Appendix II-9-6
Power System Analysis for
Expansion of Victoria Hydropower Station

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Power System Analysis for
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1. General

Expansion of Victoria Hydropower Station will be planned to supply Peak Demand of Sri Lanka. 2 new units of 114 MW capacity (total 228 MW) will be added to the existing 3 units of 70 MW. The total capacity of the station would then be 438 MW. Following analyses were carried out in order to evaluate the impact on the Power System.

- Power Flow Analysis
- Short Circuit Analysis
- Transient stability Analysis

These analyses were carried out for the Hydro-Maximum scenario and Thermal-maximum scenario during Night-Peak which were based on “Long Term Transmission Development Plan 2006-2015” prepared by CEB.

2. Conditions of Power System Analysis

2.1 Victoria Expansion

2.1.1 Expansion Plan

(1) Year of Commissioning 2015

(2) No. of Units.......................................2

(3) Rated Voltage ....16.5 kV

(4) Rated Generator Capacity.................134 MVA

(5) Rated Output.....................................114 MW

(6) Interconnection with the Power System
The new generators would be connected to the existing buses.

(7) Operating of the Victoria P/S
The new and the existing generators will be operated as Peaking Units. Therefore each generation of Victoria would be operated at its Rated Output for the Night Peak.

2.1.2 Analysis Model; Data for PSS/E

(1) Generator .... GENSAL (On)
- Reactive Power Qmax = 70.7 Mvar, Qmin = -54.0 Mvar
- Constants

Table 2-1 Generator Constants

do'	Tdo"	Tqo"	H	D	Xd	Xq	Xd'	Xd"=Xq"	Xl	S(1.0)	S(1.2)
7.79	0.06	0.08	3.14	0.5	0.84	0.577	0.254	0.184	0.104	0.075	0.219

(2) Comp................................ None

(3) Stabilizer .... None

(4) Min exciter........................ None

(5) Max exciter .... None

(6) Exciter............................... SEVS (On) (These constants are same as existing Victoria.)

(7) Governor .... HYGOV (On) (These constants are same as existing Victoria.)

2.2 Power System Data

The Power System Data of transmission lines, transformers and generators were prepared by CEB and based on “Long Term Transmission Development Plan 2006-2015”

2.3 Criteria

2.3.1 Thermal Criteria

(1) Normal Operating Condition

The loading of elements should not exceed their rated thermal loading values for steady state conditions.

(2) Single Contingency Condition

The adopted contingency level for the analysis is N-1, i.e. outage of any one element of the transmission system at a time.

The loading of all the remaining elements should not exceed their emergency ratings specified.

2.3.2 Voltage Criteria

(1) Normal Operating Condition

220 kV Bus ....-5% to +5%
132 kV Bus ....-10% to +10%

(2) Single Contingency Condition

220 kV Bus ....-10% to +5%
132 kV Bus ....-10% to +10%

2.3.3 Short Circuit Criteria

The short circuit currents at 132 kV bus and 220 kV bus should be less than the existing switchgear capacity or 40 kA.

2.4 Study Case or Scenario

Study cases for the Power System Analysis are below.

- Hydro-Maximum in Night-Peak without Victoria Expansion
- Hydro-Maximum in Night-Peak with Victoria Expansion
- Thermal-Maximum in Night-Peak without Victoria Expansion
- Thermal-Maximum in Night-Peak with Victoria Expansion

2.5 Demand and Generation

Grid Substation Demands at Night Peak in 2015 which were used for the analysis are shown in Table 2.2.

The generations for each scenario are shown in Table 2.3. In the Hydro-maximum Scenario all Hydro-generators would be in service at their output. And in the Thermal-maximum Scenario most of Hydro-generators would be out of service and Coal-generators were in service as base load power plants.

Table 2-2 Grid Substation Demand at Night Peak in 2015

Bus Name	kV	Demand at Night Peak		Bus Name	kV	Demand at Night Peak	
		(MW)	(Mvar)			(MW)	(Mvar)
Ambalangoda	33	74.3	24.4	Matara	33	75.7	24.9
Ampara	33	84.1	27.6	Mathugama	33	84.3	27.7
Aniyakanda	33	56.3	27.2	Medagama	33	20.3	6.7
Anuradhapura	33	26.4	8.7	Morat	33	52.1	25.2
Anuradhapura B	33	16.7	5.5	Naula	33	14.1	4.6
Athurugiriya	33	39.3	19.1	New Anuradhapura	33	29.5	9.7
Badulla	33	82.5	27.1	NEW Kotugoda	33	52.2	17.1
Balangoda	33	75.3	24.8	Nuwara Eliya	33	80.9	26.6
Beliatta	33	31.4	10.3	Padirippu	33	64.7	21.3
Biyagama	33	158.6	76.8	Pallekele	33	54.7	18
Bolawatta	33	82.6	40	Panadura	33	86.2	28.3
Chunnakum	33	62.9	20.7	Pannala	33	49.8	24.1
Dehiwala	33	78.8	48.8	Pannipitiya	33	79.1	49
Deniyaya	33	74	24.3	Polommaruwa	33	27	8.9
Embilipitiya	33	47.2	22.9	Puttalam	33	63.4	20.8
Galle	33	82.3	27.1	Ratmalana	33	75.4	46.8
Habarana	33	75.6	24.9	Ratnapura	33	40.6	19.7
Hambantota	33	32.2	10.6	Sapugaskanda	33	98.5	61
Horana	33	78.6	38	Sithawakapura	33	76.1	36.9
Katana	33	49.5	24	Sri Jayawardhana Pura	33	68.2	42.3
Kegalle	33	26.6	8.8	Thulhiriya	33	62.9	30.5
Kelanitissa A	33	19.9	12.35	Trincomalee	33	84.2	27.7
Kelanitissa B	33	19.9	12.35	Ukuwela	33	77.5	25.5
Kelaniya	33	61.6	29.8	Valachchena	33	38.2	23.7
Kilinochchi	33	8.6	2.8	Vavunia	33	25.1	8.2
Kiribathkumbura	33	78.6	25.8	Veyangoda	33	80.4	38.9
Kolonnawa A	33	34.8	21.6	Waligama	33	31.9	10.5
Kolonnawa B	33	50.7	31.4	Wimalasurendra	33	73.7	24.2
Kosgama	33	74.6	36.1	Colombo A	11	34.3	21.2
Kotugoda	33	99.4	32.7	Colombo B	11	21.9	13.6
Kurunegala	33	87.5	28.8	Colombo C	11	20.4	12.6
Madampe	33	79.3	49.1	Colombo E	11	27.7	17.2
Mahiyangana	33	10.9	5.3	Colombo F	11	60.1	37.2
Maho	33	19.3	6.4	Colombo I	11	37.4	23.2
				Total Demand		**3,848.8**	**1,669.9**

Table 2-3 Generation in MW

Bus Name	kV	Id	Pmax MW	Pmin MW	Qmax Mvar	Qmin Mvar	Mbase MVA	HM w/o Expansion MW	HM w/ Expansion MW	TM-w/o Expansion MW	TM-w/ Expansion MW
Laxapana P/S	132	1	25	0	18	0	29.4	25	25	25	25
		2	25	0	18	0	29.4	25	25	25	25
New Laxapana	132	1	50	0	35	0	62.5	50	50	50	50
		2	50	0	35	0	62.5	50	50	0	0
Wimalasurendra	132	1	25	0	18	0	31.3	25	25	25	25
		2	25	0	18	0	31.3	25	25	0	0
Polpitiya P/S	132	1	37.5	0	25	0	46.9	37.5	37.5	37.5	37.5
		2	37.5	0	25	0	46.9	37.5	37.5	0	0
Canyon P/S	132	1	30	0	20	0	37.5	30	30	30	30
		2	30	0	20	0	37.5	30	30	0	0
Samanalawewa P/S	132	1	60	0	40	0	70.6	60	60	60	60
		2	60	0	40	0	70.6	60	60	0	0
Ukuwela	132	1	19	0	11.27	0	21.4	18	18	18	18
		2	19	0	11.27	0	21.4	18	18	0	0
Bowatenna P/S	132	1	40	0	30	0	47	40	40	40	40
Kelanitissa P/S	132	1	16	0	8	0	28.7	0	0	0	0
		3	115	0	79.02	0	150	0	0	0	0
Sapugaskanda P/S	132	3	72	0	53.94	0	102.4	0	0	0	0
Kukule P/S	132	1	35	0	25	0	42	35	35	35	35
		2	35	0	25	0	42	35	35	35	35
KHD P/S	132	1	51	0	33.5	0	63.6	40	40	51	51
Galle	132	1	110	0	65.85	0	125	80	80	105	105
Kurunegala	132	1	37	0	25	0	42	35	35	35	35
Trincomalee	132	1	37	0	25	0	42	35	35	35	35
Chunnakum	132	1	37	0	25	25	42	35	35	35	35
Padirippu	132	1	110	0	65	0	125	69.9	55	0	0
Kotmale P/S	220	1	67	0	50	0	90	66.63	66.46	64.68	62.31
		2	67	0	50	0	90	66.63	66.46	0	0
		3	67	0	50	0	90	66.63	66.46	0	0
Upper Kothmale P/S	220	1	80	0	45	0	88	75	75	75	75
		2	80	0	45	0	88	75	75	0	0
Victoria P/S	220	1	70	0	50	0	83	70	70	70	70
		2	70	0	50	0	83	70	70	70	70
		3	70	0	50	0	83	70	70	70	70
		4	***114***	***0***	***81***	***0***	***140***	***0***	***114***	***0***	***114***
		5	***114***	***0***	***81***	***0***	***140***	***0***	***114***	***0***	***114***
Randenigala P/S	220	1	60	0	45	0	81	60	60	60	60
		2	60	0	45	0	81	60	60	0	0
Kelanitissa P/S	220	1	104	0	70	0	132	100	55	90	55
		2	61	0	40	0	76	60	31	57	30
		3	109	0	70	0	145	0	0	90	55
		4	54	0	40	0	80	0	0	57	30
Kerawala P/S	220	1	54	0	35	35	80	50	31	57	30
		2	105	0	70	70	118	100	55	90	55
		3	105	0	65	65	118	100	55	90	55
		4	54	0	45	45	80	50	31	0	0
		5	110	0	65.85	0	125	0	0	0	0
		6	110	0	65.85	0	125	0	0	0	0
Hambantota G/S	220	1	310	0	180	0	352	295	295	295	295
		2	310	0	180	0	352	295	295	295	295
		3	310	0	180	0	352	0	0	295	295
Trincomalee P/S	220	1	310	0	180	0	352	295	295	295	295
		2	310	0	180	0	352	295	295	295	295
		3	310	0	180	0	352	0	0	0	0
Puttalam P/S	220	1	310	0	180	0	352	295	295	295	295
		2	310	0	180	0	352	295	295	295	295
		3	310	0	180	0	352	0	0	295	295
Wimalasurendra	33	1	6	0	3.69	0	7	5.46	5.46	0	0
Seethawake	33	1	8.5	0	6.32	0	12	7.42	7.42	0	0
Nuwara Eliya	33	1	5	0	3.16	0	6	4.41	4.41	0	0
Balangoda	33	1	28	0	16.86	0	32	27.5	27.5	0	0
Deniyaya	33	1	7	0	3	0	7	6.35	6.35	0	0
Ratnapura	33	1	16	0	10.54	0	20	15.03	15.03	0	0
Kiribathkumbura	33	1	10	0	6.32	0	12	9.65	9.65	0	0
Rantembe P/S	12.5	1	27	0	16.86	0	32	25	25	25	25
		2	27	0	16.86	0	32	25	25	0	0
								3,931.61	**3,942.2**	**3,967.18**	**3,971.81**

3. Power Flow Analysis

3.1 Normal Operating Condition

3.1.1 Hydro Maximum

(1) Transmission Line Overloading

No thermal criteria violations were observed in the 132 kV and 220 kV transmission lines..

Many transformers connected between 132 kV and 33 kV were overloaded. However it was not due to Victoria Expansion.

(2) Bus Voltage

No Voltage violations were observed.

3.1.2 Thermal Maximum

(1) Transmission Line Overloading

No voltage criteria violations were observed in the 132 kV and 220 kV transmission lines.

Many transformers connected between 132 kV and 33 kV were overloaded. However it was not due to Victoria Expansion.

(2) Bus Voltage

Low voltages on the 132 kV buses were observed due to the outage of small hydro-power plants in Thermal-Maximum scenario and due to insufficient supply of reactive power.

The purpose of this study was to evaluate the impact of Victoria Expansion on the Power System. Therefore these buses with low voltage conditions were not adjusted by reactive power supplies.

The reactive power supplied by new Victoria units would make improvement to the bus voltage.

Table 3-1 132 kV Buses with Voltage less than 0.90 pu

Bus		w/o Expansion		w/ Expansion	
Name	kV	V(pu)	V(kV)	V(pu)	V(kV)
Kurunegala	132	0.8752	115.53	0.885	116.82
Kegalle	132	0.8857	116.92	0.8954	118.19
Kiribathkumbura	132	0.8868	117.06	0.8962	118.3
Pallekele	132	0.8874	117.13	0.8968	118.37
Thulhiriya	132	0.8892	117.37	0.8987	118.63
Ukuwela	132	0.895	118.14	-	-

Figure 3-1 Load Flow Diagram for Night Peak Hydro Maximum without Victoria Expansion

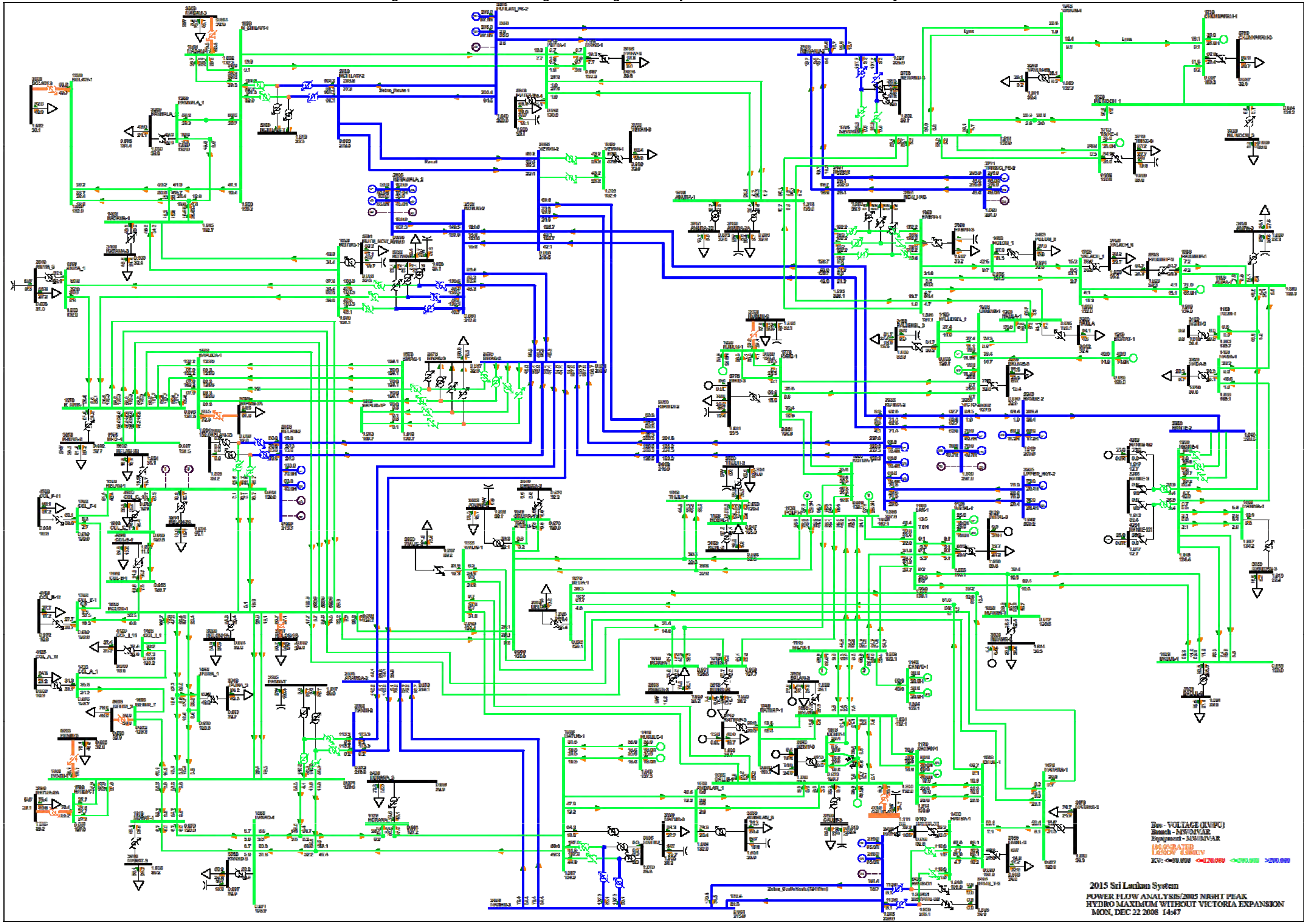


Figure 3-2 Load Flow Diagram for Night Peak Hydro Maximum with Victoria Expansion

