IESO_REP_0386

REPORT

Power to Ontario.
On Demand.

Richview SC22 Incident - January 30, 2007

Document ID	IESO_REP_0386
Document Name	Richview SC22 Incident - January 30, 2007
Issue	Issue 1.0
Reason for Issue	First release.
Effective Date	March 12, 2007

Document Change History

Issue	Reason for Issue	Date
1.0	First release	March 12, 2007

Related Documents

Document ID	Document Title

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Table of Changes

Reference (Section and Paragraph)	Description of Change

1. Synopsis

- **Extreme Event** (Category D)[1]: a phase to phase to neutral fault in the capacitor bank which progressed to a 3 phase fault to neutral after 32 ms, coincident with a three phase to ground fault in the capacitor breaker after 196 ms. Both faults were cleared after 287ms.
- **Duration:** 287 milli-seconds total
- **Root Cause:** capacitor internal fault following energization
- **Generation loss in Ontario:** one generator reported that they were automatically removed from service for a generation loss of 54 MW
- **Load loss in Ontario:** approximately 1500 MW due to customer equipment protection operation, as a result of the capacitor failure. A portion of this loss (140 MW) was reported by one wholesale market participant.
- **Impact on Tie lines:** momentary peak increase of approximately 880 MW & 600 MW on the New York & Michigan interfaces respectively to levels well within the interface capabilities.
- **Impact on other Reliability Coordinator Areas:** the impact on the interconnected system was minimal. MISO, NYISO and ISO-NE reported no adverse impact. There was no other reported impact.
- **Impact on Bulk Electricity System (BES) Security:** The Ontario bulk system remained in synchronism, voltages were stable and positively damped, and subsided within 300 ms All equipment loading and voltages remained within acceptable emergency limits.

- End of Section -

[1] As defined by NERC Standard TPL-004-0: an extreme event resulting in two or more (multiple) elements removed or cascading out of service.

2. Background

The Hydro One Richview Transformer Station, which is operated as directed by the IESO in accordance with the Hydro One – IESO transmitter agreement and IESO Market Rules, is a station on the west side of the Greater Toronto Area (GTA). The station is connected to transmission lines from Cherrywood, Claireville, Trafalgar, Cooksville, Parkway and Manby.

The Richview 230 kV yard is comprised of 20 circuits, 31 air blast breakers and two 412 MX capacitors. Current limiting reactors were installed, in part to eliminate oscillations that occur between two capacitors when switching one capacitor into service while the second is in service. The capacitor breakers have been sized based on the current limiting reactors being in service.

