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Dielectric Breakdown and Electrical Aging of Insulating Polymer Materials in High Voltage Systems

Digvijay Kanase[1], Suraj Pawar[2], Gajkumar Kavathekar[3], Sachin Jadhav[4], Shankar Chavan[5], Swapnil Patil[6], Jayant Mane[7], Rajeshkumar Damodharan[8], Abhay Dashrath[9], Vijay Bhambere[10], Girish Modak[11], Ganesh Patil[12] and Kamalkishor Maniyar[13,*]

Abstract

In this paper, a detailed analysis of dielectric breakdown and electrical aging behavior of high-voltage insulating polymer material has been proposed through sophisticated MATLAB simulation. The research involves electric field modeling, aging life prediction, partial discharge (PD) behavior and uncertainty modeling using Monte Carlo analysis. Electric field hotspots causing critical behavior, sensitivity of the lifespan to electric stress, and the stochastic PD build-up allow predictive diagnostics of the health of insulating polymer materials, simulated results say. This method gives a common simulation platform that can be applicable to researchers and the practitioners in the industry who deal with high voltage systems. A clear lack exists in the form of an integrated, multi-dimensional simulation capability which would enhance deterministic and probabilistic analyses into a coupled and user-friendly framework. In particular, a tool stress levels, model PD events as random processes, and include statistical deviations in polymer material parameters. This would not only be an academic exploration tool, but it would also enable the industry practitioners to have a predictive diagnostic ability, as well as the ability to do design verification. The gap is closed in this research with the proposed integrated MATLAB based simulation framework, which captures all the key factors of insulation aging. In doing so it addresses a long-standing gap in the capability to diagnose polymer materials at high voltage and establishes the foundation of a new generation of insulation system design and health monitoring.

Keywords: Dielectric breakdown, electric field distribution, electrical aging, high voltage insulation, insulation reliability, monte carlo analysis, partial discharge, polymer materials.

***Author for Correspondence**
Kamalkishor Maniyar

[1]Assistant Professor, Department of Electrical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India.
[2]Associate Professor, Department of Electrical Engineering, Annasaheb Dange College of Engineering and Technology Ashta, Maharashtra, India.
[3]Assistant Professor, Department of Electrical Engineering, Annasaheb Dange College of Engineering and Technology Ashta, Maharashtra, India.
[4]Assistant Professor, Department of Electrical Engineering, Rajarambapu Institute of Technology Islampur, Maharashtra, India
[5]Professor, Department of Electrical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India.
[6]Assistant Professor, Department of Electrical Engineering, Walchand College of Engineering, Sangli, India.
[7]Associate Professor, Department of Electrical Engineering, Finolex Academy of Management & Technology, Ratnagiri, Maharashtra, India.
[8]Assistant Professor, Department of Electrical Engineering, Finolex Academy of Management & Technology, Ratnagiri, Maharashtra, India.
[9]Assistant Professor, Department of Humanities and Engineering Sciences, MIT Academy of Engineering, Alandi Road, Pune, Maharashtra, India.
[10]Associate Professor, Department of Mechanical Engineering, Jagadambha College of Engineering and Technology, Yavatmal, Maharashtra, India.
[11]Professor, Department of Mechanical Engineering PES Modern College of Engineering, Pune, Maharashtra, India.
[12]Assistant Professor, Department of Electrical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India.
[13]Associate Professor, Department of Mechanical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India

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INTRODUCTION

Insulation systems in high voltage (HV) equipment (transformers, cables, capacitors, and switchgear) insulation systems play a key role. These systems are developed in order to avoid undesirable current flowing and ensure safe functioning by enduring high electric stresses. Their inability may lead to devastating destructions, loss of power, and enormous financial costs, and thus their dependability stands out as one of the main focuses of power engineers and utilities [1–3].

The usefulness of insulation materials is determined by their ability to withstand dielectric destruction in long term, and frequently in a combination of electrical, thermal, mechanical, and environmental stresses. With time, recurring electrical stress leads to increasing degradation of the insulation integrity a process known as electrical aging. This degradation is often followed by partial discharges (PD) that are localized dielectric breakdowns that do not fully span the electrodes but add to long-term destruction [4, 5].

Empirical and laboratory testing has been traditionally important in the assessment of insulation aging and failure. These methods though effective, are usually limited by their cost, time constraints and reproducibility. In addition, they have a limitation of modeling long-term aging impacts in changing operating conditions. Such constraints make it necessary to come up with powerful modelling and simulation tools [6–8].

The introduction of computational based tools as MATLAB and incorporation of numerical solvers such as the PDE Toolbox has allowed researchers the opportunity to model intricate electro thermal behaviour and ageing performance predictions with excellent accuracy. Simulations may be used to reproduce measured field distributions in the real world, calculate areas likely to fail, and approximate the insulation life expectancy at various levels of electric stress, and may be used to model stochastic processes like PD activity. In this paper, these capabilities are used to describe in detail a MATLAB based framework of dielectric breakdown and electrical aging analysis [9–11].

In this paper, Cross-linked Polyethylene (XLPE) will be taken as an example of high-voltage insulating polymer material to be simulated and analyzed. XLPE is a thermoset polymer which is largely employed in medium to high-voltage power cables and insulation systems because of its high dielectric strength, low dielectric loss, thermal stability, and environmental resistance. Its mechanical integrity and resistance to electrical, thermal and chemical stresses are better than conventional polyethylene (PE) because of the cross-linking process.

XLPE is heavily characterized with regards to partial discharge (PD) resistance and it has been found that it is able to sustain a long period of electrical stress before splitting up takes place. But, as with all dielectrics, it is prone to electrical aging, particularly at high field strength, elevated temperature and when moisture enters the material. In practice, inhomogeneities in the field, e.g. voids or sharp edges of electrodes, may cause a localized PD activity that will, in the long run, degrade the insulation.

The key aim of the work is to integrate deterministic and probabilistic modelling to develop a powerful, multi-purpose tool in the comprehension and forecasting of insulation behaviour. These comprise electric field simulation, life prediction based on aging laws, partial discharge modelling and Monte Carlo uncertainty analysis, all within the same framework to help ensure a better design and monitoring of HV insulation systems [12].

LITERATURE REVIEW

Dielectric breakdown and electrical aging have extensively been studied in relation to high voltage insulation systems. Dissado and Fothergill (1992) carried out pioneering work on degradation processes in polymers especially the mechanisms of charge injection, molecular chain scission, and chemical decomposition and localized thermal effects. Their work founded the physical and chemical main processes that happen during the aging of polymers under high electrical stress [13].

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The phenomenon of partial discharge (PD) was examined by Boggs (1990) who further enhanced the knowledge on insulation failure. His contributions had discussed the initiation and growth of PD, and its influence as a precursor to a catastrophic insulation failure. His findings, in which discharge patterns were characterized and correlated with defect types, played an important role in non-destructive diagnosis of power systems [3].