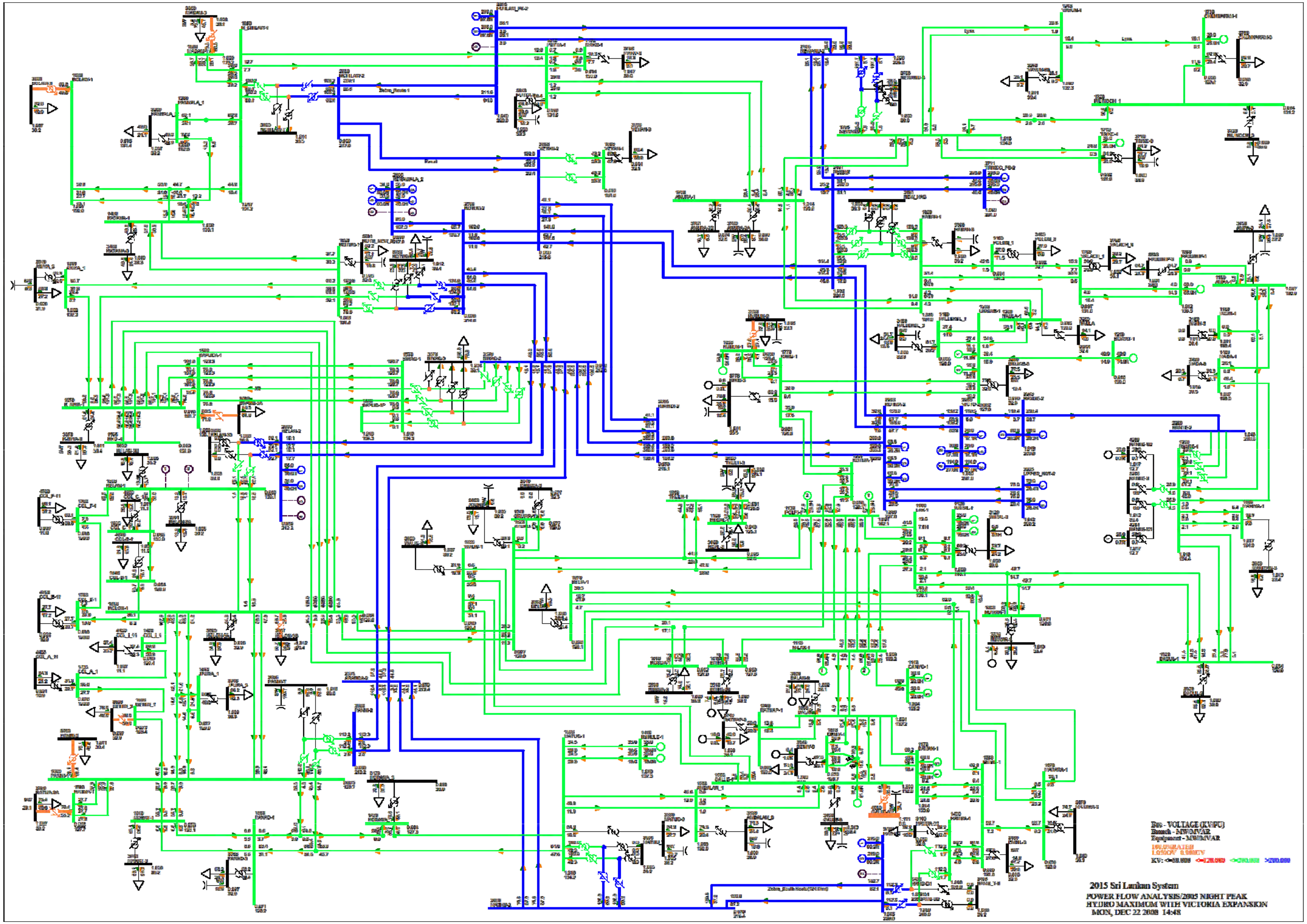


Figure 3-3 Load Flow Diagram for Night Peak Thermal Maximum without Victoria Expansion

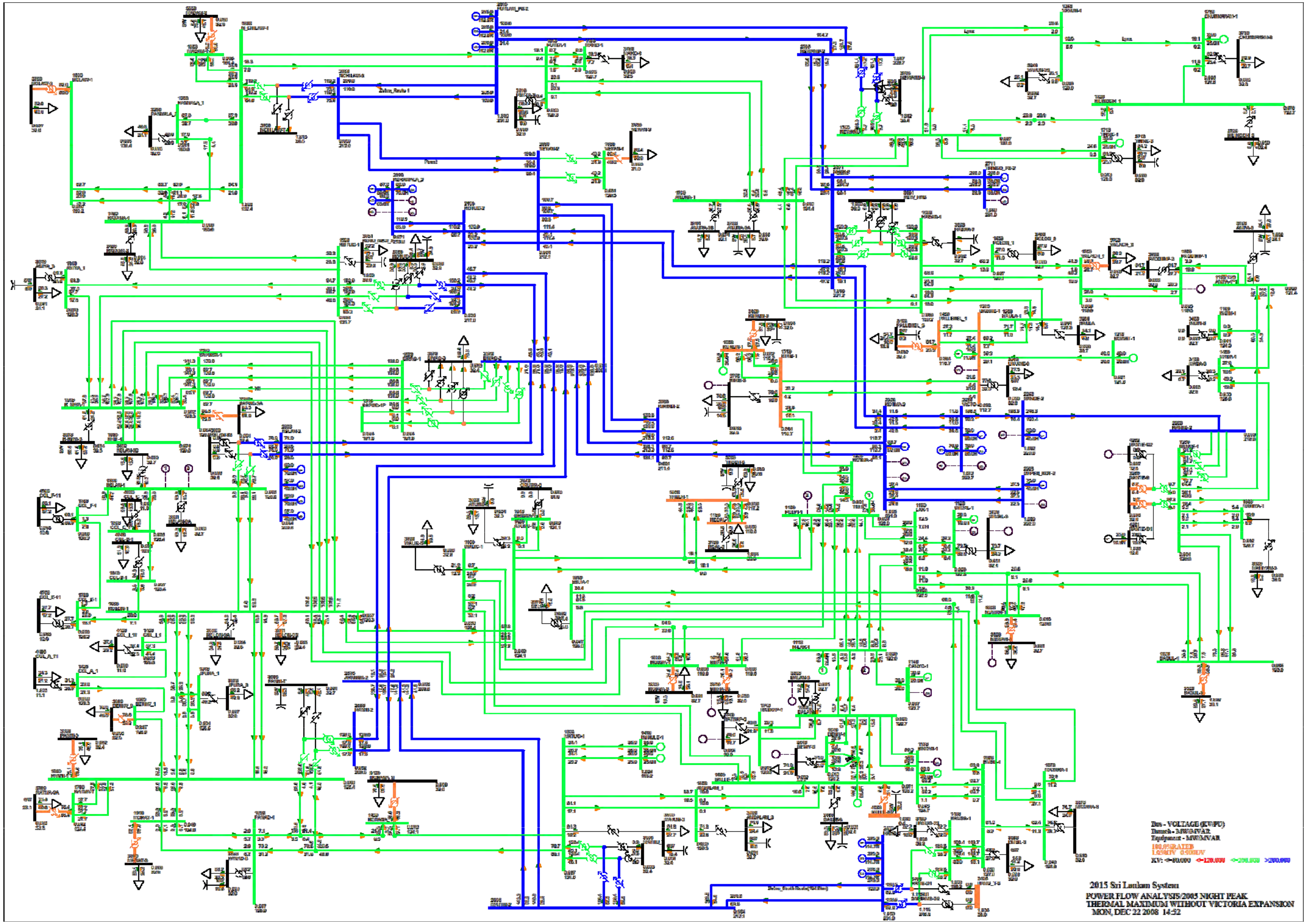
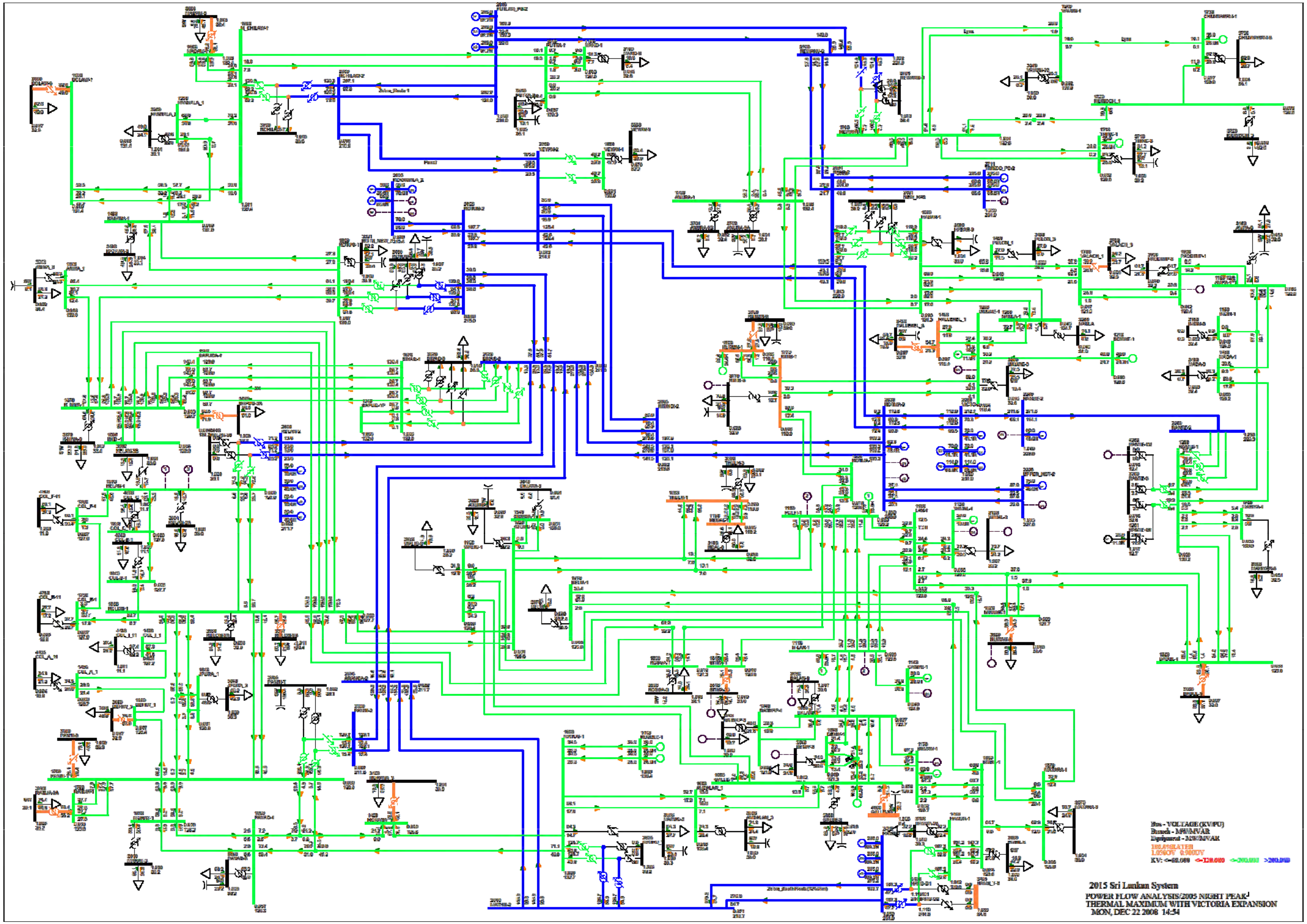


Figure 3-4 Load Flow Diagram for Night Peak Thermal Maximum with Victoria Expansion



3.2 N-1 Contingency Condition

3.2.1 Hydro Maximum

(1) Transmission Line Overloading

Overloaded transmission lines were observed. Nevertheless Victoria Expansion will not cause these overloading and any remedies for these overloaded transmission lines will be required irrespectively of Victoria Expansion.

Table 3-2 Branch Loadings above Emergency Rating

Branch				Current (MVA)					
from Bus		to Bus		w/o Expansion			w/ Expansion		
Name	kV	Name	kV	Loading	Rating	Percent	Loading	Rating	Percent
Colombo E	132	Colombo F	132	80.2	60	137	80.2	60	136.7

(2) Bus Voltage

In the N-1 Condition 220 kV Randenigala bus voltage was more than 1.05 pu. But less reactive power supplied by Victoria P/S or Randenigala P/S was able to make the bus voltage within the allowable limit.

A low voltage was observed at 132 kV Kegalle bus. However Victoria Expansion will not cause this low voltage condition, any remedies will be required irrespectively of Victoria Expansion.

Table 3-3 Buses without the Allowance

Bus		Bus Voltage (pu)			
		w/o Expansion		w/ Expansion	
Name	kV	N-1	Normal	N-1	Normal
Randenigala P/S	220	1.05158	1.049	1.05158	1.049
Kegalle	132	0.89688	0.94684	0.8978	0.9477

3.2.2 Thermal Maximum

(1) Transmission Line Overloading

Overloads in some transmission lines were observed. Nevertheless, generation of Victoria Expansion Project would reduce these overloads and however will not cause these overloads.

Table 3-4 Branch Loadings above Emergency Rating

Branch				Current (MVA)					
from Bus		to Bus		w/o Expansion			w/ Expansion		
Name	kV	Name	kV	Loading	Rating	Percent	Loading	Rating	Percent
Colombo E	132	Colombo F	132	80.9	60	142	80	60	139
Hambantota G/S	132	Embilipitiya	132	243.8	250	103.9	240.4	250	101.7

(2) Bus Voltage

The voltage less than 0.95 pu were observed at some 132 kV buses. Nevertheless, reactive power supplied by Victoria Expansion would reduce these low voltage conditions.

