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POWER OFF! CHALLENGES IN PLANNING AND EXECUTING POWER ISOLATIONS ON SHARED-USE ELECTRIFIED RAILWAYS

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ABSTRACT

Electric railways are fast, clean, and safe, but complex to operate and maintain. Electric traction infrastructure includes signal power and feeder lines that remain live during isolations and complicate maintenance processes. Stakeholders involved in power outage planning include contractors, linemen, groundmen, power directors, dispatchers, conductor-flag, and support personnel. Weekly planning processes for track time require contingencies due to the many moving parts and factors not known in advance, like personnel availability. Electrical and mechanical environments faced by crews working in adjacent areas may be entirely different and require a "bespoke" circuit configuration to de-energize catenary, which must be planned meticulously. Although recent automation has improved real-time "plate order" communications between power directors and dispatchers, each outage still requires many manual switching operations. Net effects of this isolation process reduce nightly construction work windows from a nominal 7 hours to 2 hrs, 39 mins. We recommend joint design of electrical and civil infrastructure, cross-training between disciplines, limiting concurrent outages, formal study of maintenance outage capacity, and further automation in power switching. Costs arising from the operation and maintenance of electrical infrastructure deserve careful consideration when designing electrification systems.

Keywords: Electric traction, power outage planning, construction work window, de-energizing catenary.

INTRODUCTION

The cost and complexity of maintaining electric traction infrastructure after initial construction have barely entered investment policy discussions. We present a case study of processes and solutions on a mature high-voltage alternating current (AC) overhead electrified railway in overcoming challenges associated with keeping service operational whilst infrastructure maintenance works are carried out. It also serves as a field guide for planners contemplating electrification, providing practical data on operational phase expectations. We describe four key aspects of the power isolation process: (1) work planning; (2) circuit configuration; (3) power control; and (4) switching operations.

ELECTRICAL OUTAGE PLANNING

Railway operators are familiar with track outage planning (also called "possession planning") and the trials and tribulations that it entails (see e.g. [1,2]). On electrified railways, it is necessary to engage in power outage planning (i.e. "isolation planning") in conjunction with track outages, which significantly increases the complexity of planning.

An electrified railway is a complex job site. Maintenance-of-Way personnel seek power isolations to perform routine inspection work; Class A Linemen protect Contractor work for electrical safety reasons; Power Directors deliver the planned outage; Substation Groundmen provide field grounds; Conductor Flagmen protect Contractor work for track safety purposes; Rail Dispatchers implement track outages; Support personnel erect “bridge plates” at stations or remove parts of the signal system from service. Due to the number of moving parts and the changing availability of resources (sometimes at short notice), it is critical to define contingencies if planned resources do not materialize. To coordinate these resources, a weekly cycle of planning processes has been developed to prioritize the upcoming week’s work.

CIRCUIT CONFIGURATIONS

Most rail professionals have some experience with routing trains around track obstructions, making moves using appropriate signals, crossovers, and alternative routes. Although isolating an overhead catenary segment is similar in concept, planned power outages must: (1) provide electrical paths to allow power to be delivered outside the de-energized area; (2) keep contact wires over crossovers and drawbridges energized whenever possible; and (3) maintain power supply balance, to avoid overloading specific equalizing substations. Power infrastructure generally make this easy to accomplish, by placement of motorized disconnects (MODs), air gaps, and sectionalizing insulators (SIs), e.g., Figure 1(a). However, Power Directors face the opposite challenge from Dispatchers. To allow an interlocking to remain live for crossing traffic, catenaries must be capable of being fed from both ends, adding substantially to circuit complexity. Substations are not typically co-located with interlockings for engineering reasons, introducing circuit complexity from switching requirements relating to the substations themselves. These constraints result in customizations being necessary to support wire work at any specific location. Although the crew may be working on the same track, in the same signal block and just a few catenaries apart, the electrical and mechanical environments they face may be entirely different.

