British Columbia Transmission CORPORATION™

Interior to Lower Mainland (ILM)

Horizon Year -Total Transfer Capability Study

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Transmission System Planning
British Columbia Transmission Corporation

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1 Executive Summary

This report develops a portfolio of future reinforcements that could almost double the Total Transfer Capability (TTC) of the existing Interior to Lower Mainland (ILM) grid over the next 30 years. Specifically, this report determines the near term voltage stability limits of the ILM system and demonstrates that 5L83, which is a major ILM reinforcement, is compatible with the horizon year development of the ILM grid. The study determines the TTC, including voltage stability, transient stability, and thermal limits, for the existing system, mid-term and horizon year development of the ILM system.

The conclusions resulting from these studies indicate that:

1. Without 5L83, shunt reactive power compensation would increase ILM voltage stability capability to about 6272 MW - 6355 MW. However, the existing continuous thermal limits of the grid limit the TTC to about 4500 to 5000 MW.
2. Building 5L83 is an effective and adequate solution for improving thermal and voltage stability limits of the ILM system and is appropriate with respect to the long-term development sequence;
3. Combining reactive power compensation at both sending and receiving ends of 5L83 and associated thermal upgrades of the existing series capacitor stations, an ILM system consisting of 5 – 500 kV transmission lines (including 5L83) would have up to 7500 MW of transfer capability;
4. A long-term plan, with 5L46 added after 5L83, could increase the transfer limit of ILM system up to 9100 MW.
5. One should exercise some caution in the interpretation and meaning of a horizon year study. Nevertheless, given what is known today it can be concluded that 5L83 is compatible with the most probable horizon year capital plan. It is unlikely that future scenarios would result in a horizon year development plan that did not include 5L83 given our assumptions on the resource plans. It is a good faith example of the probable development of the ILM grid and is intended to show

that it is possible to expand the system after the development of 5L83. The timing of the reinforcements is approximate, as the specific timing in any particular year is beyond the scope of this study.

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1 INTRODUCTION

This report develops a portfolio of future reinforcements that could almost double the TTC of the existing ILM grid over the next 30 years. The study models likely system reinforcements to the ILM grid and in the remote regions of the Province and determines their influence on the ILM TTC. The focus of the report is on the determination of possible ILM reinforcements to improve the ILM TTC and not on their need or timing.

Specifically, this report determines the near term voltage stability limits of the ILM grid and demonstrates that 5L83, which is a major ILM reinforcement, is compatible with the most probable horizon year development plan of the ILM grid. The study determines the TTC, including voltage stability and thermal limits, for the existing system, mid-term and horizon year development of the ILM grid. The transient stability limits of the system are tested to ensure this phenomenon does not limit the ILM TTC. This report also provides a comprehensive and long-term voltage stability evaluation of the ILM grid to serve ILM power transfer.

The ILM transmission grid delivers electricity to the largest provincial load center in the Lower Mainland and Vancouver Island. The ILM cut-plane consists of 500 KV AC transmission lines 5L41, 5L42, 5L81, 5L82 and 2L90. An outage of one of these lines may cause an overload or voltage collapse of the system unless the system is operated below its TTC or is adequately reinforced.

The ILM grid is presently voltage stability limited to a transfer of about 5800 MW and the 1-hour thermal rating of the system is used to achieve this transfer. After an hour, the system is limited to the continuous thermal limit of about 4500 to 5000 MW transfer and in the near term, the Canadian Entitlement (CE) and Burrard Generating Station are dispatched to reduce the needed ILM transfer to its continuous thermal limit.

In the first part of this study the voltage stability limits and reinforcements are determined for the existing four line ILM grid. Reactive reinforcements alone would not be able to increase the voltage stability limits of the system beyond approximately 5800 MW and a new transmission line would eventually be required in combination with new reactive reinforcements to maximize the capability of the ILM grid.

In the second part of the study, the ILM voltage stability limits are determined if 5L83 were added. Voltage stability and thermal reinforcements are then determined to maximize the capability of the five line system.

Finally, voltage stability and thermal limits are determined should 5L46, a sixth line, be added to the ILM grid and further reactive and thermal enhancements are determined to maximize the voltage stability and thermal limits of the six line system.

The 500 kV transmission system configurations in 2016, 2026 and 2036 are provided in Appendix A.

Horizon year studies by their very nature are forward-looking and uncertain. The selection of future options is determined by using BCTC's knowledge of the transmission system and by examining the most likely and practical reinforcement options with existing information. In the absence of full information, horizon year studies provide important information to demonstrate that mid-term reinforcements are compatible with a long term vision of the transmission system.

2 STUDY ASSUMPTIONS

2.1 The Study Year of Interest

To assess the voltage stability limit of the existing ILM grid and compare the voltage stability limits among several possible transmission system upgrade options in near-term, all of the near-term study cases were developed from the original F2009 PSS/E heavy winter base case. 2016 is selected as the mid-term case and 2026 and 2036 are the horizon year study periods.

2.2 Load Information

The system peak load is based on BC Hydro's 2006 December load forecast for the total integrated system peak load with demand side management included. The load was scaled with a similar growth rate to the 2006 December load forecast from 2026 to 2036.

2.3 Resource Plan and Generation Dispatching Pattern

The Amended LTAP generation resource portfolio is used as the basis for the study. After year 2026, to stress the transmission system and meet the load growth, some new generation resources were assumed to be added in the remote regions of the Province.

All of the major generation plants in the Lower Mainland and Vancouver Island were modeled as dispatched to their dependable capacity to serve the local loads. The other generation resources in the Interior of the Province were modeled as dispatched to meet the total provincial load demand.

Prior to 2014, Burrard Generating Station is modeled as dispatched to provide Reliability Must Run (RMR) generation with zero reactive power output normally, but 300 MVAR reactive power for system voltage control during outages. After 2014, Burrard generation units are modeled as synchronous condensers with 400 MVAR maximum reactive output from the plant.

2.4 Interchange

280 MW of export on the Western BCTC – BPA tie is scheduled, consisting of 230 MW of firm export to Seattle City Light and 50 MW of Transmission Reliability Margin (TRM).

2.5 Transmission System Configurations

Major transmission reinforcements in the Lower Mainland, Vancouver Island and South Interior proposed in BCTC's F2008 Capital Plan have been included in the study.

Up to 2013, the CE and Burrard Generating Station are assumed available for re-dispatch. Beginning in 2014, the CE and Burrard Generating Station are assumed not available for re-dispatch.

In the long-term cases, one 500 kV 250 MVAR Mechanically Switched Capacitor (MSC) bank at Nicola (NIC) Substation, two 230 kV MSCs (2 x 110 MVAR) at Meridian (MDN) Substation and an SVC at Ingledow (ING) Substation have been added. The requirement of a Joint Var Control (JVC) scheme at Burrard Generating station has been considered in this study.

Due to a large amount of load growth in Lower Mainland and Vancouver Island from F2016 to F2036, local shunt compensation is added in the sub-transmission system in 2026 and 2036 basecases.

An outage of 5L42 from Kelly Lake to Cheekye Substations becomes the most limiting outage of the ILM grid once 5L83 is built. Therefore, for the long-term system development of the ILM system, a new transmission line (5L46), in parallel to 5L42, is considered to be the most reasonable reinforcement option at that stage of the ILM development.

3 METHODS

The ILM TTC can be increased by improving the voltage stability, thermal, and transient limits of the ILM system. The lowest limit determines the TTC of the ILM grid. Voltage stability is the limiting phenomenon in the period immediately after a transmission line contingency and the study approach is to determine reinforcements needed to maximize the voltage stability limits by first adding shunt compensation and then transmission lines. The thermal limits of the system are then increased to match the voltage stability limits by increasing the thermal ratings of the existing series capacitor banks at Chapmans, Creekside, and American Creek stations.

3.1 Voltage Stability Study

The following assumptions were used in the voltage stability study;

a) A PV-Curve based voltage stability analysis tool is applied to calculate the voltage stability limits.

b) A 5% power margin is applied to the maximum post-contingency operating point (or the collapse point).

c) Generation resources are dispatched individually and independently in the North Interior and South Interior to meet the simulated load growth in Lower Mainland.

d) To ignore the impacts of the sub-transmission system to this ILM system voltage stability study and obtain the maximum possible voltage stability limits, the simulated load growth in Lower Mainland was modeled as active power (MW) only at 230 kV substations in near-term study. The increased reactive power load was assumed to be supplied by additional local Var sources. However, a real and reactive load model is used in the horizon year studies.

e) Under pre-contingency conditions, switched shunts, Under-Load Tap Changing Transformers (ULTCs), phase shifters are set at “adjustable” and area interchange control is enabled.

f) Under post-contingency condition, the switched shunts, ULTCs, phase shifters are set at “fixed” and area interchange control is enabled. This setting results in a conservative study result.

3.2 Thermal Limits

The continuous thermal limits of the ILM grid under N-1 conditions are shown in Figure 6.1. Presently, the thermal capacity of the ILM grid is limited by the thermal ratings of the series compensation at American Creek, Chapman's and Creekside stations. These thermal limits can be increased by thermal upgrades of these series capacitor banks to match the maximum voltage stability limits for the particular configuration under consideration.

3.3 Transient Stability Limits

The transient stability limits of the ILM grid are expected to be much higher than the voltage stability or thermal limits of the grid because of its meshed configuration. Therefore, transient stability studies are done at the thermal and voltage stability limits of the system to prove this expectation. If the system is transiently stable for this one condition then the voltage stability limit or thermal limit is deemed to be a valid TTC of the ILM grid.

4 VOLTAGE STABILITY STUDY

The system voltage stability studies are for both the near term and horizon year periods.

4.1 Voltage Stability Study in the Near-term Period

Two generation dispatch patterns are applied in the near-term study. One pattern, named "Max SI", dispatches all existing generation units in the South Interior to their maximum continuous ratings under winter peak load condition and uses Peace generation as the variable dispatch to regulate the power flow through the ILM grid. The other, named "Max NI", dispatches all existing generation units in the Peace region to their maximum continuous ratings and regulates the Columbia generation to adjust the power flow through the ILM grid.

Several transmission system reinforcement options are considered for the ILM transfer capability improvement. The study results associated with the "Max SI" generation pattern are summarized in Table 4.1.1 and the results associated to "Max NI" generation pattern are listed in Table 4.1.2.