Table 3-5 Buses without the Allowance

Bus		Bus Voltage (pu)			
		w/o Expansion		w/ Expansion	
Name	kV	N-1	Normal	N-1	Normal
Polommaruwa	132	0.80915	0.93775	0.8208	0.94594
Padirippu	132	0.81792	0.90615	0.82627	0.91208
Kosgama	132	0.82237	0.90952	0.8332	0.91913
Ampara	132	0.8227	0.92021	0.82976	0.92462
Inginiyagala	132	0.82512	0.94189	0.83048	0.94537
Kegalle	132	0.82891	0.88575	0.83971	0.89535
Valachchena	132	0.83263	0.90908	0.84634	0.91659
Thulhiriya	132	0.83264	0.88917	0.84339	0.89874
Kurunegala	132	0.84064	0.87524	0.85169	0.88501
Medagama	132	0.84558	0.95343	0.85166	0.9563
Pallekele	132	0.84592	0.88738	0.85652	0.89675
Kiribathkumbura	132	0.85355	0.88683	0.86416	0.89625
Seethawake	132	0.85386	0.90666	0.86376	0.91601
Ukuwela	132	0.85405	0.89498	0.86451	0.90424
Deniyaya	132	0.86806	0.91127	0.87641	0.919
Kotmale P/S	132	0.87768	0.90352	0.88814	0.91251
Ratnapura	132	0.88541	0.91617	0.89563	0.92359
Nuwara Eliya	132	0.89076	0.91641	0.89645	0.92208
Bowatenna P/S	132	0.89557	0.9268	-	-
Naula	132	0.8964	0.9361	-	-
Kilinochchi	132	0.89652	0.97552	-	-
Beliatta	132	0.89713	0.9476	-	-
Polpitiya P/S	132	0.89783	0.92508	-	-
Horana	132	0.89863	0.9407	-	-
Badulla	132	0.89901	0.93467	-	-
Balangoda	132	0.89986	0.92999	-	-

4. Short Circuit Current

Victoria Expansion will increase the Three Phase Fault Current at any bus. The increment beyond 1.0 kA of Fault Current were observed at 220 kV Buses around Victoria P/S. Nevertheless, they are less than the existing switchgear capacities or 40 kA.

The influence of Victoria Expansion for other buses would not be so serious.

Some 132 kV busses were beyond or as same level as their existing switchgear capacities irrespectively of Victoria Expansion and any remedies for them will be required.

Table 4-1 Maximum Three Phase Fault Current

Bus		Existing Switchgear Capacity (kA)	Three Phase Short Circuit Current (kA)					
			Hydro Maximum			Thermal Maximum		
Name	kV		w/o Expansion	w/ Expansion	Increment	w/o Expansion	w/ Expansion	Increment
Arangala	220	Future	19.7	20.0	0.2	20.3	20.8	0.4
Biyagama	220	40	23.9	24.4	0.5	24.7	25.5	0.7
Hambantota G/S	220	Future	13.6	13.6	0.0	17.1	17.2	0.0
Kelanitissa P/S	220	50	19.1	19.3	0.2	20.5	20.9	0.5
Kerawala P/S	220	Future	16.7	16.9	0.1	16.3	16.6	0.3
Kirindiwela	220	Future	23.6	24.2	0.6	23.8	24.7	0.9
Kotmale P/S	220	40	18.4	20.0	1.5	15.8	17.7	1.9
Kotugoda	220	-	21.8	22.1	0.3	21.8	22.4	0.6
Mathugama	220	Future	15.6	15.7	0.1	16.3	16.5	0.2
New Anuradhapura	220	-	12.5	12.5	0.1	13.0	13.1	0.2
New Chilaw	220	Future	15.5	15.7	0.2	16.4	16.7	0.2
New Habarana	220	Future	18.0	18.3	0.3	17.9	18.4	0.5
Pannipitiya	220	50	18.3	18.5	0.2	18.7	19.1	0.4
Puttalam P/S	220	Future	15.7	15.8	0.1	19.6	19.7	0.1
Randenigala P/S	220	31.5	11.2	12.3	1.0	9.8	11.1	1.3
Rantembe P/S	220	25	10.7	11.6	0.9	9.4	10.6	1.2
Trincomalee P/S	220	Future	13.5	13.6	0.1	13.8	13.9	0.1
Upper Kothmale P/S	220	Future	13.0	13.7	0.7	11.3	12.3	1.0
Veyangoda	220	Future	23.2	23.7	0.5	23.5	24.2	0.7
Victoria P/S	220	25	14.4	16.6	2.2	12.7	15.3	2.6
Ambalangoda	132	Future	10.7	10.7	0.0	10.6	10.7	0.1
Ampara	132	31.5	6.0	6.1	0.0	4.6	4.7	0.1
Aniyakanda	132	Future	13.9	14.0	0.1	13.9	14.1	0.2
Anuradhapura	132	15/11/20/31.5	12.8	12.9	0.1	12.9	13.0	0.2
Athurugiriya	132	-	15.6	15.6	0.1	15.0	15.3	0.2
Badulla	132	25/31.5	8.6	8.7	0.1	7.7	8.0	0.3
Balangoda	132	31.5	12.8	12.8	0.0	10.6	10.7	0.1
Beliatta	132	Future	5.5	5.5	0.0	5.4	5.4	0.0
Biyagama	132	31.5	25.4	25.4	0.0	25.3	25.8	0.5
Bolawatta	132	25/17.5/8.8/13.1	13.6	13.6	0.0	13.7	13.8	0.2
Bowatenna P/S	132	12.5	4.1	4.1	0.0	3.8	3.9	0.1
Canyon P/S	132	25/40	10.5	10.5	0.0	8.6	8.7	0.1
Chunnakum	132	Future	2.4	2.4	0.0	2.4	2.4	0.0
Colombo A	132	-	20.1	20.2	0.1	20.0	20.3	0.3
Colombo B	132	Future	24.3	24.4	0.1	24.1	24.5	0.4
Colombo C	132	Future	24.5	24.7	0.1	24.3	24.8	0.4
Colombo E	132	25	24.5	24.6	0.1	24.3	24.7	0.4
Colombo F	132	25	24.2	24.3	0.1	24.0	24.4	0.4
Colombo I	132	-	23.1	23.2	0.1	22.9	23.3	0.4
Dehiwala	132	-	20.0	20.1	0.1	19.9	20.2	0.3
Deniyaya	132	-	6.3	6.3	0.0	5.7	5.7	0.0
Embilipitiya	132	31.5	11.2	11.2	0.0	10.7	10.8	0.1

Table 4-2 Maximum Three Phase Fault Current (cont)

Bus		Existing Switchgear Capacity (kA)	Three Phase Short Circuit Current (kA)					
			Hydro Maximum			Thermal Maximum		
Name	kV		w/o Expansion	w/ Expansion	Increment	w/o Expansion	w/ Expansion	Increment
Galle	132	10.9/11/40	10.6	10.6	0.0	10.3	10.4	0.1
Habarana	132	Future	18.4	18.5	0.1	17.8	18.1	0.3
Hambantota G/S	132	31.5	13.0	13.0	0.0	13.7	13.7	0.0
Horana	132	-	7.9	7.9	0.0	7.9	8.0	0.1
Inginiyagala	132	12.5	5.2	5.2	0.0	4.4	4.5	0.1
Katana	132	Future	15.7	15.7	0.1	15.7	15.9	0.2
Kegalle	132	Future	4.9	4.9	0.0	4.6	4.7	0.1
Kelanitissa P/S	132	40	25.7	25.9	0.2	25.6	26.0	0.5
Kelaniya	132	40	27.4	27.5	0.1	27.3	27.8	0.5
KHD P/S	132	31.5	22.1	22.2	0.1	22.0	22.4	0.4
Kilinochchi	132	Future	2.2	2.2	0.0	2.1	2.2	0.0
Kiribathkumbura	132	25	9.1	9.1	0.0	8.1	8.2	0.1
Kolonnawa	132	40	27.8	27.9	0.2	27.5	28.0	0.5
Kosgama	132	25	7.9	7.9	0.0	7.4	7.5	0.1
Kotmale P/S	132	31.5	10.4	10.4	0.0	9.1	9.2	0.1
Kotugoda	132	31.5/40	21.2	21.3	0.1	21.2	21.5	0.4
Kukula P/S	132	-	8.0	8.0	0.0	8.0	8.1	0.1
Kurunegala	132	25	5.3	5.3	0.0	4.8	4.9	0.1
Laxapana P/S	132	31.5	20.8	20.9	0.1	16.5	16.8	0.3
Madampe	132	25	11.4	11.3	0.0	11.5	11.6	0.1
Mahiyangana	132	Future	8.2	8.4	0.2	7.3	7.8	0.5
Maho	132	25	4.0	4.0	0.0	4.0	4.0	0.0
Matara	132	31.5	7.9	7.9	0.0	7.7	7.7	0.1
Mathugama	132	40	16.3	16.3	0.0	16.5	16.6	0.2
Medagama	132	Future	4.3	4.3	0.0	3.9	4.0	0.1
Morat	132	-	16.6	16.6	0.1	16.5	16.8	0.2
Naula	132	-	8.7	8.7	0.0	8.1	8.3	0.1
New Anuradhapura	132	-	12.8	12.9	0.1	12.9	13.0	0.2
New Chilaw	132	Future	14.5	14.4	-0.1	14.6	14.8	0.2
New Laxapana	132	31.5/40	20.9	21.0	0.1	16.5	16.8	0.3
Nuwara Eliya	132	31.5	9.3	9.4	0.1	8.2	8.4	0.2
Oruwala	132	-	13.4	13.5	0.0	13.0	13.2	0.2
Padirippu	132	Future	6.6	6.6	0.0	4.4	4.5	0.1
Pallekele	132	Future	6.1	6.1	0.0	5.6	5.6	0.1
Panadura	132	25	16.5	16.6	0.1	16.5	16.7	0.2
Pannala	132	Future	10.0	10.0	0.0	10.0	10.2	0.1
Pannipitiya	132	31.5/40	24.4	24.6	0.1	24.4	24.8	0.4
Polommaruwa	132	Future	4.8	4.8	0.0	4.4	4.5	0.1
Polpitiya P/S	132	17.5	20.8	20.9	0.1	16.8	17.1	0.3
Puttalam G/S	132	25	7.0	7.0	0.0	7.0	7.1	0.1
Rantembe P/S	132	-	12.1	12.5	0.4	10.3	11.3	1.0
Ratmalana	132	31.5	16.3	16.4	0.1	16.2	16.5	0.2
Ratnapura	132	-	5.7	5.7	0.0	4.9	5.0	0.0
Samanalawewa P/S	132	31.5	12.0	12.0	0.0	9.9	10.0	0.1
Sapugaskanda G/S	132	40	25.8	25.9	0.1	25.7	26.2	0.5
Sapugaskanda P/S	132	25	22.3	22.4	0.0	22.2	22.7	0.4
Seethawake	132	-	8.5	8.5	0.0	7.7	7.8	0.1
Sri Jayawardhana Pura	132	-	22.4	22.5	0.1	22.3	22.7	0.4
Thulhiriya	132	25	6.5	6.5	0.0	6.1	6.1	0.1
Trincomalee	132	15.3/31.5	3.4	3.4	0.0	3.4	3.4	0.0
Ukuwela	132	11/12.5/15.3/25	8.6	8.6	0.0	7.7	7.8	0.1
Valachchena	132	-	5.9	5.9	0.0	4.6	4.7	0.1
Vavunia	132	-	4.7	4.7	0.0	4.7	4.8	0.0
Veyangoda	132	25	7.1	7.1	0.0	7.0	7.1	0.1
Waligama	132	Future	8.2	8.2	0.0	8.0	8.0	0.1
Wimalasurendra	132	25/31.5	16.5	16.6	0.1	13.3	13.5	0.2

5. Transient Stability Analysis

5.1 Study Case and Result

Following Transient Stability Analysis was carried out for the four scenarios.

As the results of study, it is judged that the power system would be stable for all cases.

- Hydro-Maximum in Night-Peak without Victoria Expansion

Successful Re-closing	Figure 5-1, Figure 5-2
Unsuccessful Re-closing	Figure 5-3, Figure 5-4
Double-circuits Trip	Figure 5-5, Figure 5-6

- Hydro-Maximum in Night-Peak with Victoria Expansion

Successful Re-closing	Figure 5-7, Figure 5-8
Unsuccessful Re-closing	Figure 5-9, Figure 5-10
Double-circuits Trip	Figure 5-11, Figure 5-12

- Thermal-Maximum in Night-Peak without Victoria Expansion

Successful Re-closing	Figure 5-13, Figure 5-14
Unsuccessful Re-closing	Figure 5-15, Figure 5-16
Double-circuits Trip	Figure 5-17, Figure 5-18

- Thermal-Maximum in Night-Peak with Victoria Expansion

Successful Re-closing	Figure 5-19, Figure 5-20
Unsuccessful Re-closing	Figure 5-21, Figure 5-22
Double-circuits Trip	Figure 5-23, Figure 5-24

5.2 Switching Sequence

- Successful Re-closing: One of 220 kV transmission lines between Kotmale and Victoria

0 ms	Three Phase Fault occurs at Victoria 220 kV Bus
120 ms	Fault Cleared & Circuit Trip
620 ms	Circuit Re-closed

- Unsuccessful Re-closing: One of 220 kV transmission lines between Kotmale and Victoria

0 ms	Three Phase Fault occurs at Victoria 220 kV Bus
120 ms	Fault Cleared & Circuit Trip
620 ms	Circuit Re-closed
740 ms	Fault Cleared & Circuit Trip

- Double-circuits Trip: Two of 220 kV transmission lines between Kotmale and Kirindiwela

0 ms	Three Phase Fault occurs at Kotmale 220 kV Bus
120 ms	Fault Cleared & Circuits Trip

