREY RELATIONAL ANALYSIS THROUGH CHROMATOGRAM DATA

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Abstract : Dissolved gas-in-oil analysis (DGA) methods developed based on experience of experts and statistical formulations. These diagnostic methods are useful in determining faults in power transformer operation; computationally simple and work well on several faults. A standard IEEE C.57.104™ categorized risk of transformer into three levels on quantities of total dissolved combustible gases i.e. TDCG in the oil. However, overall performance of the transformer is depends on parameters other than gases in oil and subsystems attached to it. In this paper, sample of key gases along with allied parameters are considered for state assessment. Grey relation analysis is performed in standardizing the DGA interpretation to judge the fitness index of transformers.

***IndexTerms* - Dissolved gas Analysis, Key gases, Grey relational analysis, Target Heart degree.**

I. Introduction

Power transformer is key component in transmission and distribution systems. Their reliability directly relate to the power system operation. Therefore, transformer must be routinely examined to find incipient faults and any potentially extended deterioration [1-4]. A variety of techniques are available for monitoring different parameters of transformer. Turns ratio provides information on magnetization problems and deformation of the coils. Transformer losses address problems like loose bus-bars, additional eddy currents and flux leakage. Power factor test determines the power loss of the bushing that is the quality of the capacitance. Furan analysis involves in insulation ageing process. Partial discharges (PD) can occur due to the presence of floating particles, cavities, or sharp points [5-7]. Frequency Response Analysis detects the mechanical deformations in transformer windings [8]. Infrared emission testing is useful in detecting thermal problems. Monitoring tap changer temperature can be used to detect problems, such as contact overheating. Hot Spot temperature of the winding is calculated from measurements of oil temperatures and load current [9]. Tap changers carries the main current, may fail due to mechanical collapse causes arcing and also erosion & decomposition of oil & contact erosion [10]. DGA is worldwide accepted method, which involves sampling the oil and testing the sample to measure the concentration of the dissolved gases. The two principal causes of gas formation within an operating transformer are electrical disturbances and thermal decomposition [11-12]. DGA based on defined principles such as, gas concentrations, key gases and key gas ratios. Interpretation Schemes such as IEC 60599, Key Gas Analysis, Roger and Doernenberg Ratio Methods, Duval triangle Method and Gas Nomograph Method and IEEE Standard C57.104-1991are common [11-12].

Grey theory proposed by J. L. Deng in 1982, deals in partial information i.e. distribution free samples of small size for system analysis. A complete description of grey systems theory on the axioms of uncertainty and grey cognitive principles are strongly treated in mathematical formats. Several methods such as grey incidence analysis, grey sequence generations, and grey GM (1,1) model are commonly used for evaluation, prediction, decision-making, control and optimization. A verity of Grey methods is also introduced in state assessment of power transformer [13-17].

II. Grey Relational Analysis on Key gases

To apply GRA, input attributes need to satisfy three conditions given as-

(i) The attributes not less than a magnitude of two.
(ii) All attributes must be of the same type i.e. benefit, cost, or optimization of a specific value.
(iii) All attributes have the same measurement scale, if uses quantitative scale (same unit or no unit).

All the above conditions are referred as scaling (for the order of magnitude), polarization (for the attribute type), and non-dimension (for the measurement scale) [13-17]. The GRA algorithm is specified as follows:

A .Constructing Standard Pattern -

Assuming ωi is the state model-i and $\omega(k)$ is the state parameter of sequence-k for constructing the model and $\omega i=\{\omega i(1),\omega i(2),\ldots\ldots\ldots\ldots,\omega i(k)\}$ is the multi-polarity criteria sequence where K refers to the k^{th} criteria.

Define ω(k) as specification model sequence - $\omega(k)=(\omega_1(k), \omega_2(k),\ldots, \omega n(k))\ \forall\omega i(k)\varepsilon=>\omega(k)=> I\ \varepsilon\ I=\{1,2,..,n\}$;

Suppose POL (max), POL (min), POL (mem) refer to the maximum polarity, the minimum polarity and the medium polarity, respectively, therefore-

While POL $\omega i(k)$ = POL(max), then $\omega_0(k)=\max_i \omega i(k), \omega i(k)\varepsilon\omega(k)$

While POL $\omega i(k)$ = POL(min), then $\omega_0(k)=\min_i \omega i(k),\omega i(k)\varepsilon\omega(k)$

While POL $\omega i(k)$ = POL(mem), then$\omega_0(k)=\mathrm{avg}_i\ \omega i(k),\omega i(k)\varepsilon\omega(k)$

and then the sequence is- $\omega_0=\{\omega_0(1),\omega_0(2),\ldots,\omega_0(k)\}$, is the standard pattern [18-22].

