TrafoGrade –
transformers management

CONTENTS:

1. Introduction 3
2. TrafoGrade system characteristics 4
3. Assessment of transformer's technical condition 4
4. Assessment of transformer's importance in a power system 7
5. Operation outlook analysis 8
6. Computer management system 9
7. Example of TrafoGrade system introduction 10
8. Economic issues of TrafoGrade system introduction 13
9. Summary 15

1. INTRODUCTION

The distribution companies in Poland operate several thousand of medium powers transformers, which connect high voltage power lines with medium voltage distribution network. Most of transformers in this group are units with powers 10, 16, 25 and 40 MVA and many of them are older than 30 years. Although they are operated for so long, their technical condition allows them to continue running, which results from the fact that at the time of their design and construction there was tendency to oversize insulation system.

The modern approach to operation of power transformers is based on the complex assessment of transformer's technical condition and its meaning in a power system. By combining these two factors it is possible to thoroughly determine possibilities of further operation and economical profitability assessment of necessary repairs or unit replacement.

Basing on mentioned reasons Energo-Complex company, cooperating with specialists from West Pomeranian University of Technology and Opole University of Technology, have introduced complex system of transformers management called TrafoGrade. It is based on the point scale for assessment of transformer's technical condition and its importance in power system and combines technical aspects of diagnostics with economical and financial issues to plan ongoing operation, repairs management and investment policy.

In this brochure, there is given basic information on TrafoGrade system, as well as exemplary results of 44 transformers assessment operated in one of Polish distribution companies. There is also presented economical analysis of system introduction referred to the costs of transformer's failure.

2. TRAFOGRADE SYSTEM CHARACTERISTICS

Transformer management system consists of four components shown on Fig. 1.

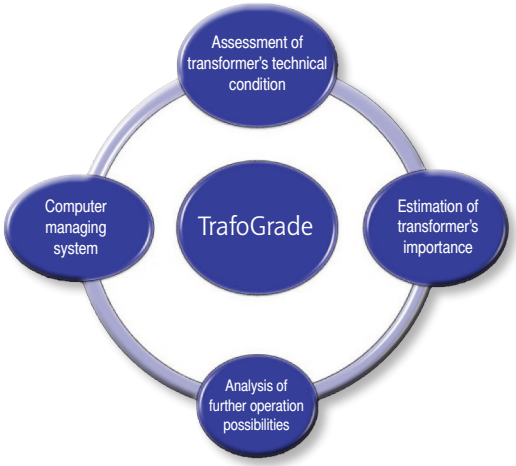

Fig. 1. Components of TrafoGrade system.

In TrafoGrade system there are points given for each property of parameter used both for technical condition assessment and transformer's importance in power system. There is three point scale introduced: good, fair, poor. The simple point-based form of technical condition assessment allows to conduct analysis of measurements results not only by engineering staff but also by economical services usually not having sufficient technical knowledge.

3. ASSESSMENT OF TRANSFORMER'S TECHNICAL CONDITION

The main part of TrafoGrade system is thorough assessment of transformer's technical condition performed by modern diagnostic methods. The assessment of technical condition is based on 14 diagnostic parameters:

- dissolved gases analysis (DGA),
- windings deformations analysis (FRA),
- history of operation,
- oil dielectric strength,
- visual examination,
- assessment of on-load tap changer (OLTC),
- assessment of cooling system,
- assessment of transformer's accessories,
- insulation resistance,
- windings resistance,
- assessment of cellulose degradation level,
- age of transformer,
- moisture contents in solid insulation,
- ageing level of oil.

All diagnostic parameters are divided into three groups:

Group I – Basic diagnostics of transformer

Group II – Technical condition of the active part

Group III – Development of ageing phenomena.

Group I contains transformer's basic properties. Even their poor results have no significant influence on transformer's ability to be operated and powered. Only extreme cases of very poor technical condition of these properties may lead to switching off the unit. It has been assumed that repairs in this group are technically easy and cheap. For instance this group contains OLTC accessories assessment.

