CIGRE-503

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

Design of Tap Connections on Overhead Transmission Lines

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SUMMARY

Tap transmission lines are commonly used to either deliver power to load customers or receive power from independent power producers. A tap line would be connected to its main line using the T-type tap connection which would usually serve as the point of interconnection (POI). Such a tap connection is very popular in BC Hydro for transmission lines from 69kV to 230kV due to the cost effectiveness.

In this paper, we present the design practice in BC Hydro for overhead transmission line tap connections. To ensure the success of the project delivery, it is critical to engage all the stake holders from very beginning to the end of the project. The key stake holders may include: the customer of the project, the local property owner, the relevant indigenous community, environmental, forestry, planning, operations, maintenance, etc. Accordingly, design considerations may include: (1) ease of system operations; (2) need for wave traps or tele-communications; (3) need for disconnect switches for the ease of maintenance; (4) minimizing line outage during construction and future maintenance; (5) allowance for live-line maintenance; (6) proper measures to ensure the security of the tap connection; (7) need for interrupter for a long tap line; and (8) need for additional right of way.

This paper may serve as a good reference for the industry in designing tap connection of overhead transmission lines, as few information is available in the literature on this subject.

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KEYWORDS

Disconnect switch; Engineering; Overhead transmission line; Point of Interconnection; Stake holder; Tap connection.

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INTRODUCTION

Tap transmission lines are commonly used to either deliver power to load customers or receive power from independent power producers (IPP). Often, tap lines would be owned by customers, and the main lines would be owned by the utility companies. A tap line would be connected to its main line at the T-type tap connection which would usually serve as the point of interconnection (POI). Such a tap connection is very popular in BC Hydro for transmission lines between 69kV and 230kV due to the cost effectiveness. As examples, Figure 1(a) shows a typical 138kV tap, and Figure 1(b) shows a typical 69kV tap.

In this paper, we present the design practice on tap connection based on our experience of working on many 69kV - 230kV tap connections in BC Hydro. Both stake holder engagement and detailed engineering considerations are covered.

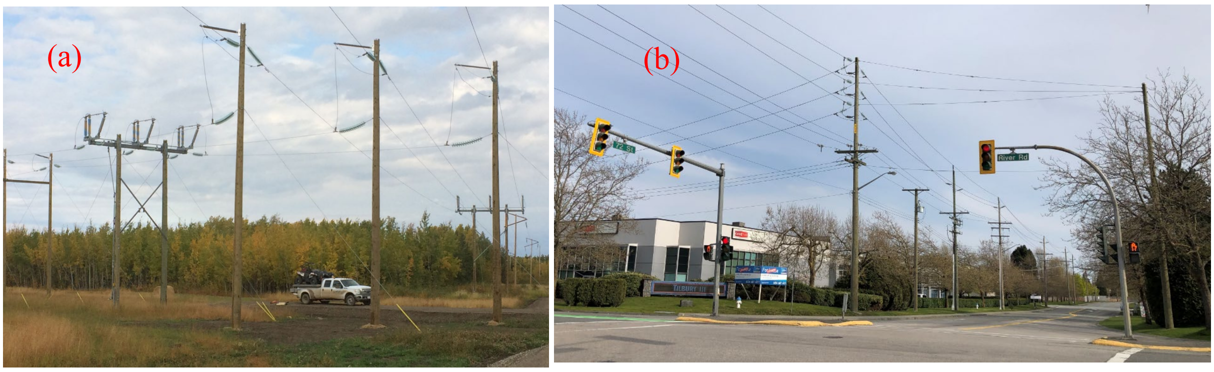

Figure 1. Photos showing typical examples of tap connections for **(a)** 138kV; and **(b)** 69kV transmission lines in BC Hydro.

STAKE HOLDER ENGAGEMENT

To ensure the success of the project delivery, it is critical to engage all the stake holders from very beginning to the end of the project. Some of the key stake holders are described below.

