**BC HYDRO**

**REAL TIME OPERATIONS**

# OPERATING ORDER 7T-23

## VANCOUVER ISLAND – MAINLAND H.V.D.C. TRANSMISSION SYSTEM

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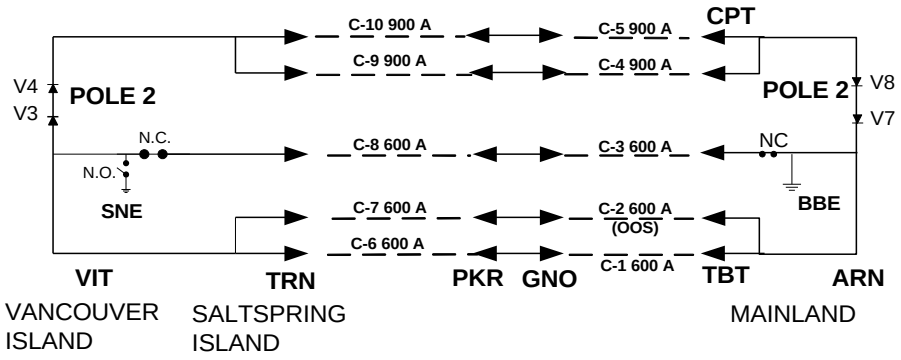
| Denotes Revision

## 1.0 GENERAL

The Vancouver Island - Mainland HVDC transmission link is a single pole system with metallic neutral and ground return capabilities across Georgia Strait.




## 2.0 RESPONSIBILITIES

* Refer to Operating Orders 1J-11.

## 3.0 EQUIPMENT AND RATINGS

### 3.1 General

Pole 2 consists of two series - connected, 6-pulse bridges. 6-pulse operation at half pole capacity or a 12-pulse operation at full pole capacity is possible. Each bridge is fed separately from the 230 kV ring bus through a disconnect switch.

Each bridge is located in a separate valve hall with the high voltage AC and DC bus connections through wall bushings.

### 3.2 Pole 1 Groups

Pole 1 valve groups at VIT and ARN are decommissioned. D1 and D2 Disconnect switches at ARN are permanently open. D2 Disconnect switch at VIT is permanently open. A permanent bus cut at VIT between SG1 and GD1 separates Pole 1 from DC1L1. Bypass switches ARN D15 and VIT D1 are permanently closed utilizing pole 1 cables DC1L5 as pole 2 metallic return.

### 3.3 Pole 2 Groups

In Pole 2 a bridge is made up of three valve structures, each containing two valves. The midpoint of the twin valves is connected to the AC bus. The valve cooling fans are located in the basement of the valve hall, and the air-to air heat exchanger is located just outside of the valve hall.

Pole 2 consists of 2 CGE thyristor valve groups and is nominally rated at -280kV, 1320 amps (370 MW), or at 1700 amps (476 MW) for outside air temp. <7.2 deg C. The current rating of Pole 2 is based on the higher of the instantaneous ambient temperatures at Arnott and VIT:

| Instantaneous Ambient Temperature (deg. C) | Pole 2 Current Rating (amperes) |
|---|---|
| < 7.2 | 1700 amps |
| 10. | 1670 |
| 15. | 1615 |
| 20. | 1560 |
| 25. | 1505 |
| 30. | 1450 |
| 35. | 1395 |

Note; Due to the failure of DC cable 2, Pole 2 will normally be operated at 1200amps or less with metallic return only or as per the chart above in ground return (sea return). See section 3.6

Operation between 1200-1240 amps is only allowed 2 hours per day with the metallic neutral in service.

Operation between 1200-1240 amps longer than 2 hours per day or greater than 1250 amps requires the **sea return** to be in service and should only be done under emergency conditions via approval from the SCM or RTO Manager. VIT D5 is closed automatically via metallic neutral protection if current exceeds 1250 amps. The Sector 2 Grid operator must avoid this PN operation.

### 3.4 AC Voltage Range and Control

The system AC voltage normally fluctuates between the extreme values of 210 kV and 253 kV, while the equipment design voltage is 236 kV. Small changes in the AC voltages are compensated for by the control action of the valve firing angle, and large changes are compensated for by the transformer tap change control.

### 3.5 DC Voltage Control

The DC voltage of Pole 2 is regulated by controlling the inverter DC voltage and compensating for the DC line drop. The DC voltage is controlled automatically by the control equipment, and cannot be adjusted by the dispatcher.

### 3.6 HVDC Cables

There are 5 HVDC cable paths between the Mainland and Vancouver Island. Cable paths 1-6, 2-7 and 3-8 are impregnated paper solid type rated 600A with a 2 hour 10% current overload capability every 24 hours. **Cable 2 is currently out of service and will not be repaired**. Cable paths 4-9 and 5-10 are impregnated paper, high pressure, oil filled rated 900 amps and have no current overload capability. Oil pumping stations are required at CPT, GNO and a closed loop system on TRN to maintain oil pressure. After any protection operation involving these cables the pumping station alarms should be reviewed prior to energizing.

MODS at TRN, TBT and CPT are provided so that the metallic neutral cables 3-8 can be switched to replace a Pole 2 path in case of a cable fault (or cable oil system failure in case of Pole 2). It should be noted that if the metallic neutral cables 3-8 are switched to replace a Pole 2 cable path, Pole 2 loading will be restricted to 1200 amps normal, 1240 amps for 2 hr. overload. During this scenario Pole 2 will be required to be operated in sea return to transfer 1200amps.

