Predicting the impact of future decarbonisation strategy on railway electrical control rooms

Charlotte Kaul[1], Joanne Smyth[1] & Christopher Patrick[2]

[1]SYSTRA Scott Lister, [2]Arcadis

ABSTRACT

In 2018, the Department for Transport (DfT) challenged the rail industry to remove all diesel-only trains from the network by 2040. Therefore, over the next 20+ years, the railway will need to undertake large scale electrification programmes in order to achieve this. An increase in amount of electrification on the GB rail network will in turn create an increased demand for monitoring and maintaining this infrastructure. For people to access trackside equipment in electrified areas, electrical isolations are required. The electrified rail network is managed by Electrical Control Operators (ECOs). They are responsible for the electrified network under their control, including granting isolations. It is therefore essential to understand the processes undertaken in Electrical Control Rooms (ECR) and predict the impact that increased electrification will have on ECOs.

A workload assessment was undertaken to understand the current workload of ECOs in York ECR to create a baseline model that accurately reflects their planned workload relating to granting isolations. This model was then used to predict the impact of future changes following electrification of new areas. The key inputs to the baseline model were number of isolations, task occurrences, task durations, and task complexity. This model was then used to predict the impact of future electrification projects on ECO workload and inform decisions about future requirements for ECRs and ECOs. The predictive model had the key inputs of baseline number of isolations, baseline and additional single-track kilometres (STK) introduced, future increases to the complexity of the infrastructure.

KEYWORDS

Workload, Electrical Control Room, predictive workload, railway operations, electrification

Introduction

In June 2019, the UK government set out its legal commitment to achieve ‘net zero’ greenhouse gas emissions by 2050. In respect of the railway, the DfT challenged the rail industry in 2018 to remove all diesel-only trains from the network by 2040.

For rail to support the UK in achieving its net-zero legislative target, diesel operation will need to reduce and potentially cease. For areas of the network with significant freight flows or long-distance high-speed services, electrification is the only technology currently able to support these service types. Analysis suggests that electrification is also the best whole life cost solution for more intensively used areas of the network (Network Rail, 2020). Electrification is typically measured in Single Track Kilometres (STKs). STK is the absolute length of track within a route kilometre (i.e. one route km of two track railway is 2 STKs). It is estimated that an additional 13,000 STKs of electrification are required to achieve government & DfT targets. This increase in electrification will in turn create an increased demand for monitoring and maintaining the infrastructure.

For people to access trackside equipment in electrified areas, electrical isolations are required. The electrified rail network is managed by Electrical Control Operators (ECOs) who are based in 13 Electrical Control Rooms (ECRs) across the network. They are responsible for the electrified network under their control, including granting of isolations to enable maintenance work to take place safely. It is therefore essential to understand the processes undertaken in ECRs and predict the impact that increased electrification will have on ECOs so that operational strategies can be put in place to provide the additional support required.

York ECR is one of the 13 ECRs and was the focus of this study. There is a concern that York ECR may be unable to cope with any more electrification in its current state. Many electrification projects are planned over the next 20 years which will increase demand on York ECR. Plans are underway to build a new ECR at East Midlands Control Centre (EMCC) in Derby which would alleviate some of this additional workload demand. This paper outlines a baseline assessment of current operations at York ECR that was undertaken to inform future requirements to meet the additional increased demand. This work was undertaken on behalf of Network Rail.

Similar work has been carried out in other ECRs across the UK, including Cathcart and Crewe. Both the Cathcart and Crewe studies have been integral to understanding the workload and staffing demands of those ECRs as new electrification projects are planned. Each ECR in the UK has its own processes and ways of working, so individual workload studies are required for each location. This project has taken learning from these previous studies and built on existing findings and workload models, adapting them for the unique processes and challenges of York ECR.

Operational Roles and Responsibilities

One of the core responsibilities of ECOs is to monitor the system under their control. At York ECR, 92 substations are monitored across eight different lines of route spanning roughly 2,600 STK. ECOs must monitor the system status and alarms for this area throughout their shift. They must also respond to phone calls and emails. During a Saturday night shift (the busiest shift for ECOs) the system generates around 400 alarms of different levels of urgency and priority.

The peak demand for isolation requests is on a Saturday night shift and there are often situations where the number of isolation requests exceeds the capability for the ECR to manage them. In this situation, the number of isolations must be capped to allow the ECR to manage the workload.

