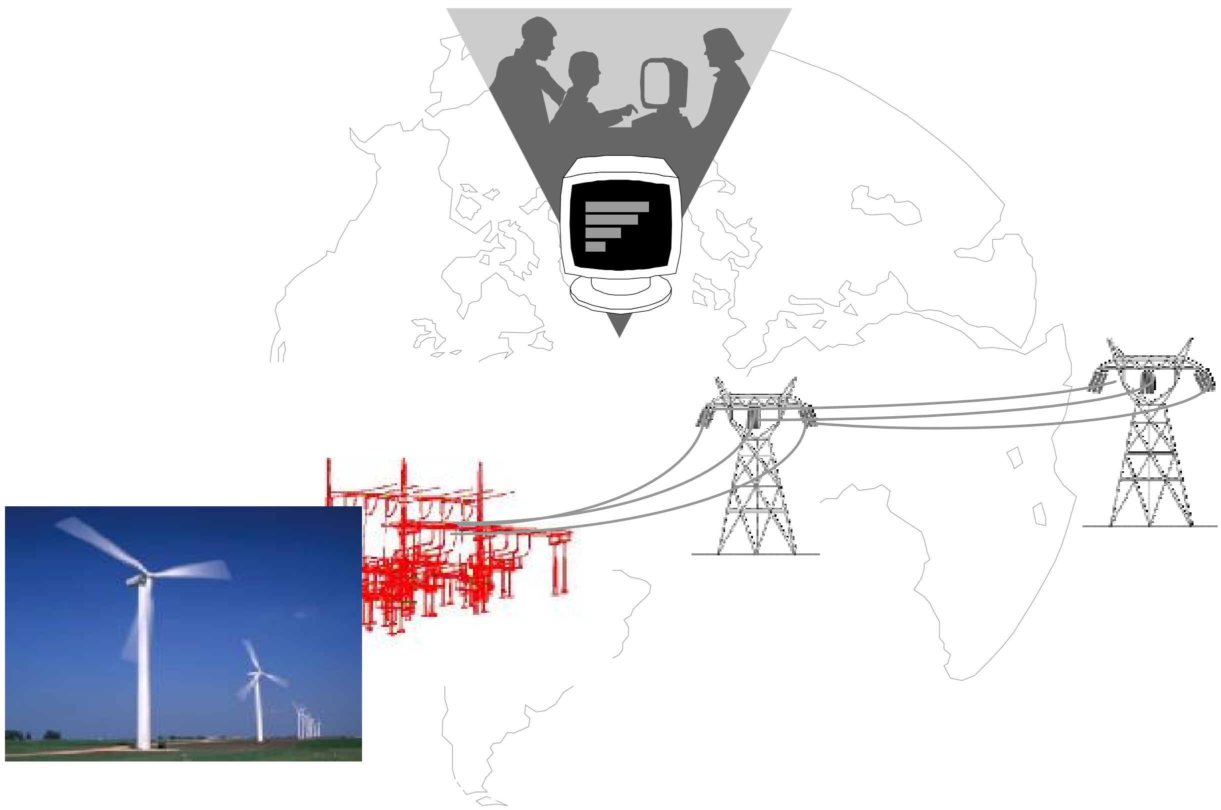
APPENDIX 1

AIM Power Generation Corporation



ERIE SHORES WIND FARM

SYSTEM IMPACT STUDY

July 2004

Final Report

POWER-tek Global Inc.

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1.0 INTRODUCTION

AIM PowerGen Corporation has contracted POWER-tek Global Inc. to carryout a System Impact Assessment of their proposed Wind Farm development at Port Burwell vicinity. The proposed Wind Farm will deliver power to the System via a 115 kV line which would tap into Hydro One's transmission line W8T from Buchanan TS to Tillsonburg TS. The study commenced with a 150 MW size Wind Farm and later a 100 MW Wind Farm was added to the scope.

The IMO provided significant support by providing the system models, study scope and assessment of results. MacViro Consultants Inc provided the wind farm electrical design and manufacturers' data about the wind generators and turbines. This project is assumed to be based upon the GE 1.5 MW Wind Turbine system.

The purpose of this system study is to determine the system impact of the Wind Farm Connection upon the IMO system under a variety of local and system-wide scenarios as proposed by the IMO. The findings will ensure that the Wind Farm will not reduce system performance as outlined in the IMO published criteria. The results could also guide the specification of Wind Farm parameters. The findings are valid for a 150 MW and 100 MW size of Wind Farm at this location.

Section 2 of this report summarizes the data being used while input data and detailed results are contained in the Appendix A. The scenarios to be studied were outlined in the IMO Study Scope document attached in Appendix A. Section 3 outlines the studies the 150 MW size Wind Farm for the local impact of the Wind Farm and the Reactive Power requirements under peak and light load conditions. The 100 MW size of Wind Farm was added to the study scope later and Section 4 outlines local impact studies of this Wind Farm size. Some of the transient stability studies of the 100 MW Wind Farm use the advanced GE/PTI Wind Turbine/Generator/Controls model. This model was used for the Bruce-Milton-Claireville outage and other studies such as the impact of Wind Gusts on local voltages as outlined in Section 4. Section 5 contains the 150 MW Wind Farm load flow study where the system contingencies and local voltages impacts are studied under two major system dispatch scenarios namely 'BLIP' power flows of -1500 and of 3000 MW. A Light Load scenario is also included in the load flow studies. The dynamics of the system is reported in the transient stability study in Section 6 for the 150 MW Wind Farm. These studies are also valid for the smaller 100 MW Wind Farm. The findings and conclusions of the System Impact Study are contained in Section 7.

The IMO required that the report and associated computer files record sufficient detail about the assumptions, system conditions and detailed graphs and plots. Detailed plots and tables are provided in the Appendix A. Also, several CDs containing the load flow and dynamics models and results is provided.

2.0 IMO System and Erie Shores Wind Farm Model

2.1 *Wind Farm Data*

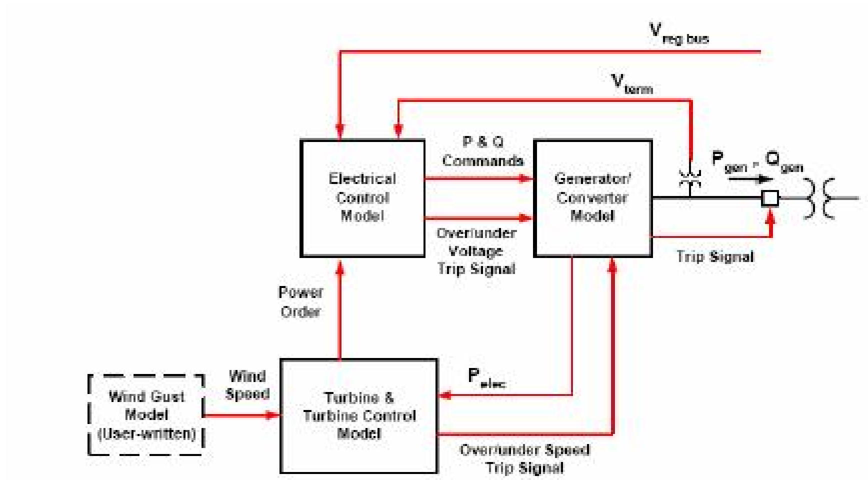
The data for the above wind farm was obtained from the preliminary drawings and manufacturers' data. The input data was interpreted and is summarized in figures on the next four pages. Figures 2.3 and 2.5 display the equivalent circuit; an electrical equivalent and not the physical layout. The physical layout is shown in Figures 2.2 and 2.4. Figure 2.1 displays the overall generator/wind turbine/controls that are encapsulated in the model of the GE 1.5 MW Wind Farm obtained from PTI for use in the PSSE software used for the simulations. Details are also given in the Appendix A.

The two major available features of the GE 1.5 MW model are:

- Use of double-wound induction generator which is capable of producing MVARS and a VAR control system by which the voltage at the collector station can be controlled

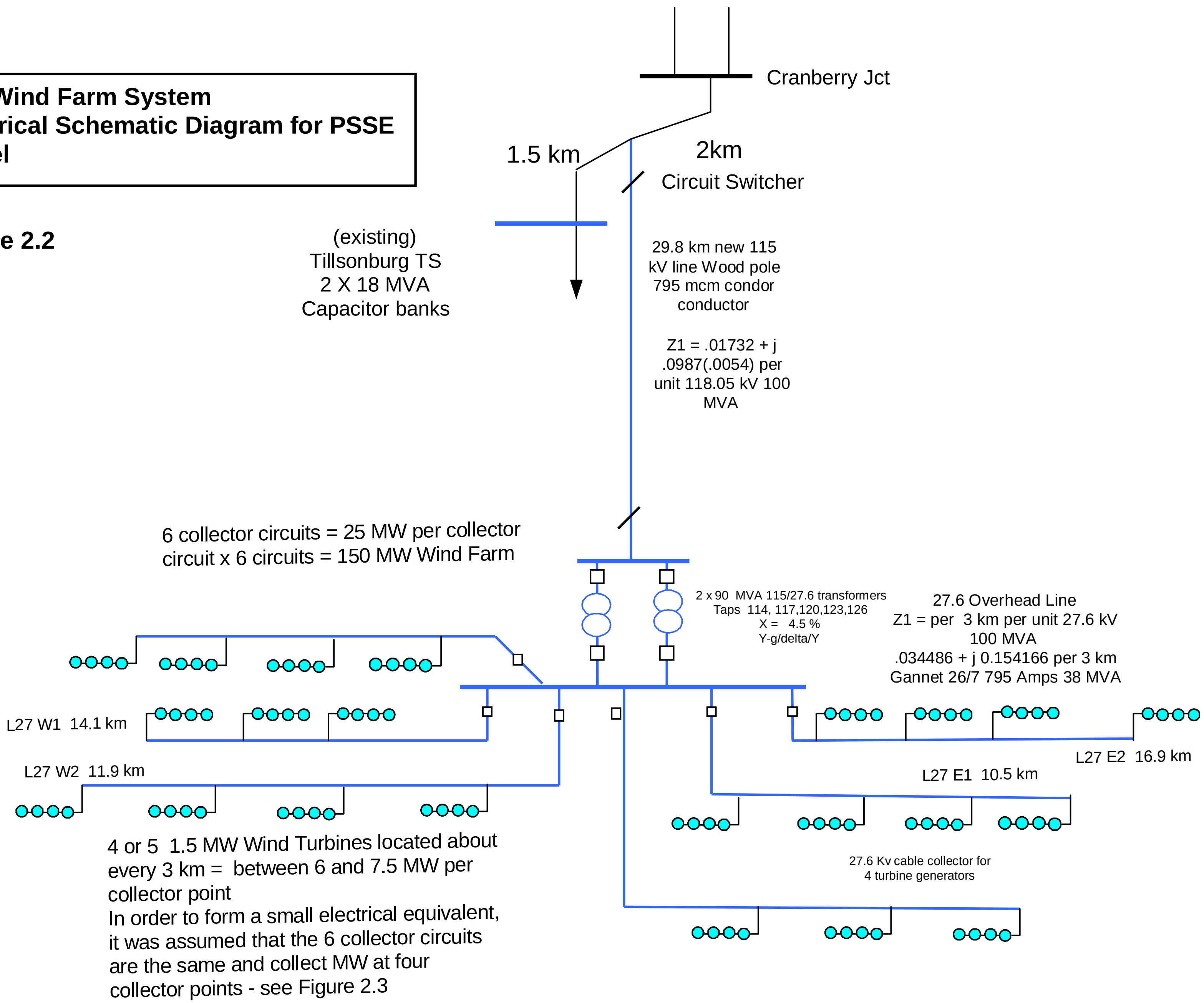
- Input of Wind Speed and Wind Gusts into the model enabling impact of wind gusts to be studied. Wind Gusts models required that the initial wind speed and the peak wind speed to be input as well as the duration of the wind gust. Nominal values of 6m/s for the initial and 15 m/s for the peak and a 5 second Wind Gust was used.

Figure 2.1 GE 1.5 MW Wind Turbine-Generator and Controls in PSSE Model



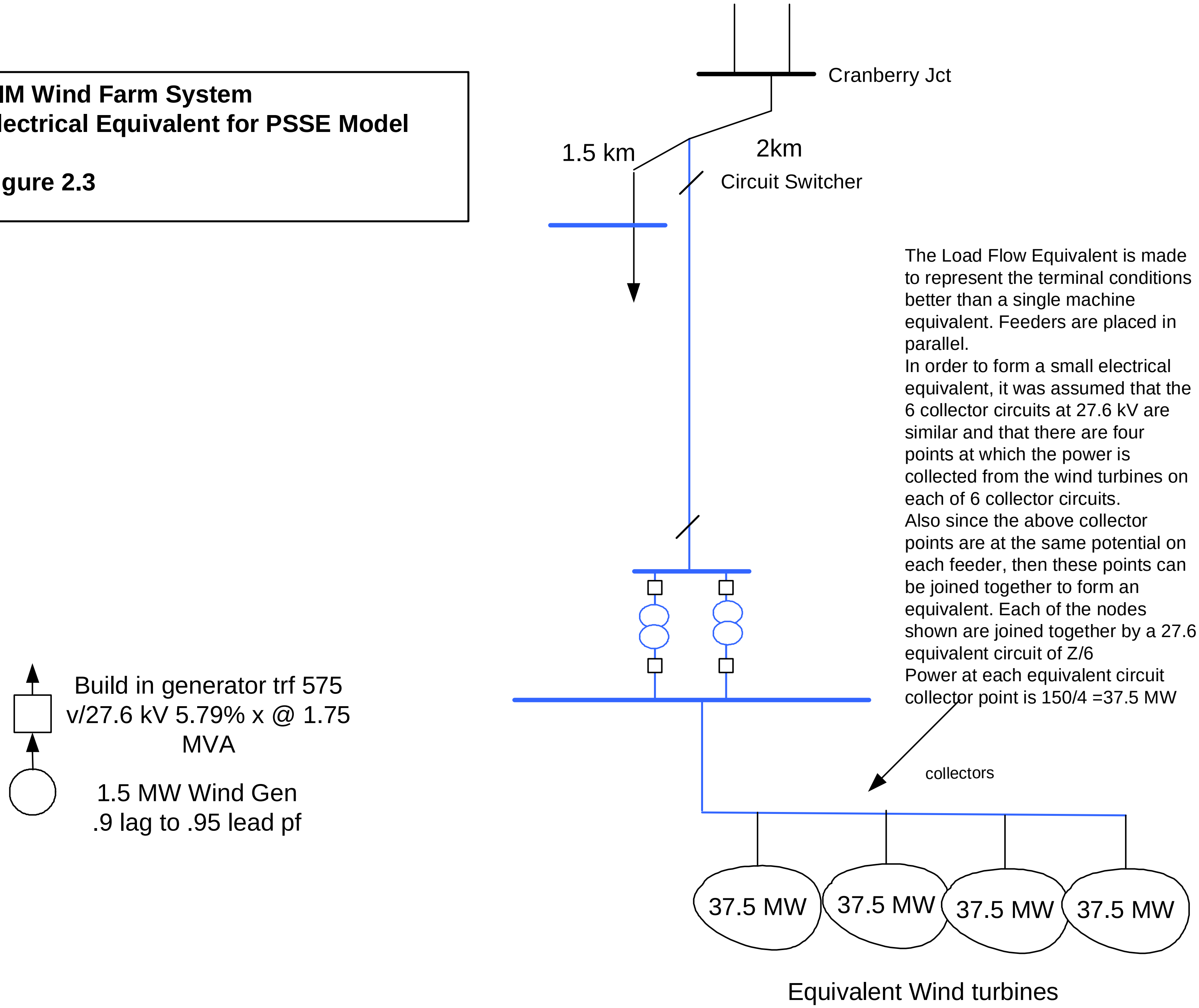
**AIM Wind Farm System
Electrical Schematic Diagram for PSSE Model**

