PETERBOROUGH GROUND FRAME PANEL– A NOVEL DESIGN DEVELOPMENT APPROACH

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SUMMARY

Atkins' Signalling Systems team in India has been delivering work packages of Detailed Signalling Design for the UK main line railway for over a decade. Recently the team has delivered designs for Peterborough Line Speed Increase Project. The main scope of this project was to upgrade tracks to improve the permissible line speed for trains near Peterborough station.

Within the area of upgrade there was an existing mechanically operated ground frame (local control for sidings). The mechanical ground frame was assessed and found to be incompatible with the proposed upgrade to deliver the line speed enhancements and hence had to be decommissioned and replaced with a new Ground Frame Panel with power operated points.

This paper aims to describe the technical challenges associated with the mechanical ground frame renewal and the design solution proposed by the author using novel circuit design. The design solution produced by the author followed a systematic approach to a novel design solution and ensured minimal interference to existing infrastructure.

This paper concludes with guidance for younger members on best practices for tackling such situations in the future projects.

1 INTRODUCTION

Atkins' Signalling Systems team in India (also known as the Global Design Centre (GDC)) had successfully delivered all packages of detailed design for the 'Peterborough Line Speed Increase' project in 2018 and the project had been commissioned in March 2019. The design for the Fletton Ground Frame Panel was conceptualised, designed and verified by GDC team. The aim of this paper is to share the lessons learnt to a wider team to reiterate the importance of following a well-defined systematic approach to resolve complex system solutions.

2 PROJECT BACKGROUND

The Peterborough Line Speed Increase is a project required the completion of a package of detailed signalling design to support the implementation of Line Speed Enhancement on the Down Slow line in the vicinity of Peterborough Station.

Peterborough station lies on the East Coast Main Line (ECML) at approximately 76 ½ miles from London along Engineering Line Reference (ELR), East Cost Main Line Engineering Line Reference 1 (ECM1). The ECML including Peterborough platform areas are currently electrified, by a 25KV overhead traction system.

All signalling in the area affected by this project is controlled from Peterborough Signal Box (SB) with signalling assets prefixed with the signal box identifier 'P'. Peterborough SB has a combined eNtrance and eXit (NX) type signaller's control and indication panel, interfaced to three Solid State Interlocking (SSI) interlockings controlling the station area and all approaches.

The proposed line speed enhancements work provided an alternative routeing option for Long Distance High Speed (LDHS) passenger services travelling northwards from Kings Cross with associated capacity benefits on the ECML and potential journey time improvements.

Figure 1: Peterborough location map

3 DESIGN SCOPE AND CHALLENGES

Figure 2 below shows the track layout in the area adjacent to Peterborough station. Figure 3 below shows an extract of the signalling scheme plan for the project.

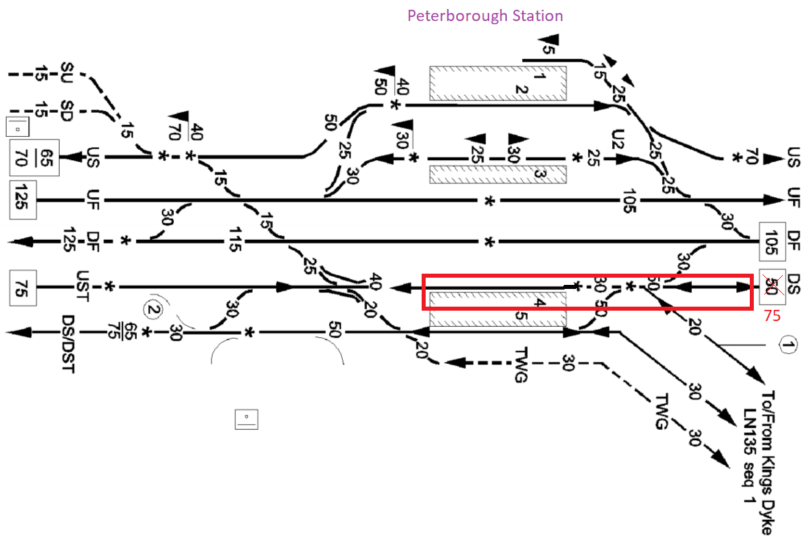


Figure 2. Peterborough station layout – Project area is highlighted

The proposed arrangements allowed LDHS services to access Peterborough Station Platform 4 faster, when local services are held on the Down Fast at signal P423 waiting to cross the Up Fast to access Platforms 1 and 2. This way the Down Slow route will become the primary route into Platform 4. (Figure-3)

