BC HYDRO

T&D SYSTEM OPERATIONS

SYSTEM OPERATING ORDER 7T – 22

SYSTEM VOLTAGE CONTROL

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Original signed by

APPROVED BY: ____________________

Steven Cullen
Operations Planning Manager
T&D System Operations

Highlight Denotes Revision

- Requires same day posting on bchydro.com and on BCRC Extranet upon release.
- Requires same day MRS conveyance notification upon posting

1.0 POLICY

Tolerances for abnormal voltage levels are based on equipment limitations and on customer acceptance. The voltage levels specified in this order act as a general guide and are applicable during all hours of the day, and constitute a voltage schedule (VAR-001-02). However this guide does not supersede operating orders issued which limit voltage levels for a specific equipment or a specific customer. Voltage requirements for non-BC Hydro generating plants are specified in their joint operating orders.

Appendix 1 lists BC Hydro generators and IPP generators and their respective reference buses (VAR-002)

Appendix 2 Provides a summary table of system voltage limits, exceptions and inclusions that are System Operating Limits (SOL), as can be found in the details of Section 3 of this System Operating Order. (SOO)

1.1 Transmission, Breaker, CVT, CT, and Disconnect Tolerance:

- Voltage deviation of plus or minus 10% can be tolerated for several hours.
- Voltage deviation of 20% below normal cannot be tolerated for a more than a few minutes (1-2 min).
- Load must be dropped where voltage deviation exceeds 10% above or 15% below normal and correction is not possible within a few minutes.
- Sub-transmission circuit voltage (60 kV and 138 kV) deviations of up to 15% below nominal level are acceptable for indefinite periods provided the connected distribution voltage levels and transmission customer voltage levels are within acceptable limits as outlined below. Load shedding is not required under these circumstances.

1.2 Transformer, Shunt Reactor and Shunt Capacitor Bank Tolerance:

- 5% Overvoltage can be tolerated continuously and up to 10% overvoltage can be tolerated for several hours.
- Take immediate action to correct voltage deviations greater than plus 10%.

1.3 Generator Tolerance:

- Generator voltage deviations of +/- 10% are permissible but limited by the unit capability curve.

1.4 Distribution Tolerance:

- The normal distribution bus voltage is targeted between 102% and 104% of the nominal voltage level.
- The extreme distribution bus low voltage is 95% of the nominal voltage level. Dispatchers/Operators are authorized to shed load manually in order to prevent the distribution voltage from dropping below the 95% level.

Example:
A transformer with 130-25.2 kV windings with +/- 10% LTC can regulate the distribution bus voltage as long as transmission voltage is between 117 kV and 143 kV. The distribution voltage does not drop to 95% of nominal (23.94 kV) until the transmission voltage drops to 111 KV.

Note: These guidelines for distribution bus voltages are not applicable where Volt-VAR Optimization automation has been applied. These automated VVO schemes will model customer voltage at all services along the distribution feeder and adjust the station bus voltage for satisfactory customer voltages accordingly. Therefore, the distribution bus voltage at locations controlled by VVO will be, at some times, lower than 102% of the nominal voltage level.

1.5 Transmission Voltage Customers (TVCs):

Voltage on transmission system should be regulated within +/- 5% of nominal voltage at the customer site but it must stay within +/- 10% under all operating conditions.

Note: This System Operating Order (SOO) does not supersede limits listed in TVC OO's. If no limit is listed in TVC OO's then the limits listed in this SOO are applicable.

1.6 Responsibilities

The BC Hydro System Operator on the Transmission Coordinator desk is responsible for:

- Monitoring voltages on all 500 kV buses and on the 230 kV buses at MDN, ING and BSY and ensuring that voltages are acceptable.
- Ordering the energization and de-energization of all 500 kV reactors and all reactive equipment at ING, MDN, CBK, SKA, TKW and MSA. The Transmission Coordinator may operate other reactive devices as long as the area voltage limits are maintained. (i.e. KI-2, MUR, PIK, SAT).
- Optimizing the insertion and removal of reactive and capacitive devices for supporting transfers and for next contingency support under high and light loading.
- Ordering the BC Hydro Plant Interchange Operator, GMS Operator or BSY Operator to affect changes in reactive output and/or voltage at the following generating stations: GMS, PCN, MCA, REV, BRR, SEV, KCL and BSY.
- Directing the GMS Operator and BC Hydro Grid Operators to adjust normal target voltages in their area, to the extent possible, to assist during system high voltage conditions or system low voltage conditions.
- Ensuring the dynamic reactive reserve criteria is met at GMS, PCN, MCA, REV, KCL, SEV, BRR, CMS, SFN, RUS, SCA, LDR, JHT, VIT and BSY. The Transmission Coordinator monitors the EMS DVAR display and will request the GMS Operator or BC Hydro Plant Interchange Operator to make changes based on limits and alarms from the system.
- Communicate with BPA prior to operating reactive devices at ING and with AESO prior to operating reactive devices at CBK. (Reciprocal communication responsibilities exist with BPA and AESO prior to their operation of reactive devices at their Custer (CUS), Bennett (BNS) and Langdon (LGN) substations).

The BC Hydro System Operators on the Sector 1, 2, and 3 Grid Desks are responsible for:

- Monitoring and maintaining voltages in their area except as noted above.
- Controlling sub-transmission and distribution voltages using local reactive and on-load tap-changing devices.
- Requesting assistance from the BC Hydro Plant Interchange Operator to adjust voltage on generators that connect directly into the sub-transmission system except as noted above.
- Responding to directions from the Transmission Coordinator regarding adjustments to area voltage and equipment to the extent possible without violating local voltage criteria.
- Receive approval from the Transmission Coordinator before operating reactive device that may impact the 500kV and 230kV bus voltages (i.e. KI-2, MUR) or could impact total transfer capabilities (i.e. PIK, SAT) on the BC-US (Path 3) intertie.

Note: IT IS IMPORTANT NOT TO RE-ENERGIZE ANY SHUNT CAPACITOR AFTER IT HAS BEEN DE-ENERGIZED UNTIL AT LEAST 5 MINUTES HAS ELAPSED.

2.0 DYNAMIC REACTIVE RESERVES

It is essential to maintain adequate dynamic reactive reserves (DVAR) across the electric system to ensure that post-contingency voltages are acceptable. This may require significant absorbing capability to cover for the loss of the interties, under-frequency load shedding and other contingencies. Alternatively, significant boosting capability may be required to cover for a contingency leading to a heavily loaded transmission line. The system requirement is met by ensuring that the unit MVAR loading at GMS, PCN, MCA, REV, BR, KCL, SEV, BSY, SFN, RUS, CMS, SCA, LDR, JHT and VIT meet the following criteria:

- For each plant with more than one unit on line, including synchronous condensers at VIT, the total actual plant VAR absorption must be less than 95% of the plant VAR absorption capability after loss of the largest on-line unit.

For example:

VIT SC2, SC3 and SC4 have VAR absorption capabilities of -50, -79, and -79 MVAR respectively.

