Classification of power transformers' faults in Latvian electrical transmission network

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***Abstract* – Issues on power transformers' complex diagnostics and ways for systematization of faults are described in this paper. A case study is presented – analysis of statistical data on faults from period of time from 1998 to 2008 for power transformers in Latvian electrical transmission network. Faults are subdivided by cause and by location indicating damaged sub-component of transformer to determine typical characteristics.**

***Keywords* – Power transformer, maintenance, statistics of faults**

I. INTRODUCTION

Power transformer is one of the main elements of energy system determining largely the reliability of electric supply. Well timed detection of the faults in their early stage is extremely important as it provides high coefficient of readiness, reduces outages and costs for repair, as well as prolongs the working life of the power transformer. Therefore diagnostics is very significant moment in determination of transformer technical condition.

Complex diagnostic gives the most accurate survey of the power transformer condition and has generally following basic steps:

1. Design analysis including estimation of typical faults of particular power transformer type;
2. Analysis of operation and maintenance data history (loading and overloads, environmental conditions, abnormal operating experience, outages etc.);
3. Inspections, tests, measurements on-line and off-line (dissolved gas analysis, oil sampling and chemical analysis, infrared thermography, tan delta measurement, insulation resistance measurement etc.);
4. Interpretation of the test results based on standards and technical documentation;
5. Development of technical report.

Selection of appropriate tests and the specification of correct test levels, which ensure reliability in service, are important moments of power transformer's complex diagnostics. The objective of this paper is related to the first and the second step of above mentioned algorithm.

Electrical lines and substations with the voltage 330 kV and 110 kV are the base of the transmission network in Latvia. Currently 264 power transformers are set up in substations with installed capacity 7897.8 MVA [1]. This network developed intensively in the time period from the 1960's to 1990's as depicted in Fig.1. One of the most significant factors determining total reliability stage of electric supply is ageing of equipment in electrical stations and substations. Exploitation of obsolete units worsens technical economic parameters of power system – the number, amount and expenses of service and planned repair works increases, as well as probability of failure.

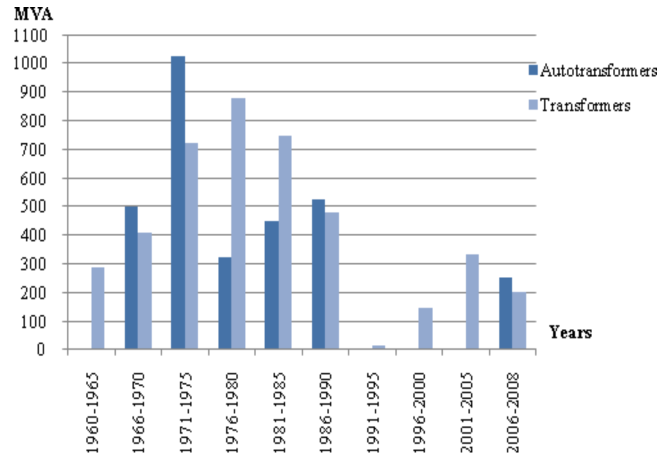

Fig.1. Total additional installed capacity of transformers and autotransformers

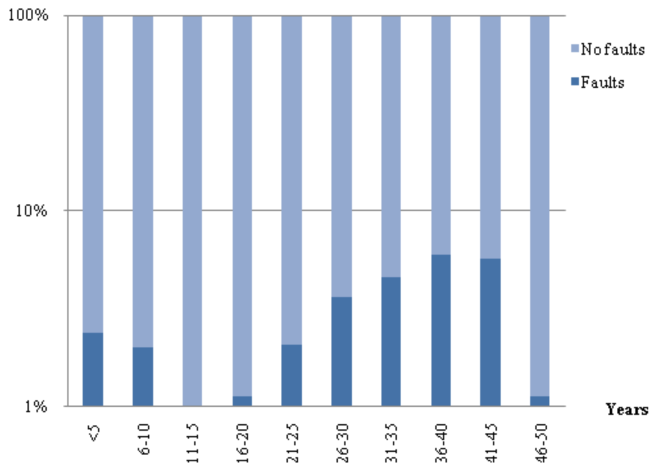

Fig.2. Proportion faulty transformers vs. service life

All transformers and autotransformers were divided into groups according to their service life. Statistical data on faults from period of time from 1998 to 2008 were analyzed. Fig.2. shows that the proportion of transformers that had a fault within each group. It is obvious that higher proportion of transformers that experienced a fault during this time period is directly proportional to service life.