Figure 2.2



AIM Wind Farm System
Electrical Equivalent for PSSE Model

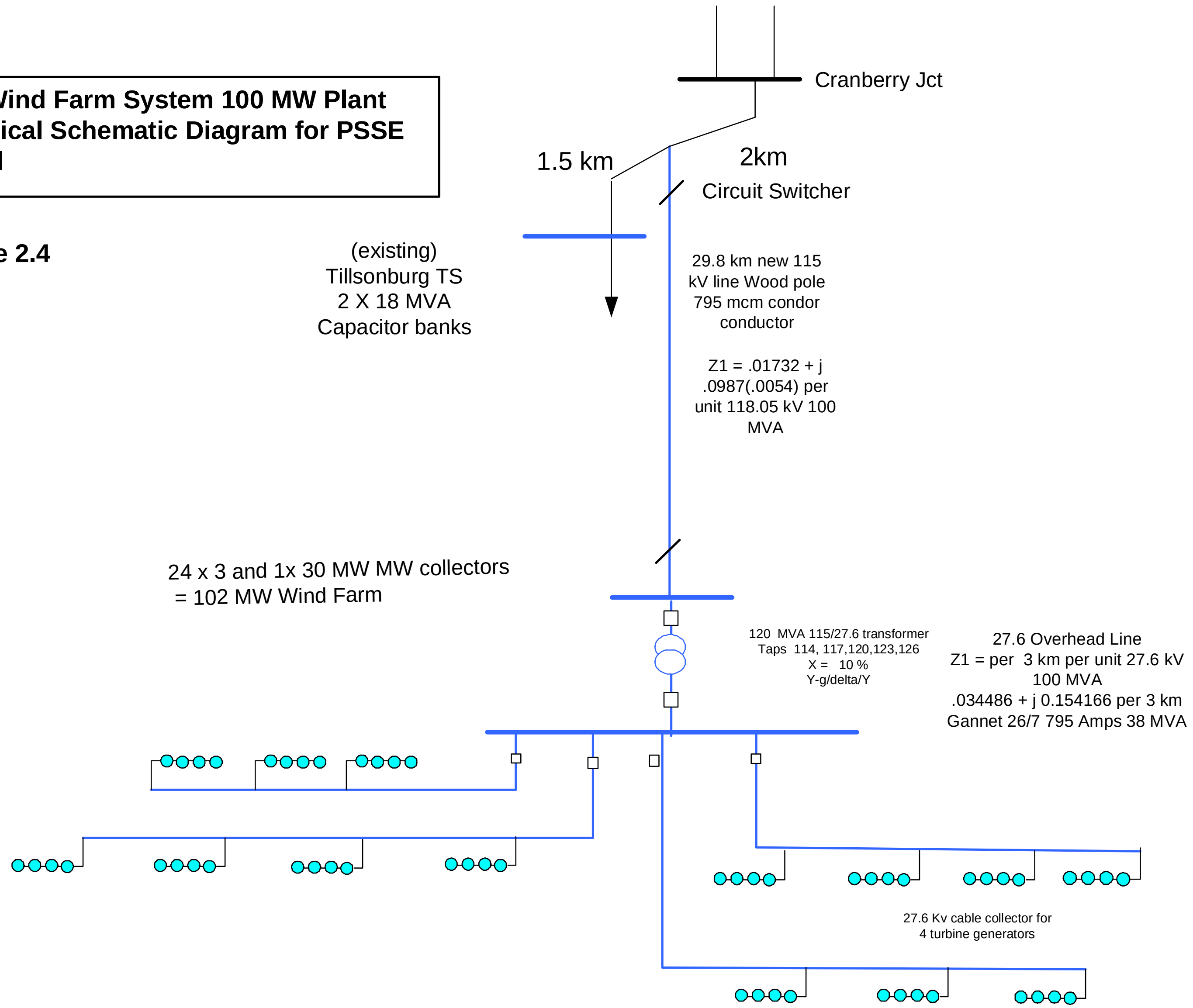
Figure 2.3



The Load Flow Equivalent is made to represent the terminal conditions better than a single machine equivalent. Feeders are placed in parallel.
In order to form a small electrical equivalent, it was assumed that the 6 collector circuits at 27.6 kV are similar and that there are four points at which the power is collected from the wind turbines on each of 6 collector circuits.
Also since the above collector points are at the same potential on each feeder, then these points can be joined together to form an equivalent. Each of the nodes shown are joined together by a 27.6 equivalent circuit of Z/6
Power at each equivalent circuit collector point is 150/4 =37.5 MW

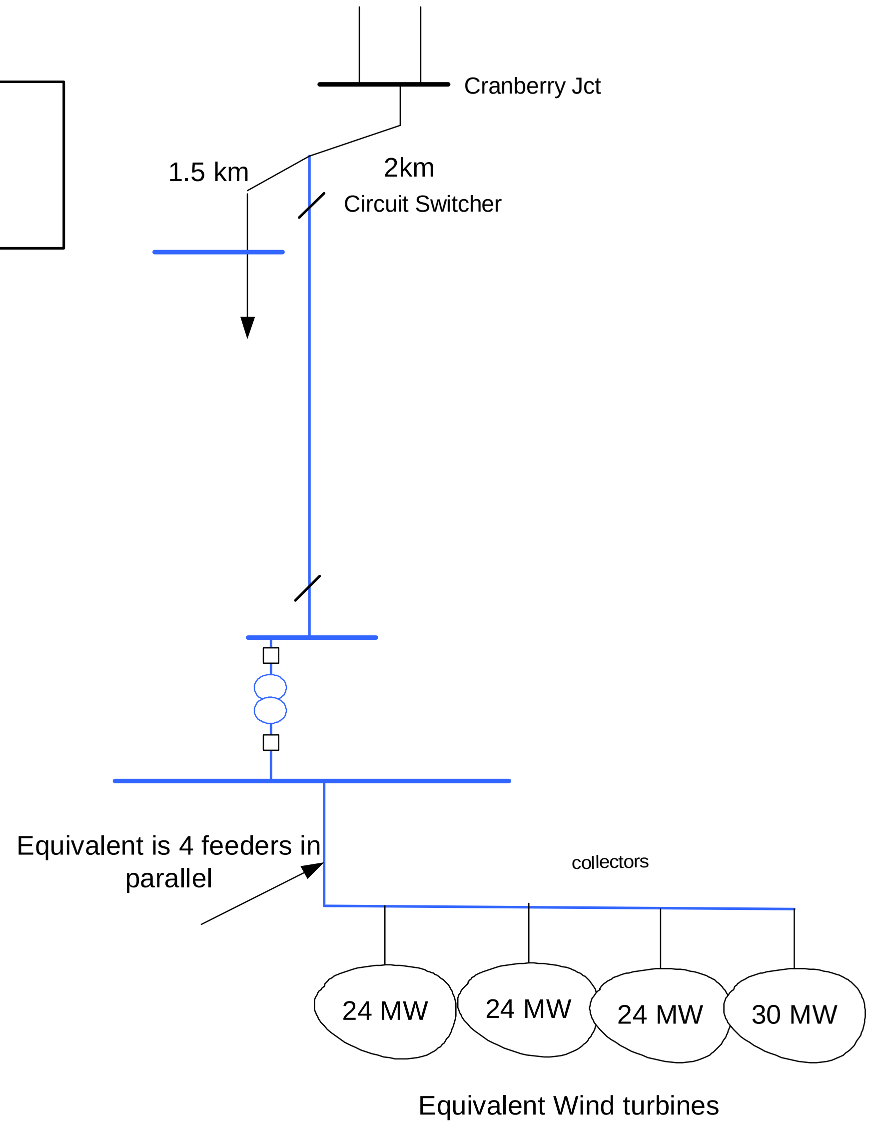
AIM Wind Farm System 100 MW Plant Electrical Schematic Diagram for PSSE Model

Figure 2.4



AIM Wind Farm System 100 MW
Electrical Equivalent for PSSE Model

Figure 2.5



2.2 *IMO Load Flow and Stability Models and Data*

The IMO provided load flow and stability models for PSSE. The systems provided modeled the 2005 peak conditions. The IMO system load was 24,888 MW and losses 866 MW for a total demand of 25,741 MW. The model represented the Eastern Interconnected system of North America in about 40,000 nodes.

The IMO model was updated to include the 150 MW AIM Wind power equivalent as was explained in Section 2.1 while displacing coal fired generation at Lakeview. The Wind Generator was modeled as an Induction Generator (CMITR3 model in PSSE) in most of the 150 MW Wind Farm studies. The Wind Turbine/Generator/Controls were updated to use the PTI's advanced GE 1.5 MW Wind System models that were approved by GE.

The Wind Farm is connected to a radial W8T arrangement as per the open points (see the diagram in the Appendix) provided by the IMO. The loads at Aylmer and Tillsonburg TS are a major factor in the study the net power is exported to the system. The IMO provided these values for the loads and existing capacitors in the Load Flow Base Case:

Table 2.1 Local Load Levels

Load	Peak Load MW	Peak Load MVAR	Light Load MW	Light Load MVAR	Available Capacitors
Tillsonburg	97	36	28	11	2 x 18 MVAR
Aylmer	11.4	4.4	5	2.7	5 MVAR
Totals	108.4	40.4	33	13.7	41 MVAR
Local excess power before losses For 100 MW Wind Plant	-8.4	0.6	67	N/A	

3.0 Local Area Impact for a 150 MW Wind Farm

The IMO scope outlined various studies and quantities that must be studied. The power flow on the circuit that connects the Wind Farm to the IMO main grid at Buchanan was evaluated. The voltage profile of the system was studied for various states of the Wind Farm from full power to zero power and to an offline state. The result of these studies is the reactive power requirements on the Wind Farm so that the impact on the system is positive or at the least not outside the required voltage criteria.

3.1 *W8T Power Flows*

The flows at Buchanan on W8T are shown in Table 3.1 under various conditions. When the 150 MW Wind Farm is online at 150 MW output, the W8T flow out of Buchanan is -33.4 MW and 34 MVAR. The Wind Farm generators are set to control the Wind Farm Voltage at 27.6 kV with that 27.6 kV transformer at the 120 kV tap ratio. As will be shown later, this voltage profile is recommended. When the Wind Farm is offline, the same power flow is 114.2 MW and 31.5 MVAR. Since the total local peak load (see Table 2.2) is 108.4 MW then the local line losses are 5.8 MW without the Wind Farm. Table 3.1 also displays the change is Ontario system losses which indicate that the losses are lower when the Wind Farm is on-line.

Under Light Load Conditions, W8T Flow is -105 MW and 51.8 MVAR with the Wind Farm at 150 MW.

3.2 *Voltage Profiles for Various Wind Farm Power Output Levels*

3.2.1 Peak Load Study

Figure 3.1 shows the voltages at Buchanan 115 kV, Aylmer 115 kV, Tillsonburg 115 kV and AIM 115 kV buses. A longer list of voltages is documented in the Appendix A for each case. Load Flow Plots are also available in the Appendix A and two sample plots are shown before Figures 3.1 and 3.2 for peak and light load conditions respectively.

It is possible to use the 0.9 pf reactive capability of the Wind Farm to control various types of voltage profile in the system between Buchanan and AIM Wind Farm. A high voltage profile plot shows 126 kV voltage level at both ends and the voltage profile is flatter with 122 kV at Tillsonburg. If the AIM voltage is held at 120 KV then the voltage profile is lower with 118.5 kV level at Tillsonburg.

In either case, when the Wind Farm goes offline, at peak load, the Tillsonburg voltage will be about 115 kV even with the available capacitors (see Table 2.1) online. This shows that the Wind Farm generators should hold the voltages at the 120 kV level in order to avoid too much of a voltage change at the load centers of Tillsonburg and Aylmer, when the Wind Farm goes off line. The overall objective is to keep the voltage at the WIND at below 120 kV (although the wind farm can also hold much higher voltages while it is on line).

3.2.2 Light Load Study

Figure 3.2 shows the voltages at Buchanan 115 kV, Aylmer 115 kV, Tillsonburg 115 kV and AIM 115 kV buses. A longer list of voltages is documented in the Appendix A for each case. Load Flow Plots are also available in the Appendix A.

Under light load conditions, the area voltage profile can be quite flat if some of the available capacitors are switched off as the load drops off during the overnight periods. There is less than 2 kV change in the Tillsonburg voltage when the Wind Farm goes off line, and if the voltage profile is controlled.

3.2.3 Reactive Power Requirements

The Wind Turbines are to be specified to have a reactive capability of 0.9 pf lagging (exporting vars to the system) to 0.95 leading. The output of the wind turbines is collected at 27.6 kV and the stepped up to the 115 kV systems. The location of the Wind Turbines is 30 km from the Tillsonburg load center and about 90 km from the major Buchanan substation. As shown previously, the required local voltage profile is below about 120 kV at the Wind Farm to cater for the situation where the Wind Farm goes off –

line at peak load. This is a requirement even though the voltage drop is less than 4% in this case because there are situations where this drop can be greater (when the Buchanan voltage is lower). When the Wind Farm is on-line, the reactive capability to be provided results is a good voltage control at Tillsonburg and Aylmer and a tight voltage control at the Port Burell collector station. When there is insufficient wind and the Wind Turbine stop and the generators are disconnected, the Tillsonburg and Aylmer voltage profiles return to the present day voltage profiles. This change will need to be compensated by addition of MVAR sources at the time that the Wind Farm is off-line and if the area demand is high.