If SC2, 3, 4 are on line, the maximum allowable VAR loading is:

0.95 * (-50 -79) = -122 MVAR (assumes loss of SC4)

If SC2, 4 are on line, the maximum allowable VAR loading is:

0.95 *-50 = -47.5 MVAR (assumes loss of SC4)

The 95% factor is to compensate for the reduced VAR absorption capability as the terminal voltage of units is reduced to absorb more VARs.

2.1 Applicability

Under some operating conditions, the DVAR criteria above may be relaxed in Operating Plans to address specific operating requirements that arise for planned outages or abnormal operating topologies. TDSO Operations Planning Engineers are responsible for preparing those Operating Plan requirements.

For the specific case of 2L129 out of service, DVAR criterion are suspended for the double contingency leading to Vancouver Island separation, as the islanded area will collapse regardless of the VAR reserves.

3.0 SYSTEM VOLTAGE LIMITS

3.1 General Guidelines

The maximum continuous voltage acceptable for any equipment is 10% above nominal rating. However, oil-filled cables and SF6 buses at some locations must be restricted to 5% over nominal rating. Refer to Section 12.0 for the listing of system nominal voltages.

In general,

- 550 kV is the maximum continuous limit acceptable on any 500 kV bus, 570 kV is acceptable for up to 5 minutes, and further restrictions are as listed below in Section 3.2.

- 380 kV is the maximum continuous limit acceptable on any 345 kV bus.

- 316 kV is the maximum continuous limit acceptable on any 287 kV bus.
- 253 kV is the maximum continuous limit acceptable on any 230 kV bus.

- 152 kV is the maximum continuous limit acceptable on any 138 kV bus.
- 145 kV is the maximum continuous limit acceptable on any 132 kV bus.

Acceptable limits for Generation resources are governed by capability curves. Generators are operated to maintain voltages at station transmission buses. Appendix 1 lists the BC Hydro generators and their associated transmission buses, as well as Generator step-up transformers and tap positions.

IPP owned generation is listed in Appendix 1 for the purpose of identifying transmission buses that IPP generators regulate.

3.2 Exceptions to General Guidelines

Station / Bus	Maximum Limits	Limitation
Any 500 kV Bus	550 kV	up to 570 kV is acceptable for up to 5 minutes
DMR & MSA 500 kV Bus	544 kV	544 kV on 5L29/5L31 cables
BRT 230 kV Bus	245 kV	original maximum kV station design specification including bus insulation
All 230 kV cables	242 kV	maximum continuous ratings for 230 kV cables
SPG 230 kV Bus	242 kV	230 kV SF-6 bus
SEV 230 kV Bus	242 kV	maximum rated voltage for equipment built to ANSI standards
ACK 230 kV Bus	242 kV	230 kV SF-6 bus, & oil filled cables

4.0 RAS SCHEMES TO REDUCE HIGH SYSTEM VOLTAGES, LOSS OF BOTH 5L51 AND 5L52 OR LOSS OF EITHER 5L51 OR 5L52 WITH PARALLEL CIRCUIT (5L52 OR 5L51) OOS

4.1 Reactive Power Remedial Action Scheme (RX RAS)

The Reactive Power Remedial Action Scheme (RX RAS) was designed to operate for the loss of both 5L51 and 5L52. It will be armed by TSA when the Ingledow to Custer transfer exceeds 2000 MW. When it operates, the six components will switch out shunt capacitors and switch in shunt reactors to reduce system voltage, as follows:

- RX RAS at KLY
- RX RAS at NIC
- RX RAS at ING
- RX RAS at MDN
- RX RAS at ACK
- RX RAS at SEL

The details are described in SOO 7T-18, and in SOO 2T-34 (Appendix 2) under the 5L51 and 5L52 RAS.

4.2 5L61 Tie Tripping RAS Action

The 5L61 Tie Tripping RAS Action (5L61 RAS) is described in SOO 7T-18, and in SOO 2T-34 (Appendix 2) under the 5L51 and 5L52 RAS. It will trip 5L61 and separate the North Coast area to reduce high system voltages during high imports from the US and from ALCAN for:

1) the loss of both 5L51 and 5L52
2) the loss of either 5L51 or 5L52 with its parallel circuit 5L52 or 5L51 OOS.

5.0 GRID SECTOR 1 VOLTAGE OPERATING RANGES

5.1 Normal Operating Voltage Range (kV)

Station / Bus	Normal Operating Range	Comments
GMS, WSN, TKW, SKA	510 – 540 kV	The Peace River Area 230 kV will be in an acceptable range for these 500 kV voltages. The area 138 kV voltage is controlled by on-load tap changers. TKW 5RX1, GLN 5RX5 and WSN 5RX1 should normally be in service at all times. Concern is very high post-contingency voltages. If SKA voltage drops below 510 kV adjust WSN voltage before switching out reactors.
ACK 500 kV Bus	510 – 540 kV	
KLY 500 kV Bus	520 – 545 kV	
KLY 230 kV Bus	< 253 kV	
BRT 345 kV Bus	< 375 kV	
BRT 230 kV Bus	< 245 kV	
ACK 230 kV Bus	< 242 kV	230 kV SF6 bus, and oil filled cables.
SEV 230 kV Bus	< 242 kV	
GLN 230 kV Bus	< 258 kV	
BR1/2	> 13.8 kV	If possible with less than 370 kV and 245 kV when BR is above 250 MW.
RPG		Plant should normally be absorbing VARs. Use RUP OLTC to adjust 60 kV voltages.

Wide variations in 500 kV bus voltages can occur as a result of the wide range of generation levels possible in the South Interior. Close monitoring of voltages and frequent voltage regulation will be required during large plant load changes.

The Kitimat (KIT) bus is normally regulated to 285 +/- 3 kV using KIT shunt capacitors and Kemano (KMO) generators.

SOO 7T-30 contains specific conditions for energizing WSN to SKA 500 kV lines when 500 kV reactors are unavailable and for operation during separation from Alcan.

5.2 WSN Auto VAR Control Scheme

This scheme:

- Controls high voltages after loss of high exports to the US by switching in available reactors at WSN.
- Will switch WSN 12RX1 (75 MVAR), 12RX2 (75 MVAR), 5RX2 (5L1 line reactor), 5RX4 (5L2 line reactor) and 5RX6 (5L7 line reactor).
- Is enabled at all times except for maintenance in which case it will be disabled by a local switch at WSN. Status indication of this maintenance switch is available at BC Hydro Control Centre (on the Reactive Overview display in EMS).
- Will initiate SCADA alarms at BC Hydro Control Centre when it operates.
- Has two voltage sources:
    - The primary voltage source is supplied from 5CC6 (5L7) or 5CC2 (5L1) with 5CC6 being the preferred source.
    - The standby voltage source is supplied from 5CC6 (5L7) and 5CC4 (5L2) also with 5CC6 as the preferred source.
- Continuously monitors the WSN 500 kV voltage.
    - If the voltage is higher than 545 kV, it will switch in both 12RX1 and 12RX2 after 5 seconds.
    - It will then continue to switch in 5RX2, 5RX4 and 5RX6 reactors, whichever is available, one reactor every 5 seconds until the voltage is less than 530 kV or all available reactors are energized.
- Has a timer that resets the control scheme in 60 seconds, in case the WSN voltage does not drop below 530 kV after all available WSN reactors are energized. This will return control of the WSN reactors to Transmission Coordinator and Grid Desk Operators.

