CIGRE-482 **2022 CIGRE Canada Conference & Expo**
Calgary, Alberta, Oct.31 – Nov. 3, 2022

Case Study Live Work Maintenance on Legacy Double Circuit 144kV H Frame Structures

V. BARR, S. JIANG, D. VACHON, R. MALTAIS, K. OBERLE, S. NEELAWALA
ATCO Electric
Canada

SUMMARY

Transmission line maintenance on legacy transmission structure has become more challenging, especially where the live work is required. Concerns were raised when ATCO Electric planned to replace deteriorated wooden crossarms on a portion of 6 km of D/C (Double Circuit) 144kV line 7L20/7L80 c/w 25kV distribution underbuilt. This portion of D/C line was installed in 1971 on legacy wooden H-Frame structures. This legacy structure is not in compliance with current ATCO standard design in terms of inter circuit clearance requirements and cause potential maintenance limitations. As each crossarm carries phase conductor(s) from different circuits, it is ideal to de-energize both transmission circuits to replace the cross arms. As 7L20 and 7L80 are the only two transmission lines connecting power generation and community to rest of the system, simultaneous de-energization of lines is not possible to perform maintenance. Live work maintenance on this D/C line therefore becomes the only acceptable approach in this case.

Various live work options were assessed prior to on-site maintenance. The option of temporary by-passing of one circuit on a single pole line about 10m away and leaving the other circuit live on H-Frame was examined first. This approach became expensive since additional temporary structures were required within very limited ROW width and on very rough terrain. Moreover, the rough terrain significantly restricted equipment access. After thorough in-house and on-site assessment, an innovative live work crossarm replacement method with optimized cost, reduced construction time and environment impacts was selected.

Live work and equipotential bonding and grounding (EB&G) on de-energized conductors were required in this work method. Crossarm replacement work were to be executed within existing H-Frame without using additional supporting structures. Over 20 dedicated safe work steps including combination of bare hand and hot stick live work methods were identified based on calculations and assessments.

KEYWORDS

Transmission line D/C H Frame; Live work; Cost; Environmental protection

1. INTRODUCTION

Power line maintenance on legacy infrastructure becomes more challenging when live line work methods are required. ATCO Electric has been in the electrical utility industry for several decades. ATCO is operating approximately 11500 km of transmission lines and 62000 km of distribution lines in its' service territory in Northern and Eastern Alberta. Though ATCO design standards evolved over the time with the advancement of Industry Codes and Standards, and safety and reliability requirements, the legacy designs still exist in the system. ATCO legacy structures were built with wooden poles, crossarms and braces and deterioration of wooden components over the decades is becoming a system reliability issue. System constraints and geographic locations are limiting the maintenance and restoration work of some of these lines. On the other hand, configurations of some of the legacy structures are not favouring live line maintenance work. This paper will examine a specific case where maintenance had to be performed on a legacy line with system constraints, access constraints as well as structure configuration constraints. The issue, alternatives considered, and the steps taken to complete the work will be discussed.

2. PROBLEM SUMMARY

7L20 and 7L80 are two 144kV 1egacy lines built to connect Grand Cache area to the rest of the transmission system. Both lines were built in hilly terrain. 7L80 was built in 1968 with Partridge conductor. 7L20 was added to the system in 1972 and built with bundle Ibis. Approximately 6 km of the parallel section of the lines was built with double circuit H-frame structures with distribution underbuilt due to terrain and ROW constraints.

Figure 1: 7L20/7L80 D/C Section ROW

Figure 2: Crossarm Failure Causing Grass Fire

Crossarm failures and inter-circuit clearance issues of double circuit section became a reliability issue of these lines. Crossarm failures caused some environmental impacts too. Though ATCO had taken some temporary measures for inter-circuit clearance issues of the double circuit section over the years, the load transfer in emergency situations continue to cause outages in the energized line. Therefore, ATCO planned to replace the deteriorated wooden crossarms in these lines and to give the priority to double circuit section.

Though the work was planned, the circuit configuration of the double circuit section, de-energization constraints and inter-circuit clearances added complexity to the task. Triangular configuration of the circuits and the limited inter-circuit clearances required simultaneous de-energization of the lines to perform work safely. Simultaneous de-energization was not possible due to the transmission limitations. 7L20 and 7L80 are the only two lines connecting the Grand Cache community to the system.

