Radio activated dual Control Switch System Application in Dark Territory

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ABSTRACT

This paper describes the introduction of a Radio activated dual Control Switch system, at a typical location of passing tracks including two End of Sidings, focuses on the engineering and operational issues considered.

This paper will provide an overview of the system design considerations, system selection, system design principles, system configuration, signage designs and system assurance.

The potential lessons learned during the process will also be introduced at the end.
The RCS system is designed to permit approaching train crews to remotely request the power switch to the desired position, at either end of the siding, using an onboard DTMF radio keypad. The switch position status is broadcasted to the train crew through the Railway’s existing wayside radio communication network, and is also displayed on dual direction wayside switch position indicators.

Hatch Mott MacDonald has been overseeing several RCS system projects with respect to the system design, system assurance, installation, testing and commissioning.

Figures 1 on the next page provide an overview of the typical location with RCS system application.
Overview Diagrams

Figure 1: Overview
### TABLE 1: Legend of Figures 1

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>ITEM</th>
<th>DESCRIPTION - APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="RCS &quot;LED&quot; Switch Position Indicator" /></td>
<td>RCS &quot;LED&quot; Switch Position Indicator.</td>
<td>Green – Normal; Yellow – Reverse; Red – not locked in either Normal or Reverse. If the “requested” indicator light is extinguished the train crew must use either the push-button or manually throw switch using the hand throw lever.</td>
</tr>
<tr>
<td><img src="image" alt="AFO track circuit" /></td>
<td>AFO track circuit</td>
<td>Extends 100 feet, from the OST track circuit limit, on each approach portion of the main track and on the siding. Used to confirm train presence, two track restoration of the “ASR’s” and to enable the Push Button.</td>
</tr>
<tr>
<td><img src="image" alt="RCS Push Button" /></td>
<td>RCS Push Button</td>
<td>Push-button box located on the bungalow, used to locally control the switch points at each end of siding. Train crews must observe the switch point indicator and verify the switch points are in the proper position before continuing movement through the switch.</td>
</tr>
<tr>
<td><img src="image" alt="Snow Clearing Device" /></td>
<td>Snow Clearing Device</td>
<td>Gas fired Snow Clearing Devices are installed at both ends of the siding.</td>
</tr>
<tr>
<td><img src="image" alt="Advance DTMF Sign West / East" /></td>
<td>Advance DTMF Sign West / East</td>
<td>Located on the approaches to West and East respective end of siding switch points. Approaching train crews must receive the radio broadcast message acknowledging the requested switch position before passing the sign or proceed preparing to stop.</td>
</tr>
<tr>
<td><img src="image" alt="Advance DTMF Sign East / West" /></td>
<td>Advance DTMF Sign East / West</td>
<td>Located on the eastward to approach East and West respective end of siding switch points. Approaching Train crews must receive the radio broadcast message acknowledging the requested switch position before passing the sign or proceed preparing to stop.</td>
</tr>
<tr>
<td><img src="image" alt="RCS Location Sign" /></td>
<td>RCS Location Sign</td>
<td>Located at the “OST” track Circuit limits at each end of siding location. Informs the train crew where they must stop their train to ensure they do not shunt the OST track and electrically lock the switch machine.</td>
</tr>
</tbody>
</table>
EXISTING OPERATION

In dark territory all train operations are governed by Occupancy Control System (OCS) rules. Typically all mainline switches are equipped with a standard switch stand c/w targets and governed by the Canadian Railway Operating Rules (CROR) 104.

CROR 104 requires all trains to reduce speed and prepare to stop when approaching the facing point of a hand throw switch in OCS territory, until the switch position have been verified visually by train crew.

When a train is provided an OCS clearance to enter the siding for a meet, the train crew will stop the train on the mainline before the switch, hand throw the switch to reverse, move train into the siding, hand throw the switch back to normal position preparing it for the meet of the main line movement.

Following the meet and once the train on the siding track is provided an OCS clearance to move onto the main track, the train crew will hand throw the switch back to reverse position, move the train onto main track, hand throw the switch back to normal position, then re-start the train movement on the mainline.

If the OCS clearance requires the first train to "Hold the Main Track" for a meet, the train crew is required line the switch reverse for the approaching train movement (unless relieved by the other train/employee) and wait until the movement is clear before throwing the switch normal and proceeding.