5.3 TKW Auto VAR Control Scheme and SKA Auto VAR Control Scheme

When the North Coast is connected to WSN, both the TKW Auto VAR Control Scheme and SKA Auto VAR Control Scheme should be turned “ON”.

When TKW is not connected to WSN:

1) Both TKW and SKA schemes should be turned “OFF”.
2) The TKW and SKA 12 kV reactors that should be in service will be determined prior to TKW being islanded from WSN.

The TKW scheme will regulate the pre- and post- contingency voltage at the TKW 500 kV bus within 510 and 535 kV.

The SKA scheme will regulate the pre- and post- contingency voltage at the SKA 500 kV bus within 510 and 535 kV.

The details of the two schemes are described in SOO 7T-30.

5.4 ACK Auto VAR Control Scheme

This scheme:

- To control voltage, reactors and capacitors will automatically be energized or de-energized at ACK via 5CB47, 5CB48, 5CB49, 5CB50.
- During an overvoltage condition, will switch the in-service capacitors out first before the available reactors are switched in.
    - o If a capacitor circuit breaker fails to open, there is no logic to prevent the switching of the reactors.

- During an undervoltage condition, will switch the in-service reactors out first before the available capacitors are switched in.
    - If a reactor circuit breaker fails to open, there is no logic to prevent the switching of the capacitor banks.
- Is enabled at all times except for maintenance in which case the scheme will be disabled by a local switch at ACK. Status indication of this maintenance switch is available at BC Hydro Control Centre (on System Reactive Overview display in EMS).
- Will initiate SCADA alarms at BC Hydro Control Centre when it operates.
- Has two voltage sources:
    - the primary voltage source for this control scheme is 5CVT7 (5MB1)
    - the backup voltage source is 5CVT8 (5MB2).
- Continuously monitors the ACK 500 kV voltage.
    - If the voltage is higher than 540 kV, it will switch off 5CX1 after 5 seconds. If the high voltage persists, it will switch off 5CX2 5 seconds after 5CX1 has been switched.
    - If 5CX1 is out of service, 5CX2 will switch off after 5 seconds if the voltage is higher than 540 kV.
    - It will then continue to switch in one reactor; 5RX7, 5RX8 or 5RX4 every 5 seconds until the ACK voltage is less than 525 kV or all available reactors are energized.
    - Has a timer that resets the control scheme in 60 seconds, in case the ACK voltage does not drop below 525 kV after all available ACK reactors are energized. This will return control of the ACK reactors to Transmission Coordinator and Grid Desk Operators.
    - If the voltage is below 518 kV, it will switch off 5RX7 after 5 seconds. It will switch off 5RX8 in 5 seconds if 5RX7 is out of service or after 5 seconds if 5RX7 is in service.
    - It will then continue to switch in one capacitor, 5CX1 or 5CX2 every 5 seconds until the ACK voltage is above 525 kV.
    - Has a timer that resets the control scheme in 60 seconds, in case the ACK voltage does not rise above 525 kV after all available ACK capacitors are energized. This will return control of the ACK capacitors to Transmission Coordinator and Grid Desk Operators.

5.5 <u>5L92 and 5L94 CBK RX/CX RAS</u>

This scheme:

- Controls the 230 kV voltages at CBK after loss of both 5L92 and 5L94 circuits, by switching CBK 12RX32, 12RX6, 12RX7, 12CX2 and 12CX3.
- Monitors the status of 5L92 and 5L94 circuit breakers at CBK.
- Monitors 230 kV bus voltage (2CVT4).
- on loss of both 5L92 and 5L94 circuits, and if the CBK 230 kV voltage is lower than 218.5 kV:
    - trips 12RX32 (75 MVAR) after 0.2 sec,
    - trips both 12RX6 (10 MVAR) and 12RX7 (10 MVAR) after 0.5 sec,
    - switches in both 12CX2 (19.2 MVAR) and 12CX3 (19.2 MVAR) after 0.8 sec,
    - stops the switching if the CBK 230 kV voltage has recovered to 218.5 kV or higher.
- On loss of both 5L92 and 5L94 circuits, and if the CBK 230 kV voltage is higher than 248.4 kV:
    - trips both 12CX2 (19.2 MVAR) and 12CX3 (19.2 MVAR) after 0.4 sec,
    - switches in both 12RX6 (10 MVAR) and 12RX7 (10 MVAR) after 0.7 sec,
    - switches in 12RX32 (75 MVAR) after 1.0 sec,
    - stops the switching sequence if the CBK 230 kV voltage has dropped to 248.4 kV or lower.

- Is enabled at all times except for maintenance in which case the scheme will be disabled by a local switch at CBK. Status indication of this maintenance switch is available at BC Hydro Control Centre (on System Reactive Overview display in EMS).
- Will initiate SCADA alarms at BC Hydro Control Centre when it operates.

5.6 Operating Guidelines for Joint VAR Controllers

There are currently no Joint Var Controllers (JVC) installed on the BC Hydro system.

The MCA JVC has been removed.

The KCL JVC has been removed.

5.7 CBK Overvoltage RAS Scheme

The CBK O/V RAS is designed to reduce over-voltage conditions at Seven Mile (SEV) due to a 5L91/ 5L96 / 5L98 contingency during light loading conditions. SEV plant cannot sustain voltages above 241 kV so the RAS is meant to safeguard SEV SF6 bus. The RAS operates as a one-time process that is triggered by a simultaneous 5L91 and 5L96 or 5L91 and 5L98 contingency (provided that 5L92 AND 5L94 are not both open).

The RAS is supervised by the 230 kV voltage source from CBK 2CVT4. The RAS will wait 5 seconds after the contingency and will switch CBK 12CX2, 12CX3, 12RX6, 12RX7, and 12RX32 in succession in half second intervals based on whether the CBK voltage is below a preset level and whether the reactors or capacitors are in their final desired state. Should the voltage drop below the preset level of 235 kV, all further equipment switching is stopped. The CBK O/V RAS is prevented from operating when the CBK Auto VAR control scheme (5L92/5L94 RAS) operates. The CBK O/V RAS will be normally armed and can only be disarmed locally for maintenance purposes. Remote on/off indication is provided to FVO.

5.8 SEL Auto VAR Control Scheme and RX RAS

This scheme:

- Switches in SEL 5RX3 automatically upon SEL 230 kV bus voltage exceeding 1.05 p.u. (241.8 kV) for more than 5 seconds (if it is off-line and available).
- Switches out SEL 5RX3 automatically upon SEL 230 kV bus voltage dropping below 1.02 p.u. (234.8 kV) for more than 5 seconds (if it is on-line).
- The RX RAS quickly switches in SEL 5RX3 (10 ~ 12 cycles from time fault initiated to CB contact closed) to prevent transient overvoltages at SEL 500 kV bus in response to the following contingencies:

N-2	N-1-1
5L51&5L52	5L51 (or 5L52) contingency while 5L52 (or 5L51) OOS
5L76&5L79	5L76 (or 5L79) contingency while 5L79 (or 5L76) OOS
5L81&5L82	5L81 (or 5L82) contingency while 5L82 (or 5L81) OOS
5L91&5L96	5L91 (or 5L96) contingency while 5L96 (or 5L91) OOS
	5L91 contingency while 5L98 OOS
	5L98 contingency while 5L91 OOS

The arming of the RX RAS does not block the SEL auto VAR scheme operation. When the RX RAS operates, the SEL auto VAR scheme is frozen for 10 seconds. After 10 seconds the auto VAR scheme is automatically re-enabled. With the RX RAS armed, SEL 5RX3 can still be manually switched in or out.