Table 4.1.1, Voltage Stability Study Results with "Max SI" Generation Pattern

1	Conditions				System Upgrade Solution				Total Transfer Capability (Voltage Stability)	
2	Year	Load Condition	Area slack	JVC	230 kV Static Shunt Capacitor (MVAR)		500 kV Static Shunt Capacitor (MVAR)	SVC (MVAR)	TTC1 (without 5L83)	TTC2 (with 5L83)
					MDN	CBN	NIC	ING-SVC		
3	**Maximizing the Columbia Generation under winter peak load condition**									
4	Near-Term	Heavy Winter	GMS #1	No					5807	6431
5	Near-Term	Heavy Winter	GMS #1	yes					5846	----
6	Near-Term	Heavy Winter	GMS #1	yes			250		6046	----
7	Near-Term	Heavy Winter	GMS #1	yes	220		250		6272	6828
8	Near-Term	Heavy Winter	GMS #1	yes	220	220	250		6314	6890
9	Near-Term	Heavy Winter	GMS #1	yes	220		250	250	6335	7116
10	Near-Term	Heavy Winter	GMS #1	yes	220		250		6315	7007
11	Near-Term	Heavy Winter	GMS #1	yes	220	220	250	250	6355	7177

Table 4.1.2, Voltage Stability Study Results with “Max NI” Generation Pattern

1	Conditions				System Upgrade Solution				Total Transfer Capability (Voltage Stability)	
					230 kV Static Shunt Capacitor (MVAR)		500 kV Static Shunt Capacitor (MVAR)	SVC (MVAR)		
2	Year	Load Condition	Area slack	JVC	MDN	CBN	NIC	ING-SVC	TTC1 (without 5L83)	TTC2 (with 5L83)
3	Maximizing the Peace Generation under winter peak load condition									
4	Near-Term	Heavy Winter	MICA #1	No					5985	6550
5	Near-Term	Heavy Winter	MICA #1	yes	220		250		6355	7120
6	Near-Term	Heavy Winter	MICA #1	yes	220	220	250		6456	7239
7	Near-Term	Heavy Winter	MICA #1	yes	220		250	250	6521	7386
8	Near-Term	Heavy Winter	MICA #1	yes	220	220	250	250	6646	7531

The observations and discussions based on the study results in Table 4.1.1 and Table 4.1.2 follows:

1. The voltage stability limit of the ILM grid varies with the generation dispatch patterns in the Peace and Columbia regions. The “Max SI” condition is the worst case for ILM system transfer limit assessment.
2. In “Max SI” case, the existing system with a 250 MVAr shunt capacitor at NIC and 2x110 MVAr shunt capacitors at MDN is the most cost-effective shunt compensation solution for improving the ILM voltage stability limit as shown in Figure 4.1. The further addition of shunt compensation equipment in the Lower Mainland will not substantively increase the voltage stability limit of the ILM grid. For example, adding 470 MVar of shunt compensation at CBN and an SVC at ING only increases the voltage stability limit by about 80 MW. Therefore, the practical limit for the four 500 kV line ILM grid is between 6272 and 6355 MW. To increase this limit further requires the addition of 5L83.

3. The Joint Var Control scheme at Burrard Generating Station, 250 MVAR MSC at NIC and 220 MVAR MSC at MDN would increase the ILM voltage stability transfer limits by 465 MW for maximum SI generation dispatch and 370 MW for maximum NI generation dispatch without 5L83 in-service.
4. 5L83 is an effective system upgrade solution to improve both voltage stability and thermal limits of the ILM grid.
5. The reactive additions described in item 3 increase the ILM voltage stability transfer limits by 400 MW for maximum SI generation dispatch and 570 MW for maximum NI dispatch after 5L83 is in-service. These amounts are not in addition to the amounts identified in item 3.
6. An SVC at ING is effective to improve the ILM voltage stability limit under the “Max NI” dispatch pattern after 5L83 is in-service, providing about 260 MW of incremental TTC. Therefore, an ING SVC could be one of the options to improve voltage stability further after 5L83 is in-service.

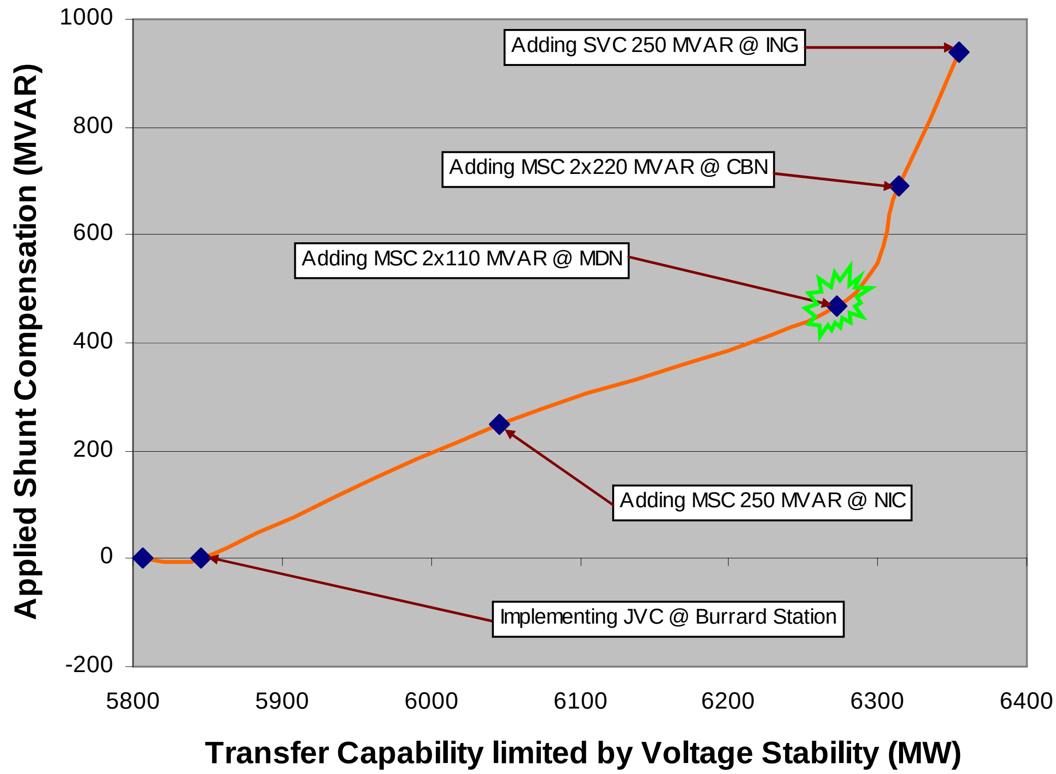


Figure 4.1 Effectiveness of applying shunt compensation to improve voltage stability in Interior to Lower Mainland system

4.2 Long-term Overlook: Voltage Stability Study

5L83 has been proposed as the primary system upgrade option for the ILM grid and its earliest in-service-date is 2014. This new transmission line and eventually series and shunt compensation reinforcements to existing lines will significantly increase the transfer capability of the ILM grid, especially for the generation development scenario in the South Interior. To assess the ILM transfer capability after 5L83 is in-service with several long-term system upgrade options, voltage stability studies were performed for the mid-term development year 2016 and two horizon years, 2026 and 2036. The study results, transfer limits dominated by voltage stability, are shown in nomograms. Some new shunt capacitor banks in the Lower Mainland and Vancouver Island are included to compensate the increased reactive power load in these areas.

The possible system upgrades and the associated voltage stability limits are summarized as follows:

Mid-Term Year 2016:

Table 4.2.1 Transmission System Upgrades Expected by 2016

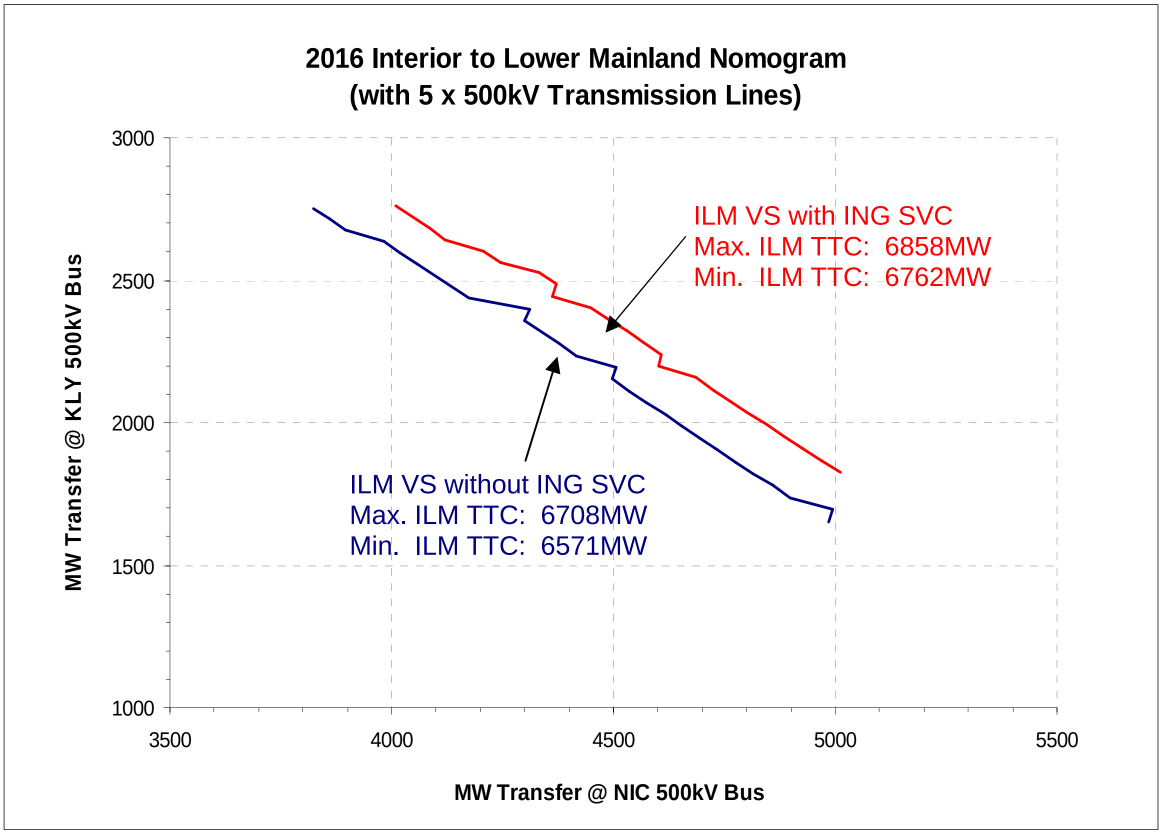
Item	Description
1	Upgrade of 50% series compensation on 5L91 & 5L98
2	50% compensated 5L83 circuit in service

Table 4.2.2 Mechanically Switched Shunt Capacitors by 2016

Item	Bus No.	Bus Name	Shunt (MVAR)	Steps
1	203	MDN 230	220	2 x 110
2	5510	ACK 230	500	2 x 250
3	5511	NIC 500	250	1 x 250
4*	1001	ING 230	250	250