Group II contains elements having significant impact on transformer's functionality. Bad technical condition of any of these elements eliminates the unit from operation and restoring it to proper condition needs considerable financial and organizational efforts. This group contains e.g. DGA analysis, as its negative result leads to switching off the transformer and at least need of internal inspection.

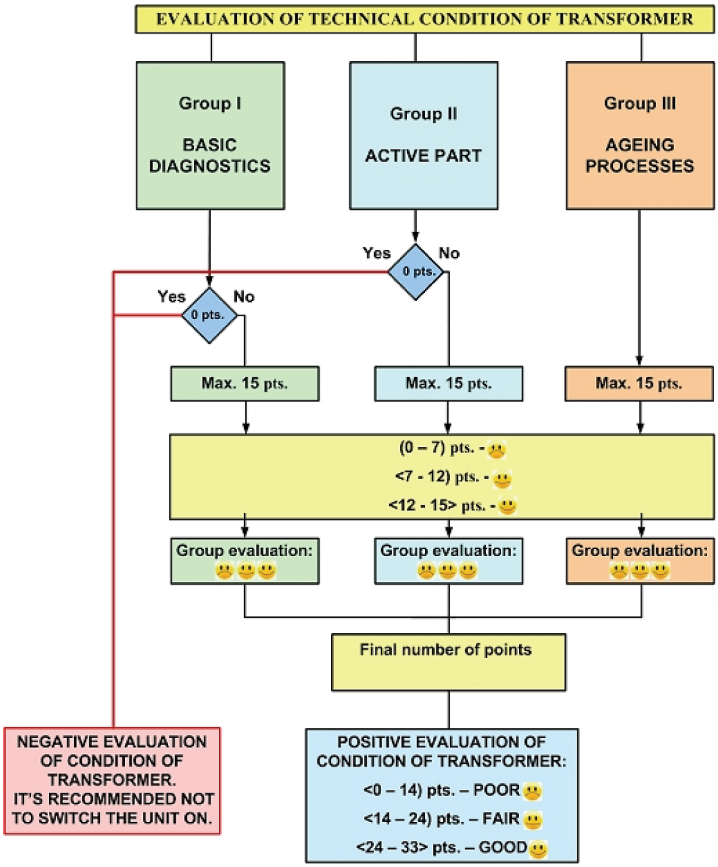

Fig. 2. The algorithm of transformer's technical condition assessment in TrafoGrade system.

In Group III there are properties which are not directly connected with current operation of transformer, but take into consideration expected "lifetime" of the transformer and planning of repairs and modernization. Therefore even negative assessment of any property from this group does not eliminate the unit from operation, however it needs proper repairs to be planned. In this group there are such parameters as age of the unit or physicochemical properties of transformer oil.

For the requirement of TrafoGrade system there has been prepared detailed instruction, which contains definitions and values of all parameters and also methodology of preparing the group and final grading scale.

4. ASSESSMENT OF TRANSFORMER'S IMPORTANCE IN A POWER SYSTEM

There are two important factors influencing the decision-making process of investment and repair policy: technical condition of transformer and its importance in the power system. This issue has significant meaning for improving reliability of electric energy distribution and energetic safety of the given region. TrafoGrade system has importance of a unit also given in the point scale and introduced by the analysis of:

- configuration of power network in which transformer is working, with detailed analysis of reliability parameters,
- the type of powered consumers,
- backup possibilities of transformers etc.

The combination of two issues, very important for the distribution company activity, allows to match the transformer to proper operation group. Fig. 3 shows the assessment results of 44 transformers performed in one of distribution companies.

In the TrafoGrade system transformers are divided into three basic operational groups: (Fig. 3):

- transformers with simplified operation (U),
- transformers with normal operation (N),
- transformers with special care operation (S).

