e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:05/May-2024 Impact Factor- 7.868 www.irjmets.com

FUNCTIONAL TESTING OF RELAY USING ARTIFICIAL INTELLIGENCE

Dr. T. Maris Murugan[*1], Mr. Bala S[*2], Mr. Sanjay P[*3],
Ms. Shanmugapriya R[*4], Mr. Stalin S[*5]

[*1]M.E. Ph.D Associate Professor, Department Of Electronics And Instrumentation Engineering, Erode Sengunthar Engineering College, Erode, Tamil Nadu, India.

[*2,3,4,5]UG Students, Department Of Electronics And Instrumentation Engineering, Erode Sengunthar Engineering College, Erode, Tamil Nadu, India.

DOI : https://www.doi.org/10.56726/IRJMETS55367

ABSTRACT

The project aims to develop an innovative approach for automating the functional testing of relays using Artificial Intelligence (AI) techniques. Relays play a critical role in various industries, ensuring the protection and control of electrical systems. Each consumer has a right to know the expected lifetime of the product. The Relay functions like Operating voltage, Drop voltage, Coil resistance, Contact resistance, Pullup time and Release time have direct influence on its Lifetime in electrical operations. However, traditional testing methods can be time-consuming and prone to human error. This project proposes the implementation of machine learning algorithms to analyze relay behavior and forecast its lifetime. By leveraging historical data and real-time sensor inputs, the AI model will check the normal relay operations in the production and generates the test report with the expected lifetime.

Keywords: The Functional Testing Of Relays Using Artificial Intelligence (AI) Techniques, This Project Proposes The Implementation Of Machine Learning Algorithms To Analyze Relay Behavior And Identify Potential Faults Or Anomalies.

I. INTRODUCTION

The electrical actuator plays a vital role in the automation process especially the electromagnetic relay forms a key for automation, telemetry and communication system. The functional and reliability testing of such an actuator is an important criterion to determine its lifetime. The lifetime of the relay depends on many factors and can bring under direct and indirect category. The operating voltage, release voltage, on time, off time, coil resistance, coil current, ampere-turns, contact resistance are some of the important parameters to be tested for the relays. Apart from this, the dielectric strength between the coil and body armature and between the changeover and the normally open contact also govern the lifetime. These will come under direct influencing category. The environmental situation of the plant, the type of chemical composition of the material, humidity, temperature, and other atmospheric conditions may also impact the epoch of the actuator, comes under indirect category. The failure modes of electromagnetic relays are generally classified as

- Random failure: The relay can return to normal after there is one or several bad contact.
- Permanent failure: The relay cannot return to normal when the relay is failure.
- Mechanical failure: The mechanical structure of the relay breaks off.

II. METHODOLOGY

The methodology for this project involves several key steps: First, gather historical data and real-time sensor inputs to train machine learning algorithms, enabling them to recognize normal relay operation patterns and detect anomalies indicative of faults or degradation. Second, implement advanced signal processing techniques such as wavelet analysis and Fourier transforms to extract meaningful features from the relay's electrical signals, enhancing the accuracy of the analysis. Third, integrate the outputs of the machine learning models with the results of signal processing techniques to achieve a comprehensive understanding of relay behavior, enabling precise fault detection and diagnosis. Finally, design and develop a user-friendly testing system with intuitive interfaces to streamline the process and minimize training requirements, ultimately revolutionizing relay testing practices for increased reliability and safety in various industries.

