



## **SILVER CORROSION RISK ASSESSMENT AND MITIGATION**

**Jelena Lukic, Jelena Jankovic, Valentina Vasovic, Dejan Kolarski  
Nikola Tesla Institute of Electrical Engineering**

### **ABSTRACT**

In recent years, problems with sulfur corrosion have been frequently correlated to the corrosion of the silver-plating on-load tap changer (OLTC) contacts. Apart from contamination by oil during regeneration with reactivating adsorbent, other possible causes of oil contamination have been recognized, such as: gasket materials, cements, rubbers, reservoirs, oil production and storage, etc. The problem became amplified when failure investigation records showed that minute concentrations of elemental sulfur ( $S_8$ ) in the oil may be enough to trigger failure. This is due to a high ratio of oil mass to surface area of silver-plated contacts that can be affected, especially in designs with in-tank OLTC selectors. Silver corrosion became a severe global problem, as it was found in other types of insulating liquids, such as esters.

This paper provides inputs for power transformer risk assessment based on the insulating liquids propensity to deposit silver sulfide, based on the concentration of elemental sulfur in the oil, and data on liquid quantity and surface area in the OLTC. Reactivity of  $S_8$  to silver is high; reaction starts at ambient temperatures of 30 to 40°C in cases of high concentrations of 10-20 ppm of  $S_8$ . Metal passivator (tolyltriazole derivative) was found to be ineffective at protecting silver surfaces against sulfur corrosion, as shown in previous publications and by service experience [1-4]. This paper provides insights for risk assessment and addresses the introduction of new sulfur corrosion test methods, which aim to adequately detect different types of corrosive sulfur species corrosive to silver that corresponds to service experience. Methods for quantitative detection of minute concentrations of elemental sulfur in mineral oils and synthetic esters are also presented in this paper. Gas chromatography equipped with a micro electron capture detector ( $\mu$ ECD) was found to reach low detection limits of elemental sulfur (below 0.1 ppm), both in mineral oils and synthetic esters. Service experiences show that minute concentrations of  $S_8$ , below 1 ppm can cause severe corrosion of OLTC silver plated contacts. Owing to this, mitigation solutions are needed urgently, both related to the removal of corrosive sulfur from insulating liquids and the cleaning of corroded OLTCs contacts (removal of silver sulfide deposits). Removal of elemental sulfur from mineral oil and synthetic ester in "as delivered" state was successful on a pilot scale. Nikola Tesla Institute (NTI) patented technology was found to be efficient in the removal of high concentrations of DBDS and elemental sulfur from different types of insulating liquids.

### **INTRODUCTION**

The presence of corrosive sulfur in the insulating liquids of power transformers still presents severe problems, causing failures during operation.

Observations from the field identified two possible failure modes due to silver corrosion: dielectric flashover and or a thermal hotspot. Flashover is initiated by detachment of silver sulfide particles from the contacts, most often due to the sliding on the contacts after a tap-changer operation. When silver sulfide flakes detach from the surface of the contact, they become free to move into dielectric-stressed areas. As silver sulfide is rather conductive, these flakes create a weak insulation path, which can lead to a sudden flashover [1]. In cases where sulfide deposits remain on the contacts, they may cause rise of resistance which leads to overheating of the contacts. Conventional detection methods, such as dissolved gas analysis (DGA) and winding resistance measurements, often fail to identify these imminent failures, which can result in unexpected flashovers without any preceding signs. Most of the reported failures in mineral oils occurred after oil regeneration processes with reactivating adsorbents [4]. This working mode causes the creation of elemental sulfur during reactivation of adsorbent at high temperatures (from 300°C to above 600°C) and subsequent contamination of the oil following oil circulations after reactivation of adsorbent [2-8]. However,

recent failure cases have been reported that are not directly correlated to oil regeneration involving reactivating adsorbents [3]. While the annual count of reported instances has remained consistent in recent years, there has been a noticeable shift in the root causes, particularly concerning the nature and origin of the corrosive sulfur. Recently, silver corrosion was reported in synthetic ester insulating liquids, with elemental sulfur detected in small concentrations (0.5 up to 1 ppm).