6.0 GRID SECTOR 2 VOLTAGE OPERATING RANGES

Station / Bus	Normal Operating Range	Comments
VIT	225 kV – 245 kV 137 kV – 143 kV	The VIT bus voltage may be lowered to 135 kV to control high system voltage.
DMR	530 kV ± 15 kV	5L31 O.V. alarm and 8 min. time p.u. at 545 kV. 5L29 O.V. alarm and 14 min. timer also p.u. at 545 kV. The voltage has reached 544 kV during light load conditions.
DMR	230 kV – 242 kV	253 kV is the max. voltage rating of the DMR SF6 CBs (242 kV nominal).
DMR	141 kV ± 2 kV	If problems with high voltage on the bulk system, then the Transmission Coordinator will request the Sector 2 Grid Desk to adjust DMR SVC 138 setpoint and DMR 230/138 kV taps to maximize VAR absorption on the SVC.
CK5	515 kV – 545 kV	
PAL	139 kV ± 2 kV	PAL T5 and T6 are limited to a maximum voltage of 142 kV.
ICG	137 kV ± 2 kV	ICG should be asked to regulate the 138 kV voltage to 136 kV.
HWW	135.5 kV ± 2 kV	LTC setpoint at 135.5 kV.
JHT/SCA/ LDR	130 kV -145 kV	
GOW/GTP	122 kV – 142 kV	
HSY/PIK/ ESQ/GOW	217 kV – 242 kV	The alarm level on HSY 2L143 cable is 242 kV and trips at 250 kV.
GLD	218 – 253 kV	
GLD	135 – 144 kV	Maximum GLD 138 kV bus voltage is presently constrained by TSV T1/T2 at 145 kV.

WOS		The voltage on the WOS T1 must be monitored as the transformer is designed on a 120 kV base with ± 15% taps. It can withstand 148 kV continuous overvoltage in tap 1 position under light load conditions.
KGH	122 kV – 145 kV	

KGH 25CX1 should be kept in service, as much as possible, and only removed for maintenance or when KGH 25.2 kV and 132 kV buses exceed over voltage limits without other means of control. When the bank is removed from service for planned maintenance or is unavailable for an extended period (> 1 day) due to a forced outage, notify Cape Scott Wind (CSS).

The KGH distribution bus should not be operated continuously above 26.5 kV (105%). The bank will automatically be tripped if the voltage exceeds 28.0 kV (111%) for 50 seconds. The KGH 132 kV bus should not be operated above 145 kV.

The principle purpose of KGH 25CX1 is to mitigate the 5th harmonic resonance condition around PHY Substation and potential impact on CSS's equipment.

The Sector 2 Grid Desk will monitor and control voltages on Vancouver Island using generators, shunt capacitors and VIT synchronous condensers, and will call the Transmission Coordinator for coordination of voltage control on the DMR 500 kV buses through reactor switching and operation of the DMR SVC.

PIK reactor should be in unless 230 KV is below 220 KV in Victoria or we need to switch out for voltage control in DMR or at VIT.

The Sector 2 Grid Desk controls Arnott 230/138 kV transformer tap changers and will also on request from the Transmission Coordinator, load the HVDC and switch VIT HVDC filters to assist in Lower Mainland voltage control.

Reactor switching at either MSA or DMR will produce near-equal voltage changes at both stations. MDN and KLY voltages, however, will be affected very little by voltage changes at MSA.

7.0 GRID SECTOR 3 VOLTAGE OPERATING RANGES

7.1 Normal Operating Voltage Range (kV)

Station / Bus	Normal Operating Range	Comments
CBN	530 – 547	
ING	520 – 545	
MSA	515 – 540	
UHT	355 – 363	
ING	233.9 - 240.1	autoVar set points
MDN	235.3 – 241.5	autoVar set points
BND	< 242	2L51 cable rating
COK	< 242	2L51 cable rating
CSN	< 242	2L45, 2L55 cable rating
HPN	< 242	2L51, 2L32 cable rating
MAN	< 242	2L56, 2L55 cable rating
MUR	< 242	2L50, cable rating
SPG	< 242	2L45, 2L64 cable + GIS rating
ALZ	65 – 69	
CBN	64 – 66	
DGR	63 – 65	
PKL	63 – 65	
BND	62 - 64	
COK	62 - 64	
HPN	62 - 64	
MUR	62 - 64	
MLN	62 - 64	
NEL	62 - 64	
KI2	62.5 - 63.0	Ensures SEA distribution bus voltage less than 13.2 kV

The Metro 60 kV system is robust with respect to voltage and 63 kV is typically a good target voltage. Fraser Valley circuits will have larger voltage operating ranges and the target will also be higher. Please refer to 3T- Station operating orders for more information on voltage ranges.

UHT-ROS 345 kV system operating voltage range is normally between 355 kV to 363 kV except in winter peak load season, when UHT can be allowed to operate between 360 kV to 363 kV to avoid area low voltage on the subtransmission. In light load periods (seasonally) when system high voltages can occur, UHT operating voltage can be permitted to exceed 363 kV for short time period but not to exceed 380 kV, if all the operating strategies to reduce UHT voltage to less than 363 kV have been applied.

These strategies include:

1. Ensure all UHT reactors online.
2. Reduce bulk system voltage especially at KLY/CBN/ING as much as possible in order to reduce ING-CBN-ALZ-UHT-ROS-BRT path voltage.
3. BC Hydro Operators contact KWL operators to request KWL generators absorb more reactive power from BC Hydro system to reduce UHT voltage.
4. Adjust BRR unit terminal voltage to absorb more reactive power from 345 kV path.
5. Switch out 3L5 as the last option.

On-line BSY units, when required for voltage support by the VSAT program, are to be operated in the under-excited region (0 to -25 MVARs). See SOO 6T-34 (Automatic Undervoltage Load Shedding (AUVLS)) for more specific requirements when operating outside of the RT-VSAT program limits. When not required on-line by the RT-VSAT program, BSY S/C units may be used as necessary for system voltage regulation.

Additional regulation can be obtained by requesting the Sector 3 Grid Desk to use available reactive equipment and generator capability within local voltage constraints.

MUR and KI-2 reactor operation is only to be done after consulting with the Transmission Coordinator.

During the period November 1 to February 28, Sector 3 Grid Desk has a winter distribution capacitor schedule with they will follow after informing the Transmission Coordinator.

The ING and MDN Auto VAR Control Schemes are to be kept in service normally to assist in voltage control during emergencies.