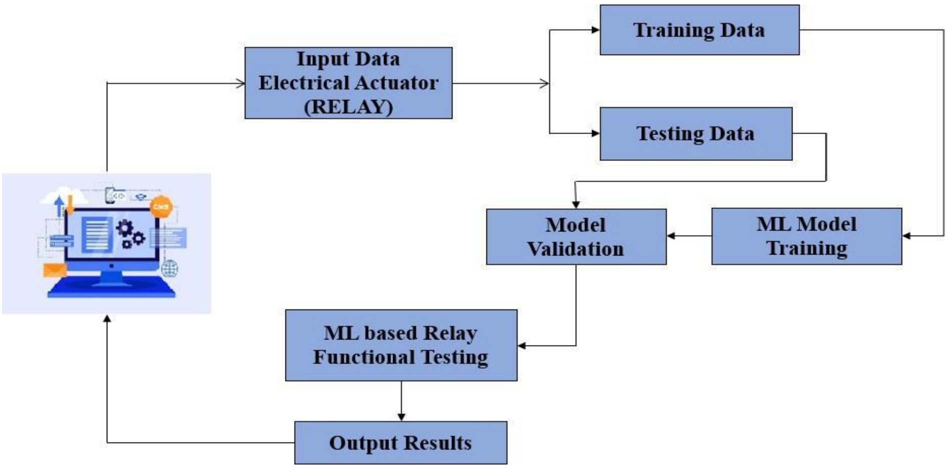

Fig 1: Block Diagram of Machine Learning

The block diagram shows the steps involved in training and testing an ML-based relay model. The first step is to collect training data, which consists of input data (such as the electrical characteristics of the relay) and output data (such as the state of the relay). This data is then used to train the ML model. Once the model is trained, it can be tested using testing data. The testing data is used to evaluate the performance of the model and to identify any areas where it needs to be improved. The final step in the process is to deploy the ML model to production. This means making the model available to users so that they can use it to predict the state of the relay. The block diagram also shows that the ML model can be used to perform functional testing of the relay. This involves using the model to simulate the behavior of the relay under different conditions. This can be used to identify any potential problems with the relay before it is deployed to production. The block diagram shows that the ML model can be used to improve the performance of the relay in a number of ways. By using the model to train and test the relay, engineers can identify and correct any problems with the relay before it is deployed to production. This can help to ensure that the relay is reliable and performs as expected.

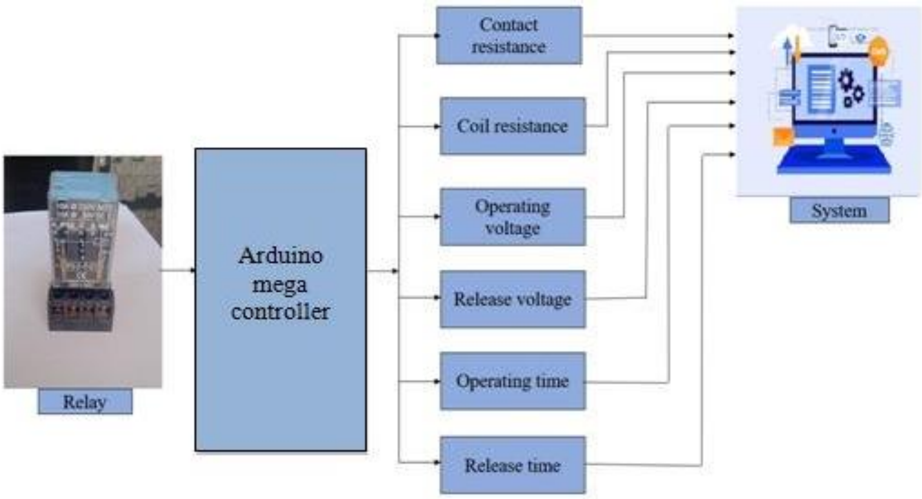

Fig 2: Block Diagram of Functional Checking of Relays

The block diagram shows the functional testing of relays using AI. The first step is to collect real-time functional testing data of relays from the industry. This data is then used to train an AI model, which can then be used to identify deep learning techniques for the life prediction of the relay. The AI model can also be used to design and fabricate reliability testing Zig to check the relay parameters and predict the lifetime with AI. Finally, the AI model can be used to design and fabricate the life time determining Zig of relay and compare it with predicted lifetime. The existing system for relay testing involves using embedded technology or computerized functional testing. However, these systems have limitations in terms of accuracy and efficiency. The proposed system, which integrates AI into the relay testing process, can overcome these limitations and provide more accurate and efficient testing. The block diagram shows the functional testing of relays using AI. The first step is to

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:05/May-2024 Impact Factor- 7.868 www.irjmets.com

collect real-time functional testing data of relays from the industry. This data is then used to train an AI model, which can then be used to identify deep learning techniques for the life prediction of the relay. The AI model can also be used to design and fabricate reliability testing Zig to check the relay parameters and predict the lifetime with AI. Finally, the AI model can be used to design and fabricate the life time 45 determining Zig of relay and compare it with predicted lifetime. The existing system for relay testing involves using embedded technology or computerized functional testing. However, these systems have limitations in terms of accuracy and efficiency. The proposed system, which integrates AI into the relay testing process, can overcome these limitations and provide more accurate and efficient testing.

