ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome X [2017]
Fascicule 1 [January – March]
ISSN: 2067 – 3809

[1.]Dragisa DJORDJIC, [2.]Slavko DJURIC, [3.]Miodrag HADZISTEVIC

TRANSFORMER OIL AND POTENTIAL RISKS FOR ENVIRONMENT

[1-3.] University of Novi Sad, Faculty of Technical Sciences, Novi Sad, SERBIA

Abstract: Safe handling and manipulation of transformer oil in the electrical energy distribution and other sectors are to be realised in a manner and procedure that will not pose a risk of water, soil or air pollution for the protection of environment, life and health of people. Implementation of the necessary preventive and corrective measures for environmental protection, fire protection, safety and health at work is, among other things, mandatory, including the respect for and the realisation of legal provisions, standards and regulations for the purpose of safe and optimal treatment and management of transformer oil, and prevention or reduction of negative impact on the environment and human health. The study presents the sources of transformer oil, testing and determining the trend of transformer oil's important features in the exploitation, with particular emphasis on potential negative impact on the environment, safety and health, therefore the results, recommendations and conclusions are given.
Keywords: transformer oil, electric power distribution, potential risk, environmental protection, safety and health of people, fire protection

INTRODUCTION

Transformer or insulating oil is often used in the operation of oil transformers, which also includes transport, storage, filling, handling of oil in the operation of various devices and managing used oil. There is a potential risk of environmental pollution and/or danger to human health and life in every operation stage, especially in emergency situations in case of spillage, evaporation and/or formation of flammable products. In order to prevent or mitigate undesirable consequences of such phenomena, timely inspections, implementation of all the measures needed and appropriate rehabilitation are required. The study analysed essential characteristics of oil and transformers in the power transformer stations belonging to the MH "ERS" ZEDP "Elektro-Bijeljina" joint-stock company Bijeljina and the potential risks to the environment. Business activities of the above mentioned company are: distribution, supply and production of electricity [1].

MATERIAL AND METHOD

Ξ Transformer oil

The oil in a transformer, as shown in Figure 1, is insulation, cooling; it assists in extinguishing sparks, dissolves gases formed during the degradation of oil, and dissolves gases and moisture from the cellulose insulation and atmosphere. Transformer oil may be of mineral or synthetic plant origin. [2]

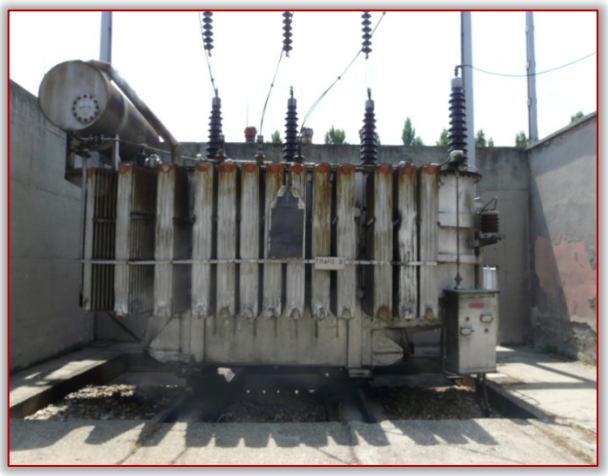

Figure 1: Transformer connected to electrical grid in an insulated bulkhead [2]

Transformer oil is transported in rail tank cars or tanker trucks, barrels or metal containers, with mandatory inspection in order to prevent uncontrolled spillage and contamination. Supply of transformer oil depends on the need for replacement, topping up,

sampling and other ordinary and extraordinary situations.

The transport containers must be clearly marked with a tag containing the name of oil and the manufacturer, designation according to the standard, batch number, and date of delivery. Storage areas must comply with the regulations that apply to the corresponding petroleum products, i.e. must be well ventilated and cool with ambient temperature not higher than 50°C, and without potential sources of fire. The barrels are stored in either closed or covered area, not exposed to contamination and corrosion, and are laid on wooden pallets [3], as shown in Figure 2.

Figure 2: Stacking of barrels on wooden pallets

Ξ Classification and generation of waste transformer oil

Waste transformer oil is classified as hazardous waste [4]. Waste transformer oil and other types of hazardous and non-hazardous waste are generated in the processes of maintenance, overhaul, replacement of electrical equipment and other activities of electricity distribution companies. Waste transformer oil is generated in the following situations:

- After the analysis of transformer oil sample; if the results show unsatisfactory quality, the replacement with new oil follows;
- If damage to the power transformer caused discharge of transformer oil into the environment;
- If damage to the power transformer caused discharge of transformer oil in the transformer oil pit collector.

Metal barrels containing waste insulating/transformer oil is marked with stickers (displaying hazardous properties of the substance), and identification card.