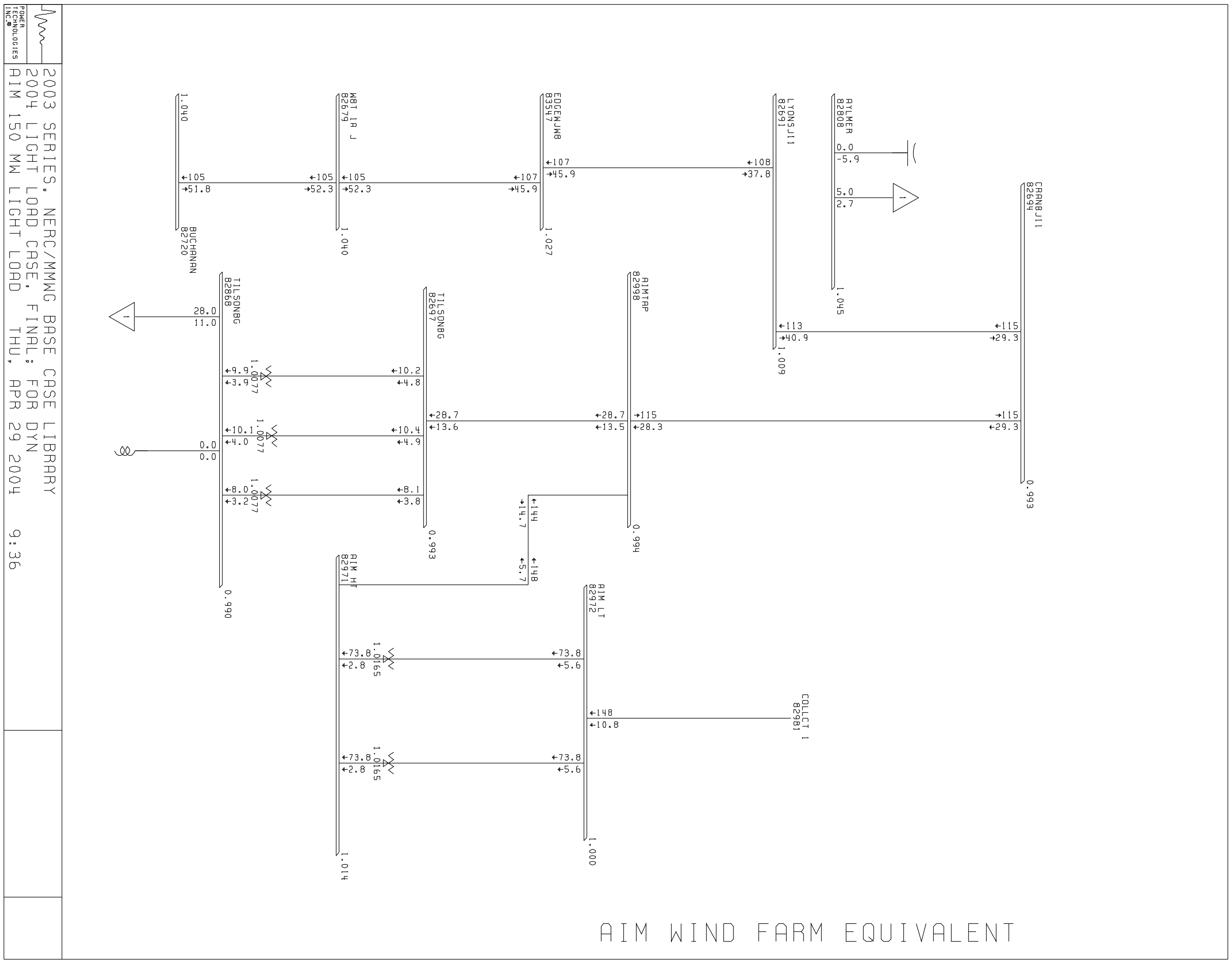
The study of reactive power requirements is shown in Table 3.1. Five load flow cases were studied for the peak load situation. The Wind Farm may be generating low MVArs or may be absorbing MVars because we are trying to keep the Tillsonburg voltage at 120 kV to cater for the loss of the Wind Farm. The base case load flow had 2 x 18 MVAR capacitors at Tillsonburg 27.6 kV bus and a 5 MVAR capacitor at Aylmer 27.6 kV bus. These capacitors were placed in service. As shown in Table 3.1, when the Wind farm is off line at peak load, 114.2 MW and 31.5 MVAR is transmitted on line W8T out of Buchanan TS. As shown in the Load Flow plots, the peak load demand at Tillsonburg is 97 MW and 36 MVAr while the peak load at Alymer is 11.4 MW and 4.4 MVAR. The total MW load is 108.4 MW so that the losses on W8T is 5.8 MW. When the Wind Farm is at 80 MW output, the W8T flow out at Buchanan is 31.8 MW and 17.9 MVAR. The voltage drop is about 4% if the wind farm goes from 80 MW to offline. Addition of 10 MVAR of capacitors at either Tillsonburg LT bus or at AIM LT bus is enough to limit the voltage drop. The Buchanan voltage was about 126 kV in these studies. It is expected that the MVAR support required will be higher (up to 20 MVAR) if the Buchanan voltage was at the lower end of its desirable range of 120 to 127 kV.

Table 3.1 Reactive Requirements 150 MW Plant at Peak Loads

Case	**Wind 150 MW Plant at 150 MW output**	**Wind 150 MW Plant at 80 MW output**	**Wind Plant Off line**	**Wind Plant Off line 10 MVAR cap switched on at Tillsonburg 27.6 kV bus**	**Wind Plant Off line 10 MVAR cap switched on at AIM 27.6 kV bus**
Wind Generation MW + j MVAR	150 + j 17.88	80 – j 1.44	0	0	0
W8T output Power at Buchanan 115 kV	-33.4 + j 34	31.8 + j 17.9	114.2 +j 31.5	113.9 + j 14.4	113.9 +j16
Flow into IMO grid at AIM 115 kV tap point	-144 + j 25.5	-78.3 + j 13.6	0 - j 0.5	0 - j 0.5	- -j 10.6
System Losses at peak hour MW	-2.2	-5.4	Reference (719.5)	N/A	N/A
Tillsonburg Voltage kV	118.70	119.70	114.73	119.55	119.065
Maximum Tillsonburg Voltage Change %			**- 4.152** for 80 MW case		

3.3 *Summary of Local Area Study 150 MW Wind Farm*

The reactive power capability of the Wind Farm results in an improved voltage profile along the load centers fed from circuit W8T. System and local losses are reduced when the Wind Farm is producing power. The only possible issue is that when the Wind Farm goes off line, the local voltage profile returns suddenly to its existing voltage profile. This change can be minimized by having the voltage profile of W8T stations lower than 120 kV. In addition a new capacitor (about 20 MVAR) is required to be switched on to reduce the voltage change when the Wind Farm goes offline.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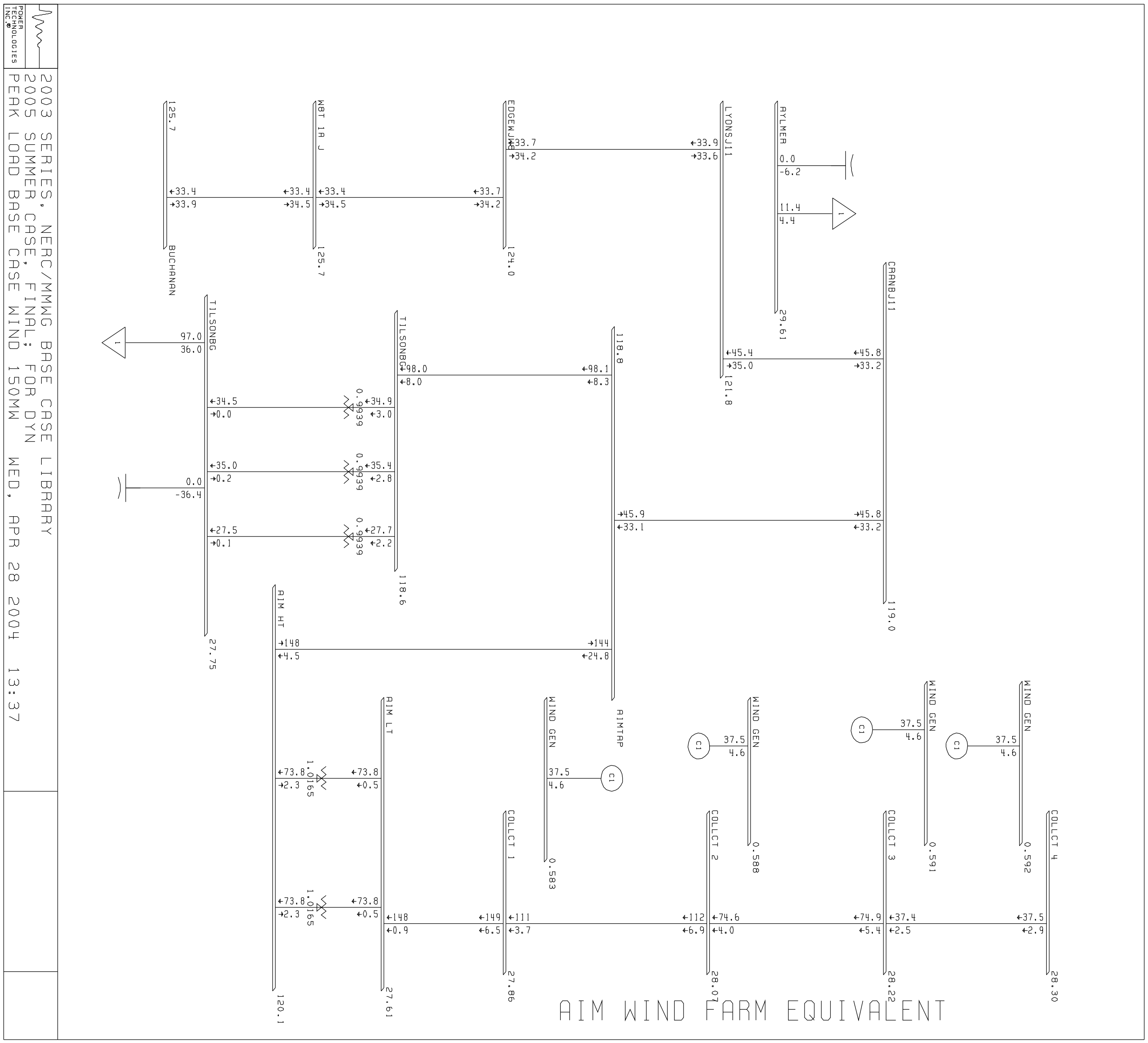
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FIGURE 3.1 Local Voltage Profiles at Peak Load and Various Wind Farm Scenarios

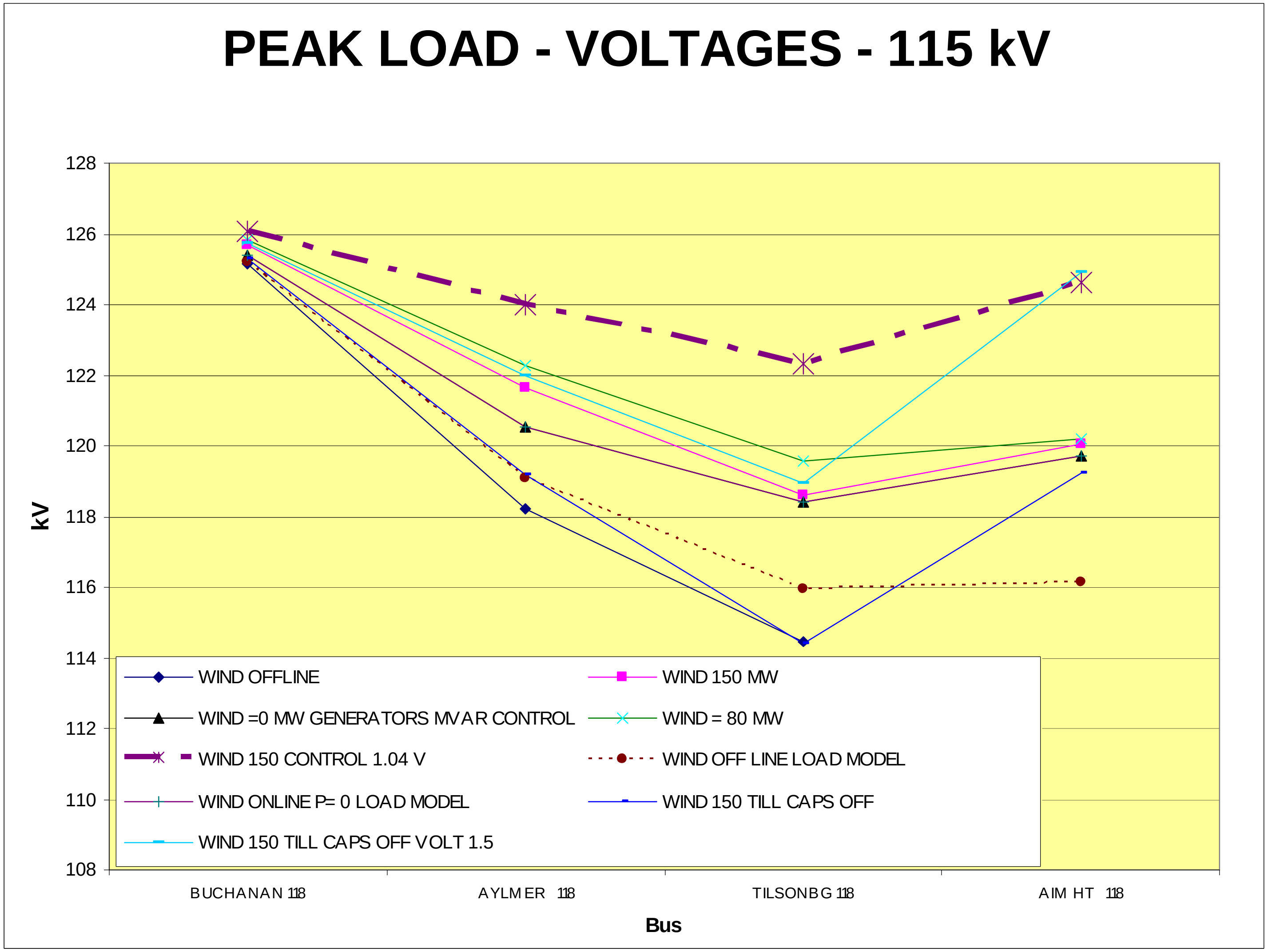
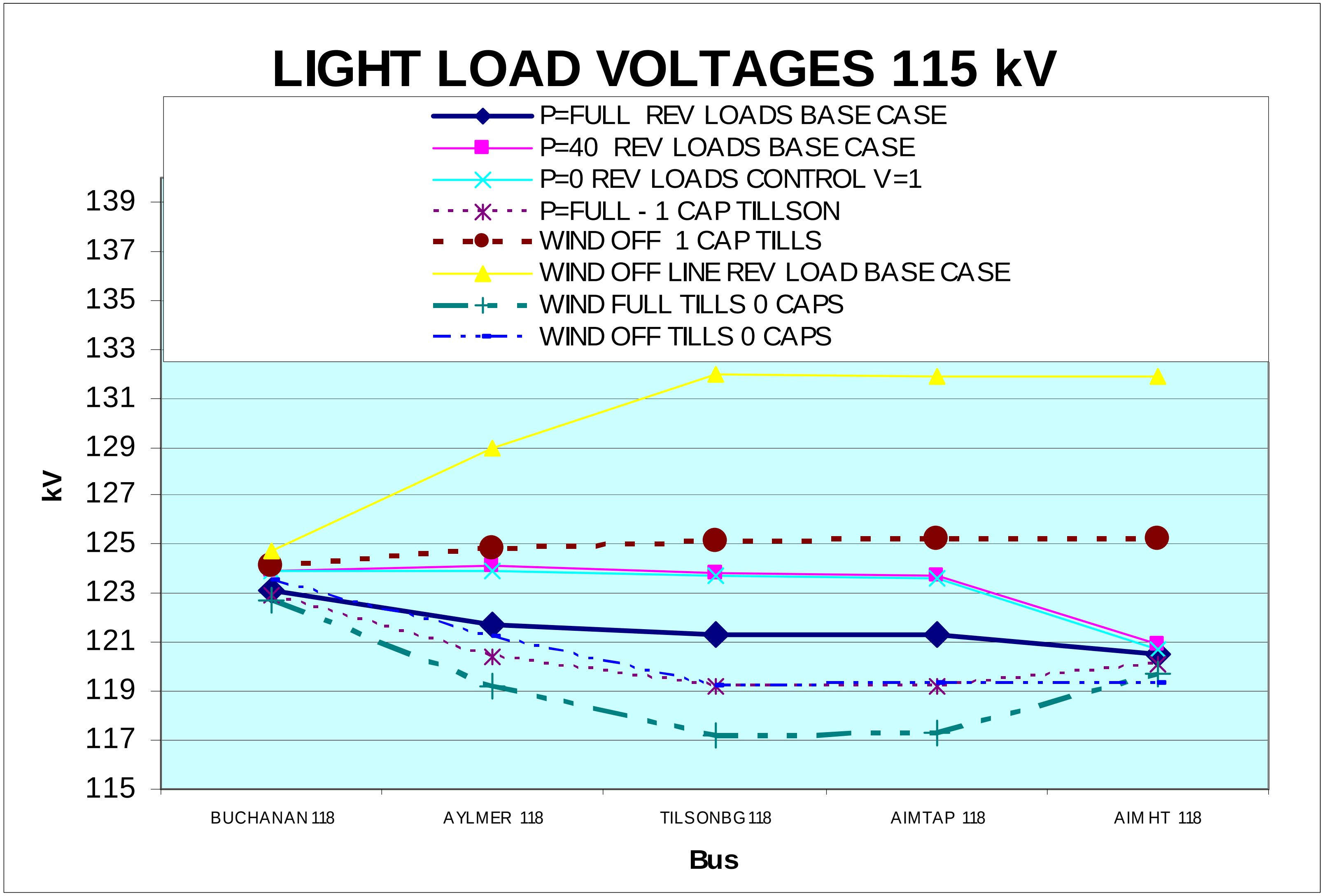