III. MODELING AND ANALYSIS

ARTIFICIAL INTELIGENCE AND MACHINE LEARNING

Artificial Intelligence (AI) stands at the forefront of technological innovation, promising to revolutionize the way we live, work, and interact with the world around us. In its essence, AI refers to the development of computer systems that can perform tasks that typically require human intelligence. These tasks encompass a wide range of activities, from understanding natural language to recognizing patterns in data, making decisions.

The concept of AI traces its roots back to antiquity, with early philosophical debates on the nature of thought and reasoning. However, it wasn't until the mid-20th century that AI began to take shape as a formal field of study. In 1956, the Dartmouth Conference marked the birth of AI as a distinct discipline, bringing together researchers from various fields to explore the possibility of creating machines that could mimic human intelligence.

AI-DEFINITION

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to mimic human-like cognitive functions such as learning, problem-solving, reasoning, perception, and decision-making. AI encompasses a broad range of techniques, algorithms, and methodologies aimed at enabling computers to perform tasks that typically require human intelligence. AI systems can be designed to analyze vast amounts of data, identify patterns, and make predictions or decisions based on that data. These systems can also adapt and improve their performance over time through iterative learning processes. AI technologies are used in various applications across different industries, including healthcare, finance, transportation, education, manufacturing.

Machine Learning (ML):

- Supervised Learning: Algorithms learn from labeled data to make predictions or decisions. Common applications include classification and regression tasks.
- Unsupervised Learning: Algorithms learn from unlabeled data to discover patterns or structures. Clustering and dimensionality reduction are typical applications.
- Semi-supervised Learning: Combines elements of supervised and unsupervised learning, utilizing both labeled and unlabeled data for training.
- Reinforcement Learning: Agents learn to interact with an environment by receiving rewards or penalties for actions taken. This technique is used in applications like gaming, robotics, and autonomous systems.

AI Algorithms

- Decision Trees: Decision trees are tree-like models where an internal node represents a feature or attribute, the branches represent decision rules, and the leaf nodes represent the outcome. They are used for classification and regression tasks.
- Random Forest: Random Forest is an ensemble learning method that builds multiple decision trees and combines their predictions to improve accuracy and robustness. It's widely used for classification and regression tasks and is known for handling high-dimensional data well.
- Support Vector Machines (SVM): SVM is a supervised learning algorithm used for classification and regression tasks. It finds the optimal hyperplane that separates classes in the feature space and maximizes the margin between classes.

- K-Nearest Neighbors (KNN): KNN is a simple and intuitive algorithm used for classification and regression tasks. It predicts the label of a data point by considering the labels of its nearest neighbors in the feature space.
- Neural Networks: Neural networks are a class of algorithms inspired by the structure and function of the human brain. They consist of interconnected nodes (neurons) organized in layers and are capable of learning complex patterns from data. Popular architectures include Multilayer Perceptron's (MLPs), Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs).
- Clustering Algorithms: Clustering algorithms are used for grouping similar data points together based on their features. Examples include K-Means Clustering, Hierarchical Clustering, and DBSCAN (Density-Based Spatial Clustering of Applications with Noise).
- Dimensionality Reduction Algorithms: Dimensionality reduction algorithms are used for reducing the number of input variables or features in a dataset while preserving its important characteristics. Examples include Principal Component Analysis (PCA), t-Distributed Stochastic Neighbor Embedding (t-SNE), and Auto encoders.
- Naive Bayes: Naive Bayes is a probabilistic algorithm based on Bayes' theorem with an assumption of independence between features. It's commonly used for classification tasks, especially in text classification and spam filtering.
- Linear Regression: Linear Regression is a simple and widely used algorithm for predicting continuous values based on linear relationships between input features and target variables. It's used for regression tasks where the output is a continuous value.
- Logistic Regression: Logistic Regression is a statistical algorithm used for binary classification tasks. It models the probability that a given input belongs to a particular class using a logistic function.