Ξ Test method and trend determination of dielectric strength of transformer oil in exploitation for the aim of analysis of environmental impacts, potential risks and safety

Dielectric strength of transformer oil is tested according to the standards JUS N.A5.014, SRPS N.A5.014, SRPS EN 60156. Testing the dielectric strength of insulating oil is, in principle, the same for all types of oil (for transformers, switches and capacitors), whether they are new or used ones.

Since the dielectric strength is extremely sensitive to the slightest contamination of the sample, careful sampling is essential. Insulating oil samples for testing dielectric strength are to be taken only by persons qualified and experienced in the handling of insulating transformer oil or persons working under their direct supervision.

The oil sample is taken at the spot, which is considered to be less pure, for example, at the lowest point of the transformer [5], as shown in Figure 3.

Figure 3: Discharge of oil
at the lowest point of transformer

The control sample is taken in dry weather, but if taken in wet weather conditions, special protective measures (e.g. protection from rain, wiping, drying, and waterproof covers for sample transport, etc.) are to be taken [6].

During sample preparation, the sample container needs to be shaken gently and overturned several times in order to provide, to the fullest extent possible, the homogeneous distribution of impurities contained in the oil and avoid creation of air bubbles. Immediately thereafter, the sample is poured into a test cell, slowly, to avoid the formation of air bubbles. The oil temperature at the time of the test should be equal to the ambient temperature; the best is around 20 °C. This temperature must be recorded. [5]

Samples of the new oil delivered in tankers or barrels and used oils are tested in the existing state, without prior processing.

Testing is conducted as the electrodes are connected to alternating voltage frequency of 50 Hz, which, starting from zero, is evenly increasing by 2 kV/s until it reaches a value causing the overshoot. The test will be repeated six times with the same filling of the cell.

Dielectric strength is the arithmetic mean value of the six results obtained, if no value deviates by more than

25% from the arithmetic mean value. If there is a deviation, the entire procedure is to be repeated.[5] Record on testing is to include overshoot voltage, expressed in kV, obtained in the course of all tests carried out and the mean value of all results. The type of electrodes used, the frequency of the test voltage and oil temperature are to be also entered into the records. [5]

RESULTS AND DISCUSSION

During the exploitation (operation) of a transformer, the transformer/ insulating oil is often used, thus there is a potential risk of environmental pollution and/or danger to human health and life, especially in emergency situations. It is highly significant not only for the users of the transformers in associated substations and other high-voltage installations, but also for the relevant professional engineering institutions, to know the prescribed transformer oil's features values and their monitoring, what the potential risks to the environment and humans' safety are and what the life cycle of the individual elements of the plant is. This is particularly important for the power transformers, which are the most expensive, the most sensitive and the most risky part of the plant.

The transformer lifetime depends on the lifetime of its insulation, which consists of transformer oil and solid compounds [1]. In this respect, the importance of testing and trend determination of dielectric strength of transformer oil at substations and other power installations is recognized.

When it comes to defining the time limits for the purpose of this analysis, the adopted time limit is 5 years.

Significant facts and results are observed on the basis of the analysis of various factors, small or great influence on the dielectric strength of oil in the transformers installed in power transformer stations belonging to the "Elektro-Bijeljina" joint-stock company Bijeljina within the above mentioned time period.

The average value of dielectric strength of oil in the transformers installed in various associated substations (TS) and other power transformer stations of voltage level 35/10 kV, has ranged from 138.5 to 261.6 kV/cm [1].

In general, the strength of oil indicates a downward trend, as shown in Figure 4.

Age of the transformers installed in the power transformer stations belonging to the Company, voltage level 35/10 kV, in the reporting period ranged from 8 to 50 years [1] and is on the rise, as shown in Figure 5, which is not a positive trend from the standpoint of environmental protection, labour safety, technical, economic and other aspects.

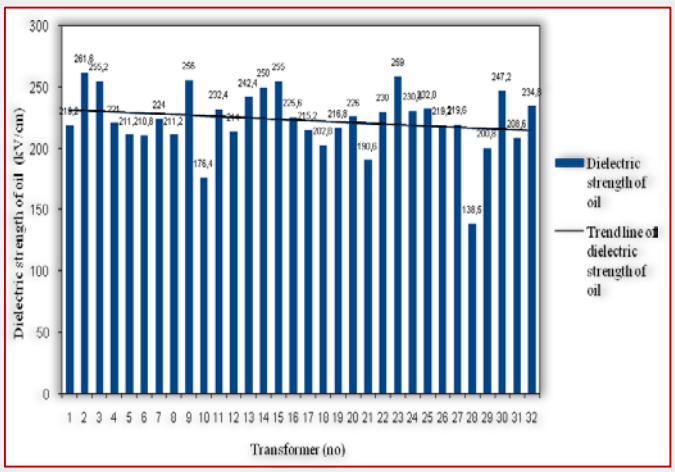

Figure 4: Dielectric strength of oil in transformers installed in power transformer stations belonging to the "Elektro-Bijeljina" joint-stock company Bijeljina