The line speed enhancement at Fletton Junction will also increase the capacity on the Down Fast for non-stopping LDHS services and semi-fast suburban services that will turn back towards London in Platform 1 or Platform 2. This is achieved by reducing the time of Fletton Junction occupancy for diverging routes, so the next fast train will not have to reduce the speed on approach to the junction.

Points 1198 with an existing 40mph turnout will be replaced with a 75mph turnout. Fletton 1194 Ground frame release to the Nene Valley Railway will be modified with upgraded track and power operated points provided to strengthen the layout.

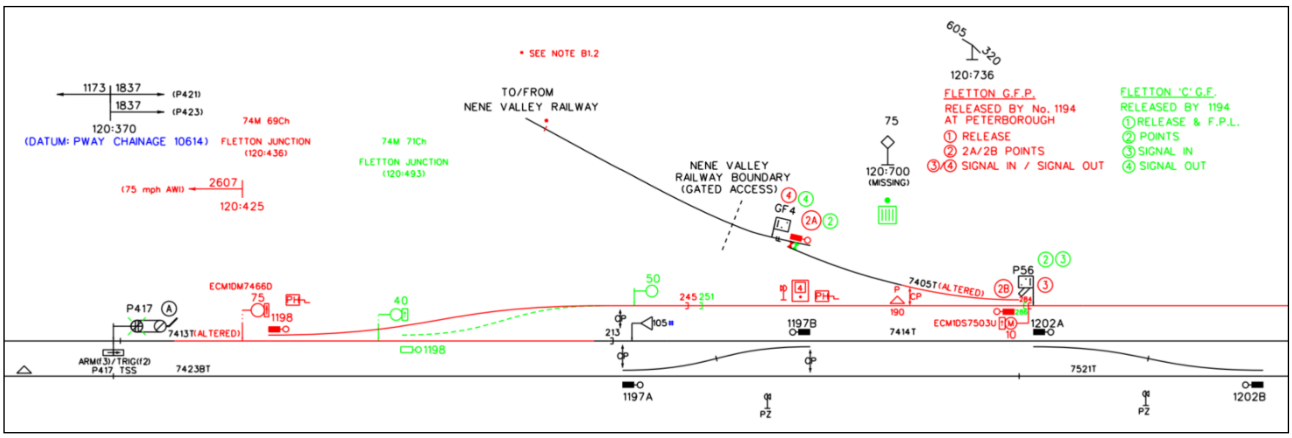


Figure 3. Scheme Plan Layout showing alterations proposed

3.1 Mechanical Ground Frame – Technical Information

A mechanical lever frame is designed to harness mechanical advantage to operate switch points, signals or both under the protection of the mechanical interlocking logic. The levers are connected to field assets such as Signals, Points etc via solid pipes or taut wires such that the full travel of the lever will reliably cause full travel in the asset.

Each lever is engaged with the interlocking logic such that movement of the lever is only possible when all necessary conditions for safety are met. To assist the operator in determining their functions, each lever in a frame will generally be uniquely labelled, one common method being to number the levers in order from left to right. The asset being controlled is also given the same identity.

Figure 4. A typical three lever Mechanical Ground Frame

In Peterborough Line Speed Increase project, the existing mechanical points 1194 is renewed with longer layout to achieve the line speed increase desired. The ergonomics assessment concluded that after the renewal of 1194 points, it would not be feasible to control these points from existing Mechanical lever frame due to increased human effort from Fletton Ground Frame (GF). Hence it is proposed to replace with a **Ground Frame Panel.**

3.2 Ground Frame Panel – Technical Information

A Ground Frame Panel is equivalent to a Mechanical Ground Frame in the provision of the interlocking function of local signals and points but uses Push Buttons or two position switches mounted on a control panel housed in a local trackside equipment housing for the operation of the trackside assets. This allows the trackside assets to be power operated improving reliability, area of operation and reducing the human effort significantly.