RELAY

Relays are the primary protection as well as switching devices in most of the control processes or equipment regardless of whether they are electronic or electromechanical. All the relay responds to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits. A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another. These are found in all sorts of devices.

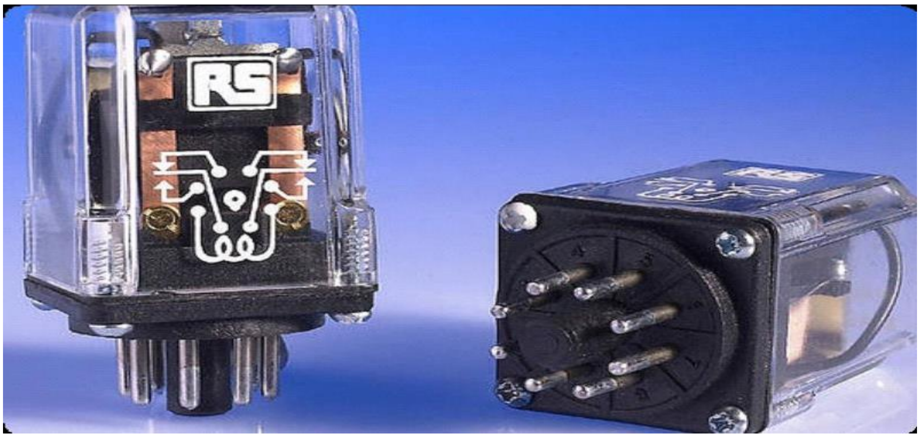

Fig 3: Relay

Second circuit that can be completely separated from the first. There is no electrical connection inside the relay between the two circuits–the link is magnetic and mechanical only. Basically, Relay consists of an electromagnet coil, an armature, a spring and a series of electrical contacts. The electromagnet coil gets power through a switch or a relay driver and causes the armature to get connected such that the load gets the power supply. The armature movement is caused using a spring. Thus, the relay consists of two separate electrical circuits that are connected to each other only through a magnetic connection, and the relay is controlled by controlling the switching of the electromagnet.

Common Challenges in Model Creation and Training

While model creation and training are essential steps in building AI systems, they come with their own set of challenges:

- **Data Quality:** The quality of training data is crucial. No matter how sophisticated the model is, it can only learn from the data it's given. Noisy or biased data can lead to poor models.
- **Overfitting:** Overfitting occurs when a model becomes too complex and fits the training data noise rather than the underlying patterns. Techniques like cross validation and regularization are used to combat overfitting.
- **Underfitting:** Underfitting is the opposite problem, where the model is too simple to capture the complexities in the data. This can be addressed by using more complex models or improving feature engineering.
- **Hyperparameter Tuning:** Selecting the right hyperparameters can be challenging. Grid search and random search are techniques to find optimal hyperparameter values.
- **Computational Resources:** Training deep learning models, especially on large datasets, can be computationally intensive and require access to powerful hardware, such as GPUs.
- **Data Imbalance:** In classification tasks, imbalanced datasets can lead to models that perform well on the majority class but poorly on the minority class. Techniques like resampling and cost-sensitive learning can be used.
- **Convergence:** Ensuring that the training process converges to an optimal 4142 solution can be challenging. Learning rate schedules and early stopping are strategies to help with convergence.
- **Interpretability:** Deep learning models, in particular, can be highly complex and difficult to interpret. This is a challenge when model interpretability is required. The lifetime of relay depends on Contact Resistance between Common terminal & Normally Closed and Normally Opened contacts, Operating Voltage, Drop out Voltage, Pull up Time, Release Time and Coil Resistance. The data of contact resistance in milliohms and corresponding lifetime in electrical operations is Table gives the Operating voltage in %, Drop out voltage in %, Pull up time in nsecs, Release time in nsecs and coil resistance in % with the lifetime of relay in electrical operations.