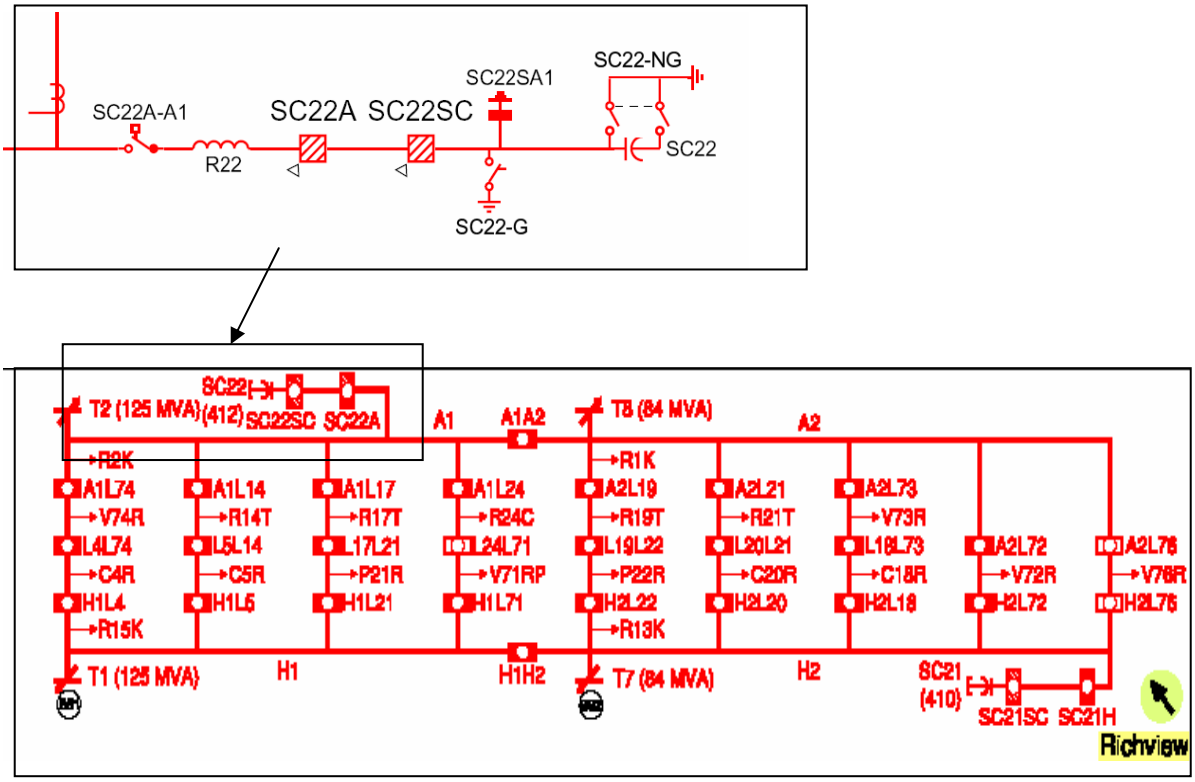

Figure 1: Richview Station Diagram

- End of Section -

3. Description of the Event

On January 30, 2007 at 06:24:38 EST a 3 phase fault occurred at the Richview Transformer Station, located in the west end of Toronto. The fault subsequently led to the loss of approximately 1500MW of load in Ontario. Digital fault recorders were reported to operate in the New York and Michigan control areas.

The fault occurred following routine switching to place the Richview 230 kV capacitor SC22 (412 MX) in service. The capacitor failed explosively resulting in a phase-to-phase to neutral fault developing in SC22 (t=0). Capacitor bank protections B and A operated to open the two 230 kV capacitor breakers SC22A and SC22SC, at t+14 ms and t+16ms respectively, but the fault current was not interrupted. The initial phase-to-phase fault developed into a 38 kA 3-phase-to-neutral fault after 32 ms. At t+65 ms the contacts of SC22SC and SC22A parted, but the arc re-ignited. At t +196 ms a sustained arc in SC22SC caused vaporized metal to create an electric path to grounded elements of the breaker. Eight milliseconds later the 230 kV A1 A and B bus protections, saw the relatively small current path to ground and the bus breakers at Richview operated. The 230 kV circuit R2K (Richview to Manby TS) was removed from service via a remote trip at Toronto Horner TS and a transfer trip at Manby TS. Ultimately, the fault was cleared after 287 ms.

The voltage decline at Richview TS from 250 to 75 kV propagated through the grid causing consumer equipment protection schemes to operate resulting in approximately 1500 MW of load loss across southern Ontario. As a consequence of the load loss, intertie flows increased momentarily into neighboring Reliability Coordinator Areas, by approximately 880 MW on the New York interface and by approximately 600 MW on the Michigan interface.

With the large load loss in Ontario, automatic dispatch was suspended at 06:27, and verbal dispatches from the IESO control room to market participants were given to reduce the Area Control Error (ACE). The large positive ACE, which occurred at 06:25, as a result of the load loss, was returned to zero by 06:30. Manual dispatch continued until 7:14 in order to maintain the online status of units that would be required for the eventual return to normal load pick up. This pickup resumed at 07:24.

During the event, frequency fluctuated throughout the interconnected system and oscillations were damped within 300 ms seconds. No adverse impact was reported by neighboring Reliability Coordinators.

The capacitor bank, the 230 kV bus structure and 230 kV capacitor breakers SC22A and SC22C sustained substantial damage. Shortly after the incident a fire was reported at Richview TS. A police and fire investigation ruled out any possibility of criminal activity.

The Ontario bulk system remained in synchronism, voltages were stable and positively damped, and the oscillations subsided within 300 ms. All equipment loading and voltages remained within acceptable emergency limits. Hydro One immediately took action to investigate the factors contributing to the capacitor fault.

End of Section –

4. Sequence of Events

Time	Summary
06:24	The SC22SC breaker closed placing Richview SC22 capacitor in service (412 MX), 4.5 seconds later the SC22 breaker tripped on 'A' and 'B' over-current protection operation. The SF6 low density Capacitor 'A' and 'B' protection operated on the SC22A breaker. The Richview A1 Bus was automatically removed from service when 'A' and 'B' differential protection operated due to a fault to ground in SC22SC. The 230 kV R2K A1 and B line protections operated at Richview. A transfer trip was received at Manby and a remote trip at Horner TS. Three 13.8 kV, 150 MX Longwood reactors tripped out of service on low voltage with the fault and closed on high voltage following the subsequent loss of load. Multiple digital fault recorder (DFR) operations were reported and approximately 1500 MW of load was lost across Southern Ontario. In order to control the subsequent high system voltage, the Detweiler SC21 and Burlington SC21 capacitors were requested out of service. With the Richview SC22A-A1 disconnect open, the A1 Bus was unavailable pending inspection. NYISO reported that they observed an increase in power flow on their system from West to East, believed to be a result of the load loss in Ontario. NYISO also reported that DFRs operated on their system at Niagara and at St. Lawrence.
06:25	Area Control Error (ACE) was +1706 MW due to the Richview Bus Fault. IESO verbally dispatched generator market participants to reduce 870 MW of hydroelectric generation.
06:27	Resource Dispatch (RD) placed in Manual operation. Market participants were informed that all dispatches would be verbal until instructed otherwise.
06:29	IESO verbally dispatched generation to reduce 300 MW. Due to the transient nature of the incident and expected load increases during the morning pick up, the fossil units were not used for ACE control during this event. All MW reductions for ACE control were requested solely on hydro electric resources to allow the fossil units to continue loading in a timely fashion to meet the rapid primary demand pick up.
06:30	ACE returned to 0 MW.
06:31	A Local Distribution Company reported a fire at the Richview Transformer Station
06:32	A wholesale connected load informed the IESO that their process is offline due to the power disturbance, with a load loss of 140 MW.
06:33	The following Reliability Coordinator Information System (RCIS) message was issued by the IESO: “IESO have experienced a fault on the Ontario system that has caused a momentary 1500 MW load loss.”
06:37	Des Joachims station was reloaded to 418 MW from 285 MW.

