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A STUDY ON: DISSOLVED GAS ANALYSIS (DGA) USING ARTIFICIAL INTELLIGENCE TECHNIQUES FOR POWER TRANSFORMER FAILURE AND FAULT CONDITION

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Abstract: In the middle of 80-90s, identify the power system problems, distribution and fault were a laborious task in many fields. Power transformer is a crucial and costly asset in distribution of electricity. Due to high demand of electricity, power systems are generally breakdown as using of different types of power capacity transformer. Although there are many concerns and summons in power transmission like design, optimize, distribution, flow, power capacity and fault, which need to be solved for precisely explained calculated data obtained from different AI techniques and for constructing hard core solution of a transformer's condition. But recently added various techniques of Artificial Intelligence, solved many hurdles of power transmission that minimize the fault, transformer condition, health and reduced most of the efforts in power system analysis.

***Index Terms*:** DGA, Health, Transformer, Fault, AI, Fuzzy Logic, Neural, SVM, GAA

I. INTRODUCTION

For power distribution in multiple areas, the most primary equipment devices like power transformers, are played an important role. As power transformer distributes power at many voltage levels and in many areas, it causes the failure or fault of this many times [1][2][3]. The power failure causes impact at economic and productive activities as transformers are very costly element [3][4]. Therefore, it is necessary to identify a fault and failure incident before it impacts on productivity cost, high maintenance and timely service.[2][4][6]

From many years, power transformer is monitoring by many researchers, industry persons, engineers and electrical expert to identify the fault and failure causes of power transformer [3][7]. Many devices are also invented to overcome of this problem like Buchholz relays or differential relays but these devices always work after power failure or detect any faults and very useful to fight with power failure and fault.[3][1][2]. So, after overcome of this problem, many of researchers and experts have been investigated power failure and faulty problem using different analysis techniques such as: frequency response analysis [7], the vibration analysis [8], dissolved gas analysis (DGA) [9], etc.

After reading and research lots of work, this paper presented a most used analysis method to identify the power transformer fault and failure is dissolved gas analysis (DGA) [2][3][10][11]. Dissolved gas analysis (DGA) is a very methodical technique among above all analysis techniques, as it alerts about the causes and provides statistics and facts of the power transformer [1][3][12].

To identify the causes of faults and failure, Dissolved Gas Analysis (DGA) is a finest method to test the transformer insulation oil, to identify the formulation of the gases that presented in the oil due to failure of material presented in the transformer [3][4][5]. This method, identify the facts and presented the causes like: Percentage of various dissolved gas concentrations, their initiation rates and all explosive gases that are used causes of the fault alerts [2][14]. The different possible solutions stages were investigated to identify the possible fault causes: e.g., the conventional key gas method used in [16], ratio method presented in [13] and [14], and graphical representation method introduced in [15].

Now widely use of artificial intelligence techniques based on DGA methods have been used in many field of power distribution and identify the fault and failure of power transformer such as artificial neural networks(ANN) [17], support vector machine(SVM) [18], fuzzy logic (FL) [19], adaptive neuro fuzzy inference system (ANFIS) [20],random forest (RF) [21], Bayesian network [22], gene expression programming(GEP) [23], time series analysis [24], expert system [24], association rule [26], set pair analysis [27], evidential reasoning [28], etc. The results of these analysis methods play a valuable role in the area of fault and failure of power transformer, these methods presented many models to create a bridge between machines and machines good conditions [28]. In this paper DGA method will be described here:

II. DISSOLVED GAS ANALYSIS

The different types of gases produced by the oil presented in the working transformer, is the earliest sign of the fault and failures. Spinning, electric current, light sparkling, insulator overheat, power high-demand, Low cost colling system etc. are the likely reason to producing the gases. [30][31]

Different type of gases has different impact on power transformer failure and fault. It is totally depended on gas nature, volume and temperature like: hydrogen (HR 2R), methane (CHR 4R), ethylene (CR 2RHR 4R), ethane (CR 2RHR 6R), acetylene (CR 2RHR 2R), carbon monoxide (CO), and carbon dioxide (COR 2R).[2][30][31][32]