When any cable path is isolated from the HVDC system, the cable path shall be grounded by closing the appropriate grounding switch at TRN. This situation most often arises during the annual Pole maintenance outages.

Five DC current transformers (transducers) are installed at the TRN cable potheads. These DCCT's are used in a DC cable overload protection scheme and also provide an input for current telemetering to FVO.

### 3.7 HVDC Cable Overload Alarms and Trips Tabulation

| Cable | Alarm | Trip |
|---|---|---|
| 6 | 660 | 720 |
| 7 | 660 | 720 |
| 8 | 660 | 720 |
| 9 | 900 | 990 |
| 10 | 900 | 990 |

Cable overload alarms are priority 2 and require the dispatchers to take immediate action to reduce load. Overload tripping will result in closing the cables' associated ground switch at TRN, resulting in the line protection clearing the cable.

### 3.8 Location of Switches

The grounding switches for the AC and DC buses are located in the valve hall. The isolating and bypass switches are located outdoors. Current interruption is limited to designated switches. These switches are 3 pole series switches equipped with arcing horns located around the neutral bus to reduce the nominal operating voltage.

### 3.9 Converter Transformers

The converter transformers are of the single-phase type equipped with on load tap changers with provision for a spare unit for each Pole at each terminal. For protection, maintenance and switching purposes the transformers and the associated valve groups are considered one zone.

All converter transformers must be de-energized via associated breakers. ARN T8 is energized using breakers. VIT T3, T4 and ARN T7 are energized via the transformer disconnects.

### 3.10 Smoothing Reactors

Smoothing reactor are provided at both Arnott and VIT to reduce the DC voltage ripple.

### 3.11 Neutral Bus

The neutral bus has a shunt RC comprising VD2 and CX3 for surge protection and to provide a path for the high-frequency currents generated during commutation or switching of valves. At VIT, lightning arrestor LA9 was added to the neutral bus to protect against over voltages. This device is protected by breaker NBP, which is operated by an overcurrent relay monitoring current in the arrestor. Refer to sect. 8.3 for NBP operation

### 3.12 System Grounding

In the 'metallic return' mode, the system is grounded only at the Arnott end by connecting the common neutral bus to the land electrodes at Boundary Bay via a lower voltage overhead electrode line LN2. A loss of the ground will cause the pole to shut down. D5 at ARN must remain closed at all times. The VIT neutral bus therefore floats at a potential equal to the voltage drop in the neutral circuit.

In the 'sea return' mode the system is grounded both at ARN and VIT.

## 4.0 HVDC OPERATION

### 4.1 General

Some of the important system operating conditions and requirements are described below.

### 4.2 Current Control Modes

The Sector 2 Grid Operator can select any of the following current control modes: manual separate, manual synchronized, Pole 2 auto freq. mode, and Pole 2 high VAR mode control**. See** the section on control modes for more detail. Manual synchronized is the normal mode of operation.

In manual synchronized mode the current is adjusted in 20 amp steps. In manual separate mode, the operators can regulate the current in 40 amp steps.

Pole 2 can be operated

- between 120 and 1200 amps continuous
- 1240 amps max. for 2 hour 10% overload (sea return required over 1240 amps)
- 1700 amps max. with sea return in service but temperature dependent as per table in section 3.2.

### 4.3 Current Limit Settings

Depending on the configuration of the HVDC transmission system, the full capabilities of Pole 2 may not be useable. Current limits are provided to allow the pole to be de-rated to match the capacity of the system. Pole 2 has four current limit settings of 600, 850, 1320 and 1700 amps. These limits are designed to safeguard the equipment and cables from being overloaded in various operating configurations. The current limit places a maximum value on the current produced by the pole, regardless of the current order.

### 4.4 Metallic Neutral Return Current

In the preferred metallic return configuration two 600 amp cables are utilized as the metallic return. Continuous rating of these metallic return cables is 1200 amps. The HVDC control automatically detects neutral current greater than 1235 Amps, and generates an alarm. At 1250 Amps PN will close VIT D5 placing the sea return in service.

The neutral return circuit can have the following different configurations in order of priority:

1) metallic return (preferred mode of operation) using DC1L1, and DC1L3 ( VIT D1,D4 closed, VIT D12,D5 and D2 open , TRN D5,D6 closed, TRN D4,D3,D7 open, TBT D1,D3 closed, TBT D2,D4,D5 open, ARN D4,D15 closed, ARN D1,D10,D12 open).
2) sea return using the electrode lines via disconnect D5 at VIT
3) a parallel combination of the metallic return path and the sea return. This mode is used only temporarily during changeover periods.

HVDC protection will close VIT D5 if neutral return current exceeds 1250 amps placing the sea return in service. The Sector 2 Grid operator must ensure VIT D5 does not close as we do not want to operate in sea return except in emergency conditions.

## 4.5 Interlocking

### 4.5.1 Interlocking General

Interlocking of valve isolating switches, grounding switches and shorting switches, etc., requires that a set of conditions must be satisfied prior to starting or manual isolation of a bridge. SCADA interlocks are provided for the switchyard disconnects to allow for proper sequential operating. These interlocks can be overridden as conditions permit. The sections that follow list hard wire interlocks that must be satisfied to permit de-blocking of Pole 2 valve groups

### 4.5.2 Pole 2 Hard Wire Start Interlocks

For Pole 2, the ARN and VIT ends of the selected valve group are started simultaneously by the Pole and valve control. Both ends must be in the "Ready" condition to start. This condition is satisfied when external interlocks are in the correct state and the control scheme measure the correct value of AC bus voltage.