II. SYSTEMATIZATION OF FAULTS

There are several methods of faults' systematization developed by various organizations, for example by:

- Nordic Grid (*Nordel*) – covering overhead lines, cables, transformers, and reactive compensation plants [2];
- Canadian Electricity Association – covering overhead lines, cables, transformers and reactive compensation plant [3];
- CIGRE (International) – covering power transformers, high voltage circuit breakers, gas insulated substations [4].

This paper offers analysis of faults by *Nordel* methodology, as Latvian TSO is a member of this organization and also works in accordance with this normative.

Nordel defines fault as an inability of a component to perform its required function. A fault is any defects or deviation resulting in a unit being incapable of fulfilling its intended function in the power system. A fault is: a primary fault or a secondary/ latent fault; temporary or permanent; intermittent or non – intermittent; system disturbances and faults in components.

The cause of a fault must be indicated for each fault. Definition of cause of fault is the cause relating to design, production, installation, operation or maintenance which results in a fault. Categorization of causes applied in *Nordel* is following:

1. Technical equipment - dimensioning, fault in technical documentation (e.g. guidelines, manuals), design, corrosion, materials, installation, production, vibration, ageing;
2. Operation and maintenance – lack of monitoring, fault in settings, fault in connection plan, fault in relay plan, incorrect operation, fault in documentation, human fault;
3. Unknown;
4. Other – operating problems, faults at customers`, faults in other networks, problems in conjunction with faults in other components, system causes, other;
5. External influences – fire, animals and birds, aircraft, excavation, collision, explosion, tree felling, vandalism;
6. Other natural causes – moisture, ice, low temperatures, natural disasters, pollution, rain, salt, snow, vegetation, wind, heat;
7. Lightning [5].

In the *Nordel* statistics, only one cause is included. This is normally the primary cause, but if the primary cause is unknown or unidentified, the underlying cause is used.

Additional information is obtained from categorizing defects in accordance with power transformer sub – components which are:

I. Foundation (including oil sumps);
II. Bushing;
III. Sensors, gas, temperature and pressure guards, oil level sensors;
IV. Cooling, (including integrated automatics for cooling);
V. Core;
VI. Windings;
VII. Tap, changers and control equipment, including integrated automatics;
VIII. Instrument transformers if integrated in power transformer;
IX. Tank.

In the event of many faults occurring in the power system, it can be difficult to identify the exact cause of the faults as there may be insufficient evidence. It is therefore recommended that the cause not be reported as "unknown" and that the most likely cause be reported instead [5].

III. CASE STUDY

Information about all power transformers and autotransformers in period from 1998th by 2008th was analyzed to estimate the situation of Latvia power system`s power transformer faults. The database contains 259 different types of high power transformers and autotransformers with rated voltages 110 – 330 kV, with a capacity from 6.3 MVA to 200 MVA that are set up in Latvia`s substations. Each transformers service time data was calculated until 2008 year starting from installation date. The main purpose was to analyze 1 275 fault application forms that were received by TSO dispatchers in case of faults. From a total of 1 275 fault application forms, 485 were selected by equipment type, power and voltage criteria that correspond to 91 power transformer and autotransformer. Fault application forms contained detailed information about power transformers type, location, exact time and reason of each fault.