Percentage of the gas presented in oil can be a big reason to take a decision by some expert system by taking some sample of it. SI techniques is used to solved how many percentages is presented of various gas dissolved in oil of transformers. The different AI techniques used by many expert and researches for DGA Expert Systems, Fuzzy Inference Systems (FIS), Artificial Neural Networks (ANN), Genetic Algorithm (GA)and even Novel Cerebellar Model Articulation Controller based method. These methods are used for both mode online and offline.[3][30][31]

III. DGA FAULT MECHANISM

DGA identified Power Transformer Fault and failure are included (few of them) into the IEEE Standard C57.104-1991[30] are: [2][3][30][33][35]

3.1 Key Gas Method

The founded gases in the oil due to high temperature or power energy can erupt the chemical bond. This method is used to calculated the amount of the gases presented in the oil, the amount of the gases calculating process is called “Key Gas”. Gases that are utilized in this are combination of CO, CO_2, H_2, CH_4, C_2H_2, C_2H_4 and C_2H_6.

3.2 Dorrnenburg Ratio Method

This method used only four gases ratio based on the coding done for special types of faults. A fault can identify, if the gas ratio percentage match with the already available code value. These four gases are: H_2, CH_4, C_2H_2, C_2H_4 and C_2H_6.

3.3 Roger’s Ratio Method

This method also used the combination ratios of these gases H_2, CH_4, C_2H_2, C_2H_4 and C_2H_6. It checked the range of the gas’s ratios. The range ratio value of the gases has different types ranges like <.01, >1, >3,<0.5 etc.

3.4 Nomograph Method

This method is used to present a graph of fault gas data using vertical lines for ratio of gases and horizontal line for gases. The connected line presented the formulation of gases. The fault can be identified by slopes and point presented on the graph.

3.5 Duval Triangle Method

This is the most popular method to identified the power transformer fault. This method only used three gases CH_4, C_2H_2 and C_2H_4. The total of the gases volume and percentage of the gases is pointed on a triangle. This fault is divided on seven zones: Partial Discharge, Thermal Faut<300^0C, Thermal Fault range between 300^0C-700^0C, Thermal Fault>700^0C, Sparking, Arcing, Thermal and Electrical Faults.

3.6 Iec Basic Ratio Method

This is a revised and updated method of rogers ratio range and different evaluation method. In this method we used only 3 Gas ratio H_2, C_2H_2 and C_2H_4. These are the 6 methods used to identify the fault in power transformer. [2][3][30][33][35]

IV. ARTIFICIAL INTELLIGENCE CONCEPTS USED IN POWER TRANSFORMER

The different AI techniques used by many experts and researches for DGA Expert Systems, Fuzzy Inference Systems (FIS), Artificial Neural Networks (ANN), Genetic Algorithm (GA) and Support Vector Machine.[3][30][31]

4.1 Expert System

This is one of a decision support system that has been used for fault identification and maintain the health of transformer.3][6][31]. The expert system is very complicated because it cannot collect the data itself and calculate automatically, it works on knowledge and precision

basis. C. F. Lin et al. has created an expert system to identify the faults of power using DGA and suggested many ways to solved it. They have taken many data samples from transformer from Taiwan Power Company. They discussed 3 test cases in which first 2 samples give the actual fault type reason and solutions. Third Case was on an old transformer, which was triggered by arc tracing fault after [10][13][31][35]

4.2 Fuzzy Logic

The fuzzy logic investigates any case using three parts: fuzzification, fuzzy inference and defuzzification. The fuzzy relations analysis a faulty tree of power transformer and gives a best solution of a problem. Yann-Chang Huang et al. investigated an Evolutionary Fuzzy Logic to designed a diagnostic system using the DGA methods like Rogers Ratio, Doernenburgs' & IEC taking all the seven gases ratio. N.A Muhamad et al. construct a comparative study & analysis system using fuzzy logic for all DGA methods. There were lots of Power fault samples used and developed an automated coded evaluation method using MATLAB. [2][3][19][31][32][33][35]