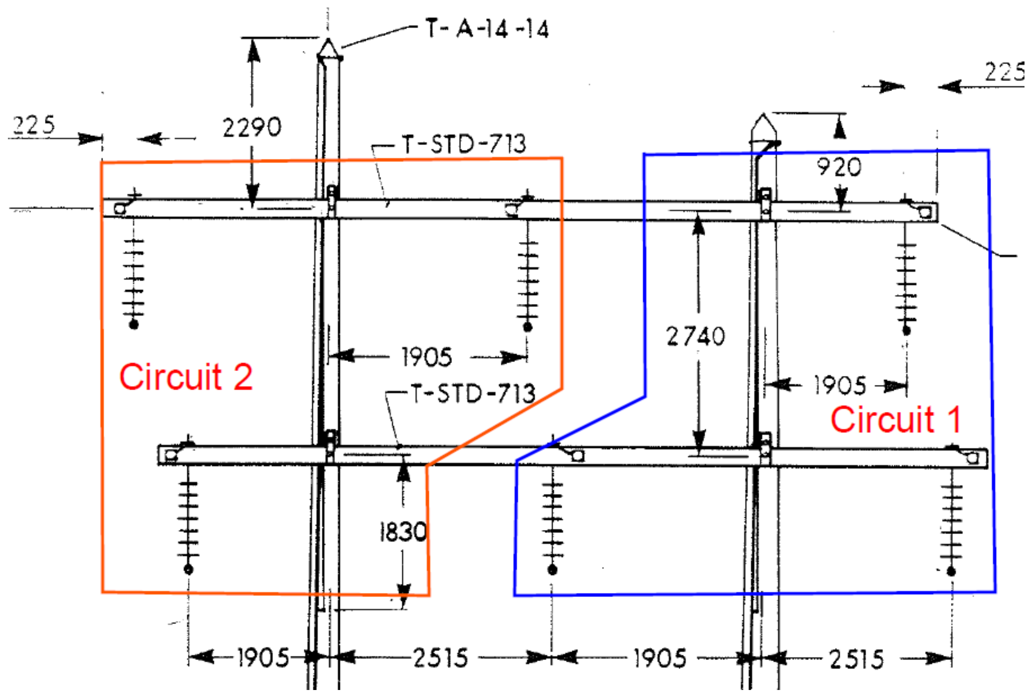

Figure 3 - Circuit Configuration of 7L20/7L80 Double Circuit Section

Due to the complexity, Engineering and Maintenance groups together evaluated possible options to complete crossarm replacement safely and successfully. The options with de-energization of single circuit and with de-energization of both circuits with temporary bypass were evaluated. Each option was assessed for work method feasibility, operational risk, environmental impact, and cost impact.

3. EVALUATED OPTIONS

OPTION 1: REPLACE WOOD CROSSARMS WITH STEEL CROSSARMS

This option was intended for replacing wood crossarms with steel crossarms without changing the structure configuration. The option addresses the immediate concerns of deteriorating crossarms. The adequacy of insulation, air-gap clearances, and line to ground clearances of the old configuration was analysed to decide required alterations. Addition of one more insulator for the insulator string and lowering the lower crossarm by 0.6m were recommended.

This option was evaluated with temporary bypassing of one of the circuits by building a single pole line in parallel to the existing. The line was to be built approximately 10m away from the closest conductor and with stand-off insulators to have safe working space. With the completion of bypass, it was intended to de-energize single circuit or both circuits complying to system operational requirements. Live line working crews and methods were to be utilized in case of single circuit de-energization.

Access and ROW constraints, vegetation control requirements and regulatory notifications limited the use of this option. Moreover, this option was not intended to address the long-term operational concerns due to structure configuration though the construction and salvage of temporary bypass accumulate the cost to it.

OPTION 2: REBUILD THE LINES

This option was to rebuild whole double circuit section with two compact single circuit wood pole lines within the same Right of Way. New compact lines were to build either side of the existing structures approximately 6m away from the current H-frame alignment. The de-energization of one circuit at a time was considered for the installation of structures and for transferring conductors for the newly built. When one line is built, the procedure will be followed to the other line. This option was to utilize the existing 30m ROW and addresses the long operational concerns. However, the cost of rebuild and salvage of existing, access constraints and requirement of regulatory approvals limited the utilization of this option.

OPTION 3: UTILIZATION OF TIF ARMS

The replacement of crossarms with K-line fully insulated polymer crossarms was also analysed as an option. ATCO worked closely with K-line to design insulated crossarms as they suit to the existing H-frame structure configuration. However, unbalanced loading and installation constraints eliminated the use of these crossarms.