Customer

A tap connection is typically driven by a customer (either a load or IPP customer) so that the customer need is always of the utmost importance. Usually, it will dictate the location of the tap as well as majority of the tap line parameters. Naturally, a tap connection closet to the customer's substation is always preferred if feasible. Those key line parameters such as voltage level, conductor type, structure type, electrical capacity, are determined mostly by the customer depending on the particular needs of the customer.

Property

Nowadays, property is likely the most important factor in considering tap location. Basically, right of way (ROW) is required to accommodate both the tap line and the tap connection point. Acquiring ROW is usually not only costly but also time consuming. Thus, it is always preferred that the line route is selected so that it is fast and easy to acquire and less costly.

Environmental Impact

Another key factor to consider is the environmental impact. A severe environmental issue could be a show stopper for the project. In principle, the tap line and the tap connection point shall meet all the requirements imposed by all relevant laws, regulations, and bylaws at federal, provincial and municipal levels. For this purpose, it is important to hire environmental professionals/specialists to conduct environmental impact assessments on as need basis throughout the project. Environmental concerns may include wet lands, rivers, streams, wildlife habitations, bird nesting, archaeology, vegetation, danger species of plants and wildlife, wild fire, etc.

Indigenous Relations

It is important to consult local indigenous communities for the project as long as they may likely have interests in the project area (even without owning the land). Proper procedure shall be followed for the engagement.

Field Operations

It is a good practice to seek feedback from local transmission line field operation (FO) team to ensure the tap line and the tap connection is maintainable. Usually the need for disconnect switches (the number, type and locations) is dictated mainly by FO for the ease of maintenance. FO may also help to decide some key line parameters, such as type of structures, need for access roads, and ROW width to ensure maintainability (lively or with minimal outage).

System Operations

Transmission system operations (TSO) is a key stake holder to consult for any issues related to outages required for both construction and maintenance. The intention is to minimize or even eliminate the need for outage during construction work and any future maintenance work. Thus, the TSO's input is important for identifying the need for disconnect switches.

Construction

Constructability is another important factor to consider in designing the tap connection in order to achieve a cost effective design with minimal demand or no need at all for outage during construction.

System Planning

Normally System Planning will dictate whether or not a specific tap connection is acceptable to the utility company on a high level. For this purpose, a system impact study (SIS) is usually conducted to assess the acceptability of the customer's tap connection request, and come with a high level cost estimate associated with the proposed tap connection to help the customer to make a business decision whether or not the investment shall be made regarding the tap connection. In BC Hydro, SIS is typically lead by System Planning with support from all other relevant planning and engineering teams. The outcomes of SIS will form the basis of the scope of work of a tap connection project. The tap connection designer shall consult System Planning for any question or confusion, particularly in the very beginning of the project.

ENGINEERING CONSIDERATIONS

Based on the feedbacks from all of the stake holders, both user requirements and high-level scope of work shall be defined in the beginning of the project. Then conceptual, preliminary and detailed designs will be carried out subsequently. For each design stage, following engineering considerations shall be made in various details.

Performance Criteria

A tap connection is essentially a special portion of its main transmission line. Accordingly, the performance criteria shall match those of the main line. For example, a 69kV transmission line shall be designed to withstand 50-year loads so that its tap connection shall be designed to withstand the same loads. In principle, a tap connection shall be designed to meet all the reliability, security and safety requirements for the transmission lines of the given voltage level.

Layout

A typical tap connection layout is illustrated in Figure 2. It may consist of the following:

- A tap structure "TS";
- Up to three disconnect switch structures "DS";
- One or two wave trap structures may be included on one phase if there is a power line carrier;
- A deadend structure may be installed as a demarcation between the two owners: the utility owned tap connection and the customer owned tap line. The deadend structure can be owned either by the customer or the utility company depending on the mutual agreement. Accordingly, the demarcation could be either side of the deadend structure.