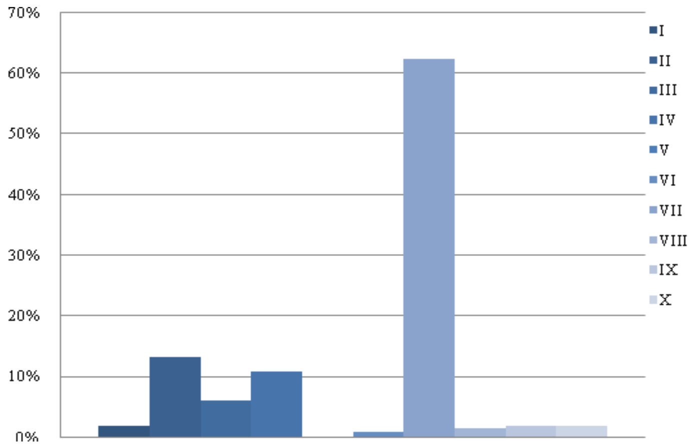

Fig.3. The division of the transformers failures causes according to the *Nordel* for sub – components for the period from 1998 to 2008

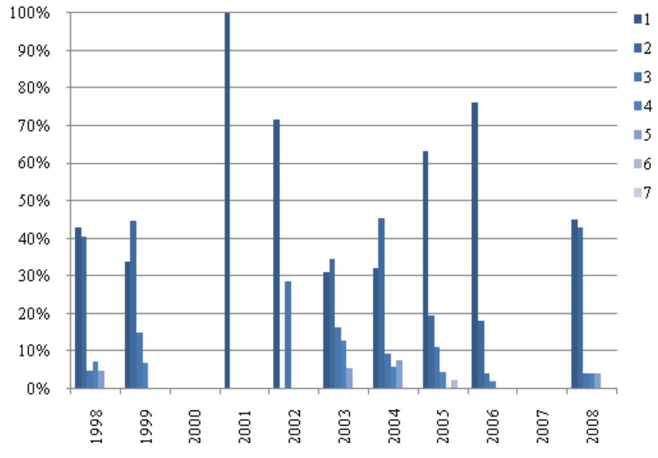

Fig.4. The division of the transformers faults causes according to the *Nordel* classification for the period from 1998 to 2008

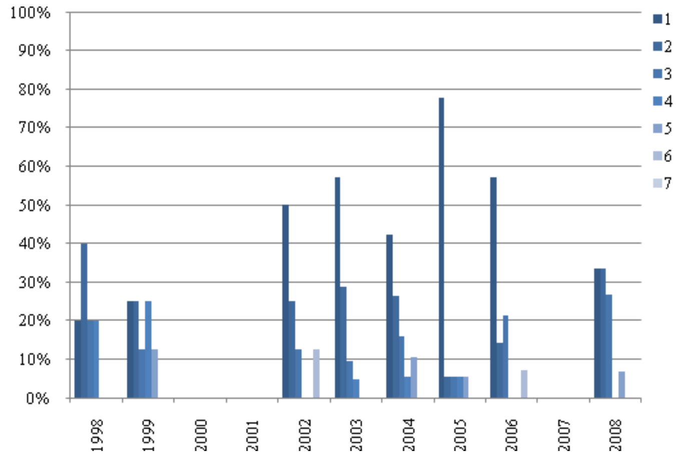

Fig.5. The division of the autotransformers faults causes according to *Nordel* classification for the period from 1998 to 2008

TABLE 1

DIVISION OF FAULTS ACCORDING TO CAUSE FOR TRANSFORMERS AND AUTOTRANSFORMERS

Years	Number of devices		Number of faults	Number of faults per 100 devices	Faults divided by cause (%)						
					1	2	3	4	5	6	7
1998	Tr.	214	42	19.63	42.9	40.5	4.8	7.1	4.8	0	0
	ATr.	19	5	26.32	20.0	40.0	20.0	20.0	0	0	0
1999	Tr.	218	74	33.94	33.8	44.6	14.9	6.8	0	0	0
	ATr.	19	8	42.11	25.0	25.0	12.5	25.0	12.5	0	0
2000	Tr.	219	*	*							
	ATr.	19	*	*							
2001	Tr.	221	1	0.45	100.0	0	0	0	0	0	0
	ATr.	19	0	-	0	0	0	0	0	0	0
2002	Tr.	223	7	3.14	71.4	0	28.6	0	0	0	0
	ATr.	19	8	42.11	50.0	25.0	12.5	0	0	12.5	0
2003	Tr.	226	55	24.34	30.9	34.5	16.4	12.7	5.5	0	0
	ATr.	19	21	110.53	57.1	28.6	9.5	4.8	0	0	0
2004	Tr.	230	53	23.04	32.1	45.3	9.4	5.7	7.5	0	0
	ATr.	19	19	100.00	42.1	26.3	15.8	5.3	10.5	0	0
2005	Tr.	233	46	19.74	63.0	19.6	10.9	4.3	0	2.2	0
	ATr.	19	18	94.74	77.8	5.6	5.6	5.6	5.6	0	0
2006	Tr.	237	50	21.10	76.0	18.0	4.0	2.0	0	0	0
	ATr.	19	14	73.68	57.1	14.3	21.4	0	0	7.1	0
2007	Tr.	239	*	*							
	ATr.	20	*	*							
2008	Tr.	239	49	20.50	44.9	42.9	4.1	4.1	4.1	0	0
	ATr.	20	15	75.00	33.3	33.3	26.7	0	6.7	0	0