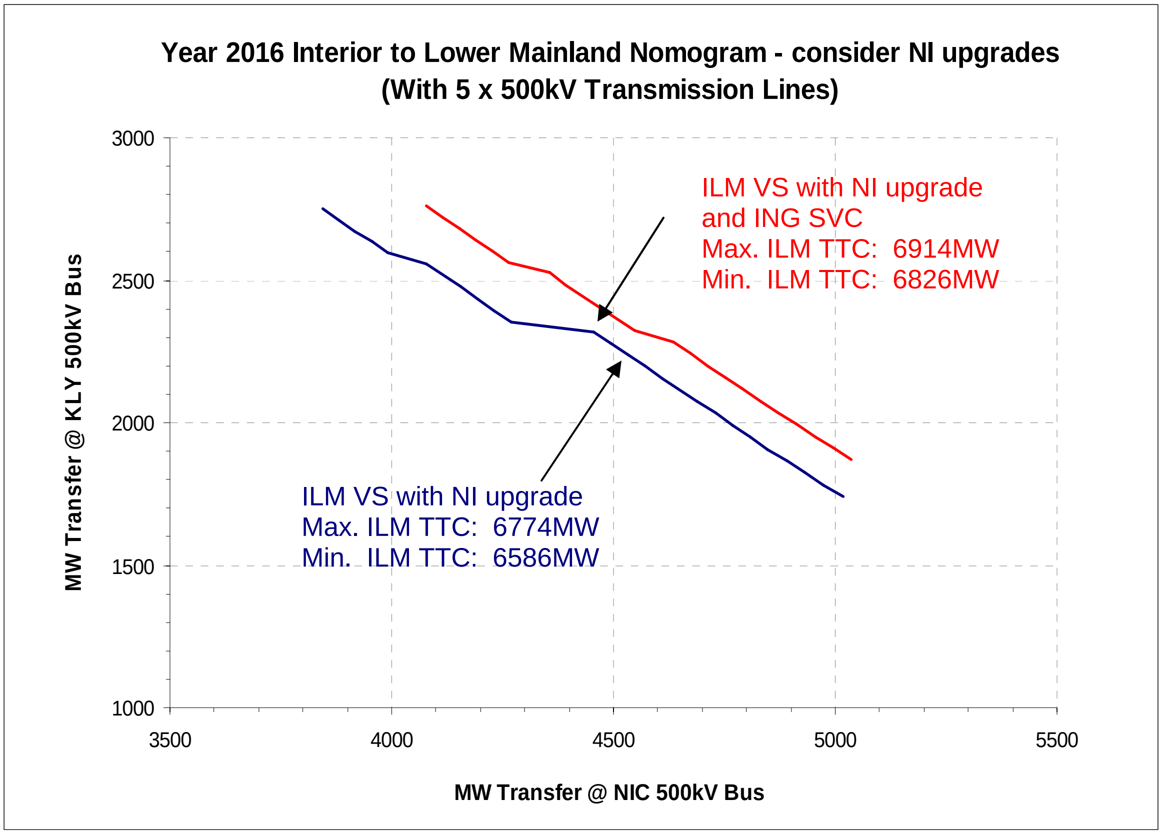
The ING SVC (250 MVAr) is used for the following sensitivity study. Two voltage stability results for the cases with ING SVC and without ING SVC are shown in the Nomograms in Figure 4.2.1 and Figure 4.2.2.

Figure 4.2.1 Voltage Stability Capabilities at the ILM Cut-plane with and without an Ingledow SVC



In addition, a sensitivity study is performed to investigate the possible impact from system upgrades in the North Interior system, such as an SVC (300/-200 MVAR) and 2x250 MVAR shunt capacitors at Williston substation and one 250 MVAr MSC bank at Kelly Lake substation. The sensitivity study result is provided in Figure 4.2.2.

Figure 4.2.2 Voltage Stability Capabilities at the ILM Cut-plane with and without an SVC at Williston



Study result observations for Mid-Term Year 2016:

a) Around 2016, the ILM grid with 5L83 in-service has 6820 ~ 6910 MW of voltage stability capability. However, as indicated in Year 2026 voltage stability study result, the voltage stability limit can be increased up to around 7500 MW with further shunt compensation at the sending and receiving ends of the ILM grid.

b) The North Interior system upgrades have less impact on ILM system transfer capability.

Horizon Year 2026:

The following reinforcements are expected to be in-service by 2026 and some of them increase the ILM voltage stability limits even though they are not installed in the ILM grid. The voltage stability impact along with the ILM grid reinforcements are shown in Figure 4.2.3.

Table 4.2.3 Transmission System Reinforcements by 2026

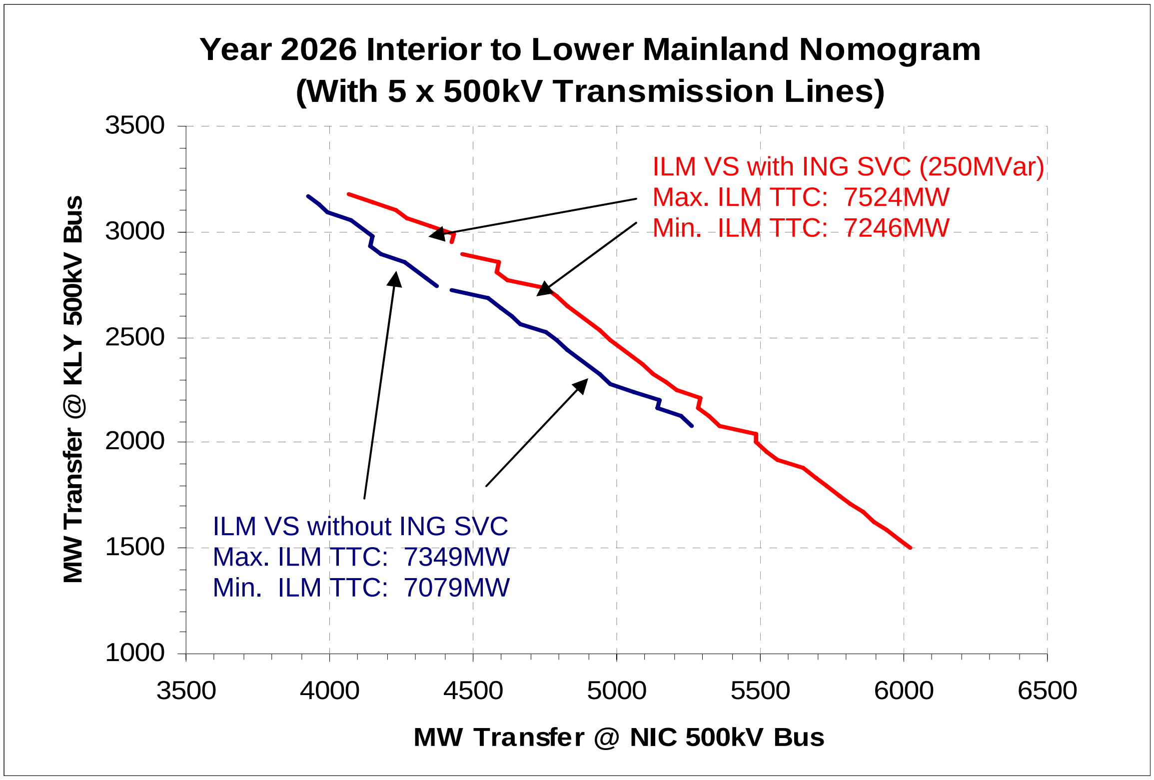
Item	Description	Scope
1	Upgrade of series compensation on 5L91 & 5L98 - 50%	Upgrades expected by 2016 Year
2	50% compensated 5L83 circuit in service	
3	2nd 230 kV cable to VI in service	
4	Add 50% series compensation to 5L96.	
5	Add 50% series compensation to 5L76 and 5L79	New upgrades by 2026 Year
6	Add 40% series compensation to 5L72 and 5L71	
7	Thermal upgrades of series capacitors in American Creek, Creekside and Chapmans stations	

Table 4.2.4 Mechanically Switched Shunt Capacitors and SVC by 2026:

Item	Bus No.	Bus Name	Shunt (MVAR)	Steps
1	203	MDN 230	220	2 x 110
2	5511	NIC 500	250	1 x 250
3	5510	ACK 230	500	2 x 250
4	213	WLT 230	108	2 x 54
5	1201	ING 230	110	1 x 110
6	1202	MLN 230	54	1 x 54
7	1244	CBN 230	110	1 x 110
8	4511	WSN 500	500	2 x 250
9	5512	KLY 500	250	1 x 250
10	4311/4411	WSN 12.6	300	2 x 150
11*	1001	ING 230	250	250

The ING SVC (250 MVAr) is used for the following sensitivity study. Two voltage stability results for the cases with ING SVC and without ING SVC are shown in the nomogram in Figure 4.2.3.

Figure 4.2.3 2026 Voltage Stability Capability at ILM Cut-plane



Study result observations for Horizon Year 2026:

a) With some shunt compensation in the Interior and Lower Mainland system, the transfer capability limited by voltage stability in the ILM grid (consisting of five 500 kV transmission lines) will reach about 7500 MW maximum. The further increase in the voltage stability capability may require the addition of new transmission line, for example 5L46 from Kelly Lake substation to Cheekye substation.

b) To achieve this 7500 MW of voltage stability capability at maximum, the thermal rating of the ILM grid needs to be increased by thermal upgrades of the series capacitor banks at Creekside, Chapmans and American Creek.

Horizon Year 2036:

The following reinforcements are expected to be in-service by 2036 and some of them increase the ILM voltage stability limits even though they are not installed in the ILM grid. The voltage stability impact along with the ILM grid reinforcements are shown in Figure 4.2.4.

Table 4.2.5 Transmission System Upgrades by 2036

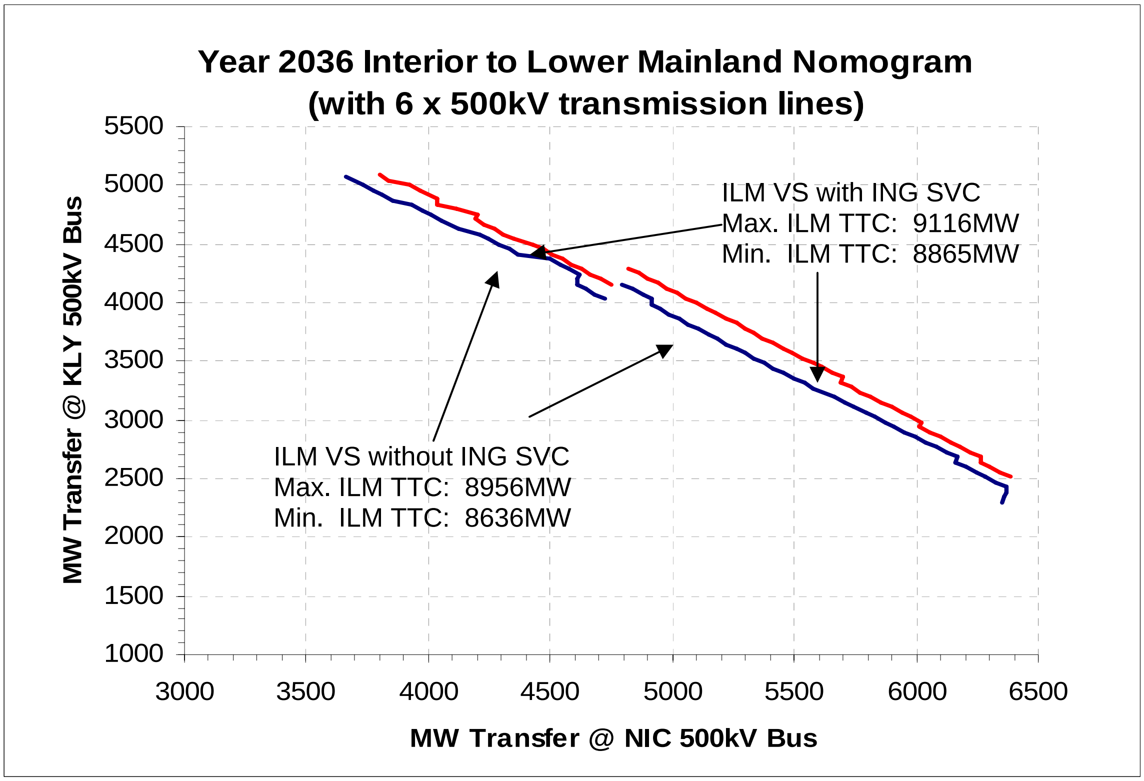
Item	Description	Scope
1	Upgrade of series compensation on 5L91 & 5L98 - 50%	Upgrades expected by 2016 Year
2	50% compensated 5L83 circuit in service	
3	2nd 230 kV cable to VI in service	
4	Add 50% series compensation to 5L96.	Upgrades by 2026 Year
5	Add 50% series compensation to 5L76 and 5L79	
6	Add 40% series compensation to 5L72 and 5L71	
7	Add 5L46 in service	New upgrades by 2036 Year
8	Increase the series compensation level on 5L71 and 5L72 to 50%	
9	Loop 5L81 into CBN substation	
10	900 MW Site C generation is connected to PCN by two new 500 kV transmission lines	
11	The new line 5L8 (PCN – WSN) is added	
12	Two large generation plants in Central Interior are integrated into WSN substation by two new 500 kV transmission lines	
13	The new line 5L14 parallel to 5L11/5L12/5L13 (WSN – KLY) is added	
14	Thermal upgrades of series capacitors at American Creek, Creekside and Chapmans stations	