FIGURE 3.2 Local Voltage Profiles at Light Load and Various Wind Farm Scenarios



4.0 Local Area Impact for 100 MW Wind Farm

For a 100 MW Plant, data, which is outlined in Section 2, the IMO revised their SIA scope to include a repeat of the local voltage impact and reactive power requirements as well as a study of transients for local faults and associated with Wind Gusts.

Section 4.1 shows the results of the load flow study of the local voltage impact of the Wind Farm and also the reactive requirements when the Wind Farm goes offline. Section 4.2 shows the transient voltages during wind gusts. Section 4.3 shows the results of the transient stability study for local 115 kV faults including longer duration faults which are cleared in about 300 ms.

4.1 *Local System Voltage Impact of 100 MW Wind Farm*

The result of the local area peak load voltage study is shown in Tables 4.1(a) and 4.1(b). The sensitivity of the voltage level at Buchanan was included in the study parameters. Table 4.1(a) displays the results for 126 kV initial supply voltage at Buchanan whereas Table 4.1(b) shows the results for 122 kV at Buchanan.

The power flow at Buchanan out on W8T is 11.8 MW and 22.6 MVAR as shown in Table 4.1(a) for the 126 kV Buchanan voltage case. When the Buchanan voltage starts out lower, the same flow is 11.9 MW and 12.9 MVAR as the Wind Farm generator MVAR output is higher at 17 MVAR. At peak load, when the Wind Farm goes off line, the 115 kV bus voltage drop at Tillsonburg is 3.6% as opposed to 5.7% for the lower voltage case (Table 4.1(b)). It is apparent that the local system is sensitive to the starting voltage at Buchanan.A study was carried out to evaluate the system with local capacitor compensation when the Wind Farm goes offline. Tables 4.1 (a) and (b) show that the compensation required at Tillsonburg 27.6 kV bus ranges from 10 MVAR (with the 126 kV starting voltage at Buchanan) to 20 MVAR (with 122 kV starting voltage at Buchanan). In addition, Table 4.1(b) shows that the compensation of 20 MVAr is not as effective at AIM 27.6 kV bus.
Also given the fact that the normal voltage range at Buchanan is between 120 and 127 kV, the required capacitor should be available in smaller increments than 20 MVAR. Four 5 MVAR banks are therefore specified. If space is not available at Tillsonburg then the capacitors could be located at AIM but the amount should be increased to four 6 MVAR banks. Table 4.1 (c) is

data from Tables 4.1 (a) and (b) and Buchanan Transformer flows in the table format requested by the IMO

Table 4.1 (a) 100 MW Plant Peak Load– Buchanan 126.7 kV - Reactive Power Requirements

Case	**Wind 100 MW Plant at 100 MW output**	**Wind Plant Off line**	**Wind Plant Off line 2 x 5 MVAR cap switched on at Tillsonburg 27.6 kV bus**
Wind Generation MW + j MVAR	102 + j 10.8	0	0
W8T output Power at Buchanan 115 kV	11.8 + j 22.5	114.1 + j 31	114.1 + j 13.8
Flow into IMO grid at AIM 115 kV tap point	-98 + j 18.7	N /A	N/A
System Losses at peak hour MW And relative to Offline case	714.8 MW -3.7%	718.5 MW reference value	N/A
Buchanan & Tillsonburg Voltage kV	Buchanan 126 kV Tillsonburg 120.0 kV	Tillsonburg 115.7 kV	10 MVAR Caps On at Tillsonburg 120.5 kV
Maximum Tillsonburg Voltage Change %	Base	-3.6 %	+0.41%

Table 4.1 (b) 100 MW Plant Peak Loads– Buchanan 122 kV - Reactive Power Requirements

Case	**Wind 100 MW Plant at 100 MW output**	**Wind Plant Off line**	**Wind Plant Off line 4 x 5 MVAR cap switched on at Tillsonburg 27.6 kV bus**	**Wind Plant Off line 4 x 5 MVAR cap switched on at AIM LT 27.6 kV bus**
Wind Generation MW + j MVAR	102+ j 17	0	0	0
W8T output Power at Buchanan 115 kV	11.9 + j 12.9	115 + j 41.9	114 + j 8.5	114 + j 11
Flow into IMO grid at AIM 115 kV tap point	98 - j 7.8	0 + j 0.4	0 + j 0.5	-0.1 + j 20.1
System Losses at peak hour MW And relative to Offline case	714.1	719	N/A	N/A
Tillsonburg & Buchanan Voltages kV	117.6 121.98	107.58 120.75	+20 MVAR Cap on at TIllsonburg in addition to existing caps of 2x 18 MVAR 117.2 121.56	116.33 121.56
Maximum Tillsonburg Voltage Change %	Base	-5.7%	OK, -0.34%	OK, -1.1% but Tillsonburg new capacitor location is more effective

Table 4.1 (c) 100 MW WIND FARM Peak Load Conditions IMO Format Table

Reactive Power Requirements – Buchanan Voltage 126.7 kV					
WF Status (MW, Mvar)	WF Injection at Tillsonburg Jct	Flow into W8T at Buchanan 115 kV	Flow on Buchanan 230 to115 kV transformers	Tillsonburg Voltage	
				No Shunt Cap	10 Mvar Shunt Cap at Tillsonburg LV*
In service (102, 10.8)	98 MW, -18.7 Mvar	11.8 MW, 22.5 Mvar	-383.9 MW, -115 Mvar	120 kV	120 kV (no cap)
Loss of Entire WF	0, -0.5 Mvar	114 MW, 13.8 Mvar	-498.7 MW, -106.1 Mvar	{115.7 kV**}	120.5 kV
				-3.6%	0.41%
Reactive Power Requirements – Buchanan Voltage 122 kV					
WF Status (MW, Mvar)	WF Injection at Tillsonburg Jct	WF Injection at Buchanan 115 kV	Flow on Buchanan 230/115 kV transformers	Tillsonburg Voltage	
				No Shunt Cap	20 Mvar Shunt Cap at Tillsonburg LV*
In service (102, 22)	98 MW, -7.8 Mvar	11.7 MW, 12.9 Mvar	-388.7 MW, -51.2 Mvar	117.2 kV	117.6 kV (no cap)
Loss of Entire WF	0, -0.5 Mvar	114 MW, 8.5 Mvar	-504.1 MW, -51.9 Mvar	{107.6 kV**}	117.2 kV
				-5.7%	-0.34%

* Shunt Capacitors switched on in load flow that modeled the Wind Farm Generators going off line
** This voltage was obtained in a separate load flow without the capacitors switched on

4.2 *Light Load Impact 100 MW Wind Farm*

Table 4.3 summarizes the voltages with the Wind Farm at 100 MW and after the Wind Farm goes offline. A study of light load voltages showed that the voltage will rise by 1 kV when the Wind Farm goes offline from full output. The light load study showed that as long as the various capacitors are controlled to keep the voltage in the desired 120 kV levels then the Wind farm going off line does not change the system voltages by more than one or two percent.

Table 4.3 Light Load Case Voltages

LIGHT LOAD - VOLTAGES - 115 kV			
		1	2
Bus Number	Bus Name	Light Load 100 MW Plant Base Case	OFF LINE
82600	LAMBTON 220	238.41	238.46
82555	CHATHAM 220	239.47	239.56
82645	SCOTT 220	239.91	239.96
82620	LONGWOOD 220	242.86	242.89
82550	BUCHANAN 220	241.61	241.70
81615	MIDDLDK1 220	245.00	244.98
80211	BRUCE A 220	253.65	253.65
82720	BUCHANAN 118	123.24	123.54
82692	AYLMER 118	120.80	121.26
82697	TILSONBG 118	118.77	119.18
82998	AIMTAP 118	118.87	119.28
82971	AIM HT 118	119.94	119.31
82972	AIM LT 27.6	27.61	27.45
82981	COLLCT 127.6	27.91	27.44
82982	COLLCT 227.6	28.16	27.44
82983	COLLCT 327.6	28.33	27.44
82984	COLLCT 427.6	28.43	27.44
82991	WINDGEN1.575	0.59	0.57
82992	WINDGEN2.575	0.60	0.57
82993	WINDGEN3.575	0.60	0.57
82994	WINDGEN4.575	0.60	0.57
82808	AYLMER 27.6	29.24	29.35
82868	TILSONBG27.6	27.70	27.80

4.3 *Local System Voltage Impact of Wind Gusts*

The PSSE Wind Gust model was used to input a Wind Gust of 9 m/s over a 5 second period. Wind Gust means wind that comes and dies down in a few seconds. The Wind Generator output will rise and then fall as the wind dies down. But if the wind generator was initially at 100 MW (say for the 100 MW wind farm) then higher winds will not produce higher power than 100 MW due to the built-in controls in the Wind Turbine.

The Wind Farm was initially set at a low output corresponding to a wind speed of 6 m/s and then the Wind Gust was set to peak to 15 m/s (corresponding to full power). The wind Gust was set to die out in 5 seconds. The output of the Wind Farm is proportional to the Wind above about the 6 m/s sec point. The Wind Gust is speed displayed in Figure 4.1 as is the total wind speed in m/s. Figure 4.2 displays the total output MW and MVAR of the Wind Farm at the 27.6 KV bus. The increase in the output power at the start of the gust is evident with a delay of a few seconds, and then the drop-off after 6 seconds. The variation in total MVAR output is less that 20 MVAR peak to peak.

The local voltage impact is shown in Figure 4.3. The Buchanan voltage is not affected while the Tillsonburg voltage change is less than 2%. The Wind Farm generators are attempting to control the AIM 2.6 kV voltage at 27.6 kV during the Wind Gust, using the available group control system. The Wing Generator terminal voltage shows the largest change as it attempts to control the AIM 27.6 kV voltage during the Wind Gust. The system stabilizes after about 10 seconds.

Figure 4.1 100 MW Plant – Buchanan 122 kV – Wind Gust from 6 to 15 m/s over 5 sec

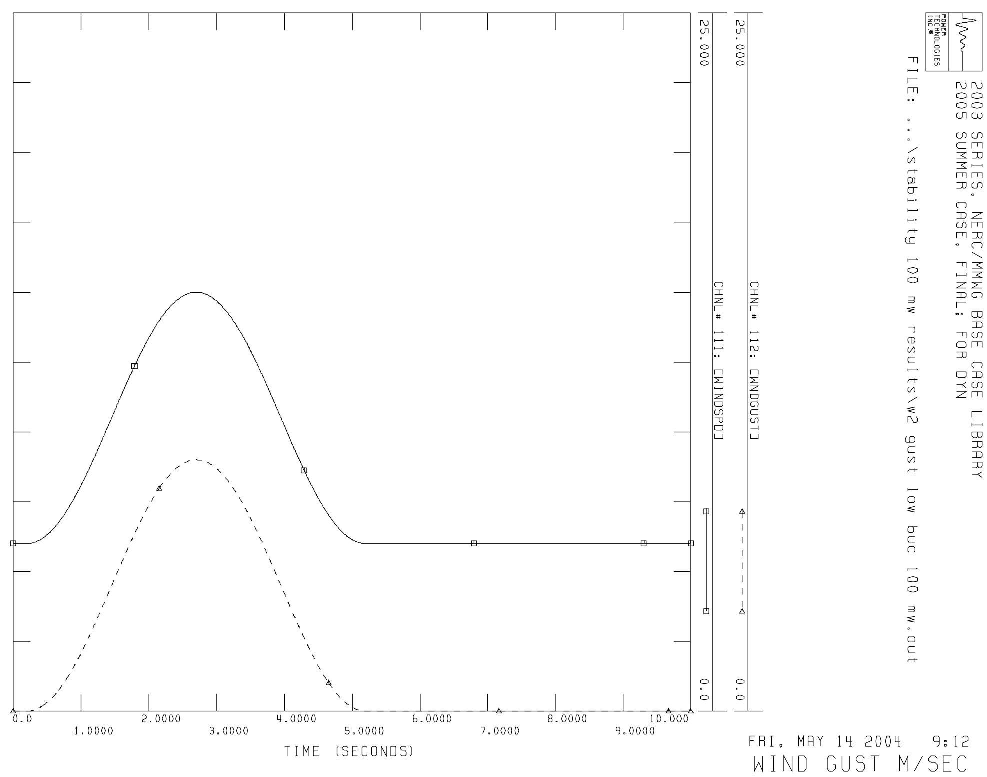


Figure 4.2 Wind Farm 27.6 Bus Input Flows P+j Q
100 MW Plant – Buchanan 122 kV –
Wind Gust from 6 to 15 m/s over 5 sec