CONTACT RESISTANCE in mohms	OPERATING VOLTAGE in %	DROP VOLTAGE in %	PULL UP TIME in nsecs	RELEASE TIME in nsecs	COIL RESISTANCE in %	LIFE TIME
20	0.0	0.0	0.0	0.0	85.0	0
20	0.0	0.0	0.0	0.0	86.0	0
20	0.0	0.0	0.0	0.0	87.0	0
20	0.0	0.0	0.0	0.0	88.0	0
60	50.0	50.0	15.0	10.0	86.0	61556
60	50.0	50.0	15.0	10.0	87.0	61809
60	50.0	50.0	15.0	10.0	88.0	62053
60	50.0	50.0	15.0	10.0	89.0	62288
60	50.0	50.0	15.0	10.0	90.0	62516
60	50.0	50.0	15.0	10.0	91.0	62736
60	50.0	50.0	15.0	10.0	92.0	62948
60	50.0	50.0	15.0	10.0	93.0	63152
60	50.0	50.0	15.0	10.0	94.0	63350
60	50.0	50.0	15.0	10.0	95.0	63541
60	50.0	50.0	15.0	10.0	96.0	63726
80	80.0	10.0	30.0	20.0	87.0	54805
80	80.0	10.0	30.0	20.0	88.0	55049

Fig 4: Data of Contact Resistance and Relay Lifetime

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:05/May-2024 Impact Factor- 7.868 www.irjmets.com