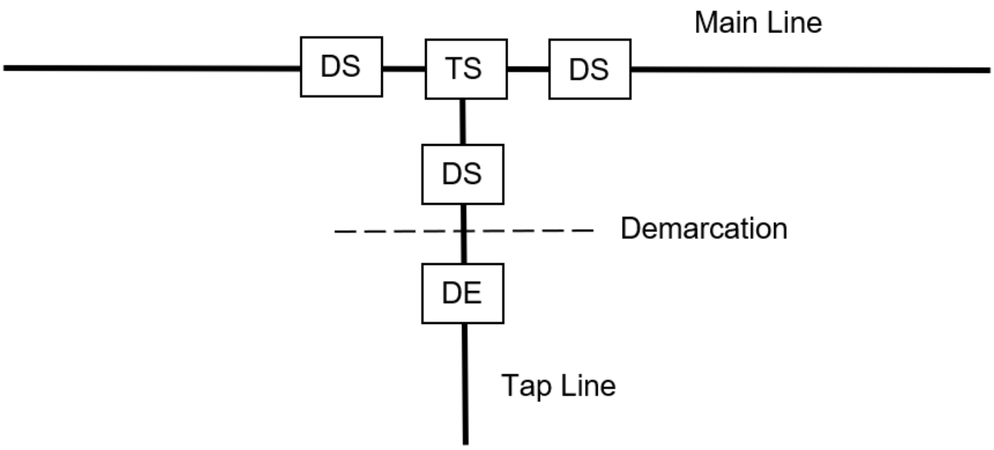

Figure 2. Illustrating a typical layout of a tap connection.

Figure 3 shows a real-life example of a 138kV tap connection, where the new structure 18/7 is a three-pole tap structure, and the new structure 18/8 is a VBSA type disconnect switch structure. Both of the structures are located on the main line. The new structure 0/2 is a VBSA type disconnect switch located on the tap line, and the new structure 0/3 is a three-pole deadend structure served as the demarcation point. The actual demarcation line is located at the mid-span between Str.0/2 and Str.0/3.