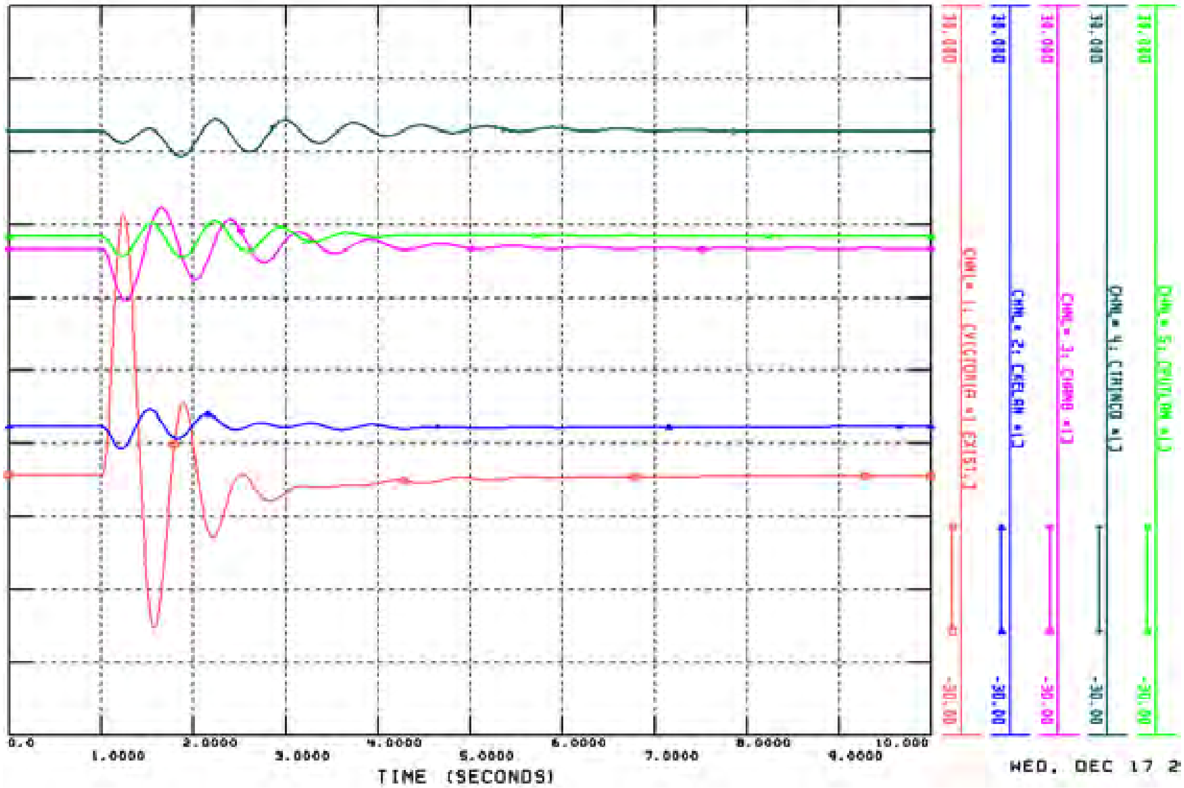


Figure 5-1 HMNP without Victoria Expansion - Successful Re-closing; Rotor Angle

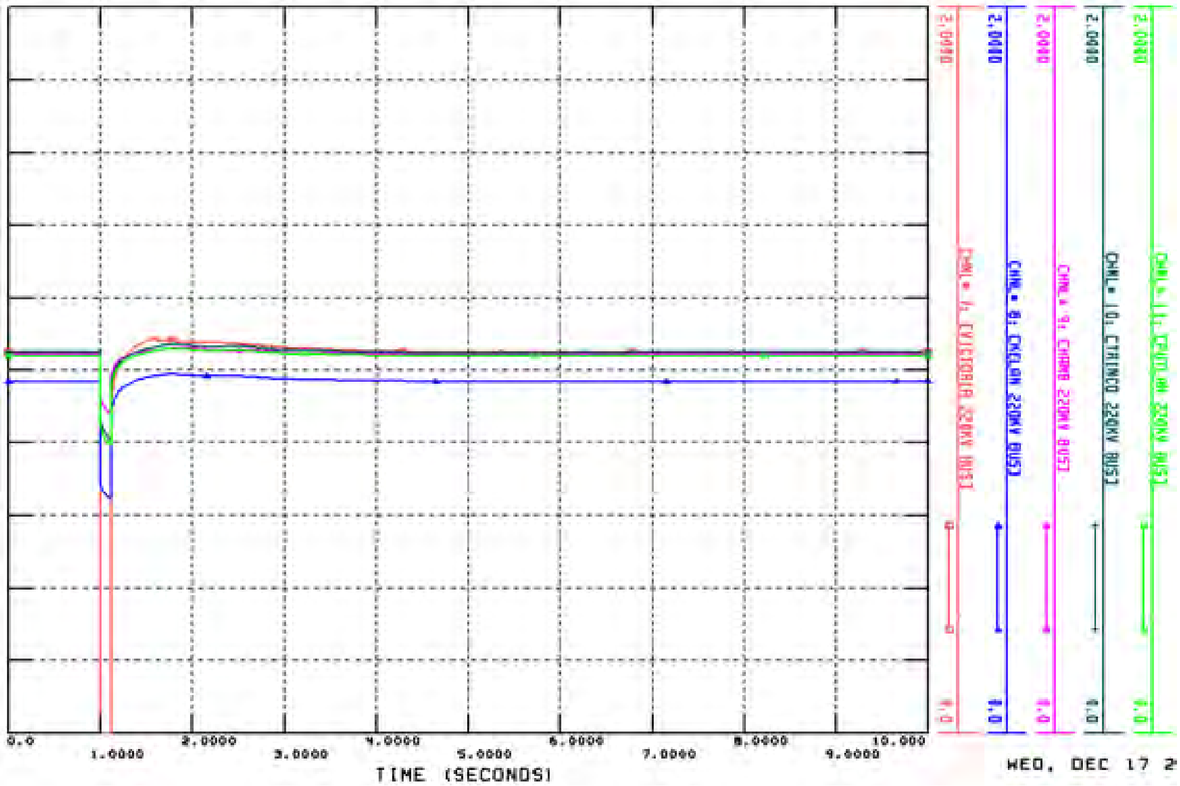


Figure 5-2 HMNP without Victoria Expansion - Successful Re-closing; Bus Voltage

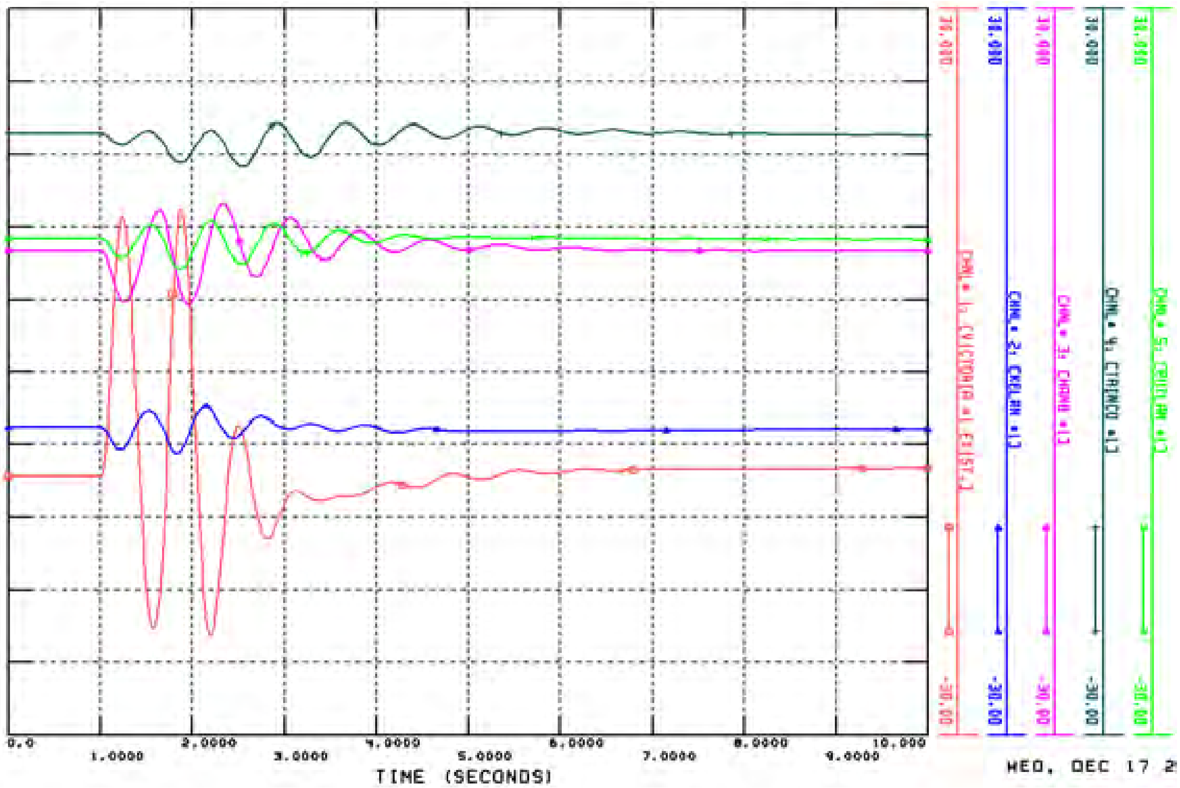


Figure 5-3 HMNP without Victoria Expansion - Unsuccessful Re-closing; Rotor Angle

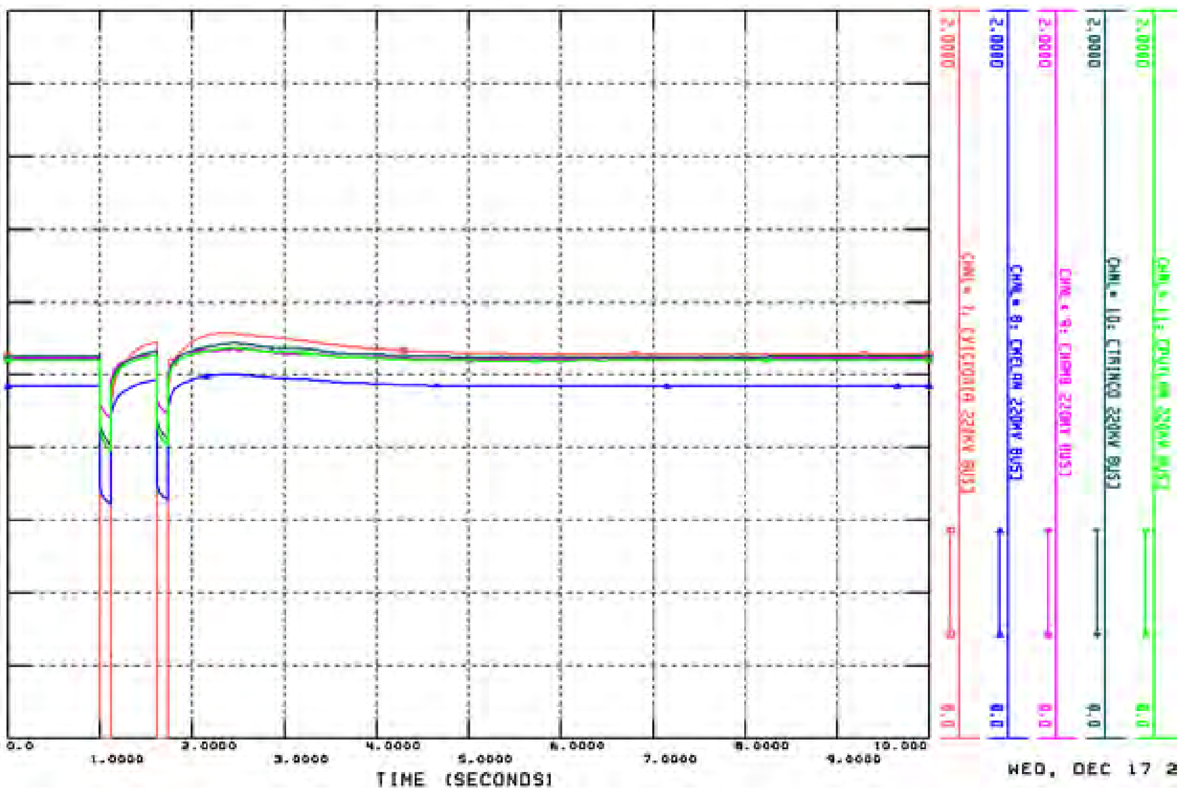


Figure 5-4 HMNP without Victoria Expansion - Unsuccessful Re-closing; Bus Voltage