External hard wire interlocks for Pole 2 that affect starting are:

- 1st grade supply inverter 1 or 2 output voltage present
- valve cooling blowers started up
- 2D3/4/7/8 closed for the valve groups being started
- D13 and D14 closed at both terminals
- Shorting switches closed for the valve groups being started
- DV3/4/7/8/ closed for the groups being started
- GDV3/4/7/8 open for the groups being started
- Converter transformer interlocks OK: taps in step, control voltages present, etc.
- HF2 filter banks in service at ARN and VIT

### 4.5.3 Software (SCADA) Interlocks

Pole 2 starting is blocked if any of the following disconnects are closed: VIT GD10, TRN GD1, TRN GD2, TRN GD3, CPT GD1, CPT GD2, CPT GD3, TBT GD4, ARN GD10, ARN GD9.

Operation of VIT D5 has interlocking implemented in the SCADA software. The logic is as follows:

- Block open VIT D5 if any of the following disconnects are open: VIT D4 or VIT D1 or TRN D5 or TRN D6 or TBT D1 or TBT D3 ARN D15 or ARN D4
- Block open VIT D5 if metallic neutral current is less than 20 amps for more than 10 minutes
- If Pole 2 is running then D5 should be opened after the sea return current is reduced to less than 600 amps.

## 4.6 Preferred Pole 2 Valve Group

VIT being the lead terminal, the operator can control both VIT and Arnott terminals providing microwave communications are available.

The Sector 2 Grid Operator can pre-select a Pole 2 Arnott valve group on his EMS display for a preferred first group to start or stop. In addition to this pre-select switch located on the EMS display, there are local switches on the Pole control cabinet for a preferred protective stop. The preferred protective stop operates when one terminal is in 12-pulse with the other terminal in 6-pulse.

### 4.7 Live Line Capability

There is a live-line capability for Pole 2. Specific instructions for ARN and VIT are as follows:

The Line Protection Restart Inhibit switches should be in the “Inhibit” position at both ARN and VIT. The switches are located in Pole Control Cabinet 2102, page frame C.

**LN1, LN2 (Metallic Neutral)**

A fault on the metallic neutral causes VIT D5 to close and ARN D4 and VIT D4 to open. Pole 2 does not shut down. For ANR and LLP permits on the metallic neutral, place tags on VIT D4 and ARN D4’s.

**EL1, EL2 (VIT to SNE)**

When VIT D5 is closed and Pole 2 is in ground return (sea return) a fault on EL1 or EL2 will not initiate a protection operation only resulting in an alarm in the Neutral zone. For non reclose work on these lines it is only required to tag VIT D5 to identify crews working on the lines.

### 4.8 VAR Requirements of HVDC Transmission

For its operation, the HVDC equipment requires at each terminal an amount of reactive power (MVARs) equal to about 50% of transmitted power (MWs).

This point is especially important to consider when changing the mode of operation from six to twelve pulse operation or vice versa.

For example, when the HVDC system, operating at 1000A and 130 kV (130 MW), is changed to 260 kV, the amount of power would be increased by 130 MW which would require an additional 65 MVAR's at each end. The Mainland system is large enough to supply the remaining MVAR's without difficulty, but the island system should be prepared by having sufficient capacity prior to the change in order to maintain required system voltage.

## 5.0 DEBLOCKING HVDC VALVE GROUPS

### 5.1 Preparing HVDC Equipment For Service After Maintenance Outages (Check List For EL And PN Staff At ARN And VIT)

1) Check with all crews that:

   - all buswork, drops, or wiring have been reconnected
   - all test equipment has been removed from transformers, reactors, valve hall, switchyard, etc.
   - any field grounds they have been using have been removed
   - everyone is aware that the equipment is being returned to service.

2) Check with Protection that all protection and control equipment has been returned to service.

3) Check that all transformer, reactor, etc. fans are turned to their normal operating condition - i.e. either "AUTO" or "ON".

4) The transformers need to be energized before this can be completed. All converter transformers are energized via the disconnects (except T8 which uses 2CB1 or 17).

5) Check that all valve cooling (fans, pumps, etc.) is in normal operating condition.

6) Check that all field grounds have been removed.

7) Visually check all equipment within the zone of isolation to ensure that no abnormal conditions exist.

8) Reset all flags.

9) Reset alarms on control panels (some Pole 2 alarms will not reset until the converter transformer is energized).

10) Reset all control desk alarms (except as noted in 9 above).

11) Contact Sector 2 Grid Operator and proceed with switching and energization according to local instructions or local operating orders.

12) After equipment is energized, but before valve groups are deblocked check that all alarms reset and Pole 2 that all "ready" lights are on. Check that all cell monitoring lights on the valve structure are lit.

13) Pole 2 blowers started.

### 5.2 Station Status Prior To De-blocking

The following conditions must be met prior to de-blocking HVDC valves:

- Pole 2 "Start/Stop Sequence" switches in "AUTO".
- Pole 2 "Current Control Mode" switches in "Synch".
- Pole 2 current limit at 1320A position.
- (Current limit may be set at 1700 amps if VIT D5 is closed and outside air temperature plus current order comply with limits set out in the table in Section 3.2)
- Appropriate Harmonic Filters in service (see section on filters)
- Metallic neutral in service. Normal configuration as follows:
  - VIT D5, D12 and D2 open. TRN D4 open VIT D4 open.
  - ARN D4, D5 and D15 closed. ARN D16, D12 open. TBT D5 open
  - ARN/VIT D10 open. TRN D3 open. TBT D4 open.
- Other metallic neutral configurations are possible for certain operating conditions, such as maintenance outages.
- Arnott is the ground reference for the HVDC system.
- Ensure tap changers are matched and in auto
- Ensure adequate SS supply
- Inverter #1 and #2 energized and supplying Pole 2 first grade power
- Energize Valve halls. The converter bridges require be tied down to ground via the DC system prior to valve hall energization or this may result in valve group damage. Valve group DV disconnects MUST be closed prior to energizing the valve hall. The required energization sequence is as follows:

  1. Close the DV disconnects (DV3 for Valve group 3, DV4 for valve group 4, DV7 for valve group 7, DV8 for valve group 8)
  2. Close the transformer disconnect (VIT 2D3, VIT 2D4, ARN 2D7, or ARN 2D8)
  3. Close a VIT or ARN ring breaker – energizing the valve hall

### 5.3 Operating Pole 2 Valves

#### 5.3.1 De-blocking

1) Select the desired ARN valve group to start (V7 or V8).
2) Reduce the current order to 800 amps or less.
3) Ensure metallic neutral path in place. Alternately if metallic neutral not available, place sea return in service via closing VIT D5.
4) De-block the desired VIT valve group. The selected ARN group will start automatically.
5) To open D5, reduce metallic neutral current to 600 amps or less.

#### 5.3.2 Blocking

1) Select desired ARN valve group to stop
2) Reduce current order to 800A
3) Stop either VIT valve and the selected ARN valve will follow
4) Stop the other VIT valve, which will be followed by the remaining ARN valve

### 5.4 Pole 2 Valves in Standby Mode

V3, V4, V7, and V8 have automatic cooling system controls to regulate the temperature, pressure and humidity in the valve halls. These valves can be left in standby mode indefinitely.

During periods of shutdown of the Pole 2 valves (e.g. during annual maintenance), one circulation fan should be left running in manual whenever possible to prevent excessive humidity.

### 5.5 VIT Ferroresonance

Due to the possibility of ferroresonance, single phase switching is not to be carried out on 12D1SS3/12D2SS3 when T9/T10 are energized.

## 6.0 CONTROL MODES

### 6.1 General

At Arnott the current control mode can be selected as SEPARATE or SYNCHRONIZED. When Arnott is in SEPARATE, VIT must also be in SEPARATE. When Arnott is in SYNCHRONIZED current control mode, VIT can be in MANUAL SYNCHRONIZED. Separate or synchronized refers to communication connection and does not refer to the AC power system.

This should also not be confused with the START/STOP control mode which can be either in MANUAL or AUTO. In manual START/STOP mode an operator is required at Arnott in voice communication with the Sector 2 Grid Operator. For a Start, the inverter is started first and the rectifier must be started within 8 seconds. For a stop both ends should be stopped within 2 seconds. With communications in-service and the START/STOP control in Auto at both ends, VIT can operate the Arnott valve groups.

### 6.2 Manual Separate Mode

Manual separate is the simplest control mode of operation. It allows the HVDC transmission to be maintained during malfunction of a stepping device, associated circuits, or the loss of the communication link between VIT and Arnott terminals. This mode requires an operator at the Arnott terminal as well as at VIT and telephone communications between the two. A current order is presented to the rectifier and inverter inputs via a hand controlled potentiometer.

There is no automatic synchronizing of current orders. Both operators must be in verbal communication during any change of current settings to insure the maintenance of the current margin. During an increase in current orders, the rectifier operator must advance his potentiometer to the specified value first, with the same action then followed by the inverter operator. During decreases in current orders, the inverter operator must lead, with the operator on the rectifier following.

## 6.3 Manual Synchronized Mode

This is the control mode normally used.
The manual synchronized mode allows the Sector 2 Grid Operator to start, stop and change load on either HVDC Pole without communicating with an ARN operator.

In the manual synchronized mode, both poles are base loaded without any automatic consideration for AC power flow. Each Pole may have its power transmission raised or lowered in single steps by operator activation of the appropriate control button on the Sector 2 Grid Operators EMS display. A single command of a raise or lower will synchronously increment or decrement the pole's stepping devices at both terminals. No further change will then occur in pole's transmission until operator action again changes the order by one step.

Should the stepping devices at either terminal get out of step by more than one, the devices will freeze and prevent any further raising or lowering regardless of mode of operation. In such an abnormal situation, the Sector 2 Grid Operator may activate a manual sub-mode called Arnott step synchronization. This must be carried out on the DC control board on the second floor. This mode allows operator raising or lowering of the Arnott stepping device. Once synchronized, the two stepping devices may be reverted to normal operation. Again, no verbal communication is required.

## 6.4 Changing From Manual Sync to Manual Separate Mode and Back

### 6.4.1 Change from SYNC to SEP

1) Ensure VIT & ARN step indicators are in the same step position.
2) Match the manual current order to the STEP SYNCHRONIZATION digital display at both VIT & ARN by moving the MANUAL CURRENT ORDER dial. There are two ways to check that they are matched:
3) Use the formula (STEP X 20 AMPS) + 120 AMPS. e.g. If MANUAL CURRENT ORDER IS @ 1000 AMPS STEP SYNCHRONIZATION digital display will be @ 44, i.e. (44 x 20 AMPS) + 120 = 1000 AMPS.
4) Use of MANUAL SEP TRANSFER DC Volt Meter
5) Select range either 200A (fine) or 600A (coarse) then bring the meter indicator to approx. ‘0’. If 200A is used (fine selection) 2 divisions either side of ‘0’ is acceptable. If 600A is used (coarse selection) 1 division either side of ‘0’ is acceptable.
6) Ensure VIT & ARN manual current order dials are now in the same position.
7) When match is made, select “SEP” MAN push button, then push JP CN CHANGE button.
8) Ask ARN to change from SYNCH to SEPARATE on the CURRENT CONTROL MODE buttons. At this time the Pole load can only be changed by use of MANUAL CURRENT CONTROL dial in conjunction with ARN electricians.
9) Note: To avoid losing current margin make changes one step at a time. RAISE: ARN end must be raised first. LOWER: VIT end must be lowered first.