The Transmission Coordinator will coordinate the operation of DMR, TIR and MSA reactors, DMR SVC and other reactive compensation as necessary to maintain 5L29 and 5L31 cable circuits below 540 kV whenever possible. Time delayed over-voltage tripping of 5L29 or 5L31 will occur at 544.5 kV. Switching of the cables for voltage control will be resorted to only after all normal means of voltage control has been utilized. See SOO 7T-40 for more details. Further:

- System Operators on the Sector 1, 2 and 3 Grid Desks will monitor and control other 230 kV and 360 kV bus voltages using shunt reactors, capacitors, and local hydro generation. Lower voltages will be controlled with OLTC transformers and feeder voltage regulators.

7.2 <u>MDN Auto VAR Control Scheme</u>

The MDN Automatic VAR Control scheme energizes or de-energizes 2CX1, 2CX2, 2CX3, 2CX4, 2RX1, 2RX2, 12RX31, 12RX32, as required, to prevent the MDN voltage from exceeding 241.5 kV or falling below 235.3 kV. The details are provided in LOO 3T-MDN-01.

7.3 <u>ING Auto VAR Control Scheme</u>

The ING Automatic VAR Control scheme energizes or de-energizes 2RX1, 2RX2, 2CX11, 2CX2, 2CX31 or 2CX32 as required to maintain the voltage from exceeding 240.1 kV and from falling below 233.9 kV. ING 12RX4 and 12RX5 are not included in the automatic VAR Control scheme. The details are provided in LOO 3T-ING-01.

8.0 GENERAL VOLTAGE OPERATING CONSIDERATIONS

The transmission voltage profile should be kept as flat as practical at all times to minimize losses due to VAR transmission. During heavy transmission loadings voltages should be maintained in the 525 kV to 535 kV range to minimize losses and increase stability margins. During lighter loadings voltages should be reduced to 520 kV, or lower if practical, to reduce VAR generation from the lightly loaded transmission.

Reactive compensation should be applied at the buses where it is most needed. Transmitting VARs from remote locations requires large voltage differences and causes additional system losses. Proper compensation at the load buses will result in a flat voltage profile.

Some 500 kV transmission lines will have to be switched out for voltage control during extremely light loading and/or heavy imports. This method should only be used as a last resort after all normal reactive control has been utilized. The 500 kV and 230 kV cables should not be switched for voltage control except in emergencies because of the deteriorating stress this places on the cables.

Low voltage reactive equipment should be used for system voltage control providing acceptable distribution voltages can be maintained using OLTC transformers and/or feeder voltage regulators.

Generator and synchronous condenser voltage regulators, joint voltage controllers, minimum excitation limiters and Power System Stabilizers are to remain in service to the greatest extent possible, to improve system stability.

9.0 500 kV OVERVOLTAGE TRIPPING

9.1 Near-Instantaneous Uncoordinated Overvoltage Tripping

The voltage setting of the near-instantaneous (250 msec or as indicated below) uncoordinated tripping of most 500 kV circuits is:

CIRCUIT	SETTING (kV)	DETECTOR LOCATION
5L1	625	WSN
5L2	625	WSN
5L3	625.5	KDS
5L7	625.5	KDS
5L11	625	WSN
5L12	625	WSN
5L13	625	both ends
5L29	625.5	both ends
5L30	625.5	MSA
5L30	625.5 (200 msec)	CKY
5L31	625.5	both ends
5L32	625.5 (200 msec)	CKY
5L32	625.5	MSA
5L41	623.5	CBN
5L41	625	KLY
5L42	625	KLY
5L45	625.5	CKY
5L63	625	SKA
5L71	630	NIC
5L72	630	NIC
5L75	625.5	both ends

5L76	624.4	ACK
5L76	630	NIC
5L77	625.5	both ends
5L79	625.5	ACK
5L79	630	NIC
5L81	630	NIC
5L82	630	NIC
5L87	625	KLY
5L87	630	NIC
5L91	624.4	both ends
5L92	624.4	both ends
5L94	625	both ends
5L96	624.4	SEL
5L96	624	VAS
5L98	625	NIC
5L98	624	VAS

9.2 Sequential Overvoltage Tripping

Sequentially timed tripping of most 500 kV circuits at voltages between 570 kV and 585 kV is as shown below.

CIRCUIT (seconds)		SETTING (kV)	DETECTOR LOCATION
5L91	0.500	570	ACK
5L91	0.500	568.1	SEL
5L2	0.850	580	WSN
5L31	0.900	571.5	both ends
5L82	0.900	575	NIC (see note below)
5L12	1.000	580	WSN
5L32	1.050	580.5	both ends
5L72	1.050	575	NIC (see note below)
5L92	1.250	579.4	SEL
5L63	1.250	580	SKA
5L29	1.250	571.5	both ends
5L41	1.250	575	both ends (see note below)
5L77	1.250	580.5	both ends
5L13	1.350	580	both ends (see note below)
5L1	1.450	580	WSN
5L30	1.450	580.5	both ends
5L87	1.450	585	both ends
5L79	1.450	585	both ends
5L11	1.600	580	WSN
5L42	1.600	580	KLY
5L45	1.600	580.5	CKY
5L96	1.600	585	SEL
5L98	1.600	585	NIC
5L76	1.700	585	both ends
5L75	1.850	585	ACK
5L75	1.850	580.5	REV
5L81	1.850	585	NIC (see note below)
5L3	1.900	580	KDS
5L7	1.900	580	KDS
5L71	2.050	585	NIC (see note below)

5L94	5	575	CBK
5L92	6	580	CBK
5L96	6	585	VAS
5L98	6	585	VAS
5L94	300	575	LGN
5L31	480	544.5	both ends
5L29	840	544.5	both ends

Note: 5L13, 5L41, 5L71, 5L72, 5L81 and 5L82 first stage overvoltage protection (time delayed) tripping is supervised to prevent tripping if the terminal circuit breakers are open. This means follow end tripping will occur only above the near-instantaneous (250 msec) uncoordinated overvoltage setting. This was done to make it easier to return these circuits to service.

10.0 ENERGIZING LINES WITHOUT REACTORS

When energizing 500 kV lines without reactors connected, there is a possibility of the over-voltage protection at the open-ended terminal tripping the circuit before it can be put on load. This is due to a combination of the energizing bus voltage rise and the Ferranti rise on the line. The higher the initial voltage of the energizing bus prior to energizing, the more will be the bus rise on energizing, and the higher will be the Ferranti rise along the line. Depressing the energizing bus voltage prior to energizing therefore has a compounding effect in reducing the open-end line voltage after energizing.

Lines of 300 km and longer with no remote-end reactor will have Ferranti rises of 40 kV to 50 kV, depending on line length and energizing bus voltage after energizing. The energizing bus may rise 10 kV or more depending on the proximity of the bus to a strong MVAR source, and on the MVAR charging requirement of the line. Therefore, to avoid over-voltage relay tripping (at 570 kV to 585 kV) a bus voltage of 520 kV or lower is required at the energizing bus prior to line pick-up, for lines of 300 km and longer.

