Retraction

Retraction: AC Contactor Electrical Health Estimator Model
(IOP Conf. Ser.: Mater. Sci. Eng. 1145 012070)

Published 23 February 2022

This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

Retraction published: 23 February 2022
AC Contactor Electrical Health Estimator Model

S Abirami¹, S Ruthvik¹, M Sathiq Ali¹, R Sathish Kumar¹ and J P Sujith Kumar¹
¹Department of Electrical and Electronics Engineering, Sri Krishna College of Technology, Coimbatore, India, 641042
s.abirami@skct.edu.in¹

Abstract. In this paper, a new model for estimating the remaining electrical life of the AC contactor is proposed. The model involves an equation that use the rated and operational parameters, material properties and geometries to estimate electrical health of contactor. The variation in the contact resistance as a function of time is found varying in accordance with the remaining electrical life of the contactor. This characteristic parameter along with the data regarding the quantity of material lost at the contact surface has been fed as the sample data for the machine learning model. The sample data is carefully chosen from the contactors operating at different environmental conditions and utilization categories to include wide range of data. Using the collected data from contactors operating in varied environments and utilization categories a Stochastic Gradient Descent Classifier model is generated and used to estimate the remaining electrical life.

1. Introduction

Contactors are electromagnetically operated switches. The functional principle is described as follows: when control power flows through the magnet coil of a contactor, the resulting magnetic field attracts the mechanical contact carrier. By interruption of the coil control circuit, the mechanical contact carrier returns to the starting position. It can control various power loads, primarily motors, electric vehicles, geysers, and lights [1]. Contactors should have high reliability in order to reliably control the circuit. Life expectancy and remaining useful life are studied by many scholars [2, 3]. Residual Electric life is a major indicator of the quality of the contactor. So, estimating quantitative value of expected life of the contactor becomes an important criterion to state the reliability of contactor [4, 5]. The remaining useful life prediction of the contactor is realized quantitatively by this model as shown in Figure 1.
Figure 1. Contactor

Stochastic Gradient Descent (SGD) is a straightforward and effective approach for fitting linear classifiers and regressors under convex loss functions such as linear and logistic regression. This classification model is preferred because of the computational advantage: optimum uniqueness and ease of use for predicting the category of contactor quantitatively.

2. Background Theory
The dynamic process of AC contactor to open and cut off the supply in connected and breaking operations can go up to 1200 times per hour resulting in collision and contact bounce of the iron core thus occurs inevitable wear and tear. High pressure electric arc further makes contact with wear and tear and impacts the electrical and mechanical health of the contactor. On closure, the contact experiences 6 times of its rated current, which can be seen as an important cause of contact erosion [6]. Along with the debris, high temperature in the contact area results in undesired buildup of braze alloys. Excess of braze alloys rises the sides of the contact tip and reduces the thickness of the contact tip [7].

Studies by many scholars recite that the failure of the contactors can be predicted closely examining the operational parameters of the contactor [8]. The contact resistance and contactor compression, as stated in the paper cited above, is helpful in estimating the remaining useful life of the contactor.

3. Modelling of Electrical Health Estimator
A good health estimator should reliably state the health status of the device and remaining lifetime of the device with similar condition of operation. Knowing that there exists a relationship between contact resistance and remaining life cycles from the literature survey, finding the remaining life cycles given that contact resistance is also should be possible. This characteristics relation is further studied and by passing this knowledge to an artificial neural network model, the characteristic feature can be utilized for estimating the remaining cycles of the contactor. For viewing and accessing the results obtained from the model, a mobile application with model deployed on the cloud in the back-end is build and utilized.

3.1. Contact Resistance
The contact resistance is calculated from the voltage and current measured from the contactor under action and is given in the equation (1)

\[ \text{Contact Resistance} = \frac{\text{Voltage measured}}{\text{Current measured}} \]  
(1)

3.2. Remaining Cycles
While modeling the health estimator it is essential to note down each and every cycles i.e., contactor open and close operation. The remaining cycles are calculated as given in the equation (2)

\[ \text{Remaining Cycles} = \text{Completed cycles before contact failure} - \text{Current cycle} \]  
(2)

4. Experimental Procedure
The electrical contactor is connected as represented in figure 2 with the micro-controller. This micro-controller reads and notes down the electrical parameters of voltage and current of the contacts. From which the contact resistance is calculated using Ohm's Law, \( R = V / I \).
In this case of contact resistance, since the voltage between the contacts are due to short-lived momentary arcs, the voltage is given in units of milli-volts (mV). The current measured is found to be in straight amperes (A). Thus, the contact resistance is in units of milli-ohms (mΩ).

Figure 2. Block Diagram

Approximately after 250,000 cycles, most of the tested contacts failed. The failed contactors and the number of cycles they lasted are given in the table 1.

| S. No | Completed Cycles | Contact Resistance Before the failed cycle |
|-------|------------------|-------------------------------------------|
| 1     | 249857           | 11.65                                     |
| 2     | 251456           | 11.53                                     |
| 3     | 250245           | 11.59                                     |
| 4     | 249987           | 11.34                                     |
| 5     | 279823           | 11.84                                     |

The calculated contact resistances along with the remaining cycles until failure are noted down as rows in a comma separated file (sample_data.csv). This file serves as the primary data for the artificial neural network model to get trained.

