Power Off! Challenges in Planning and Executing Power Isolations on Shared-Use Electrified Railways

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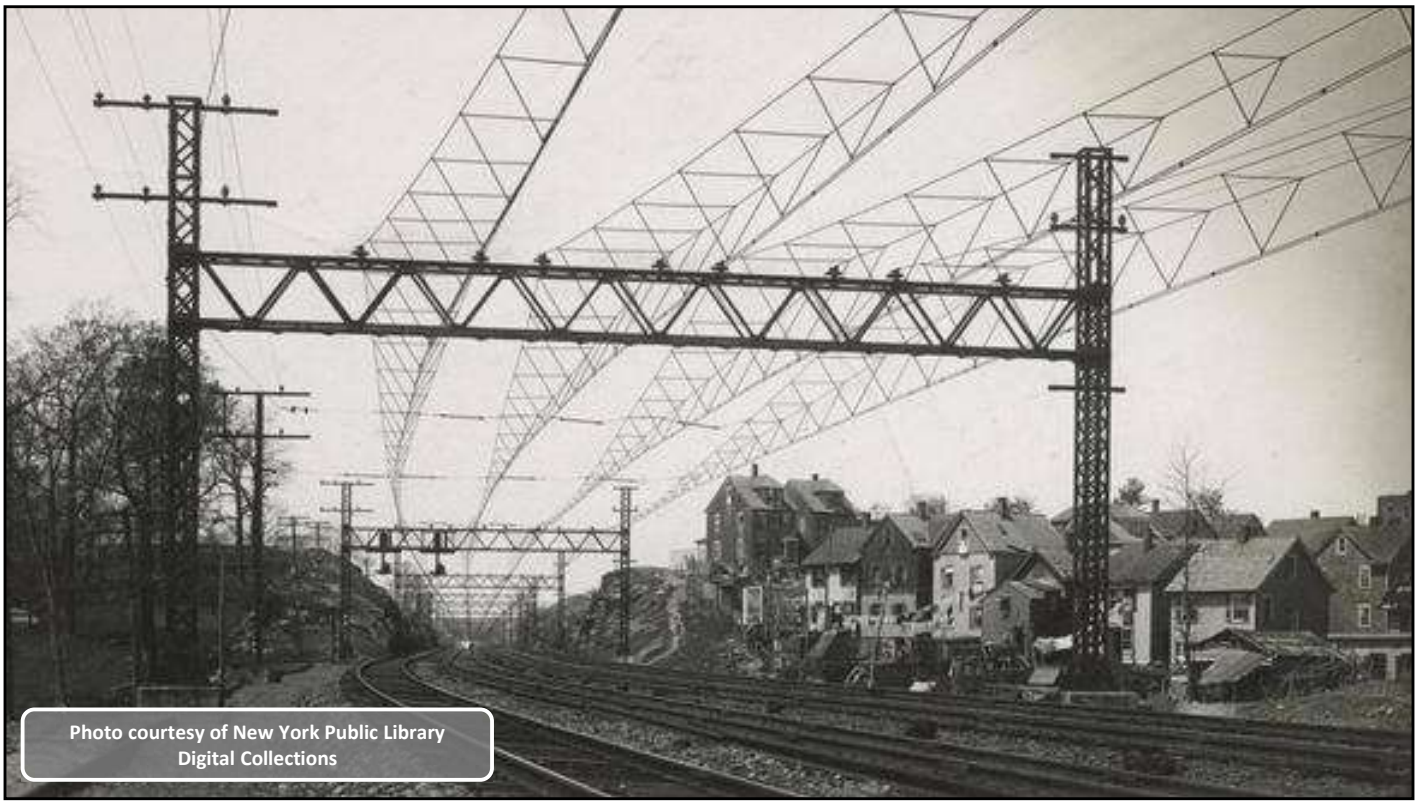
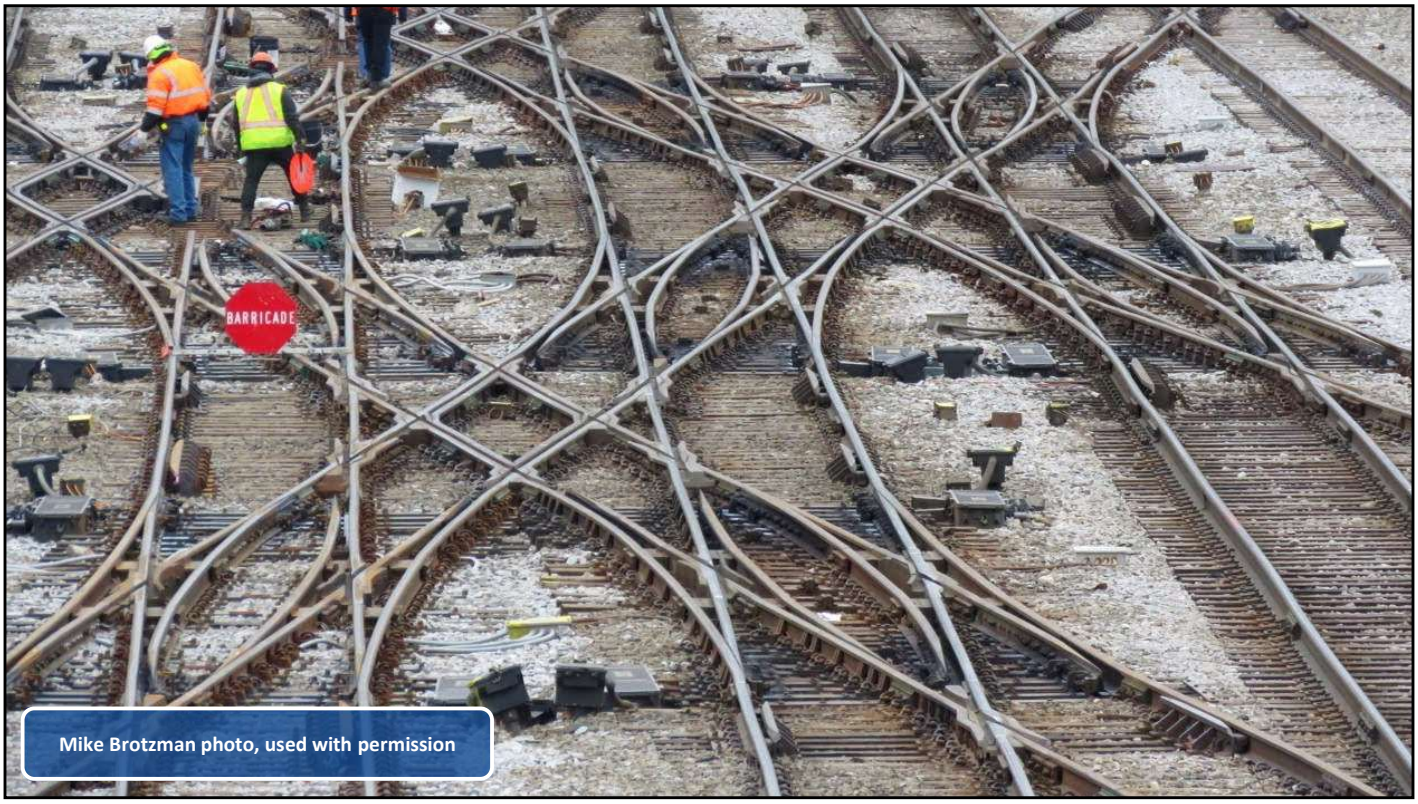
Electric railroads are fast, clean, safe, modern, noiseless, can reduce emissions, and be quite sustainable. Or at least we think so.

Yet investment decisions largely overlook the cost and complexity of maintaining the electric traction infrastructure after initial construction – especially after several decades when major elements need renewal or replacement.



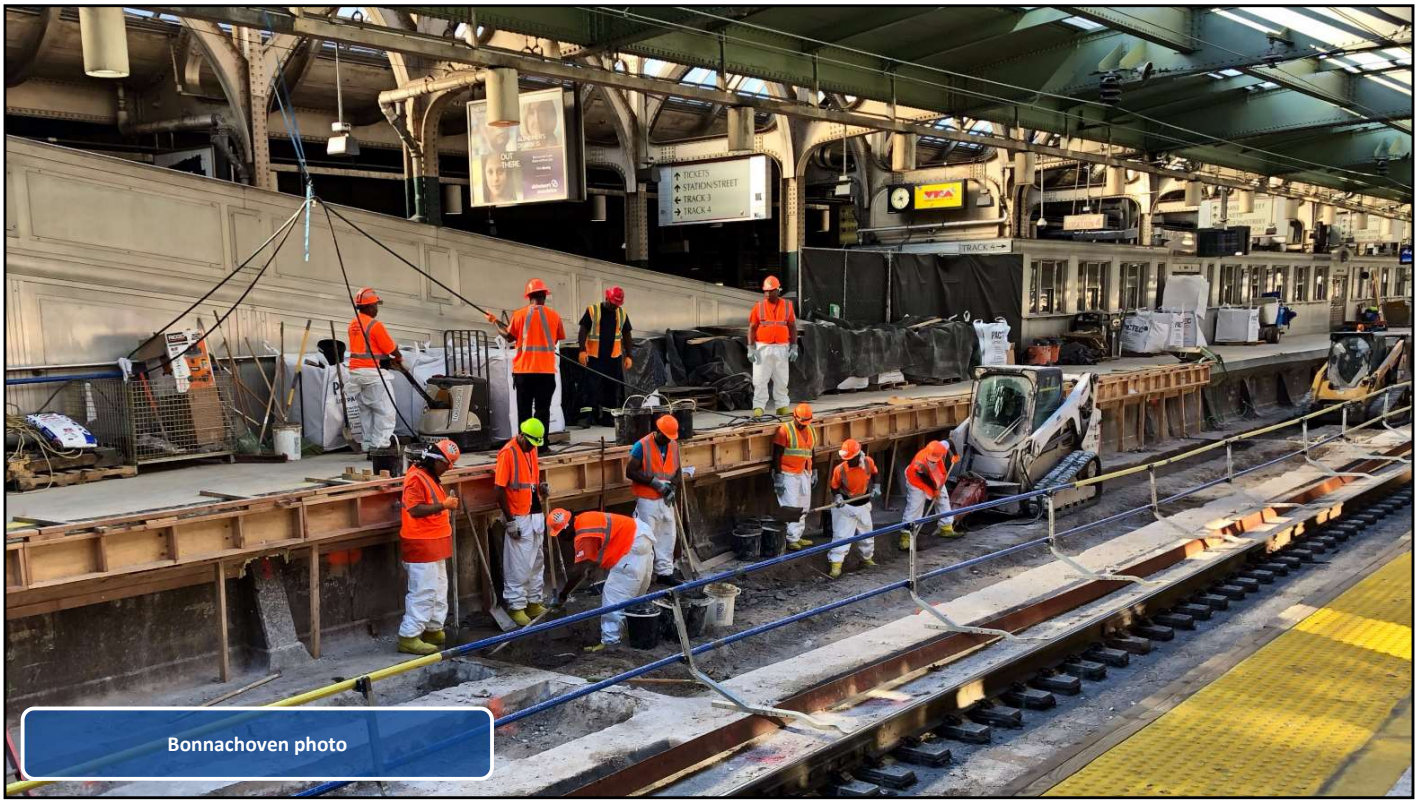
On this National Historic Engineering Landmark, high-voltage alternating current overhead-electrified railroad, it is a complex challenge keeping service operational while carrying out infrastructure maintenance and upgrades.



Mike Brotzman photo, used with permission

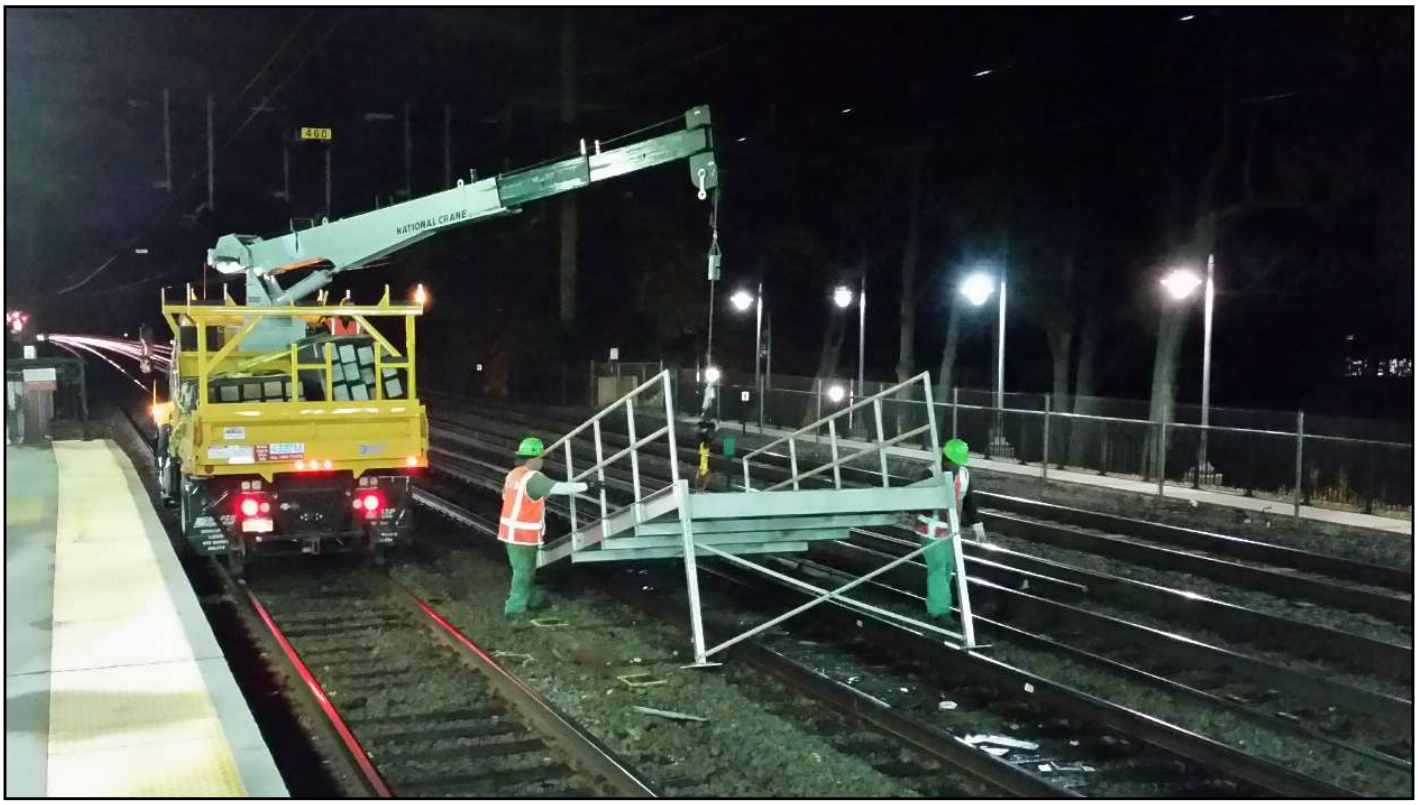
You are probably familiar with track outage planning and the trials and tribulations that it entails. On electrified railroads, it is necessary to plan power outages in conjunction with track outages, significantly increasing the complexity of planning.