Although the CROR rules and timetable instructions are effective at governing the safe operation of train movements through hand throw switches in OCS dark territory, train operation is relatively inefficient, and the safety is heavily relied on the human factor.
SYSTEM DESIGN CONSIDERATIONS

Two basic design approaches could be considered, both of which employing a Remote Control Power Switch (RCS) system utilizing FAS-PAS™ DTMF radio communication control equipment, one with Approach Locking and one without. This section summarizes the essential differences between the two and discusses the operational and design issues considered.

Option 1 - No Approach Locking

The initial design option considered was not to have “approach locking”. For one reason it has been the traditional approach taken by many Class I railroads for remote control switch applications in OCS. Other similar systems were also reviewed as well as the relative AREMA Manual parts. From this analysis it was determined the basic system would use Time locking only, set for 15 minutes and ensure the timer is reset by a subsequent status request. Signs would be required approaching the locations, installed at designated location along the ROW, based on the worst case train braking capability to indicate to train crews when they must receive a radio broadcast message of the switch position. If a train was delayed in the approach section, after making switch a position request and receiving a status broadcast message, the train would have to request the switch status (or position) after 10 minutes. Also, the RCS switch position indicator light should extinguish after 10 minutes to be in sync with the RCS control system.

It was realized that without approach locking, the switch could be requested by another train or track unit, even though the time table instructions state they should not be. It was resolved that this has been the accepted standard for similar systems installed on Railways.
Option 2 - Approach Locking Included

The option of including approaching locking in the design was also considered. Intuitively it was thought to be an expensive option considering the dark territory and if there are level crossings in the vicinity. Electronic coded track circuits would be required approximately 2 miles from the siding in each direction. Approach locking would essentially maintain the electric locking of the route, previously established by the initial switch position request, (which would initiate the route locking) and the route would remain in the locked state as long as the approach track was occupied. If the approach was not occupied, the RCS could be designed to release the electrical locking in the traditional method by permitting the approach stick relay to restore without having to run Time locking.

It was understood that once the train had entered the approach track section the power switch would be electrically locked in the position it was last requested and would remain locked until the switch was accepted by a train or/and the OST LOS time expired. It was also recognized that Loss of shunt logic would be required on the approach locking circuits.

The approach locking design would require two sets of signs on each approach, one to indicate where to initiate the radio request and the second to indicate the limit of the approach locking section. The following table explains some of the operational issues considered.
### TABLE 2: Approach Locking Scenarios and Design Considerations

<table>
<thead>
<tr>
<th>Issue</th>
<th>Scenario</th>
<th>Design Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trains entering within the second advance RCS sign and the switch will lock the switch. The train entering the approach track section may be a local switcher which has no intention of using the siding, therefore the RCS switches will be electrically locked and not be available for a legitimate train</td>
<td>Approach locking would only be effective if there was a legitimate request for switch status from an approaching train. The state of the RCS switch position request would be set high only when a radio transmission request is received. If the approach is already occupied when a request is received the design will have to include the request output in the stick portion of the approach locking and as well in the switch locking circuit to permit the switch to move to the requested position and then lock it once it is in correspondence.</td>
</tr>
<tr>
<td>2</td>
<td>Trains trailing away from the RCS switch on the main track will occupy the approach locking section and therefore lock the switch, self-restoration feature will not be possible since the approach track is occupied</td>
<td>The design would require directional stick circuits to prevent locking the route on a trailing move and in order for the self-restoration feature to work.</td>
</tr>
<tr>
<td>3</td>
<td>Westbound trains stopped facing the east end of the siding will effectively lock the east and west end switches.</td>
<td>A timer circuit would be required on the east approach to release the approach locking and permit the controller to move the east end switch to the required siding position.</td>
</tr>
<tr>
<td>4</td>
<td>Eastbound trains stopped facing the west end of the siding will effectively lock the east and west end switches.</td>
<td>A timer circuit would be required on the west approach to release the approach locking and permit the controller to move the west end switch to the required siding position.</td>
</tr>
</tbody>
</table>

### Conclusion – Option 1

It was concluded that the approach locking scheme would be significantly more complex from an engineering perspective and far more expensive, requiring as a minimum either coded track circuits extending approximately 5000 to 10000 feet in both directions plus the additional control logic mentioned above. Considering the relatively low density of rail traffic, the operational benefits were very limited and it introduced more complexity in terms of identifying the approach locking section to train crews, the Approach Locking scheme was not recommended.
**ADDITIONAL DESIGN CONSIDERATIONS**

**Train Braking Calculations**

Although there is no signal system involved, train braking calculations / analysis had to be performed for the various types of trains (freight, passenger) operating on the specific subdivision through the project area, to determine the location of the advance DTMF signs.

