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Diagnostic of transformer oil with gas chromatography using artificial intelligence

Streszczenie. *Jedną z dokładniejszych metod diagnozowania transformatorów jest chromatografia gazowa. Dla określenia stanu oleju transformatorowego opracowano różne metody oceny, bazujących na analizie różnych gazów i stosunków gazów, jednak ich interpretacja jest zadaniem dla człowieka. Może ono być jednak automatyzowane np. poprzez zastosowanie sieci neuronowych, które eliminują konieczność ingerencji człowieka. W artykule dokonano porównania kilku metod analizy poprzez ocenę ich rezultatów dla konkretnych uszkodzeń transformatorów. (**Chromatograficzne diagnozowanie oleju transformatorowego z wykorzystaniem sztucznej inteligencji**).*

Abstract*. One of the more accuracy diagnostic methods of transformer diagnostics is gas chromatography. Evaluation of various relations of the gases has to be done for determination of transformer oil quality state. There are several method based on different gases and different value of ratios. Interpretation of them is a human deal yet. This task can be automatic using neural network. Furthermore, no human influence to answering process. Comparison of several methods can be made by matching statement of probability of particular failures in transformers.*

Słowa kluczowe: olej transformatorowy, chromatografia gazowa, sieci neuronowe, diagnostyka.
Keywords: transformer oil, gas chromatography, neural network, diagnostics.

Introduction

Among material used in electrical transformer oil has special state. It is not only for its extraction, but also for several responsibilities, above look like insulation and coolant.

Phenomena, which controlled toward change natural, chemical alternatively electric facilities in working condition, and which they can subject cut-down safety in service facilities are calling ageing process. Working assurance reduces above from this reason:

- degradation of annealing treatment implication: by implication settlement bailer in oily conduit,
- degradation of mechanical fortresses cellulose insulating material implication: by implication their raid acid come into existence process ageing process,
- degradation of electric fortresses oil and insulation system oil - paper effect assistance ageing process.

Speed ageing process transformer oil affection temperature (growth temperature about 8 till 10K will cause doubling velocity ageing process) and catalyst (especially copper and iron).

Gas chromatography

In transformer oil they can dissolve apart from oxygen, nitrous and dioxide carbonic from air too. Gas appears within decomposing insulation system oil due to paper natural, whether thermal decomposition. Each of this process induces scission hydrocarbon chain and is block with finite composition and quantity scanning gas. Near beginning perturbation, escort development gas, stay created gas at first resolution in liquidity dielectric and near given temperature constitute balance interim intermediate inflation pressure individual element fluent mixture in space up surface oil and interim gas resolution in oil. An analysis resolution gas exhibits genesis static earlier, then come about activity gas relay (also called Buchholz’s relay). Decomposing gas is possible obtain their crowding out from transformer oil alternatively straight from gas relay, though composition fluent stage in gas relay mismatch extract parallel response, because is out of drawing solubility individual gas in oil.

Methods gas chromatography is possible look like only diagnostic system employ on indication thermal ageing process transformer oil, eventually insulation system oil - paper. Following quantitative and qualitative analysis scanning gas is possible call in question not only stage thermal ageing (quantity gas), relative circumstances gas, which accelerated ageing influences (partial discharge, mercury arc,). This system is so appropriate on working service machine and on finding constructional and technological failures new machines.

Most used application methods is quantity main gas by support system ratio analyses. Interpretation results aren't whenever single and claim exact knowledge and know-how from usage insulation system oil - paper. Be for all that comprehensible, that in literature is possible trace sundry boundary attributes and interpretation reason ageing process. In ours labor we are bearing especially on appraisal reason thermal ageing process, so identification errors, which accelerated ageing subject, for all that we are endowment system ratio analyses.

Experiment

In our experiment we are bearing on application neural networks applied on identification error in oil filling electric machine and instrument, particularly in transformer, following service results gas chromatography their oiling refill. Foundation for learning neural networks at the same time produces five systems on scoring results gas chromatography. We tried every network to teach a system.

Generated neural networks we tested by 28 objective results gas chromatography transformer oil from ultra high voltage transformer with known state of failure (partial discharge, arc discharge, overheating).

There are five wide used diagnostic methods for gas chromatography:

1. IEC 599 China [2],
2. IEC 60599 [1],
3. GPU (R. M. Glass) [2],
4. Duval’s [1],
5. GE [1].

Each method recognizes several types of failures. There is table with their specification of evaluated methods.

We designed for each method its neural network. In projection expert's diagnostic system is built-in five artificial neural networks. Each of this networks we are vote for a method of analysis gas chromatography. Main better service of such diagnostic system is that, that to process scoring isn't foul subjective fleshly input.

Given diagnostic system make possible:

- input measure out quantity scanning gas namely: hydrogen H_2, methane CH_4, ethane C_2H_6, ethylene C_2H_4 and acetylene C_2H_2,
- presentation results everybody methods (arrangements everybody neural networks),
- presentation resultant arrangements,
- ability safekeeping both presentation on computer.