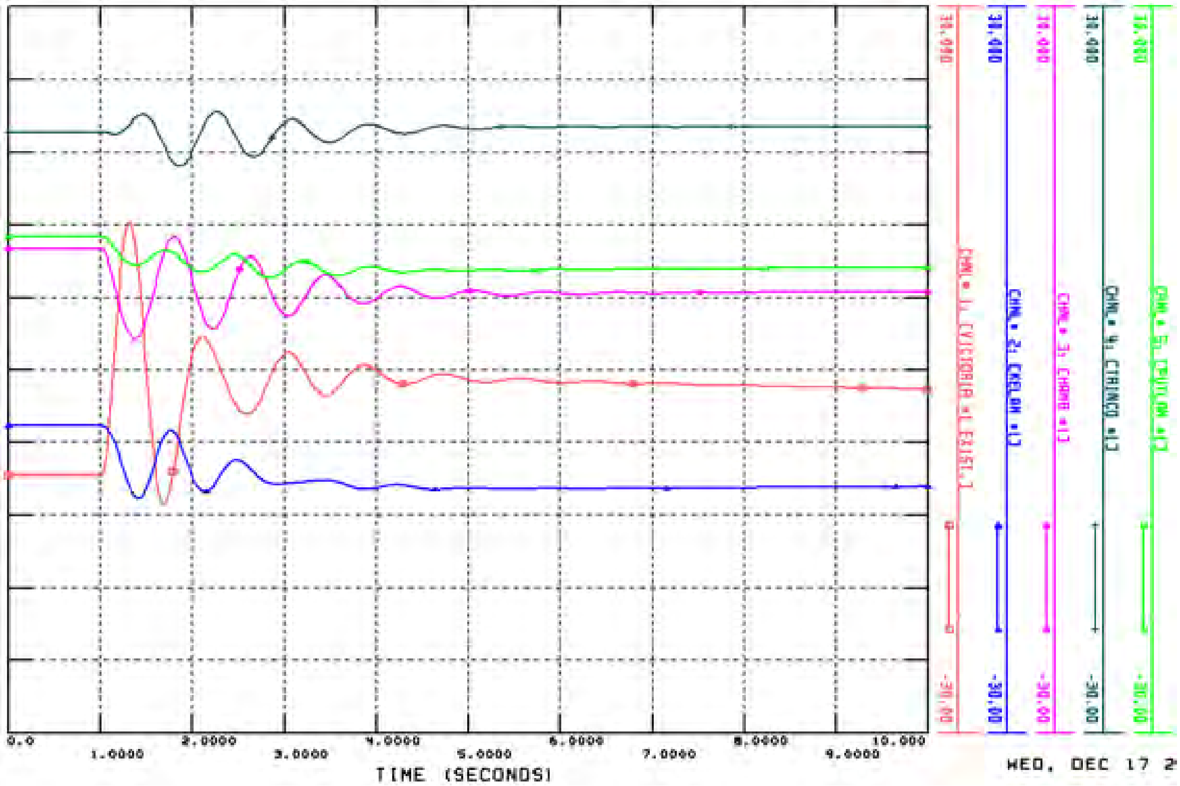


Figure 5-5 HMNP without Victoria Expansion - Double-circuits Trip; Rotor Angle

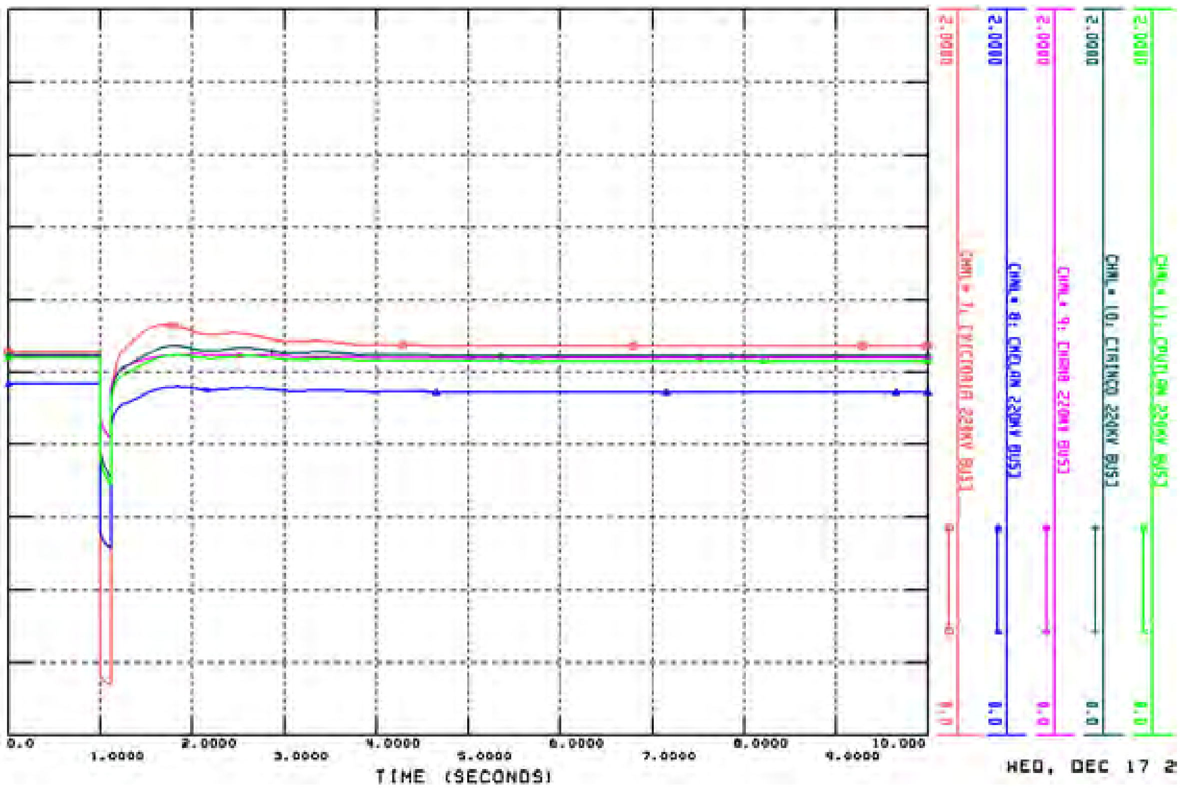


Figure 5-6 HMNP without Victoria Expansion - Double-circuits Trip; Bus Voltage

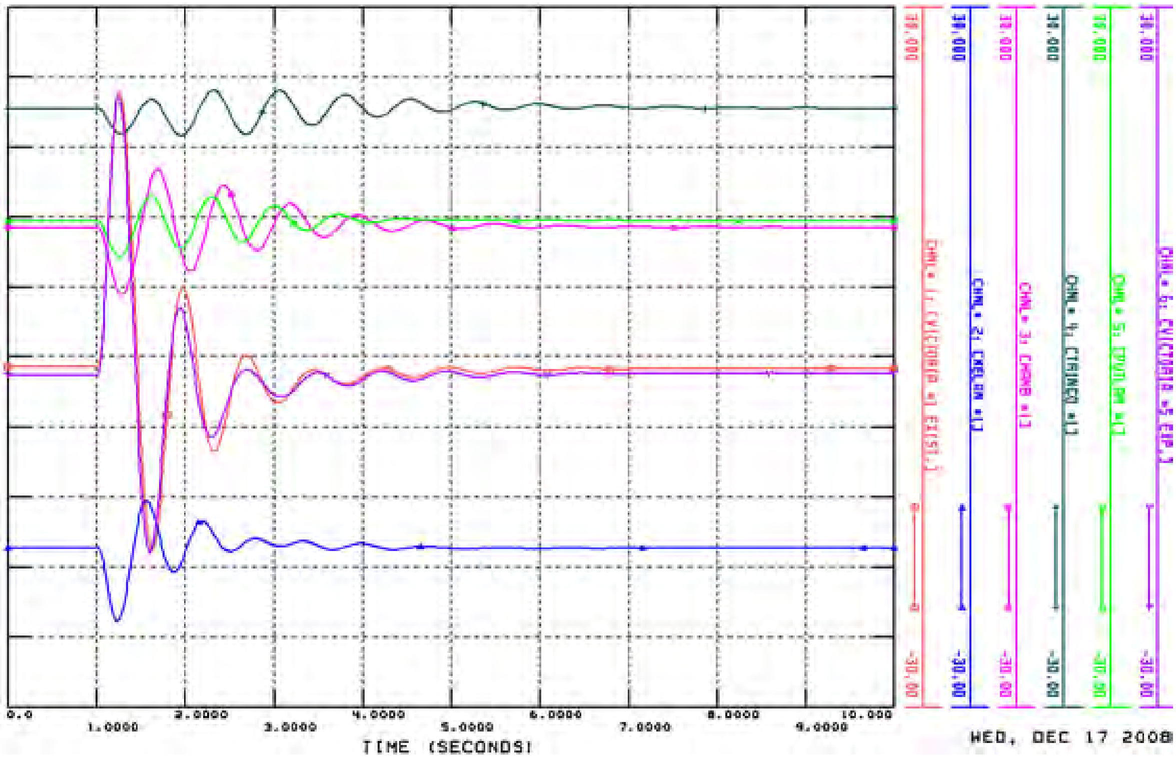


Figure 5-7 HMNP with Victoria Expansion - Successful Re-closing; Rotor Angle

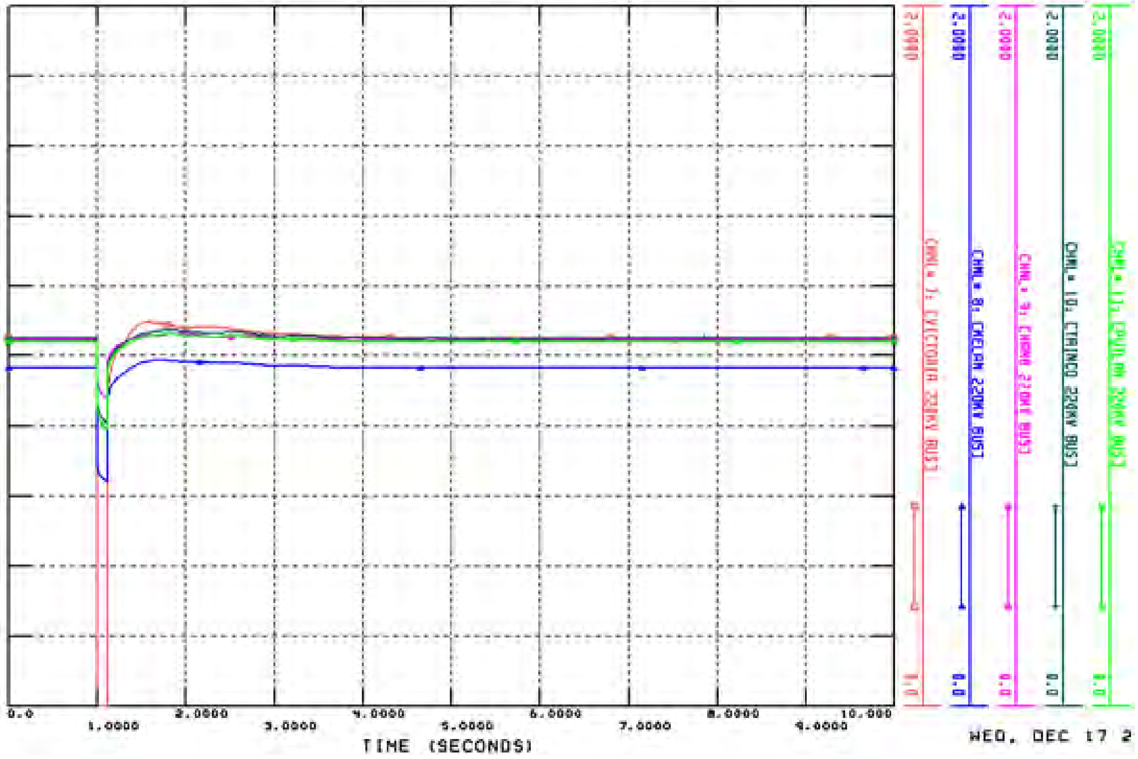


Figure 5-8 HMNP with Victoria Expansion - Successful Re-closing; Bus Voltage

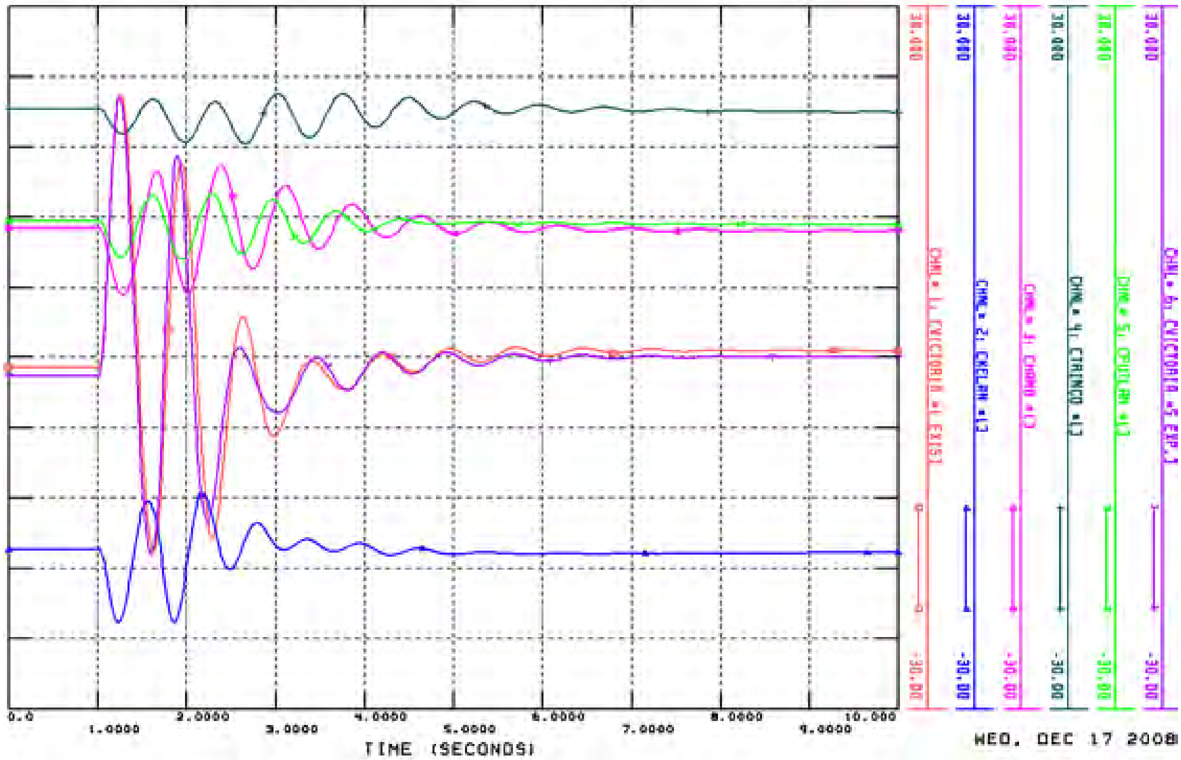


Figure 5-9 HMNP with Victoria Expansion - Unsuccessful Re-closing; Rotor Angle

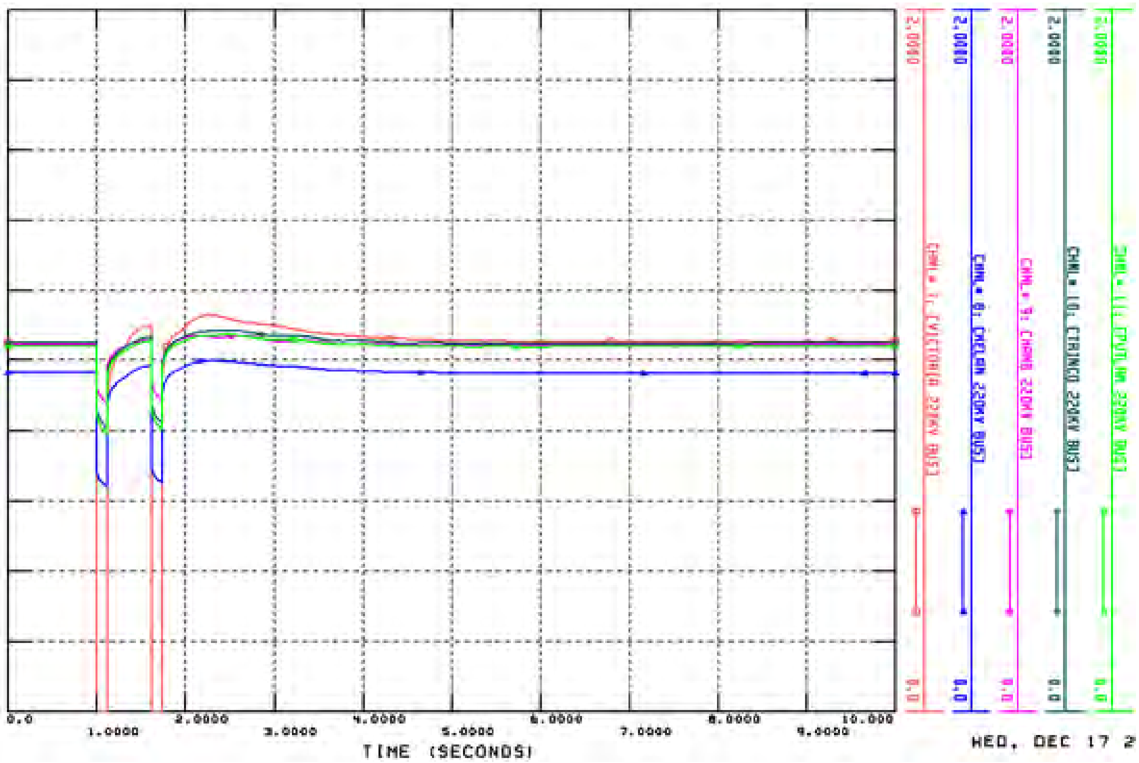