A Ground Frame Panel is different from the Mechanical Ground Frame in the following ways: -

- Control of the Mechanical Interlocking is not possible from the electrical control panel.
- Hence the Interlocking of signals and points is achieved through the use external relay based control circuits located in the trackside equipment housing.
- It is possible to provide visual indications of the asset condition in the form LED lights in a Ground Frame Panel. It would very difficult to provide these indications on a Mechanical Ground Frame.

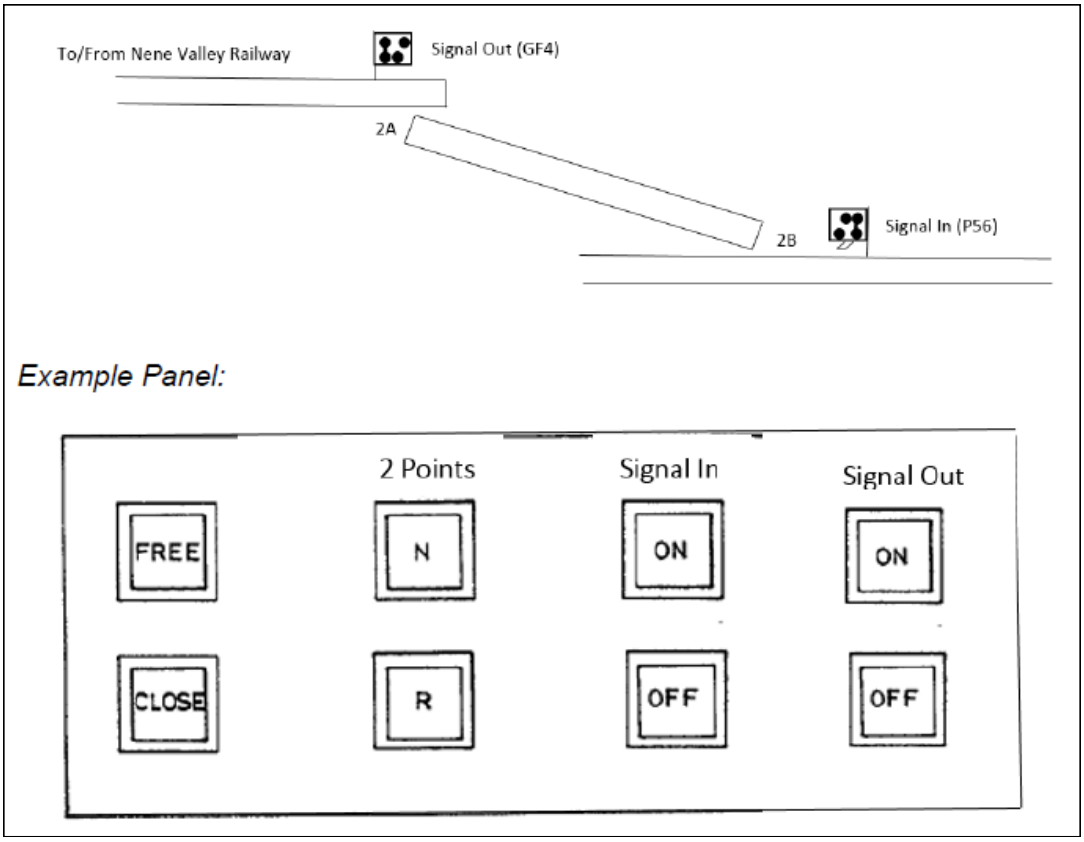


Figure 5. Ground Frame Layout and Push Button Panel

3.3 Ground Frame Panel – Design Challenges

A Ground Frame Panel is an operator friendly alternative of Mechanical Ground Frame as recommended in the Ergonomics assessment; The design of the Ground Frame is significantly different in comparison to Mechanical Ground Frames.

