ARE YOU FAMILIAR WITH GAS ANALYSIS FOR THE EARLY PREVENTION OF WIND TURBINE TRANSFORMERS?

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INTRODUCTION

In recent years, the analysis of dissolved gasses in wind farm transformers has caused many controversial comments about its behavior because of the elevated gas generation levels during its operation. Nowadays, gas level issue doesn't have a solution in the industry and there is not a specification or a standard defined for these types of units.

Wind energy producers monitor their wind turbine transformers to assess their health condition and diagnose them based on IEEE C57.104 Guide for the Interpretation of Gases Generated in Oil-Immersed Transformer.

Even though some transformers have been inspected, neither root cause nor conclusive results have been found for these units. Based on this guide, users make decisions such as to increase monitoring or to take them out of operation, sometimes unjustified because the IEEE guide is applicable for bigger units with different application and internal components. So the gas limits established in the standard should be different to determine the health condition of a wind transformer.

CHALLENGE

The wind energy industry is extremely sensitive to unexpected downturn of their wind turbine transformers, as availability of generation resources is in general not programmable. Among other tools, the standard IEEE C57.104 is used by operators to assess transformers health condition, commonly as a diagnostic tool for large power transformers. However, the use of such analysis for small network distribution transformers is still uncommon and the development for the standards and guidelines regarding distribution network transformer DGA analysis is still at its infancy.

By means of a foot note on Table 1 in IEEE document, it is clarified that the gas levels tabulated there correspond to large power transformers. This is fully explainable, as mainly medium and large size power transformers have been monitored for decades by dissolved gasses in oil, while it is an infrequent practice to monitor by this technique smaller transformers.

The IEEE Guide stands clearly its limitation regarding to the oil volume quantity, and to the possibility that internal operation components could increase gas level concentrations, without a real failure condition of the active parts. However, for the case of wind farm step up transformers, it has become a practice to perform diagnostics based on the referred Guide, and decisions are made to take transformers out of operation to inspect, repair and/or replace them; nevertheless any failure condition was not found in many units

So, the gas limits established in the standard do not accurately determine the transformer health condition and more suitable diagnostics guidelines are a stringent need.

CRITERIA BACKGROUND

Depending on the gas levels and their profile, specialists are able to predict the type of defect and its severity. There are some standards associated with sampling and testing of liquid immersed transformers and others for analyzing the results. One of the most common guides used in the electric power systems industry is the already referred standard IEEE C57.104 (Table 1), currently under revision, developed mainly for application in power transformers, since this equipment is usually the most single expensive item in generation, transmission, and primary distribution systems, with the possibility of

Table 1. IEEE Dissolved key gas concentration limits according to IEEE C57.104.

Status	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
Condition 1	100	120	65	50	1	350	2500
Condition 2	101 - 700	121 - 400	66 - 100	51 - 100	2 - 9	351 - 570	2500 - 4000
Condition 3	701 - 1800	401 - 1000	101 - 150	101 - 200	10 - 35	571 - 1400	4001 - 10000
Condition 4	> 1800	> 1000	> 150	> 200	> 35	> 1400	> 10000

high forced outage costs and likely collateral damage from any fire or explosion.

As already mentioned, in recent years DGA monitoring has been expanded to application in Wind Farm Transformers, but this practice have raised more questions than answers, with regard to the conditions of the units under surveillance.

In a case fully similar to the one dealt with in this paper, in 2012, the utility Con-Edison published a study on application of DGA monitoring to its Network Transformers, and they found specific gas limits, surprisingly in order of 10 times higher than those specified in IEEE C57.104, see Table 2 below. Definition of “Status A” is approximately equivalent to definition of “Condition 1” IEEE. There is another criterion using an oil-volume correction factor of 10, considering the ratio of oil volumes from large to small transformers. In table 3 are shown the adjusted limits.

Table 2. ConEdison Dissolved Gas Concentration Criteria for 1000 and 2500 kVA Network Transformers.

Status	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2
A	2000	1600	400	400	20
E	5000	3000	500	400	
F	18000	10000	1500	2000	100

** When samples show any of the key combustible gases between level A and level E, the DGA samples will be taken from the transformers periodically to see if the conditions of these transformers were stabilized.*

** Level F, the transformer will be removed from service.*

The results from application of the different criteria here introduced are shown in Figure 1. Gas generation data from a population of more than 900 wind turbine transformers expressed in form of the percentage of units exceeding the first limit according to those criteria are presented. The units were installed in different locations and they had been reported as in an abnormal condition, based on the IEEE guide.

NEW CRITERIA

In our investigation we confirmed that direct application of IEEE Guide criteria to wind farm transformers would produce frequent false alarms.