Table 1. Specification of recognized failures

Failures	Method				
	IEC 599 China	IEC 60599	GPU	Duval	GE
Regular ageing	no	no	yes	no	no
Partial discharges	yes	yes	PD,C PDt	no	Only common electrical failures (EF)
Discharges (except PD)	AD	D1 D2	D1 AD2 AD+S	D1 D2 D+T	
Over-heating	TF1 TF2 TF3 Without specifi-cation of tempera-ture	TF1 TF2 TF3 Specifi-cation of tempe-rature	TF1 TF2 TF3 OHc OHcl OHtl (TFx specifi-cated local temper a-ture)	TF1 TF2 TF3 With-out specifi-cation of tempe-rature	TF1 TF2 without specifica-tion of tempera-ture

Designed neural networks results

1. IEC 599 China
   - is equally sensitive on partial discharge, from 5 incident right designate 5 (precision 100%),
   - the system is relatively well sensitive arc discharge, though arc discharge with low energy allowed designate look like partial discharge (incident item 24 - cf. answers rest system), from 10 incident right designate 9 (precision 90%),
   - the system is equally sensitive on overheating, from 13 incident right designate 13 (precision 100%).
2. IEC 60599
   - the system everything incident partial discharging designate look like discharge with low energy - aggressively partial discharge system defines look like partial discharge with low energy,
   - the system is relatively well sensitive arc discharge, from 10 incident right designate 9 (precision 90%), in a incident designate arc discharge look like mix arc discharge and thermal defect with high local temperature ,
   - the system is relatively well sensitive on overheating, from 13 incident right designate 12 (precision 92,31%).
3. GPU
   - the system GPU in four incident partial discharging their designate look like arc discharge and permanent sparkle - allowed that be implication thereof, that look like we are already remember near system IEC 60599, aggressively partial discharge and system define look like partial discharge with low energy, incident partial discharge are designate as mix partial discharging and thermal defect,
   - the system is relatively well sensitive arc discharge, from 10 incident right designate 9 (precision 90%), arc discharges look like overheating of core, tank scatter,
   - the system is equally sensitive on overheating, from 13 incident right designate 13 (precision 100%).
4. Duval's
   - the system undetermined partial discharge, everything incident partial discharging designate look like discharge with low energy,
   - the system is equally sensitive on arc discharge, everything incident arched discharging (10) right designate look like discharge with big energy, in a incident look like mix discharging with thermal defect (precision 100%),
   - the system is equally sensitive on thermal static, everything incident thermal failures right designate (precision 100%).
5. GE
   - the system is relatively well sensitive on static electric extraction, from 15 incident right designate 13 (precision 86,67%),
   - the system is equally sensitive on static thermal extraction, from 13 incident designate everything right (precision 100%).

Then it is possible to make this suitability in Table 2:

Table 2. Suitability of used methods

Method	Type of known failures		
	Partial discharges	Arc discharges	Overheating
IEC 599 China	Most suitable	Suitable	Most suitable
IEC 60599	Less suitable	Suitable	Suitable
GPU	Less suitable	Suitable	Most suitable
Duval	Unsuitable	Most suitable	Most suitable
GE	Suitable		Most suitable

Evaluation of block power transformer

For evaluation of transformer oil quality state the artificial neural networks for all five methods were designed. Networks were based on back error propagation principles. There is input screen on software in the Figure 1. Gases as hydrogen, methane, ethane, ethylene and acetylene were used.

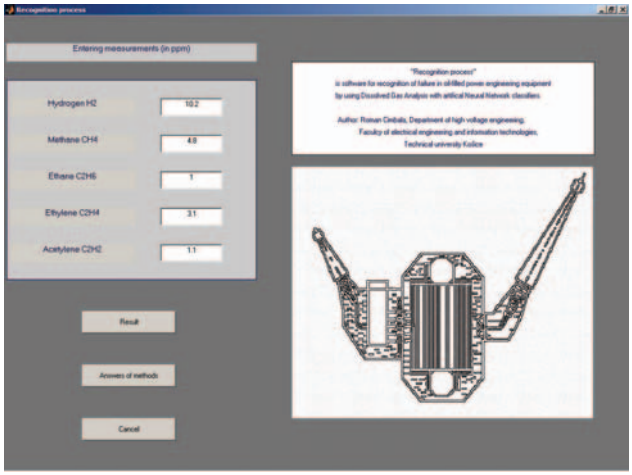

Fig. 1. Input screen of evaluation software

After input of gases five neural nets get results for all methods in probability of failures. Results are shown in the Figure 2.