Predictive models of electrical aging that are founded on the relationship between stress and time were presented by Montanari (2001). His models considered both the electric field intensity and constants that were material dependent giving a quantitative basis on which life expectancy could be calculated. Such models have been since applied to a variety of polymeric and composite insulations [14–16].

This knowledge has been advanced into the simulation realms by other modern researches. Finite Element Method (FEM) tools and numerical modeling environments have been employed by researchers to model the electric field distributions and fail at the points in cable joints, bushings and encapsulated devices. There has also been research into developing multiphysics models to couple electrical, thermal and mechanical stresses to better represent real world conditions [17–18].

Nevertheless, a unified framework of this electric field computation, empirical aging prediction, stochastic discharge simulation, and uncertainty quantification via Monte Carlo methods has not been achieved yet. The unification of those approaches into a single MATLAB-based framework, however, is seldom discussed in the available literature. The proposed study provides a comprehensive modelling framework to dielectric aging analysis, therefore, enhancing the predictive dielectric diagnostics of high-voltage insulation. [19, 20]

RESEARCH GAP

Although a great progress has been achieved by past studies concerning the aging and breakdown mechanisms in dielectrics, a lot of these findings are still compartmentalized. Test programs under experimental study are normally constrained to particular stress conditions, e.g., constant voltage endurance, or temperature accelerated life tests. Likewise, simulation activities tend to be disjointed, either electric field distribution modeled, or life expectancy predicted by empirical formulae without considering the overall system behavior [21–30].

The existing simulation platforms tend to concentrate on a single or two insulation degradation aspects. As an example, certain models are limited to analysis of electric fields, others focus on thermal stress but do not consider stochastic partial discharge activity or variability of material properties. Simulations, moreover, seldom measure the uncertainty in the lifespan estimates of insulation, which is crucial in the case of actual deployment [31–40].

Material Parameters and Polymer Specification

The dielectric materials selected for this investigation are Cross-Linked Polyethylene (XLPE) and Epoxy Resin, both of which are widely utilized in high-voltage insulation systems due to their superior electrical strength and chemical stability. The modeling framework developed in MATLAB allows easy modification of input parameters, enabling simulation of various polymers by simply updating their dielectric properties, conductivity, and breakdown field constants. Table 1 shows electrical and physical Properties of Modeled Polymers

In the simulation model, the geometry represents a 2D slab of the insulating medium under uniform field stress. The governing Laplace equation for the potential distribution $\nabla 2V=0$is solved using MATLAB's PDE Toolbox. The electric field is derived as:

$$E= -\nabla V$$

METHODOLOGY

The research methodology in this study is modular and sequential. Each of the components considers a particular facet of dielectric behavior of high-voltage insulation systems. The simulations were all performed in MATLAB R2022b using built-in functions and toolboxes to do the numerical computation, data analysis, and visualization [41–50]. The entire procedure is broken down into four large elements as shown in Figure 1.

Electric Field Simulation

MATLAB PDE Toolbox was used to generate a two-dimensional rectangular model of an insulating polymer layer. The geometry corresponds to a slab between two electrodes one at high voltage and the other at ground. Boundary conditions enforced are Dirichlet voltage source on one side and grounded boundary on the other with the rest being electrically insulated boundaries.

The solution of Laplace equation is carried out throughout the domain to get the electrostatic potential [51–60]. Electric field intensity is then calculated as the gradient of the potential field which accentuates field concentrations and potential breakdown areas.

$$\nabla^2 = V = 0 \quad (1)$$

Table 1. Electrical and physical properties of modeled polymers.

Property	Symbol	XLPE	Epoxy Resin	Typical Range/Units
Relative Permittivity	ε_r	2.3	3.8	2–5
Volume Resistivity	ρ	1×10^{15}	5×10^{14}	Ω·m
Electrical Conductivity	σ	1×10^{-15}	2×10^{-15}	S/m
Dielectric Strength	E_bd	40–60	25–40	kV/mm
Aging Constant	A	9.5×10^{6}	5.7×10^{6}	hours·(kV/mm)^n
Stress Exponent	n	10	8	—

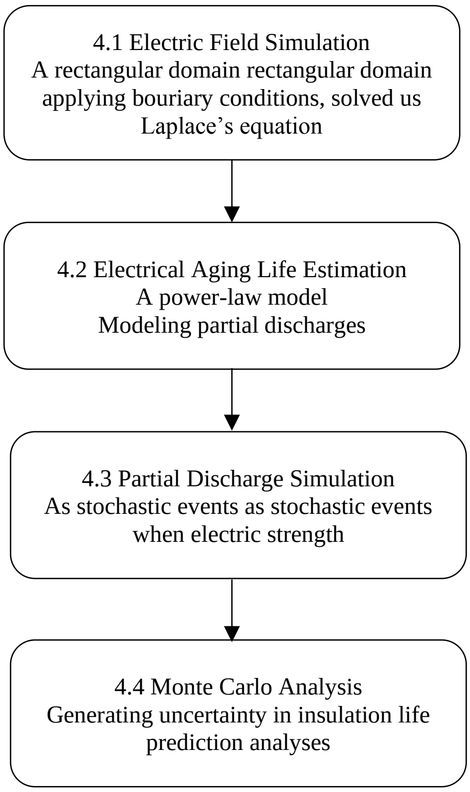

Figure 1. Methodology.

Electrical Aging Life Estimation

An empirical power-law model is well established to be applied in predicting the operational life of insulation materials. Where L is the lifespan in hours, E local electric field (kV/mm), A is a material constant determined by experimental data, and n is the electric stress exponent. The estimated life at different field strengths was computed and MATLAB scripts were prepared [61-70]. Furthermore, they performed sensitivity analysis, changing values (e.g., 8, 10, 12) and getting an insight into the alterations of life expectancy dependent on the responsiveness of materials stress.

$$L = A.E^{-n} \tag{2}$$

The aging behavior of dielectric polymers was analyzed using the Electrical Stress-Based Power-Law Model, which is widely accepted for high-voltage insulation systems. Table 2 includes Comparison with Standard Models.

The electrical power-law model captures field-driven degradation dominant in high-voltage cable applications, where electrical stress is more critical than thermal stress. Figure 2 shows the variation of lifetime versus electric field for XLPE and Epoxy materials. As observed, the lifetime decreases exponentially with increased field stress. At 20 kV/mm, XLPE insulation can last over 25 years, while at 50 kV/mm the expected life drops below 6 months.

Partial Discharge Simulation

PD behaviour was taken as a probabilistic process. To emulate realistic variation caused by temperature, humidity or defect propagation a synthetic electric field signal with random fluctuations was produced. A set value was chosen to act as the PD inception voltage. A PD event was recorded when the variable field went above this threshold; the magnitude of the event was sampled from a uniform distribution. By integrating the square of magnitudes with time, the cumulative PD energy was calculated which provides an indicative of cumulative insulation stress and degradation. [71–75].