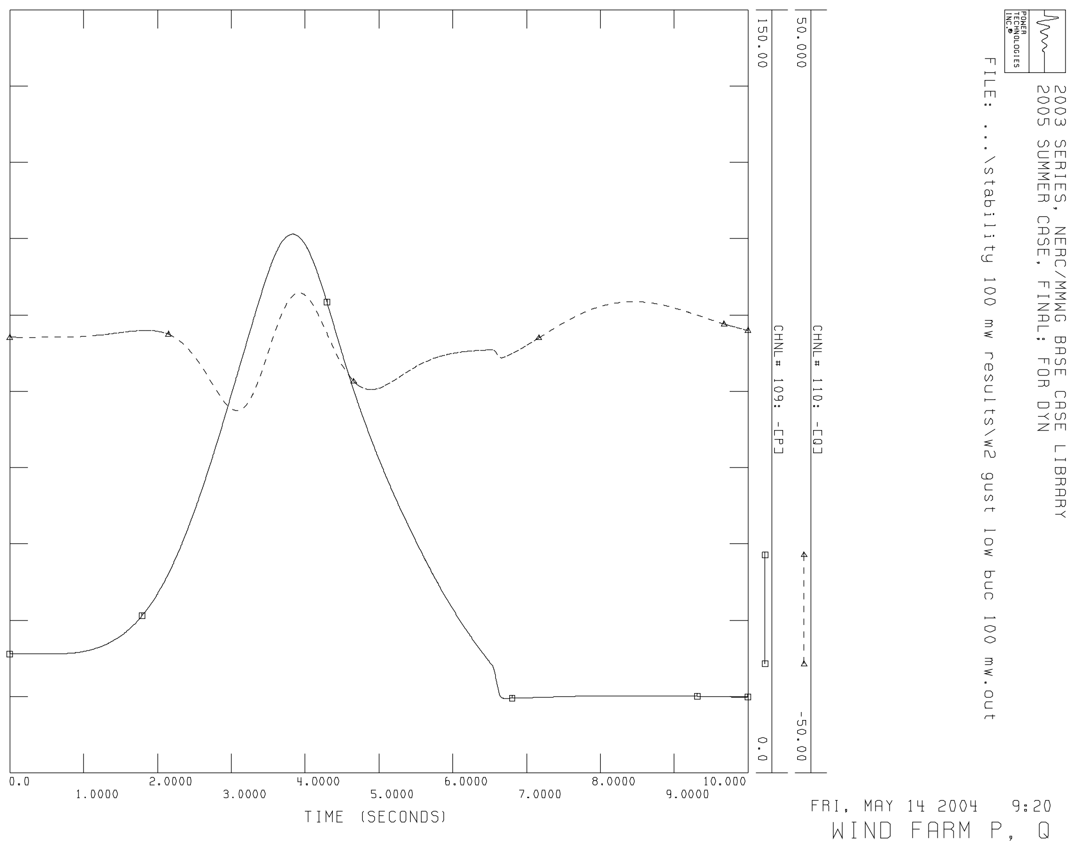
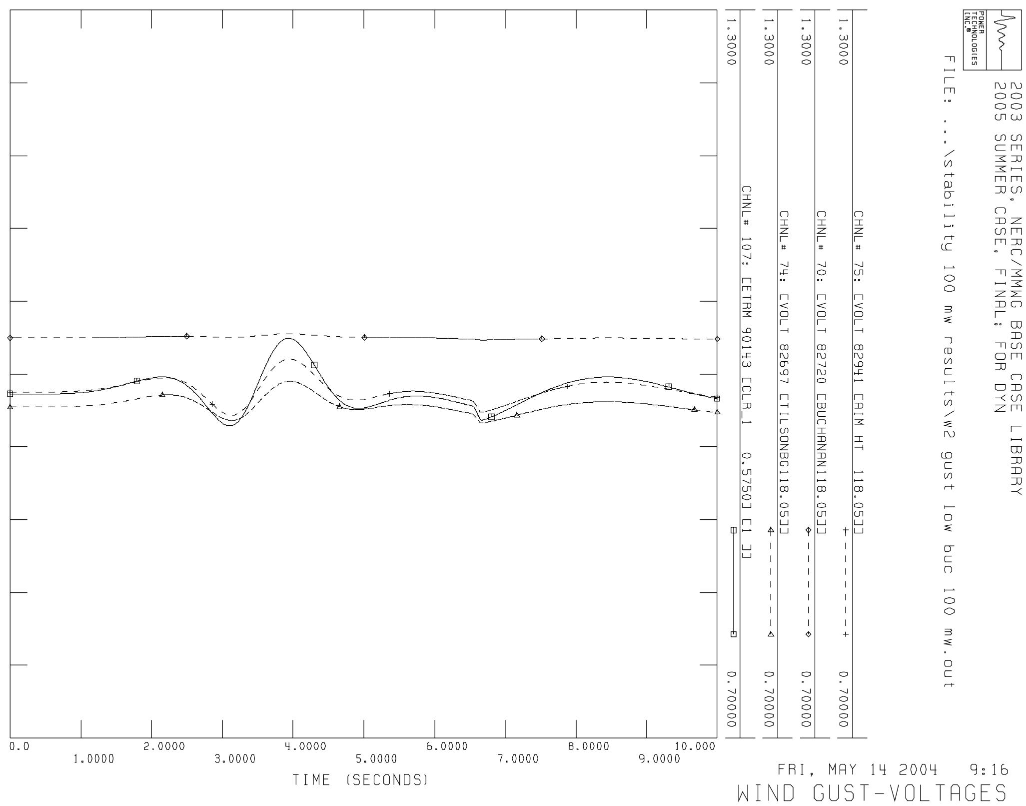


Figure 4.3 Local System 115 kV Voltages

100 MW Plant – Buchanan 122 kV –

Wind Gust from 6 to 15 m/s over 5 sec



4.4 *Transients and Wind Farm 'Ride-Through' for Local Faults*

The capability of the Wind Farm to ride through local faults and severe system contingencies was required to be studied where the detailed model of the Wind Farm machines and controls were used. The following studies were added to the scope by the IMO:

1) 3 Phase Fault on W12W at Buchanan 115 kV bus, normally cleared

2) A single-line to ground fault with delayed clearing of about 300 mS

3) A severe 500 kV contingency

The first two studies are outlined in this section, while the severe 500 kV contingency (Loss of Bruce double-circuit 500 kV line) was studied as part of the System Impact for system contingencies reported in Section 6. The transients of the Wind Farm going offline is also examined in Section 4.4.3

4.4.1 3 Phase Fault on W12W at Buchanan 115 kV bus

Figures 4.4 to 4.6 display the transients as a result of a normally cleared 3 phase fault on W12W to Woodstock. The conclusion is similar to other transient stability studies, in that the Wind Farm can ride through system faults as long as the local voltages can be controlled by the Wind Farm. An oscillation in Wind Generator speed is evident but this is because the damping factor has been set to zero, as a value for this parameter was not provided. The Wind Turbine system is likely to be quite well damped although it is oscillatory.

Figure 4.4 100 MW Plant – 3 Phase Fault on W12W

Wind Farm Total P and Q

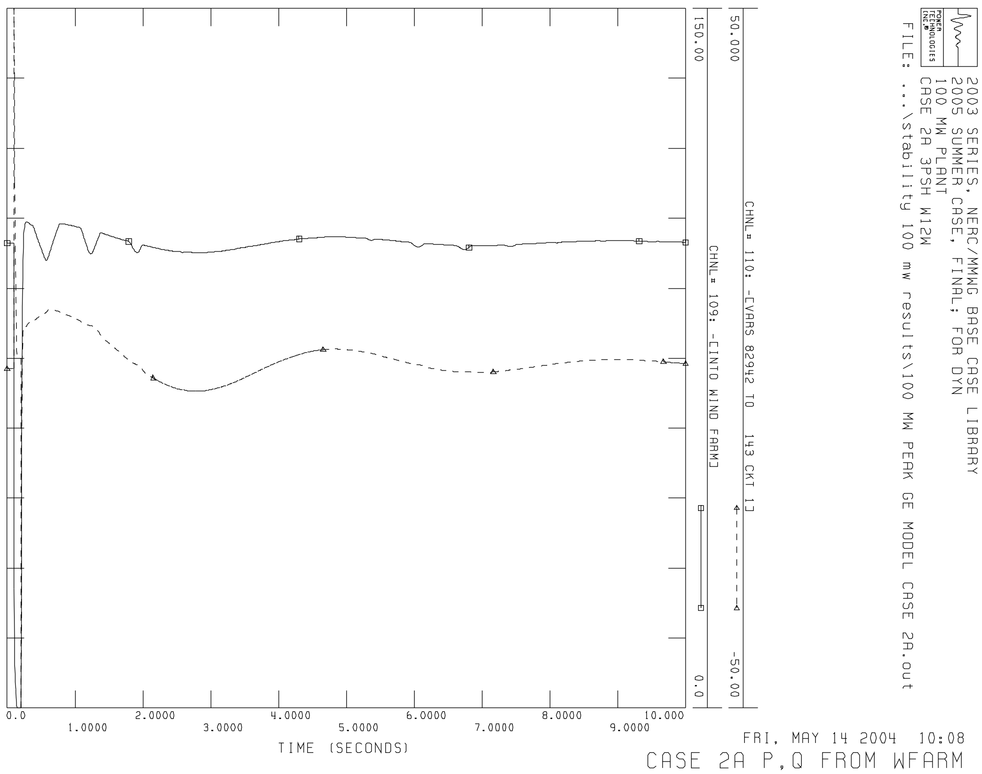


Figure 4.5 100 MW Plant – 3 Phase Fault on W12W

Wind Generator Output

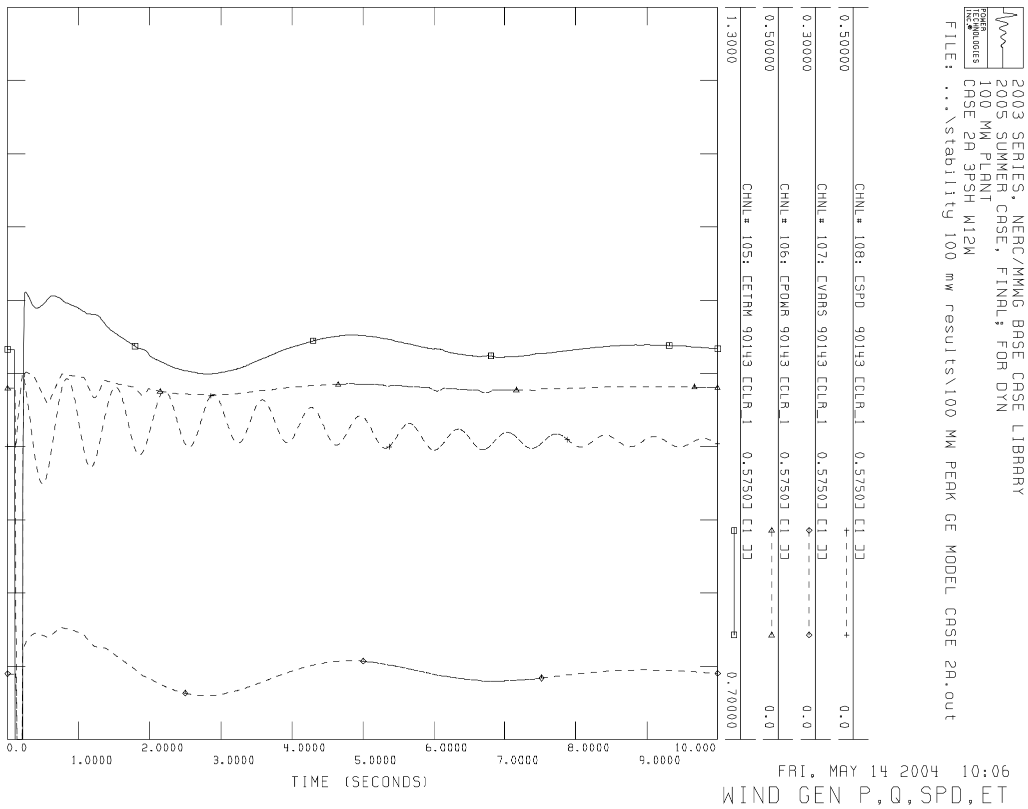
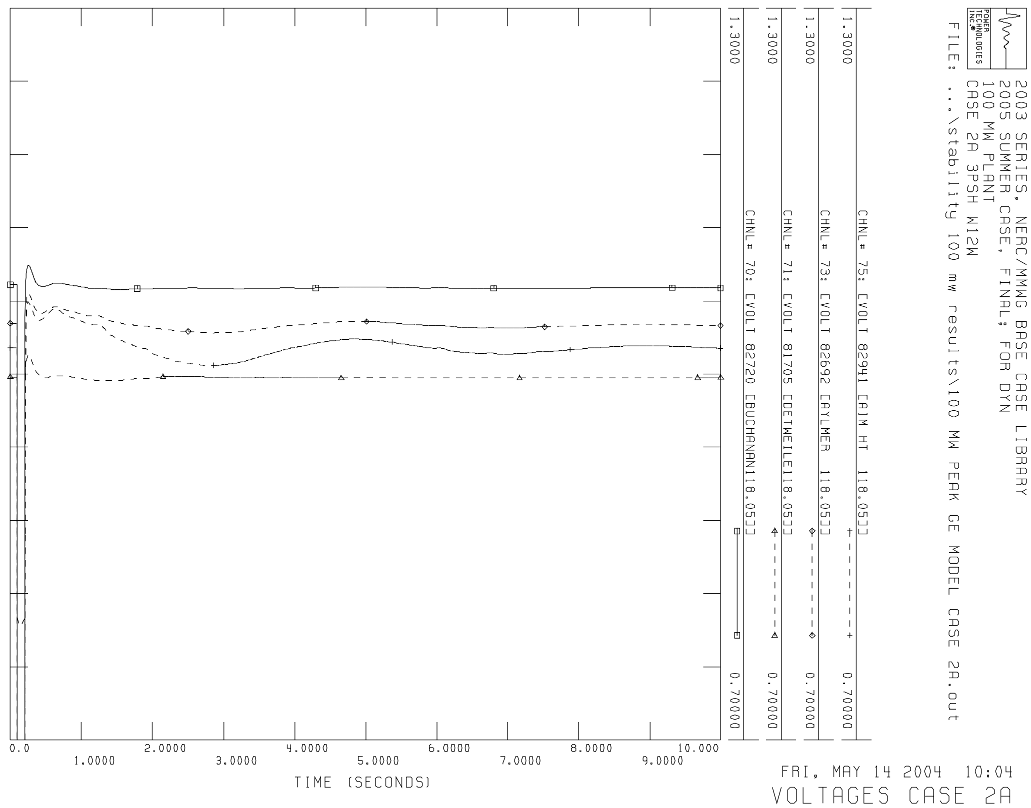


Figure 4.6 100 MW Plant – 3 Phase Fault on W12W

Local System Voltages



4.4.2 Delayed Clearing of 115 kV fault

A single line to ground fault at Buchanan on a 115 kV line but with 300 ms delay was simulated in this part of the study. Figures 4.7 to 4.9 display the transients as a result of a delayed clearing L-G fault at Buchanan 115 kV. The conclusion is similar to other transient stability studies, in that the Wind Farm can ride through system faults as long as the local voltages return to close to the original values and can be controlled by the Wind Farm.Unlike synchronous machine stability, it appears that if the local voltage recovers (e.g. by the GE Var support) then we would expect that the induction generators would not stall.

