

Northeast Wisconsin/Upper Peninsula Separation 11/14/01

Incident Investigation Report

Summary

Contact by a high voltage electric transmission line with a tree in northeastern Wisconsin initiated a series of events which forced the American Transmission Company electric grid into an abnormal configuration, affecting electric service for some customers in northeastern Wisconsin and in portions of the Upper Peninsula of Michigan on November 14. Under ATC direction, crews from Wisconsin Electric-Wisconsin Gas and Wisconsin Public Service Corporation responded to restore the system to normal configuration, allowing service to be restored to all customers. This report reflects information currently available. However, investigation into this event is continuing and this report will be updated as required.

Description of Area:

The northeast Wisconsin/western and central Upper Peninsula of Michigan area is served by three 138 kV lines from the south and two 69 kV lines from the east. Two of the 138 kV lines (64441 and 64451) extend from the Pulliam Power Plant to Stiles Switching Station and the third 138 kV line (6851) extends from North Appleton Substation to White Clay Substation. The two 69 kV lines extend from Indian Lake Substation to Manistique and Hiawatha substations. Various ATC customers and certain other municipal and co-op

systems (who are not ATC transmission customers) all have residential, commercial, and industrial customers in this area with a total connected load of approximately 1000 MW at the time of the separation. Generation resources in the area (with those off line at the time of the incident so noted) include the Presque Isle Power Plant (500 MW), Shiras Steam Plant (60 MW total), Marquette Diesel Plant (23 MW off line), Portage combustion turbine (20 MW off line), Gladstone combustion turbine (20 MW off line), West Marinette combustion turbines (two fast start units M31 (45 MW) and M32 (60 MW) and two simple cycle CT's – M33 (87 MW) and M34 (80 MW) all off line), a few small diesels, and many small (0.5 - 7MW range) hydro-electric generators.

Pre-Planning of Outage:

The North Appleton to White Clay 138 kV (Line 6851) line was scheduled out of service for two consecutive days beginning 11/14/2001 for a number of projects. These included relocating the line in preparation for construction of a new WE-WG 138/34.5 kV distribution substation (Lawn Rd SS), replacement of two weakened wood poles, and replacement of a defective relay.

Detailed analysis prior to the scheduled outage indicated that it was necessary to require generation (Presque Isle #2) be brought on line out of economic order to control flows, as well as to verify that additional combustion turbine generation at West Marinette, Portage, and Gladstone be available should there be a problem

with the base load generation scheduled to be on line. The field work was arranged so that the line would be restored to service over the night time hours.

Results of the final pre-outage analysis performed at 1330 hours on Tuesday Nov. 13 indicated that the transmission system could withstand the loss of any single element without causing a subsequent overload. There was no anticipated change in the output from any of the hydro units in the area. The availability of all peaking units was again verified.

November 14, 2001

Weather - Cloudy, dense fog, no wind & 39°F

Initial Conditions:

6851 North Appleton - White Clay	410 Amperes
64441 Pulliam - Stiles	375 Amperes
64451 Pulliam - Stiles	375 Amperes
Indian Lake Hiawatha 69 kV system	OPEN

Ratings

64441/64451 Summer Normal (90° F)	839 Amperes
Summer Emergency	839 Amperes
Winter Normal (30° F)	1090 Amperes
Winter Emergency	1090 Amperes

Winter ratings were in effect throughout the MAIN Region for transfer capability calculations as well as in ATC for real time monitoring and contingency analysis. The SCADA system Alarm processor uses summer ratings since it is difficult to change these ratings on the existing EMS system.

Timeline:

At **0600**, Line 6851 North Appleton to White Clay was opened at White Clay. The loading on the 138 kV Pulliam to Stiles lines (Lines 64441 and 64451) increased to 580 amperes each. These values were below the Winter Normal/Emergency Rating (1090 amps) assumed in the pre-outage analysis as well as in the real time condition. The real time operator determined that the West Marinette CT's could start fast enough to mitigate any overload should a contingency occur (see lesson learned #8).

At **0604** Line 6851 was opened at North Appleton. As time progressed, the load in the UP increased and the loading on Lines 64441 and 64451 increased.

At **0635**, the ATC operator elected to close the Hiawatha - Manistique 69 kV ties. These ties, though normally closed, are frequently opened at night to prevent excessive flows across the UP caused by nighttime generation and load configuration in the lower peninsula of Michigan. This made a third tie into the area (see lesson learned #9).