An electrified railroad is a complex job site. Maintenance-of-Way personnel seek power isolations to perform routine inspections;



Class A Linemen protect Contractor work for electrical safety reasons; Substation Groundmen provide field grounds;

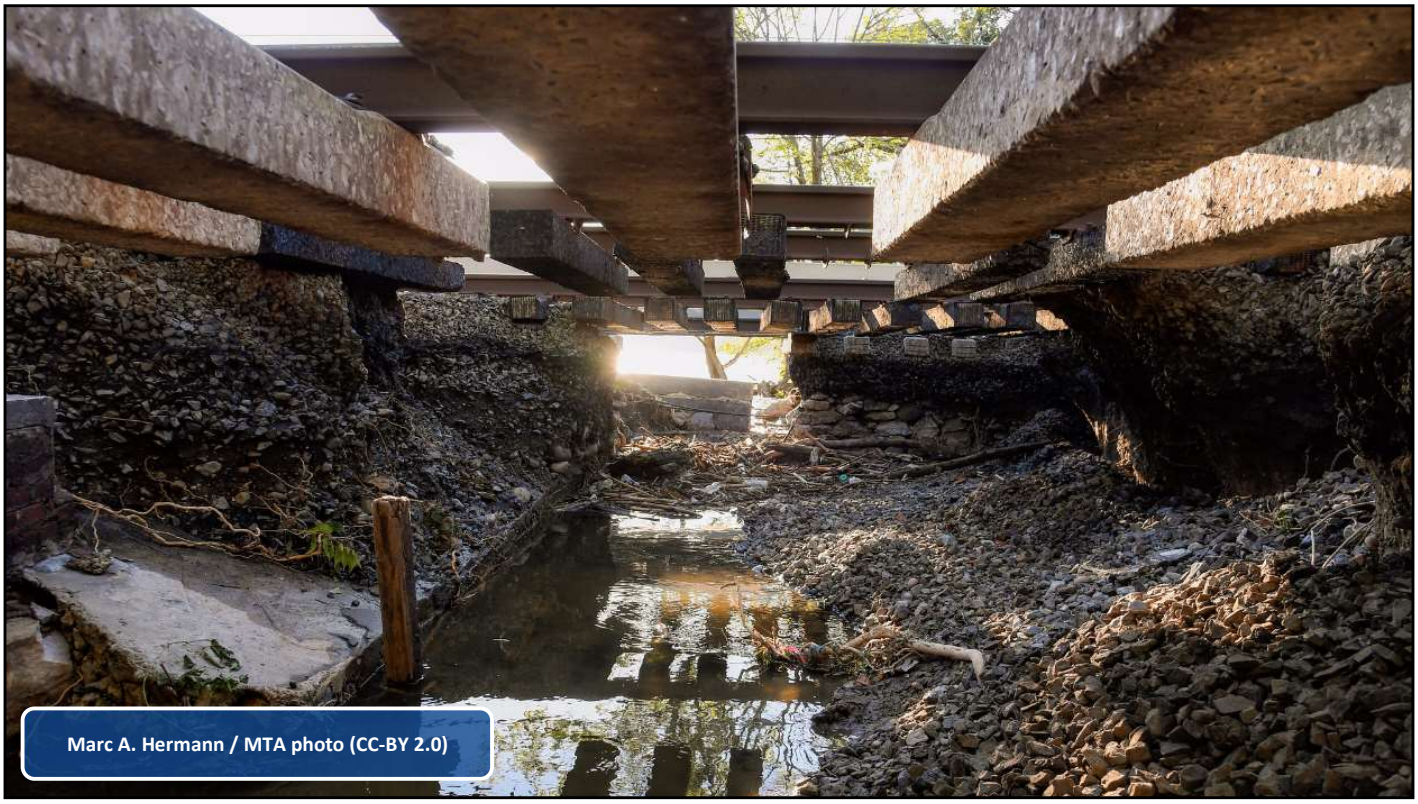
Dispatchers (or as we call them, “Rail Traffic Controllers”) implement track outages; Power Directors deliver the planned power isolations;



Conductor Flagmen protect Contractor work for track safety purposes; Support personnel erect “bridge plates” at stations …

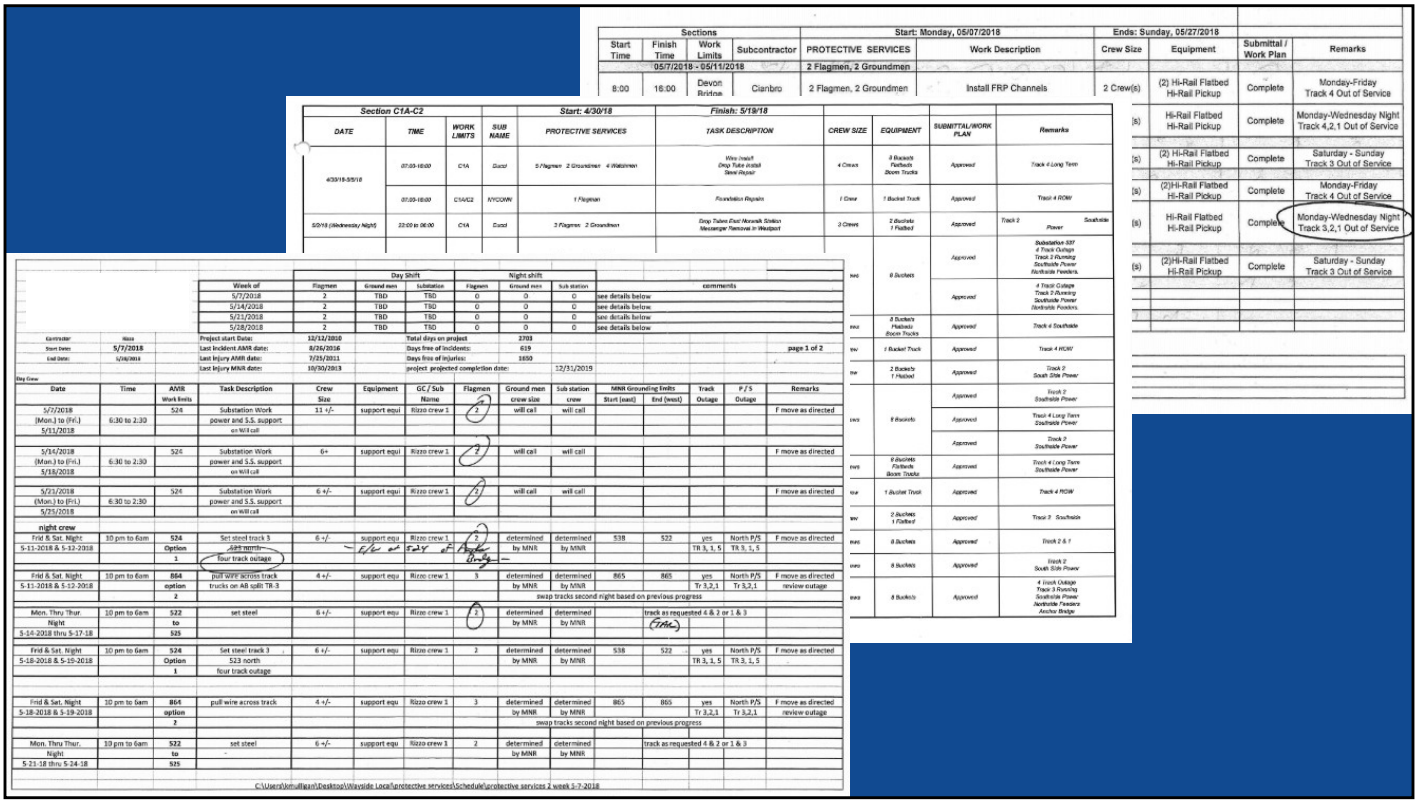
… or remove parts of the signal system from service.

All of this work ultimately depends on coordination of a team of highly skilled employees and contractors. Skilled labor is human. People get sick, have family emergencies, or can't get to work.



Weather can play havoc with infrastructure, or require preparation that uses the same pool of skilled employees needed for the outage.

On-track machines can fail. Planned track outages might be cancelled at the last minute because of an unrelated emergency, like a switch machine getting stuck, a failed train, or a fire on the wayside.

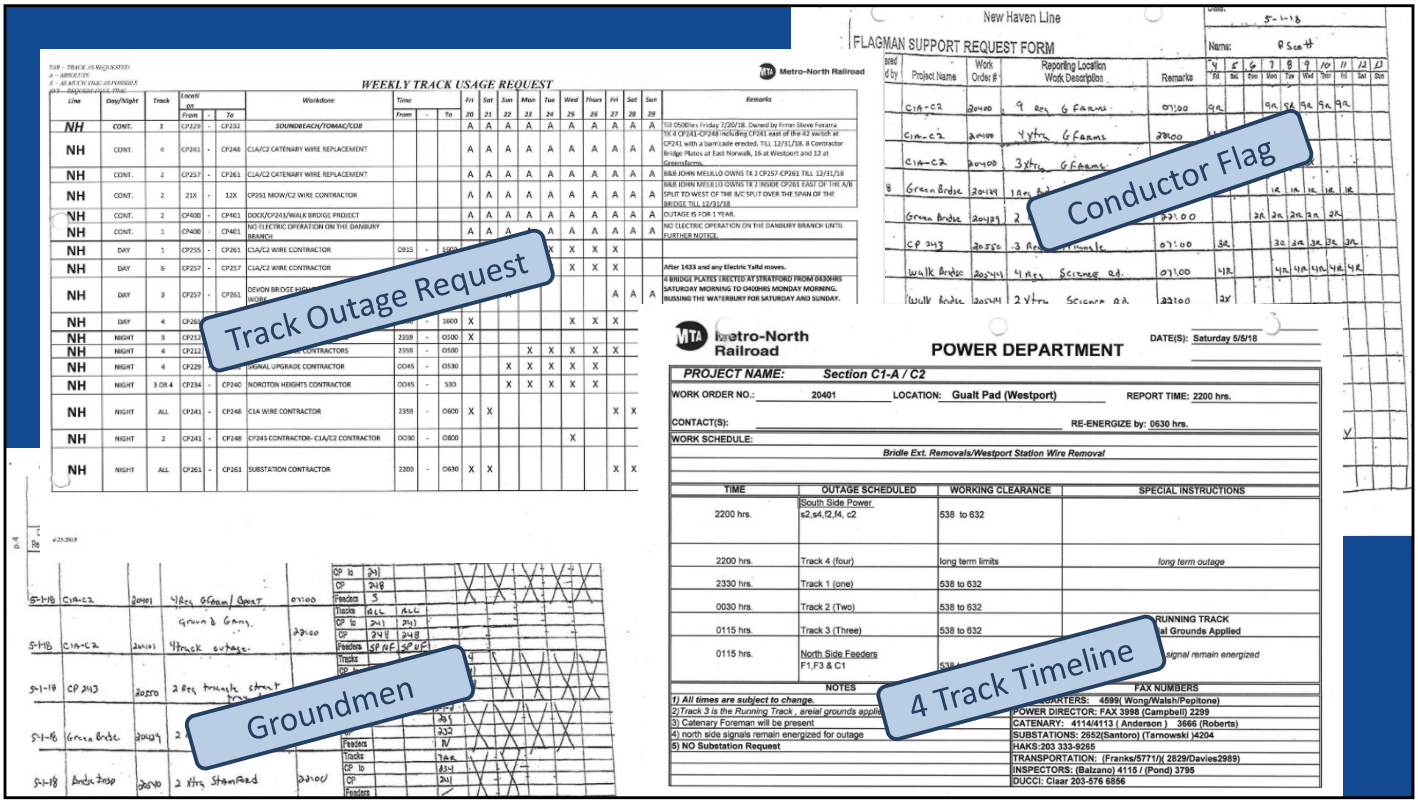


We use a weekly planning cycle to ensure that we can make the most of the weekend. On Mondays, Contractors submit a rolling “four-week look ahead”. Plans for the upcoming week are concrete. The remaining three weeks are contingent on this week’s progress.

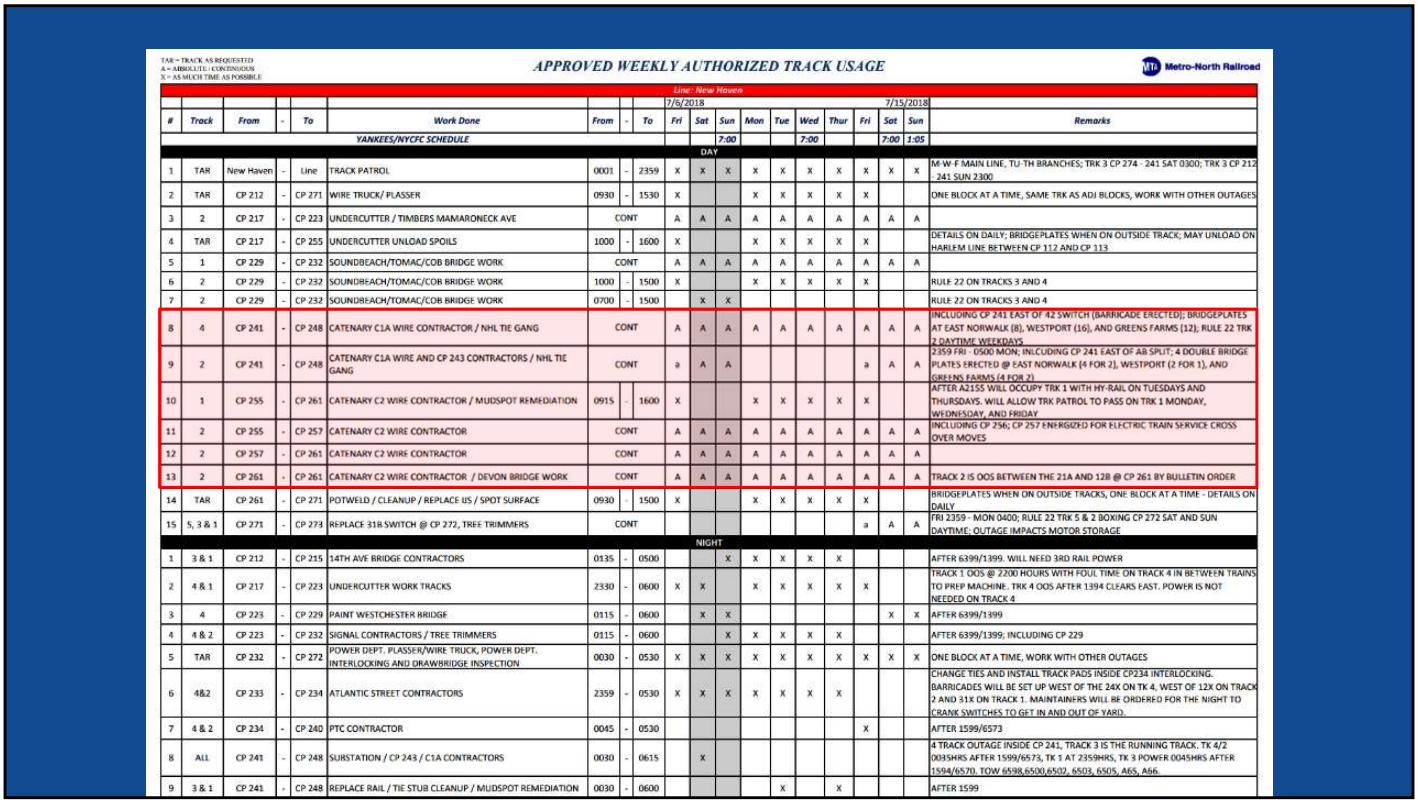
Below is the proposed schedule for this weekend (6/29/18):

Date	*Project*	*Outage*	*Task*	*Priority*
(TBD) Friday (night) 6/29/18	(TBD) Verde: 14th Ave Bridge	(TBD) CP 212-215 Track 3 and north side	(TBD) Conduits	7
Friday (night) 6/29/18	MNR-Track: Undercutter	CP 217-223 Track 1 and 2	Undercutter work, Larchmont area	5
(TBD) Friday (night) 6/29/18	(TBD) MoW-Track: Soundbeach & Tomac	(TBD) CP 229-232 Track 1 and 2	(TBD) Bridge work	TBD

On Tuesdays, the Power department decides what work to cancel if there is a critical resource shortage. Contingency plans are drawn up, like Plan B if don't have enough personnel, Plan C if outages weren't approved, or Plan D if we have equipment failures.



On Wednesdays, requests go out to other areas to get track time, Flagmen, Linemen, Groundmen, and Power Directors. Supervisors in each area account for regular maintenance workloads, and commit resources only when not needed elsewhere.



