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Random Forest Algorithm based on Life Assessment and Reliability Test Procedures for Relays used in Circuit Breaker Operating Mechanisms

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ABSTRACT- The essential parts of the circuit breaker working system is the relay which is susceptible to performance deterioration when operating in extreme conditions like salt spray. This can eventually impair the circuit breakers functionality and compromise the power system's ability to function effectively and consistently. This study used an existing test structure to conduct rapidly deteriorating tests on a specific design of additional switch under salt spray in order to assess the relay's lifetime condition effectively. As distinctive parameters impacted by salt spray, contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance of the relay were examined. The results demonstrated that the presence of salt spray reduced the coil effectiveness of the relay, necessitating a higher operating voltage in order to supply the electromagnetic force required for functioning. Moreover, actual and predicted lifetime from individual parameter is calculated. However, coil deterioration also led to a reduction in the electromagnetic force that the step voltage produced, which lengthened the operating period. A Random Forest algorithm model was then created that was appropriate for determining the relay status in this investigation. The existing Gradient Boosting, XGBoost algorithm is compared with proposed method to analyze the performance metrics such as accuracy, precision, recall, F1-score, R2 score, specificity, sensitivity, Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) is determined.

Keywords: Circuit breaker, random forest, gradient boosting, XGBoost, lifetime, relay.

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1. INTRODUCTION

Relays are essential technological components that are used extensively in a variety of electrical devices applications. The proper functioning of the device is directly impacted by the state of the relays [1]. As a crucial safety feature in the electrical system, the circuit breaker functioning system, for instance, quickly isolates malfunctioning components by tearing on its own. However, relay collaboration is required for the relay to operate and close. As a result, the security and reliability of the circuit breaker functioning technique are directly tied to the relay's performance. The mechanism for operating might fail as a result of a relay failure, raising the possibility of the electricity system to break down. Thus, analyzing the relay's performance and performing life estimation can aid in enhancing the system's overall balance as well as the tools stability [2].

High off-isolation, minimal energy consumption, and a small insertion error make electromechanical switching devices popular throughout communication science and technology and manufacturing. The significant reduced size of mechanical relays and the increasing need for longer life and improved reliability all achieved at less cost have been the main trends in recent years. Relay designers are finding the technical issues in this field to be increasingly fascinating and crucial for relay manufacturers. However, contact the welding process, contact resistance corrosion and transmission of material consequence, not-closing and not-opening, can be categorized as the main failures caused by the electric arc erosion. Relay life extension has limitations imposed by the aforementioned failure modes.

The working relationship between the antagonistic force features and the pulling force behaviors is adjusted by the physical parameters. More significantly, it appears to have an impact on the length of the electric arc and the bounce process. The best arrangement of engineering variables limits the rate of bounce during making while also reducing the arc length in breaking operations. Therefore, one of the most important steps in extending the relay's contact life is to optimize the mechanical adjustment parameters. Considerable research has been done in the past 60 years on the individual topics of improved effectiveness contact materials, arc erosion effect and dynamic contact mechanism. Understanding the real closing and opening times could help determine the real effective contact distance, and an obstructed opening could reduce relay lifespan.

The organization of this paper is structured as follows: *Section 2*, explains the relay used in circuit breaker mechanism literature review. *Section 3*, describes the experimental platform and test algorithms of proposed method. *Section 4*, describes the results and discussion. Finally, *Section 5*, concludes the paper.

2. LITERATURE SURVEY

The majority of relays are made up of mechanical and electrical components, each of which can deteriorate to varying degrees over extended operation, leading to inconsistent operation. As a result, scholars have studied the relay in great detail [3-6]. To examine the effect of outside factors on the contact resistance of the relay, mentioned in [3] employed a variety of methods for identifying to find electrical defect to the inner and outer components of the relay that had been stored for an extended period of time. The author has proposed [4] recorded the relay's contact resistance while it was in operation, and the author have presented [5] the resistance change, used the established testing platform to measure the relay's pull-in time at various temperatures, and examined the malfunctioning system. The author [6] identified the essential parameters that characterize the breakdown process of electromagnetic relays. Models for life prediction and accuracy based on unpredictable theory were developed. This prediction model was useful within a given relay range.

The author [7] proposed relay feedback examinations are carried out in this study on a variety of handles with varying demands and dead-time-to-time-constant proportions. Based on the relay feedback test response form, these methods can be grouped together into three main groups (model structures). Different tuning rules are used to determine the proper PI controller settings after treatments are provided to find variables for the corresponding model frameworks. The methods are applied to both noisy and noiseless linear systems. Simulation results clearly show that improved autotuning can be obtained easily by incorporating the shape information. Furthermore, when needed, higher-order reimbursement and potential dead-time payment can be developed.

The author in [8] proposed a relay condition recognition technique based on PSO-ELM has been suggested in order to address the issue that it is challenging to determine the true indicate of a transportation relay because of the numerous unpredictability of the running state. Initially, the relay contact life test was used to extract a range of performance deterioration variables that affected the functionality state of transportation relays. CCA correlation analysis was then used to conduct initial selection, and the impact degree and categorization ability of the initial choice results in different status intervals were analyzed using the random forest the significance score. The author [9] proposed Electromagnetic Relays, are ubiquitous in electrical networks, from extremely specialized, hazardous manufacturing processes to mass-produced everyday items. The methods used to estimate the State of Health or the Remaining Useful Life were highlighted in our extensive literature review, which focused on Electromagnetic Relays dependability. It also highlighted the easy availability and utilization of Electromagnetic Relays life cycle data sets, as well as the limited analysis and understanding of conveyed Electromagnetic Relays loss signs.