IV. RESULTS AND DISCUSSION

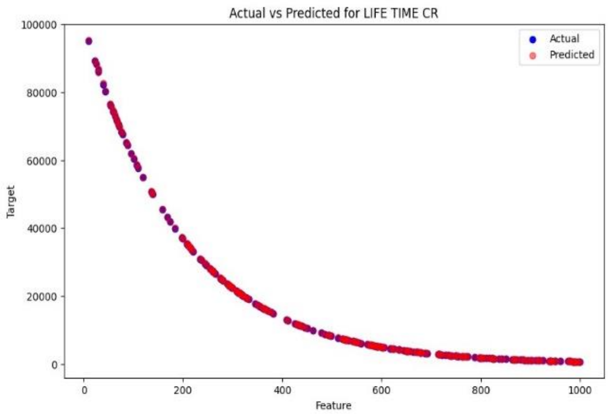

Fig 5: Actual Vs Predicted Lifetime

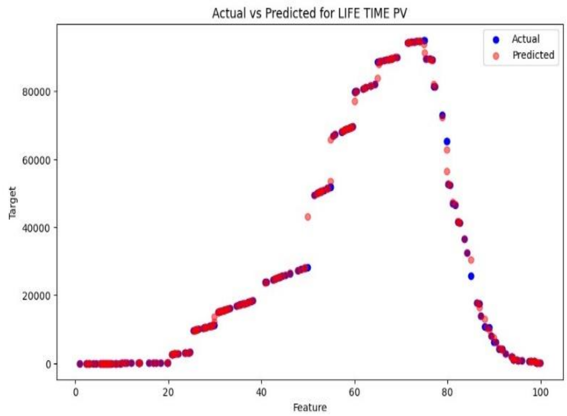

Fig 6: Actual Vs Predicted Lifetime of Relay

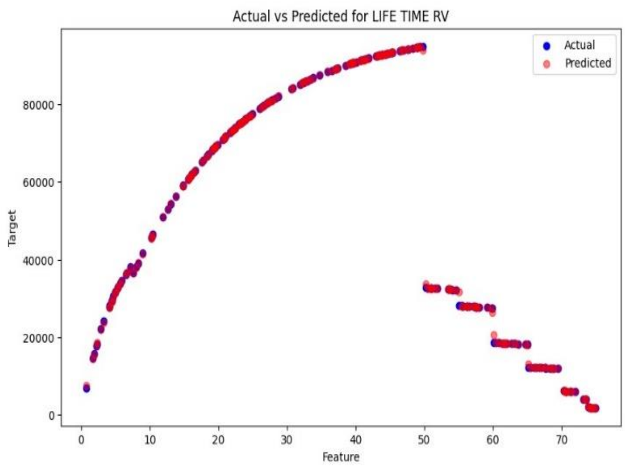

Fig 7: Actual Vs Predicted Lifetime of Relay

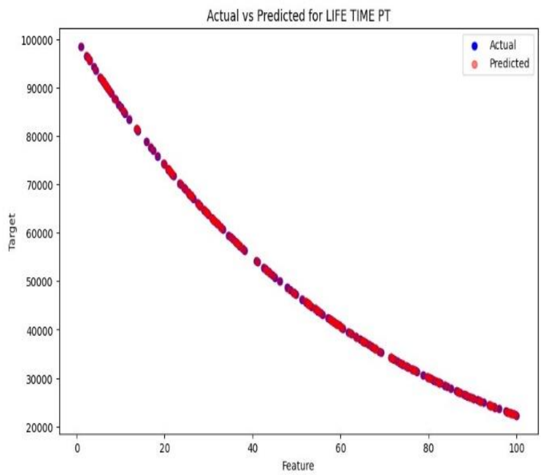

Fig 8: Actual Vs Predicted Lifetime of Relay

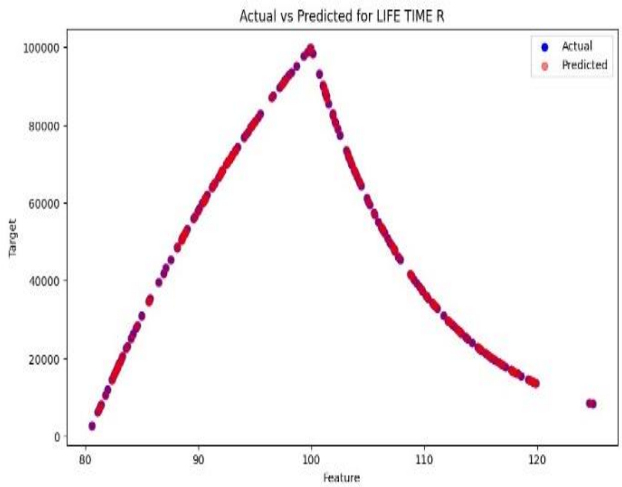

Fig 9: Actual Vs Predicted Lifetime of Relay

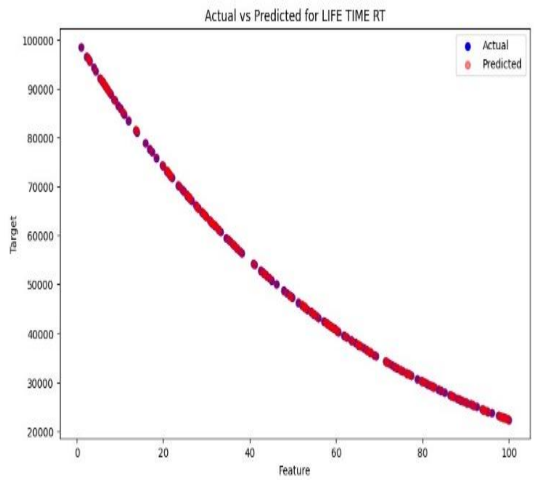

Fig 10: Actual Vs Predicted Lifetime of Relay

The result shown above gives the prediction of lifetime of the relay for an individual parameter. The combined data has been trained with Random Forest Regressor with 2,66,58, 480 data sets. **The r2 score of this model for the combined data is 99.77%.** The distribution of Predicted and Actual Lifetime and Actual and Predicted lifetime of different combination of functional parameter of relay.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:05/May-2024 Impact Factor- 7.868 www.irjmets.com

