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NIA ENWL029

A Statistical Model for Determining Cut-Out Failures

Closedown Report

31 July 2023

VERSION HISTORY

Version	Date	Author	Status	Comments
V0.1	14/06/23	Geraldine Paterson	Draft	
V1.0	21/07/23	Geraldine Paterson	Final	

REVIEW

Name	Role	Date
Ben Ingham	Innovation Technical Manager	26/07/23
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APPROVAL

Name	Role	Date
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CONTENTS

GLOSSARY

Term	Description
LA	Local Authority
LSOA	Lower layer Super Output Area
NARM	Network Asset Risk Metric
NEDWG	NARMs Electricity Distribution Working Group
MOCOPA	Meter Operation Code of Practice Agreement

1. EXECUTIVE SUMMARY

1.1 Aims

The project aims to use the combination of literature review and data analysis around modes of cut-out failure along with laboratory analyses of failed units to generate a condition assessment model to allow targeted replacement of cut-outs in a controlled manner.

1.2 Methodology

The project will examine existing Electricity North West data around cut-out failures, along with publicly available manufacturer data and use this to create a statistical model of cut-out failure modes.

1.3 Outcomes

The literature review showed that the published information related to historical developments and failure mechanisms of cut-outs is quite sparse but using data available from manufacturers and Electricity North West a statistical model could be developed to examine the failure rates of metallic, phenolic and GRP cut-outs.

The project developed and applied these models to Electricity North West and demonstrated that:

- the predicted failure rate that corresponds to that observed,
- a failure intensity can be calculated which enables a projection forward in time,
- there are clusters of more vulnerable assets that require attention,

1.4 Key learning

To improve the quality of the data to feed into the model, Asset Management Policy should be amended to require field staff replacing cut-outs to record:

- Manufacturer of the removed cut-out,
- Location the cut-out was removed from,
- cause of failure from visual examination,

before returning the cut-out to a central store. Additionally, a sample of the returned units should be examined to audit the inspection report and feed into the growing asset database.

1.5 Conclusions

The project produced a statistical model to determine cut-out failures which, whilst already providing valuable information, will require further development before it is used in business as usual. The project outputs will be presented at the NARMs (Network Asset Risk Metric) Electricity Distribution Working Group (NEDWG) to disseminate the learning and discuss the future development requirements.

1.6 Closedown reporting

This project was compliant with Network Innovation Allowance (NIA) governance and this report has been structured in accordance with those requirements.

This report and the associated documents are available via the Energy Networks Association's Smarter Networks learning portal at www.smarternetworks.org or via the Electricity North West website.

2. PROJECT FUNDAMENTALS

Title	A Statistical Model for Determining Cut-Out Failures
Project reference	NIA_ENWL029
Funding licensee(s)	Electricity North West Limited
Project start date	July 2021
Project duration	18 months
Nominated project contact(s)	innovation@enwl.co.uk

3. PROJECT BACKGROUND

Across the UK, DNOs are faced with an aging population of cut-outs in customer premises. With the rise of self-submitted meter readings, and the roll out of Smart Meters, these are no longer routinely observed by trained personnel. As such these units are currently replaced on failure when reported by customers or meter change operatives, leading to disruption and potential safety issues.

The project proposes to take an engineering-led approach by carrying out a combination of literature review and data analysis around modes of cut out failure. This will be coupled with a set of laboratory analyses of failed units to understand how these failure modes manifest. The aim will be to use this information to generate a condition assessment model to allow targeted replacement of cut outs in a controlled manner.

4. PROJECT SCOPE

The project will carry out the following:

Examine existing Electricity North West data around cut-out failures, along with publicly available manufacturer data and use this to create a statistical model of cut-out failure modes. If required a forensic analysis of around 100 units from the Electricity North West license area will be carried out and used to further refine the model.