Figure 5-10 HMNP with Victoria Expansion - Unsuccessful Re-closing; Bus Voltage

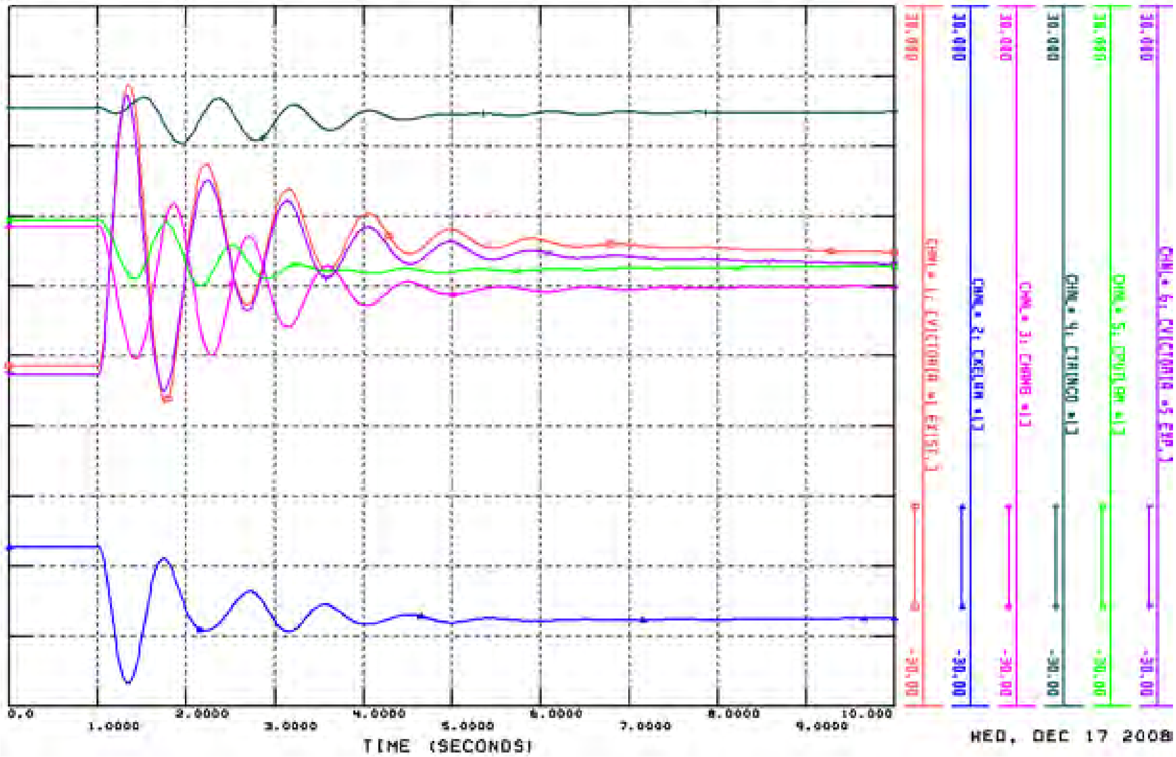


Figure 5-11 HMNP with Victoria Expansion - Double-circuits Trip; Rotor Angle

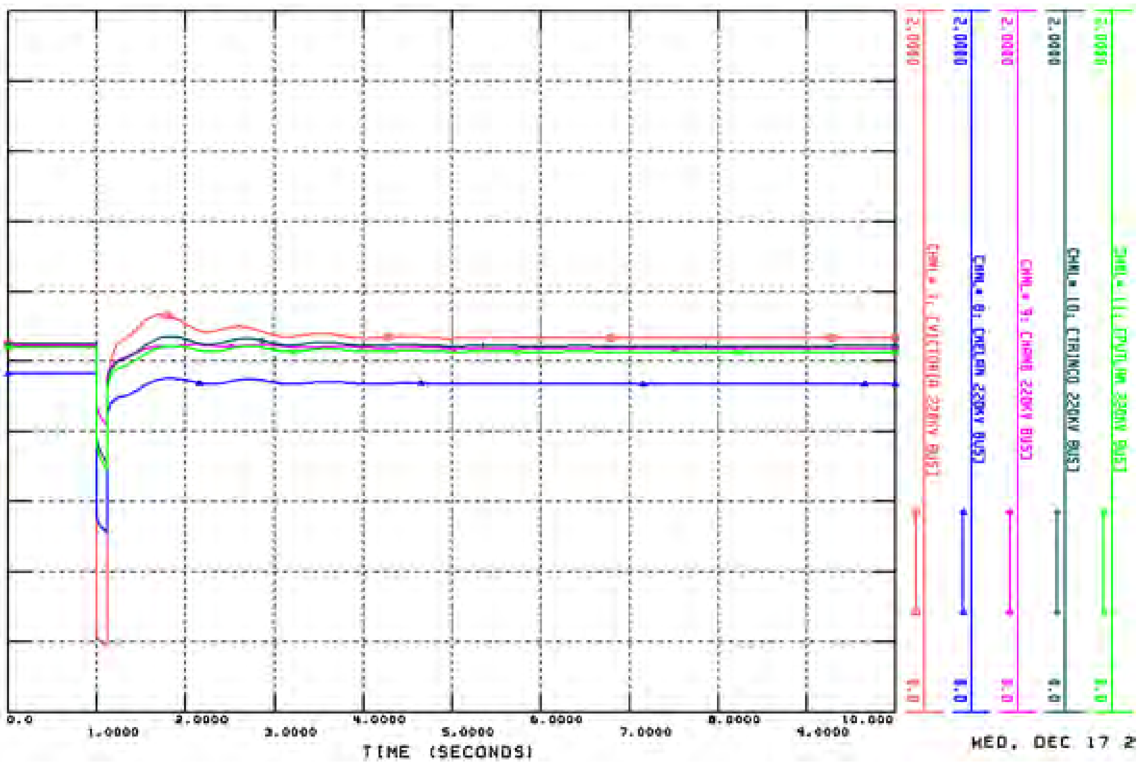


Figure 5-12 HMNP with Victoria Expansion - Double-circuits Trip; Bus Voltage

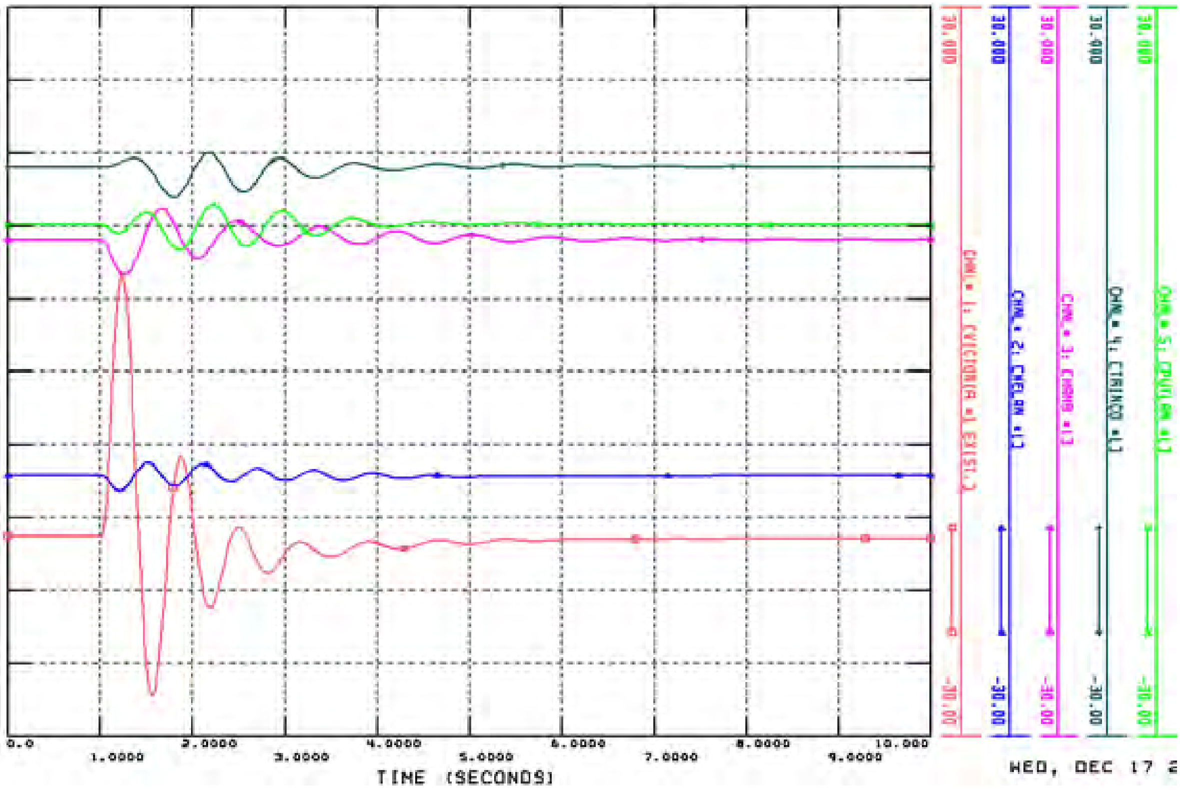


Figure 5-13 TMNP without Victoria Expansion - Successful Re-closing; Rotor Angle

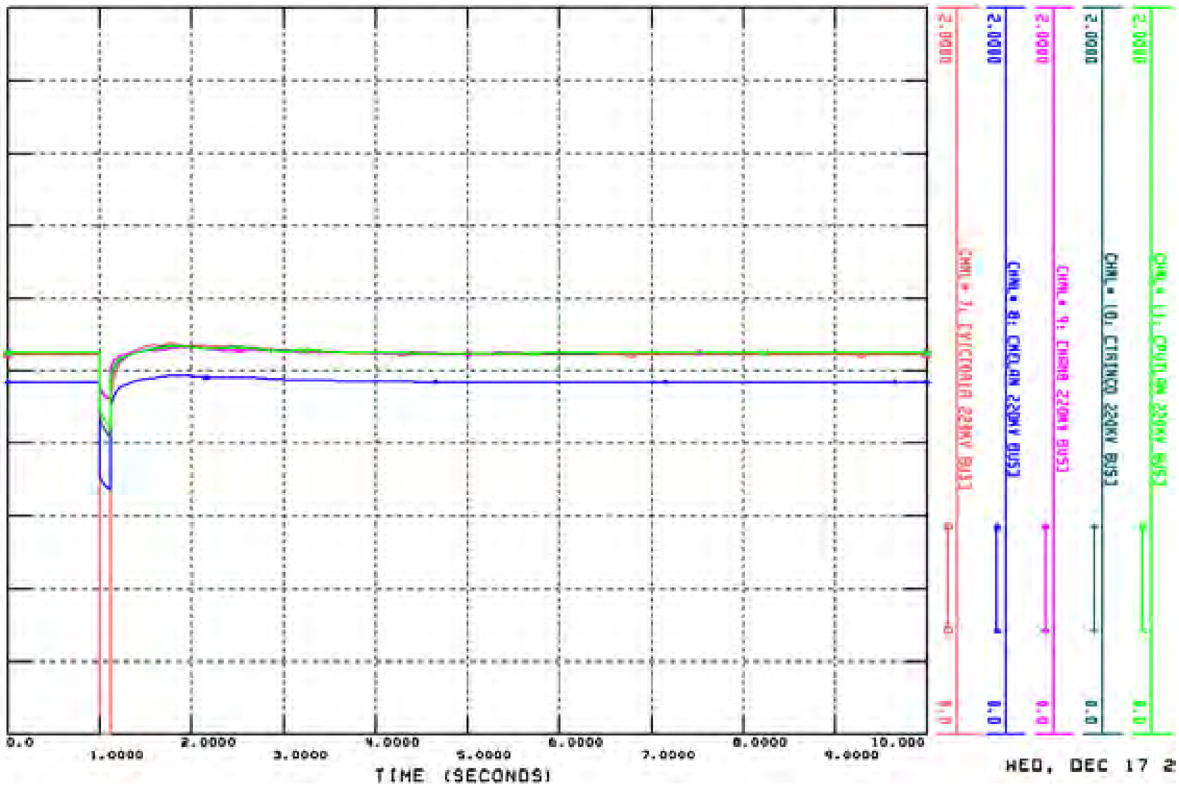


Figure 5-14 TMNP without Victoria Expansion - Successful Re-closing; Bus Voltage

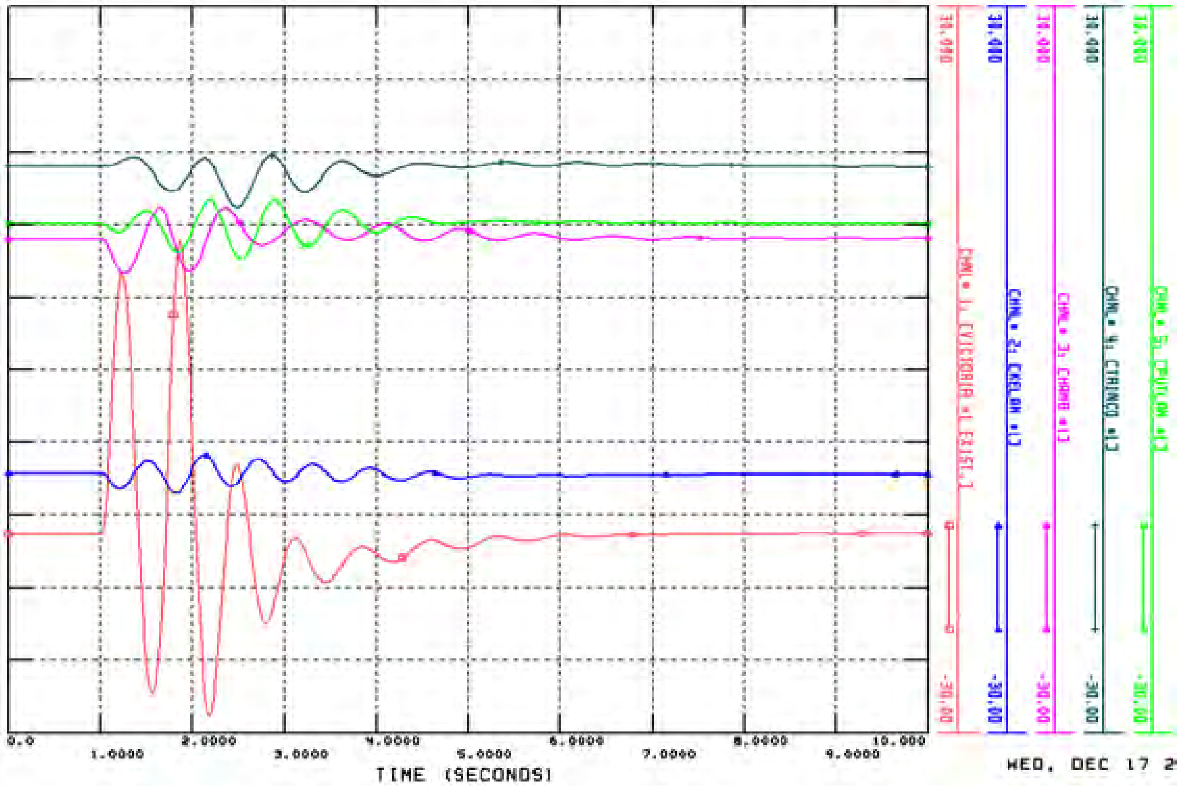


Figure 5-15 TMNP without Victoria Expansion - Unsuccessful Re-closing; Rotor Angle