Time	Summary
06:38	TA Douglas reported that the GE101 unit was automatically removed from service for a generation loss of 54 MW. They reported that the unit tripped due to a system voltage spike and that the unit gas valve did not react fast enough. Unit to re-synchronize.
06:38	Beck 2 GS was released to follow dispatch and AGC operation.
06:38	Lennox G3 was verbally dispatched from 240 MW to 280 MW, and Lennox G4 from 340 to 350 MW
06:40	Brighton Beach GS was informed that the station would be verbally dispatched until further notification.
06:40	Canyon GS was verbally dispatched from 0 MW to 100 MW.
06:44	Hydro One reported compressor failure alarms for both the Cherrywood North and South buildings. Air pressure at the station was at normal levels and holding. It was believed that this was an AC power supply trip due the Richview Fault. Crews were emergency dispatched.
06:45	The IESO placed a hold on all outages in southern Ontario until further notice.
06:50	Canyon GS station was verbally dispatched from 100 MW to 200 MW.
07:08	All Cherrywood compressors were reset. Hydro One determined that the cause of trip was an AC surge.
07:09	Beck generator was verbally dispatched from 75 MW to 225 MW, Canyon GS from 195 MW to 240 MW, Brighton Beach G1-A from 95 MW to 145 MW, and Brighton Beach G1-1B from 238 MW to 290 MW.
07:14	Resource Dispatch was placed back in Auto mode. Market participants were instructed to follow electronic dispatch.
07:20	TA Douglas GE101 was back in service.
07:23	One time dispatch was sent to Lennox G4 to 350 MW.
08:00	Hydro One was notified that the IESO would again entertain the release of planned outages on the ICG.
12:45	The Richview A1 bus and R2K in service. Hydro One informed the IESO that the delay in returning the Richview bus and R2K to service was the investigation by Fire and Police as they were treating the station as a possible crime scene. Hydro One reported that criminal activity had been ruled out.

- End of Section -

5. System Impact

5.1 Impact on System Reliability

While this was an extreme "Category D" event, the interconnected system remained stable, exhibiting voltage fluctuations and frequency oscillations that were well damped and subsided within 300 milliseconds.

5.2 Impact on Tie Lines

Immediately following the incident and as direct consequence of the load loss in Ontario, flows on the New York interface increased by 880 MW out of Ontario to 1062 MW, 45% of the intertie's total transfer capability. Flows on the Michigan interface increased by 600 MW out of Ontario to 1070 MW, 54% of the intertie's total transfer capability. New York and Michigan flows stabilized at approximately 100 MW and 350 MW out of Ontario respectively after ACE was returned to normal values.