Ferranti rise can be approximated by the following formula:

$$\Delta Vf = \frac{X1}{100} \times \frac{Y1/2}{100} \times kV$$

where X1 and Y1/2 are the percent values on 100 MVA base at 500 kV as listed on the Transmission Line Data Sheets.

e.g. for 5L11:

X1 = 4.36, Y1/2 = 204.34

And $\Delta Vf = \frac{4.36}{100} \times \frac{204.34}{100} \times 500 = 44.5$ kV

For voltages other than 500 kV, replace 500 with the actual voltage in the above formula. The following table lists the calculated Ferranti rise on all BC Hydro 500 kV lines without reactors connected, for an energizing bus voltage of 525 kV AFTER energizing. For long lines, it will be necessary to depress the energizing bus voltage to 520 kV or less before energizing.

5L11, 5L12, 5L13 and 5L94 are all over 300 km in length, but these lines each have two line end reactors and are therefore not likely to be energized with no reactor. When one of the two reactors is unavailable, each of these lines is to be energized from the end without a reactor. If required to energize one of them with no reactor, the energizing bus must be depressed to 520 kV at least, and preferably to 515 kV prior to energization and the remote terminal overvoltage relay must be reset to 585 kV. 5L94 however, has a 5 minute time delay on tripping at LGN to allow time to synchronize the circuit on load while exceeding the low-set over-voltage relay setting.

5L41, with no reactor attached, should be energized from KLY.

The Ferranti voltage rise on 5L1, 5L2, 5L11, 5L12, 5L13, 5L41, 5L42, open end voltage can be reduced by inserting their associated series capacitor prior to energizing the line. Using the series capacitor de-sensitizes the line protection and should only be used when restoring the line and when open end voltage limits cannot be met.

FERRANTI RISE AND CHARGING MVARS ON 500 KV LINES AT 525 KV ENERGIZING BUS VOLTAGE WITHOUT REACTORS

LINE	FERRANTI RISE (kV) Without Series Capacitor	With Series Capacitor	CHARGING MVARS (at 525 kV)
5L1	35	17	374
5L2	35	17	374
5L3	8		186
5L4	0		20
5L5	0		96.6
5L6	0		96.6
5L7	8		187
5L11	50		451
5L12	50		451
5L13	50	25	466
5L29	10		1153
5L31	10		1158
5L30	3		106
5L32	3		106
5L40	1		68
5L41	33		369
5L42	17		260
5L44	0		26
5L45	2		90
5L51	1		50
5L52	1		49
5L61	14		239
5L62	7		178
5L63	9		192
5L71	37		389
5L72	37		388
5L75	3		114
5L76	6		161
5L77	3		114
5L79	6		161
5L81	31		361
5L82	27		337
5L83	26		330
5L91	22		304
5L92	14		241
5L94	47		447
5L96	12		222
5L98	9		187

Notes:

1. The energizing bus voltage rise when the line is energized must also be taken into account but is not included in this table.
2. The Ferranti voltage rise when energizing two lines in series from a line terminal is not the addition of the Ferranti voltage rises of the individual lines (e.g. the Ferranti voltage rise to energize 5L40 and 5L41, with the CBN 500 kV to 230 kV connection opened, is 49 kV).

11.0 VOLTAGE CONTROL DURING LIGHT LOAD – HIGH IMPORT CONDITIONS

Loss of 5L51 and 5L52 during light load and high import conditions will result in high voltages for the Lower Mainland 230 kV cables. Operation with less than two Burrard synchronous condensers increases the severity of the problem. Post-contingency voltages can be reduced by a combination of:

- reducing the pre-contingency Lower Mainland 230 kV voltage using all available reactive devices, and removing shunt capacitors,
- removing ARN HF and HP filters,
- taking transmission circuits out-of-service for voltage control before the contingency.

The actions should be taken:

IF

- the BC Hydro integrated system load is low (less than **5000** MW) **AND**
- the import is high (the Net BC Hydro Transfer is within **200** MW of the Transfer Limit as defined in SOO 7T-64) **AND**
- there is only one Burrard unit synchronized to the system.

THEN:

- Reduce the MDN voltage to 238 kV and reduce the ING voltage to 238 kV.
- If the MDN and ING voltages cannot be reduced, then operate with:
  - 5L1 or 5L2 O.O.S. **AND**
  - 5L11 or 5L12 or 5L13 O.O.S. **AND**
  - 5L83 O.O.S. **AND**
  - 5L87 or 5L41 O.O.S **AND**
  - or 5L81 O.O.S.

12.0 SYSTEM NOMINAL VOLTAGES

Nominal voltages are the reference voltage assigned to equipment, or system for the purpose of conveniently designating its voltage class. The actual voltage at which equipment operates can vary from the nominal within a range that permits satisfactory operation of equipment and meets customer agreements.

Nominal voltages are used in the per unit system where system quantities are expressed as a fraction of a defined base unit quantity. When expressing system voltages, the base unit quantity is nominal voltage.

<u>“60” Designated Equipment (i.e. 60Lxx, 60CBxx)</u>
Equipment with a “60” designation have a nominal voltage of:

- 60 kV for Vancouver Island and Lower Mainland.
- 66 kV for North Coast, Central Interior and South Interior.
- 63 kV for KCL where the BC Hydro and FortisBC systems interconnect.

<u>“1” Designated Equipment (i.e. 1Lxx, 1CBxx)</u>
Equipment with a “1” designation have a nominal voltage of:

- 132 kV for North Shore, Vancouver Island and circuits connected to Arnott Substation (ARN) where the Vancouver Island 132 kV system connects to the Lower Mainland.
- 138 kV for North Coast, Central Interior, and South Interior.

<u>"2" Designated Equipment (i.e. 2Lxx, 2CBxx)</u>
Equipment with a "2" designation have a nominal voltage of:

- 287 kV for North Coast west of TKW
- 230 kV for all other areas of the system.

<u>"3" Designated Equipment (i.e. 3Lxx, 3CBxx)</u>
Equipment with a "3" designation have a nominal voltage of 345 kV

<u>"5" Designated Equipment (i.e. 5Lxx, 5CBxx)</u>
Equipment with a "5" designation have a nominal voltage of 500 kV

<u>Distribution Nominal Voltage</u>

- "25" designated equipment have a nominal voltage of 25.2 kV
- "12" designated equipment have a nominal voltage of 12.6 kV
- "4" designated equipment have a nominal voltage of 4.2 kV
- "34" designated equipment have a nominal voltage of 34 kV

13.0 REVISION HISTORY

Revised By	Revision Date	Summary of Revision
Mari Wood	05 October 2020	Section 10.0 Table – added 5L5.
Bob Cielen/ Brett Hallborg	14 January 2021	Section 3.1 - Added reference to the new Appendix 1 for generator voltage regulation reference points. Section 5.1 - Removed JVC notation for KCL. Appendix 1 - New addition; to address BCH and IPP generator regulation on the BES. Tables added with transformer taps and reference operating orders for voltage regulation details. Minor table updates to ensure rows have bus labels (in Sections 3, 5,and 6).
Bob Cielen	03 March 2022	Section 1.6 – clarified responsibility for optimal reactive and capacitive insertions/removals to support voltages Section 4 – revised RAS references. Section 6 – 5L6 added to table for expected charging MVars.
Amy Lam/ Paul So/ Steven Cullen/ Eric Desjardins/ Bob Cielen	09 December 2022	• Section 1 – added reference for Appendix 1 to the VAR-002 standard. Added reference to Appendix 2 for System Voltage Limits Summary. • Section 3.2 – revised 230 kV cables to 244 kV limit • Appendix 1 – added PREI generators as BES IPP units interconnected to a transmission bus. • Appendix 2 – New: added 3 tables (not highlighted) for default System Voltage Limits that are SOLs, to capture Defaults, Variances, and Exclusions.
Eric Desjardins/ Steven Cullen	15 September 2023	Updated cable maximum continuous in Section 3.0. Further changes in Appendix 1 BES – BC Hydro and Appendix 2 - cable limits. Updated KLY 230KV limitation from 245KV to 253KV
Steven Cullen	19 September 2023	Updated Appendix 2 – Notes section to provide clarity on time limit for Emergency System Limits.