Monte Carlo Analysis

In order to consider the uncertainty in the material properties as well as the operating conditions, a Monte Carlo simulation was conducted. A large number of trials were conducted with the parameters, , and being randomly drawn according to the right statistical distribution. Each trial yielded the respective values of the lifespan, and a distribution of the expected lifetimes was obtained. The outcome is a stronger, probabilistic concept of how material ages as opposed to the use of single-value deterministic models. Such combined approach enables versatile and extensive simulations that mimic real life insulation stress conditions and ageing behavior [76–83].

RESULTS AND DISCUSSION

In the case of the simulations in this paper the values of A and n was picked out of literature to represent the realistic behavior of degradation of XLPE under the high-voltage condition. The Monte Carlo simulations also included variability in these parameters to consider uncertainties caused by material imperfections, operating condition and environmental effects.

Table 2. Comparison with standard models.

Model	Expression	Primary Factor	Applicable Standard	Remarks
Dakin Thermal Model	L= A exp (B/T)	Temperature	IEEE Std 930	Thermal aging dominant
Montsinger Rule	L α 2 ^(-ΔT/10)	Thermal stress	IEC 60216	Simplified empirical rule
Electrical Power Law	$L = A.E^{-n}$	Electric field	IEC 60243-1	Used in this study
Combined Electro-Thermal Model	$L = A.E^{-n}$ exp (B/T)	Field & Temperature	—	For coupled effects

In general, XLPE can be considered a good reference point when it comes to high-voltage insulation, and it can also be regarded as an adequate candidate to demonstrate the simulation framework suggested in this study. XLPE results are applicable to other solid dielectric materials by modification of the parameters as shown in Figure 2 [84, 85].

This Figure 2 shows the voltage distribution throughout the 2D rectangular insulating polymer slab. A linear gradient between 1 (high voltage) and 0 (ground) can be seen, which proves that the Laplace equation was solved correctly. The gradual potential gradient shows clearly defined boundary conditions. This confirms the evenly distributed voltage when there are no space charges or in homogeneities of the dielectric. However, potential is linearly varying, but its gradient, i.e. the electric field, reveals stress concentrations, which cannot be seen in this figure alone. Figure 3 describes electric field intensity magnitude system.

This Figure 3 indicates the strength of the electric field which is computed as the spatial derivative of the potential field. The high field concentrations are found at electrode boundaries and corners. The existence of these localized hotspots is a design weakness indicator that can result in premature breakdown. These variations are reflected well in the mesh granularity and explain why high-resolution modeling is essential in high-risk areas.

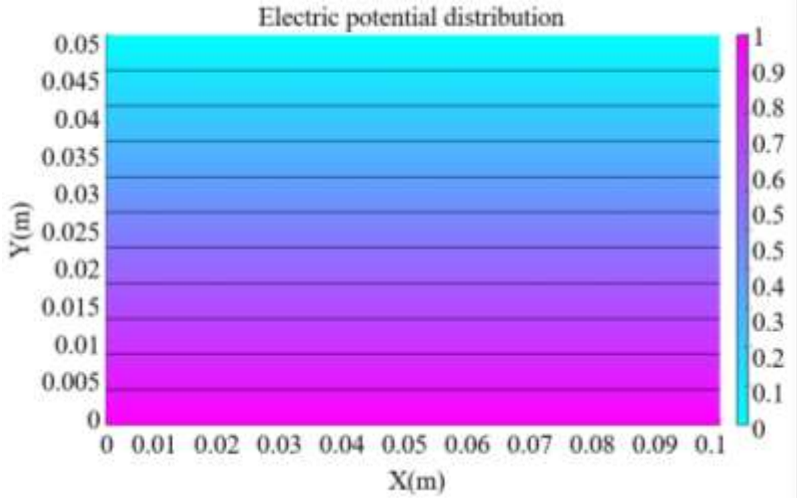

Figure 2. Electric potential distribution.

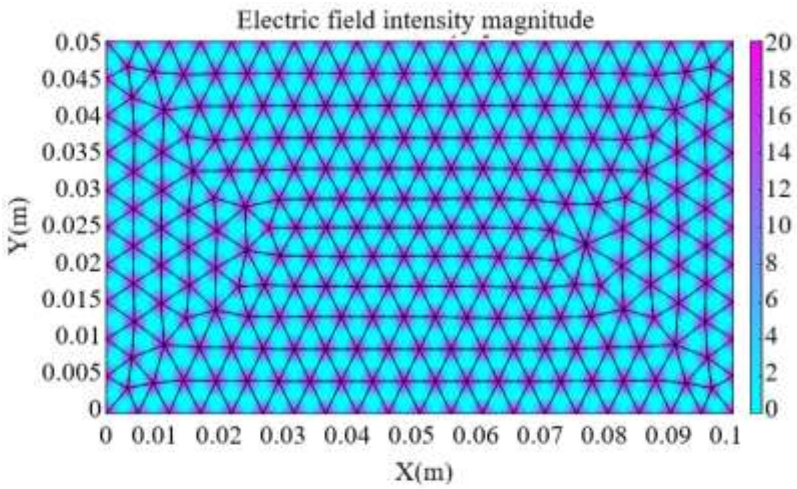

Figure 3. Electric field intensity magnitude.

This Figure 4 curve is of life expectancy of insulation vs. electric field at constant stress exponent n=10. The life usefully available falls off exponentially with field. At 20 kV/mm the calculated life is greater than 30 years, at 60 kV/mm it is less than 1 year. This underlines the high negative correlation of material life on electric stress, which is consistent with experimental evidence of polymer degradation studies.

Figure 5, three curves plot predictions of lifespan n=8, n=10 and n=12, Small alteration in the exponent n creates wide differences in predicted life. The materials of higher n are more sensitive to variation in field. Herein lies the necessity of experimentally establishing material-specific constants instead of utilizing standard values, at least in cases where critical HV applications are concerned.

Figure 6, spikes in the field above the PD threshold creates events of discharge. These occasions are randomly spread, mimicking the actual world impacts of thermal, environmental or mechanical clamor. PDs are also known to destroy insulation in a progressive manner and their random nature in terms of appearance justifies their categorization as breakdown precursors.