In this paper an innovative test instruments that simulates an electromagnetic relay is applied to contrast six different electro mechanical parameters. Numerous time parameters on a switched-type relay reflect the dynamic process that occurs during make-and-break operation rules. Contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance are recorded explicitly during relay life test. Next, an analysis was conducted to determine how mechanical parameters affected the time factors and relay contact failure process mentioned earlier.

3. EXPERIMENTAL PLATFORM AND TEST ALGORITHMS

Relays are made up of several parts that work together to accomplish their purpose. Because of their inadequate connecting ability, it is challenging to prevent damage from salt fog attack. The overall performance of the relay suffers as a result [10]. This study used the speed period test on a particular kind of relay using the following testing environment in order to examine the effects of salt fog on relay efficiency [11]. It also extracted the key features of the relay by using an insulation device. As of right now, the additional shift salt spray and switching tests lack a single, universal standard. Thus, the following test was created using the pertinent information found in IEC60069-2-30-2010 "Environmental testing".

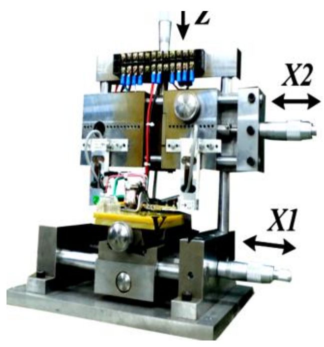

Figure 1. Relay test equipment overall view

In accordance with the pertinent experimental specifications, the LD-91B accuracy sodium chloride test the container will be

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utilized in this paper. Its forty-liter saltwater tank allows it to maintain control over its individual spray period and its temperature range of 15 to 75 °C is enough to meet test specifications [12]. Additionally, it has a high-precision temperature control method to guarantee an error of no more than 0.1 °C in the test's accuracy [13]. The sodium chloride solution (5%) with a pH value between 6.5 to 7.5 needs to be added to the salty water tank and set up in accordance with the applicable standards before using the salt spray the container. After that, further tests can be conducted. The test sample was first put in a salt spray test with a normal temperature of 55 °C for four hours. After that, it was moved to an even temperature and moisture space, where it was kept at 55 °C and 95% moisture, respectively, for four hours. A 5-hour spray plus a 4-hour storage period will now be considered one test cycle for the sake of future data, and at the conclusion of each test, the distinctive parameters will be obtained [14]. Fig. 1. shows the relay test equipment overall view.

Relays must respond quickly in accordance with predetermined goals to guarantee that this section of the circuit is connected and disconnected quickly. Inaction can result in unreliable losses because of domino effects [15]. To comprehend the variations in relay performance, contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance was chosen as a feature parameter. Moreover, the infiltration of salt spray ruins the coil and modifies the functioning voltage. Therefore, a crucial factor in gauging the relay's overall performance is the functioning voltage [16]. After a thorough examination of these two factors, the final impact of salt spray on the relay degradation can be evaluated.

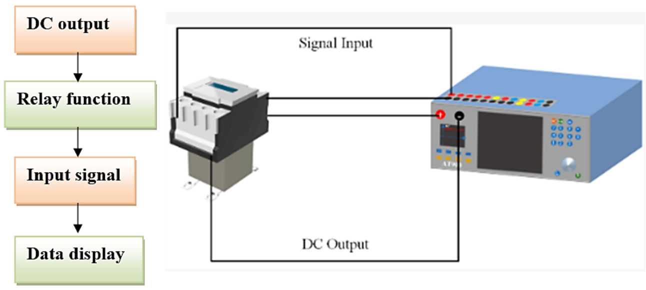

Figure 2. Test of relay operation

As seen schematically in *fig. 2*, this instrument has several signal input paths that allow it to simultaneously measure six parameters: contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance [17]. The apparatus can perform both automatic and manual measurement methods, has high measurement accuracy and responds quickly all of which contribute to the dependability of the experimental results.

3.1. Random Forest model

An ensemble method called Random Forest (RF) F uses multiple independent and independent decision trees, denoted by G= {s1, s2,⋯,ss}. By adding randomness to the decision trees, these independent trees help model F achieve an accurate generalization. These extrapolations depend on the use of a bagging methodology, which blends the ideas of collection and using bootstrapping [18]. The RF algorithm, a supervised machine learning method, consists of a set of trees and a classification given by each tree in the forest. The RF algorithm works by first creating the random forest classifier, and then predicting the results. Several decision trees are combined into an ensemble learning model called RF, which uses the Bootstrap technique. Without feature scaling, the selection method increases the Random Forest's reliability [19]. The salt spray intrusion, which includes intricate fault features with faults, is a good fit for the RF technique. In this paper, a combined feature selection algorithm and weighted proportional method are proposed as a Random Forest. The characteristics that affect model training and classification are kept after the feature selection algorithm removes the unnecessary features. By allocating weights to each decision tree based on its classification performance, the proportional deciding technique enhances the efficacy of decision trees with superior division performance and raises the standard of accuracy.

The node system draws from a subset of the training sample's features to create an attribute candidate set, and from there, it chooses its favorite characteristics to use as the characteristics of the node when developing decision trees for Random Forests. Samples are categorized in the Random Forest from each decision tree's base node to leaf node [20]. They will be categorized based on the node feature after moving through each node, and they will then proceed to the following child node to carry on with the classification process until they reach a leaf node. The samples are categorized under the leaf node category. However, because of the extensive array of notifications and the substantial dimension of the alarm features, there's a chance that not matched to sample node [21]. If the node characteristics are chosen arbitrarily, the samples might be categorized into the incorrect nodes of the leaf along the incorrect paths, which would result in classification errors and lower the Random Forest's classification performance.