4.3 Neural network

The neural network designed a complex fault detection pattern without using any process of that. They used trials data or the fault patterns for identify the solutions and patterns by system. A neural network comprises of many simple connected neurons together.[2][17][30][33][35]. M. A. Izzularab et al. designed an on-line method to identify the faults using fuzzy. They tested all of six gases for the cellulose degradation. They have created three cases to enhance the proposed system. The algorithm was tested on huge amount of data samples of Egyptian Electricity Network. All three cases were testes briefly and was used to find the transformer conditions. Many methods were tested on that and the designed system result was pretty good and capable to find a fault. [33][25]. Adriana Rosa et al testes a knowledge Expert System in NN for fault and failure diagnosis of a power transformer using fuzzy inference system. The case study recorded and used lots of data using set of rules. The three types of faults identify in this system are: thermal faults, discharges and partial discharges. The KES tested on DGA to identify the fault and the result of analysis was good and find the best knowledge discovery system.[2][3] [8][19][33][36]

4.4 Genetic Algorithm Approach

The Genetic Algorithm (GA) and ANN both has been scrutiny with Genetic Algorithm Tunes Wavelet Networks for DGA analysis and collected many faults detection in oil powered transformers. Yann-Chang Huang used huge amount of gas records data from Taipower Company from 172, 68 kV transformers using GAS methods. The GAWN's methods diagnosed with using four cases, and differentiate with ANN and conventional methods. The GAWN's method gives accurate and required result in short time. Chen et al.. collected samples fault data and used in wavelet network for power transformers failures using DGA. This sample data were processed by fuzzy logic techniques and it has many advantage over old methods for fault detection. This method is cost effective and higher accuracy with fault detection.[1][2][3][33][34]

4.5 Support Vector Machine (SVM) Approach

The purpose of SVM is to find an optimal separating hyper plane by maximizing the margin between the separating hyper-plane and the data. In SVM methods all the six polynomial and Gaussian parameters σ and C are optimized by the cross-validation method. The adjusted parameters with maximize classification accuracy are selected as the most appropriate parameters to tarin the SVM model. [2][33][37]

V. ADVANTAGES AND LIMITATIONS

To identify a Fault and failure of an oil filled power transformer using DGA with artificial intelligence methods on computer- based software is the better solution for the problem. As DGA uses four methods to forecast the faults in transformer and at the same time it provides the solution for the problem with in no time. It also reduces the time to calculate and analyse the faults by using DGA system. It also helps to decrease the man-made-error on the fault on DGA system.

VI. CONCLUSIONS

After study of the DGA techniques using several AI methods on power transformer to identify the fault and failure detection, it has been proved that these methods can be used to calculate the problem of the power transformer. All the AI techniques and combination of these, provide the effective solutions to identify the fault and failure points. The DGA and AI technology can be a good mixture of solutions to find out the fault and gives an accurate results or possible ways to remove faults. There are 3 types of faults with partial discharge, thermal faults and discharge fault are the main fault and failure of a power system. It has many methods to dealt with the problems because we cannot depend on a single solution in man-made real equipment. Many case studies presented the reliable and accurate results and has presented its efficiency for fault diagnosis in power transformer.

REFERENCES:

[1] A.Shintemirov, W. Tang and Q. H. Wu, "Power Transformer Fault Classification Based on Dissolved Gas Analysis by Implementing Bootstrap and Genetic Programming", IEEE transactions on systems, man, and cybernetics—part c: applications and reviews, Vol. 39, NO. 1, January 2009, 69-79.

[2] Seifeddine Souahlia, Khmais Bacha and Abdelkader Chaari "Artificial Intelligence Tools Aided-decision for Power Transformer Fault Diagnosis" International Journal of Computer Applications (0975 – 8887) Volume 38– No.3, January 2012.

[3] Xiaohui Han, Shifeng Ma, Zhewen Shi, Guoqing An, Zhenbin Du and Chunlin Zhao, "A Novel Power Transformer Fault Diagnosis Model Based on Harris-Hawks-Optimization Algorithm Optimized Kernel Extreme Learning Machine", https://link.springer.com/article/10.1007/s42835-022-01000-x.