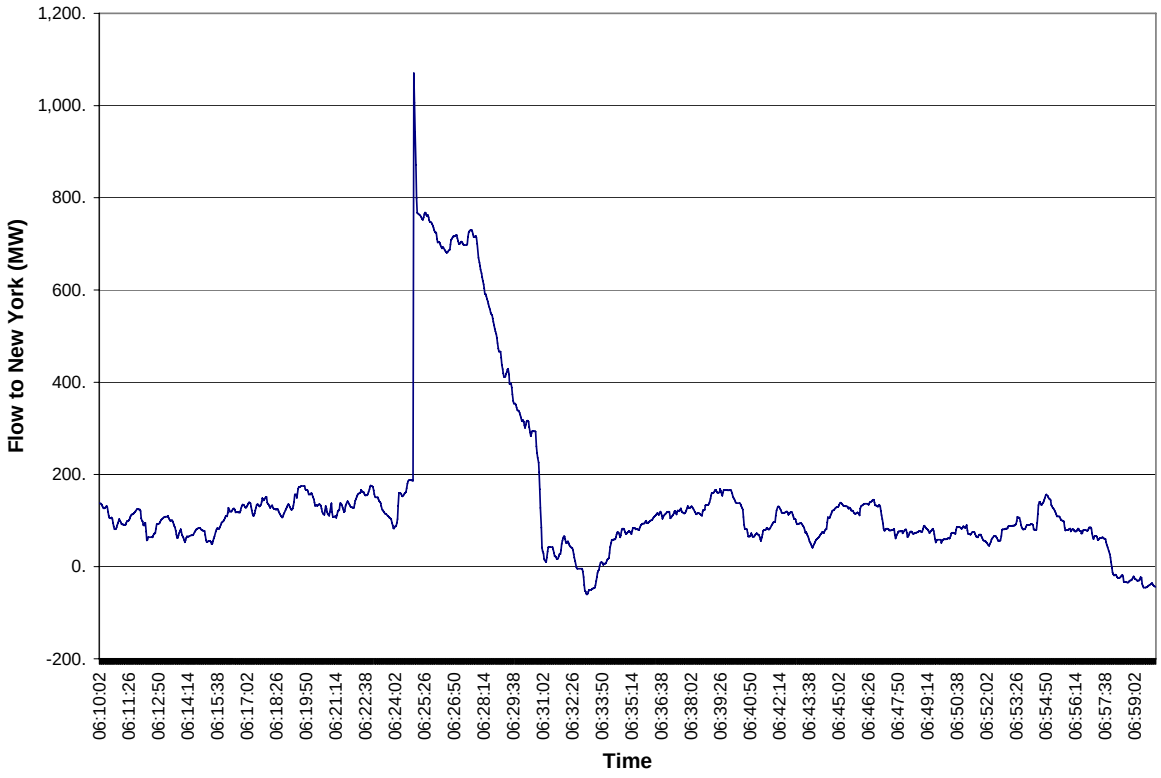

Figure 3: Ontario to New York Tieline Flow – January 30th, 2007

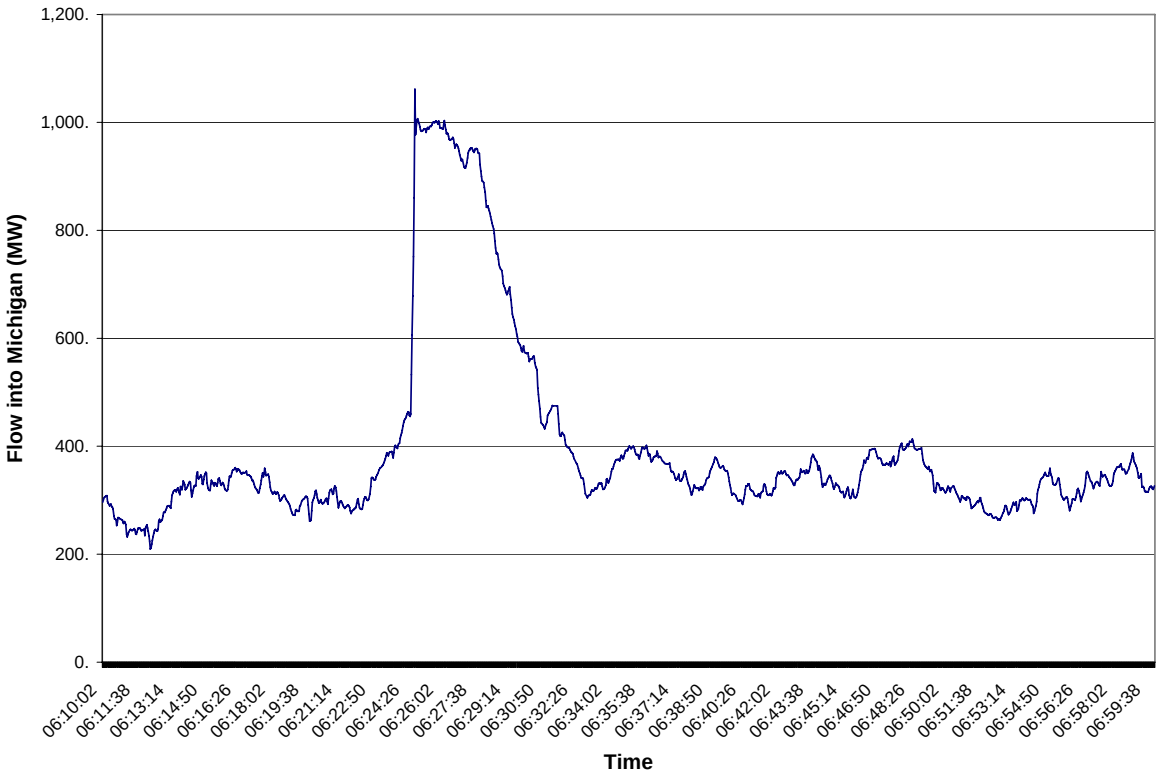

Figure 4: Ontario to Michigan Tieline Flow – January 30th, 2007

No adverse impact was reported by the neighboring Reliability Coordinators.