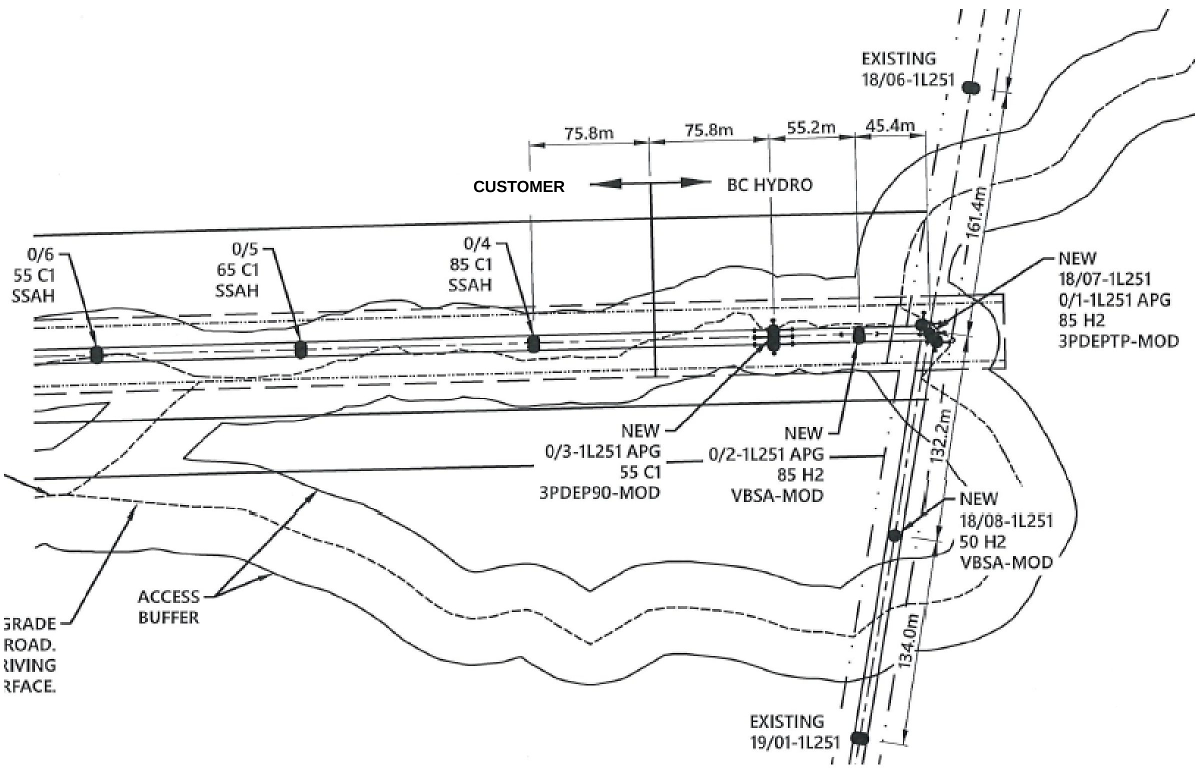

Figure 3. The layout of a typical 138kV tap connection.

Conductor Selection

Usually, the tap line will use the same conductor as the main line. However, a different conductor can be used with proper justification.

Design Tension

Usually, the main line portion of the tap connection shall be designed to maintain the same tension after inserting the new tap structure and new switch structures (if any). On the other hand, the tap line portion of the connection shall be designed to match the conductor tension of the customer side of the tap line if there is no deadend structure as a demarcation point. Otherwise, if there is a deadend structure as the demarcation, it is desirable to design the section between this deadend structure and the tap structure with slack tensions so that the structures involved are less stressed.

Tap Structure

Tap structure is essential as it is where the T-connection is made. Wood pole structures are usually used as the tap structure in BC Hydro for transmission lines up to 230kV due to cost effectiveness. Steel poles or even steel latticed towers could be used if necessary, particularly if the main line uses steel poles or steel towers.

If feasible, three-pole dead end (3PDE) structure is preferred type for tap structure for the enhanced security. See Figure 1(a) and Figure 3 for the examples of 138kV 3PDE type tap structures.

However, single pole tap structure is commonly used for 69kV lines for areas with limited right of way. For example, many of 69 kV transmission lines in BC Hydro are located within road allowance or street sides, and single poles are often used accordingly. In such scenarios, single pole tap structure would be preferred, and self-support, single steel pole structure could be used for the tap structure if necessary to avoid guying. See Figure 1(b) for an example of 69kV single pole tap structure.

For a flat configured transmission line, flying tap connection would be preferred from engineering perspective. Figure 4 illustrates the concept of a flying tap connection, and Figure 5 shows an example of 230kV flying tap connection.

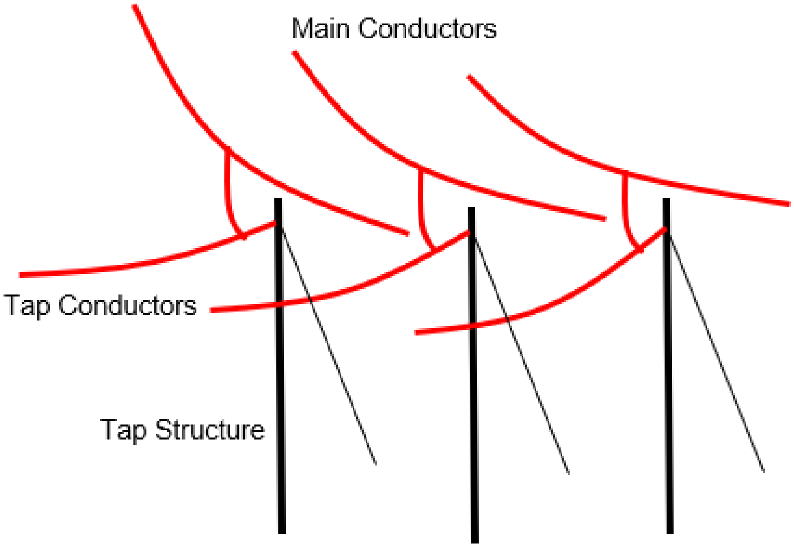

Figure 4. Illustrating the concept of a flying tap connection.