The key design challenges identified by the designer at the start of the design were: -

- Ground Frame Panel is very rarely used in UK and no previous design experience on Electrical Ground frame panel within Atkins signalling design teams.
- The client typical drawings don't cover the project requirements and hence novel circuits to be drawn from first principles.
- The operational requirements are bespoke and were not clearly defined. Hence designer had to develop operational proposal that was reviewed and agreed by the operators.
- Existing anomalies identified during principles review to be resolved.
- No change is to be made to the main interlocking, Peterborough SSI in connection with the introduction of Ground Frame Panel.
- Parallel design activities, the design of Ground Frame Panel is to be progressed in parallel to the other design documents to maintain the programme.

4 SEVEN DESIGN PRINCIPLES

Utilising the Atkins Technical Delivery Framework which details a series of seven high level Engineering Design Principles, a systematic approach was employed in developing a formal response to the challenge statements shown below, this ensured that the key requirements were captured early to enable the design of the best possible technical solution given the project constraints.

Understanding and clarifying the project

1. We have fully understood customer requirements, assessed these as being reasonable and translated them into a clear basis of design.

2. We have assessed what resources (e.g., key people, skills, accommodation and tools) are required and confirmed they are available.

3. We have understood our scope of work within the project lifecycle and have split this into appropriate phases. The work breakdown structure and deliverables for each phase are well defined.

4. We have understood and communicated roles and responsibilities for our operations and our customer's and any third parties such as a regulator.

Quality control measures to assist in undertaking the project

5. We have put in place suitable processes for managing change, risk and information flow.
6. We have put in place suitable processes to ensure that our deliverables meet the design requirements.

Enhancing and improving the business on completion of the project

7. We will capture lessons learned during the project and feed these back into our design processes.

5 DESIGN SCOPE AND CHALLENGES

Once the technical challenges were identified and a design solution proposed a detailed programme of works was developed to ensure the delivery was in accordance to the design plan. The narrative below describes how the challenges were managed by following the design principles completely.

5.1 Understanding the Operational Requirements

The designer analysed the layout and working principles of the circuits proposed and developed the detailed operational proposal. This operational proposal was reviewed and agreed with the operators via formal review process. This operational proposal was documented in the design in a very simple language for the operator to follow while operating the ground frame. The designer had also created a flowchart to describe the operational requirements. **Design Principle #1**