TAR = TRACK AS REQUESTED
A = ABSOLUTE / CONTINUOUS
X = AS MUCH TIME AS POSSIBLE

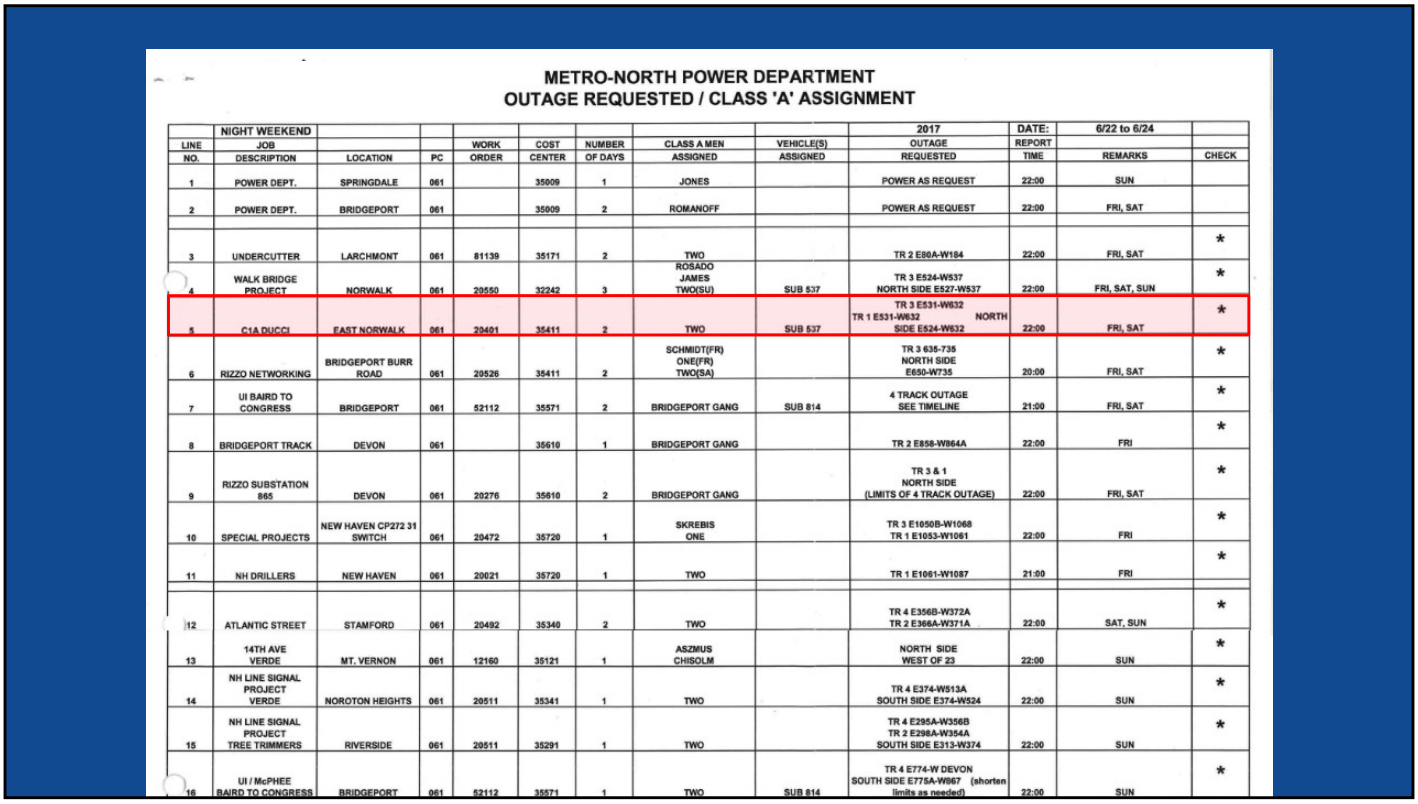
APPROVED WEEKLY AUTHORIZED TRACK USAGE

Metro-North Railroad

Line: New Haven

#	Track	From	-	To	Work Done	From	-	To	7/6/2018 Fri	Sat	Sun	Mon	Tue	Wed	Thur	7/15/2018 Fri	Sat	Sun	Remarks
					YANKEES/NYCFC SCHEDULE						7:00			7:00			7:00	1:05	
					DAY														
1	TAR	New Haven	-	Line	TRACK PATROL	0001	-	2359	X	X	X	X	X	X	X	X	X	X	M-W-F MAIN LINE, TU-TH BRANCHES; TRK 3 CP 274 - 241 SAT 0300; TRK 3 CP 212 - 241 SUN 2300
2	TAR	CP 212	-	CP 271	WIRE TRUCK/ PLASSER	0930	-	1530	X			X	X	X	X	X			ONE BLOCK AT A TIME, SAME TRK AS ADJ BLOCKS, WORK WITH OTHER OUTAGES
3	2	CP 217	-	CP 223	UNDERCUTTER / TIMBERS MAMARONECK AVE	CONT			A	A	A	A	A	A	A	A	A	A	
4	TAR	CP 217	-	CP 255	UNDERCUTTER UNLOAD SPOILS	1000	-	1600	X			X	X	X	X	X			DETAILS ON DAILY; BRIDGEPLATES WHEN ON OUTSIDE TRACK; MAY UNLOAD ON HARLEM LINE BETWEEN CP 112 AND CP 113
5	1	CP 229	-	CP 232	SOUNDBEACH/TOMAC/COB BRIDGE WORK	CONT			A	A	A	A	A	A	A	A	A	A	
6	2	CP 229	-	CP 232	SOUNDBEACH/TOMAC/COB BRIDGE WORK	1000	-	1500	X			X	X	X	X	X			RULE 22 ON TRACKS 3 AND 4
7	2	CP 229	-	CP 232	SOUNDBEACH/TOMAC/COB BRIDGE WORK	0700	-	1500		X	X								RULE 22 ON TRACKS 3 AND 4
8	4	CP 241	-	CP 248	CATENARY C1A WIRE CONTRACTOR / NHL TIE GANG	CONT			A	A	A	A	A	A	A	A	A	A	INCLUDING CP 241 EAST OF 42 SWITCH (BARRICADE ERECTED); BRIDGEPLATES AT EAST NORWALK (8), WESTPORT (16), AND GREENS FARMS (12); RULE 22 TRK 2 DAYTIME WEEKDAYS
9	2	CP 241	-	CP 248	CATENARY C1A WIRE AND CP 243 CONTRACTORS / NHL TIE GANG	CONT			a	A	A					a	A	A	2359 FRI - 0500 MON; INCLUDING CP 241 EAST OF A8 SPLIT; 4 DOUBLE BRIDGE PLATES ERECTED @ EAST NORWALK (4 FOR 2), WESTPORT (2 FOR 1), AND GREENS FARMS (4 FOR 2)
10	1	CP 255	-	CP 261	CATENARY C2 WIRE CONTRACTOR / MUDSPOT REMEDIATION	0915	-	1600	X			X	X	X	X	X			AFTER A2155 WILL OCCUPY TRK 1 WITH HY-RAIL ON TUESDAYS AND THURSDAYS. WILL ALLOW TRK PATROL TO PASS ON TRK 1 MONDAY, WEDNESDAY, AND FRIDAY
11	2	CP 255	-	CP 257	CATENARY C2 WIRE CONTRACTOR	CONT			A	A	A	A	A	A	A	A	A	A	INCLUDING CP 256; CP 257 ENERGIZED FOR ELECTRIC TRAIN SERVICE CROSS OVER MOVES
12	2	CP 257	-	CP 261	CATENARY C2 WIRE CONTRACTOR	CONT			A	A	A	A	A	A	A	A	A	A	
13	2	CP 261	-	CP 261	CATENARY C2 WIRE CONTRACTOR / DEVON BRIDGE WORK	CONT			A	A	A	A	A	A	A	A	A	A	TRACK 2 IS OOS BETWEEN THE 21A AND 12B @ CP 261 BY BULLETIN ORDER
14	TAR	CP 261	-	CP 271	POTWELD / CLEANUP / REPLACE IJS / SPOT SURFACE	0930	-	1500	X			X	X	X	X	X			BRIDGEPLATES WHEN ON OUTSIDE TRACKS, ONE BLOCK AT A TIME - DETAILS ON DAILY
15	5, 3 & 1	CP 271	-	CP 273	REPLACE 318 SWITCH @ CP 272, TREE TRIMMERS	CONT										a	A	A	FRI 2359 - MON 0400; RULE 22 TRK 5 & 2 BOXING CP 272 SAT AND SUN DAYTIME; OUTAGE IMPACTS MOTOR STORAGE
					NIGHT														
1	3 & 1	CP 212	-	CP 215	14TH AVE BRIDGE CONTRACTORS	0135	-	0500			X	X	X	X	X				AFTER 6399/1399. WILL NEED 3RD RAIL POWER
2	4 & 1	CP 217	-	CP 223	UNDERCUTTER WORK TRACKS	2330	-	0600	X	X		X	X	X	X	X			TRACK 1 OOS @ 2200 HOURS WITH FOUL TIME ON TRACK 4 IN BETWEEN TRAINS TO PREP MACHINE. TRK 4 OOS AFTER 1394 CLEARS EAST. POWER IS NOT NEEDED ON TRACK 4
3	4	CP 223	-	CP 229	PAINT WESTCHESTER BRIDGE	0115	-	0600		X	X						X	X	AFTER 6399/1399
4	4 & 2	CP 223	-	CP 232	SIGNAL CONTRACTORS / TREE TRIMMERS	0115	-	0600			X	X	X	X	X				AFTER 6399/1399; INCLUDING CP 229
5	TAR	CP 232	-	CP 272	POWER DEPT. PLASSER/WIRE TRUCK, POWER DEPT. INTERLOCKING AND DRAWBRIDGE INSPECTION	0030	-	0530	X	X	X	X	X	X	X	X	X	X	ONE BLOCK AT A TIME, WORK WITH OTHER OUTAGES
6	4&2	CP 233	-	CP 234	ATLANTIC STREET CONTRACTORS	2359	-	0530	X	X	X	X	X	X	X				CHANGE TIES AND INSTALL TRACK PADS INSIDE CP234 INTERLOCKING. BARRICADES WILL BE SET UP WEST OF THE 24X ON TK 4, WEST OF 12X ON TRACK 2 AND 31X ON TRACK 1. MAINTAINERS WILL BE ORDERED FOR THE NIGHT TO CRANK SWITCHES TO GET IN AND OUT OF YARD.
7	4 & 2	CP 234	-	CP 240	PTC CONTRACTOR	0045	-	0530								X			AFTER 1599/6573
8	ALL	CP 241	-	CP 248	SUBSTATION / CP 243 / C1A CONTRACTORS	0030	-	0615		X									4 TRACK OUTAGE INSIDE CP 241, TRACK 3 IS THE RUNNING TRACK. TK 4/2 0035HRS AFTER 1599/6573, TK 1 AT 2359HRS, TK 3 POWER 0045HRS AFTER 1594/6570. TOW 6598,6500,6502, 6503, 6505, A65, A66.
9	3 & 1	CP 241	-	CP 248	REPLACE RAIL / TIE STUB CLEANUP / MUDSPOT REMEDIATION	0030	-	0600					X		X				AFTER 1599

On Thursdays, the track outage conference takes place and the Dispatching Chiefs decide whether outages will be granted.

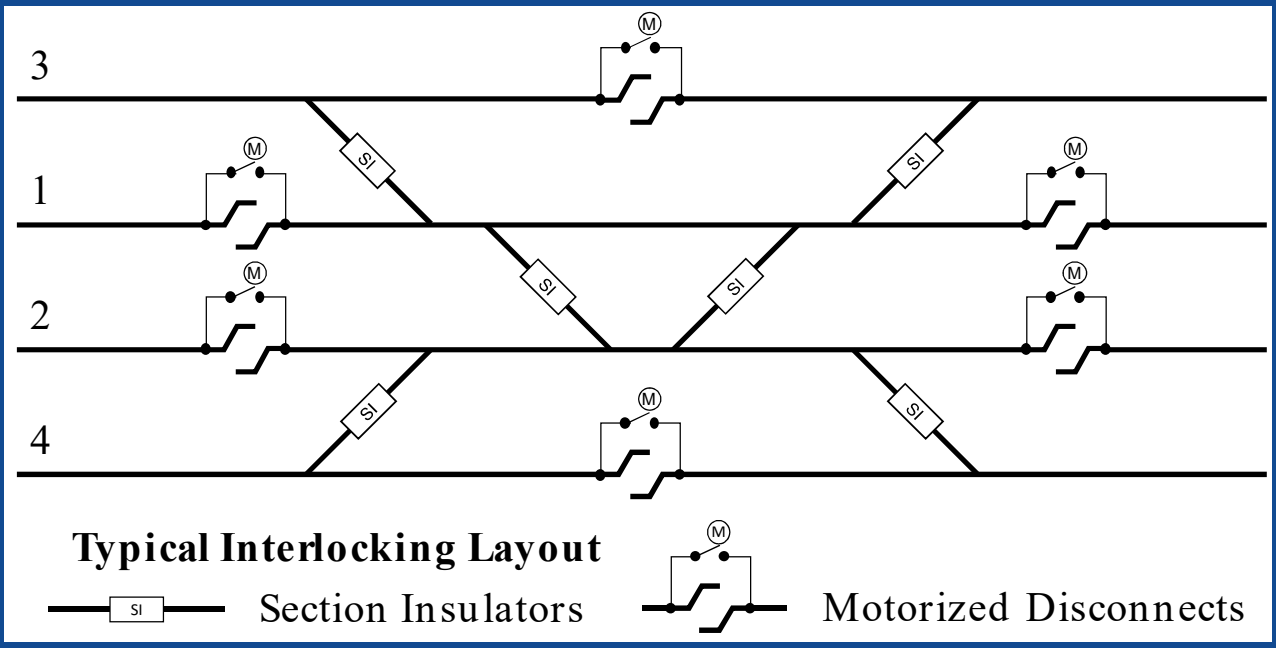


METRO-NORTH POWER DEPARTMENT
OUTAGE REQUESTED / CLASS 'A' ASSIGNMENT

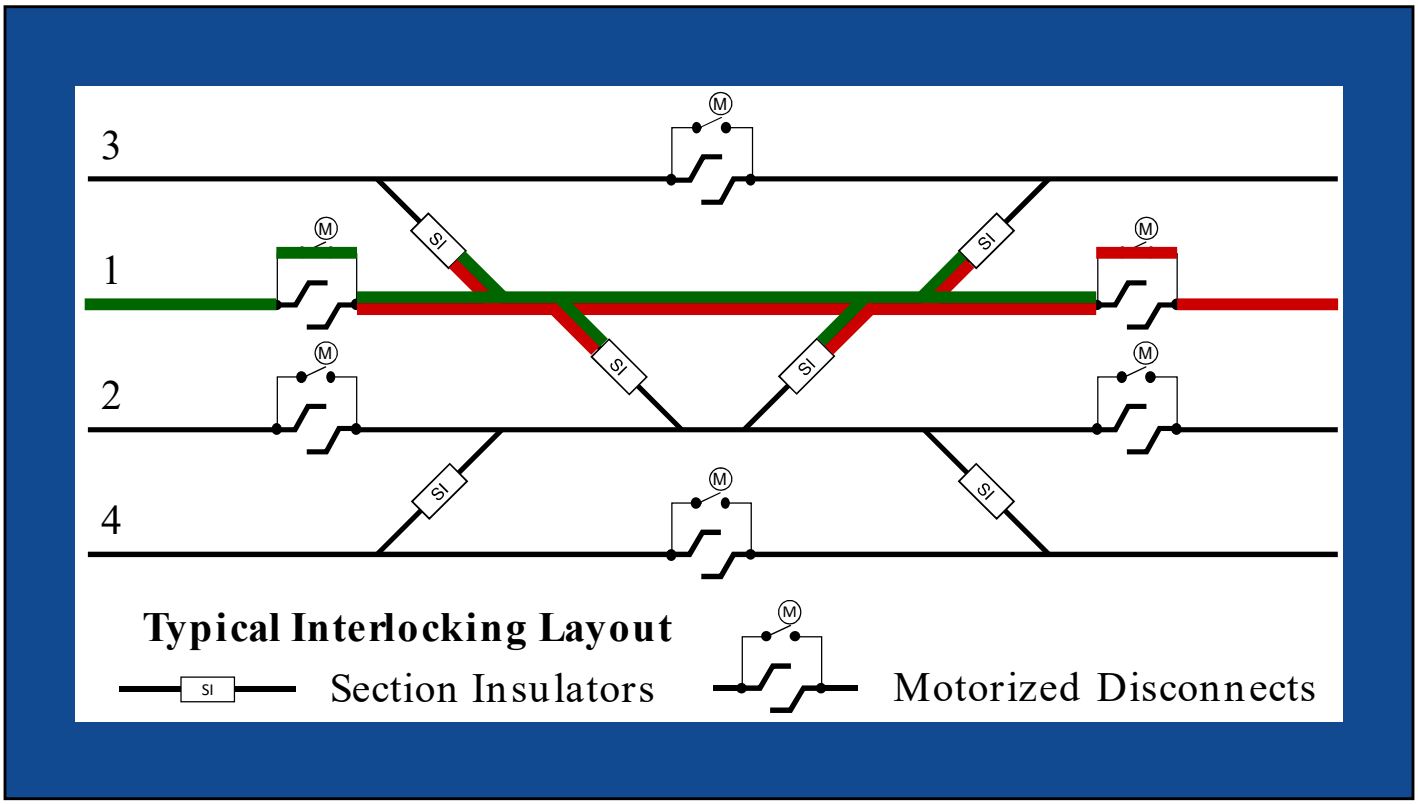
LINE NO.	NIGHT WEEKEND JOB DESCRIPTION	LOCATION	PC	WORK ORDER	COST CENTER	NUMBER OF DAYS	CLASS A MEN ASSIGNED	VEHICLE(S) ASSIGNED	2017 OUTAGE REQUESTED	DATE: REPORT TIME	6/22 to 6/24 REMARKS	CHECK
1	POWER DEPT.	SPRINGDALE	061		35009	1	JONES		POWER AS REQUEST	22:00	SUN	
2	POWER DEPT.	BRIDGEPORT	061		35009	2	ROMANOFF		POWER AS REQUEST	22:00	FRI, SAT	
3	UNDERCUTTER	LARCHMONT	061	81139	35171	2	TWO		TR 2 E80A-W184	22:00	FRI, SAT	*
4	WALK BRIDGE PROJECT	NORWALK	061	20550	32242	3	ROSADO JAMES TWO(SU)	SUB 537	TR 3 E524-W537 NORTH SIDE E527-W537	22:00	FRI, SAT, SUN	*
5	C1A DUCCI	EAST NORWALK	061	20401	35411	2	TWO	SUB 537	TR 3 E531-W632 TR 1 E531-W632 NORTH SIDE E524-W632	22:00	FRI, SAT	*
6	RIZZO NETWORKING	BRIDGEPORT BURR ROAD	061	20526	35411	2	SCHMIDT(FR) ONE(FR) TWO(SA)		TR 3 635-735 NORTH SIDE E650-W735	20:00	FRI, SAT	*
7	UI BAIRD TO CONGRESS	BRIDGEPORT	061	52112	35571	2	BRIDGEPORT GANG	SUB 814	4 TRACK OUTAGE SEE TIMELINE	21:00	FRI, SAT	*
8	BRIDGEPORT TRACK	DEVON	061		35610	1	BRIDGEPORT GANG		TR 2 E858-W864A	22:00	FRI	*
9	RIZZO SUBSTATION 865	DEVON	061	20276	35610	2	BRIDGEPORT GANG		TR 3 & 1 NORTH SIDE (LIMITS OF 4 TRACK OUTAGE)	22:00	FRI, SAT	*
10	SPECIAL PROJECTS	NEW HAVEN CP272 31 SWITCH	061	20472	35720	1	SKREBIS ONE		TR 3 E1050B-W1068 TR 1 E1053-W1061	22:00	FRI	*
11	NH DRILLERS	NEW HAVEN	061	20021	35720	1	TWO		TR 1 E1051-W1087	21:00	FRI	*
12	ATLANTIC STREET	STAMFORD	061	20492	35340	2	TWO		TR 4 E356B-W372A TR 2 E366A-W371A	22:00	SAT, SUN	*
13	14TH AVE VERDE	MT. VERNON	061	12160	35121	1	ASZMUS CHISOLM		NORTH SIDE WEST OF 23	22:00	SUN	*
14	NH LINE SIGNAL PROJECT VERDE	NOROTON HEIGHTS	061	20511	35341	1	TWO		TR 4 E374-W513A SOUTH SIDE E374-W524	22:00	SUN	*
15	NH LINE SIGNAL PROJECT TREE TRIMMERS	RIVERSIDE	061	20511	35291	1	TWO		TR 4 E295A-W356B TR 2 E298A-W354A SOUTH SIDE E313-W374	22:00	SUN	*
16	UI / McPHEE BAIRD TO CONGRESS	BRIDGEPORT	061	52112	35571	1	TWO	SUB 814	TR 4 E774-W DEVON SOUTH SIDE E775A-W867 (shorten limits as needed)	22:00	SUN	*

On Friday is when the real-time factors, like labor shortages, equipment malfunctions, severe weather, or unexpected operational incidents will be definitively knowable. Although fraught with points requiring short-notice revisions, this process works well if all stakeholders actively support the process and are fully engaged.