Table 4.2.6 Mechanically Switched Shunt Capacitors and SVCs by 2036:

Item	Bus No.	Bus Name	Shunt (MVAR)	Steps
1	203	MDN 230	220	2 x 110
2	5511	NIC 500	250	1 x 250
3	5510	ACK 500	500	2 x 250
4	204	COK 230	108	2 x 54
5	5511	NIC 500	250	1 x 250
6	213	WLT 230	108	2 x 54
7	222	NEL 230	108	2 x 54
8	226	KI2 230	108	2 x 54
9	1201	ING 230	110	1 x 110
10	1202	MLN 230	54	1 x 54
11	2216	DMR 230	110	1 x 110
12	1244	CBN 230	220	2 x 110
13	2202	SAT 230	220	2 x 110
14	5512	KLY 500	250	1 x 250
15	4511	WSN 500	500	2 x 250
16	4311/4411	WSN 12.6	300	2 x 150
17*	1001	ING	250	250

The ING SVC (250 MVAr) is used for the following sensitivity study. Two voltage stability results for the cases with ING SVC and without ING SVC are shown in the nomogram in Figure 4.2.4.

Figure 4.2.4 2036 -Voltage Stability Capability at the ILM Cut-plane



Study result observations for Horizon Year 2036:

a) After adding 5L46, the ILM transmission grid consists of six 500 kV transmission lines. The transfer capability limited by voltage stability may reach about 9100 MW.

5 TRANSIENT STABILITY RESULTS

A series of transient stability studies have verified that transient stability is not the dominant limitation in ILM grid when compared with the voltage stability limits. The dynamic simulations were conducted with 5L83 in-service at 7500 MW of transfer at the ILM cut-plane and with 5L83 and 5L46 additions at 9100 MW transfer at the ILM cut-plane. The transient stability results are summarized in Table 5.1 and Table 5.2 and the detailed study results are attached in Appendix B.

Table 5.1 Transient Study Results for ILM System with 5L83 In-service at 7520MW Transfer Level

1	Fault Location	Fault Type	Protection and Control Sequence					**Study Result**	Reference Figure
			Fault Clearing Time	Line Tripped	Time Delay for Reclosing	The Worst Reclosing End	Second Fault Clearing Time		
2	5L82 near Nicula	3 -Phase	4 Cycles	5L82	1.0 Seconds	Nicola	4 Cycles	Stable	Figure B-1
3	5L82 near Meridian	3 -Phase	4 Cycles	5L82	1.0 Seconds	Meridian	4 Cycles	Stable	Figure B-2
4	5L42 near Kelly Lake	3 -Phase	4 Cycles	5L42	0.5 Seconds	Kelly Lake	4 Cycles	Stable	Figure B-3
5	5L42 near Cheekey	3 -Phase	4 Cycles	5L42	0.5 Seconds	Cheekey	4 Cycles	Stable	Figure B-4

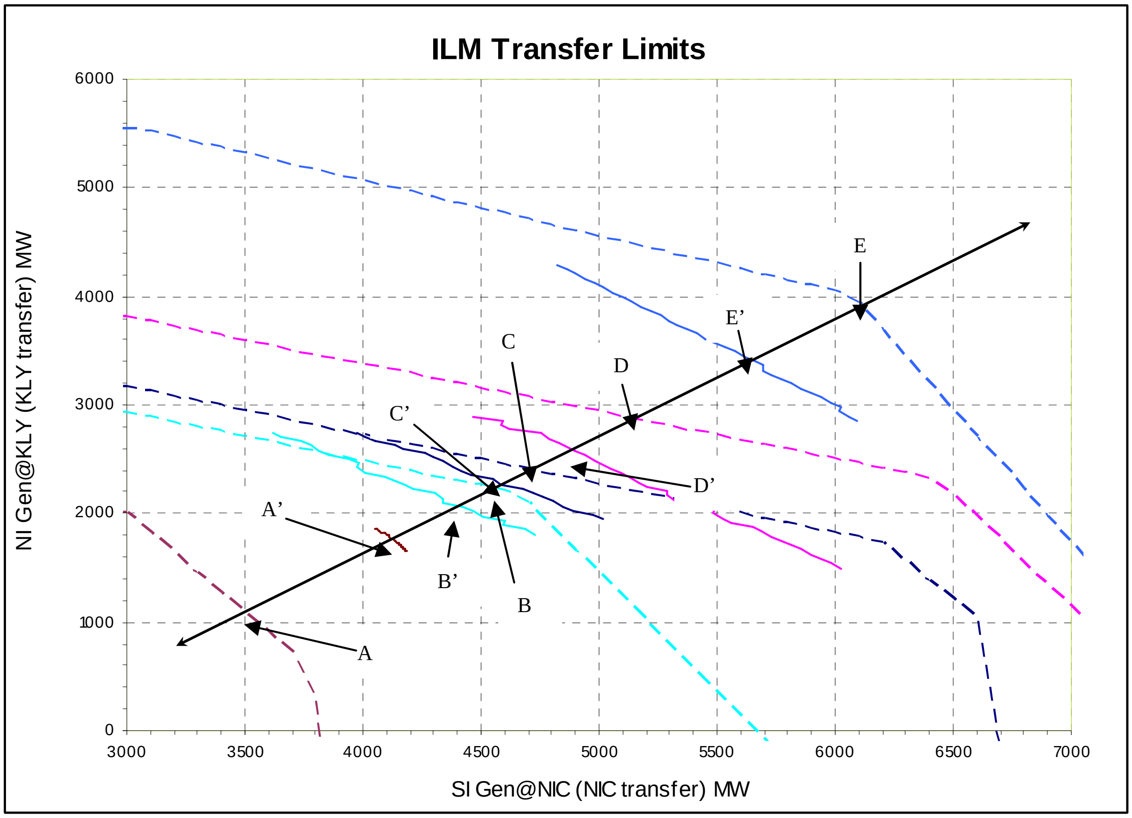
Table 5.2 Transient Study Results for ILM System with 5L83&5L46 In-service at 9110MW Transfer Level

1	Fault Location	Fault Type	Protection and Control Sequence					**Study Result**	Reference Figure
			Fault Clearing Time	Line Tripped	Time Delay for Reclosing	The Worst Reclosing End	Second Fault Clearing Time		
2	5L82 near Nicula	3 -Phase	4 Cycles	5L82	1.0 Seconds	Nicola	4 Cycles	Stable	Figure B-5
3	5L82 near Meridian	3 -Phase	4 Cycles	5L82	1.0 Seconds	Meridian	4 Cycles	Stable	Figure B-6
4	5L42 near Kelly Lake	3 -Phase	4 Cycles	5L42	0.5 Seconds	Kelly Lake	4 Cycles	Stable	Figure B-7
5	5L42 near Cheekey	3 -Phase	4 Cycles	5L42	0.5 Seconds	Cheekey	4 Cycles	Stable	Figure B-8

6 ILM HORIZON YEAR TOTAL TRANSFER CAPABILITIES

The voltage stability limits, thermal limits and TTC of the ILM grid are shown in Figure 6.1 for the existing four line system, the five line development and the six line development.

Figure 6.1 Voltage Stability Limits and Thermal Limits at ILM Cut-plane



Legend

A ------- Thermal continuous rating of exisitng ILM grid

B ------- Thermal continuous rating of existing ILM grid with 5L83 added

C ------- Thermal continuous 5L83 +Thermal uprating 5L42 2500 A + Series capacitor uprating @ Chapmans, Creekside (2300A) and American Creek (2560A)

D ------- Thermal continuous rating of 5L83 + Series capacitor uprating @ Chapmans (2185A), Creekside (2525A) and American Creek (2800A)

E ------- Thermal continuopus rating of 5L83 + 5L46 + Series capacitor uprating @ Chapmans (2185A), Creekside (2700A) and American Creek (2800A)

A' ——— Voltage stabiltiy existing

B' ——— Voltage stability with 5L83 added

C' ——— Voltage stability with 5L83 added+ Shunt capacitors @ Meridian (2X110 MVAr) & Nicola (1X250 MVAr)

D' ——— Voltage stability with 5L83+ Meridian (2X110 MVAr) & Nicola (1X250 MVAr) +Additional 436 MVAr shunt capacitors in LM +SVC @ Ingledow + 500 MVAr in South Interior + 750 MVAr in North Interior and 300 MVAr SVC @ Williston

E' ——— Voltage stability with 5L83 + 5L46 + Shunt capacitors @ Meridian (2X110 MVAr) & Nicola (2X250 MVAr) + additional 1200 MVAr shunt capacitors in LM + 250 MVAr SVC @ Ingledow + Ashton Creek (500 MVAr) + 750 MVAr in North Interior and 300 MVAr SVC @ Williston

To show the incremental TTC among several system reinforcement options, an arbitrary straight line was introduced in Figure 6.1. The straight line represents a starting ILM transfer resulting from surplus Columbia and Peace generation at point A, with almost equal additions over time of Columbia and Peace resources to get to point E. The associated transfer limits along this dispatch pattern are provided in Table 6.1. Because the transfer limit, governed by either thermal or voltage stability, of the ILM cut-plane is significantly impacted by the generation patterns between Peace Region and Columbia Basin, the transfer limit is a range rather than a single number as shown in table Figure 6.1. This is an example case to show conceptually what TTC improvement in the ILM grid is possible with different system reinforcements.