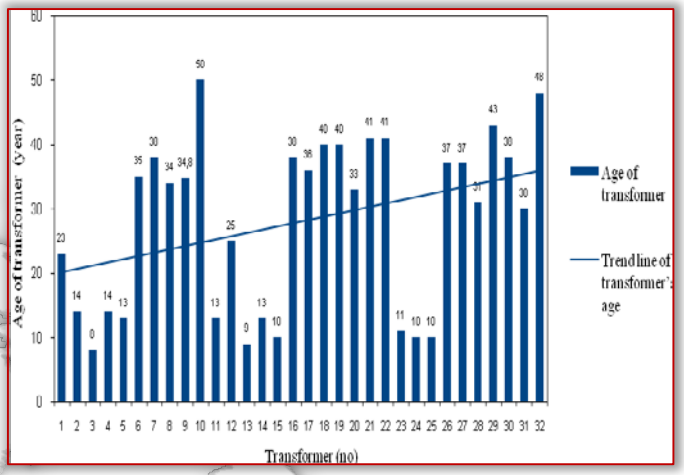

Figure 5: Age of transformers installed in power transformer stations belonging to the "Elektro-Bijeljina" joint-stock company Bijeljina

In the reporting period, the trajectory of transformer age was inversely proportional to the value of dielectric strength of oil, as shown in Figure 6.

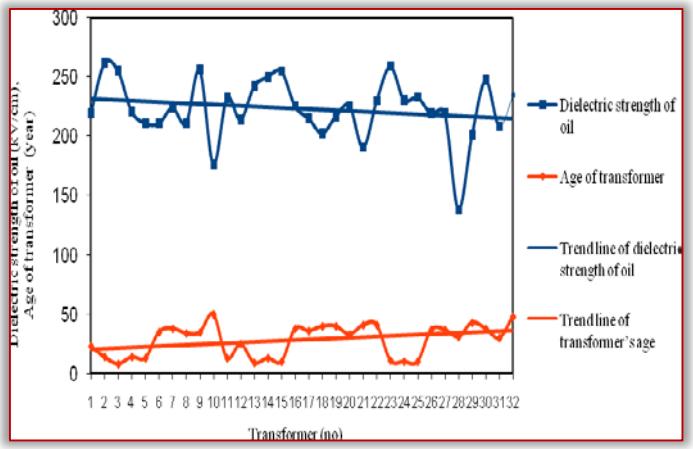

Figure 6: Dielectric strength of oil and age of transformers in power transformer stations belonging to the "Elektro-Bijeljina" joint-stock company Bijeljina

With the increasing trend in transformer's age, the decreasing trend in the value of dielectric strength of oil is recorded at the same time.

The lifespan of the power transformer is difficult to assess. This causes a great deal of attention, both here and on the global scale, because a large number of transformers, particularly in developing countries, are at the end of life. Most power transformers in the world have been in operation for over 30 years [7]. The average age of transformers in power transformer station of 35/10 kV voltage level in the "Elektro-Bijeljina" joint-stock company Bijeljina is 28 years [1].

Available methods do not provide a fully accurate data for determining the status or the end of transformer's operating life. Therefore, a team consisting of experienced engineers, technicians and other experts is obliged to carry out a series of additional analyses, tests, inspections and audits regarding the above mentioned. The most common transformer related problems are about transformer oil leaks, the malfunctions of cooling systems and various elements, which in certain situation, particularly in emergency situations, may pose a risk to the environment.

In accordance with previously analyzed data, it is evident that dielectric strength of transformer oils in operation has a decreasing trend, as opposed to the age structure of the transformers in researched systems, which has significantly deteriorated. Unless appropriate measures and activities are taken, the continuation of the decreasing trend in dielectric strength of oil in the transformers installed in the power transformer stations of the above mentioned and other similar power distribution systems in the region, is forecasted. Such forecast requires a quicker response by the relevant experts in order to cease these trends, or at least partially reversed them. When reviewing aforementioned problems, be sure to take into account the requirement that the minimum value of dielectric strength of transformer oil is 120 kV / cm [6] in the transformers installed in associated substations of 35/10 kV voltage level, which represents the required threshold of used insulating oil, according to the standards [5]. Those findings, based on the results of conducted research and forecasted future trends of mentioned factors, need to be taken extremely seriously, with special emphasis on increasing risk of accidents and possible negative effects on the environment, safety and health of people.