At **0636**, 138 kV Line 64441 tripped due to contact with vegetation. The contact occurred approximately 15 miles north of Pulliam, with a shoot of a willow tree extending above the trimmed level of several adjacent pine trees (see lesson learned #1). This trip subjected line 64451 and the Hiawatha 69 kV lines to an

overload exceeding the emergency ratings. West Marinette units M31 and M32 were called upon to start.

At **0637:30**, ninety seconds after the trip, the ATC operator successfully reclosed Line 64441. Neither West Marinette unit had been synchronized and a stop was initiated.

At **0644**, Line 64441 tripped after again contacting the tree. Once again Line 64451 and the Hiawatha 69 kV ties were subjected to the overload and the West Marinette fast start peaking units (M31 and M32) were needed. However, since these turbines were spinning down, they could not be restarted until they stopped (see lesson learned #8). West Marinette unit M33 was started.

At **0645**, Line 64451 sagged into a distribution line crossing under the transmission line between towers #1421 and #1422. This distribution feeder had been reworked some time in the recent past (see lesson learned #2).

Almost simultaneously, Hiawatha Manistique 69 kV lines 6912 tripped automatically with the Manistique end reclosing. Indian Lake line 6916 tripped, islanding the affected area of northeast Wisconsin and the central and western UP. The island was generation deficient and the frequency dropped. All three levels of automatic under-frequency relaying operated as designed, arresting the frequency decline. Alarms indicated that the frequency at Presque Isle dropped to 57.988 Hz and recovered to about 59 Hz within a minute. The island operated between 58 and 59 Hz. WPS lost approximately 58 MW of load on nine feeders due to under-frequency relay trips. UPP lost approximately 42 MW of load due to under-frequency tripping. WE-WG lost approximately 152 MW of industrial load

(Empire and Tilden Mine load and International Papers) and approximately 11 MW of load due to under-frequency load shedding at the White Clay Substation. A total of approximately 263 MW of load was lost in the island upon its formation.

The City of Marquette (MQT) separated from Presque Isle Power Plant. Breaker 4691 opened on under-frequency (59.0 Hz) and MQT lost two hydro units and two feeders on under-frequency load shedding. MQT reconnected to the Presque Isle Power Plant bus at 0950.

Edison Sault Electric customers fed from Indian Lake and Manistique substations were dropped due to under frequency/under voltage conditions since they were in the island. The remainder of Edison Sault Electric remained connected to the Eastern Interconnection through the 138 kV cables across the Straits of Mackinac.

The ATC operator established telephone contact with Presque Isle Power Plant. They discussed the low frequency (around 58 Hz). To prevent a possible cascading outage to the entire island, a decision was made to drop load in the island. The ATC operator called WE-WG operators and requested to have 100 megawatts dropped within the island as soon as possible.

At **0658**, West Marinette M33 on line.

At **0700**, West Marinette M31 on line.

At **0712**, West Marinette M32 on line.

At **0716**, frequency returned to 59.98 Hz

At **0716**, breaker 3358 closed automatically, reconnecting the island with the Eastern Interconnection with one 69 kV line. However, operators were

unaware that the island had been automatically resynchronized until much later (see lesson learned #5).

At **0721**, the ESELCO operator closed the Indian Lake breakers placing the second 69 kV line in service.

During the time period between **0645 and 0928**, ATC operators were attempting to restore line 6851 to re-synchronize, what they still believed to be an island, to the Eastern Interconnection.

At **0928**, 138 kV Line 6851 was restored to service, securing the island.

At **1154**, after the willow that had caused the original contact had been cleared, three large pine trees adjacent to it had been trimmed lower and the distribution line and crews working on them were in the clear, lines 64441 & 64451 were closed. After these lines were closed the remaining load was released to return to service.

Follow-up Issues and Lessons Learned

1. Tree contact initiated the fault. **Action: Review tree trimming practices for the UP corridor and modify if necessary.**
2. Distribution contact caused Line 64451 to trip. **Action: Review clearances for the UP corridor and modify if necessary. Complete survey and evaluation of the distribution at the point of second line contact (between towers #1421 and #1422 on Line 64451).**

3. Real time monitoring and contingency analysis programs alarm at the normal line rating. In this case, the normal and emergency ratings are identical which does not give the operator much time to react when reaching the normal rating in real time or in contingency conditions.
Action: Review all line ratings and adjust alarm points to 95% of normal rating in situations where the normal rating equals the emergency rating.
4. Standard winter ratings were in effect, however, an unusual localized still air condition was present. The weather conditions at the location and time of the event were no wind, heavy fog, and 39 degrees F. The lack of wind significantly deteriorates the ability of the line to dissipate heat (winter ratings assume a wind speed of 3 mph and an ambient temperature of 30 degrees F). This resulted in a significant difference between the standard winter conductor rating (1090 amps) and the effective capability calculated after the fact (680 amps). **Action: Review existing line rating assumptions with operators. Also, investigate alternative rating methodologies and their applicability to the ATC transmission system.**
5. Auto-reclose of 69 kV breaker re-synchronized the island independent of operator action/knowledge. **Action: Review auto-reclosing scheme and modify to prevent future island re-synchronizing without direct operator action.**