## REACTIVE SULFUR SPECIES AND TESTING CONDITIONS

**Elemental sulfur ( $S_8$ )** is the most reactive sulfur compound to silver. From service experience, it was found to be more reactive to silver than to copper. Silver sulfide deposition can occur at lower temperatures, owing to the low activation energy of the reaction of silver sulfide formation [2].

Minute concentrations of elemental sulfur are enough to create silver sulfide. This is due to a high ratio of oil mass to surface area of silver-plated contact in the case of in-tank selector parts. This ratio is approximately 20 times higher than the ratio in the silver corrosion test (DIN 51353, ASTM D 1275-15).

**Table 1**  
**Approximate Ratios (Order of Magnitude) of Sulfur to Silver Mass in**  
**ASTM D1275-15 Test (Oil with 20 ppm of  $S_8$ ) and PT with 30 Tons of Oil with 0.6 ppm of  $S_8$**

PT with 30 tons of oil containing 0.6 ppm of $S_8$	Mass of $S_8$ in the oil, g / mass of Ag, g
	0.098
ASTM D1275-15 silver corrosion test (oil containing 20 ppm of $S_8$ )	Mass of $S_8$ in the oil, mg / mass of Ag, mg
	0.005

Oil subjected to the silver corrosion test (DIN 51353, or ASTM D 1275-15) containing 20 ppm of  $S_8$ , corresponds to 1 ppm of  $S_8$  in 30 tons of oil in a power transformer in operation with OLTC silver plated contacts (Table 1). Since the reaction is governed by low activation energy [1], low concentrations and gradients are not restrictive for deposition of silver sulfide.

In order to simulate these conditions, synthetic ester was spiked with 20 ppm of  $S_8$  and subjected to silver corrosion tests (ASTM D 1275-15) at a temperature of 40°C (Figure 1). Silver sulfide deposition occurred after 18 hours.



**Deposition of Silver Sulfide After 18h at 40°C – Left, and at Room Temperature – Right**  
**from the Synthetic Ester Spiked with 20 ppm of  $S_8$**

**Figure 1**

Obtained results correlate well with previous findings of silver sulfide deposition in mineral oils [8]. It can be concluded that oil in power transformers, which contains 0.5 ppm to 1 ppm of  $S_8$ , has the potential to deposit silver sulfide at the temperature of 40°C. Silver sulfide formation is promoted in low oxygen conditions. With increasing oxygen contents, competitive reactions of oxides formations are becoming dominant.

**Dibenzyl disulfide (DBDS)** has been recognized as the most abundant corrosive sulfur compound in mineral oils in the past few decades. It is not so reactive as elemental sulfur, but its reactivity increases at higher temperatures (above 100°C) and with oxygen ingress. Typical concentrations in mineral oils are above 20 ppm up to 200 ppm from samples received and tested at NTI.

**Disulfides other than DBDS** behave similarly to DBDS and they can be detected in significant concentrations in uninhibited oils. Disulfides were tested as a group as individual species. Typical concentrations are similar to DBDS, from 20 to 100 ppm.

**Elemental sulfur ( $S_8$ )** molecule was detected in both mineral and synthetic ester insulating liquids, usually in the concentration range, from 0.3 ppm to 10 ppm. The causes are not known, but it is suspected that oil contamination had occurred, either by oil reclamation with reactivating adsorbents or some other contamination from materials of transformer construction, reservoirs, adsorbents, and was so far the only reactive sulfur compound detected in synthetic ester liquid.

**Other sulfur compounds** of different compositions coming from different non-metallic material can contaminate insulating liquids. Since their composition is not known, quantification by measurement of total sulfur content in conjunction with silver strip corrosion tests can be helpful in the silver corrosion assessment.

### Testing

Methods for assessment of oil corrosiveness to silver are not adequately addressing the conditions of power transformers in service, nor are they adequately reflecting the reactivity of different sulfur species. In practice, corrosive sulfur tests were shown to provide different results depending on the type of sulfur compounds in the oil and their reactivity to copper and silver.