The image 3 illustrates the Random Forest algorithm, detailing the training and node-splitting processes. The algorithm begins with the construction of multiple decision trees. For each tree, a subset of the training data is selected randomly. Then, at each node of the tree, the algorithm checks whether a stop condition is met. If not, it proceeds to build the next split. To determine the best split, a subset of variables is selected, and for each variable, a sample of data is drawn and sorted. The Gini Index is computed at each potential split node to evaluate the quality of the split. The best split is selected based on the lowest Gini Index. This process continues recursively until the stop condition is satisfied. Once the tree is fully grown, the prediction error is computed. The entire process repeats for the specified number of trees, and once all trees are built and evaluated, the algorithm stops. This ensemble method improves predictive performance and reduces overfitting by averaging the results of multiple decision trees.

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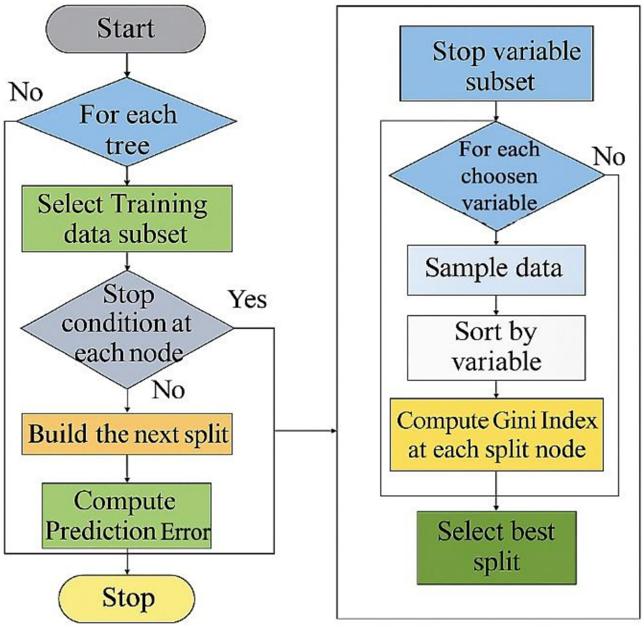


Figure 3. Flowchart for Random Forest algorithm

The overall variable importance for a feature in the forest is defined as the summation or the average of its importance value among all trees in the forest. Permutation importance measure (PIM) is arguably the most popular variable's importance measure used in RF. The RF algorithm does not use all training samples in the construction of an individual tree. That leaves a set of out of bag (OOB) samples, which can be used to measure the forest's classification accuracy. In order to measure a specific feature's importance in the tree, randomly shuffle the values of this feature in the OOB samples and compare the classification accuracy between the intact OOB samples and the OOB samples with the particular feature permutated. In this work, we have used permutation importance measure (PIM) and developed two algorithms to measure PIM and select an important subset of feature among all features, as shown in *algorithm 1*.

Algorithm 1: Pseudo code of Random Forest model

Step 1: *Measure of Variable Importance*

1) *Build 50 Random Forest. For each Random Forest, k = 1 to 50, repeat Steps 2 to 4.*
2) *For each tree t of the k-th Random Forest, Consider the associated* OOB_t *sample.*
3) *Denoted by the error of a single tree t on this* OOB_t *sample.*
4) *Randomly permute the values of* X_j *in* OOB_t *to get a perturbed sample denoted by After that, compute* OOB_t^j *and the difference of the error between the intact* $errOOB_t$ *samples and the OOB samples with the permutated feature* X_j*. Finally, find out permutation importance measure (PIM) for the permuted feature* X_j *using the following equation:*

$$PIM_k(X^j) = \frac{1}{n_{tree}} \sum_t (errOOB_t^j - errOOB_t)$$

5) *5) Find out the average permutation importance measure (APIM) of each variable from the 50 Random Forest using following equation*

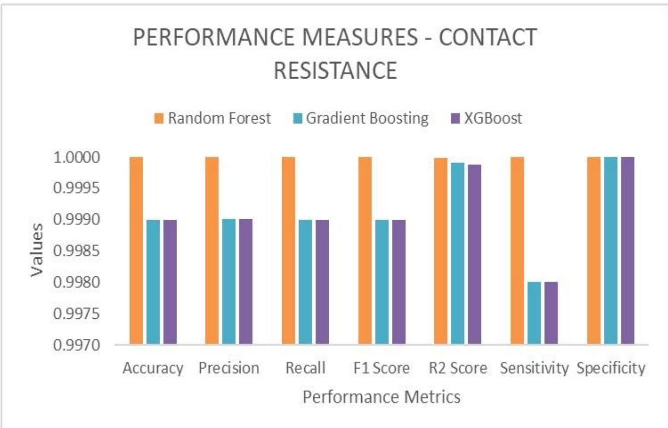
$$APOM(X^j) = \frac{1}{50} \sum_{k=1}^{50} PIM_k(X^j)$$

Step 2: *Variable Selection*

1. *Rank the variables by sorting the APIM score (averaged from the 50 runs of RF using Algorithm 1) in descending order.*
2. *Perform a sequential variable introduction with testing: a variable is added only if the error gain exceeds a threshold. The variables of the last model are selected.*

4. RESULTS AND DISCUSSION

The relay was subjected to an aging test by salt spray, in accordance with the above testing plan. The relay's surface metal components developed noticeable corrosion during the testing period, and all of its parameters changed to levels that varied. This can eventually impair the circuit breaker's functionality and compromise the power system's ability to function effectively and consistently. This study used an existing test structure to conduct rapidly deteriorating tests on a specific design of additional switch under salt spray in order to assess the relay's lifetime condition effectively. As distinctive parameters impacted by salt spray, contact resistance, pickup voltage, release voltage, pickup time, release time, and coil resistance of the relay were examined. A total of 1,200 data samples were collected during the testing process, covering multiple degradation stages across several cycles. The results demonstrated that the presence of salt spray reduced the coil effectiveness of the relay, necessitating a higher operating voltage in order to supply the electromagnetic force required for functioning. To ascertain the impacts of relay salt spray a thorough analysis of the characteristic variables gathered will be provided in this section.