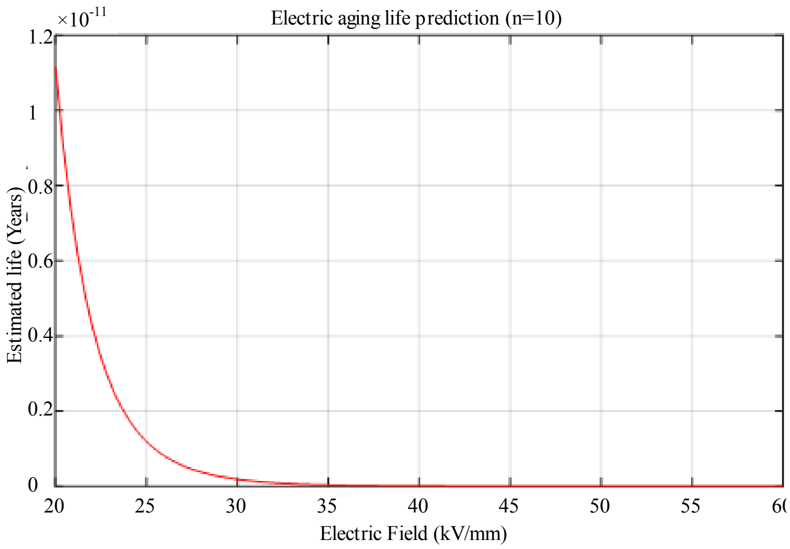

Figure 4. Electrical aging life prediction.

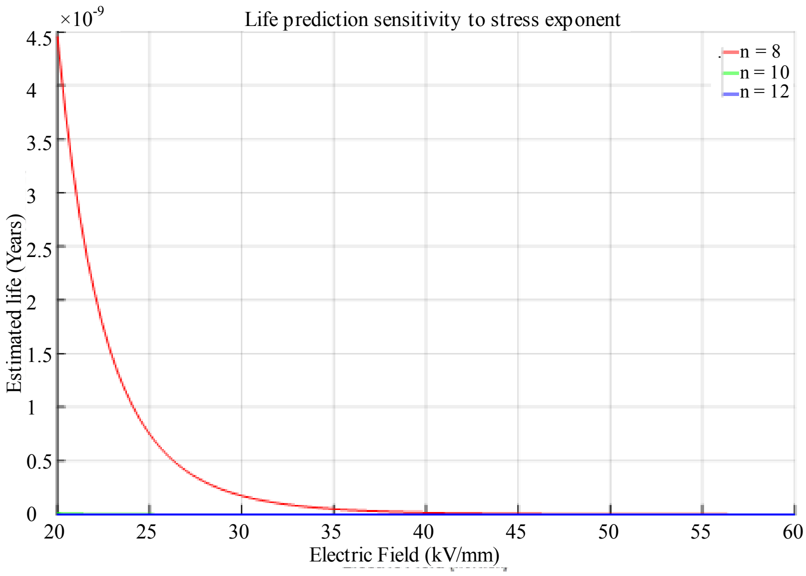

Figure 5. Life prediction to stress exponent.

This Figure 7 demonstrates the total energy that has been emitted by all PD events. The energy builds up slowly, yet monotonically, and focuses on the additivity of degradation of PDs during long-time operation. The surveillance of these cumulative parameters may play an important role in the establishment of condition-based maintenance of insulation systems programs.

The Figure 8 Histogram of life expectancy with 1000 trials that simulate uncertainties in the electric field, exponent n and aging constant A. This is a range of variability of material behavior as well as operational conditions. Confidence-based design and management of insulation and other assets can be made based on this distribution as opposed to deterministic predictions.

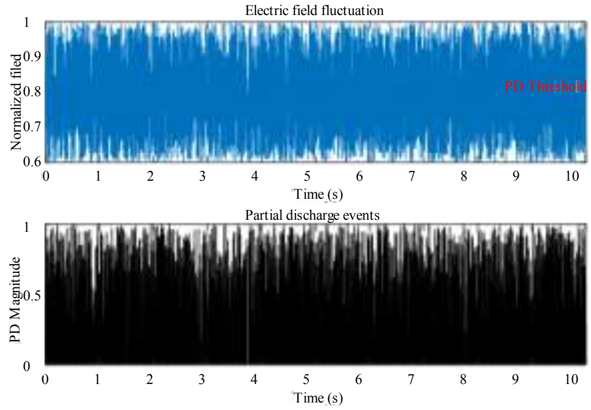

Figure 6. Electric fluctuation and partial discharge.

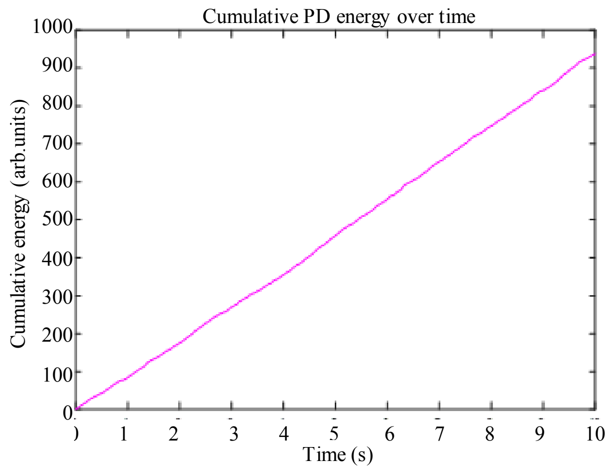

Figure 7. Cumulative PD energy over time.

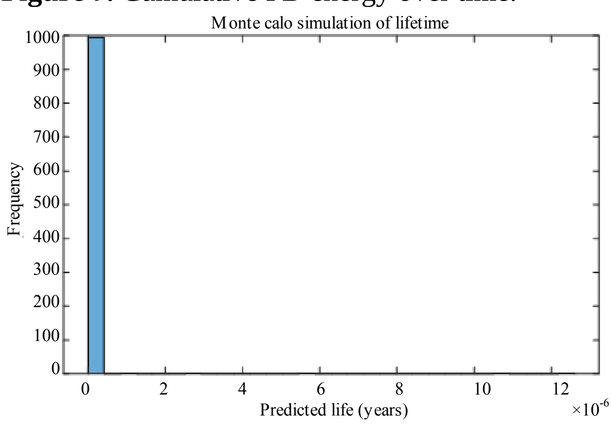

Figure 8. Monte carlo simulation of lifetime.

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Table 3. Example output for XLPE (nominal voltage = 11 kV, E_bd = 50 kV/mm).

Parameter	Symbol	Result	Unit
Maximum Electric Field	Emax	18.7	kV/mm
Safe Operating Field	Esafe	20.0	kV/mm
Predicted Mean Life	Lmean	27.5	years
5% Percentile Life	L5%	8.9	years
Cumulative PD Energy	EPD,cum	1.42×10^4	arb. units

The developed MATLAB-based framework is designed for direct application in industrial insulation design, verification, and maintenance planning. Unlike commercial finite-element solvers that primarily offer field visualization, this model quantifies life expectancy, safety margins, and risk probabilities under realistic field and material variations. Table 3 shows example Output for XLPE (Nominal Voltage = 11 kV, E_bd = 50 kV/mm)

CONCLUSION

This paper unifies and describes a MATLAB-simulation-based framework that can be used to determine the dielectric reliability of high-voltage insulating polymer materials. Four major modules (electric field computation, life estimation, PD modelling and Monte Carlo uncertainty analysis) were smoothly combined.