Most rail professionals have some experience with routing trains around a track obstruction, making moves using appropriate signals, crossovers, and tracks. Isolating a segment of overhead catenary is similar in concept, but outages must provide electrical paths to deliver power outside the de-energized area, keep crossovers and drawbridges energized whenever possible, and ensure that the power supply doesn't become "unbalanced".



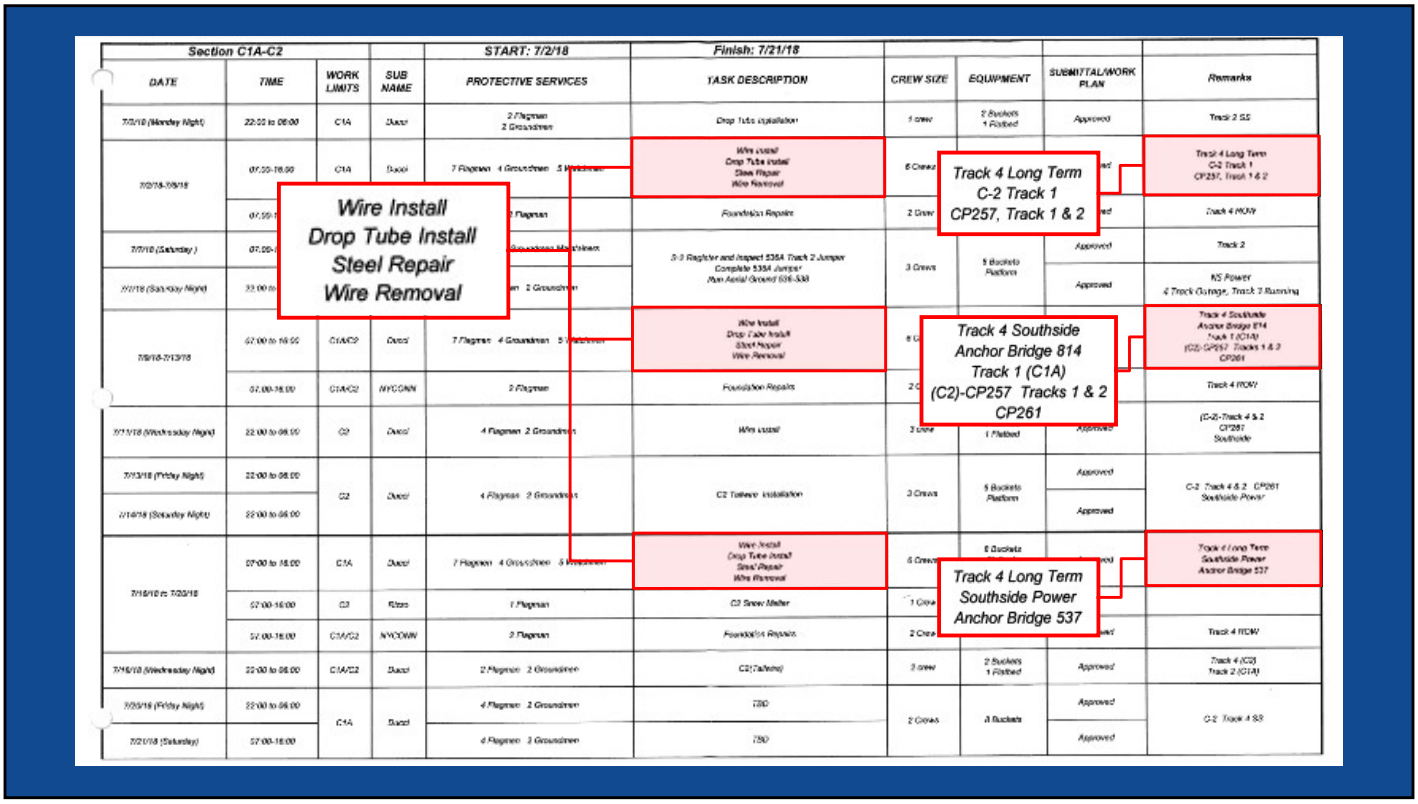
By placing six motorized disconnects (or MODs) around an universal interlocking, we can keep the crossovers live even when a middle track needs to be isolated.



The catenaries within the interlocking can essentially be fed from either end. However, this adds to the circuit complexity and complicates switching operations.

Substations are not typically located at interlocking locations. Interlocking locations are based on train service needs and physical site characteristics …

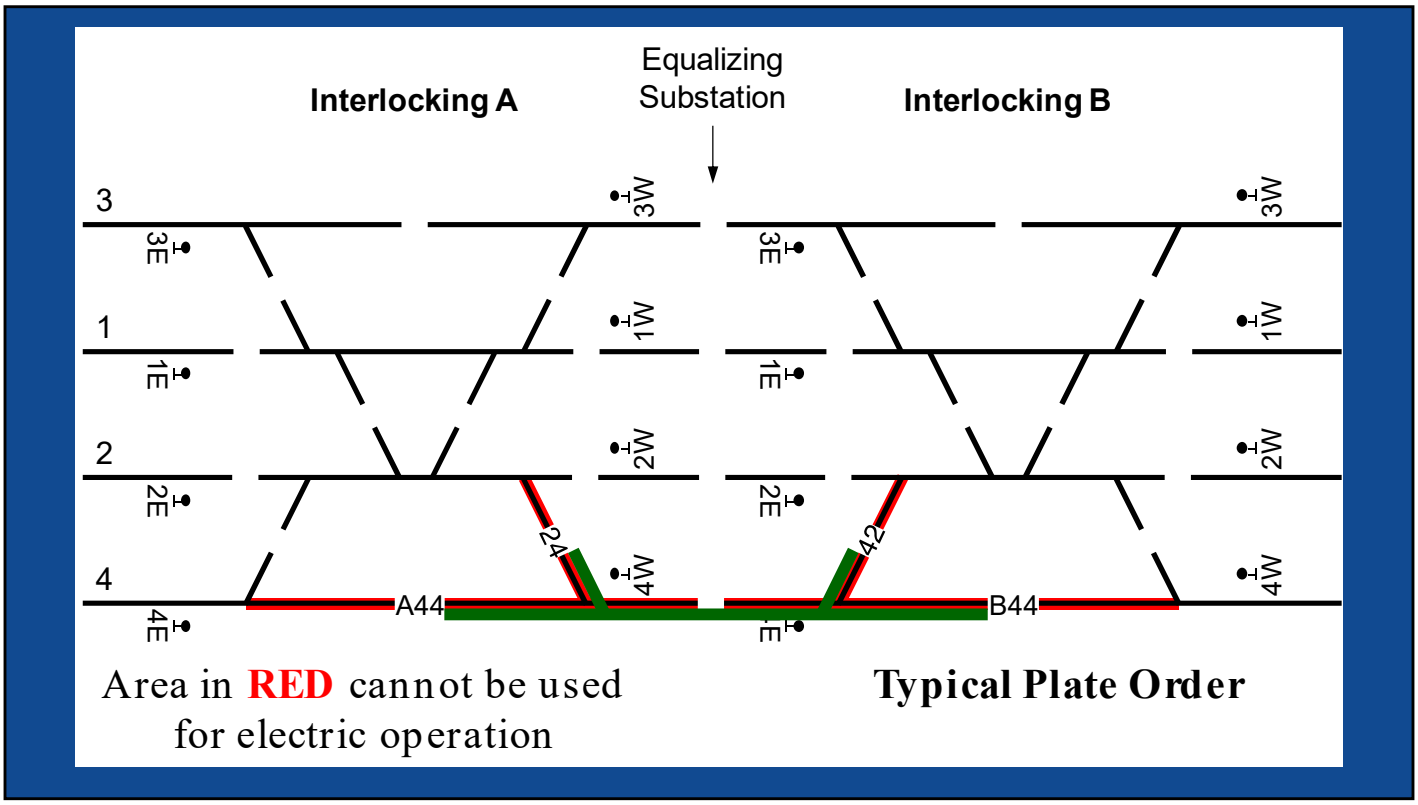
… whereas substation locations are based on power demand constraints, electrical resistance considerations, supply convenience, and space needs. This introduces additional circuit complexity to accommodate substation switching requirements.



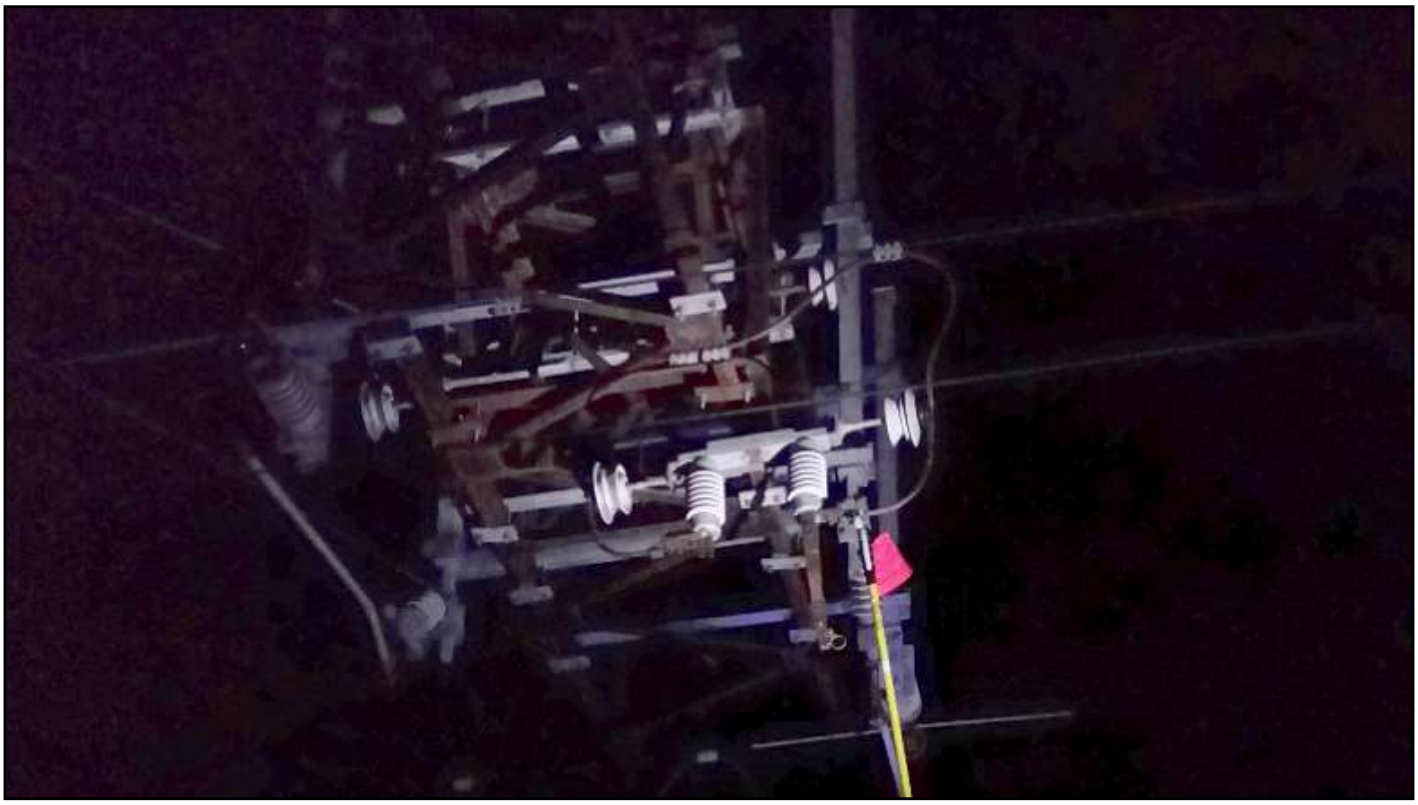
A high degree of customization is required to configure circuits for wire work at any given location. Work on the same track and the same signal block a few catenaries apart on two consecutive nights may have entirely different electrical and mechanical environments, and may require a different circuit set-up to provide the necessary isolation. Each outage in effect requires a tailor-made circuit configuration and must be meticulously planned by Power Directors responsible for switching operations.

The actions of Power Directors and Dispatchers at the same physical locations must line up. Where the catenary is grounded for an outage, the signals and switches must be set such that no electric trains enter the segment.

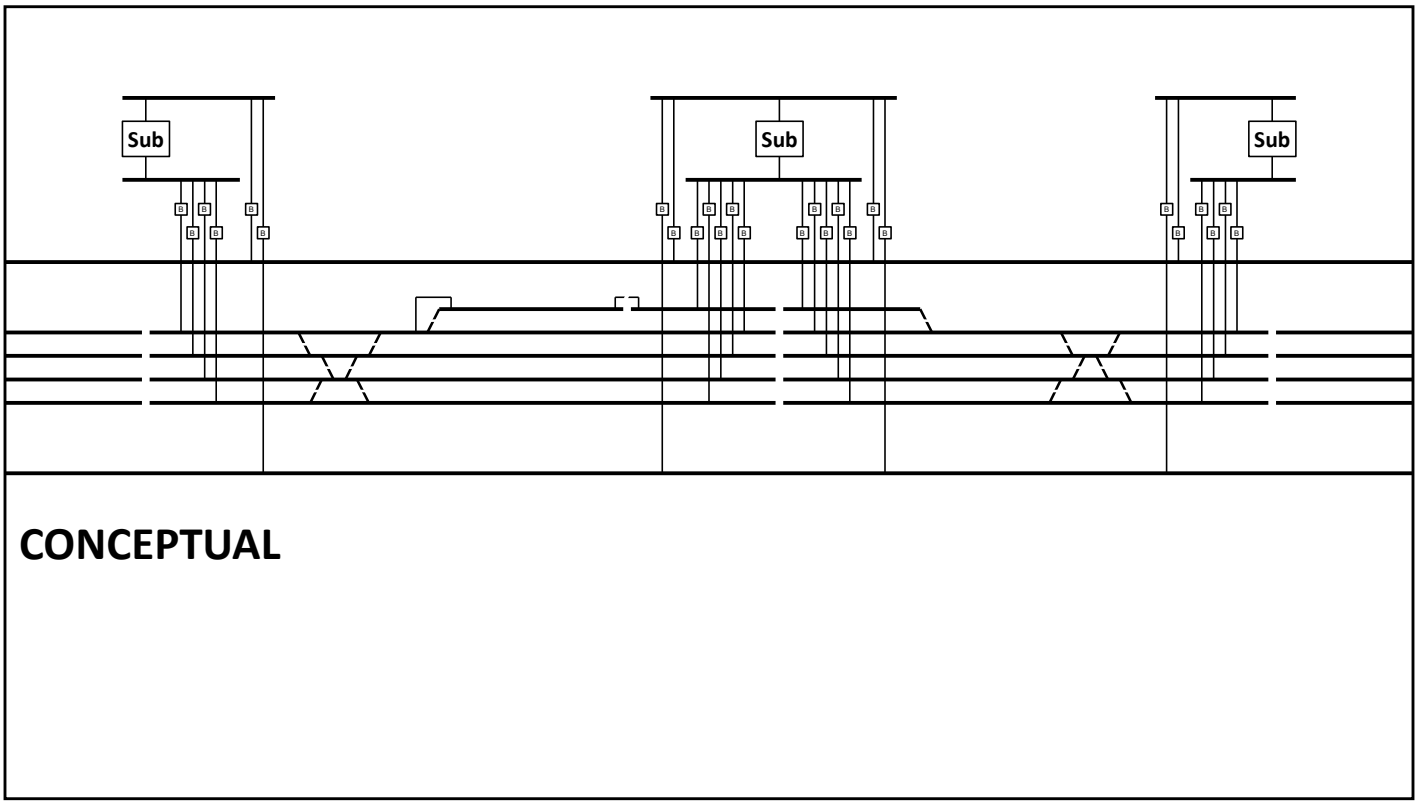
Some equipment have multiple pantographs bussed together. Allowing an electric train to travel across an air gap or section insulator between energized and de-energized sections momentarily allows two sections to be electrically connected, resulting in backfeeding through the high voltage bus onboard the train.