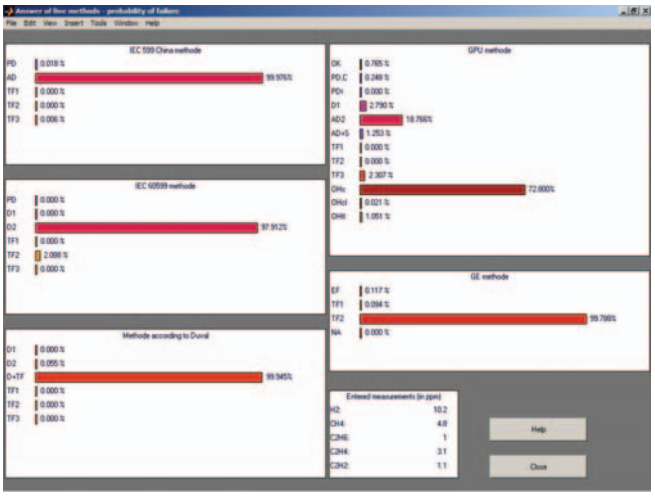

Fig. 2. Results of five used methods

Five results are collected together to get only one final result according to Table I and Table II. Result frame is shown in the Figure 3.

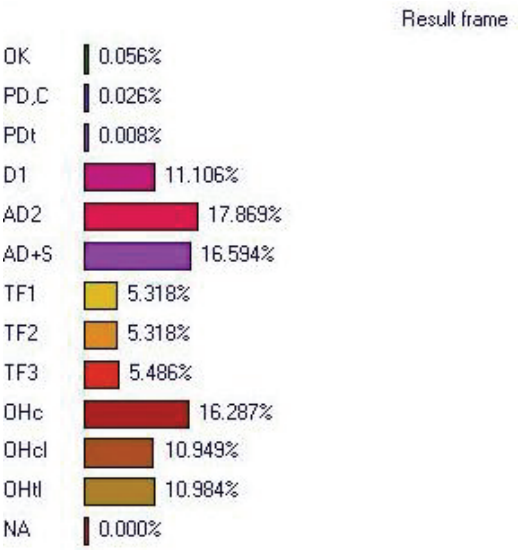

Fig. 3. Final result of evaluation

The following failures can be determined with using software:

- OK – normal ageing
- PD,C – partial discharge, corona
- PDt – partial discharges with tracks on paper insulation
- D1 – discharge without energy
- AD2 – arc discharge with energy
- AD+S – arc discharge with energy and sparking
- TF1 – thermal failure with low local temperature
- TF2 – thermal failure with middle local temperature
- TF1 – thermal failure with high local temperature
- OHc – overheating of coil
- OHcl – overheating of coil caused whirl current
- NA – disability to answer

The results for one real block transformer 110/6.3 kV during 23 years are shown in the Figure 4.

As can be seen, there are several breakpoints which represented service works of regeneration or replacement of oil fulfill.

1. In the year 1983 has been carried out oiling filling transformer.
2. In the year 1992 replacement of oil fulfill.
3. In the year 1997 seals have been changed.
4. In the year 2001 the filtration of oil in transformer has been carried out.

It means that all important changes of oil quality has been noticed with artificial intelligence system and probabilities of failures have changed too. This is the main verification of expert system sensitivity.

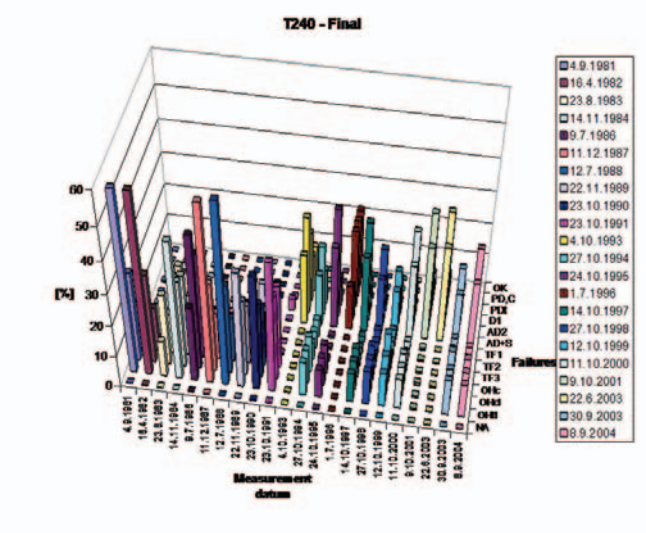

Fig. 4. Life trend of block transformer

Conclusion

According to written above it is possible to give such conclusion for ability of using neural networks for gas chromatography diagnostic purposes.

It is evident, that near finding reason decomposition transformer oil system gas chromatography, fall acquirement objective judgement needs compare results several system, because each of they fit on diagnosing another type of failures. That is why we deal with several methods.

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REFERENCES

[1] Gockenbach E., Isolationsmonitoring durch Öl Analyse, Symposium Hochspannungsprüftechnik und Monitoring, Stuttgart, 1998

[2] Electrical railway station 110kV Ždaňa, Interpretation of gas analysis in transformers and other oily electric instrument meanwhile operation, non-about to be published, 1998

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