For each isolation there is a set of paperwork that contains safety critical information about that unique isolation. Some of these forms are to be completed by ECOs with signallers and some are to be completed with the person in charge of each site where an isolation is planned (referred to as a Nominated Person (NP)). At the beginning of the shift, ECOs receive phone calls from the NP for each isolation. Their first task is to run through the paperwork (Form B) with the NP and confirm details. Next, ECOs will call signallers to issue the next form (Form AE part 1) requesting a block to electric traction for each isolation. They then wait to receive a call back from the signallers to complete part 2 of the Form AE which confirms the block to electric traction. This allows the ECOs to operate circuit breakers on the screens in front of them to grant the isolation. They ECOs can then call the NPs to issue Form B part 1 to them instructing them to apply local earths and commence work. All of these tasks tend to occur between 19:00 and 02:00, with a peak in workload between 13:00 and 00:00 when they are granting isolations. At York, these tasks are not formally split between ECOs to manage workload (e.g. geographically) and the ECO on shift may be required to manage an isolation from any location. This can make the tasks particularly complicated because there is a large amount of local instructions and of paperwork.

From about 05:00 onwards, isolations begin to be handed back (meaning ECOs can revoke them). This begins with the NP ringing to issue Form B part 2 and 3 confirming the completion of works.

This then allows the ECOs to operate the circuit breakers on the screens in front of them again to revoke the isolation. They then call the signaller to issue the Form AE part 3 cancelling the block to electric traction. Often ECOs are busy revoking isolations when their shift ends which can lead to delays to handing back the railway while ECOs carry out a handover with the next shift.

ECOs are not only responsible for granting and revoking isolations, but they also manage a detailed planning and preparation process in the week preceding the isolation. This is another form based iterative process in which the ECOs work with isolation planners. These planning shifts take place only a few days before the isolations occur which does not allow much time to resolve any issues. However, the planning shift does help ECOs to familiarise themselves with the upcoming isolations.

Method

This assessment was carried out to establish a baseline of current workload for York ECR and to inform modelling of workload prediction for future electrification and infrastructure projects. This was achieved through:

- **Review of previous reports.** Previous workload studies have been carried out at Cathcart and Crewe ECRs. The workload model developed for these projects was used as a basis for this work.
- **Workshops.** Three workshops were held with ECOs at York. The purpose of the first two workshops was to confirm details of the isolation workflow process, confirm task durations and frequency and discuss any workload influencing factors. Information gathered from these workshops has been used as one of the inputs for developing the baseline workload model.
- **Desk-top analysis.** A sample of isolation planning data was analysed to identify average isolation start and end times. Data downloads from the system used by York ECR (SCADA) were also examined to identify quantity, timings, and types of alarms that ECOs receive.
- **Time on task data collection**. Data collection was conducted during a Saturday nightshift on Saturday 21st August to develop data on standard task timings to input into the workload model. This shift was selected to ensure that the observations were undertaken at the most demanding period of time for the ECR. Two ECOs were on shift at the time of assessment with a total of thirty isolations to manage during the shift. Two Human Factors consultants worked on-site to carry out direct observations and collect data.
- **Subjective workload assessment.** Integrated Workload Score (IWS) subjective workload scale (Pickup et al., 2005) was used due to reservations regarding the intrusion that other more intrusive workload rating scales would create during a shift given the level of workload currently experienced.

The York ECR workload model was adapted from a tool for the modelling of ECO workload developed by Arcadis in 2018 as part of the Northwest Electrification Project. The tool was based on Time-on-Task observations of over 100 isolations undertaken at Crewe ECR. These observations identified the tasks involved in the application/removal of isolations and the sequencing of those tasks relative to the time of request for application/removal. Task sequences were built to represent simple, complex, and “GBSIPS” isolations (GBSIPS isolations involved additional complex processes for the ECO).

An Excel tool was built to allow a user to input the start time for different complexities of isolations and to modify the average duration of the activities within the task sequences based on locally collected data. The Excel file automatically populates a graph of the controller's activities based on the specified inputs. The graph counts minutes per hour of activity on the Y axis across a nightshift. A threshold value is displayed representing 80% occupancy based on the number of ECO's. The tool also incorporates aggregated IWS (Integrated Workload Scale) data to overlay against the activity graph to support analysis.

After successful application at Crewe ECR the tool was subsequently re-applied at Cathcart ECR with minor modifications. These included including a facility to assign workload to individual controllers and amending the task sequences to match processes observed at Cathcart. On conclusion of this project the Excel file was shared with Network Rail to allow further application to other projects. At the time of publication Arcadis is working with Network Rail to develop the tool into an online format with dashboard display output.