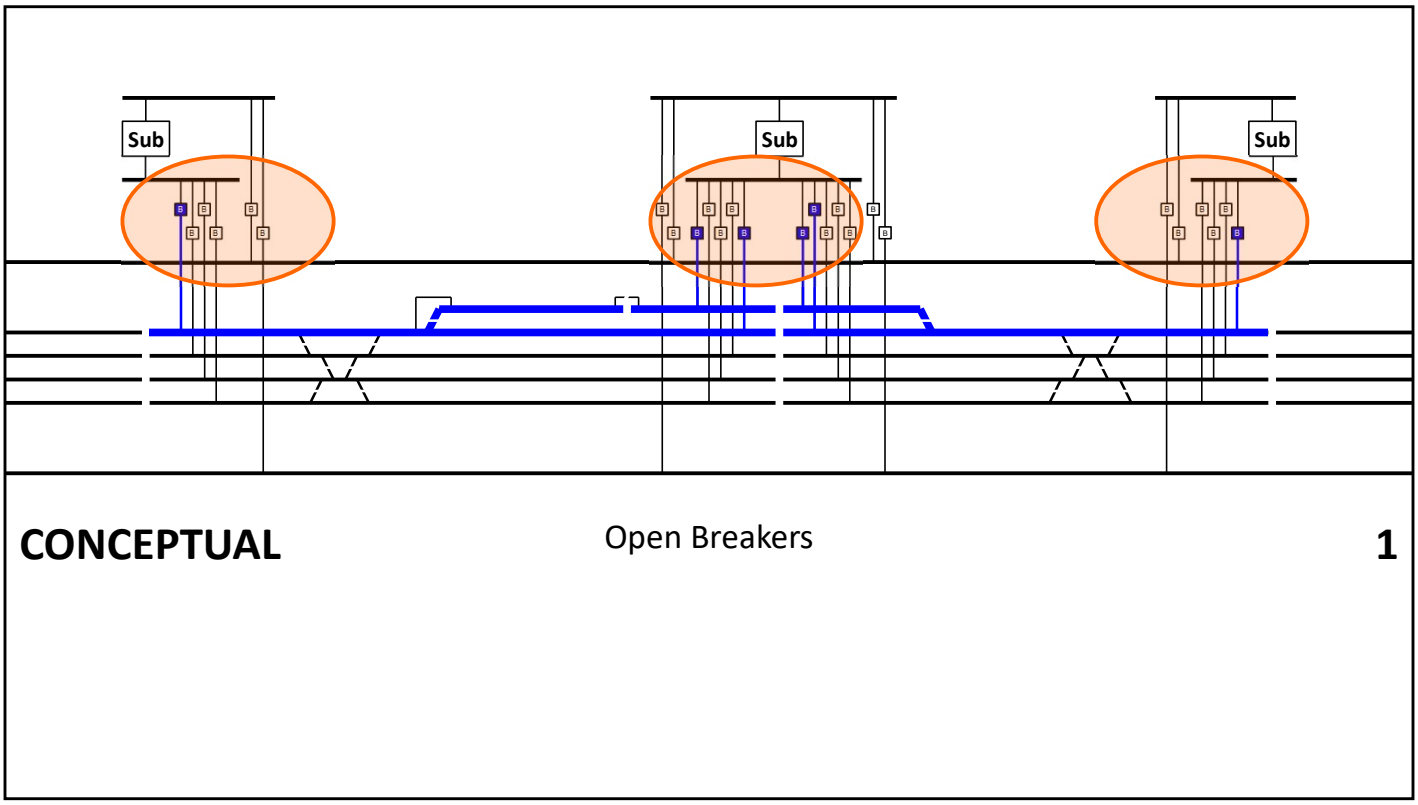
To ensure safe operations, we use Plate Orders, which are pre-defined limits showing track segments that cannot be used for electric operations, and identify switches that must be blocked unless required by a diesel train. Typically, the area having electric operations barred (from switch to switch) is slightly larger than segments of catenary being isolated (from SI to SI), as a safety backstop.



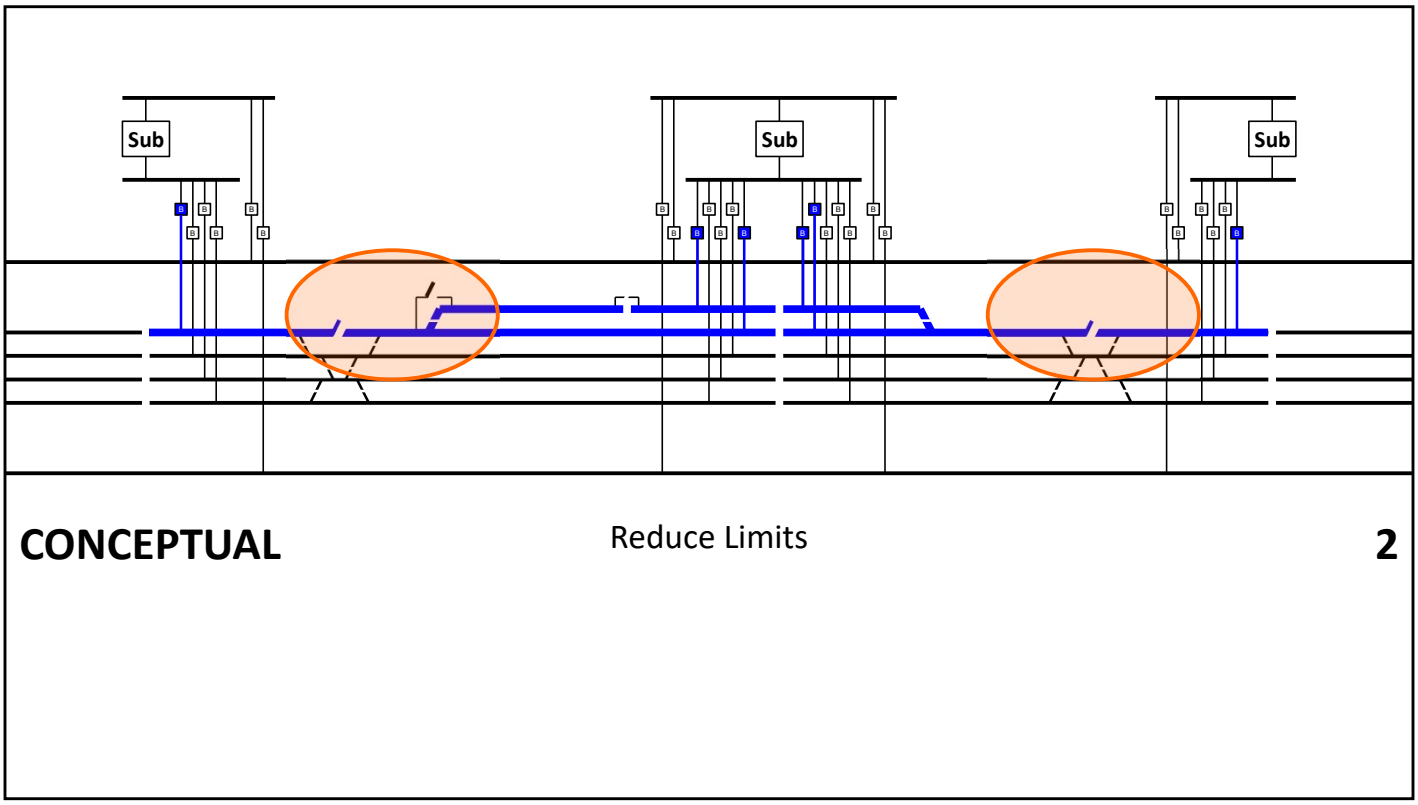
Typically, to accomplish a circuit change, four steps are necessary. First, the request is received from the Field. The change is then commanded via SCADA or paperwork. Then an employee will execute the change, whether by operating an in-line knife switch, motoring an MOD, racking out a breaker, or attaching grounds. The device is then tagged out to prevent resetting in error. For a fully remote-controlled device, this sequence may take only 30 to 90 seconds. However, where physical operations are necessary in the Field, it will take longer.



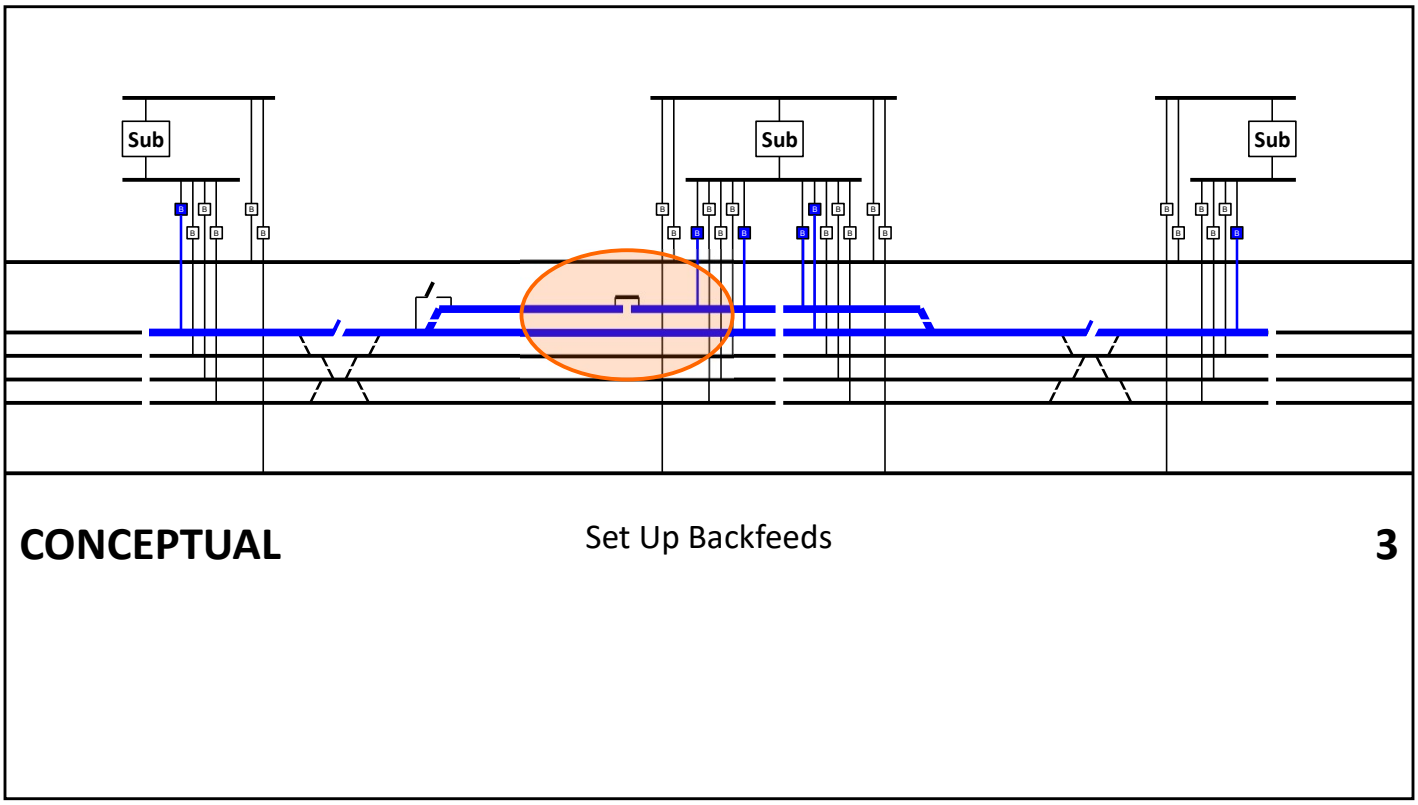
These (conceptual) steps are needed to isolate a segment of catenary:



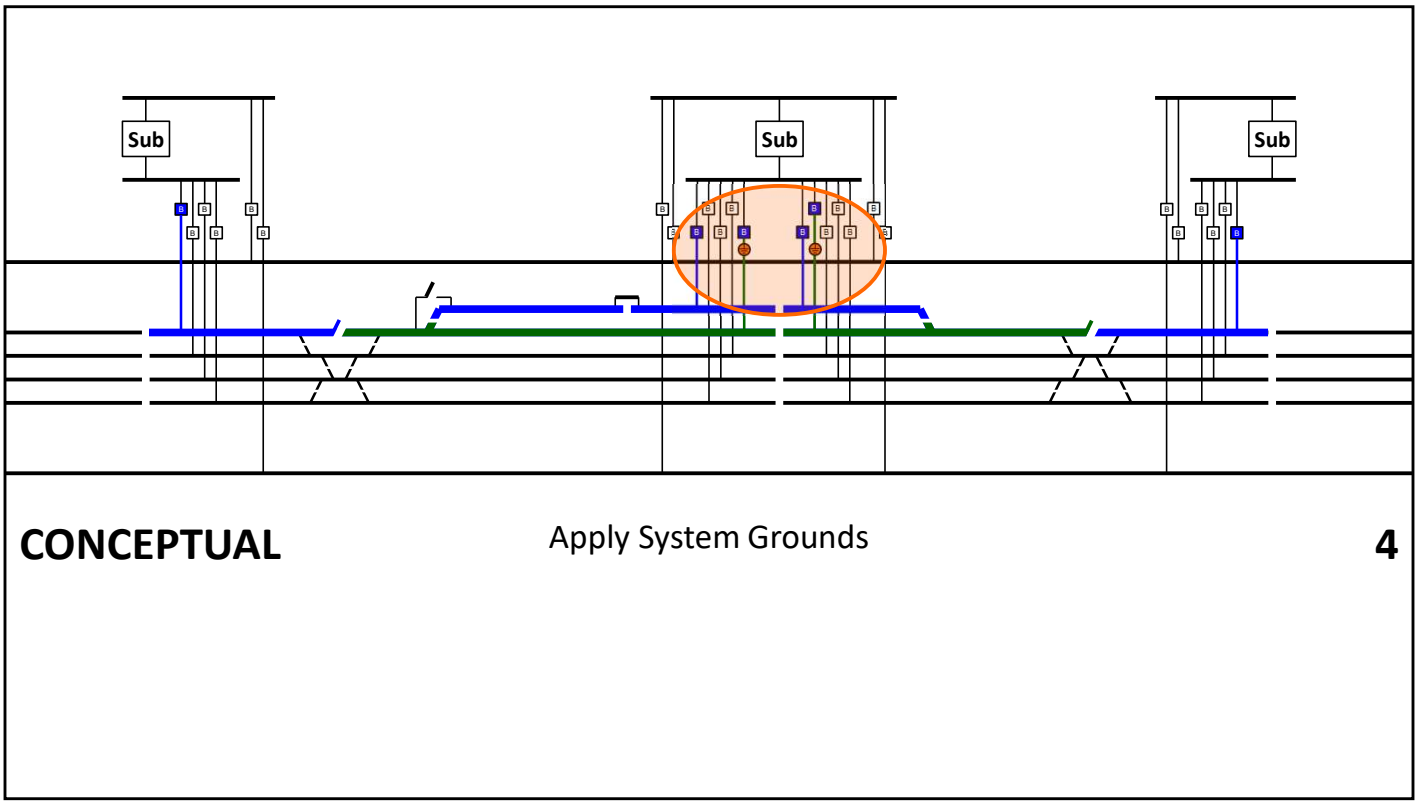
(1) Open appropriate breakers at all substations within the section.



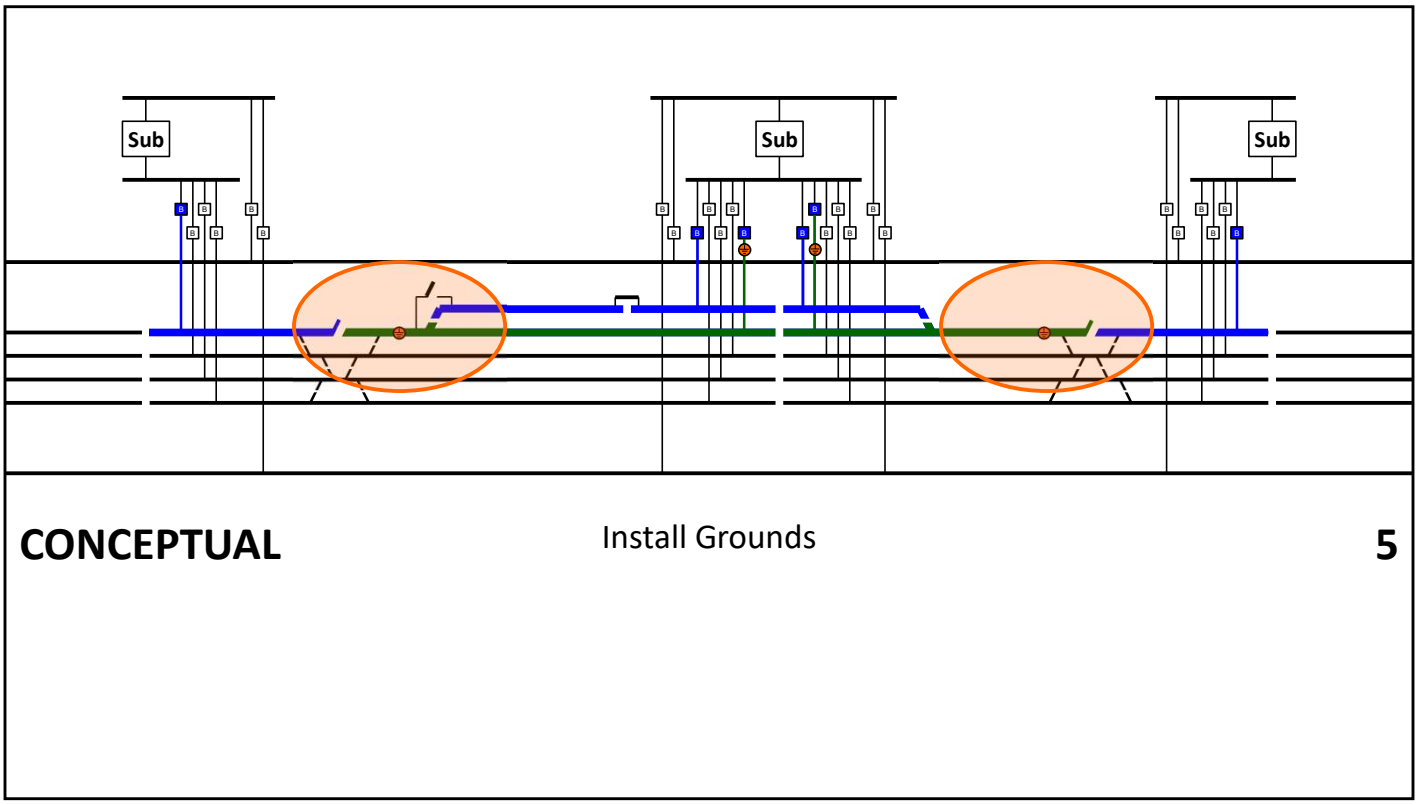
(2) Operate MODs or in-line switches with power de-energized to reduce outage limits.