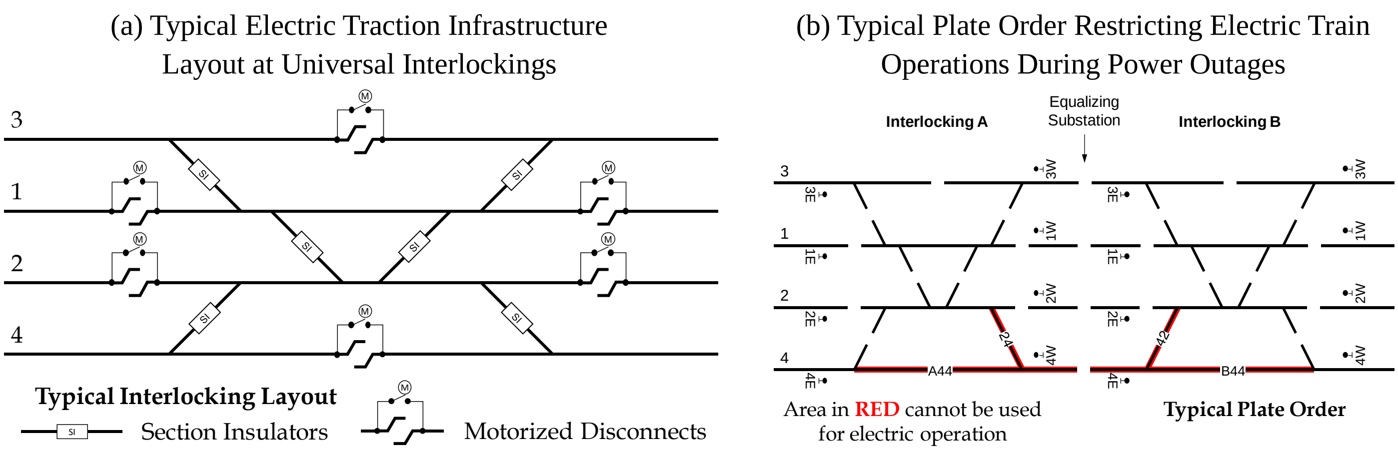

FIGURE 1: BASIC ELECTRIC TRACTION INFRASTRUCTURE OPERATING CONSIDERATIONS

POWER DIRECTOR–TRAIN DISPATCHER INTERFACE

Train Dispatchers operate signals, switches, and electric locks remotely using Centralized Traffic Control (CTC) systems; they also operate dark (non-CTC) territory by issuing paper movement authorities to field personnel. Dispatchers have systems that automate tasks, like Entrance-Exit (NX) controls, and interlocking logic. These industrial control systems provide a high degree of safety through system checks against possible human errors. Similarly, Power Directors (“System Operators” in utility parlance) operate power distribution systems remotely using Supervisory Control and Data Acquisition (SCADA) systems; they order field switches opened or lines grounded by issuing operating orders to Linemen in the field who fulfill them (e.g. [3]). Power system operating tasks is not as automated as those governing train movements. Power Directors make circuit changes by commanding operation of individual disconnects or tie breakers in sequence, whereas Dispatchers can "line a route" and have switches and signals set automatically. SCADA relies more on paper checklists than system logic to ensure safety, but it is more flexible in how circuits can be (validly) configured.

Despite utilizing independent control systems having different operating philosophies, Power Director and Dispatcher actions at the same physical locations must line up. If a catenary segment is grounded, then signals and switches must prevent electric trains from entering, to avoid backfeeding isolated sections. Interfaces between them are governed by Plate Orders (e.g., Figure 1(b)). These pre-defined limits delineate track segments not to be used for electric operations and identifies switches to be blocked. They constrain the locations of track outage limits and can become a limiting factor for work planning and thus productivity.

RESULTS: AVAILABLE WORK WINDOWS

How long does it take to deliver a power outage, given all necessary steps? On a weeknight, work is typically scheduled between 10 PM and 5 AM on one track. Of seven hours overnight typically considered a "work window", it was usually 2 AM by the time the Contractor's safety briefing was completed. With Dispatchers granting a time extension, the job can work until 4:45 AM, with tracks opening to traffic at 5:30 AM. The total available on-track time on a typical night was 2 hours and 39 minutes. Figure 2 shows the time consumption by process steps.

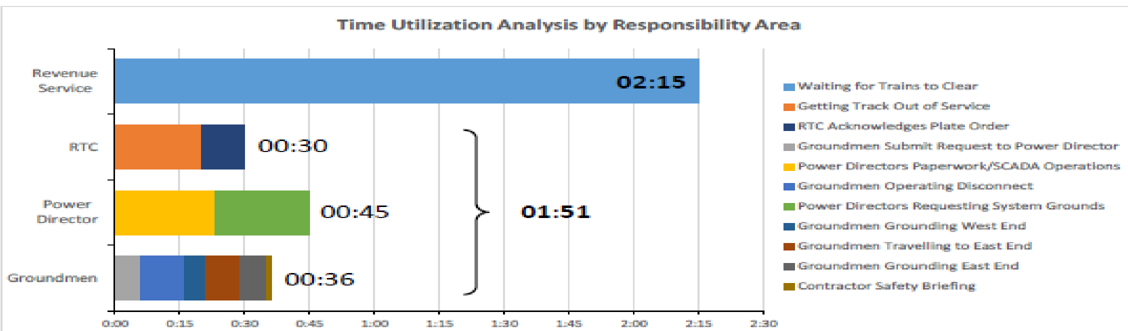

FIGURE 2: OVERNIGHT POWER ISOLATION TIME UTILIZATION BY RESPONSIBILITY AREA

Joint design of electrical and civil infrastructure, cross-training between disciplines, limiting maximum numbers of concurrent outages, formal study of maintenance outage capacity, further automation in power switching, research on work window optimization, and application of artificial intelligence "advisors" could provide improvements in this area.

CONCLUSIONS

Electric railways are fast, clean, safe, modern, noiseless... but complicated to operate and maintain! The benefits of electric traction are most evident in high-density, high-utilization corridors, but the complexity of ongoing maintenance and operations can impose significant costs. These costs ("hassle" factor) might explain why U.S. railroads have historically preferred diesel traction. However, with recent advent of high-capacity battery-electric locomotives (BELs) that can haul typical loads over a 200-mile gap in electric catenaries, electrification may now be possible over a wide area while concentrating electric traction infrastructure in highest density segments, re-charging the BELs whilst in-motion.

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