For the York ECR study, this tool was developed further through a Saturday nightshift observation, analysis of isolation planning data, data downloads from SCADA, and workshops with ECOs. Firstly, additional tasks were captured and included in the model in order to better understand the full range of ECO responsibilities. ECO workload naturally peaks during the granting and revoking of isolations, but it is important to understand the additional tasks ECOs carry out when not directly managing isolations. Secondly, more emphasis was placed on the location specific challenges and complexities that ECOs deal with when managing isolations.

York ECR supervises a total of 92 substations, many of which are extremely complex. This means that isolations in certain locations present specific complexities, and therefore take more time for ECOs to manage. A workshop was held with the ECOs to identify key complexity factors for each substation. These complexity factors are:

1. **Local instructions.** For example, feeding irregularities, specific instructions for filters and transformers, interfaces with National Grid, etc.
2. **Auto-transformer feeding (ATF).** ATF creates more switches for ECOs to manage.
3. **Principal Supply Points (PSPs)**. PSP mean that standby signalling supplies need to be altered as part of the isolations process on a nightly basis.
4. **Associated depots**. Depot interfaces can be affected when feeding arrangements have to be altered. This can cause delay to getting paperwork back from signallers ultimately delaying work.
5. **Static Frequency Converter (SFC)**. SFC sites take longer to implement isolations as they have more circuit breakers to operate.
6. **Signalling, maintenance, & ECR boundaries.** Isolations spanning more than one maintenance, ECR, or signalling boundary requires additional phone calls, forms and coordination with more people.

For the purpose of this analysis, any isolation with none of the above complexity modifiers was classified as 'simple'. Isolations with one type of complexity modifier was classed as 'standard' and any with two or more was classified as 'complex'. Of the 92 sites, 52 of the sites managed by York ECR are 'standard' or 'simple' sites to manage. The remaining 40 are 'complex'. In terms of the model, 'simple' 'standard' and 'complex' isolations have different task durations.

The workload model assumes that the task profile for planned workload surrounding granting and revoking isolations should never account for more than 80% of total time available during the shift.

In addition to granting and revoking isolations, ECOs are expected to monitor the system, respond to faults, monitor the email inbox, keep the ECR log updated, as well as manage any other unplanned tasks. By capping the planned isolation related workload at 80%, this effectively allows each ECO 20% of their time (12 minutes per hour) to deal with faults or other unplanned events. In addition to managing unplanned work alongside planned work, requirements for breaks to manage fatigue and breaks must also be considered.

The workload model makes the assumption that forms are received and issued in accordance with the pattern observed during data collection. The workload model also allocates time to the ECR as a whole and does not consider how the work is split between roles. The model also assumes that ECOs observed during the site visit demonstrated the average level of competence of those undertaking duties within the ECR. Actual task duration may be higher than indicated by the model where trainees or less experienced staff are undertaking duties.