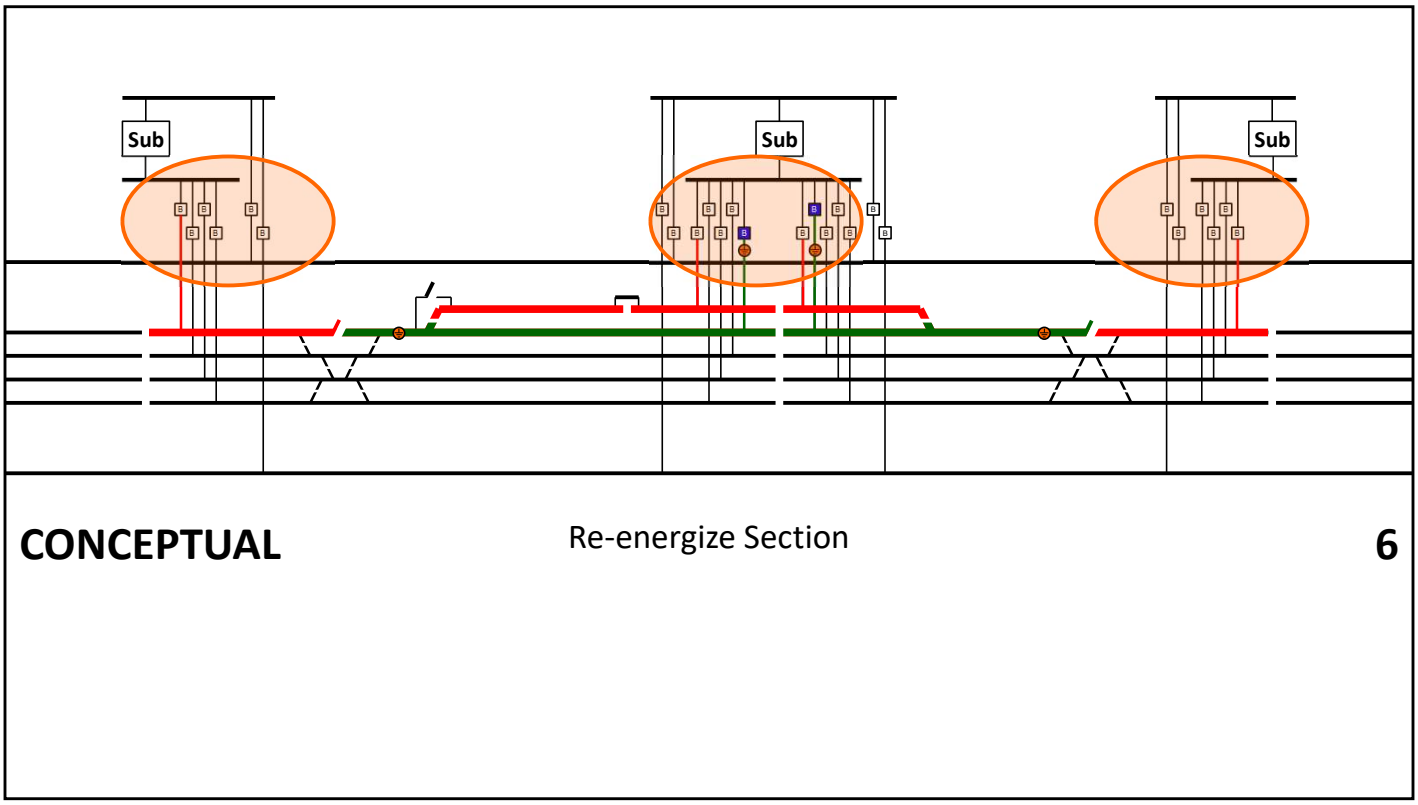
(3) If adjacent sections become de-energized as a consequence, close appropriate switches to provide backfeed.



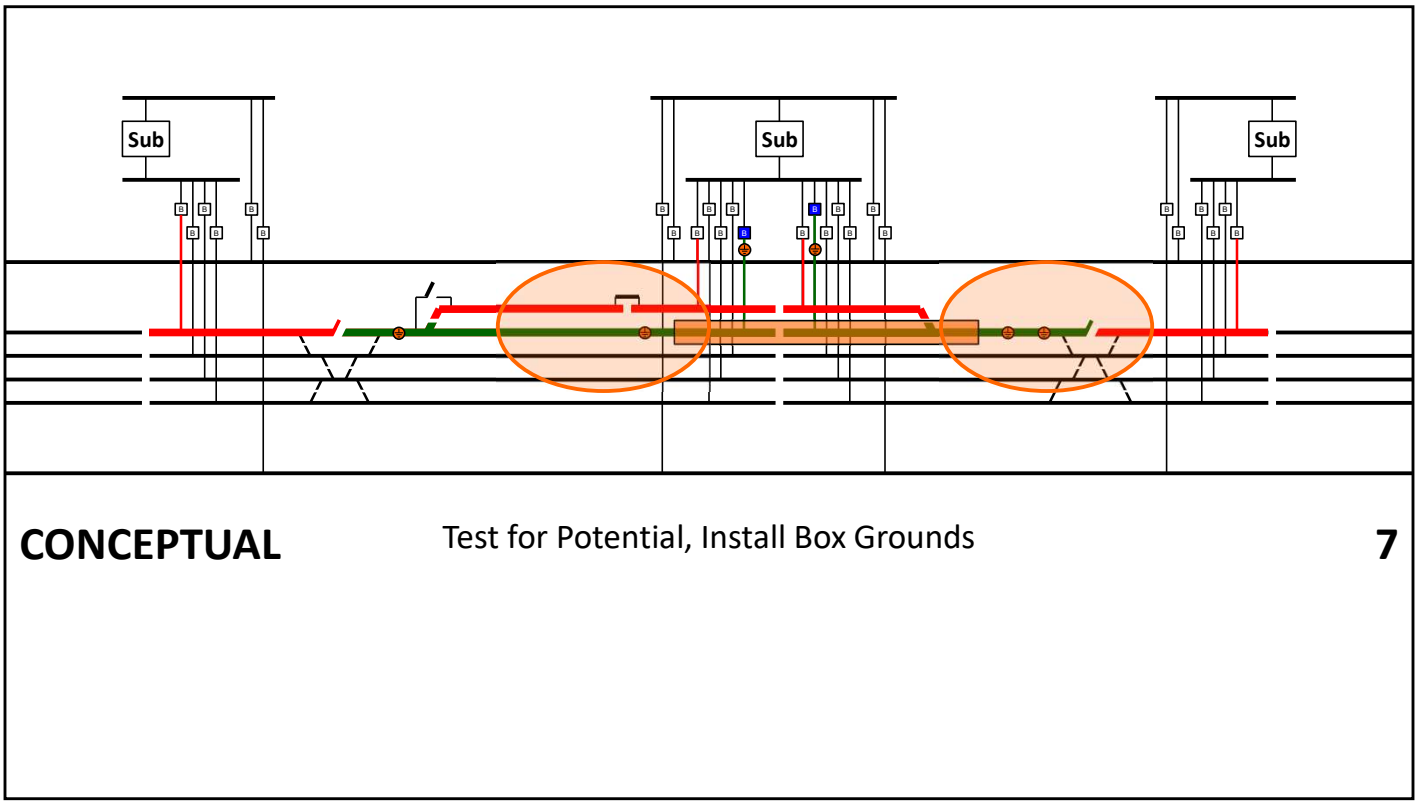
(4) If there's a substation in the dead section, open breakers and apply system grounds.



(5) Install grounds. If aerial grounds are used, more de-energizing may be needed to allow safe access.

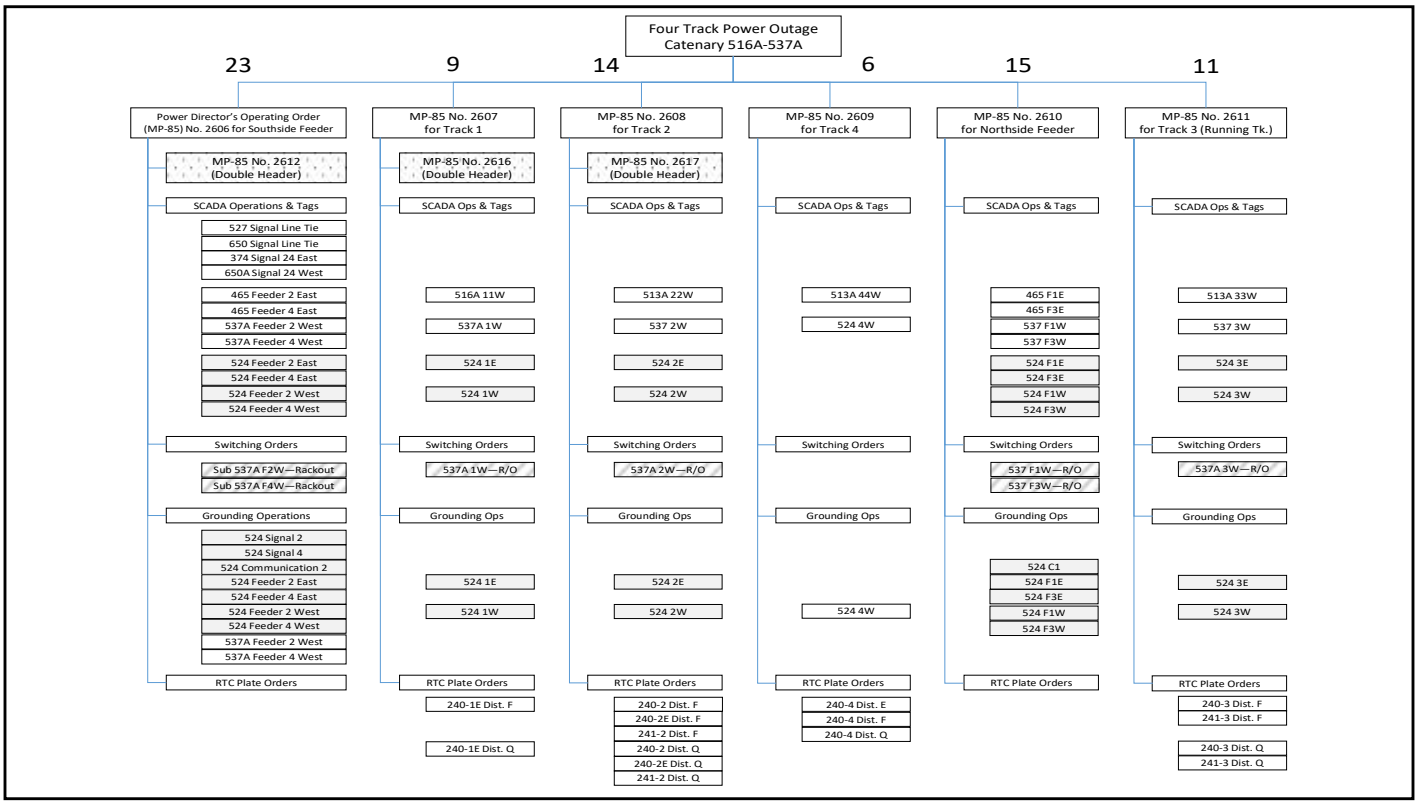


(6) When everything is set up, the entire area is re-energized by closing the substation breakers.



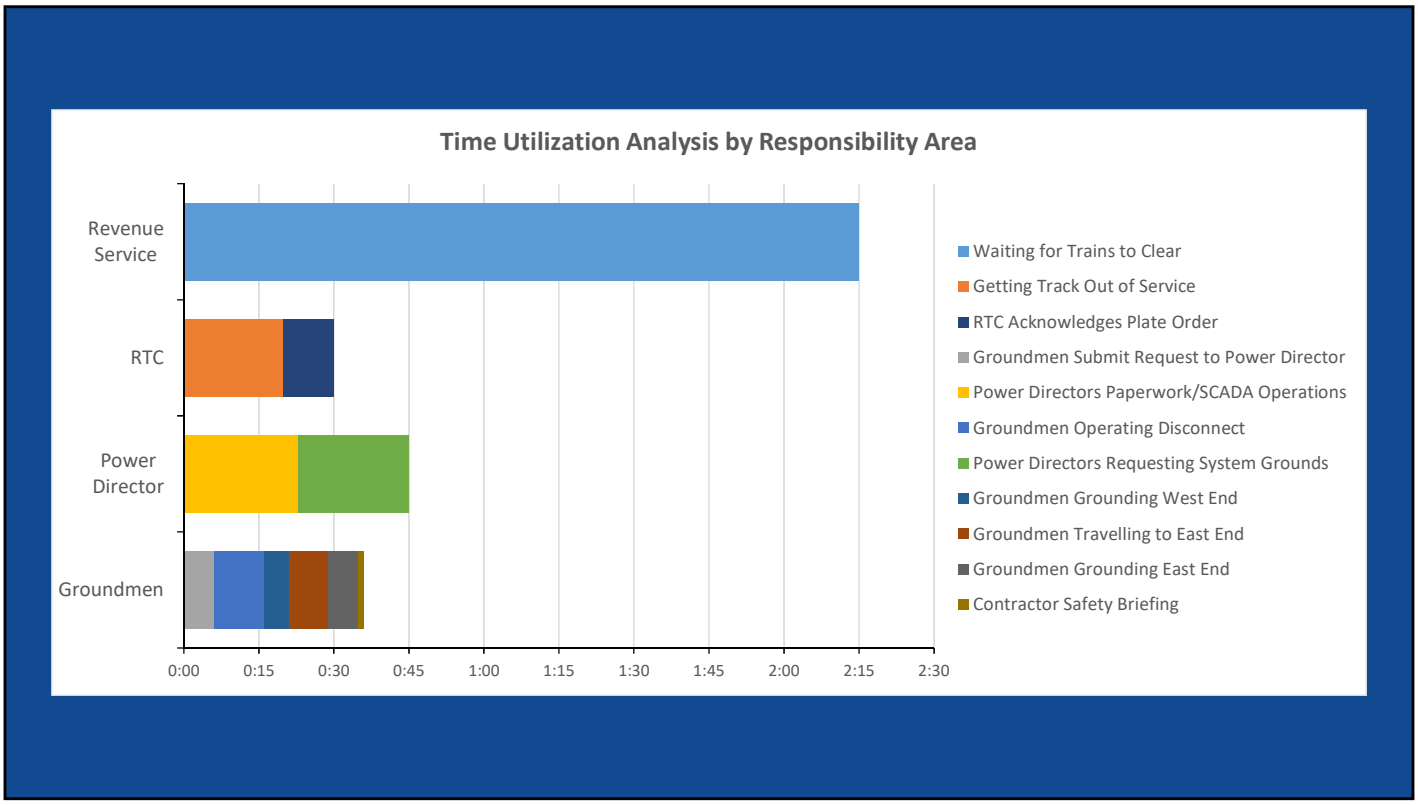
(7) Test for potential within the outage, and install box grounds.

How many circuit changes does it take to implement a typical outage? We have an example where an outage across all four tracks was necessary to remove bridle wires. One anchor bridge (awaiting final decommissioning), one malfunctioning substation, and one movable river bridge all fall within the outage limits.