5. OBJECTIVES

The project objectives are as follows:

- To create a statistical model around cut-out failure modes
- To refine the model following the forensic examination of around 100 units

6. SUCCESS CRITERIA

A statistical model of cut-out failure modes produced to help inform the asset replacement strategy

7. PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

A literature review was carried out which looked to:

- Identify the timeline of cut-out manufacturers, materials, construction and quality standards involved.
- Carry out a failure modes and effects analysis to identify the different cut-out failure modes and degradation mechanisms.
- Develop a strategy for data gathering and cleansing.

Following the literature review our project partner, Kinectrics, liaised with manufacturers and held several workshops with relevant internal stakeholders to identify and collate appropriate data sets. Due to the nature of some of the data sets additional data protection processes needed to be put into place, although this delayed access to the data the additional value it provided outweighed the delay.

Kinectrics carried out some analysis on the data to

- identify any links to materials used in the construction of the cut-out boxes (e.g., phenolic resin-impregnated laminate composites),
- examine and link to Electricity North West's reports on failure and replacement, looking at the manufacturer, age, type of dwelling, geographical location and load,
- carefully distinguish between condition and obsolescence-based removals,
- demonstrate the use of these data to construct draft statistical models.

To help move this analysis forward whilst waiting for the data sets which were subject to data protection processes, Kinectrics used proxy data, such as housing records, combined with the timeline of cut-out types to identify the gaps in data and steer any future data requirements.

The models were initially set up with very simple failure statistics, based on a percentage failure by population at that time. Application of the models, down to Local Authority (LA) level enabled us to see LAs where certain cut-out types are likely to be different in population to the average. Early work on further increasing the granularity showed that this could be extended to the Lower Super Output Area (LSOA) level. This "heat-map" of cut-out type distribution could then be validated through a comparison with substation age and failure reports.

The project plan originally included forensic examination of cut-outs to inform the model development but on reflection it was concluded that the forensic examination of cut-outs where their provenance was doubtful was unnecessary and sufficient information on failure modes exists in the literature. Therefore, this element was removed from the project.

Building on the initial models, Kinectrics then constructed draft statistical regression models to model, predict and characterise the failure rate based on chronological age, "effective age" based on asset condition, manufacturer and material composition.

This work used publicly available data sets for the number of consumers across the UK and coupled that with housing data, to provide both LA and LSOA data sets of the age distribution

of housing. These data sets provide reference points for the total population when there were changes in technology.

Cut-out replacement data provided a more accurate estimate of the changes seen in the field.

MOCOPA data that covered over one million units enabled a representative sampling of the cut-out population over 2019-2021 and strongly indicated a majority of phenolic cut-outs in the overall population, closer to 60%, overturning some earlier assumptions which considered only 35%.

Currently, the model is consistent with total cut-out population, replacement rates of metallic and phenolic cut-outs and a MOCOPA data set.

We have not specifically constructed health indices for these assets, but by assigning a ranking to the age distribution, this could be implemented, to provide further granularity and identify areas at higher risk.

8. THE OUTCOME OF THE PROJECT

The literature review conducted by Kinectrics has shown that the published information related to historical developments and failure mechanisms of cut-outs is quite sparse. The information is either retained by manufacturers that are still operating to date or has disappeared with manufacturers that no longer exist.

The literature review also showed that certain cut-out issues can be detected by authorised meter operatives during meter replacements, which are reported back to the DNO. However, these issues do not necessarily relate to cut-out failures. Further research on identifying the most common failure mechanisms experienced by cut-outs concluded that the most common failure modes are overheating and short circuits caused by overloading, poor electrical contact, and moisture ingress.

The detailed output from this review is contained in the WP1 report on the Electricity North West website.

The project developed a statistical model to examine the failure rates of metallic, phenolic and GRP cut-outs. The model used:

- a consistent body of data relating to cut-out replacements from 2019 – 2022, where two of these years also enabled the ratio of the three technology failure rates to be established,
- a large smart meter (MOCOPA) database that conclusively showed that a majority of phenolic cut-outs were in good service.