The advance DTMF signs had to be located ensure an approaching train with the worst case braking characteristics would be able to stop at East or West, after passing the advance DTMF sign without having first received a RCS broadcast message confirming the requested switch position. Another consideration was the actual time for the various types of trains operating at their maximum Timetable operating speed to reach the end of the siding after passing the sign. This time could not be longer than 10 minutes.

Also considered was the main track gradient approaching the Siding from both directions as well as the gradient between the siding ends on both the main and siding tracks.

Additionally, it was also determined that speed restrictions would be necessary for certain trains, due to the gradient and distance between the ends of the siding, for eastward movement from West when their OCS clearance requires them to stop at East, and / or for westward movement from East when their clearance requires them to stop at West.
CONTROL SYSTEM SELECTION

Global Rail Systems developed a Dual Tone Modulated Frequency (DTMF) radio activated dual control power switch (RCS) system “FAS-PAS™” specifically for remotely controlling switches in yard or dark territory to improve train operation safety and efficiency. Global Rail Systems’ FAS-PAS™ radio control system was most commonly used for the RCS System Project primarily because their communication package had a proven track record and had been applied successfully in other similar Class I applications. FAS-PAS™ is also patented in the US and has been applied for international coverage as well.

The FAS-PAS™ RCS system utilizes the Railway’s radio communication network to broadcast radio messages, unique to the location, confirming the status (position) of the switch to approaching the train crews. Trains approaching a location equipped with an RCS system must first initiate a DTMF radio broadcast message requesting the desired switch position. The approaching train must then operate prepared to stop at the switch unless the required broadcast reply message confirming the switch position is received from the RCS system.

While Global Rail Systems provides a complete “package” of the signal equipment required for a typical end of siding application. I.e. the bungalow, switch machine, switch point indicators, etc. sometimes it was determined these items would be acquired separately in order to match the customer’s standards equipment inventory used through-out their various system corridors.

Another significant consideration for the equipment selection was customer’s future plans of upgrading to a CTC system. This paper will focus on the consideration of selecting GE’s ElectrologIXS the vital application logic controller, US&S’s M23A switch machine and using a high signal mast for the switch position indicators. All of which would be re-used and help reduce installation costs when the corridor is eventually be upgraded to CTC.
SYSTEM DESIGN PRINCIPLES

The following system design principles were defined by Hatch Mott Macdonald engineers, and could be considered as the fundamental rules for the software development for RCS System project.

1. If the train crew initiates DTMF radio request to throw the switch to the desired position, the audio module will broadcast a long tone first to acknowledge the receipt of the request, then the switch will be thrown and locked for the requested route, either for the main track or the siding track.

2. Time locking is described as 10 minutes in the timetable but will actually be set to 15 minutes in software. The switch will be locked in that position for 15 minutes. The switch position indicator light will extinguish after 10 minutes unless a second DTMF is received.

3. If the switch is already aligned for the requested position at the time a valid DTMF request is received, the switch will be locked in that position for 15 minutes.

4. If the switch is already locked in the requested position at the time a valid DTMF request is received, the timer will be reset to 15 minutes, and the switch will remain locked in that position.

5. If the switch is already locked for the main track or siding, and the 15 minute timer is in operation, and the request is received to throw the switch to the other position, the request will be discarded.

6. If the switch is in hand throw position at the time the request is received, the request will be discarded.

7. If a second request is received before the system has completely cycled through the requirements for the first request, the second request will be discarded.

8. Anytime the system broadcasts the “locked” message for normal or reverse, it shall reset the timer.
9. If the switch is in hand thrown position, it will remain in the same position as set by hand when restored to power, unless the auto restore is enabled – i.e. when restored to power, the switch will have no memory of the last requested position, even if the switch was locked when taken off power.

10. Pushbutton position will be checked to protect against the possibility of being stuck while operated.

11. A detected light out condition of the switch indicator LED light for the requested route will generate a broadcast message.