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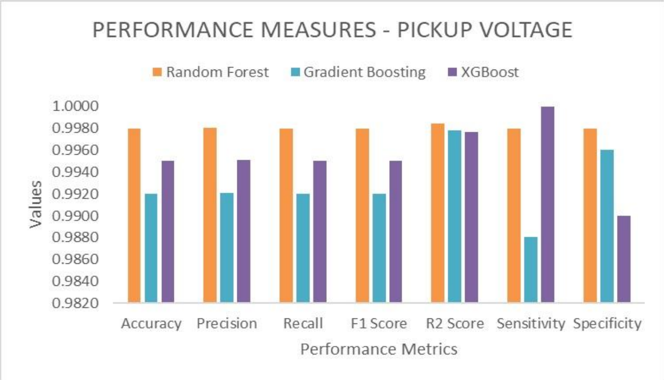

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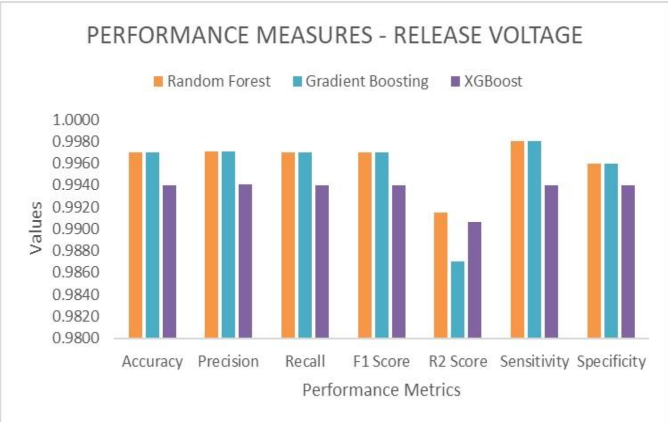

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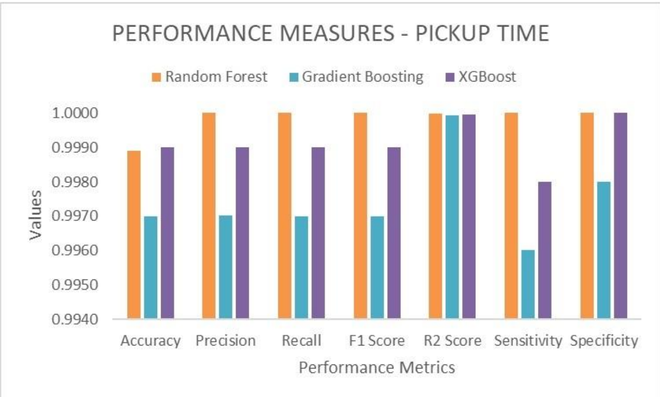

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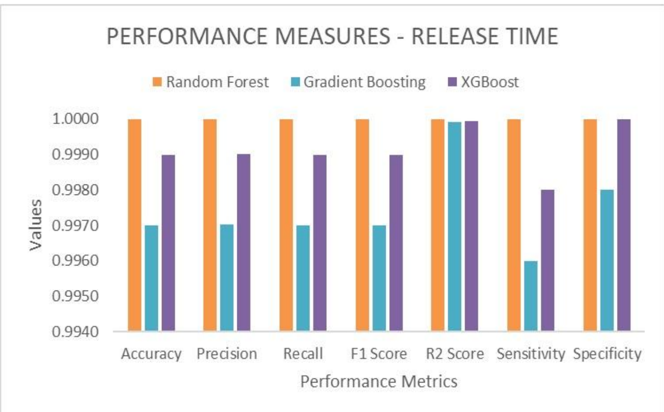

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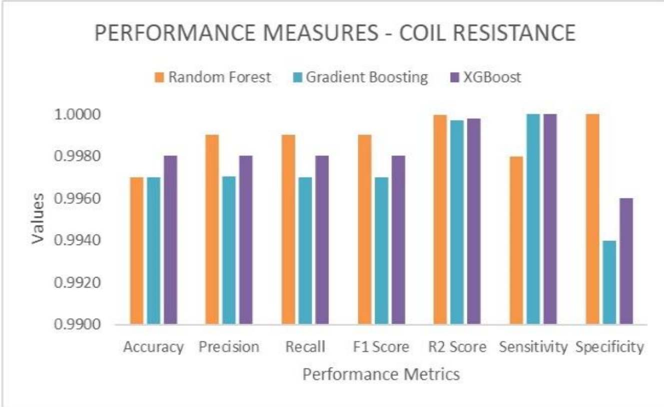
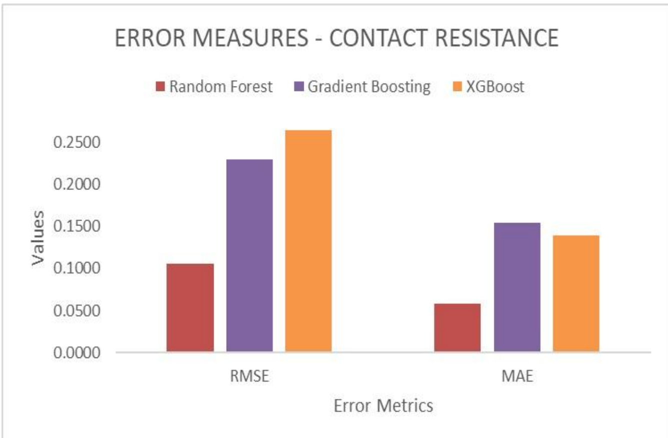


(f)

Figure 4. Graphical representation of proposed and existing algorithm performance measures obtained values (a) contact resistance, (b) pickup voltage, (c) release voltage, (d) pickup time, (e) release time and (f) coil resistance.