An oscillation in Wind Generator speed is evident but this is because the damping has been set to zero as a value for this parameter was not provided. The Wind Turbine system is likely quite well damped.

Figure 4.7 100 MW Plant – LG Fault on Buchanan 115 cleared in 300 ms
Wind Farm Output

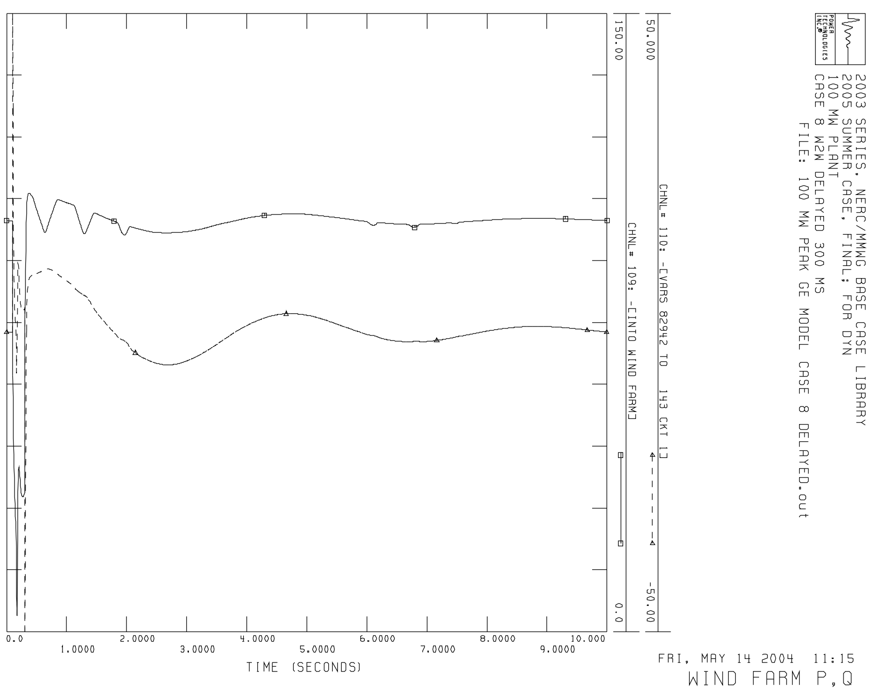


Figure 4.8 100 MW Plant – LG Fault on Buchanan 115 cleared in 300 ms

Wind Farm Generator Quantities

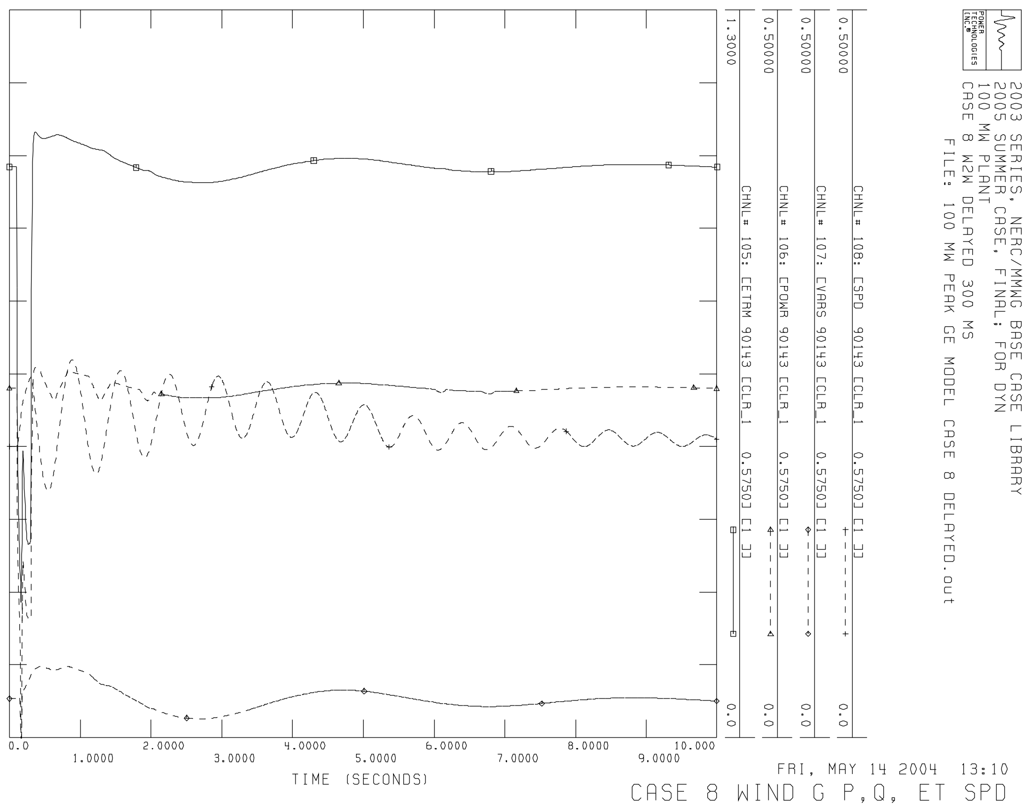
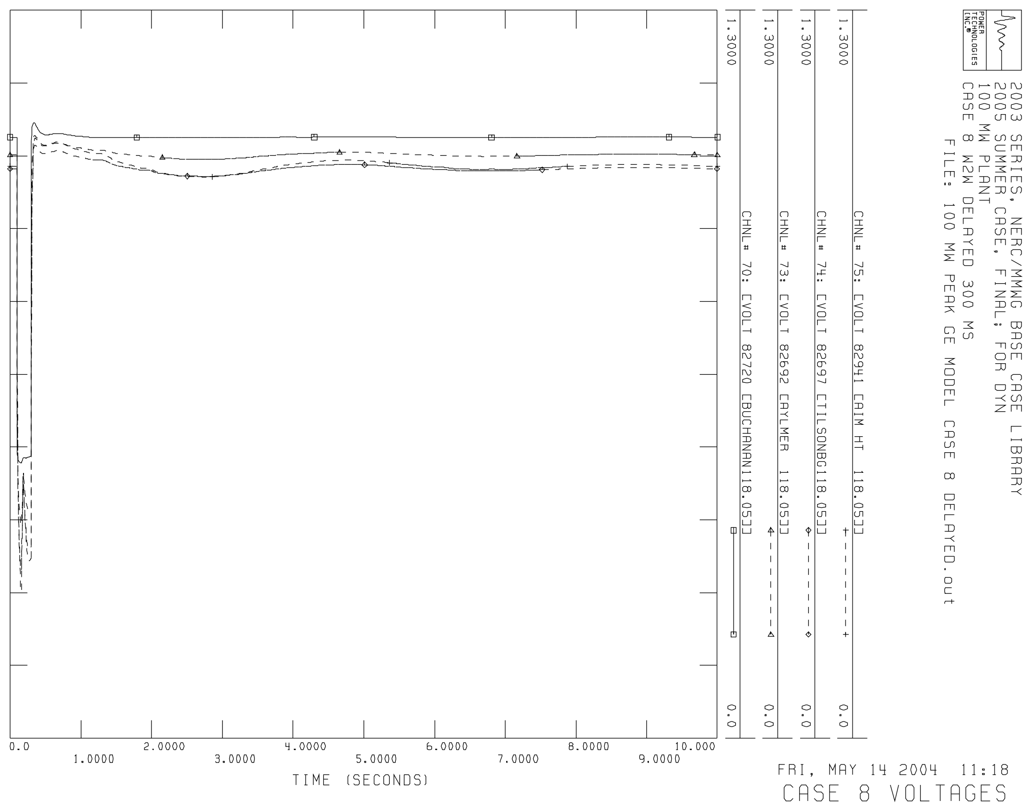


Figure 4.7 100 MW Plant – LG Fault on Buchanan 115 cleared in 300 ms

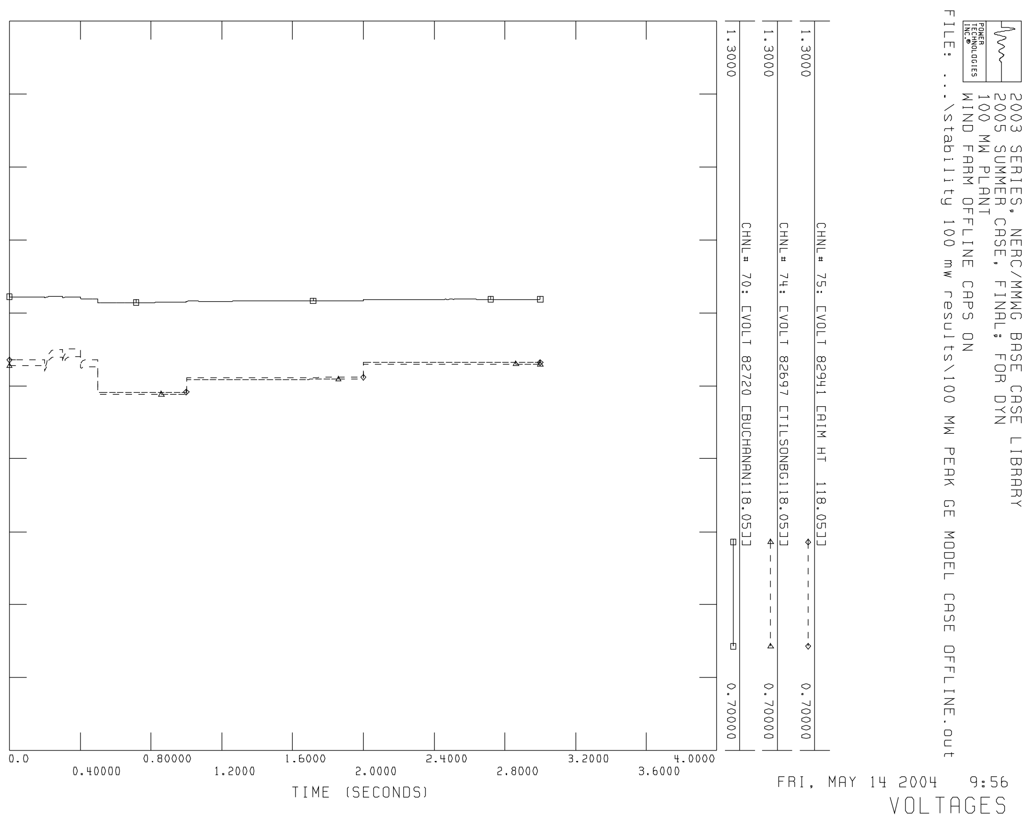
Local System Voltages



4.4.3 Transients for 100 MW Wind Farm going offline

The voltages were studied for the situation where the Wind Farm goes offline, the voltages drop and the new capacitors are switched on in two sets. Figure 4.10 shows the local voltages during this period. When the Wind Farm goes offline the Buchanan voltage is not affected but the Tillsonburg voltage is shown to drop. In this case 10 MVAR capacitors are switched in (automatically) and the voltage is restored.

Figure 4.10 100 MW Plant – Wind Plant Going Offline and Capacitor Switching to Restore Voltages



4.5 *Summary of Local Area Impact for 100 MW Wind Farm*

The local voltage profiles under peak an light load conditions and with and without the Wind Farm were studied. The reactive power requirements were also examined under two Buchanan input voltage scenarios (126 and 122 kV). The local voltages were also studied under sudden power output variations under Wind Gusts and local severe system faults by carrying out transient stability studies. The Wind Farm can ride through the severe local faults and the voltage changes for a large Wind Gust are small.

The only issue is the Wind Farm going offline at peak load periods. In such a case, the reactive power requirements were studied so that the effect of the local area was minimized. It was found that the reactive requirement were sensitive to Buchanan input voltage levels. It was determined that 20 MVAR of switchable capacitors (in 5 MVAR blocks) would be sufficient to minimize the voltage impact of the Wind Farm going offline. It was also determined that these capacitors are most effective when located at Tillsonburg 27.6 kV bus.

5.0 Voltage Impact for System Scenarios for the 150 MW Wind Farm

Three major system scenarios were specified by the IMO Scope

A) Peak Load with NBLIP of 1500 MW
B) Peak Load with BLIP (Buchanan Longwood Input flowing Westwards) of 3000 MW.
C) Off Peak Conditions

The voltage impact of six major system outages was evaluated. The off-peak conditions were only studied under local conditions as the system voltages are on the high side and outages do not cause major voltage problems.

The following contingencies were evaluated:

1) Loss of one Buchanan transformer T3 (Buchanan K2 bus) 3phsc 115 kV bus
2) Loss of M31/32W (Buchanan to Middleport)
3) Loss of D4/5W (Buchanan to Detweiler)
4) Loss of W44/45LC (Buchanan to Chatham to Longwood)
5) Loss of N21/22W (Buchanan to Scott)
6) Loss of B560V/B561M

5.1 Case A - Summer Peak BLIP -1500 MW

Figure 5.1 displays the local voltage profile for the BLIP of -1500 MW. Voltages in the local system near the Wind Farm are well controlled and improved by the Wind Farm available var control capability. The worst outage is Case 6 – loss of Bruce-Milton-Clairevile double circuit line with six Bruce and six Nanticoke units on-line. Various shunt reactors were tripped off in the 500 kV systems.

5.1.1 Sensitivity of Woodstock Supply from Buchanan/Burlington

A sensitivity study comparison was performed for the following system conditions:

a. Woodstock TS supplied from Burlington
b. Woodstock TS supplied from Buchanan

Table 4.1.1-1 in the Appendix A shows the comparisons and voltage sensitivity at different buses of interest as Woodstock TS is supplied from each of the above points. The results show that there is a small difference in voltage conditions if load at Woodstock is supplied either from Buchanan or Burlington. The Buchanan 115 kV bus voltage increases by about 0.6 kV if Woodstock is supplied from Burlington.