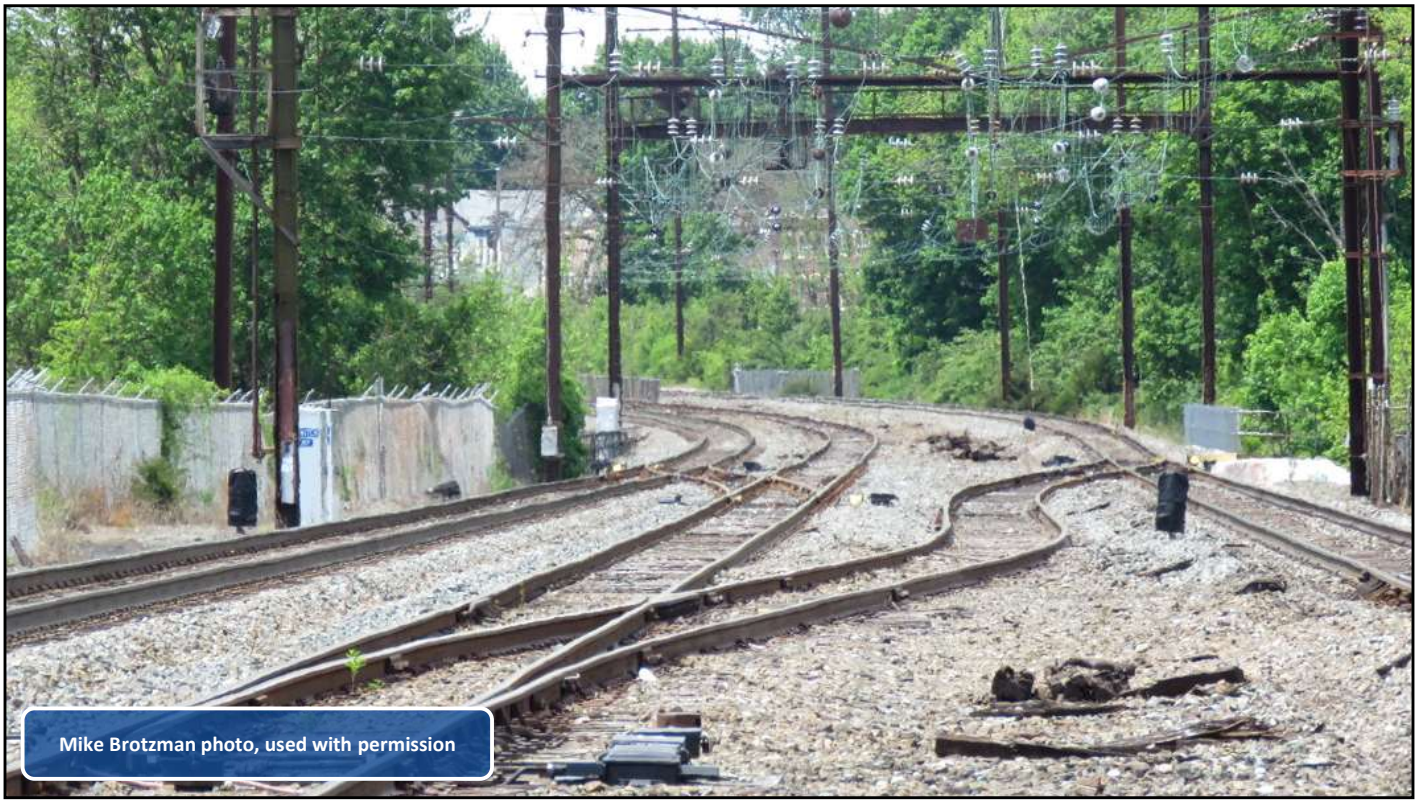


It is not unusual to find these "obstructions" while trying to set up an outage. Six forms were needed, one for each track and one each for feeder line groups on either side of the right-of-way, which together required 78 individual operations to be commanded.

How long does this all take? We measured this on a typical night of operations, and found that the longest delay was actually caused by overrunning service due to trains from an afternoon baseball game affecting the overnight work window.

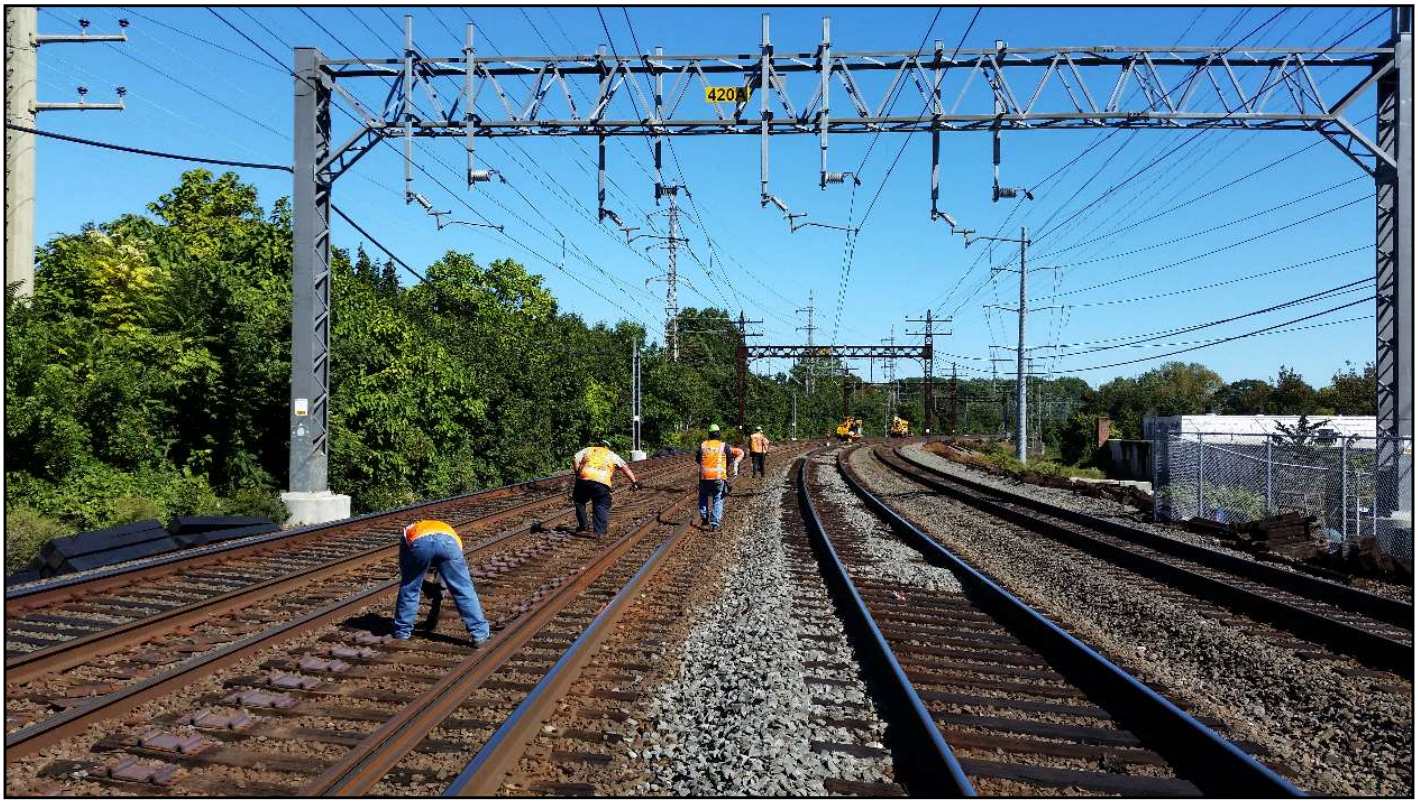


Once track outages became effective, it was fairly fast to run through all the necessary steps, but because of their complexity, even under near-ideal conditions with proper planning, it still took one hour and 51 minutes to accomplish this. Factor in the time required to restore the power before the morning rush, that six-hour overnight work window can quickly become a two-and-a-half-hour work window. That, ladies and gentlemen, is the fundamental reason why catenary renewals under traffic always seem to take longer than generally thought.

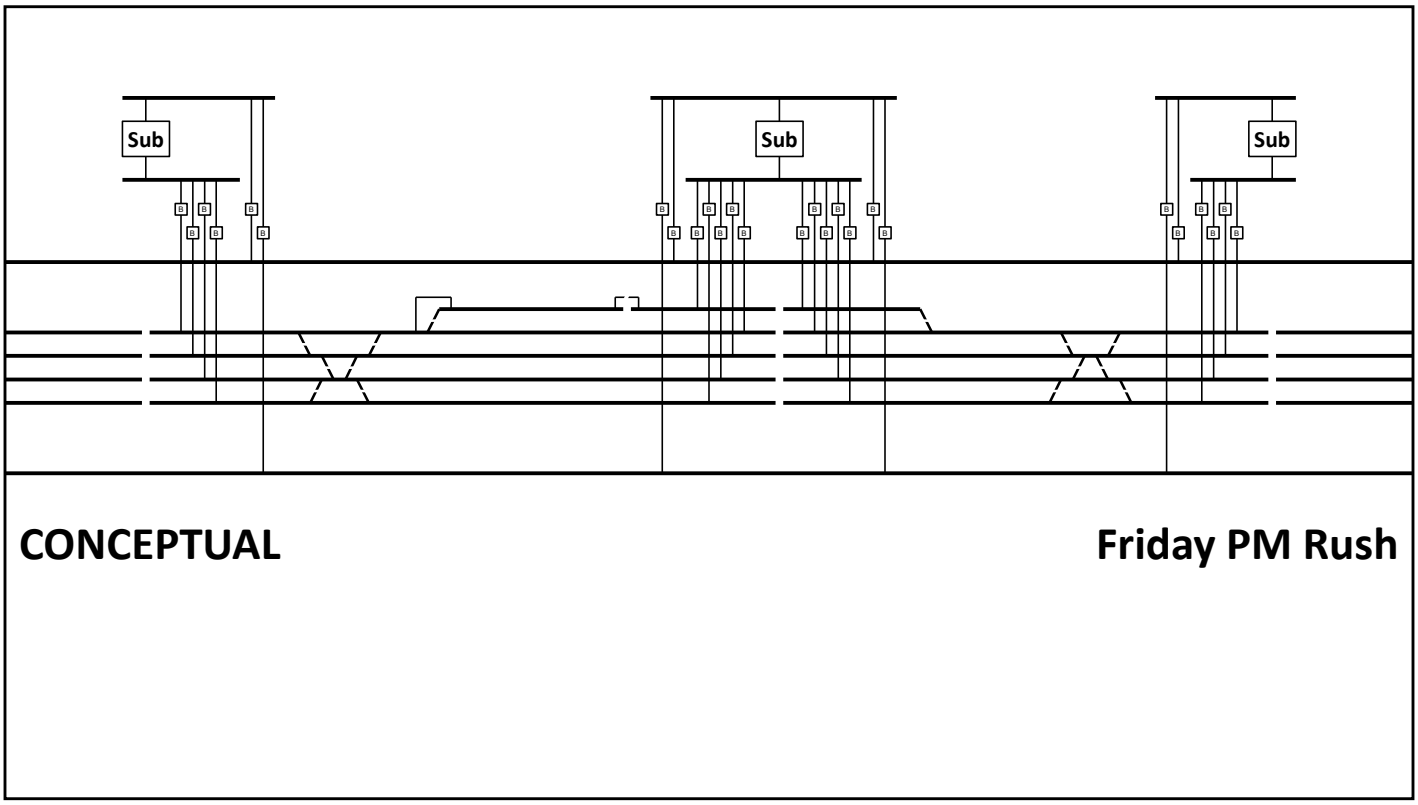


While track layout is the domain of the civil engineer, where the priorities are track speed, capacity, and safety …

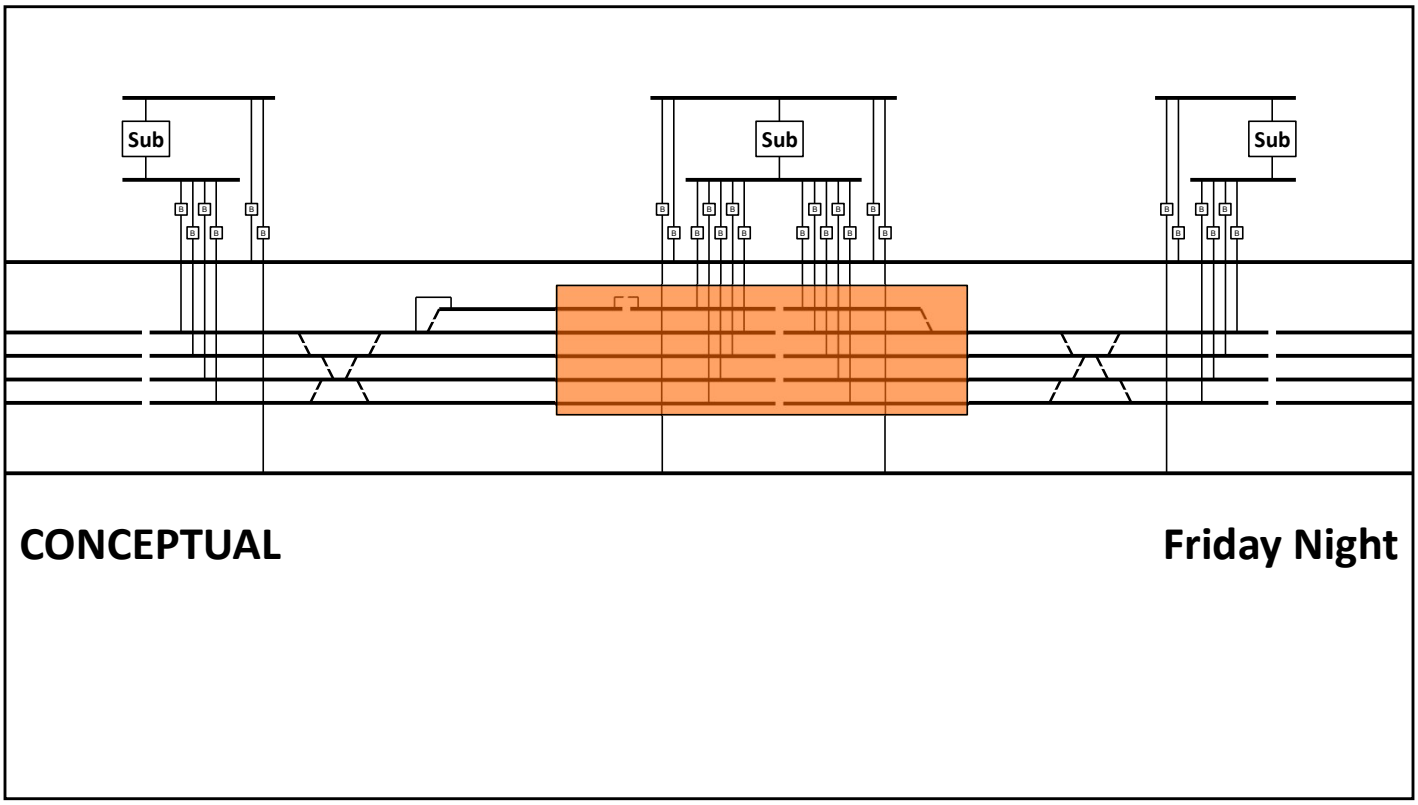
… power infrastructure is designed by the electrical engineer where the concerns are cost, load capability, and safety. When possible, interlockings and traction substations could be co-located, or at least designed jointly, to simplify maintenance and emergency power isolations.



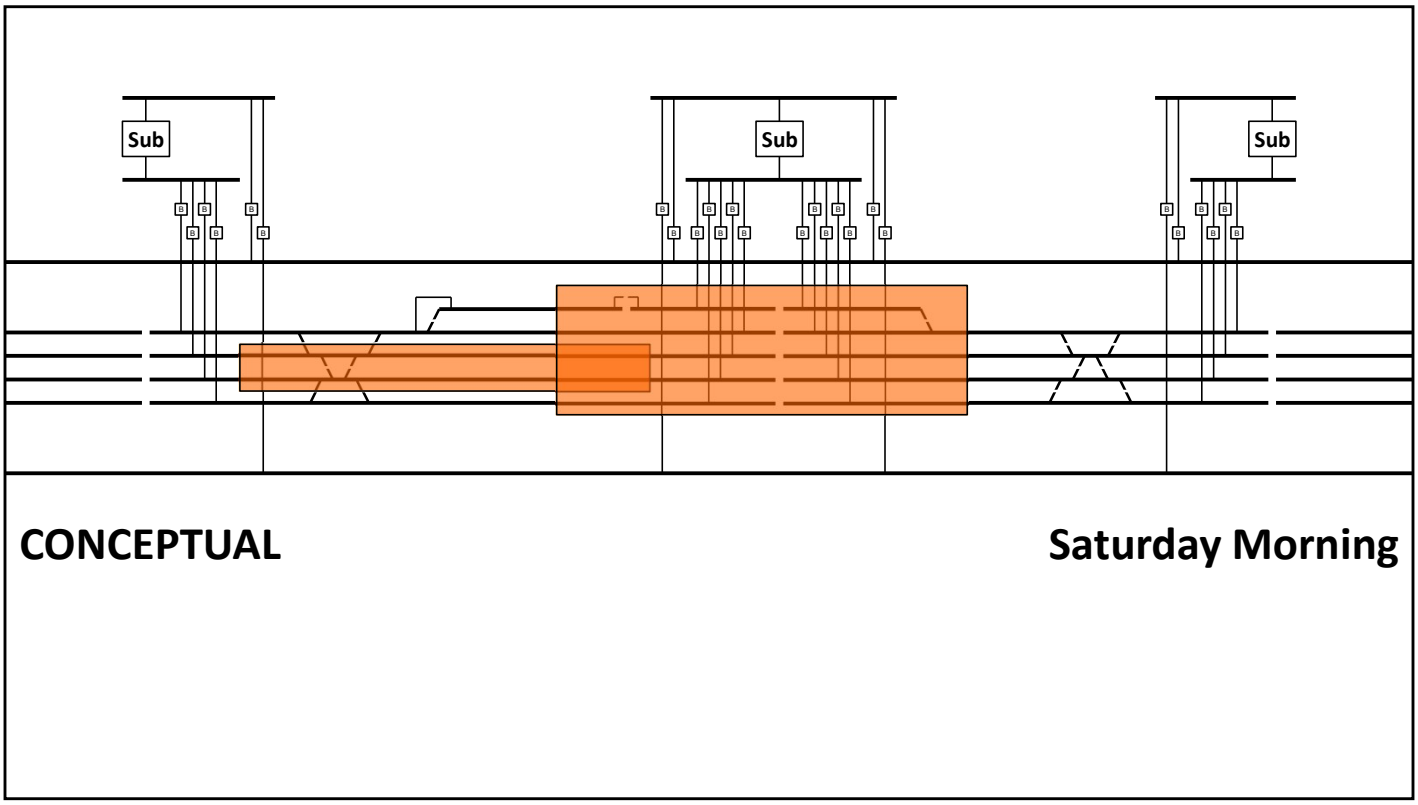
Personnel with a solid understanding of both electrical and track infrastructure and processes are vital in both planning and construction. Typically, Transportation, Track, and Power are different departments, but cross-training is possible with agreements and promotional paths that facilitate the acquisition of such knowledge.



