Application of Dissolved Gas Analysis to Load Tap Changers

Rick Youngblood
Cinergy Corporation

Charles Baker
South Carolina Electric and Gas

Fredi Jakob and Nick Perjanik
Analytical ChemTech International, Inc.

I. INTRODUCTION

Thermal and electrical faults dissipate energy. If dielectric fluid or solid insulation is in the vicinity of a fault, energy transfer will occur and this will result in non-reversible partial molecular degradation of insulating materials. The existence of irreversibly generated decomposition products is the basis for dissolved gas analysis (DGA)[1]. These processes are not limited to transformers and can occur in any oil filled electrical equipment. The application of DGA to transformers has been universally accepted as a valuable diagnostic tool. When consideration is taken of the operating parameters of Load Tap Changers and Oil Circuit Breakers, there is no reason why the DGA methodology cannot be applied in a cost-effective preventive maintenance program.

II. APPLICATION OF DGA TO LOAD TAP CHANGERS

Load tap changers (LTCs) often have a higher failure rate than transformers. Accepted diagnostic methods that have been applied to evaluate the condition of LTCs include infra-red scanning (IR) and differential temperature measurements. Infra-red scans and differential temperature methods are not always conclusive and may not detect problems at the initial stages. Early detection of LTC problems is essential since problems develop rapidly. Contact coking is a major problem. Initial deposition of carbon on LTC contacts leads to increased contact resistance, which in turn leads to increased heating and the buildup of carbon. This process continues at ever accelerating rates.

In Resistive and Reactive designs, arcing occurs in oil filled tap changers whenever they operate. A result of arcing in oil filled equipment is the production of hydrogen and acetylene fault gases. One might conclude that DGA would thus not be applicable to LTCs since fault gases are produced during the normal operation of the LTC. This conclusion, however, is incorrect and is not supported by data now available.

Identification of “key gases” has been used widely as an empirical diagnostic tool for fault characterization in transformers. Acetylene, the key gas for arcing, is routinely found in LTC compartments and will vary with the number of operations. Ethylene, methane and ethane, which are sometimes referred to as the “hot metal gases”, are the key gases associated with pyrolysis or overheating. R. Youngblood[2] suggested that the presence of high levels of methane, ethane and especially ethylene, would indicate overheating of the LTC contacts. His interpretation has proven to be correct and as a consequence the application of DGA to LTC diagnostics has become an accepted diagnostic procedure. More recent work by Youngblood[3] has revealed that the levels of acetylene and hydrogen should not be ignored since the concentrations of these gases in a “problem” LTC are significantly higher than the levels in a trouble free unit.

Empirical methods for the interpretation of DGA have been used to correlate fault gases found in transformers with specific fault types. The most frequently used empirical methods are the key gas or interpretive method and methods based on the ratios of fault gas concentrations. The key gas method, based on establishing maximum threshold concentrations for each fault gas, can be applied without modification to the analysis of fault gases formed in LTCs. An essential requirement for utilization of the key gas method is the actual establishment of the threshold or flag points for each of the fault gases. The selection of these values is always based on case history studies, and therefore, threshold fault gas concentration values for LTCs must be empirically determined. The determination of these values, however, is further complicated by variations in mechanical design and breathing characteristics. Free breathing LTCs lose fault gases readily to the atmosphere, while LTCs with desiccant bottles lose fault gases at a slower rate and sealed LTCs tend to accumulate all the fault gases.

Development and application of ratio based interpretation methods require data correlations between gas concentration ratios and known faults. In the case of transformers the applicable ratio methods are generic. In the case of LTCs generic ratios may not be applicable because mechanical differences, ranging from the design of the reversing, transfer or main dial contacts, to resistive, reactive or vacuum technologies generate varying quantities of key gases during normal operation. The development of suitable ratio methods would also have to consider these variables.