### 6.4.2 Change from SEP to SYNC

1) Match the STEP SYNCHRONIZATION digital display with the MANUAL CURRENT ORDER using the Manual Sync Raise or Lower buttons.
2) Use the same procedure to check that they are matched as in change from SYNC to SEP.
3) Note: To avoid losing current margin make changes one step at a time. RAISE: ARN end must be raised first. LOWER: VIT end must be lowered first.

4) When the MANUAL CURRENT ORDER & STEP SYNC are matched, select “SYNC” MAN on POLE CONTROL GROUP, then push JP CN CHANGE button.
5) Ask the ARN Operator to change from SEPARATE to SYNCH on the CURRENT CONTROL MODE buttons.
6) At this time, the Pole load can only be changed using the “SYNC” MAN Raise, Lower buttons, with one push causing a 20 AMP change in loading.
7) MANUAL CURRENT SETTING should be left in the “Fail Safe” mode; i.e. VIT Pole 2 600A and ARN 1200A

### 6.4.3 Synchronization of Out-Of-Step Condition

1) If an out-of-step condition exists, push OFF/ON button on ARNOTT STEP SYNCHRONIZATION to turn it on, then on the same group push the Raise or Lower button as required to match steps. When steps are matched push the OFF/ON button again to turn it off; all lights on the group will go out.

2) The limit for out-of-step condition on Pole 2 is 170 AMPS or approximately 8 steps. 9 steps difference between VIT and ARN will initiate trip.

## 6.5 Pole 2 Auto Frequency Control Mode

The Pole 2 Auto Frequency control mode adjusts the Pole 2 current order in response to fluctuations in the Vancouver Island AC system frequency. This mode will only be in service following loss of all 500KV and 230KV lines to the mainland. In auto freq. mode, the VIC dispatcher does not have control of the Pole 2 current order.

The transfer from manual synchronized control mode to frequency control is made automatically by the master control upon detection of frequency above 60.5Hz or below 59.5Hz. There is a 10 cycle time delay prior to enabling the auto frequency control mode. This is indicated by an alarm and the 'reset' button illuminating on the VIC HVDC control console. The island frequency error is detected and corresponding raise or lower commands are sent to the HVDC control system. V.I. frequency will be regulated to 60 Hz +/- 0.32 Hz

The Pole 2 auto frequency mode must be manually switched off by the Sector 2 Grid dispatcher.

## 6.6 Pole 2 High VAR Mode

Pole 2 High VAR mode is selectable from the EMS display. This control increases VAR absorption by Pole 2 at both ARN and VIT in order to reduce system voltage.

The high VAR mode process is controlled by PLC’s at ARN and VIT. The VIT PLC is the master end. Both PLC’s have failure alarms to indicate device failure or abnormal termination of high VAR mode. If either alarm comes up, a reset pushbutton must be pressed in the joint pole control panel prior to any attempted restart of this operating mode.

How it works: selecting high VAR mode results in the T3/T4/T7/T8 tap changers being placed in manual. A control signal is then applied to the pole 2 control to increase the valve firing angle. This has the effect of increasing VAR absorption by 50-80 MVAR.

The process of entering high VAR mode takes approx. 1 second after selection on the SCADA terminal. Exiting this mode takes a similar amount of time.

Pre-conditions for selecting high VAR mode:

- Pole 2 current order must be set to 1200 amps
- All Pole 2 valves must be de-blocked (12 Pulse mode)

Automatic actions taken by the high VAR mode controller PLC's:

- T3/T4/T7/T8 tap changers will be placed in manual.
- Pole 2 current limit will be set to 1320 amps, if not already set to this value.
- A control signal will be applied to the VIT Pole 2 control cabinet that will increase the valve firing angles at VIT. The Pole 2 DC line voltage will decrease by up to 40KV. ARN firing will increase in response to the lower DC line voltage.

Conditions that will automatically terminate high VAR mode: any of the following conditions can either prevent entering high VAR mode, or will terminate this mode once started. Abnormal start or termination will result in alarms from VIT only, or from both VIT and ARN. The reset pushbutton in the joint pole control cabinet at VIT must be pressed prior to re-start of the high VAR mode control.

- snubber thermal alarms at ARN or VIT persisting for 5 seconds will terminate high VAR mode
- loss of tone channel between ARN and VIT
- current order changed from 1200 amps plus or minus 30 amps
- current limit changed from 1320 amps
- VI frequency decrease to less than 59.8 Hz

## 7.0 FAULT ISOLATION ZONES

The following main isolation zones exist in the event of faults or abnormal conditions:

### 7.1 Filter Yard

The filters are tripped only when there is a fault within the filter yard or a system overvoltage exists. The transformers are not isolated.

### 7.2 Transformer

A fault in this zone isolates the transformer and shuts down the affected bridge. Filters are not isolated.

### 7.3 Valve Hall

For severe internal faults in Pole 2 the affected group is automatically stopped and isolated. For ground faults in Pole 2 the affected group is stopped and isolated while the unaffected group is stopped but is ready for operator restart after the fault clearing sequence is completed.