*No faults were presented for 2000 and 2007 years

Results after collection and processing all available information using *Nordel* classification are following: the apportionment of the transformers faults causes is shown in Fig.4; the apportionment of the autotransformers faults causes is shown in Fig.5. The information about causes of transformers and autotransformers faults is shown in Table 1. Faults were divided on the recommendations of *Nordel*, if there was not given a reason for fault, the fault was divided on a possible reason for this fault. It was also difficult to determine the causes of possible faults, and then they were added to an unknown group of faults. The collected information on faults was sorted by the fault`s location in the sub – components of transformers and autotransformers in correspondence with *Nordel* system. The obtained results are displayed in Fig.3. Faults division numbering corresponds to the above considered *Nordel* system in Fig.3, 4 and 5.

As shown in Table 1 no fault application forms were received and processed for years 2000 and 2007. Only one transformer fault application form was received for year 2001 that is doubtful. This data is very questionable, if considering the information obtained from the charts, especially for year 2007 where a very high reduction of fault number is seen. This could be due to incorrectly tracked data or data loss. To analyze technical condition of transformers and autotransformers more accurately it is suggested to pay attention to the each transformer and autotransformer full faults histories availability and storage.

The following conclusions about the transformer and autotransformer parks condition can be drawn from the analysis of the obtained data. Analysis of Fig.3 shows that the most common components where faults occurred were tap changers with control equipment including integrated automatics, bushings and cooling with integrated automatics. This high fault rate of tap changers could be caused by frequent movement of the element and switching from one position to another. At the same time, the most common categories of fault causes are technical equipment, operation and maintenance that are displayed in Fig.4 and 5. If particular transformer had the same fault several times, then for the first time this fault was sorted into fault cause category of technical equipment (the cause is in the device), but for a second time - into operation and maintenance (the cause is in monitoring, settings, incorrect operation, human fault).

Corrosion of materials fits the category technical equipment similar as oil leakage, which occurs very often, but it is not so important, therefore it is suggested to set a filter to analyze fault priority, to gain more accurate analysis. Nevertheless, comparing received results number of faults per 100 devices with *Nordel* system [6] it is seen that *Nordel* system is 1.55 for a 2007 year but in this paper calculated the number of faults is 24.71 for a 2008 year.

IV. Conclusion

Complex diagnostic provides large amount of information on the power transformer including analysis of design, operation and maintenance history, measurement and test results, technical reports etc. Yet vital issue is effective organizing system for the viewing, archiving, and storage of above mentioned data to ensure the most accurate survey on unit's technical condition. Research revealed necessity to improve current method for registration and categorization of faults.

Research based on statistical data about power transformer's faults allows concluding that probability of fault is directly proportional to service life of a unit. Typical cause of a fault of power transformers in Latvian electrical transmission network involves technical equipment and maintenance issues; however as sub-component that experienced faults most frequently tap changers and control equipment automatics were indicated.

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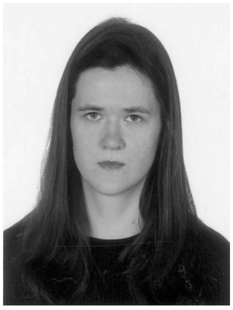

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