Constructing the sequence according to minimum polarity, refer to Table no.1

$\omega 0= \{18, 24, 806, 1, 13,270\}$

B. Grey Target Transform -

Assume that T is a grey target transformation [19-22] as- $\Delta oi(k) = \frac{\min\{\omega i(k), \omega 0(k)\}}{\max\{\omega i(k), \omega 0(k)\}}$

Where x_0 refers to the standard bull's eye criteria-

$T\omega_0 = x_0 = (1, 1, 1, 1, 1, 1)$;

$T\omega_1 = x_1 = (0.152, 0.156, 0.212, 0.045, 0.282, 0.091)$

$T\omega_2 = x_2 = (1, 0.857, 0.984, 2, 0.928, 0.490)$;

$T\omega_3 = x_3 = (0.9, 1, 1, 0.2, 1, 1)$

$T\omega_4 = x_4 = (0.173, 0.142, 0.210, 0.0384, 0.232, 0.125)$;

$T\omega_5 = x_5 = (0.360, 0.187, 0.571, 1, 0.565, 0.114)$

C. Calculating Different Information Space -

Different information space [19-22] is calculated by - $\Delta oi\ (k) = |x0(k) - xi(k)| = |1 - xi(k)|$

Where, i=1,2,..,5 and k=1,2,3,4,5,6;

Where,$\Delta_0 i(k)$ shows the grey relational different information between evaluated sequence $x_0(k)$ and xi(k)

$T\omega_0 = x0 = (1, 1, 1, 1, 1, 1)$

$\Delta01 = (0.847, 0.843, 0.787, 0.954, 0.717, 0.908)$;

$\Delta02 = (0, 0.142, 0.015, 0.80, 0.071, 0.509)$

$\Delta03 = (0.1, 0, 0, 0.80, 0, 0)$

$\Delta04 = (0.826, 0.857, 0.789, 0.961, 0.767, 0.874)$

$\Delta05 = (0.640, 0.812, 0.429, 0, 0.434, 0.885)$

$\Delta0i(max) = max_i\ max_k$

$\Delta_0 i(k) = 1.0000$

$\Delta0i\ (min) = min_i min_k$

$\Delta_{0i}(k) = 0$

D. Calculating Coefficient of Target Heart –

The coefficient of target heart [19-22] is calculated by- $\gamma[X0(k), Xi(k)] = \frac{\{\text{mini maxk } \Delta oi(k) + \rho \max \max \Delta oi(k)\}}{\{\Delta oi\ (k) + \rho \text{maximaxi} \Delta oi(k)\}}$

Where, ρ is the resolving coefficient, ρ∈[0, 1]. Assume ρ=0.5.

Grey target coefficient obtained for sample 1are: γ(x0(1),x1(1)) = 0.3710; γ(x0(2),x1(2)) = 0.3722;γ(x0(3),x1(3)) = 0.3883; γ(x0(4),x1(4)) = 0.3437;γ(x0(5),x1(5)) = 0.4107; γ(x0(6),x1(6)) = 0.3551; Similarly other coefficients can be obtained.

E. Calculating Target Heart Degree –

Target Heart Degree [19-22] is calculated by formula, $\gamma(X0, Xi) = \frac{1}{n}\sum_{k=1}^{n} \gamma[X0(k), Xi(k)]$

According to grey theory, the THD can be ranked into different interval levels such as [0.9,1.0],[0.8,0.9],[0.7,0.8],[0.6,0.7],[0.5,0.6],[0.4,0.5], [0.3,0.4],[0.2,0.3],[0.1,0.2].

Suppose ζ= 0.5, then Target Heart Degree obtained for sample '1' is γ(X0, X1) ρ/1+ρ= 0.37354.

Similarly, for other samples also the THD is obtained. The Target Heart Degree in terms of Transformer's fitness index from key gas samples is shown in table no.1.

Table-1: Target Heart Degree of five Transformers

Tranf. No.	DGA Samples of Testing Transformer						THD
	CO	CH4	CO2	C2H4	C2H6	H2	
1	18	153	3795	22	46	2936	0.3735
2	18	28	819	5	14	550	0.7503
3	20	24	806	5	13	270	0.8696
4	104	169	3828	26	56	2152	0.3721
5	50	128	1412	1	23	2349	0.5422

III. THD Calculation using empirical data

Chromatogram data of transformers are further referred to observe the effect of other parameters on the fitness index. This will be adjudging by adding other parameters with key gases. Mainly oil temperature, ambient temperature, humidity, tan delta, resistivity and water content are selected.

Here THD calculation is again perform and find the fitness indices of the same transformers which are previously referred. The MINIMUM and MAXIMUM polarity for the corresponding parameters are selected according to gas guide IEC 60599:1999 to construct the standard pattern.

Table 2: Effect of additional parameters on THD

Attributes	THD of Tr-1	THD of Tr-2	THD of Tr-3	THD of Tr-4	THD of Tr-5
Key Gas only	0.373	0.750	0.869	0.372	0.542
KG + Resistivity	0.461	0.786	0.878	0.430	0.539
KG + water contain	0.391	0.714	0.813	0.390	0.607
KG + Oil temp.	0.422	0.751	0.888	0.397	0.545
KG + tan δ	0.369	0.692	0.794	0.461	0.513
Composite(Including all)	0.600	0.796	0.874	0.577	0.650

IV. CONCLUSIONS

Collecting the data of all subsystems and for different tests results is unreasonable. Hence chromatogram based DGA data is considered which shows partial information of a huge system and therefore power transformer identifies as a grey system. Grey relational analysis on key gas is performed and THD is relating with the health index. It is observed that GRA will useful when a string of transformers are considered for state ranking comparison. Secondly, as the other parameters get added, result shows diversity in fitness index. Therefore, it is observed that characteristics of additional parameters may reflect different aspects of insulations that relatively discriminate the state assessment of transformers.

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