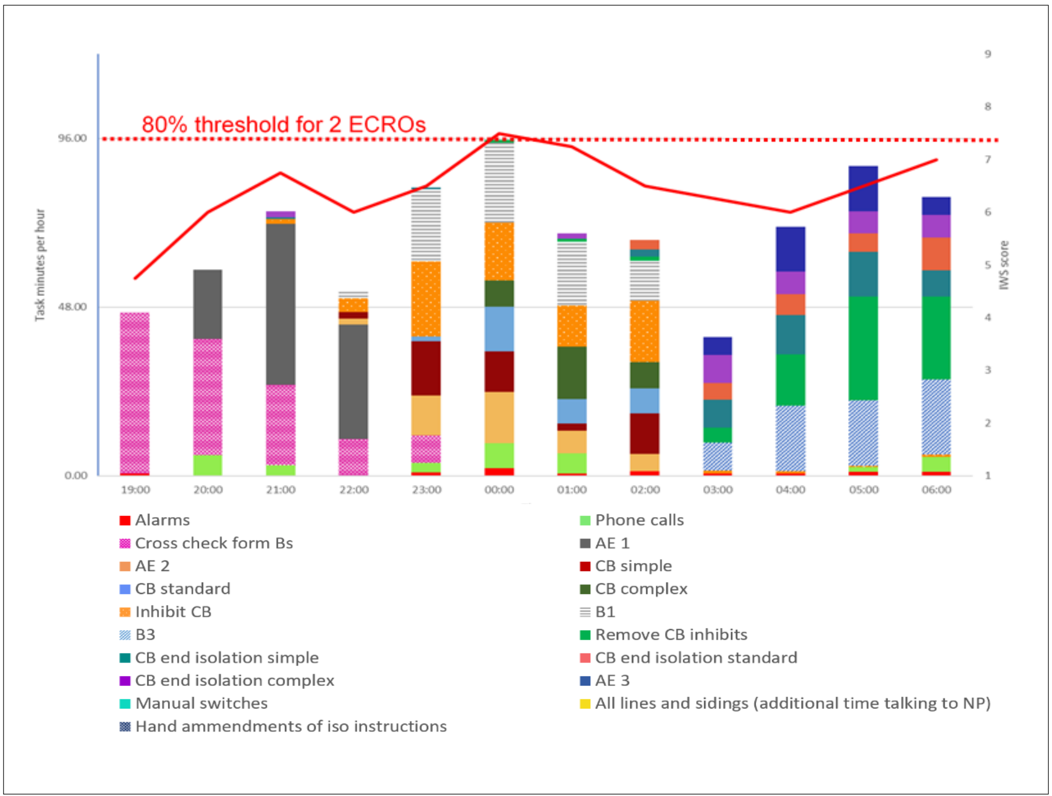
Baseline Model Results

The baseline workload model was used to model several scenarios. A Saturday nightshift with 2 staff and the number of isolations capped accordingly at 30 is displayed in **Error! Reference source not found.**. The split of simple, standard, and complex isolations reflects what was observed during the site visit and is displayed in

Figure 1: Baseline workload scenario with subjective workload overlaid

Table 1.

The workload model illustrates that the workload was acceptable for 2 ECOs to manage within the 80% threshold. The workload model was supported by IWS data collected from the ECOs throughout the shift. When averaged and overlaid on the baseline model, as shown in **Error!**



Reference source not found., this data illustrates that ECOs' perceived workload was aligned with the workload levels indicated by the workload model, thus supporting the efficacy of the model.

Figure 1: Baseline workload scenario with subjective workload overlaid

Table 1: Number of isolations and complexity configuration

Variable	Value
No. of total isolations	30
% isolations simple	62%
% isolations standard	28%
% isolations complex	10%

Predictive Model Method

The baseline workload model was used to make predictions about how future electrification projects would affect ECO workload at York ECR. The key inputs to the predictions were:

- **Isolation numbers.** For the predictive workload model, the current uncapped demand for isolations was used as a baseline.
- **Additional STK added by future electrification projects.** It can be assumed that as STK increase, so will the number of isolations required to maintain the infrastructure. Therefore, the predictive model uses the cumulative % increase in STK introduced by a comprehensive list of future electrification projects until the year 2050 to uplift the number of expected isolations that will be required.
- **Complexity of infrastructure.** Many of the future projects will increase the complexity of infrastructure already controlled by the ECR, as well as introducing additional STK with more complex infrastructure. We amended the complexity classifications of existing sites to account for the increase in control points following a selection of projects that will roll out in the near future.

Predictive Model Results

Due to the significant increase in future demand, a decision has been made to build a new ECR in Derby to share the workload with York. Further into the future, there may be a requirement to split the work carried out at York into an additional ECR at this location. Because of the potential need to split York ECR, and the agreement to build an additional ECR at Derby, the baseline workload model was split out into who predictive models to inform requirements for both York ECR and Derby ECR.

The existing complexity spread of York and Derby was determined through a workshop applying complexity modifiers to the sites controlled by each ECR (discussed in the introduction). However, it is understood that future projects will increase the complexity of the infrastructure so a new complexity spread was used in the predictive model. Table 2 outlines the current and future complexity spread of sites controlled by York and Derby ECRs.

Table 2: Current and future complexity spread for York and Derby

	York	Derby

	Current Complexity Spread	**Future Complexity Spread**	**Current Complexity Spread**	**Future Complexity Spread**
Simple	54%	22%	20%	20%
Standard	28%	51%	40%	35%
Complex	18%	27%	40%	45%

Using the current uncapped demand for isolations as a baseline, the model predicted what the demand for isolations will be in future following new electrification projects which introduce additional STK to York and Derby ECR area of control. **Error! Reference source not found.** illustrates the predicted increase in demand for isolations until 2050.