With 250,000 plus data records each from the five contactors tested, the data-set is ready and the suitable machine learning parameters for processing the data was found out by trial and error with various tried models reaching around only 60% to 70% accuracy. Finally with the SGD classifier...
model which is set at learning rate of 0.03, ReLU activation and 2 hidden layers of 3 and 2 neurons respectively, we are able to achieve negligible training loss of 0.005 and accuracy of 92.1%

4.1. Sample Data

Sample data has a column each for the Contact resistance and remaining cycles. Each rows of the sample data represents the calculated contact resistance and calculated remaining cycles as shown in Table 2.

| S. No | Contact Resistance in mΩ | Remaining Cycles |
|-------|--------------------------|------------------|
| 1     | 9.24                     | 245068           |
| 2     | 10.9                     | 198691           |
| 3     | 10.18                    | 139030           |
| 4     | 11.95                    | 88477            |
| 5     | 10.41                    | 116836           |

4.2. Test Data

In case of test data only one column of contact resistance is present because the model predicts the remaining cycles as shown in Table 3.

| S. No | Contact Resistance in mΩ |
|-------|--------------------------|
| 1     | 9.24                     |
| 2     | 10.9                     |
| 3     | 10.18                    |
| 4     | 11.95                    |
| 5     | 10.41                    |

5. Results

A created scatter chart with dots indicating a set of similar records and red trend-line that indicating the trend of the contact resistance vs remaining cycles is represented in the figure 3. From the graph, the contact resistance is found increasing as the contactor gets older and older. The slope of the trend-line is found to be going down as the number of cycles left before failure is decreasing.

With 250,000 plus records of sample data from contactors operating in different environmental and operating conditions, we are able to categorize contactors based on the quantity of remaining electrical life. With the created model, we can test the contactors and find the remaining life.
Figure 3. Contact Resistance vs. Remaining Cycles

We have created an indicator for the health condition of the contactor given in table 4. A contactor with less than 10% of life left as indicated by the SGD model is deemed to be replaced and is colour coded in red. Table 4 shows the health indicator.

| Colour Code | Reliability Range | Remaining Life | Status         |
|-------------|-------------------|----------------|---------------|
| Green       | 30 - 100%         | > 30%          | OK            |
| Yellow      | 20 – 30%          | > 20%          | Acceptable    |
| Orange      | 10 – 20%          | > 10%          | Cautious      |
| Red         | < 10%             | < 10%          | Needs to be replaced |

6. Conclusion
Based on the results presented above, we conclude that a SGD Classifier model can be used on the AC contactor to find the expected lifetime and health conditions of the contactor. With this model, Electrical Durability of the contactor can be stated spot on with minimum deviation from the actual values. With high accuracy rate, the created model is promising to behold the light of power of neural networks and their applications in the electrical equipment for superior manufacturing, fine tuning and noteworthy testing methods. The mobile application with the back-end having the model helps in easier health estimation reports.

References

[1] J R R Ruiz, A Garcia, J Cusidó and M Delgado 2011 Dynamic model for AC and DC contactors – simulation and experimental validation *Simulation Modeling Practice and Theory* 19, pp 1918-32
[2] S J Ahladas and E J Seminario 1993 Electromagnetic contactor with closure fault indicator U.S. Patent PN5, 204, p 633

[3] Xin Zhou, Lian Zhou and Roger Briggs 2009 Prognostic and Diagnostic Technology for DC Actuated Contactors and Motor Starters IEICE Trans. Electron., E92-C(8)

[4] Haldorai, A. Ramu, and S. Murugan, Social Aware Cognitive Radio Networks, Social Network Analytics for Contemporary Business Organizations, pp. 188–202. doi:10.4018/978-1-5225-5097-6.ch010

[5] R. Arulmurugan and H. Anandakumar, Region-based seed point cell segmentation and detection for biomedical image analysis, International Journal of Biomedical Engineering and Technology, vol. 27, no. 4, p. 273, 2018.

[6] Bao-ying Wang 2015 The Study on the Design of Low voltage AC Contactor in the Electrical System and the Control Applications 4th Int. Conf. on Mechatronics, Materials, Chemistry and Computer Engineering

[7] V Behrens, H Cinaroglu, B Meidel, S Fuchs and Th Hoing, 2019, Analytical Methods to Identify Root Causes for Early Failure of an AC Contactor with Heavy Load Service Life Test IEEE Holm Conf. on Electrical Contacts

[8] Sonam Kumari, Pavan Kumar M and M Muralidhar, 2016, Reliability Estimation of Distribution Components Contactors IEEE PES Asia-Pacific Power and Energy Conf. (Xi'an, China)