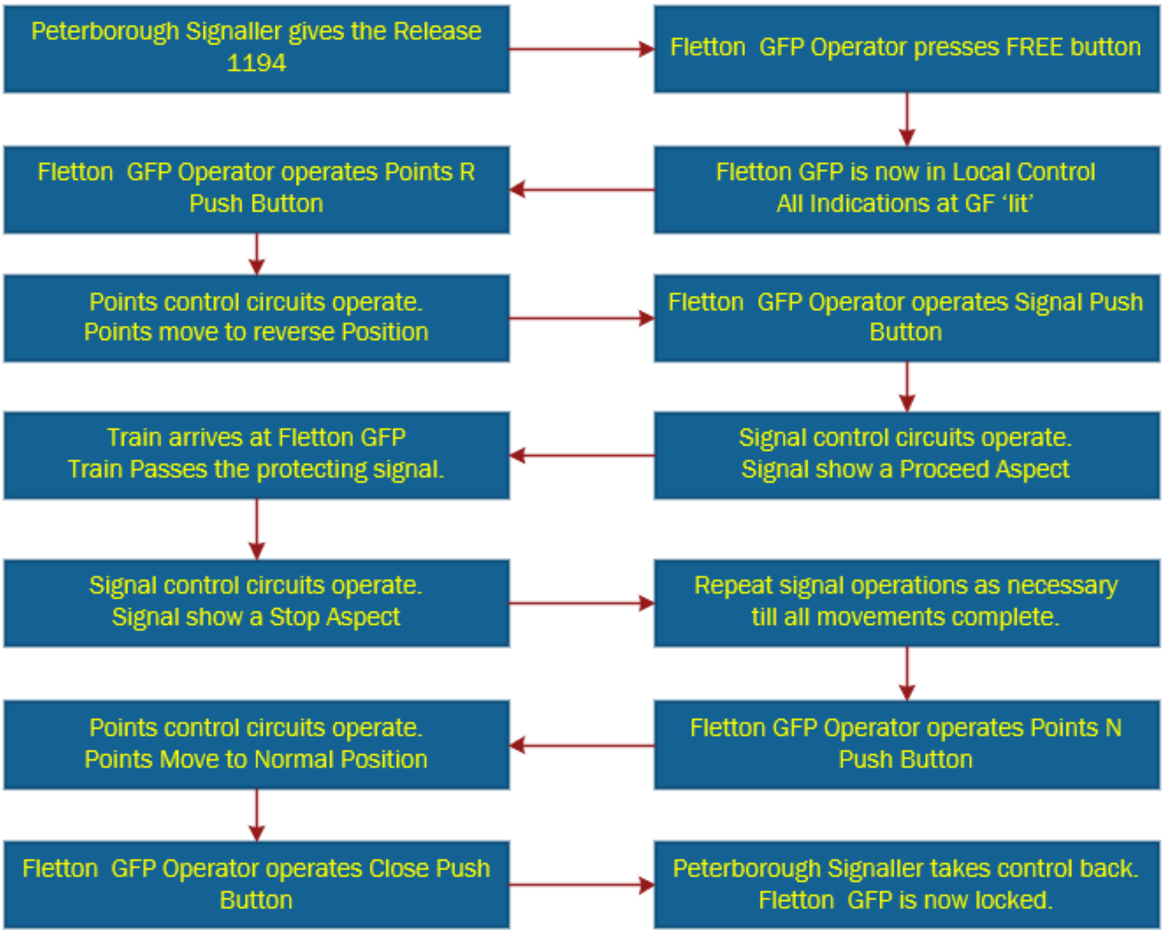


Figure 6. Flowchart describing the operational scenario by the designer

5.2 Understanding the Client Standard Diagrams and Developing Novel Circuits

Once the Operational proposal was agreed, a detailed study was carried out on the client standard diagrams on the Ground Frame Panel. These covered only 40-50% of the design requirement and the rest of the circuits have been developed from first principles by the designer.

These circuits are intellectual property and hence not included in this technical paper.

To understand the concept, the designer had prepared a detailed table listing key circuit functions and their operation for better understanding of the circuit and further troubleshooting if necessary. The detailed table is provided in the Appendix A. **Design Principle #1**

5.3 Identifying the existing expertise

To provide further validation to the operational requirements and preliminary design an assessment was made to establish if there were any other similar installations on Network Rail Infrastructure. One installation at Ashchurch was identified. Copies of the design for Ashchurch were assessed. This assessment identified many discrepancies between the Fletton and Ashchurch ground frames – e.g Direct signal control verses indirect signal control. However, there were similarities in other areas of the design and therefore the control panel circuits were developed to be similar to the existing system already employed at Ashchurch. **Design Principle #2**

5.4 Anomalies in the Existing Ground Frame Design

While understanding the circuitry of the existing design, two anomalies have been identified. The existing standards at the time of first delivery did not contain these requirements therefore we took reasonable opportunity to bring the signalling controls up to date whilst still providing a level of flexibility for simple operation. **Design Principle #3**

5.4.1 Lack of Approach Locking

It was noticed that the existing circuitry didn't have approach locking for signals. Hence it would be possible to replace a signal to 'Stop' aspect while a train is approaching and set an opposing route.

5.4.2 Lack of Automatic Replacement of signal

It was noticed that the existing circuitry didn't have automatic replacement of the signals after the passage of train. Hence it would be possible to continue to display a 'Proceed' aspect for second train following the first train. This is an unacceptable safety condition in the current standards.

Both conditions are unacceptable safety conditions in accordance with the current standards.