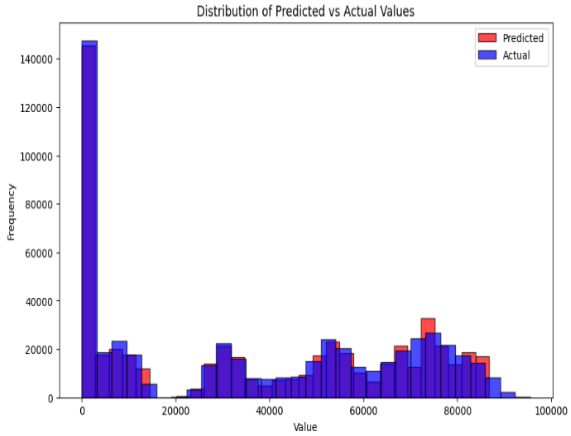

Fig 11: Distribution of Predicted and Actual

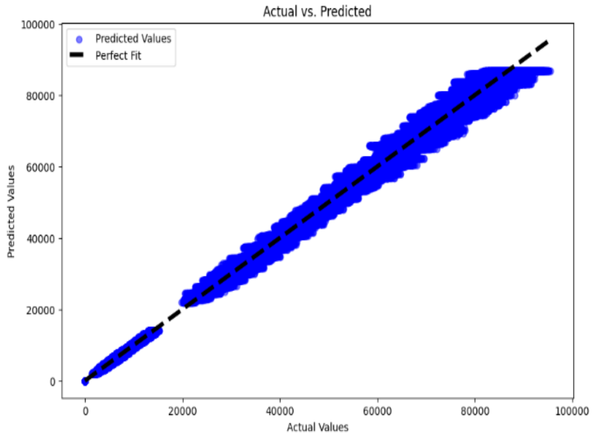

Fig 12: Actual and Predicted Lifetime

The different functional parameter of the one changeover relay is measured with embedded system using Arduino mega controller and the measured data is fed to the trained AI model and the expected life time of that relay has been predicted. The prototype model of the embedded kit is shown in Figure 14.

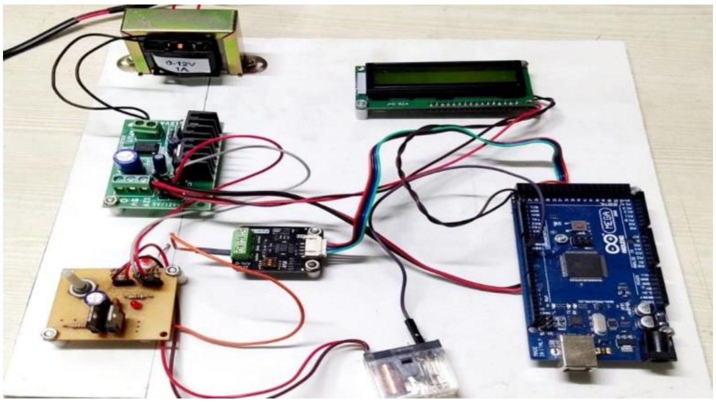

Fig 13: Functional Measuring of Relay with Arduino Controller

V. CONCLUSION

In conclusion, the ultimate goal of the proposed work is to furnish the Lifetime details of the Relay to the customer along with the test report. The Lifetime of the Relay for each and every functional parameter have been trained. The performance of the prediction will be less and hence the model for the combination of different functional elements for the lifetime prediction is considered. The controller for the measurement of Operating and Drop Voltage with the Ramp signal is achieved. The Pullup time and Release time is measured along with the coil Resistance. The Contact resistance in milli ohm is also measured with the Arduino controller. All these parameters are displayed in the LCD display. These data are fed to the trained model for the lifetime prediction of the Relay. the actual and predicted comparison gives more accuracy when compared to the individual parameter model.

VI. FUTURE SCOPE OF THE PROJECT

The results and complications uncovered throughout this examination recommend some future paths. One of the main possessions is forecast using Deep Learning. Since 2,66,58,480 data have been collected, the prediction accuracy will be more with DL methods

VII. REFERENCES

[1] T. Hoang, T. Duong, and S. Lambotharan, "Secure wireless communication using support vector machines," in Proc. IEEE Conf. Common. Netw. Secure. (CNS), Jun. 2019.

[2] Dias, O.; Tavares, M.C.; Magrin, F. Hardware implementation and performance evaluation of the fast adaptive single-phase auto reclosing algorithm. Electr. Power Syst. Res. 2019

[3] Alkhawatrah, Y. Gong, G. Chen, S. Lambotharan and J. A. Chambers, "Buffer-Aided Relay Selection for

Cooperative NOMA in the Internet of Things," IEEE Internet of Things Journal, vol. 6, no. 3, pp. 5722-5731, June 2019.

