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3차원 그래픽을 이용한 전력용 변압기 유지보수 프로그램 개발

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Development of 3D Power Transformer Maintenance Application

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Abstract - This paper presents a maintenance application for power transformer. High quality maintenance and accurate diagnosis are essential for all transformers, especially for older ones. The developed application provides maintenance guides for dry type transformer and oil-filled transformer to prevent any malfunctions and to lengthen the lifetime of transformers. Based on windows application, TTS (text to speech) and 3D graphics technologies have been used to enhance the user friendly interface. Developed application is helpful for both expert and novice operators at substation.

1. Introduction

Power transformer is one of the most important machinery in the power system. A breakdown of a power transformer can lead to the disastrous results. The development of mechanisms and machineries provides tolerance to any faults in the power system. Yet, those developed technologies has been proved to be insufficient to prevent some of the catastrophic breakdown of power system in United States in 2003.[1] Prevention of any faults is much more important than the restoration of the faults. Even a momentary power failure can cause great financial loss. Focusing on the preventive measures, the power transformer has been chosen and effective maintenance solution has been developed in this paper. Standards organizations such as American National Standards Institute/Institute of electrical and Electronic Engineers(ANSI/IEEE) consider average transformer life to be 20 to 25 years.[2] But, Reclamation, Bonneville Power Administration, and Western Area Power Administration has showed in the studies that the average life of a Reclamation transformer is 40 years.[3] The life time of a transformer can be lengthen about 1.5~2.0 times under high quality maintenance and accurate diagnostics, especially for older ones. Both the maintenance and diagnostics are important and they cannot be considered separately. But this paper focuses more on the effective maintenance solution. Not only the maintenances of each part of power transformer also key gas method and DGA solution are given in this developed application.

2. Body

2.1 Transformer Maintenance

The transformer maintenance is basically to be performed after 1 month of service, annually and every 3 to 5 years.[4] A transformer maintenance application must be based on thorough routine inspections. Some monitoring may be done remotely using SCADA systems, but this cannot substitute for thorough inspections by competent maintenance and operation operators.

2.1.1 Maintenance List

Before energizing a power transformer thorough inspect and test of all controls, wiring, fans, alarms, and gages must be preceded. After the initiation, indepth inspection of transformer and cooling system, and proper operations must be executed. Also leaks need to be checked following the schedule. Tests of all controls, relays, gages and alarms are to be performed according to the schedule and state of the transformer. Lists below are the main parts of a power transformer maintenance.[5]

- Windings
- Busing and Arresters
- Insulating Oil
- Core
- Conservator
- Tanks and Auxiliaries
- Cooling System

2.2 Dissolved Gas Analysis

Dissolved gas analysis(DGA) is the most important tool in determining the condition of the power transformer. It can identify deteriorating insulation and oil, overheating, hot spots, partial discharge, and arcing. Once, dissolved gas analysis consisted of sending transformer oil samples to a commercial laboratory for testing, but now a dissolved gas measuring instrument has been developed and attached to the transformer.[6] The data can be collected at anytime remotely at a management center.

2.2.1 Individual and Total Key Gas Method

Key gases formed by degradation of oil and paper insulation are hydrogen(H_2), methane(CH_4), ethane(C_2H_6), ethylene(C_2H_4), acetylene(C_2H_2), carbon monoxide(CO), oxygen(O_2), and nitrogen(N_2). Gas type and amounts are determined by where the faults occurs in the transformer and the severity of the faults.

A four-condition DGA guide to classify transformer risks has been published in the Standard IEEE Standard. C57-104™. The guide uses combinations of individual gases and total dissolved combustible gas(TDCG) concentration[4][7]

- Condition 1: The transformer is operating normally.
- Condition 2: Any individual combustible gas exceeding specified levels should have additional investigation. A fault may occur.
- Condition 3: A high level of decomposition of cellulose insulation and oil. Faults are probably present.
- Condition 4: Excessive decomposition of cellulose insulation and oil. The transformer operation could stop.

Status	Condition1	Condition 2	Condition 3	Condition 4
H_2	100	101-700	701-1800	>1800
CH_4	120	121-400	401-1000	>1000
C_2H_2	35	36-50	51-80	>80
C_2H_4	50	51-100	101-200	>200
C_2H_6	65	66-100	101-150	>150
CO	350	351-570	571-1400	>1400
CO_2	2500	2500-4000	4001-10000	>10000
TDCG	720	721-1920	1921-4630	>4630

Table 1. Dissolved Key Gas Concentration Limits in Parts Per Million (ppm)

*CO_2 is not a combustible gas

2.2.2 Duval Triangle

Michel Duval of Hydro Quebec developed the method in the 1960s using database of thousands of DGAs and transformer problem diagnosis. The Duval triangle does not determine whether or not a problem exists in a transformer, because there is no area that does not have a problem on the triangle. Before applying the Duval triangle, key gas method or Table 2 should be used to determine if a problem exists. The Duval triangle is used only to diagnose what the problem is.