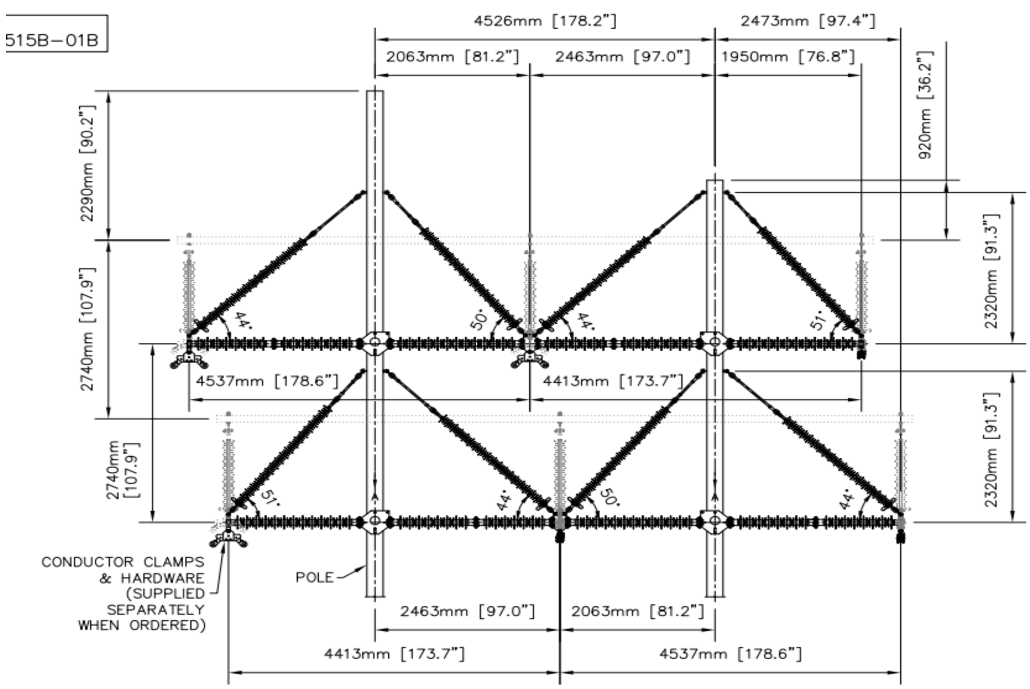

Figure 4 – K-line TIF Arm Design

OPTION 4: LIVE LINE RESTORATION

After thorough in-house and on-site assessment, crossarm replacement with innovative line work methods was selected. This option was favoured due to less dependency on environmental and ROW constraints, and optimized cost and with optimized cost, shorter construction time.

Instead of using temporary bypass, use of temporary K-line arms were considered in this option. The K-line arms were assessed for strength requirements and load bearing capability as well as against safe work regulations. As all the work needed to be completed within the same structure, assessment of work environment, suitability of material and live line tools, utilization of bare hand and hot stick live line work methods, insulation requirements and MAD (minimum approach distance) requirements to perform live line work were required to utilize this option. Over 20 dedicated safe work steps were identified based on the assessment of followings.

- Selection and monitoring weather conditions such as wind, lightning, snow, rain for safe live work
- Determination of maximum line capacity for each circuit based on ambient weather conditions as two circuits were built with different conductor types
- Possibility of derating of generation at Grand Cache end to match the maximum line capacity of live circuit
- Evaluation of safety factors for load bearing live work tools based on regulatory safe work standard
- Possibility of live monitoring of power flow by coordinating with system operator and with possibility of disabling recloser and preparation for potential emergency response
- Selection of proper live work tools based on MTID and limited TOV
- Evaluation of MAID and selection of proper MAD for experienced utility worker
- Optimization of conductor inter-circuit clearances (between both transmission to transmission and transmission to under built distribution)
- Evaluation of existing wooden pole condition and assess pole strength based on limited weather conditions