[4] Tao, F., Zhang, H., Liu, A., & Nee, AYC (2019). Digital twin in Indus- try: State-of-the-art. IEEE Transactions on Industrial Informatics.

[5] Zhou, M., Yan, J. F., & Zhou, X. X. (2020). Real-time online analysis of power grid. CSEE Journal of Power and Energy Systems,

[6] J. Zhang, L. Liu, Y. Fan, L. Zhuang, T. Zhou and Z. Piao, "Wireless Channel Propagation Scenarios Identification: A Perspective of Machine Learning," in IEEE Access, vol. 8, pp. 47797-47806, 2020.

[7] Naveen, P.; Jena, P. Directional Overcurrent Relays Coordination Scheme for Protection of Microgrid. In Proceedings of the IEEE First International Conference on Smart Technologies for Power, Energy and Control (STPEC 2020), Nagpur, India, 25–26 - September 2020.

[8] Ali R. Al-Roomi, El-Hawar Mohamed E. Optimal coordination of directional overcurrent relays using BBO when electromechanical, static, digital, and numerical relays all exist. IEEE Electric Power and Energy Conference (EPEC). 09-10 November 2020

[9] Fan, W.; Liao, Y.; Kang, N. Optimal fault location for power distribution systems with distributed generations using synchronized measurements. Int. J. Emerg. Electr. Power Syst. 2020

[10] J. Luo, S. Zhao, Z. Yang, G. Huang and D. Tang, "Data-Driven-Based Relay Selection and Cooperative Beamforming for Non-Regenerative Multi-Antenna Relay Networks," in IEEE Access, vol. 9, pp. 167154167161, 2021

[11] Marai, O. E, Taleb, T., & Song, J. S. (2021), Roads infrastructure digital twin: A step toward smarter cities realization, IEEE Network.

[12] Erdiwansyah, M., Husin, H., Nasiruddin, Z., & M., & Mohiuddin. (2021). A critical review of the integration of renewable energy sources with various technologies. Protection and Control of Modern Power Systems.

[13] Sidwall, K.; Forsyth, P. A Review of Recent Best Practices in the Development of Real-Time Power System Simulators from a Simulator Manufacturer's Perspective. Energies 2022

[14] Asbery, C.; Liao, Y. Fault Identification on Electrical Transmission Lines Using Artificial Neural Networks. Ph.D. Thesis, University of Kentucky, Lexington, KT, USA, 2022.

[15] Afshar, M.; Majidi, M.; Gashteroodkhani, O.A.; Amoli, M.E. Analyzing Performance of Relays for High Impedance Fault (HIF) Detection Using Hardware-In-The-Loop (HIL) Platform. Electr. Power Syst. Res. 2022

[16] S.P. Ramli, H. Mokhlis, W.R. Wong, M.A. Muhammad, N.N. Mansor Optimal coordination of directional overcurrent relay based on combination of firefly algorithm and linear programming n Shams Eng J, 13 (6) (2022)

[17] T.P. Sari, A. Priyadi, M. Pujiantara, M.H. Purnomo Enhancing the coordination of reverse power, overcurrent, underfrequenc, and under-voltage relays using transient stability analysis in real plant applications in Shams Eng J, 11 (2020)

[18] Sergio Danilo Saldarriaga-Zuluaga, Jesús María López-Lezama, Nicolás Muñoz-Galeano. Optimal coordination of overcurrent relays in microgrids considering a non-standard characteristic . Energies 2020.

[19] Rajalwal, N.K.; Ghosh, D. Recent trends in integrity protection of power system: A literature review. Wiley 2020

[20] Bračevac O, Wei G, Jia S, Abeysinghe S, Jiang Y, Bao Y and Rompf T. (2023). Graph IRs for Impure Higher-Order Languages: Making Aggressive Optimizations Affordable with Precise Effect Dependencies. Proceedings of the ACM on Programming Languages. 7:OOPSLA2. (400-430). Online publication date: 16-Oct-2023.