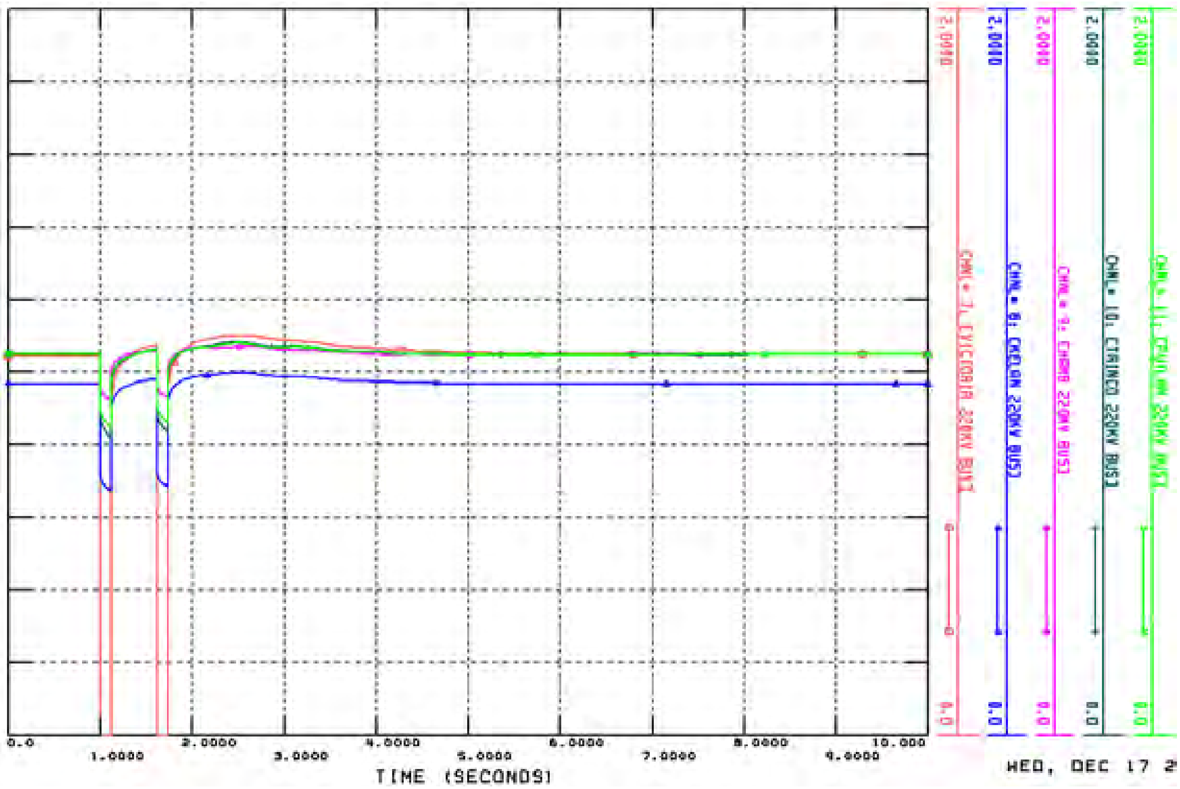


Figure 5-16 TMNP without Victoria Expansion - Unsuccessful Re-closing; Bus Voltage