Some power plants - substations are missing transformer oil pit collector, which would prevent oil spills from the transformer into the environment in case of malfunctions, system elements failures and emergencies.

Experts from the field of engineering, protection etc, as well as the competent authorities, must have open communication based on an integrated basis, and the possibility of efficient cooperation between themselves, with responsible persons and the public [8], that all are the indispensable system links.

CONCLUSION

The negative impact of transformer oil on the environment is multiple. The most common risk is the risk of waterways and soil contamination. Particularly dangerous is the presence of oil in the water flow of so-called sanitary protection zone used to supply the settlements with top quality water.

Main conclusions resulting from the analysis in this study are that the dielectric strength of transformer oils in operation has a trend of constant decrease and that the age structure of the transformers installed in the substations and other power transformer stations in researched or other similar power systems in developing countries has significantly deteriorated. It is necessary to act urgently and to rapidly procure and install new transformers and transformer oils in the power systems or generally overhaul the existing transformers with transformer oil regeneration in the most power transformer stations, or to carry out the activities as a combination of the aforementioned. This is very important, especially when taking into account the fact that the transformer operation safety directly depends on the dielectric strength of transformer oil, likewise potentially negative impact of transformer oil on the environment in case of system failure or small/large spillage/ discharge of oil into either water or soil, especially in case of emergencies. The need for consistent preventive actions is imposed as imperative in the integration with the implementation of technical measures and activities from the fields of environmental protection, fire protection, safety and health at work, as well as other forms of protection. The aforementioned activities are to eliminate or reduce to a minimum any potential contingency situations and the above listed negative trends in the power transformer stations, which could lead to accidents, the negative impact of transformer oil on the environment, as well as substantial risk to both the environment and the life and health of people.

Some substations of 35/10 kV voltage level are missing transformer oil pit collector, which would prevent oil spills from the transformer into the environment in case of emergencies or accidents, thus it is necessary to construct, as soon as possible, a transformer oil pit collector, which is a preventive measure and recommendation, in accordance with general and specific environmental objectives, investment plans and priority activities.

The local authorities are to be requested to establish the centers for waste oil collection at preferred and safe locations in their area of responsibility. Waste

collection centers should have an easy access and enabled quick evacuation in case of spillage and/or other emergencies. This will eliminate the additional costs for preparatory works and other activities, and provide easier access and manipulations with minimum risk to the environment and human health.

Based on the conducted research presented in this paper (study) and data synthesis from the domain of subject matter, it can be concluded that the results, recommendations and conclusions, in addition to the researched system, may be applied to most power distribution systems, particularly in transition economies of European Union.

Note

This paper is based on the paper presented at The 7th International Conference on Mass Customization and Personalization in Central Europe – MCP–CE 2016 – Mass Customization and Open Innovation, organized in Novi Sad, SERBIA, September 21-23, 2016, referred here as [9].

References

[1] Technical and other documentation of the MH ''ERS" ZEDP "Elektro-Bijeljina" joint-stock company Bijeljina.

[2] Anita Petrovic Gegic, Dragan Zivkovic: Safe disposal of transformer oil; Higher Education Technical School of Professional Studies Novi Sad, Transmission System and Market Operator "Elektromreza Srbije" Belgrade, 2010.

[3] Bozena Musulin: Ecological aspects of use and disposal of transformer oil, Fourth counseling; Croatian Committee of the International Conference on Large Electric Systems, Koncar - Electrical Engineering Institute, Zagreb, 1999.

[4] Reference Document 'BREF' on best available techniques for industrial waste treatment, Integrated environmental prevention and control of environmental pollution, European Commission, 2006.

[5] JUS N.A5.014, SRPS N.A5.014, SRPS EN 60156.

[6] Technical rules and manuals for the maintenance of power distribution plants and devices, MH "Electric power industry of Srpska", Banjaluka, 2008.

[7] Ksenija R. Djurdjevic, Mirjana Vojinovic-Miloradov etc: The life cycle of transformer oils; NIS Novi Sad, Faculty of Technical Sciences Novi Sad, Faculty of Technology, Novi Sad, 2008.

[8] Maja Todorovic, Sasa Bakrac: The integration of environmental risk assessment process in the evaluation process of the environmental protection impact - methodological approach; the Singidunum University, the Ministry of Defence of the Republic of Serbia, Belgrade, 2010.

[9] Dragisa Djordjic, Slavko Djuric, Miodrag Hadzistevic, Transformer oil and potential risks for environment, The 7th International Conference on Mass Customization and Personalization in Central Europe – MCP–CE 2016 – Mass Customization and Open Innovation, Novi Sad, SERBIA, 2016

ISSN:2067-3809