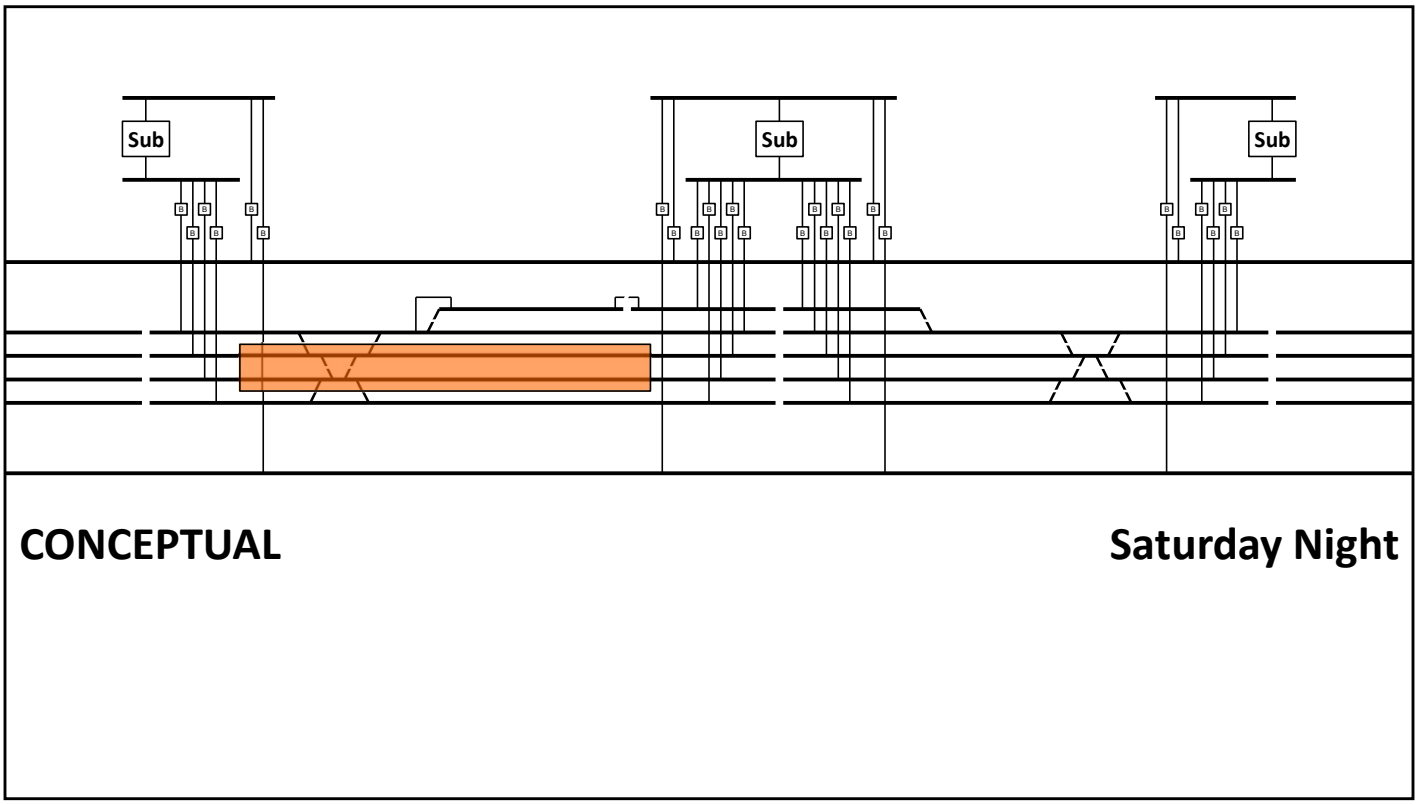
Overlapping isolations are particularly disruptive when two outages overlap but do not begin and end at the same time, requiring re-configuration of circuits four times that weekend:



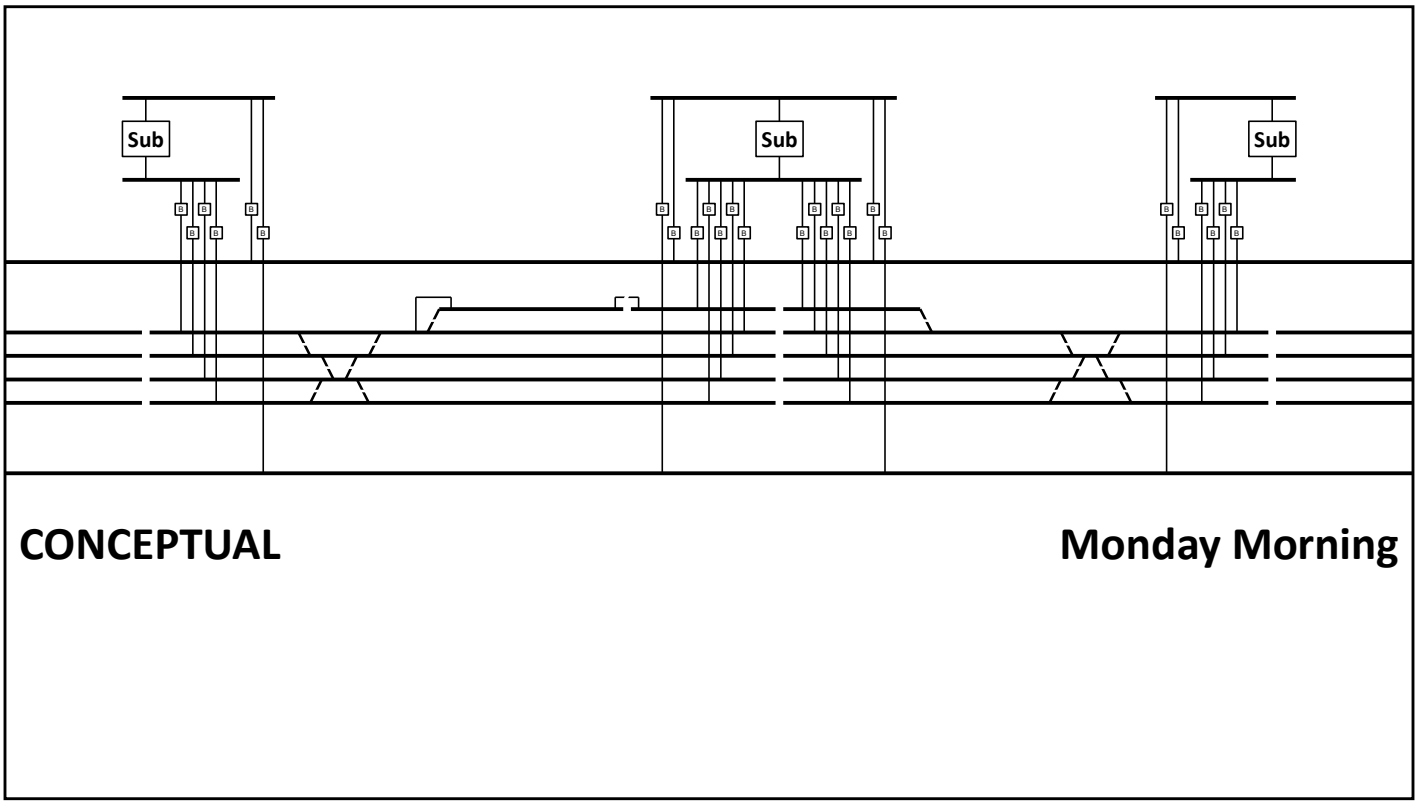
… for outage A, …



… for outages A and B together, …

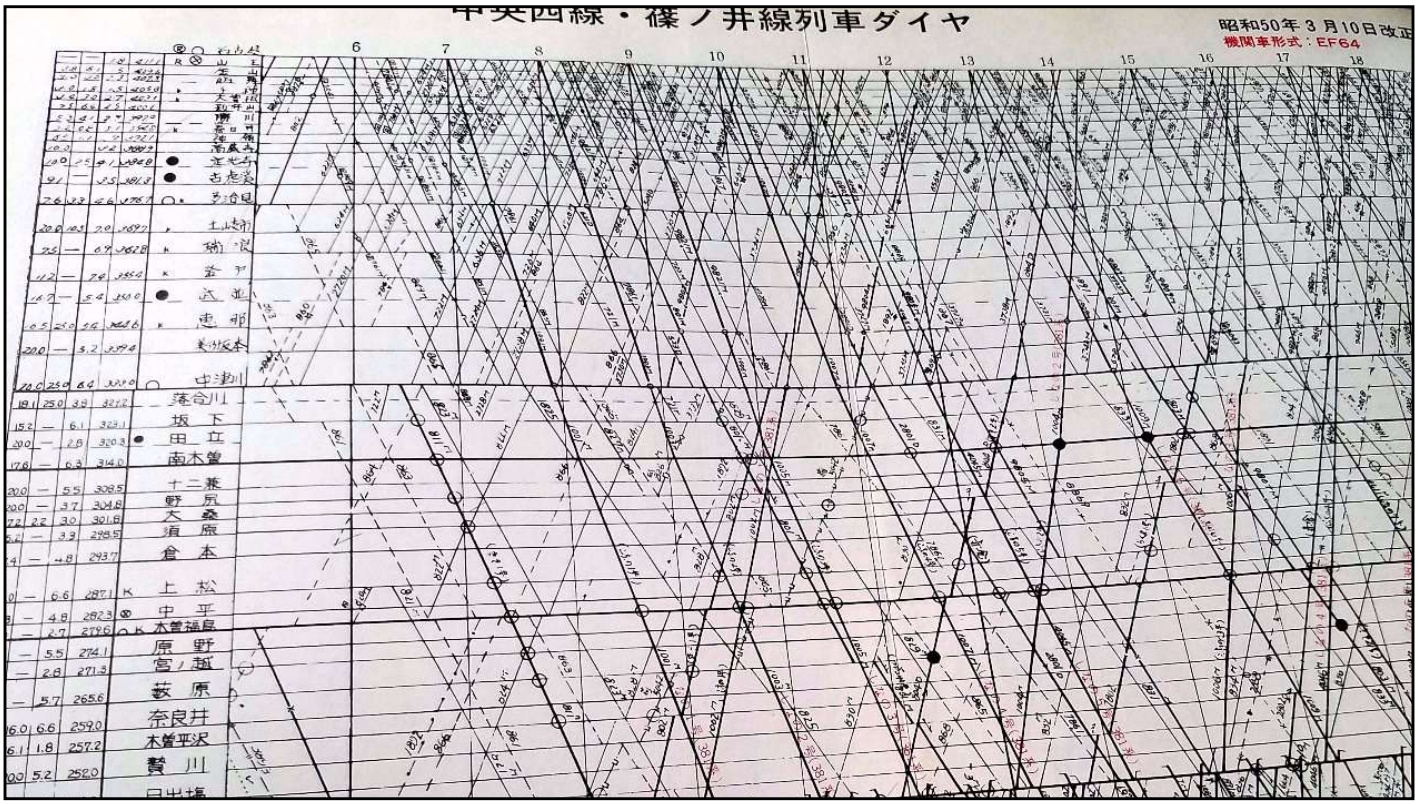


… for outage B, …

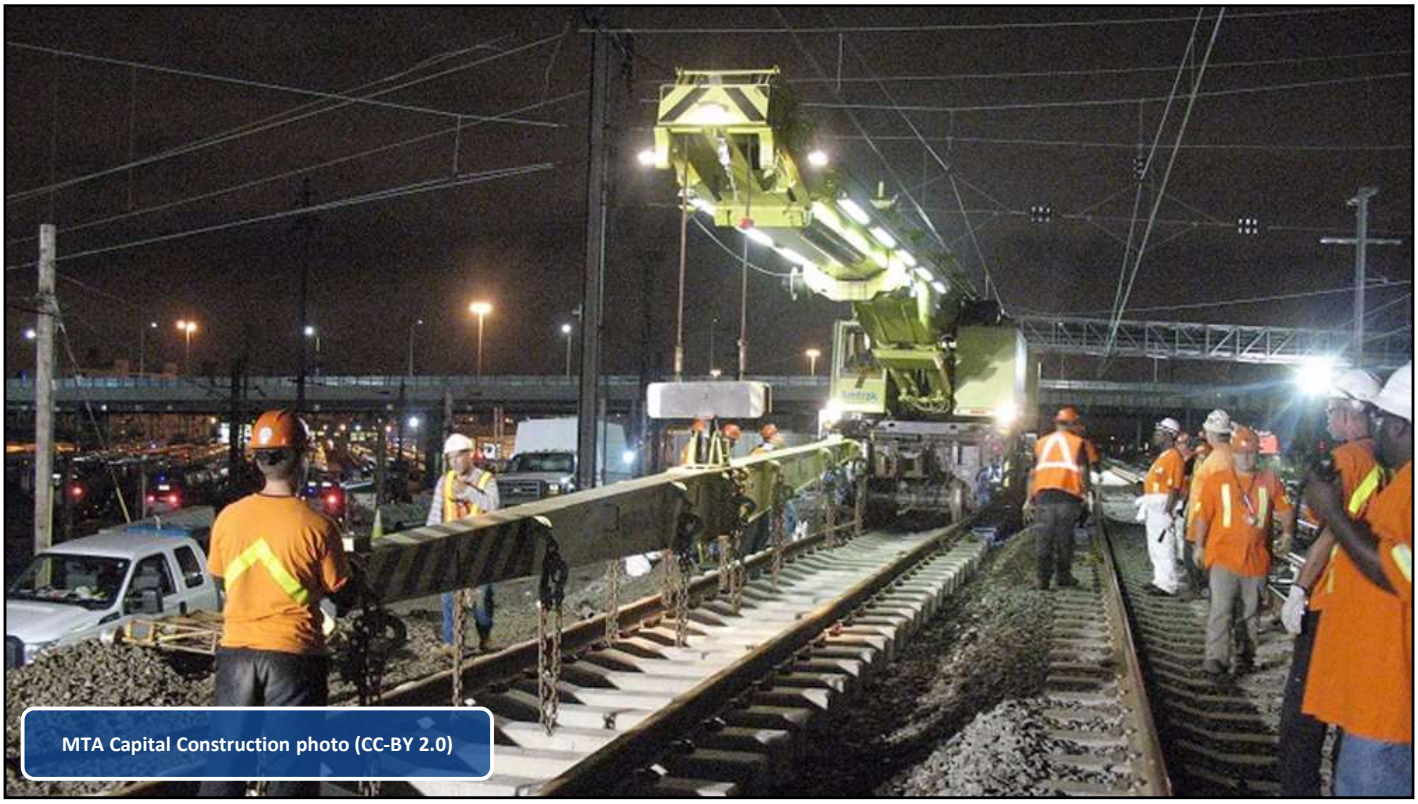


… and to clear up.

The trade-off between piggybacking work to spread the costs of alternative service and construction support, and the increased risks and complexity that come with overlapping outages, should be carefully considered.



Maximum maintenance outage capacity should be assessed formally, separately for track and power infrastructure. There exists a maximum practical operational capacity to provide track and power outages while maintaining train service, which is something that may not be fully appreciated. This “outage capacity” should be assessed formally, similar to how track signaling capacity is assessed now.



The benefits of electric traction are most evident in high-density, high-utilization corridors, but ongoing maintenance can impose significant costs. These “hassle” factors help explain why U.S. railroads have historically preferred diesel traction.

However, with the recent advent of high-capacity battery-electric locomotives that can haul typical loads over a 200-mile gap in electric catenary, electrification may now be possible over a wide area while concentrating electric traction infrastructure in the highest density segments, re-charging the locomotives in motion.

If you'll now think twice before wiring up every track mile, then I've done my job for today.

Any Questions?
Discussion? Comments?

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Thank you!