III. LTC CASE HISTORIES

Youngblood[3] and Baker[4] have tabulated extensive data on gassing levels in both trouble free and problem LTCs. Fault gas levels in both normal and problem units are very dependent on the breathing mechanism of the unit. Case histories for each type of breathing mechanism are documented below. In addition to breathing mechanism variations, design parameters have a significant effect on the “normal” fault gas levels that will be observed in problem free units. Fault gas levels in problem units will vary based on number of operations, maintenance procedures followed, modifications to the operating parameters of the unit, and the progression of the fault process. The following DGA case studies are presented to illustrate the monitoring of LTC fault processes.

CASE STUDY #1

AC TLH-21 138KVx12KV 50 MVA Free Breather

DATE: FEB. 25 1993

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
02/25/93	AC	018226580301	0	5	1	4	34	71	350

This unit was determined to be operating properly. The low concentrations of hydrogen and acetylene are considered normal for a free breathing unit. The unit was scheduled for annual testing.

DATE: FEB. 25, 1994

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
02/25/94	AC	018226580301	44	1812	576	3143	149	33	645

This unit was in “thermal runaway” when tested. Notice the high level of ethylene, which is the key gas for overheating. This unit was already heavily coked when the DGA test was conducted. The unit was removed from service and repaired. The reversing switch and some moveable dial contacts were replaced.

DATE: FEB. 27, 1995

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
02/27/95	AC	018226580301	55	9	2	11	22	33	440

The unit is operating normally after the repairs were completed. The LTC was placed on a six-month test interval based on of its previous failure history.

CASE STUDY #2

Federal Pacific TC-25 69KVx12KV 20 MVA Desiccant Breather

DATE: MAR. 12, 1992

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
03/12/92	FP	504701	589	60	2	89	144	270	7323

The test indicates a possible early stage of mechanical difficulties. The acetylene and hydrogen levels are high but the ethylene level is less than 1000 ppm. This unit would remain on an annual DGA testing schedule.

DATE: FEB. 1,1993

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
02/01/93	FP	504701	1625	342	70	534	3099	378	1652

With an acetylene level of 1625 ppm and hydrogen level of 3099 ppm, the ethylene level of 534 ppm was still below the 1000 ppm threshold utilized by PSI to take it out of service. The unit was placed on a six-month test interval.

DATE: AUG. 12, 1993

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
08/12/93	FP	504701	1633	53434	55535	253024	2217	1198	8534

By August this unit was in thermal runaway. Ethylene levels peaked at 253,024 ppm while the acetylene remained stable at 1633 ppm. Hydrogen had decreased to 2217 ppm. Heating rather than arcing had been occurring at this point. The unit was removed from service and repaired. Replacement parts included a tap shaft board, slip rings and a complete reversing switch assembly. Repairs made to this type of LTC are common due to insufficient contact pressure and too few operations through neutral that results in high contact resistance.

CASE STUDY #3

Westinghouse UTT-A 138KVx69KVx13.8KV Sealed System

DATE: AUG. 31, 1992

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
08/31/92	WES	RNP38871	8527	3279	1135	9606	9083	381	4769

Based on the DGA results this unit was immediately removed from service. Serious damage was found on the transfer contacts due to misalignment. Notice higher than normal ratios of acetylene and hydrogen as compared to the other “heating” gases. The transfer contact is primarily tungsten, which will continue to arc instead of coking and heating. Overall gas levels are high since this is a sealed unit.

DATE: DEC. 17, 1993

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
12/17/93	WES	RNP38871	501	387	16	375	2883	421	1061

Following the repair of the unit, the levels of gas are typical for a sealed unit. The unit was placed on a six-month test interval.

DATE: MAY 1994

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
05-94	WES	RNP38871	451	534	9	313	3800	900	1671

The level of gas shown from this 1994 DGA test was typical for a sealed unit and did not indicate a problem. Individual gas concentrations have slightly changed, but overall the gas levels are remaining stable. This indicated that the repairs were effective.