These safety discrepancies have been addressed by the designer with suitable mitigation measures designed into the new control circuits.

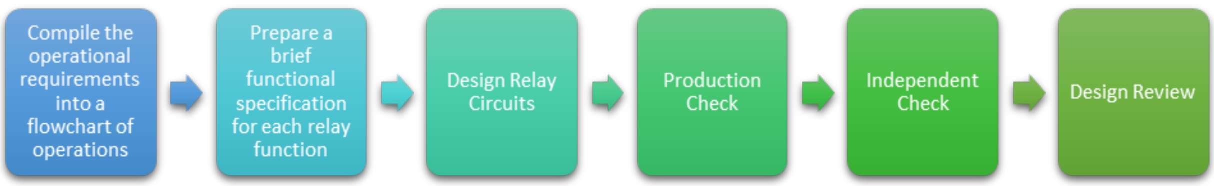
5.5 Main Interlocking – No Alterations

The main interlocking which controls the adjacent railway signalling to the Ground frame is an SSI type. The design challenge was to ensure that the main interlocking remains unchanged following the upgrade of the Ground Frame from Mechanical to Panel, due to commercial and programme constraints. The interlocking sends only a single control function for the interface. The design for the Ground Frame Panel must be more robust and complete to work with this single function including provision of approach locking timers within the ground frame control circuits. **Design Principle #3**

5.6 Design Strategy

The Ground Frame Panel design roles and responsibilities were discussed and agreed beforehand. The novel design solution would be developed in GDC and checked in GDC. This will be reviewed by a UK technical expert.

The following process has been devised for the novel design solution.



As per the agreed strategy, the Ground Frame Panel was fully conceptualised, produced and checked in GDC. The design was reviewed by a technical expert in UK and had no significant comments.

Design Principle #4

5.7 Parallel Design Activities

Due to the compressing timescales, the Ground Frame Panel design must be produced along with the other documentation which would form inputs to the Ground Frame Panel design. One such key deliverables was Control tables which gives the signalling logic in a tabular format. The control tables were produced in a different design office and being produced in parallel. To mitigate the parallel design risk, the ground frame designer produced the draft Ground Frame Panel design and sent this design to the UK control tables designer to align the control tables to the panel design. This ensured that both deliverables were very much aligned before released. **Design Principle #5**

5.8 Post Design Stage

The Peterborough ground frame panel design had been reviewed by the client and the client accepted that the design meets the requirements. The design has been successfully installed and commissioned in Jan 2019 without any design modifications. **Design Principle #6**

5.9 LESSONS LEARNT

Several key lessons were learnt by the designer while working on this design and summarised here mainly for the benefit of the younger members who may work on similar assignments; **Design Principle #7**

- It is very important to understand the existing issues and complexities; some of them not even known to the client, hence unknown client technical requirements needed managing to ensure agreement was reached with all stakeholders.
- Once it is established a novel circuit is to be designed, a clear strategy is to be agreed with the client on production, checking, review and approval of these novel circuits. This is crucial when the relevant technical expertise or operational expertise is rare in an organisation. This is also important both in terms of cost and timescales.
- While developing novel circuits, discussions at regular intervals with mentors and seniors would be useful rather than wait till the end. This has helped the designer to quickly rework any changes required.
- A flowchart of the circuit and their operation with respect to timing is very useful. This has eliminated many issues which would have created problems at site. In future a tool could be produced to handle timing analysis and race conditions thus eliminating manual errors.
- Preparing supporting documentation such as that shown in Appendix A table would help the understanding of the circuits better for everyone during the project lifecycle and others in future for carrying out any circuit alterations in a safe and efficient manner.

6 CONCLUSION

In completing the analysis of the operational problem and developing the technical solution the design team in the GDC gained invaluable technical experience of developing novel safety critical signalling circuits. Following the structured design approach during the design phase and the lessons learnt feedback process, this experience, equally applicable to any other project or novel application, has been implemented in our standard engineering processes to ensure we achieve consistent positive outcomes for novel design development.