Table 5.1

MW flow -50 MW Change at AIM	Base Case	To Nanticoke	To Lambton
Buch to West 230	-1612	-1632	-1644
Buch to East 230	1086	1061	1074
BLIP	-1466	-1421	-1458

Transfer Distribution Factors from AIM Wind	To Nanticoke	To Lambton
Buch to West 230	39	65
Buch to East 230	50	22
BLIP	89	16

5.1.2 Linear Analysis

A linear analysis of power flows was carried out by reducing generation at the AIM Wind Farm by 50 MW and increasing the generation at the specified plants by an equal amount. Table 5.1 shows the resulting power flows and transfer distribution factors in percent.

5.2 *Case B - Summer Peak BLIP 3000 MW*

Figure 5.2 displays the local voltage profile for the BLIP of 3000 MW. Voltages in the local system near the Wind Farm are well controlled and improved by the Wind Farm available var control capability. The worst outage is the loss of Bruce-Milton-Claireville double circuit line with six Bruce (and six Nanticoke unit)s online. Various shunt reactors were tripped off in the 500 kV systems. The voltage declines are not as high as the BLIP -1500 case.

Figure 5.1 System Voltage Impact - NBLIP -1500

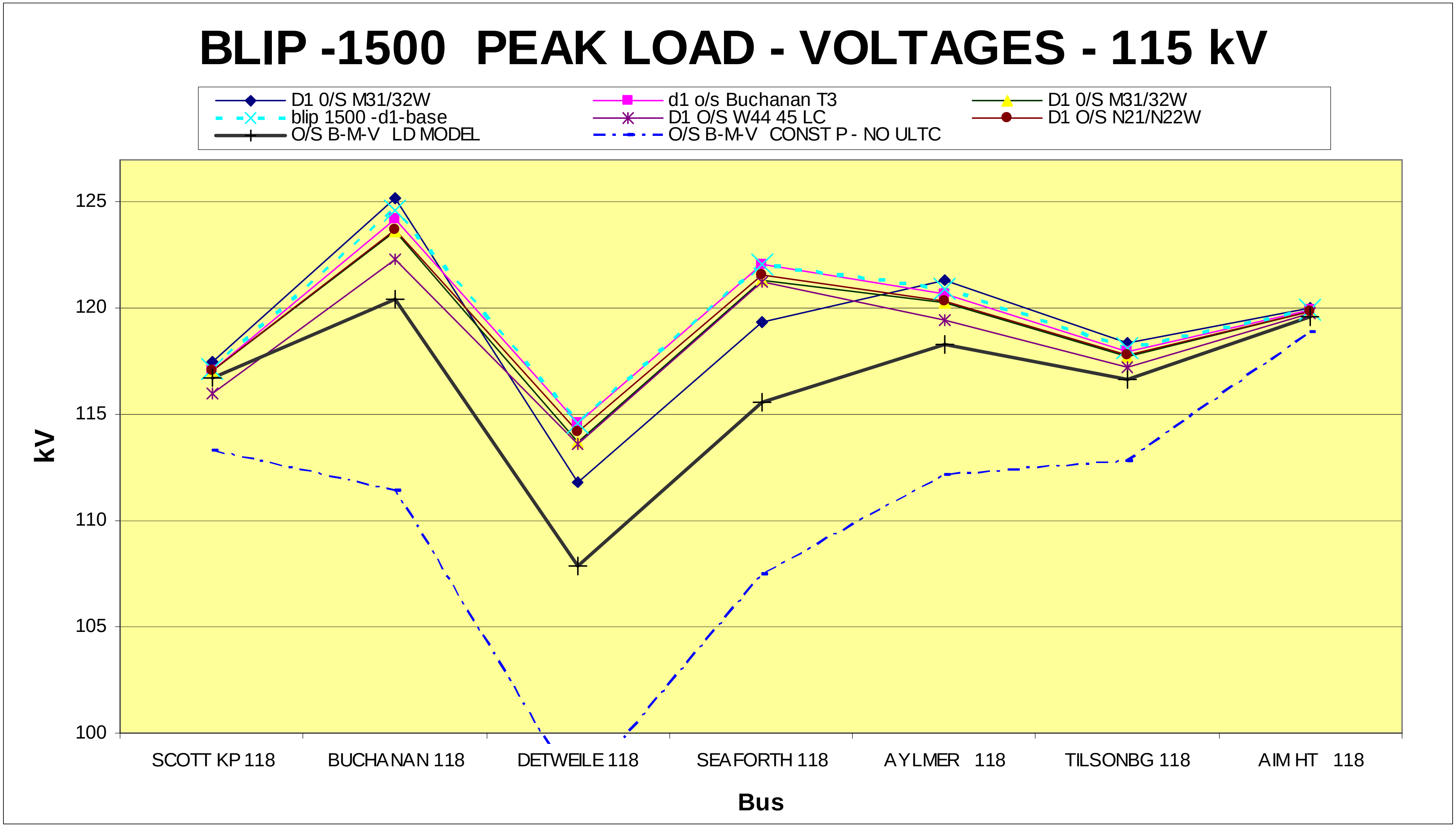
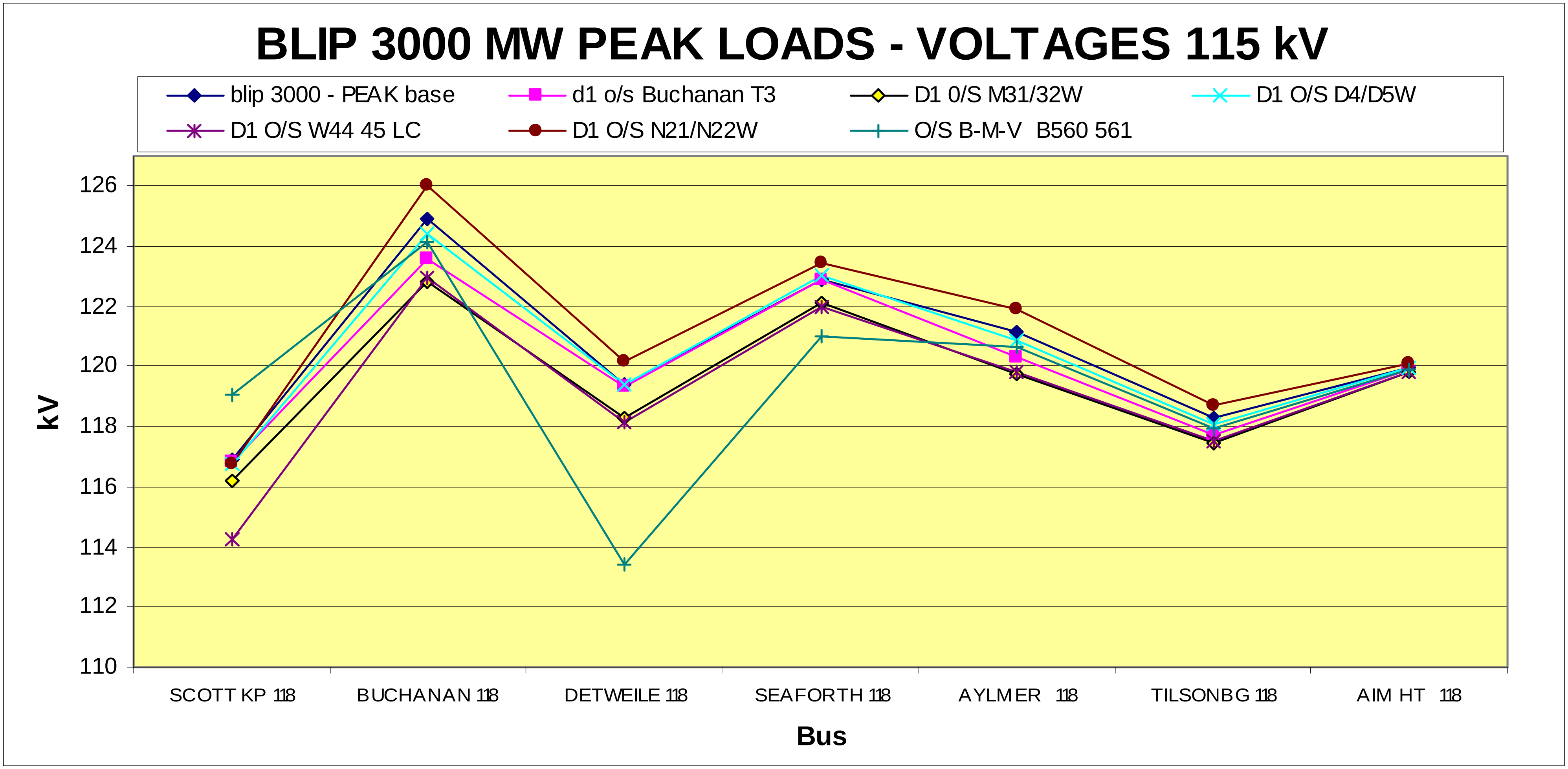


Figure 5.2 System Voltage Impact - BLIP 3000



6.0 Transient Stability Study 150 MW Plant

6.1 BLIP = -1500 MW 150 MW Plant

The ability of the Wind Farm to ride through system faults was studied by simulation of these contingencies. The Wind Farm was initially modeled as an induction generator (CIMTR3) as recommended by PTI/IMO as the pessimistic but simple representation of the GE 1.5 MW system. The voltage control is absent in this model. The 150 MW Wind Farm rode through contingencies Cases 1 to 6 with only the simple CIMTR3 Wind Generator Model.

In Case 7, loss of the 500 kV double circuit line, the system voltages are depressed as seen in Section 5. This resulted in the Wind Farm stalling when the simple CIMTR3 model was used. The voltage at the Wind Farm gives a good indication of motor stalling. When a capacitor was switched in (Case 7B), to represent the var capability of the GE wind generator, the system stabilized. (This was CIMTR3 plus a cap switched in. DFIG with CGEN group voltage control in the GE Wind Farm package gives very good voltage control. CIMTR3 aolne gives pessimistic results If there is a sustained local voltage depression the CIMTR3 will show stalling of induction gens. Whereas the DFIG + CGEN controls will quickly restore local voltages)

Case 7C repeats the case 7 outage but with the PSSE GE wind system model which incorporates the voltage control ability of that Wind generator. In this case the Wind Farm rode through the severe Case 7 contingency. Figures 6.1 to 6.3 show the results. Figure 6.1 shows the response of the Wind Generator (Etrm, PE, QE) during and after the fault clearance. The sustained increase in the MVAR (QE) output is seen, which will maintain the desired controlled 27.6 kV voltage at the Wind Farm. The sustained voltage increase at the Wind Generator terminals (Etrm) is about 1%. Figures 6.2 and 6.3 compare the voltage results of the three different Wind Farm models (Case 7 - CIMTR3, Case 7B – CIMTR3 plus capacitor switched in at 0.5 seconds, Case 7C – delayed DFIG double wound induction generator with group voltage controls and turbine representation). Figure 6.2 shows that the voltage at Tillsonburg returns to about 1% below its pre-fault voltage at 10 seconds in Case 7C. Figure 6.3 shows that the AIM 27.6

voltage is controlled to its 1.0 per unit set point voltage. Case 7B shows the system recovers when MVAR support was provided by the capacitor. Case 7 results show the voltage effect of the stalling of the Wind Farm when the simple induction motor model is used. The results show in Case 7C, the Wind Farm can ride through the severe Bruce system outage given the local voltage control capability.

Table 6.1 Transient Stability Contingencies

Case#	Contingency	Results
1	Loss of one Buchanan transformer T3 (Buchanan K2 bus) with a 3 phase fault at 115 kV bus	Wind Plant rides through the disturbance
2A	3-phase fault at W12W (#2A) at Buchanan 115 kV bus	Wind Plant rides through the disturbance
2B	3 phase fault on M31W at Buchanan (#2B)	Wind Plant rides through the disturbance
3	LLG on M31/32W (Buchanan to Middleport)	Wind Plant rides through the disturbance
4	LLG on D4/5W (Buchanan to Detweiler)	Wind Plant rides through the disturbance
5	LLG on W44/45LC (Buchanan to Chatham to Longwood)	Wind Plant rides through the disturbance
6	LLG on N21/22W (Buchanan to Scott)	Wind Plant rides through the disturbance
7	LLG on 500 kV B560V/B561M (Bruce-Milton-Claireville)	Wind Plant stalling due to sustained voltage depression at Buchanan
7B	As in case #7 but switch on 20 MVAR cap at 0.5 seconds	Wind Plant rides through the disturbance
7C	As in case #7 but with detailed Double Winding Induction Generator Model and Voltage Controls	Wind Plant rides through the disturbance – voltage and var support is evident