The *figure 4* describes a graphical comparison between the proposed and existing algorithms based on key performance metrics relevant to relay or switching device evaluation. These metrics include: *Figure 4(a)* contact resistance, which indicates the electrical resistance across the relay contacts and reflects wear or oxidation; *Figure 4(b)* pickup voltage, the minimum voltage required to activate the relay; *Figure 4(c)* release voltage, the voltage at which the relay deactivates; *Figure 4(d)* pickup time, the duration taken for the relay to switch on after voltage application; *Figure 4(e)* release time, the time required for the relay to switch off once voltage is removed; and *Figure 4(f)* coil resistance, which reflects the health and integrity of the relay's coil. Each sub-figure likely presents comparative bar or line graphs showing the measured values for both proposed and existing methods, highlighting the efficiency or improvements achieved by the proposed algorithm across these operational characteristics. From the obtained results RF algorithm obtained outperforms than the other algorithms. For relay users, the relative time and pickup/release voltage parameters are crucial indices. They will be directly impacted by changes made to the relay frame position, which cause the magnetic gap to fluctuate.



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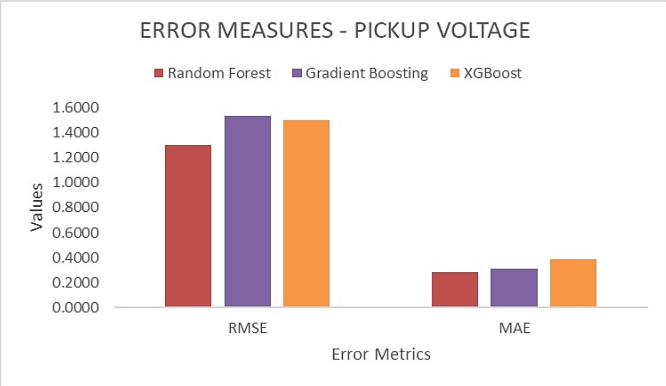

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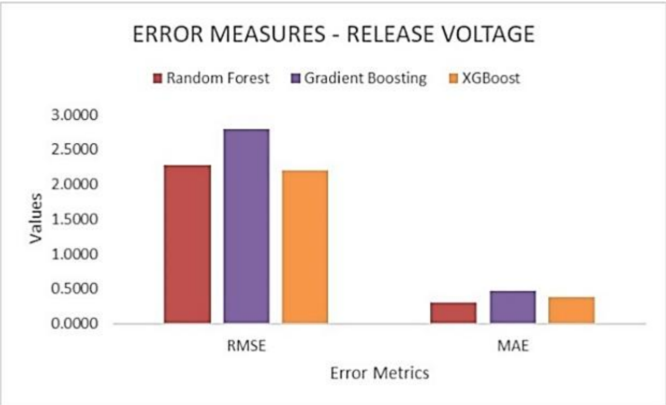

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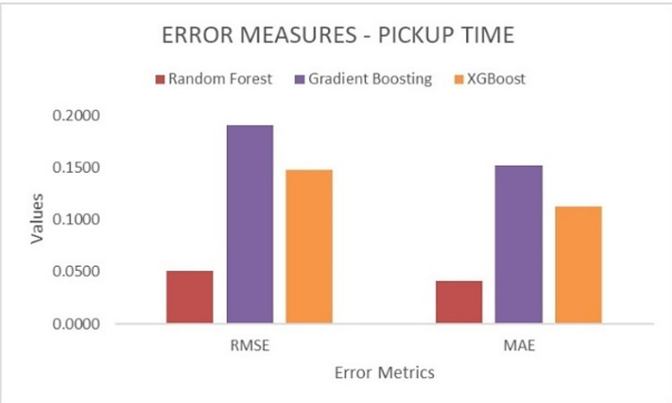

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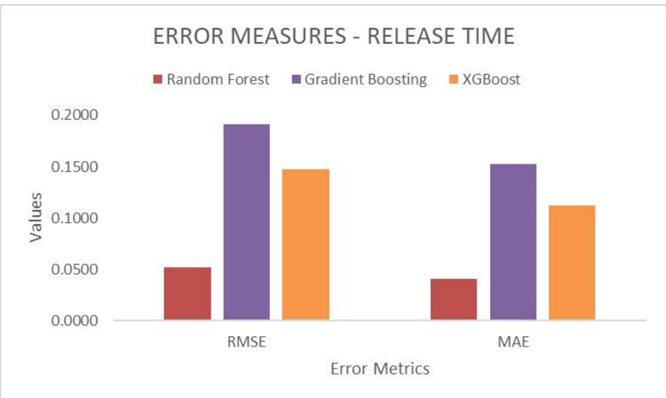