Appendix 1 – Generator Regulation Reference Points

BES – BC Hydro

All BC Hydro owned generators must meet BC Hydro Transmission Operator (TO) requirements to regulate associated transmission system buses, while operated within their respective unit capability curves.

- All generator transformer tap settings are sourced from the BC Hydro Transformer Data Book System (TDBS), listed in the tables below for convenience.
- All generator transformers are off-load transformers.

All generator transformers will remain in the prescribed setting in the TDBS as set by BC Hydro Transmission Planning. Recommendations or proposed changes can be made with a formal request to BC Hydro Transmission Planning to undertake a study or review the proposed setting, prior to consulting with the Generation Owner representatives. Any change accepted by Transmission Planning will be established by a change/revision in TDBS, and communicated to all of the above parties for implementing the change in the field and update of operating order documentation.

Station	Generator	Transformer	Tap	Transmission Bus
ASH	G1	T1	3	ASH 1L142 tap
BR1	G1	T1	3	BRT 345 kV Bus
	G2	T2	3	BRT 345 kV Bus
	G3	T2	3	BRT 345 kV Bus
	G4	T1	3	BRT 345 kV Bus
BR2	G5	T5	3	BRT 345 kV Bus
	G6	T6	3	BRT 345 kV Bus
	G7	T7	3	BRT 345 kV Bus
	G8	T8	3	BRT 345 kV Bus
CMS	G1	T1	3	CKY 230 kV Bus
	G2	T2	3	CKY 230 kV Bus
COM	G1	T1	3	COM 1L44 tap
FNG	G1	T1	3	FNG 1B1
	G2	T2	3	FNG 1B1
GMS	G1	T1	3	GMS 500 kV Bus
	G2	T2	3	GMS 500 kV Bus
	G3	T3	3	GMS 500 kV Bus
	G4	T4	3	GMS 500 kV Bus
	G5	T5	3	GMS 500 kV Bus
	G6	T6	3	GMS 500 kV Bus
	G7	T7	3	GMS 500 kV Bus
	G8	T8	3	GMS 500 kV Bus
	G9	T9	3	GMS 500 kV Bus

Station	Generator	Transformer	Tap	Transmission Bus
	G10	T10	3	GMS 500 kV Bus
JHN	G1	T11	3	JHT 138 kV Bus
	G2	T12	3	JHT 138 kV Bus
	G3	T13	3	JHT 138 kV Bus
JOR	G1	T1/T2	3/3	JOR 138 kV Bus
KCL	G1	T1	4	SEL 230 kV Bus
	G2	T2	4	SEL 230 kV Bus
	G3	T3	4	SEL 230 kV Bus
	G4	T4	4	SEL 230 kV Bus
LDR	G1	T1	3	LDR 1B1
	G2	T2	3	LDR 1B1
MCA	G1	T1	3	MCA 500 kV Bus
	G2	T2	3	MCA 500 kV Bus
	G3	T3	3	MCA 500 kV Bus
	G4	T4	3	MCA 500 kV Bus
	G5	T5	3	MCA 500 kV Bus
	G6	T6	3	MCA 500 kV Bus
PCN	G1	T1	3	PCN 5B2
	G2	T1	3	PCN 5B2
	G3	T2	3	PCN 5B5
	G4	T2	3	PCN 5B5
PUN	G1	T1	3	PUN 1B1
REV	G1	T1	3	REV 500 kV Bus
	G2	T2	3	REV 500 kV Bus
	G3	T3	3	REV 500 kV Bus
	G4	T4	3	REV 500 kV Bus
	G5	T5	3	REV 500 kV Bus
SCA	G1	T1	3	SCA 1B1
	G2	T2	3	SCA 1B1
SEV	G1	T1	4	SEL 230 kV Bus
	G2	T2	4	SEL 230 kV Bus
	G3	T3	4	SEL 230 kV Bus
	G4	T4	4	SEL 230 kV Bus
WAH	G1	T2	3	WAH 60 kV Bus
WAN	G1	T1	3	WHS 230 kV Bus
	G2	T2	3	WHS 230 kV Bus

Station	Generator	Transformer	Tap	Transmission Bus
	G3	T3	3	WHS 230 kV Bus
	G4	T4	3	WHS 230 kV Bus
WGS	G1	T1	3	WAH 138 kV Bus

BES – IPP

All Independent Power Producers (IPP), which are non-BC Hydro owned and operated generators in the BES, have interconnection agreements that reference Transmission Interconnections Requirements (TIR) for voltage support. These operating requirements are incorporated into facility operating orders for the generator site (i.e. LOO 4T-DKW-01 for the Dokie Wind IPP).

All non-BC Hydro generation transformer tap changes can be made with a formal request to BC Hydro Transmission Planning to undertake a study or review the proposed setting, prior to consulting with the Generation Owner representatives. Any change accepted by Transmission Planning will be established by a change/revision in TDBS, and communication to all of the above parties for implementing the change in the field, and for update of operating order documentation.

Station/ Generator Unit	Transformer	Tap (Position or OLTC)	Regulating Bus	Operating Order
ASL G1	ASL MPT1	3	CKY 230 kV Bus	4T-ASL-01
ASL G2	ASL MPT1	3	CKY 230 kV Bus	4T-ASL-01
ASL G3	ASL MPT1	3	CKY 230 kV Bus	4T-ASL-01
BMW Plant	BMW XFMR T1	OLTC	BMW 138 kV Bus	4T-BMW-01
CSS Plant	CSS T1/T2	OLTC	CSS 1B1/1L141	4T-CSS-01
DKW Plant	DKW T1/T2	OLTC	DKT 230 kV Bus	4T-DKW-01
ICG G1			ICG 138 kV Bus	4T-ICG-01
KMO G1			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G2			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G3			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G4			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G5			KIT 287 kV Bus	7T-22 (S3 and 5.1)