12. Refer to Table 4 – Summary of Voice Message Control for the key messages to be broadcasted and the transmitting control conditions for the typical RCS System application.
The GE ElectrologIXS system was selected to perform all the vital application functions required for the RCS system. All the inputs including the AFO track circuits, OS track circuit, PB, SCD, DTMF request, switch correspondence etc, are directly input to the ElectroLogIXS controller. All the required outputs are also driven by the ElectrologIXS controller, including the switch machine control, switch position indicator, FAS-PAS™ audio modules control, etc.

Figure 2: Block Diagram of System Configuration

Figure 3: I/O Chart Example
Vital Input Examples

TABLE 3: Vital Input Examples

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLT</td>
<td>AFO overlay tack circuits (all 3) for facing track, trailing track main and trailing track siding</td>
</tr>
<tr>
<td>OST</td>
<td>OST - DC track circuit.</td>
</tr>
<tr>
<td>NPB/RRB</td>
<td>Normal/Reverse position of Pushbutton.</td>
</tr>
<tr>
<td>DOOR_PB</td>
<td>PB Door contact.</td>
</tr>
<tr>
<td>AR_ENA</td>
<td>Enable the automatic restore to normal feature. When enabled, the switch if in reverse position will automatically restore to the normal position once the train has completed the movement through the switch and the loss of shut of OST timer is expired</td>
</tr>
<tr>
<td>1NWC and 1RWC</td>
<td>Normal and reverse switch correspondence.</td>
</tr>
<tr>
<td>1N_DTMF and 1R_DTMF</td>
<td>DTMF Radio - Normal and Reverse switch requests.</td>
</tr>
<tr>
<td>SLP_IN</td>
<td>Switch lever contact. While this input is high, the switch is in power position. The switch machine hand throw and crank contacts are closed.</td>
</tr>
</tbody>
</table>

Vital Output Examples

*RCS Switch Position Indicator*

The ElectroLogIXS VLD-R16S lamp driver is used to drive the RCS LED switch position indicators. The application logic shall be designed to ensure the GREEN LED indicator light will be illuminated only if the switch points are locked in NORMAL correspondence in 10 minutes and The YELLOW LED indicator light will be illuminated only if the switch points are locked in REVERSE correspondence in 10 minutes. The
RED LED indicator light will be illuminated if the conditions of illuminating GREEN or YELLOW LED indicators are not satisfied.

**MRR and SRR**

The application logic will ensure that when a valid request is received and the switch moves to the desired position and is in correspondence it is electrically locked in position for a certain period of time (10 minutes). Once in correspondence, either the MRR (Main Route Relay) or SRR (Siding Route Relay) outputs will be true and will enable the corresponding voice messages of “Switch lined and locked in normal (or reverse) position.” to be broadcasted to the train crew.

**NWR and RWR**

NWR and RWR (NORMAL and REVERSE Switch Controls) are similar to the power operated switch machine control outputs / relays used in a conventional signal control system, to move the RCS switch machine to the desired position.

![Figure 5: RCS Switch Machine Control](image)
**Audio Modules**

Five (5) different Audio Modules are applied for the typical location. All the modules are controlled individually by the vital logic controller.

![Audio Module Circuits](image)

*Figure 6: Audio Module Circuits*
### TABLE 4: Summary of Voice Messages Control

<table>
<thead>
<tr>
<th>Audio Module</th>
<th>Broadcast Message</th>
<th>Transmit Condition(s)</th>
</tr>
</thead>
</table>
| 1            | Switch at (Station Name, mile post, subdivision) Unable to verify request. | - OS track is down and DTMF request is received;  
- Green light is out and DTMF request to normal is received;  
- Yellow light is out and DTMF request to reverse is received;  
- Switch machine is in overload and DTMF request is received;  
- Switch is taken off "power", switch is unlocked, and DTMF request is received. |
| 2            | Switch at (Station Name, mile post, subdivision) lined and locked in NORMAL position. | Switch has been lined and locked in the normal position. |
| 3            | Switch at (Station Name, mile post, subdivision) lined and locked in REVERSE position. | Switch has been lined and locked in the reverse position. |
| 4            | WARNING switch at (Station Name, mile post, subdivision) not locked. | - When switch is locked then taken off power.  
- When switch is locked then loses correspondence. |
| 5            | Long tone       | Long tone (DTMF Switch Control Request Received). |

### DTMF Radio Codes

The FAS-PAS™ radio system could be programmed to receive and transit unique multi-digit address codes for each siding end. This was an important consideration since sometimes there might be other Remote Crossing Activation systems on the same subdivision using the same Radio channel. Normally the codes are derived from the mileage location, E.g. #1234 and adding a suffix 06 (letter N for Normal on a DTMF radio keypad) and 07 (letter R for Reverse on a DTMF radio keypad). Note also the suffix numbers are on opposite sides of the keypad to reduce the possibility of input error.