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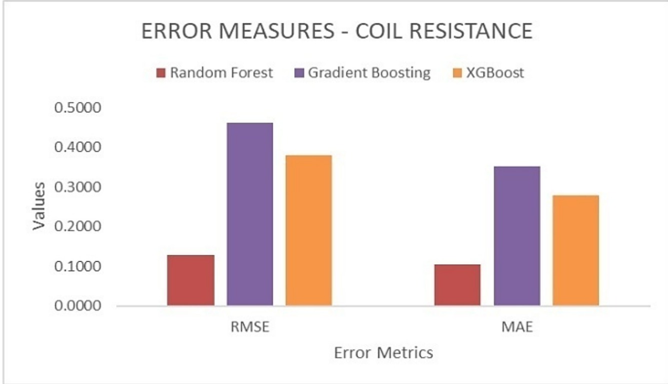
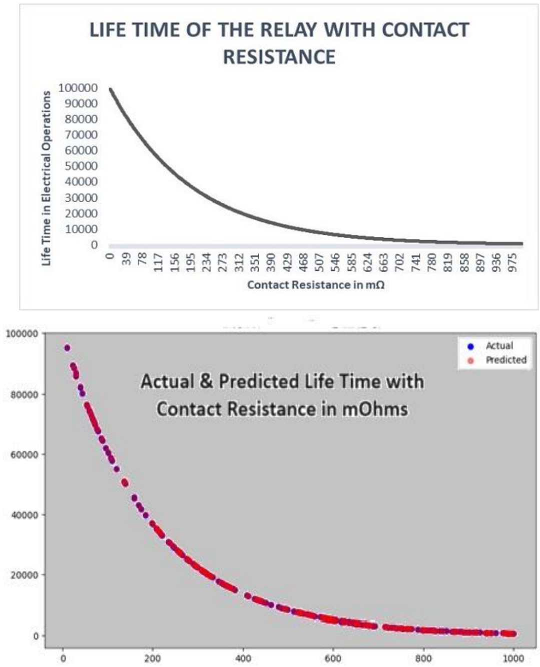


(f)

Figure 5. Graphical representation of proposed and existing method error measures obtained values (a) contact resistance, (b) pickup voltage, (c) release voltage, (d) pickup time, (e) release time and (f) coil resistance.

The *figure 5* refers to a graphical comparison between the error measures of the proposed and existing methods across six critical parameters in relay or switch performance analysis. These parameters include: *Figure 5(a)* contact resistance, representing the deviation in electrical resistance at the relay contacts; *Figure 5(b)* pickup voltage, showing the error in the voltage needed to activate the relay; *Figure 5(c)* release voltage, indicating error in the voltage at which the relay turns off; *Figure 5(d)* pickup time, measuring discrepancies in how quickly the relay activates; *Figure 5(e)* release time, reflecting errors in how long it takes the relay to deactivate; and *Figure 5(f)* coil resistance, assessing inaccuracies in the resistance of the relay coil. The figure likely illustrates that the proposed method demonstrates lower error values across these parameters when compared to the existing method, thereby validating its improved precision and reliability in evaluating relay performance.



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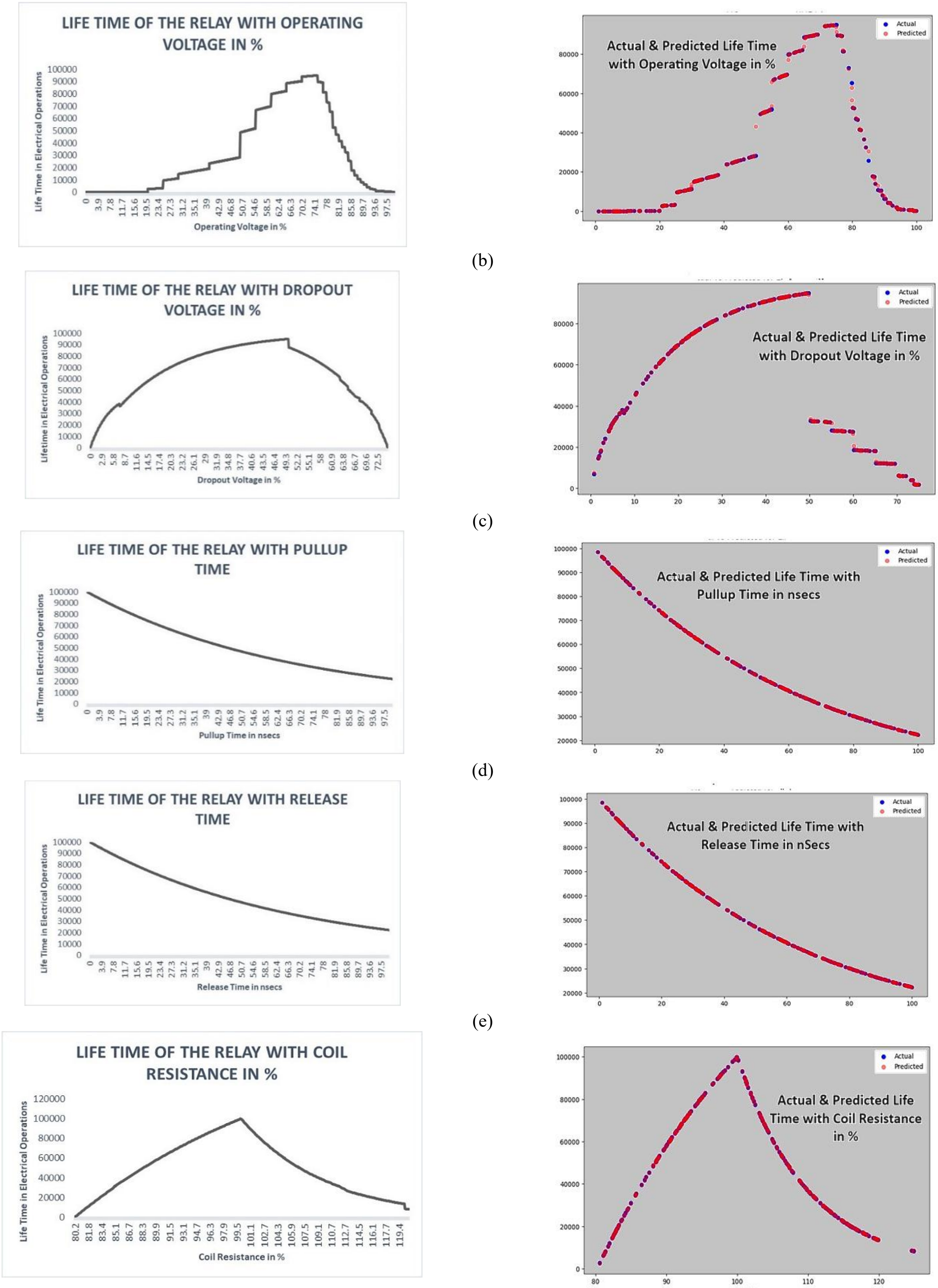