To use the Duval Triangle, at least one of the hydrocarbon gases or hydrogen should be in Condition 3 and at the generation rate(G2) from the table 2. To use table 2 without the key gas method table, at least one of the individual gases must be at L1 level or above and the gas generation rate at least at G2. This method is more reliable, but one should use both methods to confirm that a problem exists.[4][7]

Gas	L1 Limits	G1 Limits (pm per month)	G2 Limits (ppm per month)
H_2	100	10	50
CH_4	75	8	38
C_2H_2	3	3	3
C_2H_4	75	8	38
C_2H_6	75	8	38
CO	700	70	350
CO_2	7000	700	3500

Table 2. L Limits and Generation Rate Per Month Limits

2.3 Maintenance & Diagnosis Application

The purpose of the developed application is to

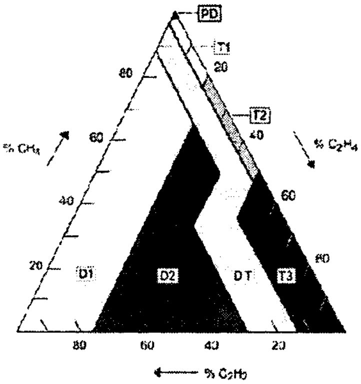

Figure 1. The Duval Triangle

PD = Partial Discharge
T1 = Thermal Fault Less than 300°C
T2 = Thermal Fault Between 300°C and 700°C
T3 = Thermal Fault Grater than 700°C
D1 = Low Energy Discharge (Sparking)
D2 = High Energy Discharge (Arcing)
DT = Mix of Thermal and Electrical Faults

facilitate and to enhance the maintenance efficiency of power transformer operators. Easy and intuitively comprehensible interface is one of the most important aims of the developed application. Not only the various technologies but also the database based on the International Standards and algorithm have been applied to the application.

2.3.1 Schedule System

Firstly, the main theme of the application is the scheduling system. The convenient schedule system would not miss even a trifling maintenance that need to be proceeded. An annual schedule is established when the basic information of a power transformer is inputted. Each time when a maintenance is required, the alarm note will be displayed at the bottom edit box as shown in Figure 2. Once click on the appropriate button in the maintenance, new maintenance dialog box will appear with detailed information and proceeds.

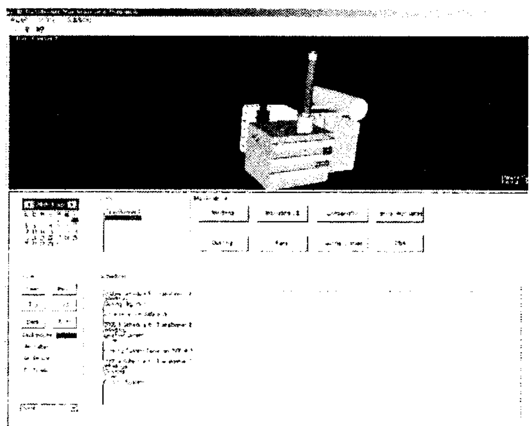

Figure 2. Windows GUI based Maintenance Application

2.3.2 3D Graphic Visualization

The transformer has been 3D modeled. The advantage of the 3D model is that a part behind cannot be observed on a 2D model, but using 3D model every part of a transformer can be observed by an operator.

When it is a time for a part of a transformer to be maintained, the part will be changed in color indicating the severity of maintenance. An operator can apprehend the state of a transformer at a glance. Figure 3. is the 3D modeled transformer indicating a need for maintenance at bushing.

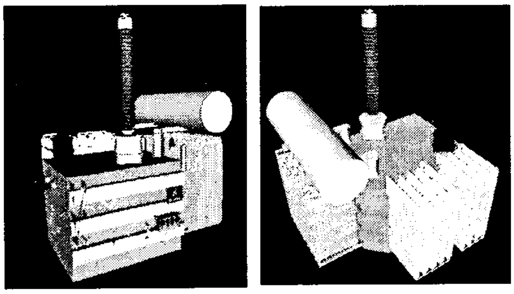

Figure 3. 3D modeled transformer

2.3.3 DGA Solution

As mentioned above, this developed application includes dissolved gas solution. Various DGA algorithm have been developed and proved to be faithful[8].In this paper, key gas method and Duval Triangle have been used for the DGA solution. As shown in Figure 4., after the calculation, results and proper diagnosis are proposed on the edit box.

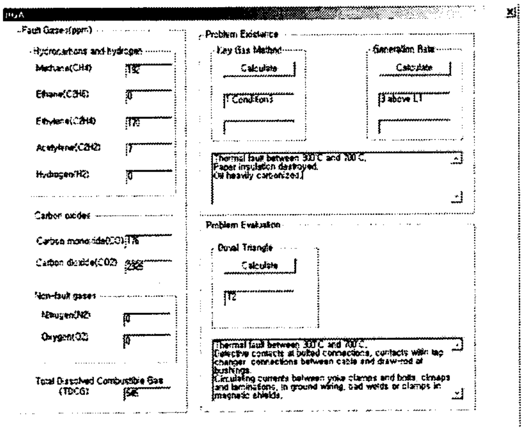

Figure 4. DGA calculation Dialog Box

2.3.4 TTS

Text-to-Speech technology has been used in the developed application to enhance the efficiency of an operator. Using the VoiceTEXT, the TTS engine of Vocieware Co. Ltd, the system informs the state of the transformer with voice when a maintenance is needed. So, an operator can recognize the state directly and indirectly and work efficiency will be improved effectively.

3. Conclusion

The developed application has provided effective solutions for transformer maintenance. The well-visualized 3D modeled transformer and windows based user friendly interface provides operators conveniences and intuitive comprehensions of a power transformer maintenance. Also, the TTS system enhances the performance of operators by informing the condition and the tasks with voice. Operators will be able to deal with the power transformer skillfully and will not miss any important maintenances to be performed. The power transformer life time can be lengthened and the chances of the breakdown of the power transformer will be decreased.

For future work, more detailed maintenance and diagnostics data and algorithm are to be installed into the application, and the accuracy of the diagnosis tests are to be increased by applying more detailed intellectual algorithms.

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