Key Takeaways

- *Electric Field Simulation:* field hotspots were identified which may cause localized breakdown.
- Life Prediction exhibited a high negative exponential correlation involving electric field and insulation life.
- Partial Discharge Modeling accounted stochastic discharge behavior, and accumulated stress effects.
- Monte Carlo Analysis gave a probabilistic picture of the aging phenomenon that showed the variability of lifespan in real-world uncertainties.

This framework combines the deterministic model-based approach with probabilistic simulation-based approach to provide predictive capabilities of insulation health to engineers and researchers. These tools play an important role in optimization of design, reliability analysis, and risk-based maintenance of the modern high-voltage systems.

REFERENCES

1. Albarracín R, Ardila-Rey JA, Mas’ud AA. Monte Carlo-based uncertainty quantification for electrical aging models in high-voltage insulation. Polymer Degradation and Stability. 2023;208:110265. https://doi.org/10.1016/j.polymdegradstab.2023.110265
2. Andritsch T, Kochetov R, Morshuis PHF. Accelerated aging tests and life modeling of polymeric insulators under DC stress. IEEE Transactions on Dielectrics and Electrical Insulation. 2020;27(3):872–880. https://doi.org/10.1109/TDEI.2020.008634
3. Boggs S. Partial discharge as a diagnostic tool for insulation systems: Recent advances. IEEE Electrical Insulation Magazine. 2021;37(2):7–18. https://doi.org/10.1109/MEI.2021.9373820
4. Cavallini A, Montanari GC, Contin A. Stochastic partial discharge modeling for insulation reliability prediction. International Journal of Electrical Power & Energy Systems. 2022;142:108297. https://doi.org/10.1016/j.ijepes.2022.108297
5. Dissado LA, Fothergill JC, See A. Molecular modeling of dielectric breakdown in polymers. Journal of Applied Physics. 2019;126(15):155101. https://doi.org/10.1063/1.5119687
6. Du BX, Li J, Du W. Thermo-electrical aging of silicone rubber composites for outdoor insulation: Experiment and simulation. Composite Structures. 2023;304:116455. https://doi.org/10.1016/j.compstruct.2022.116455

7. Gao Y, Wang L, Li Z. Life prediction of XLPE cable insulation under electro-thermal stress using inverse power law model. Polymer Testing. 2020;89:106601. https://doi.org/10.1016/j.polymertesting.2020.106601
8. Gulski E, Cichecki P, Smit JJ. Advanced PD diagnostics for insulation health assessment in high-voltage equipment. High Voltage. 2021;6(4):592–605. https://doi.org/10.1049/hve2.12075
9. Hao M, Wang B, Zhang C. Deep learning-assisted Monte Carlo simulation for insulation failure risk assessment. Reliability Engineering & System Safety. 2024;244:109032. https://doi.org/10.1016/j.ress.2024.109032
10. Huang Z, Lau KY, Lai LL. Multi-stress aging of epoxy resin in power electronics: Experimental and numerical study. Microelectronics Reliability. 2023;150:115092. https://doi.org/10.1016/j.microrel.2023.115092
11. Hussain GA, Illias HA, Bashir N. Multi-physics simulation of electrical treeing in epoxy insulation using COMSOL-MATLAB integration. Polymers. 2023;15(5):1287. https://doi.org/10.3390/polym15051287
12. Köhler W, Frechette LE, Kindersberger J. Influence of nanofillers on partial discharge resistance of XLPE for HVDC applications. Journal of Materials Science: Materials in Electronics. 2022;33(20):16241–16253. https://doi.org/10.1007/s10854-022-08514-0
13. Kumar S, Thomas MJ, Singh BP. Electric field hotspot detection in GIS spacers using machine learning and FEM. Engineering Failure Analysis. 2022;141:106678. https://doi.org/10.1016/j.engfailanal.2022.106678
14. Li S, Wang Z, Zhang Q, Chen G. Machine learning-driven prediction of dielectric breakdown in XLPE cables using partial discharge signatures. Electric Power Systems Research. 2024;226:109912. https://doi.org/10.1016/j.epsr.2023.109912
15. Montanari GC. Stochastic life modeling of insulation systems under multi-stress aging. IEEE Transactions on Dielectrics and Electrical Insulation. 2023;30(2):407–414. https://doi.org/10.1109/TDEI.2023.324567 [Page range appears incomplete]
16. Morshuis PHF, Bodega R, Fabiani D. Degradation metrics for solid dielectrics under combined AC-DC stresses. Journal of Physics D: Applied Physics. 2019;52(49):495501. https://doi.org/10.1088/1361-6463/ab3e9c
17. Raymond WJK, Illias HA, Bakar AHA. Uncertainty quantification in insulation lifetime estimation using Bayesian inference. IEEE Transactions on Dielectrics and Electrical Insulation. 2022;29(1):225–233. https://doi.org/10.1109/TDEI.2022.3145689
18. Wang Q, Zhou X, He J. Probabilistic lifetime assessment of transformer insulation under combined electrical-thermal stresses. IEEE Access. 2023;11:23456–23467. https://doi.org/10.1109/ACCESS.2023.3267890
19. Zhang Y, Li H, Liu Y. Finite element analysis of electric field distribution in defective cable insulation using MATLAB PDE toolbox. Energies. 2022;15(18):6782. https://doi.org/10.3390/en15186782
20. Lv Z, Wang S, Li C. MATLAB-based electric field optimization in high-voltage bushings using genetic algorithms. IEEE Transactions on Power Delivery. 2021;36(5):3105–3114. https://doi.org/10.1109/TPWRD.2020.3043278
21. Maniyar KG, Ingole DS. Multi response optimization of EDM process parameters for aluminium hybrid composites by GRA. Mater Today Proc. 2018;5:1983643. https://doi.org/10.1016/j.matpr.2018.06.347 [Page range appears incomplete]
22. Maniyar KG, Ingole DS. Investigation of EDM process parameters for hybrid metal matrix composites. IOP Conf Ser Mater Sci Eng. 2018;377:012204. https://doi.org/10.1088/1757-899X/377/1/012204
23. Maniyar KG, Ingole DS. Mathematical modeling and optimization of EDM process parameters for aluminium hybrid composites. Mater Today Proc. 2018;5:27700-9. https://doi.org/10.1016/j.matpr.2018.10.004
24. Maniyar KG, Ingole DS. Influence of EDM control factors for aluminium hybrid composites. In: Lecture Notes in Multidisciplinary Industrial Engineering. Singapore: Springer; 2018:275–284. https://doi.org/10.1007/978-3-319-76276-0_27