### Mineral Oils

The DIN 51353 test was found to be unresponsive to all reactive sulfur compounds except elemental sulfur, while ASTM D 1275-15 was found to be sensitive to elemental sulfur, but in number of cases investigated at NTI, was not sensitive to DBDS.

Mineral oils with a minute concentration of  $S_8$  were tested in both silver corrosion tests, DIN 51353 and ASTM D1275-15. Both tests gave an adequate response, i.e. the oils were found to be corrosive to silver (Figure 2).



**Results of Silver Corrosion Tests with Minute Concentrations of Elemental Sulfur in Mineral Oil ( $S_8=0.35$  ppm), Left – DIN 51353, Right ASTM D 1275-15 (EDX: S wt. %=1.54)**  
**Figure 2**

Significant numbers of inhibited mineral oils containing DBDS did not respond as corrosive to silver according to the ASTM D 1275-15 silver strip corrosion test. There were a number of samples (more than 30%) of oils containing DBDS above 40 ppm that tested as non-corrosive to silver [5]. This was observed as a discrepancy in relation to the practical experiences and observations in the field.

These observations have initiated investigations of testing condition modifications in order to achieve better response of the oils with higher concentrations of DBDS (above 40 ppm). Higher oxygen contents were introduced in the ageing study performed on seven oils containing DBDS in a wide range of concentrations (from 40 ppm to 210 ppm). The ASTM D 1275-15 silver strip corrosion tests were performed under two different oxygen contents (low and high) for 48 hours.

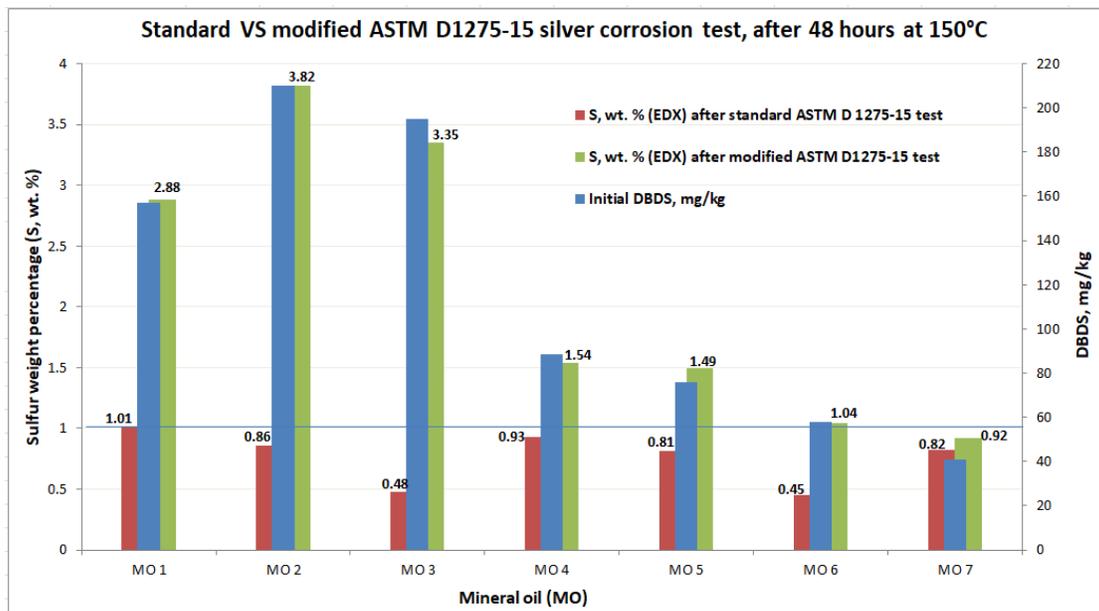
The first set up was performed according to the standard ASTM D1275-15 test procedure in low oxygen environment (0.1-1%), while the second set up was performed using a higher content of oxygen (1.0-2.5%),

simulating free-breathing conditions with three needles punched into the screw caps on the bottles), leaving the oil quantity, silver strip dimensions and duration the same as in standard ASTM test. The first and second set-ups are shown in Figure 3.