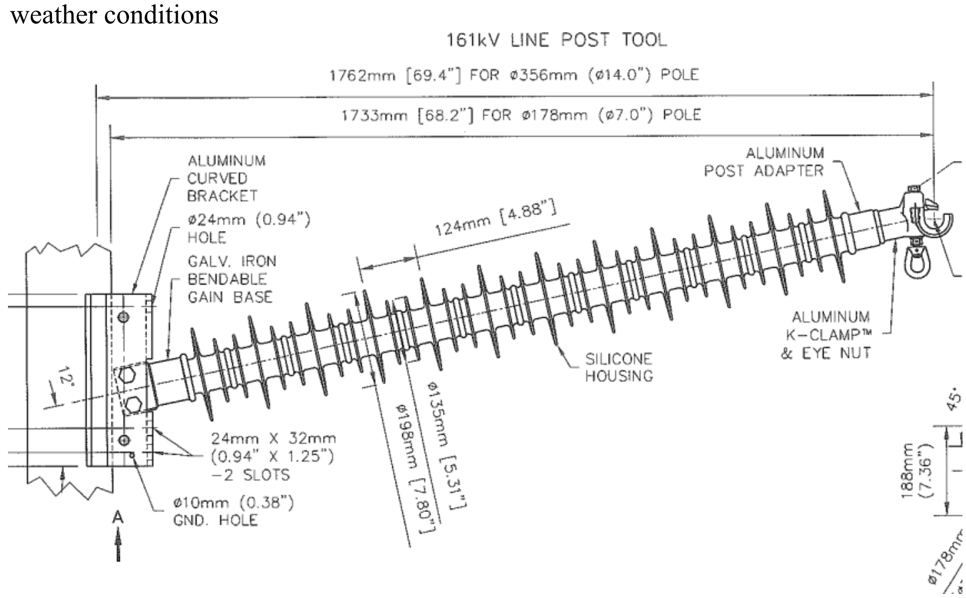

Figure 5 – K-line Live Line Arm

4. RISK ASSESSMENT

There were two primary risks to be assessed specifically due to restrictive work environment to ensure that the work execution is safe and operationally viable.

1. Risk of working in mountainous terrain and crowded and overlapping ROW with pipelines and rail roads. This required the assessment of access to each transmission structure on an individual basis taking into consideration these factors while facilitating access for a minimum of three pieces of large construction equipment.
2. Risk of working on legacy D/C structures with less clearances than required. Careful assessments were needed as the middle phase of the top crossarm to be kept energized and the inadequacy of clearance from top phase to bottom crossarm for live line work execution. The

approximate clearance from top phase to bottom crossarm was 1370mm and was much closer to the safe minimum approach distances (MAD) for qualified Powerline Technicians (PLTs). As per ATCO Standards, MAD for 144kV is 1350mm. Despite the clearance issue, it was determined to keep the middle phase energized and carefully execute the crossarm replacement work.

5. EXECUTION OF WORK

5.1 WORK SUMMARY

The following steps provides the high-level work summary of the procedure adopted for the completion of the cross-arm replacement safely and successfully. Figure 5 provides the illustration of the steps.

1. Starting position with both circuits energized
2. Relocate phases A & B from circuit 1 to temporary K-arms located below.
3. Install a temporary K-arm for phase C on circuit 1 and relocate phase C.
4. Remove de-energized circuit 2, Replace appropriate materials
5. Move to final position with both circuits energized