(b)

(c)

(d)

(e)

(f)

Figure 6. Lifetime in relay operation of proposed method actual data and actual & predicted values. (a) contact resistance, (b) pickup voltage, (c) release voltage, (d) pickup time, (e) release time and (f) coil resistance

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Figure 6(a) shows the proposed Random Forest (RF) lifetime of the relay with contact resistance actual value and lifetime of the relay with contact resistance actual & predicted value is determined. In the largest contact force scenario, the resistance of contacts was maintained between 190 and 198 mΩ. Furthermore, resistance of contacts did not exhibit any discernible variation trend over the course of the life tests under various test conditions. It is observed that by increasing contact force, the contact resistance of the contact pair could be stabilized. It is important to emphasize that, even though eroded surface morphology has an impact on electrical contact resistance in arc conditions, contact resistance may not be the only indicator of contact failure mechanisms. *Figure 6(b)* illustrates how the stepping voltage's electric field force reduced following the performance degradation. At this moment, the force f1 produced by the new relay's stepping voltage was larger than the force ΔF2 produced as a result of aging. The aging relay's maximum electric field force f2 was obviously less than f1 at the beginning, even though both could be higher than the electric field force needed for contact closing. An accelerated salt spray aging examination was carried out using the aforementioned methodology, and the action voltage was gathered at the completion of each test. The relay was unable to finish its task after ten cycles of aging. *Figure 6(c)* shows the dropout voltage actual value. Also, the lifetime of actual and predicted value comparison results. As a result, *figure 6(d)* combined the information from the beginning tests and the information from the resultant relay. The x and y axes show the number of tests conducted in a cycle and the functioning voltage, respectively. Along with measuring the pull-up voltage, another important factor in the experiment was also measured: the released voltage. The precise findings are displayed in *figure 6(e).* It is evident from the figure that as the release time increases, the opening voltage varies considerably. After being impacted by salt spray, the functioning voltage such as the pull-up voltage also displayed an erratic rising trend, continuing until it was unusable. *Figure 6(f)* shows the proposed RF lifetime of the relay with contact resistance actual value and lifetime of the relay with coil resistance actual & predicted value is determined. *Table 1,* mentioned the weighting age value for the proposed approach.

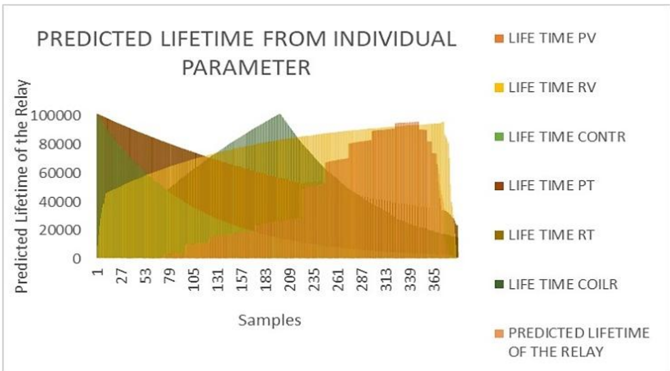

Figure 7. Predicted lifetime from individual parameter obtained results

Figure 7, illustrates the predicted lifetime from individual parameter is determined. Here, x-axis represents the number of samples and y-axis denotes the predicted lifetime of the relay for six parameters. *Table 2*, depicts the overall obtained results in terms of six parameters such as contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance based on the performance metrics such as precision, accuracy, F1-score, recall, R2 score, specificity, sensitivity, RMSE and MAE is determined. For contact resistance, the proposed RF obtained the accuracy, precision, recall, F1-score, R2 score, specificity, sensitivity, of 100%, RMSE and MAE value of 0.1058 and 0.0576 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score, R2 score of 100% and the obtained specificity value of 99.8%, the obtained sensitivity value of 100%, RMSE and MAE value of 0.2301 and 0.1549 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score, R2 score of 100% and the obtained specificity value of 99.8%, the obtained sensitivity, value of 100%, RMSE value of 0.265 and MAE value of 0.1391 respectively.

Table 1. Weighting for age values

Criteria	Weight
UPTO 40% Operating Voltage, Lifetime	0
40% and above Operating voltage	0.6
Dropout voltage	0.15
Contact resistance	0.1
Pullup time	0.05
Release time	0.05
Coil resistance	0.05

For pick up voltage, the proposed RF obtained the precision, accuracy, F1-score, recall, obtained the value of 99.8%, R2 score obtained the value of 99.84%, specificity of 99.8%, sensitivity of 99.8%, RMSE and MAE value of 1.2994 and 0.2827 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score obtained the value of 0.992 R2 score of 0.9978 and the obtained specificity value of 0.996 the obtained sensitivity value of 0.996, RMSE value of 1.5347 and MAE value of 0.308 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score, R2 score, RMSE and MAE value of lower value than the other.

For release voltage, the proposed RF obtained the precision, accuracy, F1-score, recall, obtained the value of 0.997, R2 score obtained the value of 0.9915, specificity of 0.996, sensitivity of 0.998, RMSE and MAE value 2.2751 and 0.3034 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score obtained the value of 0.997 R2 score of 0.987 and the obtained specificity value of 0.996 the obtained sensitivity value of 0.998, RMSE and MAE value of 2.7891 and 0.4701 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score, R2 score, RMSE and MAE value of lower value than the other.