Figure 5. Photo showing an example of 230kV flying tap connection.

Disconnect Switch

Up to three disconnect switches are usually required for a tap connection (as shown in Figure 2). The disconnect switch on the tap side is required almost always. It is intended to take the tap line out of service if necessary when there is a need to conduct maintenance work on the main line. This switch is required solely by the utility company.

If power flows on the main line from left to right in Figure 2, a disconnect switch may be installed on the down stream side (or the righthand side) of the tap structure so that the tap line can maintain energized if the down stream portion of the main line has to be taken out of service for maintenance purpose. This can be done easily by switching off this particular disconnect switch. If power can follow either way, two disconnect switches may be installed, one per side of the tap structure. Such a disconnect switch is intended mostly for the benefit of the customer by minimizing the outages to the customer owned tap line.

A disconnect switch may be installed on the customer side of the demarcation line of the tap connection. However, this is completely decided by the customer. Such arrangement of two back-to-back disconnect switches is quite common if the tap line is relatively long.

In addition, for a long tap line (say > 20km for a 138kV line), special interrupters may have to be installed to take care of the charging current.

Furthermore, to operate and maintain a disconnect switch, proper grounding shall be designed and installed, as shown in Figure 6 as an example. Proper access road may also be required (as shown in Figure 3 as an example).

To ensure the normal operation of the switches, it is important that the switch structure does not deflect much under everyday conditions. It is BC Hydro's standard practice to set the deflection limit at 0.5% of the pole height under everyday conditions.

Figure 6. Photo showing an example of grounding for a 138kV disconnect switch structure.

Wave Trap

Wave traps may be required to prevent transmission of communication signals to unwanted destinations when there is power line carrier (PLC) on the main transmission line. Figure 7 shows an example 138kV wave trap structure. Typically, a wave trap structure is installed on one phase only. Accordingly, design may vary depending on the phase selected. The tap connection designer shall consult Tele-communication Planning and/or Tele-communication Design for the detailed requirements of the wave trap: its type, location, etc.

Figure 7. Photo showing an example 138kV wave trap structure.

Deadend Structure

For a relatively long tap line (say >1km), it is desirable to have a deadend structure as demarcation between the utility owned tap connection and the customer owned tap line. The actual demarcation can be either side of the deadend structure. The deadend structure shall be designed to be a cascading stopping structure so that any failure on one side of the demarcation will not cause any failure on the other side. For example, Str 0/3 in Figure 3 is such a 3PDE structure for a 138kV line. Figure 8 shows the tap portion of a 69kV tap connection that includes a single pole deadend structure (the first structure from left), and a disconnect switch structure (the third structure from left). Two tangent structures are also required within the tap connection because both deadend structure and switch structure have to be located at proper locations, and the two tangent structures have to be installed to keep the tap line within the ROW.

Figure 8. Photo showing the tap portion of a 69kV tap connection.

CONCLUSION

Following conclusions can be made from this paper:

- To deliver a tap connection design project successfully, it is important to identify all the relevant stake holders and try to engage them from the very beginning.
- It is critical to ensure that the tap connection is located with ease to meet those key requirements of property, environmental, operational and maintenance, etc.
- It is important to ensure the number, type and location of the equipment (both disconnect switch and wave trap) are determined properly by consulting with relevant stake holders.
- It is equally important to ensure that the entire tap connection (including structures, foundations, conductors, insulators, hardware etc.) is designed meet all the engineering requirements while considering adequately the feedback from all the relevant stake holders.