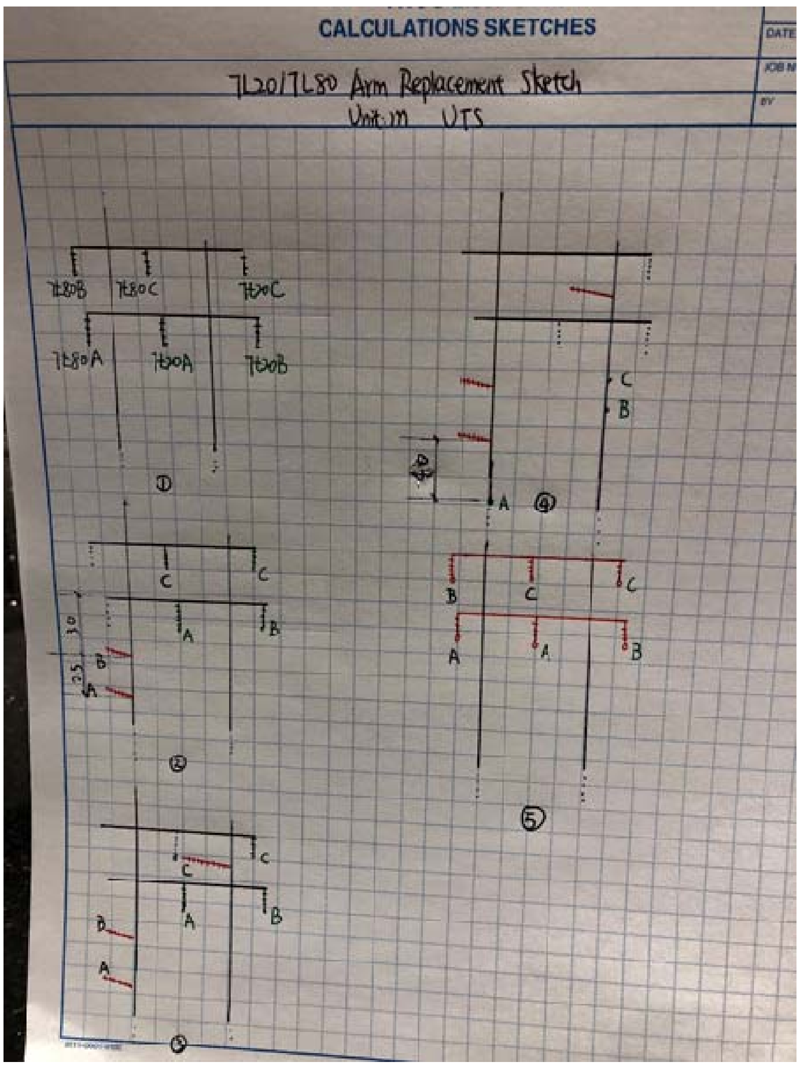

Figure 6 – Work Summary

5.2 WEATHER LIMITS

It was needed to select appropriate weather conditions for safe execution of the steps. Weather conditions and limits largely impact and restrict live line work practices and nature of high-risk work. Selected weather limits were ambient temperature -20°C or above, wind gust below or at 28 km/Hr. with no rain or snow/ice. These limits were favourable for the safe execution of the work described.

5.3 TOOLS AND TECHNIQUES

Due to the complexity, skilled and trained personnel for live line work were required for the safe execution of the work. PLTs had to work between three different voltage levels, 144kV, 25kV and deenergized Circuits. PLTs were needed to be skilled with both insulated stick techniques and barehand techniques for temporary relocation of the conductors, for replacing crossarms and for returning conductors to their permanent positions on newly installed crossarms. Though barehand techniques was the preferred method for executing this work, combination of barehand and insulated stick techniques was necessary due to clearance issues between phases and grounded conductors and structural components. Insulated stick techniques require safe approach distances between PLTs, bucket and grounded structural components as the bucket and PLTs being energized at line potential. As a result, PLTs were required to utilize insulated stick techniques to relocate conductors when the safe approach distances couldn't be maintained.

In addition, PLTs utilized 25kV rubber glove live line techniques for the relocation of underbuilt distribution circuit. ATCO distribution typically utilizes rubber glove live line techniques on distribution voltages up to 25kV. PLTs wear specialized insulated rubber gloves tested for industry standard safety limits and they are a part of their primary personal protective equipment (PPE). An insulated boom was used as a second layer of protection from ground and grounded structure components for safe handling energized conductors and live components.

The complexities of working on energized circuits in different voltages compounded by clearance issues was a challenge for PLTs for integrating different live line work techniques strategically throughout the job. Transfer from one technique to another causes some construction delays. Setting up the bucket and transferring bucket liners to suit for different technique is a challenge and requires strategic planning for safety and reduce construction delays. Barehand work requires a conductive bucket liner while rubber glove work requires an insulated bucket liner and switching between bucket liners are time consuming. This resulted PLTs to relocate the distribution circuit on several structures using rubber glove techniques, then return to each structure to complete work on the transmission circuits using barehand and insulated stick techniques. This helped minimize the time required to change bucket liners to shift between live line methodologies.

5.4 WORK INSTRUCTIONS

Following is the detailed work instructions provided for PLTs for safe execution of work.

1. De-energize 7L20 two-bundle Ibis line and obtain GOI (Guarantee Of Isolation), turn auto-reclosing off for 7L80 (single Partridge) and obtain HOP (Hold Off Permit).
2. Test for potential and install trip and protective grounds on 7L20. When installing trip grounds on 7L20, grounds must be installed on each conductor of the bundle. For bonding, one ground chain may be used per phase as yoke plate is considered as a sufficient electrical connection between conductors of a phase. For more information, refer to ATCO's EB&G (Electrical Bonding and Bonding) procedures.
3. Install a K-line live arm 3m below the bottom cross arm on the taller pole facing outwards from the structure.
4. Install a second K-line live arm 5.5m below bottom cross arm or 2.5m below the top K-line live arm. Depending on field assessment of middle span ground clearance assessment, the bottom arm can be lowered as required.