[4] Duval M (1989) Dissolved gas analysis: it can save your transformer. IEEE Electr Insul Mag 5:22–27.

[5] Li YC, Ma LQ (2019) Fault diagnosis of power transformer based on improved particle swarm optimization OS-ELM. Arch Electr Eng 68(1):161–172.

[6] Mahmoudi N, Samimi MH, Mohseni H (2019) Experiences with transformer diagnosis by DGA: case studies. IET Gener Transm Distrib 13:5431–5439.

[7] Premalatha V, Sruthi SS, Vikash M et al (2012) Instrument transformer winding fault analysis using frequency response analysis. IEEE international conference on advanced communication control and computing technologies (ICACCCT), Syed Ammal Engn Coll, Ramanathapuram, INDIA, August, 370–374.
[8] Bagheri M, Zollanvari A, Nezhivenko S et al (2018) Transformer fault condition prognosis using vibration signals over cloud environment. IEEE Access 6:9862–9874.
[9] Apte S, Somalwar R, Wajirabadkar A et al (2018) Incipient fault diagnosis of transformer by DGA using fuzzy logic. 2018 IEEE international conference on power electronics, drives and energy systems (PEDES), Chennai, India, December, 1–5.
[10] Benhamed K, Mooman A, Younes A, Shaban K, El-Hag A (2018) Feature selection for effective health index diagnoses of power transformers. IEEE Trans Power Deliv 33(6):3223–3226.
[11] Jiang J (2018) TDLAS-based detection of dissolved methane in power transformer oil and field application. IEEE Sens J 18(6):2318–2325.
[12] DGA and AI Technique for Fault Diagnosis in Distribution Transformer, January 2021, DOI:10.1007/978-981-15-7511-2_4, book: Advances in Smart Grid and Renewable Energy (pp.35-46).
[13] W. H. Tang, J. Y. Goulermas, Q. H.Wu, Z. J. Richardson, and J. Fitch, "A Probabilistic Classifier for Transformer Dissolved Gas Analysis With a Particle Swarm Optimizer", IEEE transactions on power delivery, Vol. 23, No. 2, April 2008, 751-759.
[14] Chin-Pao Hung, Mang-Hui Wang, "Diagnosis of incipient faults in power transformers using CMAC neural network approach", Electric Power Systems Research 71, 2004, 235–244.
[15] Michel Duval, "A Review of Faults Detectable by Gas-in Oil Analysis in Transformers". IEEE Electrical Insulation Magazine, Vol.18, No. 3, June 2002, 8-17.
[16] SUN Yan-jing, ZHANG Shen, MIAO Chang-xin, LI Jing meng, "Improved BP Neural Network for Transformer Fault Diagnosis", Journal of China University of Mining & Technology Vol.17 No.1, Mars 2007, 138-142.
[17] Sherif SM, Ibrahim BM, Nagy IE (2016) Integrated ANN-based proactive fault diagnostic scheme for power transformer using dissolved gas analysis. IEEE Trans Dielectr Electr Insul 23:1838–1845.
[18] JZ, Zhang QG, Wang K, Wang JY (2016) Optimal dissolved gas ratios selected by genetic algorithm for power transformer fault diagnosis based on support vector machine. IEEE Trans Dielectr Electr Insul 23(2):1198–1206.
[19] Abu-Siada A, Hmood S, Islam S (2013) A new fuzzy logic approach for consistent interpretation of dissolved gas-in-oil analysis. IEEE Trans Dielectr Electr Insul 20:2343–2349.
[20] Khan SA, Equbal MD, Islam T (2015) A comprehensive comparative study of DGA based transformer fault diagnosis using fuzzy logic and ANFIS models. IEEE Trans Dielectr Electr Insul 22:590–596.
[21] Dai CX, Liu ZG, Hu KT (2016) Fault diagnosis approach of traction transformers in high-speed railway combining kernel principal component analysis with random forest. IET Electr Syst Transp 6(3):202–206.