Ontario generation was immediately dispatched down by the IESO to reduce the tie line flows. The Area Control Area (ACE) returned to zero in 5 minutes, well within the North American Electricity Reliability Corporation (NERC) Disturbance Control Standard of 15 minutes.

5.3 Impact on Load

Approximately 1500 MW of load was removed from the Ontario grid due to the fault at Richview. A sharp drop was observed in Ontario Demand, which was approximately 19175 MW pre-fault and fell to approximately 17690 MW post.

One industrial load reported their process was interrupted due to the power disturbance.

Within 20 minutes of the initial event, the 1500 MW load loss had been recovered and within an hour the expected normal load pickup was being observed

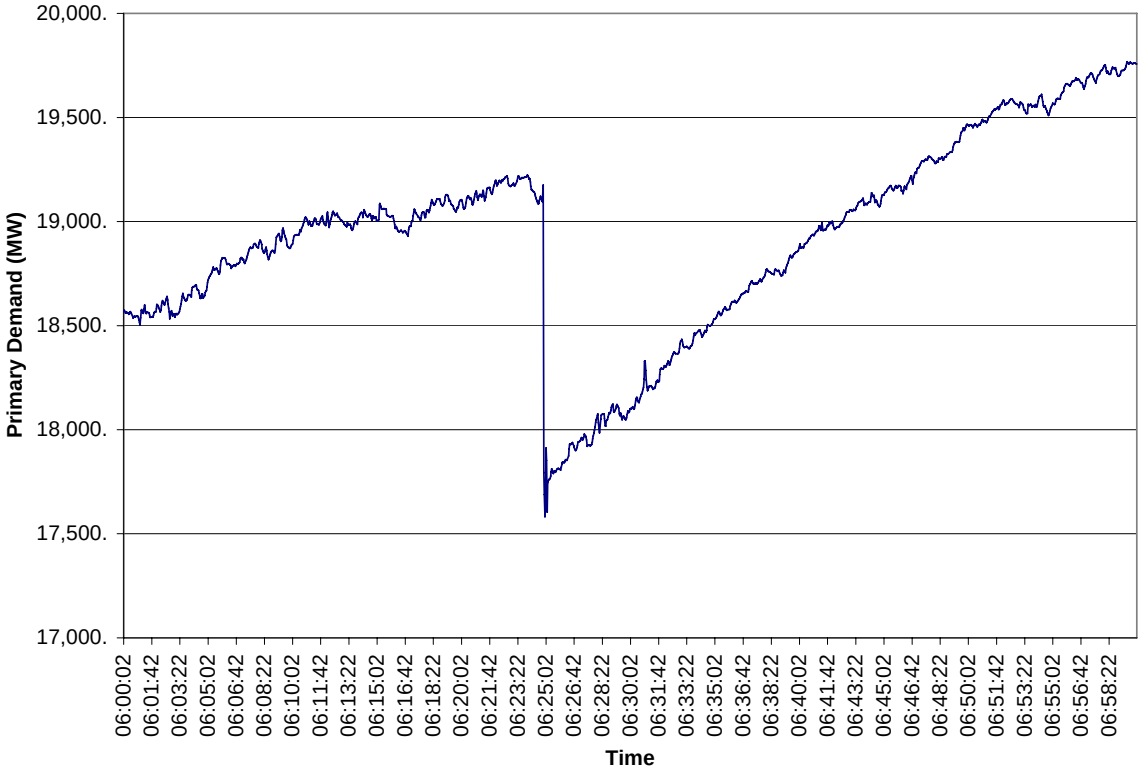

Figure 5: Ontario Primary Demand – January 30, 2007

5.4 Impact on Generation

Coincident with the fault at Richview, Darlington GS reported significant reactive swings on all of their units as well as a momentary vibration alarm on Unit 3. At 06:38 EST TA Douglas reported that the GE101 unit was automatically removed from service due to a voltage spike for a generation loss of 54 MW. This unit was returned to service at 07:20 EST.

In order to return ACE to normal, a number of hydro-electric generators were manually dispatched down to compensate for the temporary load loss. All generators were placed on manual/verbal dispatch at 06:27 and remained as such for 47 minutes.

5.5 Impact on Voltages

During the 3-phase fault the 230kV voltages at Richview decreased from 250 kV to 75 kV. For the duration of the fault, low voltages were also observed throughout the grid in Southern Ontario, momentarily dropping the 230 kV voltages by approximately 80 kV in Ottawa, 20 kV in Niagara and 10 kV in Sarnia.

As a result of the temporary decrease in voltage, a significant amount of load was lost in the Greater Toronto Area (GTA). The significant load loss, coincident with the fault being

cleared, resulted in a system which had reactive resources (i.e. capacitors) in service for 19000 MW of load, with only 17500 MW of load in service. This caused the system voltages to increase. In order to control the high system voltage Detweiler SC12 and Burlington SC21 capacitors were requested out of service.