6. After the island was created, frequency was low. The control area operators, distribution operators, etc., were attempting to reclose under-frequency load-shedding operations without coordinating through the ATC system operator. Re-setting of this load requires permission of the ATC operator. **Action: This needs to be discussed at the ATC Network Operating Committee Load Shedding Subcommittee and procedures need to be established.**
7. Synchrosopes were not present or functional in the expected locations. **Action: A survey of ATC stations in the area will be made regarding the status of synchrosopes. The survey will establish which stations have synchrosopes, when they were tested last and whether they are operative. Additional synchrosopes will be added where necessary. Once this is complete, the WUMS map and the System Operators map board will be updated.**
8. The maintenance outage of line 6851 was done based on the availability of the fast start West Marinette generation. After the initial successful reclosure of the first tripped breaker at 0637, operators cancelled the order to bring the West Marinette fast-start units on-line which, in retrospect, impacted the contingency analysis assumptions by making these units unavailable for subsequent rapid synchronization. **Action: Review practices for deciding whether to continue redispatch of generation until satisfied that a line which has been reclosed after a trip will hold.**

9. After the real time contingency analysis indicated a slight overload in the event of a contingency, ATC elected to re-close the Hiawatha 69 kV ties to increase the connectivity to the area. This did increase the connectivity and helped line 64451 after 64441 tripped but, prior to the trip, closing the Hiawatha ties actual increased the loading on Lines 64441 and 64451 by about 20 Amperes. **Action: Operators will be reminded that contingency analysis should be run, time permitting, to give an indication of the impacts on the system while exploring switching options.**
10. Not all breaker alarms were reported to the ATC system operator by the EMS computer system. In addition, some breaker alarms were reported with incorrect alarm priority colors. **Action: The EMS support group will review these modeling issues and correct the routing and color of the alarms.**
10. ATC's involvement with frequency control during emergencies needs to be defined. The control areas are normally responsible for frequency, but under a system separation, the control area operator may not know if the system is islanded. Under these conditions, frequency can be off nominal and will need attention from both the loads and generators within the island. **Action: This needs to be discussed at the ATC Network Operating Committee's Load Shedding subcommittee and procedures need to be established.**

11. It is recommended that the new EMS system have a process that when an operator selects a breaker to open the powerflow and contingency analysis programs run automatically. Any new contingencies or contingencies that change will be reported to the operator. **Action: The EMS support group to investigate.**
12. Dealing with the situation resulted in not being able to immediately contact everyone that was affected by this outage. System Operating is always faced with the challenge of solving the physical problem at the same time it is communicating with and receiving communications regarding the problem. System Operating may need a designated communications person in the control center during emergencies. In this event, senior management assisted with this. **Action: The ATC Emergency Response Plan should be reviewed to address having an emergency communication person in the control center during emergencies.**
13. Significant alphanumeric pager messages were sent out well into the outage, but little information was provided when it was sent out. **Action: Remind ATC system operators to send out page within 1 hour or as soon as possible.**

Appendix A

Line Information

- KK6851 138 kV North Appleton-White Clay, 29.8 miles, 795 kcmil ACSR H-Frame, 800 amps normal rating and 960 amps emergency rating. All ratings are limited by the wave trap at White Clay.
- KK64441 138 kV Pulliam-Stiles, 25.7 miles, 494 ACAR double circuit steel tower, 1091 amps normal rating and 1091 amps emergency rating. All ratings are limited by both the Stiles CT and the 494 ACAR line conductor.
- KK64451 138 kV Pulliam-Stiles, 25.7 miles, 494 ACAR double circuit steel tower, 1091 amps normal rating and 1091 amps emergency rating. All ratings are limited by both the Stiles CT and the 494 ACAR line conductor.
- 6912 69 kV Manistique-Hiawatha, 40 miles, single circuit 1/0 ACSR, normal rating of 33 Mva is limited by the line conductor.
- 6913/6916 69 kV Indian Lake-Glen Jenks-Manistique-Hiawatha, 42 miles, single circuit 396 ACAR, normal rating of 70 mva is limited by the line conductor.