By assuming a single Weibull-like replacement distribution function, and treating both metallic and phenolics cut-outs on a year-by-year basis, where the constraints were offered by:

- the number of cut-outs in the Electricity North West area from 1920 through to 2022,
- the number of metallics in service in 1966, at the time of the technology change over to phenolic cut-outs,
- the total number of consumers in 1993, at the time of the technology change over to GRP cut-outs,

- the current replacements rates, and
- the current ratio between phenolic and metallic cut-outs,

provided a constrained model to fit the population and replacement rate for these components based on perceived chronological age derived from the housing age distribution. The analysis showed that when years away from the technology change over, the tail of the Weibull distribution could be approximated by a linear proportional rate.

However, the model has not been able to assess an “effective age” based on asset condition, manufacturer and material composition. There is currently insufficient data to assess the effect of age- or condition-related on changing the failure rate.

As the model was “derived” from the Electricity North West cut-out population, increasing year-by-year, this same approach was applied to the number of increasing households by year by LA and LSOA. The latter is valuable as the variance in the number of households per LSOA is comparatively small, offering a normalised unit.

When the Electricity North West-wide methods were applied to the LAs and LSOAs, there were significant differences across the LAs and LSOAs, clearly related to various new builds. By relating the relative populations to the Electricity North West mean, the areas where higher than average phenolic and metallic populations are present become clearly visible.

Application of these models to Electricity North West datasets and to LSOA levels of granularity shows:

- a predicted failure rate that corresponds to that observed,
- a failure intensity, that then enables a projection forward in time,
- a clustering of more vulnerable assets that require attention,
- an easy correspondence from postcode, to LSOA, to current excess of phenolic cut-outs over the Electricity North West mean for total number and rateable value of households.

Currently, the model is consistent with total cut-out population, replacement rates of metallic and phenolic cut-outs and the MOCOPA data set. Additionally, the model of cut-out populations provides estimates of current and near-future replacement rates, “heat” maps of any particular technology at the LSOA level, a health index, using housing data at the LSOA level and hence, LSOAs that provide higher risk.

To further improve the model Kinectrics recommend the continued acquisition of good quality cut-out replacement data ensuring that emergency, reactive and campaign replacements are captured and consolidated in a single asset database. With this increased data an algorithm can be developed that adjusts the failure rate parameters to “match” replacement location and re-evaluates the risk profile for a given location.

The WP3 and WP4 reports on the Electricity North West website provide the full details on the data analysis and model development.

9. REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

Due to the nature of some of the required data sets additional data protection processes needed to be put into place, this delayed access to the data but the additional value it provided outweighed the delay.

The project plan originally included forensic examination of cut-outs to inform the model development but on reflection it was concluded that the forensic examination of cut-outs where their provenance was doubtful was unnecessary and sufficient information on failure modes exists in the literature. Therefore, this element was removed from the project.

10. LESSONS LEARNED FOR FUTURE PROJECTS

It is important to identify the available data and any data protection requirements early so appropriate measures can be but in place.

To improve the quality of the data available Asset Management Policy should be amended to require field staff replacing cut-outs to record:

- Manufacturer of the removed cut-out,
- Location the cut-out was removed from,
- cause of failure from visual examination,

before returning the cut-out to a central store. Additionally, a sample of the returned units should be examined to audit the inspection report and feed into the growing asset database.

11. PLANNED IMPLEMENTATION

The project produced a statistical model to determine cut-out failures which, whilst already providing valuable information, will require further development before it is used in business as usual. The project outputs will be presented at the NARMs (Network Asset Risk Metric) Electricity Distribution Working Group (NEDWG) to disseminate the learning and discuss the future development requirements.

12. DATA ACCESS

Electricity North West's innovation data sharing policy can be found on our website.

There has been no data gathered so far during the project.

13. FOREGROUND IPR

There is no foreground IPR associated with this project.

14. FACILITATE REPLICATION

As stated previously, the project outputs will be presented at the NARMs (Network Asset Risk Metric) Electricity Distribution Working Group (NEDWG) to disseminate the learning to the GB

DNOs. This will allow the other networks to review the project and assess how they could implement the findings.

15. OTHER COMMENTS

None.