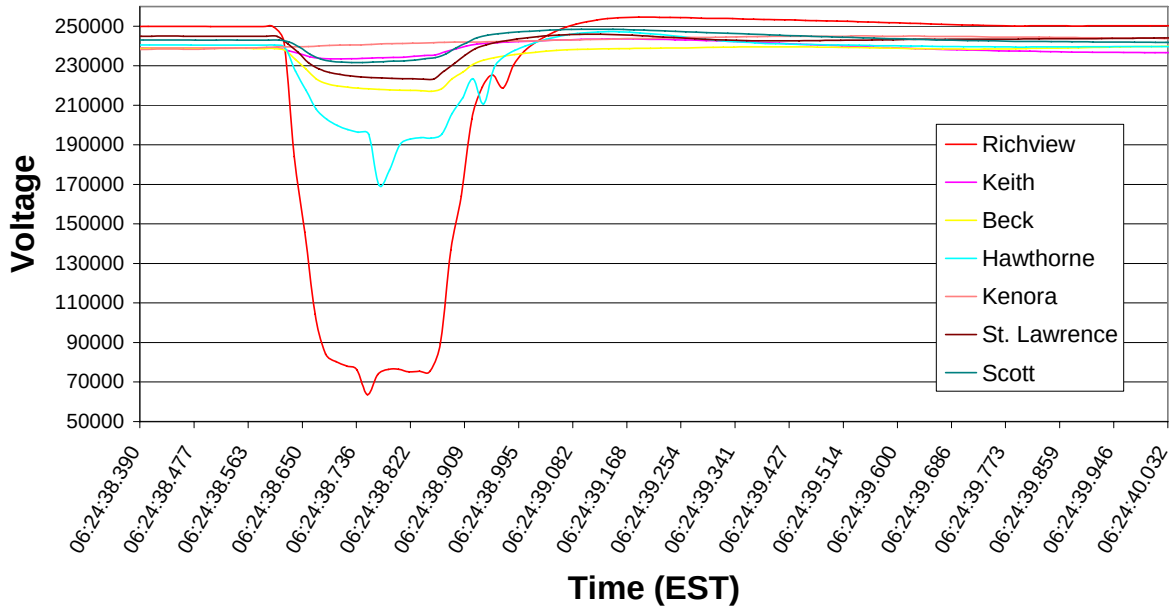

Figure 6: Voltage Fluctuations – January 30, 2007

5.6 Impact on Frequency

Local frequency oscillations occurred across Southern Ontario and were well damped within 300 ms. The oscillations were consistent with what would be expected from a normally cleared fault on the system.

As shown in Figure 7, the system frequency experienced much smaller variations between 59.952 and 60.04 Hz, which are well within normal operating criteria.

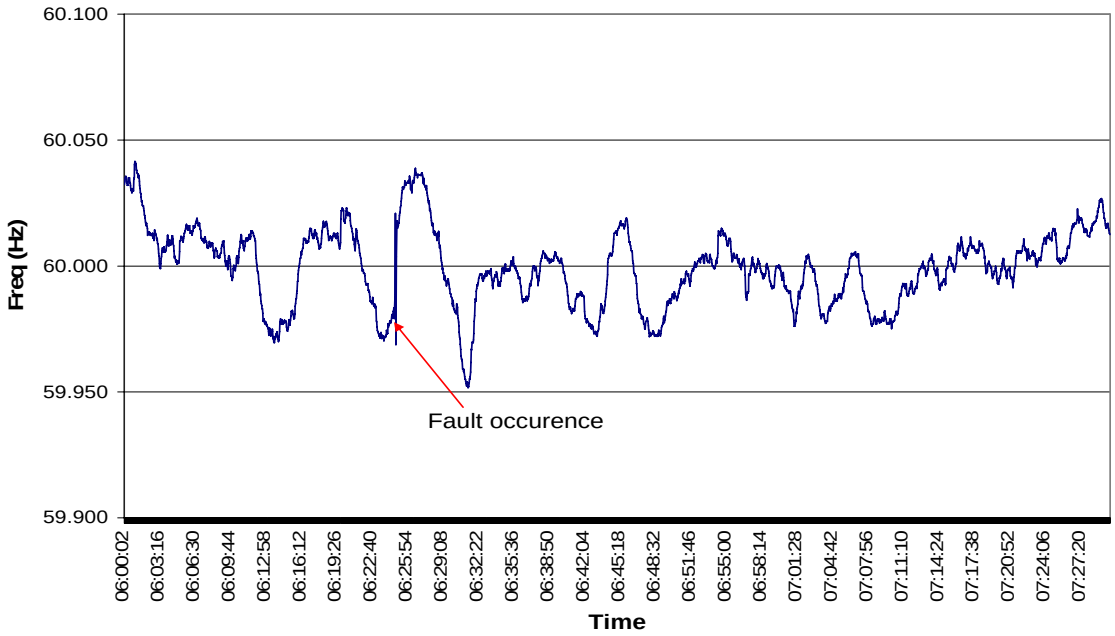

Figure 7: System Frequency Oscillations – January 30, 2007

- End of Section -

6. Market Impact

6.1 Market Clearing Price

With the loss of 1500 MW of load the market clearing price (MCP) dropped from $85.19 to $30.10. MCPs were simulated based on the primary demand that would have been expected between the time of the incident and when the primary demand recovered (Interval 4 of HE7 and Interval 3 of HE8).