**ASTM D1275-15 Silver Corrosion Tests. Left – Standard; Right – Modified  
Figure 3**

The sulfur weight percentage (S, wt. %) on silver strips after standard and modified ASTM D1275-15 silver corrosion tests, in oils with DBDS, was determined using a scanning electron microscope (SEM) with an energy-dispersive X-ray (EDX) spectrometer. The results are shown in Figure 4.



**Comparison of Sulfur Weight Percentage on Silver Strip After Standard (Red) and Modified (Green) ASTM D 1275-15 Silver Corrosion Tests in Oils with Different Initial Concentrations of DBDS  
Figure 4**

The results of the modified ASTM D 1275-15 silver corrosion test, with continuous oxygen ingress over 48 hours, showed that oils were corrosive to silver compared to the standard ASTM D 1275-15 test for the same test duration (Figure 4). Therefore, it can be concluded that oxygen ingress during the test promoted the reaction of disulfides with silver [3]. The exception is mineral oil 7 (MO 7), with lower initial concentration of DBDS (40.7 ppm), in which the reaction of DBDS with silver was less pronounced. In our experience, oils with lower DBDS concentrations (less than 40 ppm) were found to be less responsive, possibly due to side reactions and overall low potential to form substantial amounts of sulfides.

## Synthetic Esters

Low concentrations of  $S_8$  were detected in samples of synthetic ester insulating liquid and so far, no other reactive sulfur species were found. The DIN 51353 test was found to be unresponsive to low level of  $S_8$  in the liquid, while the ASTM D 1275-15 test showed a good response (Figure 5). Exclusion of oxygen was found to be very important to obtain silver sulfide deposition in the reaction of elemental sulfur with silver. Small oxygen ingress through the non-hermetic sealing lid of the vessel can lead to absence of silver sulfide formation (non-corrosive result), Figure 5.



**Results of Silver Corrosion Tests with Minute Concentrations of Elemental Sulfur in Synthetic Ester ( $S_8=0.53$  ppm), Left – DIN 51353 (EDX: S wt. %=0.09), Right – ASTM D 1275-15 (EDX: S wt. %=3.07)**

**Figure 5**

Conditions in which insulating liquids will create silver sulfide are dependent on the type of reactive sulfur compound, and the reaction rates can vary between oil types. Namely, liquids with elemental sulfur will require exclusion of oxygen by nitrogen purging, while liquids with disulfides will require higher oxygen contents. Increases in temperature and duration can be used to fine tune the method.

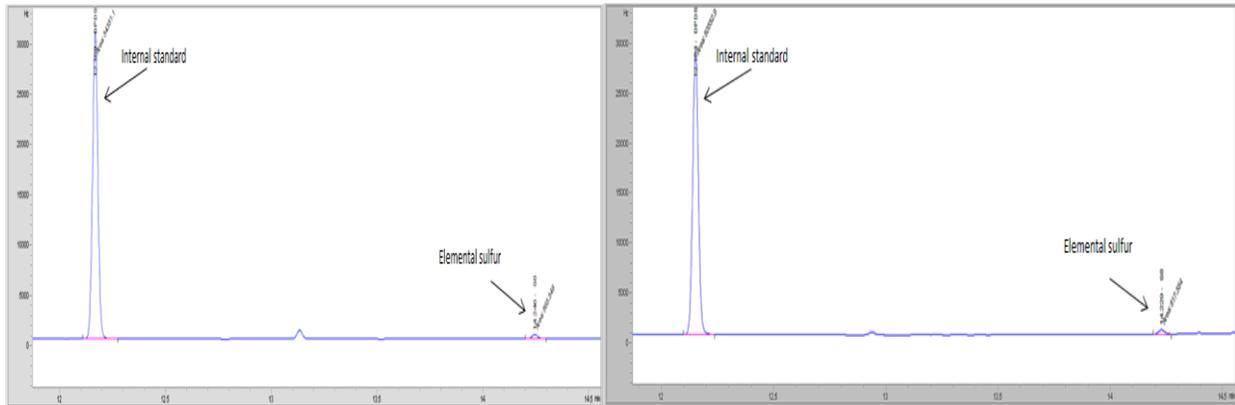
From experience, it was found that those mineral oils having sulfur contamination, usually contain higher concentrations of  $S_8$  than ester-based liquids, in the range of 2 to 12 ppm, while concentrations in synthetic esters are below 1 ppm. Nevertheless, minute concentrations in any of the insulating liquids have the capacity to deposit silver sulfide in low oxygen conditions, as shown in the test above. It was observed that the reaction of  $S_8$  with silver was to some extent faster in mineral oils than in synthetic esters. On the other hand, disulfides, to date have only been detected in mineral oils.