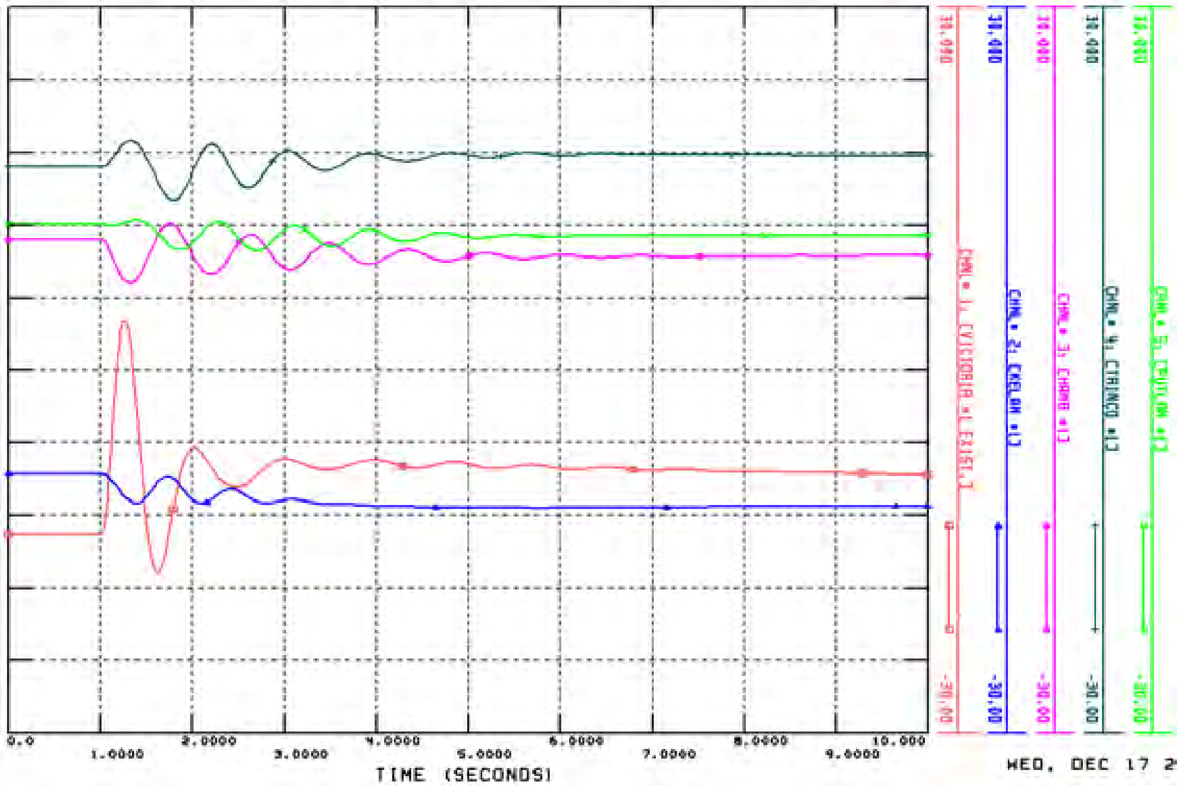


Figure 5-17 TMNP without Victoria Expansion - Double-circuits Trip; Rotor Angle

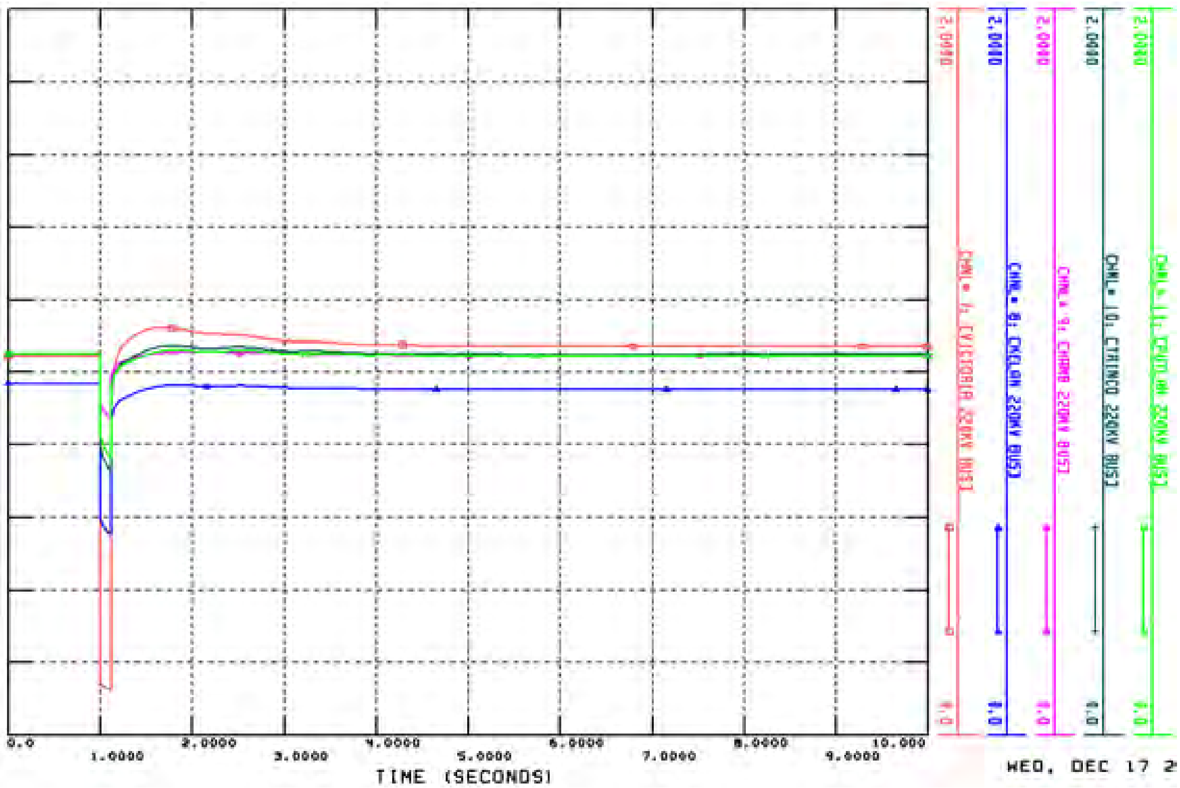


Figure 5-18 TMNP without Victoria Expansion - Double-circuits Trip; Bus Voltage

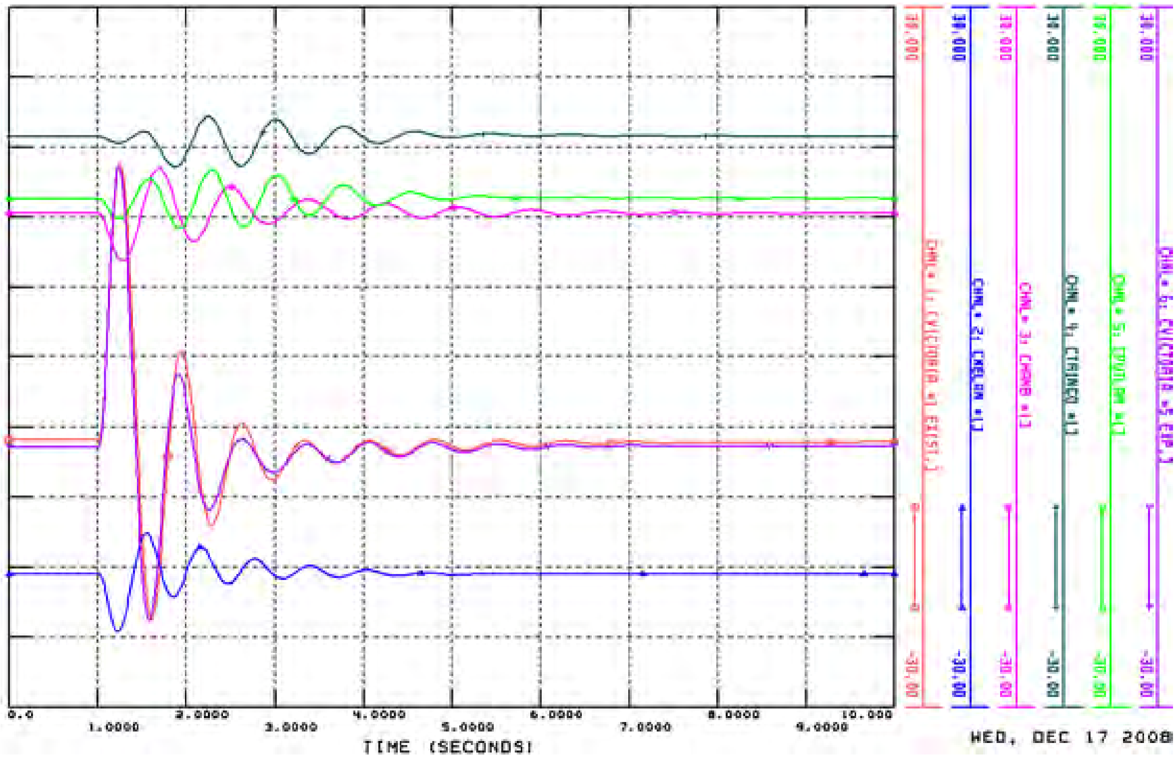


Figure 5-19 TMNP with Victoria Expansion - Successful Re-closing; Rotor Angle

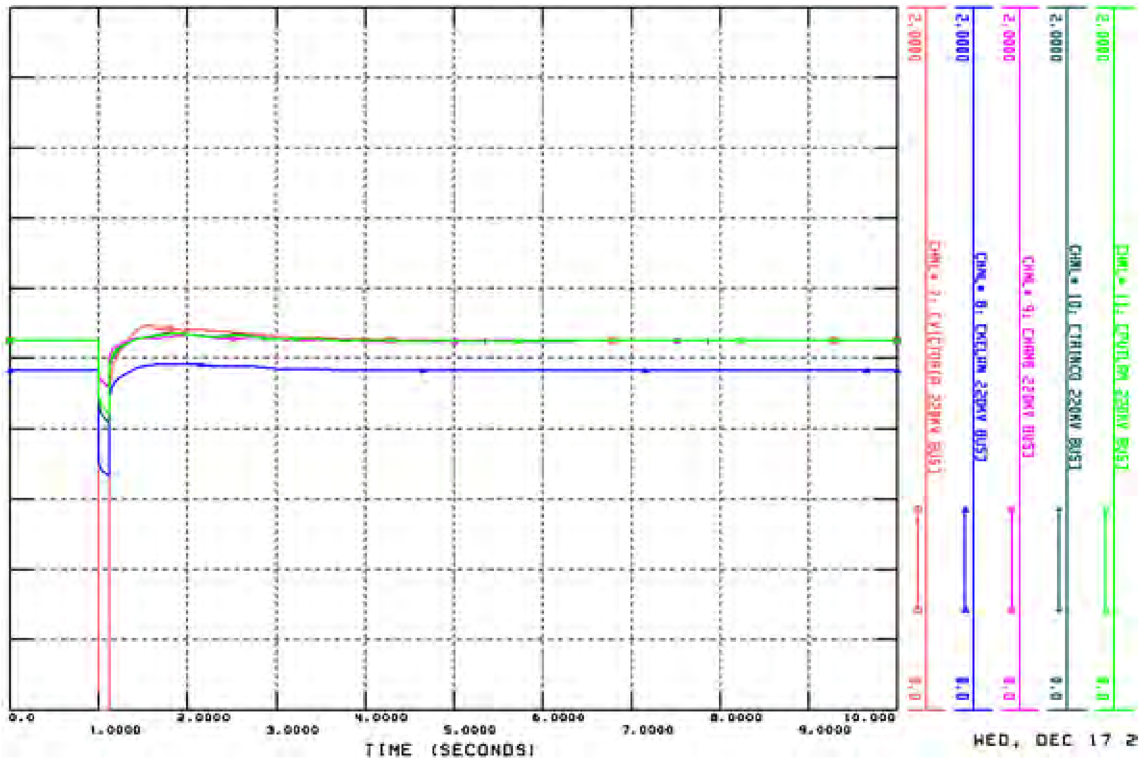


Figure 5-20 TMNP with Victoria Expansion - Successful Re-closing; Bus Voltage

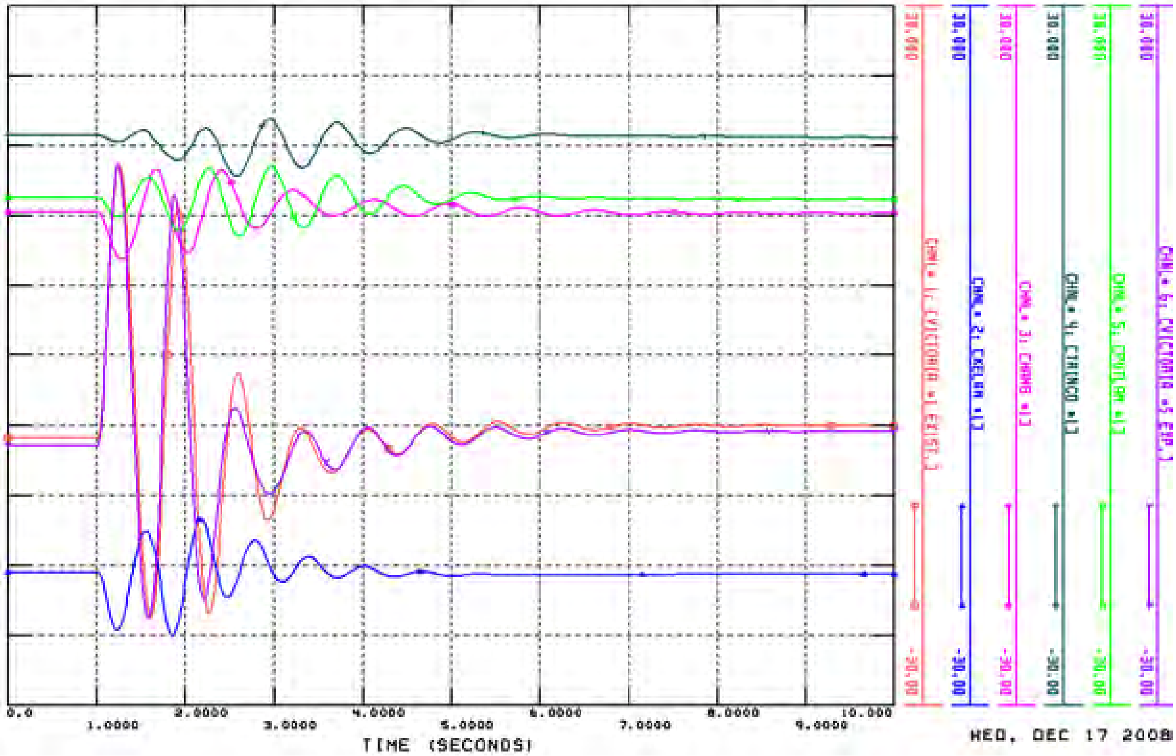


Figure 5-21 TMNP with Victoria Expansion - Unsuccessful Re-closing; Rotor Angle

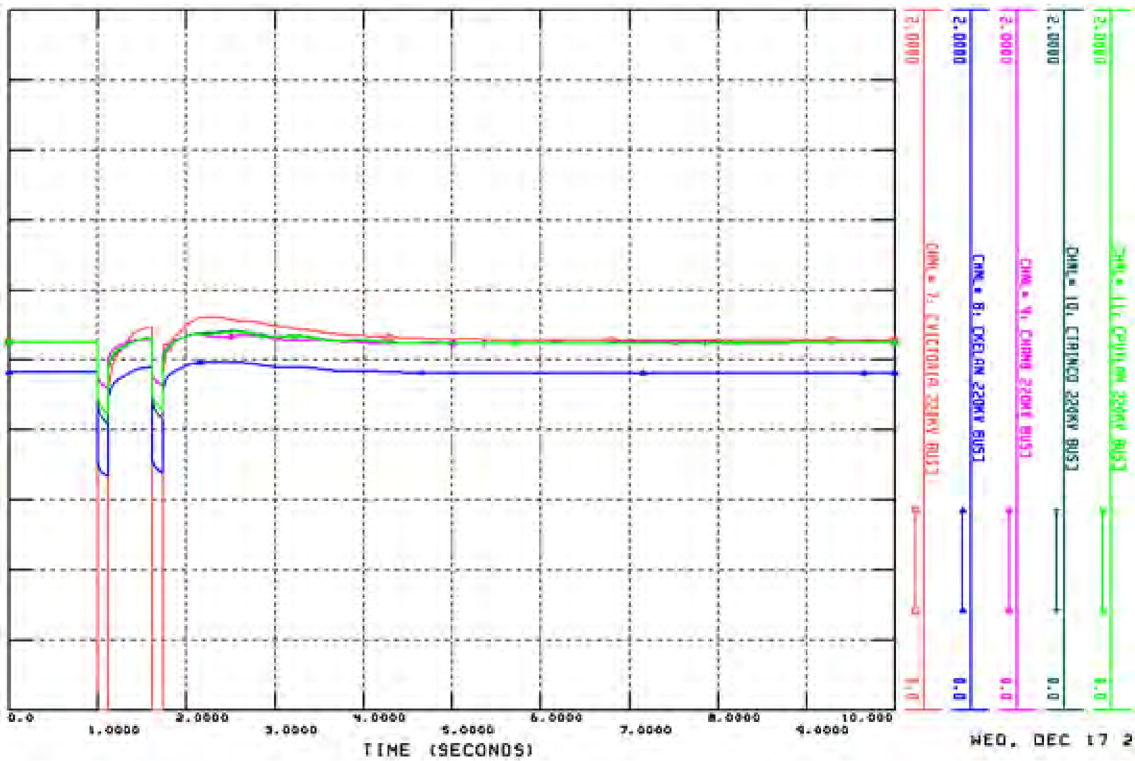


Figure 5-22 TMNP with Victoria Expansion - Unsuccessful Re-closing; Bus Voltage

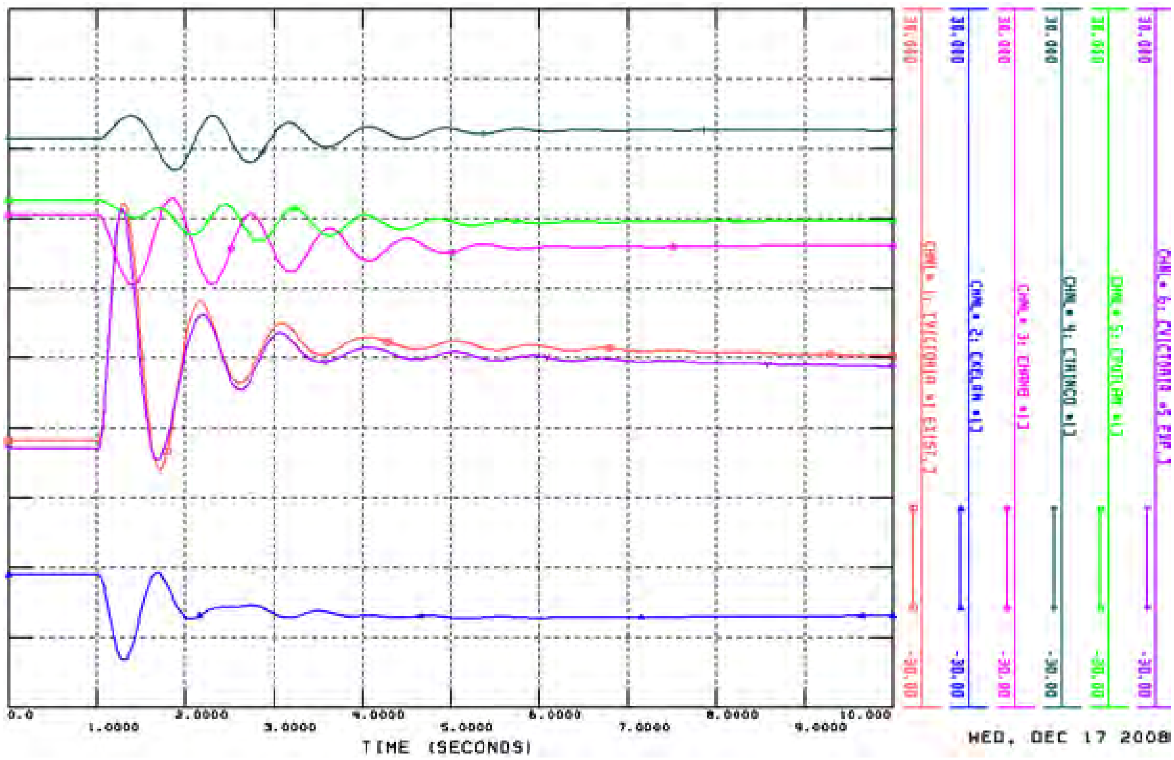


Figure 5-23 TMNP with Victoria Expansion - Double-circuits Trip; Rotor Angle

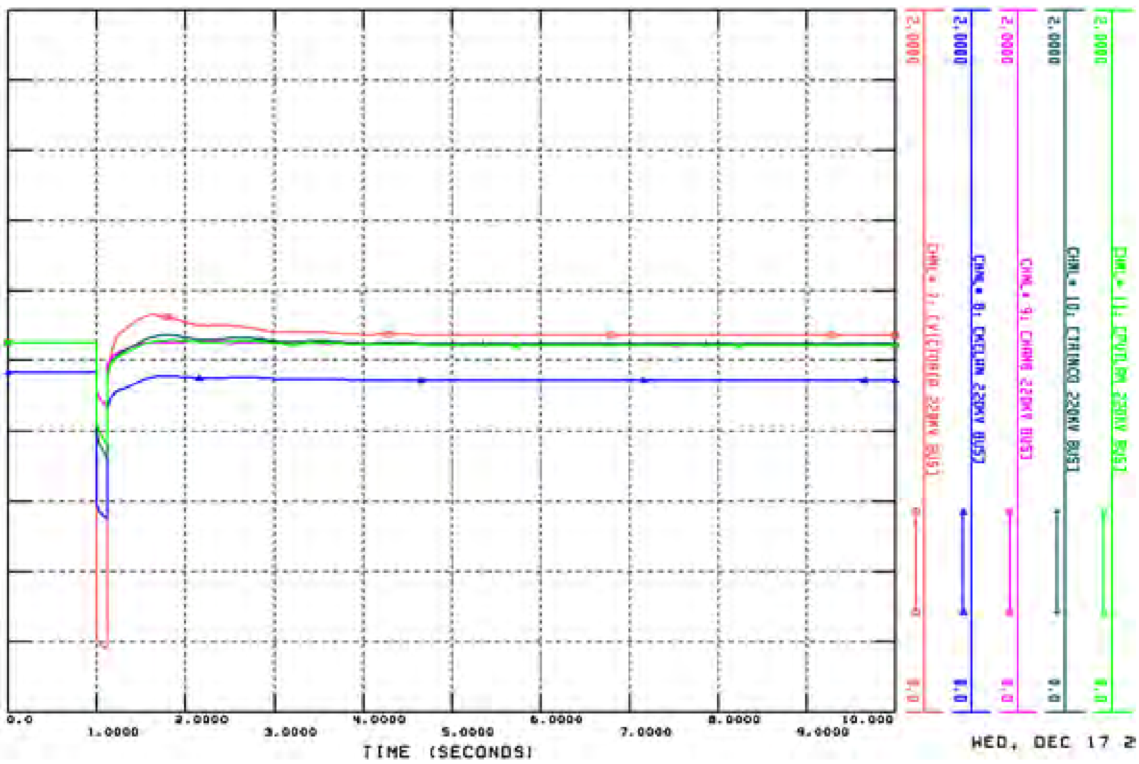


Figure 5-24 TMNP with Victoria Expansion - Double-circuits Trip; Bus Voltage

6. Conclusion

Following analyses were carried out for the scenarios of Hydro Maximum Night Peak and Thermal Maximum Night Peak.

- Power Flow Analysis
- Short Circuit Analysis
- Transient Stability Analysis

Many overloaded transformers were observed in the power system less than 132 kV, and low voltage of the buses were observed since most of small hydro-power plants were out of service in the scenario of Thermal-Maximum. However these problems would not depend on Victoria Expansion and the result of the analysis shows that any problems of the power system were not occurred by Victoria Expansion.

A brief study on the Victoria Expansion was carried out by CEB Transmission Planning Branch. No technical limitations were found in the study.

Chapter 10

Construction Planning and Cost for Construction

Appendix II-10-1

Estimate on Vibration of Victoria Dam

due to Blasting for Tunnel Works

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Estimate on Vibration of Victoria Dam due to Blasting for Tunnel Works

In this appendix, vibration of the Victoria dam due to blasting for excavation works of the new tunnel for the Project is estimated when the explosive amount used in the construction planning in the Study as follows:

1. Equation and Conditions for Estimate on Vibration due to Blasting

Velocity of vibration is estimated in the Study by following empirical equation;

$V = K \cdot W^{2/3} \cdot D^{-2}$

Where,

V : Velocity of vibration (cm/s)

K : Coefficient related to blasting conditions (Center-cut: 750, Side hole blasting: 350)

W : Loading of explosive per 1 rotation (kg)

D : Distance from the center of blasting

The following loading of explosive per 1 rotation (W) is assumed under the conditions that 2.5 m excavation by one blasting is required in consideration of total construction schedule and that vibration of the existing tunnel, which is located 36 m away from the new tunnel, due to the blasting does not exceed 2.0 cm/s;

W = 9.0 kg for center-cut

W = 15.5 kg for side hole blasting

2. Estimate on Vibration of the Victoria Dam

The nearest points to the Victoria dam in the new access adit and new headrace tunnel are selected as the blasting points for estimate of vibration of the Victoria dam (see **Figure 1**). The approximate distance between the nearest point in the new adit and the dam is 85 m, and that from the point in the new headrace tunnel is 175 m.

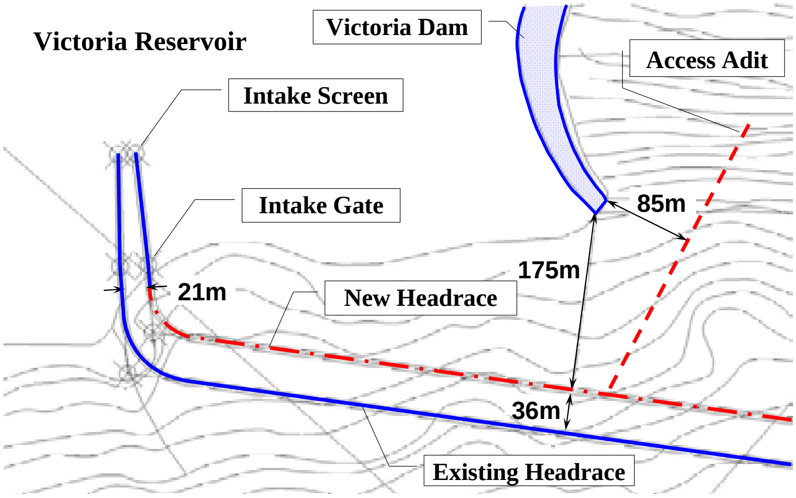

Figure 1 Blasting Points for Estimate of Vibration

Vibration of the dam due to the blasting at the selected points is calculated with the equation and conditions mentioned Section 1. Vibration of the dam due to the blasting at the nearest point in the new adit is estimated at 0.4 cm/s, and that due to the blasting at the point in the new headrace tunnel is estimated at 0.1 cm/s (see **Figure 2**). Therefore, vibration velocity of the dam is less than 2.0 cm/s which is set as the maximum allowable vibration velocity.

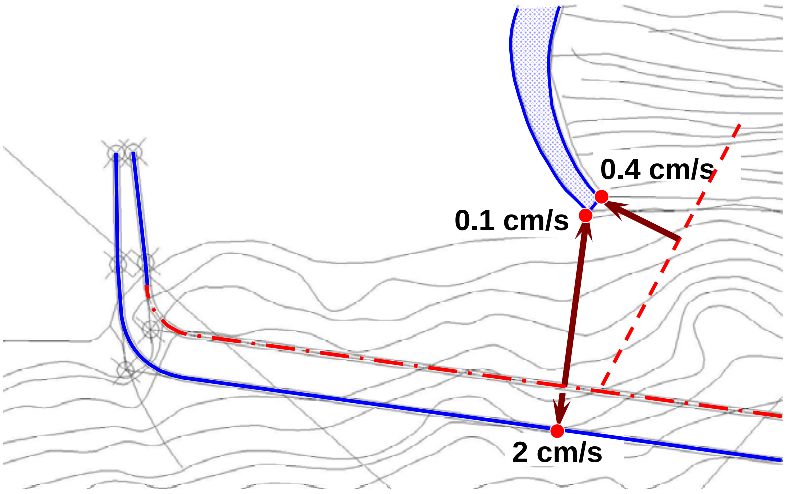

Figure 2 Estimated Vibration Velocity of the Dam