### 7.4 DC Line Fault

Pole 2 will attempt 3 restarts, with the final restart being of one valve group only.

If unsuccessful the Pole is isolated on the DC side by opening the line and neutral disconnects and closing the sea return. This isolation is done automatically for Pole 2.

In the event of a fault on the paralleled cables, the Sector 2 Grid dispatcher can isolate the faulted cable using motor operated disconnects at TRN, TBT and CPT.

### 7.5 Neutral Bus Alarm ("E" zone)

In this case only an alarm is provided by the Pole 2 control.

### 7.6 Neutral Line

A fault or abnormal condition calls for the closure of the electrode line switch D5 at VIT. The metallic neutral line is isolated by opening the D4's but the poles are not shut down.

### 7.7 Power Cross Protection

The power cross protection at ARN and VIT detects AC voltages on an HVDC circuit. It blocks the affected pole, closes HVDC line ground switches at both stations, tripping an AC circuit in contact with the HVDC. AC voltages on the metallic return blocks both poles.

### 7.8 Over Frequency Protection

In the case of loss of the AC connection to the mainland, the 81HVDC relay located in panel E3 will detect VI over frequency. This relay will block the HVDC valves according to the following logic:

Block V3 logic – block V3 if freq. > 63.5Hz
Block V4 logic – block V4 if freq. > 64Hz AND V3 is blocked OR
block V4 if freq. > 63.5Hz AND V3 has been blocked for > 10 sec.

To summarize the above settings, the 81HVDC relay will block Pole 2 valves in the priority order V3, V4, providing frequency stays above the set point of the device.

The 81HVDC relay has an LED type target on the front panel. Valve blocking for frequency above 63.5Hz will illuminate the 81 target.

## 8.0 VIT NEUTRAL BUS ARRESTER

### 8.1 Function of the Neutral Bus Arrestor

The purpose of the neutral bus arrestor at VIT is to limit over voltages caused by system disturbances such as lightning strikes. The neutral bus is not grounded at VIT. The neutral bypass breaker is in parallel with the arrestor, and will close if required to protect the arrestor from being damaged.

### 8.2 Operating Procedures

The normal operating position for DNPB is closed, and NBP open. If NBP closes, the following operating procedure is recommended:

- Reduce the HVDC output to minimum as soon as possible. On March 19, 2003 DC current flowing to Victoria saturated the transformer cores and produced high second and fourth harmonics. Block Pole 2 if possible.
- Inspect VIT LA9, LA4, and LA8 for damage. Determine cause of fault and respond accordingly.
- If LA9 is damaged, an HVDC outage is required to isolate the failed column in LA9. When the repair is completed, and cause of the fault is mitigated, NBP can be opened using the procedure below.

### 8.3 Procedure to Open NBP

- Verify VIT D5 is closed, and ARN neutral bus is connected to the Boundary Bay sea electrode.
- Block Pole 2.
- Open DNBP.
- Open NBP.
- Close DNBP.
- Restart Pole 2.

**NBP should never be opened prior to blocking Pole 2. The DC current flowing through the CB will cause damage to NBP.**

### 8.4 Operating Considerations When NBP Closes

Substation transformer cores may saturate and this will result in high harmonics, so Pole 2 should be blocked or their output reduced immediately. There will be ground current flowing from the neutral bus into the VIT station ground grid and this current could be as high as 1200A.

If Pole 2 is in metallic return operation, this ground grid current could cause some metal corrosion in buried metal structures (pipelines) in the Duncan area. However, the VIT ground grid is protected from corrosion since it is a cathode in this configuration.

### 8.5 Protection of Neutral Bus Arrestor

The O/C relay connected to the DC CT (CT6) is set at 180A dc primary with the delay timer set at the minimum setting of 50ms. During normal system operation, the current through the arrestor should be much less than 180A; during lightning or transient conditions, the disturbance should last much shorter than 50ms. But for a loss of metallic return path or an AC power cross to neutral fault, the excessive current through the arrestor will trigger the O/C relay which initiates the closing of the bypass switch (NBP) to ensure that there is a solid ground on the neutral bus until the problem is investigated. There is no adverse effect on the HVDC operation even if the bypass switch (NBP) is closed by the mis-operation of the relay except transformer core saturation that can result in high harmonics as listed in 8.4.

### 8.6 CX2/CX3 Operating Procedures

Two capacitor banks are provided for redundant operation. Only one bank is required to be in service.

## 9.0 HARMONIC FILTERS

### 9.1 Filters and Reactive Equipment – General

The firing action of the HVDC valves in the converter bridges produces AC harmonics of order (6n +/- 1) for 6 pulse operation and (12n +/- 1) for 12 pulse operation where n = 1, 2, 3 ... AC harmonic filters (HF) for each Pole comprising the 5th, 7th, 11th, 13th and high pass filter (HP) are connected to the 230 kV bus. These filters provide a low impedance path to ground for the harmonic currents generated by the converters. They also provide VARs for the converters which consume them in either rectifier of inverter mode of operation.

Pole 1 filter (HF1 and HP1) was removed from the system in May 2015. Pole 2 filter (HF2 and HP2) are still operational.

The MVAR contribution of the various filters is shown in the following table:

| STATION | HF2 | HP2 |
|---|---|---|
| ARN | 60.1 MVar | 34.6 MVar |
| VIT | 60.1 MVar | 34.6 MVar |

Both terminals have filter banks composed of harmonic filter units and one high pass filter unit per bank.