5. Relocate the 7L80 Phase A conductor to the bottom K-line arm followed by 7L80 Phase B to the top K-line arm using live work practices. The midspan clearances of Phase A on either side need to be monitored to ensure that safe line to ground clearances are achieved. Two method that can be utilized to monitor line to ground clearances are sated below.
    a. Using an insulated jib on an IAD (Isolated Ariel Devise)
    b. Using an insulated strain link stick and traveler at the end of a winch line.
6. Install a third K-Line live arm on short pole such that the live end of the K arm is directly in-line with 7L80 Phase C. This will ensure that the conductor moves in a straight line laterally and will not change vertical clearances to the top and bottom of the crossarms.
7. Use live work practices to relocate 7L80 phase C to new K Line arm in the window created by the enclosure caused by the structure configuration with two poles on each side and the two cross arms above and below.
8. Remove deenergized and grounded 7L20 Phase A on the bottom crossarm from the insulator strings. lower and suspend on taller pole, at least 4m below the bottom K-line arm, with slings. The in-span separation between energized 7L80 phase A conductor and 7L20 phase A conductor need to be closely monitored. If needed lower the deenergized 7L20 phase A conductor to just above ground.
9. Remove deenergized and grounded 7L20 Phases B from the insulator strings on the bottom cross arm, lower and suspend on shorter pole with slings.
10. Remove deenergized and grounded 7L20 Phase C from the top, lower and sling to short pole with a sling.
11. Remove all existing insulator strings from wooden crossarms.
12. Remove the existing bottom crossarm while maintaining MAD of 1350mm from energized 7L80. If MAD distances cannot be maintained due to the crossarm balance point or if the crossarms is not in condition to be removed as one piece, it will be removed strategically in sections based off on site assessment by PLT.
13. Remove the existing top crossarm while maintaining MAD of 1350mm from energized 7L80.
14. Install the new top crossarm followed by the new bottom crossarm without insulator strings attached.
15. Reinstall all insulator strings for both circuits.
16. Clip in deenergized and grounded 7L20 Phase C to the new top crossarm and Phases A & B to the new bottom crossarm in the same configuration in which they were removed.
17. Use live work practices to relocate and clip in 7L80 phase C from K-Line arm to the new insulator sting and cross arm.
18. Remove 7L80 Phase C K-arm.
19. Use live work practices to relocate and clip in 7L80 Phase B to the new insulator string on the top cross arm.
20. Use live work practices to relocate and clip in 7L80 Phase A to the new insulator string on the bottom cross arm.
21. Remove K-line arms that were holding 7L80 Phases A & B.
22. Remove trip and/or protective grounds from 7L20.
23. At this with point either
    a. Maintain 7L80 under HOP and 7L20 under GOI, move to the next structure and continue work.
    b. Identify all men and equipment clear and release 7L80 HOP and 7L20 GOI.

6. CONSTRUCTION CHALLENGES

The execution to crossarm replacement encountered several challenges that needed to be overcome for safe completion of the work. Some of the challenges are stated below.

1. The mountainous terrain required significant and thorough access development as the terrain varies considerably from structure to structure. Even with proper access, use of skilled operators was needed for proper placement of moving equipment to conduct the work safely.

2. Terrain challenges in the area resulted in several utility and infrastructure stakeholders to have their facilities constructed within the same corridor resulting in overlapping and encroaching ROWs. Acquiring proximity and crossing agreements with other stakeholders were costly and logistically complicated and needed significant planning lead times.
3. The work was conducted in fall and winter seasons, and the weather conditions created less than ideal working conditions due to fall rains and early winter wet snow. Despite the difficulties, an expedited work schedule was selected in collaboration with the generation company to reduce disruptive impacts on their operations and the nearby community. In addition, the expedited schedule had to be selected to comply with environmental restrictions including biodiversity and wildlife including caribou, grizzly bear and nesting birds.

Figure 7 – Work Execution

7. CONCLUSION

The work was completed safely in 2021. All deteriorated crossarms were replaced while serving the community. As there is no structure replacement or foundation work was required, the work imposed little environmental impacts. The project cost was significantly less compared to other options.

BIBLIOGRAPHY

1. IEEE. 2009. "IEEE Guide for Maintenance Methods on Energized Power Lines," IEEE Power & Energy Society. IEEE Std 516TM-2009.
2. IEC. 2013. "Live Working – Minimum Approach Distances for A.C. Systems in the Voltage Range 72.5 kV to 800 kV – A Method of Calculation," IEC 61472, 2013.
3. OHSC. 2009. "Occupational Health and Safety Code 2009," The Government of Alberta.