## Quantification of Elemental Sulfur

Owing to the fact that currently available standards can't adequately replicate service conditions and silver corrosion appearance in power transformers, it is essential to apply detection and quantification methods with low detection limits.

Elemental sulfur quantification can be effectively performed in mineral oils and synthetic esters using gas chromatography (GC) with a micro electron capture detector ( $\mu$ ECD).

This specific type of detector enables a very low limit of detection (LOD) and quantification (LOQ) of elemental sulfur. The LOD/LOQ of  $S_8$  in mineral oil is 0.07/0.24 ppm and in synthetic ester it is 0.05/0.18 ppm. The GC-ECD chromatograms of  $S_8$  in mineral oil and synthetic ester are shown in Figure 6.



**GC-ECD Chromatogram of 0.8 ppm of S8, in Mineral Oil – Left  
and in Synthetic Ester – Right  
Figure 6**

### Silver Sulfide Deposition Risk Assessment Guidelines

The order of reactivity of different sulfur species implies that elemental sulfur has the highest reactivity in both mineral and synthetic ester insulating liquids. It was observed that elemental sulfur can easily react at lower operating temperatures (from 40°C onwards) [1,2,5], while disulfides including DBDS require higher temperatures to start reacting (from 100°C onwards). Besides temperature as the main influential factor, low oxygen level was found to promote silver sulfide deposition from elemental sulfur, while higher oxygen content favored deposition of silver sulfide from DBDS. The difficulty is that there are no clear-cut conditions in real in-service operation that drive the reactions of silver sulfide deposition, unlike in laboratory testing, and moreover the effect of electrical stresses in service cannot be simulated in the laboratory.

Minute concentrations of elemental sulfur in both insulating liquids ( $\geq 0.3$  ppm) can cause significant silver sulfide deposition, owing to the high ratio of oil mass to the affected silver-plated surfaces immersed in the oil in a transformer's active part.

The addition of metal passivators based on benzo- or toly-triazole cannot prevent the risk of silver sulfide deposition, since those compounds were found to be ineffective to passivate silver [2-4]. Higher concentrations of reactive sulfur compounds in general increase the risk of higher silver sulfide deposition and silver sulfide multilayer formation, which can further increase the risk of power transformer failure, through electrical fault or flashover in the oil. However, the evaluation of the risk of silver sulfide deposition of oils in service can be jeopardized due to advanced sulfur compounds consumption and silver sulfide deposition.

### Mitigation

Experience gained from the last two decades at NTI showed the complexity of the sulfur corrosion phenomenon. This is related to the presence of different sulfur compounds with different reactivity to copper and silver, as well as to variable dissolution of sulfur from rubber and other materials of transformer construction in different liquids, and finally due to thermal and electrical stresses in the active part of a transformer during operation. Consequently, mitigation solutions may not fully solve the problem, or at least not a single solution will mitigate all aspects of the problem.

Oil replacement was always the first choice, simply from a lack of other solutions. However, oil replacement is usually more costly and always connected to the highest environmental burden, in terms of high carbon footprint. Compatibility with materials of transformer construction and residual oil corrosiveness may appear as a drawback.