This project is an excellent example of applying a systematic approach to a complex project and delivering it right first time.

7 ABBREVIATIONS

ECM1 – *East Cost Main Line Engineering Line Reference 1*

ECML – *East Cost Main Line*

ELR – *Engineering Line Reference*

GDC – *Global Design Centre*

GF – *Ground Frame*

LDHS – *Long Distance High Speed*

NX – *eNtrance and eXit Signaller's control Panel*

SB – Signal Box

SSI – Solid State Interlocking

8 ACKNOWLEDGEMENTS

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APPENDIX A – BRIEF FUNCTIONAL SPECIFICATION OF RELAYS

1194 RLPR

Description: Ground Frame Release Repeat Relay
Pickup: When Signaller Operates Release Switch to Reverse and all controls are proved in SSI available then this relay picks up. This relay will then allow ground frame to be locally controlled. When RLPR is picked up then 'FREE' indication will be lit.
Drop: When Signaller Operated Release Switch to Normal then this relay drops.
Special Remarks: When the RLPR is dropped then, If GFP is already normal then dropping this relay will lock the ground frame controls. If GFP is not already normal then dropping this relay will not impact local operations until the GFP is normalized.

(GF)ZR

Description: Ground Frame Control Latch Relay (Equivalent to Release Lever in Mechanical GF)
Pickup (R): When RLPR pickup is received, FREE indication is lit at GFP. If GFP Operator presses the FREE push button for a while then this relay picks up and latches.
Drop (N): At the end of local operations, GFP operator presses the CLOSE push button and then this relay is normalized and latches.
Special Remarks: (GF)ZR is the first relay that picks up for the local operation and remains latched. This is also the last relay that drops when the operation is complete. Once (GF)ZR is picked up the Points and Signal button indications would be lit.

2 RR

Description: Points Reverse Relay
Pickup: When points are normal and GFP Operator will press POINTS 'R' push button for a while then RR is picked up.
Drop: This relay will drop after the POINTS 'R' push button is released (break).
Special Remarks: This is a temporary pickup to allow 2 WZR to be latched reverse. Slow to Drop feature added for this purpose.

2 NR

Description: Points Normal Relay
Pickup: When points are reverse and GFP Operator will press POINTS 'N' push button for a while then NR is picked up.
Drop: This relay will drop after the POINTS 'N' push button is released (break).
Special Remarks: This is a temporary pickup to allow 2 WZR to be latched normal. Slow to Drop feature added for this purpose.

2 WZCSR

Description: Points Anti Preselection Relay
Pickup: When the train clears the points track circuit and no point request (RR when point is normal – NR when point is reverse) is present at that time, this relay will pickup
Drop: This relay will drop for every train movement
Special Remarks: WZCSR up and NR/RR up in 2 WZR circuit proves that the request has come just now and not a stored request.

2 LR

Description: Points Lock Relay
Pickup: When the Points are free of Track Locking (TPR) and Route Locking (ALSR) and there is a point request NR or RR then this relay will pick up. This relay will be maintained via stick path till points move from Normal to Reverse or vice versa.
Drop: This relay will drop once points movement is complete and detected. LR down means points are locked.
Special Remarks: ALSR proves 120 seconds time delay or Train passed by train

2 WZR

Description: Points Control Latch Relay (Equivalent to Points Lever in Mechanical GF)
Pickup (R): When Points are free (LR up) and not preselected (WZSCR up) then 2 WZR will latch Normal or Reverse depends on the points push button pressed NR or RR.
Drop (N): When Points are free (LR up) and not preselected (WZSCR up) then 2 WZR will latch Normal or Reverse depends on the points push button pressed NR or RR.
Special Remarks: WZCSR up and NR/RR up proves that the push button request has come just now and not a stored request.

(GF) T2PR

Description: Repeat Relay of Track Clear Relay 7405
Pickup: When track 7405 is clear.
Drop: When track 7405 is occupied or failed.
Special Remarks: 7405 is the only point zone track.