DATE: AUG. 17, 1995

Date	Mfr.	Serial Number	C_2H_2	CH_4	C_2H_6	C_2H_4	H_2	CO	CO_2
08/17/95	**WES**	**RNP38871**	**648**	**590**	**52**	**836**	**3995**	**621**	**5921**

The level of gas from this 1995 test is typical of a sealed unit and did not indicate a problem. Individual heat gas levels show small increases or decreases, but overall the gas levels still remain stable. The fifty-percent increase in the acetylene level, however, resulted in the placement of this unit on a six month DGA test cycle.

IV. CONCLUSION

Rates of gas generation in healthy LTCs vary greatly depending on the make, model, and operating parameters. Of the major LTC manufacturers, each of them builds various models with each of the possible breathing configurations. In attempts to improve upon or correct poor designs, modifications over the years have created even greater variability. When combined with other LTC operating variables it is evident that standard DGA threshold values cannot be applied. It is possible, however, to determine ranges of normal gassing levels for each type and apply them generally to a class of units. As multiple tests are taken on similar units, these threshold values can be refined and become more unit-specific.

It is obvious that in addition to the breathing configuration, additional information is required to correctly determine the extent of damage and the best time to take the unit out of service for maintenance. If a unit is removed too early, it will be difficult to find the problem. If the maintenance cycle is too long, extensive damage or a failure may occur. The cost per DGA is minimal compared to the cost of one set of contacts, the cost of unscheduled maintenance, or the ultimate cost of a failure. It has, therefore, become the policy at Cinergy Corp. that each transformer and LTC be tested for dissolved gases three times a year. Any suspect unit, defined as a unit with acetylene above 500 ppm and a significant rate of acetylene generation is put on a monthly test interval until the unit is taken out of service or the condition stabilizes. An indicator of the severity of the problem is then evaluated on the basis of the ethylene level. The acetylene is therefore the initial flag and ethylene is the indicator of the severity of the problem.

Cinergy Corp. has established the following guidelines for its system based on the three categories of LTC breathing configuration. When the level of acetylene or hydrogen reaches a threshold level of 500 ppm, the unit is placed on a monthly DGA testing schedule. If the ethylene exceeds the maximum value, the unit is removed from service for inspection and/or repair. In the specific case of the vacuum designed LTC, the unit should be removed from service and checked if any of the threshold values in Table I are exceeded. It is important to note that these values can only be used as a general guide. Each LTC has its own set of unique operating characteristics and individualized benchmarks should be set once the service history of a LTC is known.

TABLE I

LTC MONTHLY WATCH CRITERIA

LTC Type	Hydrogen	Acetylene	Ethylene
Free or Dessicant Breather	>1500 ppm	>1000 ppm	>1000 ppm
Sealed	>5000 ppm	>9000 ppm	>1200 ppm
Vacuum	>10 ppm	>5 ppm	>100 ppm

An additional approach to the establishment of LTC breathing configuration threshold or flag points is to apply unit specific thresholds. These values, like those based on an extensive database complied by Mr. Charles Baker (Appendix A), can be used to categorize test results. From the data collected, Baker established three warning levels for each type of LTC. The gas limits, designated as LT1=Abnormal, LT2=High and LT3=Very High, have been revised over the years as more data became available. They are currently being utilized by South Carolina Electric and Gas. This type of database approach provides unit specific information and is being incorporated into Analytical ChemTech International’s (ACTI) existing diagnostic software. As ACTI’s LTC database increases, additional unit and operation-specific diagnostics will be developed and provided with DGA reports.

REFERENCES

1. Haupert, T.J. and Jakob, F. “Electrical Insulating Oils” STP 998, American Society for Testing and Materials, 1988, pp 108-115.

2. Youngblood, R., Jakob, F., Haupert, T.J. “Application of DGA to Detection of Hot Spots in Load Tap-Changers”, Minutes of the Sixtieth Annual International Conference of Doble Clients, 1993, Sec. 6-4.1.

3. Youngblood, R. “An Update on LTC Hot Spot Detection Through the Use of DGA”, Minutes of the Sixty-First Annual International Conference of Doble Clients, 1994.

4. Baker, Charles, Private Communication.