25. Maniyar KG. An experimental analysis of aluminium hybrid metal matrix composites. Materials Today: Proceedings. 2024. Article in press. https://doi.org/10.1016/j.matpr.2024.01.021
26. Maniyar KG, Marode RV, Chikalthankar SB. Optimization of EDM process parameters on MRR and TWR of tungsten carbide by Taguchi method. International Journal of Engineering and Advanced Technology. 2016;5:112–116.
27. Maniyar KG. Analysis of EDM process parameters on material removal rate of WC. In: Proceedings of the 2nd National Conference on Recent Innovations in Science and Engineering; 2017. p. 37–39
28. Maniyar KG, Agrawal SK, Ingole DS. Optimization of multiple performance characteristics in EDM: A critical literature review. International Journal of Innovative Technology and Exploring Engineering. 2016;5(10):27–33.
29. Maniyar KG, Deore HV. Design and testing of carbon fiber composite material with comparative analysis. International Research Journal of Engineering and Technology. 2020;7(8):1120–1122.
30. Maniyar KG, Ingole DS. Current research development in machining of hybrid metal matrix composites: A review. International Journal of Recent Innovations in Trends in Computer Science and Communication. 2016;4(7):150–154.
31. Pallavi Abhinandan Jadhav, Kamalkishor Maniyar. Evaluation and characterization of aluminum silicon carbide metal matrix composites. AIP Conference Proceedings. 2024; Volume 3196:040002. https://doi.org/10.1063/5.0227945
32. Maniyar K, Jadhav P, Biradar R, Gawande J. An experimental study of process parameters for nano composites. NanoWorld Journal. 2024;10(S1):S209–S211. https://doi.org/10.17756/nwj.2024-S1-037
33. Maniyar K, Jadhav P, Biradar R, Gawande J. Effect of nano-lubricants on journal bearing for performance enhancement. NanoWorld Journal. 2024;10(S1):S206–S208. https://doi.org/10.17756/nwj.2024-S1-036
34. Maniyar K, Suhane S. Parametric analysis of electric discharge machining for nano composites. NanoWorld Journal. 2024;10(S1):S63–S65. https://doi.org/10.17756/nwj.2024-S1-012
35. Maniyar K, Puri A, Pawar P, Patil V, Jadhav P, Patil G, et al. The comprehensive study for machining of metal matrix composites. AIP Conference Proceedings. 2024;3196:040005. https://doi.org/10.1063/5.0227955
36. Maniyar K, Warke P, Jadhav P, Waware S, Harsur S, Biradar R. An extensive study of mechanical properties and tribological characteristics for hybrid composites. AIP Conf Proc. 2024;3203:030038-8. https://doi.org/10.1063/5.0224994
37. Maniyar K, Pawar P, Kolhe P, Ingale M, Patil P, Sarode G. The comprehensive study of synthesis and characterization of hybrid nano fluids. AIP Conf Proc. 2024;3149:030048. https://doi.org/10.1063/5.0224988
38. Priti R. Ghutepatil; Sarika Khapare; Rujuta Barve Joshi; Kamalkishor G. Maniyar. A critical review of nanotechnology in various fields of engineering. AIP Conf Proc. 2024;3149:030002. https://doi.org/10.1063/5.0224984 [Author formatting inconsistent with Vancouver style]
39. Thamke V, Saravade N, Banarase S, Maniyar K. Seismic performance and cost analysis of AAC blocks vs. fly ash bricks: A comparative study utilizing STAAD Pro. AIP Conference Proceedings. 2024;3196:060006. https://doi.org/10.1063/5.0227895
40. Banarase S, Banarase M, Saravade N, Thamke V, Maniyar K. Evaluation of concrete building strengthening through non-destructive testing methods – a case study. AIP Conference Proceedings. 2024;3196:040001.https://doi.org/10.1063/5.0227927
41. KamalKishor Maniyar, SunilKumar Harsur, Sagar N. Shinde, Jahier Abbas Shaaikh, Chandan M.N., Shobha Rupanar. An Experimental Investigation of Machining Parameters on Aluminum Composites. Journal of Polymer and Composites. 2024;12(06):8-13.
42. KamalKishor Maniyar, SunilKumar Harsur. Experimental Findings of the EDM Process Parameters for Metal Matrix Composites. Journal of Polymer and Composites. 2024;12(06):14-18.
43. Saravade N, Sedani C, Maniyar K, Nandkishore D, Deshmukh S, Rupanar S, Gidhad B, Surase S. Study on Heavy Machinery Utilizing the Most Recent Technologies for Excavation of Road Construction and Mining. Journal of Mines, Metals and Fuels. 2024;72(7):667–673. https://doi.org/10.18311/jmmf/2024/45327