Station/ Generator Unit	Transformer	Tap (Position or OLTC)	Regulating Bus	Operating Order
KMO G6			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G7			KIT 287 kV Bus	7T-22 (S3 and 5.1)
KMO G8			KIT 287 kV Bus	7T-22 (S3 and 5.1)
MCM G1			MCM 138 kV Bus	4T-MCM-01
MCM G2			MCM 138 kV Bus	4T-MCM-01
ETR G1			SAY 230 kV Bus	4T-PSY-01
ETR G2			SAY 230 kV Bus	4T-PSY-01
MTC G1			SAY 230 kV Bus	4T-PSY-01
MTC G2			SAY 230 kV Bus	4T-PSY-01
JMC G1			SAY 230 kV Bus	4T-PSY-01
JMC G2			SAY 230 kV Bus	4T-PSY-01
QTY Plant	QTY T1	2	TLR 230 kV Bus	4T-QTY-01
RUT G1			2L2	4T-RUT-01
RUT G2			2L2	4T-RUT-01
FKR G1	2T1	1	BQN 287 kV Bus	4T-FKR-01
FKR G2	2T1	1	BQN 287 kV Bus	4T-FKR-01
FKR G3	2T1	1	BQN 287 kV Bus	4T-FKR-01
FKR G4	2T2	1	BQN 287 kV Bus	4T-FKR-01
FKR G5	2T2	1	BQN 287 kV Bus	4T-FKR-01
FKR G6	2T2	1	BQN 287 kV Bus	4T-FKR-01
FKR G7	2T3	1	BQN 287 kV Bus	4T-FKR-01
FKR G8	2T3	1	BQN 287 kV Bus	4T-FKR-01
FKR G9	2T3	1	BQN 287 kV Bus	4T-FKR-01
MCY G1	-		BQN 287 kV Bus	4T-FKR-01
MCY G2	-		BQN 287 kV Bus	4T-FKR-01
MCY G3	-		BQN 287 kV Bus	4T-FKR-01
MIG G1	-		MIG/1L249 POI	4T-MIG-01
ULR G1	ULR T1		TIS 230 kV Bus	4T-ULR-01
ULR G2	ULR T1		TIS 230 kV Bus	4T-ULR-01
ULR G3	ULR T1		TIS 230 kV Bus	4T-ULR-01
ULR G4	ULR T1		TIS 230 kV Bus	4T-ULR-01
MKL Plant			MKT 230 kV Bus	4T-MKL-01
PREI	G1		POW 132 kV Bus	3T-POW-01
PREI	G5		POW 132 kV Bus	3T-POW-01
PREI	GL1		POW 132 kV Bus	3T-POW-01
PREI	GL2		POW 132 kV Bus	3T-POW-01

Appendix 2 – Summary of System Voltage Limits

The following three tables summarize the System Voltage limits that are defined as SOLs in Section 1 and Section 3 of this System Operating Order. These tables include the Default limits by voltage class, Variances from the defaults, and any Exclusions.

These System Voltage Limit SOLs were established in accordance with the Reliability Coordinator's SOL Methodology and are entered into the EMS Real Time Contingency Analysis application for the purpose of performing Real Time Assessments. Note that this table indicates 0.9 p.u. low voltage limit for 132 and 138 kV buses; however, low voltage up to 0.85 p.u. is acceptable as long as Transmission Voltage Customers stay above 0.9 p.u. under all operating conditions.

All emergency system voltage limits are 30 minute ratings, unless otherwise specified.

DEFAULT - System Voltage Limits

Voltage Class (kV) EMS	Base kV (1.0p.u.)	Normal System Voltage Limits				Emergency System Voltage Limits			
		Low Limit		High Limit		Low Limit		High Limit	
		kV	p.u. (calc)	kV	p.u. (calc)	kV	p.u. (calc)	kV	p.u. (calc)
132	132	118.8	0.90	145	1.10	118.8	0.90	145	1.10
138	138	124.2	0.90	152	1.10	124.2	0.90	152	1.10
230	230	207	0.90	253	1.10	207	0.90	253	1.10
287	287	258.3	0.90	316	1.10	258.3	0.90	316	1.10
360	345	310.5	0.90	380	1.10	310.5	0.90	380	1.10
500	500	450	0.90	550	1.10	450	0.90	550 (Note 1)	1.10

Note 1: 570 kV for max 5 mins. This will require to have an Approved & Agreed upon plan from the BCRC to reduce voltages within 5 mins.

VARIANCES - System Voltage Limits

Buses	Voltage Class (kV)	Base kV (1.0p.u.)	Normal System Voltage Limits				Emergency System Voltage Limits				Rationale
			Low Limit		High Limit		Low Limit		High Limit		
			kV	p.u. (calc)	kV	p.u. (calc)	kV	p.u. (calc)	kV	p.u. (calc)	
BND 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
COK 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
CSN 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
CSQ 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
MAN 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
SPG 230	230 kV	230	207	0.90	242	1.054	207	0.90	242	1.054	GIS Bus
ACK 230	230 kV	230	207	0.90	242	1.054	207	0.90	242	1.054	SF6 bus
SEV 230	230 kV	230	207	0.90	242	1.054	207	0.90	242	1.054	Equipment built to ANSI standard
HSY 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
PIK 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
ESQ 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
GOW 230	230 kV	230	207	0.90	242	1.054	207	0.90	244	1.06	230kV Cables
BRT 230	230 kV	230	207	0.90	245	1.065	207	0.90	245	1.06	230kV bus limit
DMR 500	500 kV	500	450	0.90	544	1.088	450	0.90	544	1.088	500 kV cable limit
MSA 500	500 kV	500	450	0.90	544	1.088	450	0.90	544	1.088	500 kV cable limit
ING 230	230 kV	230	221	0.9595	253	1.10	221	0.9595	253	1.10	6T-34 AUVLS at ING
DMR 230	231 kV	230	221	0.9609	253	1.10	221	0.9609	253	1.10	6T-34 AUVLS at DMR
HPN 230	232 kV	230	221	0.9609	242	1.054	221	0.9609	244	1.06	6T-34 AUVLS at HPN 230kV cables
Continues on next page											

MDN 230	233 kV	230	223	0.9696	253	1.10	223	0.9696	253	1.10	6T-34 AUVLS at MDN
SAT 230	234 kV	230	223	0.9696	253	1.10	223	0.9696	253	1.10	6T-34 AUVLS at SAT
VIT 230	235 kV	230	223	0.9696	253	1.10	223	0.9696	253	1.10	6T-34 AUVLS at VIT

Cables	Normal		Emergency		Other Variances and Comments
	Low Limit (kV)	High Limit (kV)	Low Limit (kV)	High Limit (kV)	
5L29				544	5L29 will trip if >545 kV for 14 mins
5L31				544	5L31 will trip if >545 kV for 8 mins
230 kV cables					253 kV for max 15 mins
2L146 cable		242		250	253 kV for 15 mins, cct trips at 250 kV
2L143 cable		242		244	258 kV for 15 mins
2L145 cable		242		244	258 kV for 15 mins
2L142 cable		242		244	266 kV for 15 mins
2L129 cable		242		244	266 kV for 15 mins 266 kV trip in 14 mins 280 kV trip in 1.3 secs
2L31 cable		242		244	266 kV for 15 mins
2L33 cable		242		244	266 kV for 15 mins
2L39 cable		242		244	266 kV for 15 mins
2L40 cable		242		244	266 kV for 15 mins
2L20 cable		242		244	266 kV for 15 mins
2L44 cable		242		244	266 kV for 15 mins

EXCLUSIONS - System Voltage Limits		
Excluded Bus	**Voltage Class**	**Rationale**
none		