Table 6.1 Horizon Year ILM Transfer Limits (an example case)

System Condition		Transfer Capability							
Code	Brief Description	Thermal Limit (MW)		Voltage Stability Limit (MW)		Increamental VS Limit (MW)	TTC (MW)	Increamental TTC (MW)	Notes
i	Existing	A	4570	A'	5840	------	4570	-----	Base
ii	Add 5L83 to i	B	6770	B'	6480	640	6480	1910	Compared to i
iii	Other upgrades to ii	C	7120	C'	6830	990	6830	2260	Compared to i
iv	Additional upgrades to iii	D	8020	D'	7500	1660	7500	2930	Compared to i
v	Add 5L46 to iv	E	10000	E'	9050	1550	9050	1550	Compared to iv

Notes: The above limits are applicable only to the dispatch pattern associated with the straight line trajectory shown in Figure 6.1

Legend

i	Exisitng ILM grid
ii	Existing ILM grid with 5L83 added
iii	5L83 +Thermal uprating 5L42 2500 A + Series capacitor uprating @ Chapman, Creekside (2300A) and American Creek (2560A)
	Var Compensation: Shunt capacitors @ Meridian (2X110 MVAr) & Nicola (1X250 MVAr)
iv	5L83 + Series capacitor uprating @ Chapman (2185A), Creekside (2525A) and American Creek (2800A)
	Var Compensation: Meridian (2X110 MVAr) & Nicola (1X250 MVAr) +Additional 436 MVAr shunt capacitors in LM +SVC @ Ingledow + 500 MVAr in South Interior + 750 MVAr in North Interior and 300 MVAr SVC @ Williston
v	5L83 + 5L46 + Series capacitor uprating @ Chapman (2185A), Creekside (2700A) and American Creek (2800A)
	Var Compensation: Shunt capacitors @ Meridian (2X110 MVAr) & Nicola (2X250 MVAr) + additional 1200 MVAr shunt capacitors in LM + 250 MVAr SVC @ Ingledow + Ashton Creek (500 MVAr) + 750 MVAr in North Interior and 300 MVAr SVC @ Williston

7 CONCLUSIONS

1) Without 5L83, shunt reactive power compensation would increase ILM voltage stability capability to about 6272 MW - 6355 MW. However, the existing continuous thermal limits of the grid limit the TTC to about 4500 to 5000 MW.

2) 5L83 alone (without any supplementary Var support addition) would increase the ILM TTC to about 6530 MW.

3) 5L83 with shunt and series capacitor reinforcements would increase the ILM TTC up to 7500 MW.

4) Building 5L83 is an effective and adequate solution for improving thermal and voltage stability limits of the ILM grid and is appropriate with respect to the long-term development sequence;

5) The addition of 5L46 in the horizon year, along with more shunt compensation, would increase the voltage stability capability of the ILM grid to about 9100 MW. Furthermore, series capacitors reinforcement at Chapmans, American Creek and Cheekye would allow the thermal ratings of the grid to be increased to match the voltage stability limits.

6) With the load growth in the Lower Mainland, further shunt compensation equipment in the Lower Mainland should not be centralized at the 500 kV

substations and should be distributed into the 230 kV and lower voltage systems if possible.

7) The specific determination of shunt capacitors in the lower voltage systems to compensate for the increased reactive power load is difficult because the long term regional system plan lags the bulk system development plans. Nevertheless, some compensation must be modeled to determine the bulk system voltage stability limits and this has been done in the horizon year basecase preparation. However, one should not conclude that these specific lower voltage shunt capacitors are the recommended reinforcements. All that can be concluded is this quantity of reactive reinforcement is likely required but the size and location has to be determined closer to the required in-service date.

8) One should exercise some caution in the interpretation and meaning of a horizon year Study. Nevertheless, given what is known today it can be concluded that 5L83 is compatible with the most probable horizon year capital plan. It is unlikely that future scenarios would result in a horizon year development plan that did not include 5L83 given our assumptions on the resource plans. It is a good faith example of the probable development of the ILM grid and is intended to show that it is possible to expand the system after the development of 5L83. The timing of the reinforcements is approximate, as the specific timing in any particular year is beyond the scope of this study.

APPENDIX A:

500 kV Transmission System Configuration Diagrams

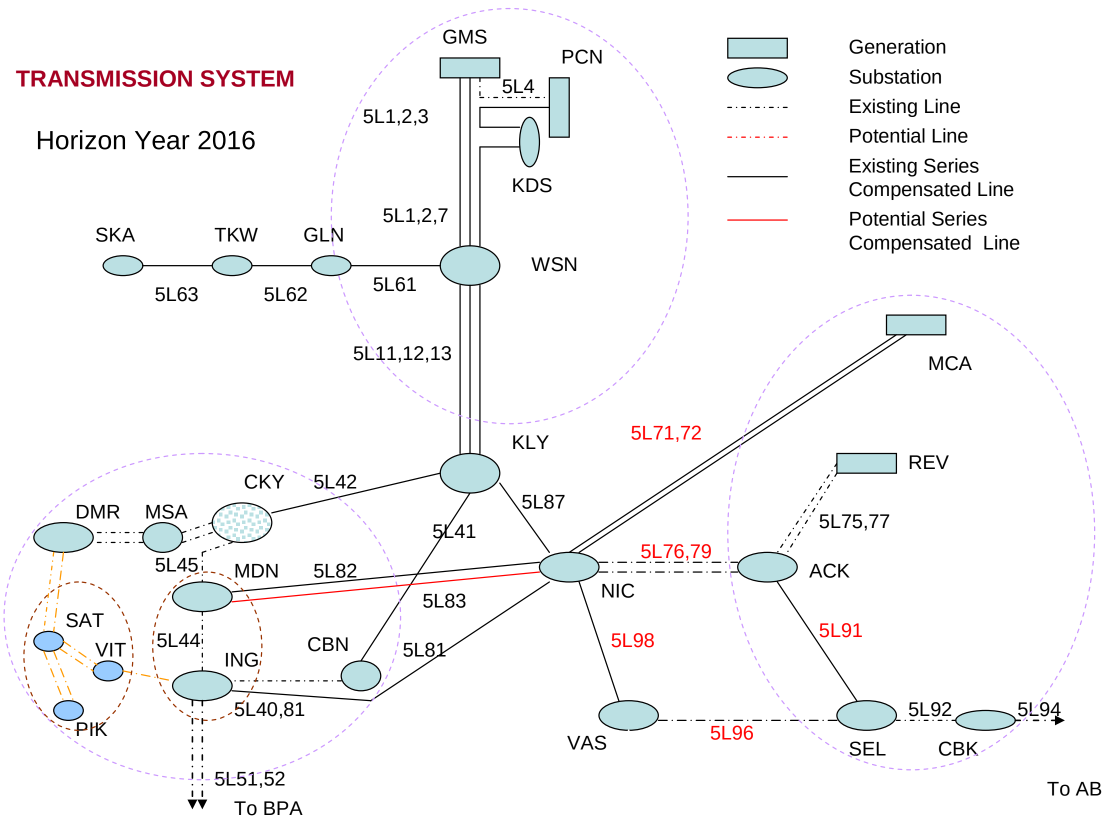


Figure A-1, Expected System Configuration by 2016

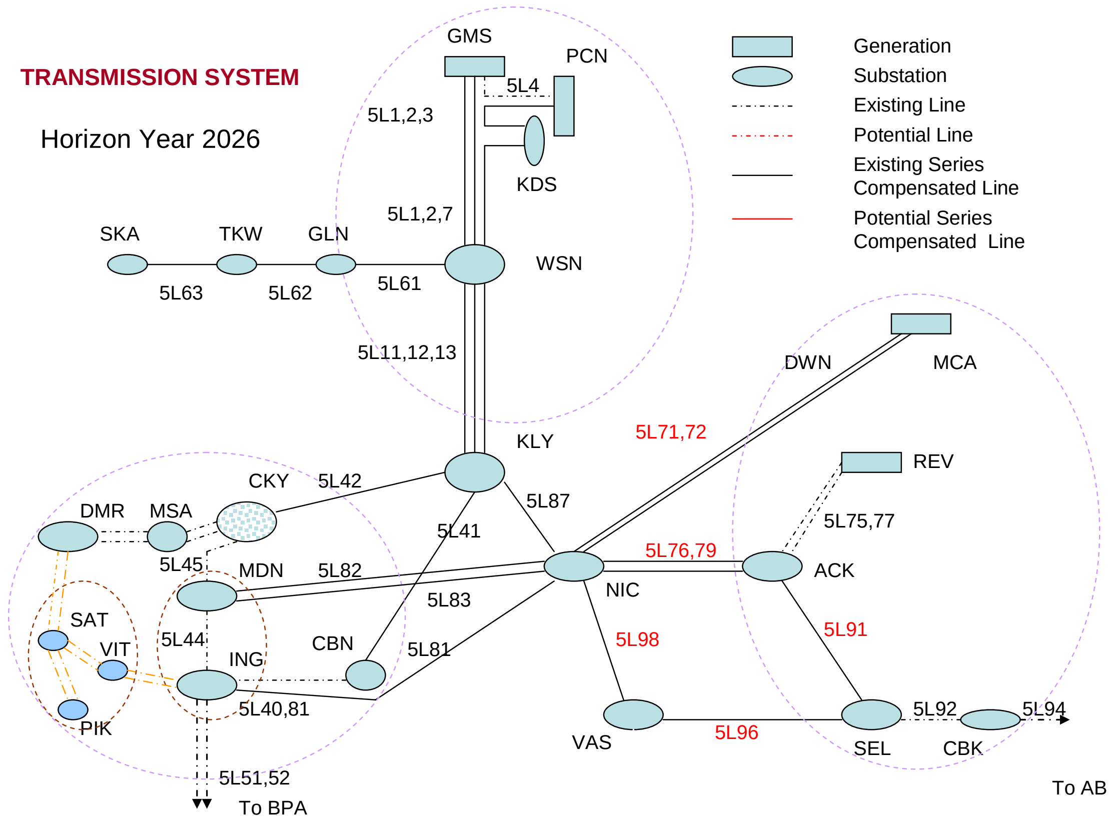


Figure A-2, Expected System Configuration by 2026

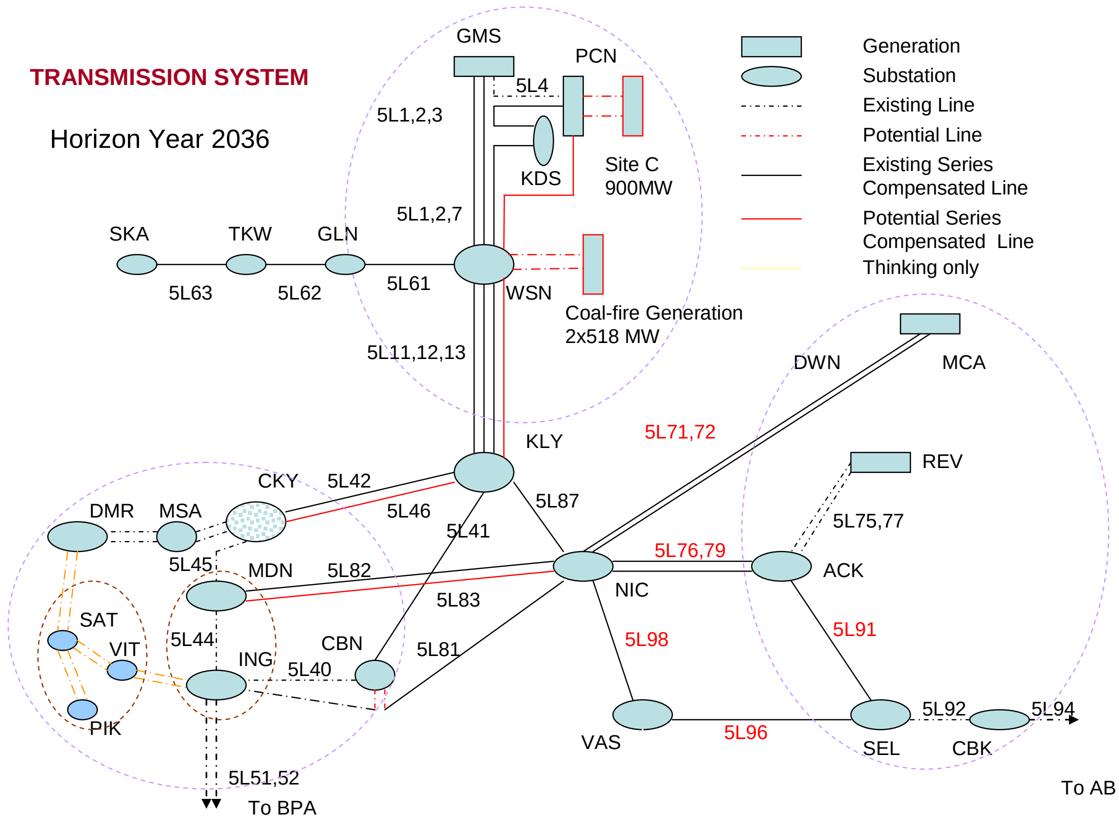
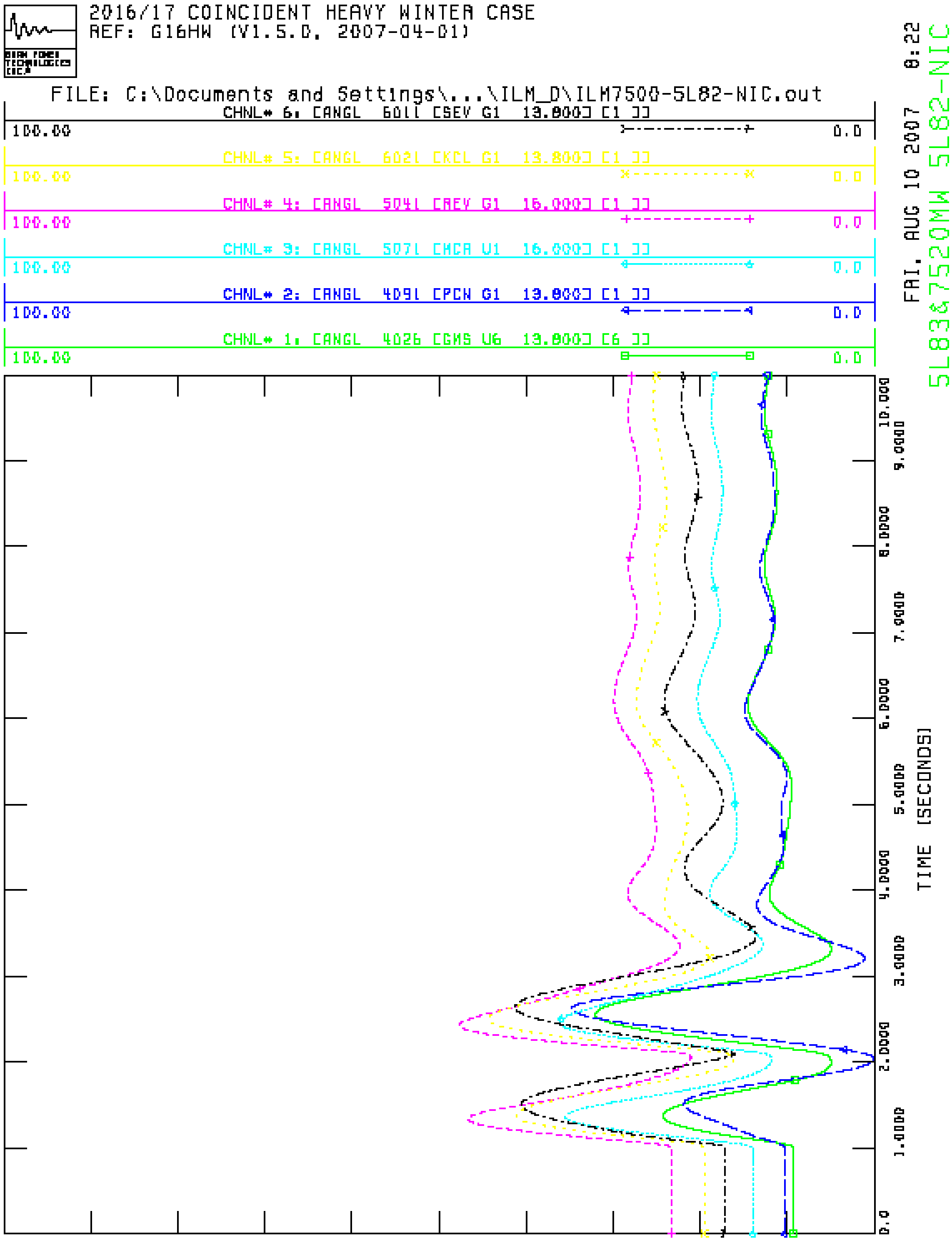


Figure A-3, Expected System Configuration by 2036

APPENDIX B:

Transient Stability Study Results – Rotor Angle Diagrams

(Figure B-1 ~ Figure B-8)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CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
100.00
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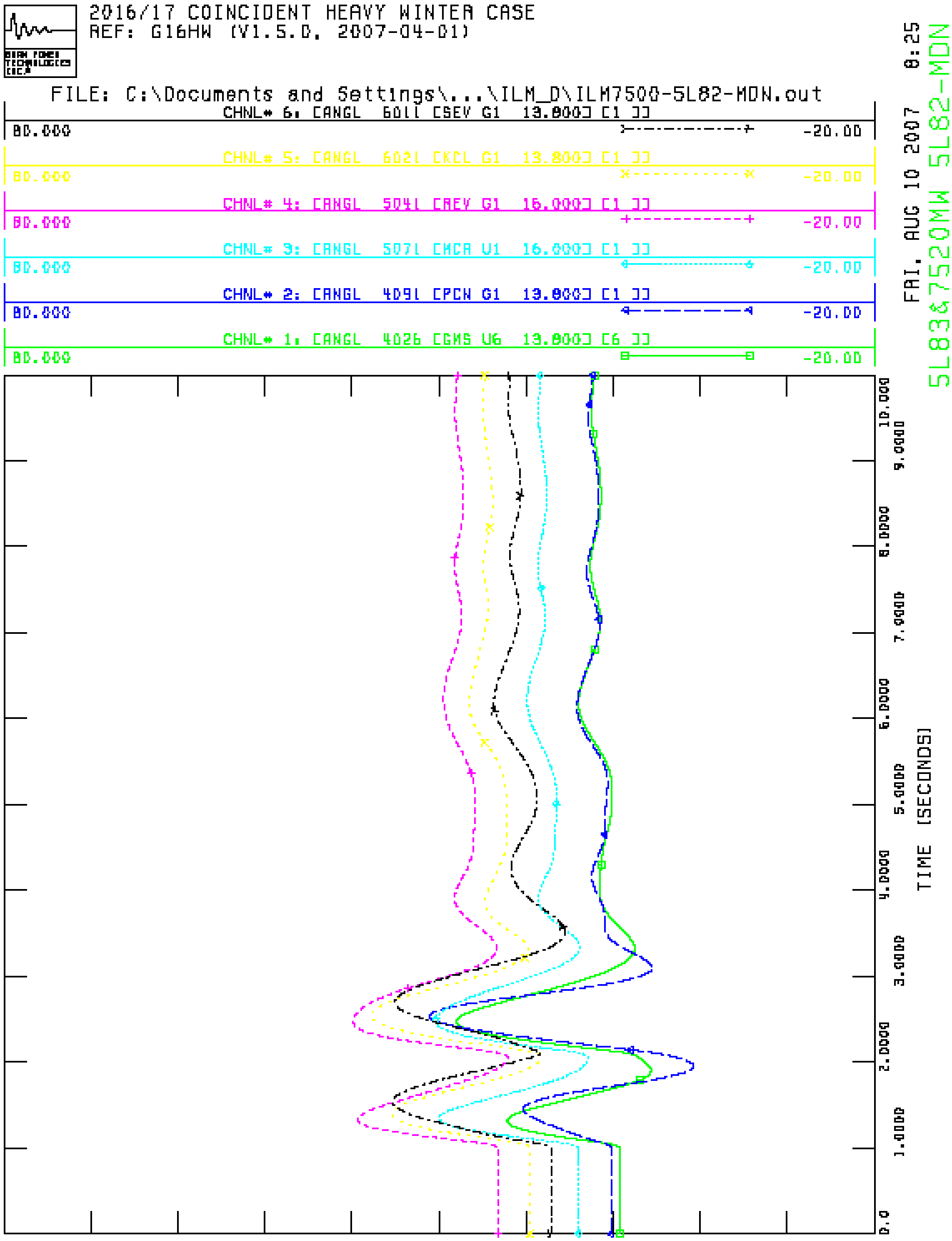
FRI, AUG 10 2007 8:22
5L83&7520MW 5L82-NIC
TIME (SECONDS)

Figure B-1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-20.00
CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
80.000
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80.000
-20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000
-20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
80.000
-20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
80.000
-20.00
FRI, AUG 10 2007 8:25
5L83&7520MW 5L82-MDN
TIME (SECONDS)
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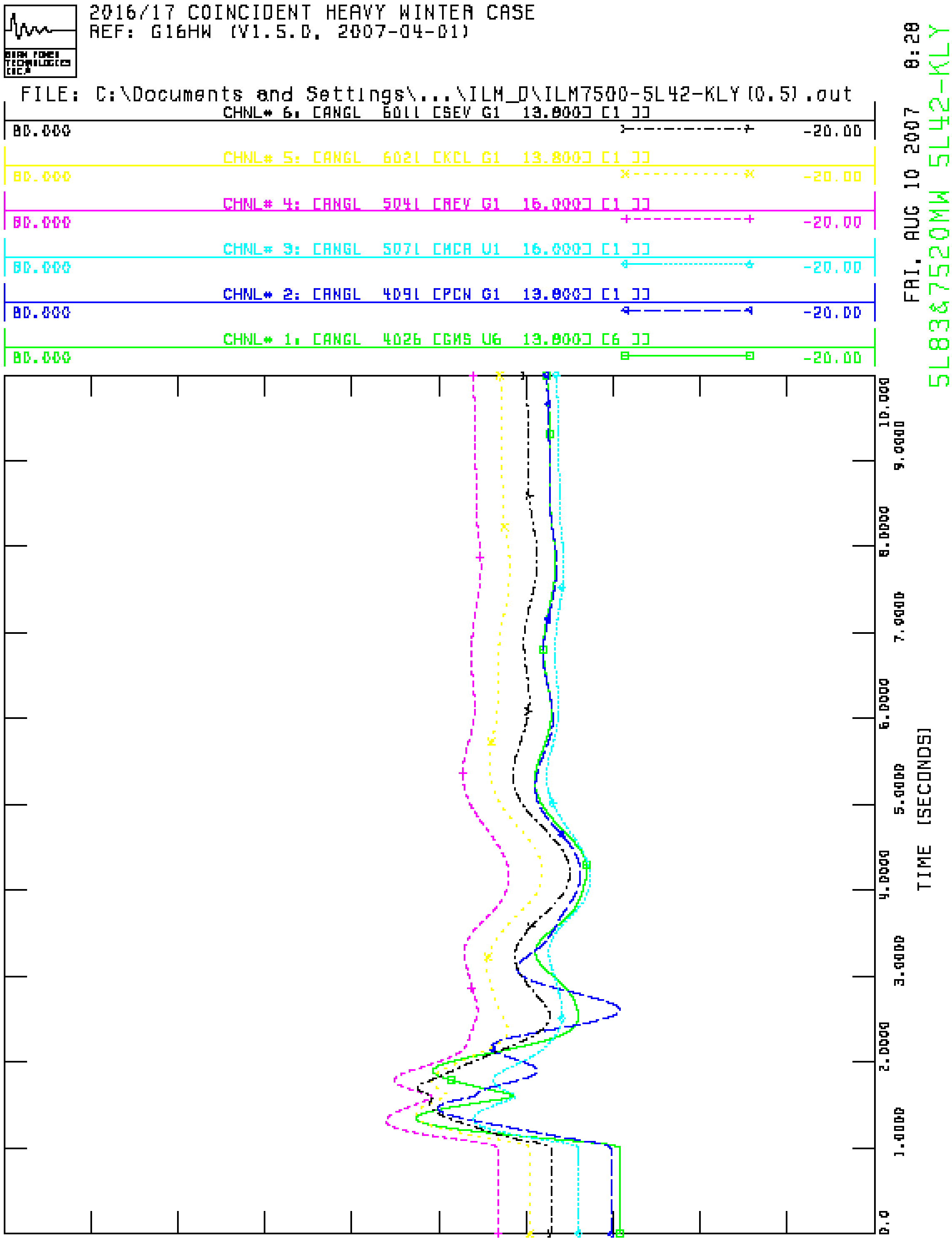
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000