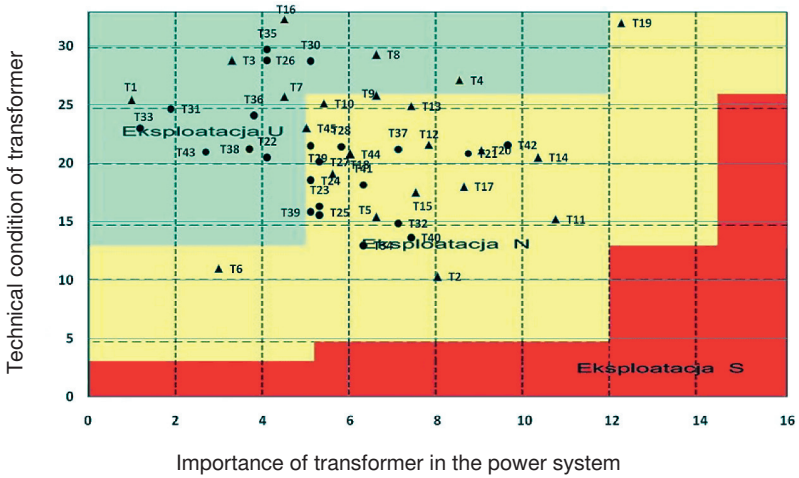

Fig.3. Results of complex analysis of technical condition and importance of transformers in power system

The first group (U) contains units having a very good technical condition or with insignificant meaning for the power system. In these cases costs for current diagnostics can be limited just to periodical visual inspections and DGA analysis of insulating oil. On the other hand, in the group (S) there are included all units with strategic meaning to the system or transformers with poor technical condition. Of course each of operation group needs separate instruction to be prepared, but such system, based on real technical condition and importance of the transformer leads to effective reduction of operation costs of electric energy distributor.

5. OPERATION OUTLOOK ANALYSIS

The final result of transformer's complex assessment of its technical condition is preparing its operation outlook, individually for each unit. This information is especially helpful for staff managing transformers' operation, as it allows preparing thorough plan of diagnostics and

repairs for next years. The Table 1 presents two examples of operation outlooks prepared for transformers having different technical condition.

Table 1. Examples of operation outlooks for transformers operation

TDR3b 25000/110 rok prod. 1980, 10,4 pkt.	
Technical condition	Operation outlook
Many leaks, OLTC: loud drive movement, DGA: low temperature overheating, Moisture X = 3,3%, Furane: 3,24 ppm, Phenol: 1,94 ppm, Physicochemical properties of oil: fair	The transformer has high level of ageing processes development in oil and solid insulation. High moisture contents and existing thermal defect accelerate insulation deterioration. Due to decreasing the short-circuit strength and possible appearance of bubble effect further operation is unreliable. Limitations of operation: - oil temperature max 75 ^{O}C, - do not switch off to cold reserve in low temperature. Repairs need large expenditures, e.g. rewinding and oil refilling
TDR3b 16000/110, rok prod. 1985, 27,1 pkt	
OLTC: fair DGA: early stage of PD (low hydrogen contents) Moisture X = 2,8 % Furane: none Physicochemical properties of oil: good	No restrictions in operation. In the period of 5-7 years there might be need of insulation drying.

6. COMPUTER MANAGEMENT SYSTEM

Ongoing work on TradfoGrade system development is leading to elaborate the computer system of transformers' management. All data on technical condition, importance in the system and operation outlook analysis of given population of transformers will be gathered in the computer managing system. Its main aims are:

- support of decision making process of repair-investment policy,
- creation of reliable budged prognosis based on the real condition of transformers,
- ergonomic data presentation in graphic form,
- easy access to archive results of measurements.

TrafoGrade system computer managing tool will be a program fit to the individual needs of users adjusted to specific character of distribution company.

7. EXAMPLE OF TRAFOGRADE SYSTEM INTRODUCTION

TrafoGrade system has been introduced in one of distribution companies and performed complex assessment of 44 distribution transformers. Fig. 4 presents the pie-chart showing the age of tested transformers population.