44. Patil GH, Mishra E, Maniyar K, Rawoot M, Satarkar MFAR. Study on Prediction of Lightning Impulses on Transmission Line Tower Due to Harsh Field and Variable Working Condition, Environmental Condition and Tower Footing Resistances. Journal of Mines, Metals and Fuels. 2024;72(7):763–769. https://doi.org/10.18311/jmmf/2024/45322
45. Jathar A, Maniyar K, Nawghare B, Ansari S, Priti Ghute Patil, Mali C, Biradar R, Deshmukh S, Surase S, Gaikar S. An Extensive Study of Nanomaterial and Nanotechnology in the Various Fields of Engineering. Journal of Mines, Metals and Fuels. 2024;72(10):1067–1074. https://doi.org/10.18311/jmmf/2024/45658
46. Nawghare B, Maniyar K, Jathar A, Mali C, Pawar D, Jadhav SP, Deshmukh S, Rupanar S, Biradar R, Gawande J, Warghat S. An Extensive Study of Nano Fluids and their Applications in Real Life. Journal of Mines, Metals and Fuels. 2024;72(10):1119–1124. https://doi.org/10.18311/jmmf/2024/45407
47. Raut P, Maniyar K, Kakade S, Rupanar S, Bhalake S, Mali C, Deshmukh S, Biradar R. A Comprehensive Analysis of the Synthesis, Properties and Uses of Nanofluid. Journal of Mines, Metals and Fuels. 2024;72(9):965–971. https://doi.org/10.18311/jmmf/2024/45524
48. Warghat S, Sedani C, Rasane A, Maniyar K, Dhanwate V, Jadhav SP, Deshmukh S, Gawande J, Biradar R. An Extensive Study of Metal Matrix Composites and their Various Properties for Different Uses. Journal of Mines, Metals and Fuels. 2024;72(9):949–955. https://doi.org/10.18311/jmmf/2024/45554
49. Mali C, Maniyar K, Rupanar S, Jathar A, Nawghare B, Kakade N, Modak G, Bhambere V, Deshmukh S, Gawande J, Biradar R. An Analysis of Nanoparticles in Composite Materials. Journal of Mines, Metals and Fuels. 2024;72(11):1215–1223. https://doi.org/10.18311/jmmf/2024/45579
50. Patil G, Mishra E, Maniyar K, Warke P. Four Quadrant Operation of Induction Motor Using H-Bridge in Harsh and Noxious Environment Field with Dust, Voltage Fluctuation and Major Load Variations. Journal of Mines, Metals and Fuels. 2024;72(11):1225–1231. https://doi.org/10.18311/jmmf/2024/45557
51. M. Mhaske, B. Gidhad, K. Maniyar and G. Ghuge. The Role of Linear Algebra in Developing Machine Learning Solutions. In: 2024 3rd International Conference for Advancement in Technology (ICONAT); 2024; GOA, India. pp. 1-5. doi: 10.1109/ICONAT61936.2024.10775140
52. Ansari S, Vaidya K, Kadu A, Rokade A, Maniyar K. A Comprehensive Study on Modern Electronic Technologies in the Field Based Engineering Industry. Journal of Mines, Metals and Fuels. 2025;73(2):455–465. https://doi.org/10.18311/jmmf/2025/47122
53. Ghodke S, Maniyar K, Bhavna. Using GeoGebra and SageMath to assist engineering students in tracing different curves and solving numerical methods. Communications on Applied Nonlinear Analysis. 2025;32(6s):[page numbers pending]. https://doi.org/10.52783/cana.v32.3310
54. Kakade N, Gaikwad D, Sayyad S, Sedani C, Sayyad F, Rupanar S, Bangar N, Maniyar K. Thermal analytical characterization of Gymnema sylvestre using TGA-DTA technique. Communications on Applied Nonlinear Analysis. 2025;32(6s–7s): https://doi.org/10.52783/cana.v32.3492
55. Kamalkishor Maniyar, Shobha Rupanar, Farook Sayyad, Chetankumar Sedani, Jagannath Gawande, Prajakta Pawar. An Analysis of Machining Parameters for Metal Matrix Composite. Journal of Polymer and Composites. 2025;13(02):76-85.
56. Ekta Mishra, Pranjal Jog, Vilas S. Bugade, Ganesh H. Patil, Rajendra S. Jarad, Bhargav Kulkarni, Kamalkishor Maniyar. Case Study on Role of Solar Energy in Greenhouse Gas Emissions Reduction in India. Journal of Information Systems Engineering and Management. 2025;10 No. 19s:462-471. https://doi.org/10.52783/jisem.v10i19s.3058
57. Patil, S., Kute, U., Jakhete, M., Ansari, S., Maniyar, K., Chimkode, S., Modak, G., Bhambere, V., Kolte, R., Warghat, S., Desai, S., Mathur, J., Warke, P., Patil, G., & Mishra, E. (2025). The Role of Internet of Things, Cloud Computing, Artificial Intelligence and Robotics in the Fourth Industrial Revolution. Journal of Mines, Metals and Fuels, 73(4), 1089–1095. https://doi.org/10.18311/jmmf/2025/47334
58. Shastri, M. V. et al.(2026). The Role of Artificial Intelligence and Machine Learning in Mining Industry. Journal of Mines, Metals and Fuels, 74(2), 247–253. https://doi.org/10.18311/jmmf/2026/54371

59. Mishra E, Patil GH, Chavan SD, Jarad RS, Satarkar M, Thakare M, Maniyar K. Analysis of Impact of STATCOM on Distance Relay Using MATLAB. Journal of Mines, Metals and Fuels. 2025;73(3):743–750. https://doi.org/10.18311/jmmf/2025/48052
60. Choudhari RM, Chopde PV, Kharche NA, Shekokar SR, Kharche YA, Warke P, Maniyar K, Patil G. (2025)Determinant factors for the development of rural entrepreneurship. Journal of Information Systems Engineering. 10(25s):111–118. https://doi.org/10.52783/jisem.v10i25s.3951
61. Ganesh Patil, Sunita Upasani, Harshal Vaidya, Kamalakar Desai, M. F. A. R. Satarkar, Ekta Mishra, Kamalkishor Maniyar. (2025) DTMF Phone Call Control Home Appliance Using Arduino and GSM Module & Home Automation. J INFORM SYSTEMS ENG. 10(25s):249-257 https://doi.org/10.52783/jisem.v10i25s.3976
62. Janhavi Kadam, Gauri Phadtare, Ashwini Pawar, Kamalkishor Maniyar. (2025) Offline Signature Verification USING Siamese Neural Network. J INFORM SYSTEMS ENG. 10(26s):431-439https://doi.org/10.52783/jisem.v10i26s.4245
63. Garad RN, Hudgikar SRK, Maniyar K. An Extensive Study on the Optimized Piston Bowl with Spiral Grooves for the CI Engine. Journal of Mines, Metals and Fuels. 2025;73(5):1389–1394. https://doi.org/10.18311/jmmf/2025/48016 https://informaticsjournals.co.in/index.php/jmmf/article/view/48016
64. Choudhari RM, Adhaye AM, Sulakhe VN, Warke PS, Maniyar KG. An Analysis of Tensile Strength and Performance of Resistance Spot Welding Parameters for HSLA 355 Stainless Steel. Journal of Mines, Metals and Fuels. 2025;73(5):1409–1418. https://doi.org/10.18311/jmmf/2025/48684 https://informaticsjournals.co.in/index.php/jmmf/article/view/48684
65. Warke PS, Chaudhari DM, Naik VS, Patil DD, Dhokale SS, Maniyar KG, Patil GH. Wet Scrubber System for Exhaust Gas Emission Reduction. Journal of Mines, Metals and Fuels. 2025;73(5):1331–1341. https://doi.org/10.18311/jmmf/2025/48623 https://informaticsjournals.co.in/index.php/jmmf/article/view/48623
66. Maniyar K, Puri A, Suhane S, Deshmukh S, Modak G, Biradar R. An Experimental Performance of EDM Process Parameters for Aluminum Composites. In: Joseph D., P., V., J., Thangaraju, K. (eds). Proceedings of the International Conference on Emerging Multifunctional Materials and Devices for Sustainable Technologies. IEMDST 2024. Springer, Singapore; 2025. https://doi.org/10.1007/978-981-96-5863-3_44
67. Maniyar K, Saravade N, Suhane S, Deshmukh S, Modak G, Biradar R. Investing Experimental Effect of Welding Parameters in Friction Stir Welding on Aluminium Alloy. In: Joseph D., P., V., J., Thangaraju, K. (eds). Proceedings of the International Conference on Emerging Multifunctional Materials and Devices for Sustainable Technologies. IEMDST 2024. Springer, Singapore; 2025. https://doi.org/10.1007/978-981-96-5863-3_45
68. Kulkarni H, Patel P, Jape V, Soman A, Mishra E, Maniyar K, Patil G. The Hybrid PSO-ANN Methodology for Enhancing Net Load Prediction in Modern Power Systems. Journal of Mines, Metals and Fuels. 2025;73(6):1833–1838. https://doi.org/10.18311/jmmf/2025/49104
69. Kulkarni H, Jape V, Shiralkar A, Soman A, Lokhande N, Bhandare D, Maniyar K, Patil G. Design of an Intelligent PLC-Based Protection for Power Transformers with Auto-Re-Closer. Journal of Mines, Metals and Fuels. 2025;73(7):1915–1923. https://doi.org/10.18311/jmmf/2025/49137
70. Kulkarni H, Jape V, Shiralkar A, Soman A, Bugde V, Bhandare D, Maniyar K, Patil G. The Role of Electric Vehicles in a Sustainable Future and Environment. Journal of Mines, Metals and Fuels. 2025;73(7):1925–1933. https://doi.org/10.18311/jmmf/2025/49119
71. Patil G, Dabhade A, Jog P, Bugade V, Patil M, Gurav J, Desai K, Maniyar K, Mishra E, Kulkarni H, Patel P, Jakhete M, Ghodke P, Yadav M. Comprehensive Analysis of Solar Photovoltaic System Power Inverter Topologies. Journal of Mines, Metals and Fuels. 2025;73(7):1935–1943. https://doi.org/10.18311/jmmf/2025/49149