[22] Carita AJQ, Leita LC, Junior APPM, Godoy RB, Sauer L (2013) Bayesian networks applied to failure diagnosis in power transformer. IEEE Lat Am Trans 11(4):1705–1082.
[23] Malik H, Mishra S (2016) Application of gene expression programming (GEP) in power transformer's fault diagnosis using DGA. IEEE Trans Ind Appl 52(6):4556–4565.
[24] Wang XL, Li QM, Yang R, Li CR, Zhang Y (2015) Diagnosis of solid insulation deterioration for power transformers with dissolved gas analysis-based time series correlation. IET Sci Meas Technol 9(4):393–399.
[25] Sarkar S, Sharma T, Baral A, Chatterjee B, Chakravorti D (2014) An expert system approach for transformer insulation diagnosis combining conventional diagnostic tests and PDC, RVM data. IEEE Trans Dielectr Electr Insul 21(2):882–891.
[26] Yang Z, Tang WH, Shintemirov A, and Wu QH (2009) Association rule mining-based dissolved gas analysis for fault diagnosis of power transformers. IEEE Trans Syst Man Cybern Part C: Appl Rev 39(6):597–610.
[27] Li L, Cheng Y, Xie LJ, Jiang LQ, Ma N, Lu M (2015) An integrated method of set pair analysis and association rule for fault diagnosis of power transformers. IEEE Trans Dielectr Electr Insul 22(4):2368–2378.
[28] Liao RJ, Zheng HB, Grzybowski S, Yang LJ, Zhang YY, Liao YX (2011) An integrated decision-making model for condition assessment of power transformers using fuzzy approach and evidential reasoning. IEEE Trans Power Deliv 26(2):1111–1118.
[29] Qi G, Zhu Z, Erqinhu K (2018) Fault-diagnosis for reciprocating compressors using big data and machine learning. Simul Model Pract Theory 80:104–127.
[30] Viral R Avalani Kishan V Dave," Dissolved Gas Analysis of Transformer", International Journal of Scientific Research & Engineering Trends, Volume 4, Issue 6, Nov-Dec-2018, ISSN (Online): 2395-566X.
[31] Manoj Kumar Jha, P PNisha Barle, Ruchi Trivedi, "Application of Artificial Intelligence Techniques for Dissolved Gas Analysis of Transformers -A Review", IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 12, December 2015, ISSN 2348 – 7968.
[32] Dhanu Rediansyah, Rahman Azis Prasojo, Suwarno, A. Abu-Siada," Artificial Intelligence-Based Power Transformer Health Index for Handling Data Uncertainty",IEEE Access, VOLUME 9, 2021.
[33] Sadeq Yasoob Jasim, Jyoti Shrivastava," Dissolved Gas Analysis of Power Transformers", International Journal of Electrical and Electronics, Engineering Research (IJEEER), ISSN(P): 2250-155X; ISSN(O): 2278-943X, Vol. 3, Issue 5, Dec 2013, 1-10, © TJPRC Pvt. Ltd.
[34] Standard IEC 60599, 2007, "Guide for the interpretation of dissolved gas analysis and gas-free".
[35] A. Abu-Siada, "Improved Consistent Interpretation Approach of Fault Type within Power Transformers Using Dissolved Gas Analysis and Gene Expression Programming", February 2019, Energies 12(4):730, DOI:10.3390/en12040730
[36] https://www.academia.edu/3724700/Application_Of_Artificial_Intelligence_In_Diagnosis_Of_Power_Transformer_Incipient_Fault_Application_In_Vietnam_Power_Sector_Application_In_Vietnam_Power_System
[37] V.N. Vapnik, 1995, The Nature of Statistical Learning Theory, Springer-Verlag, New York
[38] https://espace.library.uq.edu.au/view/UQ:287571
[39] https://vtechworks.lib.vt.edu/handle/10919/28594
[40] https://www.electricalindia.in/artificial-intelligence-an-advanced-approach-in-power-systems/
[41] https://aip.scitation.org/doi/10.1063/5.0032820