Figure 6.1 150 MW Plant – Case 7C PSSE DFIG model
Wind Farm Generator Quantities

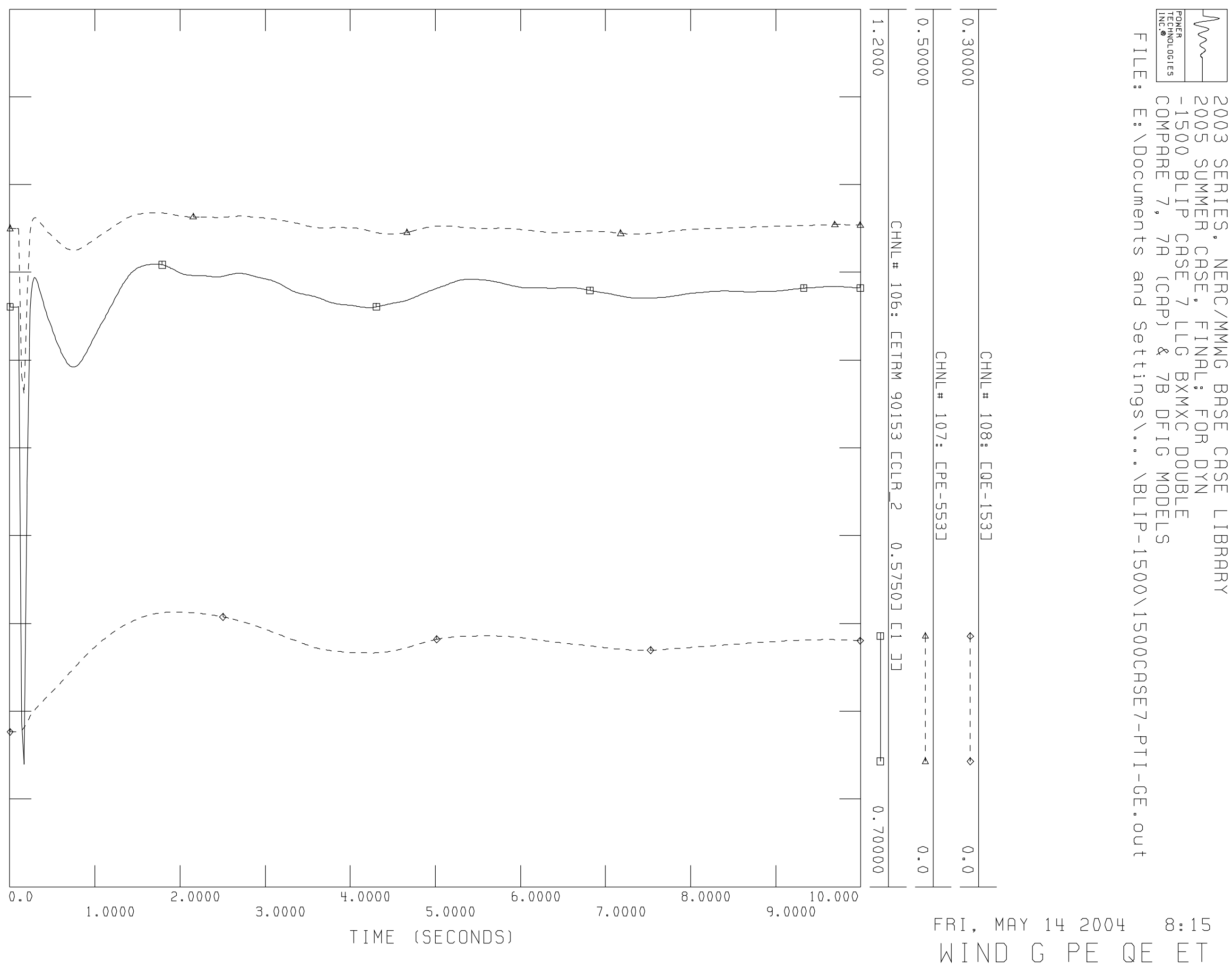


Figure 6.2 150 MW Plant – Case 7, 7B, 7C - Compared Tillsonburg 115 kV Voltage

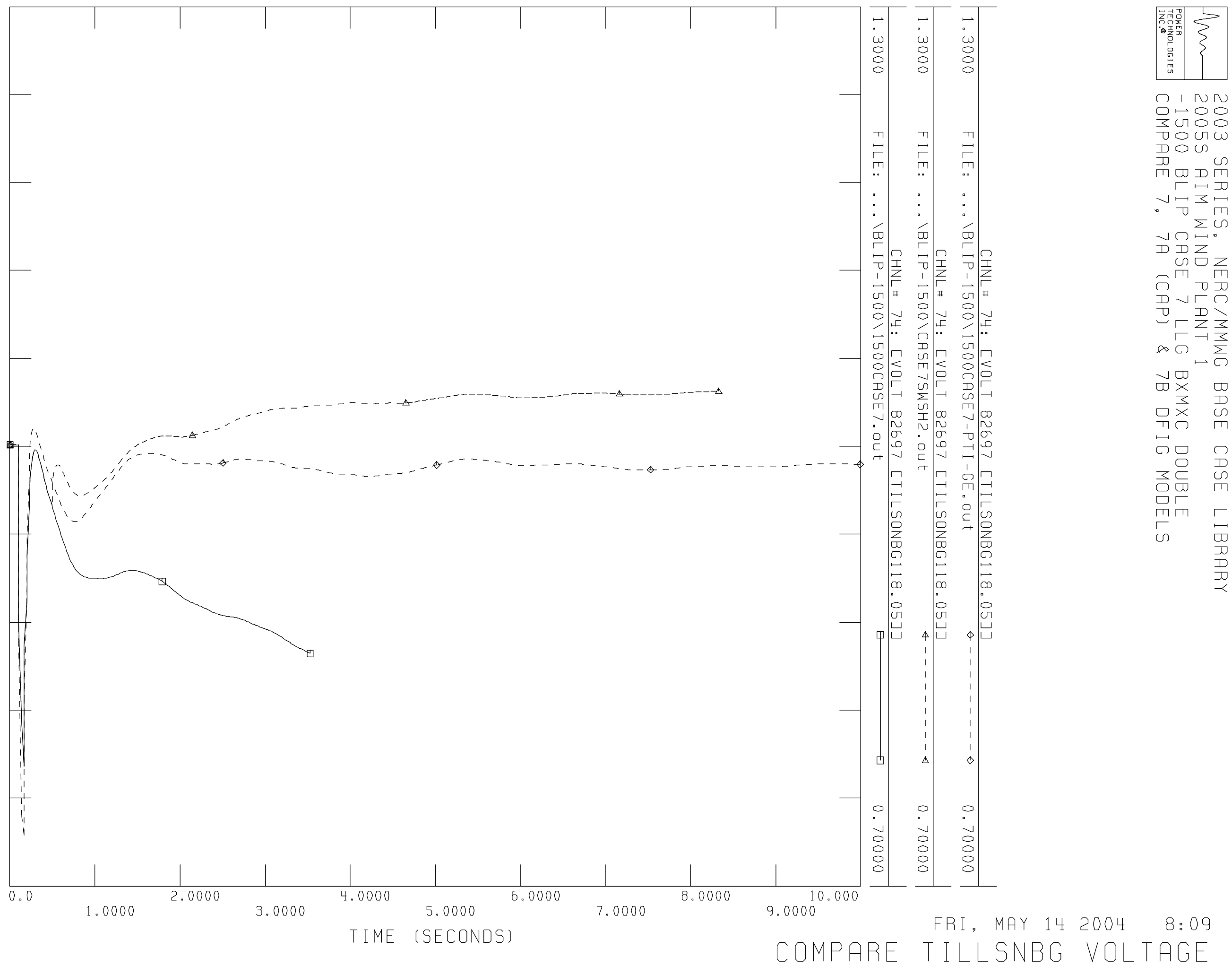
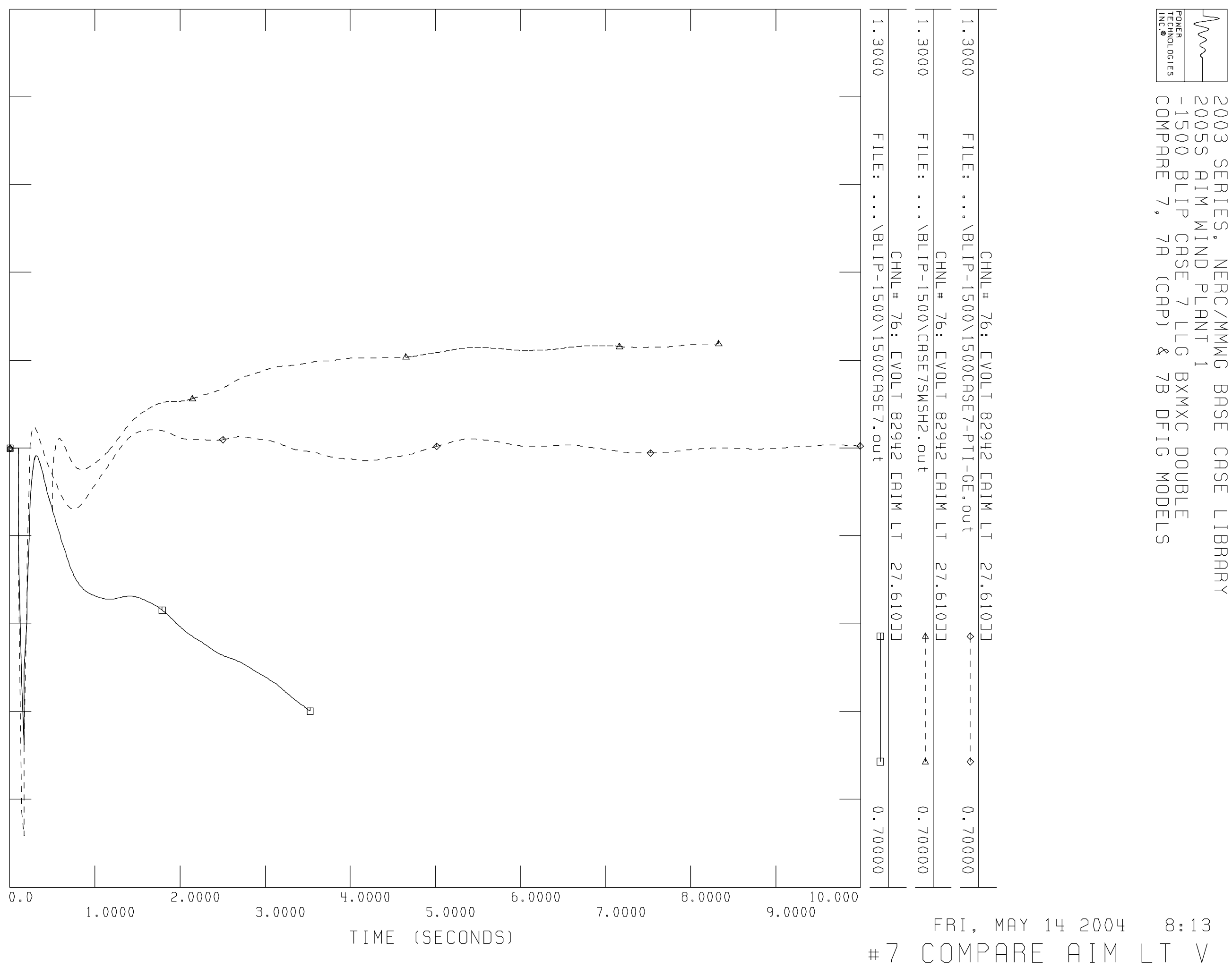


Figure 6.3 150 MW Plant – Case 7, 7B, 7C - Compared AIM LT Voltage



6.2 BLIP=3000 MW 150 MW Plant

The ability of the Wind Farm to ride through system faults was studied by simulation of these contingencies. The Wind Farm was modeled as an induction generator (CIMTR3) as recommended by PTI/IMO as the pessimistic but simple representation of the GE 1.5 MW system. The voltage control is absent in this model. The 150 MW Wind Farm rode through contingencies Cases 1 to 6 with only the simple CIMTR3 Wind Generator Model. There was stalling in Case 7 but this case is expected to recover with the advanced model as the system behaviour was not as severe as in the BLIP -1500 MW case.

The stability of the 100 MW Wind Farm was not required by the IMO since this 150 MW study showed that the Wind Farm will ride through the severe contingencies and the 100 MW Wind Farm will be a less severe case.

Table 5.2 Contingencies for BLIP of 3000

Case#	Contingency	Results
1	Loss of one Buchanan transformer T3 (Buchanan K2 bus) with a 3 phase fault at 115 kV bus	Wind Plant rides through the disturbance
2A	3-phase fault at W12W (#2A) at Buchanan 115 kV bus	Wind Plant rides through the disturbance
2B	3 phase fault on M31W at Buchanan (#2B)	Wind Plant rides through the disturbance
3	LLG on M31/32W (Buchanan to Middleport)	Wind Plant rides through the disturbance
4	LLG on D4/5W (Buchanan to Detweiler)	Wind Plant rides through the disturbance
5	LLG on W44/45LC (Buchanan to Chatham to Longwood)	Wind Plant rides through the disturbance
6	LLG on N21/22W (Buchanan to Scott	Wind Plant rides through the disturbance
7	LLG on 500 kV B560V/B561M (Bruce-Milton-Claireville)	Voltages are depressed at Buchanan and Wind Plant stalling using induction generator model. Wind Plant will ride through the disturbance using DFIG PTI model

6.3 Summary of Transient Stability Results

The 150 MW and 100 MW Wind Farm can ride through the specified severe system disturbances by using the available voltage controls under a range of severe system loading conditions. The BLIP of -1500 MW is a more severe condition that the BLIP of 3000 MW case. The conclusion for the 150 MW Wind Farm is also valid for the smaller 100 MW Wind Farm.

7.0 Findings and Conclusions

The System Impact of the proposed Erie Shores Wind Farm project has been studied under various local and system loading conditions. This Wind Farm is connected to the IMO system near Tillsonburg transformer station. The Wind Farm maximum output will be up to 100 MW or up to 150 MW and the local Tillsonburg load demand varies from about 28 to 94 MW during the year. The Erie Shores AIM 115 kV collector transformer station is about 30 km from the connection point near Tillsonburg TS and Tillsonburg TS is about 60 km from the major IMO 230/225 kV grid station at Buchanan near London.

The output from the Wind Farm would be expected to fluctuate between zero to full power although the Wind Farm output is likely to be high coincident with the peak load periods according to the developer. The Wind Farm generators are proposed to be GE 1.5 MW induction generators (double wound) and are equipped with MVAR production/absorption capabilities and thus the capability to control the voltage at the collector point during the fluctuations in output. The voltage impact of the Wind Farm in its various output modes and in various system conditions was studied.

7.1 *Local Area Impact - 100 and 150 MW Wind Farms*

The voltages between Buchanan, Aylmer, Tillsonburg and the Wind Farm were studied during system peak and light load conditions. With the Wind generators on-line, the area 115 kV voltage profile is improved, when compared to the present situation of radial power supply to the Tillsonburg area. Power losses are also reduced.

When the Wind generators go offline, this voltage control is lost to the system and the local voltage resorts to its radial supply profile. This variation was studied under various wind farm power outputs to an offline mode and the 115 kV voltage changes could be limited to below 3 kV under proper system control. The Wind Farm normal control voltage should therefore below about 120 kV so that the voltage variations are below 4%. The impact of sudden Wind Gusts when the Wind Farm output climbs and falls in a short period was investigated and found not to impact the Tillsonburg voltage by more than about one percent, given the available voltage control capability of the GE 1.5 MW generators and controls.

The required reactive requirements (when the wind farm goes off line) was studied for the 100 (and 150 MW) Wind Farms and for two different Buchanan starting voltage levels. It was determined that 20 MVAr of capacitor compensation was required for peak load periods when the Wind Farm goes offline. The most appropriate location and sizing of these new capacitors is four switchable 5 MVAR capacitors at Tilsonburg 27.6 kV bus.

7.2 *System Wide Conditions*

The impact of a wide range of system conditions and line outages on the Wind farm was studied. The voltage control capability assumed for the Wind Farm Generators results in a much improved voltage profile in the Tillsonburg area under the wide range of power flows.

The impact of the system dynamics on the Wind Farm and local area was studied in transient stability studies which simulated seven cases of major system faults under two major system flow patterns. The Wind Farm was modeled by an induction generator which is a simplified and pessimistic model since the available voltage control was not modeled. The Wind Farm rode through all these faults except for the loss of the Bruce-Milton/Clairville double circuit lines. The latter fault and outage had resulted in depressed voltages in the London area and therefore in the Buchanan supply point. This case was repeated with an injection of 20 MVAr of reactive power from the Wind Farm and this was sufficient for the Wind Farm to ride through this outage as well. The replacement of the simple model with the GE 1.5 MW double wound generator and controls resulted in the Wind Farm riding through this severe contingency as well. It can be concluded that the Wind Farm will ride through the specified system fault conditions.

7.3 *Conclusions*

The system impact studies showed that the Erie Shores Wind Farm (100 MW or 150 MW size) will have a positive impact on the voltages in the local area and will also reduce system line losses. The Wind Farm is expected to ride through the specified system fault conditions. The only issue is the voltage change at Tillsonburg when the Wind Farm goes offline which can be moderated by operation of the Wind Farm at about 120 kV and by providing the specified MVAR support at Tillsonburg from four 5 MVAR switchable capacitor banks.