For pickup time, the proposed RF obtained the accuracy obtained the value of 0.9989, precision, recall, F1-score obtained the value of 99.8%, R2 score, specificity, sensitivity obtained the value of 1, RMSE and MAE value of 0.0509 and 0.0412 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score obtained the value of 0.997 R2 score of 0.9999 and the obtained specificity value of 0.996 the obtained sensitivity value of 0.999, RMSE and MAE value of 0.1909 and 0.1525 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score obtained the value of 0.999, R2 score of 1, specificity of 1, sensitivity of 0.998, RMSE and MAE value of 0.1477 and 0.1123 respectively.

For release time, the proposed RF obtained the precision, accuracy, F1-score, recal, R2 score, specificity, sensitivity obtained the value of 1, RMSE and MAE value of 0.0518 and 0.041 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score obtained the value of 0.997 R2 score of 0.9999 and the obtained specificity value of 0.996 the obtained sensitivity value of 0.999, RMSE and MAE value of 0.1909 and 0.1525 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score obtained the value of 0.999, R2 score of 1, specificity of 1, sensitivity of 0.998, RMSE and MAE value of 0.1477 and 0.1123 respectively.

For coil resistance, the proposed RF obtained the accuracy obtained the value of 0.997, precision, recall, F1-score obtained the value of 0.999, R2 score of 1, specificity value of 1, sensitivity obtained the value of 0.998, RMSE and MAE value of 0.1273 and 0.1038 respectively. For, the gradient boosting obtained the accuracy, precision, recall, F1-score, R2 score of 0.9997 and the obtained specificity value of 0.994 the obtained sensitivity value of 1, RMSE and MAE value of 0.4621 and 0.3524 respectively. For, the XGBoost obtained the accuracy, precision, recall, F1-score, R2 score obtained the value of 0.998, specificity of 0.996, sensitivity of 1, RMSE and MAE value of 0.3796 and 0.2797 respectively. By analyzing the results, the proposed Random Forest obtained better results compared to Gradient Boosting and XGBoost algorithm.

Table 2. Overall performance of various methods obtained results

Algorithm	Accuracy	Precision	Recall	F1 Score	R2 Score	Sensitivity	Specificity	RMSE	MAE
CONTACT RESISTANCE									
Random Forest	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0.1058**	**0.0576**
Gradient Boosting	0.999	0.999	0.999	0.999	0.9999	0.998	1	0.2301	0.1549
XGBoost	0.999	0.999	0.999	0.999	0.9999	0.998	1	0.265	0.1391
PICKUP VOLTAGE									
Random Forest	**0.998**	**0.998**	**0.998**	**0.998**	**0.9984**	**0.998**	**0.998**	**1.2994**	**0.2827**
Gradient Boosting	0.992	0.9921	0.992	0.992	0.9978	0.988	0.996	1.5347	0.308
XGBoost	0.995	0.9951	0.995	0.995	0.9976	1	0.99	1.5036	0.3878
RELEASE VOLTAGE									
Random Forest	**0.997**	**0.9971**	**0.997**	**0.997**	**0.9915**	**0.998**	**0.996**	**2.2751**	**0.3034**
Gradient Boosting	0.997	0.9971	0.997	0.997	0.987	0.998	0.996	2.7891	0.4701
XGBoost	0.994	0.9941	0.994	0.994	0.9906	0.994	0.994	2.1987	0.3873
PICKUP TIME									
Random Forest	**0.9989**	**1**	**1**	**1**	**1**	**1**	**1**	**0.0509**	**0.0412**
Gradient Boosting	0.997	0.997	0.997	0.997	0.9999	0.996	0.998	0.1909	0.1525
XGBoost	0.999	0.999	0.999	0.999	1	0.998	1	0.1477	0.1123
RELEASE TIME									
Random Forest	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0.0518**	**0.041**
Gradient Boosting	0.997	0.997	0.997	0.997	0.9999	0.996	0.998	0.1909	0.1525
XGBoost	0.999	0.999	0.999	0.999	1	0.998	1	0.1477	0.1123
COIL RESISTANCE									
Random Forest	**0.997**	**0.999**	**0.999**	**0.999**	**1**	**0.998**	**1**	**0.1273**	**0.1038**
Gradient Boosting	0.997	0.997	0.997	0.997	0.9997	1	0.994	0.4621	0.3524
XGBoost	0.998	0.998	0.998	0.998	0.9998	1	0.996	0.3796	0.2797

5. CONCLUSION

In this work, used an existing experimental system to conduct salt spray increased period tests on a specific category of relay, study the relay's deterioration under a salt spray circumstance and examine the manner in which external surrounding factors affect the relay's functioning voltage and functioning time. At the same time created a relay state identification model through Random Forest based on the crucial parameters of the relay and the pertinent data gathered throughout the experimental process. The parameters impacted by salt spray, contact resistance, pickup voltage, release voltage, pickup time, release time and coil resistance of the relay were examined in this study. The proposed results demonstrated that the presence of salt spray reduced the relay effectiveness of coil, necessitating a higher operating voltage in order to supply the electromagnetic force required for functioning. Moreover, actual and predicted lifetime from individual parameter is calculated in this paper. The performance metrics is determined for Random Forest algorithm model, Gradient Boosting and XGBoost algorithm.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, Maris Murugan T and Mishmala Sushith; methodology, Maris Murugan T and Sundar R; software, Sridhar S; validation, Reeda Lenus C, Mishmala Sushith and Srithar S; formal analysis, Maris Murugan T and Sundar R; investigation, Reeda Lenus C; resources, Srithar S; data curation, Sridhar S; writing—original draft preparation, Sridhar S and Sundar R; writing—review and editing, Mishmala Sushith; visualization, Reeda Lenus C; supervision, Maris Murugan T; project administration, Maris Murugan T; funding acquisition, Srithar S. All authors have read and agreed to the published version of the manuscript".

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