Viable solutions to mitigate silver corrosion are narrowed to either oil change or oil treatment, since metal passivator addition is not an effective solution [1-4].

The NTI process developed for the removal of corrosive sulfur from mineral oils was successfully performed on oil containing high concentrations of S<sub>8</sub>, demonstrated on a pilot-scale and on-site treatment on a real power transformer [9]. The pilot scale design was found to be very efficient in estimating the real scale performance in terms of treatment time, i.e. number of oil circulations. High capacity of the adsorbent was verified in reaching almost the same end values below 1 ppm from 42 ppm of as well as from 17 ppm of S<sub>8</sub> initially [9]. Oils were non-corrosive after treatment. In the first case, a high concentration gradient as a driving force, played an important role in enabling exceptionally high conversion rates of S<sub>8</sub>. Results of mineral oil treatment containing 15.4 ppm of S<sub>8</sub> are shown in Table 2, together with oil properties. Oil was found to be corrosive to silver according to DIN 51353. This test is responding to S<sub>8</sub> very well in concentration ranges above 1 ppm. ASTM D1275 was not used in this earlier study provided in Table 2. Besides the complete removal of S<sub>8</sub>, oil properties were improved, while DBPC inhibitor content was just slightly decreased.

**Table 2**  
**Change in Oil Characteristics Pre- and Post-Treatment**

Characteristic	Pre-treatment	Post-treatment
S <sub>8</sub> content, ppm	15.4	0 (n.d.)
Dielectric dissipation factor (tg δ), ‰	11.4	2.9
Acid number (Nb), mgKOH/g	0.05	< 0.01
Oil-water interfacial tension (σ), mN/m	25	38
Specific electrical resistance ρ, GΩm	22	127.9
Content of DBPC (2,6-di-t-butylparacresol), %	0.25	0.21
Silver plate corrosion test according to DIN 51353	Corrosive	Non-corrosive

n.d. – not detected

The most recent research work related to the mitigation was dedicated to the removal of corrosive sulfur from synthetic ester liquid. Process was developed specifically for application on ester liquids which are behaving differently from mineral oils when subjected to reclamation and reconditioning process, in terms of corrosive sulphur removal efficiency and oil properties change, due to their different chemical composition. Laboratory scale synthetic ester liquid treatment was performed using innovative adsorbent material to investigate applicability and efficiency in the removal of elemental sulfur and improvement of the liquid properties. Samples of synthetic ester liquid were found to be corrosive in the ASTM D1275-15 silver strip test, which was used for the purpose of laboratory scale and pilot scale treatment. The innovative reclamation process with adsorbents was designed to perform efficient treatment of synthetic ester insulating liquids, remove elemental sulfur and improve insulating liquid properties. The results after both treatments showed that the elemental sulfur was removed efficiently from synthetic ester liquid, down to concentrations below 0.07 and 0.05 ppm (Table 3, Figure 7).

**Table 3**  
**Elemental Sulfur Content in the Synthetic Ester before and after Lab and Pilot Scale Treatment**

Content of S <sub>8</sub> , ppm	Before	After
Laboratory scale treatment	5.4	<0.07
Pilot scale treatment	0.50	<0.05



**ASTM D 1275-15 Silver Strip Test before – Left and after – Right,  
Pilot Scale Treatment of Synthetic Ester Oil  
Figure 7**

## CONCLUSIONS

Silver corrosion has been a serious problem for the reliable operation of power transformers. It was found to affect power transformers filled with mineral oils and synthetic ester insulating liquids. Besides DBDS as a well-known corrosive sulfur compound from the past decade, nowadays elemental sulfur was found to be more widespread and present in both types of insulating liquids. It has a high reactivity to silver and can create silver sulfide deposits at low temperatures, even if present in minute concentrations (below 1 ppm). This is due to the fast reaction kinetics and high ratio of oil mass to the surface of silver-plated contacts. Currently available test methods to determine oil corrosiveness to silver are not adequate, since they often provide false negative results, such as DIN 51353 failing to recognize DBDS in mineral oils and  $S_8$  in synthetic ester liquids, whereas the same liquids cause corrosion of silver-plated contacts as found in the course of power transformer inspection or failure investigation. To obtain adequate silver sulfide deposition risk assessment, existing test methods need to be revised and new methods for silver corrosion introduced. Another very important step is the development of mitigation solutions for this emerging problem. As of today, oil replacement is the only available solution. NTI innovative oil treatment processes were found to be highly efficient in the removal of elemental sulfur from mineral oils and synthetic ester insulating liquids, as demonstrated by the results on laboratory and pilot scale systems shown in this paper.