Figure B-2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-20.00
CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
80.000
-20.00
CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
80.000
-20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000
-20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
80.000
-20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
80.000
-20.00
FRI, AUG 10 2007 8:28
5L83&7520MW 5L42-KLY
0.0
1.0000
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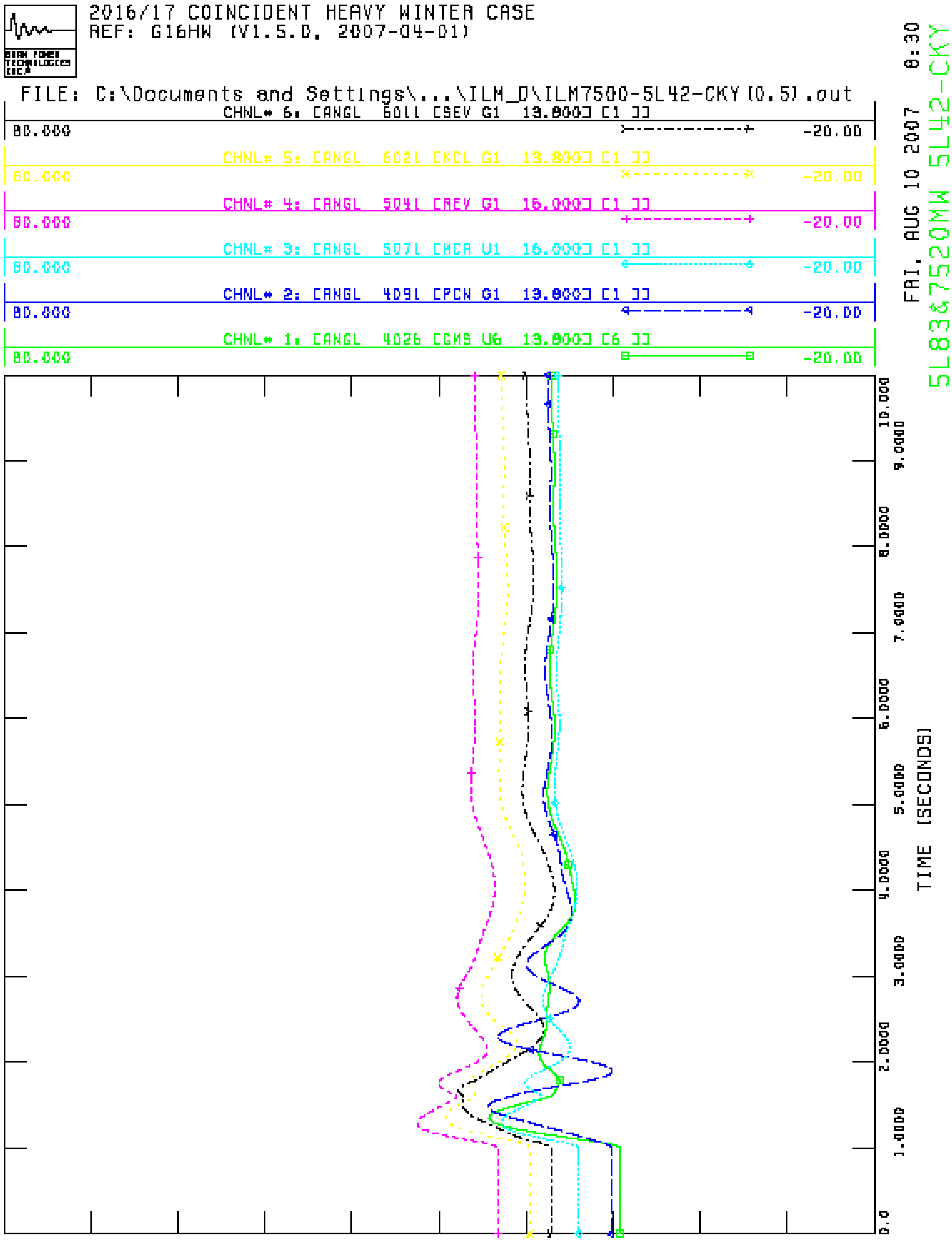
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

Figure B-3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CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
80.000
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CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
80.000
-20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000
-20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
80.000
-20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
80.000
-20.00
FRI, AUG 10 2007 8:30
5L83&7520MW 5L42-CKY
TIME (SECONDS)
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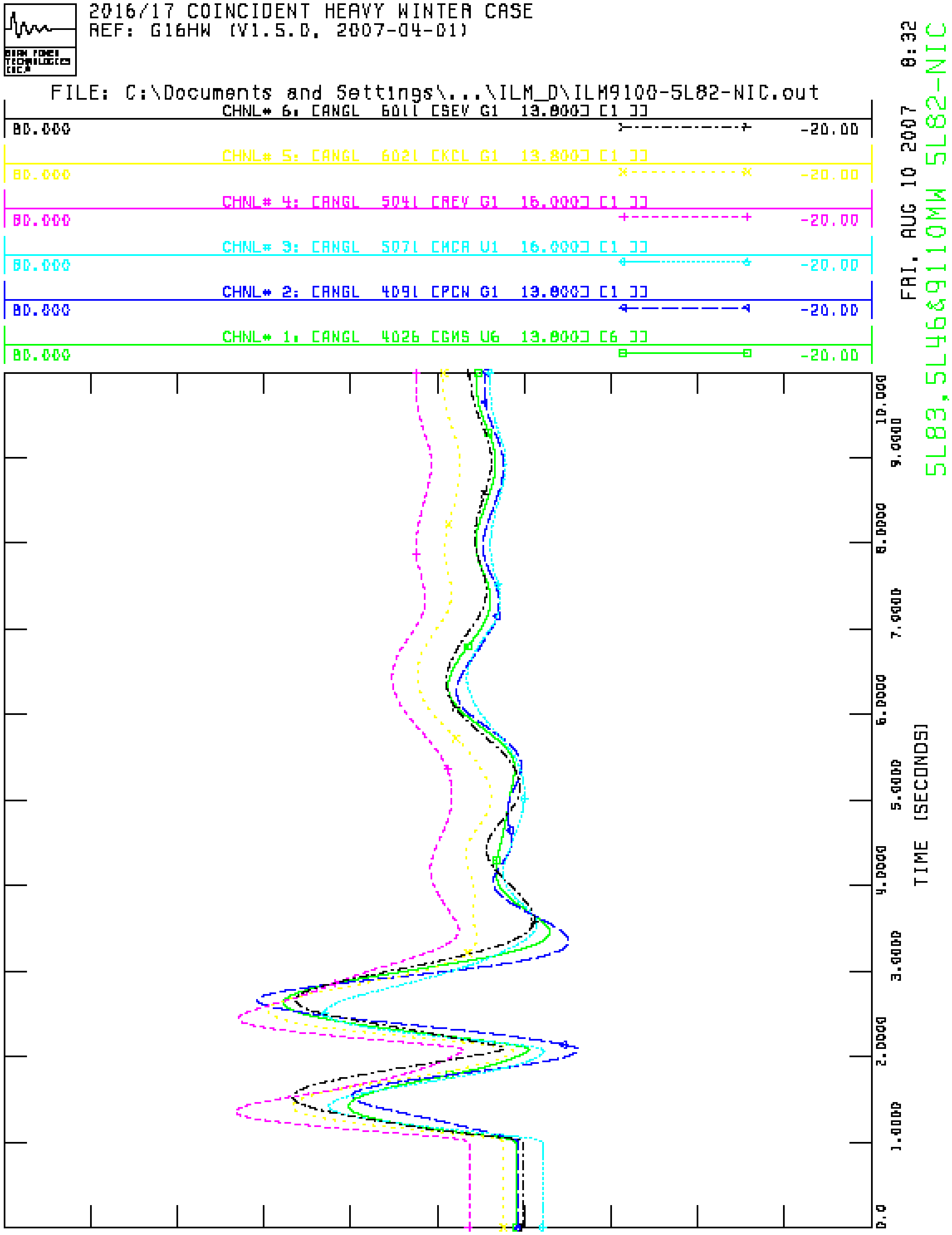
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000