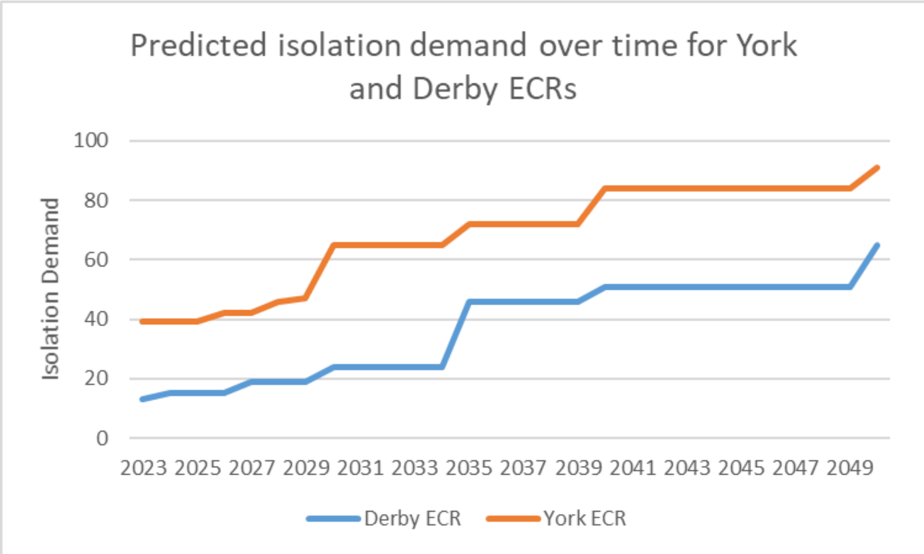


Figure 2: Predictive isolation demand over time for York ad Derby ECRs

The predictive model combines the predicted isolation demand with the future complexity spread and calculates how many ECROs would be needed to manage that level of workload. This information can be used to inform decision around ECR design and layout, as well as future staffing decisions.

However, in the coming years several factors may affect isolation processes and consequently impact the accuracy of these predictions. These are to be monitored and the predictive model reviewed if any changes are made to the process. One of these factors is remote securing. Remote securing of switches is a potential new process for granting isolations, planned to be introduced by 2029. The remote securing process has successfully been trialed 'off infrastructure' and will change the current processes for implementing isolations.

The new process will create an additional task for ECOs who will be required to operate earth switches as well as normal circuit breakers using the SCADA system. However, the new processes will also streamline the paperwork issuing process and reduce the amount of time spent on the phone with NPs. It is likely that if there is some additional switching required for the earths, then that will be compensated for by savings in the paperwork timings. In the future, there may also be the potential to implement switching schedules where isolations can be pre-programmed into SCADA allowing the system to automatically carry out switching to provide greater benefits. In the longer term, future technology / automation and/or AI improvements that eliminate many of the tasks altogether.

Many of these changes may improve isolation processes and reduce the dependency on physical paperwork. This will become increasingly important as the number of isolations continues to rise, as it becomes infeasible for ECOs to complete, store, and locate such large quantities of paperwork.

Finally, at York ECR it will become increasingly important for the workload and tasks to be split between the ECOs on duty during each shift. Currently with 2 or 3 ECOs on shift on a Saturday night it is possible for them to respond to calls from the all lines of route as they are received. However, with more ECOs on shift this will become confusing and therefore needs more structure.

Conclusion

Over the next 20+ years, the railway will need to undertake large scale electrification programmes in order to support the UK in achieving its net-zero legislative target. It is essential that the industry understands the impact this will have on ECO workload and ensures that ECRs have the capacity to manage this additional demand.

This study sought to understand the workflows undertaken by ECOs at York ECR and identify both current and potential future issues with ECR processes. It modelled a baseline of current planned workload at York ECR, whilst leaving 20% capacity for unplanned tasks. This model supports the view that that action is required to support introduction of additional STK to the York ECR area of control.

The baseline model was then used to make predictions about future workload considering a set of electrification projects due to take place between now and 2050. Due to the amount of future electrification scheduled, a new ECR has been planned for Derby which will take some of York's existing infrastructure and some future electrification projects too. The workload model shows the number of ECOs required on a Saturday night shift at York ECR and Derby ECR, and when additional staff will be required to support the additional new electrification.

The baseline and predictive models will need to be monitored and updated in light of any future changes to isolation processes. The current processes for granting and revoking isolations are paperwork driven and there are several factors that may lead to them being updated and improved, such as new Network Rail standards and remote securing.

Ensuring that ECRs are properly staffed is essential to meeting the industry's targets of reducing diesel only trains from the network. However, it is more complex than simply increasing the number of ECOs on shift. It is important that the processes and workflows are understood, and consideration is given to how effective they will be one the demand for isolations increases.

ECO workload should be considered in a holistic way that captures both the basic workload demands, and issues and vulnerabilities in the way things are done. This type of understanding will ensure that the rail industry is fully prepared to rise to the challenge of future decarbonisation strategy.

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