HF2 and HP2 are energized and de-energized through circuit switchers. These switches are interlocked with automatic ground switches that open first on a close command to the filter circuit switcher and close after the circuit switcher indicates fully open.- has tuned filters for the 5th, 7th, 11th and 13th harmonics and a high pass filter for the higher harmonics.

The VIT HP2 high pass filter is fed through a circuit switcher. The remaining filters in each bank have a manually operated disconnect.

VIT SC1 was removed from the system in 2015.There are three synchronous condensers currently operational at VIT. SC2 is rated at +50/-50 MVARs. SC3 and SC4 are rated at +100/-79 MVARs each.

Minimum of 2 synch condensers are required if both 500 KV lines and 2L129 is OOS.

### 9.2 Pole 2 Operating Conditions

With both ARN HF2 and VIT HF2 in service, HVDC Pole 2 can operate up to full overload capacity

When either of ARN HF2 or VIT HF2 is out of service HVDC Pole 2 must be shut down.

### 9.3 Telephone Interference

The high pass filters ARN HP2 and VIT HP2 must be kept in service. Otherwise, when operating the HVDC, telephone interference by harmonics will be too high.

### 9.4 (Removed)

### 9.5 Use of VIT HF2 To Control South Vancouver Island (SVI) Resonance

VIT HF2 assists in controlling the SVI 230kV AC resonance. If VIT HF2 filter bank is switched out of service, then HSY 12HF3 and ESQ 12HF3 must be kept in service at all times. Refer to 7T-45.

### 9.6 Harmonic Filter Re-Energizing Delay

If the VIT or ARN HF2 harmonic filter is de-energized, they must not be re-energized, until the trapped charge on the capacitors has been discharged to ground (approximately 5 minutes).

### 9.7 Use of VIT and ARN HF2 to Control Harmonics

VIT and ARN HF2 assist in controlling the harmonics in the AC systems, specifically $5^{th}$ harmonics. In order to control the harmonics in both the Lower Mainland, and Vancouver Island these banks must be in service all of the time even Pole 2 is shut down.

#### 9.7.2 VIT HF2

VIT HF2 can be reconfigured with only the $5^{th}$ and $7^{th}$ harmonic filter elements in service.
VIT HF2 will be used by the Grid 2 System Operator to control Vancouver Island $5^{th}$ harmonic voltage issues.

It is not possible to have only the 5th harmonic section of HF2 by itself. The protection works in a balance scheme that involves 2 filter sections. Either the 5th + 7th harmonic filters in service or the 5th + 11th harmonic filters in service are possible operating configurations. The Sector 2 Grid Operator must have CPC techs block parts of the HF2 protection to operate in these configurations.

### 9.8 Blocking Of Pole 2 Upon Loss Of Harmonic Filters

If either ARN or VIT HF2 is removed from service due to a protection operation or a switching error, Pole 2 will block. The control scheme that performs the action will also prevent de-block of Pole 2 if there are no harmonic filters in service. If both ARN HF2 and VIT HF2 are in service, it will be possible to de-block Pole 2.

## 10.0 STATION SERVICE SUPPLY TO HVDC EQUIPMENT

### 10.1 Station Service Reference Drawings and Description

The station service one line diagram is drawing 563-E06-D2 for VIT, 441-E06-D2 for ARN. For a detailed description of the VIT Station Service supplies see document of the same title in file: 1517.2S
For a detailed description of VIT Station Service supplies see document of the same title with drawing no. 563-E25-A3 in file 1517.2S.

### 10.2 Station Service Normal Status

It is essential that station service power supplies be maintained to the valve auxiliaries at all times. Restoration of one station service should have top priority. Since all station service equipment is level V equipment, operating permission must be obtained from the FVO dispatcher before manual changeover of the station service. Loss of Pole 2 is possible due to a failure of the transfer scheme.

Normally SST1 and SST3 are both energized, SST1 0.6 CB and SST3 0.6 CB are closed; AC0.6 CB is normally open, and all other CB's are closed as required. Both Inverter 1 and Inverter 2 are in service supplying Pole 2 first grade power. Normal status is: A0.6 bus energized, C0.6 bus energized, AC0.6 CB open, C0.2 bus energized via LT1 0.2 CB and LT2 0.2 CB open.

### 10.3 Station Service Auto Changeover

With control in auto, an undervoltage on SST1 or SST3 will cause SST1 0.6 CB or SST3 0.6 CB respectively to open, and AC 0.6 CB will close. This automatic sequence is both reliable and fast and results in only a minor disturbance on cooling pumps, blowers, fans, etc.

Upon loss of either SST1 or SST3 sources, AC0.6 CB will close. Upon loss of both sources, no switching occurs.

Alternate feeds are available for the station service transformers; see station one lines.

**NOTE: SST1 and SST3 must not be paralleled.**

Loss of the A0.6 bus and failure of the changeover scheme results in loss of:

- Synchronous condenser #4 at VIT
- Lighting transformer #2 (LT2).

Loss of the C0.6 bus and failure of the changeover scheme results in loss of:

- Synchronous condenser #3 at VIT
- Lighting transformer #1 (LT1).

A total loss of station service (AO.6 and CO.6 buses) for longer than approximately three seconds results in loss of the following:

- POLE 2
- SC3 and SC4

### 10.4 Pole 2 First Grade Power System

The purpose of the first grade system is to isolate the critical control equipment, all converter control and DC sensing, from the AC power system. This isolation is obtained by having a rectifier charge a battery and the battery feed an inverter which converts the DC into a 120 volt 60 hertz, single phase, control power supply. The converter control power is completely isolated from transient voltage disturbances and complete loss of AC power.