### Release Track

The release track (OLT) is an AFO track circuit, extending 100 feet from the RCS location “OS” track circuit limits. Three release sections (OLT) are provided on each side of the switch (main facing, main trailing and siding). When an OLT section occupied by a train, it will permit the train crew to request or change the switch status, in the event the RCS system did not respond to the initial request while the train was on the advance approach. Train occupancy of any of the (3) OLT release sections will enable the
push button. This was done primarily to mitigate and risk of vandals accessing the push button, and depressing a button to move the switch, while a train was approaching. The application of release track is discussed further in the following section.

The occupancy of both facing AFO track circuit and the OS track circuit shall be also used to “two track” restore the approach stick relay (ASR) logic and release the electrical locking on the switch. Using only OS track circuit to pick up the ASR and release the switch is prohibited, since a “bobbing” OS track circuit could inadvertently release the electrical locking of the switch.
Push Button

The RCS system design considers that for whatever reason an approaching train is unable to communicate with the RCS system, requiring the train to stop at the location, the train crew has the option of using the RCS push button. The software ensures the push button will only be active when a train occupies any one of the three (OLT) release tracks. As mentioned earlier in this document, when the OLT is occupied, the push-button in “enabled” thus can then be used by the train crew to move the RCS switch to the desired position.

Another feature which is included is the Push button door contact detection. If the door is left opened for any reason while a legitimate RCS switch request is being processed, the design of the system will disable the push button activation. The design also considers the situation where two trains arrive at the location and each are occupying the “OLT” release sections. The push button is enabled in this situation. Also, again for safety reasons when the OST occupied it will disable the push button activation.
The RCS application was be subjected to a full Systems Assurance process to ensure that the hazards introduced through the introduction of the technology, and its specific application, were identified, understood, mitigated and managed for the entire lifecycle of the system. This process consisted of identification and analysis of the system level and operation & maintenance level hazards, through a Preliminary Hazards Analysis and Operation and Support Hazards Analysis. The output of these analyses was subjected to Fault Tree Analysis to identify the root causes. These root causes were then subject to mitigation identification, with pre- and post- mitigation risk quantification. In parallel, the entire design was subjected to a detailed FMECA and again, pre- and post- mitigation risk quantification was undertaken.

The entire package of identified hazards, causes and mitigations was concentrated to a single Hazard Log, which is used to ensure that all mitigations are transferred to the respective owners and that mitigations are confirmed, through sign off of the owner, as being implemented prior to Testing and Commissioning.

Additionally, the Hazard Log, in conjunction with a wrap-up Safety Case, will be used to transfer, with Acceptance, residual risk to the customer and to ensure that all post commissioning mitigations requiring ongoing activity, are implemented throughout the Operation and Maintenance phases of the system lifecycle.
LESSONS LEARNED

Although there are similar FAS-PAS™ RCS systems installed throughout North America it seems the design for one location is always slightly different from the next. Most if not all the systems in service today have been customized to some degree. At this point in time there is not a “generic” standard design guideline for an RCS system in Dark Territory published or available yet for Signal Design Engineers to refer to.

Since the RCS system is a becoming more popular option for use in OCS or dark territory applications Hatch Mott MacDonald engineers invested in standardizing the design as much as possible and documenting the design principles used, which were derived through intensive internal discussions, and externally with other railways, our counterparts and our clients.

Once a standardized or generic RCS design guideline is developed and made available, the design, engineering, installation, testing and commissioning process will be far more efficient reducing overall project costs for all concerned.
ACKNOWLEDGEMENTS

We would like to express our appreciation to CN Operating Practices, GE Transportation Systems Global Signaling LLC, Global Rail Systems Inc. Without their guidance and assistance this paper would not have been possible.
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