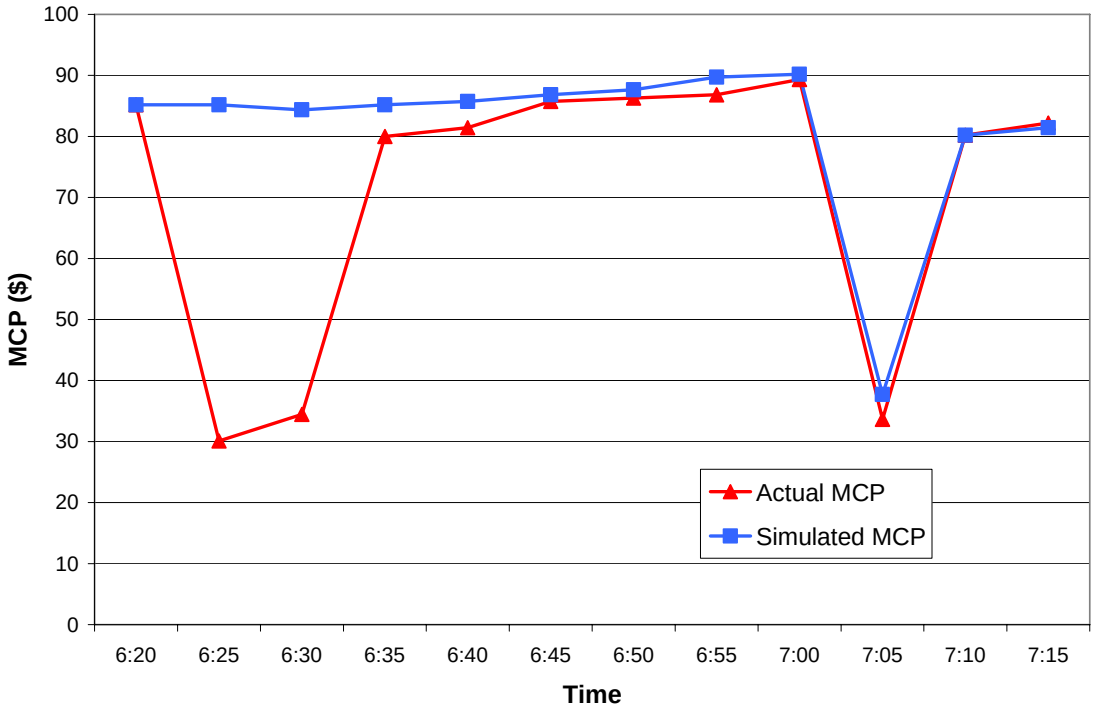

Figure 8: Actual vs. Simulated Market Clearing Price – January 30th, 2007

6.2 Costs to IESO Market

In addition to costs associated with the impact on load productivity and generator opportunity, the events associated with the fault at Richview had various cost implications on the IESO market. Some of those cost implications are quantified in lost energy revenues, overpaid Intertie Offer Guarantee payments and Congestion Management Settlement Credits.

Based on the expected demand and the simulated MCPs as shown above, it is estimated that this event resulted in $210,000 in lost energy revenues.

The same simulated MCPs were used to calculate revised IOG payments which would have resulted had the load not been lost. Based on the simulated MCPs this event resulted in approximately $17,500 additional IOGs being paid for HE 7 and HE 8.

In an effort to rebalance the grid following the load loss many generators in the IESO controlled grid were constrained off. The market costs associated with these constraints have totaled $4000.00 to date.

End of Section –

7. Actions Following Event

7.1 Preliminary Investigations by Hydro One

Preliminary analysis by Hydro One determined that the Transient Recovery Voltage (TRV) that occurred as a result of the fault at Richview exceeded the design values of the 230 kV capacitor breakers SC22A and SC22SC. The rapid rising voltage is a result of the current limiting reactor at Richview interacting with stray capacitances at its terminals.

In the event of the TRV capability of a breaker being exceeded there is a possibility of arc re-ignition. When arc re-ignition occurs the fault current is interrupted, but for only microseconds, and the arc is sustained across the breaker contacts.

It was determined by Hydro One that the TRV capabilities would have been exceeded in the event of either a phase to phase or a three-phase to neutral fault. It was also determined to be immaterial whether the reactor is on the bus side, or the capacitor side, of the breaker.