## ACKNOWLEDGEMENTS

This research was supported by the Science Fund of the Republic of Serbia, GRANT No. 6700, Development of green technology to mitigate power transformer failures induced by elemental sulfur and change current hazardous practice in transformer oil regeneration – GreenCleanS.

## REFERENCES

- [1] J. Lukic, M. Foata et al, "Sulfur Corrosion Mitigation in Power Transformer Life Extension," presented at the CIGRE Workspot IX, Brazil, 2018.
- [2] Jelena Lukic, Jelena Jankovic, Dejan Kolarski, Draginja Mihajlovic, Sandra Glisic, Aleksandar Orlovic, "Silver Corrosion Testing and Mitigation," D1 - Materials and emerging test techniques, PS2 - Materials for Electrotechnical Technical Purposes and Modelling, Paper ID\_10893, CIGRE Paris Session 2024.
- [3] J.Jankovic, J.Lukic, D.Mihajlovic, M.Foata, B.Myburgh, "Development of a New Method for the Assessment of Mineral Insulating Oil Corrosivity Against Silver," accepted for publication in IEEE Transactions on Dielectrics and Electrical Insulation, DOI: 10.1109/TDEI.2024.3382641, 2024 (ISSN: 1070-9878).
- [4] CIGRE Technical Brochure 625, "Copper Sulfide Long-Term Mitigation and Risk Assessment," 2015.
- [5] M. Foata, K.H. Lindl, M. Da Costa, J. Lukic, J. Jankovic, D. Mihajlovic, "Risk Assessment and Mitigation of Corrosive Sulfur Other Than DBDS," Presented at the Cigre Workspot X, Brazil, 2022.

- [6] A.F. Holt, M. Facciotti, P. Amaro, R.C.D. Brown, P.L. Lewin, J.A. Pilgrim, G. Wilson and P. Jarman, "An Initial study into Silver Corrosion in Transformers Following Oil Reclamation," in Proceedings of the 2013 IEEE Electrical Insulation Conference (EIC), Ottawa, Canada, August 29th, 2013; pp. 469–472.
- [7] S. Samarasinghe, H. Ma, D. Martin, and T. Saha, "Investigations of Silver Sulfide Formation on Transformer OLTC Tap Selectors and its Influence on Oil Properties," IEEE Trans. Dielectr. Electr. Insul., vol. 26, no. 6, pp. 1926–1934, Dec. 2019.
- [8] S.Samarasinghe, C. Ekanayake, H. Ma, T. Saha, J. Baniya D.Allan and G.Russel, "A Risk Assessment for Utilities to Prevent Transformer OLTC Failures Caused by Silver Sulfide Corrosion," IEEE Trans. Power Del., vol. 37, no. 3, pp. 2394-2402, June 2022.
- [9] Jelena Jankovic, Jelena Lukic, Jelena Planojevic, Dejan Kolarski, Djordje Janackovic, "Application of Highly Selective Adsorbent in the Removal of Elemental Sulfur and other Corrosive Sulfur Compounds from Mineral Insulating Oils," IEEE Trans. Dielectr. Electr. Insul., vol. 29, no. 1, pp. 54-61, Feb. 2022. DOI: 10.1109/TDEI.2022.3148479,
- [10] Standard Test Method for Corrosive Sulfur in Electrical Insulating Liquids, ASTM Standard D1275-15, 2015.
- [11] Testing of Insulating Oils – Detection of Corrosive Sulfur, Silver Strip Test, DIN Standard 51353, December 1985.