72. Mukadam S, Sulakhe V, Kaware K, Maniyar K. A Comprehensive Study on Challenges in Gear Manufacturing using Fused Deposition Modeling. Journal of Mines, Metals and Fuels. 2025;73(7):1973–1985. https://doi.org/10.18311/jmmf/2025/49194
73. Chimkode S, Mane J, Jakhete M, Moharil U, Sedani C, Rao N, Garad R, Rupanar S, Kakade N, Choudhari R, Bhambere V, Modak G, Paliwal R, Desai S, Maniyar K, Patil G, Mishra E, Ghodke P, Dixit S, Yadav M. Recent Advancements in the Field of Nanotechnology Using Artificial Intelligence, Data Science and Machine Learning. Journal of Mines, Metals and Fuels. 2025;73(7):1987–1994. https://doi.org/10.18311/jmmf/2025/49272
74. Pawar NR, Hudgikar SRK, Sarnobat SS, Channapattana SV, Maniyar KG. Optimization of Multi-Cylinder Four-Stroke SI Engine Performance under Magnetic Field Interference Using CNG Fuel. Journal of Mines, Metals and Fuels. 2025;73(7):2009–2013. https://doi.org/10.18311/jmmf/2025/49144
75. Mahamulkar V, Jadhav S, Pawar A, Wagh D, Bhaware A, Jadhav S, Patil G, Maniyar K, Ghodke P, Mishra E. Dynamic Wireless Power Transmission System for EV. Journal of Mines, Metals and Fuels. 2025;73(7):2155–2161. https://doi.org/10.18311/jmmf/2025/49252
76. Lodha K, Mohod S, Yadav S, Tomar P, Thawali B, Jahagirdar A, Burande P, Patil G, Maniyar K. Innovative Algorithms for State-of-Charge Estimation in Electric Vehicle Batteries. Journal of Mines, Metals and Fuels. 2025;73(7):2207–2220. https://doi.org/10.18311/jmmf/2025/49439
77. Warbhe R, Jadhav P, Kamble P, Londhe N, Rajguru P, Patil G, Maniyar K, Ghodke P. The Role of Radio Frequency Identification (RFID) Technology in Mining Industries and Other Fields. Journal of Mines, Metals and Fuels. 2025;73(7):2233–2240. https://doi.org/10.18311/jmmf/2025/49174
78. Snehal Banarase, Jayant Mane, Yugesh Kharche, Ramakant Choudhari, Chetankumar Sedani, Shobha Rupanar, Nirmala Kakade, Mayur Jakhete, Prasad Ghodke, Mahendra Yadav, Vijay Bhambere, Girish Modak, Kamalkishor Maniyar, Ganesh Patil. An Experimental Investigation of Process Parameters for Aluminum Alloy Composites. Journal of Polymer and Composites. 2025;13(04):[185-193]. https://journals.stmjournals.com/jopc/article=2025/view=215453
79. Kamalkishor Maniyar et.al. Comparative Study of Hybrid Vehicles with Traditional Vehicles. In: Green Technology and Smart Materials for Engineering Applications. CRC Press; 2025. pp. 385-396. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003516071-19/comparative-study-hybrid-vehicles-traditional-vehicles-kamalkishor-maniyar
80. Nirmala Kakade, Abhay Dashrath, Yugesh Kharche, Ramakant Choudhari, Chetankumar Sedani, Shobha Rupanar, Devidas Gaikwad, Jayant Mane, Ramdas Biradar, Mayur Jakhete, Prasad Ghodke, Mahendra Yadav, Kamalkishor Maniyar, Ganesh Patil. Examining Experimentally the Impact of Spot-Welding Process Variables on Metal Matrix Composites. Journal of Polymer and Composites. 2025;13(05):-. Available from: https://journals.stmjournals.com/jopc/article=2025/view=221853 [Page No. 193-201]
81. Kharche NA, Vishal N. Sulakhe, Baviskar PR, Kaware K, Maniyar K. Optimisation and Analysis of Laser Cutting Parameters for AISI 304 Stainless Steel: Enhancing Cut Quality and Surface Roughness. Journal of Mines, Metals and Fuels. 2025;73(8):2321–2337. https://doi.org/10.18311/jmmf/2025/49219
82. Bugade V, Kamble V, Kharade M, Patil M, Ingle A, Patil G, Maniyar K. Electrical Power Theft Detection and Monitoring Using Innovative Technique. Journal of Mines, Metals and Fuels. 2025;73(8):2361–2370. https://doi.org/10.18311/jmmf/2025/49237
83. Suhane S, Jakhete M, Vaidya H, Barde S, Sedani C, Mane J, Kakade N, Rupanar S, Biradar R, Bhambere V, Modak G, Paliwal R, Ghodke P, Yadav M, Bangar N, Warbhe R, Dixit S, Ashwini Pawar, Mahamulkar V, Maniyar K, Patil M, Patil G. The Role of Nano Materials in the Numerous Areas of Manufacturing. Journal of Mines, Metals and Fuels. 2025;73(8):2639–2648. https://doi.org/10.18311/jmmf/2025/47375
84. Chopade P et al. An Experimental Examination of Concrete for Seven and Twenty-Eight Days of Cement Mortar Recursion. Journal of Mines, Metals and Fuels. 2025;73(10):3055–3065. https://doi.org/10.18311/jmmf/2025/48741

85. P. Jadhav et al. The Impact of Fillet Radius on Spur Gears Made from Aluminum-Silicon Carbide Metal Matrix Composite. In: 2025 4th International Conference on Innovative Mechanisms for Industry Applications (ICIMIA); 2025; Tirupur, India. pp. 320-324. doi: 10.1109/ICIMIA67127.2025.11200982