Hydro One reported that the TRV condition could occur in all instances where the current limiting reactors are in series with HV capacitor banks, even where the breakers are in the open position. Additionally, if a fault were to occur between the reactor and the capacitor breaker, the bus breakers would be subject to the same condition and to re-ignition.

After further investigation it was determined that HV reactors are in series with capacitor banks at 32 installations in the IESO controlled grid.

Capacitor breakers were sized based on the current limiting reactors being in service; hence the removal of the reactors introduces the possibility of fault current exceeding the interrupting capability of the breakers.

A possible long term solution to the problem is to install small “surge capacitors” in parallel with the current limiting reactors to reduce the transient recovery voltage. In the short term, temporary modifications must be made at all installations.

7.2 Actions to Date

On February 9th, 2007 the IESO declared all 230 kV capacitors with current limiting reactors connected to the Ontario Bulk Power System unavailable for service, even for reliability concerns. All 115 kV capacitors with current limiting

reactors were deemed available for emergency operation only to be used as a last resort before load shedding.

In order to safely restore reactive support on the system, The IESO and Hydro One began to take action immediately on a short term temporary solution to allow the capacitors to be available without the possibility of this TRV condition. This action has taken two forms depending on the existing configuration of the station:

- Temporarily bypassing the current limiting reactors on at least one capacitor bank at a station. At stations that require both capacitors available, reactors on both units were bypassed and the bus will be split for operation. In some installations it may also be necessary to remove lines from service to limit fault current.

- At some stations the reactors were installed with the expectation of a second capacitor being installed in the future. Seven of the 32 installations where the second capacitor has yet to be installed will have the reactors removed or bypassed following analysis by Hydro One and the IESO.

- Capacitors at six stations are currently out or service and will remain that way until a long term solution is implemented.

Due to the restrictions on the HV capacitor installations, the IESO will at times constrain on generating units to provide the reactive support needed to maintain acceptable voltage levels where needed. As of February 28, 2007 the market costs associated with this action have totaled $4000.00.

7.3 Ongoing Actions

The IESO and Hydro One are continuing to work together to bypass the current limiting reactors at all installations.

After further study all 115kV capacitors with series reactors were deemed not available for use.

The long term solution is being designed and an implementation plan developed.

At the time of this report, Hydro One indicates that all capacitors, except Richview SC22, should be restored to service with either permanent or temporary fixes in time for the coming summer peak season. Nevertheless, the IESO is reviewing all system limits and related implications in the event that a long term solution cannot be in place for the summer months, when maximum reactive support is required.

End of Section –

8. Conclusions

A preliminary analysis of the events provided by Hydro One concluded that a single incident caused the failure of both the main and backup breakers. The phase-to-phase fault resulted from a capacitor failure after energization. After the capacitor breakers failed to interrupt the fault current the initial phase to phase fault developed into a three phase fault. The Transient Recovery Voltage (TRV) exceeded the design levels on the capacitor bank breakers.

Had one of the breakers not developed a fortuitous ground fault during the incident, the fault would have been cleared by all zone-two protections on circuits terminating at Richview TS after approximately 400 ms. Had the double phase fault not evolved into a three phase fault, bus breakers which are not generally designed for capacitor bank duty, would have been called to clear the fault on the undamaged part of the capacitor bank.

The impact on the interconnected system was minimal. Voltage fluctuations and frequency oscillations were well damped and subsided within 300 milliseconds. No adverse impact was reported by our neighboring Reliability Coordinators.

The Ontario bulk system remained in synchronism, voltages were stable and positively damped, and subsided within 300 ms. All equipment loading and voltages remained within acceptable emergency limits.

The high TRV can occur at any location where a current limiting reactor is in series with a high voltage capacitor bank. This arrangement was found at 32 installations in the IESO controlled grid.

All current limiting reactors at key stations in the IESO controlled grid have been bypassed making the capacitors at those stations available. In some installations it may be necessary to split the bus, and or remove lines from service to limit fault current. Work to bypass the remaining reactors is ongoing.

Co-incident with the fault the Hydro One reported compressor failure alarms at Cherrywood.

- End of Section -

9. Recommendations

- IESO and Hydro One to continue implementation of temporary mitigation measures to allow all capacitors to be made available for service.
- Based on the outcomes of Hydro One's protection operation study, the IESO is to study the impact of the operation or misoperation of the protections that occurred and the impact on the BES. The results and modifications if necessary to be available by the end of April 2007.
- The IESO is to continue investigating limits and options for voltage support in the absence of the high voltage capacitors in the summer months by early April 2007.
- Hydro One to continue its proposal for a long term solution, to be reviewed in conjunction with the IESO. All work is required to be completed prior to June 2007.
- Hydro One to continue its investigation into the compressor failure that occurred co-incident with this event, with results and any necessary plans for resolution to be available by the end of April 2007.
- Hydro One to notify the NPCC Task Force on System Protection of the potential for breaker re-ignition in high voltage capacitor installations with current limiting reactors.

- End of Document