## BIOGRAPHY



Jelena Lukic, PhD in Chemical Engineering, has been working in the field of power transformers paper/oil insulation testing, condition and risk assessment and development of mitigation techniques in the domain of corrosive sulfur removal, PCB decontamination and aged oils reclamation. She holds three patents, published more than 80 papers, among them, 9 peer review papers in scientific journals and 10 papers as an invited lecturer at international conferences worldwide. Jelena is a delegate of the Serbian National Committee in International Electrotechnical Committee Technical Committee 10 (IEC TC 10) – Liquids for Electrotechnical Applications,

member of advisory groups of CIGRE SC A2- Power Transformers AG 2.4 and SC D1- Material and emerging testing techniques AG D1.01. She has been a member of more than 30 CIGRE and IEC TC 10 working groups and a convener of CIGRE WGs: A2.40: "Copper sulfide long-term mitigation and risk assessment" (2015-2019), currently ongoing CIGRE D1.76: "Tests for verification of quality and ageing performance of cellulose insulation for power transformers" (2021-2024) and CIGRE SC A2.02 TF on silver corrosion (2024-2025). In 2024 she was selected as a distinguished member of CIGRE.



Jelena Jankovic has a PhD in Chemical Engineering and is the Head of specialized laboratory for insulating oil and paper testing accredited according to ISO 17025. Her main fields of work and expertise are insulating oil and paper analysis, power transformers condition and risk assessment, and research activities related to oil re-refining, removal of corrosive sulfur compounds and ageing products from the insulating liquids. She published more than 50 papers in international and domestic journals and conferences. She is the

co-author of the National registered patent 2019, for removal of sulfur compounds corrosive to silver from mineral transformer oils. Jelena Jankovic is a member of IEC TC 10 MT 43 for Revision of IEC 60666 - Detection and determination of specified additives in mineral insulating oils and CIGRE SC A2.02 TF on silver corrosion. She is a member of Serbian National Committee CIGRE SC A2 – Transformers and a member of Technical Committee KS N010 - Liquids for electrotechnical applications of Institute for Standardization of Serbia.



Valentina Vasovic is a Senior Associate in Laboratory for insulating oil and paper testing of the Nikola Tesla Institute of Electrical Engineering, Belgrade, Serbia. She earned Ph.D. degree in chemical engineering from the Faculty of Technology and Metallurgy, University of Belgrade, Serbia. Her main fields of expertise are insulating oil and paper analyses, power transformers condition assessment, water distribution phenomena in the oil/cellulose insulation, thermal parameters and aging process of insulation system of power transformers, risk assessment related to power transformer insulation ageing and applicability of alternative liquids in power transformers. She is a member of currently ongoing CIGRE WG D1.76 and CIGRE JWG D1/A2.80, and member of Serbian National Committee CIGRE SC A2 as well as Technical Committees N010 and N015 of the Serbian Institute for Standardization.



As a student in the final year of his Bachelor's Degree at the Faculty of Technology and Metallurgy, Department of Organic Chemical Technology, University of Belgrade, Mr. Kolarski was admitted to a professional internship at the Nikola Tesla Institute of Electrical Engineering. After graduating in 2018, Mr. Kolarski started working at the Institute in the specialized laboratory for oil and paper insulation testing, accredited according to ISO 17025, and he has been working at the laboratory since. In September 2019, Dejan Kolarski defended his Master's thesis on the topic: "Modeling the kinetics of the process of adsorption of levulinic acid from insulating oil of different degrees of aging using natural adsorbents." In November 2019, Mr. Kolarski enrolled in doctoral academic studies at the University of Belgrade, Faculty of Technology and Metallurgy, Department of Chemical Engineering. His research area is the desulfurization of corrosive insulating oil. Dejan has been the author and co-author of several published scientific papers and he is the author of the invention for which a patent application was submitted in 2023 under the title 'Process for desulfurization,' registered under the number П-2023/0532.