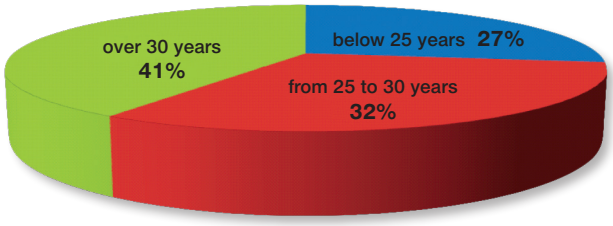

Fig. 4. The age of tested transformers

Taking into consideration statistical data on Polish distribution companies it can be noticed that due to the period of operation this population is representative for all distribution transformers. Therefore it is expected that technical condition characteristic and operation outlook obtained with TrafoGrade method, as well as main technical problems concern also other companies distributing electric energy.

Among 44 tested transformers four units had poor technical condition, 33 – fair condition and seven had good condition. Thorough assessment of technical condition is based on modern high technology diagnostic methods. Fig. 5 shows generalized for the whole population exemplary results of DGA, moisture contents in solid insulation measurement and assessment of mechanical deformations with FRA method.

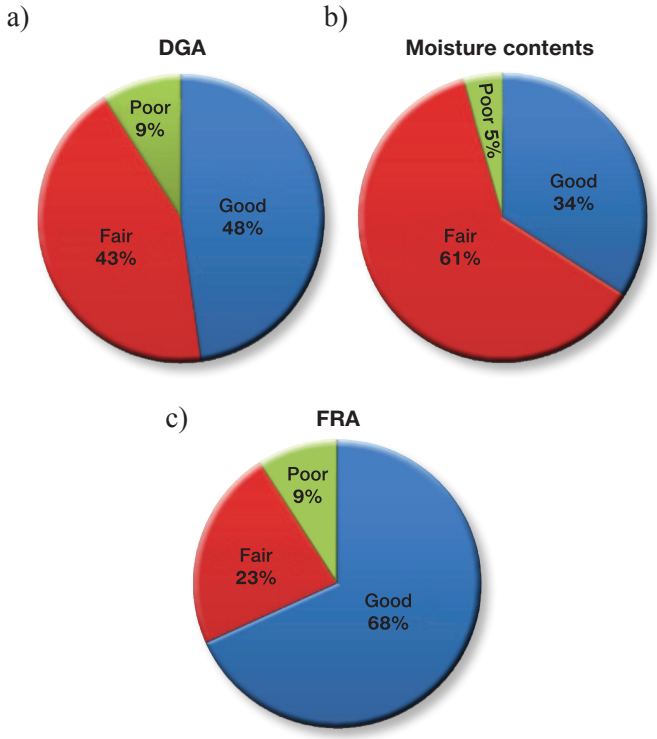

Fig. 5. The technical condition assessment of chosen parameters of transformers population: DGA oil analysis (a), cellulose moisture contents (b), FRA (c)

On the basis of results given on Fig. 5 it can be stated that in tested population only few percent of transformers have serious technical problems which may involve significant assets.

The Fig. 6 presents operation outlook of analyzed population of 44 transformers.