(GF) ALSPR

Description: Repeat Relay of 3/4 ALSR
Pickup: When the train occupies and clears 7405 track the ALSR will be up (First track occ and clear sequence) – Also if there is no train then after 120 seconds delay after GFP operator pressing the signal ON push button the ALSR will pick up.
Drop: When signal GR is picked up (GF4 GR or 56 GR).
Special Remarks: ALSR circuit in Case A is replicated from existing circuit

2 NWCR

Description: Normal Controlled and Detected Relay
Pickup: When the points are controlled and detected Normal
Drop: When the points are moving or detected Reverse
Special Remarks: To be proved in Signal circuits and Points Normal indication

2 RWCR

Description: Reverse Controlled and Detected Relay
Pickup: When the points are controlled and detected Reverse
Drop: When the points are moving or detected Normal
Special Remarks: To be proved in Signal circuits and Points Reverse indication

3 (ON) ZNR

Description: 3 ON push button not pressed
Pickup: Normally picked up when the push button is not pressed
Drop: Drops when the push button is pressed
Special Remarks: Push button not stuck in ON position is checked.

3 (ON) NR

Description: 3 ON push button pressed
Pickup: Normally picked up when the push button is pressed
Drop: Drops when the push button is not pressed
Special Remarks:

3 (OFF) ZNR

Description: 3 OFF push button not pressed
Pickup: Normally picked up when the push button is not pressed
Drop: Drops when the push button is pressed
Special Remarks: Push button not stuck in ON position is checked.

3 (OFF) NR

Description: 3 OFF push button pressed
Pickup: Normally picked up when the push button is pressed
Drop: Drops when the push button is not pressed
Special Remarks:

3 RR

Description: 3 Signal OFF Operation relay
Pickup: Normally picked up when the push button is pressed, Points are detected reverse and locked, Signal 4 is normal.
Drop: Drops when the signal 3 ON button is pressed
Special Remarks:

3 GYR

Description: 3 Signal Latch relay (Equivalent to Signal Lever in Mechanical GF)
Pickup (R): When 3 RR is picked up.
Drop (N): Drops when the signal 3 ON button is pressed and (GF) ALSPR is picked UP
Special Remarks: This relay will be normalized only when the Approach locking is clear. This is to ensure the signal 4 cannot be set unless this route is normalized. Addresses the signalling principles review comment.

56 GR

Description: 56 Signal Control Relay
Pickup (R): Proves all controls for Signal 56 to clear to an OFF aspect. Tracks, Points etc
Drop (N): When train occupies track 7405 or GFP Operators presses 3 'ON' button
Special Remarks: 56 GR is an intermediate relay to drop ALSR before the Signal clears to OFF aspect

56 (PL)GR

Description: 56 Signal Aspect Relay
Pickup : Proves 56 GR is up and ALSR is down
Drop : When 56 GR is down
Special Remarks: 56 (PL)GR controls the signal directly and controls the Push button indications directly.

Same for Signal 4 related relays

3/4 AJR ALSR

Description: Signal Approach Locking Relay including Timer
Pickup : When the train occupies and clears 7405 track the ALSR will be up (First track occ and clear sequence) – Also if there is no train then after 120 seconds delay after GFP operator pressing the signal ON push button the ALSR will pick up.
Drop: When signal GR is picked up (GF4 GR or 56 GR).
Special Remarks: Single relay – replicated as per existing location circuitry. 120 seconds retained as stated in Signalling Principles Review.

7405 TSR

Description: Track Stick Relay (Functionally equivalent to GSR function)
Pickup : When the train clears the 7405 Track and the Approach Locking is free.
Drop: When signal GR is picked up (GF4 GR or 56 GR).
Special Remarks: Track Stick Relay is used to prevent the Signal aspect being cleared again without the buttons being pushed.

1194 WCR

Description: GFP is normal and Signaller can cancel the GFP release and take back control
Pickup: GFP operations are completed and GFP is closed with points detected Normal.
Drop: When GFP is operated again for next time by RLPR and FREE button.
Special Remarks: This function is proved in SSI data for normalizing the ground frame released. Same as NCR function.