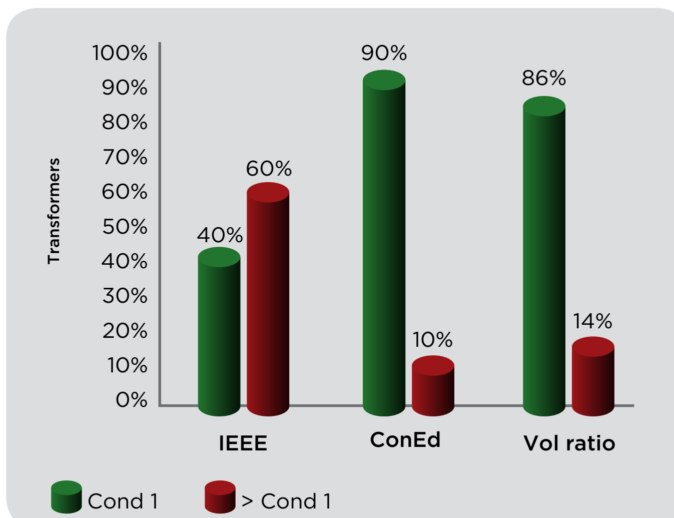


Figure 1. Percentage of Units Exceeding Satisfactory Gas Levels

Table 3. Correction Factors for Interpretation of Gas Levels.

DGA Limits based on IEEE C57.104 with a correction factor due oil volume quantity Average Power Transformer oil volume: 5000 gal Wind Farm oil volume (1750 kVA): 500 gal Volume correction factor = 10					
Volume Adjusted Limits for 1750 kVA Wind Farm Transformer					
H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO
<= 1000	1200	650	500	10	3500

Application of a single oil volume correction factor is not recommended, as each gas behaves differently and a single factor applying for all the gases might be misleading. From our preliminary assessment, and building up on ConEd's investigators previous work with network transformers, it can anticipate that a new Guide for evaluation of gas levels and profiles in wind farm step up transformers would allow for significantly higher gas contents, before alarm levels would be reached.

Prolec has working on develop a tool to diagnose a wind farm transformer relying on different investigations, transformer inspections, field measurements and expertise analysis.

The new criterion was developed with three levels where all are indicated as secure operation condition depending on its rate of gas generation. Those conditions are described below:

- **Condition 1.** In this range of gas generation, it is considered that the equipment is in Satisfactory Condition.

- **Condition 2.** In this range of gas generation, the equipment can continue in service, it is in a safe condition; however, it is necessary to evaluate the gas generation rate to confirm or discard a possible trend that could represent a situation against to equipment operation. The monitoring will be moderate.

- **Condition 3.** In this range of gas generation, the equipment can continue in service, it is still in a safe condition; however, it is necessary to proceed with an intensive monitoring. In this condition, the rates of gas generation will be more critical than in Condition 2, therefore we must not neglect the unit because any time you have to take action to avoid problems and / or possible drive failures.

In Table 3 and Table 4 are shown the levels for individual gases, rates and operation procedures depending on gas generation rates.

Table 3.1. Permissible gas concentrations.

	H_2	CH_4	CO	CO_2	C_2H_6	C_2H_4	C_2H_2	TDCG
Condition 1	940	265	710	4400	105	300	5	1499
Condition 2	941-2210	266-1320	711-1050	4401-7650	106-920	301-1900	6 - 5	1500-4999
Condition 3	> 2210	> 1320	> 1050	> 7650	> 920	> 1900	> 35	≥ 5000

Table 4. Operating procedures depending on gas generation rates.

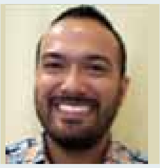
Condition	TDCG (ppm)	TDCGrate (ppm/day)	Sampling intervals and operating procedures for gas generation rates	
			Sampling interval	Operating procedure
1	< 1500	NA	Sampling in 12 months	Continue normal operation
2	≥ 1500 < 5000	< 10	Sampling in 12 months	Continue normal operation
		≥ 10 & <20	Sampling in 6 months	Continue normal operation Determine load dependence Exercise extreme caution Analyze for individual gases
		≥ 20	Sampling in 3 months	
3	≥ 5000	< 10	Sampling in 6 months	Continue normal operation
		≥ 10 y < 20	Sampling in 3 months	Continue normal operation Exercise extreme caution Analyze for individual gases Determine load dependence *Consider removal from service
		≥ 20	Sampling in 1 month*	

SUMMARY

IEEE Guide is not adequate to wind farm transformers, produce false alarms. This new criterion will help to obtain a more accurate method of monitoring and diagnosing this kind of distribution transformers.

The use of this criterion will reduce highly the number of taking samples compared to IEEE Guide; it was studied that these kind of transformers are more gaseous than conventional distribution transformers.

This criterion could be supported by other technical methods as Duval Triangle, Rogers, Doernenburg, to more accurate diagnosis.



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