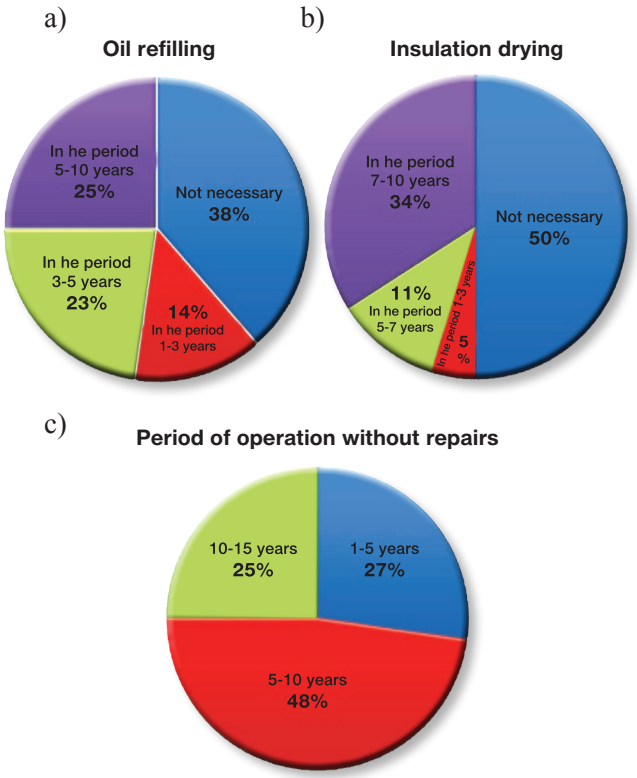

Fig. 6. The operation outlook: period of operation to oil refilling (a), drying of solid insulation (b), estimated period of operation without repairs (c)

The operation outlook determined on the base of technical condition indicators is the starting point for economical analysis.

8. ECONOMIC ISSUES OF TRAFOGRADE SYSTEM INTRODUCTION

The classical approach to measurement results working up needs performing by unit's owner the analysis of data gathered usually in several reports and drawing proper conclusions on this basis. Integration of all measurement data in a computer system and introducing point based scale for technical condition assessment makes the analysis of results easier and allows to make a decision for managing staff, not having detailed knowledge on diagnostics of transformers. Expenditures spent on repairs and modernization can be optimized due to introduction of complex managing system based on the multi-parameter assessment of transformer's technical condition. Such an approach to transformers population managing allows to easily catch the proper time, when technical condition of given unit can be significantly improved with relatively low costs involved. An example here is the transformer with high moisture contents in the solid insulation, poor parameters of oil, but having good mechanical condition of windings and solid insulation. For such unit following repairs to are to be performed:

- drying and cleaning of windings,
- pressing the core and windings,
- oil refilling,
- radiators replacement,
- renovation of on-load tap changer,
- accessories replacement.

The cost of presented repairs is estimated to be approx. 15-20% of a new unit value. Such repairs would allow to operate the unit for another 10-15 years.

In the case of poor technical condition of transformer there must be decision taken on repairs or replacement. This decision should be based on following factors:

- no-load losses analysis,
- analysis of demand for electric energy in the point of transformer's operation,
- change of transformers connection setup.

The estimated cost of a new 25 MVA transformer is 1.4-2.0 million PLN, whereas performing the complex repairs costs 650,000-850,000 PLN. Additional costs related to disassembly and transport are approx. 170,000 PLN.

The main aim of performing the complex diagnostics of transformer is avoiding its breakdown, especially catastrophic. Such catastrophic breakdown covers usually the whole HV field and sometimes additionally MV field leading to considerable increase of damages. As an example the breakdown in one of distribution companies can be given, where fire of 25 MVA transformer destroyed MV and HV fields. Total cost of breakdown consequences elimination reached 6.5 million PLN and was 10 times higher than cost of complex repairs of such unit.

Taking into consideration typical distribution company, estimated cost of TrafoGrade system introduction returns when due to prevention just one transformer breakdown can be avoided.

Application of point based scale and adjusting transformers operation instructions to TrafoGrade method standards, makes it possible to reduce costs related to periodic diagnostics. The individual approach to given unit allows to limit the range of tests for transformers from U operation group and also rationalization of costs of necessary tests in group N and S.

9. SUMMARY

The approach to management of transformers described in this paper allows to conduct rational repair management, which increase quality and reliability of operated units and significantly decrease the number of breakdowns, especially catastrophic ones. The assessment of transformers importance in a power system allows to take actions leading to increase power network reliability. In this assessment the most important issue is importance of energy receivers powered from analyzed transformer. This data together with technical condition assessment give estimation of a real breakdown consequences, including costs of undelivered energy. For distribution companies prevention of power delivery breaks is very important, not only because of economical losses, but also for improving company's brand reception. The complex assessment of technical condition gives many important information useful in logistic actions and financial policy of companies operating transformers of medium and high powers.