A switching arrangement is provided to manually permit the connection of either charger with either battery, and the connection of either battery with either inverter.

Each inverter has a minimum rating of 2 kVA and feeds a first grade AC distribution bus. An automatic throw over scheme is provided in case of an inverter failure.

In case both inverters are inoperative, and Pole 2 has to be used in an emergency, a shielded 20 kVA, 575 - 120V, single phase isolation transformer is provided which can supply unregulated power to the Pole 2 first grade distribution bus through key lock switches.

Two sets of batteries are provided, one set for each inverter. Each set is rated for 1 hour of operation when supplying the full load of both circuits 1 and 2 of the Pole 2 first grade power supply (15 kVA).

### 10.5 Emergency Diesel

The emergency diesel maintains supplies to battery chargers and other critical loads during station service interruptions. The emergency diesel cannot be used to operate Pole 2 during a total station service outage.

A loss of voltage on C 0.2 bus (208 V) will start the emergency diesel in 30 seconds. 60 seconds later the 'ROBONIC' will transfer the diesel supply to the essential S.S. panel.

The emergency diesel must be shutdown manually after restoration of the station service.

## 11.0 REVISION HISTORY

| Revised By | Revision Date | Summary of Revision |
|---|---|---|
| DSG | 04 February 2005 | Revised section 4.4. |
| RPG | 17 October 2005 | Revised section 4.2. |
| DSG | 05 March 2009 | Replaced 7T-VIC-05. |
| DSG/HDQ/RPG/JPM | 07 April 2010 | Major revision. Pole 1 decommissioning. |
| DSG | 05 April 2011 | Minor updates. |
| JPM | 04 May 2011 | Added Section 9.7.2 configure HF2 to 5$^{th}$ harmonic filter. |
| DSG/JPM | 06 Dec 2011 | Revised section 4.4 and minor updates. |
| Lawrence Ryan | 30 March 2012 | Remove reference to Pole 2 High Var not being available. |
| DSG | 05 June 2012 | Minor corrections in section 5.1 and 5.2. |
| John Marusenko | 30 October 2012 | Revised section 5.2. |
| Lili Bu, Yan Ling Cong, Bob Cielen | 06 January 2016 | Sections 4.5.2, 9.1, 9.2, 9.3, 9.5, 9.6, 9.7, 9.8, 10.3 – removal of VIT HF1, HP1, ARN HF1, HP1 and VIT SC1. Section 9.4 and 9.7.1 have been removed. |

## Appendix 1 – Isolation of Valve Groups

### To Isolate Valve Group V3

a) Check to confirm the valve group which will be blocked at ARN and select same for stop.
b) Adjust the Pole II current setting to 800 amps (or as system conditions permit).
c) Block V3.
d) Check VIT bus voltage and adjust as required.
e) 2CB8 and 2CB9, open.
f) 2D3, open.
g) 2CB8 and 2CB9, close.
h) DV3, open (GDV3 closes auto - check).
i) Instruct Electrician to carry out switching below.

FIELD PROCEDURE

1. 2D3, check open, lock in “Manual” and tag.

2. DV3, check open, lock in “Manual” and tag.

3. T3, transformer gas relay trip blocking "state switch" open and tag "caution".

NOTE: If using GDV3 as working grounds, they must be checked closed and locked in “Manual” and tagged with grounding/ blocking tags.

### To Isolate Valve Group V4

a) Check to confirm the valve group which will be blocked at ARN and select same for stop.
b) Adjust the Pole II current setting to 800 amps (or as system conditions permit).
c) Block V4.
d) Check VIT bus voltage and adjust as required.
e) 2CB12 and 2CB13, open.
f) 2D4, open.
g) 2CB12 and 2CB13, close.
h) DV4, open (GDV4 closes auto - check).
i) Instruct Electrician to carry out switching listed below.

FIELD PROCEDURE

1. 2D4, check open, lock in “Manual” and tag.

2. DV4, check open, lock in “Manual” and tag.

3. T4, transformer gas relay trip blocking "state switch" open and tag "caution".

NOTE: If using GDV4 as working grounds, they must be checked closed and locked in “Manual” and tagged with grounding/ blocking tags.

## Appendix 2 – Re-energization of Valve Groups

### To Re-energize Valve Group V3

FIELD PROCEDURE

1. T3 gas relay “state switch” detag and close.
2. 2D3, remove tag and lock in “Auto”.
3. DV3, remove tag and lock in “Auto”.

a) Check with electrician that all V3 cooling is running in AUTO
b) GDV3, open.
c) DV3, close.
d) 2D3, close.
e) Check to confirm that the ARN Valve Group is ready to be released.
f) Check VIT synchronous condenser MVAR loading and prepare for the release of valve group.
g) Adjust Pole II current setting to 800As (or as system conditions permits).
h) Close VIT D5 prior to starting first valve group.
i) Release V3.

### To Re-energize Valve Group V4

FIELD PROCEDURE

1. T4 gas relay “state switch” detag and close.
2. 2D4, remove tag and lock in “Auto”.
3. DV4, remove tag and lock in “Auto”.

a) Check with electrician that all V4 cooling is running in AUTO
b) GDV4, open.
c) DV4, close.
d) 2D4, close.
e) Check to confirm that the ARN valve group is ready to be released.
f) Check VIT synchronous condenser MVAR loading and prepare for the release of valve group.
g) Adjust Pole II current setting to 800A (or as system conditions permit).
h) Close VIT D5 prior to starting first valve group.
i) Release V4.