Figure B-4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CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
80.000 -20.00
CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
80.000 -20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000 -20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
80.000 -20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
80.000 -20.00
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
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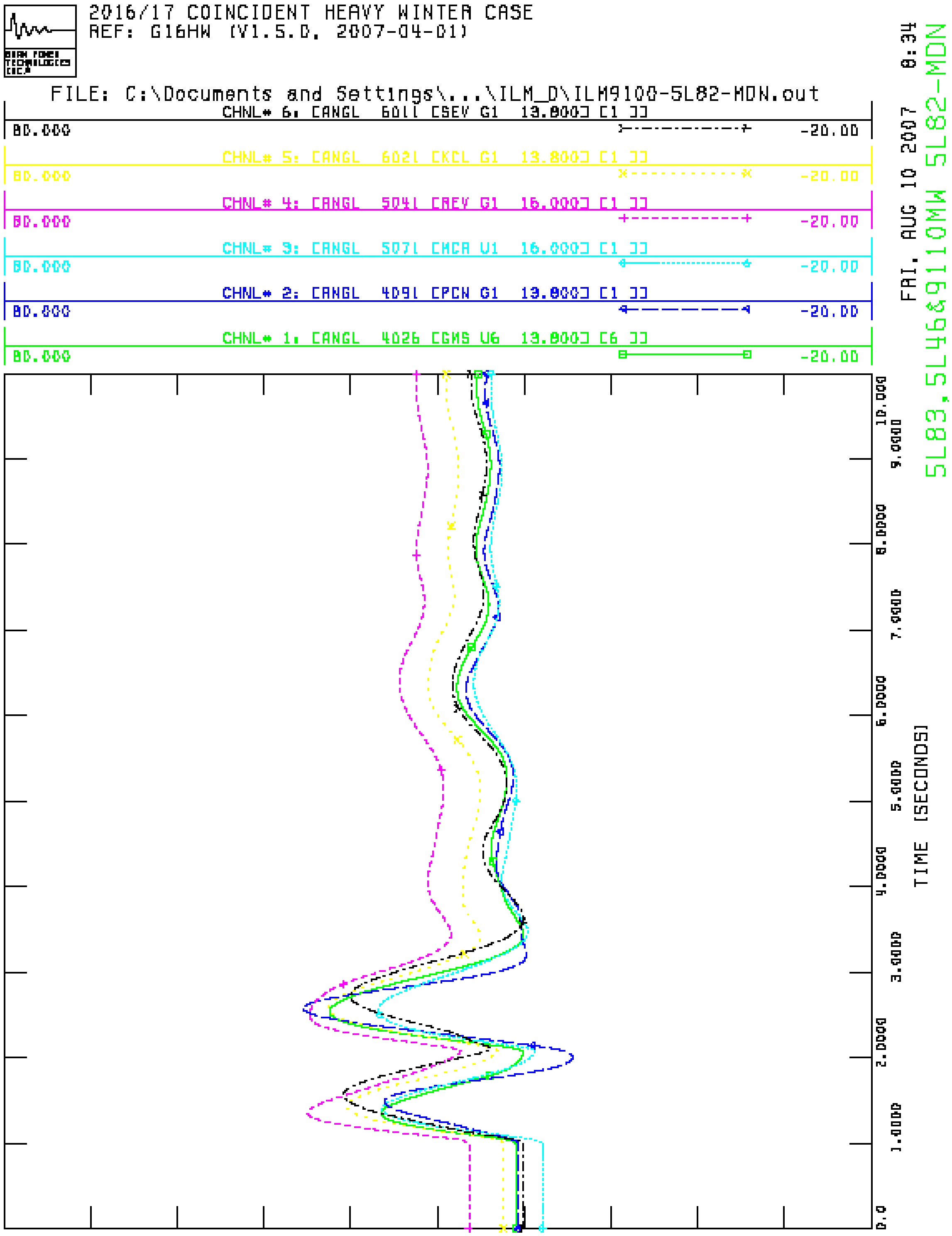
10.000
TIME (SECONDS)
FRI, AUG 10 2007 8:32
5L83,5L46&9110MW 5L82-NIC

Figure B-5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CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
80.000 -20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000 -20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
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CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
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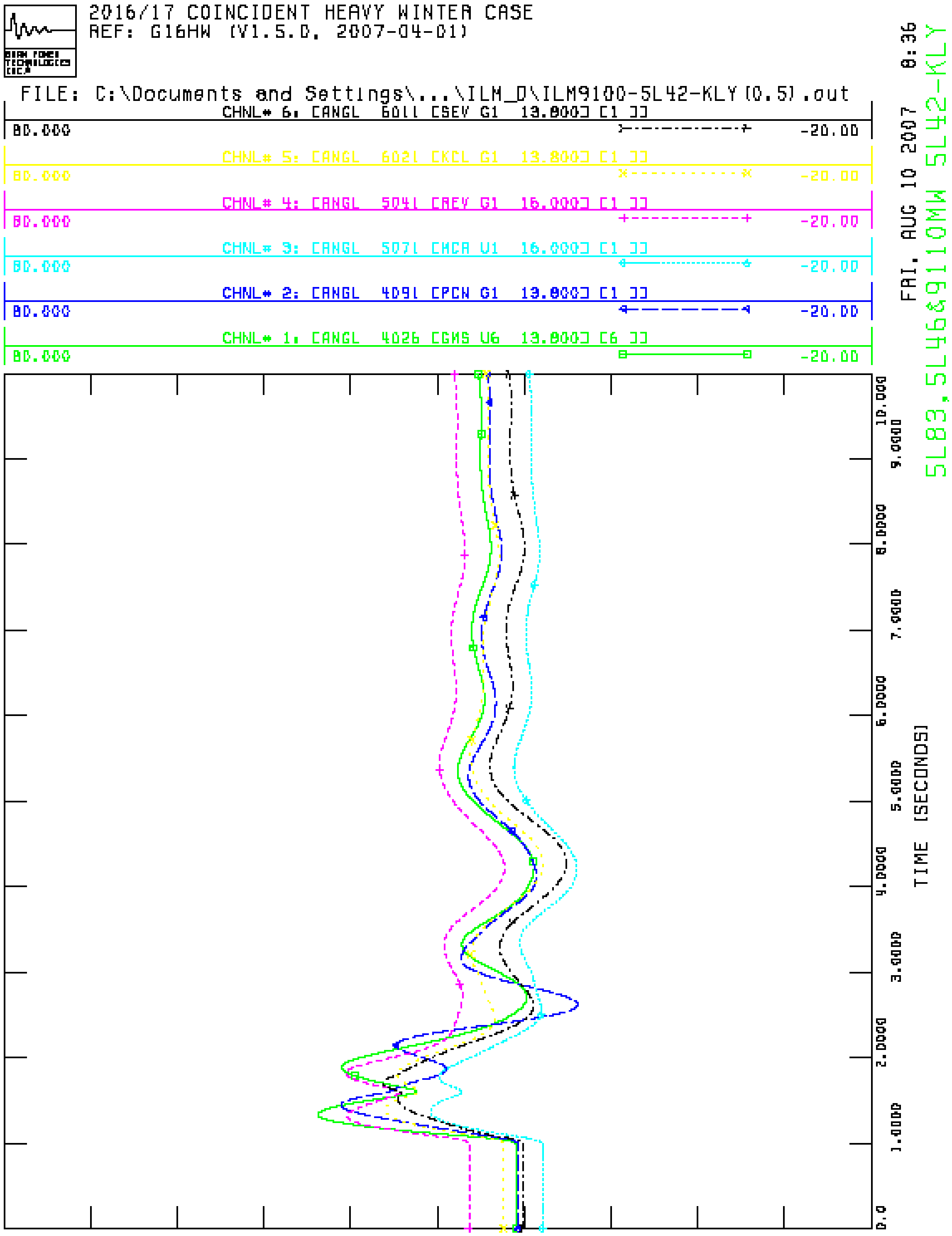
5L83,5L46&9110MW 5L82-MDN
TIME (SECONDS)

Figure B-6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CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
80.000
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80.000
-20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
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80.000
-20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
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-20.00
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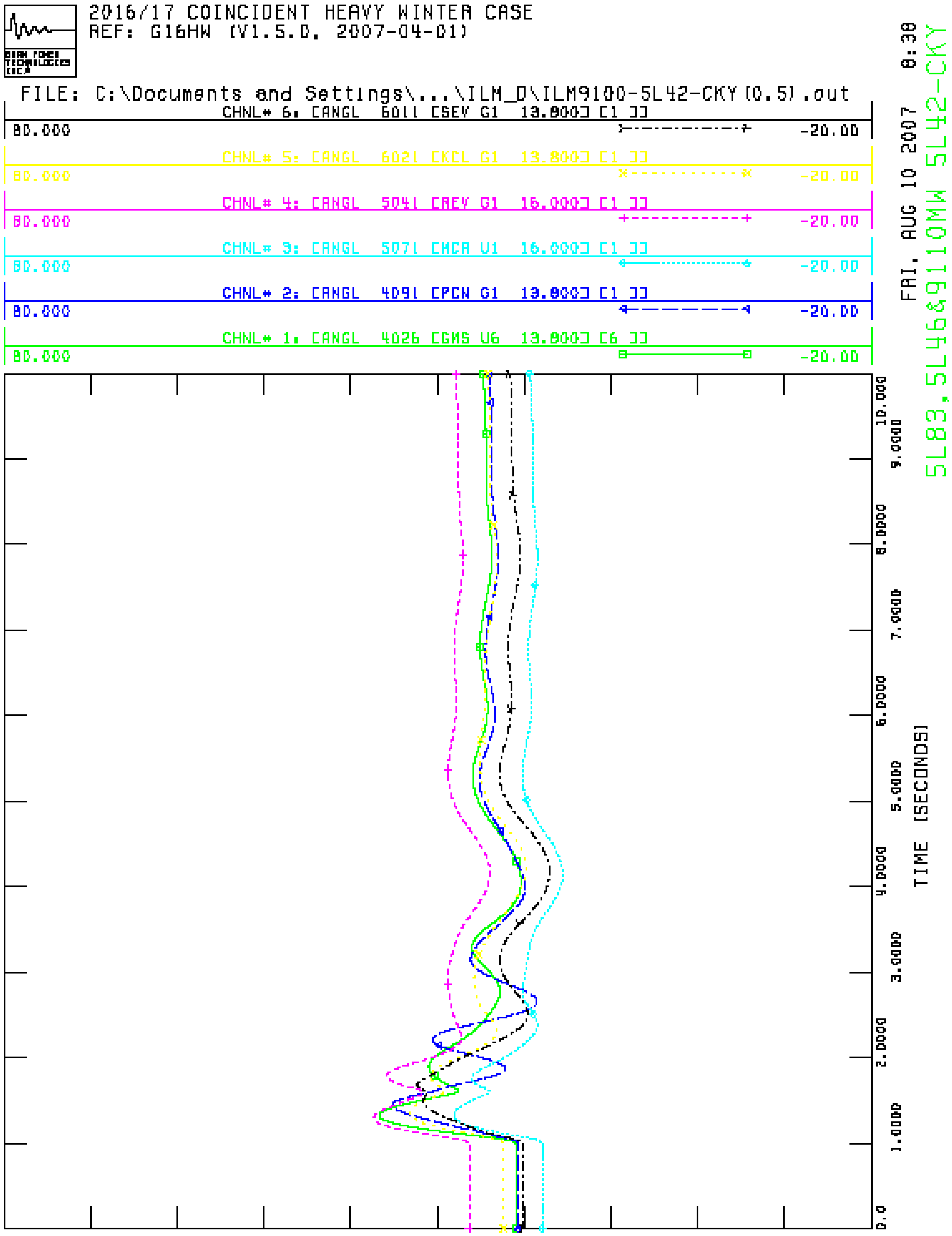
5L83,5L46&9110MW 5L42-KLY
TIME (SECONDS)

Figure B-7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CHNL# 5: [ANGL 6021 [KCL G1 13.800] [1]]
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CHNL# 4: [ANGL 5041 [REV G1 16.000] [1]]
80.000 -20.00
CHNL# 3: [ANGL 5071 [MCA U1 16.000] [1]]
80.000 -20.00
CHNL# 2: [ANGL 4091 [PCN G1 13.800] [1]]
80.000 -20.00
CHNL# 1: [ANGL 4026 [GMS U6 13.800] [6]]
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TIME (SECONDS)
FRI, AUG 10 2007 8:38
5L83,5L46&9110MW 5L42-CKY

Figure B-8